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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SKYLAB

OPERATIONS HANDBOOK COMMAND/SERVICE MODULES

CSM 116 THRU 118

VOLUME 1
COMMAND AND SERVICE MODULE DESCRIPTION

PREPARED BY
ROCKWELL INTERNATIONAL
UNDER DIRECTION
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SYSTEMS PROCEDURES BRANCH

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NOTICE

This issue contains the latest changed pages and all the pages previously issued. Therefore it is a complete manual and supersedes previous issue SM2A-03-SKYLAB-(1) dated 14 July 1972

RECORD OF PUBLICATION

This issue of the Skylab Operations Handbook (SOH), Volume 1 is the basic issue. Changes will be issued to maintain current information with the CSM configuration through completion of the mission. This record will reflect the publication date of any released changes.

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15 July 1970	23 Oct 1970
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CONTENTS

FOREWORD

The Skylab Operations Handbook (SOH) is a contractual document. The SOH (Volume 1) is system-oriented and not specifically designed for utilization by any special group.

Volume 1 is the description portion of the SOH. It provides the description of all command-service module (CSM) systems. Volume 2 is separately bound and contains performance data and crew operational data.

NASA comments or suggested changes to this handbook should be addressed to the Systems Procedures Branch/Crew Procedures Division, Office Code CG2, Telephone HU3-5558.

SECTION 1

SPACECRAFT

1.1 SPACECRAFT CONFIGURATION

The Skylab spacecraft consists of a launch escape assembly (LEA), command module (CM), service module (SM), and the spacecraft LM adapter (SLA). The overall configuration is shown in figure 1-1 and the reference stations are shown in figure 1-2.

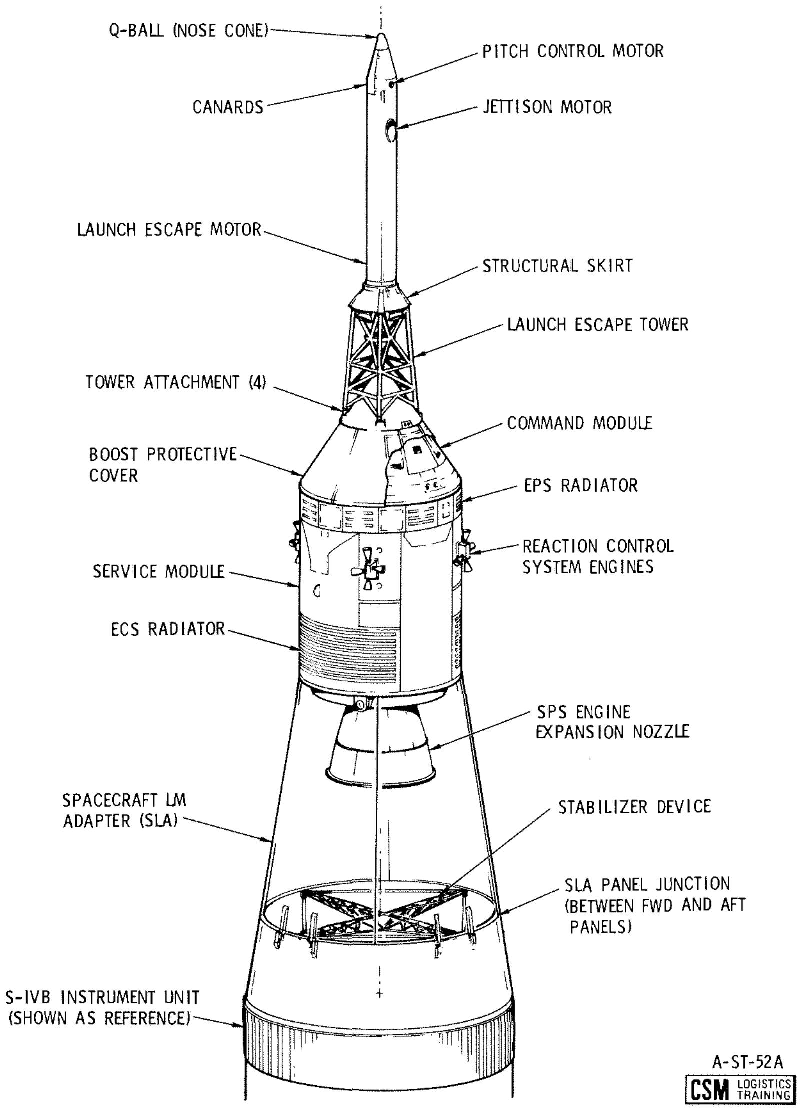


Figure 1-1. Spacecraft Configuration

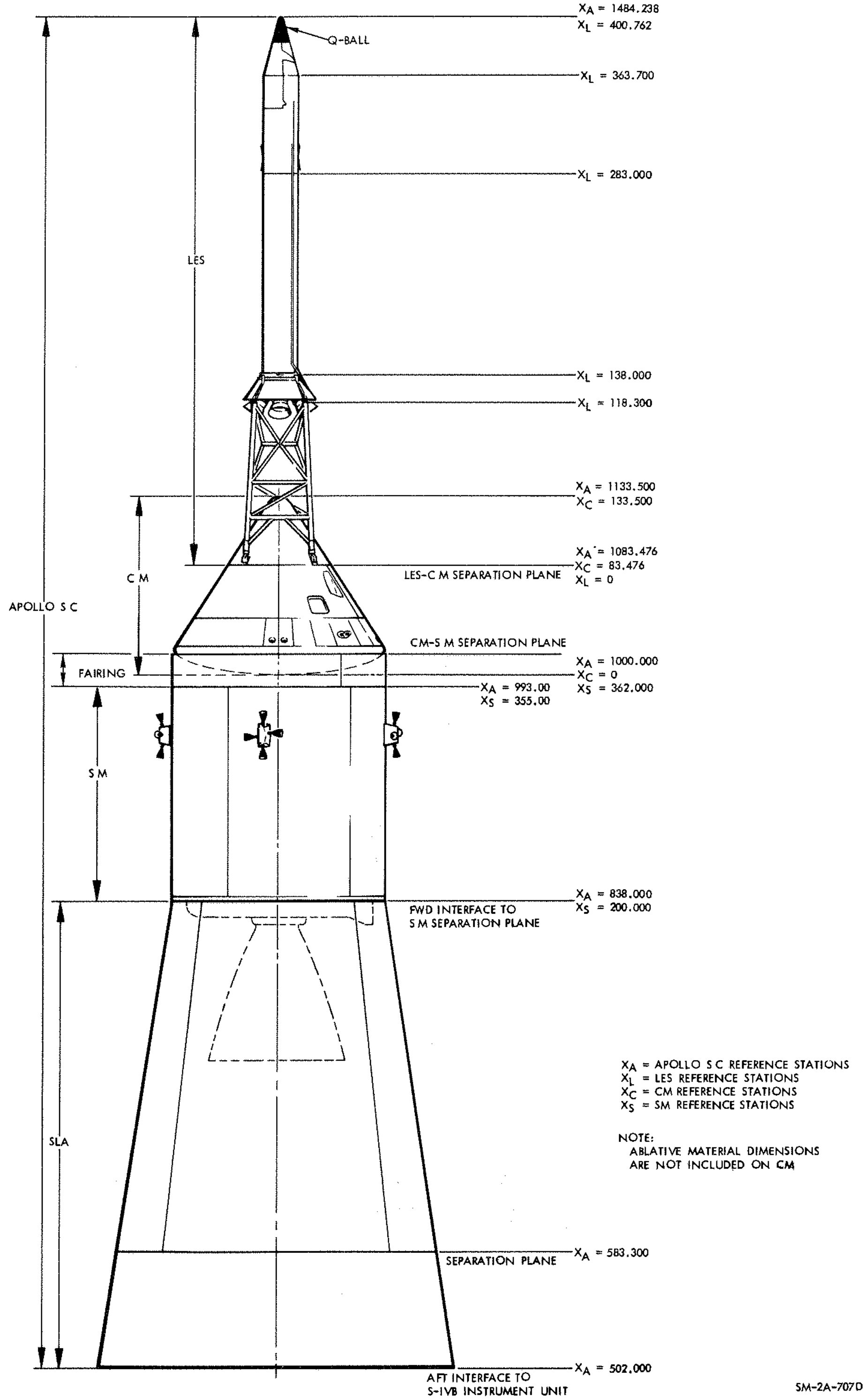


Figure 1-2. Spacecraft Reference Stations

1.1.1 LAUNCH ESCAPE ASSEMBLY

The LEA (figure 1-3) provides the means for separating the CM from the launch vehicle on the pad or during first-stage booster operation. This assembly consists of a Q-ball instrumentation assembly (nose cone), ballast compartment, canard surfaces, pitch control motor, tower jettison motor, launch escape motor, a structural skirt, an open-frame tower, and a boost protective cover (BPC). The structural skirt at the base of the housing, which encloses the launch escape motor nozzles, is secured to the forward portion of the tower. The BPC (figure 1-4) is attached to the aft end of the tower to protect the CM from heat during boost, and from exhaust damage by the launch escape and tower jettison motors. Explosive nuts, one in each tower leg well, secure the tower to the CM structure. (For additional information, refer to the sequential systems in section 2, subsection 2.9.)

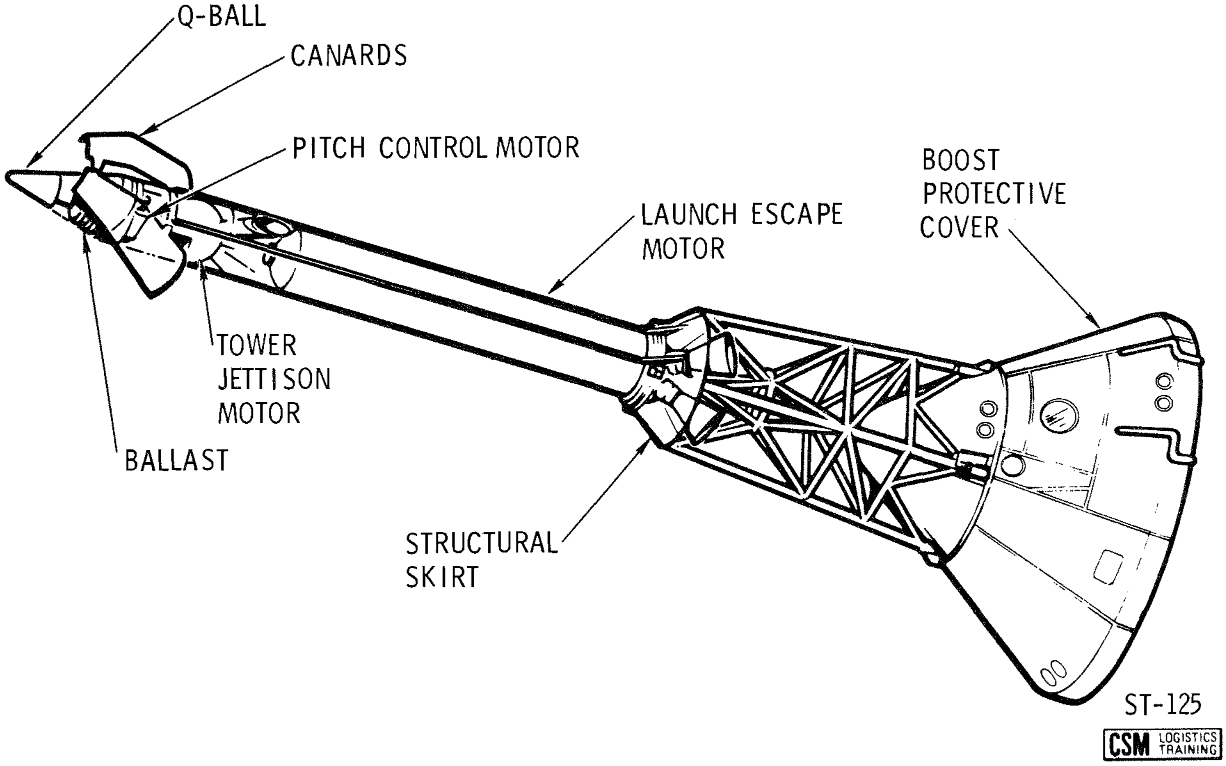


Figure 1-3. Launch Escape Assembly

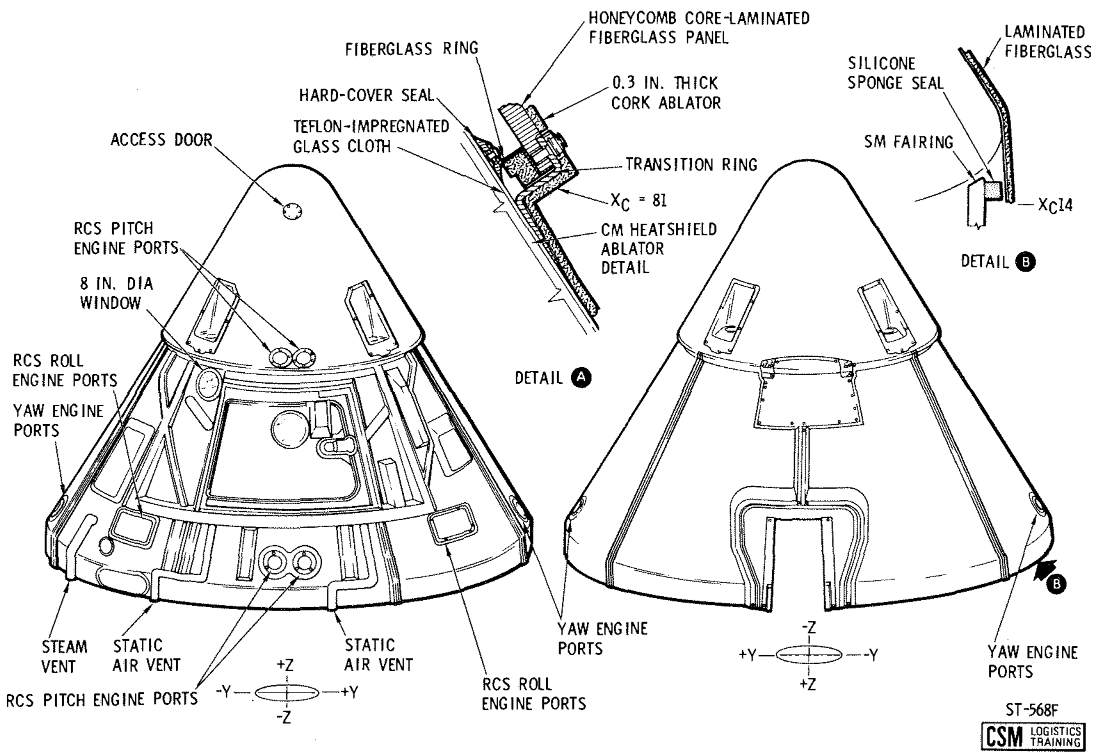


Figure 1-4. Boost Protective Cover

1.1.2 COMMAND MODULE

The CM (figure 1-5), the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems; it also contains the required equipment for safety and comfort of the flight crew. The module is an irregular-shaped, primary structure encompassed by three heat shields (coated with ablative material and joined or fastened to the primary structure) forming a truncated, conic structure. The CM consists of a forward compartment, a crew compartment, and an aft compartment for equipment and a crew. (See figure 1-6.)

The command module is conical shaped, 11 feet 1.5 inches long, and 12 feet 6.5 inches in diameter without the ablative material. The ablative material is non-symmetrical and adds approximately 4 inches to the height and 4 inches to the diameter.

1.1.2.1 Forward Compartment

The forward compartment (figure 1-6) is the area outside the forward access tunnel, and is covered by the forward heat shield. Four 90-degree segments around the perimeter of the tunnel contain the recovery equipment, two negative-pitch reaction control system engines, and the forward heat shield release mechanism. Most of the equipment in the forward compartment consists of earth landing (recovery) system (ELS) components.

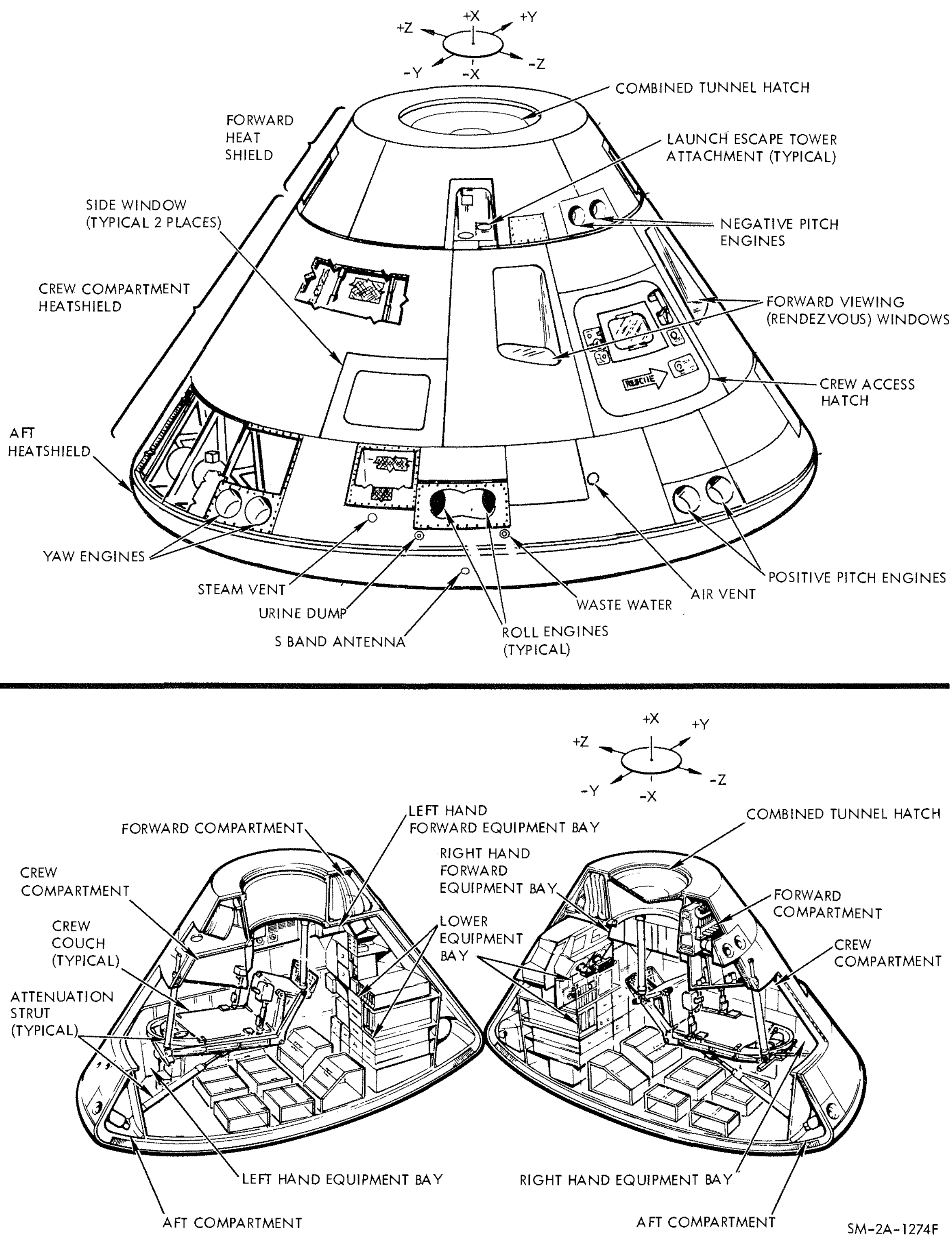


Figure 1-5. Skylab Command Module (Without Docking Probe)

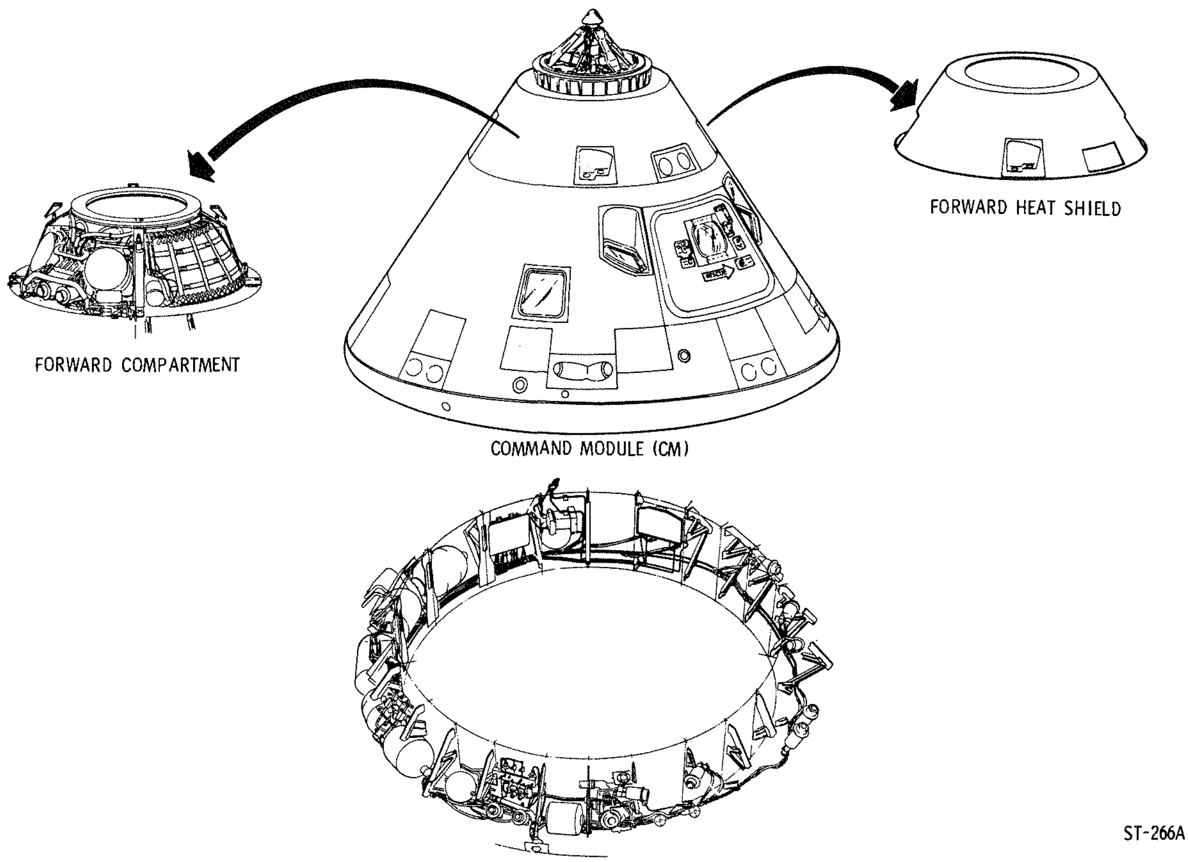


Figure 1-6. CM External Compartments

The forward heat shield is made of brazed stainless steel honeycomb covered with ablative material. It contains four recessed fittings which permit the launch escape tower to be attached to the CM inner structure. Jettison thrusters separate the forward heat shield from the CM after entry or after the LEA is separated during an abort.

1.1.2.2 Aft Compartment

The aft compartment (figure 1-6) is the area encompassed by the aft portion of the crew compartment heat shield, aft heat shield, and aft portion of the primary structure. This compartment contains ten reaction control engines, impact attenuation structure, instrumentation, and storage tanks for water, fuel oxidizer, and gaseous helium. Four crushable ribs, along the spacecraft +Z axis, are provided as part of the impact attenuation structure to absorb energy during impact.

The aft heat shield, which encloses the large end of the CM, is a shallow, spherically contoured assembly. It is made of the same type of materials as the forward heat shield. However, the ablative material on this heat shield has a greater thickness for the dissipation of heat during entry. External provisions are made on this heat shield for connecting the CM to the SM.

1.1.2.3 Crew Compartment

The crew compartment or inner structure (figure 1-5) is a sealed cabin with pressurization maintained by the environmental control system (ECS). The compartment, protected by a heat shield, contains controls and displays for operation of the spacecraft and spacecraft systems, crew couches and restraint harness assemblies, window shades, etc., and is provided with crew equipment, food and water, waste management provisions, and survival equipment. Access hatches, observation windows, and equipment bays are attached as part of the compartment structure. The interior volume is 366 cubic feet. However, the lower, right, and left equipment bays, lockers, couches, and crewmen occupy 156 cubic feet, leaving a usable volume of 210 cubic feet.

The crew compartment structure is made entirely of aluminum. The walls are constructed of aluminum honeycomb sandwiched between two aluminum face sheets. Additional structural support is provided by solid aluminum pieces called longerons and ring assemblies.

The crew compartment heat shield like the forward heat shield, is made of brazed stainless-steel honeycomb and covered with ablative material. This heat shield, or outer structure, contains the SC umbilical connector outlet, ablative plugs, a copper heat sink for the optical sighting ports in the lower equipment bay, two side observation windows, two forward viewing windows, and the side access hatch.

1.1.2.3.1 Crew Equipment

Each crew member has personal and accessory equipment provided for his use in the crew compartment. Major items of personal equipment consist of a spacesuit assembly with attaching hose and umbilical, a communications assembly, biomedical sensors, and radiation dosimeters. Major items of accessory equipment shared by the crew consist of an in-flight tool set and a medical kit. For a description of crew equipment, refer to section 2.12.

1.1.2.3.2 Protection Panels (Figure 1-7)

The protection panels prevent loose equipment (tools, etc.) and debris from getting into the various nooks and crevices in the crew compartment. They also suppress fire by closing out the equipment bays with covers around the aft bulkhead, and protect the ECS tubing from the zero g activities of the crew and the prelaunch activities of ground personnel. The location and configuration of the protection panels are illustrated in figure 1-7.

The protection panels (also referred to as close-out panels) are a series of aluminum panels and covers that fair the irregular structure to the equipment bays and wire troughs and covers. The panels vary in thickness and are attached to secondary structures by captivated fasteners. Access panels and penetrations are located at or over equipment and connectors needed for the mission.

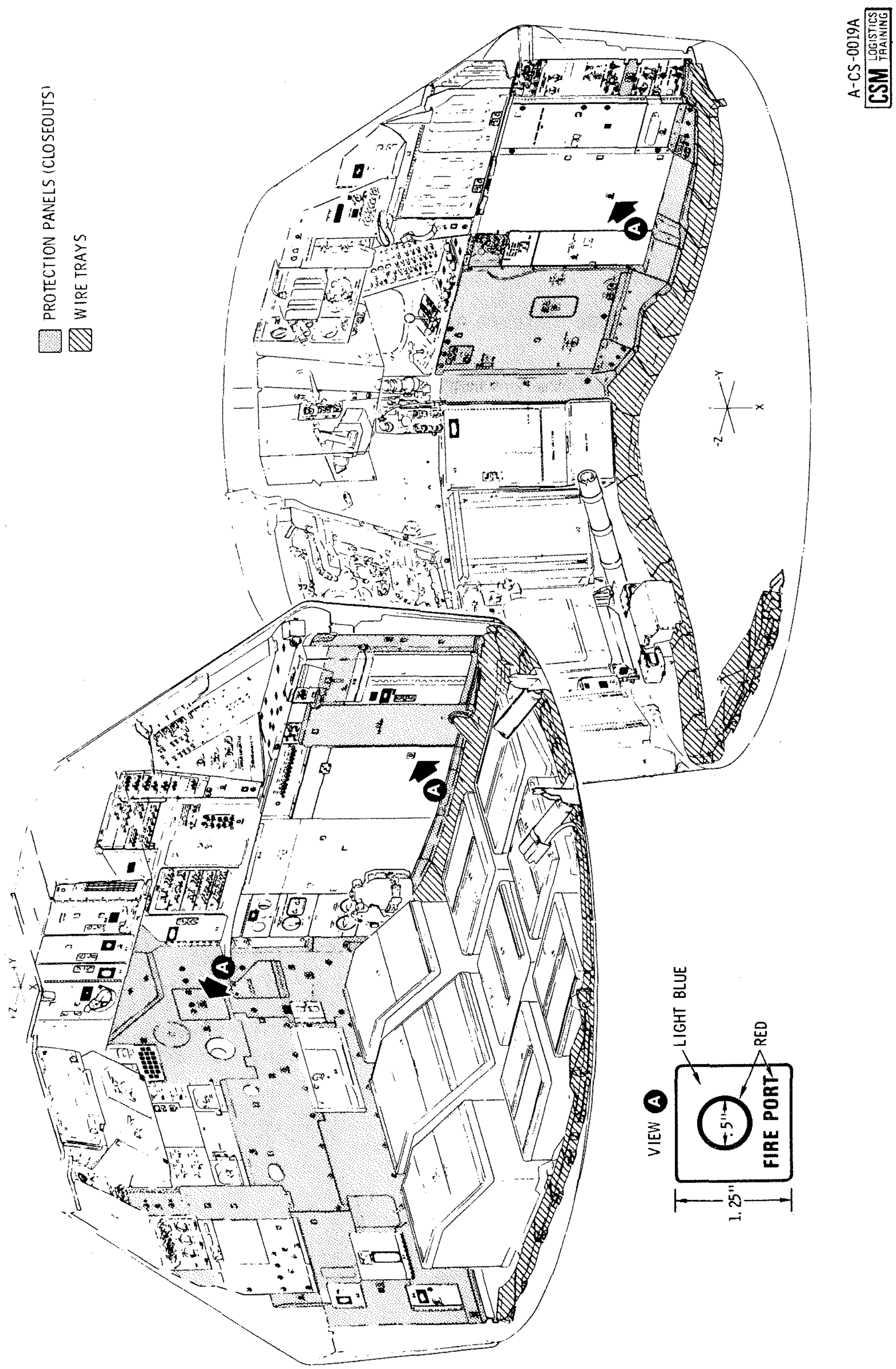


Figure 1-7. Closeout or Protection Panels

1.1.2.3.2A Fire Ports (Figure 1-7)

Located on, or adjacent to, all controls and displays panels (paragraph 1.1.2.4) are fire ports. The protection panels also have fire ports in accessible locations. The function of a fire port is to give access to the compartments behind the controls and displays or protection panels, and through which a fire retarding or extinguishing agent can be discharged.

A fire port is a hole 0.5-inch in diameter which is marked with a decal approximately 1.25 inches square, with a 0.12-inch-wide red circle around the hole, and the words FIRE PORT in red.

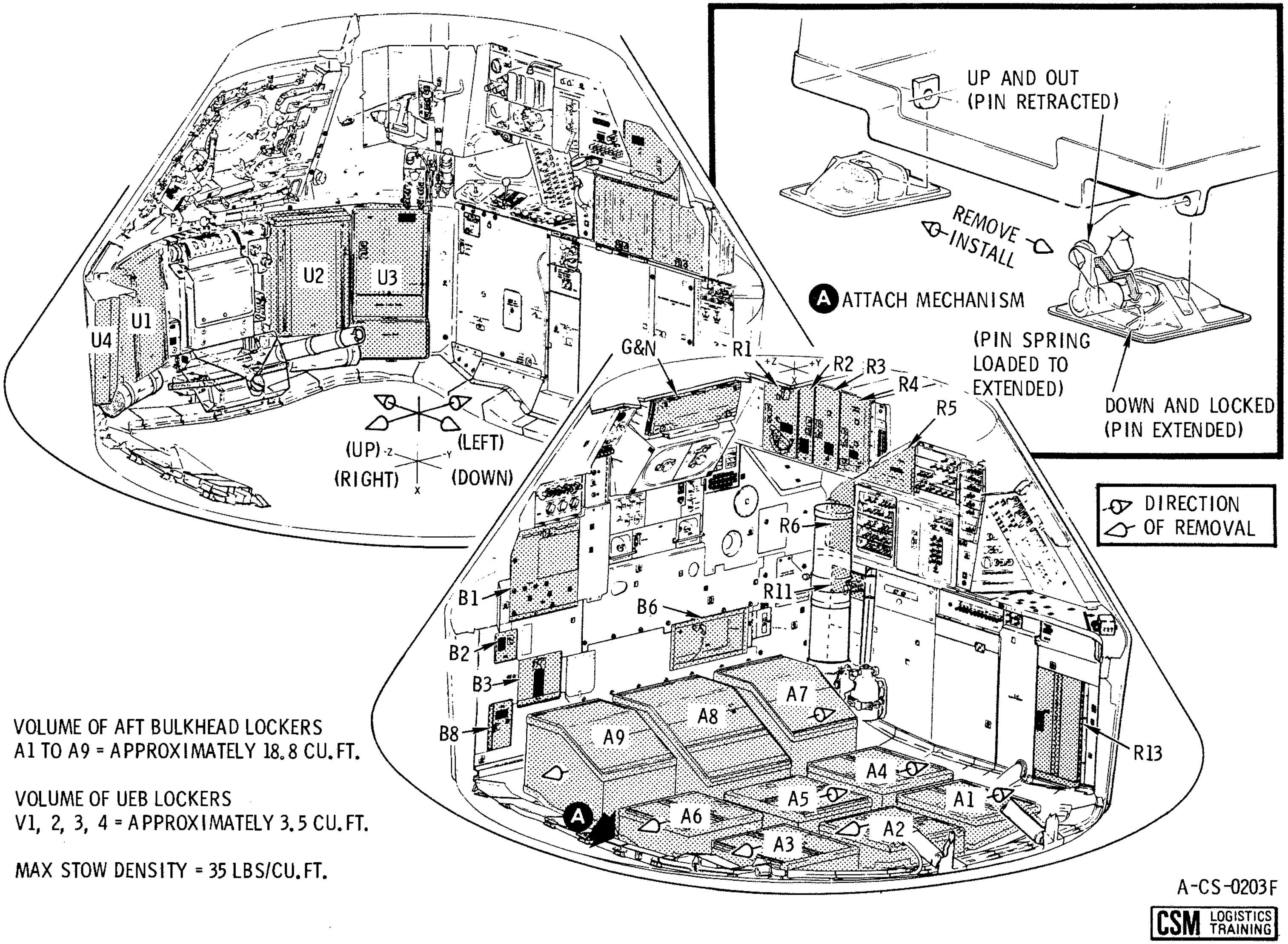
1.1.2.3.3 Loose Equipment Stowage (Figure 1-8)

The stowage of numerous items of personal and systems loose equipment is in compartments and lockers (figure 1-8). Compartments are part of the crew compartment structure. Equipment is placed in "cushions" and inserted into the compartments.

The aluminum lockers are packed with equipment in an assembly building and are quickly attached to the aft bulkhead and equipment bays a short time before launch, allowing aft bulkhead access during spacecraft ground processing. The compartment and locker doors have squeeze-type latches and can be opened and closed with one hand. The lockers are numbered A-1 through A-9 from the upper left corner (under right crewman's head) and reading from left to right (when facing the side hatch). For detailed information, refer to section 2.12.9.3.

1.1.2.4 SC Controls and Displays Panel Numbering System (Figure 1-9)

The controls and displays (panels, switches, meters, valve handles, etc.) for operation of the spacecraft and its systems are located throughout the crew compartment. The location, nomenclature, function, and power source of the controls and displays are provided in section 3 of this handbook. The panel numbers indicate the equipment bay and area of location. The panel numbering system is shown in figure 1-9. For instance, the 100 to 199 series will be located in the lower equipment bay (LEB). The LEB is divided into panel areas such as 100-119 in the upper left, 120-139 in the upper center, etc. The advantage of this system (given a panel number and knowing the numbered areas) is to enable the crew to pinpoint the area and locate the panel very quickly.



VOLUME OF AFT BULKHEAD LOCKERS
A1 TO A9 = APPROXIMATELY 18.8 CU.FT.

VOLUME OF UEB LOCKERS
V1, 2, 3, 4 = APPROXIMATELY 3.5 CU.FT.

MAX STOW DENSITY = 35 LBS/CU.FT.

Figure 1-8. Stowage Compartments and Lockers

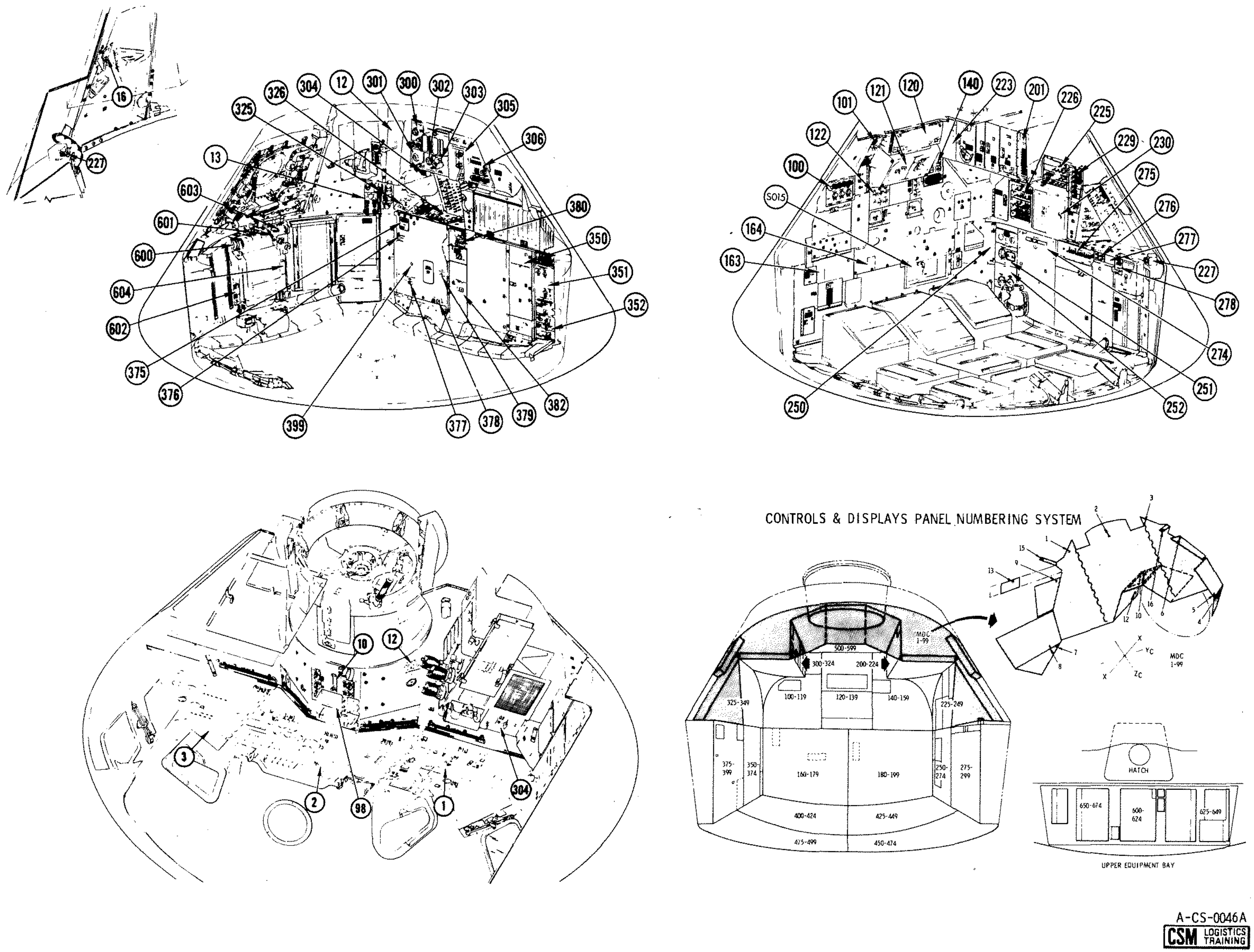


Figure 1-9. Control and Display Panels Numbering System

1.1.2.5 Crew Couches

The primary function of the couches is to support the crew during accelerations/decelerations up to 30 g forward and aft (±X), 18 g up and down (±Z), and 15 g laterally (±Y). Because the critical g-load is during landing, an attenuation system is used to reduce the deceleration load on the crew. There are two attenuation subsystems, external and internal. Secondary function of the crew couches is to position crew at duty stations and provide support for the translation and rotation hand controls, lights, and other equipment.

The couches are designated (structurally) as left, center, and right; by crew position they are (left to right) commander (CDR), scientist pilot (SPT), and pilot (PLT).

1.1.2.5.1 CM Impact Attenuation System

During a water impact, the CM deceleration force will vary from 3 to 27 g, depending on wave shape and horizontal velocity at impact. The impact attenuation system reduces the impact forces on the crew to a value within their tolerance level. A major portion of the energy (75 to 90 percent) is absorbed by the impact surface (water) and the deformation of the CM structure. The impact system is divided into two subsystems: external and internal, which are described in the following paragraphs.

External Attenuation. The external attenuation subsystem consists of four crushable ribs installed in the aft compartment (figure 1-10). The ribs, located between the inner and outer structure in the vicinity of the +Z axis, are constructed of bonded laminations of corrugated aluminum. The CM is suspended, during atmospheric descent, at a 27.5-degree angle (hang angle) by the parachute subsystem. Because of the hang angle, the first point of contact at impact is in the area of the crushable ribs.

Internal Attenuation. Eight attenuation struts are provided for connecting the crew couches to the CM inner structure. Each strut is capable of absorbing energy at a predetermined rate; two through the use of crushable aluminum core and six through the use of "cyclic struts." The cyclic strut utilizes cyclic material deformation concept of energy absorption by rolling ductile metal torus elements (bracelets) in friction between a concentric rod and cylinder. The force applied to the struts causes the bracelets to roll, absorbing energy (figure 1-11).

Two Y-Y axis struts (crushable aluminum) are located at the outer extremities of the couch assembly at the hip beam. The cylinder end of each strut is firmly attached to the unitized couch while the piston end, containing a flat circular teflon coated bearing, reacts against a flat bearing plate (attenuation panel) attached to the structure, the clearance being 0.040 to 0.064 inch.

Two Z-Z axis struts ("cyclic") are attached to the side stabilizer beams and the aft bulkhead of the structure, just below the side access hatch.

Four X-X axis struts ("cyclic") are attached to the forward CM structure and the beam extremities of the couch. These struts, except for the addition of a lockout mechanism, are basically the same as the Z-Z axis struts. A lockout mechanism is provided on each X-X strut to prevent any strut attenuation prior to landing (during normal mission flight loads). After deployment of the main parachute, the lockouts are manually unlocked.

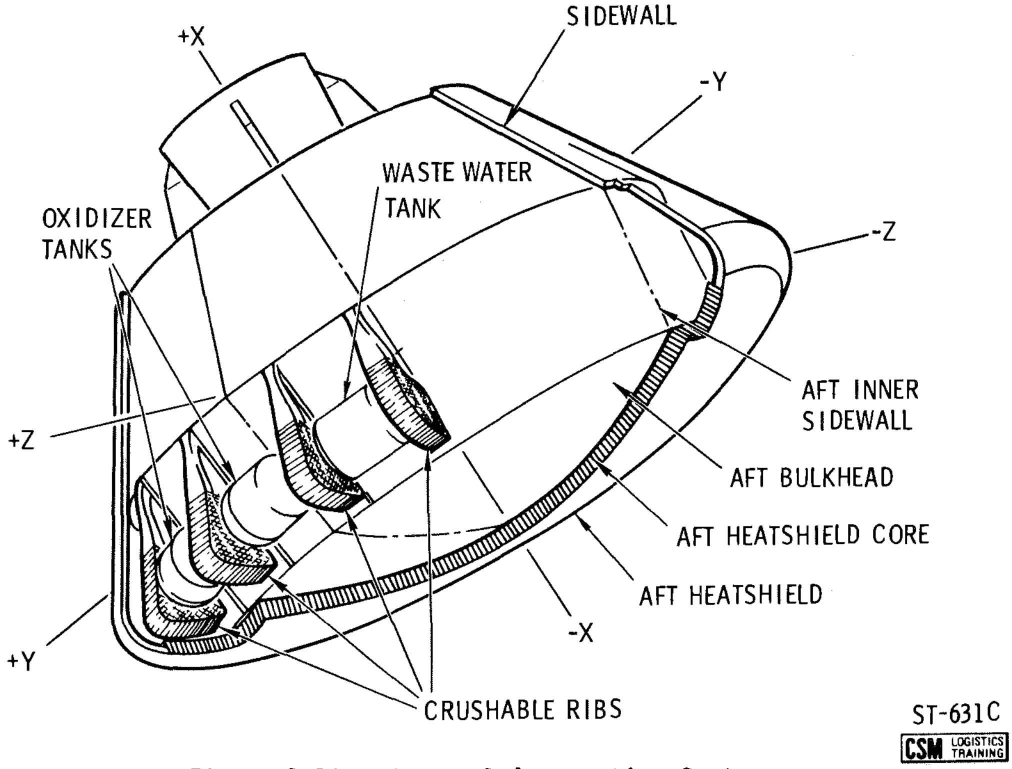


Figure 1-10. External Attenuation System

The external and internal attenuation systems restrict the crew couch structure to an excursion envelope as shown in figure 1-12. The excursion envelope also determines the size or height of the aft bulkhead stowage lockers. The land landing envelope must not exceed with stowage during the launch phase or exceed the water landing envelope during the entry phase or physical injury to the crew may result.

1.1.2.5.2 Foldable Couch Structure (Figure 1-13)

The three foldable couches are supported by strong beams. The backpan angle to the Y-Z plane (horizontal) is 4 degrees 30 minutes.

Description. The couch structure utilizes two strong side stabilizer beams for attachment of the foot XX and ZZ attenuator struts and a cross-member head beam for attachment of the head XX attenuator struts. The left, center, and right couches are attached to the head beam by a hinge/pip pin and are attached to the side stabilizer beam by a large Marmon-type clamp (figure 1-13).

Each couch consists of a headrest, body support with backpan, seatpan, legpan, and footpan. The left couch has two controller supports/armrests, inboard and outboard. The right couch has only the inboard, or left armrest. Support for the body is accomplished by a web of Armalon (multiple layers of fiberglass beta cloth, impregnated and covered with Teflon) over the support frame from the headrest to the foot pan (figure 1-14). Static electricity is grounded to the body supports by a network of metal buttons and an inter-connecting metal screen in the backpan.

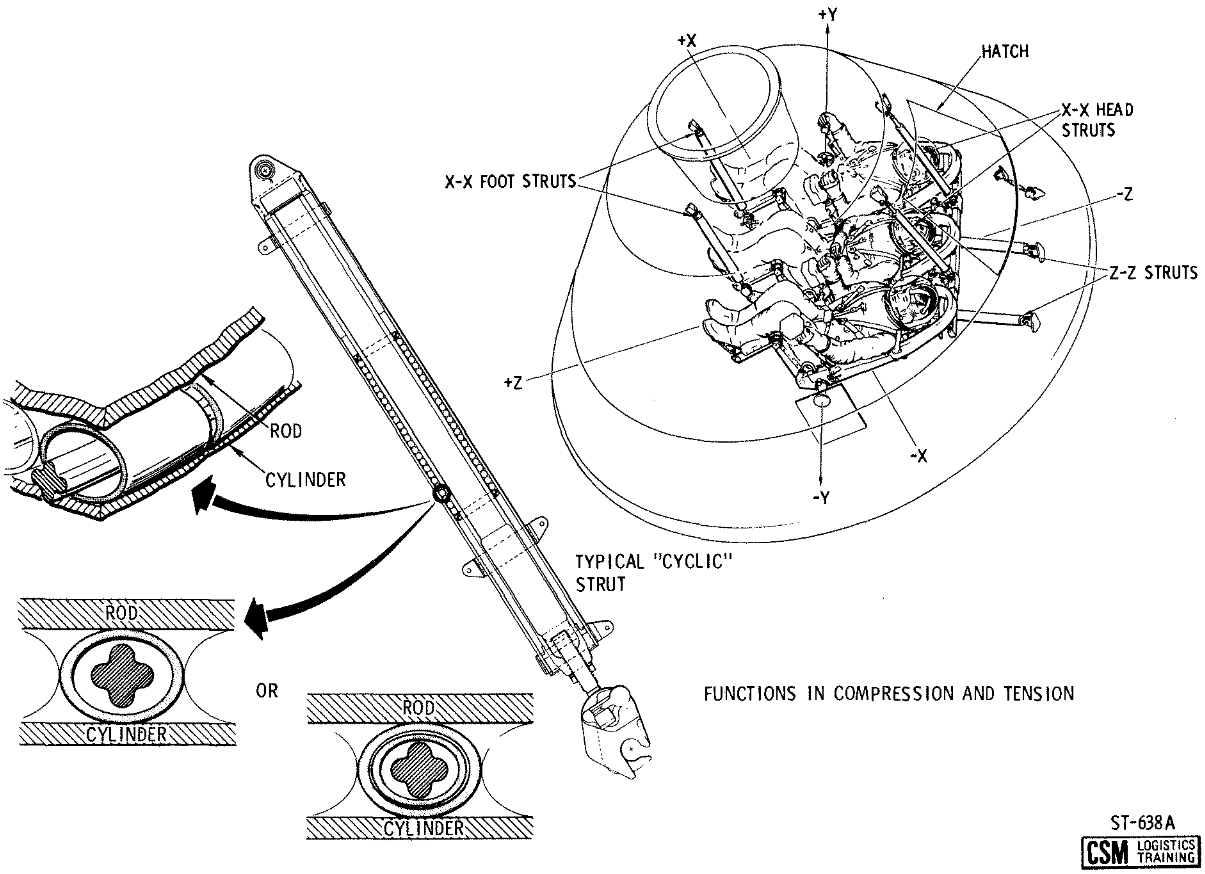


Figure 1-11. Internal Attenuation System

The headrest is sheet steel with Teflon pad. To adjust it for crewman torso length, the headrest has 6-1/2 inches of longitudinal adjustment headward or footward in 1/4-inch increments. Adjustment is accomplished by the gearshift-type handle alongside the headrest.

The body support, or backpan, consists of a steel rectangular-tube frame with a shoulder beam and a hip Y-Y beam. The hip beams of the outboard couches (1 and 3) house the Y-Y attenuator struts on the outboard side.

The Marmon clamps that attach to the side stabilizer are part of the hip Y-Y beam. The body support frame can rotate around its attach point on the head beam and can fold at the shoulder beam. The shoulder straps of the restraint harness and one-half of the lap belts are solidly attached to the shoulder beam.

Controller supports/armrests rotate and are attached to the body support tubes in the area of the crewman's elbow and have various positions. The left couch outboard armrest has 65-, 90-, 120-, and 180-degree positions, measured from the backpan, and supports the translation control (figure 1-15). The other two armrests have 65-, 90-, 125-, and 180-degree positions. The armrests are held in position by a spring-loaded wedge into a slotted cam. The wedge is lifted by a bell crank actuated by a pistol

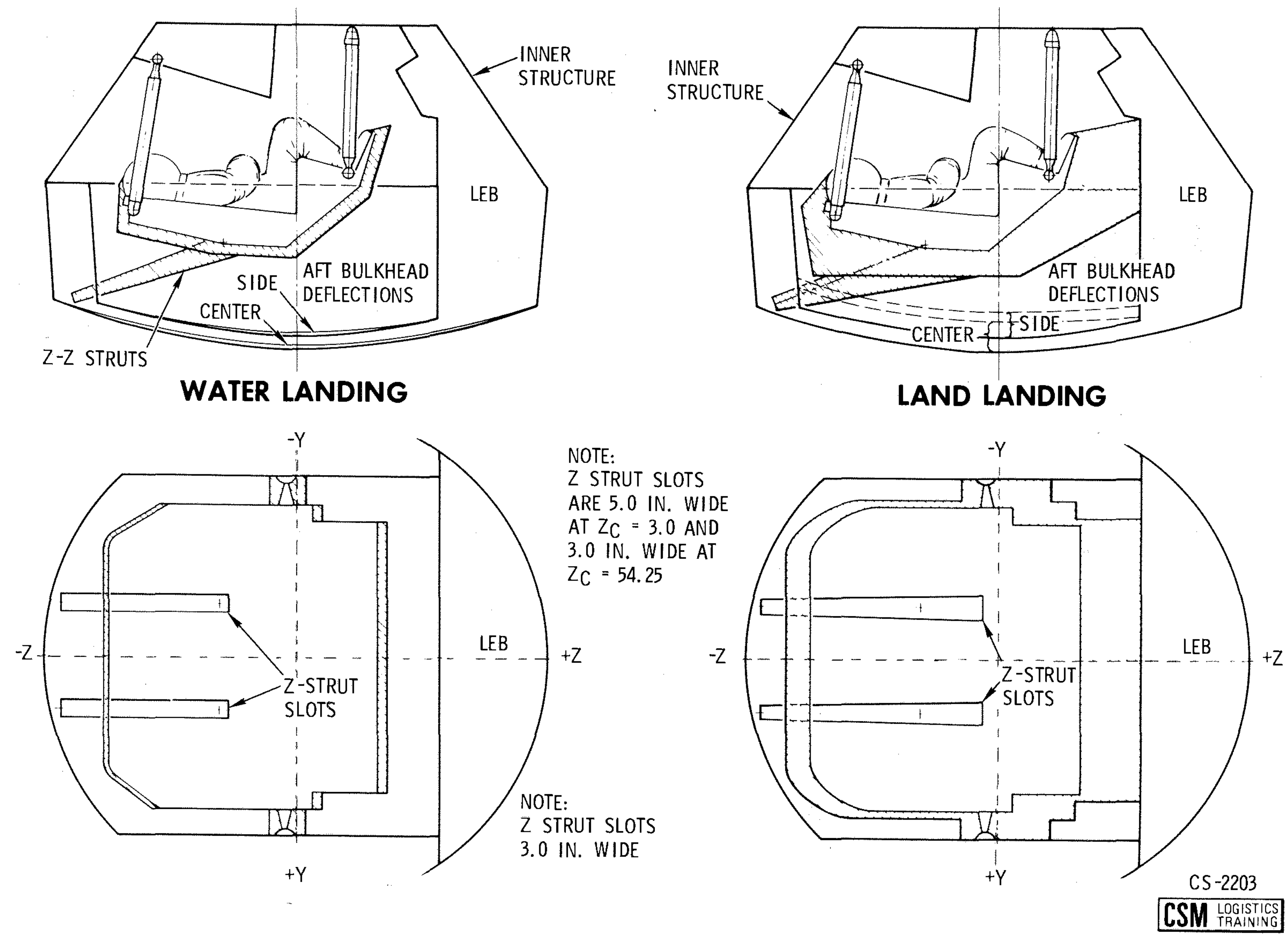


Figure 1-12. Couch Excursion Envelope

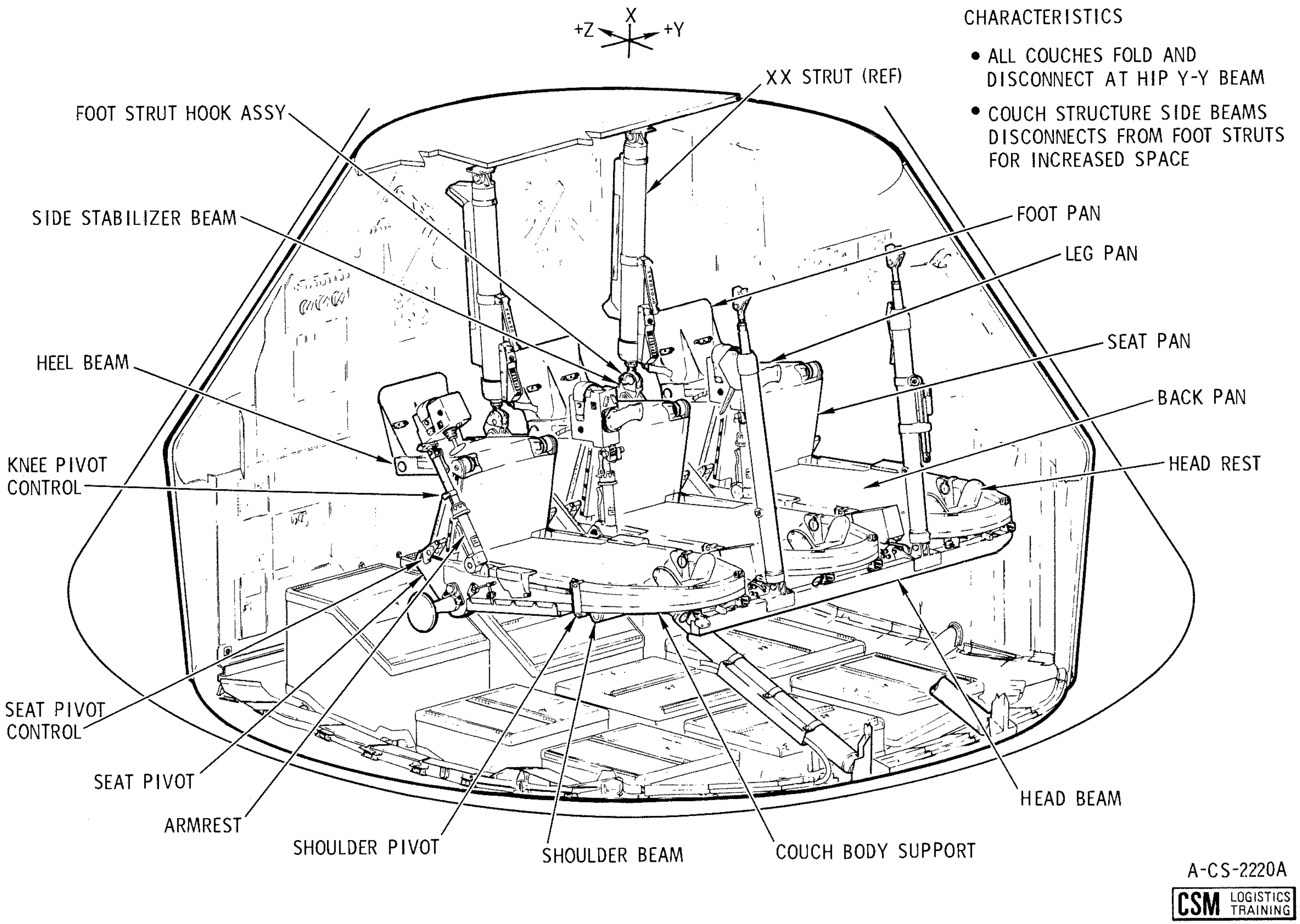


Figure 1-13. Skylab Foldable Crew Couch Structure

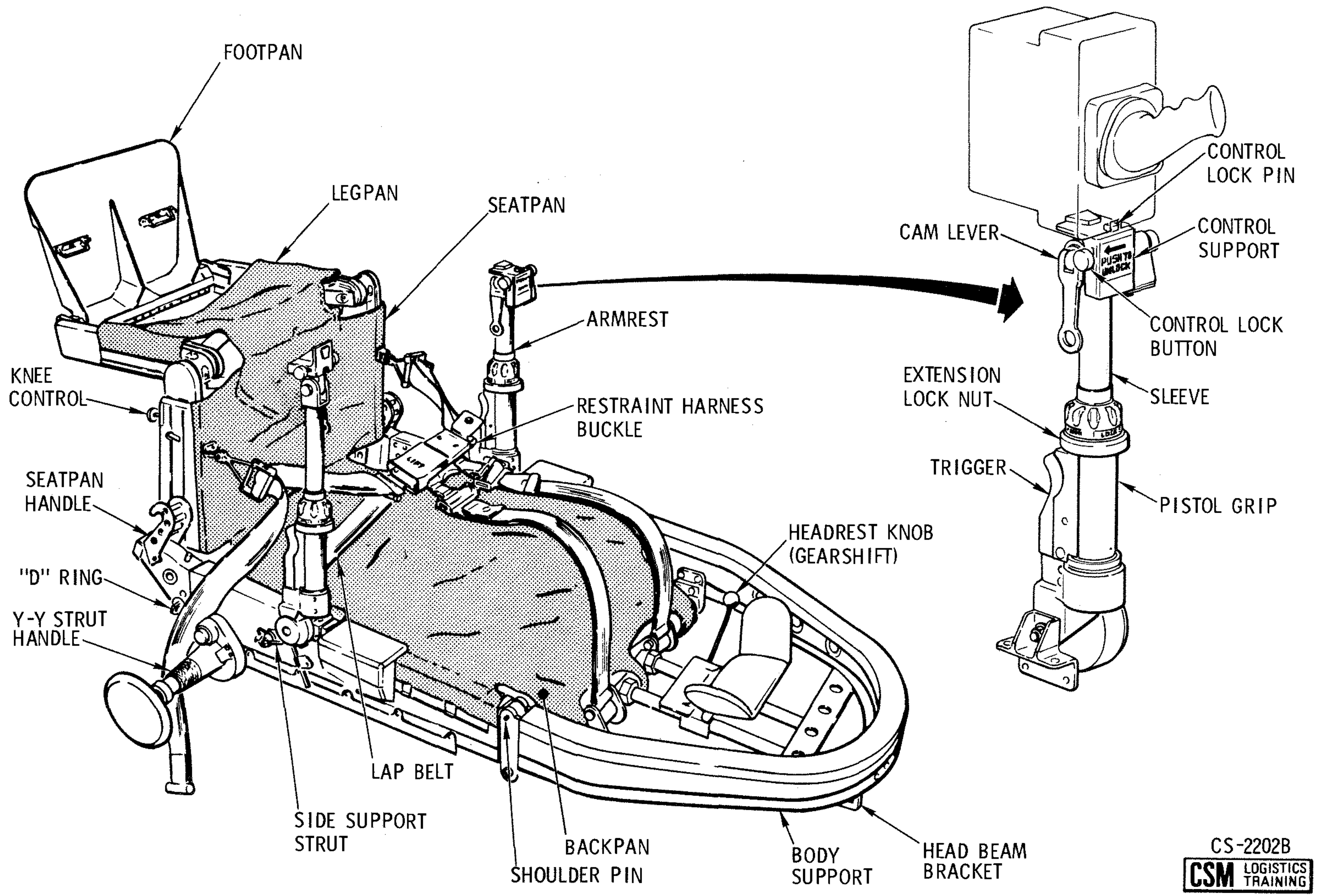


Figure 1-14. Foldable Couch Components

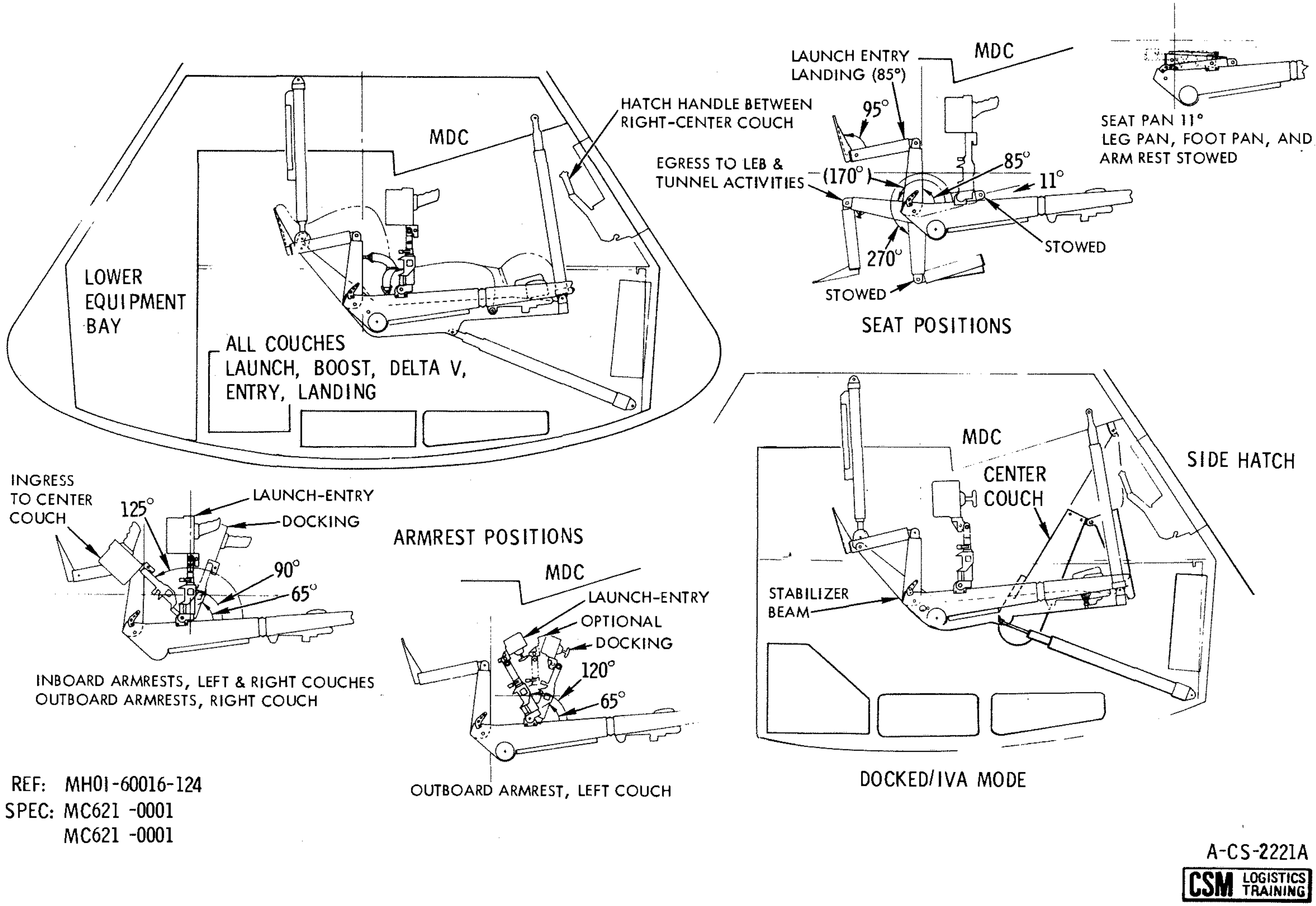


Figure 1-15. Skylab Foldable Couch Positions

grip handle/trigger attached to the armrest. To rotate the armrest, the pistol grip handle is squeezed, pulling the wedge out of the cam, and the armrest rotated to the desired position. The sleeve can extend 3.5 inches from the armrest and is locked by a serrated nut. The nut unlocks the sleeve when turned CCW, and locks the sleeve when turned CW. The rotational and translation controls are locked on a dovetail by extending a pin; however, the controlling button extends into the center couch area. There is a danger of the center crewman bumping the control lock button and retracting the pin; therefore, a lock is located on the shaft to prevent the button from being actuated accidentally.

The control support (with dovetail) pitches up and down, and is locked and unlocked at its pivot by a cam lever. The control support pivots to allow the correct positioning of the translation or rotation control during docking and the normal mission phases.

The seatpan (seat) angles are 9, 85, 170, and 270 degrees. The 9-degree position is held by a detent, the 85- and 170-degree positions are lockable, and the seat travel is stopped at 270 degrees. The seatpan controls are located on the body supports at each side of the hips. The seat locked position is with the lever footward; the unlocked position is with the lever headward. One-half of the lap belt is attached to the seatpan frame.

The seatpan is connected to the legpan frame at the knee beam in a 78-degree angle. The knee control on each side of the couch locks and unlocks the seatpan to legpan angle. Unlocked, the seatpan-to-legpan angle will go to 15 degrees (folded), and to 180 degrees (flat).

The footpan has two positions, 95 degrees and folded (0 degrees). There are mechanical stops at each position. The footpan has two cleats and clamps which restrain the boots when properly engaged.

Seatpan, Legpan, Armrest, and Footpan Mission Positions. During the mission phases, there is a need to place the couch components into various positions. The following chart indicates the positions of the couch components during launch, boost, entry, and landing; egress-ingress to center couch to LEB and tunnel activities; IVA activities; and docking.

Mission Phases or Tasks (Figure 1-15)	Launch, Boost, Entry and Landing	Docked, Sleeping, and IVA	Docking
Seatpan angle	85°	170°	85°
Legpan angle	78°	78°	78°
Footpan angle	95°	95°	95°
Shoulder angle	180°	180° (left, right) 310° (center only)	180°

SPACECRAFT

Mission Phases or Tasks (Figure 1-16)	Launch, Boost, Entry and Landing	Docked, Sleeping, and IVA	Docking
Armrest angle outboard left couch	120°	120°	65°
Armrest angle inboard left couch	90°	125° to 180°	65°
Armrest angle inboard right couch	90°	125° to 180°	65°
Control support pitch angle	0°	0°	-25°

Foldable Couch Adjustments. The couch has many adjustments that can be performed during the mission. The following chart gives a step by step procedure for making the adjustments, beginning with the headrest and progressing to the footrest. Because the couches are actuated in training during 1 g, the 1-g procedures are given also.

Task	Procedure	Results/Remarks
	NOTE • Directions are for person lying on couch. • Inboard/outboard movements - relative to couch.	
A. Headrest adjustment, headward - footward movement of 6.5 in.	1. Lift control knob (gearshift) toward head. 2. Hold gearshift knob in unlocked position and slide headrest to desired position. 3. Release gearshift knob.	1. Disengages lock. 2. Lock is spring-loaded to locked position. 3. Engages lock.
B. Folding couch at shoulder pivot (bar).	1. Retract both shoulder pins (figure 1-16). 2. Verify hip clamps free. 3. Grasp shoulder bar and jerk.	1. Couch free to rotate about shoulder pivot. 2. Head end attached, hip end unattached. 3. Couch can fold to approximately 310°.

SPACECRAFT

Task	Procedure	Results/Remarks
C. Armrest adjustments C1. Armrest rotation or pitching (Armrests lock in 65°, 90°, 120° (L) and 125° (R) positions) (figure 1-16)	1. Squeeze armrest handle/ trigger. 2. Rotate (pitch) armrest to desired position. (Wedge will engage at next slot unless handle is squeezed continually.)	1. Disengages wedge from slotted cam. 2. Wedge is spring-loaded to locked position. NOTE When rotating the outboard armrest of the left couch, caution should be exercised to prevent the rotational control cable from hitting the stowed O_2 hose as damage may result to either object.
C2. Armrest extension (0-3.75 in.) (figure 1-16)	1. Rotate armrest extension lock nut CCW. 2. Extend control to desired position. 3. Lock into position by rotating lock nut CW.	1. Approximately 1/4 turn will unlock sleeve. 2. Pulls sleeve out of barrel. 3. Cam will lock barrel to sleeve.
C3. Control support pitching (Translation control pitch = 0°-55°) (Rotational control pitch = 0°-25°) (figure 1-16)	1. Move end of control support cam lever. 2. Holding control or handle, pitch it to desired angle. 3. Move end of cam lever down and outboard.	1. Unlocks control support. 3. Locks control support.
C4. Control attachment and locking, unlocking	1. Press control lock button down and swing lock hook away. 2. Press control lock button inboard. 3. Slide control onto support dovetail. 4. Press control lock button outboard. 5. Swing lock hook to button and hook on shaft (inboard armrests only).	1. Unlocks button so shaft can slide. 2. Retracts control lock pin. 3. Attaches control to support. 4. Extends control lock pin, locking control onto support. 5. Prevents control lock button from sliding to unlocked position.
D. Seatpan adjustment D1. Zero g seatpan adjustment, mid-mission application (Seatpan locks in 11°, 85°, 170°/stops at 270°.) (figure 1-16)	1. Place both seatpan handles in unlocked position (headward). 2. Move seatpan to desired position. 3. Place <u>one</u> handle in locked position (footward).	1. Disengages seatpan latches. Seatpan free to move. 3. One lock is sufficient in zero g.

Task	Procedure	Results/Remarks
D2. One g or greater seatpan adjustment, training, preflight, test, launch and entry application. (During one g, stand at LEB to adjust seatpan.) (figure 1-16)	1. Support seatpan (with hands or feet) and place both seatpan handles in unlocked position (headward). 2. Move seatpan to desired position, maintain support. 3. Place both seatpan handles in locked position (footward).	1. Damage may result to mechanisms if seatpan is allowed to drop to next position. 2. Same as 1. 3. In one g or greater, both latches may be locked to reduce strain on mechanisms.
E. Legpan to seatpan adjustment (15°, 78°) (During zero g, use one control. During one g or greater, use both controls and support legpan during movement.) (figure 1-16)	1. Pull knee control out and up to unlocked position. 2. Position legpan to desired position. 3. Pull knee control out and down to locked position.	1. Retract knee control pin from slotted cam. 3. Extends knee control pin, and locks.
F. Footpan adjustment (0°-95°) (figure 1-16).	1. Swing footpan to desired position.	1. Mechanical stops at 0° 95°.
F1. Engaging-disengaging foot restraints	1. Place both spacesuit boots or entry boots on footpan with heels together. 2. Move boots outboard while heels slide on footpan. 3. To disengage, move boots inboard while heels slide on footpan.	1. Pre positioning boots. 2. Footpan cleats will engage boot heels. 3. Cleats will disengage from boot heel.

Foldable Couch Mission Operations. During the mission, there are tasks into which the couches are integrated. The following chart indicates those tasks and gives a step by step procedure. Figures are also referenced.

Task A, Preparing center couch for docked mode or IVA, describes the folding and stowing of the center couch during the docked mode, intravehicular activities, or sleeping. It clears the center aisle and allows access to the aft bulkhead lockers.

SPACECRAFT

Task	Procedure	Results/Remarks
A. Preparing center couch for docked mode or IVA		Performed after docking.
A1. Clear center couch from hip clamps. (Crewman standing in LEB) (figure 1-16) NOTE If the center couch is to be removed during one g conditions, the outboard (left and right) couches should not be occupied. Otherwise, extreme difficulty will be experienced during the removal.	1. Fold footpan to 0°, lock legpan to 15°, lock seatpan to 11°, and pull buckle from between seatpan and backpan (figure 1-16) 2. Pull center couch hip clamp knobs down 2 in. (toward aft bulkhead). 3. Using knob, unscrew shaft (CCW) until it is flush with trunnion. 4. Swing knob towards LEB opening clamp (figure 1-16). 5. Retract one or both Y-Y struts (figure 1-21). 6a. During zero g, force center couch toward aft bulkhead and disengage couch from clamp plates. 6b. During one g, place clamps in intermediate position as a caution. Hold center couch backpan firmly while forcing couch toward aft bulkhead until couch disengages. Fully open clamps and lower hip end of couch to aft bulkhead. 7. Lower couch to aft bulkhead lockers. 8. Close Marmon clamps.	1. Folding couch seatpan. 2. Knob engages shaft. 3. Trunnion will be free to rotate. 5. Relieves pressure on clamp plate. 6a. Frees footward end of couch from clamps. (Couch structure may have to be shaken.) 6b. Clamps in intermediate position will support couch if it slips. Outboard couches may have to be lifted to take pressure off center couch clamp plates. 7. Couch is now ready to fold. 8. Clears clamp area.
A2. Fold center couch at shoulder bar. (figure 1-16)	1. Retract shoulder pins. 2. Grasp shoulder bar and pull toward MDC. 3. Push upper couch and headrest toward hatch, guiding lower couch and seatpan between hockey sticks (side stabilizer beams).	1. Couch is ready to fold. 2. Couch folds at shoulder pivot. 3. Couch rotates about head beam and compactly folds against hatch.
A3. Secure folded couch with shoulder straps (figure 1-16).	1. Fully lengthen shoulder straps and route over hand bar (monkey bar) on MDC-2. 2. Connect shoulder straps to lap buckle and tighten.	2. Couch secured to MDC hand bar and center aisle clear.

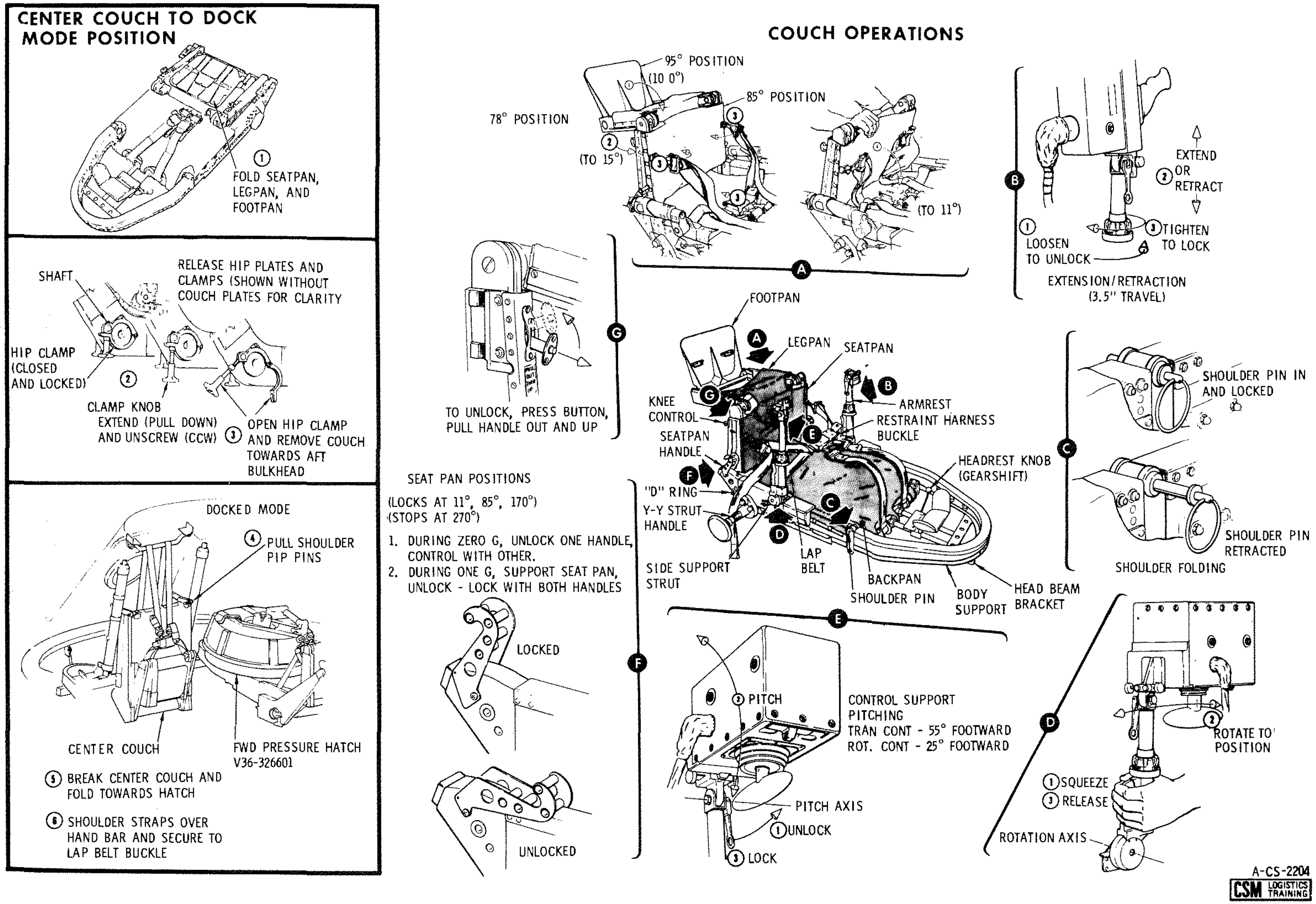


Figure 1-16. Couch Adjustments

Figures 1-17 through 1-20 deleted.

Pages 1-25 through 1-28 deleted.

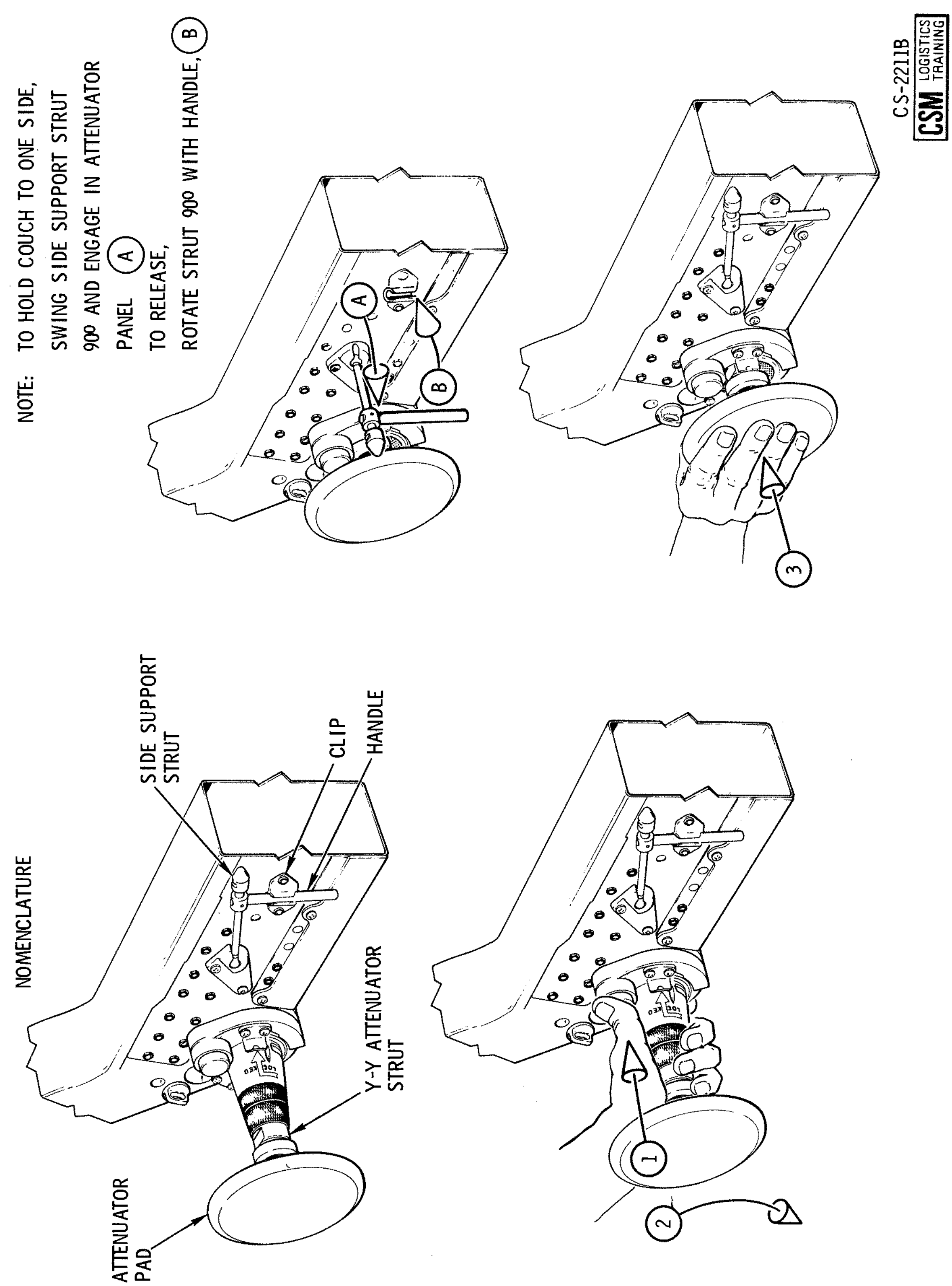


Figure 1-21. Y-Y Strut Retraction

Figure 1-22. Deleted

1.1.2.6 CM Mechanical Controls

Mechanical controls are provided in the crew compartment for manual operation of the side access hatch and the forward access tunnel hatch. Tools for emergency opening or securing the hatches are in the toolset pouch in a locker on the aft bulkhead.

1.1.2.6.1 Side Access Hatch

Side access to the crew compartment is through an outward-opening single-integrated hatch assembly and adapter frame (figure 1-23). The hatch provides for primary structure pressure loads and supports the hatch thermal protection system. It includes a primary flexible thermal seal, hinges, and a latch and linkage mechanism. Provisions for a scientific airlock, window, or closeout adapter, a pressure dump valve, and a GSE cabin purge port are also incorporated. A secondary thermal seal is attached to the heat shield ablator around the hatch opening and bears against the inner structure. The adapter frame, which closes out the area between the inner and outer structure, provides the structural continuity for transmitting primary structure loads around the hatch opening without transmitting the tension or compression loads to the hatch. The inner structure adapter frame contains a single primary pressure seal.

Hatch opening is accomplished by a manually driven mechanism which operates the latch and linkage mechanism. The latch and linkage mechanism provides a hatch lock for pressure loads and for pressure sealing of the crew compartment. (It does not provide shell continuity for hook tension or compression loads.) The door deployment mechanism is driven by a single handle with a ratchet mechanism. The internal lever operation is normal to the hatch with the inboard stroke driving the latches closed while the outboard stroke drives the latches open. The hatch opens 100 degrees minimum to provide clearance for the crewman past the scientific airlock when mounted on the hatch. A counterbalance system is provided to assist in opening the hatch in both normal and emergency conditions and attenuate the opening and closing velocity of the hatch (figure 1-24).

The hatch is normally latched and unlatched manually from the inside by an actuating handle permanently attached to the gear box (figure 1-23). Prior to handle actuation, the two control levers are positioned to the LATCH or UNLATCH positions as shown in view E and G. Both selectors are placed in identical positions when operating the latches. Next, the shear pin release lever is placed in the UNLOCK position. This will extend the orange-yellow shear pin permitting free rotation of the gear box. When the latches are fully engaged, the orange-yellow pin will retract, locking the gear box. The shear pin may be sheared during an emergency opening of the hatch. A sheared condition is indicated by the protruding red pin, within the orange-yellow pin, as indicated in view E.

After the preceding steps have been performed, the handle is unstowed. This is accomplished by gripping the handle (which depresses the trip bar) and pumping approximately five 60-degree strokes. This will fully engage or disengage the latches.

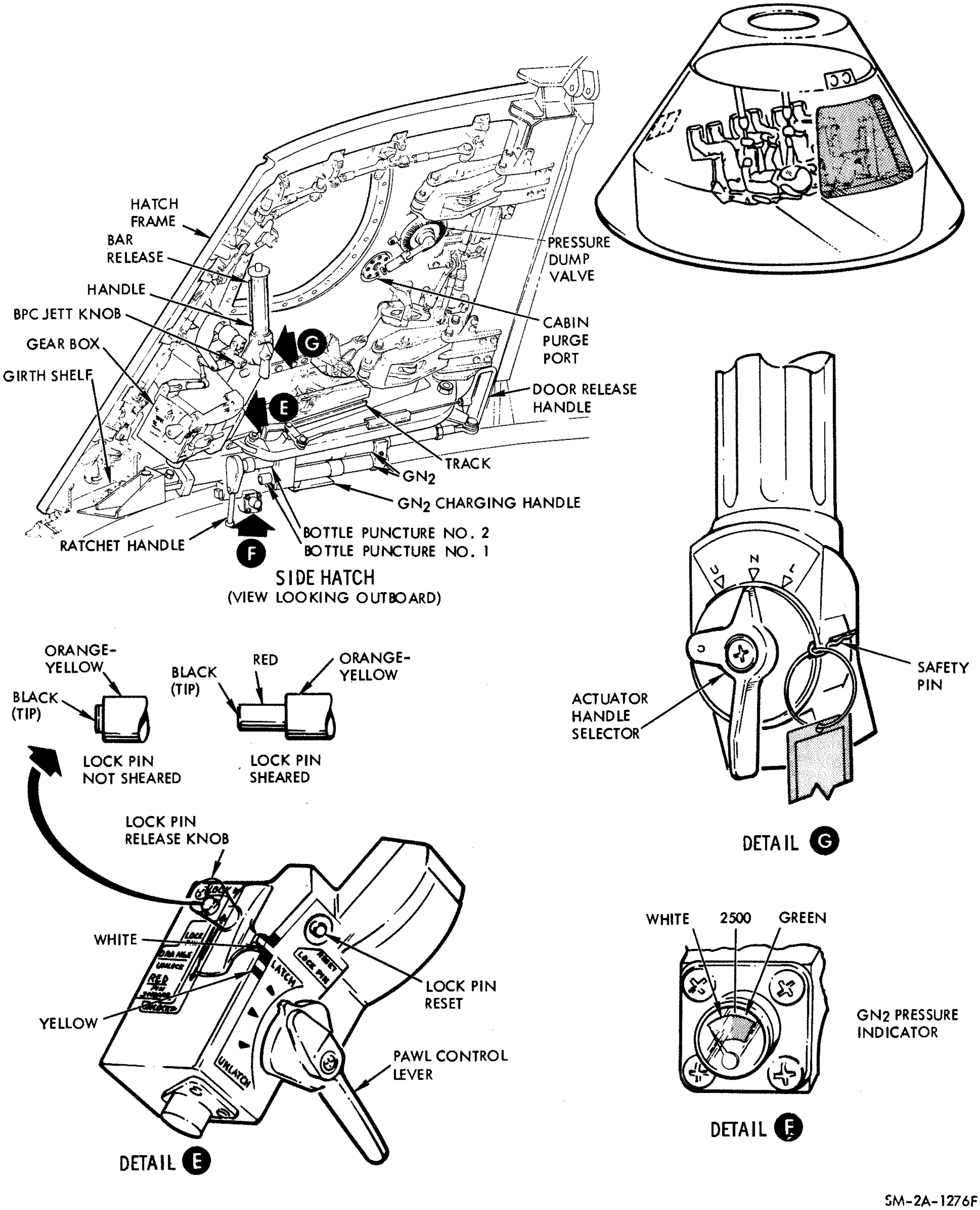
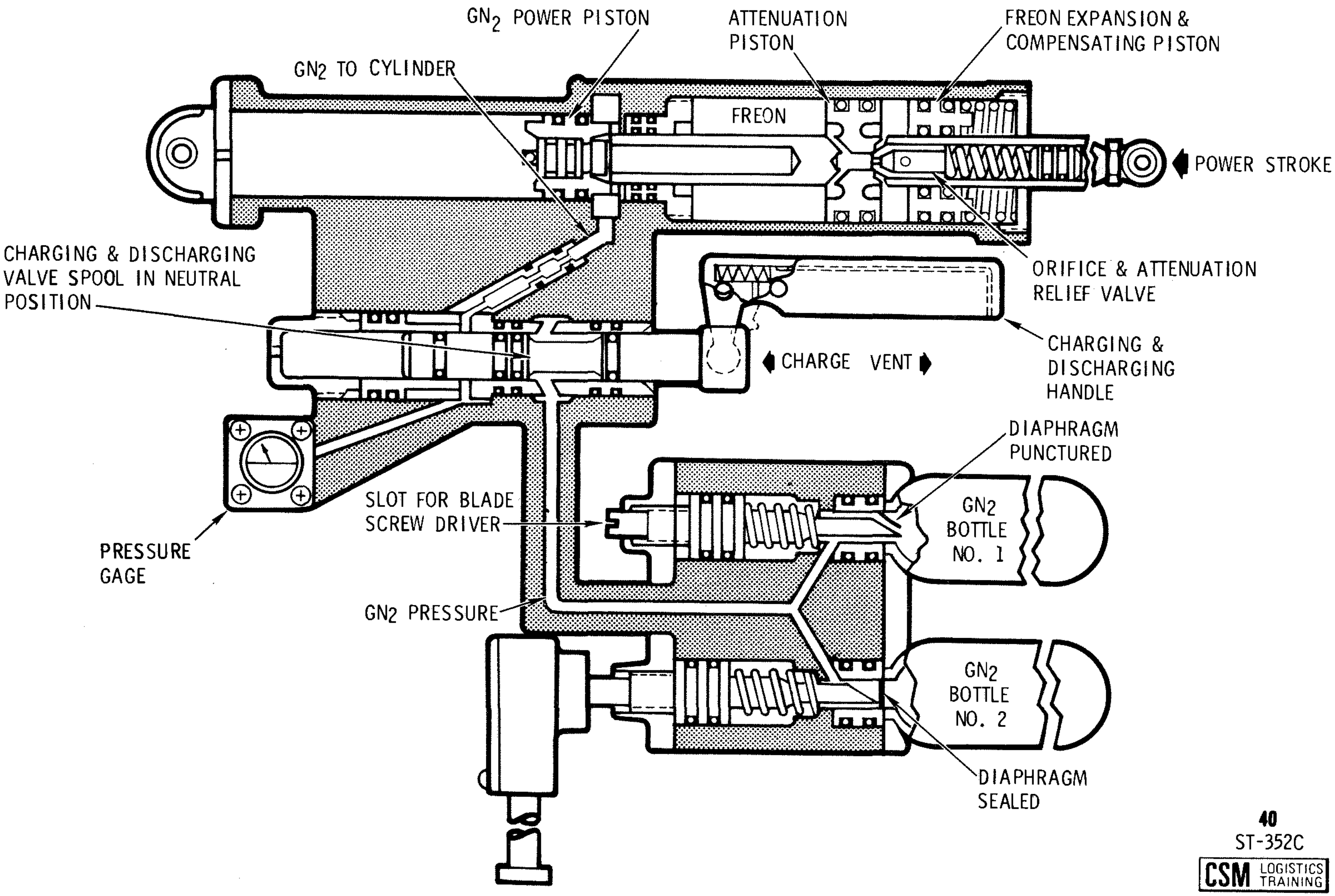


Figure 1-23. CM Side Access Hatch



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CSM LOGISTICS TRAINING

Figure 1-24. CM Hatch Counterbalance Schematic

External operations are accomplished by using GSE or the in-flight tool through the penetration on the outside of the hatch (figure 1-25). With no one inside the CM, the hatch should not be closed from outside without the safety pin installed (view G) and the pawl control lever (view E) in the neutral position.

Located around the outer periphery are 15 mechanically actuated latches that engage the inner structure frame. In the event of a linkage jam or if the hatch will not hold in the closed position, auxiliary devices are utilized to provide thermal protection and structural continuity during entry and render the CM in a water-tight condition for limited flotation capability. The devices are called jack screws and are part of the in-flight tool set. (Refer to section 2.12.)

A manually operated pressure dump valve is located in the hatch. The valve is capable of venting the cabin from 5 to 0.1 psig in one minute. The valve may be operated from the inside or outside by a suited crewman. A tool interface on the hatch exterior is provided for preflight, space flight, and postflight operation.

The hatch has provisions for installation of a window assembly or scientific airlock. Depending on the mission, or spacecraft, the window or airlock may be attached using the appropriate adapter.

The hatch mechanism operates the boost protective cover (BPC) mechanism for emergency modes, and is sequenced to ensure release of the BPC hatch prior to unlocking the CM hatch. The BPC is hinged and retained with a tethering device when the combined unified and BPC hatch are opened. A permanent release handle (D-ring) is utilized on the outside of the BPC to manually unlatch the drive mechanism (figure 1-25).

The counterbalance assembly is a stored energy device capable of opening the unlatched CM and BPC hatches in a one g environment. It is mounted below the CM hatch and connected to a track on the hatch inner surface. Figure 1-24 illustrates schematically the mechanization of the counterbalance assembly. To pressurize the system for normal pad operation, the number one bottle diaphragm is punctured utilizing a blade screwdriver. The charging and discharging handle is actuated and the gas bleeds into the cylinder. The high-pressure gas provides an opening force that opens the hatch when the latches are released. The cylinder must be vented after launch to adjust the system for zero-g operation.

The counterbalance maintains an outward force on the hatch to balance the weight, overcome seal drag, and assist in opening the hatch when the latches are actuated. The ground crew can easily close the hatch by pushing it closed and recompressing the gas (nitrogen). In this manner the nitrogen is not vented. Additional nitrogen is introduced only if the cylinder pressure has decayed. A pressure indicator permits monitoring the system pressure.

The number two bottle may be punctured after landing by ratcheting the ratchet handle until the diaphragm is pierced. This bottle should not be punctured until ready to open the hatch.

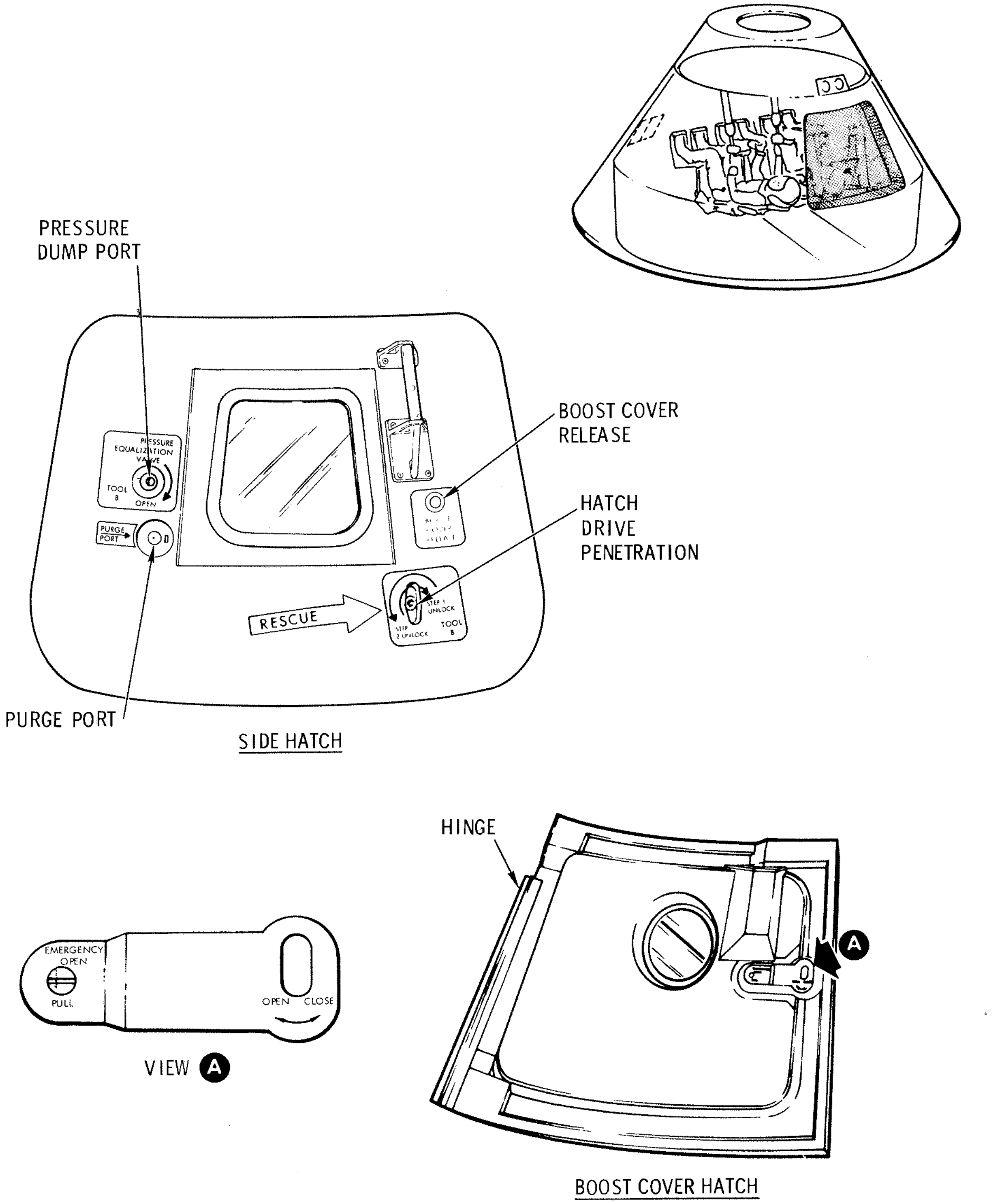

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Figure 1-25. Exterior Hatch Views

1.1.2.6.2 Forward Hatch (Figure 1-26)

The spacecraft utilizes a combined tunnel (forward) hatch. This single hatch serves as a pressure and thermal hatch. The hatch latching mechanism consists of six separate jointed latches whose linkage is driven by a handle from within the crew compartment. The latch operation from the inside is a 60-degree compression stroke selected by rotating the handle to the latch or unlatch position. A sealed drive is provided through the hatch, making the mechanism operable from the outside. A pressure equalization valve is provided to equalize pressure in the tunnel prior to hatch removal.

Should the gear box fail when the hatch is being installed, the crew, using the in-flight tool set, can disconnect the gear box (view B) and operate the latches using the auxiliary drive (view D). Refer to section 2.13 for further details.

1.1.2.6.3 Windows and Shades

Five windows are provided through the inner structure and heat shield of the CM: two forward viewing and two side observation windows and a hatch window. (See figure 1-5.) During orbital flight, photographs of external objects will be taken through the viewing and observation windows. The inner windows are made of tempered silica glass with 0.25-inch-thick double panes, separated by 0.1 inch of space, and have a softening temperature point of 2000°F. The outer windows are made of amorphous-fused silicon with a single 0.7-inch-thick pane. Each pane contains an anti-reflecting coating on the external surface, and has a blue-red reflective coating on the inner surface for filtering out most infrared and all ultraviolet rays. The glass has a softening temperature point of 2800°F, and a melting point of 3110°F.

Shades are provided for controlling external light entering the CM. These shades, individually designed for each window configuration, are made of aluminum sheet. The shades are opaque for zero-light transmittal, have a nonreflective inner surface, and are held in place by wing levers.

1.1.2.7 Crew Stations

The place of crew activity, the objects of crew activities, and crew activity requirements are referred to as "crew stations." Generally, the term "crew stations" includes anything that supports the flight crew and is synonymous with crew systems and equipment; thus, the terms are generally interchangeable. A major distinction is that crew stations include controls and displays requirements, certain aspects of the environmental control system, and crew couches, whereas in crew systems and equipment they are not usually included.

This section does not describe crew activities but briefly relates the scope of crew systems and equipment by grouping. For a comprehensive description, refer to section 2.12.

1.1.2.7.1 Spacesuit

The spacesuit is a flexible environmental chamber in which the crewman is supplied a flow of pressurized oxygen. It includes undergarments, ventilation ducts, and the communication system. There are many accessories such as the oxygen hose, communication cables, couplings, screen caps, connector plugs, and maintenance kits.

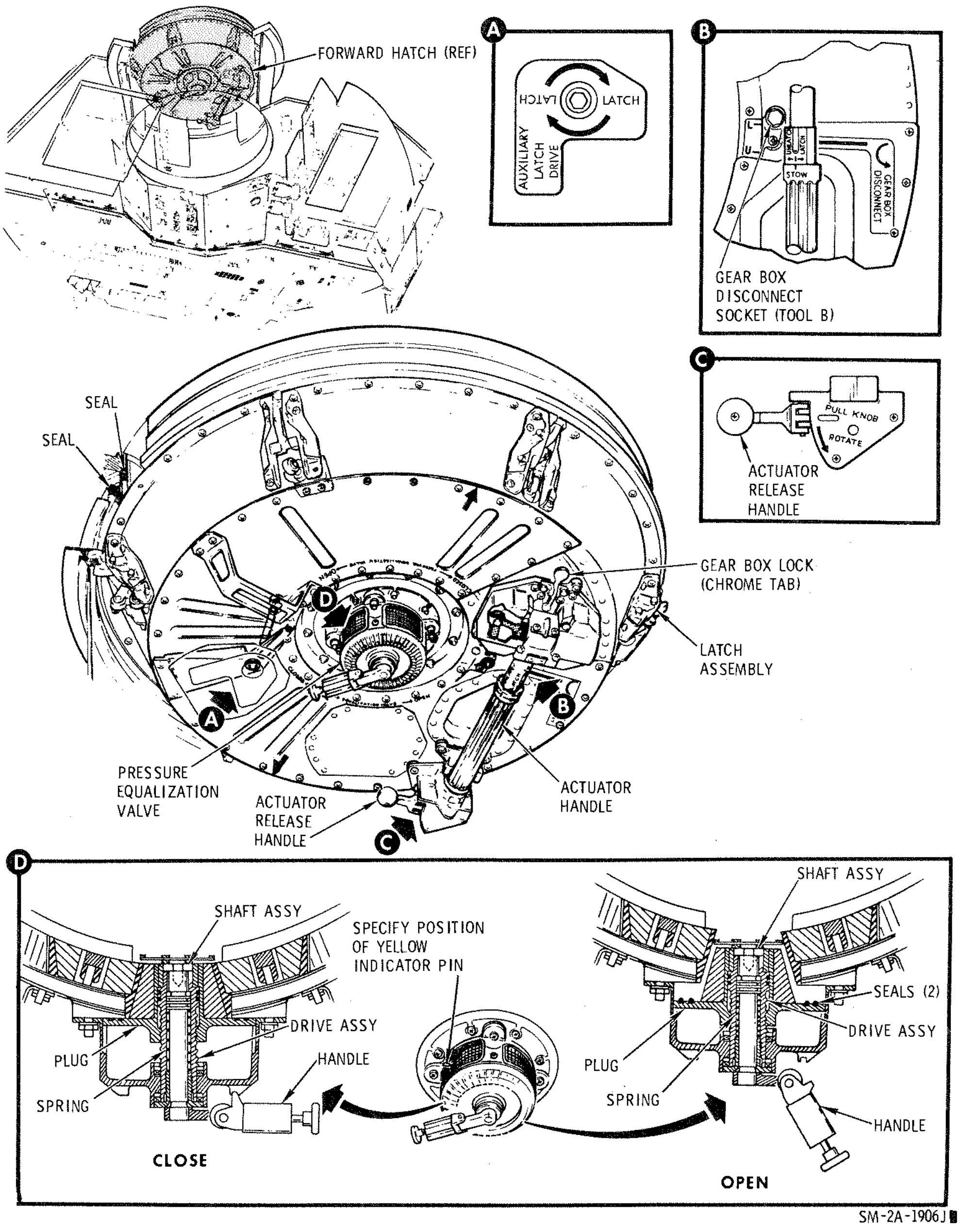


Figure 1-26. CM Forward Access Hatch

1.1.2.7.2 Restraints

Crew restraints range from the restraint harness to restrain the crew in the couches to the zero-g restraints, such as the sleep station restraints, and hand-holds. Equipment restraints include a number of snaps and Velcro patches on the crew compartment structure and utility straps which clasp to the snaps.

1.1.2.7.3 Internal Sighting Aids

Internal sighting aids are objects that assist the crew in controlling light or sighting. These include shades, mirrors, crewman optical alignment sight, and window markings.

1.1.2.7.4 External Illumination Aid

The external illumination aid is a light on the exterior of the spacecraft called the docking spotlight.

1.1.2.7.5 Mission Operational Aids

Objects or devices that assist the crew in the mission and the operation of the spacecraft are operational aids. The aids are the flight-data file, tool set, cameras, and miscellaneous accessories.

1.1.2.7.6 Crew Life Support

Items included are drinking and food reconstitution water devices, food, waste management, and personal hygiene. Waste management consists of equipment for collecting, disinfecting, and storing the feces, and expelling urine overboard.

1.1.2.7.7 Medical Equipment

The medical requirements are filled by the bioinstrumentation harness that transmits the respiration and pulse of the crew to the communications system, and a medical kit that contains medication for contemplated contingencies.

1.1.2.7.8 Radiation Monitoring Equipment

The crew wears passive and active dosimeters for recording dosages. For measuring the radiation present in the crew compartment, a radiation survey meter is utilized.

1.1.2.7.9 Postlanding Recovery Aids

Upon landing, the crew deploys the dye marker for daytime signaling, or turns on the recovery beacon for night signaling, connects cloth ducts for air, and deploys a grappling hook to snag a sea anchor line. In the event the crew would be forced to abandon the command module, the survival kit would be used for flotation and signaling.

1.1.2.7.10 Stowage and Internal Configuration

In the crew compartment, numerous items of equipment are stowed in lockers or compartments designed to withstand the landing impact. The interior configuration of the crew compartment is shown in figure 1-27. The illustrations also show the equipment bays and spacecraft axes.

1.1.3 SERVICE MODULE (Figure 1-29)

The service module is a cylindrical structure formed by 1-inch-thick aluminum honeycomb panels. Radial beams, from milled aluminum alloy plates, separate the structure interior into six unequal sectors around a circular center section. Equipment contained within the service module is accessible through maintenance doors located around the exterior surface of the module. Specific items, such as propulsion systems (SPS and RCS), fuel cells, and most of the SC onboard consumables (and storage tanks) contained in the SM compartments, are listed in figure 1-29. The service module is 12 feet 11 inches long (high) and 12 feet 10 inches in diameter.

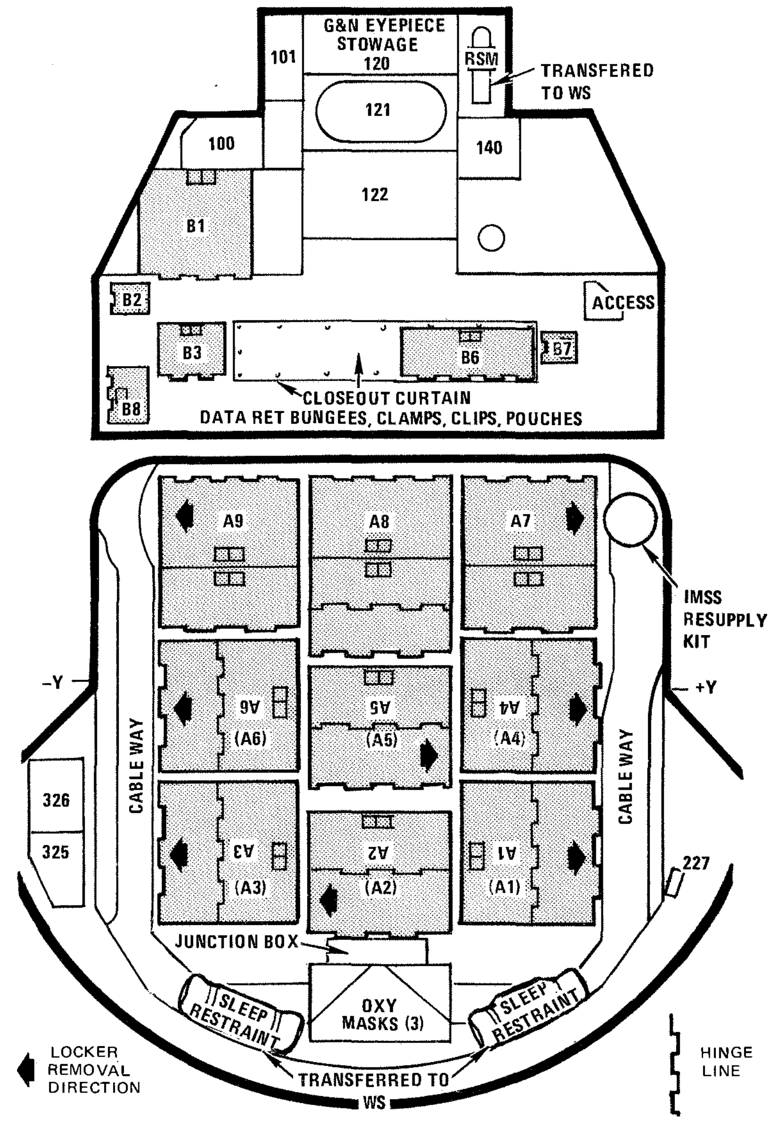
Radial beam trusses on the forward portion of the SM structure provide a means for securing the CM to the SM. Alternate beams, one, three, and five, have compression pads for supporting the CM. Beams two, four, and six, have shear-compression pads and tension ties. A flat center section in each tension tie incorporates redundant explosive charges for SM-CM separation. These beams and separation devices are enclosed within a fairing (26 inches high and 12 feet 10 inches in diameter) between the CM and SM.

1.1.4 SPACECRAFT ADAPTER

The spacecraft adapter (figure 1-30) is a large truncated cone which connects the CSM and S-IVB on the launch vehicle. For the Skylab flights 2, 3 and 4, the adapter is empty with the exception of a stabilizing device for providing structural support to the outer shell. The adapter, constructed of eight 2-inch-thick aluminum honeycomb panels is 154 inches in diameter at the forward end (SM interface) and 260 inches at the aft end. The overall height is approximately 28 feet. Separation of the CSM from the adapter is accomplished by means of explosive charges which disengage the four adapter forward panels from the aft portion. The individual panels are restrained to the aft portion by hinges and accelerated in rotation by pyrotechnic-actuated thrusters. When reaching an angle of 45 degrees measured from the vehicles X-axis, the panels are snubbed by a system of cables and 8 attenuators. Another cable and reel system retains the panels at the 45° orientation.

LOC	PHASE	ITEM NO.	NOMENCLATURE
A1	LAUNCH	0127	HEC BATTERY (2)
	1	1055	IVA PRESS GAGE & CONT
		1150	IVA UMBILICAL & CONT
	ORBIT	1055	IVA PRESS GAGE & CONT
		1150	IVA UMBILICAL & CONT
ON-A1	RETURN	0694	XUV FILM MAG & CANISTER
	LAUNCH	0002	LIQUID COOLED GARMENT
	ORBIT	0089	FECAL CONTAINMENT SYSTEM
	RETURN	0014	HELMET STOWAGE BAG
		0014	ACCESSORY BAG
		0023	ITLSA-EV & ACCESSORIES *
		0080	CONSTANT WEAR GARMENT
		0202	SUIT HARNESS & COVER
		1032	PGA CONTAINER & TIE DOWN STRAP
A2	LAUNCH	–	CONTINGENCY RESUPPLY
	ORBIT	–	CONTINGENCY RESUPPLY
	RETURN	–	EMPTY
ON A-2	RETURN	0600	FECAL VOMITUS RETURN BUNDLE
		1300	M071/073 SAMPLE CONTAINER
A3	LAUNCH	1048	PROBE STOWAGE BAG
		1075	POLY CHOKE ORIFICE ASSY
		1151	O_2 CRYO VENT VALVE
		–	RETURN STOWAGE STRAPS, CUSHIONS, ETC
	ORBIT	0162	SPARE DAC FUSE
		0165	INFLIGHT EXERCISER
		1007-8-	REST STATION RESTRAINTS (3)
		1081-2-3-4	B/U WASTE MANAGEMENT SYSTEM
		–	RETURN STOWAGE STRAPS, CUSHIONS, ETC
	RETURN	0693	XUV FILM MAG & CANISTER
ON A-3	RETURN	0600	FECAL VOMITUS RETURN BUNDLE
		1300	M071/073 SAMPLE CONTAINER
A4	LAUNCH	1057	CO_2 ABSORBER ELEMENTS (4) SHIMS & BAGS
		1101-2	INSTRUMENT SHIELDS (3) & CONT
	ORBIT	1057	CO_2 ABSORBER ELEMENTS (4) SHIMS & BAGS
	RETURN	0190	ETC FILM CANISTER (4) BAGS & CANISTER
		0506	D024 FLIGHT MATERIAL CONT (1) & SAMPLE TRAYS
ON A-4	RETURN	0014	HELMET STOWAGE BAG
		0014	ACCESSORY BAG
		0023	ITLSA – EV & ACCESSORIES *
		0080	CONSTANT WEAR GARMENT
		0202	SUIT HARNESS & COVER
		1032	PGA CONTAINERS (2) & STRAP
A5	LAUNCH	0600	BUNDLE FECAL COLLECTION BAGS
		1154	PORTABLE WASTE STOWAGE CONT
		1201	TV EQUIPMENT-CAMERA (2) LENS (2) MONITORS (2), ETC
		1317	FECAL/VOMITUS BAG CONT (2)
		0137	16 MM POWER PAC & CONT
	ORBIT		EMPTY
	RETURN	0301	S019 FILM & CANISTER
		0310	S190 FILM CASSETTE
ON A-5	RETURN	0600	FECAL VOMITUS RETURN BUNDLE
		1300	M071/073 SAMPLE CONTAINER
A6	LAUNCH	0028	UCTA (6), CLAMPS, CONT
		1057	CO_2 ABSORBER (4) SHIMS, BAGS
	ORBIT	0028	UCTA (3)
		1057	CO_2 ABSORBER (4) SHIMS, BAGS
	RETURN	0230	M133 TAPE CAN & 2 TAPES
		0310	S190 FILM CASSETTES (10) & CONT (4)
		0654	S009 DETECTOR PACKAGE
		0686	M552 EXOTHERMIC PACKAGE & CONT
		0686	M555 SINGLE CRYSTAL GRANIT PACKAGE & CONT
		0686	M551 WELD SAMPLES (3)
		0686	VACUUM CLEANER CUP ASSY (2)
		0695	T003 FILTER, INSERT, LOG CARDS & CONT
ON A-6	RETURN	0014	HELMET STOWAGE BAG
		0014	ACCESSORY BAG
		0023	ITLSA – EV & ACCESSORIES *
		0080	CONSTANT WEAR GARMENT
		0202	SUIT HARNESS & COVER
		1425	PGA TIE DOWN STRAPS (2)

LOC	PHASE	ITEM NO.	NOMENCLATURE
A7	LAUNCH	0009	SECONDARY O_2 PACK (2) & CONT
		0080	CWG (3) & CONT
		0091	MINI CALCULATOR (HP 35) BATT PACK, CONT
	ORBIT	0082	TISSUE DISPENSER (2)
		1072	M512 POWER CABLE
		–	RETURN STOWAGE STRAPS, CONTAINERS, ETC
	RETURN	0250	SAMPLE PROCESSOR (12)
		0600	URINE SPECIMEN RETURN CONTAINER, TRAYS, SAMPLES, VIALS



* INCLUDES POCKET ASSEMBLIES, HELMET, IVA GLOVES, COMM CARRIER, WRIST DAM

LOC	PHASE	ITEM NO.	NOMENCLATURE
A8	LAUNCH	0002	LIQUID COOLED GARMENT
		0007	PRESSURE CONTROL UNIT (2) BRACKETS & CONT
		0020	EVA GLOVES (2) PR
		0089	FECAL CONTAINMENT SUBSYSTEM
		1066	MDA POWER UMBILICAL
		1067	MDA CONTROL UMBILICAL (A&B)
	ORBIT	0002	LIQUID COOLED GARMET
		0089	FECAL CONTAINMENT SUBSYSTEM
	RETURN	0103	16 MM FILM CASSETTES (25)
		0688	S052 CAMERA, COVER & CONT
		0689	S054 CASSETTE, SHUTTER ACTUATOR, CONT
		0691	S056 FILM MAG & CONT
		0692	HA1 FILM MAG & CONT
		0699	T027 SAMPLES & CANISTER
		1302-3-4-15	16 MM FILM CONTAINERS (9)
		–	RETURN CUSHIONS – STRAPS – RESTRAINTS
ON A8	RETURN	0600	FECAL VOMITUS RETURN BUNDLE
		1300	M071/73 SAMPLE CONTAINER
A9	LAUNCH	0141	55 MM F/2 UV LENS
		0143	35 MM FILM CASSETTE & CONT
		0686	M555 SINGLE CRYSTAL GROWTH PACKAGE, CONTAINER, SUPPORT, ETC
		–	RETURN STOWAGE STRAPS, BRACKETS, CUSHIONS, ETC
	ORBIT	1479	EREP TAPE STOWAGE SUPPORTS
	RETURN	0314	EREP TAPE, REEL, CONT, SUPPORT
		0317	S149 CASSETTE & HOLDER
		0682	S183 FILM CAROUSEL & CONT
		–	RETURN STOWAGE STRAPS, CUSHIONS, BRACKETS, ETC
B1	LAUNCH	0004-5	HEEL RESTRAINTS (LEFT & RIGHT) (3)
		0057	ENTRY HEAD REST PAD (3)
		0082	TISSUE DISPENSER (4)
		0083-4-5	UTILITY TOWEL ASSEMBLIES (3)
		0701	PERSONAL RADIATION DOSIMETER (4)
	ORBIT	0004-5	HEEL RESTRAINTS (LEFT & RIGHT) (3)
		0082	TISSUE DISPENSER (2)
		0083-4-5	UTILITY TOWEL ASSEMBLIES (3)
		0260	IODINE DISINFECTANT TABLETS (3)
		0701	PERSONAL RADIATION DOSIMETER (1)
		1139	WATER BAG & DRINKING VALVE (3)
		1201	TV CABLE
	RETURN	0082	TISSUE DISPENSER (2)
		0083-4-5	UTILITY TOWEL ASSEMBLIES (3)
		0260	IODINE DISINFECTANT TABLETS (3)
		0701	PERSONAL RADIATION DOSIMETERS
		1139	WATER BAG & DRINKING VALVE (3)
		1201	TV CAMERA, LENS, MONITOR, CABLES, ETC
B2	LAUNCH	1022	PGA O_2 COUPLING ASSY (3)
	ORBIT	1042	PGA CONNECTOR COVER CONT (1)
	RETURN	1149	UMBILICAL SCREEN CAPS (3)
B3	LAUNCH	0100	16 MM DAC
		0106	75 MM KERN LENS
		0107	16 MM FILM MAGAZINE
		0111	16 MM MIRROR
		0113	POWER CABLE
		0117	18 MM KERN LENS
		0120	70 MM HEC
		0121	70 MM FILM MAG
		0127	HEC BATTERY (2)
B3	LAUNCH	0128	80 MM LENS
		0133	SPOTMETER
	ORBIT	0106	75 MM KERN LENS
		0120	70 MM HEC
		0127	HEC BATTERY (2)
		0128	80 MM LENS
		0133	SPOTMETER
	RETURN	0102, 8	16 MM FILM MAG (5)
		0120	70 MM HEC
		0121	70 MM FILM MAG
		0127	HEC BATTERY (2)
		0128	80 MM LENS

Figure 1-27. Skylab 2 (CM 116) Stowage Chart (Sheet 1 of 2)

, ETC

, ETC

BAGS

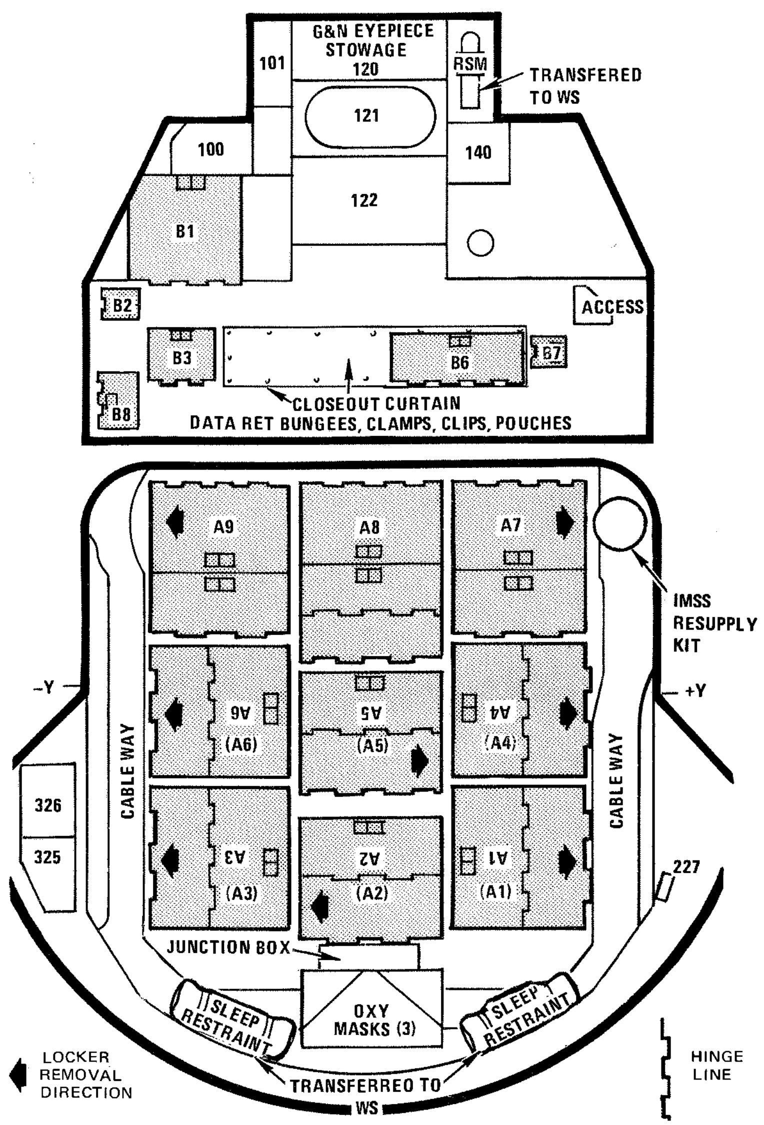
BAGS
TER
MPLE TRAYS

IONITORS (2), ETC

GE & CONT

NT

LOC	PHASE	ITEM NO.	NOMENCLATURE
A7	LAUNCH	0009 0080 0091	SECONDARY O_2 PACK (2) & CONT CWG (3) & CONT MINI CALCULATOR (HP 35) BATT PACK, CONT
	ORBIT	0082 1072 –	TISSUE DISPENSER (2) M512 POWER CABLE RETURN STOWAGE STRAPS, CONTAINERS, ETC
	RETURN	0250 0600	SAMPLE PROCESSOR (12) URINE SPECIMEN RETURN CONTAINER, TRAYS, SAMPLES, VIALS



*INCLUDES POCKET ASSEMBLIES, HELMET, IVA GLOVES, COMM CARRIER, WRIST DAM

LOC	PHASE	ITEM NO.	NOMENCLATURE
A8	LAUNCH	0002 0007 0020 0089 1066 1067	LIQUID COOLED GARMENT PRESSURE CONTROL UNIT (2) BRACKETS & CONT EVA GLOVES (2) PR FECAL CONTAINMENT SUBSYSTEM MDA POWER UMBILICAL MDA CONTROL UMBILICAL (A&B)
	ORBIT	0002 0089	LIQUID COOLED GARMET FECAL CONTAINMENT SUBSYSTEM
	RETURN	0103 0688 0689 0691 0692 0699 1302-3-4-15 –	16 MM FILM CASSETTES (25) S052 CAMERA, COVER & CONT S054 CASSETTE, SHUTTER ACTUATOR, CONT S056 FILM MAG & CONT HA1 FILM MAG & CONT T027 SAMPLES & CANISTER 16 MM FILM CONTAINERS (9) RETURN CUSHIONS – STRAPS – RESTRAINTS
ON A8	RETURN	0600 1300	FECAL VOMITUS RETURN BUNDLE M071/73 SAMPLE CONTAINER
A9	LAUNCH	0141 0143 0686 –	55 MM F/2 UV LENS 35 MM FILM CASSETTE & CONT M555 SINGLE CRYSTAL GROWTH PACKAGE, CONTAINER, SUPPORT, ETC RETURN STOWAGE STRAPS, BRACKETS, CUSHIONS, ETC
	ORBIT	1479	EREP TAPE STOWAGE SUPPORTS
	RETURN	0314 0317 0682 –	EREP TAPE, REEL, CONT, SUPPORT S149 CASSETTE & HOLDER S183 FILM CAROUSEL & CONT RETURN STOWAGE STRAPS, CUSHIONS, BRACKETS, ETC
B1	LAUNCH	0004-5 0057 0082 0083-4-5 0701	HEEL RESTRAINTS (LEFT & RIGHT) (3) ENTRY HEAD REST PAD (3) TISSUE DISPENSER (4) UTILITY TOWEL ASSEMBLIES (3) PERSONAL RADIATION DOSIMETER (4)
	ORBIT	0004-5 0082 0083-4-5 0260 0701 1139 1201	HEEL RESTRAINTS (LEFT & RIGHT) (3) TISSUE DISPENSER (2) UTILITY TOWEL ASSEMBLIES (3) IODINE DISINFECTANT TABLETS (3) PERSONAL RADIATION DOSIMETER (1) WATER BAG & DRINKING VALVE (3) TV CABLE
	RETURN	0082 0083-4-5 0260 0701 1139 1201	TISSUE DISPENSER (2) UTILITY TOWEL ASSEMBLIES (3) IODINE DISINFECTANT TABLETS (3) PERSONAL RADIATION DOSIMETERS WATER BAG & DRINKING VALVE (3) TV CAMERA, LENS, MONITOR, CABLES, ETC
B2	LAUNCH ORBIT RETURN	1022 1042 1149	PGA O_2 COUPLING ASSY (3) PGA CONNECTOR COVER CONT (1) UMBILICAL SCREEN CAPS (3)
B3	LAUNCH	0100 0106 0107 0111 0113 0117 0120 0121 0127	16 MM DAC 75 MM KERN LENS 16 MM FILM MAGAZINE 16 MM MIRROR POWER CABLE 18 MM KERN LENS 70 MM HEC 70 MM FILM MAG HEC BATTERY (2)
B3	LAUNCH	0128 0133	80 MM LENS SPOTMETER
	ORBIT	0106 0120 0127 0128 0133	75 MM KERN LENS 70 MM HEC HEC BATTERY (2) 80 MM LENS SPOTMETER
	RETURN	0102, 8 0120 0121 0127 0128	16 MM FILM MAG (5) 70 MM HEC 70 MM FILM MAG HEC BATTERY (2) 80 MM LENS

LOC	PHASE	ITEM NO.	NOMENCLATURE
B7	LAUNCH	1141 1142 1144-5-6	CHLORINATION AMPULE (5) BUFFER AMPULE (5) CHLORINATION SYRINGE & NEEDLE
B8	LAUNCH	0107 1031 –	16 MM MAGAZINE DAC MOUNT RETURN CONTAINERS, STRAPS, ETC
	RETURN	0102-7 0121 –	16 MM FILM MAGAZINES (3) 70 MM FILM MAGAZINES (2) RETURN STRAPS, CONT, ETC
COUCH	LAUNCH –	0601 1038	URINE BAG (3) RE-ENTRY ENCLOSURE BAG (3)
	ORBIT	0051 0601 1038	HEAD REST PAD (3) URINE BAG (3) RE-ENTRY ENCLOSURE BAG (3)
	RETURN	0057	HEAD REST PAD (3)
LEB	LAUNCH	0703 0911 1072 1155-68 –	RADIATION SURVEY METER VERB/NOUN LIST M512 POWER CABLE CLOSE OUT CURTAIN AND COVER VARIOUS DATA RETENTION DEVICES
	ORBIT	0911 1155-68	VERB/NOUN LIST CLOSE OUT CURTAIN & COVER
	RETURN	0911 1155-68	VERB/NOUN LIST CLOSE OUT CURTAIN & COVER

A-CS-8116H

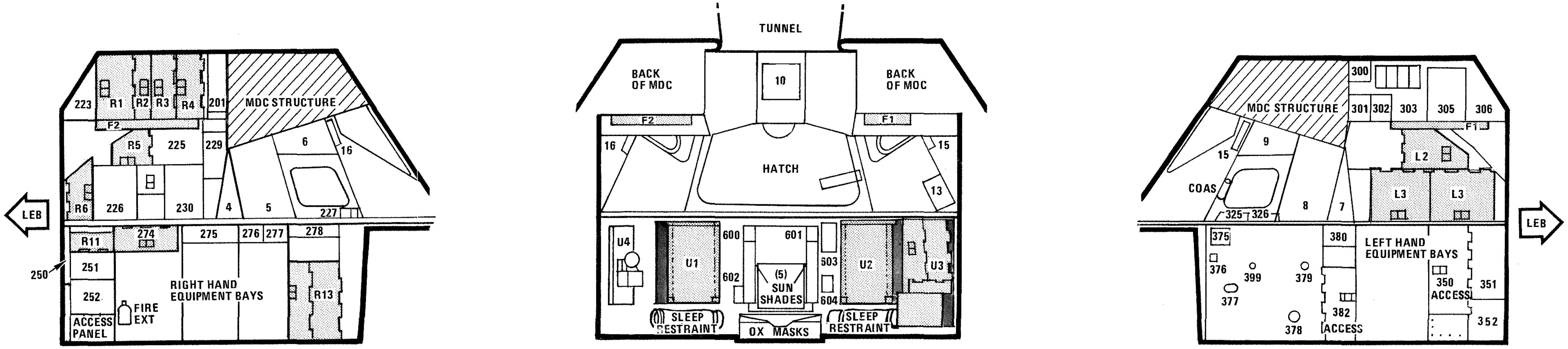
CSM LOGISTICS TRAINING

ge Chart (Sheet 1 of 2)

LOCATION	PHASE	ITEM NO.	NOMENCLATURE
R-1-2	LAUNCH	0184	LAUNCH DATA FILE
	RETURN	0184	RETURN DATA FILE
R-3	LAUNCH ORBIT	0162 0167 0168-70 0173 0704-5	DAC FUSE DATA CARD CLIP (2) DATA CARD KITS BOOK TETHER (3) CIRCUIT BREAKER CAP, LATCH
	RETURN	0167 0168-70 0173	DATA CARD CLIP (2) DATA CARD KITS BOOK TETHER (3)
R4	LAUNCH ORBIT RETURN	0011 0012	SURVIVAL RUCKSACK NO. 1 SURVIVAL RUCKSACK NO. 2
R5	LAUNCH	0157 1043-45 1085-6 1087-8	TAPE, GENERAL PURPOSE & CONTAINER UTILITY & INFLIGHT STRAPS (13) COVER STOWAGE STRAPS (2) PROBE TIE DOWN STRAP (2)
	ORBIT	0157 1043-45 1027-8	TAPE, GENERAL PURPOSE & CONTAINER UTILITY & INFLIGHT STRAPS (13) PROBE TIE DOWN STRAP (2)
	RETURN	0157 1043 1087-8	TAPE GENERAL PURPOSE & CONTAINER UTILITY STRAPS (5) PROBE TIE DOWN STRAPS (2)
R6	LAUNCH ORBIT RETURN	0203 0906 1041	CWG ELECTRICAL HARNESS WITH COVERS (4) SEXTANT SUN FILTERS (2) CWG ADAPTER CONT
R11	LAUNCH ORBIT RETURN	0013 0036 0037-8-9 0058 0086 1024 1026 1081 1082 1083 1084	UCTA CLAMP (3) UTS (3) ROLL-ON CUFFS (3) UCTA XFER ADAPTER UTS RECEIVER URINE FILTER (2) & CONT URINE HOSE & CONT WASTE DUMP B/U CABLE QD COUPLING ASSY (WMS) O_2 DUMP NOZZLE ADAPTER DISCON PRESSURE CUP B/U WMS

LOCATION	PHASE	ITEM NO.	NOMENCLATURE
R13	LAUNCH	0018 0020 0166 0245 0246 –	EMU MAINTENANCE KIT EVA GLOVES ASTRO PREFERENCE KIT (3) MEDICAL ACCESS KIT AUX DRUG KIT STOWAGE STRAPS
U1	LAUNCH ORBIT	0002 0023 0089 1047	LIQUID COOLED GARMENT (2) COMM CARRIER FECAL CONTAINMENT SYSTEM (2) TEMP STOWAGE BAG (3)
	RETURN	0213 1047	OTOLITH TEST GOGGLES TEMP STOWAGE BAG (3)
U2	LAUNCH	0014 0014 0077 0078 0079 1032 1200	HELMET STOWAGE BAG (3) ACCESSORY BAG (3) BOOTS (3) JACKET (3) TROUSERS (3) PGA CONTAINER (3) LIGHT WEIGHT HEAD SET & EAR TUBE (3)
	ORBIT	0025 0077 0078 1061 1200	DUAL LIFE VEST (3) BOOTS (3) JACKET (3) CIRCUIT BREAKER ACTUATOR HANDLE LIGHT WEIGHT HEAD SET & EAR TUBE
	RETURN	1061	CIRCUIT BREAKER ACTUATOR HANDLE
U3	LAUNCH	1000 1026-29 1030 1053 1131 0165	TOOL SET PLV DUCT (3) & BAG LINE SNAGGING HOOK & BAG COAS BULB COAS FILTER INFLIGHT EXERCISER
	ORBIT RETURN	1000 1028-29 1030 1053 1131	TOOL SET PLV DUCT (3) & BAG LINE SNAGGING HOOK & BAG COAS BULB COAS FILTER

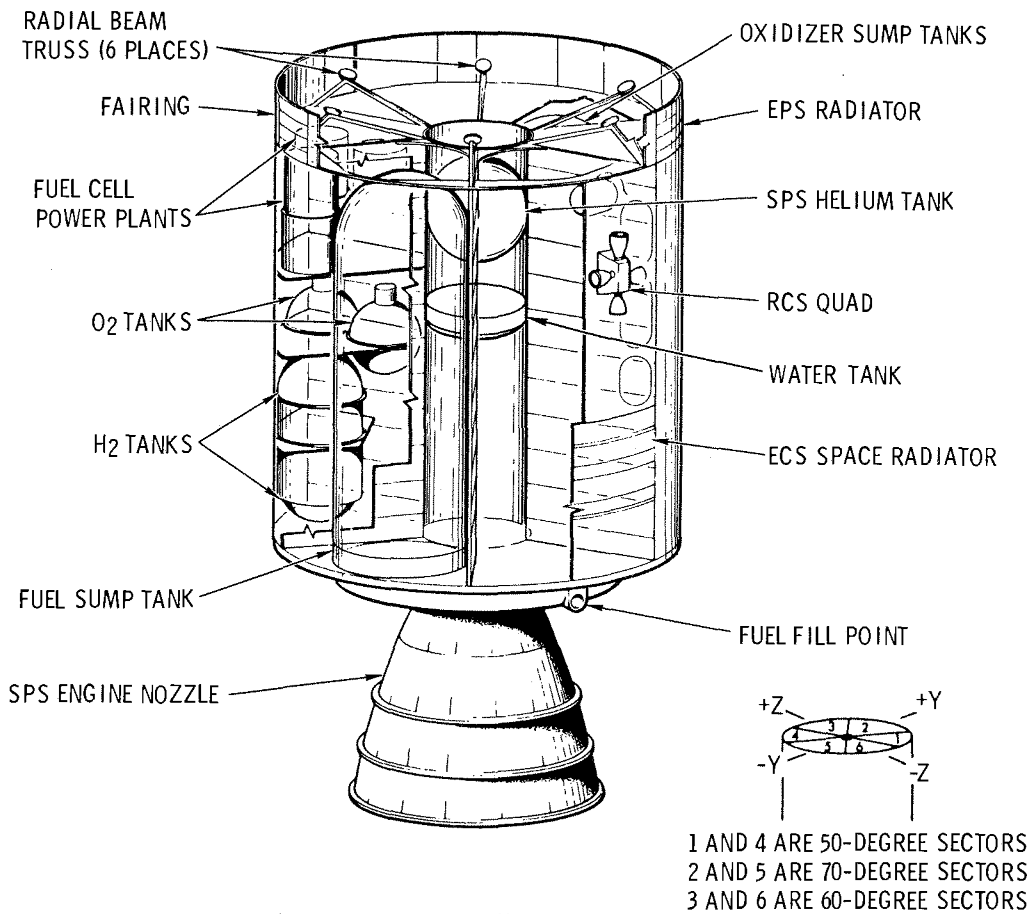
LOCATION	PHASE	ITEM NO.	NOMENCLATURE
L_2	LAUNCH LAUNCH ORBIT RETURN	0073 1001 1002 1006 1056 1128	GAS SEPERATOR CARTRAGE "E" TOOL CCU CONTROL HEAD & BAG CCU CABLE "133" DOCKING PROBE AUX CABLE LiOH GND CABLE
L3	LAUNCH	0209	FOOD PACKAGE ASSY (1-9 MAN DAY, 1-6 MAN DAYS, WATER BAG, & CONT)
	ORBIT & RETURN	0209 0600 1154 1317	FOOD PACKAGE ASSY (1-6 MAN DAY & CONT) BUNDLE, CONTINGENCY FECAL BAGS (12) PORTABLE WASTE STOWAGE BAG FECAL VOMITUS BAG CONTAINER
	RETURN	0028	UCTA (3)
RHEB	LAUNCH	0244 1013 1061	IMSS RESUPPLY KIT FIRE EXTINGUISHER CIRCUIT BREAKER ACTUATOR HANDLE
	ORBIT	0113 1013 1031	DAC SHORT POWER CABLE FIRE EXTINGUISHER DAC MOUNT
	RETURN	0100 0244 0250 0550 1013 1031	16 MM DAC, FILM MAG, POWER CABLE, LENS IMSS RESUPPLY KIT FIXED VIAL OF WHOLE BOOD (6) MEDIA FILLED PETRI DISH FIRE EXTINGUISHER DAC MOUNT



A-CS-8116G
CSM LOGISTICS TRAINING

Figure 1-27. Skylab 2 (CM 116) Stowage Chart (Sheet 2 of 2)

Figure 1-28. Deleted



SERVICE MODULE ITEMS

Sector I
- Descent battery pack
- Propellant storage module
- Experiments S071/ S072 (Third CSM mission only)

Sector II
- Environmental system space radiator
- Reaction control system package (+Y-axis)
- Service propulsion system oxidizer sump tank

Sector III
- Reaction control system package (+Z-axis)
- Environmental system space radiator

Sector IV
- Fuel cell power plant (two)
- Helium servicing panel
- Oxygen tank (two)
- Hydrogen tank (two)

Sector V
- Environmental control system space radiator
- Service propulsion system fuel sump tank
- Reaction control system package (-Y-axis)

Sector VI
- Environmental control system space radiator
- Reaction control system package (-Z-axis)

Center Section
- Service propulsion system helium tank
- Service propulsion system engine
- Water Tank

Fairing
- Electrical power system space radiators (eight)

A-ST-1061B

Figure 1-29. Service Module

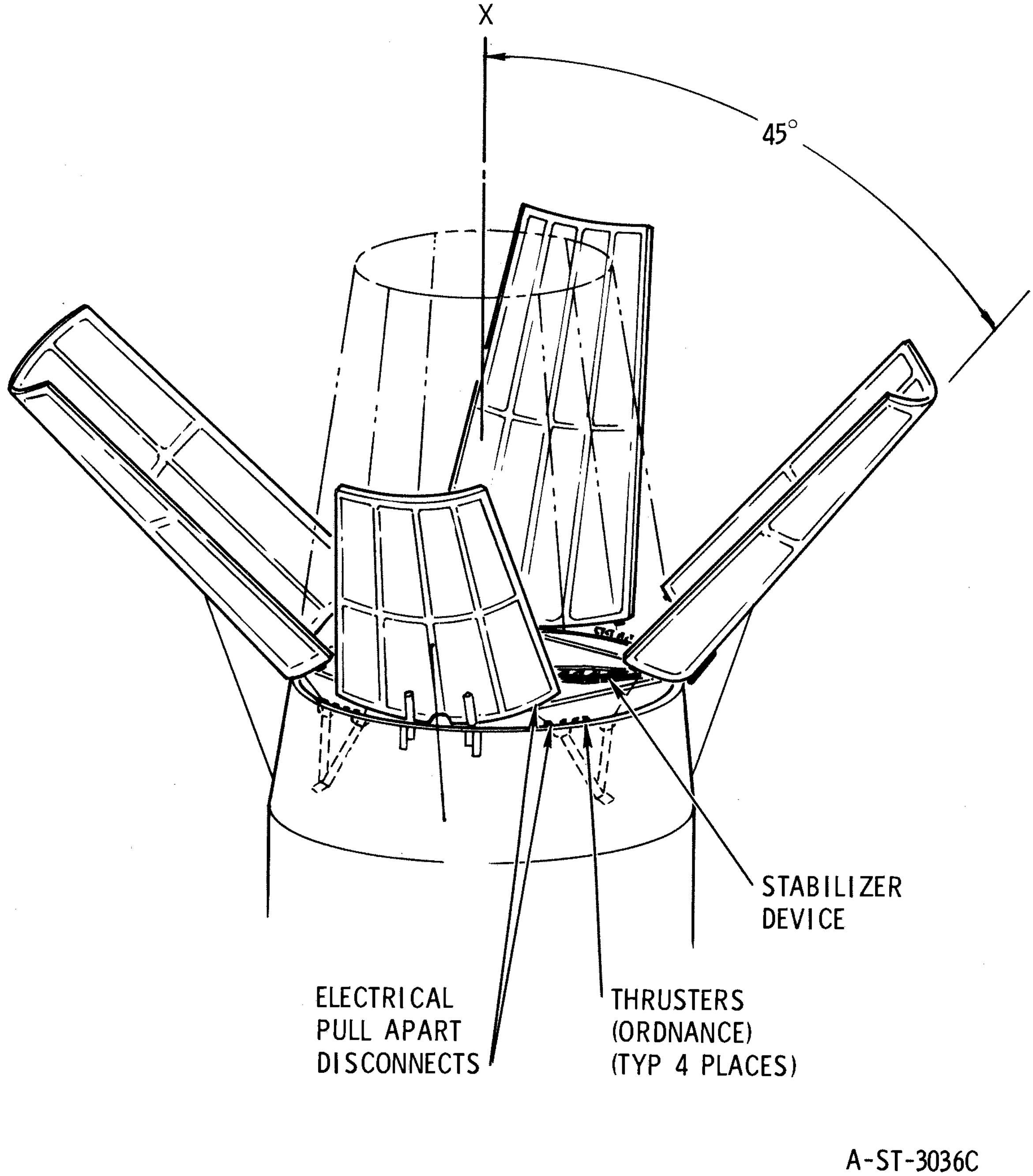


Figure 1-30. Adapter and SLA Panel Deployment

SECTION 2

SYSTEMS DATA

INTRODUCTION

Systems data include the operations, component description, and operational limitations and restrictions.

Subsection 2.1 describes the overall spacecraft navigation, guidance and control requirements, and systems interface.

Subsections 2.2 through 2.10 present descriptive data grouped by spacecraft systems, arranged in the following order:

2.2 Guidance and Navigation System

2.3 Stabilization and Control System

2.4 Service Propulsion System

2.5 Reaction Control System

2.6 Electrical Power System

2.7 Environmental Control System

2.8 Telecommunications System

2.9 Sequential System

2.10 Caution and Warning System

Subsection 2.11 describes the miscellaneous systems data (CSM experiments); subsection 2.12 describes the crew personal equipment; and subsection 2.13 describes the docking and crew transfer.

G&N

SECTION 2

SUBSECTION 2.1

GUIDANCE AND CONTROL

2.1.1 GUIDANCE AND CONTROL SYSTEMS INTERFACE

The Apollo guidance and control functions are performed by the primary guidance, navigation, and control system (PGNCS), and stabilization and control system (SCS). The PGNCS and SCS systems contain rotational and translational attitude and rate sensors which provide discrete input information to control electronics which, in turn, integrate and condition the information into control commands to the spacecraft propulsion systems. Spacecraft attitude control is provided by commands to the reaction control system (RCS). Major velocity changes are provided by commands to the service propulsion system (SPS). Guidance and control provides the following basic functions:

- Attitude reference
- Attitude control
- Thrust and thrust vector control

The basic guidance and control functions may be performed automatically, with primary control furnished by the command module computer (CMC), or manually, with primary control furnished by the flight crew.

2.1.2 ATTITUDE REFERENCE

The attitude reference function (figure 2.1-1) provides display of the spacecraft attitude with respect to an established inertial reference on the two flight director attitude indicators (FDAI) located on the main display console (MDC), panels 1 and 2. The displayed information consists of:

- Total attitude displayed by the FDAI ball.

- Attitude errors by three needles across scales on the top, right, and bottom of the apparent periphery of the ball.

- Angular rates by needles on the top, right, and bottom of the FDAI face.

Total attitude information is derived from the inertial measurement unit (IMU) or the gyro display coupler (GDC). The total attitude provided by the IMU is the gimbal angles from the gyro-stabilized platform aligned to an inertial reference (spacecraft attitude with respect to inertial reference). Angular rates from the gyro assemblies are transformed and converted to inertial angles in the GDC for total attitude display.

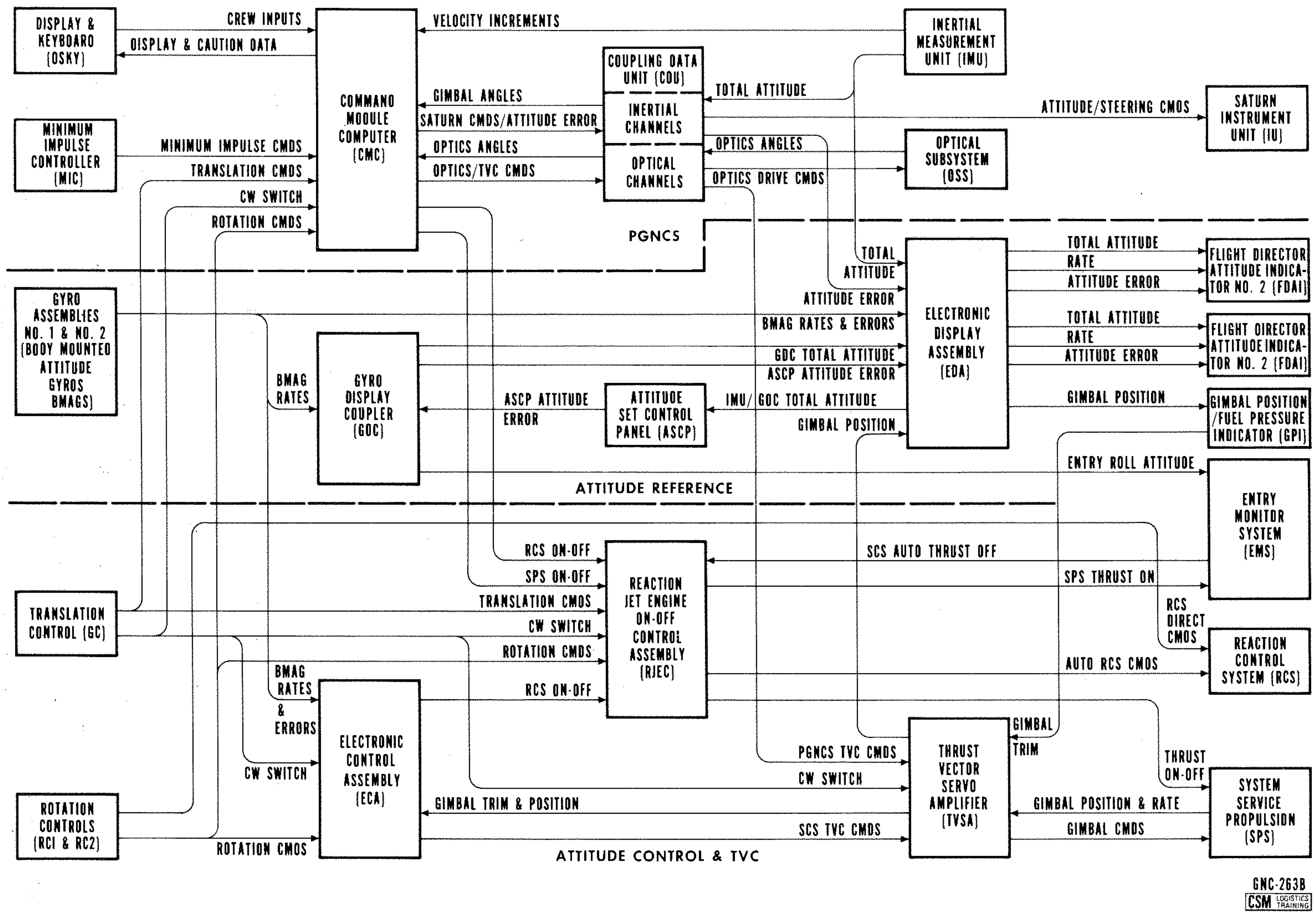


Figure 2.1-1. G&C Block Diagram

Attitude error is derived from the following three sources:

- PGNCS coupling data unit (CDU) inertial channels.
- Gyro assembly No. 1 body-mounted attitude gyros (BMAGs).
- GDC produced attitude set control panel (ASCP) attitude errors.

The attitude errors from the PGNCS are computed in the CMC as angular differences between the desired attitude (gimbal angles) and present IMU gimbal angles. The coupling data unit converts the digital output of the CMC to analog signals for the FDAI. The body-mounted attitude gyros (one for each of the X, Y, and Z axes) are single degree-of-freedom attitude gyros. Any spacecraft rotation about an axis will offset the case of the gyro from the float. This rotation is sensed as a displacement off null, and a signal is produced representative of the magnitude and direction. The GDC produces attitude errors by comparing the transformed and converted angular rates with the stored attitude from the attitude set control panel. The attitude error signals from PGNCS, gyro assembly No. 1, and the GDC are processed in the electronic display assembly (EDA) and applied to the FDAI attitude error needles.

Rate information from the roll and yaw gyros is transformed and converted in the GDC to provide an entry roll attitude signal to the entry monitor system (EMS). This entry roll attitude is an indication of the spacecraft lift vector orientation about the stability axis.

Angular rates are derived from either gyro assembly No. 1 or No. 2. Normally, the No. 2 assembly is used; however, gyro assembly No. 1 may be switched to a backup rate mode if desired. The output signal from the caged gyro assembly is applied to the GDC for updating of spacecraft attitude and to the EDA for processing. The processed rate information from the EDA is applied to both FDAIs for rate display.

2.1.3 ATTITUDE CONTROL

The attitude control as illustrated in figure 2.1-1 is used to maintain a specific orientation or to command small rotations or translations. Attitude control consists of:

- Automatic maneuvers.
- Maintaining a specific orientation (attitude hold).
- Manual maneuvers.
- Direct commands.

Automatic maneuvers are controlled by the PGNCS. During phases of the mission automatic maneuvers are initiated by computer programs or the crew to align the attitude of the spacecraft. The command module computer (CMC) will supply a discrete RCS on-off signal to the reaction jet engine on-off control assembly (RJEC). The RJEC conditions the CMC input and applies an auto RCS command to the reaction control system (RCS) to fire the appropriate engines to perform the desired maneuver.

Attitude hold is controlled by the PGNCS or SCS. The attitude is maintained within a specified deadband (attitude and rate limits) limit. The crew specifies the deadband by switch settings for SCS control or by use of the display and keyboard (DSKY) to the CMC.

The CMC has the present orientation of the spacecraft stored, and with the deadband specified by the crew, any spacecraft drift is sensed by the IMU which transmits the gimbal angle changes to the CMC through the coupling data unit (CDU). When the spacecraft exceeds the limits specified by the crew, the CMC will issue discrete RCS on-off commands to the RJEC to turn on the appropriate engine to return the spacecraft within the specified deadband. To maintain attitude hold in the SCS, the attitude error signals from gyro assembly No. 1 and rate signals from assembly 1 or 2 as described in the attitude reference section are applied to the electronic control assembly (ECA). The crew specifies the deadband in the SCS by switch settings on MDC panel 1. If the spacecraft exceeds the limits specified, the ECA provides RCS on-off commands to the RJEC to turn on the appropriate engine to return the spacecraft within the specified deadband.

Manual maneuvers are provided by the PGNCS or SCS by use of the rotation controls (RC 1 and RC 2), translation control (TC) or minimum impulse controller (MIC). Movement of the rotation or translation controllers from the detent position closes switches (breakout) and applies a discrete to the CMC and RJEC. If the PGNCS is providing attitude control, the CMC will issue commands for rate maneuvering (rotation control input) about the selected axes or acceleration commands (translation control input) along an axes to the RJEC.

The RJEC will condition the PGNCS rate (rotation) and acceleration (translation) inputs and accept the discrete acceleration (rotation and translation) inputs during SCS attitude control to provide the auto RCS commands to the RCS system to turn on the appropriate engine. The rotation commands to the ECA are analog signals which change in amplitude proportional to the amount of rotation control deflection from detent. The analog signal is summed with the gyro assembly 1 or 2 rate feedback signal to provide a proportional rate output (RCS on-off) to the RJEC. The RJEC accepts the proportional rate command and discrete (breakout) command during SCS attitude control to provide the auto RCS commands to the RCS system. The minimum impulse controller (MIC) provides discrete inputs to the CMC, which supplies a 14 millisecond RCS on-off command to the RJEC each time the MIC is moved from the detent position. RCS direct commands to turn on the appropriate engine are provided from the rotation controls when the controller is deflected beyond the hard stop. The RCS direct commands bypass all electronics in the G&C system and are used in emergency conditions.

2.1.4 THRUST VECTOR CONTROL

The guidance and control system provides control of the following thrust functions:

- Guidance (thrust measurement and control)
- Thrust vector control (steering)

Primary control of the guidance function is performed by the PGNCS. Prior to a thrust maneuver, the CMC computes, or is supplied through up data-link or crew DSKY input, the thrust magnitude, direction, and time of thrust initiation. At time of thrust initiation and crew response to a display, the CMC will provide the SPS ON command to the RJEC. The RJEC conditions the command and supplies the thrust-on command to the service propulsion system (SPS) to ignite the engine and the SPS thrust-on signal to the EMS to illuminate the thrust-on lamp. The measurement of the thrust is performed by the three orthogonally mounted accelerometers on the stable platform of the inertial measurement unit (IMU). When the desired velocity change has been achieved, the CMC removes the SPS on command. Secondary control of the guidance function is performed by the SCS. Prior to a thrust maneuver, the thrust magnitude is set into the velocity counter of the EMS. Thrust initiation is performed by the crew by depressing the thrust-on switch located on MDC panel 1. The thrust-on command is conditioned by the RJEC which supplies the thrust-on command to the SPS and SPS thrust-on to the EMS to illuminate the thrust-on lamp. The velocity change is sensed by the +X axis accelerometer of the EMS which produces an output representative of the velocity change. These signals decrement the EMS velocity counter toward zero. When the velocity counter reaches zero the EMS issues the SCS auto thrust-off command to the RJEC.

Thrust vector control is required to steer the vehicle to maintain a fixed thrust line or fixed inertial orientation. In addition, the control system is used to maintain the thrust vector through the center of gravity of the vehicle for stability. Prior to a thrusting maneuver (whether PGNCS or SCS controlled), the SPS engine is trimmed (aligned) with the thrust vector through the center of gravity and the spacecraft is aligned (maneuvered) with the +X axis along the desired thrust line.

PGNCS thrust vector control is performed by the TVC digital autopilot (computer software) of the CMC which accepts steering commands from the thrusting program and maintains the thrust vector through the center of gravity. Attitude changes of the vehicle caused by center of gravity shift because of propellant usage, fuel slosh, bending moments, or trim misalignment are sensed by the IMU.

The gimbal angle changes are converted to vehicle body rates, differenced with thrusting program steering commands (vector rate), integrated to attitude errors and differenced with the present computed trim of the SPS engine. This error signal is applied to the CDU optical channels for conversion (digital to analog). The PGNCS TVC command is then applied to the thrust vector servo amplifier (TVSA).

SCS thrust vector control is provided automatically or manually. Attitude changes and vehicle body rates are sensed by gyro assembly No. 1 and No. 2 respectively. The attitude errors from GA 1 are differenced with the SPS gimbal position and trim, integrated and summed with rate from GA 2 to provide the SCS TVC command from the electronic control assembly (ECA) to the TVSA during the automatic mode. Manual thrust vector control utilizes the analog output of the rotation controls moved from detent. The analog signal is summed with rate feedback from GA 1 or GA 2 to provide the proportional rate command. This signal is integrated and applied to the TVSA as the SCS TVC command (manual thrust vector control - MTVC). The PGNCS and SCS TVC commands to the TVSA are summed with the gimbal position and rate commands from the SPS. The resultant signal is applied to the servo amplifier which supplies the extend or retract (gimbal commands) commands to the SPS.

G&N

SECTION 2

SUBSECTION 2.2

GUIDANCE AND NAVIGATION SYSTEM

2.2.1 INTRODUCTION

The primary guidance, navigation and control system (PGNCS) provides the following functions:

- Inertial velocity and position (state vector) computation
- Optical and inertial navigation measurements
- Spacecraft attitude measurement and control
- Generation of guidance commands during CSM powered flight and CM atmospheric entry

The PGNCS system consists of three subsystems:

- Inertial subsystem (ISS)
- Optical subsystem (OSS)
- Computer subsystem (CSS)

They are located in the command module lower equipment bay (figure 2.2-1). System circuit breakers, caution and warning indicators and one of the display and keyboard panels (DSKY) are located on the main display console.

2.2.2 PGNCS DATA FLOW

2.2.2.1 Inertial Subsystem

The inertial subsystem (ISS) is composed of an inertial measurement unit (IMU), part of the power and servo assembly (PSA), part of the controls and displays, and three coupling data unit (CDU) channels. The IMU provides an inertial reference with a gimbaled, three-degree-of-freedom, gyro-stabilized platform. The alignment of the stable platform (figure 2.2-2) is accomplished by the command module computer (CMC) providing a digital pulse train and control commands to the CDU. The CDU converts the pulse train to analog signals which drive the IMU to the desired orientation. Attitude change sensing is accomplished by monitoring the spacecraft attitude with reference to the stable platform. Resolvers are mounted at the gimbal axes to provide signals representative of the gimbal angles. The CDU converts these analog signals to digital pulses for the CMC. The CMC compares these angles with the CMC desired angles, if the angles differ, error signals are generated. The error signals can be used as steering commands to the SIVB guidance system, attitude error display signals or RCS on-off commands to the stabilization and control system (SCS).

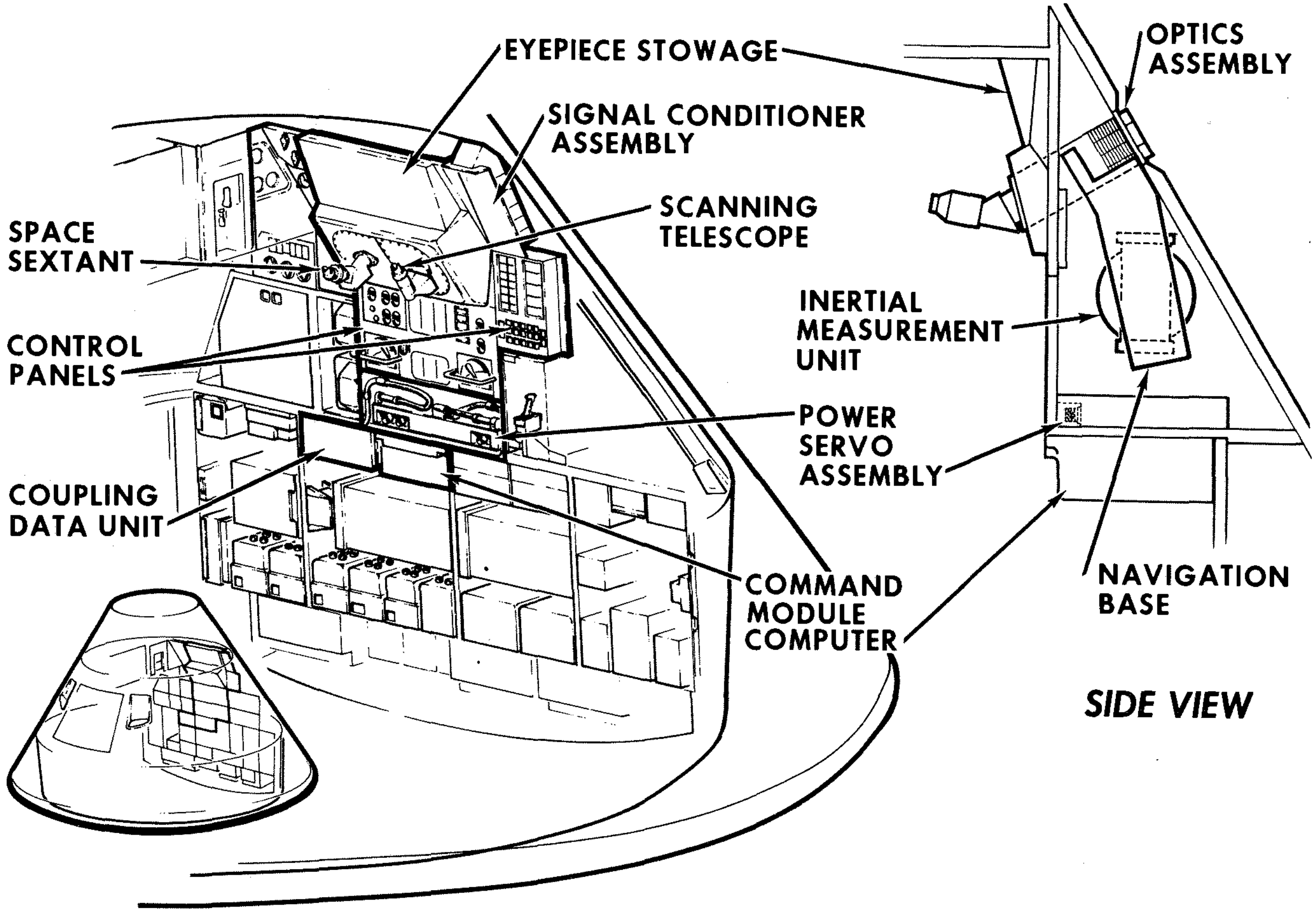


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Figure 2.2-1. G&N Equipment Location

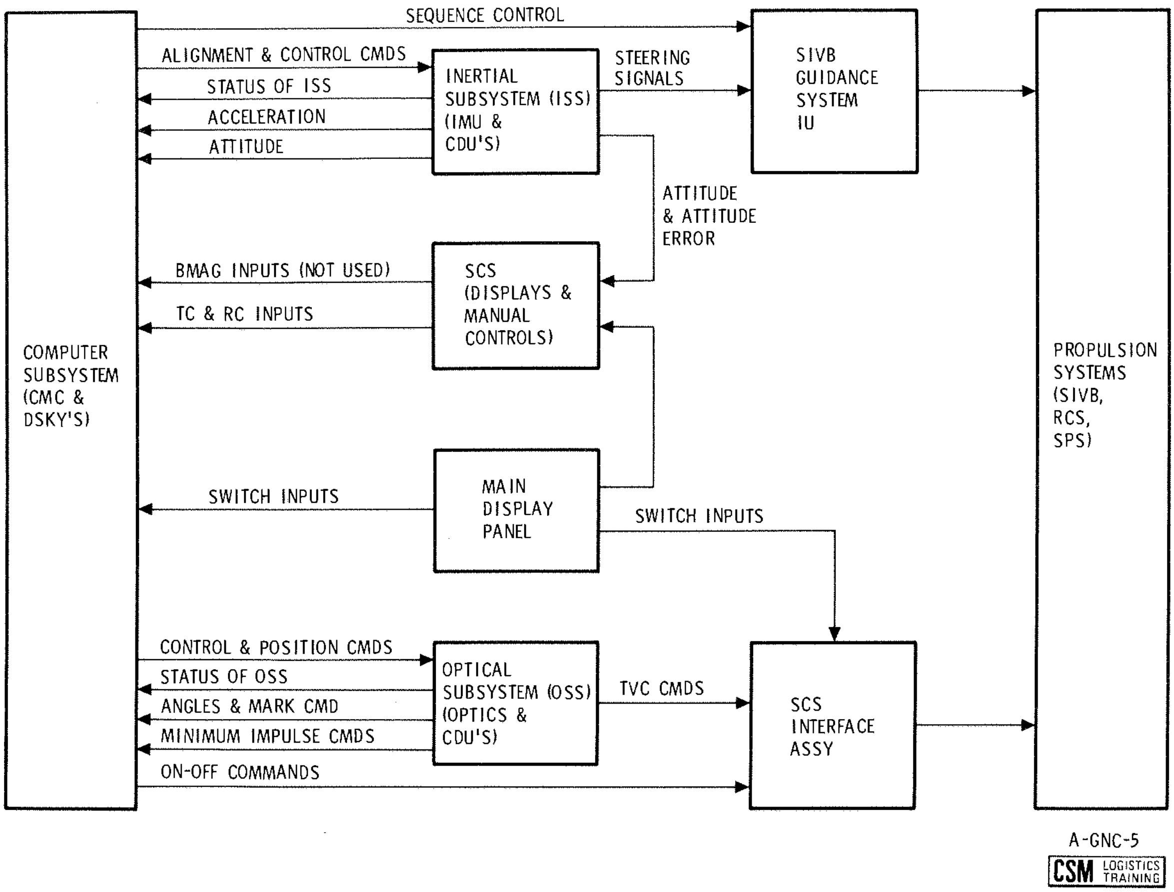


Figure 2.2-2. PGNCS Data Flow

Mounted on the stable platform are the pulsed integrating pendulous accelerometers (PIPA's) which sense changes in spacecraft velocity. An acceleration or deceleration results in output signals which are representative of the magnitude and direction of the velocity change. The output signals are applied to the CMC which uses the information to update spacecraft velocity data.

Also applied to the CMC are discrete signals reflecting the status (caution and warning information) of the IMU and CDU.

2.2.2.2 Optics Subsystem

The optics subsystem is composed of a scanning telescope (SCT), sextant (SXT), drive motors for positioning the SCT and SXT, parts of the PSA, part of the controls and displays, and two CDU channels. The SCT and SXT are used to determine the spacecraft position and velocity with relation to the orbital workshop (OWS) and stable platform orientation with respect to navigation stars.

The optics are positioned by drive motors commanded by the optics hand controller (located on the optics control panel, lower equipment bay) or by a digital pulse train from the CMC. The digital pulse train is converted to an analog drive signal in the CDU.

When the navigator is satisfied with the image position, he issues a mark command to the CMC. The position of the optics is provided by resolvers mounted on the optics. The CDU converts the analog resolver signal to digital pulses representative of the optics angles. The CMC reads these angles, IMU angles, and time of mark command. From this information the CMC computes the spacecraft position.

The minimum impulse commands from the minimum impulse controller (on the optics control panel - lower equipment bay) are discrete inputs to the CMC. The CMC provides on-off commands to the SCS for firing of the RCS jets to maintain attitude during sightings with the optics.

The channels of the CDU used to position the optics are also used to convert the digital pulse train from the CMC to a dc signal to the SCS as guidance commands (TVC) during CSM powered flight.

Also applied to the CMC are discrete signals reflecting the status (caution and warning information) of the CDU optics channels.

2.2.2.3 Computer Subsystem

The computer subsystem (CSS) consists of the command module computer (CMC) and two display and keyboard panels (DSKYs), which are part of the controls and displays.

The CMC provides automatic execution of computer programs, automatic control of ISS and OSS modes, and in conjunction with the DSKY's, manual control of ISS and OSS modes and computer displays. The CMC contains a two-part memory which consists of a large nonerasable (fixed) section and a smaller erasable section. Nonerasable memory contains mission and system programs, and other predetermined data which are wired in during assembly. Data readout from this section is nondestructive and cannot be changed during operation. The erasable section of memory provides for data storage, retrieval, and operations upon measured data and telemetered information. Data readout from this section is destructive, permitting changes in stored data to be made as desired. Information within the memory may be called up for display on the two DSKY's. The DSKY's enable the flight crew to enter data or instructions into the CMC, request display of data from CMC memory, and offer an interrupt control of CMC operation.

The CMC performs guidance functions by executing internal programs using predetermined trajectory parameters, attitude angles from the inertial channels of the CDU, velocity changes from the PIPA's, and commands from the DSKY's (crew) to generate control commands. The navigation function is performed by using stored star data, optics angles from the optics channels of the CDU, and velocity changes from the PIPA's in the execution of navigation programs.

G&N

2.2.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION

2.2.3.1 Inertial Subsystem

The function of the inertial subsystem is to provide a space-stabilized inertial reference from which velocity changes and attitude changes can be sensed. It is composed of the navigation base (NB), the inertial measurement unit (IMU), parts of the power and servo assembly (PSA), parts of the control and display panels, and three coupling data unit (CDU) channels.

2.2.3.1.1 Navigation Base

The navigation base (NB) is the rigid, supporting structure which mounts the IMU and optical instruments. The NB is manufactured and installed to close tolerances to provide accurate alignment of the equipment mounted on it. It also provides shock-mounting for the IMU and optics.

2.2.3.1.2 Inertial Measurement Unit

The inertial measurement unit (IMU) is the main unit of the inertial subsystem. It is a three-degree-of-freedom stabilized platform assembly, containing three inertial rate integrating gyros (IRIGs), and three pulsed-integrating pendulous accelerometers (PIPAs). The stable member itself is machined from a solid block of beryllium with holes bored for mounting the PIPAs and IRIGs.

The stable platform attitude is maintained by the IRIGs, stabilization loop electronics, and gimbal torque motors. Any displacement of the stable member is sensed by the IRIGs which generate error signals. IRIG error signals are resolved, amplified, and applied to stabilization loop electronics. The resultant signal is conditioned and applied to the gimbal torque motors, which restore the desired attitude.

The stable platform provides a space-referenced mount for three PIPAs, which sense velocity changes. The PIPAs are mounted orthogonally to sense the velocity changes along all three axes. Any translational force experienced by the spacecraft causes an acceleration or deceleration which is sensed by one or more PIPAs. Each PIPA generates an output signal proportional to the magnitude and direction of velocity change. This signal, in the form of a pulse train, is applied to the CMC. The CMC will use the signal to update the velocity information, and will also generate signals to enable the torquing of each PIPA ducosyn back to null.

The temperature control system is a thermostatic system that maintains the IRIG and PIPA temperatures within their required limits during both IMU standby and operate modes. Heat is applied by end-mount heaters on the inertial components, stable member heaters, and a temperature control anticipatory heater. Heat is removed by convection, conduction, and radiation. The natural convection used during IMU standby modes is changed to blower-controlled, forced convection during IMU operating modes. IMU internal pressure is normally between 3.5 and 15 psia enabling the required forced convection. To aid in removing heat, a water-glycol solution passes through coolant passages in the IMU support gimbal. Therefore, heat flow is from the stable member to the case and coolant. The temperature control system consists of the temperature control circuit, the blower control circuit, and the temperature alarm circuit. A separate external temperature control system is also provided for test configurations but will not be discussed in this manual.

2.2.3.1.3 Coupling Data Unit

The CDU, an all electronic device, is used as an interface element between the ISS and CSS, the OSS and CSS, and the CSS and various controls and displays. It functions primarily as an analog-to-digital (A/D) or digital-to-analog (D/A) converter. There are five, almost identical, channels, one each for the inner, middle, and outer IMU gimbals, and one each for the shaft and trunnion optical axes. The ISS portion of the CDU performs the following functions:

a. Converts IMU gimbal angles from analog-to-digital form, and supplies the CMC with this information.

b. Converts digital signals from the CMC to either 800-cps or dc signals.

c. Controls the moding of the ISS through logical manipulation of computer discretes.

The analog signal from the 1X and 16X resolvers, located on the IMU gimbals, is transmitted to the CDU. This angular information, proportional to the sine and cosine of the gimbal angle, is converted to digital form with one pulse to the CMC equivalent to 40 arc-seconds of gimbal movement.

During coarse align, attitude error display, and Saturn takeover modes, the ISS channels of the CDU provide the digital to analog conversion of the CMC output to generate an a-c or d-c output. The a-c output is applied to the servo amplifiers of the PSA to drive the gimbals to the desired angle, and is also applied to the FDAI for deflection of the attitude error needles. The d-c signal is applied to the Saturn flight control computer which will gimbal the Saturn engine or provide commands to the Saturn attitude control system.

2.2.3.1.4 Power and Servo Assembly

The purpose of the power and servo assembly (PSA) is to provide a central mounting point for the majority of the G&N system power supplies, amplifiers, and other modular electronic components.

The PSA is located on the lower D&C panel rack directly below the IMU. It consists of 42 modules mounted to a header assembly. Connectors and harnessing are integral to the construction of the header assembly, and G&N harness branches are brought out from the PSA header. A thin cover plate is mounted on the PSA, providing a hermetic seal for the interior. During flight, this permits pressurization of the PSA to remain at 15 psi. Connectors are available at the PSA for measuring signals at various system test points.

2.2.3.2 Computer Subsystem

The computer subsystem (CSS) consists of the command module computer (CMC), and two display and keyboard panels (DSKYs). The CMC and one DSKY are located in the lower equipment bay. The other DSKY is located on the main display console.

2.2.3.2.1 Command Module Computer

The CMC is a core memory, digital computer with two types of memory, fixed and erasable. The fixed memory permanently stores navigation tables, trajectory parameters, programs, and constants. The erasable memory stores intermediate information.

The CMC processes data and issues discrete control signals, both for the PGNCS and the other spacecraft systems. It is a control computer with many of the features of a general purpose computer. As a control computer, the CMC aligns the stable platform of the inertial measurement unit (IMU) in the inertial subsystem, positions the optical unit in the optical subsystem, and issues control commands to the spacecraft. As a general purpose computer, the CMC solves guidance problems required for the spacecraft mission. In addition, the CMC monitors the operation of the PGNCS and other spacecraft systems.

The CMC stores data pertinent to the flight profile that the spacecraft must assume in order to complete its mission. This data, consisting of position, velocity, and trajectory information, is used by the CMC to solve the various flight equations. The results of various equations can be used to determine the required magnitude and direction of thrust required. Corrections to be made are established by the CMC. The spacecraft engines are turned on at the correct time, and steering signals are controlled by the CMC to reorient the spacecraft to a new trajectory, if required. The inertial subsystem senses acceleration and supplies velocity changes to the CMC for calculating the total velocity. Drive signals are supplied from the CMC to coupling data unit (CDU) and stabilization gyros in the inertial subsystem to align the gimbal angles in the IMU. Error signals are also supplied to the CDU to provide steering capabilities for the spacecraft. CDU position signals are fed to the CMC to indicate changes in gimbal angles, which are used by the CMC to keep cognizant of the gimbal positions. The CMC receives mode indications and angular information from the optical subsystem during optical sightings. This information is used by the CMC to calculate present position and orientation, and is used to refine trajectory information. Optical subsystem components can also be positioned by drive signals supplied from the CMC.

CMC Organization. The CMC is functionally divided into seven blocks. (See figure 2.2-6.)

1. Timer
2. Sequence generator
3. Central processor
4. Memory
5. Priority control
6. Input-output
7. Power

Timer. The timer generates all the necessary synchronization pulses to ensure a logical data flow from one area to another within the CMC. It also generates timing waveforms which are used by (1) the CMC's alarm circuitry, and (2) other areas of the spacecraft for control and synchronization purposes.

The master clock frequency is generated by an oscillator and is applied to the clock divider logic. The divider logic divides the master clock input into gating and timing pulses at the basic clock rate of the computer. Several outputs are available from the pulses at the basic clock rate of the computer. Several outputs are available from the scaler, which further divides the divider logic output into output pulses and signals used for gating, to generate rate signal outputs and for the accumulation of time. Outputs from the divider logic also drive the time pulse generator which produces a recurring set of time pulses. This set of time pulses defines a specific interval (memory cycle time) in which access to memory and word flow take place within the computer.

The start-stop logic senses the status of the power supplies and specific alarm conditions in the computer, and generates a stop signal which is applied to the time pulse generator to inhibit word flow. Simultaneously, a fresh-start signal is generated which is applied to all functional areas in the computer. The start-stop logic, and subsequently word flow in the computer, can also be controlled by inputs from the computer test set (CTS) during preinstallation systems and subsystem tests.

Sequence Generator. The sequence generator directs the execution of machine instructions. It does this by generating control pulses which logically sequence data throughout the CMC. The control pulses are formed by combining the order code of an instruction word with synchronization pulses from the timer.

The sequence generator contains the order code processor, command generator, and control pulse generator. The sequence generator executes the instructions stored in memory by producing control pulses which regulate the data flow of the computer. The manner in which the data flow is regulated among the various functional areas of the computer and between the elements of the central processor causes the data to be processed according to the specifications of each machine instruction.

The order code processor receives signals from the central processor, priority control, and peripheral equipment (test equipment). The order code signals are stored in the order code processor and converted to coded signals for the command generator. The command generator decodes these signals and produces instruction commands. The instruction commands are sent to the control pulse generator to produce a particular sequence of control pulses, depending on the instruction being executed. At the completion of each instruction, new order code signals are sent to the order code processor to continue the execution of the program.

Central Processor. The central processor performs all arithmetic operations required of the CMC, buffers all information coming from and going to memory, checks for correct parity on all words coming from memory, and generates a parity bit for all words written into memory.

The central processor consists of the flip-flop registers, the write, clear, and read control logic, write amplifiers, memory buffer register, memory address register and decoder, and the parity logic. All data and arithmetic manipulations within the CMC take place in the central processor.

Primarily, the central processor performs operations indicated by the basic instructions of the program stored in memory. Communication within the central processor is accomplished through the write amplifiers. Data flows from memory to the flip-flop registers or vice versa, between individual flip-flop registers, or into the central processor from external sources. In all instances, data is placed on the write lines and routed to specific register, or to another functional area under control of the write, clear, and read logic. This logic section accepts control pulses from the sequence generator and generates signals to read the content of a register into the write lines, and write this content into another register of the central processor or to another functional area of the CMC. The particular memory location is specified by the content of the memory address register. The address is fed from the write lines into this register, the output of which is decoded by the address decoder logic. Data is subsequently transferred from memory to the memory buffer register. The decoded address outputs are also used as gating functions within the CMC.

The memory buffer register buffers all information read out or written into memory. During read-out, parity is checked by the parity logic and an alarm is generated in case of incorrect parity. During write-in, the parity logic generates a parity bit for information being written into memory. The flip-flop registers ary used to accomplish the data manipulations and arithmetic operations. Each register is 16 bits or one computer word in length. Data flows into and out of each register as dictated by control pulses associated with each register. The control pulses are generated by write, clear, and read control logic.

External inputs through the write amplifiers include the content of both the erasable and fixed memory bank registers, all interrupt addresses from priority control, control pulses which are associated with specific arithmetic operations, and the start address for an initial start condition. Information from the input and output channels is placed on the write lines and routed to specific destinations either within or external to the central processor. The CTS inputs allow a word to be placed on the write lines during system and subsystem tests.

Registers. Registers A, L, Q, Z, and B consist of 16 bit positions each. These are numbered 16 through 1 reading from left to right. Register E BANK consists of three bit positions numbered 11 through 9. Register S consists of 12 bit positions numbered 12 through 1. Register SQ consists of seven bit positions, SQ, EXT, 16 and 14 through 10. Registers X and Y comprise the adder and each register consists of 16 bit positions. The 16 output gates of the adder are called register U, note, however, that U is not a register in the sense of the flip-flop registers comprising the central processor. Register U and the write amplifiers each consists of 16 bit positions numbered 16 through 1. All registers mentioned so far may contain addresses, a code, etc. They do not, however, contain a parity bit. Whenever a number is contained in these registers, the lowest order bit is stored in bit position 1 and the highest order bit is stored in bit position 14. The sign bit is stored in bit position 16. A zero in this bit position signifies a positive number and a one signifies a negative number. Bit position 15 is used for storing either the overflow or underflow bit.

Register G serves as a buffer between the central processor and memory. It consists of 16 bit positions numbered 16 through 1. Any parity bit received from memory is transferred to the parity block but not to the central processor register. The 16 inputs to the parity block are numbered 16 and 14 through 0. No provision is made for entering an overflow bit into the parity block.

Register A is called the "accumulator." It contains the results of arithmetic operations.

Register L is called the "lower order accumulator." It contains the least significant bits of the product or quotient after a multiplication or division process.

Register B is called the "buffer register." It also provides a means of complementing since its reset side can also be interrogated. The reset side is sometimes called "register C."

The Z register is the program counter. It contains the address of the next instruction word in the program. As each instruction is executed, this register is incremented by one because the instruction words usually are stored sequentially in memory.

The Q register is named the "return address register." When the CMC transfers control to another program or routine, the contents of the Z register are stored in register Q. When the CMC returns to the original program, register Q contains the address of the appropriate instruction.

The write amplifiers provide the current driving capabilities for the registers. These amplifiers in no way store information, they simply route information.

Register S contains the address of the word to be called out from memory. Register E BANK is also used when erasable memory is addressed. Register F BANK is used when fixed memory is addressed.

Memory. Memory provides the storage for the CMC and is divided into two sections: erasable memory and fixed memory. Erasable memory can be written into or read from; its readout is destructive. Fixed memory cannot be written into and its readout is nondestructive.

The CMC has erasable and fixed memories. The erasable memory can be written into and read out of; fixed memory can only be read out of. Erasable memory stores intermediate results of computations, auxiliary program information, and variable data supplied by external inputs from the PGNCS and other systems of the spacecraft. Fixed memory stores programs, constants, and tables. There is a total of 38,912, sixteen bit word storage locations in fixed and erasable memories. It should be noted that the majority of the memory capacity is in fixed memory (36,864 word locations). Both memories are magnetic core storage devices; however, the cores are used differently in each type of memory. It is assumed that the reader is familiar with the basic magnetic properties of a ferrite core as described by a square hysteresis curve. A core is a static storage device having two stable states. It can be magnetized in one or two directions by passing a sufficient current, I, through a wire which pierces the core. The direction of current determines the direction of magnetization. The core will retain its magnetization indefinitely until an opposing current switches the core in the opposite direction. Wires carrying current through the same core are algebraically additive. Sense wires which pierce a switched core will carry an induced pulse.

Priority Control. Priority control establishes a processing priority of operations which must be performed by the CMC. These operations are a result of conditions which occur both internally and externally to the CMC. Priority control consists of counter priority control and interrupt priority control. Counter priority control initiates actions which update counters in erasable memory. Interrupt priority control transfers control of the CMC to one of several interrupt subroutines stored in fixed memory.

The start instruction control restarts the computer following a hardware or program failure. The counter instruction control updates the various counters in erasable memory upon reception of certain incremental pulses. The counter instruction control is also used during test functions to implement the display and load requests provided by the computer test set. The interrupt instruction control forces the execution of the interrupt instruction (RUPTOR) to interrupt the current operation of the computer in favor of a programmed operation of a higher priority.

Input-Output. The input-output section routes and conditions signals between the CMC and other areas of the spacecraft. In addition to the counter interrupt and the program interrupts previously described, the CMC has a number of other inputs derived from its interfacing hardware. These inputs are a result of the functioning of the hardware or an action by the operator of the spacecraft. The counter interrupts in most cases, enable the CMC to process inputs representative of data parameters such as changes in velocity. The program interrupt inputs to the CMC are used to initiate processing of functions which must be processed a relatively short time after a particular function is present. The other inputs to the CMC, in general, enable the CMC to be cognizant of "conditions" which exist in its environment. These inputs are routed to CMC and are available to the CMCs programs through the input channels.

The outputs of the CMC fall in one of the following categories: data, control, or condition indications. Some of these outputs are controllable through the CMC program while others are present as a function of the CMC circuitry. All of the outputs which are controlled by the CMC programs are developed through the CMC output channels.

Channel 01 is the L register.
Channel 02 is the Q register.
Channel 03 the high-order scaler channel.
Channel 04 the low-order scaler channel.

Output channel 05 has eight bit positions and is associated with the reaction control system jets.

Output channel 06 has eight bit positions and is also associated with the reaction control system jets. A logic one in any of the bit positions will cause the appropriate reaction control jets to be fired. The outputs of this channel control the jets used for Z and Y translations, and the roll rotation. The logic is the same as for output channel 05. Assume that it was desired to perform a pure roll maneuver. One of the ways this could be implemented would be to have logic ones in bit positions 1 and 3 while all other bit positions contained a logic zero. There are other methods, of course, but these will not be detailed.

Channel 07 is the F EXT register. It is associated with the selection of word locations in fixed memory. This channel has three bit positions.

Output channel 10 routes information contained in this channel to the DSKYs. The different configurations light various displays on the DSKYs.

Output channel 11 routes information contained in bits 1 through 7 of this channel to the DSKYs. Bit 13 is routed to the SCS system.

Output channel 12 consists of 15 bit positions, 14 of which are presently used. The outbits are d-c signals sent to the spacecraft and PGNCS.

Output channel 13 bit positions 12 through 14 have been covered under program interrupt priority control.

Output channel 14 associates bit positions 11 through 15 with the CDU drive control. This control generates the following pulse trains which are sent to the CDUs: CDUXDP (X CDU positive drive pulse), CDUXDM (X CDU negative drive pulse), CDUYDP, CDUYDM, CDUZDP, CDUZDM, TRNDP, TRNDM, SHAFTDP (shaft CDU positive drive pulse), and SHAFTDM. The CDU drive control also enters the following d-c signals into the counter priority control to request the execution of a DINC instruction: X IMU, CDU, Y IMU, CDU, Z IMU CDU, S OP CDU and T OP CDU.

Signal X IMU CDU is generated when bit position 15 contains a logic one. Signal Y IMU CDU is generated when bit position 14 contains a logic one, signal Z IMU CDU when bit position 13 contains a logic one, signal T OP CDU when bit position 12 contains a logic one, and signal S OP CDU when bit position 11 contains a logic one. More than one of these signals can be generated simultaneously.

Once a desired quantity, e.g., -432, has been entered into a CDU counter, e.g., erasable memory address 0050, and output channel 14 has been properly set (logic 1 in bit position 15), the CDU drive control generates signal X IMU CDU which sets a flip-flop in counter priority control and commands the sequence generator to execute a DINC instruction. As the instruction is executed, the counter control is diminished by one to -431. The CDU drive control then generates a CDUXDM pulse and routes it to the X CDU. Since the priority flip-flop is still set, another DINC instruction is requested. This is repeated until the counter content has diminished to zero. Once the counter contains zero and a DINC instruction is executed, a signal is generated which clears bit position 15 of output channel 14, resets the priority cell, and stops the transmission of pulses.

The gyro drive control selects a gyro to be torqued positively or negatively, and then applies a 3200-cps pulse train to the appropriate gyro to accomplish this function. There are six signals associated with selection of the gyro and the direction in which it will be torqued: GYXP (drive gyro x positive), GYXM (drive gyro x negative), GYYP, GYYM, GYZP, and GYZM. The appropriate signal is determined by the bit configuration of bits 7 through 9 of output channel 14. If bit positions 6 and 10 are a logic one, a 3200-cps pulse train is routed to the gyro electronics specified by bit positions 7 through 9, and a d-c signal is entered into the counter priority control which commands the sequence generator to perform a DINC instruction.

Assume that it is desired to torque the X-gyro in the negative direction by 123 pulses. The GYROS counter in counter priority control would be set to 123. Bit positions 7 through 9 would be 101 respectively, and bit positions 6 and 10 would be logic one. Each time a pulse is sent to the gyro, the GYROS counter is DINCed. The d-c signal to counter priority will remain until the GYROS counter goes to zero which will terminate the torquing.

Input Channel 15. This channel consists of five bit positions. When a key on the main panel DSKY is pressed, a unique five-bit code is entered into this channel. The RUPT 5 interrupt routine is also developed whenever a key on the main panel DSKY is pressed.

Input Channel 16. This channel consists of seven bit positions. If the MARK pushbutton has been pressed, a logic one is entered into bit position 6. This would cause a KEYRUPT 2 (RUPT 6) interrupt routine.

If the MARK REJECT pushbutton has been pressed, a logic one is entered into bit position 7 of this channel. This will also cause a KEYRUPT 2 interrupt routine to be performed. When a key on the navigation panel DSKY is pressed, a unique five-bit code is entered into bit positions 1 through 5. The insertion of this code into input channel 16 initiates a KEYRUPT 2 interrupt routine.

Input channels 17 through 27 are spares.

Input channel 30, channel consists of 15 bit positions. The inputs to these positions are inverted and utilized as follows:

a. Bit positions 1 through 5 to be supplied at a later date.

b. Bit position 7 (OCDU FAIL). This input is generated in the OSS and is a logic zero when a failure has occurred in one of the optical CDUs.

c. Bit position 9 (IMU OPERATE). A binary zero in this bit position indicates that the IMU is turned on and is operating with no malfunctions.

d. Bit position 10 (SC CONTROL OF SATURN). A logic zero in this bit position indicates that the SC has control over the SATURN stage.

e. Bit position 11 (IMU CAGE). A logic zero in this bit position indicates that the IMU gimbals are at their null position.

f. Bit position 12 (IMU CDU FAIL). A logic zero in this bit position indicates that a failure has occurred in one of the inertial CDUs.

g. Bit position 13 (IMU FAIL). A logic zero in this bit position indicates that a malfunction has occurred in the IMU stab loops.

h. Bit position 14 (ISS TURN ON REQUEST). A logic zero is inserted into this bit position when the ISS has been turned on, or commanded to be turned on.

i. Bit position 15 (TEMP IN LIMITS). A logic one is inserted into this bit position if the stable member temperature has not exceeded its design limits. If the limit has been exceeded, a logic zero will be stored.

Input channel 31, channel consists of 15 bit positions. Bit positions 1 through 6 receive their inputs from the rotational hand controller. A logic zero in any one of these bit positions is associated with roll, pitch, or yaw commands. Bit positions 7 through 12 receive their inputs from the translational hand controller. A logic zero in any one of these bit positions is associated with the X, Y, or Z translation commands.

A logic zero in bit position 13 indicates that the present SC attitude is being held and the hand controller is not being used. A logic zero in bit position 14 indicates that the SC is drifting freely, and that the CMC is not receiving inputs from the hand controller or minimum impulse controller. A logic zero in bit position 15 indicates that the CMC is controlling the present SC attitude and the hand controller is not commanding an attitude change. All inputs to this channel are inverted.

Input channel 32, the first six bit positions of this channel receive their inputs from the minimum impulse controller. A logic zero in any of these bit positions is associated with the pitch, yaw, or roll motion commanded by the minimum impulse controller. All inputs to this channel are inverted.

Input channel 33, inputs to this channel are generated in the CMC and optics. Bit positions 4 and 5 receive d-c signals from the optics control panel. The d-c signals are generated by switch and relay closures. A logic zero appears in bit position 10 if the BLOCK UPLINK switch is thrown to the BLOCK position. Bit positions 11 or 12 contain a logic zero if the uplink or downlink telemetry rates are too high. Bit position 13 contains a logic zero if a failure occurs in the accelerometer loops. All inputs to this channel are inverted.

Output channels 34 and 35 provide 16 bit words including a parity bit for downlink telemetry transmission.

Power. This section provides voltage levels necessary for the proper operation of the CMC.

CMC power is furnished by two switching-regulator power supplies: a +4-volt and a +14-volt power supply which are energized by fuel cells in the electrical power system.

Input voltage from the electrical power system is chopped at a variable duty cycle and then filtered to produce the required voltages. Chopping is accomplished by varying the pulse width of a signal having a fixed repetition rate and known amplitude.

Source voltage, +28 vdc, is supplied from the electrical power system through the power switch to the control module. The control module, essentially a pulse generator, detects the difference between the primary feedback output of the power supply and a reference voltage. (A secondary feedback path is connected to the CTS for marginal-voltage test operations.) A differential amplifier detects any change in the output voltage from the desired level. The output of the differential amplifier and a 51.2-kilocycle sync pulse from the timer drive a one-shot multivibrator in the control module. The differential amplifier output determines the multivibrator pulse width. The resultant +14-volt pulse is supplied to the power switch.

The power switch filters the control module output to produce the desired d-c voltage. Additional filtering action protects the electrical power system from the wide-load variations caused by the chopping action of the power supply. The power switch also contains a temperature sensing circuit. Because of load requirements, the +4-volt power supply requires two power switches.

The power supply outputs are monitored by a failure detector consisting of four differential amplifiers. There are two amplifiers for each power supply, one for overvoltage and one for undervoltage detection. If an over-voltage condition exists, a relay closure signal indicating a power failure is supplied to the spacecraft.

2.2.3.2.2 Display and Keyboard

The DSKYs facilitate intercommunication between the flight crew and the CMC. The DSKYs operate in parallel, with the main display console DSKY providing CMC display and control while the crew are in their couches. (See figure 2.2-3.)

The exchange of data between the flight crew and the CMC is usually initiated by crew action; however, it can also be initiated by internal computer programs. The exchanged information is processed by the DSKY program. This program allows the following five different modes of operation:

- Display of Internal Data. Both a one-shot display and a periodically updating display (called monitor) are provided.

- Loading External Data. As each numerical character is entered, it is displayed in the appropriate display panel location.

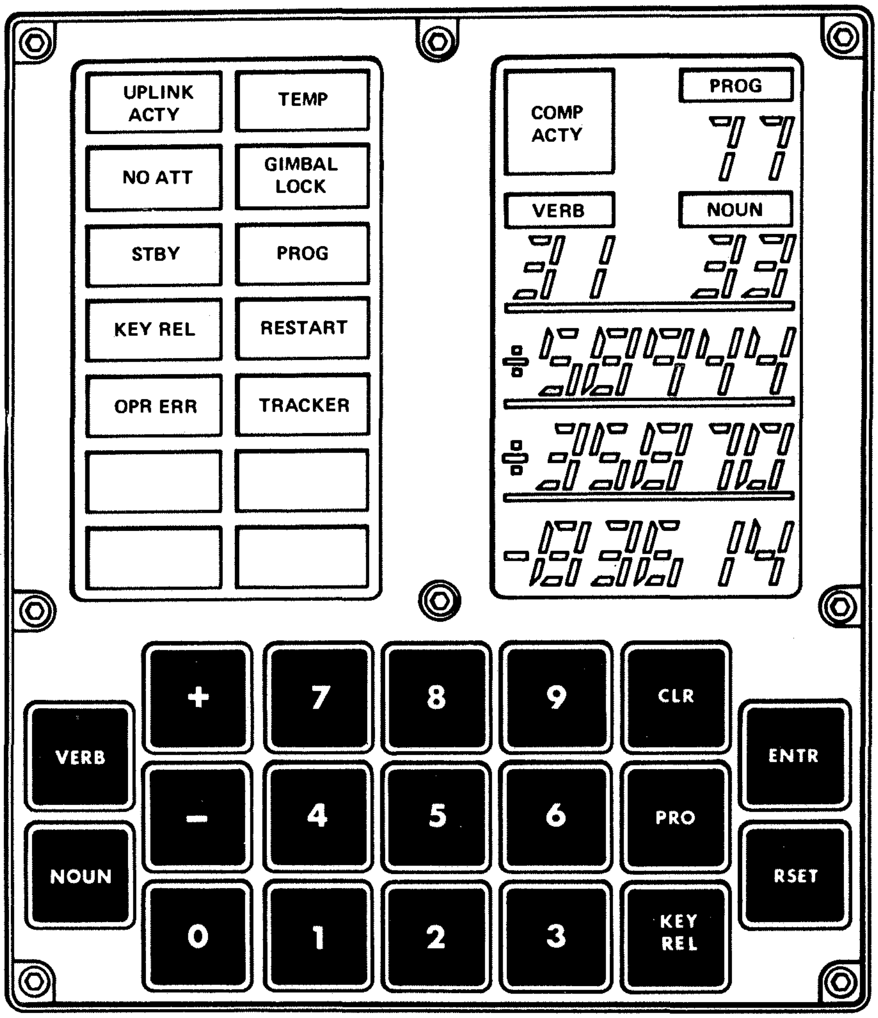


Figure 2.2-3. Display and Keyboard

- Program Calling and Control. The DSKY is used to initiate a class of routines which are concerned with neither loading nor display. Certain routines require instructions from the operator to determine whether to stop or continue at a given point.
- Changing Major Mode. The initiation of large scale mission phases can be commanded by the operator.
- Display of PGNCS Caution and Status. The DSKY is used to display the status of the ISS, OSS, and CMC and to provide an indication of hardware and software cautions.

Displays. The displays consist of eleven status and caution indicators, three decimal displays and three decimal or octal registers. The function of the indicators and displays is as follows:

Indicator/Display	Function
UPLINK ACTY light	On when the CMC has received a complete 16 bit digital uplink message.
NO ATT light	Lighted when the ISS is in a coarse align mode.
STBY light	On when the CMC is in the standby mode.
KEY REL light	Lighted when an internal display desires the use of the DSKY and the astronaut is using the DSKY or the astronaut presses a key (exceptions: PRO, RSET and ENTR) when an internal flashing display is currently on the DSKY or the astronaut presses a key (exceptions): PRO, RSET and ENTR) on top of his Monitor Verb display.
OPR ERR light	On when the operator performs an improper sequence of key depressions.
TEMP light	Lighted when the CMC receives a signal from the IMU temperature control that the stable member is outside of the temperature range of 126.3 to 134.3°F.
GIMBAL LOCK light	On when the middle gimbal angle exceeds ±70° from its zero position.
PROG light	Lighted when the internal program detects computational difficulty.
RESTART light	On when the CMC detects a temporary hardware or software failure.
TRACKER light	Lighted when the CMC receives a signal from the optical channels of the CDU indicating a failure.
COMP ACTY light	On when the CMC is occupied with an internal sequence.
PROG display	Provides a decimal display of the current mission program in sequence.
VERB display	Provides a decimal display of the verb (action) being performed.

Indicator/Display	Function
NOUN display	Provides a decimal display of the noun (location or register) where the action (verb) is being performed.
REGISTER 1, 2 and 3	Provides a display of the contents of registers or memory locations.

The keyboard consists of ten numerical keys (pushbuttons) labeled 0 through 9, two sign keys (+ or -) and seven instruction keys: VERB, NOUN CLR (clear), PRO (proceed), KEY REL (key release), ENTR (enter), and RSET (reset).

Whenever a key is pressed, +14 vdc is applied to a diode encoder which generates a unique five-bit code associated with that key. There is, however, no five-bit code associated with the PRO KEY. If a key on the main panel DSKY is pressed, the five-bit code associated with that key is entered into bit positions 1 through 5 of input channel 15 of the CMC. Note that this input will cause a request for the KEYRUPT 1 program interrupt. If a key on the navigation panel DSKY is pressed, the five-bit code associated with that key is entered into bit position 1 through 5 of input channel 16 of the CMC. Note that this input will cause a request for the KEYRUPT 2 program interrupt. The function of the keys is as follows:

Pushbutton	Function
0 through 9 pushbuttons	Enters numerical data, noun codes, and verb codes into the CMC.
+ and - pushbuttons	Informs the CMC that the following numerical data is decimal and indicates the sign of the data.
NOUN pushbutton	Conditions the CMC to interpret the next two numerical characters as a noun code and causes the noun display to be blanked.
CLR pushbutton	Clears data contained in the data displays. Pressing this key clears the data display currently being used. Successive depressions clear the other two data displays.
PRO pushbutton	Commands the CMC to the standby mode if power down program has been run. An additional depression commands the CMC to resume regular operation. If power down program has not been run, a depression commands CMC to proceed without data.
KEY REL pushbutton	Releases the DSKY displays initiated by keyboard action so that information supplied by the CMC program may be displayed.

Pushbutton	Function
ENTR pushbutton	Informs the CMC that the assembled data is complete and the requested function is to be executed.
RSET pushbutton	Extinguishes the DSKY caution indicators. (OPR ERR, PROG, RESTART, STBY and UPLINK ACTY).
VERB pushbutton	Conditions the CMC to interpret the next two numerical characters as a verb code and causes the verb display to be blanked.

Verb-Noun Formats. A noun may refer to a device, a group of computer registers or a group of counter registers, or it may simply serve to convey information without referring to any particular computer register. The noun is made up of 1, 2, or 3 components, each component being entered separately as requested by the verb code. As each component is keyed, it is displayed on the display panel with component 1 displayed in REGISTER 1, component 2 in REGISTER 2, and component 3 in REGISTER 3. There are two classes of nouns: normal and mixed. Normal nouns (codes 01 through 39) are those whose component members refer to computer registers which have consecutive addresses and use the same scale factor when converted to decimal. Mixed nouns (codes 40 through 99) are those whose component members refer to non-consecutive addresses or whose component members require different scale factors when converted to decimal, or both.

A verb code indicates what action is to be taken. It also determines which component member of the noun group is to be acted upon. For example, there are five different load verbs. Verb 21 is required for loading the first component of the selected noun, verb 22 loads the second component; verb 23 loads the third component; verb 24 loads the first and second component; and verb 25 loads all three components. A similar component format is used in the display and monitor verbs. There are two general classes of verbs, regular and extended. The regular verbs (codes 01 through 39) deal mainly with loading, displaying, and monitoring data. The extended verbs (codes 40 through 99) are principally concerned with calling up internal programs whose function is system testing and operation.

Whenever data is to be loaded by the operator, the VERB and NOUN lights flash, the appropriate data display register is blanked, and the internal computer storage register is cleared in anticipation of data loading. As each numerical character is keyed in, it is displayed in the proper display register. Each data display register can handle only five numerical characters at a time (not including sign). If an attempt is made to key in more than five numerical characters at a time, the sixth and subsequent characters are simply rejected but they do appear in the display register.

The + and - keys are accepted prior to inserting the first numerical character of REGISTER 1, REGISTER 2, or REGISTER 3; if keyed in at any other time, the signs are rejected. If the 8 or 9 key is actuated at any time other than while loading a data word preceded by a + or - sign, it is rejected and the OPR ERR light goes on.

The normal use of the flash is with a load verb. However, there are two special cases when the flash is used with verbs other than load verbs.

- Machine Address to be Specified. There is a class of nouns available to allow any machine address to be used; these are called "machine address to be specified" nouns. When the "ENTR," which causes the verb-noun combination to be executed, senses a noun of this type the flash is immediately turned on. The verb code is left unchanged. The operator should load the complete machine address of interest (five-character octal). This is displayed in REGISTER 3 as it is keyed in. If an error is made in loading the address, the CLR key may be used to remove it. Pressing the ENTR key causes execution of the verb to continue.

- Change Major Mode. To change major mode, the sequence is VERB 37 ENTR. This causes the noun display register to be blanked and the verb code to be flashed. The two-character octal major mode code should then be loaded. For verification purposes, it is displayed as it is loaded in the noun display register. The entry causes the flash to be turned off, a request for the new major mode to be entered, and new major mode code to be displayed in the PROG display register.

The flash is turned off by any of the following events:

- Final entry of a load sequence.
- Entry of verb "proceed without data" (33) or depression of PRO pb.
- Entry of verb "terminate" (34).

It is important to conclude every load verb by one of the aforementioned three, especially if the load was initiated by program action within the computer. If an internally initiated load is not concluded validly, the program that initiated it may never be recalled. The "proceed without data" verb is used to indicate that the operator is unable to, or does not wish to, supply the data requested, but wants the initiating program to continue as best it can with old data. The "terminate" verb is used to indicate that the operator chooses not to load the requested data and also wants to terminate the requesting routine.

Keyboard Operation

The standard procedure for the execution of keyboard operations consists of a sequence of seven key depressions:

VERB V_2 V_1 NOUN N_2 N_1 ENTR

Pressing the VERB key blanks the two verb lights on the DSKY and clears the verb code register in the CMC. The next two numerical inputs are interpreted as the verb code. Each of these characters is displayed by the verb lights as it is inserted. The NOUN key operates similarly with the DSKY noun lights and CMC noun code register. Pressing the ENTR key initiates the program indicated by the verb-noun combination displayed on the DSKY. Thus, it is not necessary to follow a standard procedure in keying verb-noun codes into the DSKY. It can be done in reverse order, if desired, or a previously inserted verb or noun can be used without rekeying it. No action is taken by the CMC in initiating the verb-noun-defined program until the ENTR key is actuated. If an error is noticed in either the verb code or noun code, prior to actuation of the ENTR key, it can be corrected simply by pressing the corresponding VERB or NOUN key and inserting the proper code. The ENTR key should not be actuated until it has been verified that the correct verb and noun codes are displayed.

If the selected verb-noun combination requires data to be loaded by the operator, the VERB and NOUN lights start flashing on and off (about once per second) after the ENTR key is pressed. Data is loaded in five-character words and, as it is keyed in, it is displayed character-by-character in one of the five-position data display registers; REGISTER 1, REGISTER 2, or REGISTER 3. Numerical data is assumed to be octal unless the five-character data word is preceded by a plus or minus sign, in which case it is considered to be decimal. Decimal data and octal data may be loaded with high-order zeros left out. If a decimal is used for any component of a multicomponent load verb, it must be used for all components of that verb. In other words, no mixing of octal and decimal data is permitted for different components of the same load verb. The ENTR key must be pressed after each data word. This tells the program that the numerical word being keyed in is complete. The on-off flashing of the VERB-NOUN lights terminates after the last ENTR key actuator of a loading sequence.

The CLR key is used to remove errors in loading data as it is displayed in REGISTER 1, REGISTER 2, or REGISTER 3. It does nothing to the PROG, NOUN or VERB lights. (The NOUN lights are blanked by the NOUN key, the VERB lights by the VERB key.) For single-component load verbs or "machine address to be specified" nouns, the CLR key depression performs the clearing function on the particular register being loaded, provided that the CLR key is depressed before the ENTR key. Once the ENTR key is depressed, the CLR key does nothing. The only way to correct an error after the data is entered for a single-component load verb is to begin the load verb again. For two-or three-component load verbs, there is a CLR backing-up feature. The first depression of the CLR key clears whichever register is being loaded. (The CLR key may be pressed after any character, but before its entry.) Consecutive CLR key actuations clear the data display register above the current one until REGISTER 1 is cleared. Any attempt to back up (clear) beyond REGISTER 1 is simply ignored. The CLR backing up function operates only on data pertinent to the load verb which initiated the loading sequence. For example, if the initiating load verb were a "write second component into" type only, no backing up action would be possible.

The numerical keys, the CLR key, and the sign keys are rejected if depressed after completion (final entry) of a data display or data load verb. At such time, only the VERB, NOUN, ENTR, RSET, or KEY REL inputs are accepted. Thus, the data keys are accepted only after the control keys have instructed the program to accept them. Similarly, the + and - keys are accepted only before the first numerical character of REGISTER 1, REGISTER 2, and REGISTER 3 is keyed in, and at no other time. The 8 or 9 key is accepted only while loading a data word which is preceded by a + or - sign.

The DSKY can also be used by internal computed programs for subroutines. However, any operator keyboard action (except RSET) inhibits DSKY use by internal routines. The operator retains control of the DSKY until he wishes to release it. Thus, he is assured that the data he wishes to observe will not be replaced by internally initiated data displays. In general, it is recommended that the operator release the DSKY for internal use when he has temporarily finished with it; this is done by pressing the KEY REL key.

2.2.3.3 Optical Subsystem

The optical subsystem (figure 2.2-6) is used for taking precise optical sightings on celestial bodies. These sightings are used for aligning the IMU and for determining the position of the spacecraft. The system includes the navigational base, two of the five channels of the CDU, parts of the power and servo assembly, controls and displays, and the optics, which include the scanning telescope (SCT) and the sextant (SXT).

2.2.3.3.1 Optics

The optics consist of the SCT and the SXT mounted in two protruding tubular sections of the optical base assembly. The SCT and SXT shaft axes are aligned parallel to each other and afford a common line-of-sight (LOS) to selected targets. The trunnion axes may be parallel or the SCT axis may be offset, depending upon the mode of operation.

The sextant is a highly accurate optical instrument capable of measuring the included angle between two targets. Angular sightings of two targets are made through a fixed beam splitter and a movable mirror located in the sextant head. The sextant lens provides 1.8-degree true field-of-view with 28X magnification. The movable mirror is capable of sighting a target to 50 degrees LOS from the shaft axis. The mechanical accuracy of the trunnion axis is twice that of the LOS requirement because of mirror reflection which doubles any angular displacement in trunnion axis.

The scanning telescope is similar to a theodolite in its ability to accurately measure elevation and azimuth angles of a single target using an established reference. The lenses provide 60-degree true field-of-view at 1X magnification. The telescope allowable LOS errors are one minute of arc-rms in elevation with maximum repeatability of 15 arc-seconds and approximately 40 arc-seconds in shaft axis.

2.2.3.3.2 Coupling Data Unit

The identical coupling data unit (CDU) used in the ISS is also used as part of the OSS. Two channels of the CDU are used, one for the SXT shaft axis and one for the SXT trunnion axis. These CDU channels repeat the SXT shaft and trunnion angles and transmit angular change information to the CMC in digital form. The angular data transmission in the trunnion channel is mechanized to generate one pulse to the CMC for 5 arc-seconds of movement of the SXT trunnion which is equivalent to 10 arc-seconds of SLOS movement. The shaft CDU channel issues one pulse for each 40 arc-seconds of shaft movement. The location of the SXT shaft and trunnion axes are transmitted to the CDUs through 16X and 64X resolvers, located on the SXT shaft and trunnion axes, respectively. This angular information is transmitted to the CDUs in the form of electrical signals proportional to the sine and cosine of 16X shaft angle and 64X trunnion angle. During the computer mode of operation, the CDU provides digital-to-analog conversion of the CMC output to generate an a-c input to the SXT shaft and trunnion servos. This analog input to the SXT axes will drive the SLOS to some desired position. In addition, the OSS channels of the CDU perform a second function on a time-sharing basis. During a thrust vector control function, these channels provide digital-to-analog conversion between the CMC and the service propulsion system (SPS) gimbals.

2.2.4 OPERATIONAL MODES

The PGNCS has two systems, six inertial subsystem (ISS), and three optical subsystem (OSS) modes. The system modes are listed as follows:

- Saturn takeover
- Thrust vector control.

The ISS modes are listed as follows:

- IMU turn-on
- IMU cage
- Coarse align
- Fine align
- Attitude error
- Inertial reference.

The OSS modes are listed as follows:

- Zero optics
- Manual control
- Computer control.

The moding of the system and ISS is controlled by the CDU with the exception of one mode, a cage switch on the main display and control panel. All other modes must be commanded by the CMC through the issuance of discrete moding commands to the CDU.

The modes of operation for the OSS are selected by the astronaut using controls located on the indicator control panel.

2.2.4.1 S-IVB Takeover

The S-IVB takeover capability provides steering signals to the Saturn instrument unit autopilot. There are two modes of operation, automatic and manual. The automatic mode provides the backup capability of issuing steering commands to the IU during the boost phase. This mode is initiated by positioning the LAUNCH VEHICLE GUIDANCE switch on the main display and control panel to CMC during the boost monitor program only. This switch arms the S-IVB takeover relay with 28 vdc and issues a discrete to the CMC. The CMC, on recognition of this input discrete, switches to a control routine which generates an S-IVB takeover discrete. The S-IVB takeover discrete allows the relay in the mode module (CDU) to energize, closing the interface between the DAC and the S-IVB instrument unit.

Normally the boost monitor program monitors the CDUs, computes the difference between the desired attitude (determined by a stored polynominal) and the actual attitude, and displays the error on the FDAI. During the takeover mode the commands are computed by taking the error (difference between polynominal and actual attitude) at takeover and storing as a bias. This value is subtracted from the actual error computed on succeeding cycles and is used to issue steering commands that attempt to maintain a constant error equal to that existing at takeover.

The manual mode provides the capability of issuing rotation control commands, through the CMC, to the instrument unit. The manual mode is initiated by placing the LAUNCH VEHICLE GUIDANCE switch to the CMC position and enabling the Saturn digital autopilot with an extended verb. The switch arms the S-IVB takeover relay with 28 vdc and issues a discrete to the computer. The CMC, on recognition of this discrete and the Saturn digital autopilot enabled, generates the S-IVB takeover discrete.

If either rotation control is placed to a pitch, yaw, or roll breakout position, the CMC issues an error-counter-enable discrete to the CDU. The error-counter-enable discrete is buffered in the moding module, modified by the digital mode module finally allowing the error counters to be enabled. The CMC then generates a $\pm\theta_C$ pulse train to the appropriate error counter where it is accumulated and converted to a ±d-c output signal by the DAC. The ±d-c signal is applied to the S-IVB IU as a ±0.5°/sec roll, or ±0.3°/sec yaw rate command.

When the rotation control is returned to the null position, the CMC inhibits the error-counter-enable discrete to the CDU which causes the error counter to reset. This results in a 0-vdc output signal from the DAC which is applied to the S-IVB IU as a 0°/sec roll, pitch, or yaw rate command.

2.2.4.2 Thrust Vector Control

This system mode is initiated by CMC program control.

The CMC commands a TVC discrete which energizes the TVC relay closing the interface between the CDU DAC and the SPS gimbal servo amplifiers.

The computer also issues an OSS error-counter enable and an ISS error-counter enable. The computer, when all operating requirements are met, issues an SPS engine-on command.

The read counters of the inertial channels of the CDU are repeating the gimbal angle changes indicating to the CMC the present spacecraft attitude. The accelerometers provide the program with ΔV inputs. These data are used to compute an attitude error and a SPS steering signal.

The attitude error is converted to a pulse train which is used to increment the CDU ISS error counters. The contents of these counters are converted to analog and displayed as they were in the attitude error display mode. The read counter input to the error counter is inhibited, allowing the error counter to be incremented or decremented only by CMC commands.

The OSS error counters are incremented by a $\Delta\theta$ command proportional to the steering signals required to steer the spacecraft on the proper trajectory. The error counter can operate completely independent of the read counter circuitry so the condition of the OSS is immaterial to this operation. The error counter contents are converted to analog 800 cps and then to a ±d-c voltage in the CDU OSS DAC. The pitch or yaw steering signal is routed through the TVC relay in the mode module to the SPS gimbal servo amplifiers. The TVC mode is complete when the spacecraft reaches the required velocity and the engine-off discrete is issued by the CMC. Each $\Delta\theta_C$ pulse from the CMC changes the SPS gimbals by 85 arc-seconds.

2.2.4.3 IMU Turn-On Mode

The purpose of the IMU turn-on mode is to initialize the ISS by driving the IMU gimbals to zero, and clearing and inhibiting the CDU read counters and error counters. The IMU turn-on mode is initiated by applying IMU operate power to the subsystem. The computer issues two CDU discretes required for this mode, CDU zero and coarse align. The computer also issues the turn-on delay complete discrete to the ISS after 90 seconds.

When IMU operate power is applied to the subsystem, the computer receives an ISS power-on discrete and a turn-on delay request. The computer responds to the turn-on delay request by issuing the CDU zero and coarse align discretes to the CDU. To prevent PIPA torquing for 90 seconds during the IMU turn-on mode, an inhibit is applied to the pulse torque power supply. This same inhibit is present when a computer warning has been issued. The CDU zero discrete clears and inhibits the read counters and error counters. The ISS operate power (+28 vdc) is routed through the de-energized contacts of the auto cage control relay to energize the cage relay. A 0-vdc signal, through the energized contacts of the cage relay, energizes the coarse-align relay. The energized contacts of the coarse-align relay switch the gimbal servo amplifier demodulator reference from 3200 cps to 800 cps, and close the IMU cage loop through the energized contacts of the cage relay. The coarse-align relay is held energized by the CDU coarse-align discretes and the energized contacts of the cage relay. The IMU gimbals will drive to the zero reference position using the sine output of the 1X gimbal resolvers (sin θ).

After 90 seconds, the computer issues the ISS turn-on delay complete discrete which energizes the ISS turn-on control relay. The auto cage control relay is energized by the ISS turn-on control relay. The ISS turn-on control relay then locks up through the energized contacts of the auto cage control relay. Energizing the auto cage control relay also removes the turn-on delay request and de-energizes the cage relay. This removes the sin θ signal and applies the coarse-align output to the gimbal servo amplifier.

Energizing the ISS turn-on control relay removes the pulse torque power supply inhibit. The 90-second delay enables the gyro wheels time to reach their operating speed prior to closing the stabilization loops. The pulse torque power supply inhibit prevents accelerometer torquing during the 90 seconds.

2.2.4.4 IMU Cage Mode

The IMU cage mode is an emergency mode which (1) allows the astronaut to recover a tumbling IMU by setting the gimbals to zero, and (2) to establish an inertial reference. The IMU cage mode can also be used to establish an inertial reference when the CSS is not activated.

The IMU cage mode is manually initiated by closing the spring-loaded cage switch on the main display and control panel for sufficient time to allow the IMU gimbals to settle at the zero position (5 seconds maximum). The IMU gimbal zeroing can be observed on the FDAI.

If the mode is commanded to recover a tumbling IMU after the IMU turn-on mode is completed, closing the IMU cage switch will cause the IMU gimbals to drive to zero. When the switch is released, the ISS will enter the inertial reference mode.

If the IMU cage mode is commanded to establish an inertial reference with the CSS in standby or off, the closing of the IMU cage switch will cause the IMU gimbals to drive to zero. When the switch is released, the inertial reference mode will be established.

Closing the IMU cage switch energizes the cage and coarse-align relays which apply the sin θ signals to the gimbal servo amplifier, and sends an IMU cage discrete to the computer. Releasing the switch causes the cage and coarse-align relays to de-energize. When the coarse-align relay is de-energized, the stabilization loops are closed. The computer, upon receiving the IMU cage signal, discontinues sending all of the following discretes and control signals:

- Error-counter enable (OSS)
- Error-counter enable (ISS)
- Coarse-align enable
- TVC enable
- SPS engine on (CSM only)
- Gyro-command enable (torquing)
- ±X and/or ±Y optics CDU - D/A
- ±X (outer), ±Y (inner), ±Z (middle) IMU CDU - D/A
- ±X, ±Y, ±Z gyro select
- Gyro set pulses.

The IMU cage mode should not be used indiscriminately. It is intended only as an emergency recovery function for a tumbling IMU. During the IMU cage mode, IMU gimbal rates are sufficient to cause the gyros to be driven into their rotational and radial stops because of no CDU rate limiting. This action causes both temporary and permanent (if gyro torquing was in process during cage) bias shifts on the order of several MERU (Milli Earth Rate Unit).

G&N

2.2.4.5 IMU Coarse Align

The coarse-align mode of operation is mechanized to allow the computer to rapidly align the IMU to a desired position with a limited degree of accuracy. The computer issues two discretes to the CDU in this mode, coarse-align and error-counter enable.

The coarse-align discrete is routed through the moding module where it is buffered. One buffered output provides a ground path to the coarse-align relay energizing the relay. The energized relay opens the gyro preamp output, replaces the normal 3200-cps demodulator reference with an 800-cps reference, and routes the 800-cps coarse-align output from the DAC into the gimbal servo amplifier demodulator, thereby allowing any 800-cps signal generated within the DAC to drive the gimbal until the DAC output is zero vrms.

The buffered coarse-align discrete and error-counter-enable discrete are routed from the moding module to the digital mode module for logical manipulations. The discretes at 0-vdc level are accepted by the error counter and logic module as moding commands enabling the error counter, and allowing the transfer of $\Delta\theta_g$ angles from the read counter to the error counter.

After the logic circuitry has been set up to accept commands from the computer, the CMC will begin transmitting $\pm\Delta\theta_c$ pulse trains at 3200 pps. These pulses, each equivalent to a change in gimbal angle of 160 arc-seconds, are accumulated in the error counter. The nine stages of the error counter are used solely to control ladder switches in the digital-to-analog converter module.

The $\Delta\theta_c$ pulse train is routed through a buffer stage in the DAC. The first $\Delta\theta_c$ pulse arriving at the EC&L logic will determine the direction the counter is to count, and will also provide a DAC-polarity control to the DAC. The polarity control provides an in-phase or an out-of-phase reference to the resistive ladder network through switches selected by the nine-bit error counter. An 800-cps analog signal will be generated at the ladder, the amplitude of which is dependent on the error counter content and the phase on the polarity of the input command $\Delta\theta_c$.

The ladder output is mixed with the coarse- and fine-resolver errors, after nulling, from the coarse module and the main summing amplifier module, respectively. These errors are out of phase with the ladder output and will act as a degenerative feedback providing rate limiting to the coarse-align loop drive rates.

The 800-cps mixing amplifier output of the DAC is routed through the coarse-align relay into the gimbal servo amplifier, causing the gimbal to drive in the direction commanded by the CMC.

The changing gimbal angles are recognized by the error-detection circuits in the coarse module and the main summing amplifier. These detected errors, recognized by the error counter logic circuitry, allow the $\phi 4$ pulse train at 6400 pps to increment the read counter. The incrementing read counter will close attenuation switches in the coarse, quadrant select, the main summing amplifier modules nulling the sine and cosine voltage inputs from 1X and 16X resolver into the error-detect circuits.

As the read counter is being incremented, the output of the first stage is routed through logic in the EC&L module, through a buffer in the DAC, and out to the CMC as an increase in gimbal angle of 40 arc-seconds. The output of the third stage of the counter, at 160 arc-seconds per pulse, is recognized in the EC&L logic as an incremental value to be entered into the error counter in the opposite direction to the commanded $\Delta\theta$. If $\Delta\theta$ is positive, the error counter is counted up and the $\Delta\theta_g$ from the read counter decrements the counter. For each read counter pulse into the error counter, the total content will decrease the DAC output and the rate of drive. When the number of digital feedback pulses equal the commanded pulse number, the error counter will be empty and the DAC output should be zero.

The limited read counter incrementing rate, and the fact that the fine error input to the DAC increases in proportion to $\theta - \psi$ as the drive rate exceeds the range controlled by the fine system, limits the gimbals rate of drive to a maximum of 35 degrees per second.

2.2.4.6 IMU Fine Align

The fine-align mode of operation allows the computer to accurately align the IMU to a predetermined gimbal angle within seconds of arc. The computer does not command any CDU discretes during this mode of operation; therefore, the read counter circuitry will repeat the changing gimbal angles exactly as was done in the coarse-align mode. The computer will keep track of the gimbal angle to within 40 arc-seconds.

The commanding signals for the fine-align mode are generated in the time-shared, fine-align electronics. The computer first issues a torque-enable discrete which applies 28 vdc and 120 vdc to the binary current switch and the differential amplifier precision voltage reference circuit, allowing the circuit to become operative. The circuit switch is reset to allow a dummy current, which is equal to the torquing current, to flow. This allows the current to settle to a constant value prior to its being used for gyro torquing. A gyro is then selected for either plus or minus torquing. After the preceding discretes have been issued, the computer then sends set commands or fine-align commands to the set side of the current switch. The pulse turns on the selected plus or minus torque current to the gyro, causing the float to move. The resulting signal generator output causes the platform to be driven through an angle equal to the commanded angle. The CMC will receive inputs from the CDU read counter indicating the change in gimbal angle.

The number of torquing pulses sent from the CMC to the torquing electronics is computed, based on the angle of the gimbal at an instant of time and a desired alignment angle. The difference is converted into the number of pulses necessary to drive the gimbal through the difference angle. Each pulse sent is equivalent to 0.615 arc-second of gimbal displacement. The required number of fine-align pulses is computed only once and is not recomputed based on the gimbal angle after the desired number of pulses have been sent. The fine-align loop operation is open-loop as far as the computer is concerned.

The fine-align pulses generated by the CMC are issued in bursts at a bit rate of 3200 pulses per second. The fine-align electronics will allow the torquing current to be on in the direction chosen by computer logic for the duration of the pulse burst.

2.2.4.7 Attitude Error Display Mode

The attitude error display mode of the inertial subsystem allows the computer to display to the operator, in analog fashion, an attitude error. In this mode of operation, only the CDU error-counter-enable discrete is generated by the computer. In this mode of operation, the computer is again informed of the gimbal angle and any changes to it through the read counter and the analog-to-digital conversion associated with it. The read counter 20 arc-second output is routed through logic in the EC&L module through the DAC buffer to the CMC.

The computer is then aware of the present attitude of the spacecraft. The digital autopilot program has a computed desired attitude associated with the present time and position of the spacecraft. Any difference between the desired and actual is an attitude error. The attitude error is converted to $\Delta\theta_C$ pulses, each pulse being equivalent to 160 arc-seconds of error, which are sent to the error counter at a rate of 3200 pps. The error counter is incremented to contain the number of pulses commanded. The contents of the error counter are converted to an 800-cps error signal by the DAC. The phase of the DAC output is determined by logic in the EC&L module, based on whether the input command was a plus or minus $\Delta\theta$. The 800 cps with a maximum amplitude of 5 vrms zero or pi-phase is displayed on the attitude error needles of the FDAI as an attitude error. The digital feedback from the read counter to the error counter is disabled during this mode of operation allowing only the CMC-generated $\Delta\theta$ commands to increment or decrement the error counter.

The spacecraft attitude can also be displayed on the FDAI. This information is taken from the 1X gimbal angle resolver sine and cosine windings. Pitch, yaw, and roll can be displayed from the inner, middle, and outer gimbals, respectively.

2.2.4.8 Inertial Reference Mode

The inertial reference mode of operation is a mode of operation in which no computer discretes are being issued by the computer to any part of the ISS. This mode is used as a means of obtaining an inertial reference only. This reference is taken from the 1X gimbal angle resolver sine and cosine windings. The reference can be displayed on the FDAI or used as an input to the attitude set relays of the SCS.

In this mode of operation, the 25 IRIGs hold the stable platform inertially referenced. The CDU read counter will continuously monitor the changing gimbal angles because of spacecraft motion and indicate to the CMC the changing angles. The error counter and the DAC are not used in this mode of operation.

2.2.4.9 Zero Optics Mode

During the zero optics mode, the shaft and trunnion axes of the SXT are driven to their zero positions by taking the outputs of the transmitting resolvers (1X and 64X in trunnion and 1/2X and 16X in shaft) and feeding them through the two-speed (2X) switches to the motor drive amplifier (MDA). The MDA in turn drives loops to null positions as indicated by zero output from the resolvers. The SCT shaft and trunnion axes follow to a zero position. After 15 seconds, the computer will issue a CDU zero discrete, and will initialize the shaft and trunnion counters in preparation for receiving new data from the CDU.

The zero optics mode is selected by the flight crew. Placing the ZERO switch to ZERO position will energize a relay in the PSA via a relay driver, which, in turn, will energize the two-speed switch. The computer is notified of the zero optics mode by a signal from the zero switch when the change from off to zero position occurs.

2.2.4.10 Manual Mode Operation

The manual mode can be selected to operate under either direct hand control or resolved hand control. Independent control of the SCT trunnion is possible in both of these mode variations.

2.2.4.10.1 Manual Direct Operation

When in this mode, the hand controller outputs are applied directly to the SXT shaft and trunnion motor drive amplifiers. Forward and back motion of the hand controller commands increasing and decreasing trunnion angles, and right and left motion of the hand controller commands increasing and decreasing shaft angles, respectively. The target image motion is in the R-M coordinate system, the position of which is dependent upon the position of the SXT shaft.

The apparent speed of the image motion can be regulated by the flight crew by selecting either low, medium, or high controller speed on the indicator control panel. This regulates the voltage applied to the motor drive amplifier, A_s and A_t; therefore, the shaft and trunnion drive rates. The maximum rates are approximately 20 degrees per second for the shaft and 10 degrees per second for the trunnion.

2.2.4.10.2 Slave Telescope Modes

The slave telescope modes provide for alternate operation of the telescope trunnion while the SXT is being operated manually. The alternate modes are selected by the TELTRUN switch on the mode control panel. There are three possible selections, SLAVE to SXT, 0°, and 25°. With this switch in the SLAVE to SXT position, the SCT trunnion axis is slaved to the SXT trunnion; this is the normal operating position for the SCT. With the switch in the 0° position, the SCT trunnion is locked in a zero position by the application of a fixed voltage to the SCT trunnion 1X receiving resolver. This will cause this position loop to null in a zero orientation. Therefore, the centerline of the SCT 60-degree field-of-view is held parallel to the LLOS of the SXT.

With the switch in the 25° position, an external voltage is applied to the same 1X receiving resolver which will cause the SCT trunnion position loop to null out so that the centerline of the 60-degree field-of-view is offset 25 degrees (A_t of SCT at 12.5 degrees) from the LLOS of the SXT. This position of the SCT trunnion will allow the landmark to remain in the 60-degree field-of-view while still providing a total possible field-of-view of 110 degrees if the SCT shaft is swept through 360 degrees.

2.2.4.10.3 Manual Resolved Operation

When in this mode, the hand controller outputs are put through a matrix transformation prior to being directed to the shaft and trunnion motor drive amplifiers. The matrix transformation makes the image motion correspond directly to the hand controller motion. This is up, down, right, and left motions of the hand controller command; the target image moves up, down, right, and left respectively, in the field of view. In other words, the image motion is in the X-Y spacecraft coordinate system. The matrix transformation takes place in two steps. The outputs of the hand controller are routed to the 1X resolver on the SXT shaft. Here the drive signals, $\dot{A}_s$ and $\dot{A}_t$, are transformed by the sine and cosine functions of the shaft angle ($\dot{A}_s$). One of the two outputs of the 1X resolver is sent to the SXT trunnion motor drive amplifier. The second output is then resolved through the SLOS angle (A_{LOS}) so that the target image motion will be independent of SLOS angle. This is accomplished by the cosecant computing amplifier (CSC) and the 2X computing resolver located on the SXT trunnion axis. The net result is that the shaft drive rate, $\dot{A}_s$, is inversely proportional to the sine of the SLOS angle. The speed controller is also operational in this mode.

2.2.4.10.4 Optics-Computer Mark Logic

The MARK and MARK REJECT buttons on the indicator control panel are utilized to instruct the computer that a navigational fix has taken place, and that SXT shaft and trunnion position and the time should either be recorded or rejected. The mark command is generated manually by the flight crew which energizes the mark relay. The mark relay transmits a mark command to the computer. If an erroneous mark is made, the mark reject button is depressed; this will generate a "mark reject" command to the computer.

2.2.4.10.5 Computer Mode Operation

The computer-controlled operation is selected by placing the moding switch in computer position. The mechanization of this loop is chosen by the computer program that has been selected by the flight crew. The operation of the SXT under computer control is accomplished by completing the circuit from the CDU digital-to-analog converters (DAC) to the shaft and trunnion motor drive amplifier. The computer can then provide inputs to these amplifiers via a digital input to the CDU, which are converted in the DAC to an 800-cycle signal that can be used by the MDA. This mode is used when it is desired to look at a specific star for which the computer has the corresponding star coordinates. The computer will also know the attitude of the spacecraft from the position of the IMU gimbals and will, therefore, be able to calculate the position of the SXT axes required to acquire the star. The computer can then drive the shaft and trunnion of the SXT to the desired position via the DAC.

2.2.5 POWER DISTRIBUTION

The guidance and navigation circuit breakers (panel 5) supply a-c and d-c power to switches on panel 100 and directly to the PSA and CMC. The panel 100 switch (G/N POWER - LIGHTS) supplies ac 1 or ac 2 power to the PSA (figure 2.2-4) where it is routed to the dimmer power supply. The output of the dimmer power supply is provided to the following:

- Caution and warning lamp on LEB panel 122
- Star acquired lamp on LEB panel 122
- TPAC readout on LEB panel 122
- Optics (SCT and SXT) reticles

The panel 100 switches (G/N POWER - IMU and OPTICS) supply the d-c power to the PSA for power to the ISS, OPTICS and CDU power supplies. The IMU HTR and COMPUTER circuit breakers supply power to the ISS temperature control circuits and the CMC power supplies.

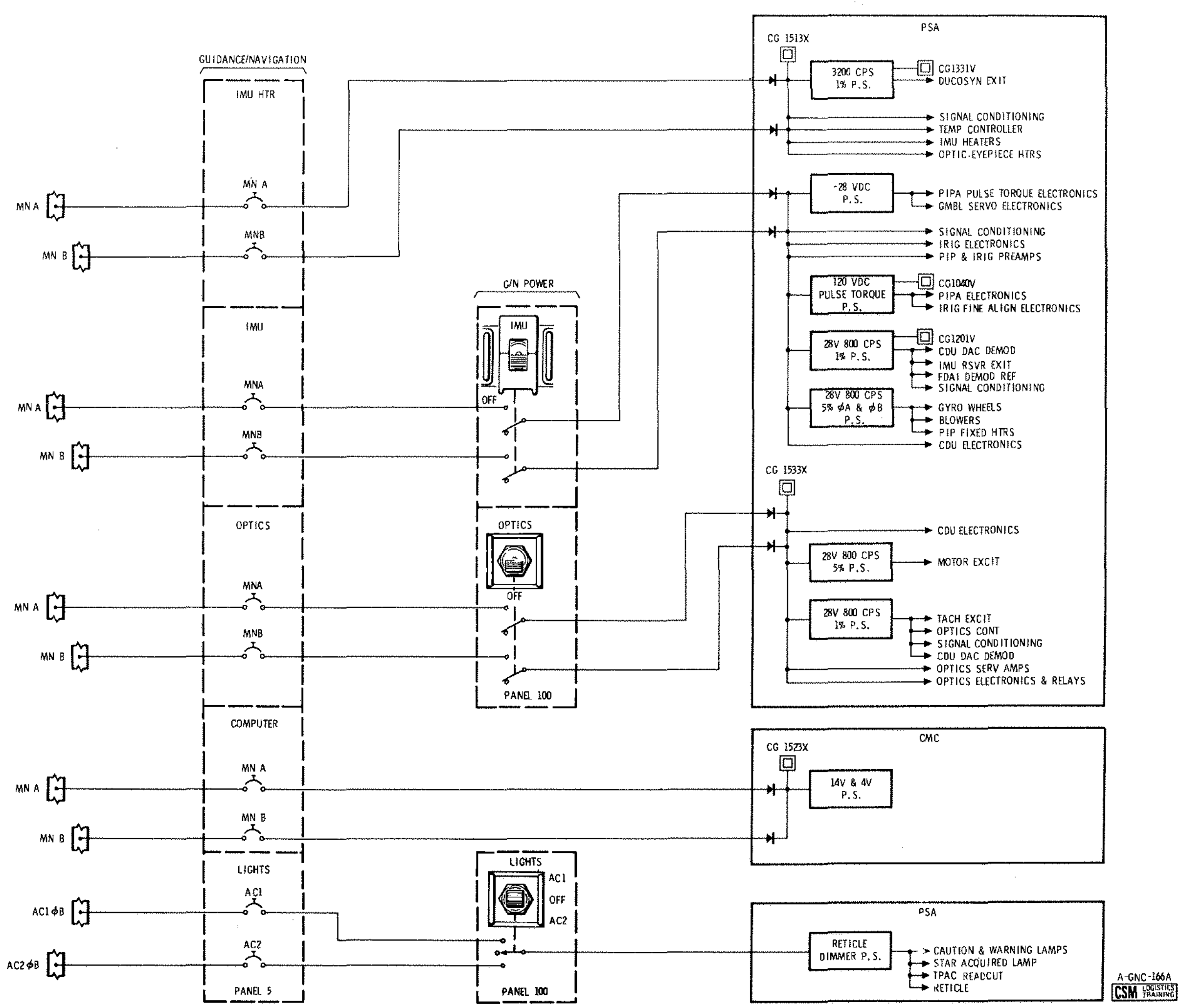


Figure 2.2-4. PGNCS Power Distribution

Circuit breakers on panel 226 supply a-c power to dimmer controls on panels 8 and 100 for lighting on the DSKYs, EMS, SCS displays and controls (FDAI 1 and 2, ASCP and GP/FPI), and LEB panel 122. The circuit breakers (LMDC-AC1 and LEB AC2) supply the a-c power to variable transformers in panels 8 and 100 and to isolation transformers (figure 2.2-5) for control of intensity of the status and key integral lamps on the DSKYs and integral lamps on the EMS, SCS displays and controls, and LEB panel 122. The intensity of the electro-luminescent displays on the DSKYs are controlled by rheostats on panels 8 and 100.

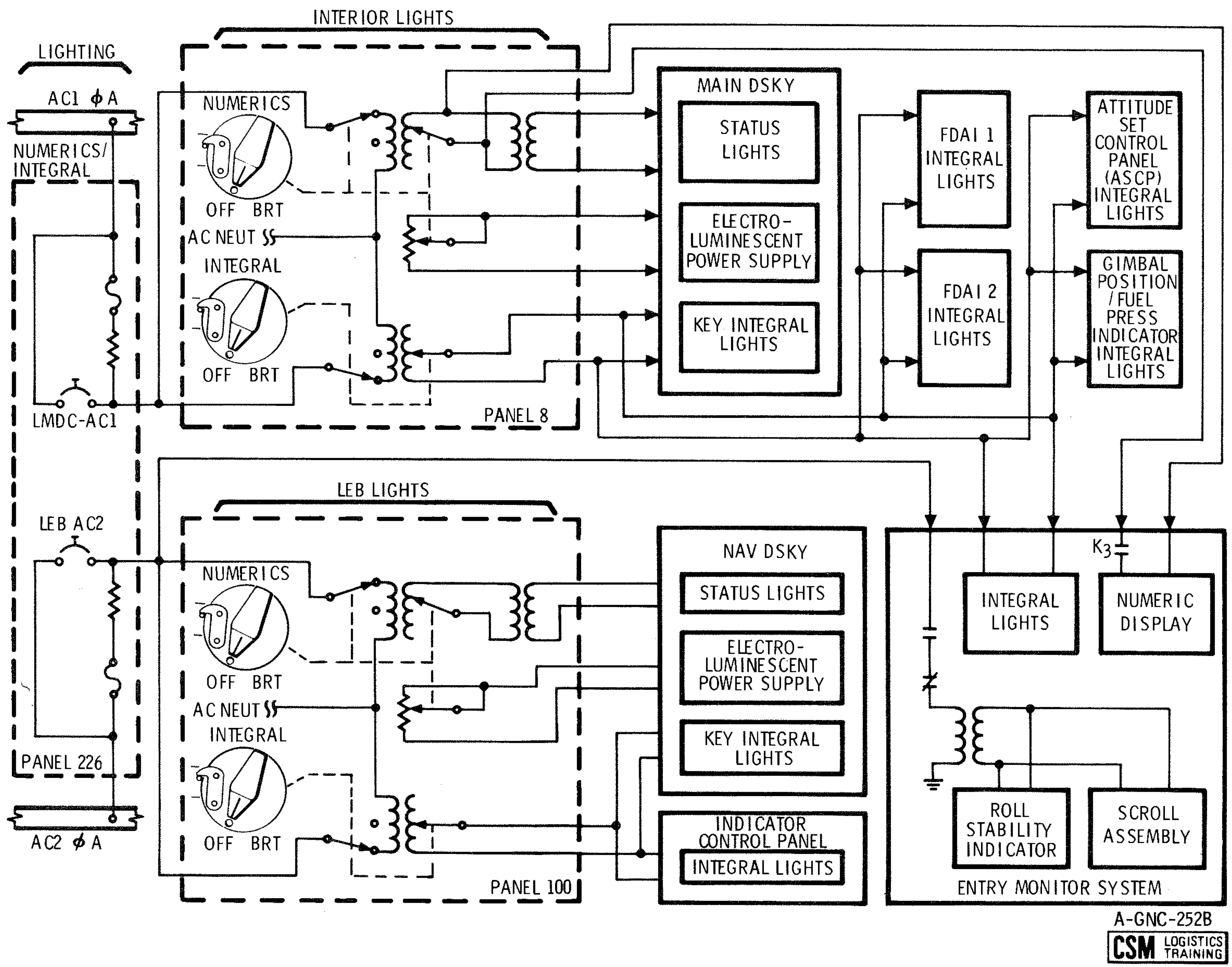


Figure 2.2-5. PGNCS Lighting

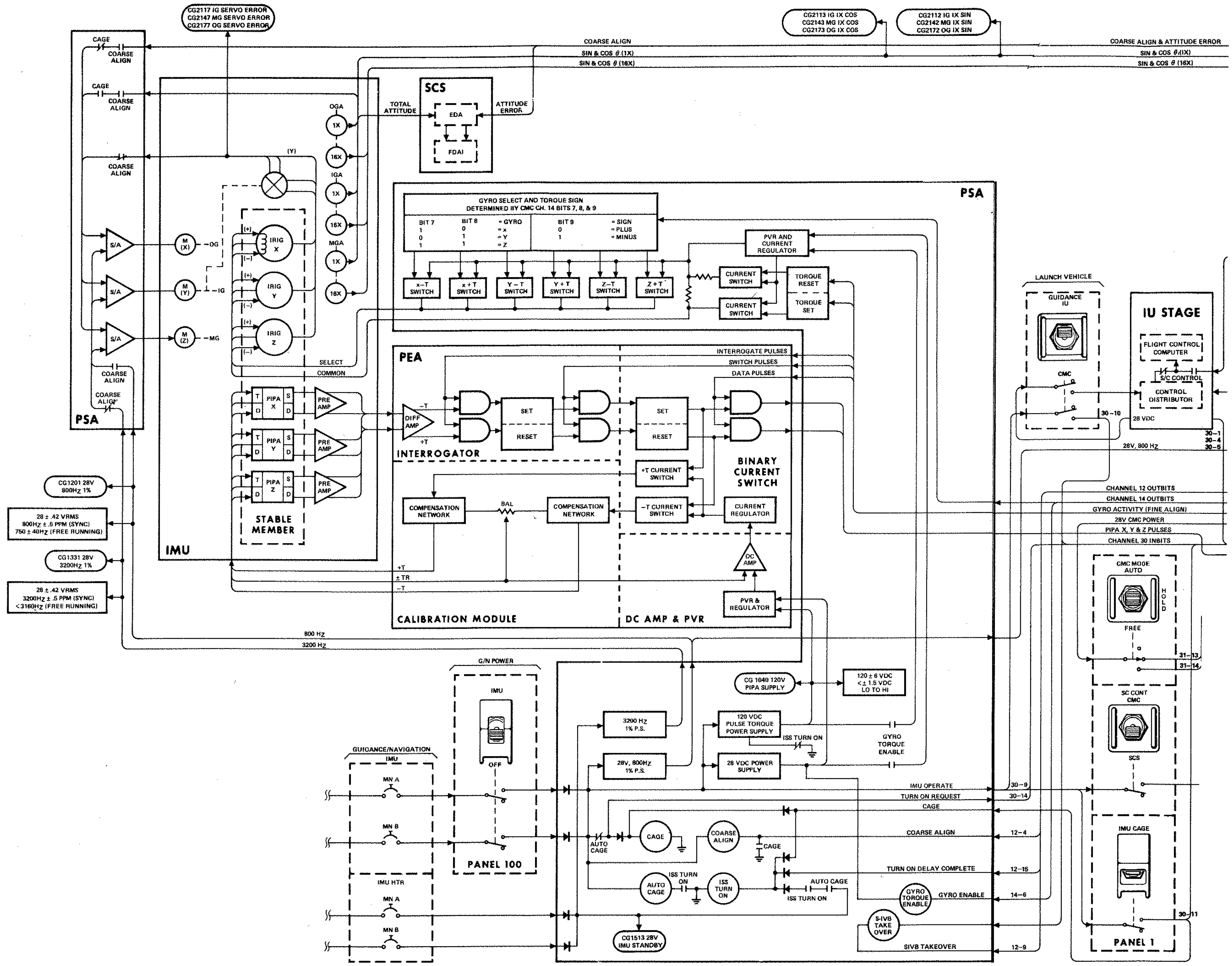


Figure 2.2-6. PGNCS Functional Diagram (Sheet 1 of 2)

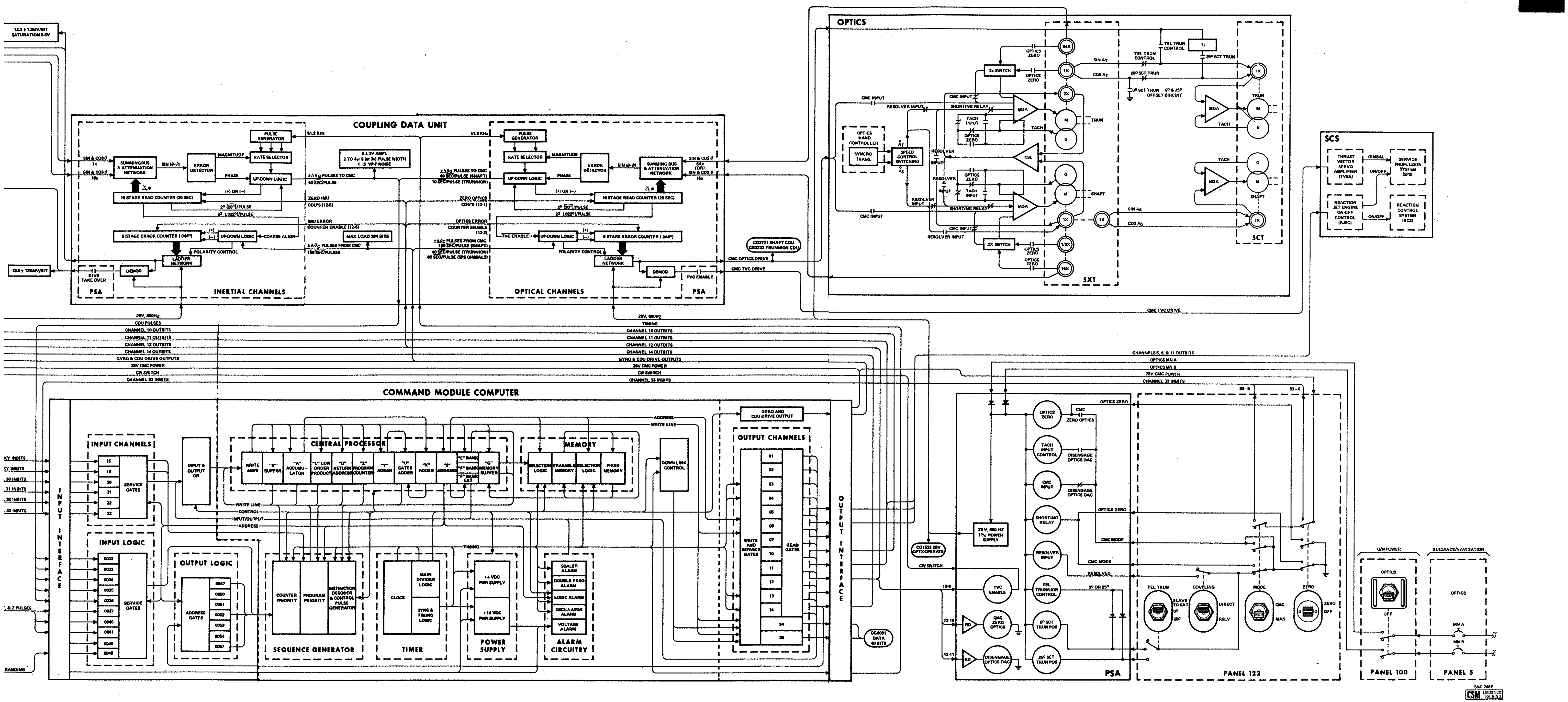


Figure 2.2-6. PGNCS Functional Diagram (Sheet 2 of 2)

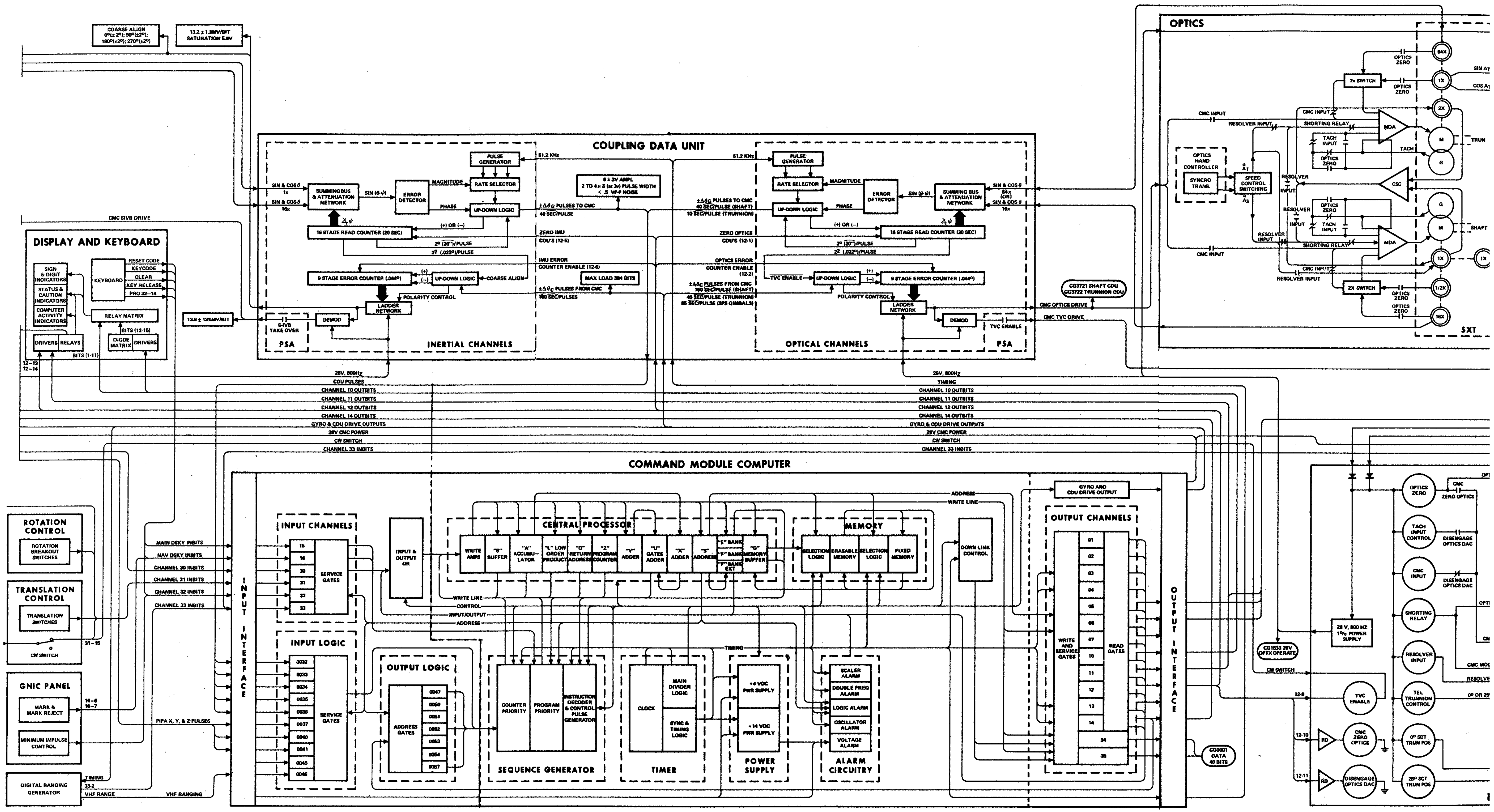

COARSE ALIGN 0°(± 2°); 90°(±2°); 180°(±2°); 270°(±2°)
13.2 ± 1.3MV/BIT SATURATION 5.6V
COUPLING DATA UNIT
PULSE GENERATOR
RATE SELECTOR
SUMMING BUS & ATTENUATION NETWORK
ERROR DETECTOR
UP-DOWN LOGIC
16 STAGE READ COUNTER (20 SEC)
9 STAGE ERROR COUNTER (.044°)
LADDER NETWORK
DEMOD
POLARITY CONTROL
MAX LOAD 384 BITS
S-IVB TAKE OVER
TVC ENABLE
PSA
INERTIAL CHANNELS
OPTICAL CHANNELS
CMC SIVB DRIVE
DISPLAY AND KEYBOARD
KEYBOARD
RELAY MATRIX
DIODE MATRIX
DRIVERS
RELAYS
RESET CODE
KEYCODE
CLEAR
KEY RELEASE
PRO 32-14
CG3721 SHAFT CDU
CG3722 TRUNNION CDU
CMC OPTICS DRIVE
CMC TVC DRIVE
OPTICS
OPTICS HAND CONTROLLER
SYNCRO TRANS.
SPEED CONTROL SWITCHING
2x SWITCH
OPTICS ZERO
CMC INPUT
RESOLVER INPUT
SHORTING RELAY
TACH INPUT
MDA
CSC
TRUN
SHAFT
SXT
28V, 800Hz
CDU PULSES
TIMING
CHANNEL 10 OUTBITS
CHANNEL 11 OUTBITS
CHANNEL 12 OUTBITS
CHANNEL 14 OUTBITS
GYRO & CDU DRIVE OUTPUTS
28V CMC POWER
CW SWITCH
CHANNEL 33 INBITS
COMMAND MODULE COMPUTER
ROTATION CONTROL
ROTATION BREAKOUT SWITCHES
TRANSLATION CONTROL
TRANSLATION SWITCHES
GNIC PANEL
MARK & MARK REJECT
MINIMUM IMPULSE CONTROL
DIGITAL RANGING GENERATOR
VHF RANGING
MAIN DSKY INBITS
NAV DSKY INBITS
CHANNEL 30 INBITS
CHANNEL 31 INBITS
CHANNEL 32 INBITS
PIPA X, Y, & Z PULSES
INPUT INTERFACE
INPUT CHANNELS
SERVICE GATES
INPUT LOGIC
INPUT & OUTPUT OR
OUTPUT LOGIC
ADDRESS GATES
CENTRAL PROCESSOR
WRITE AMPS
"B" BUFFER
"A" ACCUMULATOR
"L" LOW ORDER PRODUCT
"Q" RETURN ADDRESS
"Z" PROGRAM COUNTER
"Y" ADDER
"U" GATES ADDER
"X" ADDER
"S" ADDRESS
"E" BANK
"F" BANK
"F" BANK EXT
"G" MEMORY BUFFER
MEMORY
SELECTION LOGIC
ERASABLE MEMORY
FIXED MEMORY
DOWN LINK CONTROL
GYRO AND CDU DRIVE OUTPUT
OUTPUT CHANNELS
WRITE AND SERVICE GATES
READ GATES
WRITE LINE
CONTROL
INPUT/OUTPUT
ADDRESS
SEQUENCE GENERATOR
COUNTER PRIORITY
PROGRAM PRIORITY
INSTRUCTION DECODER & CONTROL PULSE GENERATOR
TIMER
CLOCK
MAIN DIVIDER LOGIC
SYNC & TIMING LOGIC
POWER SUPPLY
+4 VDC PWR SUPPLY
+14 VDC PWR SUPPLY
ALARM CIRCUITRY
SCALER ALARM
DOUBLE FREQ ALARM
LOGIC ALARM
OSCILLATOR ALARM
VOLTAGE ALARM
CG0001 DATA 40 BITS
OUTPUT INTERFACE
CG1533 28V OPTX OPERATE
28 V, 800 HZ 1% POWER SUPPLY
OPTICS ZERO
TACH INPUT CONTROL
CMC INPUT
SHORTING RELAY
RESOLVER INPUT
TEL TRUNNION CONTROL
TVC ENABLE
CMC ZERO OPTICS
DISENGAGE OPTICS DAC
0° SCT TRUN POS
25° SCT TRUN POS

Figure 2.2-6.

SCS

SECTION 2

SUBSECTION 2.3

STABILIZATION AND CONTROL SYSTEM

2.3.1 INTRODUCTION

The stabilization and control system (SCS) provides a capability for controlling rotation, translation, SPS thrust vector, and displays necessary for man in the loop control functions.

The SCS is divided into three basic subsystems: attitude reference, attitude control, and thrust vector control. These subsystems contain the elements which provide selectable functions for display, automatic and manual attitude control, and thrust vector control. All control functions are a backup to the primary guidance navigation and control system (PGNCS). The SCS provides two assemblies for interface with the propulsion system; these are common to SCS and PGNCS for all control functions. The main display and control panel contains the switches used in selecting the desired display and control configurations.

The SCS interfaces with the following spacecraft systems:

- Telecommunications system receives all down-link telemetering from SCS.
- Electrical power system provides primary power for SCS operation.
- Environmental control system transfers heat from SCS electronics.
- Sequential events control system provides abort switching and separation, enabling of SCS reaction control drivers, and receives manual abort switch closure from the SCS.
- Orbital rate drive electronics for interface with the pitch axis of the FDAI ball to give a local vertical referenced display.
- Guidance, navigation, and control system

  Provides roll, pitch, and yaw total attitude and attitude error inputs for display.

  Provides RCS on-off commands to the SCS interface assembly for attitude control.

  Provides TVC servo commands to the SCS interface assembly for automatic thrust vector control.

Provides automatic SPS on-off command to SCS interface assembly for ΔV control.

Receives switch closure signals from SCS translation and rotation controls.

- Entry monitor system provides SPS enabling/disabling discretes to the SCS thrust on-off logic for the SPS.

- Propulsion system

  The service propulsion system receives thrust vector direction commands and thrust on-off commands from the SCS that can originate in the PGNCS or the SCS.

  The reaction control system receives thrust on-off commands from the SCS that can originate in the PGNCS or the SCS.

Detailed descriptions of the SCS hardware, attitude reference subsystem, attitude control subsystem, and thrust vector control subsystem are contained in the following paragraphs.

2.3.2 CONTROLS, SENSORS, AND DISPLAYS

As an introduction to the SCS a brief description is given of the hardware comprising one complete system. A more detailed discussion follows for the hand controls, displays, and gyro assemblies. The configurations within the SCS resulting from panel 1 switch positions are also presented.

2.3.2.1 SCS Hardware

The function of the SCS hardware shown in figure 2.3-1 is as follows:

- Translation control (TC) provides a means of exercising manual control over rectilinear motion of the spacecraft. It also provides the capability for manual abort initiation during launch by CCW rotation. Transfer of SC control from PGNCS to SCS is accomplished by CW rotation.

- Rotation control (RC) (2) provides a means of exercising manual control of spacecraft rotation in either direction about each axis. Also the RC may be used for manual thrust vector control. It provides the capability to control spacecraft communications with a push-to-talk trigger switch.

- Gimbal position and fuel pressure indicator (GP/FPI) provides a redundant display of the SPS pitch and yaw gimbal angles and a means of manually trimming the SPS before thrusting. The indicator has the alternate capability of providing a display of launch vehicle (S-IVB) propellant tank ullage pressures.

- Attitude set control panel (ASCP) interfaces with either of the total attitude sources to enable manual alignment of the SCS total attitude.

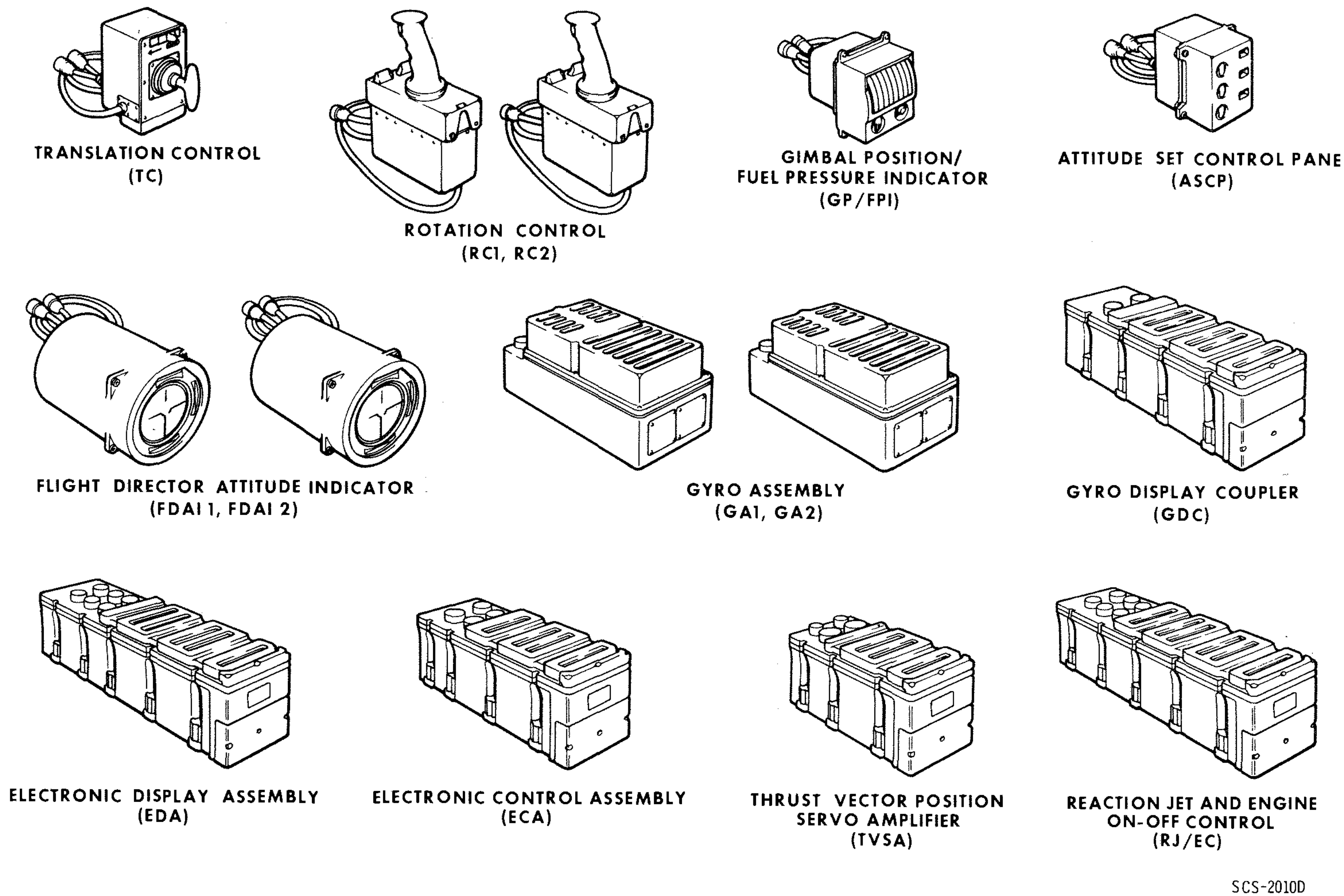


Figure 2.3-1. SCS Flight Hardware

- Flight director attitude indicators provide to the crew a display of spacecraft attitude, attitude error, from the PGNCS or SCS. The SCS will provide angular rate information.

- Gyro assembly (GA No. 1) contains three body-mounted attitude gyros (BMAG) together with the electronics necessary to provide output signals proportional to either angular rate or to angular displacement. GA No. 2 contains three BMAGs and associated electronics to provide body rates only.

- Gyro display coupler (GDC) provides the interface between the body rate sensors and displays to give an accurate readout of spacecraft attitude relative to a given reference coordinate system.

- Electronic display assembly (EDA) provides the interface between the signal sources to be displayed and the FDAIs and GPI. The EDA also provides signal conditioning for telemetry of display signals.

- Electronic control assembly (ECA) contains the circuit elements required for summing, shaping, and switching of the rate and attitude error signals and manual input signals necessary for stabilization and control of the thrust vector and the spacecraft attitude.

- Thrust vector servo amplifier (TVSA) provides the electrical interface between the command electronics and the gimbal actuator for positioning the SPS engine.

- Reaction jet and engine ON-OFF control (RJ/EC) contains the solenoid drivers and logic circuits necessary to control both the RCS automatic solenoid coils and SPS solenoid control valves.

2.3.2.2 Controls and Displays

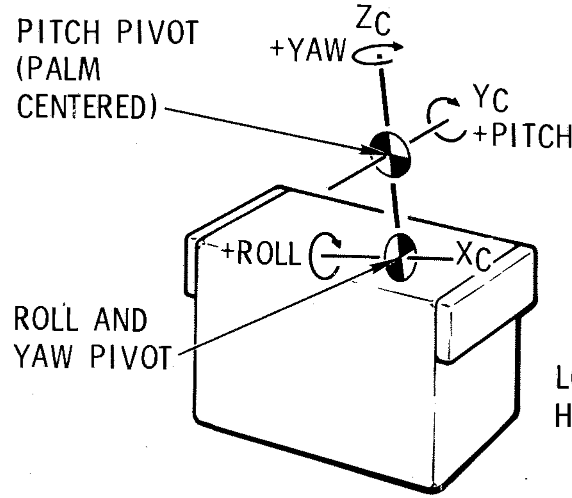
The SCS controls and displays consist of the following assemblies:

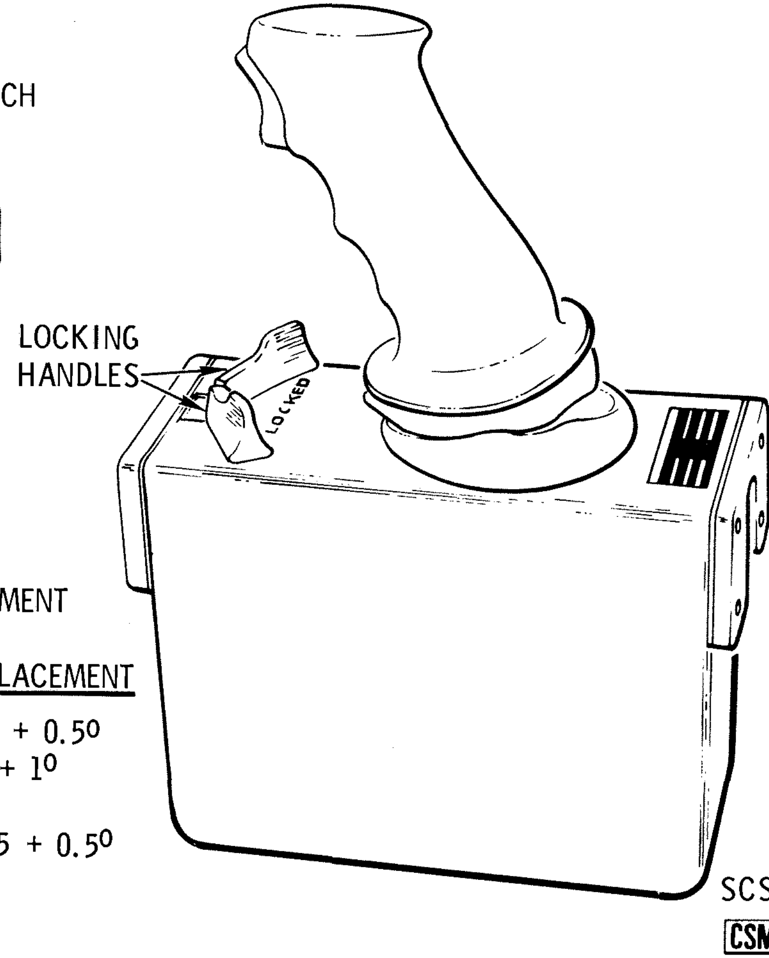
- Rotation control (RC) (2 units)
- Translation control (TC)
- Attitude set control panel (ASCP)
- Gimbal position and fuel pressure indicator (GP/FPI)
- Flight director attitude indicator (FDAI) (2 assemblies)

2.3.2.2.1 Rotation Control

Two identical rotation controls (RC) are provided. The controls are connected in parallel so that they operate in a redundant fashion without switching. Pitch commands are commanded about a palm-centered axis, yaw commands about the grip longitudinal axis, while roll commands result from a left-right motion (figure 2.3-2). Within the RC there are three command sources per axis.

a. Breakout switches ($\pm$BO). A switch closure occurs whenever the RC is moved 1.5 degrees from its null position. Separate switches are provided in each axis and for each direction of rotation. These six breakout





LOCKING HANDLES

CONTROLLER LOCK TO ARM BY 50^{0} DISPLACEMENT

ROTATION CONTROL PARAMETERS	DISPLACEMENT
BREAKOUT SWITCH ACTUATION	$1.5 + 0.5^{0}$
SOFT STOP	$10 + 1^{0}$
DIRECT SWITCH ACTUATION	11^{0}
HARD STOP	$11.5 + 0.5^{0}$

Figure 2.3-2. Rotation Control

switches are used to provide command signals to the command module computer (CMC), SCS minimum impulses, acceleration commands, BMAG cage signals, and proportional rate command enabling.

b. Transducers. Transducers produce a-c signals proportional to the rotation control displacement from the null position. These signals are used to command spacecraft rotation rates during SCS proportional rate control and to command SPS engine gimbal position during manual thrust vector control (MTVC). One, two, or all three transducers can be used simultaneously, generating corresponding command signals.

c. Direct switches. Redundant direct switches will close whenever the control is moved a nominal 11 degrees from its null position (hardstops limit control movement to ±11.5 degrees from null in all axes). Separate switches are provided in each axis and for each direction of rotation. Direct switch closure will produce acceleration commands through the RCS direct solenoids.

The rotation control is provided with a tapered female dovetail on each end of the housing. This dovetail mates with mounting brackets on the couch armrests. When attached to the armrests, the input axes are approximately parallel with spacecraft body axes. Figure 2.3-12 illustrates control motions about its axis and the resulting commands to the RCS, PGNCS, or SCS. A trigger-type push-to-talk switch is also located in the control grip. Redundant locking devices are provided on each control.

2.3.2.2.2 Translation Control

The translation control provides a means of accelerating along one or more of the spacecraft axes. The control is mounted with its axes approximately parallel to those of the spacecraft. The spacecraft will accelerate along the X-axis with a push-pull motion, along the Y-axis by a left-right motion, and along the Z-axis by an up-down command (figure 2.3-3). Redundant switches close for each direction of control displacement. These switches supply discrete commands to the CMC and the RJ/EC. A mechanical lock is provided to inhibit these commands. In addition the T-handle may be rotated about the longitudinal axis.

a. The redundant clockwise (CW) switches will transfer spacecraft control from CMC to SCS. It may also transfer control between certain submodes within the SCS.

b. The redundant counterclockwise (CCW) switches provide for a manual abort initiation during the launch phase. A discrete signal from switch closure is fed to the master events sequence controller (MESC) which initiates other abort functions.

Neither the CW or CCW functions are inhibited by the locking switch on the front of the controller. The T-handle will remain in the CW or CCW detent position without being held, once it is rotated past approximately ±12 degrees.

2.3.2.2.3 Gimbal Position and Fuel Pressure Indicator (GP/FPI)

The GP/FPI (figure 2.3-4) contains redundant indicators for both the pitch and yaw channels. During the boost phases, the indicators display

CW & CCW CONTROL MOTION	LIMITS
HARD STOP, DETENT, & SWITCH CLOSURE	17°±2°
FORCE INTO DETENT	15±5.0 LB INCHES
FORCE OUT OF DETENT	6 LB INCHES MIN

TRANSLATION CONTROL MOTION	LIMITS (+ OR - COMMANDS)
MECHANICAL STOP	0.5 ± 0.075 ARC INCHES
SWITCH CLOSURE	$0.375 \begin{smallmatrix}+0.025 \\ -0.075\end{smallmatrix}$ ARC INCHES
FORCE	1.5 ± 0.33 POUNDS

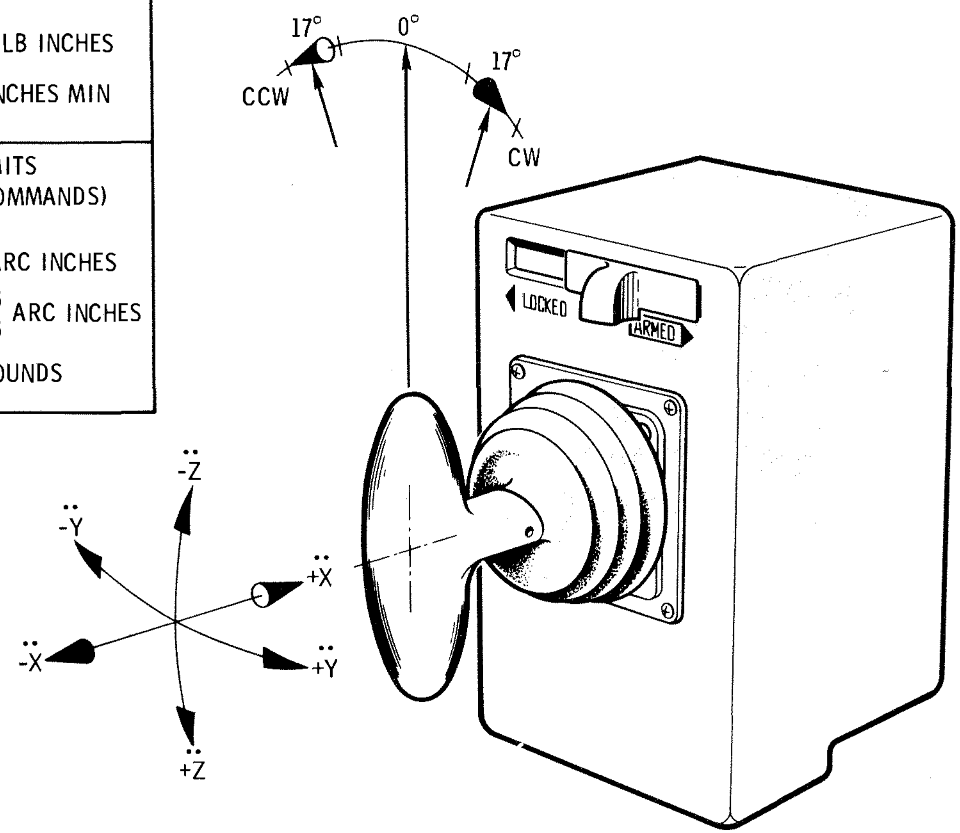


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Figure 2.3-3. Translation Control

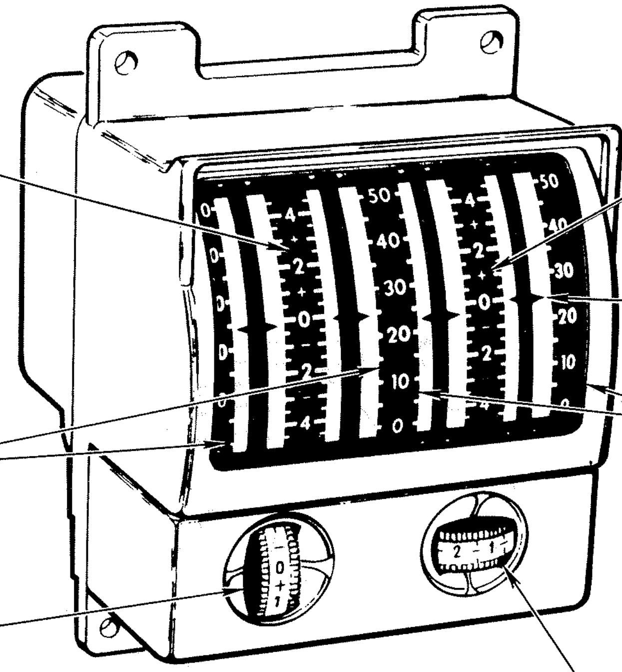

Figure 2.3-4. Gimbal Position Indicator

launch vehicle propellant tank ullage pressures. The gimbal position indicator consists of two dual servo-metric meter movements, mounted within a common hermetically sealed case. Scale illumination uses electroluminescent lighting panels.

For an SCS delta V mode, manual SPS engine gimbal trim capability is provided. Desired gimbal trim angles are set in with the pitch and yaw trim thumbwheels. The indicator displays SPS engine position relative to actuator null and not body axes. The range of the engine pitch and yaw gimbal displays is ±4.5 degrees. This range is graduated with marks at each 0.5 degree and reference numeral at each 2-degree division. The range of the fuel pressure scale is 0 to 50 psi with graduations at each 5-psi division, and reference numerals at each 10-psi division. For a functional description of the GPI display circuitry which shows the redundancy refer to paragraph 2.3.5.3.

2.3.2.2.4 Attitude Set Control Panel (ASCP)

The ASCP (figure 2.3-5) provides through thumbwheels, a means of positioning differential resolvers for each of the three axes. The resolvers are mechanically linked with indicators to provide a readout of the dialed angles. The input signals to these attitude set resolvers are from either

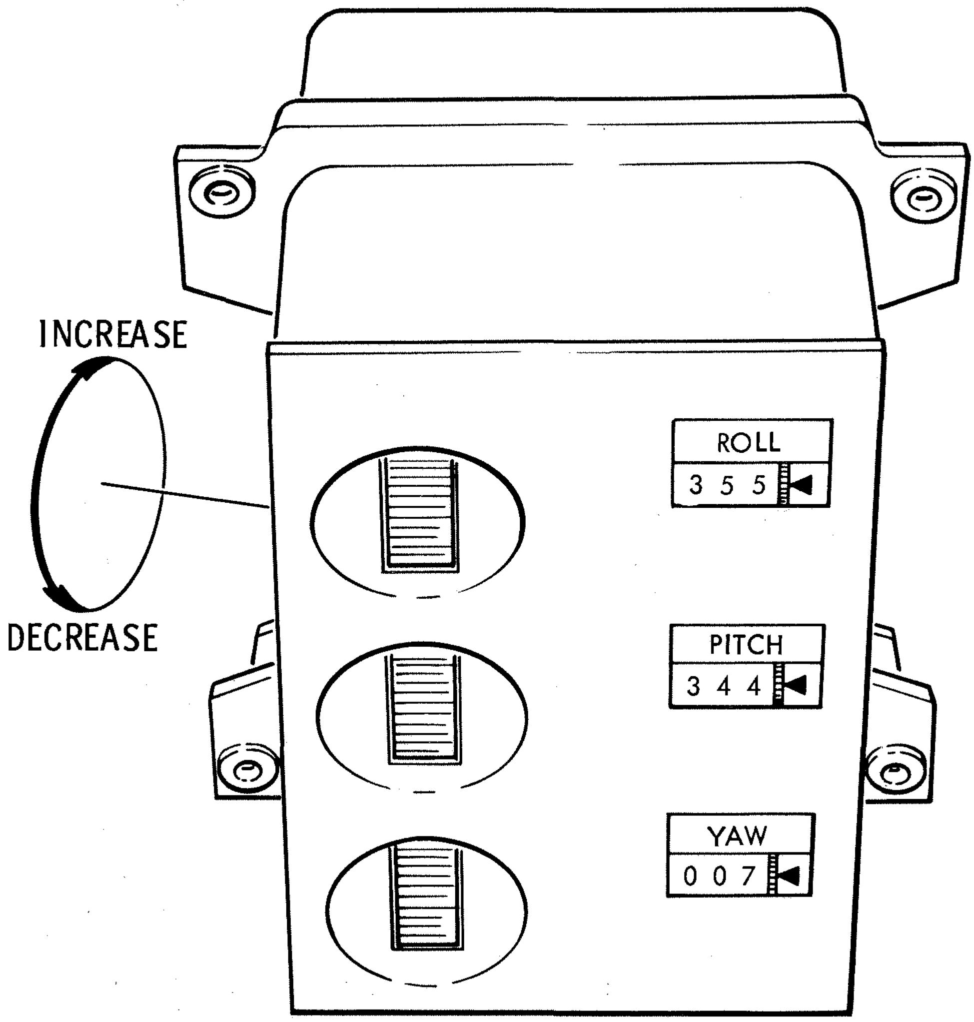

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Figure 2.3-5. Attitude Set Control Panel

the IMU or the GDC. The inertial (Euler) attitude error output signals are sine functions of the difference angles between the desired attitude, set by the thumbwheels, and the input attitude from the GDC or IMU. The Euler output can be used to either align the GDC or to provide fly-to indications on the FDAI attitude error needles.

Characteristics of the counters are as follows:

a. Indicates resolver angles in degrees from electrical zero, and allows continuous rotation from 000 through 359 to 000 without reversing the direction of rotation.

b. Graduation marks every 0.2 degree on the units digit.

c. Pitch and roll are marked continuously between 0 and 359.8 degrees. Yaw is marked continuously from 0 to 90 degrees and from 270 to 359.8 degrees.

d. Readings increase for an upward rotation of the thumbwheels. One revolution of the thumbwheel produces a 20-degree change in the resolver angle and a corresponding 20-degree change in the counter reading.

The counter readouts are floodlighted and the nomenclature (ROLL, PITCH, and YAW) is backlighted by electroluminescent lighting.

2.3.2.2.5 Flight Director Attitude Indicator (FDAI)

The FDAIs provide displays to the crew of angular velocity (rate), attitude error, and total attitude (figure 2.3-6). The body rate (roll, yaw, or pitch) displayed on either or both FDAIs is derived from the BMAGs in either gyro assembly. Positive angular rates are indicated by a downward displacement of the pitch rate needle and by leftward displacement of the yaw and roll rate needles. The angular rate displacements are "fly-to" indications as related to rotation control direction of motion required to reduce the indicated rates to zero. The angular rate scales are marked with graduations at null and ±full range, and at ±1/5, ±2/5, ±3/5, and ±4/5 of full range. Full-scale deflection ranges obtained with the FDAI SCALE switch are as follows:

- Pitch rate ±1 deg per sec, ±5 deg per sec, ±10 deg per sec
- Yaw rate ±1 deg per sec, ±5 deg per sec, ±10 deg per sec
- Roll rate ±1 deg per sec, ±5 deg per sec, ±50 deg per sec

Servo-metric meter movements are used for the three rate indicator needles.

The FDAI attitude error needles indicate the difference between the actual and desired spacecraft attitude. The attitude error signal can be derived from several sources: the uncaged BMAGs from GA-1, the CDUs (PGNCS), or the ASCP-GDC/IMU (figure 2.3-9). Positive attitude error is indicated by a downward displacement of the pitch error needle, and by a leftward displacement of the yaw and roll error needles. The ranges of the error needles are ±5 degrees or ±50 degrees for full-scale roll error, and ±5 degrees or ±15 degrees for pitch and yaw error. The error scale factors are selected by the FDAI SCALE switch that also establishes the rate scaling. The pitch and yaw attitude error scales contain graduation marks at null and ±full scale, and at ±1/3 and ±2/3 of full scale. The roll attitude scale contains marks at null, ±1/2, and ±full scale. The attitude error indicators utilize servo-metric meter movements.

Spacecraft orientation, with respect to a selected inertial reference frame, is also displayed on the FDAI ball. This display contains three servo control loops that are used to rotate the ball about three independent axes. These axes correspond to inertial pitch, yaw, and roll. The control loops can accept inputs from either the IMU gimbal resolvers or the GDC resolvers. Selecting the source is covered in paragraph 2.3.2.3.

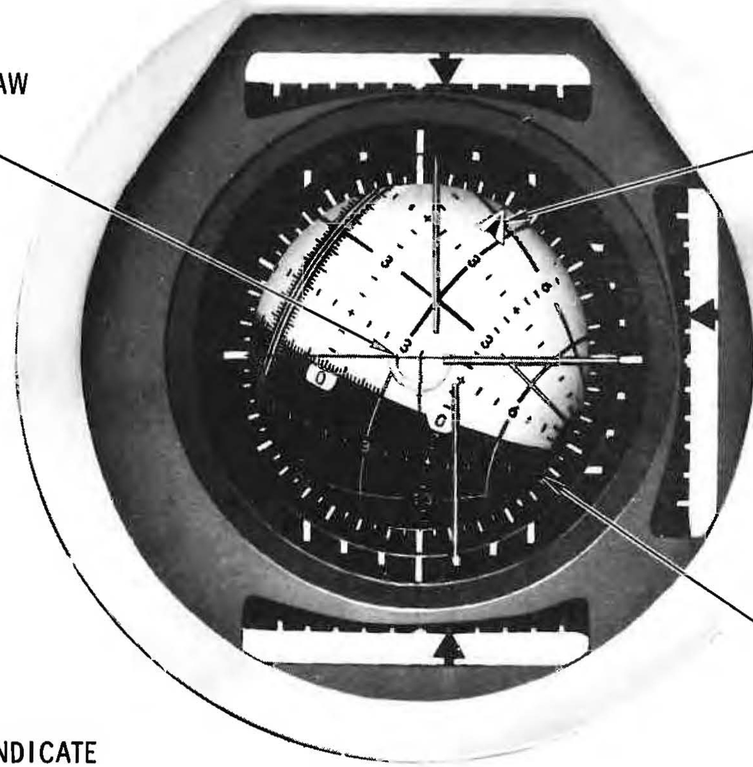


Figure 2.3-6. Flight Director Attitude Indicator

The control loops are proportional servos; therefore, the angles of rotation of the ball must correspond to the resolver angles of the source. The FDAI, illustrated in figure 2.3-6, has the following markings:

a. Pitch attitude is represented on the ball by great semicircles. The semicircle (as interpolated), displayed under the FDAI inverted wing symbol, is the inertial pitch at the time of readout. The two semicircles that make up a great circle correspond to pitch attitudes of θ and θ-180 degrees.

b. Yaw attitude is represented by minor circles. The display readout is similar to the pitch readout. Yaw attitude circles are restricted to the following inertial angles: 0+90 degrees (270 to 0 degrees and 0 to 90 degrees).

c. Roll attitude is the angle between the wing symbol and the nearest pitch attitude circle. The roll attitude is more accurately displayed on a scale attached to the FDAI mounting, under a pointer attached to the roll (ball) axis.

d. The last digits of the circle markings are omitted. Thus, for example, 3 corresponds to 30, and 33 corresponds to 330.

e. The ball is symmetrically marked (increment wise) about the 0-degree yaw and 0/180-degree pitch circles. The following comments provide clarification for areas of the ball not shown in figure 2.3-6.

1. Marks at 1-degree increments are provided along the entire yaw 0-degree circle.
2. The pitch 0- and 180-degree semicircles have 1-degree increments between the 330- and 30-degree yaw circles and 5-degree increments out to 75 and 285 degrees.
3. Numerals along the 300- and 60-degree yaw circles are spaced 60-pitch degrees apart. Note that numerals along the 30-degree yaw circle are spaced 30-pitch degrees apart.

f. The red areas of the ball, indicating impending gimbal lock, are defined by 270 <yaw <285 degrees and 75 <yaw <90 degrees.

2.3.2.3 Functional Switching Concept

The SCS utilizes functional switching as opposed to "mode select" switching.

Functional switching requires manual switching of numerous independent panel switches in order to configure the SCS for various mission functions (e.g., ΔVs, entry, etc.).

Function select switching requires more crew tasks, but offers flexibility to select various gains, display scale factors, etc., as independent system capabilities. Function select switching also allows flexibility to "switch out" part of a failed signal path without affecting the total signal source (e.g., SCS in control of the vehicle with GN displays still presented to the crew).

SCS

2.3.2.3.1 Display Switching Interfaces

The FDAI switches determine the source of display data, the FDAI(s) selected, and the full-scale deflections of the attitude error and rate needles. The source of rate information for display will always be from BMAG 2 unless BMAG 1 is put into a backup rate configuration. Other switches also modify the data displayed and these will be pointed out as they are discussed. Both FDAIs are also assumed to be properly energized from the power switching panel.

2.3.2.3.2 Spacecraft Control Switching Interfaces

There are two sources of vehicle controls selectable from the SC main display console, SCS or CMC. CMC is the primary method of control and the SCS provides backup control. The vehicle attitude control is obtained from the reaction control engines and the thrust vector control from the service propulsion engine.

2.3.3 ATTITUDE REFERENCE SUBSYSTEM

The attitude reference subsystem provides displays of spacecraft inertial attitude, attitude error, and body rates (figure 2.3-7). This information may be selected for display on one or both FDAIs by appropriate panel switching. The attitude and attitude error information for display can be selected either from the PGNCS or the SCS sources. The rate display is always supplied from the SCS BMAGs.

The SCS source of inertial (total) attitude is generated by the GDC. Since the GDC supplies a short term attitude reference it must be aligned prior to thrusting and entry modes.

2.3.3.1 Gyro Display Coupler (GDC)

There are four GDC configurations that are selectable by panel switching:

- Euler mode
- Entry (0.05G) mode
- Align mode
- Non-Euler mode (not used)

2.3.3.1.1 Euler Mode

In the Euler mode the GDC is configured to compute roll, pitch, and yaw inertial angles that define the total attitude of the spacecraft with respect to the chosen inertial reference frame.

The inputs to the GDC in this mode are d-c rate signals from the BMAGs (figure 2.3-8). The rate inputs are supplied from either the GA1 or GA2 BMAGs as selected by the BMAG MODE switches. The body rates from the BMAGs are modulated, amplified, and converted to Euler (inertial) rates by a pair of forward transformation resolvers. These transformation resolvers mechanize the transformation equations which relate the body rates (q, r, p) to the rates about the inertial reference axes ($\dot{\theta}$, $\dot{\psi}$ and $\dot{\phi}$).

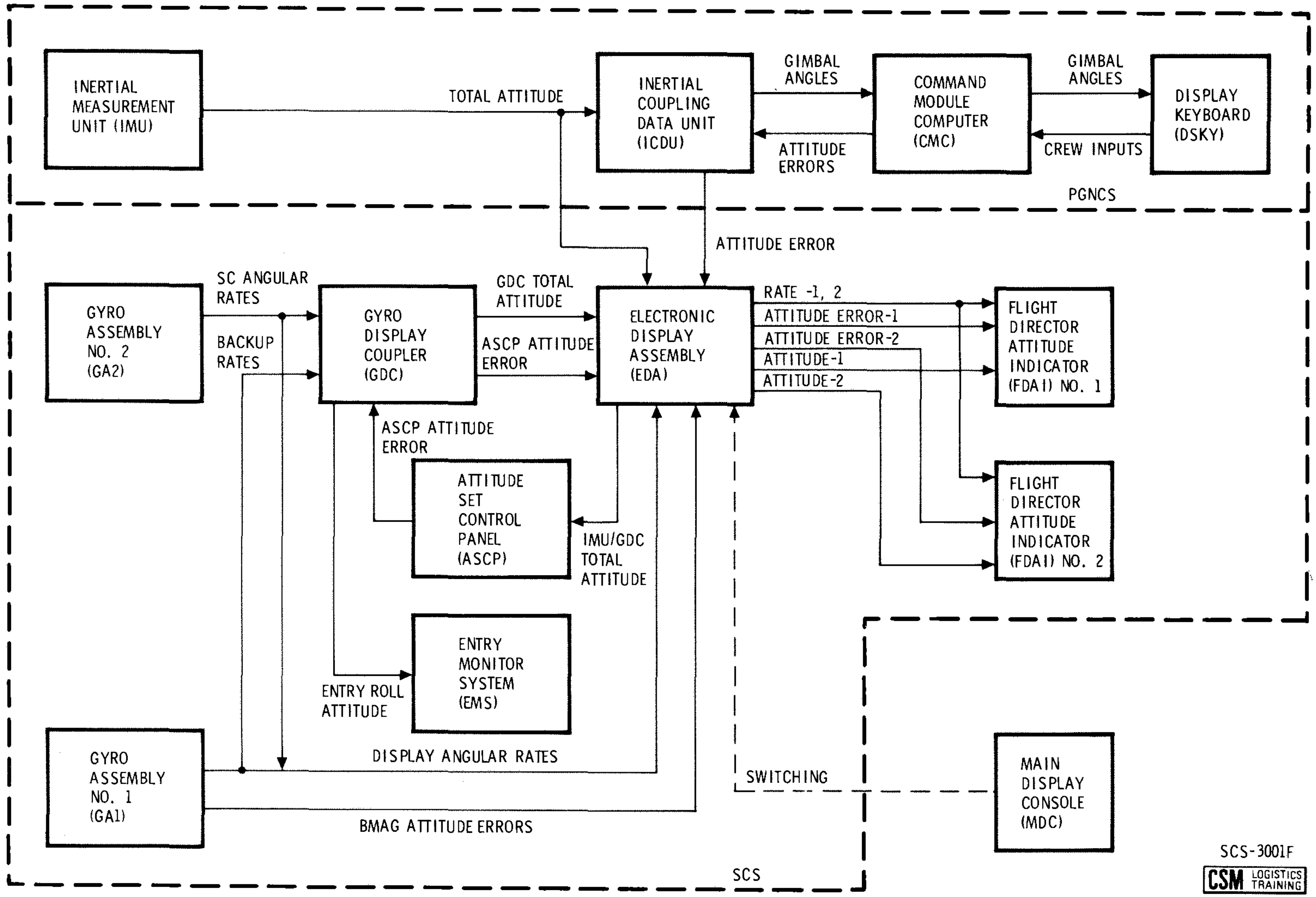


Figure 2.3-7. G&C Attitude Reference

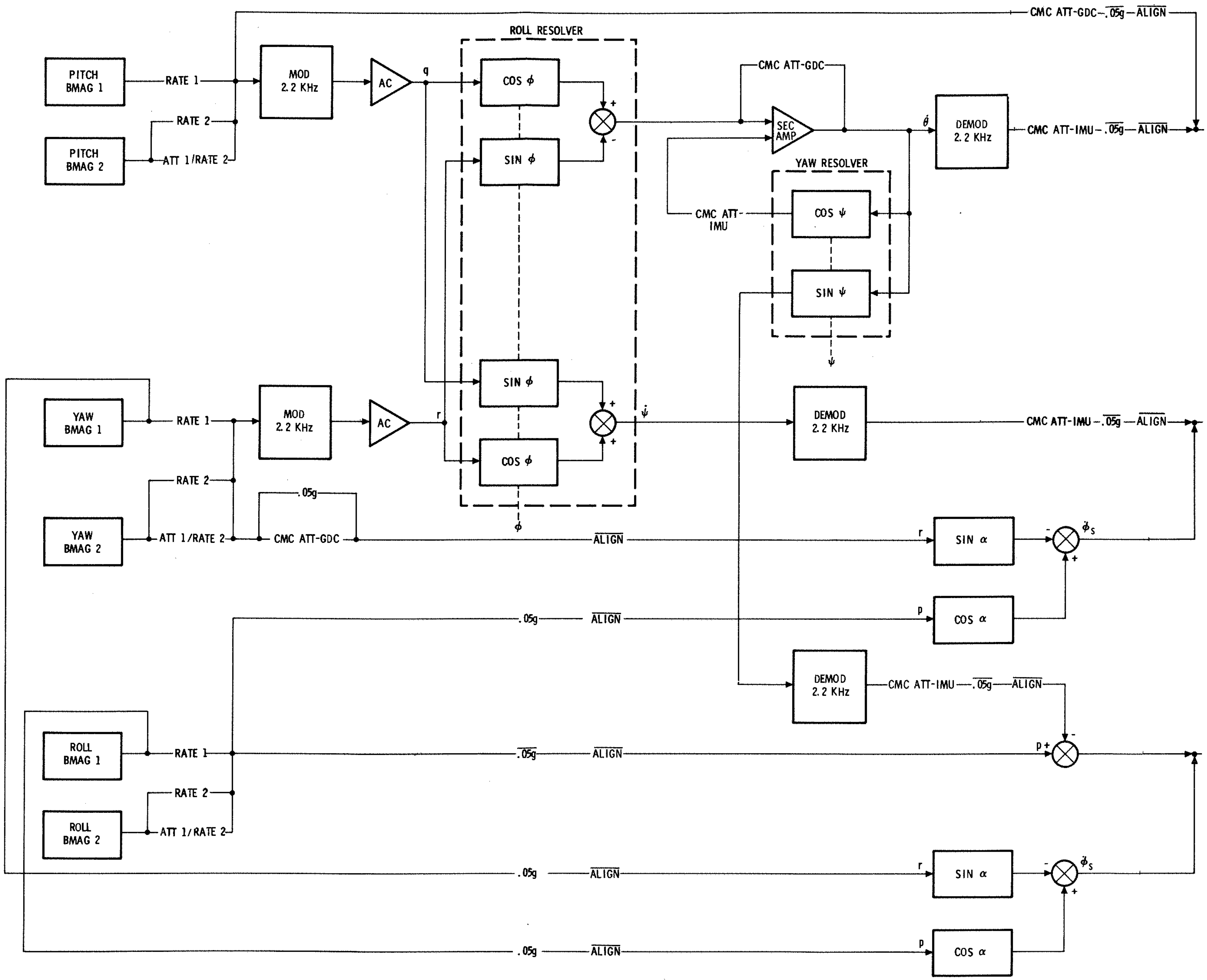


Figure 2.3-8. SCS Attitude Reference Functional Diagram (Sheet 1 of 2)

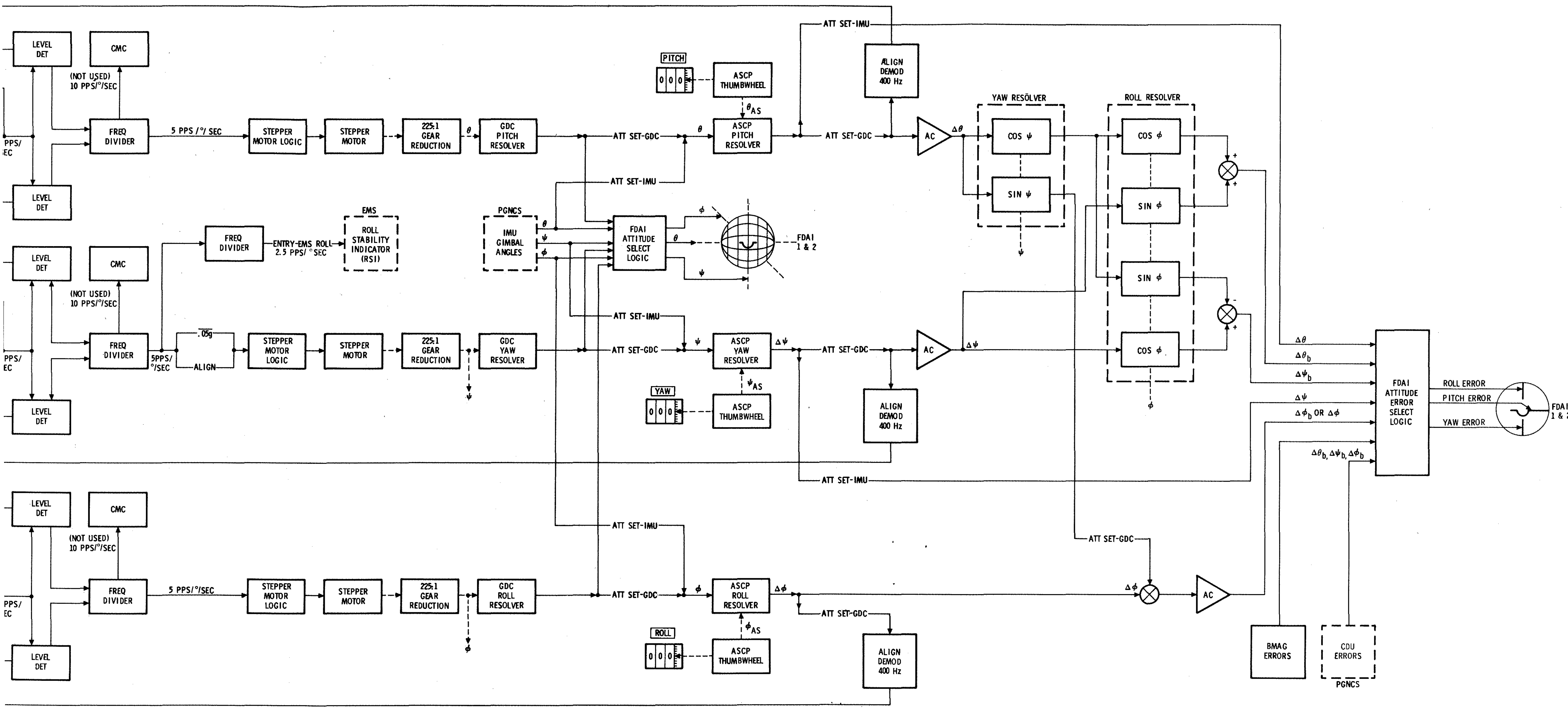


Figure 2.3-8. SCS Attitude Reference Functional Diagram (Sheet 2 of 2)

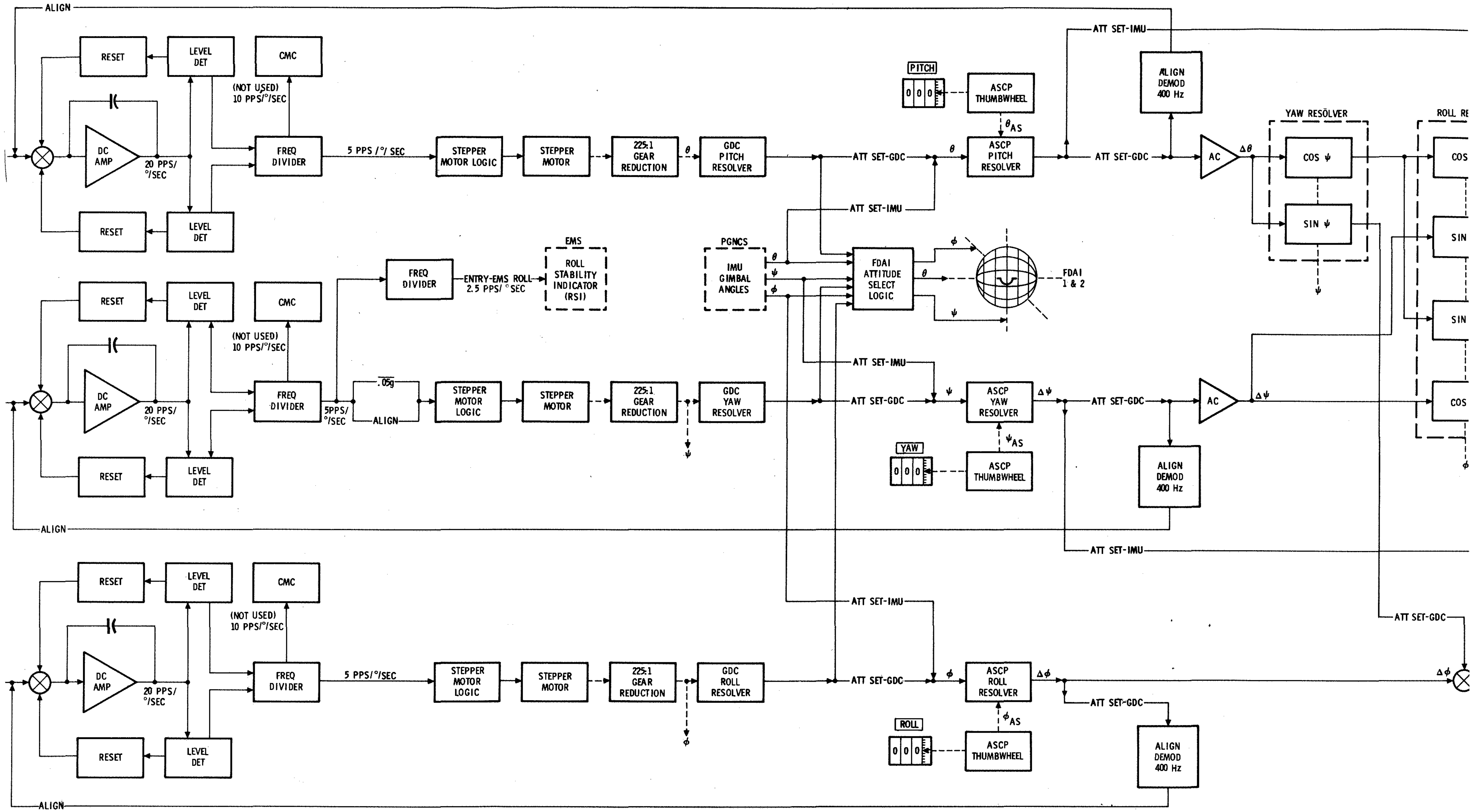


Figure 2.3-8. SCS At

SCS

The Euler rates are then demodulated, converted to pulses, and fed to stepper motors which drive the pitch, yaw, and roll transmitter-resolvers. The electrical outputs of these resolvers define the total attitude of the spacecraft. The forward transformation roll and yaw computational-resolver shafts are also driven by the stepper motors. That is, their shafts are mechanically connected to their respective transmitter-resolvers.

The GDC transmitter-resolver electrical outputs can be displayed on an FDAI via panel switch selection (figure 2.3-9).

With the GDC configured for the Euler mode (CMC ATT - IMU, .05G - OFF, GDC ALIGN - not depressed) inertial error signals can be generated by placing the ATT SET switch to the GDC position. Now the GDC transmitter-resolver outputs are fed to the ASCP differential-resolvers. The ASCP resolver outputs are proportional to the sine of the difference between the GDC angles and the selected ASCP angles. These inertial errors ($\Delta\theta$, $\Delta\psi$, $\Delta\phi$) are converted to the body (spacecraft) coordinate system by a reverse transformation before they are routed via panel switching to an FDAI (figure 2.3-9). To mechanize the reverse transformation, another set of yaw and roll computational-resolvers are utilized. Here again the yaw and roll computational-resolver shafts are in common with the transmitter-resolver shafts. Both transformations are continuously updated with the existing yaw and roll inertial angles.

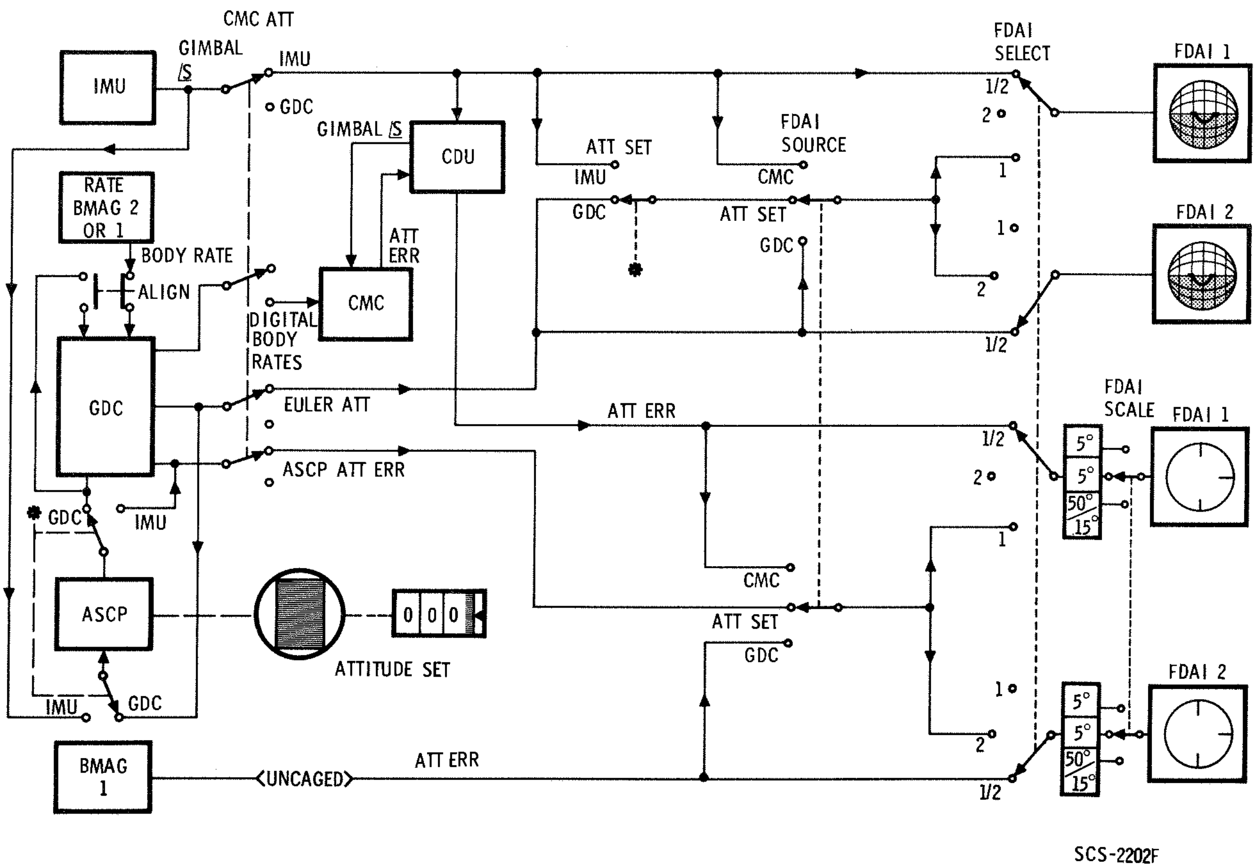


Figure 2.3-9. FDAI Attitude Select Logic

Gimbal lock is mechanized in the GDC forward transformation by a secant amplifier. The amplifier has feedback which will cause it to go unstable if the inertial yaw angle (ψ) becomes larger than ± 90 degrees. After passing through gimbal lock, the GDC pitch and roll channels are driven by the unstable secant amplifier. If the GDC is driven through gimbal lock, it should be realigned.

2.3.3.1.2 Entry Mode

During entry into the earth's atmosphere, the command module rolls about the stability roll axis, which is offset by an angle (α) from the spacecraft x-axis.

In the entry configuration (CMC ATT-IMU, .05G - up) the GDC computes the roll rate (ϕ_S) about the stability axis by combining the spacecraft body roll and yaw rates (p, r) which are sensed about the spacecraft x- and z-axes. Both the GDC yaw and roll channels compute the stability roll rate using separate transformations.

Each channel can be configured so that it receives the rate input signals from different BMAGs. The GDC roll channel can only be supplied by the GA1 yaw and roll BMAGs, but the GDC yaw channel can be supplied from GA2 (BMAG MODE-RATE 2 or ATT 1 RATE 2) or GA1 (BMAG MODE-RATE 1).

The GDC yaw axis supplies the integrated stability roll rate (stability roll attitude) to the roll stability indicator (RSI), which is on the entry monitor system (EMS). The other entry switch (EMS ROLL) must be up to provide the signal path from the GDC to the RSI.

The GDC roll axis drives either FDAI ball with stability roll attitude information. The FDAI that is driven by the GDC will be active only in the roll axis.

2.3.3.1.3 Align Mode

Since the GDC provides accurate information only during relatively short periods, it must be aligned to the desired reference periodically and is always aligned before thrusting maneuvers and prior to entry.

The align error signal is the ASCP-GDC difference signal, which is created by feeding the GDC transmitter-resolver outputs into their corresponding ASCP resolvers (ATT SET - GDC). The ASCP thumbwheels must be dialed to the correct roll, pitch, and yaw inertial angles which are usually taken from the IMU. With the ASCP set to the desired angles, the error signals will drive the GDC transmitter-resolvers to the ASCP angles when the GDC ALIGN button is pushed and held.

A convenient means of setting up the ASCP prior to aligning the GDC is obtained by feeding the IMU gimbal angles to the ASCP resolvers (ATT SET - IMU). The ASCP resolvers are then dialed to the IMU angles, where the correct settings exist when the FDAI needles are at null. In this case, the error needle indications are inertial errors, so that if only the pitch thumbwheel is dialed, then only the pitch error needle will deflect.

SCS

In order to have the ASCP - IMU errors displayed on FDAI 1, the panel switches must be positioned as follows: FDAI SELECT - 1, FDAI SOURCE - ATT SET, and ATT SET - IMU (figure 2.3-9). Once the errors are nulled, the ASCP has stored the IMU gimbal angles. Switching ATT SET switch to GDC will generate the error signals which will, when GDC ALIGN is pushed, update the GDC to the IMU. As the errors drive the GDC output to agree with the ASCP angles, the FDAI error needles will return to null again.

Prior to entry, the RSI can be repositioned, if desired, by driving it with the align error signal. All that is required is that a difference exists between the GDC yaw transmitter-resolver angle and the ASCP resolver setting. This error signal will drive the RSI as long as the EMS roll switch is up, the ATT SET switch is in the GDC position, and the GDC ALIGN button is depressed. Once properly positioned, the RSI is deactivated by placing the EMS ROLL switch to OFF.

When .05G is sensed during entry, the crew places both ENTRY switches up. At this time both the RSI and the FDAI will rotate in the same direction whenever the spacecraft rolls about the stability roll axis.

2.3.3.1.4 Non-Euler Mode

Although a switching capability exists which will configure the GDC to the non-Euler mode, the CMC is not programmed to utilize digital body rates from the GDC. Therefore, this mode is not used during flight. If the CMC ATT switch is placed to the GDC position, the FDAI ball motor power is removed so that neither FDAI ball will move when the spacecraft attitude changes. In addition, the ASCP error signals cannot be displayed.

If the CMC ATT switch is placed to the GDC position, there is no effect on either the CMC or the IMU. However, the GDC may require alignment if the spacecraft attitude changes before returning the CMC ATT switch to the IMU position. This is because the forward transformation in the GDC is bypassed while in the non-Euler mode. In this case the GDC transmitter-resolvers are driven by body-referenced attitude and not inertially-referenced attitude signals. Recall, too, that there is no display of either the GDC or IMU angles on the FDAIs when in the non-Euler mode.

2.3.3.2 FDAI Display Sources

The two FDAIs display total attitude and attitude errors that may originate within the SCS or PGNCS. They also display angular rate from the SCS. The flight crew establishes the FDAI sources by panel switch selection. (See figures 2.3-10 and 2.3-11).

2.3.3.2.1 Total Attitude and Error Display Sources

The total attitude and attitude error display selections result from combinations of panel switch positions (figure 2.3-9). When both FDAIs are selected, the platform gimbal angles will always be displayed on FDAI 1 while GDC Euler angles will be displayed on FDAI 2. In order to select the source of attitude display to a particular FDAI, that FDAI and source (G&N or SCS) must be selected (figure 2.3-11). The other FDAI will be inactive. It should be noted that any time total altitude is to be displayed on either FDAI, the CMC ATT switch must be in the IMU position.

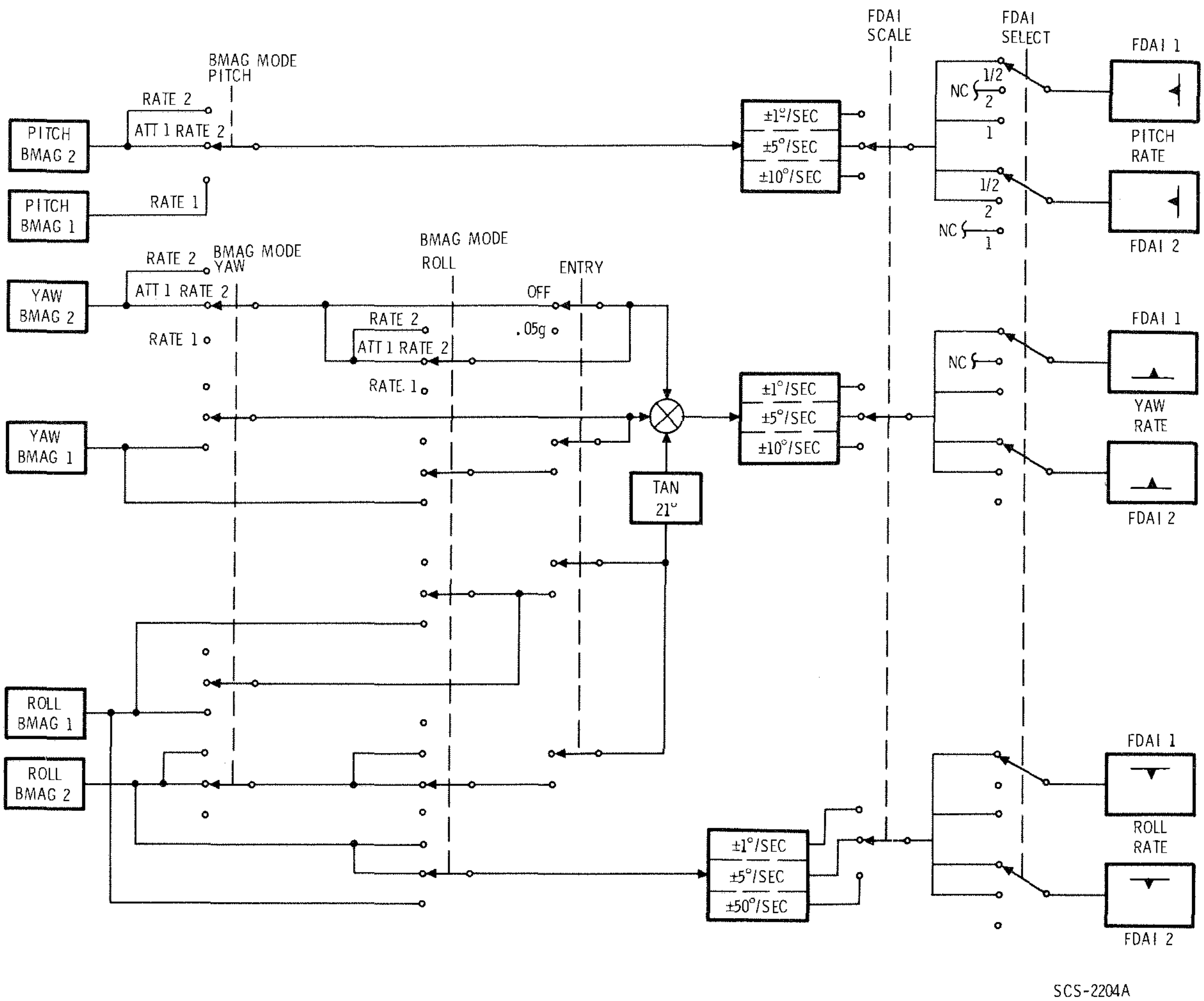


Figure 2.3-10. FDAI Rate Select Logic

The FDAI attitude display may be modified by a NASA-supplied orbital rate display-earth and lunar (ORDEAL) unit. The ORDEAL unit is inserted electrically in the pitch channel between the electronic display assembly and FDAI to provide a local vertical display in the pitch axis of either (or both) FDAIs. Controls on the unit permit selection of earth orbits and the orbital altitude.

The FDAI attitude error display source can be either the SCS or the G&N, with two sources per system. The attitude error sources are as follows:

a. The BMAG 1 error display is an indication of gimbal precession about its null point, assuming the gyro is uncaged, and may only be displayed when the SOURCE switch is in the GDC position or when the FDAI SELECT switch is in the 1/2 position.

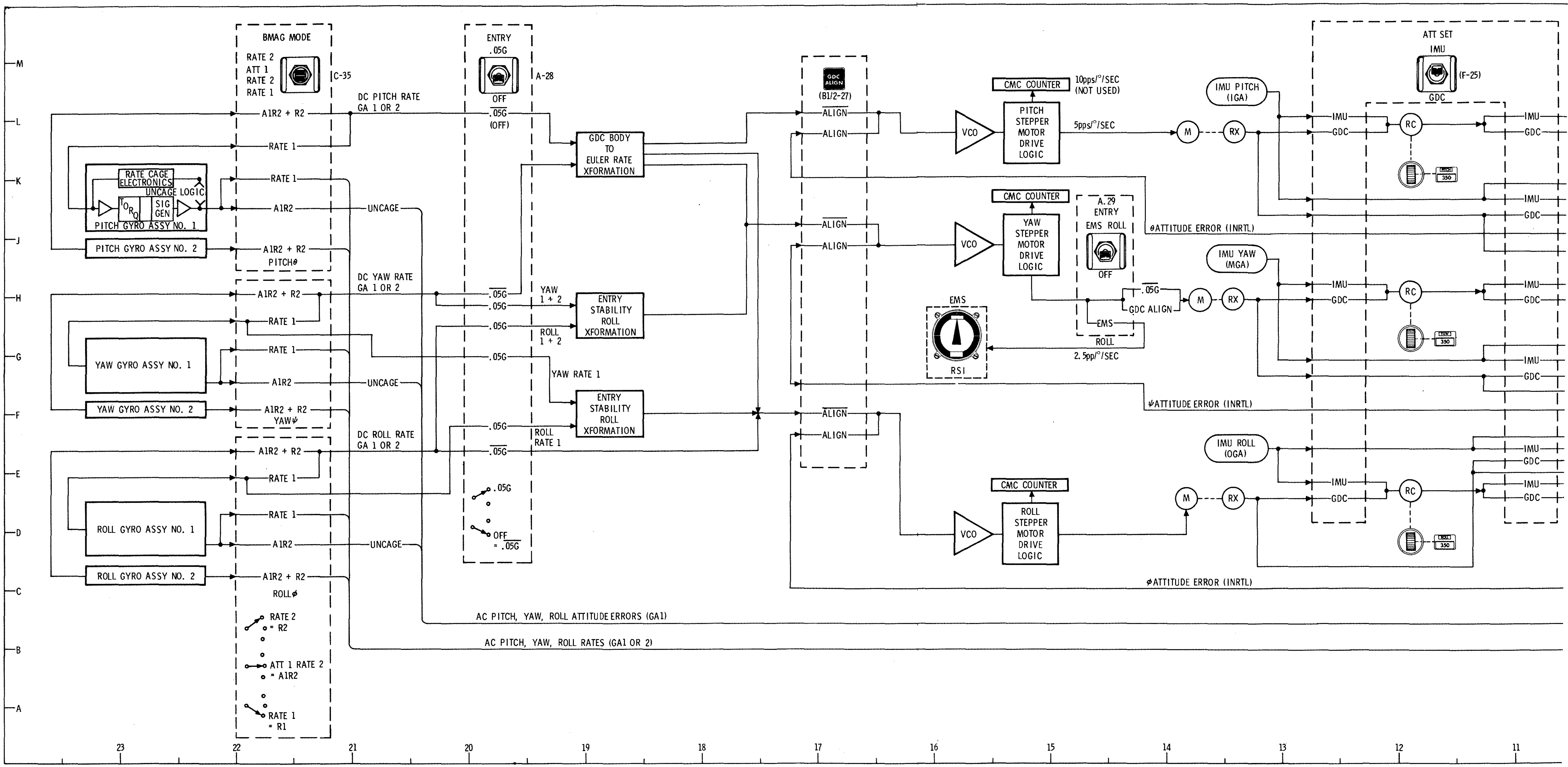
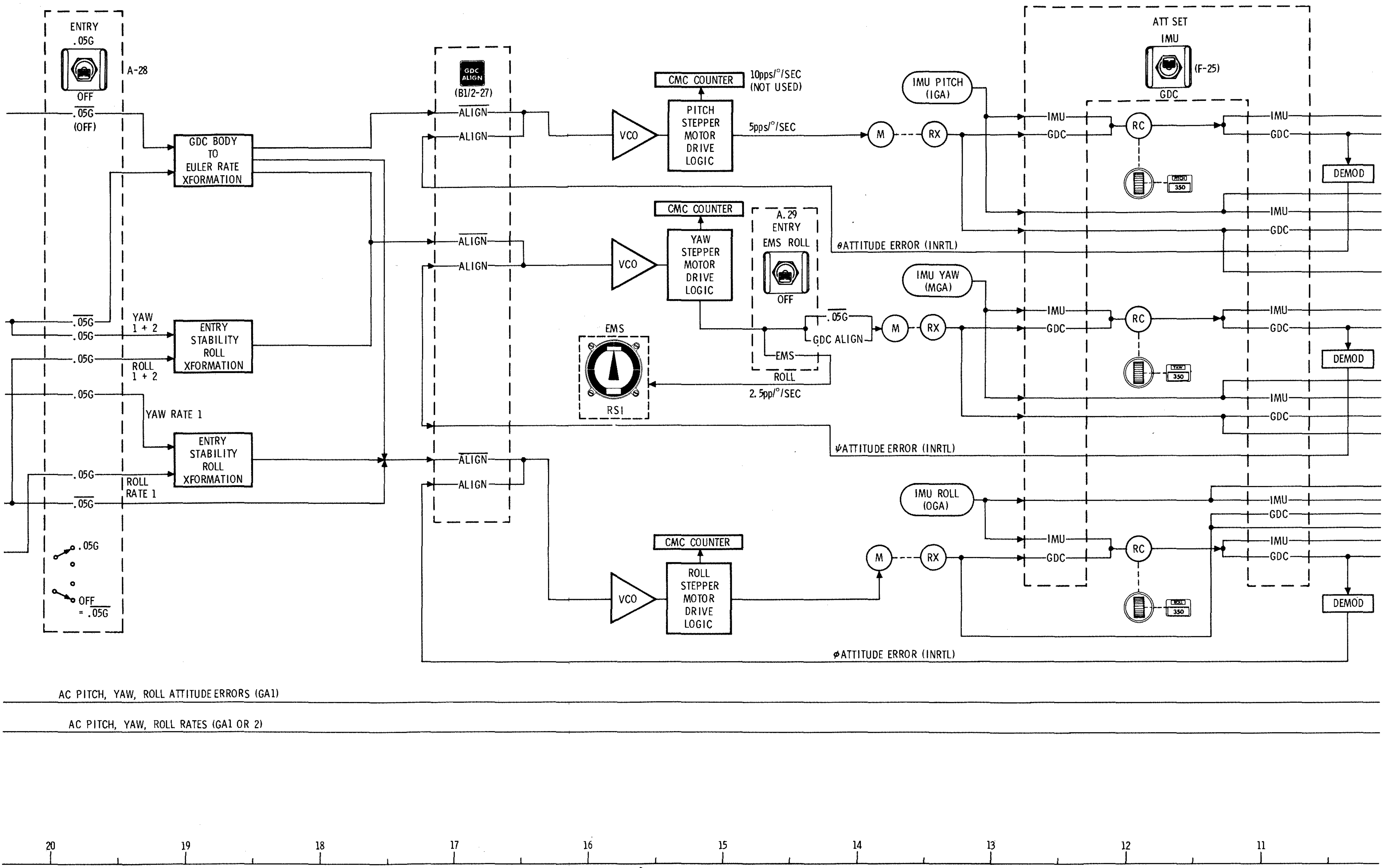


Figure 2.3-11. ARS Overview (Sheet 1 of 2)


ENTRY
.05G
A-28
OFF
.05G
(OFF)
GDC BODY TO EULER RATE XFORMATION
GDC ALIGN
(B1/2-27)
ALIGN
ALIGN
VCO
CMC COUNTER
10pps/°/SEC
(NOT USED)
PITCH STEPPER MOTOR DRIVE LOGIC
5pps/°/SEC
M
RX
IMU PITCH
(IGA)
ATT SET
IMU
(F-25)
GDC
IMU
GDC
RC
DEMOD
θATTITUDE ERROR (INRTL)
YAW STEPPER MOTOR DRIVE LOGIC
A.29
ENTRY
EMS ROLL
OFF
.05G
GDC ALIGN
EMS
ROLL
2.5pp/°/SEC
EMS
RSI
IMU YAW
(MGA)
YAW 1 + 2
ENTRY STABILITY ROLL XFORMATION
ROLL 1 + 2
YAW RATE 1
ROLL RATE 1
ψATTITUDE ERROR (INRTL)
IMU ROLL
(OGA)
ROLL STEPPER MOTOR DRIVE LOGIC
OFF
= .05G
φATTITUDE ERROR (INRTL)
AC PITCH, YAW, ROLL ATTITUDE ERRORS (GA1)
AC PITCH, YAW, ROLL RATES (GA1 OR 2)
20
19
18
17
16
15
14
13
12
11

of 2)

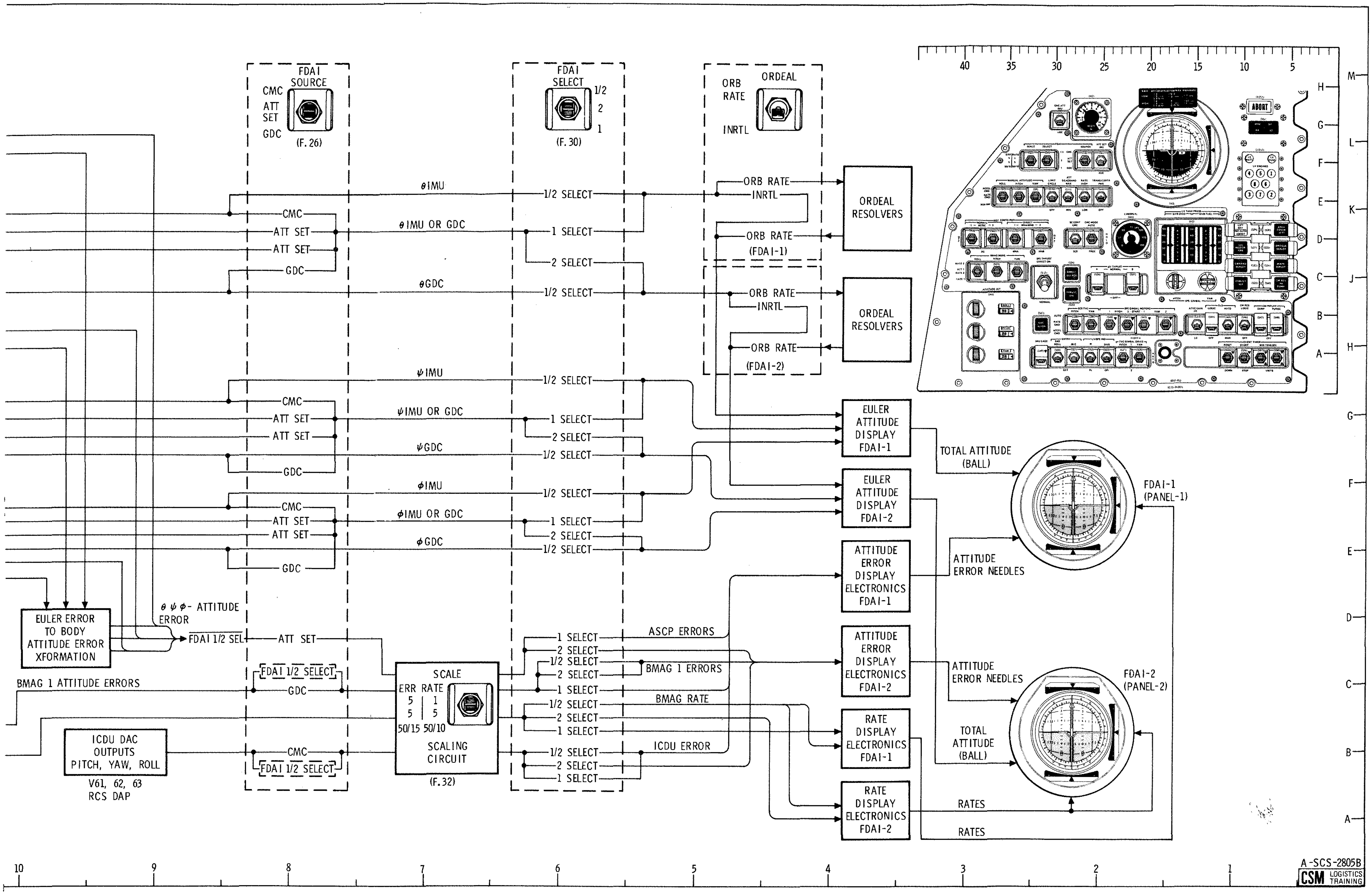


Figure 2.3-11. ARS Overview (Sheet 2 of 2)

b. Euler angles from the GDC interface with the ASCP to provide an Euler angle error (GDC-attitude set difference signal) which is then transformed to body angle errors for display on either FDAI. This display source facilitates manual maneuvering of the spacecraft to a new inertial attitude that was dialed in on the attitude set thumbwheels.

c. Inertial gimbal angles from the IMU interface with the ASCP to generate inertial errors (IMU-attitude set difference signal) which may be displayed on either FDAI. Thus, if the error needles were nulled using the thumbwheels on the ASCP, the ASCP indicators would then indicate the same inertial reference as the platform.

d. The CMC generates attitude errors that are a function of the program. These will be displayed when the SOURCE switch is in the CMC position, or when the FDAI SELECT switch is in the 1/2 position.

2.3.3.2.2 Rate Display Sources

The FDAI rate needles are driven by signals derived from the BMAGs in either gyro assembly 1 or 2 (figures 2.3-10 and 2.3-11). With the BMAG MODE switches (ROLL, PITCH, and YAW) in ATT 1 RATE 2 or RATE 2, the BMAGs in gyro assembly 2 supply the rate display. Placing the BMAG MODE switch(es) to RATE 1 rate-cages the BMAG(s) in gyro assembly 1 and routes their signals to the FDAI(s). When the ENTRY - .05G switch is up, the BMAGs in gyro assembly 1 are rate-caged. In addition, a signal is sent from the roll BMAG to the yaw rate needle circuit, with the .05G switch up, to cancel the sensed yaw signal which is due to rolling the CM about the stability roll axis. This roll-to-yaw axis coupling requires that the summed roll and yaw signals be supplied from the same gyro assembly. This is accomplished automatically, however, so that whenever either the ROLL or YAW BMAG MODE switch is placed to the RATE 1 position, the corresponding rate signal will be derived from gyro assembly 1. The roll and yaw signals must be summed from the same gyro assembly because the a-c signals out of each gyro assembly are not synchronized.

2.3.4 ATTITUDE CONTROL SUBSYSTEM (ACS)

2.3.4.1 Introduction

The SCS hardware used in controlling the spacecraft attitude and translation maneuvers include the gyro assemblies, rotation and translation controls, and two electronic assemblies. The electronic control assembly (ECA) provides commands as a function of both gyro and manual control (RC and TC) inputs to fire the RCS via the reaction jet/engine control assembly (RJEC). Alternate spacecraft attitude control configurations provide several means of both manually and automatically controlling angular rates and displacements about spacecraft axes. Accelerations along spacecraft axes are provided via the TC. The crew uses this control for both docking and delta V maneuvers.

2.3.4.2 Hardware Function (ACS)

While a description of each SCS component was given in paragraph 2.3.2.1, this description considers those functions and interfaces used in the ACS.

2.3.4.2.1 Gyro Assembly-1 (GA-1)

GA-1 contains three BMAGs that can provide pitch, yaw, and roll attitude error signals. These error signals are used when SCS automatic attitude hold is desired. The signals interface with the electronics control assembly (ECA). The BMAGs can be rate-caged independently by control panel switching to provide backup rate information, or held in standby. The GA-1 BMAGs can be uncaged independently (by axis) during SCS attitude hold if the MANUAL ATTITUDE switch is in RATE CMD, the BMAG MODE switch in ATT 1 RATE 2, the ENTRY .05 G switch is OFF and no RC breakout switch is closed (figure 2.3-12).

2.3.4.2.2 Gyro Assembly-2 (GA-2)

GA-2 contains three BMAGs that are always rate-caged. These BMAGs normally provide pitch, yaw, and roll rate damping for SCS automatic control configuration and proportional rate maneuvering. The rate signals interface with the ECA. When backup rate by axis is selected (RATE 1), the GA-2 signal(s) is not used.

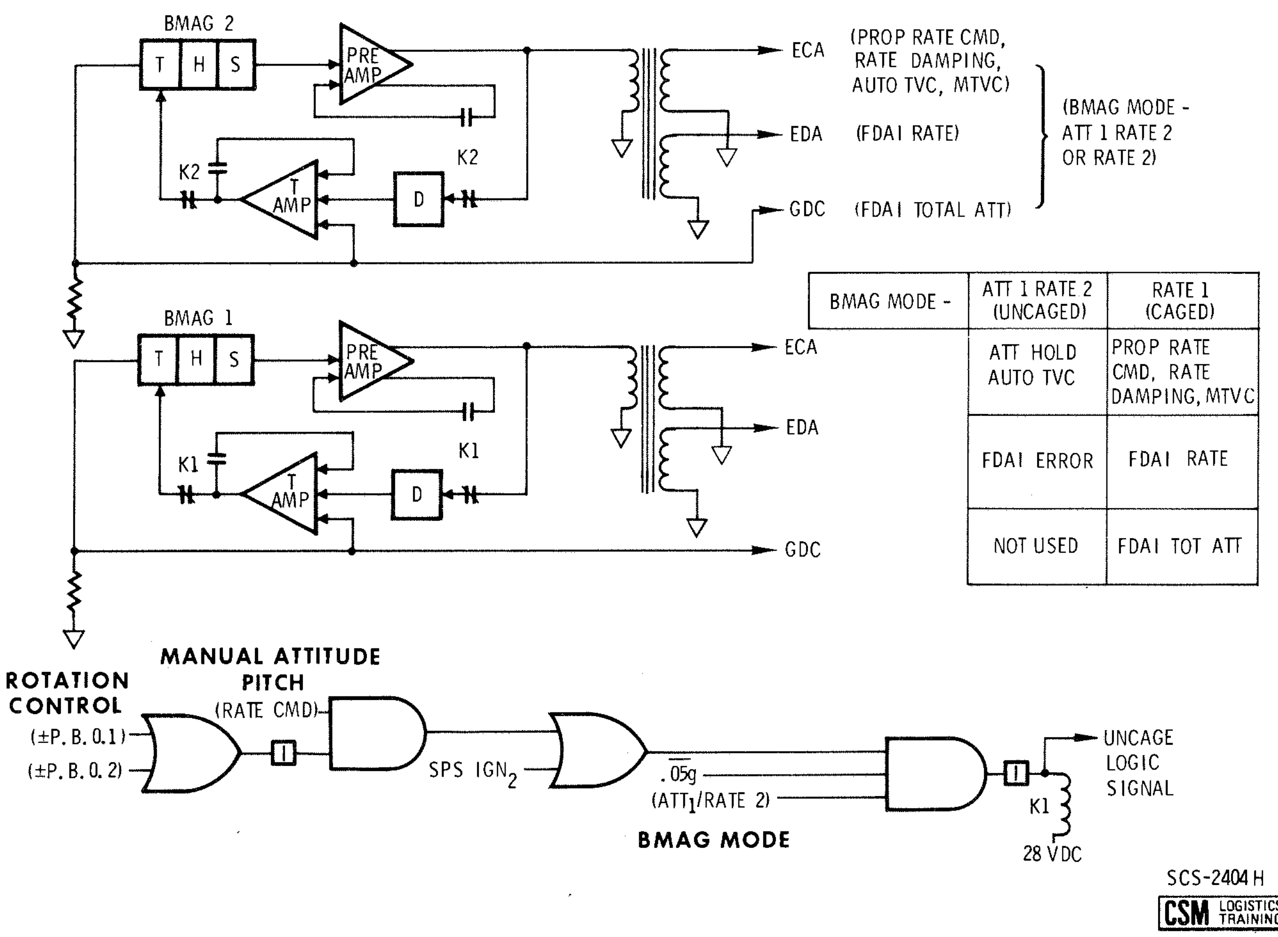


Figure 2.3-12. BMAG Logic and Outputs

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2.3.4.2.3 Rotational Controllers (RC-1 and RC-2)

The RCs provide the capability of controlling the spacecraft attitude simultaneously in three axes. Either controller provides the functions listed in the following paragraphs for each axis (pitch, yaw, roll) and for each direction of rotation (plus or minus).

Within the RC are six breakout switches, three transducers, and twelve direct switches. (See figure 2.3-13.)

Breakout Switches. A breakout switch, closed at a nominal 1.5-degree RC deflection, routes a 28-vdc logic signal to both the PGNCS and the SCS for attitude control inputs as follows:

a. Rotation Command to CMC. If the spacecraft is under CMC control, the signal commands rotations through the CMC input to the RJ/EC.

b. Acceleration Command. The signal is sent to the RJ/EC and commands rotational acceleration whether in CMC or SCS control.

c. Minimum Impulse Command. If the spacecraft is under SCS control, the logic signal goes to the ECA which provides a single minimum impulse command to the RJ/EC each time that a breakout switch is closed.

d. Proportional Rate Enable. The logic signal is used in the ECA to enable the manual proportional rate capability and to rate-cage the BMAGs in GA-1.

Transducer. The transducer is used for proportional rate maneuvers. It provides a signal to the ECA that is proportional to the stick deflection. The signal is summed in the ECA with the rate BMAG signal in such a way that the final spacecraft rate is proportional to the stick (RC) deflection.

Direct Switches. At 11 degrees of controller deflection, redundant direct switches close. If direct power is enabled, the direct switches route 28 vdc to the direct coils on the appropriate RCS engines and disable the auto coil solenoid drivers in that axis (or axes).

2.3.4.2.4 Translation Controller

The translation controller provides the capability of manually commanding simultaneous accelerations along the spacecraft X-, Y-, and Z-axes (figure 2.3-14). It is also used to initiate several transfer commands. These functions are described in the following paragraphs.

Translation Commands

a. CMC Control. If the spacecraft is under CMC control, a translation command results in a signal (28 vdc) being sent to the CMC. The CMC would provide a translation command to the RJ/EC.

b. SCS Control. If the spacecraft is under SCS control, the translation command is sent directly to the RJ/EC.

Clockwise Switch (CW). A clockwise rotation of the T-handle will disable CMC inputs to the RJ/EC. A logic signal (CW) is sent to the CMC when the T-handle is not clockwise.

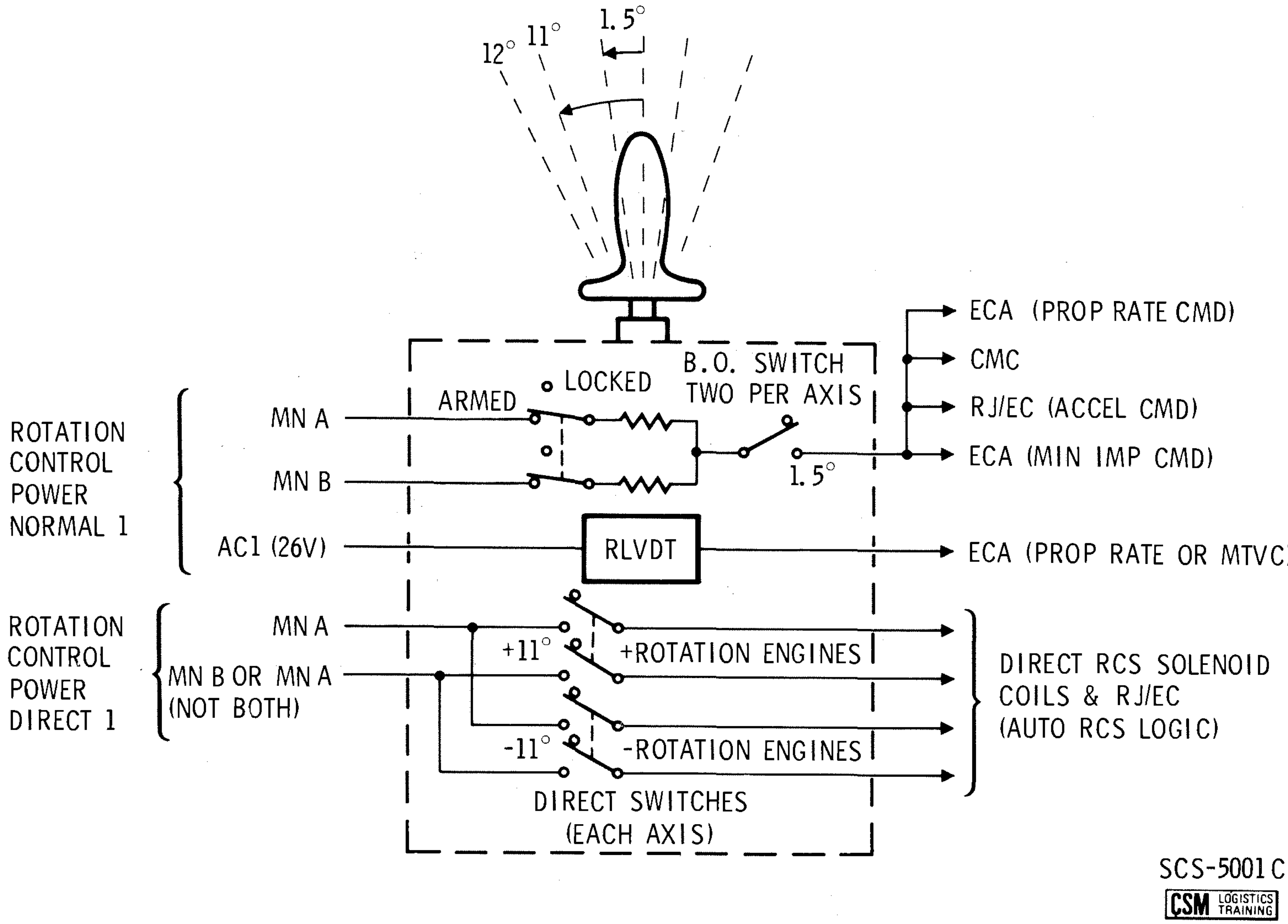

Figure 2.3-13. Rotation Control Interfaces

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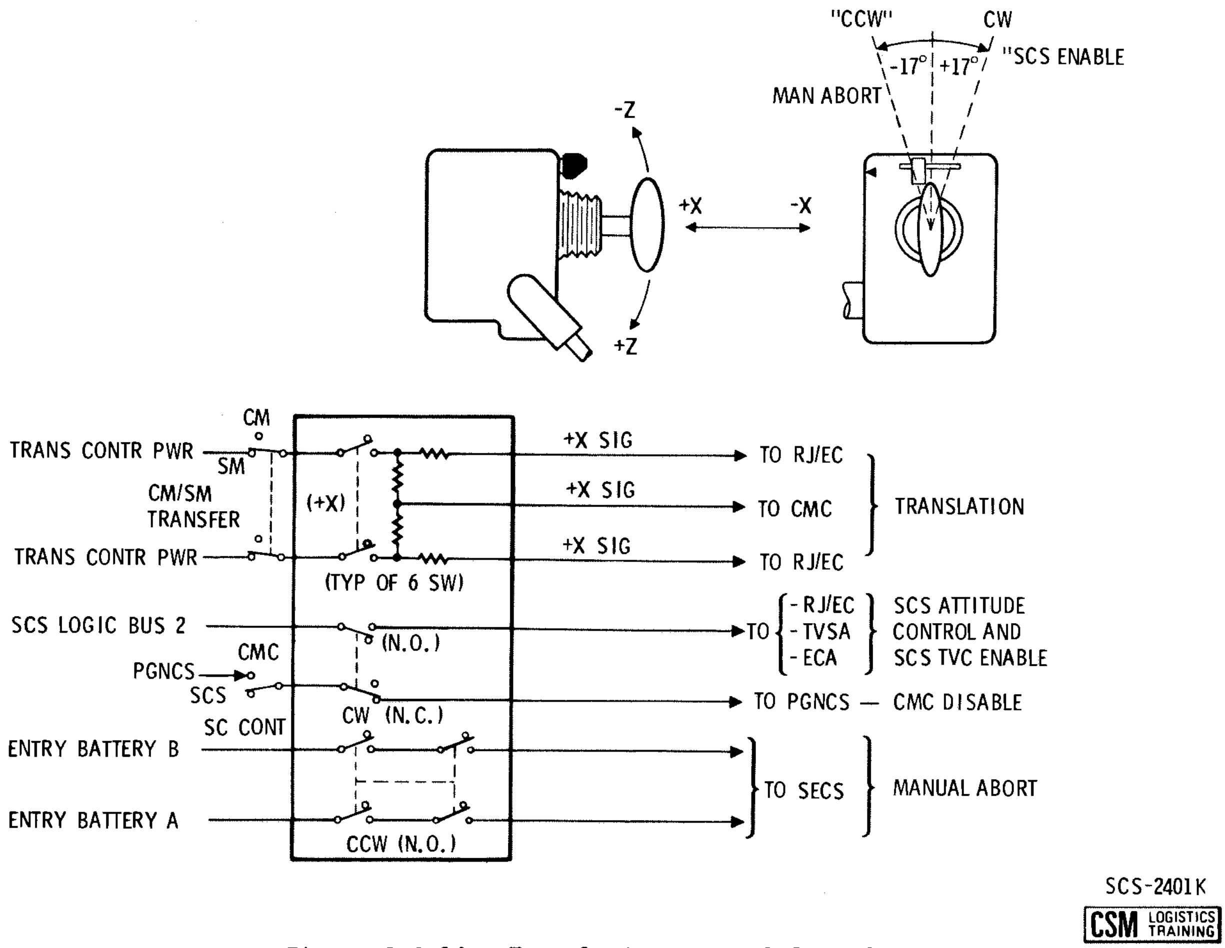

Figure 2.3-14. Translation Control Interfaces

Counterclockwise Switch (CCW). A counterclockwise rotation of the T-handle during launch, will close switches which route 28 vdc (battery power) to the MESC. The MESC, in turn, may enable the RCS auto coil solenoid drivers in the RJ/EC (figure 2.3-15).

2.3.4.2.5 Electronic Control Assembly (ECA)

The ECA contains the electronics used for SCS automatic attitude hold, proportional rate, and minimum impulse capabilities. It also contains the attitude BMAG(s) uncage logic. It receives control inputs from the gyro assemblies and the rotational controller transducers and breakout switches. The ECA provides rotational commands to the RCS logic in the RJ/EC.

2.3.4.2.6 Reaction Jet Engine Control (RJ/EC)

The RJ/EC contains the auto RCS logic and the solenoid drivers (16) that provide commands to the RCS automatic coils. The auto RCS logic receives control signals from the CMC, ECA, RC, and TC. The RCS solenoid drivers receive enabling logic power from the AUTO RCS SELECT switches on panel 8. The MESC supplies the 28 vdc to the AUTO RCS SELECT switches (figure 2.3-15).

2.3.4.3 Reaction Control System Interface

2.3.4.3.1 General

The RCS provides the rotational and translational thrusts for all ACS functions. Prior to CM/SM separation, the SM RCS engines are used for attitude control. The CM RCS is used after separation for control during entry (figures 2.3-15 and 2.3-16). The CM has only 12 RCS engines and does not have translational capability via the TC. After CM/SM separation, the A/C ROLL AUTO RCS SELECT switches have no function, as the 12 CM engines need only 12 AUTO RCS SELECT switches (figure 2.3-15).

An RCS engine is fired by applying excitation to a pair (fuel and oxidizer) of solenoid coils; the pair will be referred to in the singular as a solenoid coil. Each engine has two solenoid coils. One coil is referred to as the automatic coil, the other as the direct coil. Only the automatic coils receive commands from the RJ/EC. The direct commands are routed directly from the RC direct switches (or other switches). The automatic and direct commands are discussed in the following paragraphs.

2.3.4.3.2 Automatic Coil Commands

Power. The automatic (auto) coils are supplied 28-vdc power via one set of contacts of the AUTO RCS SELECT switches (figure 2.3-15). The solenoid is operated by switching a ground to the coil through the appropriate solenoid driver in the RJ/EC. The auto coil power is obtained from the STABILIZATION/CONTROL SYSTEM A/C ROLL, B/D ROLL, PITCH and YAW circuit breakers on MDC-8. The 28-vdc lines to the auto coils for each SM engine (jet) except A_1, A_2, C_1, and C_2 are switched at CM/SM transfer to CM coils. The wires from the A/C ROLL AUTO RCS SELECT switches to SM engines A_1, A_2, C_1, and C_2 are open-ended after transfer. These switches have no function after CM-SM transfer. Enabling power for the RCS solenoid drivers is supplied to the second set of contacts of the AUTO RCS SELECT switches through the MESC (A and B) from the SCS CONTR/AUTO MNA and MNB circuit breakers (MDC-8).

The CM jets are supplied from two separate propellant systems, 1 and 2. Each propellant system supplies half the CM jets, distributed such that one jet for each direction (plus and minus) and for each axis (pitch, yaw, and roll) is supplied from each propellant system. When the RCS TRNFR switch is placed from SM to CM, motor switch contacts transfer auto coil power from SM engines to CM engines. Each motor switch contact transfers six engines.

Auto RCS Logic. Commands to the RCS engines are initiated by switching a ground, through the solenoid driver, to the low voltage side of the auto coils. The solenoid drivers receive commands from the auto RCS logic circuitry contained in the RJ/EC. The auto RCS logic performs two functions:

a. Enables the command source selected based on logic signals received from the control panel or manual controls.

b. Commands those solenoid drivers necessary to perform the desired maneuver.

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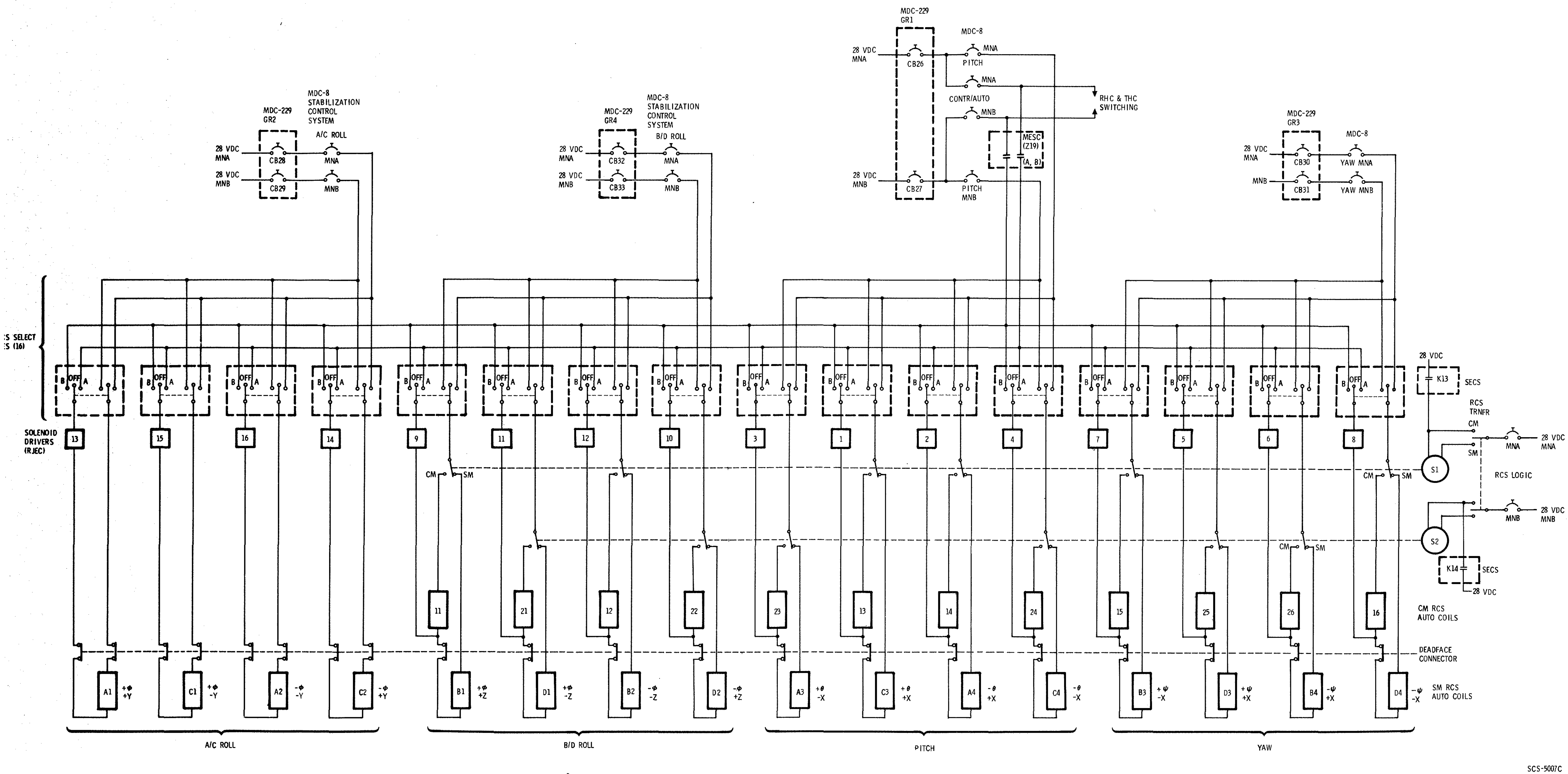
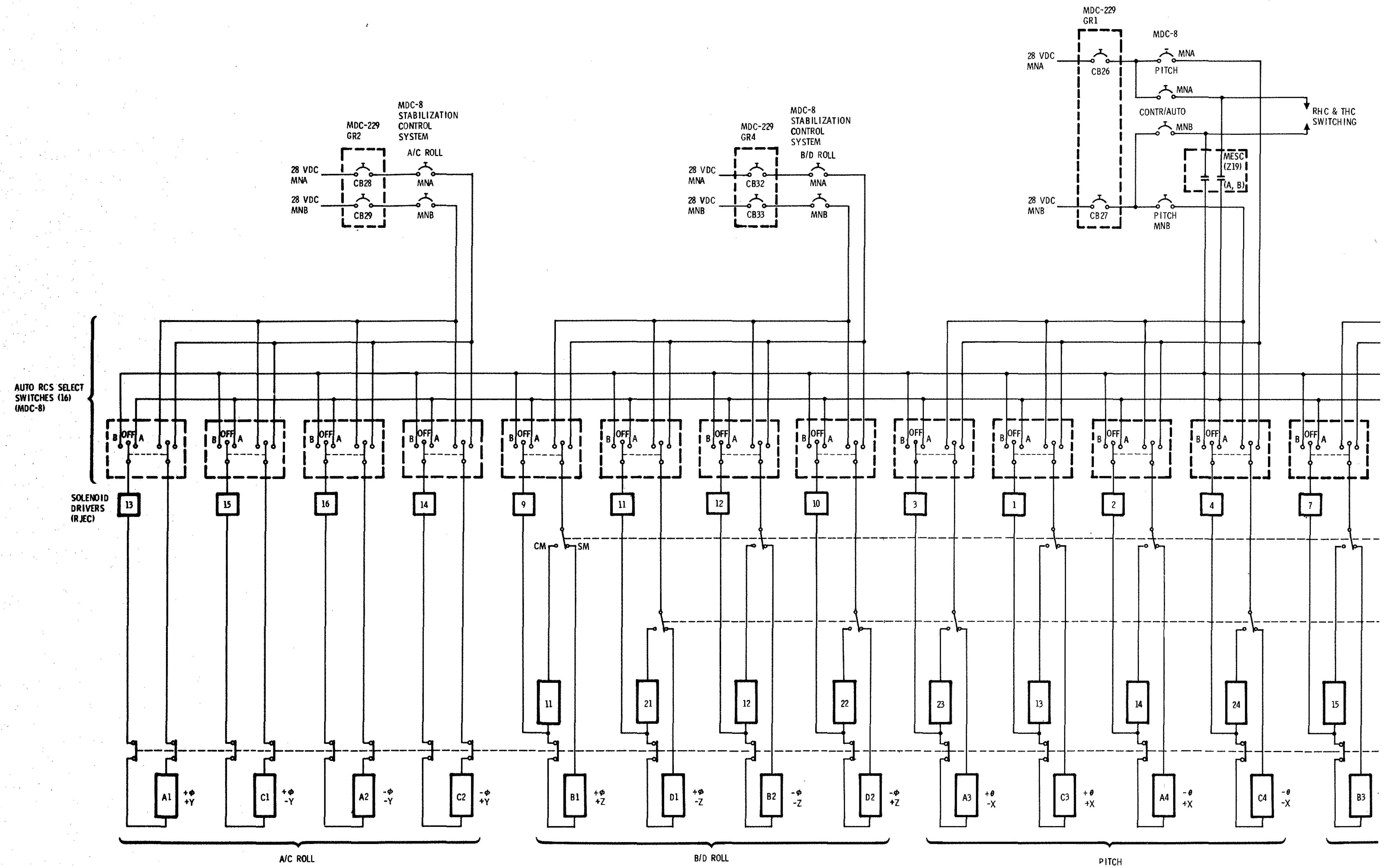


Figure 2.3-15. Auto RCS Enabling Power



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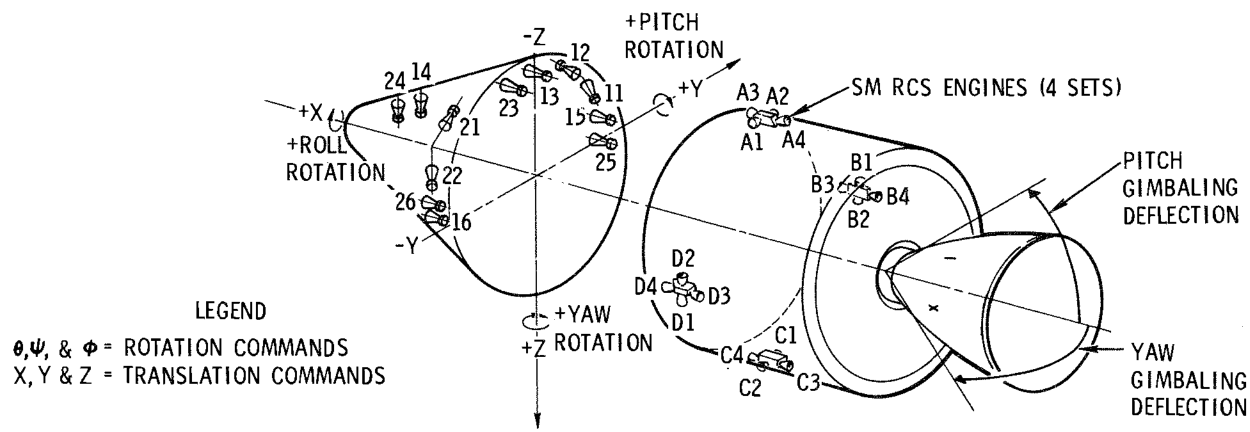

	PITCH		YAW		ROLL B/D		ROLL A/C
	+ θ (C3)		+ ψ (D3)		+ φ (B1)		+ φ (A1)
	+X		+X		+Z		+Y
	- θ (A4)		- ψ (B4)		- φ (D2)		- φ (C2)
	+ θ (A3)		+ ψ (B3)		+ φ (D1)		+ φ (C1)
	-X		-X		-Z		-Y
	- θ (C4)		- ψ (D4)		- φ (B2)		- φ (A2)

SM RCS ENGINES

	PITCH		YAW		ROLL B/D
	+ θ (13)		+ ψ (15)		+ φ (11)
	- θ (14)		- ψ (26)		- φ (22)
	+ θ (23)		+ ψ (25)		+ φ (21)
	- θ (24)		- ψ (16)		- φ (12)

CM RCS ENGINES

SCS 5004A

Figure 2.3-16. SM Jet Functions

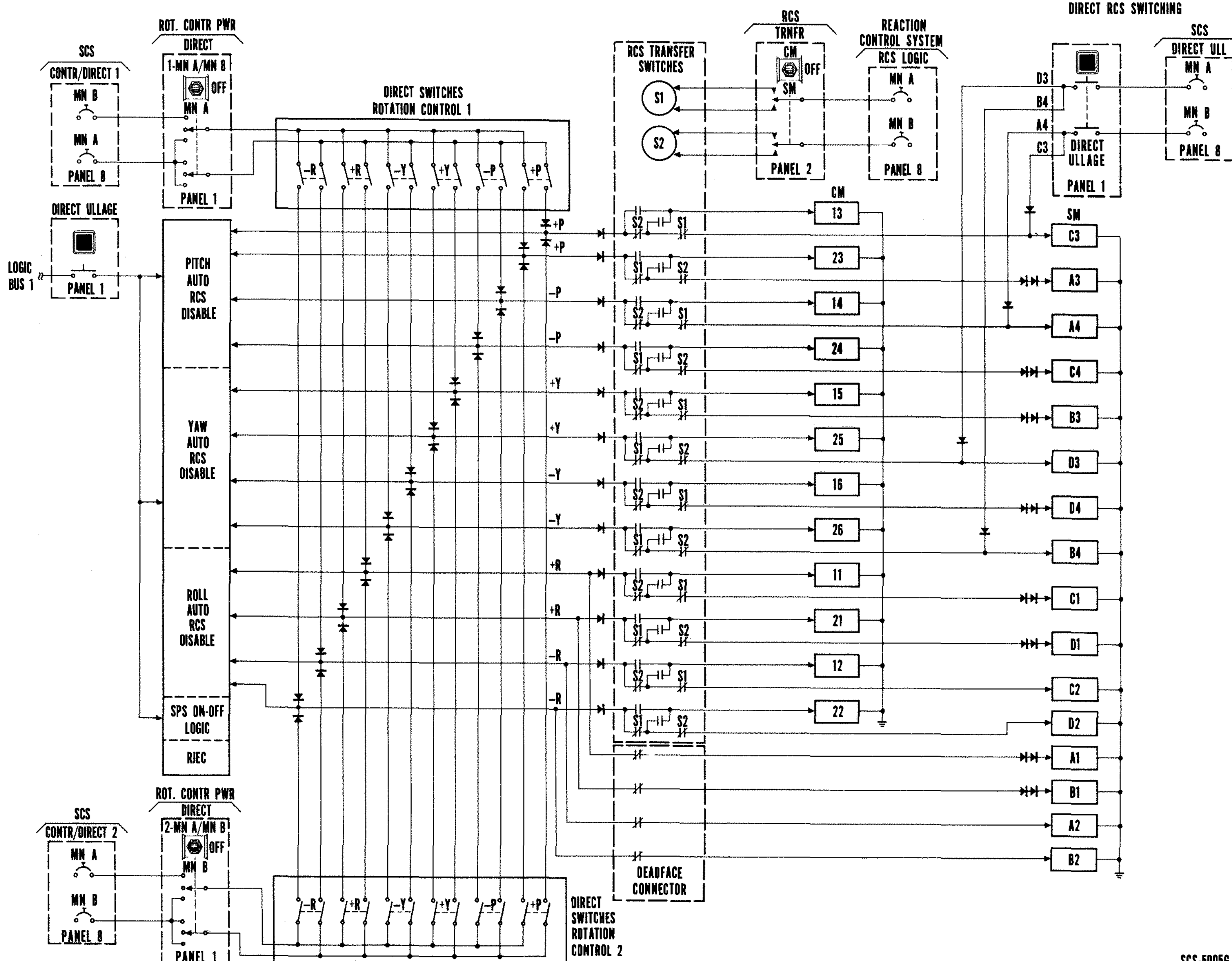

Figure 2.3-17. Direct RCS Switching

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The logic receives RCS commands from the following sources:

- CMC (provides rotational and translational commands).
- ECA (provides rotational commands for either automatic attitude hold, proportional rate, rate damping, or minimum impulse control).
- RC-1 and/or RC-2 (breakout switches [BO] provides continuous rotational acceleration).
- TC (provides translational acceleration commands).

The ACS provides the following commands, listed in order of descending priority:

Direct Coil Commands. At the initiation of direct coil commands, all command input channels to the auto RCS logic in that axis (axes) are inhibited. Pitch and yaw auto commands are inhibited during SPS thrusting (IGN 1). This prevents pitch and yaw auto coil commands from firing the RCS during SPS thrusting.

ACCEL CMD Selection. If a MANUAL ATTITUDE switch(es) is placed in the ACCEL CMD position, the CMC and ECA (except for one-shot circuit) inputs to the auto RCS logic in that axis (axes) are inhibited. Commands to fire auto coils are enabled from the RC breakout switches.

MIN IMP Selection. The ECA inputs to the auto RCS logic provide minimum impulse commands, automatic attitude hold, automatic rate damping, and proportional rate command. When MIN IMP is selected on a MANUAL ATTITUDE switch, the ECA is configured to accept RC breakout commands and supply output pulses. All other outputs of the ECA are inhibited in the ECA.

2.3.4.3.3 Direct Coil Commands

The RCS engines can be operated by applying 28 vdc to the direct coils, as the other side of the direct coils is hard-wired to ground. The coils receive commands from the sources described in the following paragraphs (shown in figure 2.3-17).

Direct Rotational Control. The direct switches in the rotation controllers (RCs) are enabled when the ROT CONTR PWR - DIRECT 1 & 2 switches on MDC-1 are up or down. The RCS commands are initiated when the RC is deflected a nominal 11 degrees about one or more of its axes. At this displacement, redundant direct switches close, routing 28 vdc to the appropriate direct coils and to the auto RCS logic (paragraph 2.3.4.3.2). The signal to the auto RCS logic disables the solenoid drivers in the channel(s) under direct control.

Direct Ullage. An ullage is often performed prior to an SPS thrust maneuver. Direct ullage is a backup to TC +X translation. Pressing the DIRECT ULLAGE pushbutton routes 28 vdc to the SM direct coils on the pitch and yaw RCS engines used for +X translations. (See table on figure 2.3-14.) A signal (28 vdc) is sent to the auto RCS logic that disables the pitch and yaw solenoid drivers. The ullage signal is also sent to the SPS ignition logic in the RJ/EC. (Refer to paragraph 2.3.5.5.)

At CM-SM separation, the lines from the RC direct switches are transferred from SM direct coils to CM direct coils. This is similar to the automatic coil transfer described in paragraph 2.3.4.3.2, except that either of the two transfer motors transfers power to all CM direct coils. The lines for direct or separation ullage (MESC), are open-ended at CM-SM separation

2.3.4.4 Attitude Configurations

2.3.4.4.1 General

The SCS hardware can be placed in various configurations for attitude control. These configurations, described briefly in the preceding paragraphs, are categorized as automatic and manual configurations. The automatic control capabilities are described in paragraph 2.3.4.4.2 and the manual capabilities in paragraph 2.3.4.4.3.

2.3.4.4.2 Automatic Control

The automatic capabilities of the ACS are rate damping and attitude hold. The rate damping configuration provides the capability of reducing large spacecraft rates to within small limits (rate deadband) and holding the rate within these limits. The attitude hold configuration provides the capability of keeping angular deviations about the body axes to within certain limits (attitude deadband). If attitude hold is selected in pitch, yaw, and roll, the control can be defined as maintaining a fixed inertial reference. The rate damping function is used together with the attitude hold configuration; therefore, the description of the rate control loop is included in the following attitude hold discussion.

Attitude hold uses the control signals provided by the rate and attitude BMAGs which are summed in the ECA (figure 2.3-18). The control loops are summed at the input to a switching amplifier which provides the on-off engine commands to the auto RCS logic. Each of the three switching amplifiers (pitch, yaw, and roll) has two outputs, providing clockwise and counterclockwise rotation commands. The polarity of the d-c input voltages to the switching amplifiers determines the commanded direction of rotation.

If the switching amplifier input signal is smaller than a specific value, neither output is obtained. This input threshold required to obtain an output is the switching amplifier deadband. Manually selectable gain authority provides flexibility in the selection of the attitude hold deadband width, the rate damping sensitivity, and the proportional rate command authority. The RATE switch controls both the rate damping threshold and the proportional rate command authority, which is discussed in paragraphs to follow. Since the attitude hold configuration utilizes the attitude and rate loops, the switching amplifiers will switch on when the summation of attitude error and rate signals equals the switching amplifier voltage deadband. Attitude error signals are scaled (20:1) as a function of the RATE switch. In addition, a deadband limiter circuit may be switched into the attitude error loops. This is accomplished by having the ATT DEADBAND switch in MAX, which, in effect, blocks the first four degrees of attitude error. Although the switching amplifier switching level is constant, the RATE and ATT DEADBAND switches provide different switching levels

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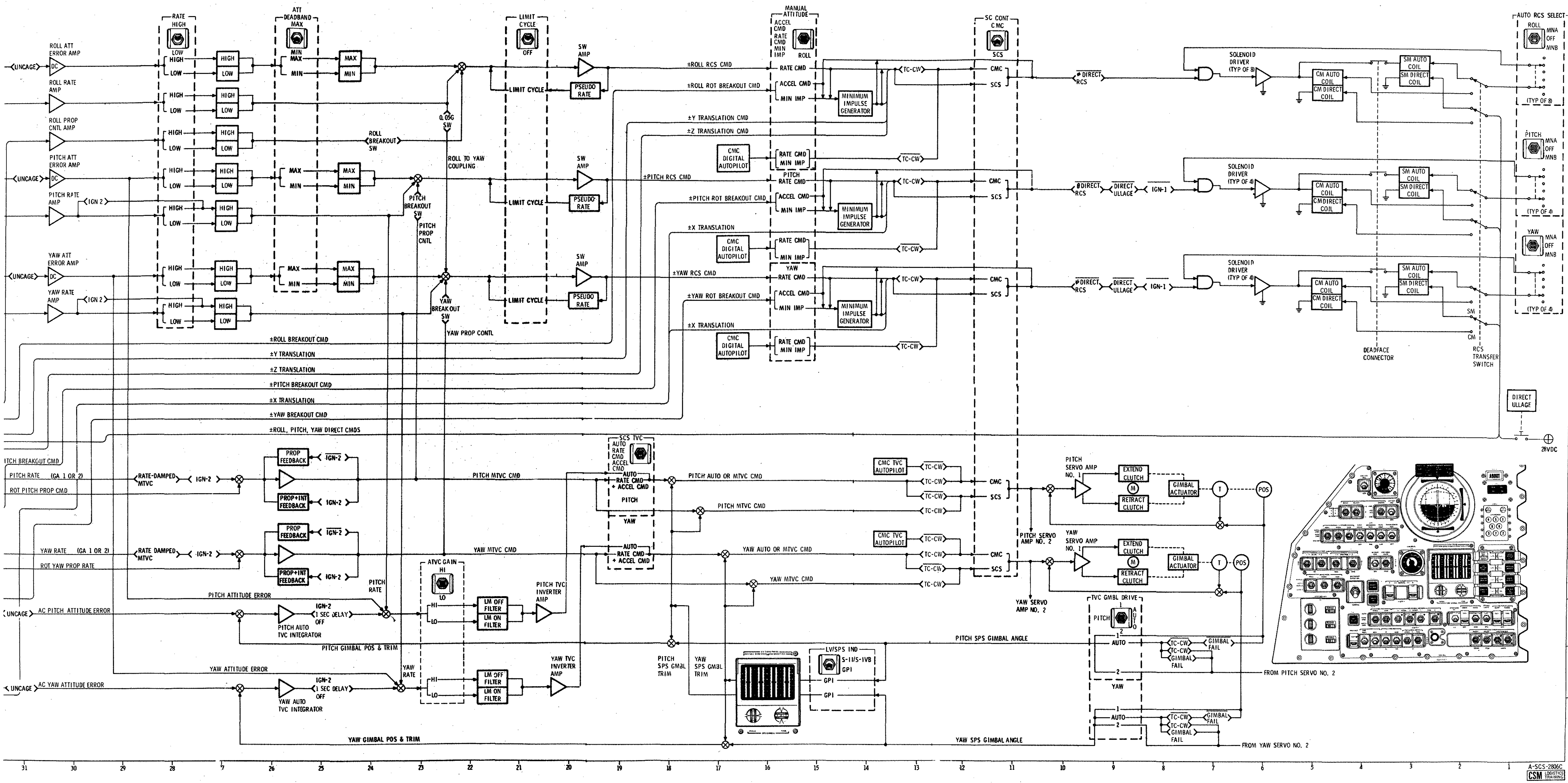

Figure 2.3-18. SCS Attitude and Thrust Vector Control System

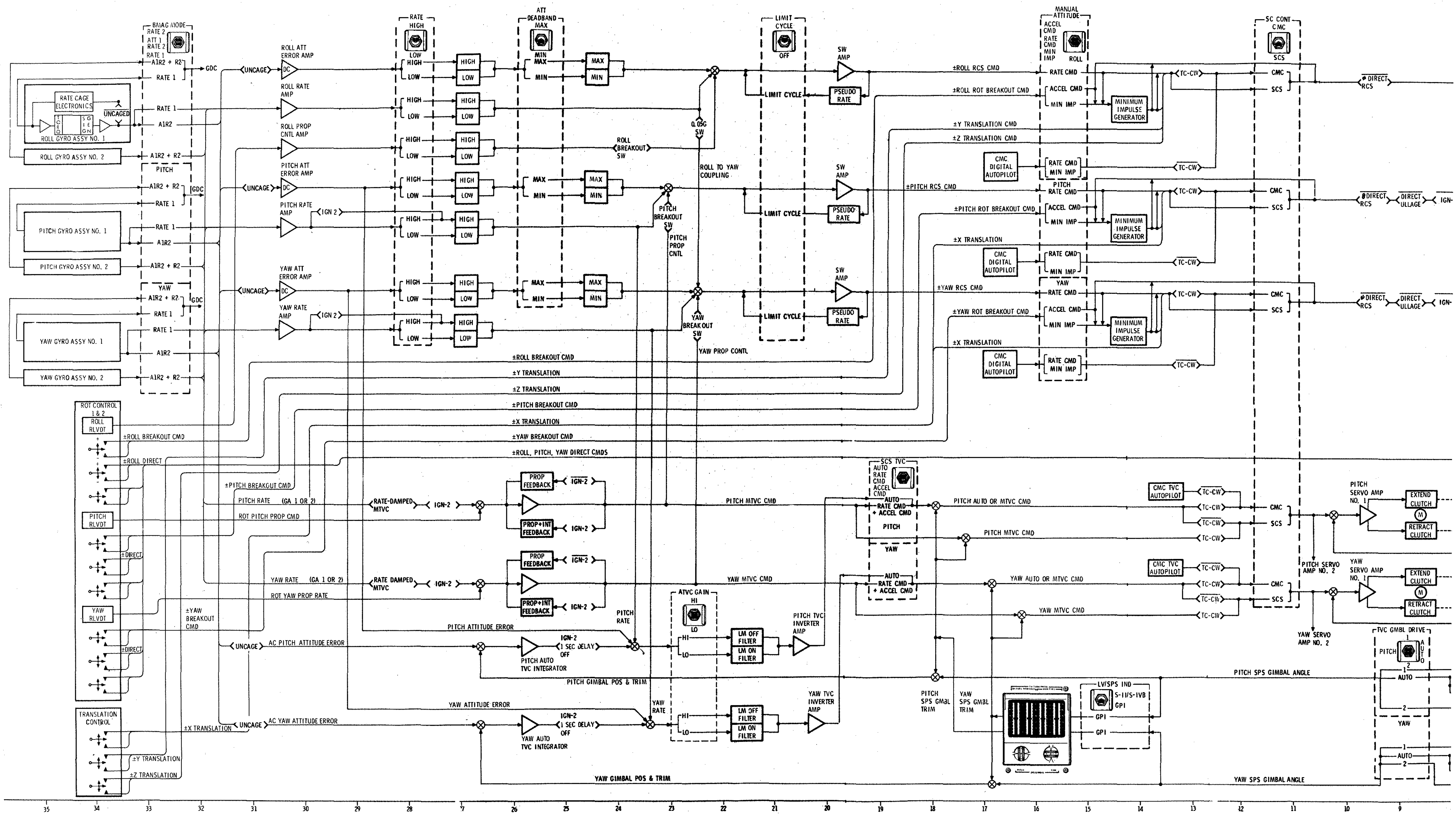

Figure 2.3-18. SCS

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expressed in terms of spacecraft rate and attitude error. The actual attitude excursions achieved during attitude hold are a function of spacecraft mass and other factors. The following chart lists the selectable switching levels for the rate and attitude deadbands as a function of the RATE and ATT DEADBAND switches.

RATE Sw Position	Rate Deadband (°/Sec)	ATT DEADBAND Sw Position	
		MIN	MAX
LOW	±0.2	±0.2 deg	±4.2 deg
HIGH	±2	±4 deg	±8 deg

During attitude hold it is desirable to maintain minimum rotation rates to conserve propellants. This capability is provided by the pseudo-rate circuit. Pseudo-rate feedback around the switching amplifier is enabled via the LIMIT CYCLE switch. Placing the LIMIT CYCLE switch up causes the switching amplifier output to pulse off and on when the input level approaches the threshold.

When the pseudo-rate mode is used, the pulse duration from the switching amplifier may be insufficient to ensure proper operation of the solenoid valves in the RCS. This applies for operation near the deadband limits. To ensure a sufficiently long pulse to the solenoids, a one-shot circuit is connected downstream from the switching amplifier. The one shot provides a single minimum-impulse command (on-time) for each switching amplifier output pulse. When the switching amplifier pulse width exceeds the one shot on-time, the longer RCS command controls the RCS firing time. The output pulse width of the one shot is a function of the d-c bus voltage; the pulse width increases as the bus voltage decreases. This is because the solenoid valve pickup time increases as the bus voltage decreases; therefore, a longer RCS "on" command is required. Thus, the one-shot circuit provides compensation for bus voltage variations. The pulse width varies approximately from 11 msec to 19 msec over a bus voltage range of 30 to 25 vdc. The one-shot circuit is also used in manual minimum impulse control. This configuration is described in the next paragraph.

An additional rate control loop is used for the yaw axis only. This loop is enabled during entry, after .05 G, and is used to cancel unwanted yaw rate BMAG signals. The unwanted yaw BMAG signals are those signals resulting from roll maneuvers about the stability X-axis. The 21-degree offset between this axis and the X-axis causes the yaw BMAG to sense a component of the entry roll rate.

2.3.4.4.3 Manual Control

Following are the manual attitude control capabilities.

- DIRECT
- ACCELERATION CMD
- MINIMUM IMPULSE
- PROPORTIONAL RATE

The commands listed are initiated by manual inputs to either rotation controller. With the exception of direct, the RC commands rotations through the RCS auto coils.

The manual rotation control capabilities are discussed further in the following paragraphs.

Proportional Rate. Proportional rate provides the capability to command spacecraft rates that are proportional to the RC deflection. The RC transducer output is summed (by axis) through the breakout switch logic path (figure 2.3-18) with the rate signal from the BMAG. Initially, the RC output (commanded rate) will be larger than the BMAG output (actual rate) so that the summed signals will be greater than the switching amplifier threshold. The RCS engines will fire until the summation of the rate and commanded rates are within the switching amplifier deadband. When the RCS engines stop firing, the spacecraft will continue to rotate at a constant rate until a new rate is commanded.

Since the MANUAL ATTITUDE switch must be in RATE CMD for proportional rate, the spacecraft will be under automatic control when the RC is released.

The rate commanded by a constant stick deflection is a function of the ratio of the control loop gains. The ratio has two possible values which are selected by the RATE switch. The nominal rate commanded at maximum stick deflection (soft stop), for both rate switch positions, are shown in the following:

RATE Switch Position	Maximum Proportional Rate CMD (By Axis)	
	Pitch and Yaw	Roll
LOW	0.7 deg/sec	0.7 deg/sec
HIGH	7 deg/sec	20 deg/sec

The switching chart (figure 2.3-19) shows the LIMIT CYCLE switch in the OFF position. Performing a proportional rate maneuver with pseudo-rate enabled (switch-on), requires more RCS fuel than the same maneuver without pseudo-rate feedback.

Minimum Impulse. Minimum impulse provides the capability of making small changes in the spacecraft rate. When minimum impulse is enabled, the switching amplifier output is inhibited. Thus, the spacecraft (attitude) is in free drift in the axis where minimum impulse is enabled, if direct control is not being used.

Minimum impulse control is commanded by the RC breakout switch. This switch provides a 28-vdc logic signal to the one-shot circuit in the ECA. The one shot (paragraph 2.3.4.4.2) provides a command to the auto RCS logic for a nominal 15 ms. Additional minimum impulse commands are obtained each time a breakout switch is closed (by repeated opening and closing of the breakout switch).

			MANUAL					AUTOMATIC	
			DIRECT	ACCELERATION CMD	TRANSLATION	MINIMUM IMPULSE	PROPORTIONAL RATE (4)	RATE DAMPING	ATTITUDE HOLD
MANUAL ATTITUDE	ROLL	ACCEL CMD		✓					
		RATE CMD					✓	✓	✓
		MIN IMP				✓			
	PITCH	ACCEL CMD		✓					
		RATE CMD					✓	✓	✓
		MIN IMP				✓			
	YAW	ACCEL CMD		✓					
		RATE CMD					✓	✓	✓
		MIN IMP				✓			
BMAG MODE	ROLL	RATE 2						✓	
		ATT 1/RATE 2							✓
		RATE 1						✓	
	PITCH	RATE 2						✓	
		ATT 1/RATE 2							✓
		RATE 1						✓	
	YAW	RATE 2						✓	
		ATT 1/RATE 2							✓
		RATE 1						✓	
SC CONT		CMC			/ ✓	/ ✓	/ ✓	/ ✓	/ ✓
		SCS			✓ /	✓ /	✓ /	✓ /	✓ /
TRANS CONTROL		CW			/ ✓	/ ✓	/ ✓	/ ✓	/ ✓
		NEUTRAL							
RHC DIRECT PWR		UP/DOWN	✓	(3)	(3)	(3)	(3)	(3)	(3)
		OFF							
ROT CONTROL		B.O. SW		CLOSE (2)		CLOSE (2)	CLOSE	OPEN	OPEN
		DIRECT SW	CLOSE						
LIMIT CYCLE (1)		UP							✓
		OFF					✓	✓	
ENTRY		.05G							
		OFF							✓

(1) NOT REQUIRED TO ENABLE A PARTICULAR FUNCTION.
INDICATES DESIRED POSITION FOR RCS PROPELLANT CONSERVATION.
(2) IF B.O. SW IS OPEN THE S/C WILL BE IN FREE DRIFT.
(3) IF "ON", DIRECT SW IN ROTATION CONTROL MUST BE "OPEN".
(4) MAXIMUM RATE ATTAINABLE IS FUNCTION OF RATE-HIGH/LOW SWITCH

GENERAL COMMENTS:
A. THE CAPABILITIES, IN GENERAL, ARE LISTED IN ORDER OF THEIR PRIORITY.
B. WHEN MORE THAN ONE SWITCH POSITION IS CHECKED (✓) THE CAPABILITY WILL BE ENABLED IN EITHER POSITION.

SCS-5016B
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Figure 2.3-19. ACS Control Capabilities

Acceleration Command. When acceleration command is enabled and a breakout switch is closed, continuous commands are sent to the appropriate RCS auto coils. The SC CONT switch has no function in enabling the acceleration command capability, which is second in priority only to direct coil operations. (Refer to paragraph 2.3.4.3.2.)

Direct. Direct control is similar to acceleration command except that the direct RCS coils are used. Also, instead of a breakout switch providing the firing command, the RC direct switches are used to provide 28 vdc straight to the direct coils (figure 2.3-18). Power to the RC direct switches is controlled by the two ROT CONTR PWR DIRECT switches on panel 1, one switch controlling the 28 vdc for each RC (figure 2.3-25). During direct control in an axis, all auto coil commands in that axis are inhibited in the auto RCS logic.

2.3.4.5 Translation Control

When power is supplied to the translation control (TC), a manual translational command fires auto coils to give acceleration(s) along an axis (or axes). The TRANS CONTR PWR switch on panel 1 supplies 28 vdc to the TC translational switches (figure 2.3-25).

TC inputs are routed as logic inputs to the auto RCS logic when the spacecraft is under SCS control. However, during CMC control, TC commands arrive at the auto RCS logic via the CMC. Since the TC uses only SM RCS engines, after CM/SM separation the TC has no translation function.

Other translational control is possible from inputs other than the TC. These are direct ullage, CSM/LV separation ullage, and CM/SM minus X translation (SM JETT CONT). These translation commands utilize direct coils (figure 2.3-17).

Certain panel switch combinations are necessary for each ACS capability that has been discussed. For a summary, see figure 2.3-19.

2.3.5 THRUST VECTOR CONTROL (TVC)

2.3.5.1 Introduction

The spacecraft attitude is controlled during a delta V by positioning the engine gimbals (TVC) for pitch and yaw control while maintaining roll attitude with the attitude control subsystem. The SCS electronics can be configured to accept attitude error inputs for automatic control (SCS auto TVC) or rotational controller (RC) inputs for manual thrust vector control (MTVC). Manual TVC can be selected to utilize angular rate feedback signals summed with the manual inputs; this comprises the MTVC/RATE CMD configuration. Selecting MTVC without rate feedback describes the MTVC/ACCEL CMD configuration. A different configuration can be selected for each axis; for example, one axis can be controlled manually while the other is controlled automatically.

The following paragraphs present the characteristics of the SCS/TVC configurations. A switching table, specifying the panel switching and logic signals required for enabling each configuration, is included. The operation of the engine ignition/thrust on-off logic is also described.

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2.3.5.2 TVC Panel Configurations

On the simplified TVC signal flow diagram shown in figure 2.3-20, functional enabling switches are used for reference. The TVC switching table (figure 2.3-21) relates the functional switching and panel switching to the TVC configuration desired. Both figures are applicable to either the pitch or yaw TVC channel.

In general, it is possible to enable a functional switch through several (alternate) panel configurations. The alternate configurations usually require the CW logic signal which is obtained from a clockwise rotation of the translation controller (TC) T-handle. This provides a convenient means of transferring from one TVC configuration to another during the thrusting maneuver. The CW signal will also enable transfer from servo No. 1 to servo No. 2 (figure 2.3-21) under certain conditions. Thus, it is possible to transfer to a completely redundant configuration by using the TC clockwise switch.

The gimbal servo control loop consists of a servo amp that drives two magnetic clutch coils; one coil extends the actuator, the other retracts the actuator. Gimbal rate and position transducers provide feedback for closed loop control. Two servo control channels are provided for both the pitch and the yaw axes. The active channel is selected through functional switch servo 2 enable (figure 2.3-20). Primary control utilizes servo No. 1. Servo No. 2, in an axis, can be engaged either by selecting the 2 position on the TVC GMBL DR switch or by automatic transfer. Automatic transfer will occur, if the TVC GMBL DR switch is in the AUTO position and either the FS (fail sense) or CW logic signal is present. The CW logic will enable transfer to servo No. 2 in both axes, whereas, the FS logic will enable transfer only in the axis where it is present. The fail sense signal is generated in the motor excitation circuitry of servo actuator No. 1, occurring when an overcurrent is sensed. The transfer logic described is included in the switching table (figure 2.3-21).

2.3.5.3 GPI Signal Flow

The gimbal position display (figure 2.3-4) is used as a monitor of SPS pitch and yaw gimbal deflections from actuator null during CMC and SCS control of a ΔV. Prior to an SCS ΔV, the SPS engine must be positioned with the trim thumbwheels on the GPI. Before SPS ignition, in this case, the GPI will display the trim gimbal angles that were set with the thumbwheels.

Since there is only one display panel of gimbal position, there are redundant indicators, servo-metric meter drivers, and power supplies associated with both the pitch and yaw position displays (figure 2.3-22). When servo channel No. 1 is controlling the SPS actuator, the position input to both GPI indicators (pitch and yaw) is supplied from the No. 1 position transducer. If actuator control is transferred to the No. 2 servo, then the No. 2 position transducer drives both indicators in that axis. If the FDAI/GPI POWER switch is in the BOTH position, then all four indicators are powered. With the switch in position 1, the first and third indicators are enabled. The second and fourth indicators are energized with the switch in position 2.

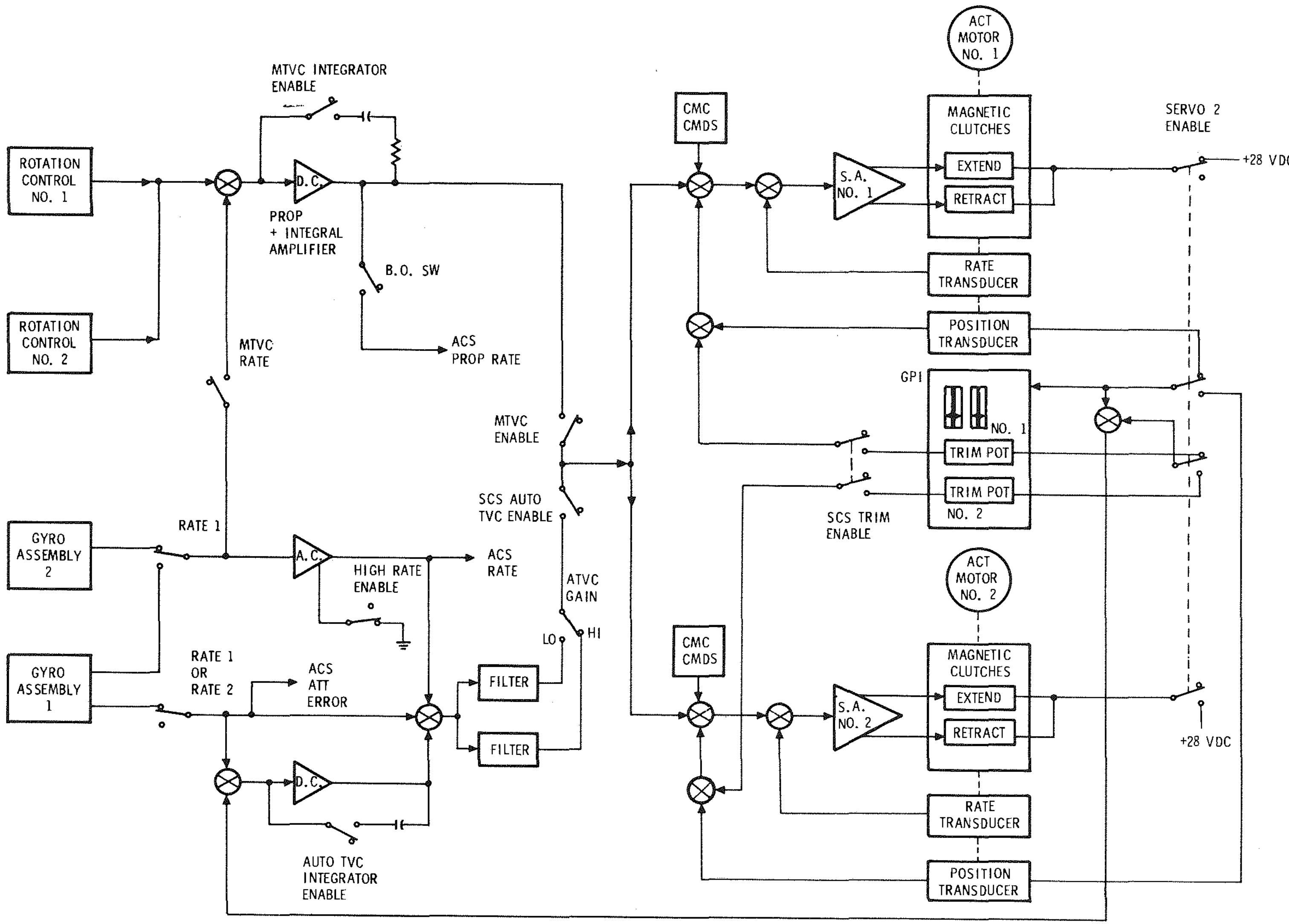

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Figure 2.3-20. TVC Signal Flow

		CMC DAP (1)	SCS AUTO		MTVC RATE CMD			MTVC ACCEL CMD		SCS GMBL TRIM		SERVO 1		SERVO 2 (3)		
SC CONT	CMC	✓	✓		✓			✓		✓						
	SCS			✓		✓	✓		✓		✓					
BMAG MODE (PITCH & YAW)	RATE 2															
	ATT 1/ RATE 2		✓	✓												
	RATE 1															
SCS TVC (PITCH & YAW)	AUTO		✓	✓		✓										
	RATE CMD				✓		✓									
	ACCELCMD							✓	✓							
TVC GMBL DRIVE (PITCH & YAW)	1												✓			
	AUTO											✓		✓	✓	
	2															✓
XLATION CONTROL	NEUTRAL	✓		✓								✓				
	CW		✓		✓	✓		✓		✓				✓		
IGN2 (2)			✓	✓	✓	✓	✓	✓	✓							
FAIL SENSE SIG (PITCH OR YAW)															✓	

(1) CMC MODE SWITCH MUST BE IN AUTO
(2) IGN2 SIGNAL APPEARS AT SPS IGNITION AND IS DELAYED OFF 1 SEC AT THRUST TERMINATION.
(3) SERVO LOOP SWITCHING BY AXIS WITH FAIL SENSE LOGIC SWITCHING

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Figure 2.3-21. TVC Switching

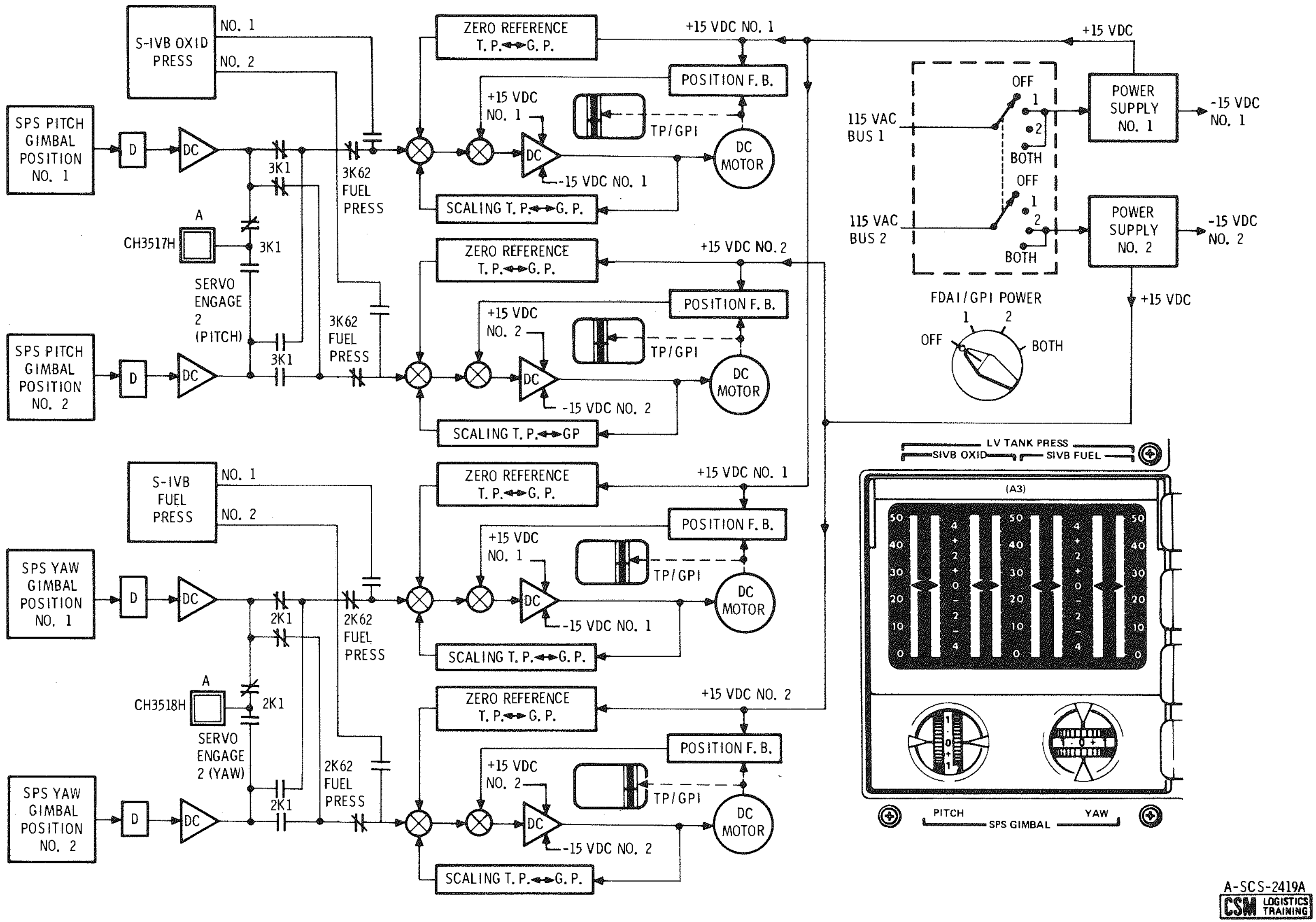

Figure 2.3-22. GPI Signal Flow

2.3.5.4 SCS Auto TVC

In order to configure the SCS electronics for an SCS auto TVC, certain panel switches must be positioned. In addition, other manual or automatic logic switching will affect the control signals and servo loops.

Since SCS auto TVC requires attitude error signals from GA-1, the gyro uncage logic must be satisfied (figure 2.3-11). This requires that the BMAG MODE switches be in ATT 1 RATE 2, the ENTRY - .05 G switch be OFF, and that the SPS ignition signal (IGN 2) be present. For attitude hold (paragraph 2.3.4.2.1), the IGN 2 logic was not needed as GA-1 can be uncaged by placing the MANUAL ATTITUDE switches to RATE CMD while having no breakout switch input.

The attitude error signal (in pitch and yaw) is summed with the SPS gimbal position and GPI trim at the input to an integrator (figure 2.3-21). The integrator output is summed with attitude error and rate, filtered for body-bending, and then applied as an input to the servo amplifiers (primary and secondary). During a delta V the integrator output ensures that the thrust vector stays inertially fixed even though the cg shifts as the propellants are consumed. The signal path requires that the delta V is under SCS control (SC CONT - SCS or TC - CW with SC CONT - CMC) with the SCS TVC switch in AUTO.

Though the control signal is applied to both servo amplifiers, only one will be positioning the SPS gimbal actuators. Selection logic controlling which servo amplifier is energized is represented by the SERVO 2 ENABLE functional switch. The TVC GIMBAL DRIVE switches on MDC-1 have AUTO positions which provide an automatic transfer from servo 1 to servo 2 if either the TC - CW switch is closed or an overcurrent logic signal is sent from the SPS. Positioning the TVC GIMBAL DRIVE switches to 1 or 2 selects the desired servo loop, but overrides the TC - CW or overcurrent transfer.

Prethrust gimbal trim is accomplished by manually turning the trim wheels on the gimbal position indicator (GPI) to obtain the desired indicator readout. The trim wheel in each axis is mechanically connected to two potentiometers. One potentiometer is associated with servo No. 1 and the second with servo No. 2. It is desirable to pretrim before an SCS delta V to minimize the transient duration and the accompanying quadrature accelerations. It is also desirable to set the trim wheels properly before a CMC delta V if the SCS AUTO configuration is to serve as a backup. This will minimize the cross-axis velocities in the event of a G&N-to-SCS transfer during a burn.

2.3.5.5 Manual Thrust Vector Control

Manual control of the thrust vector utilizes crew commands via the RC to position the gimbaled SPS. There are two types of MTVC: MTVC with rate damping (rate command) and MTVC without rate damping (acceleration command). Either mode of MTVC is selectable by panel switching. In addition, TC - CW logic provides automatic transfers to MTVC from either a PGNCS or an SCS auto delta V (figure 2.3-21).

In order to provide ease of manual control, a proportional plus integral amplifier (stick integrator) is incorporated in the MTVC signal flow path. The output of this circuit for a step input will initially be a value determined by the proportional gain and the input amplitude. It will then increase, from this value, as a straight-line function of time. The slope of the line is a function of the input amplitude and the integrator constant. When the input is removed, the output will then drop by the initial value. With no additional inputs the output will theoretically remain constant (in practice, it will slowly decay). The circuit (integrator) provides the following capabilities:

a. Maintain a gimbal deflection after returning the RC to rest.

b. Make corrections with the RC about its rest position, rather than holding a large displacement.

c. With no manual inputs, SC rate is damped out in the RATE CMD configuration.

Selecting an SCS TVC switch to RATE CMD enables BMAG rate signal summing with the RC signal at the input of the stick integrator when the IGN 2 (SPS on) logic signal is on. The position of the BMAG MODE switch determines which rate source (BMAG 1 or 2) is summed through its associated functional switch. Placing the SCS TVC switch in the ACCEL CMD position disables the rate signal input to the stick integrator.

The RATE CMD configuration is analogous to the proportional rate capability described in the ACS (paragraph 2.3.4) except there is no deadband. With no manual input, the thrust vector is under rate BMAG control. If there is an initial gimbal cg misalignment, an angular acceleration will develop. The rate BMAG, through the proportional gain, will drive the gimbal in the direction necessary to cancel this acceleration. With no integrator, a steady-state rate would be required to hold the necessary gimbal deflection (through cg). However, because of the integrator the thrust vector will go past the cg so that the rate will be driven to zero. When an RC input (manual) is present, a steady-state vehicle rate will be established when the integrator input goes to zero. Here the stick integrator output value is sufficient to place the thrust vector through the cg. When the manual input is removed the rate will be driven to zero.

When rate feedback is inhibited by selecting ACCEL CMD, the RC input must be properly trimmed to position the thrust vector through the cg. However, positioning the thrust vector through the cg only drives the rotational acceleration to zero. Additional adjustments (RC trimming) are necessary to cancel residual rates and obtain the desired attitude and positioning vector.

During SPS gimbal checks, before SPS ignition, the RC signal gives proportional SPS gimbal deflections. This is because the stick integrator is a proportional amplifier until SPS ignition.

2.3.5.6 Attitude Control and Thrust Vector Control Summary

The detailed diagram of the SCS attitude and thrust vector control subsystems (figure 2.3-23) illustrates the following:

- Discrete and analog telemetry signals
- Amplifier bias and demodulator reference AC1 or AC2 bus sources
- Boolean expressions that satisfy control signal paths.

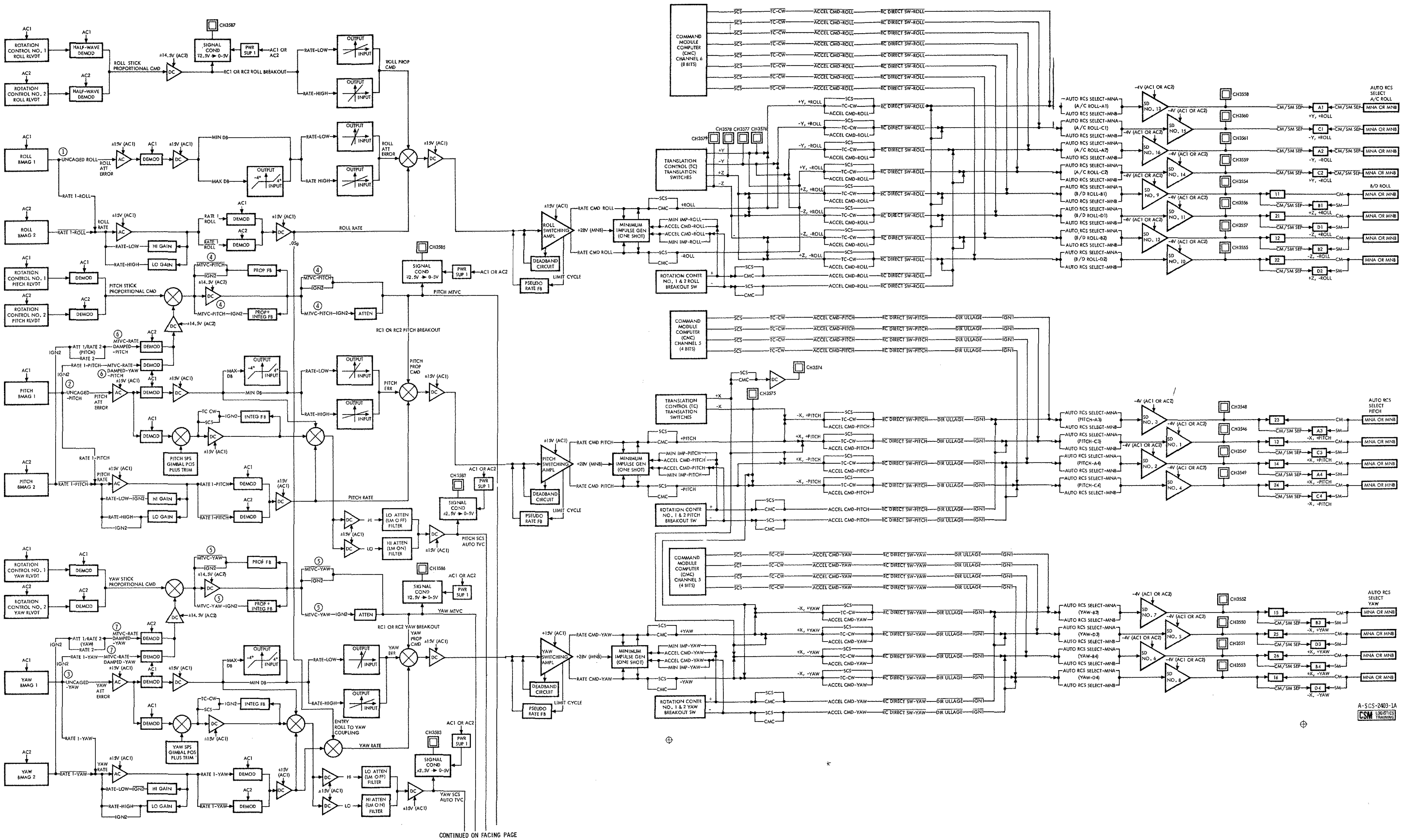

Figure 2.3-23. SCS Attitude and Thrust Vector Control (Sheet 1 of 2)

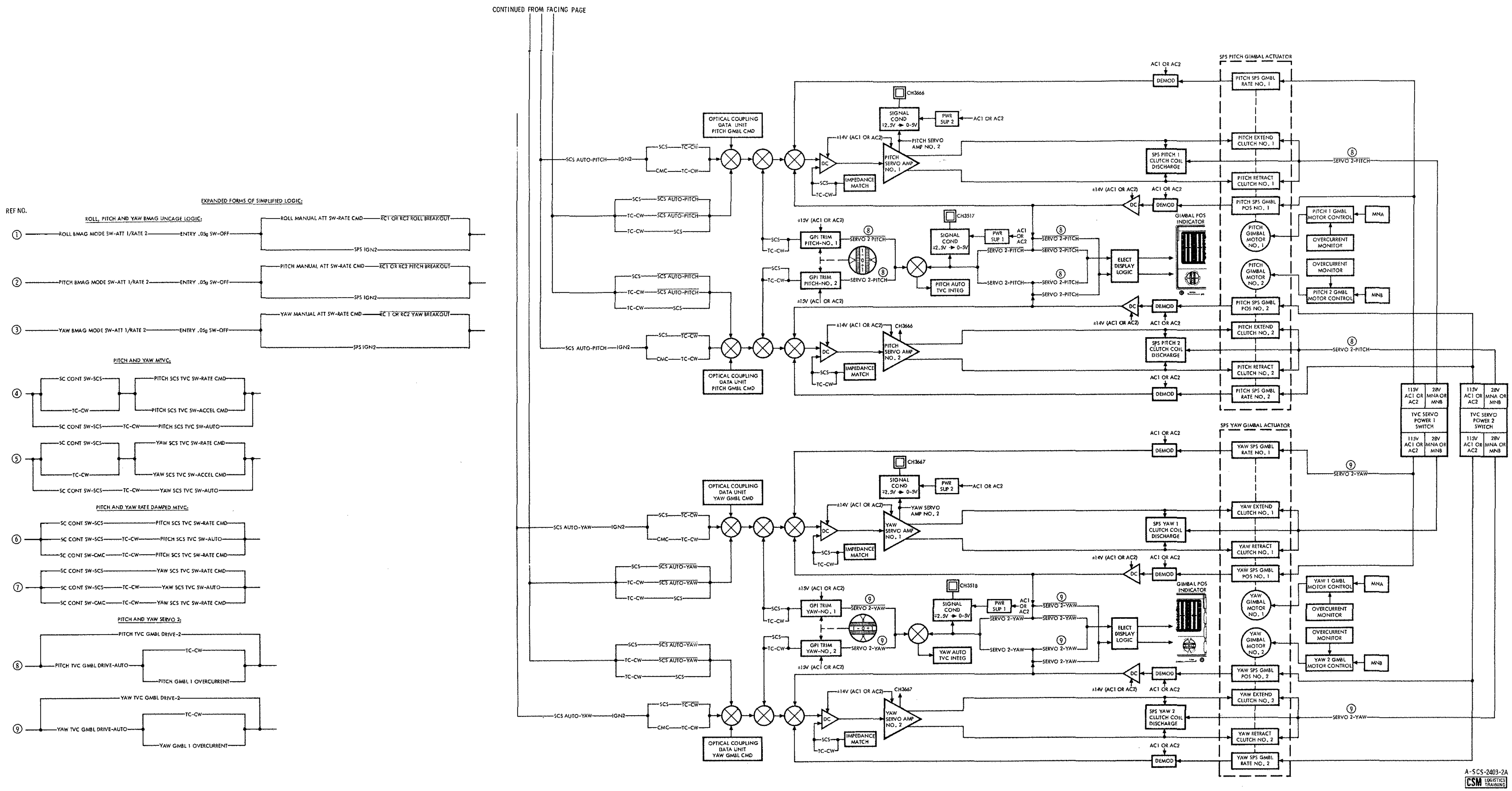

Figure 2.3-23. SCS Attitude and Thrust Vector Control (Sheet 2 of 2)

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2.3.5.7 Engine Ignition, Thrust-On-Off Logic

This section describes the configurations available for SPS ignition on-off control, the panel switch positions and/or logic signals necessary for a particular configuration, and the functions of output (logic) signals.

With the switch positions shown in figure 2.3-24, engine ignition is commanded by placing a ground on the low side of SPS control valve solenoid coils No. 1 & 2 whenever the ΔV THRUST A switch is up, enabling 28 vdc to the SPS control valve solenoids No. 1 & 2. Thrust-off is commanded when the ground is removed. The ground switching can be accomplished in two basic ways. One method is to position the SPS THRUST switch from the NORMAL to the DIRECT ON position for engine turn-on, and terminating thrusting by placing the ΔV THRUST A from NORMAL to OFF. The second method is to switch the ground through the solenoid driver as commanded by the thrust on-off logic.

Engine ignition will be commanded by the thrust on-off logic when any one of the thrust-on logic equations shown in figure 2.3-25 is satisfied. The CMC commands thrust-on (equation 1) by supplying a logic 0 to the thrust on-off logic when the SC CONT switch is in the CMC position and the translation controller (TC) is not clockwise ($\overline{CW}$). When the CMC changes the logic signal from a 0 to a 1, thrust-off is commanded.

For the SCS control configuration, the SC CONT switch must be in the SCS position or the TC handle clockwise (CW). A thrust-on enabling signal is obtained from the EMS. Thrust-on is then commanded by commanding a +X-axis acceleration while pressing the THRUST ON pushbutton. When the ground to the SPS coil has been sensed by the ignition sense logic, the THRUST ON and +X-axis commands can be removed and engine ignition will be maintained by the SCS LATCH UP signal. When the ΔV counter on the entry monitor system (EMS) display reads -0.1 fps, the EMS enabling signal is removed and thrust-off is commanded.

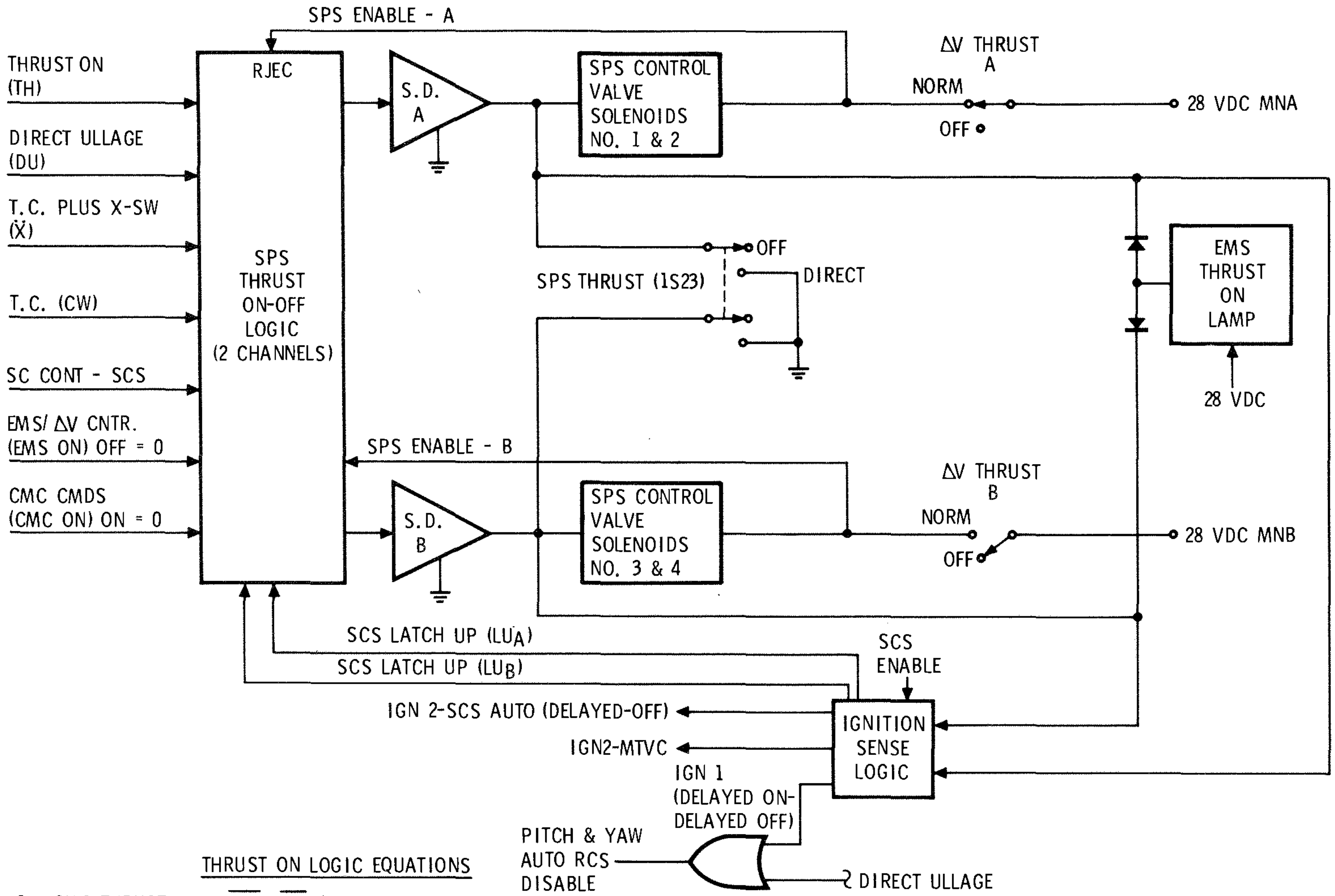
If TVC control is transferred from the CMC to the SCS (by SC CONT switch to SCS or TC to CW) after engine ignition, thrusting will be maintained by the presence of the SCS LATCH UP signal. Thrust-off will be commanded as in a normal SCS control configuration. A backup thrust-off command, for any control configuration, is obtained by placing the ΔV THRUST (A and B) switches to the OFF position.

The +X logic signal, which is necessary to enable thrust-on in the SCS configuration, can be obtained from either the DIRECT ULLAGE pushbutton or the TC +X contacts. The difference between the two commands are:

a. Direct ullage uses the direct coils and inhibits the pitch and yaw solenoid drivers; thus, attitude hold cannot be maintained in these axes. Ullage-ignition overlap time is completely under manual control.

b. When commanding a +X with the TC, attitude hold can be maintained. Ullage-ignition overlap time is automatically limited to one second.

The circuitry provides several output functions. A ground is provided for the SPS THRUST lamp on the EMS display. The ground is also sensed by



THRUST ON LOGIC EQUATIONS

1. CMC THRUST ON = $\overline{SCS} \bullet \overline{CW} \bullet$ (CMC ON)
2. SCS THRUST ON = $[TH \bullet (DU + \ddot{X}) + LU] \bullet (SCS + CW) \bullet$ (EMS ON)
3. CMC TO SCS = $LU \bullet CW \bullet$ (EMS ON) TRANSFER

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Figure 2.3-24. Engine Ignition-Thrust On-Off Logic

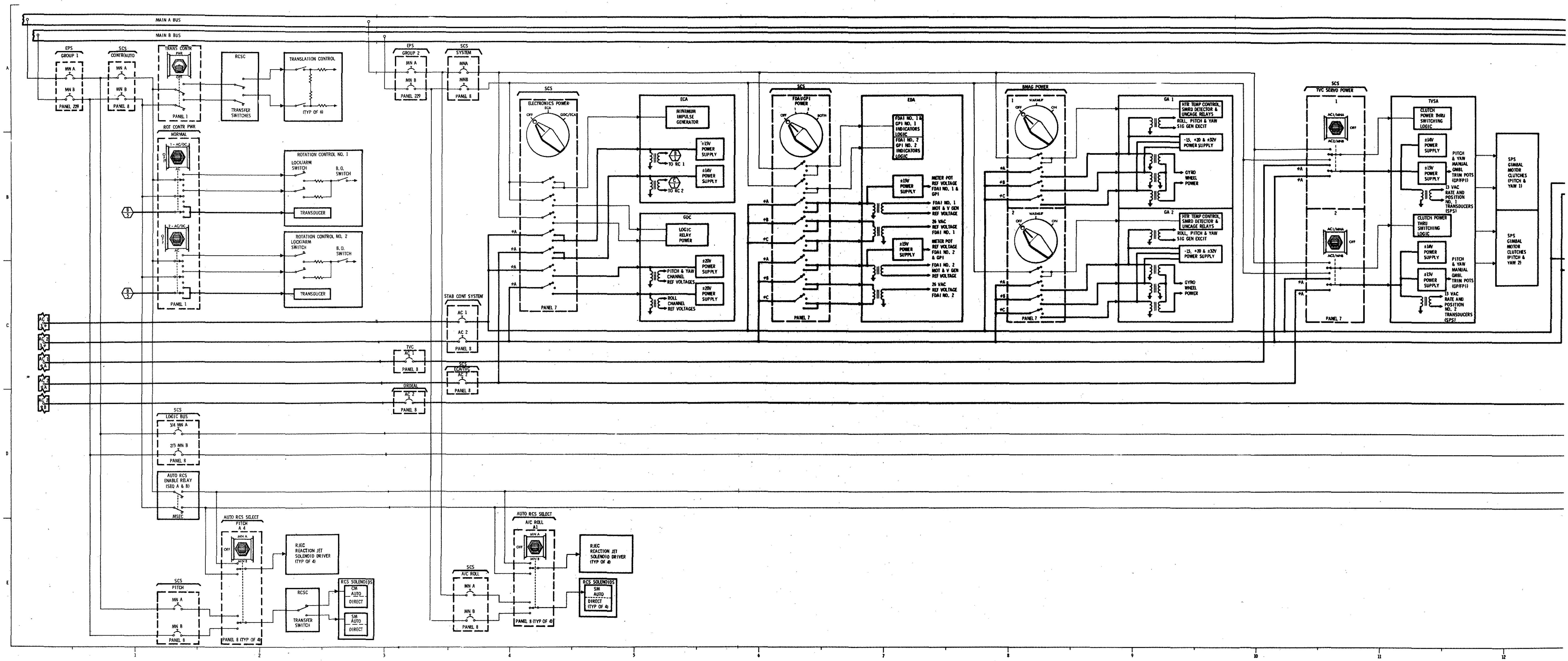

Figure 2.3-25. SCS Power Distribution (Sheet 1 of 2)

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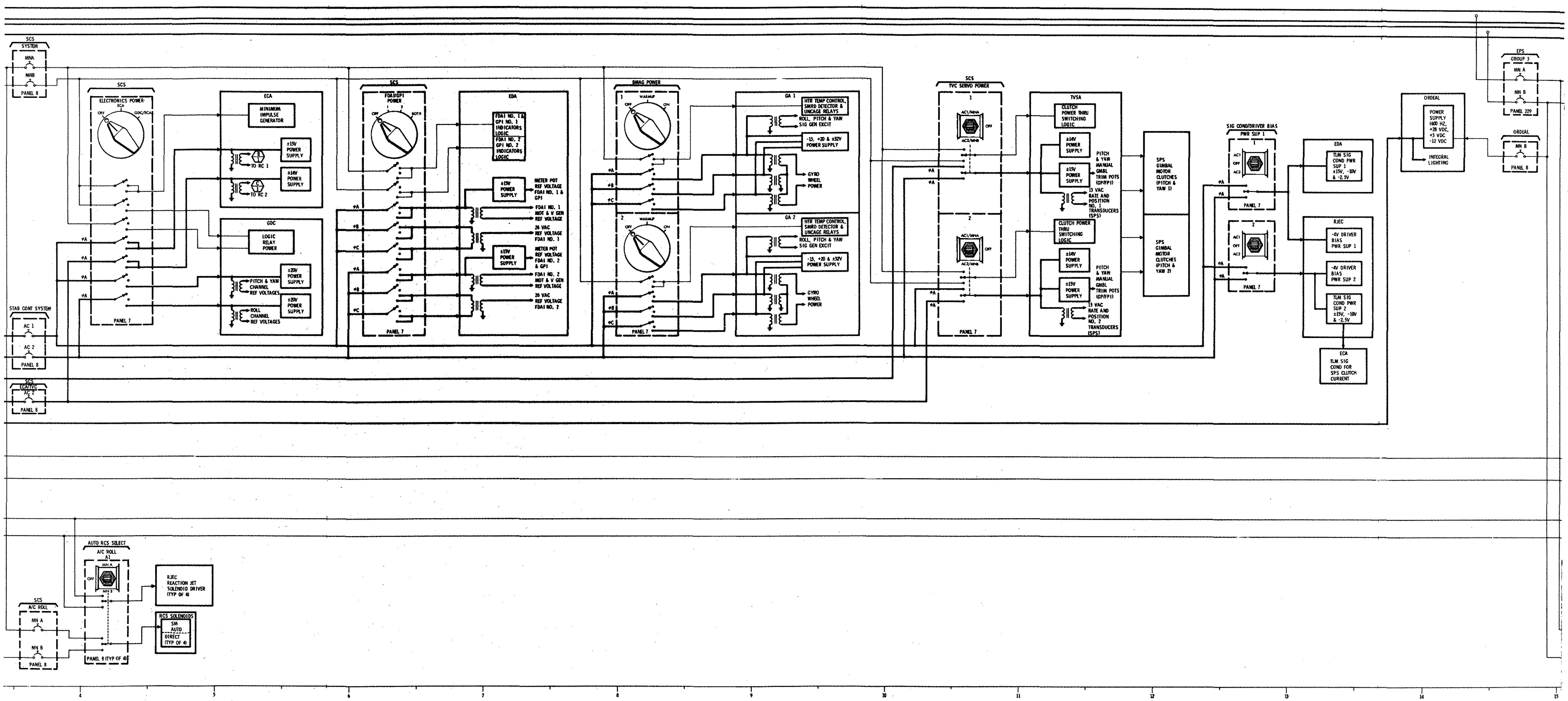

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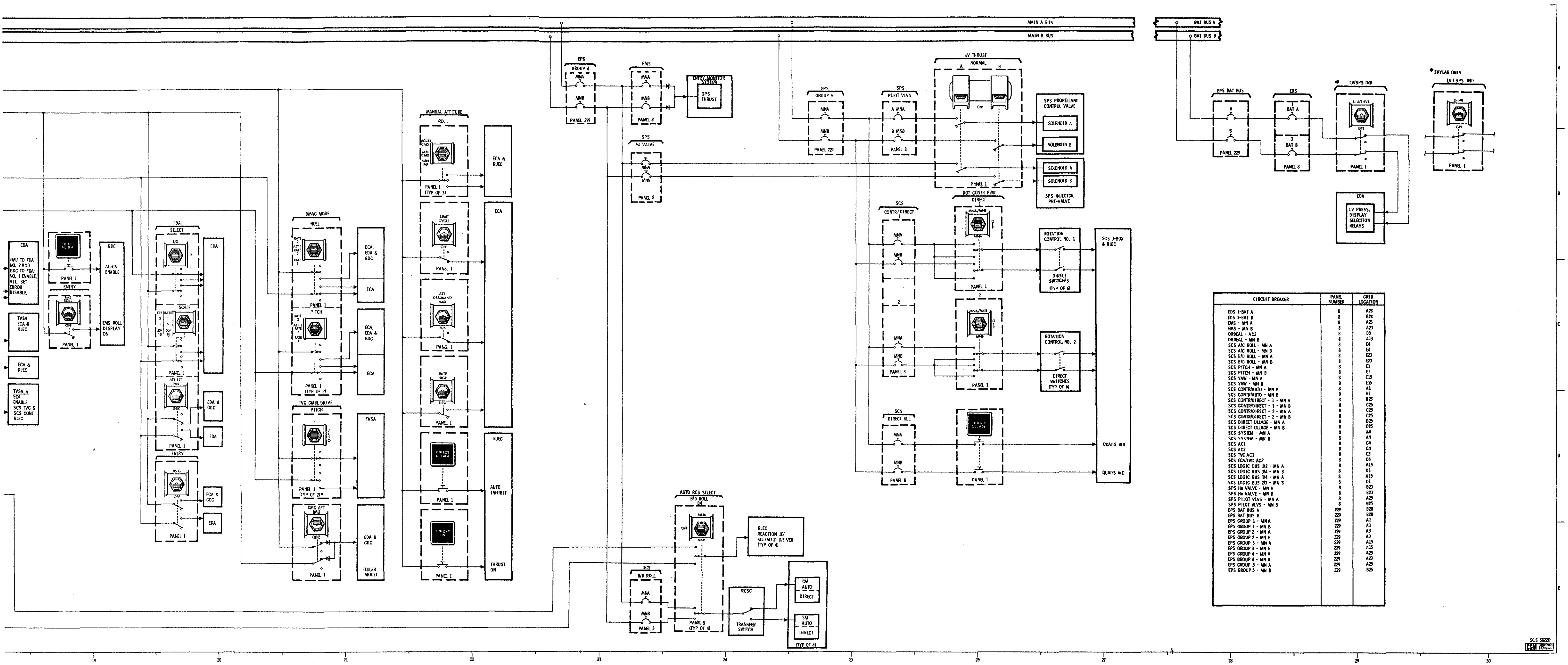

CIRCUIT BREAKER	PANEL NUMBER	GRID LOCATION
EDS 1-BAT A	8	A28
EDS 3-BAT B	8	B28
EMS - MN A	8	A23
EMS - MN B	8	A23
ORDEAL - AC2	8	D3
ORDEAL - MN B	8	A13
SCS A/C ROLL - MN A	8	E4
SCS A/C ROLL - MN B	8	E4
SCS B/D ROLL - MN A	8	E23
SCS B/D ROLL - MN B	8	E23
SCS PITCH - MN A	8	E1
SCS PITCH - MN B	8	E1
SCS YAW - MN A	8	E15
SCS YAW - MN B	8	E15
SCS CONTR/AUTO - MN A	8	A1
SCS CONTR/AUTO - MN B	8	A1
SCS CONTR/DIRECT - 1 - MN A	8	B25
SCS CONTR/DIRECT - 1 - MN B	8	C25
SCS CONTR/DIRECT - 2 - MN A	8	C25
SCS CONTR/DIRECT - 2 - MN B	8	C25
SCS DIRECT ULLAGE - MN A	8	D25
SCS DIRECT ULLAGE - MN B	8	D25
SCS SYSTEM - MN A	8	A4
SCS SYSTEM - MN B	8	A4
SCS AC1	8	C4
SCS AC2	8	C4
SCS TVC AC1	8	C3
SCS ECA/TVC AC2	8	C4
SCS LOGIC BUS 1/2 - MN A	8	A15
SCS LOGIC BUS 3/4 - MN B	8	D1
SCS LOGIC BUS 1/4 - MN A	8	A15
SCS LOGIC BUS 2/3 - MN B	8	D1
SPS He VALVE - MN A	8	B23
SPS He VALVE - MN B	8	B23
SPS PILOT VLVS - MN A	8	A25
SPS PILOT VLVS - MN B	8	B25
EPS BAT BUS A	229	B28
EPS BAT BUS B	229	B28
EPS GROUP 1 - MN A	229	A1
EPS GROUP 1 - MN B	229	A1
EPS GROUP 2 - MN A	229	A3
EPS GROUP 2 - MN B	229	A3
EPS GROUP 3 - MN A	229	A15
EPS GROUP 3 - MN B	229	A15
EPS GROUP 4 - MN A	229	A23
EPS GROUP 4 - MN B	229	A23
EPS GROUP 5 - MN A	229	A25
EPS GROUP 5 - MN B	229	B25

Figure 2.3-25. SCS Power Distribution (Sheet 2 of 2)

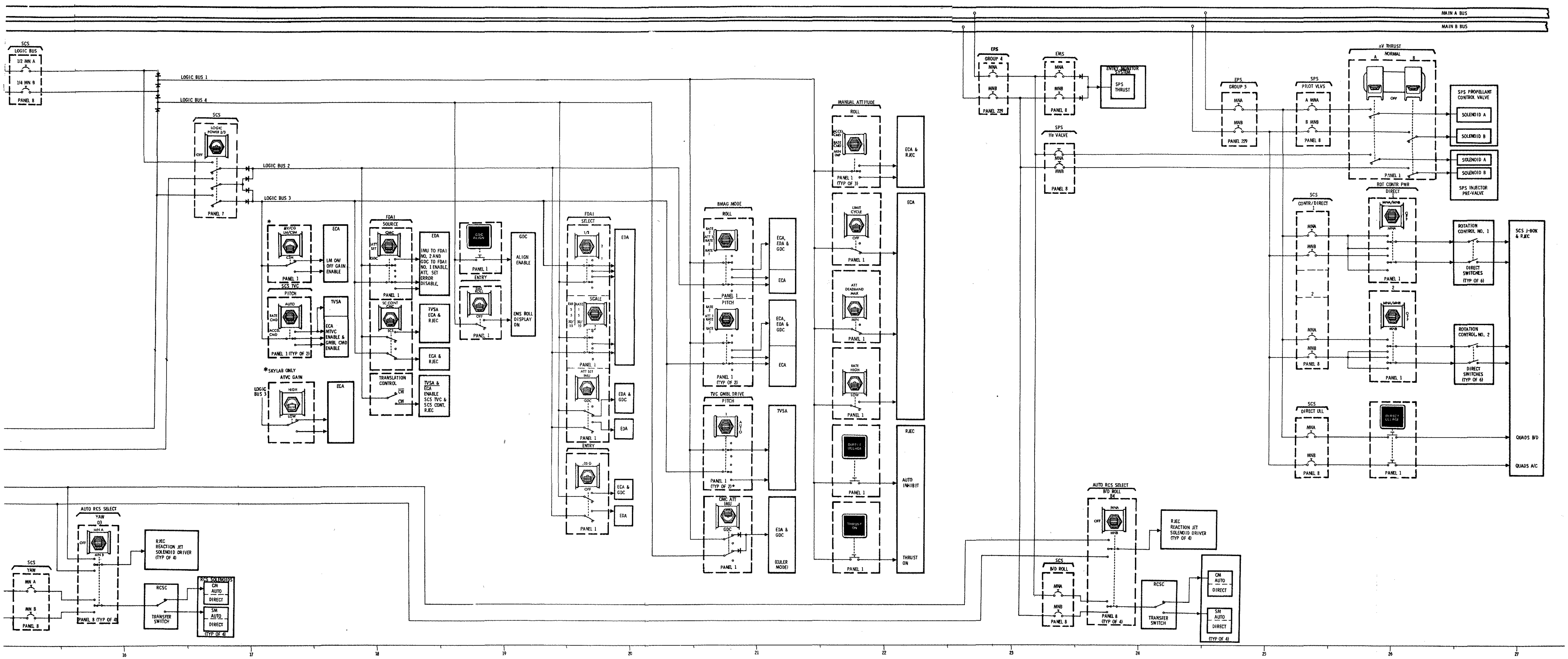
MAIN A BUS
MAIN B BUS
LOGIC BUS 1
LOGIC BUS 4
LOGIC BUS 2
LOGIC BUS 3
*SKYLAB ONLY
AUTO RCS SELECT
RCSC
TRANSFER SWITCH
RCS SOLENOIDS
MANUAL ATTITUDE
BMAG MODE
TVC GMBL DRIVE
FDAI
ENTRY MONITOR SYSTEM
SPS THRUST
ΔV THRUST
SPS PROPELLANT CONTROL VALVE
SPS INJECTOR PRE-VALVE
ROT CONTR PWR DIRECT
ROTATION CONTROL NO. 1
ROTATION CONTROL NO. 2
SCS J-BOX & RJEC
QUADS B/D
QUADS A/C
RJEC REACTION JET SOLENOID DRIVER (TYP OF 4)

Figure 2.3-25.

the ignition sense logic which generates signal for both disabling the RCS pitch and yaw auto commands (IGN 1) and also for configuring the SCS electronics for thrust vector control (IGN 2).

The RCS disabling signal, IGN 1 on figure 2.3-24, is not present until one second after engine ignition and is not removed until one second after engine-turn-off. This provides adequate time for engine thrust buildup and decay. The IGN 2 logic signal is required in the logic for the functional switches in the SCS-TVC signal flow paths. There are separate IGN 2 signals generated for SCS auto TVC and for MTVC. These signals are generated at ignition and are held on for one second after thrust-off. The one-second IGN 2 off delay enables the TVC electronics to maintain spacecraft control during thrust decay.

2.3.6 POWER DISTRIBUTION

The SCS circuit breakers (panel 8) supply electrical power to both panels 1 and 7 power switches and also to the SCS panel 1 switches for logic signals. The panel 7 SCS switches distribute a-c and d-c power to the SCS hardware (figure 2.3-25) and route the SCS logic bus power to panel 1 switches (figure 2.3-25). The power switching for the two rotation hand controllers and the translation hand controller is on panel 1 (figure 2.3-25).

The SCS performance data is included in the Skylab Program Operational Data Book - CSM Performance Data (MSC 01549, Vol. 3). The SOH, Volume 2, contains the SCS operational limitations and restrictions together with the malfunction procedures.

2.3.7 ENTRY MONITOR SYSTEM

The entry monitor system (EMS) provides a visual monitor of automatic primary guidance navigation and control system (PGNCS) entries and delta velocity maneuvers. The EMS also provides sufficient display data to permit SCS manual entries in the event of PGNCS malfunctions. For SCS TVC, the EMS sends a signal to the SCS for SPS engine cutoff. The delta velocity display can also be used as the cue to initiate manual thrust-off commands if the automatic-off command malfunctions. During rendezvous the EMS provides a display of VHF ranging information.

Self-test provisions are provided by a function switch for the three operational modes (entry, delta V, and VHF ranging) to provide maximum system confidence prior to actual use.

The EMS performance data is included in the Skylab Program Operational Data Book - CSM Performance Data (MSC 01549, Vol. 3). The SOH, Volume 2, contains the EMS operational limitations and restrictions together with the malfunction procedures.

2.3.7.1 Entry Functions

The EMS provides five displays and/or indications that are used to monitor an automatic entry or to aid in performing a manual entry.

2.3.7.1.1 Threshold Indicator (.05 G)

The threshold indicator, labeled .05 G, illuminates when the atmospheric deceleration is sensed. The altitude at which this indicator is illuminated is a function of the entry angle (velocity vector with respect to local horizontal), the magnitude of the velocity vector, geographic location and heading, and atmospheric conditions. Bias comparator circuits (figure 2.3-26) are used to initiate this indicator. The signal used to illuminate the indicator is also used internal to the EMS to start the corridor evaluation timer, scroll velocity drive, and range-to-go circuits.

2.3.7.1.2 Roll Stability Indicator

The roll stability indicator (RSI) provides an indication of lift vector position throughout entry. With the ATT SET switch in the GDC position, the RSI will be aligned prior to 0.05 G by rotating the yaw thumbwheel on the attitude set control panel with the EMS ROLL switch in the entry position while pressing the GDC ALIGN button. During entry, stability axis roll attitude will be supplied to the RSI by the gyro display coupler. There are no degree markings on the display, but the equivalent readout will be zero when the RSI points toward the top of the control panel. During the entry, the RSI rotates in the opposite direction to the spacecraft roll, the same way that the FDAI ball rotates in roll.

2.3.7.1.3 Corridor Verification Indicators

The corridor verification indicators are located above and below the RSI. They consist of two lights which indicate the necessity for lift vector up or down for a controlled entry. The indicators will be valid only for vehicles which enter with lunar return velocities (approximately 36,000 fps). The corridor comparison test is performed 10 seconds after the .05 G indicator is illuminated. The lift vector up light (top of RSI) indicates G greater than 0.262G. The lift vector down light (bottom of RSI) indicates G less than 0.262G.

Figure 2.3-27 is a typical example of the corridor evaluation function. An entry angle is the angular displacement of the CM velocity vector with respect to local horizontal at 0.05G. The magnitude of the entry angles that determines the capture and undershoot boundaries will be a function of CM lift-to-drag (L/D) ratio. The angles shown are for a L/D of 0.3 to 0.4. The EMS positive lift overshoot boundary is that entry angle that produces 0.262G 10 seconds after the .05 G indicator is illuminated. An entry angle greater than the EMS positive lift overshoot boundary will cause the upper corridor verification light to be illuminated. Conversely, an entry angle less than the positive lift overshoot boundary will light the lower corridor light. Entry angles less than the capture boundary will result in noncapture regardless of lift orientation. Noncapture would result in an elliptical orbit which will re-enter when perigee is again approached. The critical nature of this would depend on CM consumables: power, control propellant, oxgen, etc. The command module and crew will undergo excessive Gs (greater than 10G) with an entry angle greater than the undershoot boundary, regardless of lift orientation.

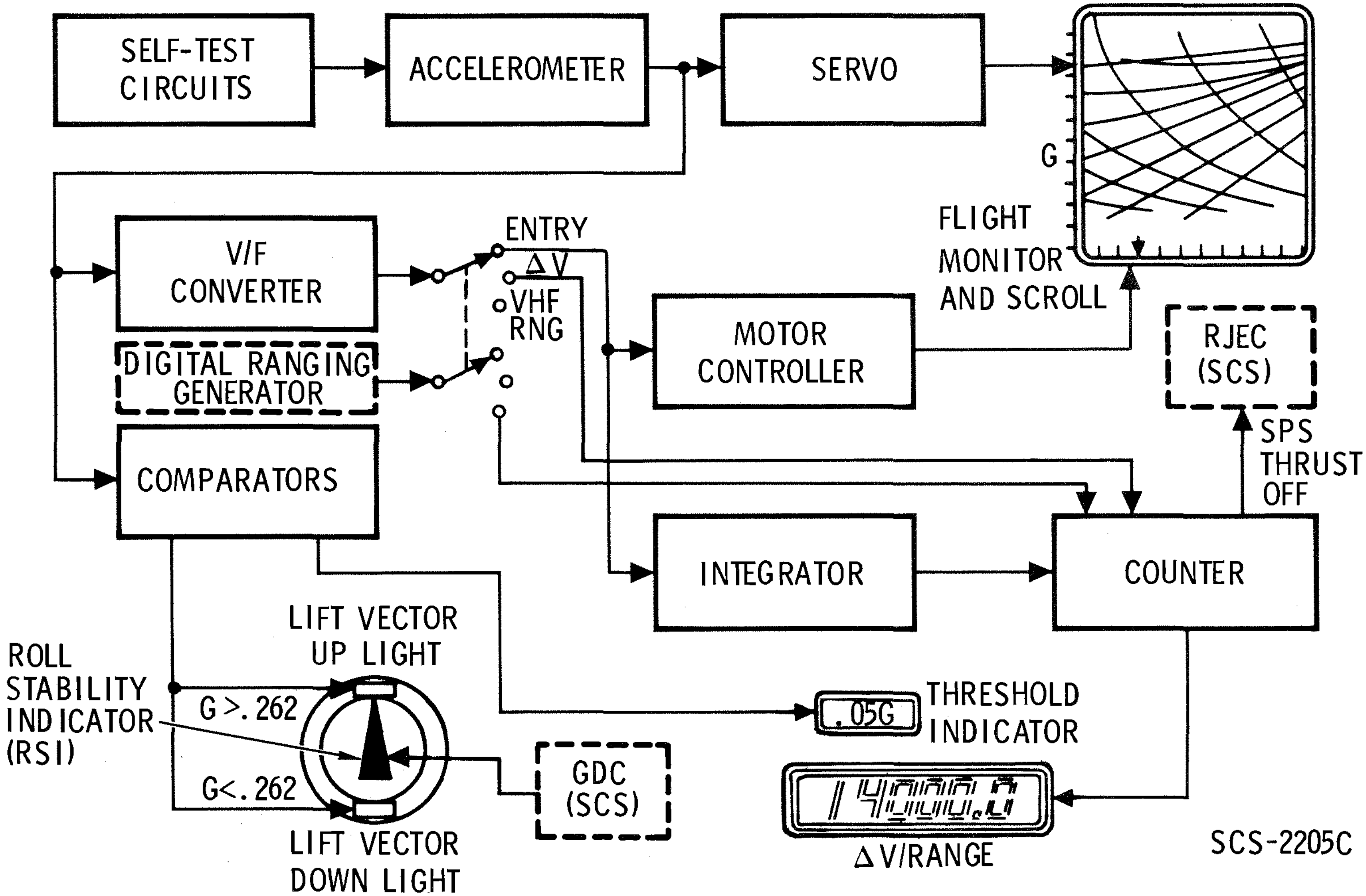

Figure 2.3-26. EMS Block Diagram

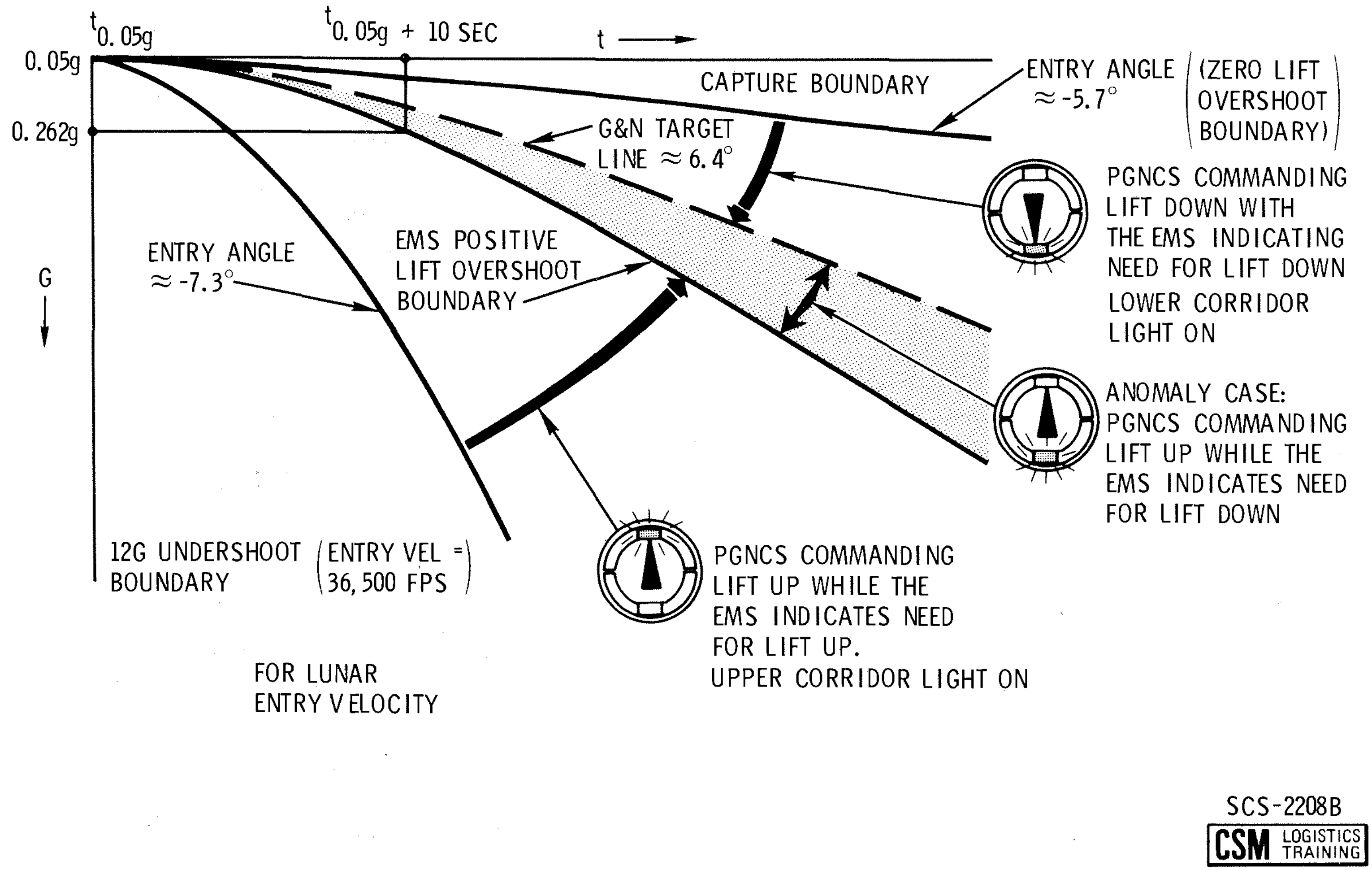

Figure 2.3-27. EMS Corridor Evaluation

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2.3.7.1.4 Delta V/Range-To-Go Indicator

The delta V/range-to-go indicator is an electronic numeric readout which has three functions. During entry, it displays the inertial flight path distance in nautical miles to predicted splashdown after 0.05G. The predicted range will be obtained from the PGNCS or ground stations and inserted into the range display during EMS range set prior to entry. For a delta V, the display will indicate the ΔV (ft/sec) remaining. For rendezvous, the display will indicate the distance to the Saturn workshop.

2.3.7.1.5 Scroll Assembly

The scroll assembly provides a trace of G versus inertial velocity during entry. The mylar scroll has printed guidelines which provide monitor (or control) information during aerodynamic entry. The entry trace is generated by driving a stylus against the pressure-sensitive scroll in a vertical direction as a function of G level, while the scroll is driven from right to left proportional to the CM inertial velocity change. Monitor and control information for safe entry and range potential can be observed by comparing the slope of the entry trace to the slope of the nearest guidelines (G onset, G offset and range potential).

2.3.7.2 <u>Delta Velocity Functions</u>

In addition to entry functions, the EMS provides outputs related to delta velocity maneuvers during SPS or RCS thrusting along the CSM X-axis. Both the SPS THRUST lamp and the ΔV numeric counter display information during a ΔV. In addition, an automatic thrust-off command signal is supplied to the SCS when the ΔV counter reaches -0.1 fps.

2.3.7.2.1 SPS Thrust-On Indicator

The SPS thrust-on indicator will be illuminated any time a ground potential is present on the low side of either of the SPS bipropellant solenoid control valves if either of the EMS circuit breakers on MDC-8 are set. None of the EMS or MDC switches will inhibit this circuit.

2.3.7.2.2 Delta Velocity Indicator

The electro-luminescent (EL) numeric readout displays the delta velocity remaining along the CSM X-axis for a thrusting maneuver. The numeric display has the capability of displaying a maximum of ±99,999.9 fps. The readout is to 1/10 fps. The ΔV/EMS SET rocker switch will be used to set in the desired delta V for all SPS thrusting maneuvers. The ΔV display will count up or down with the EMS MODE switch in the NORMAL position. The display counts down with SPS or RCS thrusting along the CSM +X-axis or up with RCS thrusting along the CSM -X-axis. The BACKUP/VHF RNG position of the MODE switch gives a decreasing readout during +X thrusting and an unchanging readout during -X thrusting.

2.3.7.2.3 SPS Thrust-Off Command

During SCS-controlled SPS thrusting, a thrust-off command is supplied to the RJEC by the EMS. This thrust-off logic signal is supplied to the SPS engine on-off circuit when the ΔV display reads minus values of ΔV. Consequently, the THRUST ON pushbutton will not turn on the SPS engine unless the ΔV display reads zero or greater.

2.3.7.3 EMS Switches

There are four switches to activate and select the desired function in the EMS. They are the MODE switch, the FUNCTION switch, the ΔV/EMS SET switch, and the GTA switch.

2.3.7.3.1 MODE Switch

The MODE switch has three positions: NORMAL, STBY, and BACKUP/VHF RNG. The STBY position applies power to the EMS circuits; it inhibits system operation but enables the set functions. The NORMAL position permits the self-tests to function. It also is the normal position for operations when the FUNCTION switch is in the ENTRY and ΔV positions. The BACKUP/VHF RNG position is used as a backup in the entry and delta V operations and is the proper position during VHF ranging. The BACKUP/VHF RNG position could be used as a backup to initiate the scroll velocity drive and the range display countdown in the event of failure of the .05 G circuits. The BACKUP/VHF RNG position energizes the .05 G light, but does not activate the corridor verification circuits for a display.

2.3.7.3.2 FUNCTION Switch

The FUNCTION switch is a 12-position switch which is used to select the desired function in the EMS. Three positions are used for delta V operations. Eight positions are used for entry, entry set and self-test. The remaining position is OFF. One position is used for VHF ranging.

Switch Position	Function
OFF	Deactivates the EMS except the SPS THRUST light and the roll stability indicator.
EMS test 1	Tests lower trip point of 0.05 G - threshold comparator and enables slewing of the scroll.
EMS test 2	Tests the high trip point of the .05 G - threshold comparator.
EMS test 3	Tests lower trip point of the corridor verification comparator and enables slewing of the ΔV/RANGE display for EMS test 4 operations.
EMS test 4 EMS	Tests the range-to-go integrator circuits, G servo circuits, G-V plotter range-to-go circuits.

Switch Position	Function
EMS test 5	Tests high trip point of corridor verification comparator and enables slewing of scroll.
RNG SET	Establishes circuitry for slewing the ΔV/RANGE display.
Vo SET	Establishes circuitry for slewing the scroll to the predicted inertial velocity at 0.05G.
ENTRY	Operational position for monitoring the CM earth atmosphere entry mode.
ΔV TEST	Operational position for self-test of delta V circuits.
ΔV SET/VHF RNG	Establishes circuitry for slewing the ΔV/RANGE display. Enables VHF ranging display.
ΔV	Operational position for accelerometer to drive the ΔV/RANGE display for X-axis accelerations.

2.3.7.3.3 ΔV/EMS SET Switch

The ΔV/EMS SET switch, a five-position rocker switch, is used to drive either the ΔV/RANGE display or the EMS scroll. With the FUNCTION switch in the ΔV SET/VHF RNG, RNG SET, and EMS TEST 3, depressing the ΔV/EMS SET switch from null to a soft stop (either INCR or DECR) will change the display readout at 0.25 unit per second. Depressing the ΔV/EMS SET switch through a soft stop to a hard stop results in a change of 127.5 units per second. With the FUNCTION switch in the Vo SET, EMS TEST 1, and TEST 5 position, depressing the ΔV/EMS SET switch results in driving the EMS scroll. Depressing the ΔV/EMS SET switch to the soft stop drives the scroll at approximately 0.0164 ips (30 fps). Depressing through to the hard stop drives the scroll at approximately 0.263 ips (480 fps). The scroll mechanism puts a constraint on the reverse slewing of the scroll (ΔV/EMS SET switch INCR). The scroll may be slewed only one inch to the right (INCR) after scroll slewings to the left (DECR) of at least three inches.

2.3.7.3.4 GTA Switch

The GTA switch provides a ground test capability. With the coverplate removed, the GTA switch will be placed up to simulate 0G in the vertical stack configuration of the SC. An adjustment pot is available to calibrate 0G when the GTA switch is on and the EMS is operating. For the coverplate to be closed, the GTA switch must be off which removes the simulated 0G function for ground test.

2.3.7.4 Entry Scroll

The EMS mylar scroll, contained in the EMS scroll assembly, contains four entry patterns together with entry in-flight test patterns and the instructions for entry, delta V and VHF ranging (figure 2.3-28). There are four sets of ΔV and VHF ranging instructions that are alternated with four entry in-flight self-test patterns (figure 2.3-29). Following the fourth in-flight self-test patterns on the scroll is the first set of entry instructions. Entry instructions precede each of the four entry patterns. Lunar-return non-exit entry patterns are alternated with lunar-return 3500 NM exit patterns, a non-exit pattern appearing first on the scroll.

Each entry pattern (figures 2.3-30 and 2.3-31) has velocity increments from 38,500 to 4,000 fps, together with entry guidelines which start at 37,000 fps. These lines are called G on-set, G off-set, and range potential guidelines. The G on-set and G off-set lines are solid lines and the range potential lines are broken.

The G on-set lines slope downward, while the G off-set lines sweep upward and terminate at 24,000 fps just to the right of the vertical line at 25,500 fps (100 NM circular earth orbit velocity). Below 24,000 fps the G on-set lines slope downward from the full-lift profile line which represents the steady-state minimum-G entry profile. During entry the trace generated should not become parallel to either the nearest G on-set or G off-set line. If the slope of the entry trace becomes more negative than the nearest G on-set line, the CM should be oriented such that a positive lift vector orientation (lift vector up) exists in order to prevent excessive G buildup. However, if the entry trace slope becomes more positive than the nearest G off-set line then the CM should be oriented to produce negative lift (lift vector down) for entry.

The G on-set and G off-set lines are designed to allow a 2-second crew response time with a single system RCS/SCS 180-degree roll maneuver should the entry trace become parallel to the tangent of the nearest guideline.

Points along the range potential lines, shown in hundreds of nautical miles, indicate the distance that the CM will travel if a constant G force is maintained until drogue chute deployment. The crew will compare the range displayed by the range-to-go counter with the range potential indicated by the entry trace. The slope and position of the entry trace relative to a desired ranging line indicates the need for lift vector up or down.

2.3.7.5 EMS Functional Data Flow

The following functional discussion of the EMS relates system mechanization to the EMS operation. (See figure 2.3-32.)

2.3.7.5.1 Accelerometer

The accelerometer, which is aligned to within ±2 degrees of the SC X-axis, is the only sensor in the EMS. It has three outputs: low level G to the threshold and corridor verification circuits, high level G to the

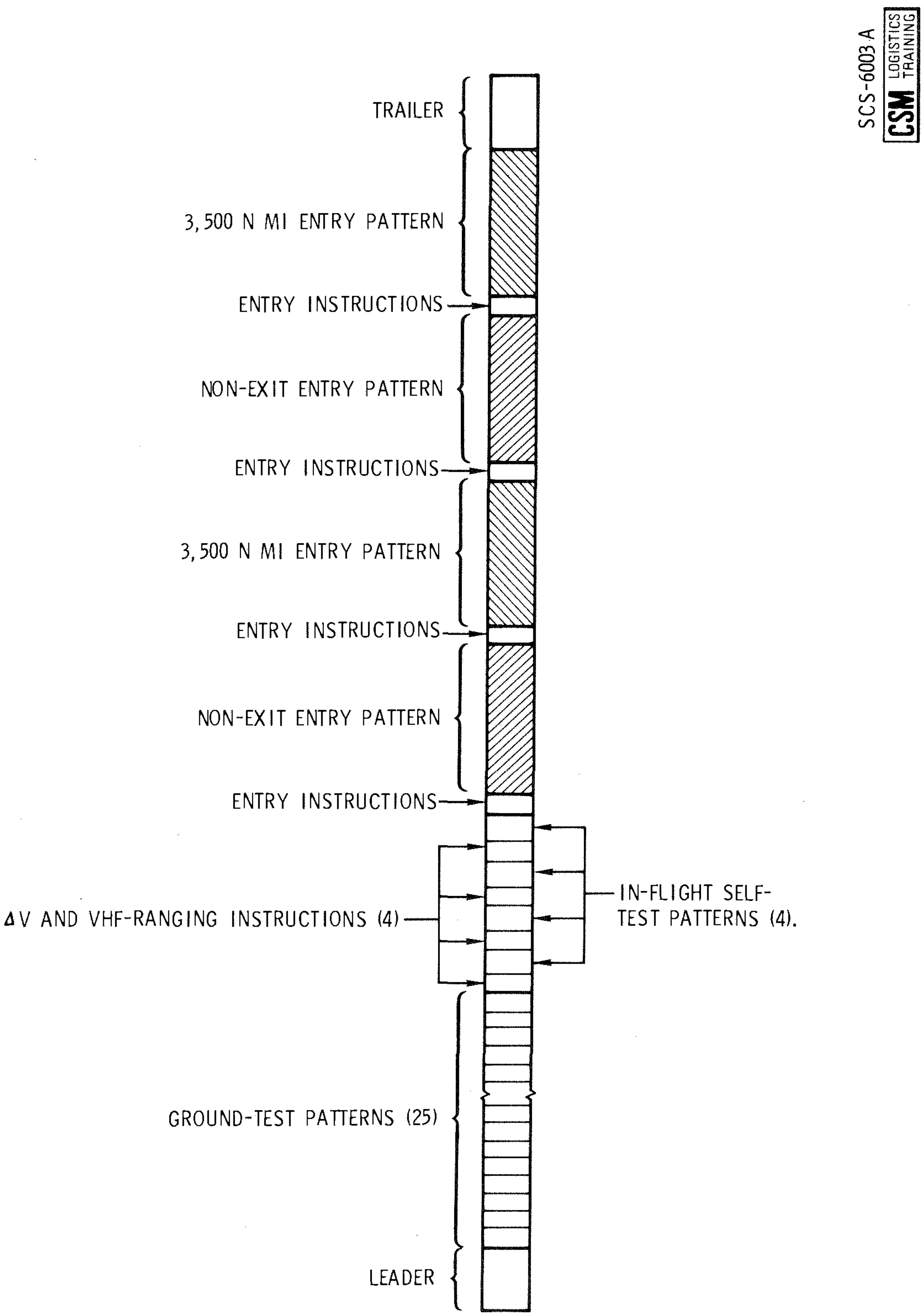
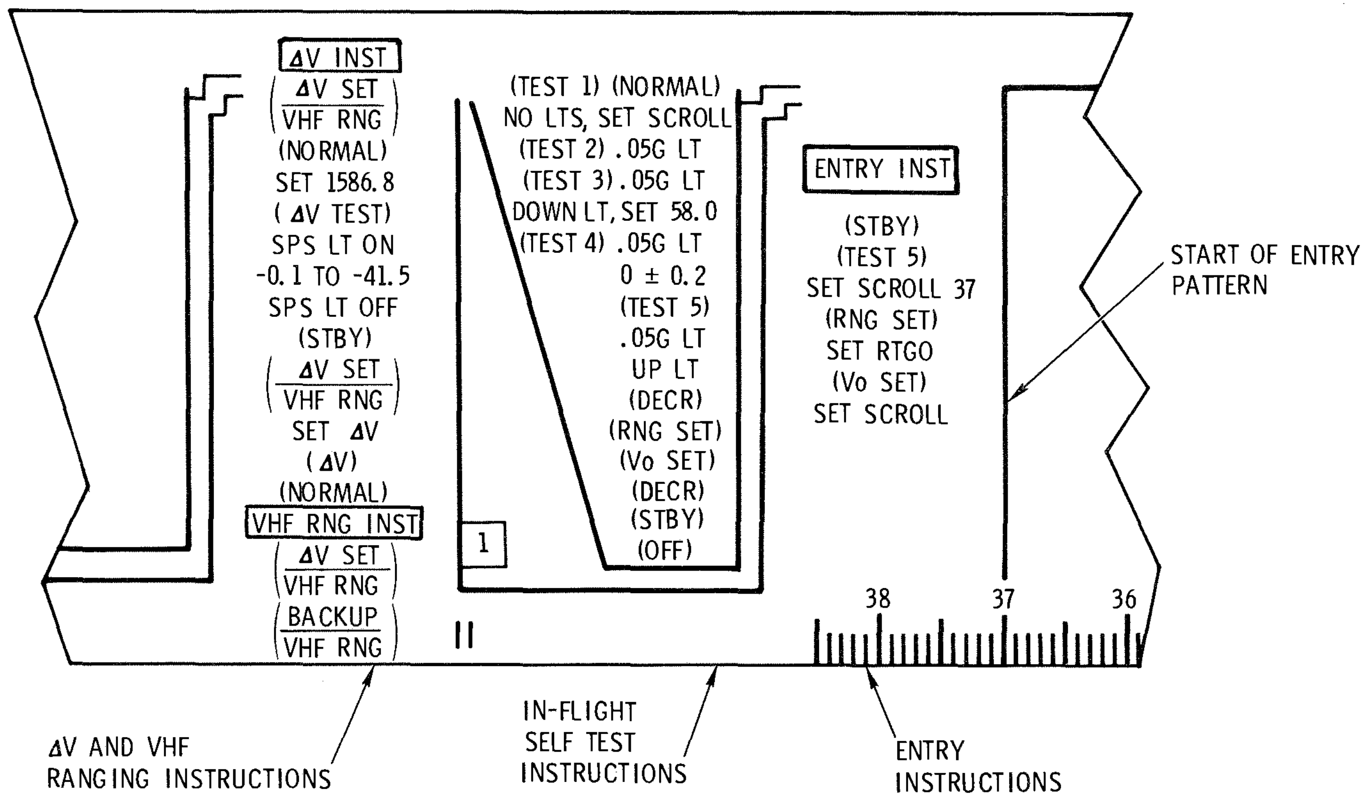


Figure 2.3-28. EMS Scroll Format



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CSM LOGISTICS TRAINING

Figure 2.3-29. EMS In-Flight Instructions for ΔV, VHF Ranging, Self-Test and Entry

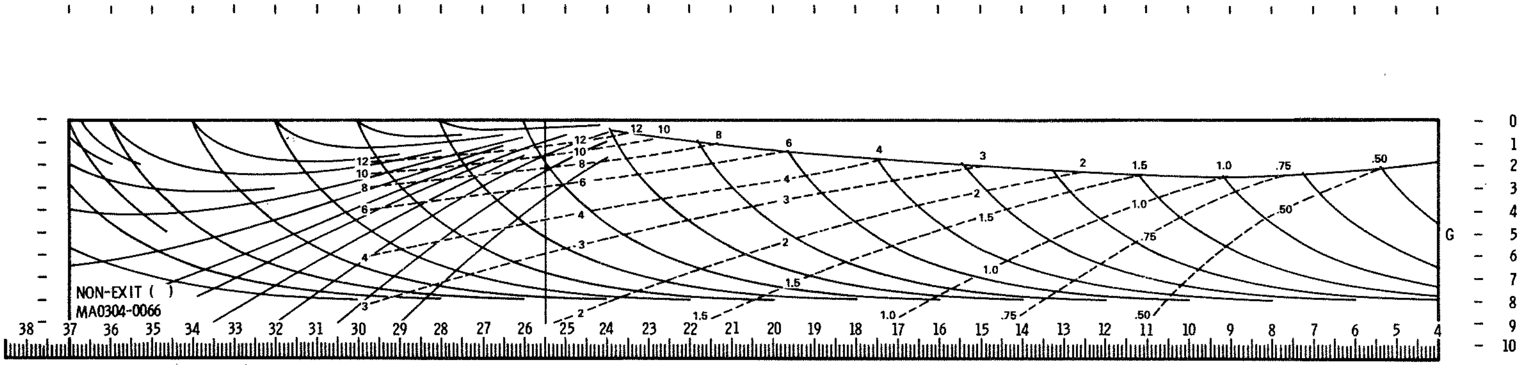

Figure 2.3-30. EMS Lunar Non-Exit Range Limit Pattern

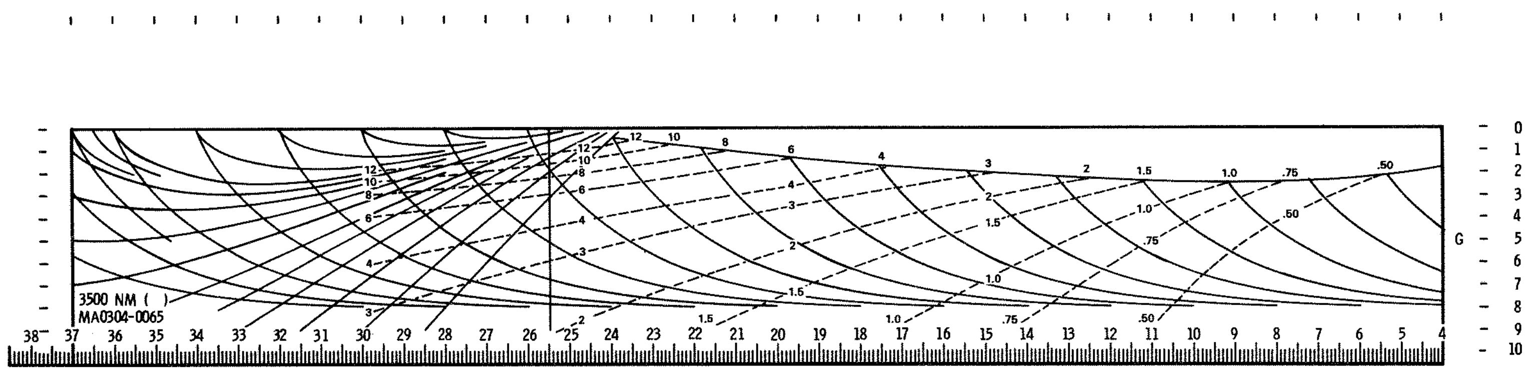

Figure 2.3-31. EMS Lunar 3500 NM Range Limit Pattern

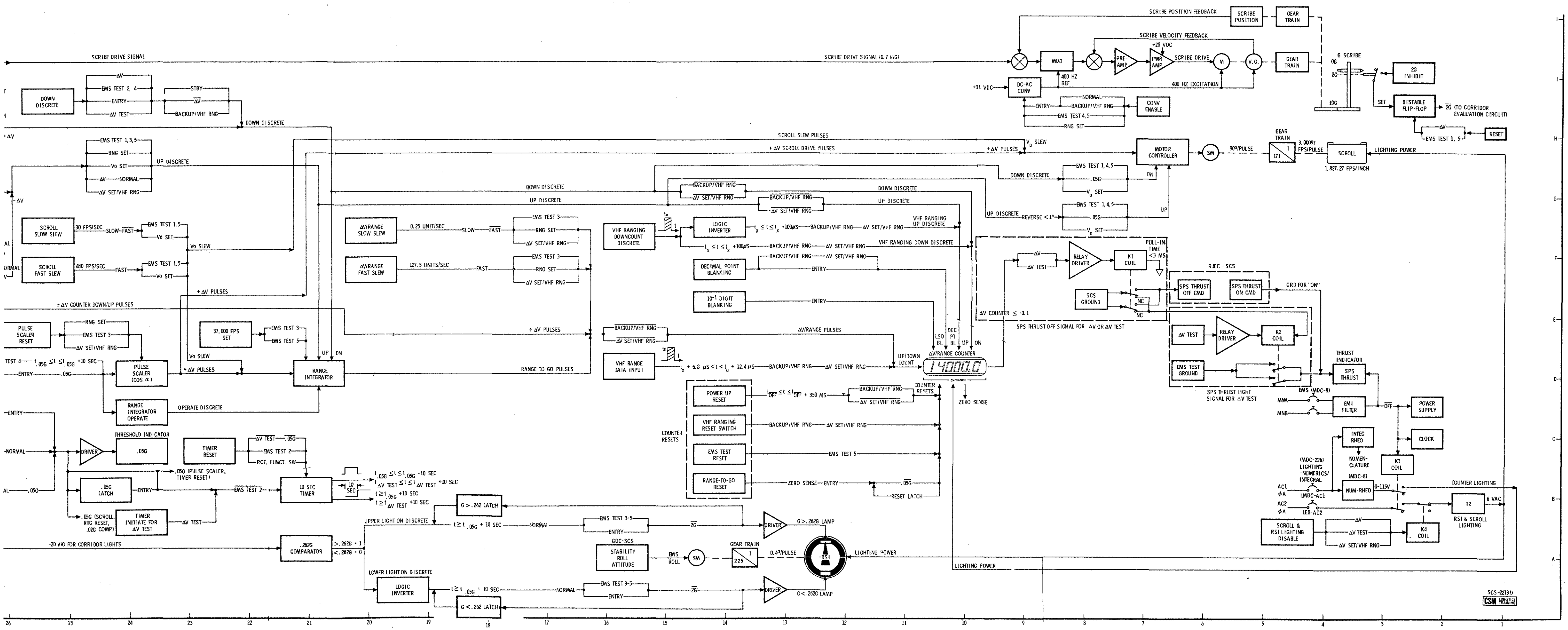

Figure 2.3-32. EMS Functional Block Diagram

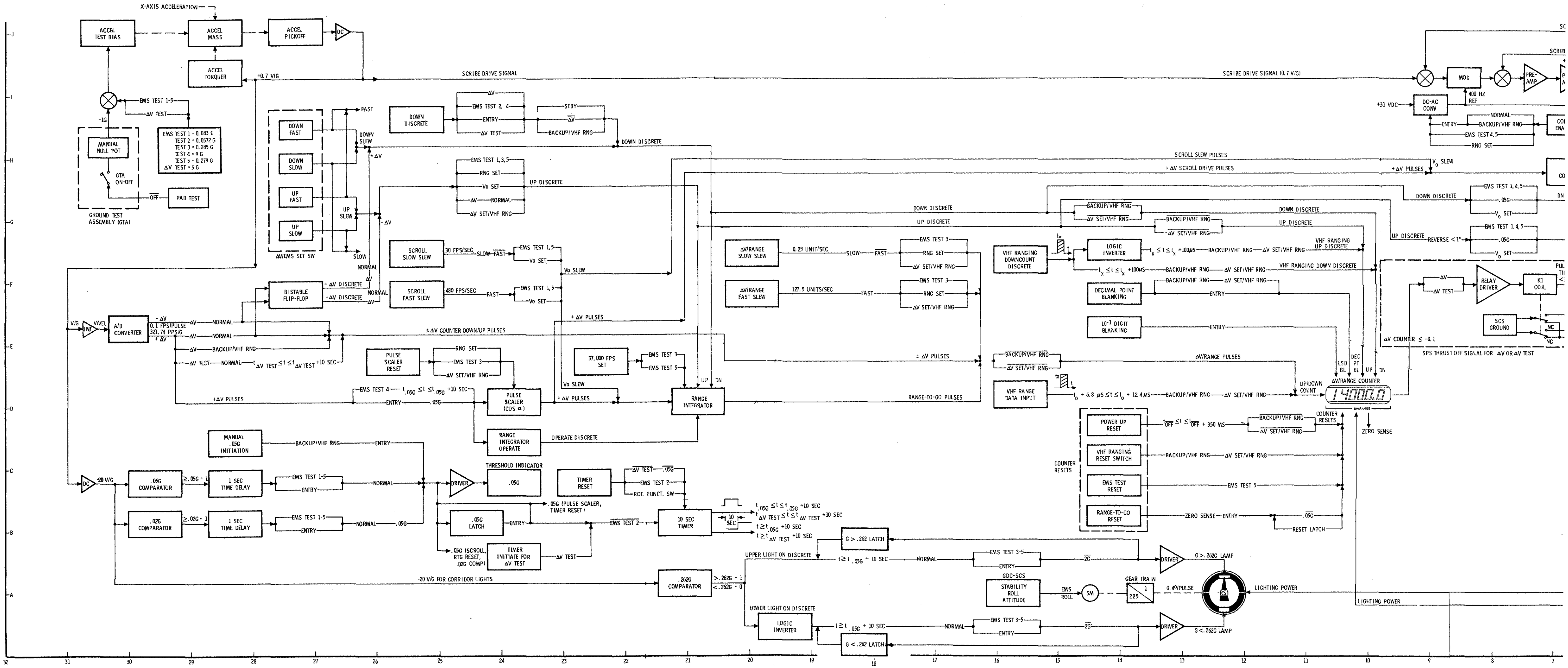

Figure 2.3

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flight monitor G axis during entry, and an output to the A/D converter which is used to drive the ΔV/RANGE display and the scroll. The difference in the low and high level G outputs is their scale factors.

2.3.7.5.2 Threshold and Corridor Verification Circuits

The threshold and corridor verification circuits use the accelerometer low level G output. The .05G comparator will trigger and illuminate the threshold light (.05 G) is a G level of 0.05G $\pm$ 0.005G is present for 1$\pm$0.5 seconds. If the G level drops to 0.02G $\mp$ 0.005G, the light will be extinguished. The corridor evaluation will occur 10.053$\pm$0.025 seconds after the .05 G threshold lamp is illuminated. The lift vector up light will illuminate if the G force is greater than 0.262$\pm$0.009G. The lift vector down light will be illuminated if the G force is less than approximately 0.262$\pm$0.009G. There will be only one corridor verification light turned ON for corridor evaluation. The corridor lights will be turned off when the flight monitor G axis drive passes the 2G level.

2.3.7.5.3 Scroll Assembly G Axis Drive Circuits

The scroll assembly G axis drive circuits receive the accelerometer high G level output signal and position the G axis scribe vertically. The stylus drive is a normal closed-loop servo circuit with velocity and position feedback. The loop is biased from zero by the magnitude of the accelerometer input.

2.3.7.5.4 Scroll Assembly Velocity Axis Drive Circuits

The scroll assembly velocity axis drive circuits use the accelerometer A/D converter output to drive the scroll from right to left. The A/D converter supplies one pulse for each 0.1 fps of velocity change. The motor control circuits and stepper motor cause the scroll to move from right to left with the existing inertial velocity shown under the index line. Before entry the scroll is initialized to the inertial velocity by setting the FUNCTION switch to the Vo SET position and using the ΔV/EMS SET switch to slew the scroll to the predicted inertial velocity value at 0.05G.

2.3.7.5.5 ΔV/RANGE Display Circuits

The ΔV/RANGE electronics directly controls the numeric display value except during VHF ranging operations. The display will be initialized by a combination of the FUNCTION switch and the ΔV/EMS SET switch except during VHF ranging operations. During ΔV operations, the accelerometer A/D converter output pulses are used to increment or decrement the display value. When the display decreases to a value of -0.1 fps, a signal is supplied to the SCS for an automatic SPS OFF command. For entry, the display will read range-to-go, being decremented by the range integrator. The output of the range integrator output will decrease as a function of the ΔV pulses to its input and initial velocity stored in it. The range integrator is decremented by the pulse input so that it contains the CM present inertial range-to-go if properly initialized. The pulse scaler sends pulses to the flight monitor velocity axis drive in order to drive the scroll from right to left after 0.05G is sensed. If the 0.05G function should fail, placing the MODE switch to the BACKUP/VHF RNG position will initiate the pulse scaler operation to decrement the range-to-go display and to drive the scroll from right to left as a function of G level.

2.3.7.5.6 Roll Stability Indicator Drive

The RSI drive function, controlled by the yaw axis of the GDC in the SCS, requires that the two ENTRY switches (.05 G and EMS ROLL) be up for its correct operation during entry. This function is described as a normal GDC function in paragraph 2.3.3.2.

2.3.7.5.7 Thrust-Off Function

The EMS provides an SPS thrust-off command via a logic signal to the RJEC when the ΔV/RANGE counter goes to -0.1 fps during a delta V. A relay energizes and provides a ground to the SCS during delta V testing as well as during a delta V.

2.3.8 SCS/EMS SPECIFICATIONS

The SCS and EMS pertinent specifications contained in this section were exerpted from the Honeywell SCS Technical Development Specifications (1001, 1401, 1002, 1402, 1003, 1004, 1404, 1005, 1006, 1007, 1008, 1009, 1010, 1011, 1012, 1412) and the North American Rockwell Space Division Entry Monitor System Procurement Specification, MC432-0129.

The SCS/EMS weight and power consumption data is shown in the following listing. The SCS and EMS device or component weight and power consumption values are given in addition to the SCS/EMS system values.

Following the weight and power data, are the performance specifications for the individual SCS and EMS components. Other specifications, not listed here, may be found in the above-mentioned specification documents.

2.3.8.1 SCS Device Specifications

2.3.8.1.1 Gyro Assembly Specifications

BMAG Spin Motor Parameters:

Synchronous speed	24,000 rpm
Starting power	5 watts
Running power	3 watts
Run-up time	25 sec (max)
Run-down time	45 sec (min)

BMAG Temperature Sensor Specifications:

Resistance	780±0.2Ω 170°±1°F
Current	10 ma
Sensitivity	1.5Ω/°F 170°F

Device or System	Weight (max) Including Cables and Connectors	Power Consumption (max) 28 VDC (watts) Steady State	28 VDC (watts) Transient	115 VAC (watts) Steady State	115 VAC (watts) Transient
Gyro assembly	22 lb 11 oz	60	40	34.6	86.1
Rotation control	9 lb 5 oz		Included in ECA allotment		
Translation control	6 lb 12 oz		Included in RJEC allotment		
Attitude set control panel	3 lb 6 oz	Not applicable		Lighting only = 1.75	
Flight director attitude indicator	9 lb 2 oz		Included in EDA allotment	Lighting only = 4.5	
Gimbal position/fuel pressure indicator	3 lb 1 oz		Included in EDA allotment	Lighting only = 0.75	
Reaction jet/engine control	20 lb 15 oz	2.1	1.0	4.0	1.0
Electronic control assembly	16 lb 12 oz	14.4	7.0	13.7	9.4
Electronic display assembly	24 lb 13 oz	50.2	10.0	34.4	20.2
Gyro display coupler	24 lb 15 oz	49.9	10.0	60.2	33.5
Thrust vector servo assembly	12 lb 8 oz	13.4	60.0 Above steady state	21.9	19.4 Above steady state
Stabilization control system	194.5 lb	275 SPS & RCS off	360 Plus 10 watts per solenoid dr	240 Quiescent	Lighting = 12.5
Entry monitor control assembly	18.5 lb	54.6 Max during entry		6.3 Incand 1.3 E.L.	
Entry monitor scroll assembly	4.5 lb				

BMAG Heater Power Specifications:

Voltage	28 vdc
Power	28 watts (max) (two heaters)

BMAG Mechanical Performance Specifications:

Angular momentum	1×10^5 gm-cm^2/sec
Time constant	400 microseconds (max)
Gimbal inertia	200 gm-cm^2
Damping constant	460,000 dyne-cm/rad/sec (OA)
Gimbal freedom	±4.4 degrees
Input angle freedom	15 degrees min, 25 degrees max

BMAG Input-Output Performance Specifications:

Input attitude angle	20±5 degrees (IA)
Input rate	50 deg/sec (max)
AC rate output	0.125 v/deg/sec ±1.75 percent (400 Hz)
AC rate output null	5 mv (max)
DC rate output	0.1 v/deg/sec ±0.3 percent
DC rate output null	0.05 mv (max)
AC attitude output	0.3 v/deg IA ±3.5 percent for 0 to 8 degrees IA ±5.5 percent for 8 to 15 degrees IA
AC attitude output null	15.0 mv (max)
g - insensitive drift	1.73 deg/hr
g - sensitive drift	4 deg/hr/g
g^2 - sensitive drift	0.42 deg/5 min period during entry
Loop gain	65 deg/sec per degree (min)

BMAG warmup time - 1 hour (55°F coldplate and 0°F ambient)

BMAG alignment - IA within 10 arc-minutes of mounting base surfaces

BMAG temperature outband indicator output (composite of three axes)

Switch output for any gyro temperature outside of 170°±2°F

BMAG spinmotor rotation detector telemetry (SMRD T/M):

SMRD T/M Outputs	Spinmotor Conditions
5.0 (+0.5, -1.5) vdc	All three gyro spinmotors operating at approximately half speed or greater (switching point)
0.0±0.5 vdc	Any one or more gyro spinmotors operating at a speed below the switching point

2.3.8.1.2 **Rotation Control Specifications**

Cable length - 180±2 inches

2.3.8.1.3 **Translation Control Specifications**

Cable length - 89±1 inches

2.3.8.1.4 Attitude Set Control Panel Specifications

Parallax Error:

Readability at a 22-inch viewing distance and at a viewing angle of 40 to 46 degrees from the normal to the panel in a vertical direction from above.

Counter indices co-planar with the counter graduations

Input Signals:

26 vac 800 Hz
10 vac 400 Hz

Accuracy Off Null:

ASCP output electrical equivalent angle is equal to the difference between the input angle and the command angle ±5 percent for difference angles up to ±15 degrees.

Thumbwheel Torques:

Force required to rotate the thumbwheel shall be 15 (+5, -10) ounces.

Maximum force to initiate thumbwheel rotations = 36 ounces.

2.3.8.1.5 FDAI Specifications

Ball radius - 2.25 inches nominal

Ball gear train ratio - 750 to 1

Ball accuracy

When a FDAI reads zero, the actual difference between the indicated and actual attitude is 0±1.0 degree (neglecting parallax and input signal errors).

Maximum ball slew speed - 50 degrees per second

Ball parallax error - 2 degrees (within certain viewing range)

Error needle accuracy - 0.85 percent of total range plus 2.0 percent of output indication.

Error needle parallax error - 5 percent of full scale (within viewing range).

Rate needle accuracy - 0.8 percent of total range plus 2.5 percent of output indication.

Rate needle parallax - 5 percent of full scale (within viewing range).

2.3.8.1.6 GP/FPI Specifications

GPI Trim Thumbwheel:

Scale factor accuracy - ±3 degrees (P, Y) = ±11.57±1.2 vdc

Torque - 10±5 ounces to rotate, stops resist 2 pounds of force

GPI Display:

Parallax error for GPI - less than 0.12 degree

Parallax error for FPI - less than 1.3 percent of full scale

2.3.8.1.7 RJEC Specifications

Duty cycle - less than 200 pulses over a 4-minute period

Step Response - on:

RJC drivers provide a ground (<+2.5 vdc) to the load within 0.20 milliseconds after CMC or SCS direct or automatic signal.

SPS drivers provide a ground (<+2.5 vdc) to the load within 10 milliseconds after CMC or SCS thrust ON signal.

Step Response - off:

RJC drivers go to dropout current (80 to 110 ma) within 7 to 9 ms maximum after removal of CMC or SCS input.

SPS drivers go to dropout current (100 ma) within 50 ms after removal of the CMC or SCS thrust ON.

Ignition Control Transfer:

SPS logic maintains ignition ON when transferring control from CMC to SCS with 50 ms or less (break-to-make) transfer time.

2.3.8.1.8 ECA Specifications

TVC Integrator Time Constant: 500 sec (min)

Switching Amplifier Response:

Turn-on time (max) - 16 ms Turn-off time (max) - 39 ms	Midcourse
Turn-on time (max) - 25 ms Turn-off time (max) - 29 ms	Entry

SCS

One-shot Pulse Width:

15 ms (nominal)
11 to 19 ms variable with main B bus voltage

2.3.8.1.9 EDA Specifications

No pertinent specifications.

2.3.8.1.10 GDC Specifications

Euler Angle Computing Equations:

$$\int \dot{\phi}\, dt = \int (p - \dot{\theta}\sin\psi)\, dt$$

$-100°/\text{sec} < \dot{\phi}, \dot{\theta}, \dot{\psi} < 100°/\text{sec}$

$$\int \dot{\psi}\, dt = \int (r\cos\phi + q\sin\phi)\, dt$$

$-60° < \psi < 60°$
p = body roll rate
q = body yaw rate

$$\int \dot{\theta}\, dt = \int \left(\frac{1}{\cos\psi} (q\cos\phi - r\sin\phi)\right) dt$$

r = body pitch rate
ϕ = roll Euler angle
ψ = yaw Euler angle
θ = pitch Euler angle

Entry Mode Computing Equation:

$$\phi_s = \int (p\cos\alpha - r\sin\alpha)\, dt$$

$\alpha = 21° \pm 0.5°$ (variable)
17° to 26°)
ϕ_s = roll stability attitude

Euler to Body Error Computing Equations:

$$\Delta\phi_b = (\Delta\phi_e + \Delta\theta_e \sin\psi_e)$$

$$\Delta\psi_b = (\Delta\psi_e \cos\phi_e - \Delta\theta_e \cos\psi_e \sin\phi_e)$$

$$\Delta\theta_b = (\Delta\psi_e \sin\phi_e + \Delta\theta_e \cos\psi_e \cos\phi_e)$$

$\Delta\phi_b$ = roll body error
$\Delta\psi_b$ = yaw body error
$\Delta\theta_b$ = pitch body error
$\Delta\phi_e$ = roll Euler error
$\Delta\psi_e$ = yaw Euler error
$\Delta\theta_e$ = pitch Euler error

$-60° \leq \phi \leq 60°$

Euler to Body Matrix Accuracy: ±2 percent (excluding null offsets)

FDAI Output Accuracy:

±0.33 percent ±7 feet of angle measured from the d-c input rates to the output signal (excluding null offset and readout errors)

EMS (RSI) Output Accuracy:

±0.33 percent measured from the d-c input rates to the output signal pulse rate (excluding null offset and readout errors)

Align Accuracy:

GDC mechanical alignment within 0.26 degree of the ASCP shaft positions (excluding ASCP errors)

2.3.8.2 Entry Monitor System

RSI Input Data:

Input scale factor - 0.4 deg/pulse

Pulse repetition rate - 150 pulses/sec (max)

Input stability roll rate - 60 deg/sec (max)

Input stability roll acceleration - 15 deg/sec^2

RSI accuracy - ±3 degrees (with respect to input signal)

Corridor Evaluation Lights:

	Upper Light	Lower Light
Time for light after .05G	10.053±0.025 sec	10.053±0.025 sec
Reference g level	0.262±0.009	0.262±0.009
G-level light trigger	>0.262±0.009	<0.262±0.009
G-level for light extinguish	>2.0±0.2	>2.0±0.2

SECTION 2

SUBSECTION 2.4

SERVICE PROPULSION SYSTEM (SPS)

SPS

2.4.1 FUNCTIONAL DESCRIPTION

The service propulsion subsystem provides the impulse for all X-axis velocity changes (ΔVs) throughout a mission and the SPS abort capability after the launch escape tower is jettisoned. The SPS consists of a helium pressurization system, a propellant feed system, and a rocket engine. The oxidizer is inhibited nitrogen tetroxide and the fuel is a blended hydrazine (approximately 50 percent unsymmetrical dimethyl hydrazine and 50 percent anhydrous hydrazine). The pressurizing gas is helium. The system incorporates displays and sensing devices to permit earth-based stations and the crew to monitor its operation. (See figure 2.4-1).

The helium pressure is directed to the helium pressurizing valves which isolate the helium during nonthrusting periods, or allow the helium to pressurize the fuel and oxidizer tanks during thrusting periods. The helium pressure is reduced at the pressure regulators to a desired working pressure. The regulated helium pressure is directed through check valves that permit helium flow in the downstream direction when the pressurizing valves are open, and prevent a reverse flow of propellant and/or vapor during nonthrusting periods. The heat exchangers transfer heat from the propellants to the helium gas to reduce any pressure excursions that may result from a temperature differential between the helium gas and propellants in the tanks. The relief valves maintain the structural integrity of the propellant tank systems if an excessive pressure rise occurs. The regulated helium pressure is directed from the heat exchanger through another set of check valves before entering the respective propellant tanks. These check valves provide an additional redundant check on reverse flow of propellant and/or vapor during nonthrusting periods.

The total propellant supply is contained within two similar tanks: an oxidizer sump tank and a fuel sump tank (figures 2.4-1 and 2.4-2). The regulated helium enters the fuel and oxidizer sump tanks, thus pressurizing the propellants in the sump tanks. The propellant in the sump tank is directed to the exit end into a propellant retention reservoir. An ullage maneuver is mandatory prior to any SPS thrusting period. The propellants exit from the respective sump tanks into a single line to the heat exchanger.

The propellant utilization gauging system is rendered inoperative because of the removal of the propellant utilization gauging control unit (PUGS) and probe simulator as the result of a weight reduction requirement. The propellant gauging probes, point sensors, propellant utilization valve, and associated controls and displays will remain installed. The associated controls and displays on MDC-3 will be inoperative. The SPS GAUGING switch on MDC-4 will be positioned to OFF. The SPS GAUGING circuit breakers AC1, AC2, MNA, and MNB on MDC-8 will be pulled OUT. The telemetry outputs are inoperative. The probes and point sensors will be utilized to service the propellant tanks to the desired load through the use of special ground support equipment.

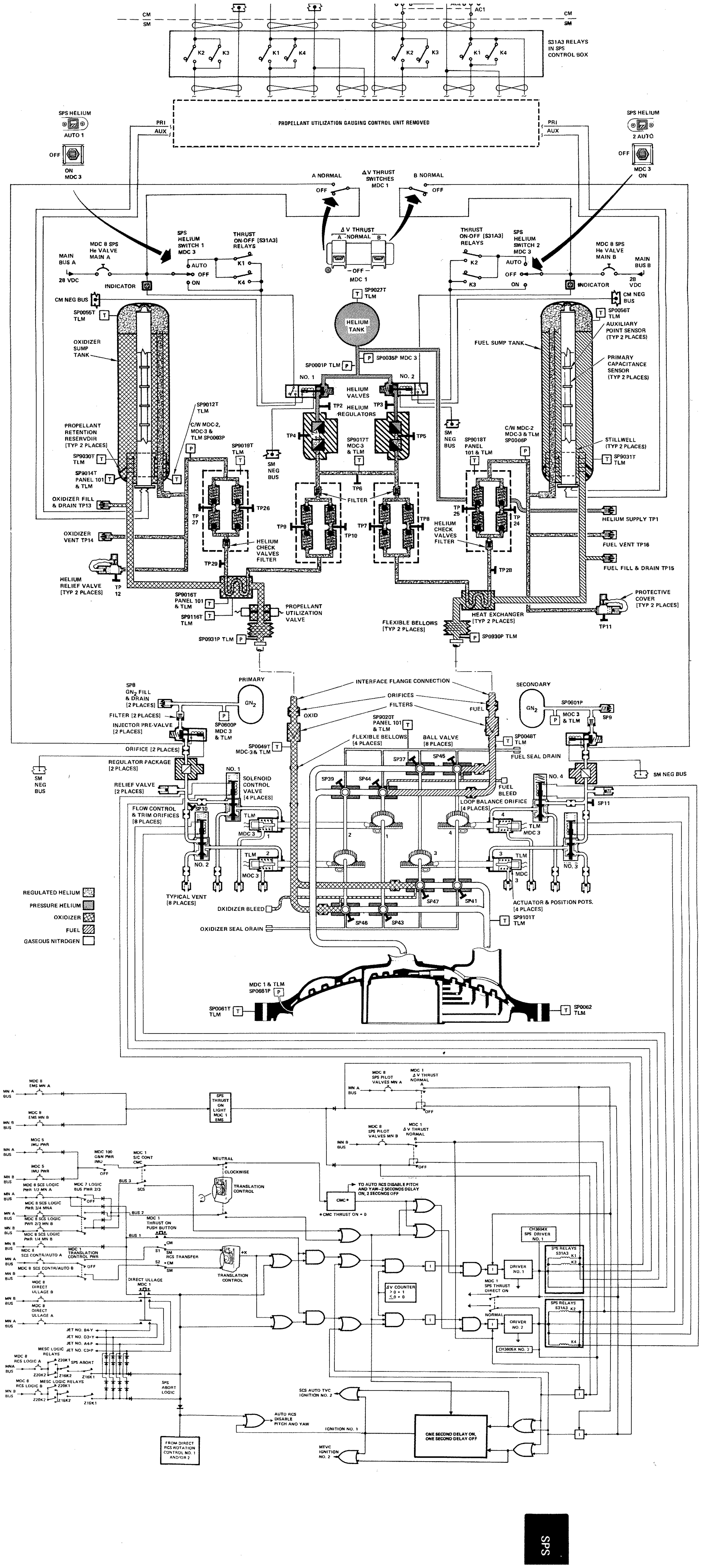
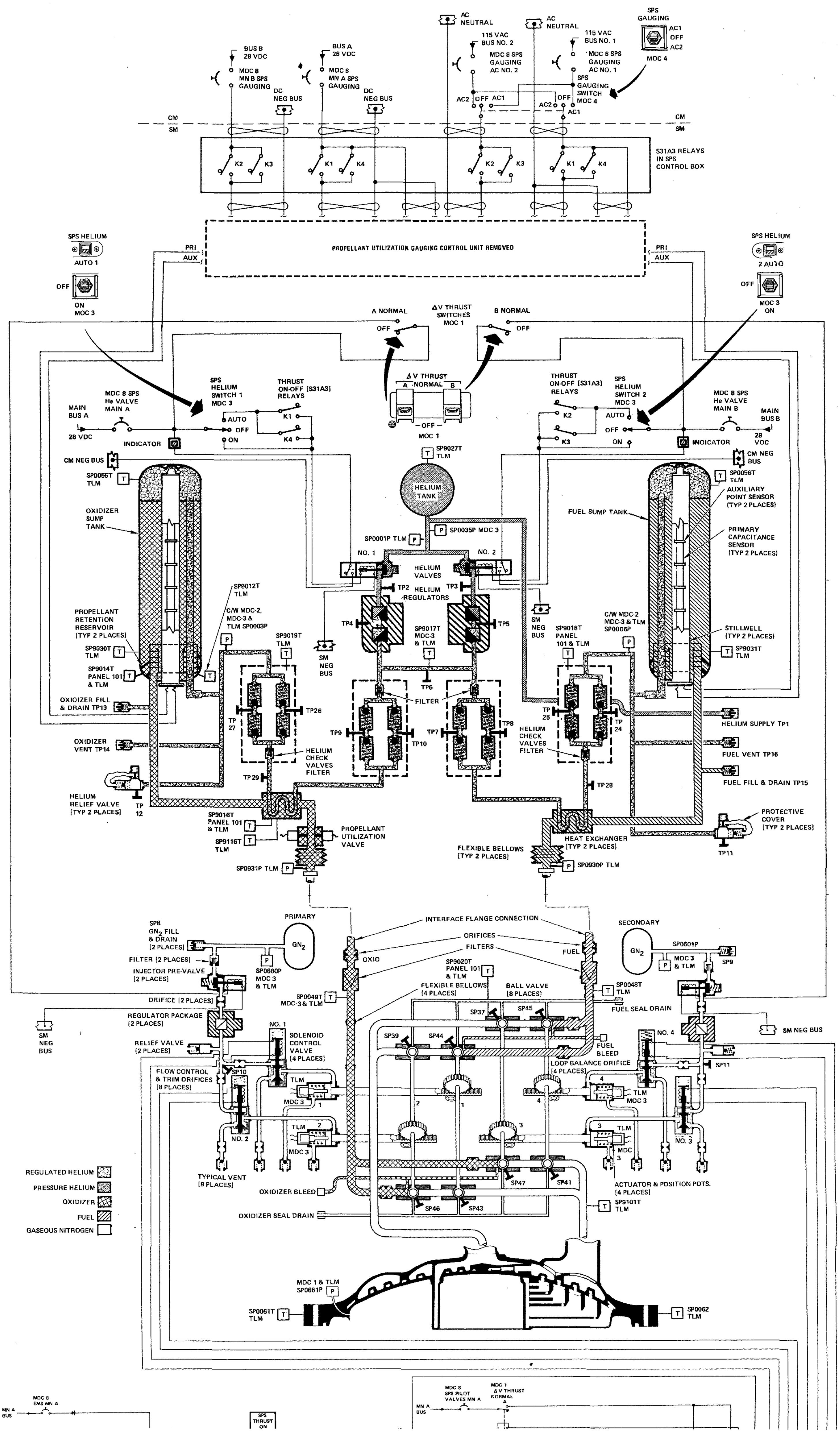


Figure 2.4-1. SPS Functional Flow

SERVICE PROPULSION SYSTEM

A-P-8003R
CSM

SPS



Mission ____ Basic Date 1

Figur

SKYL

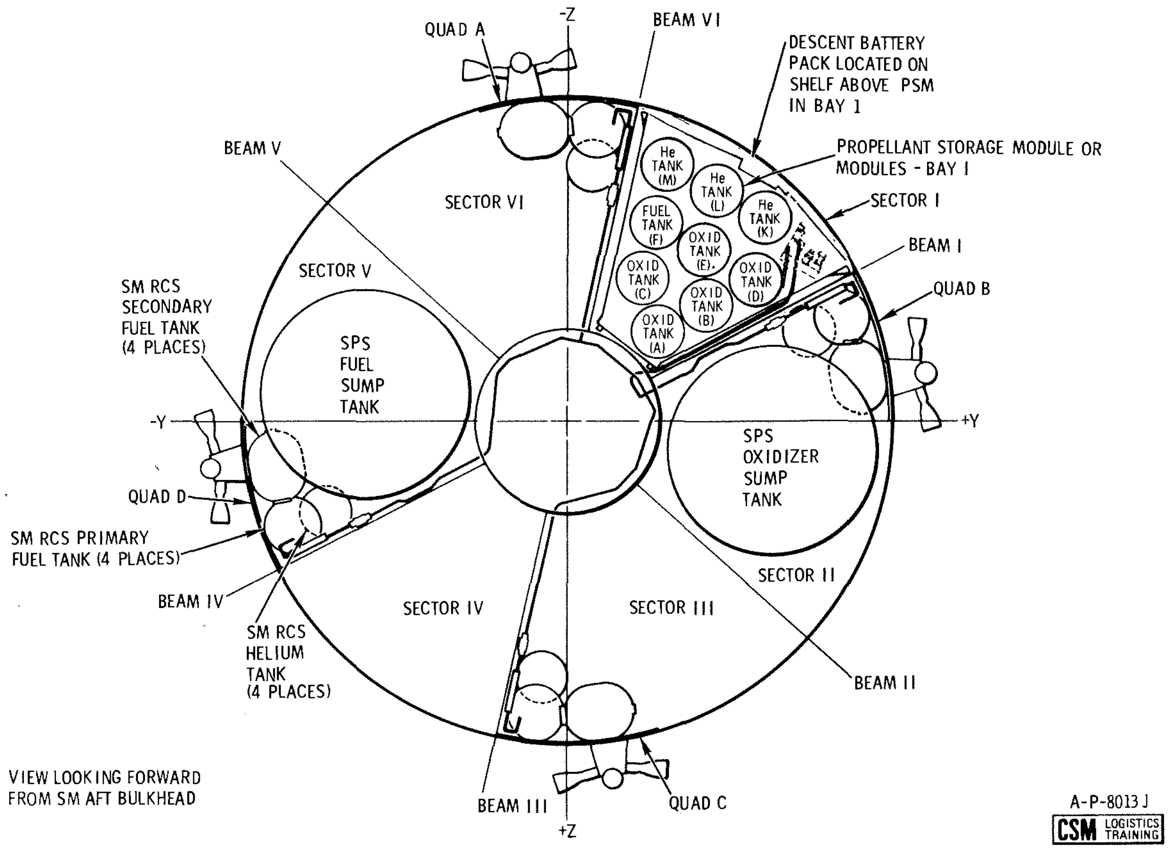


Figure 2.4-2. Service Module Sectors

The propellants flow from the propellant sump tank, through their respective plumbing, to the main propellant orifices and filters, to the bipropellant valve. The bipropellant valve assembly contains pneumatically controlled main propellant valves that distribute the propellants to the engine injector.

The thrust chamber consists of an engine injector, combustion chamber, and exhaust nozzle extension. The engine injector distributes the propellants through orifices in the injector face where the fuel and oxidizer impinge, atomize, and ignite. The combustion chamber is ablatively cooled. The exhaust nozzle extension is radiation-cooled.

The engine assembly is mounted to the structure of the SM. It is gimbaled to permit thrust vector alignment through the center of mass prior to thrust initiation and thrust vector control during a thrusting period.

The control of the subsystem is automatic with provisions for manual backup.

The various pressure and temperature monitoring points of the SPS are illustrated in figure 2.4-1. Each pressure and temperature monitoring point is identified by a measurement number. In addition, each identification indicates if it is transmitted to TLM, main display console, caution/warning, and/or panel 101. Figure 2.4-3 illustrates the measurements that are transmitted to MDC-2, MDC-3, and panel 101.

2.4.2 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION

2.4.2.1 Pressurization Subsystem

The pressurization subsystem consists of one helium tank, two helium pressurizing valves, two dual pressure regulator assemblies, four dual check valve assemblies, two pressure relief valves, and two heat exchangers. The critical components are redundant to increase reliability.

2.4.2.1.1 Helium Tank

The one helium supply spherical pressure vessel is located in the center section of the SM.

2.4.2.1.2 Helium Pressurizing Valves

The helium valves are continuous-duty solenoid-operated. The valves are energized open and spring-loaded closed. The SPS He VLV switches on panel 3 permit automatic or manual control of the valves. With the switches in the AUTO position, the valves are automatically controlled by a thrust ON-OFF signal. The valves are controlled manually by placing the switches to the ON (valve open) and OFF (valve closed) positions.

Each valve contains a position switch which controls a position (talkback) indicator above each switch. When the valves are closed, the position switch is open and the indicator is barber pole (diagonal lines), the indication during non-SPS thrusting periods. When the valves are open, the position switch is closed and the indicator is powered to gray (same color as the panel) indicating the valve is open, the indication during SPS thrusting periods.

2.4.2.1.3 Pressure Regulator Assemblies

Pressure regulation is accomplished by a pressure-regulating assembly downstream of each helium pressurizing valve. Each assembly contains a primary and secondary regulator in series, and a pressure surge damper and filter installed on the inlet to each regulating unit.

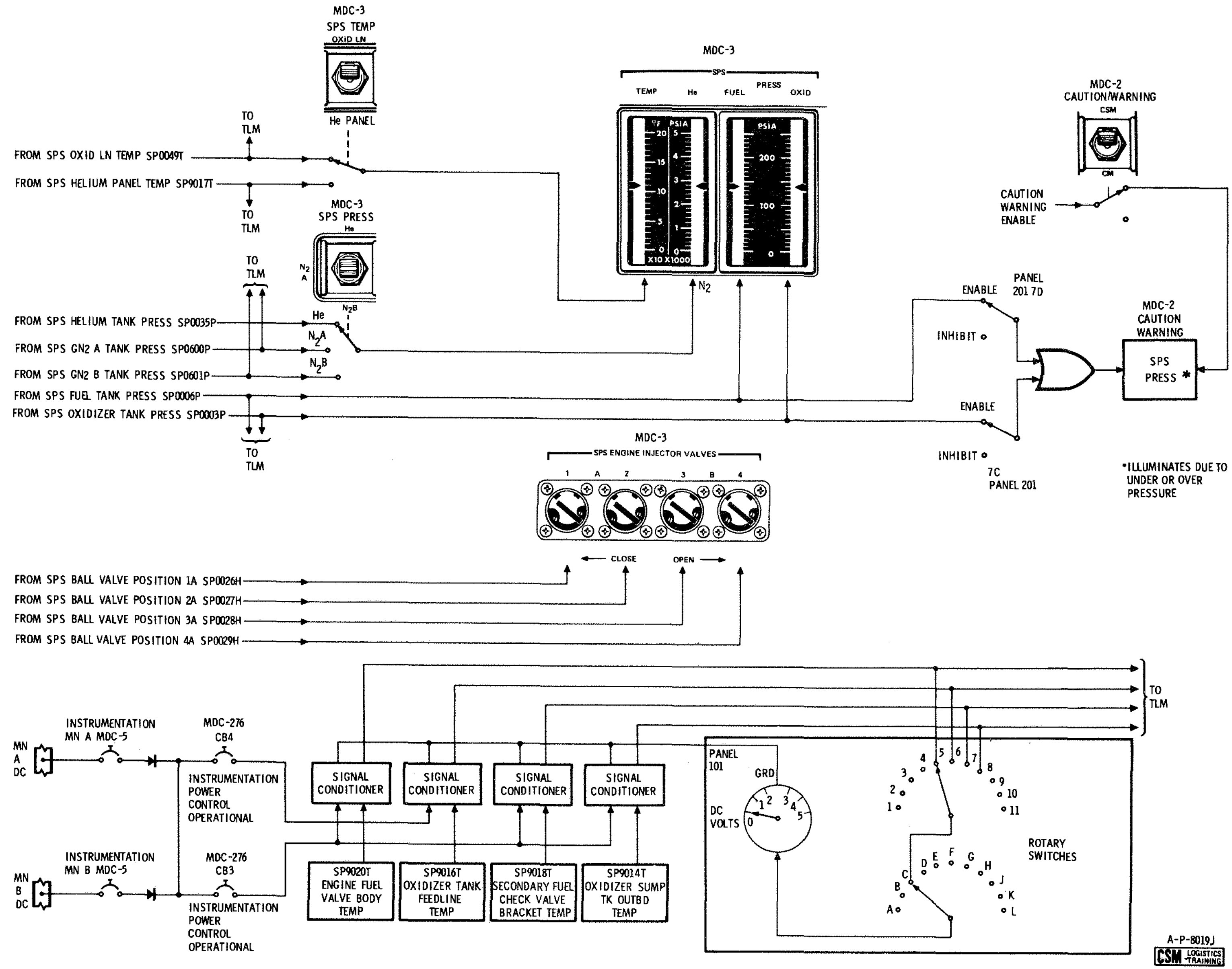


Figure 2.4-3. SPS Monitoring MDC-2, MDC-3, Panel 101

The primary regulator is normally the controlling regulator. The secondary regulator is normally open during a dynamic flow condition. The secondary regulator will not become the controlling regulator until the primary regulator allows a higher pressure than normal, thus, allowing the secondary regulator to function. All regulator pressures are in reference to a bellows assembly that is vented to ambient.

Only one of the parallel regulator assemblies regulates helium pressure under dynamic conditions. The downstream pressure causes one regulator assembly to lock up (close), normally. When the regulated pressure decreases below the lockup pressure of the nonoperating assembly, that assembly becomes operational.

2.4.2.1.4 Check Valve Assemblies

Each assembly contains four independent check valves connected in a series-parallel configuration for added redundancy. The check valves provide a positive checking action against a reverse flow of propellant liquid and/or vapor, and permit helium pressure to be directed to the propellant tanks. Filters are incorporated in the inlet to each check valve assembly and each test port.

2.4.2.1.5 Helium Pressure Relief Valves

The pressure relief valves consist of a relief valve, a burst diaphragm, and a filter.

In the event excessive helium and/or propellant vapor ruptures the burst diaphragm, the relief valve opens and vents the applicable system. The relief valve will close and reseal after the excessive pressure has returned to the operating level. The burst diaphragm provides a more positive seal of helium than a relief valve. The filter prevents any fragments from the (nonfragmentation-type) diaphragm from entering onto the relief valve seat.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage from the diaphragm. The bleed device is normally open and will close when the pressure increases to a predetermined pressure.

A protective cover is installed over the relief valve vent port and bleed valve cavity port to prevent moisture accumulation and foreign matter entrance. The covers are left in place at lift-off.

2.4.2.1.6 Heat Exchangers

Each unit is a line-mounted, counterflow heat exchanger consisting of the helium pressurization line coiled helically within an enlarged section of the propellant supply line. The helium gas, flowing through the coiled line, approaches the temperature of the propellant prior to entry into the respective sump tanks, thus reducing pressure excursions to a minimum.

2.4.2.2 Propellant Subsystem

This subsystem consists of one fuel sump tank, one oxidizer sump tank, and propellant feed lines.

2.4.2.2.1 Propellant Tanks

The propellant supply is contained in two hemispherical-domed cylindrical tanks within the service module (figures 2.4-1 and 2.4-2). The sump tanks are pressurized by the helium supply. A standpipe in the sump tanks allows the helium gas to pressurize the sump tanks. The propellants in the sump tanks are directed into retention reservoirs, to the outlet, and to the engine.

The umbrella retention reservoir, can, and screens are installed in the exit end of the sump tank. The reservoir retains a quantity of propellants at the exit end of the sump tanks and the engine plumbing during 0-g condition. An ullage maneuver (forward acceleration + X) is performed by the service module reaction control system prior to an SPS engine thrusting period to ensure that gas is not retained aft of the screens.

2.4.2.2.2 Tank Propellant Feed Lines

The propellant feed lines have flexible bellows assemblies installed to permit alignment of the tank feed plumbing to the engine interface plumbing.

2.4.2.3 Bipropellant Valve Assembly

The bipropellant valve assembly consists of two gaseous nitrogen (GN_2) pressure vessels, two injector prevalves, two GN_2 regulators, two GN_2 relief valves, four solenoid control valves, four actuators, and eight bipropellant ball valves.

2.4.2.3.1 Gaseous Nitrogen (GN_2) Pressure Vessels

Two GN_2 tanks are mounted on the bipropellant valve assembly to supply pressure to the injector prevalves. One GN_2 tank is in the primary pneumatic control system A and the remaining GN_2 tank is in the secondary pneumatic control system B.

2.4.2.3.2 Injector Prevalves

The injector prevalves are two-position solenoid-operated valves, one for each pneumatic control system, and are identified as A and B. The valve is energized open and spring-loaded closed. The injector prevalves are controlled by the ΔV THRUST NORMAL switches on panel 1. When switch A is placed to NORMAL, injector prevalve A is energized open. If switch B is placed to NORMAL, injector prevalve B is energized open. The injector prevalves, when energized open, allow GN_2 supply tank pressure to be directed through an orifice, into a regulator, relief valve, and to a pair of solenoid control valves. The solenoid control valves are controlled by the SPS thrust ON-OFF commands. The OFF position of the ΔV THRUST switches de-energizes the injector prevalves and springloads closed.

The ΔV THRUST NORMAL switch A receives power from SPS HE VALVE A circuit breaker on panel 8 for control of the injector prevalve A. The ΔV THRUST NORMAL switch B receives power from SPS HE VALVE B circuit breaker on panel 8 for control of the injector prevalve B (figure 2.4-1).

The ΔV THRUST NORMAL switches, A and/or B, also provide enabling power for the thrust ON-OFF logic circuitry.

2.4.2.3.3 GN_2 Filters

A filter is installed between each GN_2 pressure vessel and injector prevalve. A filter is also installed on each GN_2 regulator outlet test port.

2.4.2.3.4 GN_2 Pressure Regulators

A single-stage regulator is installed in each pneumatic control system between the injector prevalves and the solenoid control valves. The regulator reduces the supply GN_2 pressure to a desired working pressure.

2.4.2.3.5 GN_2 Relief Valves

A pressure relief valve is installed in each pneumatic control system downstream of the GN_2 pressure regulators. This limits the pressure applied to the solenoid control valves in the event a GN_2 pressure regulator malfunctioned open.

2.4.2.3.6 GN_2 Orifices

The orifice between the injector prevalve and regulator is installed to restrict the flow of GN_2. This allows the relief valve to relieve the pressure overboard in the event the regulator malfunctions open, thus preventing damage to the solenoid control valves and/or actuators.

2.4.2.3.7 GN_2 Solenoid Control Valves

Four solenoid-operated three-way two-position control valves are utilized for actuator control. Two solenoid control valves are located downstream of the GN_2 regulators in each pneumatic control system. The solenoid control valves in the primary system are identified as 1 and 2 and the two in the secondary system are identified as 3 and 4. The solenoid control valves in the primary system control actuator and ball valves 1 and 2. The two solenoid control valves in the secondary system control actuator and ball valves 3 and 4. The SPS thrust ON-OFF command controls the energizing or de-energizing of the solenoid control valves. Solenoid control valves 1 and 2 are energized by the SPS thrust ON-OFF command if ΔV THRUST NORMAL switch A is placed to A. Solenoid control valves 3 and 4 are energized by the SPS thrust ON-OFF command if ΔV THRUST NORMAL switch B is placed to B.

2.4.2.3.8 GN_2 Ball Valve Actuators

Four piston-type, pneumatically operated actuators are utilized to control the eight propellant ball valves. Each actuator piston is mechanically connected to a pair of propellant ball valves, one fuel and one oxidizer. When the solenoid control valves are energized, pneumatic pressure is applied to the opening side of the actuators. The spring pressure on the closing side is overcome and the actuator piston moves. Utilizing a rack and pinion gear, linear motion of the actuator connecting arm is converted into rotary motion, which opens the propellant ball valves. When the engine firing signal is removed from the solenoid control valves, the solenoid control valves de-energize, removing the pneumatic pressure source from the opening side of the actuators. The actuator closing side spring pressure now forces the actuator piston to move in the opposite direction, causing the propellant ball valves to close. The piston movement forces the remaining GN_2, on the opening side of the actuator, back through the solenoid control valves where it is vented overboard.

Each actuator incorporates a pair of linear position transducers. One supplies ball valve position information to the SPS ENGINE INJECTOR VALVES indicators on panel 3. The output of the second transducer supplies ball valve position information to telemetry.

2.4.2.3.9 Bipropellant Ball Valves

The eight propellant ball valves are used to distribute fuel and oxidizer to the engine injector assembly. Four linked pairs are arranged in a series, parallel configuration. Each pair consists of one fuel and one oxidizer ball valve, controlled by a single actuator. The parallel redundancy ensures engine ignition; the series redundancy ensures thrust termination. When GN_2 pressure is applied to the actuators, each propellant ball valve is rotated, aligning the ball to a position that allows propellant to flow to the engine injector assembly. The mechanical arrangement is such that the oxidizer ball valves maintain an 8-degree lead over the fuel ball valves upon opening, which results in smoother engine starting transients.

2.4.2.3.10 Bipropellant Valve Assembly Check Valves

Check valves are installed in the vent port outlet of each of the four solenoid control valves, spring pressure vent port of the four actuators, the ambient vent port of the two GN_2 pressure regulator assemblies and the vent port of the GN_2 relief valves. Thus, the seals of the components are protected from a hard vacuum in space.

2.4.2.3.11 Engine Propellant Lines

Integral propellant lines are utilized on the engine to route each propellant from the interface points, in the gimbal plane area, to the bipropellant valve assembly. The plumbing consists of flexible bellows that permit propellant line flexibility for engine gimbaling, orifices for adjustment of oxidizer/fuel ratio, and screens to prevent particle contaminants from entering the engine.

2.4.2.4 Engine Injector

The injector is bolted to the ablative thrust chamber attach pad. Propellant distribution through the injector is accomplished through concentric annuli machined orifices in the face of the injector assembly and covered by concentric closeout rings. Propellant distribution to the annuli is accomplished through alternate radial manifolds welded to the backside of the injector body. The injector is baffled to provide combustion stability. The fuel and oxidizer orifices impinge, atomize, and ignite because of hypergolic reaction.

2.4.2.5 Ablative Combustion Chamber

The ablative combustion chamber material extends from the injector attach pad to the nozzle extension attach pad. The ablative material consists of a liner, a layer of insulation, and integral metal attach flanges for mounting the injector.

2.4.2.6 Nozzle Extension

The bell-contoured nozzle extension is bolted to the ablative thrust chamber exit area. The nozzle extension is radiant-cooled and contains an external stiffener to provide additional strength.

2.4.2.7 SPS Electrical Heaters

The electrical heaters that are installed on the SPS are shown in figures 2.4-4, 2.4-5, 2.4-6 and 2.4-6A. Each heater contains redundant elements.

The electrical heaters are placed into operation by the SPS HTRS switch on panel 5. Positioning the SPS HTRS switch to PRIM, supplies 28 vdc from MNA to the primary thermal switches, sensors, thus the primary heaters as illustrated in figure 2.4-6. The mercury thermal control sensors associated with each thermal switch are set to open and close the heater circuit at a predetermined temperature range. The SEC position of the SPS HTRS switch supplies 28 vdc from MNB to the secondary thermal switches, sensors, thus the secondary heater circuits. The secondary thermal control sensors are set at a slightly higher predetermined temperature range than the primaries. The secondary mercury thermal control sensors will open and close the heater circuits of the secondary circuits. The OFF position of the SPS HTRS switch removes all power from the heater circuits.

Two thermoswitches are installed on the oxidizer sump tank door. One thermoswitch is installed in the primary oxidizer tank heater circuit and one thermoswitch is installed in the secondary oxidizer tank heater circuit. The thermoswitches are installed to protect the oxidizer sump tank door in the event the thermal control switches and/or sensors of the primary or secondary heater circuit fail "on". The thermoswitches utilized are the same as those used in the SM RCS engine package heater circuits.

The temperature measurements of the SPS that may be monitored by the crew are shown in figure 2.4-6.

2.4.2.8 Thrust Mount Assemblies

The thrust mount assembly consists of a gimbal ring, engine-to-vehicle mounting pads, and gimbal ring-to-combustion chamber assembly support struts. The thrust structure is capable of providing ±10 degrees inclination about the Z-axis and ±6 degrees about the Y-axis.

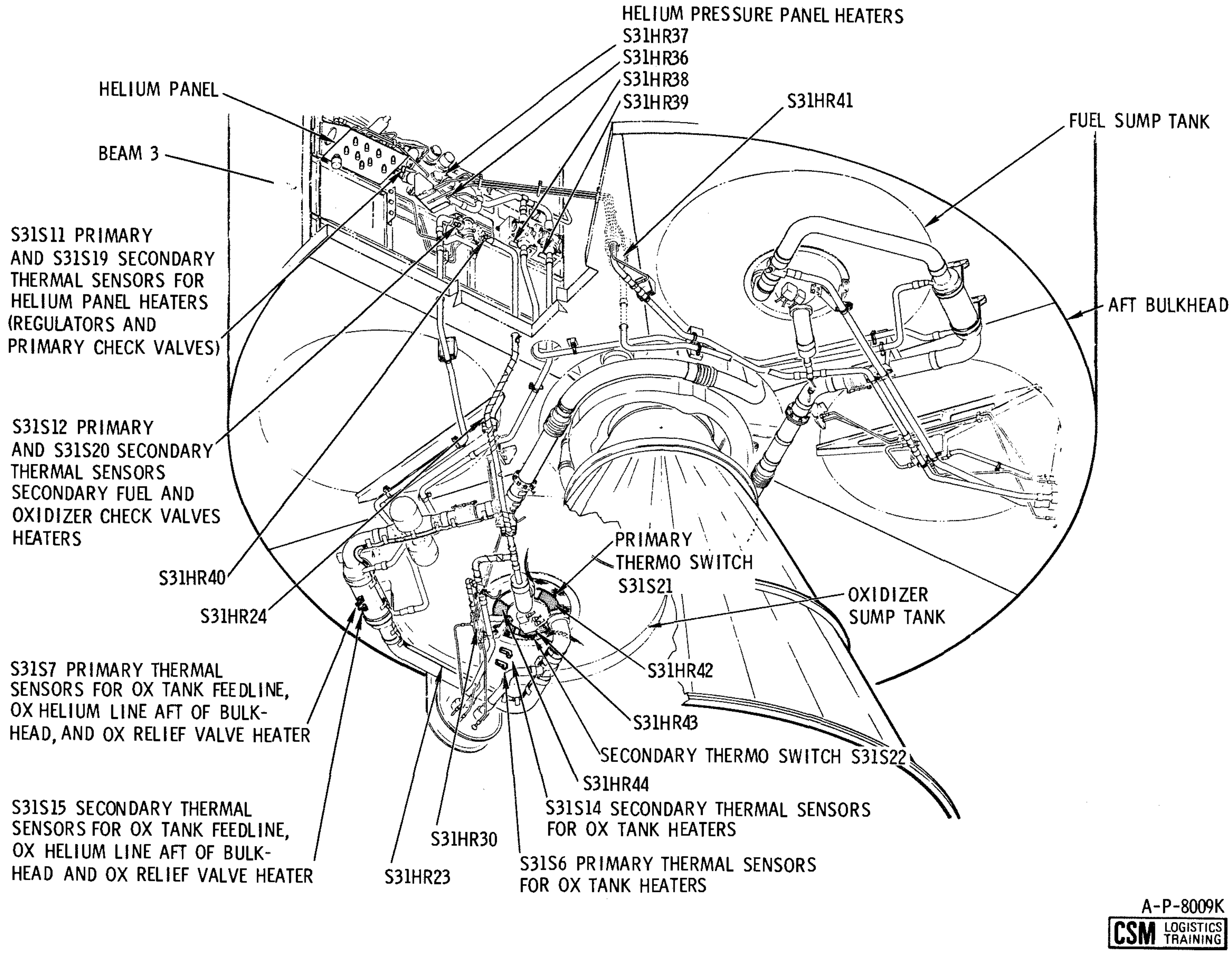


Figure 2.4-4. SPS Heater Installation, Tank Feed Lines

SERVICE PROPULSION SYSTEM

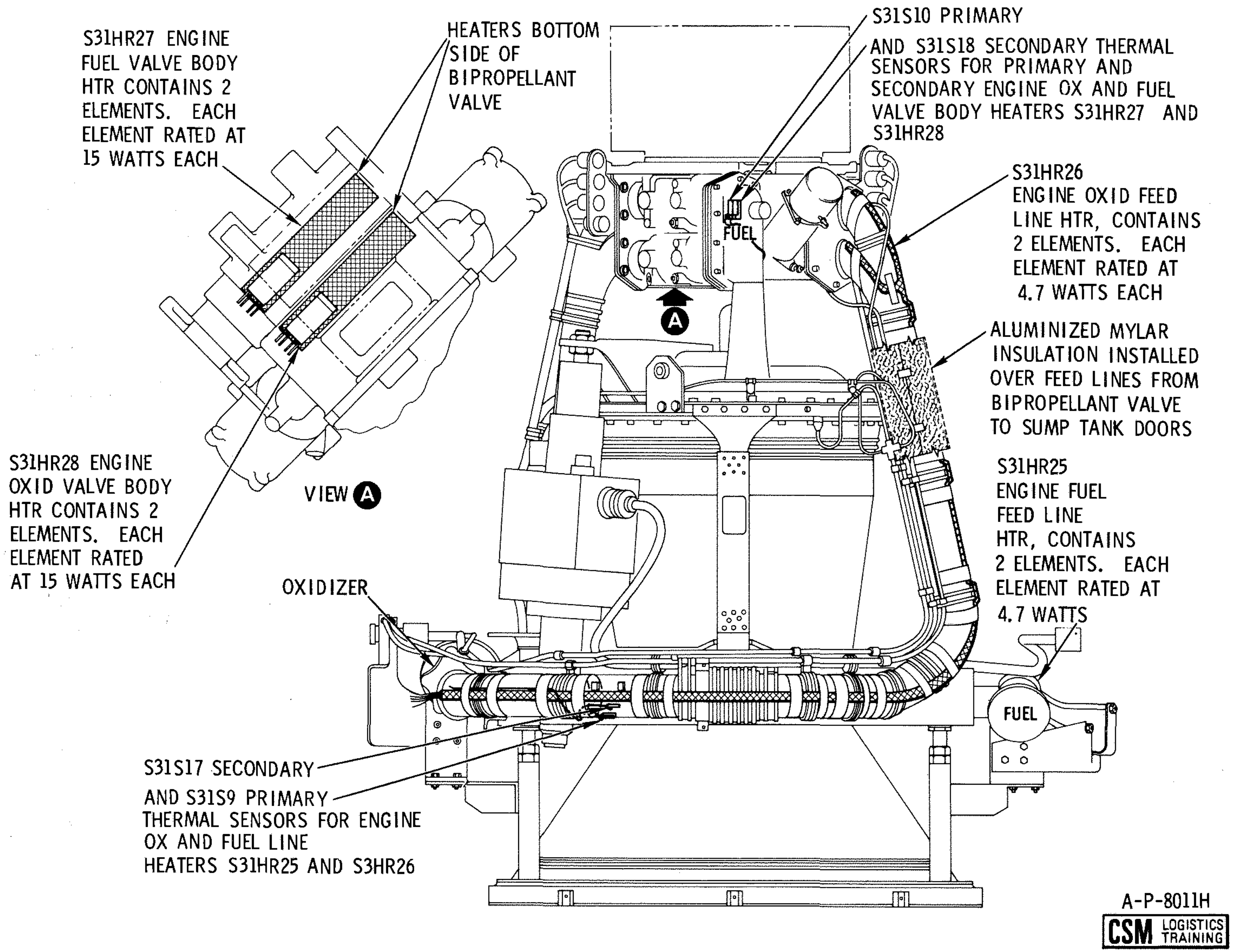


Figure 2.4-5. SPS Heater Installation, Engine Feed Lines

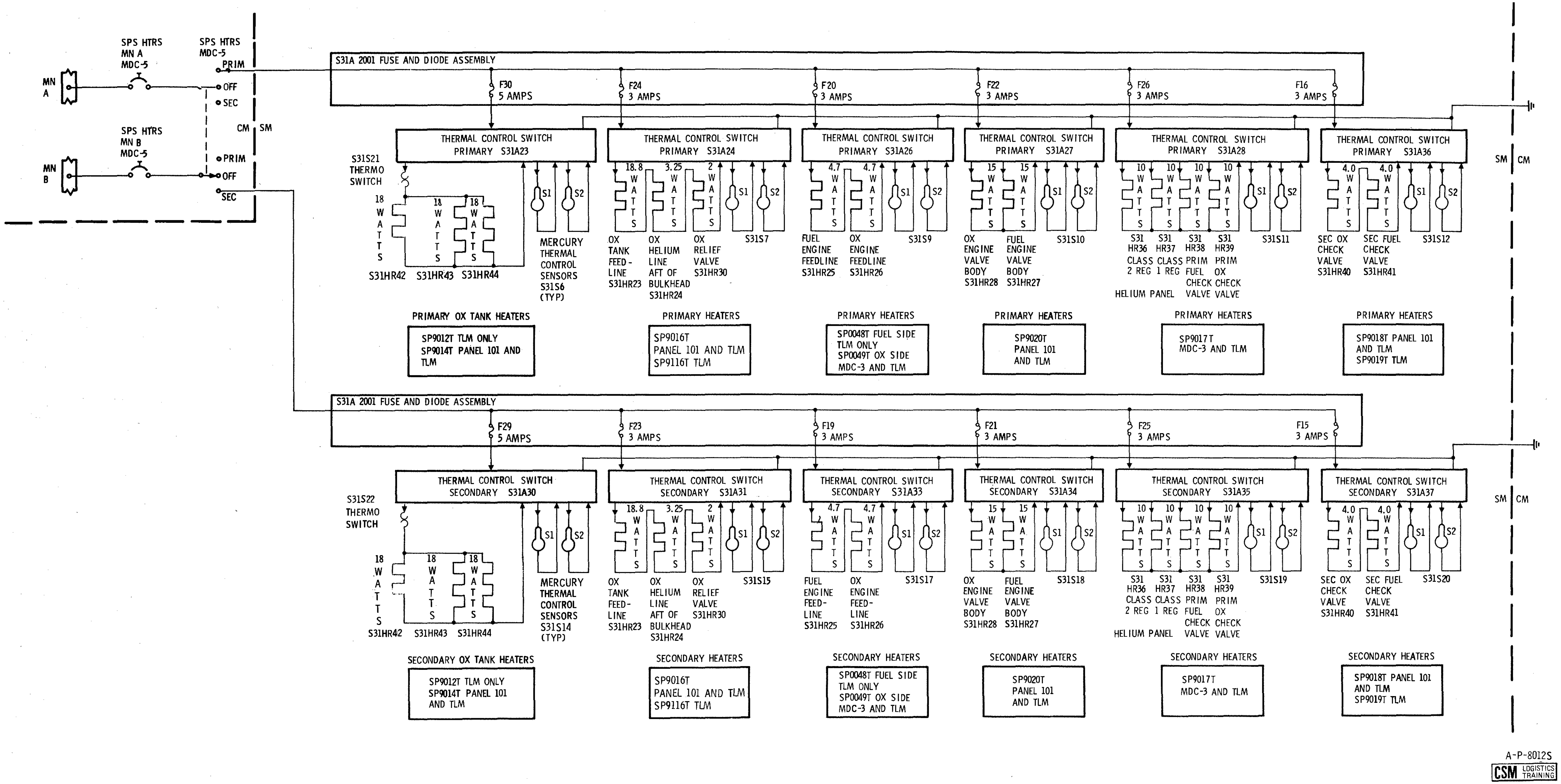
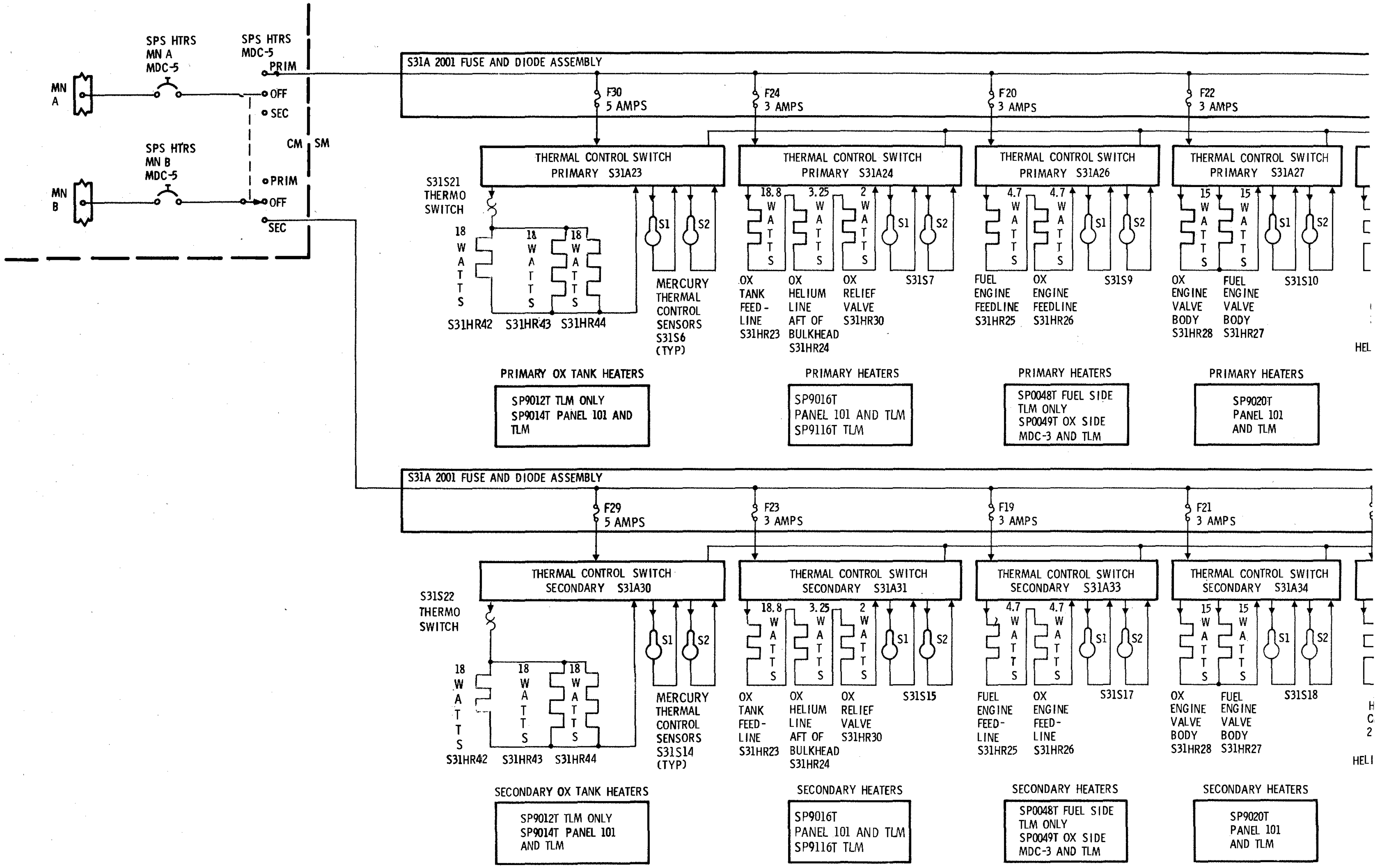


Figure 2.4-6. SPS Heaters, Electrical

SPS


SPS HTRS
MN A
MDC-5
SPS HTRS
MDC-5
PRIM
OFF
SEC
MN A
SPS HTRS
MN B
MDC-5
CM
SM
PRIM
OFF
SEC
MN B
S31A 2001 FUSE AND DIODE ASSEMBLY
F30
5 AMPS
F24
3 AMPS
F20
3 AMPS
F22
3 AMPS
THERMAL CONTROL SWITCH
PRIMARY S31A23
THERMAL CONTROL SWITCH
PRIMARY S31A24
THERMAL CONTROL SWITCH
PRIMARY S31A26
THERMAL CONTROL SWITCH
PRIMARY S31A27
S31S21
THERMO
SWITCH
18 WATTS
18 WATTS
18 WATTS
S31HR42 S31HR43 S31HR44
MERCURY
THERMAL
CONTROL
SENSORS
S31S6
(TYP)
18.8 WATTS
3.25 WATTS
2 WATTS
S1
S2
OX TANK FEED-LINE S31HR23
OX HELIUM LINE AFT OF BULKHEAD S31HR24
OX RELIEF VALVE S31HR30
S31S7
4.7 WATTS
4.7 WATTS
FUEL ENGINE FEEDLINE S31HR25
OX ENGINE FEEDLINE S31HR26
S31S9
15 WATTS
15 WATTS
OX ENGINE VALVE BODY S31HR28
FUEL ENGINE VALVE BODY S31HR27
S31S10
HEL
PRIMARY OX TANK HEATERS
SP9012T TLM ONLY
SP9014T PANEL 101 AND TLM
PRIMARY HEATERS
SP9016T
PANEL 101 AND TLM
SP9116T TLM
PRIMARY HEATERS
SP0048T FUEL SIDE
TLM ONLY
SP0049T OX SIDE
MDC-3 AND TLM
PRIMARY HEATERS
SP9020T
PANEL 101
AND TLM
S31A 2001 FUSE AND DIODE ASSEMBLY
F29
5 AMPS
F23
3 AMPS
F19
3 AMPS
F21
3 AMPS
THERMAL CONTROL SWITCH
SECONDARY S31A30
THERMAL CONTROL SWITCH
SECONDARY S31A31
THERMAL CONTROL SWITCH
SECONDARY S31A33
THERMAL CONTROL SWITCH
SECONDARY S31A34
S31S22
THERMO
SWITCH
18 WATTS
18 WATTS
18 WATTS
S31HR42 S31HR43 S31HR44
MERCURY
THERMAL
CONTROL
SENSORS
S31S14
(TYP)
18.8 WATTS
3.25 WATTS
2 WATTS
OX TANK FEED-LINE S31HR23
OX HELIUM LINE AFT OF BULKHEAD S31HR24
OX RELIEF VALVE S31HR30
S31S15
4.7 WATTS
4.7 WATTS
FUEL ENGINE FEED-LINE S31HR25
OX ENGINE FEED-LINE S31HR26
S31S17
15 WATTS
15 WATTS
OX ENGINE VALVE BODY S31HR28
FUEL ENGINE VALVE BODY S31HR27
S31S18
HELI
SECONDARY OX TANK HEATERS
SP9012T TLM ONLY
SP9014T PANEL 101
AND TLM
SECONDARY HEATERS
SP9016T
PANEL 101 AND TLM
SP9116T TLM
SECONDARY HEATERS
SP0048T FUEL SIDE
TLM ONLY
SP0049T OX SIDE
MDC-3 AND TLM
SECONDARY HEATERS
SP9020T
PANEL 101
AND TLM

Figure

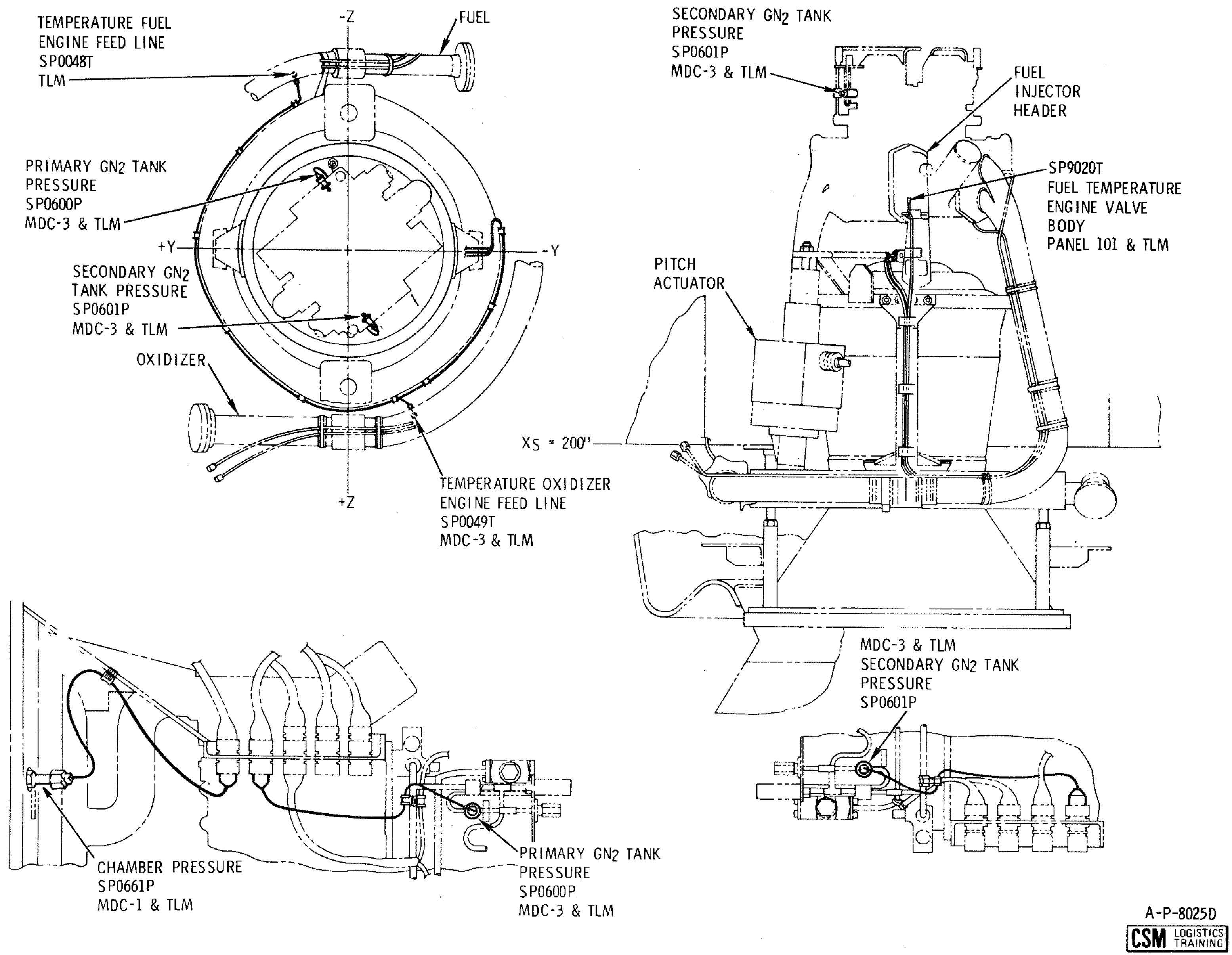


Figure 2.4-6A. SPS Engine Instrumentation

2.4.2.8.1 Gimbal Actuator

Thrust vector control of the service propulsion engine is achieved by dual, servo, electromechanical actuators. The gimbal actuators are capable of providing control around the Z-Z axis (yaw) of ±4.5 (+0.5, -0.0) degrees in either direction from a +1-degree null offset during SPS thrusting periods (0-degree null offset during non-SPS thrusting periods), and around the Y-Y axis (pitch) of ±4.5 (+0.5, -0.0) degrees in either direction from a +2-degree null offset during SPS thrusting periods (+1.5-degree null offset during non-SPS thrusting periods).

The reason for the +1-degree null offset to the +Y axis and +2-degree offset to the +Z axis during SPS thrusting periods, is the offset center of mass. The reason for the change in the null offset positions from an SPS nonthrusting period to an SPS thrusting period is due to the structural and engine deflections that occur when thrust-on is provided to the SPS engine.

Each actuator assembly (figure 2.4-7) consists of four electromagnetic particle clutches, two d-c motors, a bull gear, jack-screw and ram, ball nut, two linear-position transducers, and two velocity generators. The actuator assembly is a sealed unit and encloses those portions protruding from the main housing.

One motor and a pair of clutches (extend and retract) are identified as system No. 1, the remaining (redundant) motor and pair of clutches (extend and retract) are identified as system No. 2 within the specific actuator.

An overcurrent monitor circuit is employed for each primary and secondary gimbal motor. Each gimbal motor and overcurrent monitor circuit is controlled by its own SPS GIMBAL MOTORS switch on panel 1. There are four SPS GIMBAL MOTORS switches, PITCH 1 and 2 and YAW 1 and 2. Figure 2.4-8 illustrates the yaw actuator as an example. When the SPS GIMBAL MOTORS YAW 1 (primary) switch is positioned to START, power is applied from the battery bus to the motor-driven switch. The motor-driven switch closes a contact that allows power from the main bus to the gimbal motors. Thus, the gimbal motor is started. When the SPS GIMBAL MOTORS YAW 1 switch is released, it springs back to the center position. The center position activates the overcurrent monitor sensing circuitry. The SPS GIMBAL MOTORS YAW 2 (secondary) switch is then positioned to START. The SPS GIMBAL MOTORS YAW 2 switch activates yaw 2 motor-driven switch. The motor-driven switch of YAW 2 functions as with YAW 1. The SPS GIMBAL MOTORS YAW 2 switch released from START, spring loads to center. The center position activates the overcurrent monitor circuit of yaw 2.

The overcurrent monitor circuits of the primary and secondary system are utilized to monitor the current to the gimbal motors. This is because of the variable current flow during the initial gimbal motor start, normal operation for the main d-c bus, and gimbal motor protection.

Using the No. 1 yaw system as an example, identify the upper motor and clutches in figures 2.4-7 and 2.4-8 as system No. 1. When the overcurrent monitoring senses an overcurrent on gimbal motor No. 1, the following functions occur. The overcurrent monitor circuitry drives the motor-driven switch. This removes power from gimbal motor No. 1, rendering it inoperative. Simultaneously, a signal is sent to illuminate the YAW GMBL DR 1 caution and warning light on panel 2. This informs the crew the YAW gimbal motor No. 1 has failed because of overcurrent. Simultaneously, a fail

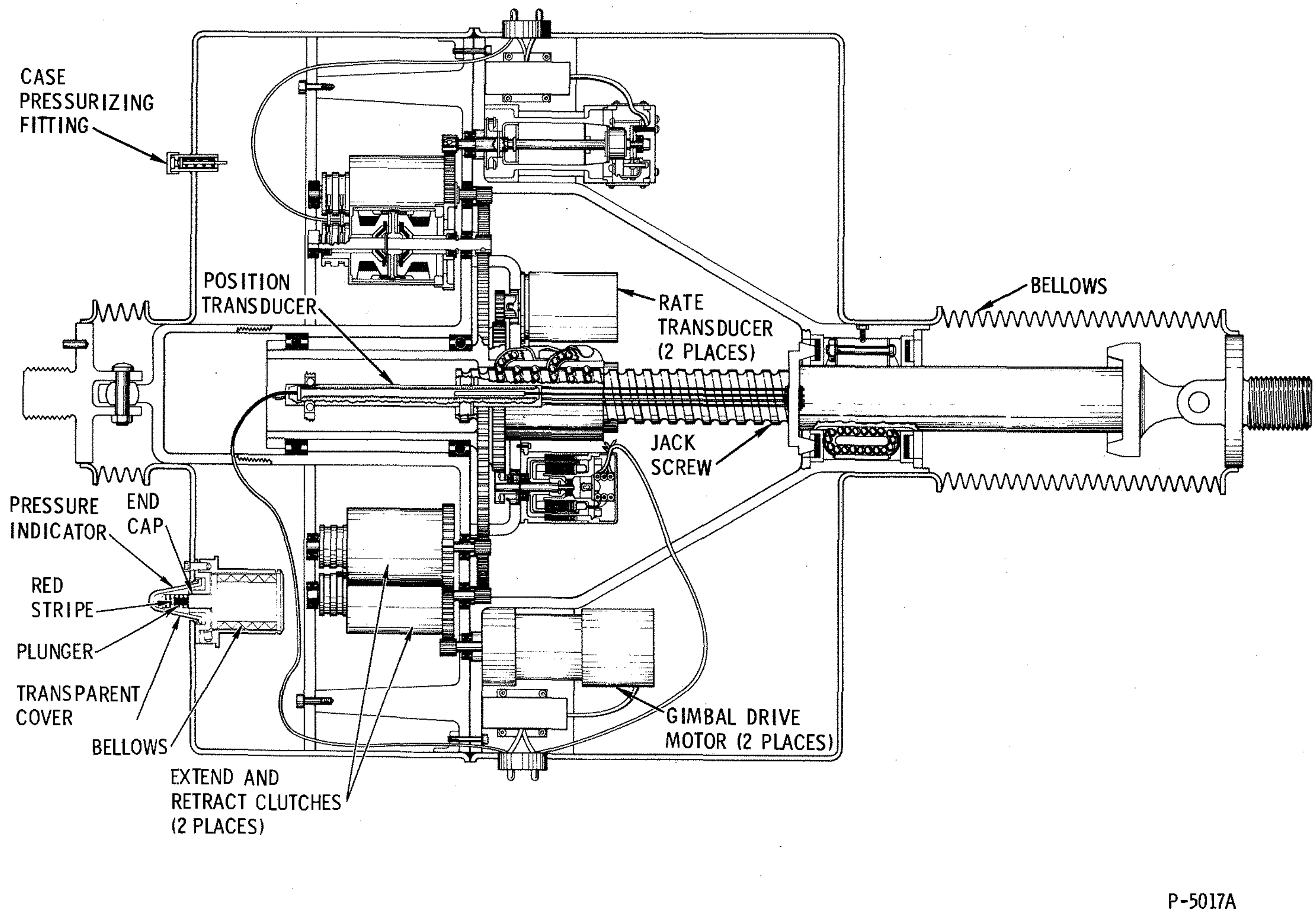


Figure 2.4-7. SPS Electro-Mechanical Gimbal Actuator

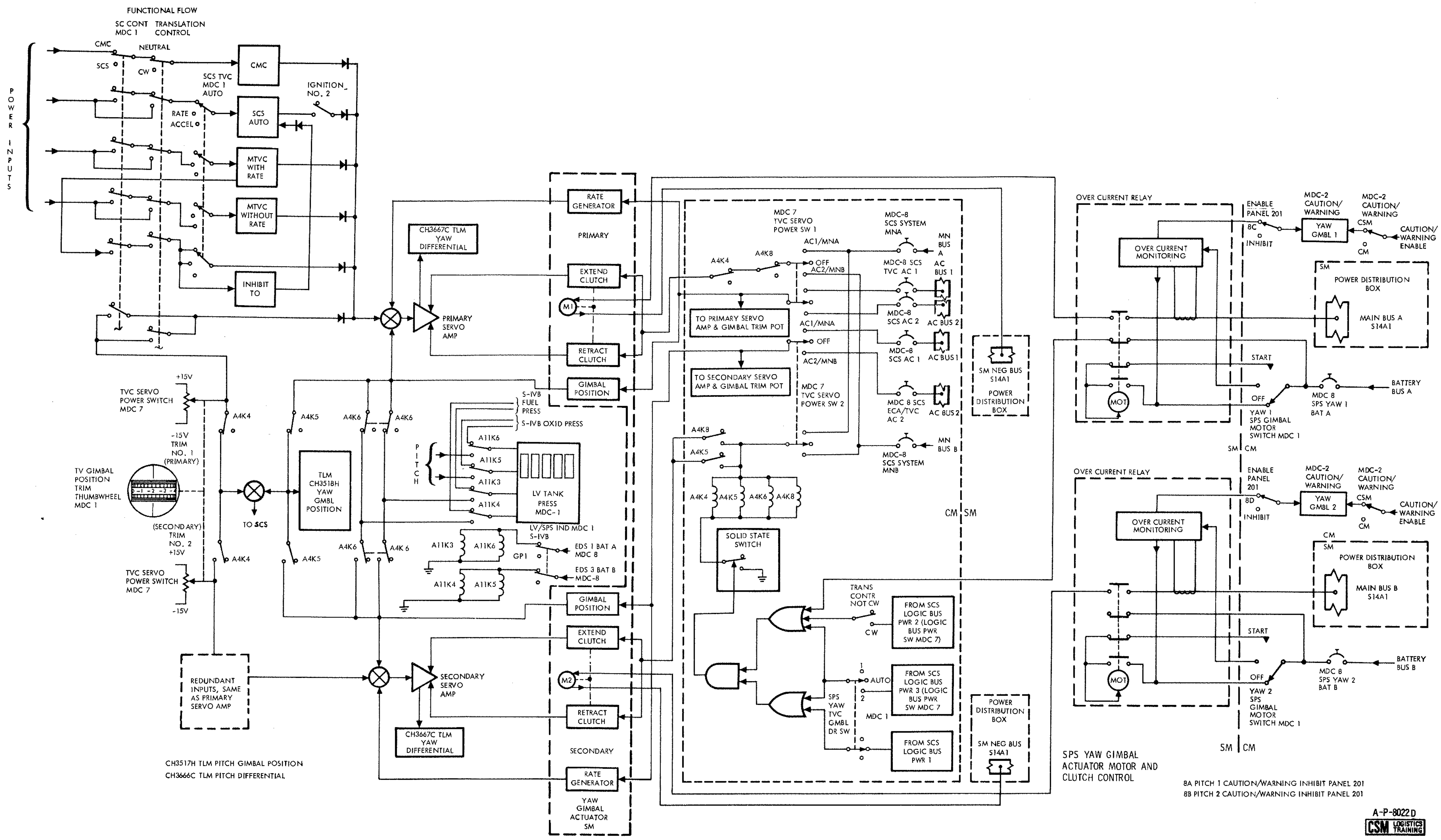


Figure 2.4-8. SPS Yaw Gimbal Actuator Motor and Clutch Control

sense signal is sent from a contact on the motor-driven switch. The fail sense signal is sent through an OR and AND gate to a solid-state switch. This switch provides a ground for relay coils A4K4, A4K5, A4K6, and A4K8. These relays are energized if the TVC GMBL DRIVE YAW switch on panel 1 is in AUTO and the SCS TVC SERVO POWER switch 2 on panel 7 is in AC2/MNB or AC1/MNA. This allows the upper relay contacts of A4K4 and A4K8 to open, and removes the power input to the No. 1 clutches.

Simultaneously, the lower relay contacts of A4K5 and A4K8 close. This applies power inputs to the No. 2 clutches within the same actuator. Simultaneously, the upper contacts of A4K4, A4K5, and A4K6 open and the lower contacts close, allowing thrust vector control monitoring. The SPS GIMBAL MOTORS YAW 1 switch on panel 1 is then positioned to OFF. Normally, the OFF position is used to shut down the gimbal motor upon completion of a thrusting period.

Using No. 2 yaw system as an example, the lower motor and clutches in figures 2.4-7 and 2.4-8 are identified as system No. 2. When the overcurrent monitoring senses an overcurrent on gimbal motor No. 2, the following functions occur. The overcurrent monitor circuitry will drive the motor-driven switch. This removes power from gimbal motor No. 2, rendering it inoperative. Simultaneously, a signal is sent to illuminate the YAW GMBL DR 2 caution and warning light on panel 2. This informs the crew the YAW gimbal motor No. 2 has failed because of overcurrent. There is no fail sense signal sent to control relay coils A4K4, A4K5, A4K6, and A4K8. If the No. 2 gimbal motor has failed as well as No. 1 gimbal motor, the specific actuator is inoperative. The SPS GIMBAL MOTORS YAW 2 switch on panel 1 is then positioned to OFF. Normally, the OFF position is used to shut down the gimbal motor upon completion of a thrusting period.

The LV/SPS IND switch on panel 1 when positioned to GPI de-energizes relay coils A11K3, A11K4, A11K5, and A11K6 (figure 2.4-8). This allows the relay contact points of A11K3, A11K4, A11K5, and A11K6 to move to the lower contact position. The actuator position transducer is then allowed to transmit gimbal position information to the SPS GPI on panel 1.

The TVC GMBL DRIVE YAW switch on panel 1 will also control through the OR and AND gate the solid-state switch (figure 2.4-8). The solid-state switch will provide the ground for relay coils A4K4, A4K5, A4K6, and A4K8. The power input to these relays is provided by positioning the TVC SERVO POWER switch 2 on panel 7 to AC2/MNB or AC1/MNA. When the TVC GMBL DRIVE YAW switch is in AUTO, the primary gimbal motor overcurrent monitor circuitry controls the solid-state switch. If overcurrent on the primary gimbal motor is sensed, the CMC, SCS, or MTVC inputs are switched automatically from the primary to the secondary clutches.

If the TVC GMBL DRIVE YAW switch on panel 1 is in position 1, the CMC, SCS, or MTVC inputs are locked into the primary clutches. If overcurrent is sensed on gimbal motor No. 1, or if the translation control is rotated clockwise, there is no automatic switchover from the primary to secondary clutches. The TVC GMBL DRIVE YAW switch positioned to 1 could be utilized to check out gimbal motor No. 1, the primary clutches, and the primary servo loop system.

If the TVC GMBL DRIVE YAW switch on panel 1 is in position 2 and the TVC SERVO POWER switch 2 on panel 7 is in AC2/MNB or AC1/MNA position, this will lock the CMC, SCS, or MTVC inputs into the secondary clutches. This position could be utilized to check out gimbal motor No. 2 the secondary clutches, and the secondary servo loop system.

If the TVC GMBL DRIVE YAW switch on panel 1 is in AUTO and TVC SERVO POWER switch 2 on panel 7 is in AC2/MNB or AC1/MNA position, the SCS or MTVC inputs are removed from the primary clutches and switched to the secondary clutches when the translation control is rotated clockwise.

The function of the pitch gimbal actuator operation and control is the same as yaw. The pitch gimbal actuator control circuits has its own PITCH GIMBAL MOTOR switches on panel 1 and its own TVC GMBL DR PITCH switch on panel 1. The TVC SERVO POWER switches on panel 7 will supply power to the pitch clutches as in the case of the yaw clutches. The LV/SPS IND switch to GPI on panel 1 allows pitch gimbal position to the GPI. The relay coils involved with the pitch actuator will have different numbers.

It is noted that the primary yaw and pitch gimbal motor receive power from MN BUS A. The primary pitch and yaw motor-driven switches receive power from BAT BUS A. The secondary yaw and pitch gimbal motors receive power from MN BUS B. The secondary pitch and yaw motor-driven switches receive power from BAT BUS B. In addition, it is noted that the applicable caution/warning light may be inhibited by the applicable caution/warning enable/inhibit switch on panel 201.

The clutches are magnetic-particle type. The gimbal motor drive gear meshes with the gear on the clutch housing. The gears on each clutch housing mesh and as a result, the clutch housings counter-rotate. The current input is applied to the electromagnet mounted to the rotating clutch housing from the SCS, CMC, or MTVC. A quiescent current may be applied to the electromagnet of the extend and retract clutches when the TVC SERVO POWER switches, on panel 7, are in AC1/MNA or AC2/MNB, preventing any movement of the engine during the boost phase of the mission with the gimbal motors OFF. The gimbal motors will be turned ON prior to jettisoning the launch escape tower to support the SPS abort after the launch escape tower has been jettisoned and will be turned OFF as soon as possible to reduce the heat that occurs because of the gimbal motor driving the clutch housing with quiescent current applied to the clutch. The friction force in the clutch housing creates heat which if allowed to increase to a high temperature, would cause the electromagnet to lose its magnetism capability, thus rendering that set of clutches inoperative.

Prior to any SCS ΔV thrusting period or in MTVC, the thumbwheels on panel 1 will be used to position the engine. The thumbwheels may be positioned prior to any CMC ΔV thrusting period but cannot position the engine. In any thrusting mode, the current input required for a gimbal angle change (to maintain the engine thrust vector through the center of mass) to the clutches will increase above the quiescent current. This increases the current into the electromagnets that are rotating with the clutch housings. The dry powder magnetic particles have the ability to become magnetized very readily, as well as demagnetized just as readily. The magnetic particles increase the friction force between the rotating housing and the flywheel, causing the flywheel to rotate. The flywheel arrangement is attached to the clutch output shaft allowing the clutch output shaft to drive the bull gear. The bull gear drives a ball nut which drives the actuator jackshaft to an extend or retract position, depending upon which clutch housing electromagnet the current input is supplied to. The larger the excitation current, the higher the clutch shaft rotation rate.

Meshed with the ball nut pinion gear are two rate transducers. The transducers are tachometer type. When the ball nut is rotated, the rate transducer supplies a feedback into the summing network of the thrust vector control logic to control the driving rates of the jackscrew (acting as a dynamic brake to prevent over- or under-correcting). There is one rate transducer for each system.

The jackscrew contains two position transducers, all arranged for linear motion and all connected to a single yoke. The position transducers are used to provide a feedback to the summing network and the visual display on panel 1. The operating system provides feedback into the summing network reducing the output current to the clutch resulting in proportional rate change to the desired gimbal angle position and returns to a quiescent current in addition to providing a signal to the visual display on panel 1.

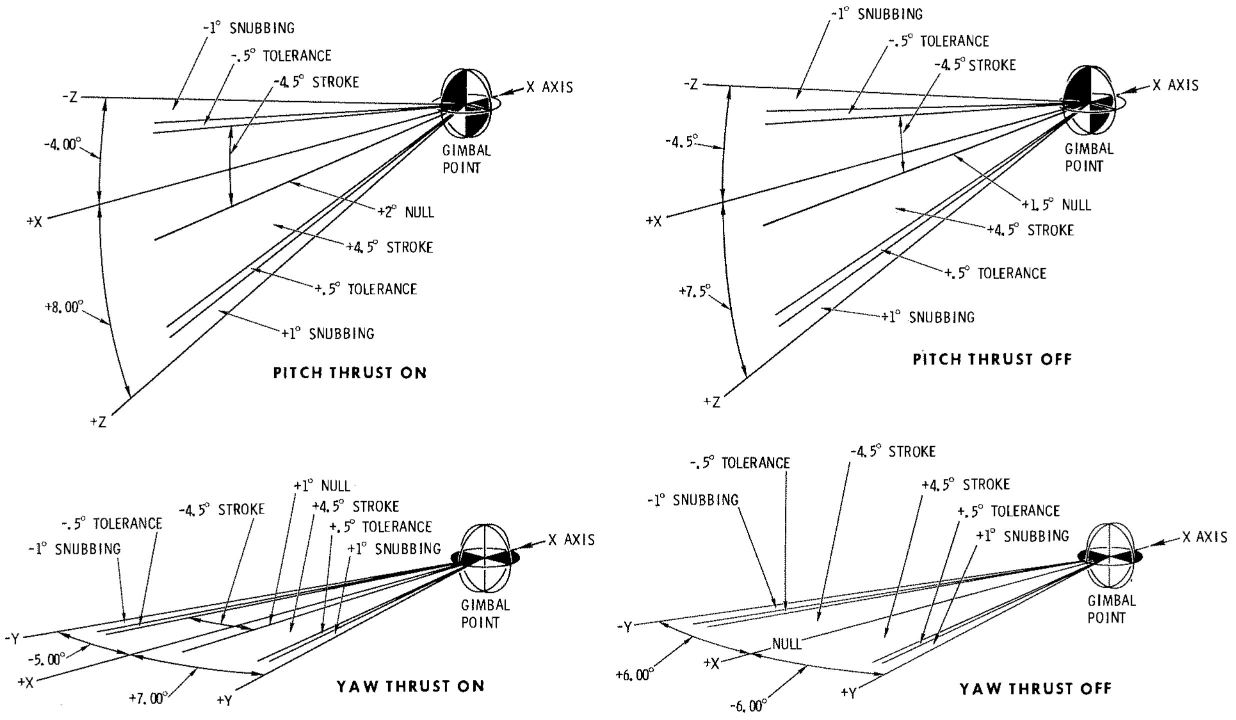
The remaining position transducer provides a feedback to the redundant summing network of the thrust vector logic for the redundant clutches in addition to the visual display on panel 1 if the secondary system is the operating system.

The spacecraft desired motion, thumbwheel positioning, rotation control (MTVC), engine nozzle position, thrust vector position, gimbal position display indicator, and actuator ram movement is identified in figures 2.4-9 and 2.4-10.

A snubbing device provides a hard stop for an additional one-degree travel beyond the normal gimbal limits.

2.4.2.9 Propellant Utilization and Gauging Subsystem (PUGS)

The propellant utilization gauging system is rendered inoperative because of the removal of the propellant utilization gauging control unit (figure 2.4-11) (PUGS) and probe simulator as the result of a weight reduction requirement. The propellant gauging probes, point sensors, propellant utilization valve and associated controls and displays will remain installed. The associated controls and displays on MDC-3 will be inoperative. The SPS GAUGING switch on MDC-4 will be positioned to OFF. The SPS GAUGING circuit breakers AC1, AC2, MNA, and MNB on MDC-8 will be pulled OUT. The telemetry outputs are inoperative. The probes and point sensors will be utilized to service the propellant tanks to the desired load through the use of special ground support equipment.



THE ENGINE MOUNTING PADS IN THE SERVICE MODULE ARE CANTED 4° (THRUST VECTOR) TO THE +Y AXIS OF THE SPACECRAFT. HOWEVER THE ACTUATOR NULL ADJUSTMENTS ARE AS FOLLOWS:

PITCH

THE PITCH ACTUATOR NULL POSITION IS +2° THRUST VECTOR TO THE +Z, ENGINE NOZZLE -2° TO THE -Z DURING AN SPS ENGINE FIRING. THE NULL POSITION IS +1.5° THRUST VECTOR TO THE +Z, ENGINE NOZZLE -1.5° TO THE -Z DURING SPS NON-THRUSTING PERIODS. THE THUMB WHEEL ON MDC 1 & GIMBAL POSITION INDICATOR/FUEL PRESSURE INDICATOR ON MDC 1 WILL BE 0.0°.

YAW

THE YAW ACTUATOR NULL POSITION IS +1° THRUST VECTOR TO THE +Y, ENGINE NOZZLE IS -1° TO THE -Y DURING AN SPS ENGINE FIRING. THE NULL POSITION IS 0° THRUST VECTOR TO THE Y, ENGINE NOZZLE IS 0° TO THE Y AXIS DURING SPS NON-THRUSTING PERIODS. THE THUMB WHEEL ON MDC 1 & GIMBAL POSITION INDICATOR/FUEL PRESSURE INDICATOR ON MDC 1 WILL BE 0.0°

THE REASON FOR THE DIFFERENCE BETWEEN A NON SPS ENGINE FIRING VERSUS AN SPS ENGINE FIRING IS DUE TO DEFLECTIONS OF ENGINE AND VEHICLE STRUCTURE.

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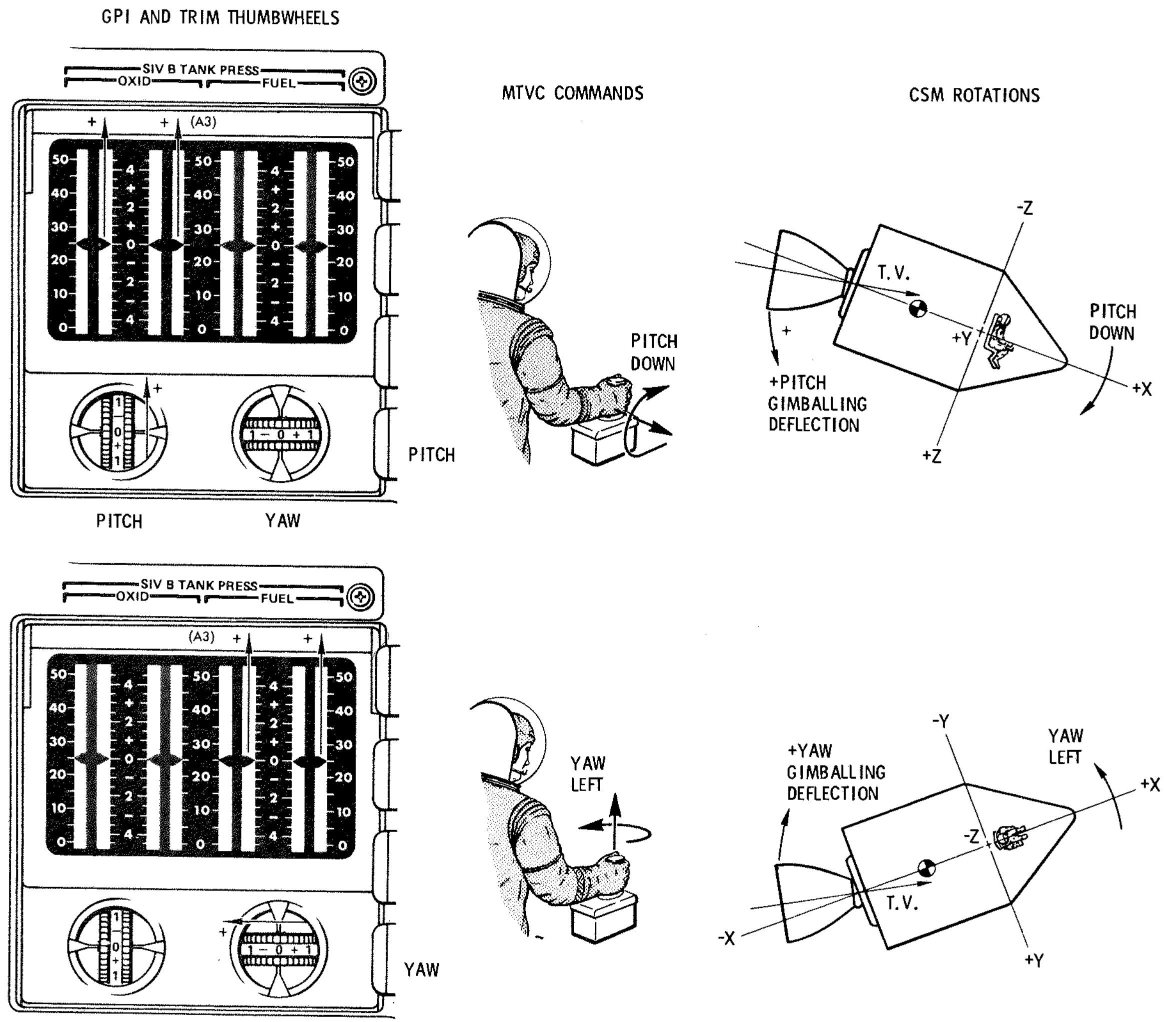
Figure 2.4-9. SPS Gimbal Angles Pitch and Yaw

2.4.2.10 Engine Thrust ON-OFF Control

Figure 2.4-1 illustrates the THRUST ON-OFF logic in the command module computer (CMC), the stabilization control subsystem (SCS), and the manual SPS THRUST DIRECT ON ΔV mode.

The SCS circuit breakers on panel 8 supply power to selected switches on panel 7 and panel 1. The panel 7 switches distribute a-c and d-c power to the SCS hardware and d-c logic power to selected switches on panel 1. The G&N (guidance and navigation) IMU (inertial measurement unit) circuit breakers on panel 5 supply power to the G/N power switch on panel 100. When the G/N power switch is positioned to IMU, power is supplied to the SC CONT switch on panel 1. When the SC CONT switch is positioned to CMC, a discrete event signal is supplied to the translation control. With the translation control not clockwise (neutral), this allows the discrete event enable to the CMC.



SPACECRAFT AXIS	PITCH	YAW
SPACE CRAFT NOSE MOTION	↓ (DOWN)	← (LEFT)
	↑ (UP)	→ (RIGHT)
THUMB WHEEL TRAVEL	↑ +NUMERAL	↑ +NUMERAL
	↓ -NUMERAL	↓ -NUMERAL
TRIM VOLTAGE	+	+
	-	-
GPI INDI-CATION	+	+
	-	-
MTVC COMMAND ROTATION CONTROL	-PITCH (FORWARD)	-Y (CCW)
	+PITCH (AFT)	+Y (CW)
ENGINE ANGLE COMM AND	+	+
	-	-
ACTUATOR RAM TRAVEL	EXTEND	EXTEND
	RETRACT	RETRACT
ENGINE INJECTOR TRAVEL THRUST VECTOR	-Z	+Y
	+Z	-Y
ENGINE SKIRT TRAVEL	+Z	-Y
	-Z	+Y

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CSM LOGISTICS TRAINING

Figure 2.4-10. SPS Gimbaling

SPS

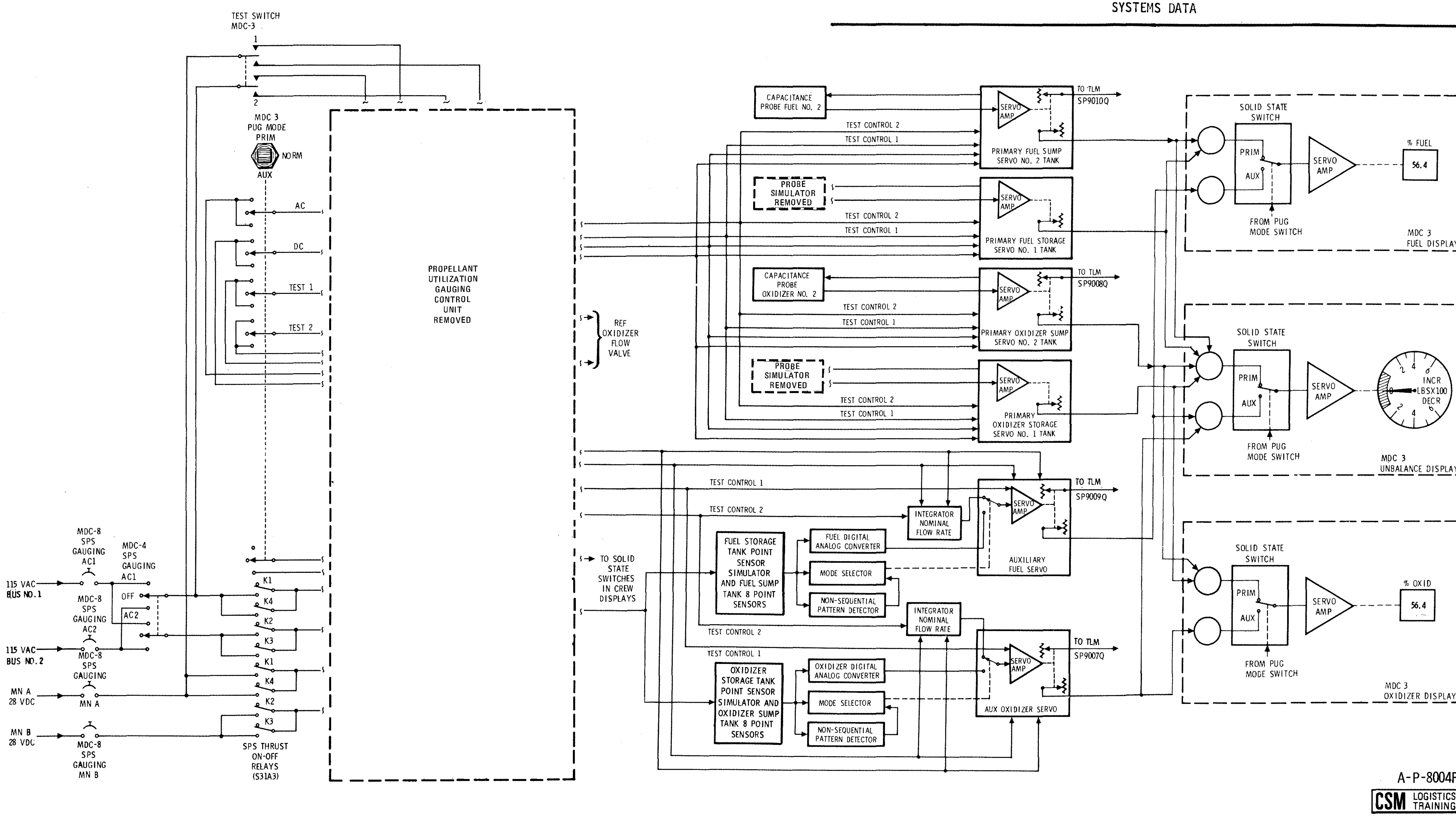

Figure 2.4-11. SPS Propellant Quantity Sensing and Gauging

SPS

Figures 2.4-12 through 2.4-14 deleted.

All information deleted from pages 2.4-32 through 2.4-36.

The SPS PILOT VALVE circuit breakers MNA and MNB on panel 8 supply power to the respective ΔV THRUST NORMAL A and B switches on panel 1. The ΔV THRUST NORMAL A and B switches on panel 1 supply arming power to the SPS relays solenoid control valves and enabling power to the THRUST ON-OFF logic.

The SPS engine THRUST-ON command is provided by the THRUST ON-OFF logic in the CMC or SCS ΔV modes. The THRUST ON-OFF logic commands the SPS DRIVERS 1 and/or 2. The SPS DRIVERS provide a ground in THRUST ON to the low side of the SPS solenoids and relays. The SPS DRIVERS provide the removal of the ground in THRUST-OFF conditions to the SPS solenoids and relays. DRIVER 1 provides a ground for the SPS solenoids No. 1 and No. 2 and SPS relays S31A3K1 and S31A3K3. DRIVER 2 provides a ground for SPS solenoids No. 3 and No. 4 and SPS relays S31A3K2 and S31A3K4. The SPS relays when energized provide power to SPS He VLV 1 and 2. The SPS He VLV switches on panel 3 must be in AUTO. The solenoid control valves when energized allow GN_2 pressure to be supplied to the respective bipropellant valve (ball valve) actuators. The respective ball valves when opened, allow propellants to flow into the injector and atomize and ignite (hypergolic).

The SPS THRUST DIRECT ON switch on panel 1 provides an alternate backup mode to the CMC and/or SCS ΔV modes. When the SPS THRUST DIRECT ON switch is positioned to SPS THRUST DIRECT ON, a ground is provided to the low side of the SPS relays and solenoid control valves. The engine is commanded ON (providing the ΔV THRUST NORMAL switches are in A and/or B) regardless of the SPS THRUST ON-OFF logic.

The SPS DRIVERS No. 1 and/or No. 2 will remove the ground on the low side of the SPS relays and solenoid control valves, when commanded by the THRUST-OFF logic in the CMC or SCS ΔV modes. The THRUST-OFF command allows the SPS relays and solenoid control valves to de-energize. This allows the solenoid control valves to dump overboard the GN_2 pressure within the actuator. The actuator spring pressure drives the ball valves closed, thus shutting the engine down.

In the SPS THRUST DIRECT ON mode, the ground on the low side of the SPS relays and solenoid control valves is removed by positioning the SPS THRUST DIRECT ON switch to NORMAL. This allows the solenoid control valves and relays to de-energize and shut the engine down in the same manner as the SPS DRIVERS.

The ΔV THRUST NORMAL A switch positioned to A enables the (A bank) logic circuitry, arms the (A bank) SPS relays and solenoid control valves and energizes injector prevalve A. The injector prevalve then allows GN_2 pressure to solenoid control valves No. 1 and No. 2. The ΔV THRUST NORMAL B switch positioned to B enables the (B bank) logic circuitry, arms the (B bank) SPS relays and solenoid control valves and energizes injector prevalve B. The injector prevalve then allows GN_2 pressure to solenoid control valves No. 3 and No. 4.

The CMC commands THRUST-ON in the CMC ΔV mode by supplying a logic 0 to the THRUST ON-OFF logic. This is providing that the SC CONT switch is in the CMC position and the translation control is not clockwise (neutral). The SPS DRIVERS then provide the ground to the SPS relays and solenoid control valves. The ΔV THRUST NORMAL A switch is positioned to A for single-bank operation. If double-bank operation is desired, 2 to 5 seconds or later after SPS THRUST-ON, the ΔV THRUST NORMAL switch B is positioned to B. When the CMC changes the logic signal from a 0 to a 1, THRUST-OFF is commanded. The ΔV THRUST NORMAL switch A and/or B is then positioned to OFF.

The SCS ΔV mode is obtained by positioning the SC CONT switch to SCS. A thrust enable signal is obtained from the EMS/ΔV display counter if at or above 00000.0. THRUST ON is commanded by a +X translation and by depressing the THRUST-ON pushbutton (panel 1). The +X command signal is necessary to enable the THRUST-ON logic. The +X command function may be obtained by depressing the DIRECT ULLAGE pushbutton on panel 1, or positioning the translation control to +X, or positioning the translation control counter-clockwise (SPS abort mode). The difference between the commands is that the DIRECT ULLAGE or SPS ABORT commands initiate an SM RCS engine direct coil firing and inhibits the SM RCS engine auto (coil) pitch and yaw solenoid drivers, IGNITION 1 (IGN-1). The translation control positioned to +X utilizes the SM RCS engine auto coils; thus, attitude hold may be obtained. The SM RCS engine auto coils (pitch and yaw) are then inhibited automatically 1 second after SPS engine THRUST ON by the IGN-1 command. When the ground to the SPS solenoids and relays are provided by the SPS DRIVER or DRIVERS, the THRUST ON pushbutton may be released and the +X command terminated. The SPS engine firing is maintained by the SCS lock-in circuit. The ΔV THRUST NORMAL A switch is positioned to A for single-bank operation. If double-bank operation is desired, 2 to 5 seconds or later after SPS THRUST ON, the ΔV THRUST NORMAL B switch is positioned to B. The +X command function and the THRUST ON pushbutton depressed must be initiated again to supply THRUST-ON to the B bank and B SCS logic. When the EMS/ΔV counter reads -.1, the EMS/ΔV counter enable signal is removed and THRUST-OFF is commanded. The ΔV THRUST NORMAL A and/or B switch is then positioned to OFF.

The SPS THRUST ON-OFF logic may be switched from the CMC to the SCS ΔV mode during an SPS engine thrusting period. The translation control may be rotated to the clockwise position or the SC CONT switch to SCS. In either case the THRUST ON-OFF logic is transferred to the SCS ΔV mode. The SPS engine would continue thrusting (providing the EMS/ΔV counter is at or above 00000.0) by the presence of the SCS lock-in circuit. THRUST OFF will be commanded as in the normal SCS ΔV mode.

If the manual SPS THRUST DIRECT ON mode is desired, the ΔV THRUST NORMAL A switch is positioned to A (for single-bank operation) and the SPS THRUST DIRECT switch is positioned to SPS THRUST DIRECT ON. The SPS THRUST DIRECT ON switch positioned to SPS THRUST DIRECT ON provides a ground to the SPS relays and solenoid control valves. If double-bank of operation is desired, 2 to 5 seconds (or later) after SPS thrust ON, the ΔV THRUST NORMAL B switch is positioned to B. To terminate thrust in the SPS THRUST DIRECT ON mode, the SPS THRUST DIRECT ON switch is positioned to NORMAL. Under certain conditions the SPS THRUST DIRECT ON switch positioned to NORMAL will not shut the engine down. The conditions are with the SCS LOGIC BUS

PWR switch on panel 7 positioned to 2/3, and with the SC CONT switch in panel 1 in SCS or SC CONT switch in CMC and translation control clockwise and ΔV counter above 0. In the aforementioned condition, the SCS ΔV mode has inadvertently paralleled the SPS THRUST DIRECT ON mode. With the SPS THRUST DIRECT ON switch in NORMAL, the EMS/ΔV counter reaching -.1 would provide THRUST OFF as in the normal SCS ΔV mode. If the SPS THRUST DIRECT ON switch was positioned to NORMAL when the EMS/ΔV counter was below -.1, the SPS THRUST DIRECT ON switch to NORMAL would shut the engine down.

A manual back-up THRUST OFF command for the CMC, SCS or SPS THRUST DIRECT ON mode is obtained by the ΔV THRUST NORMAL A and B switches. If single-bank operation was used, positioning the applicable ΔV THRUST NORMAL switch to OFF would shut the engine down. If double-bank operation was used, positioning ΔV THRUST NORMAL switches A and B to OFF would shut the engine down. Positioning the ΔV THRUST NORMAL switches A and B to OFF removes the arming power from the SPS relays, solenoid control valves, and enabling power from the THRUST ON-OFF logic.

SPS

The SPS THRUST-ON-OFF logic circuitry also provides several output functions. A ground is provided for the illumination of the THRUST-ON lamp on the EMS display. The ground is sensed by SPS ignition logic. It is noted in figure 2.4-1 that as long as the EMS MN A and/or MN B circuit breakers on panel 8 are closed, with the ΔV THRUST NORMAL switches A and B on panel 1 in the OFF position, the SPS THRUST ON light on the EMS panel 1 will not be illuminated. The SPS THRUST ON light on the EMS will illuminate when a ground is provided through the logic circuit driver No. 1 and/or No. 2, or when the SPS THRUST DIRECT ON switch on panel 1 is positioned to SPS THRUST DIRECT ON.

The SM RCS auto pitch and yaw RCS disabling signal IGN-1 is not present until one second after SPS ignition in the SCS ΔV mode, and is not removed until one second after SPS THRUST-OFF in the SCS ΔV mode. IGN-2 logic signal is required for the SCS-TVC and MTVC logic. The IGN-2 logic signal is generated at the same time the SPS solenoids are grounded when in the SCS ΔV mode, but is not removed until one second after ground is removed to maintain SC control during SPS thrust-off decay.

2.4.3 PERFORMANCE AND DESIGN DATA

2.4.3.1 Design Data

The following list contains specific data on the components in the SPS:

Helium tank (1)	3600±50 psia nominal fill pressure, 4400-maximum operating pressure. Capacity 19.4 cu ft, inside diameter 40 in., and a wall thickness of 0.46 in. Weight 393 lb, **44.0** lb of helium.
Regulator units (2)	Working regulator, primary 186±4 psig, secondary 191±4 psig. Primary lockup 200 psig. Secondary lockup 205 psig. Inlet filter 10 microns nominal, 25 microns absolute. Normally locked-up (closed) regulators, primary 181±4 psig, secondary 191±4 psig. Primary lockup 195 psig. Secondary lockup 205 psig.

Check valves - filters	Inlet port 40 microns nominal, 74 microns absolute. Test ports 50 microns nominal and 74 microns absolute. One at inlet to check valve assembly; one at each test port.
Pressure transducers (2)	SP0003P and/or SP0006P fuel and oxidizer underpressure setting (SPS PRESS light, panel 2), 157 psia. Fuel and oxidizer overpressure setting (SPS PRESS light panel 2), 200 psia.
Propellant utilization valve control	Rendered inoperative.
Helium relief valve (2)	Diaphragm rupture, 219±6 psig. Filter, 10 microns nominal, 25 microns absolute. Relief valve relieves at 212 minimum to 225 psig maximum, reseats at 208 psig minimum. Flow capacity 3 lb/min maximum at 60°F and 225 psig. Bleed device closes when increasing pressure reaches no greater than 150 psig in cavity, and reopens when decreasing pressure has reached no less than 20 psig.
Oxidizer sump tank No. 2	Total tank capacity 13,719.4 **lb., 55.146 percent** Fill pressure 110 psia. Height 153.8 in., diameter 51 in., wall thickness 0.054 in. 161.72 cu ft Maximum usable 13,273.7 lb.
Fuel sump tank No. 2	Total tank capacity 8583.7 **lb., 55.146 percent** Fill pressure 110 psia. Height 153.8 in., diameter 51 in., wall thickness 0.054 in. 161.72 cu ft. Maximum usable 8325 lb.

SYSTEMS DATA

All propellant tanks	Pressurized to 10±5 psig of helium or gaseous nitrogen GN_2 when empty to prevent collapsing of tanks (negative pressure of 0.5 psig will collapse tanks).
Interface flange filter (2)	500 microns absolute.
GN_2 bipropellant valve control systems (2)	GN_2 storage vessel pressure 2500±50 psi at 68°F, 2900 psi at 130°F. Support 43 valve actuations. 120-cu in. capacity, each. Inside diameter 4.65 in., length 9.6 in. Regulator - single stage, dynamic 187 psig minimum. Lockup pressure 195 to 225 psig. Relief valve relieves at 350±15 psi, reseats at not less than 250 psi.
	GN_2 filters, one between each GN_2 supply tank and injector prevalve, 5 microns nominal and 18 microns absolute. One at each GN_2 regulator outlet test port, 5 microns nominal and 18 microns absolute.
Engine (1)	750-second service life. Support 36 restarts minimum.
	Expansion ratio = 6 to 1 at ablative chamber exit area = 62.5 to 1 at nozzle extension exit area.
	Chamber cooling, ablation and film cooled. Nozzle extension, radiation cooled. Injector type, baffled, unlike impingement. Oxidizer lead 8 deg. Length 159.944 in. maximum. Nozzle extension exit diameter 98.4 in. inside diameter. Weight approximately 650 lb.
	SPS Pc transducer, Pc displayed on panel 1 through SPS Pc switch to SPS Pc indicator on panel 1. Green range on indicator is 65 to 125 percent (psia). Normal 95 to 105 percent (psia).
Heaters	Three heaters on oxidizer tank aft dome with two elements, each element rated at 18 watts each at 25 vdc connected in parallel. One heater on oxidizer tank feedline with two elements, each element rated at 18.8 watts at 19.5 vdc. One heater on oxidizer helium pressurization line aft of bulkhead with two elements, each element rated at 3.25 watts at 3.4 vdc. One heater on

SPS

	oxidizer relief valve contains two elements, each element rated at 2 watts at 2.1 vdc; heaters are are connected in series.
	One heater each, on engine fuel and oxidizer feed-line with two elements in each heater. The engine fuel and oxidizer feedline heaters are connected in series, thus each element is rated at 4.7 watts at 12.5 vdc.
	One heater each, on engine fuel and oxidizer valve body with two elements in each heater. Each element rated at 15 watts at 25 vdc. Heaters are connected in parallel.
	One heater each, on secondary oxidizer and fuel check valve with two elements in each heater. Each element rated at 4.0 watts at 12.6 vdc. The heaters are connected in series.
	Four heaters on helium pressurization panel connected in parallel. Each heater contains two elements. Each element rated at 10 watts at 25 vdc and are connected in parallel. One heater adjacent to outlet of each regulator unit. One heater located adjacent to each primary fuel and oxidizer check valve.
Thermoswitch	One for primary and one for secondary oxidizer tank door heaters. Will open heater circuits if tank door reaches 134°F, closes circuit at 115°F, minimum spread of 9°F.
Temperature controllers	With the SPS HTRS switch on panel 5 in PRIM, the primary mercury thermal control sensors close and open the heater circuits at approximately 50°F. With the SPS HTRS switch on panel 5 in SEC, the mercury thermal control sensors close and open the heater circuits at approximately 55°F.
Gimbal actuators	Structural mounting pad offset 4 deg to +Y. About Z-Z axis ±4.5 (+0.5, -0.0) deg with additional 1 deg for snubbing (yaw), null 1 deg to +Y (thrust vector) during SPS thrusting periods, 0 deg during non-SPS thrusting periods. About Y-Y axis ±4.5 (+0.5, -0.0) deg with additional 1 deg for snubbing (pitch), null 2 deg to +Z (thrust vector) during SPS thrusting periods, +1.5 to +Z during non-SPS thrusting periods.
	Quiescent current of 60 (+10, -5) milliamps.
	Pressurized to 3 to 5 psi of dry air. Deflection rate 0.12 rad per sec (low side, 6.87° per sec) to 0.18 rad per sec (high side, 10.314° per sec).
Gimbal motor Overcurrent relays (4)	Overcurrent dependent upon temperature during start transient and steady state.

2.4.3.2 Performance Data

Refer to CSM/LM Spacecraft Operational Data Book SNA-8-D-027 CSM (SD 68-447).

2.4.3.3 SPS Electrical Power Distribution

See figure 2.4-15 for electrical power distribution.

2.4.4 OPERATIONAL LIMITATIONS AND RESTRICTIONS

a. Deleted.

b. Pitch and yaw gimbal actuator limitations:

1. Allow one-half second between actuation of the GMBL MOTOR switches on panel 1 to minimize power transients.

2. The secondary gimbal motors should be in operation in the pitch and yaw gimbal actuator for any SPS engine firing for back-up modes of operation.

3. The TVC SERVO PWR switch 1 on panel 7 should not be positioned to AC1/MNA and TVC SERVO PWR switch 2 on panel 7 positioned to AC2/MNB or switch 1 to AC2/MNB and switch 2 to AC1/MNA in excess of one hour prior to an SPS engine firing. This would result in some preheating of the pitch and yaw gimbal actuator clutches which could result in a degradation of actuator clutch performance.

4. Do not operate the pitch and yaw gimbal actuator motors without applying power to the thrust vector control servo amplifiers as the pitch and yaw gimbal actuators have a natural tendency to extend or retract (depending on altitude and pressure) and may drive the SPS engine from snub to snub resulting in vehicle motion.

5. The pitch and yaw gimbal actuator operating time should be held to a minimum. The pitch and yaw gimbal actuator clutches with gimbal motors operating are capable of holding the SPS engine at a given position during the boost phase of the mission (820 seconds) followed by a 100-second SPS engine abort firing without degradation. If no SPS abort firing is required the gimbal motors are shut down at earth orbit acquisition.

c. Engine design minimum impulse control limit is 0.4 second; however, mission minimum impulse may be longer.

d. For other operational limitations and restrictions, refer to Volume 2 Skylab Operations Handbook.

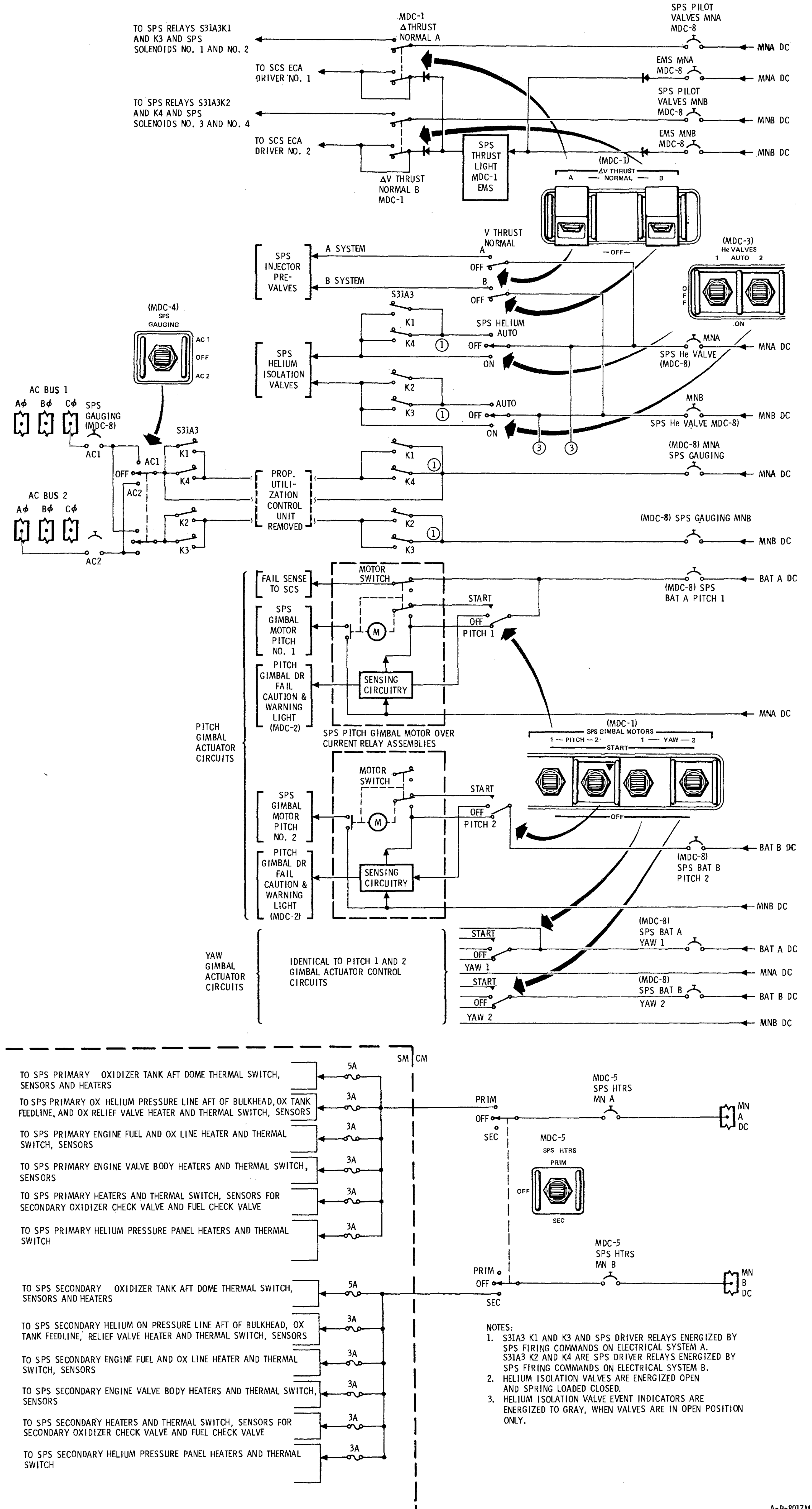

Figure 2.4-15. SPS Electrical Power Distribution

RCS

SECTION 2

SUBSECTION 2.5

REACTION CONTROL SYSTEM (RCS)

The Apollo command service module includes two separate reaction control systems which are completely independent and are designated SM RCS and CM RCS. The SM RCS is utilized to control SC rates and rotation in all three axes in addition to any minor translation requirements including CSM-SIVB separation, SPS ullage, and CM-SM separation maneuvers. The CM RCS is utilized to control CM rates and rotation in all three axes after CM-SM separation and during entry. The CM RCS does not have automatic translation capabilities.

Both the SM and CM RCS may be controlled either automatically or manually from the command module. Physical location of the RCS engines is shown in figure 2.5-1. Engine firing sequence for specific maneuvers and individual engine circuit breaker power control is shown in figures 2.5-2 through 2.5-6.

2.5.1 SM RCS FUNCTIONAL DESCRIPTION

The SM RCS consists of four individual, functionally identical quads. Each quad consists of a pressure-fed positive-expulsion, pulse-modulated, bipropellant system. The four individual quads normally are utilized to supply propellants to the respective cluster of four engines associated with that quad. The one propellant storage module 1 located in bay I of the service module may be utilized to supply propellants to all four quad engine clusters in pulse mode or steady state operation. Provisions are provided in bay I of the service module for the capability of installing another propellant storage module. The propellant storage module consists of a similar pressure-fed positive-expulsion bipropellant system to that of the four quads. The cluster of four engines on a quad produces the thrust required to perform the various SM RCS control functions. The SM RCS propellants consist of inhibited nitrogen tetroxide (N_2O_4) used as the oxidizer, and monomethylhydrazine (MMH) used as the fuel. Pressurized helium gas is the propellant transferring agent.

The SM RCS quads are located 90 degrees apart around the forward portion (+X axis) of the service module periphery, and offset from the spacecraft Y and Z axis by 7 degrees 15 minutes. Each quad is configured such that the reaction engines are mounted on the outer surface of the panel and the remaining components are on the inside. The propellant distribution lines are routed through the panel skin to facilitate propellant transfer to the reaction engines. The module or modules in bay I have propellant lines routed to each of the four SM RCS quads to facilitate transfer of propellants from the module to the cluster of engines of each quad. The engines are canted approximately 10 degrees

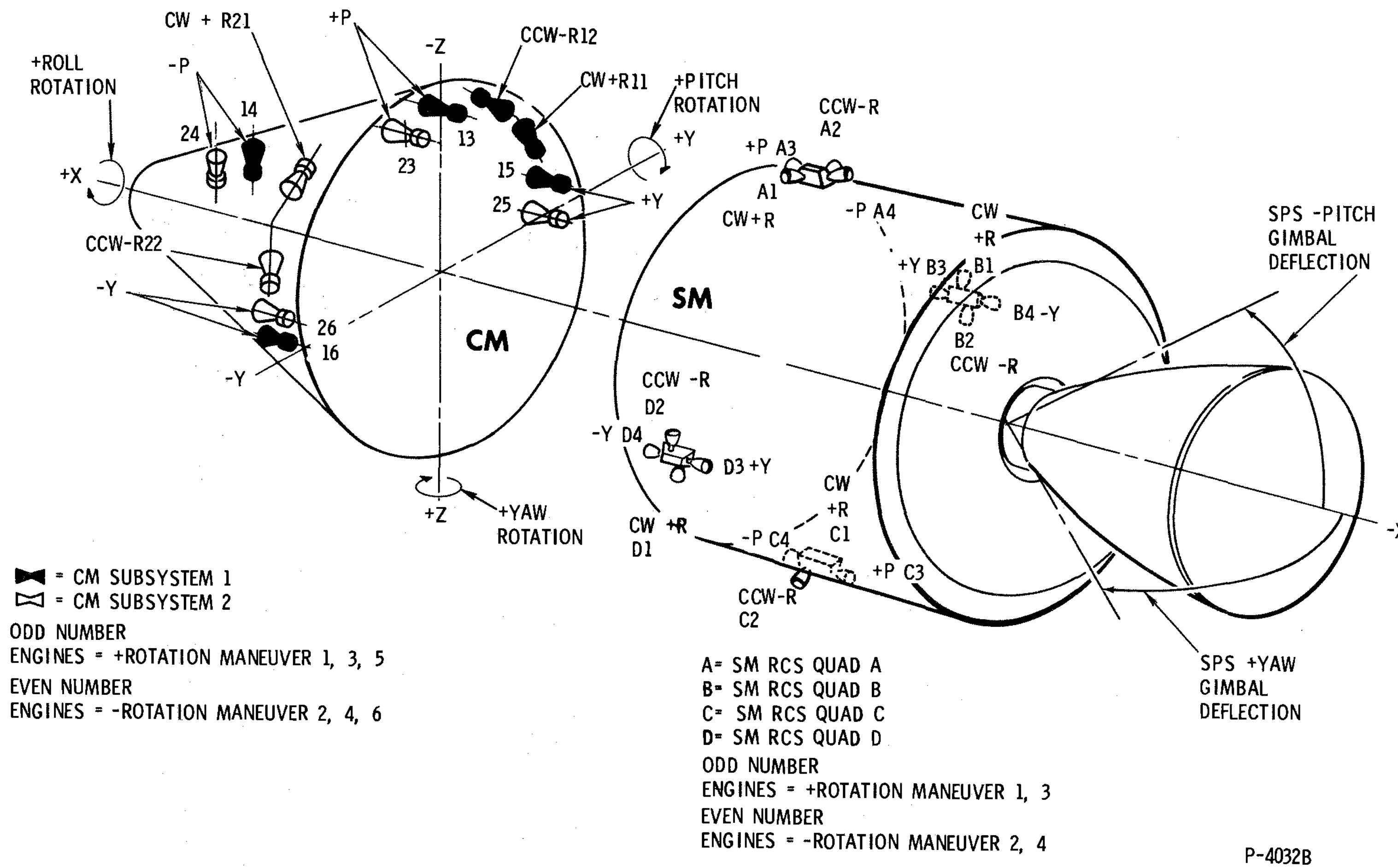

Figure 2.5-1. CM-SM Engine Locations

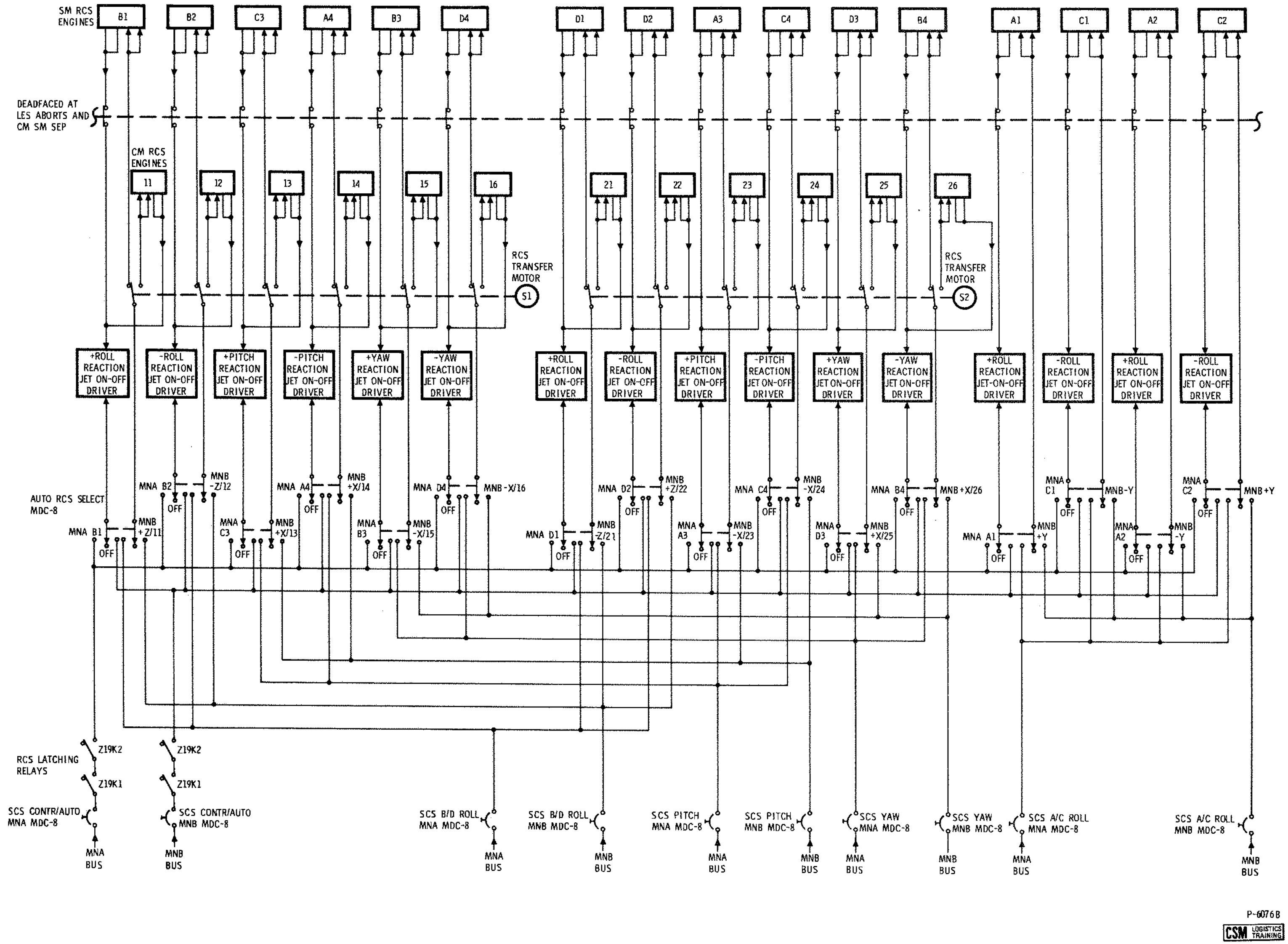

Figure 2.5-2. CSM RCS Auto Control

RCS

SYSTEMS DATA

BUS POWER	CIRCUIT BREAKER MDC 8	AUTO RCS SELECT SWITCHES MDC-8	SM ENGINE				CM ENGINE				SM ENGINE UTILIZATION FOR TRANSLATION MANEUVERS						TRANSFER MOTOR
			QUAD	MANEUVER	SCS NO.	PROP. NO.	SYSTEM	MANEUVER	SCS NO.	PROP. NO.	-X	+X	-Y	+Y	-Z	+Z	
MNA	SCS MNA PITCH	PITCH C3 +X13	C	+P	C3	S19A3B3	1	+P	13	C19B7		C3					S1
		PITCH A4 +X14	A	-P	A4	S19A1B3	1	-P	14	C19B11		A4					S1
		PITCH A3 -X23	A	+P	A3	S19A1B1	2	+P	23	C19B8	A3						S2
		PITCH C4 -X24	C	-P	C4	S19A3B1	2	-P	24	C19B12	C4						S2
MNB	SCS MNB PITCH	PITCH C3 +X13	C	+P	C3	S19A3B3	1	+P	13	C19B7		C3					S1
		PITCH A4 +X14	A	-P	A4	S19A1B3	1	-P	14	C19B11		A4					S1
		PITCH A3 -X23	A	+P	A3	S19A1B1	2	+P	23	C19B8	A3						S2
		PITCH C4 -X24	C	-P	C4	S19A3B1	2	-P	24	C19B12	C4						S2
MNA	SCS MNA YAW	YAW D3 +X25	D	+Y	D3	S19A4B1	2	+Y	25	C19B10		D3					S2
		YAW B4 +X26	B	-Y	B4	S19A2B1	2	-Y	26	C19B2		B4					S2
		YAW B3 -X15	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	B3						S1
		YAW D4 -X16	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	D4						S1
MNB	SCS MNB YAW	YAW D3 +X 25	D	+Y	D3	S19A4B1	2	+Y	25	C19B10		D3					S2
		YAW B4 +X26	B	-Y	B4	S19A2B1	2	-Y	26	C19B2		B4					S2
		YAW B3 -X15	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	B3						S1
		YAW D4 -X16	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	D4						S1
MNA	SCS MNA B/D ROLL	B/D ROLL B1 +X11	B	CW+R	B1	S19A2B2	1	CW+R	11	C19B5						B1	S1
		B/D ROLL D2 +Z22	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4						D2	S2
		B/D ROLL D1 -Z21	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6					D1		S2
		B/D ROLL B2 -Z12	B	CCW-R	B2	S19A2B4	1	CCW-R	12	C19B3					B2		S1
MNB	SCS MNB B/D ROLL	B/D ROLL B1 +X11	B	CW+R	B1	S19A2B2	1	CW+R	11	C19B5						B1	S1
		B/D ROLL D2 +Z22	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4						D2	S2
		B/D ROLL D1 -Z21	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6					D1		S2
		B/D ROLL B2 -Z12	B	CCW-R	B2	S19A2B4	1	CCW-R	12	C19B3					B2		S1
MNA	SCS MNA A/C ROLL	A/C ROLL A1 +Y	A	CW+R	A1	S19A1B4	RETURN LEADS DEADFACED AT CM SM SEPARATION AND LES ABORTS							A1			
		A/C ROLL C2 +Y	C	CCW-R	C2	S19A3B2								C2			
		A/C ROLL C1 -Y	C	CW+R	C1	S19A3B4							C1				
		A/C ROLL A2 -Y	A	CCW-R	A2	S19A1B2							A2				
MNB	SCS MNB A/C ROLL	A/C ROLL A1 +Y	A	CW+R	A1	S19A1B4								A1			
		A/C ROLL C2 +Y	C	CCW-R	C2	S19A3B2								C2			
		A/C ROLL C1 -Y	C	CW+R	C1	S19A3B4							C1				
		A/C ROLL A2 -Y	A	CCW-R	A2	S19A1B2							A2				

P-6056C
CSM LOGISTICS TRAINING

Figure 2.5-3. CM-SM RCS Engine Power Supplies (Automatic)

away from the panel structure to reduce the effects of exhaust gas on the service module skin. The two roll engines on each quad are offset-mounted to accommodate the plumbing within the engine mounting housing structure.

Acceptable propellant operating temperatures are maintained by electrical heaters.

The reaction engines may be pulse-fired, producing short-thrust impulses or continuously fired, producing a steady-state thrust level. The short-pulse firing permits attitude-hold modes of operation and

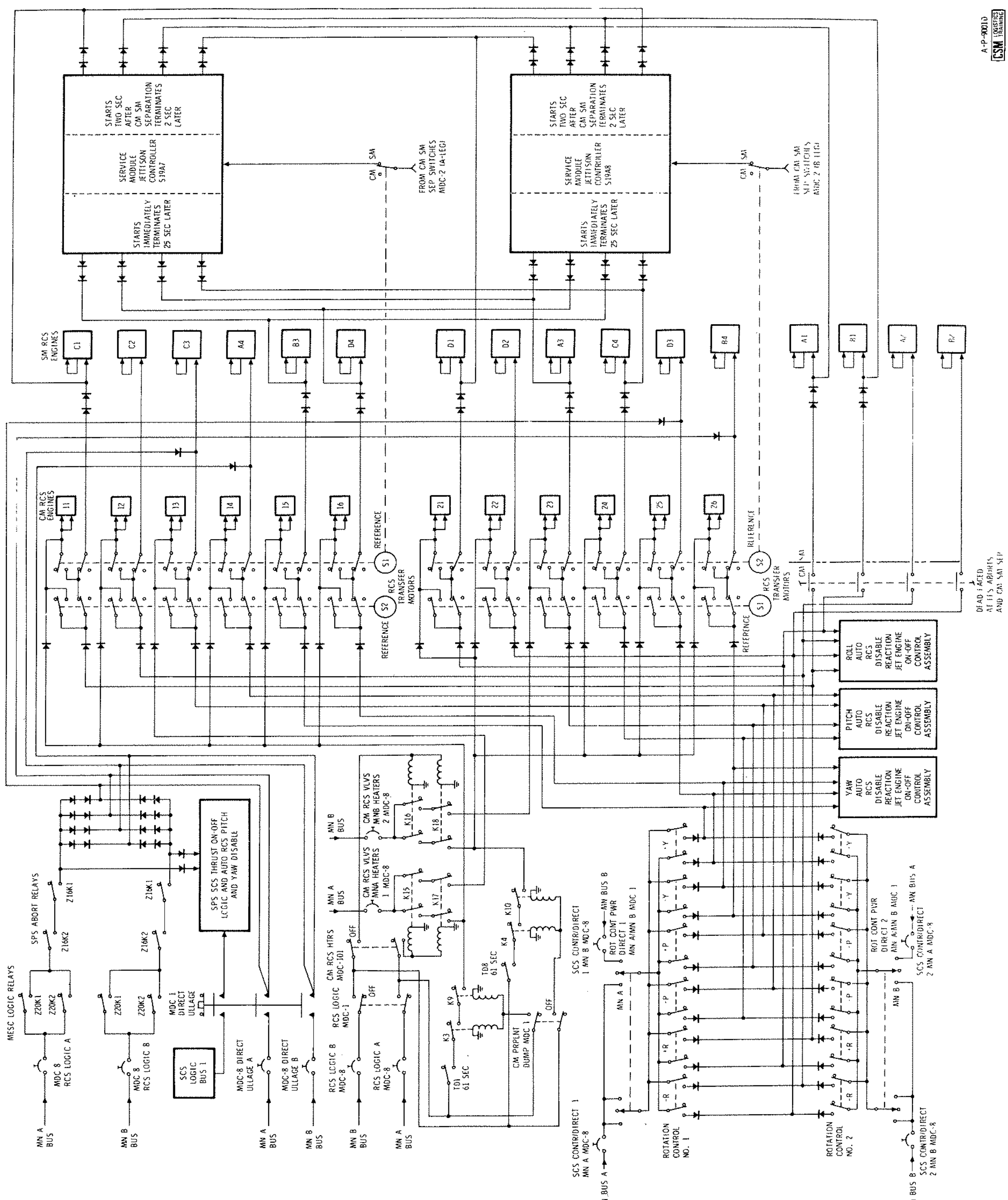

Figure 2.5-4. CSM RCS Direct Control

BUS POWER	CIRCUIT BREAKER MDC-8	DIRECT 1 SWITCH MDC 1	ROTATION CONTROL	SM ENGINE				CM ENGINE				TRANSFER MOTOR
				QUAD	MANEUVER	SCS NO.	PROP NO.	SYSTEM	MANEUVER	SCS NO.	PROP NO.	
MN A	CONTR/DIRECT RCS 1A	MNA/MNB R.C. 1	I+P	C	+P	C3	S19A3B3	1	+P	13	C19B7	S2 & S1
MN B	CONTR/DIRECT RCS 1B	MNA/MNB R.C. 1	I+P	A	+P	A3	S19A1B1	2	+P	23	C19B8	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA R.C. 1	I+P	C	+P	C3	S19A3B3	1	+P	13	C19B7	S2 & S1
		MNA R.C. 1	I+P	A	+P	A3	S19A1B1	2	+P	23	C19B8	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA/MNB R.C. 1	I-P	A	-P	A4	S19A1B3	1	-P	14	C19B11	S2 & S1
MN B	CONTR/DIRECT RCS 1B	MNA/MNB R.C. 1	I-P	C	-P	C4	S19A3B1	2	-P	24	C19B12	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA R.C. 1	I-P	A	-P	A4	S19A1B3	1	-P	14	C19B11	S2 & S1
		MNA R.C. 1	I-P	C	-P	C4	S19A3B1	2	-P	24	C19B12	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA/MNB R.C. 1	I+Y	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	S2 & S1
MN B	CONTR/DIRECT RCS 1B	MNA/MNB R.C. 1	I+Y	D	+Y	D3	S19A4B1	2	+Y	25	C19B10	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA R.C. 1	I+Y	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	S2 & S1
		MNA R.C. 1	I+Y	D	+Y	D3	S19A4B1	2	+Y	25	C19B10	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA/MNB R.C. 1	I-Y	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	S2 & S1
MN B	CONTR/DIRECT RCS 1B	MNA/MNB R.C. 1	I-Y	B	-Y	B4	S19A2B1	2	-Y	26	C19B2	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA R.C. 1	I-Y	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	S2 & S1
		MNA R.C. 1	I-Y	B	-Y	B4	S19A2B1	2	-Y	26	C19B2	S1 & S2
MN A	CONTR/DIRECT RCS 1A	MNA/MNB R.C. 1	I+R	C	CW+R	C1	S19A3B4	1	CW+R	11	C19B5	S2 & S1
		MNA/MNB R.C. 1	I+R	A	CW+R	A1	S19A1B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN B	CONTR/DIRECT RCS 1B	MNA/MNB R.C. 1	I+R	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6	S1 & S2
		MNA/MNB R.C. 1	I+R	B	CW+R	B1	S19A2B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN A	CONTR/DIRECT RCS 1A	MNA R.C. 1	I+R	C	CW+R	C1	S19A3B4	1	CW+R	11	C19B5	S2 & S1
		MNA R.C. 1	I+R	A	CW+R	A1	S19A1B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
		MNA R.C. 1	I+R	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6	S1 & S2
		MNA R.C. 1	I+R	B	CW+R	B1	S19A2B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN A	CONTR/DIRECT RCS 1A	MNA/MNB R.C. 1	I-R	C	CCW-R	C2	S19A3B2	1	CCW-R	12	C19B3	S2 & S1
		MNA/MNB R.C. 1	I-R	A	CCW-R	A2	S19A1B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN B	CONTR/DIRECT RCS 1B	MNA/MNB R.C. 1	I-R	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4	S1 & S2
		MNA/MNB R.C. 1	I-R	B	CCW-R	B2	S19A2B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN A	CONTR/DIRECT RCS 1A	MNA R.C. 1	I-R	C	CCW-R	C2	S19A3B2	1	CCW-R	12	C19B3	S2 & S1
		MNA R.C. 1	I-R	A	CCW-R	A2	S19A1B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
		MNA R.C. 1	I-R	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4	S1 & S2
		MNA R.C. 1	I-R	B	CCW-R	B2	S19A2B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				

P-6066F

Figure 2.5-5. SM-CM RCS Engine Power Supplies (Direct) Rotation Control No. 1

extremely accurate attitude alignment maneuvers during navigational sightings. CSM attitude control is normally maintained by utilizing the applicable pitch, yaw, and roll engines on all four quads. However, in the event of a malfunction or in order to conserve propellants, complete attitude control can be maintained with only two adjacent quads operating.

A functional flow diagram for the SM RCS is shown in figure 2.5-7. Each quad consists of a helium storage vessel that supplies gaseous helium to two solenoid-operated helium isolation valves that are normally open throughout the mission. This allows helium pressure to the regulators, downstream of each helium isolation valve, reducing the high pressure helium to a desired working pressure.

In each quad, the regulated helium pressure is directed through series-parallel check valves. The check valves permit helium pressure to the fuel and oxidizer tanks, and prevent reverse flow of propellant vapors and/or liquid. A pressure relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressures.

BUS POWER	CIRCUIT BREAKER MDC-8	DIRECT 2 SWITCH MDC 1	ROTATION CONTROL	SM ENGINE				CM ENGINE				TRANSFER MOTOR
				QUAD	MANEUVER	SCS NO.	PROP NO.	SYSTEM	MANEUVER	SCS NO.	PROP NO.	
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2	2+P	C	+P	C3	S19A3B3	1	+P	13	C19B7	S2 & S1
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2	2+P	A	+P	A3	S19A1B1	2	+P	23	C19B8	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNB R.C. 2	2+P	C	+P	C3	S19A3B3	1	+P	13	C19B7	S2 & S1
		MNB R.C. 2	2+P	A	+P	A3	S19A1B1	2	+P	23	C19B8	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2	2-P	A	-P	A4	S19A1B3	1	-P	14	C19B11	S2 & S1
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2	2-P	C	-P	C4	S19A3B1	2	-P	24	C19B12	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNB R.C. 2	2-P	A	-P	A4	S19A1B3	1	-P	14	C19B11	S2 & S1
		MNB R.C. 2	2-P	C	-P	C4	S19A3B1	2	-P	24	C19B12	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2	2+Y	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	S2 & S1
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2	2+Y	D	+Y	D3	S19A4B1	2	+Y	25	C19B10	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNB R.C. 2	2+Y	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	S2 & S1
		MNB R.C. 2	2+Y	D	+Y	D3	S19A4B1	2	+Y	25	C19B10	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2	2-Y	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	S2 & S1
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2	2-Y	B	-Y	B4	S19A2B1	2	-Y	26	C19B2	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNB R.C. 2	2-Y	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	S2 & S1
		MNB R.C. 2	2-Y	B	-Y	B4	S19A2B1	2	-Y	26	C19B2	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2	2+R	C	CW+R	C1	S19A3B4	1	CW+R	11	C19B5	S2 & S1
		MNA/MNB R.C. 2	2+R	A	CW+R	A1	S19A1B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2	2+R	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6	S1 & S2
		MNA/MNB R.C. 2	2+R	B	CW+R	B1	S19A2B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN B	CONTR/DIRECT RCS 2B	MNB R.C. 2	2+R	C	CW+R	C1	S19A3B4	1	CW+R	11	C19B5	S2 & S1
		MNB R.C. 2	2+R	A	CW+R	A1	S19A1B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
		MNB R.C. 2	2+R	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6	S1 & S2
		MNB R.C. 2	2+R	B	CW+R	B1	S19A2B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2	2-R	C	CCW-R	C2	S19A3B2	1	CCW-R	12	C19B3	S2 & S1
		MNA/MNB R.C. 2	2-R	A	CCW-R	A2	S19A1B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2	2-R	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4	S1 & S2
		MNA/MNB R.C. 2	2-R	B	CCW-R	B2	S19A2B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
MN B	CONTR/DIRECT RCS 2B	MNB R.C. 2	2-R	C	CCW-R	C2	S19A3B2	1	CCW-R	12	C19B3	S2 & S1
		MNB R.C. 2	2-R	A	CCW-R	A2	S19A1B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS				
		MNB R.C. 2	2-R	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4	S1 & S2
		MNB R.C. 2	2-R	B	CCW-R	B2	S19A2B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS				

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Figure 2.5-6. SM-CM RCS Engine Power Supplies (Direct) Rotation Control No. 2

In each quad, the helium entering the propellant tanks creates a pressure buildup around the positive expulsion bladders forcing the propellants in the tank to be expelled into the propellant distribution lines. Propellants from the primary fuel and oxidizer tanks flow through the primary propellant isolation valves that are normally open. Propellants from the secondary fuel and oxidizer tanks flow through the secondary propellant isolation valves that are normally open. The secondary propellant fuel pressure isolation valve will be opened when the secondary propellant fuel pressure transducer (located downstream of the primary fuel tank) senses a drop in pressure. The drop in pressure indicates the primary fuel tank is at propellant depletion. Opening the secondary propellant fuel pressure valve at this time allows regulated helium pressure to the secondary fuel tank. It has been determined that due to the O/F ratio the fuel tank will deplete ahead of the oxidizer tanks, thus

RCS

RCS

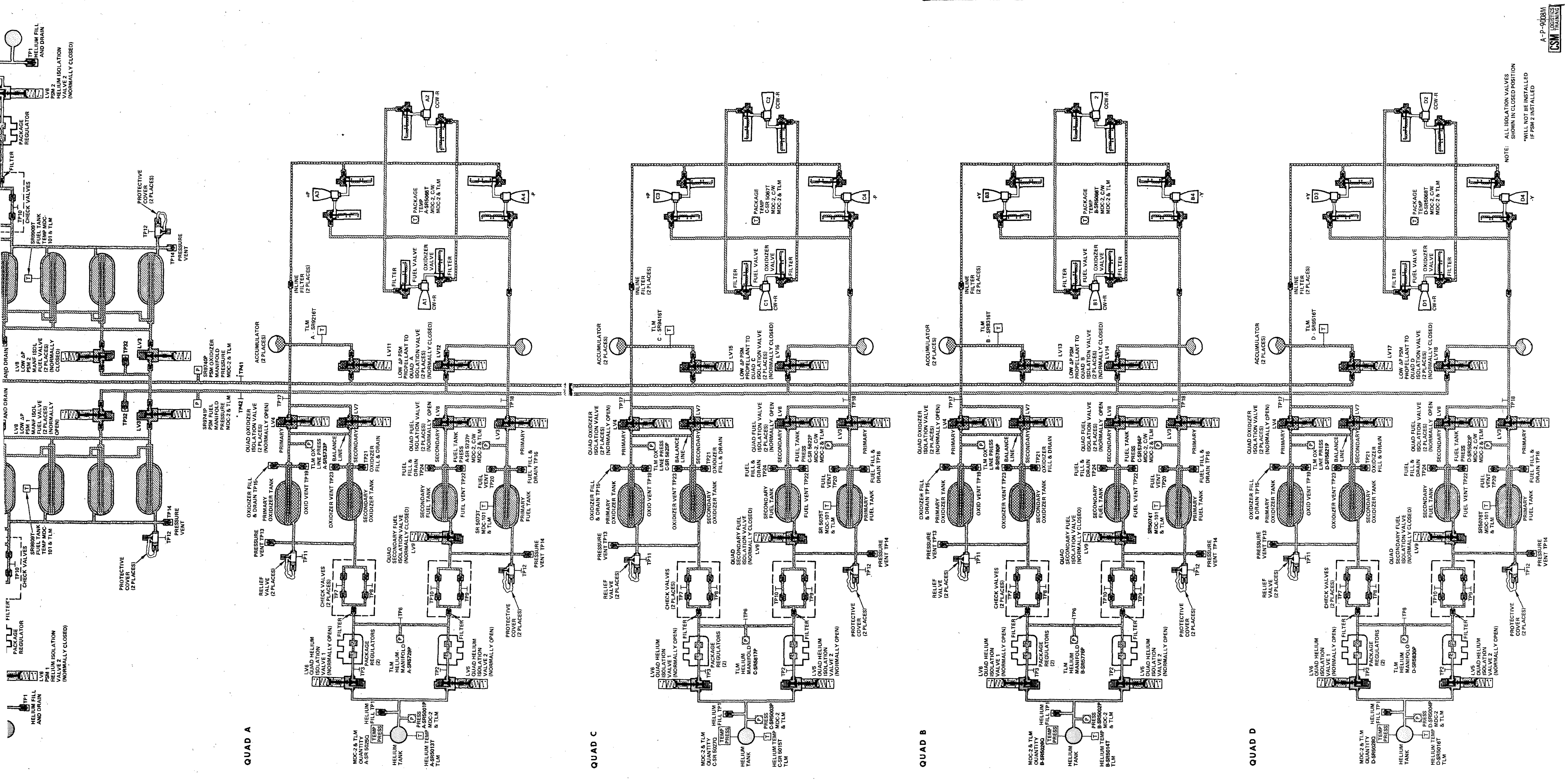
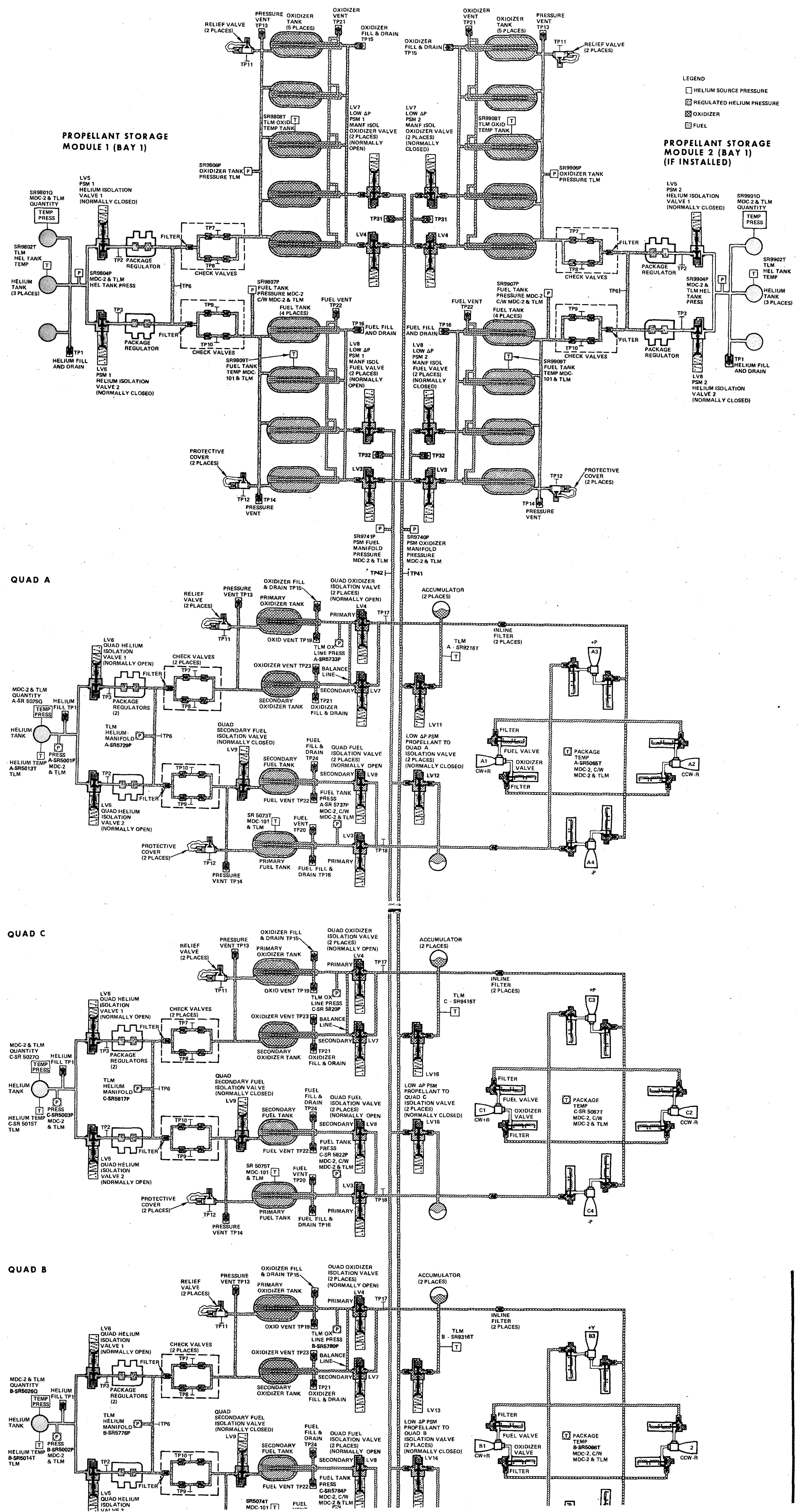


Figure 2.5-7. SM RCS Functional Flow


PROPELLANT STORAGE MODULE 1 (BAY 1)
PROPELLANT STORAGE MODULE 2 (BAY 1) (IF INSTALLED)
LEGEND
HELIUM SOURCE PRESSURE
REGULATED HELIUM PRESSURE
OXIDIZER
FUEL
QUAD A
QUAD C
QUAD B

accounting for the secondary propellant fuel pressure isolation valve installation in the helium pressurization path to the secondary fuel tank only. Thus, this is the normal method of supplying propellants to the cluster of four engines of the quad.

Each propellant storage module has three helium storage vessels. It is noted that propellant storage module 2 may not be installed. The helium storage vessels of each propellant storage module supply gaseous helium to its respective helium valves. The two helium solenoid-operated valves of each propellant storage module are normally closed throughout the mission. If the helium isolation valves of a module are opened, the helium source pressure is applied to the helium pressure regulators. The helium pressure regulators are downstream of each helium isolation valve. The regulators reduce the high source pressure to a desired working pressure.

The propellant storage module regulated helium pressure is directed through series-parallel check valves. The check valves provide the same function as in the quads. A pressure relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressures.

RCS

The propellant storage module regulated helium pressure enters the propellant tanks creating the positive expulsion of the propellants from the tanks into the respective module propellant distribution lines. The respective propellant storage module manifold fuel and oxidizer isolation valves are normally open. When the module manifold fuel and oxidizer isolation valves are open, the propellants are directed to the propellant storage module fuel and oxidizer propellant isolation valves of each quad. The propellant storage module fuel and oxidizer propellant isolation valves of each quad are normally closed. When the propellant storage module fuel and oxidizer propellant isolation valves of a quad are opened, the propellants of the respective module are supplied to the cluster of four engines for that quad.

Thus, oxidizer and fuel are distributed to the four engines by a parallel feed system. The fuel valve on each engine opens approximately two milliseconds prior to the oxidizer valve, to provide proper engine operation. Each valve assembly contains orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel impinge, atomize, and are ignited by hypergolic reaction within the combustion chamber. The injector valves are controlled automatically by the reaction jet engine ON-OFF control assembly. Direct manual control is provided for rotational maneuvers and direct ullage only. The engine injector valves are spring-loaded closed. This system configuration maintains propellants under constant pressure, at the engine injector valves, providing rapid consistent response rates to thrust ON-OFF commands.

The various pressure and temperature monitoring points of the SM RCS are illustrated in figure 2.5-7. Each pressure and temperature monitoring point is identified by a measurement number. In addition, each identification indicates if it is transmitted to TLM, main display console, caution/warning, and/or panel 101. Figures 2.5-8 and 2.5-9 illustrate the measurements that are transmitted to MDC-2, MDC-3, and panel 101.

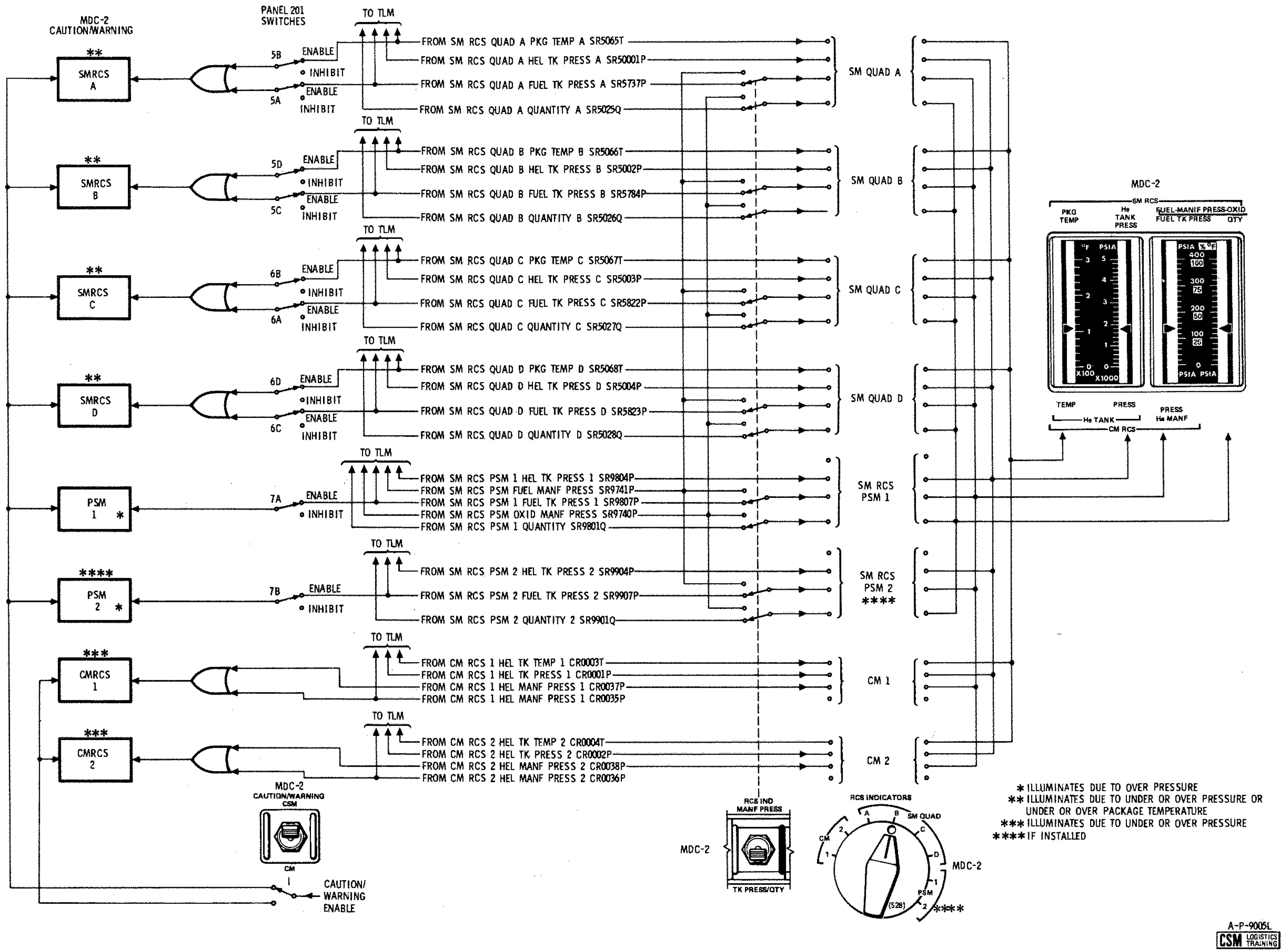


Figure 2.5-8. MDC-2 RCS Indicators

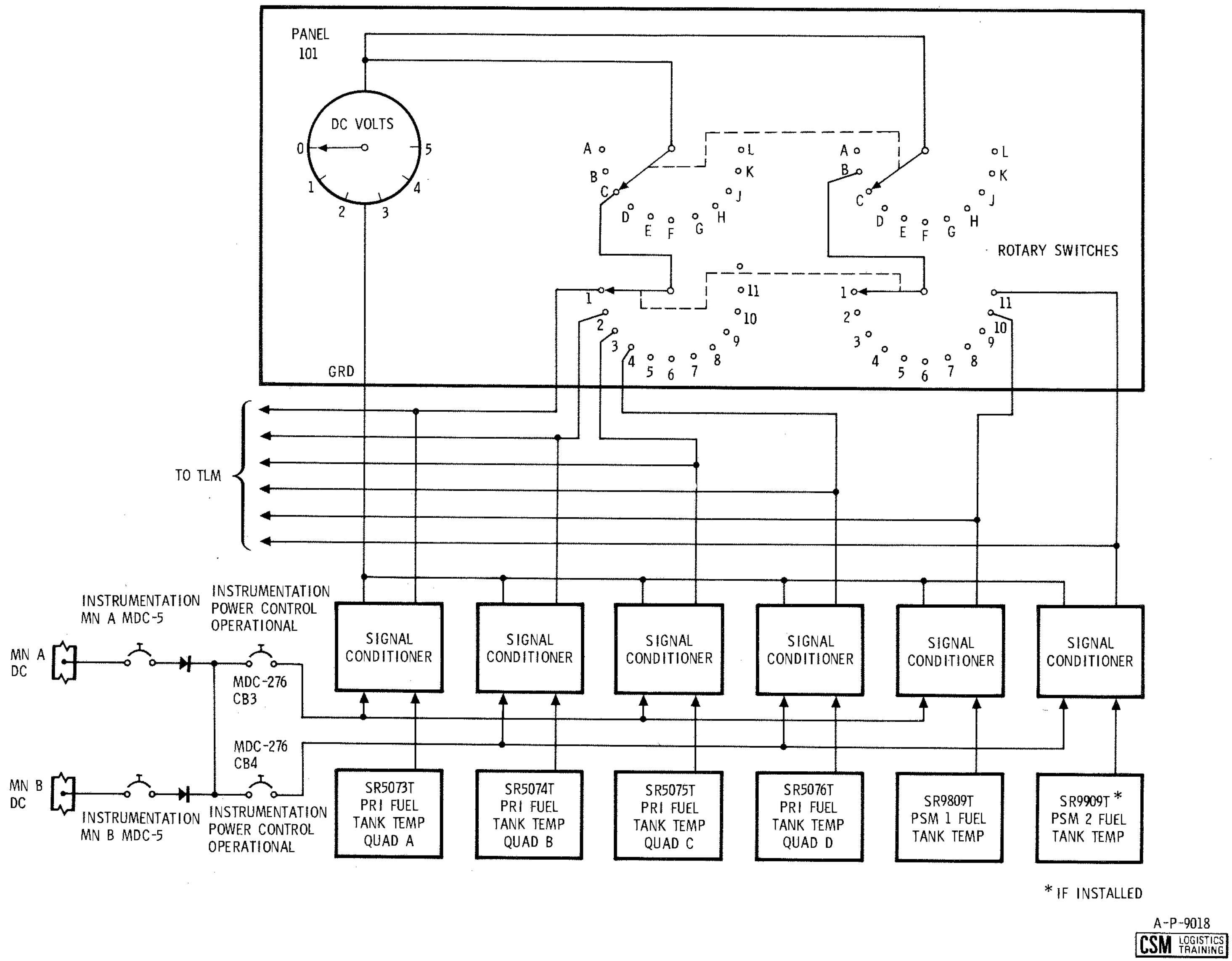


Figure 2.5-9. SM RCS Temperature Monitoring, Panel 101

2.5.2 SM RCS MAJOR COMPONENT/SUBSYSTEM DESCRIPTION

The SM RCS is composed of four separate, individual quads, each quad contains the following four major subsystems:

- Pressurization
- Propellant - primary/secondary
- Rocket engine
- Temperature control system

The SM RCS is, in addition, composed of one module in bay I of the service module plus the provisions for the installation of another module. The module consists of the following three major subsystems:

- Pressurization
- Propellant
- Temperature control system

2.5.2.1 Pressurization Subsystem

The pressurization subsystem of a quad regulates and distributes the helium to the quad propellant tanks (figure 2.5-7). Each quad consists of a helium storage tank, isolation valves, pressure regulators, and lines necessary for filling, draining, and distribution of the helium.

The pressurization subsystem of the module regulates and distributes the helium to the module propellant tanks. A module consists of three helium storage tanks, isolation valves, pressure regulators, and lines necessary for filling, draining, and distribution of the helium.

2.5.2.1.1 Helium Supply Tank

The total high-pressure helium supply for a quad is contained within a single, spherical storage tank.

The total high-pressure helium supply for a module is contained within three spherical storage tanks.

2.5.2.1.2 Quad and Propellant Storage Module Helium Isolation Valves

The helium isolation valves located between the helium tank of a quad and helium tanks of a module and the pressure regulators contain two solenoids. One solenoid is energized momentarily to magnetically latch the valve open (figures 2.5-7 and 2.5-10); the remaining solenoid is energized momentarily to unlatch the valve, and spring-pressure and helium-pressure forces the valve closed.

The two helium isolation valves of a quad are controlled by one SM RCS QUAD HELIUM switch on panel 2. The momentary OPEN position energizes both helium valves of a quad into the magnetic latch (open). The momentary CLOSE position energizes both helium valves of a quad to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid. The helium isolation valves in each quad are normally open in respect to system source pressure.

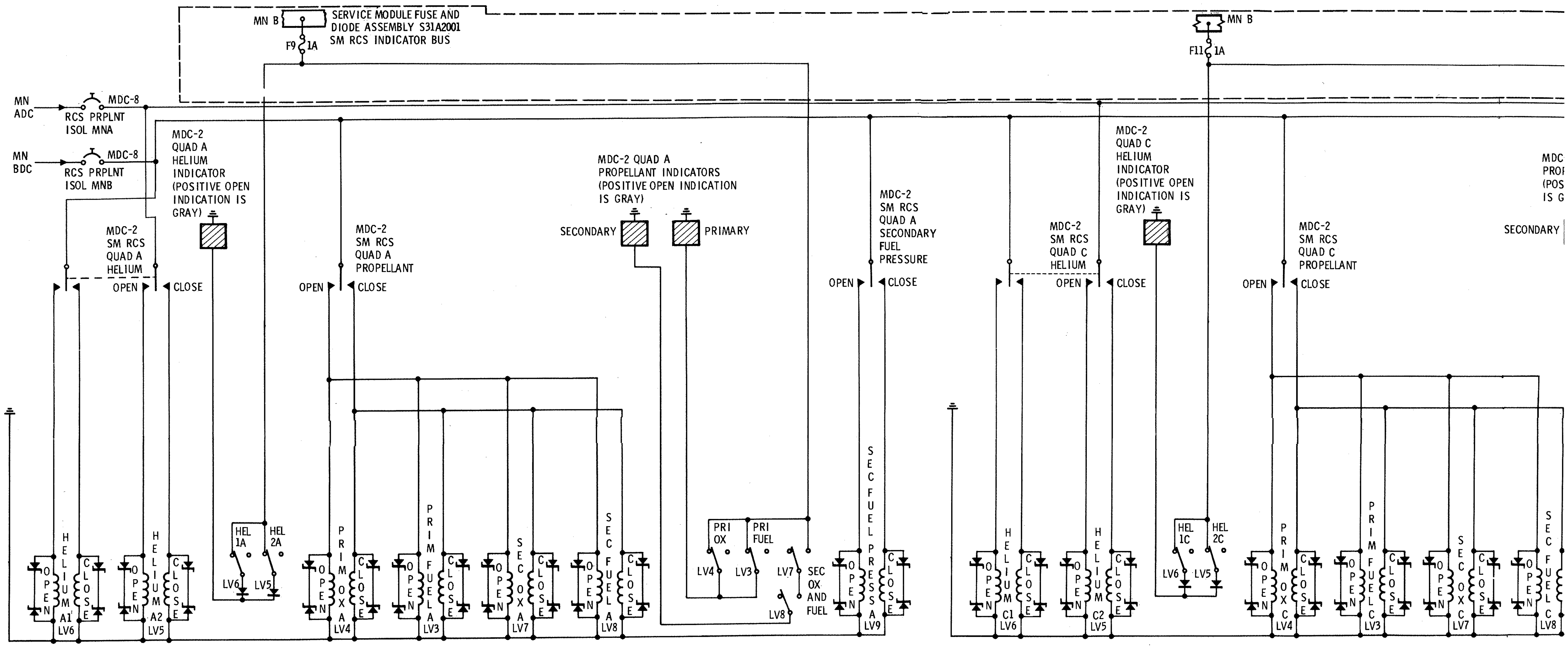
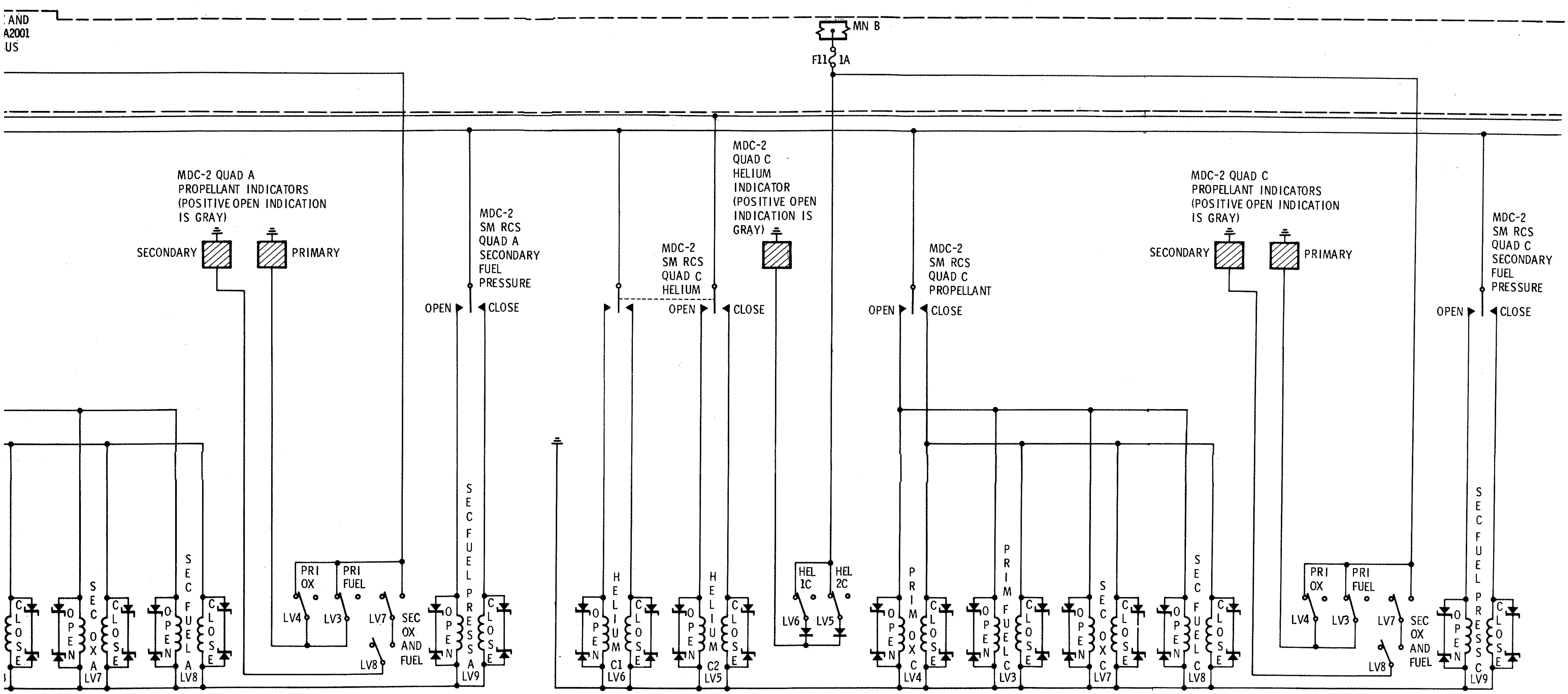


Figure 2.5-10. SM RCS Valve Control Circuits (Sheet 1 of 4)



MN B
F11 1A
MDC-2 QUAD A PROPELLANT INDICATORS (POSITIVE OPEN INDICATION IS GRAY)
SECONDARY
PRIMARY
MDC-2 SM RCS QUAD A SECONDARY FUEL PRESSURE
OPEN
CLOSE
MDC-2 SM RCS QUAD C HELIUM
MDC-2 QUAD C HELIUM INDICATOR (POSITIVE OPEN INDICATION IS GRAY)
MDC-2 SM RCS QUAD C PROPELLANT
MDC-2 QUAD C PROPELLANT INDICATORS (POSITIVE OPEN INDICATION IS GRAY)
MDC-2 SM RCS QUAD C SECONDARY FUEL PRESSURE
PRI OX
PRI FUEL
LV4
LV3
LV7
LV8
SEC OX AND FUEL
SEC OX A LV7
SEC FUEL A LV8
SEC FUEL PRESS A LV9
HELIUM C1 LV6
HELIUM C2 LV5
HEL 1C
HEL 2C
LV6
LV5
PRIM OX C LV4
PRIM FUEL C LV3
SEC OX C LV7
SEC FUEL C LV8
SEC FUEL PRESS C LV9
OPEN
CLOSE

Sheet 1 of 4)

RCS

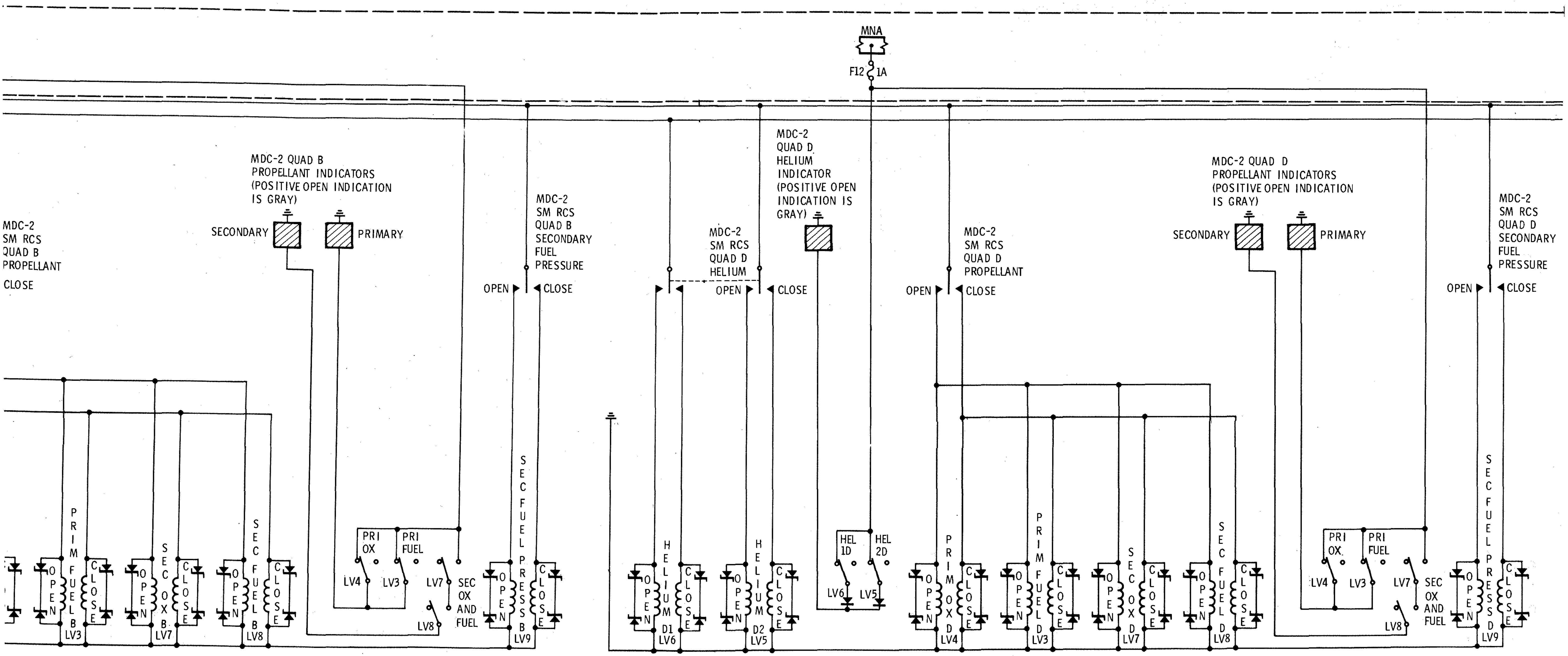


Figure 2.5-10. SM RCS Valve Control Circuits (Sheet 2 of 4)

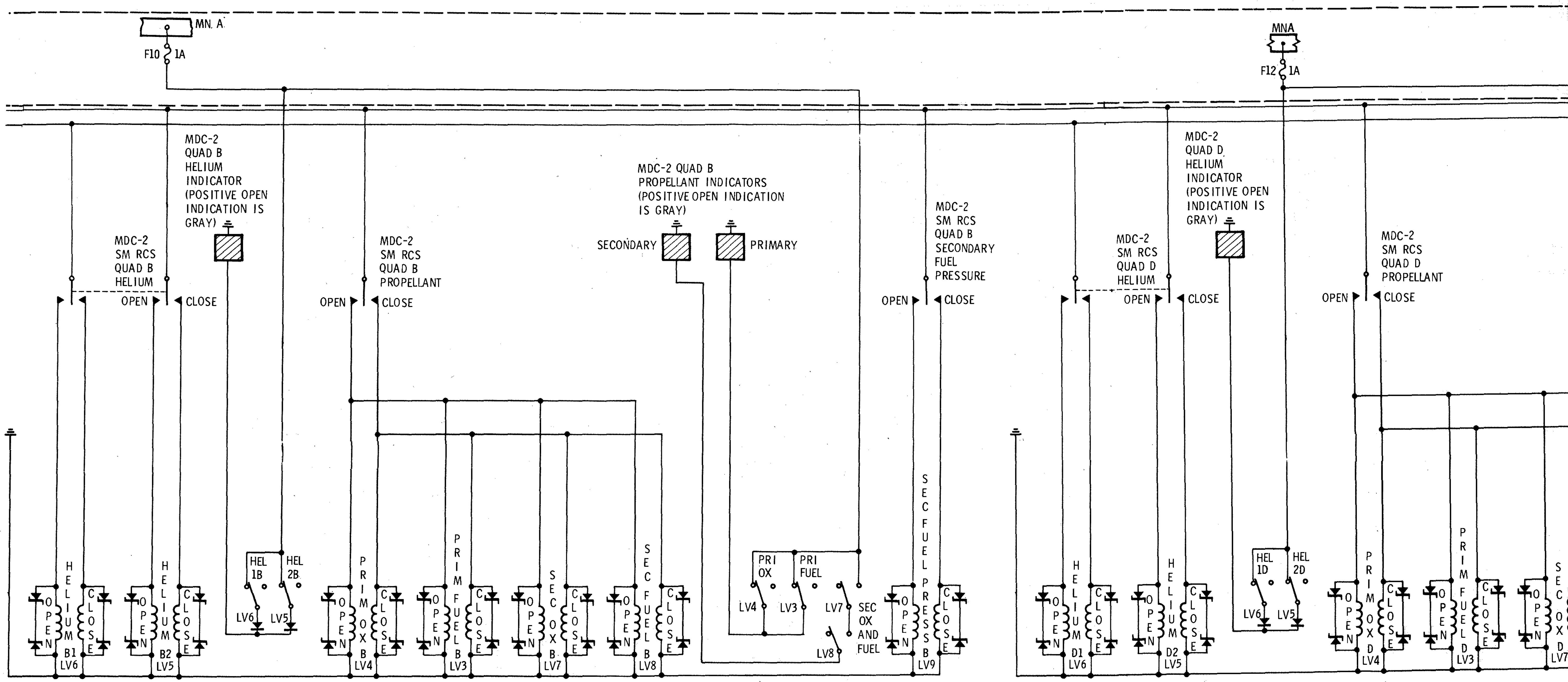


Figure 2.5-10. S

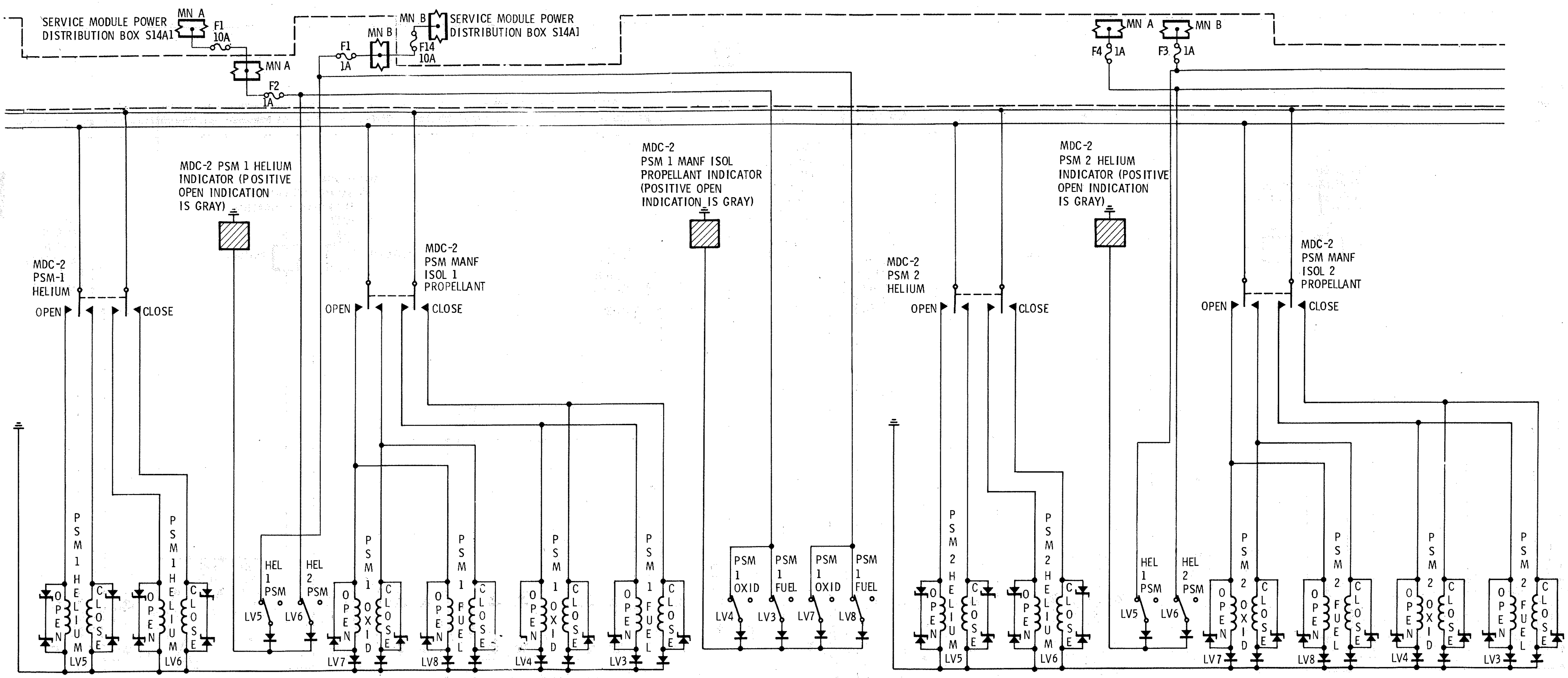
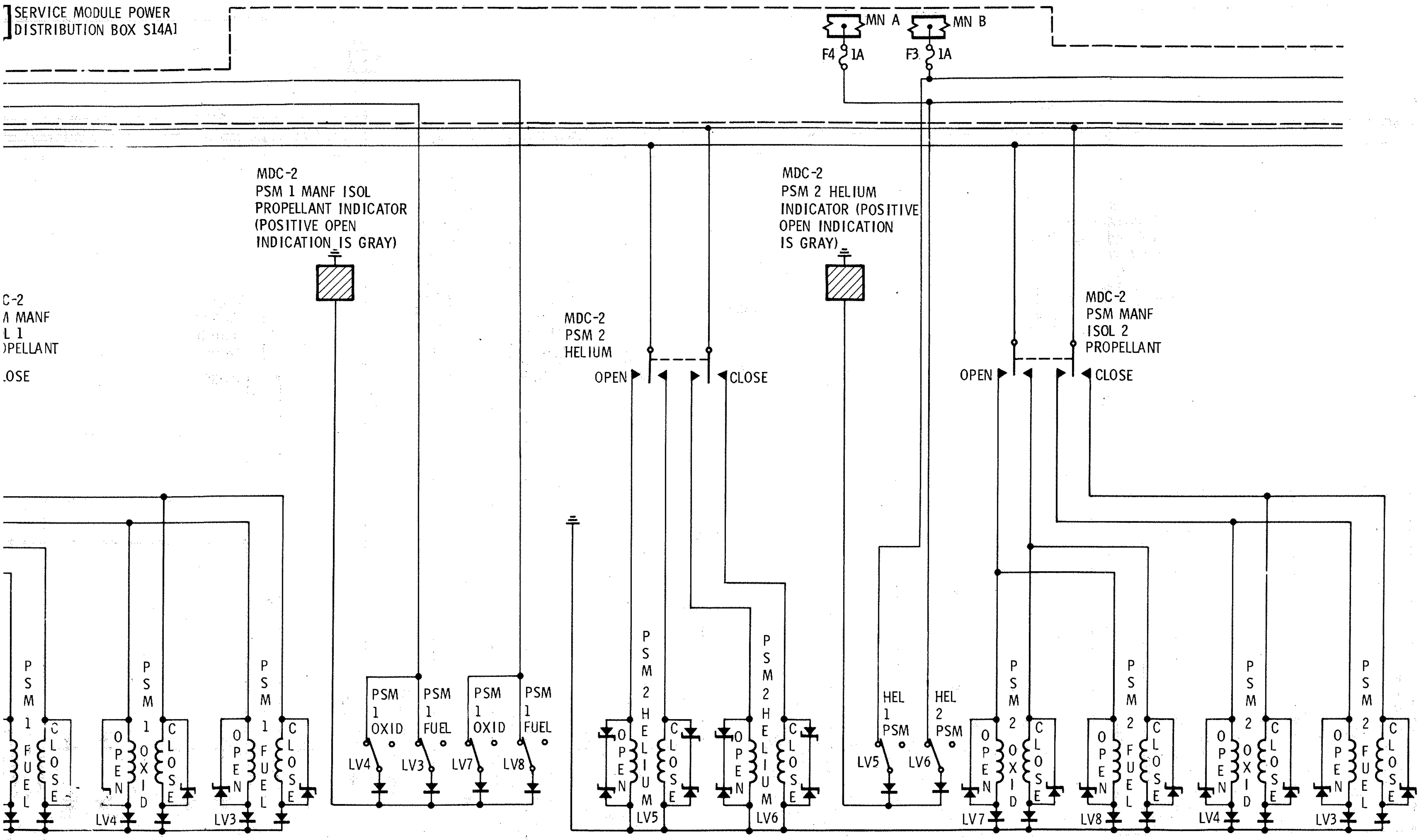


Figure 2.5-10. SM RCS Valve Control Circuits (Sheet 3 of 4)



SERVICE MODULE POWER DISTRIBUTION BOX S14A1
MN A
MN B
F4 1A
F3 1A
MDC-2 PSM 1 MANF ISOL PROPELLANT INDICATOR (POSITIVE OPEN INDICATION IS GRAY)
MDC-2 PSM 2 HELIUM INDICATOR (POSITIVE OPEN INDICATION IS GRAY)
C-2 MANF L 1 PELLANT
OSE
MDC-2 PSM 2 HELIUM
OPEN
CLOSE
MDC-2 PSM MANF ISOL 2 PROPELLANT
OPEN
CLOSE
PSM 1 FUEL
PSM 1 OXID
PSM 1 FUEL
OPEN
CLOSE
LV4
LV3
PSM 1 OXID
PSM 1 FUEL
PSM 1 OXID
PSM 1 FUEL
LV4
LV3
LV7
LV8
PSM 2 HELIUM
LV5
LV6
HEL 1 PSM
HEL 2 PSM
LV5
LV6
PSM 2 OXID
PSM 2 FUEL
PSM 2 OXID
PSM 2 FUEL
LV7
LV8
LV4
LV3

s (Sheet 3 of 4)

RCS

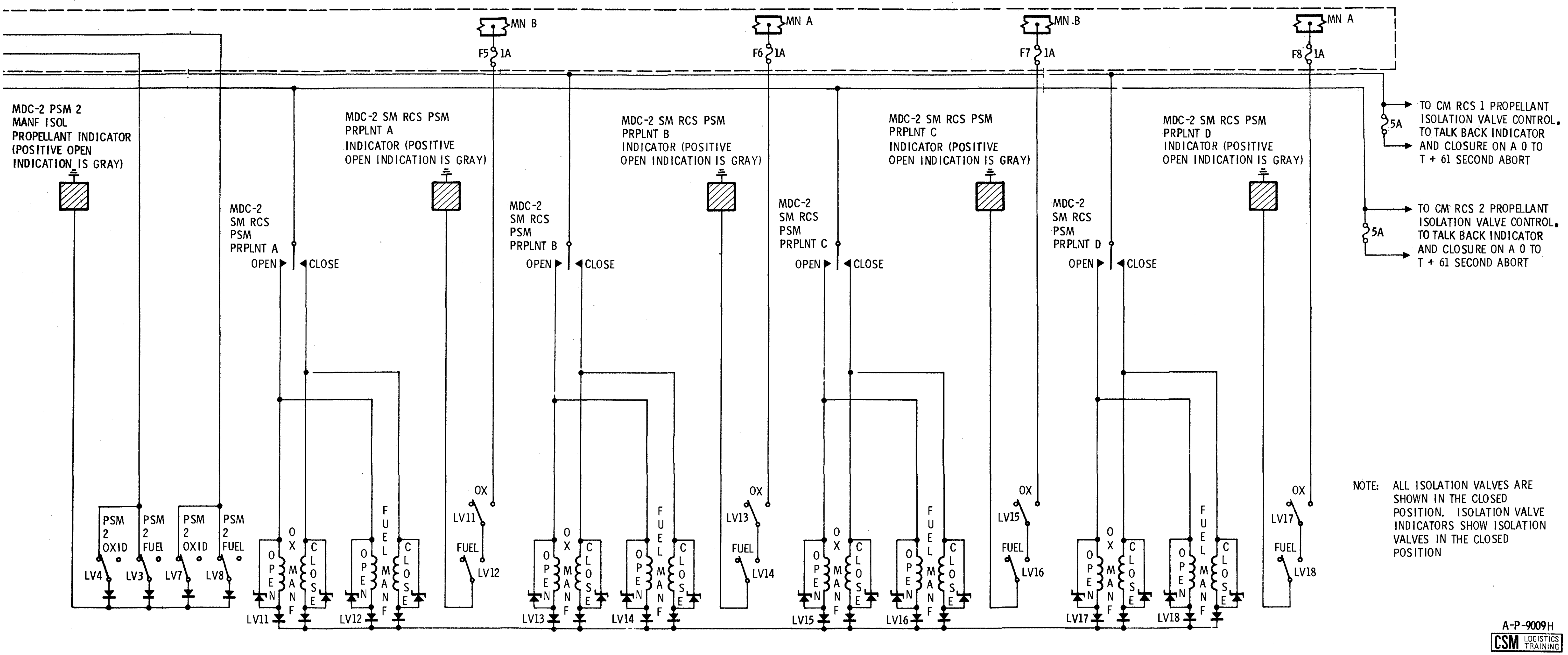


Figure 2.5-10. SM RCS Valve Control Circuits (Sheet 4 of 4)

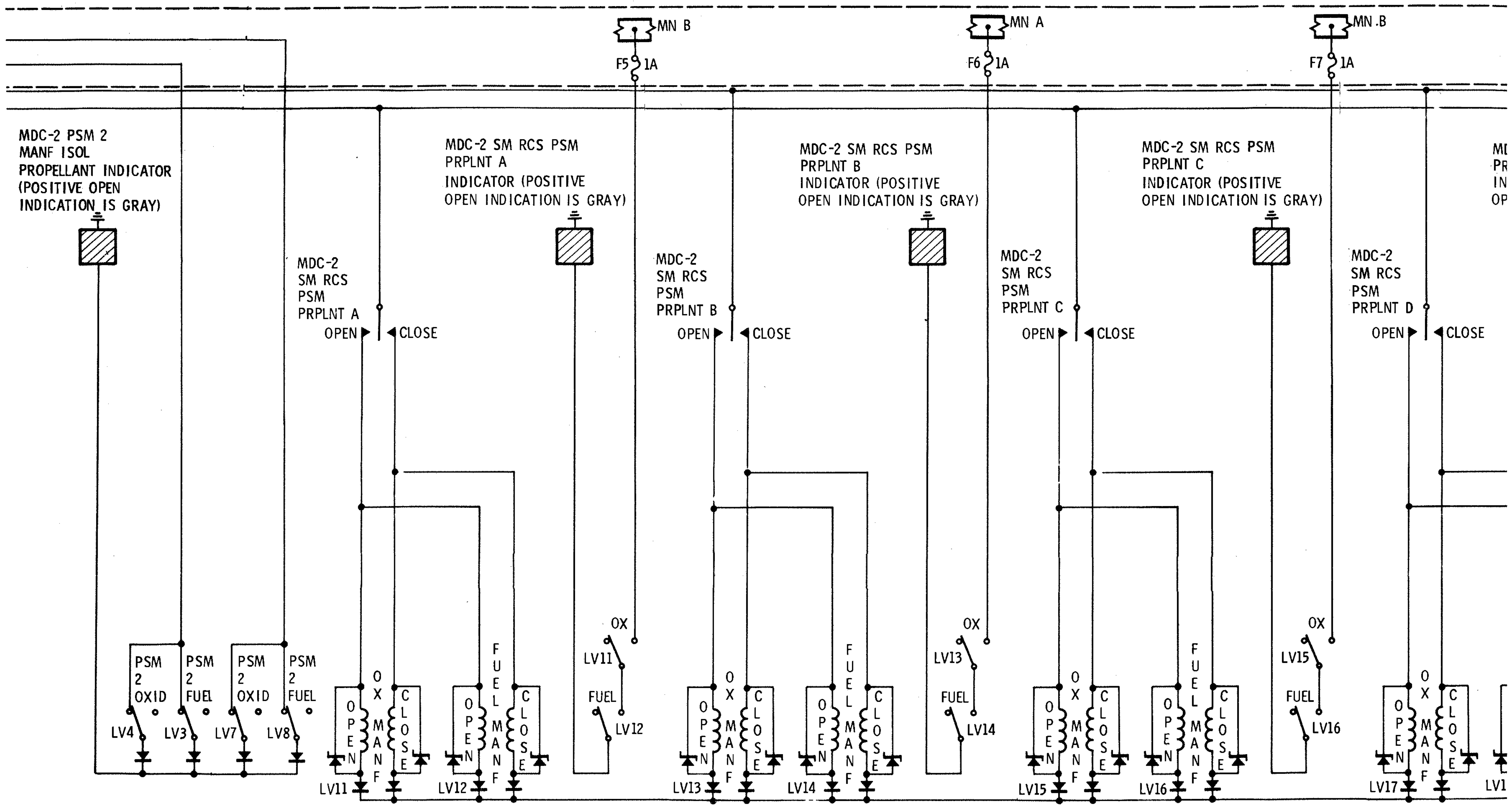


Figure 2.5-10. SI

The two helium isolation valves of a quad contain a position switch that is in parallel to a position talkback indicator above the respective quad helium switch on panel 2. When both helium valves of a quad are open, both position switches are open and the indicator on panel 2 for that quad is gray (same color as the panel) indicating positively that both valves are open. When the position switch of either helium valve of a quad is actuated closed, the helium valve indicator on panel 2 for that quad is barber pole (diagonal lines) indicating that either or both valves of that quad are closed in respect to system source pressure.

The two helium isolation valves of a propellant storage module are controlled by one SM RCS PSM He switch on panel 2. The momentary OPEN position energizes both helium valves of a PSM into the magnetic latch (open). The momentary CLOSE position energizes both helium valves of a PSM to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid. The helium isolation valves in a PSM are normally closed in respect to system source pressure. The PSM helium valves are opened when the PSM is utilized.

The two helium isolation valves of a propellant storage module contain a position switch that is in parallel to a position talkback indicator above the respective propellant storage helium switch on panel 2. When both helium valves of a PSM are open, both position switches are open, and the indicator on panel 2 for that PSM is gray (same color as the panel) indicating positively that both valves are open. When the position switch of either helium valve of a PSM is actuated closed, the helium valve indicator on panel 2 for that PSM is barber pole (diagonal lines) indicating that either or both valves of that PSM are closed in respect to system source pressure.

The helium isolation valves of a quad are normally magnetically latched to the open position, and the helium isolation valves of a PSM are normally spring-pressure closed.

2.5.2.1.3 Pressure Regulator Assemblies

Helium pressure regulation is accomplished in each quad and in each propellant storage module by two regulator assemblies connected in parallel, with one assembly located downstream of each helium isolation valve. Each assembly incorporates two regulators, a primary and a secondary, connected in series and a filter at the inlet to each regulator assembly. The secondary regulator remains open as the primary regulator functions properly. In the event of the primary regulator fails open, the secondary regulator, in series, will maintain slightly higher but acceptable pressures.

2.5.2.1.4 Check Valve Assemblies

Two check valve assemblies are incorporated in each quad and in each propellant storage module. One assembly is located upstream to the oxidizer tanks and the other upstream to the fuel tanks. The check valves permit the regulated helium pressure to be directed to the propellant tanks. The check valves also provide a checking action against a reverse flow of propellant liquid and/or vapor into the pressurization system in the event seepage or failure occurs in the propellant tank bladders. Filters are incorporated in the inlet to each check valve assembly and each test port.

2.5.2.1.5 Pressure Relief Valves

The helium relief valve in each quad and in each propellant storage module contains a burst diaphragm, filter, a bleed device, and the relief valve. The burst diaphragm is installed to provide a more positive seal against helium than that of the actual relief valve. The burst diaphragm ruptures at a predetermined pressure. The burst diaphragm is of the nonfragmentation type, but in the event of any fragmentation, the filter retains any fragmentation and prevents particles from flowing onto the relief valve seat. The relief valve will relieve at a pressure slightly higher than that of the burst diaphragm rupture pressure and relieve the excessive pressure overboard protecting the fuel and oxidizer tanks. The relief valve will reseat at a predetermined pressure.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage across the diaphragm, or vents the cavity upon completion of performing a checkout of the relief valve from the vent port on the relief valve. The bleed device is normally open and will close when the pressure increases up to a predetermined pressure. The bleed device automatically opens when the pressure decreases to the bleed valve opening pressure.

A protective cover is installed over the relief valve vent port and bleed valve cavity port to prevent moisture accumulation and foreign matter entrance. The covers are left in place at lift-off.

2.5.2.1.6 Distribution Plumbing

Brazed joint tubing is used to distribute regulated helium in each RCS quad from the helium storage vessel to the propellant tanks and in the propellant storage module from the helium storage vessels to the propellant tanks.

2.5.2.1.7 Quad Secondary Fuel Pressure Isolation Valve

The quad secondary fuel pressure isolation valve in the pressurization line to the secondary fuel tank contains two solenoids: one solenoid is energized momentarily to magnetically latch the valve open; the remaining solenoid is energized momentarily to unlatch the valve, and spring pressure and helium pressure forces the valve closed.

The secondary fuel pressure isolation valve in each quad is controlled individually by its own SM RCS QUAD SEC FUEL PRESS switch on panel 2. The momentary OPEN position energizes the valve into the magnetic latch (open); the momentary CLOSE position energizes the valve to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid. The valve is normally closed in respect to system pressure.

There is no position indicator talkback of the valve position to the control and display panel.

The valve will be opened when the quad secondary fuel pressure decreases, which is indicated on the FUEL TK PRESS indicator meter on panel 2. When the indicator meter starts decreasing in pressure, the indication is normally that the primary fuel tank of a given quad is depleted.

2.5.2.2 Propellant Subsystem

This subsystem for each quad consists of two oxidizer tanks, two fuel tanks, two oxidizer and two fuel isolation valves, a fuel and oxidizer inline filter, oxidizer balance line, a fuel and oxidizer accumulator, and associated distribution plumbing.

This subsystem for each propellant storage module consists of five oxidizer tanks, four fuel tanks, two oxidizer and two fuel manifold isolation valves, four propellant storage module quad oxidizer and four propellant storage module quad fuel isolation valves, and associated distribution plumbing.

2.5.2.2.1 Quad Primary and Secondary Oxidizer Tanks

Each quad oxidizer supply is contained in two titanium alloy, hemispherically domed cylindrical tanks. The tanks are mounted to the RCS panel. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer. The bladder is attached to the diffuser tube at each end of each tank. The diffuser tube acts as the propellant outlet.

When the tanks are pressurized, the helium surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, forcing the oxidizer into the diffuser tube assembly and on out of the tank outlet into the manifold, providing expulsion during zero g's.

An oxidizer fluid balance line is incorporated on the oxidizer tank side of the propellant isolation valves between the primary and secondary oxidizer tanks (figure 2.5-7). In prelaunch, the helium and four propellant isolation valves of each quad are opened. The primary oxidizer tank will flow oxidizer to the secondary tank because the primary tank is located above the secondary tank. This displaces the ullage area in the secondary tank to the primary and fills the secondary full of oxidizer. If the launch continues normally, this creates no problem. However, if a long hold period occurs, the four propellant isolation valves will be closed and the fluid in the secondary tank will expand because of thermal growth. The fluid balance line allows the oxidizer to bleed from the secondary to the primary tank preventing possible rupture of the secondary tank.

The fuel tanks could have a similar problem except that the secondary propellant fuel pressure valve is closed prior to the opening of the four propellant isolation valves. This prevents transfer of fuel from one tank to the other.

2.5.2.2.2 Quad Primary and Secondary Fuel Tanks

Each quad fuel supply is contained in two tanks that are similar in material construction, and operation to that of the oxidizer tanks.

2.5.2.2.3 Propellant Storage Module Oxidizer Tanks

The propellant storage module oxidizer supply is contained in five oxidizer tanks that are similar in material, construction, and operation to that of the quad oxidizer tanks.

2.5.2.2.4 Propellant Storage Module Fuel Tanks

The propellant storage module fuel supply is contained in four fuel tanks that are similar in material, construction, and operation to that of the quad fuel tanks.

2.5.2.2.5 Quad Propellant Isolation Valves

Each quad propellant isolation valve contains two solenoids: one that is energized momentarily to magnetically latch the valve open; and the remaining solenoid is energized momentarily to unlatch the magnetic latch, and spring pressure and propellant pressure closes the valve.

The propellant isolation valves located in a quad primary fuel and oxidizer lines, as well as the secondary fuel and oxidizer lines, are controlled by the respective single quad SM RCS quad propellant switch on panel 2. The switch for each quad, positioned to OPEN momentarily energizes the respective quad two primary and secondary fuel and oxidizer isolation valves into the magnetic latch (open). The CLOSE momentary position energizes the valves to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid.

The primary fuel and oxidizer valves of each quad contain a position switch that is in parallel to its respective QUAD PRIM PRPLNT position talkback indicator located above the respective SM RCS quad propellant switch on panel 2. When the position switch in both the primary fuel and oxidizer valves of a quad are actuated open, the respective QUAD PRIM PRPLNT indicator on panel 2 will be gray (same color as the panel) indicating positively that both valves of that quad are open in respect to fluid flow. When the position switch in either the primary fuel and oxidizer valves of a quad are actuated closed, the respective QUAD PRIM PRPLNT indicator will be barber pole (diagonal lines) indicating that either valve or both valves of that quad are closed in respect to fluid flow.

The two secondary fuel and oxidizer valves of each quad contain a position switch. The switch is in series to its respective QUAD SEC PRPLNT position talkback indicator, located below the respective SM RCS quad propellant switch on panel 2. When the position switch in both secondary fuel and oxidizer valves of a quad are actuated closed, the respective QUAD SEC PRPLNT indicator on panel 2 will be gray. This indicates positively that both valves of that quad are open in respect to the fluid flow. When the position switch in either the secondary fuel and oxidizer isolation valves of a quad are actuated open, the respective QUAD SEC PRPLNT indicator will be barber pole (diagonal lines) indicating that either valve or both valves of that quad are closed in respect to fluid flow.

The primary and secondary fuel and oxidizer isolation valves of each quad are normally open to the fluid flow.

The primary and secondary fuel and oxidizer isolation valves of a quad are closed to fluid flow in the event the propellant storage module is utilized to supply propellants to the cluster of four engines for that quad or in the event of a failure downstream of the quad isolation valves, such as line rupture, runaway engine, etc.

2.5.2.2.6 Propellant Storage Module Manifold Propellant Isolation Valves

Each propellant storage module manifold fuel and oxidizer low ΔP isolation valve contains two solenoids: one that is energized momentarily to magnetically latch the valve open; and the remaining solenoid is energized momentarily to unlatch the magnetic latch, and spring pressure and propellant pressure closes the valve.

The two manifold fuel and two oxidizer valves of a propellant storage module are controlled by the respective PSM single SM RCS PSM MANF ISOL switch on panel 2. The switch for a PSM, positioned to OPEN momentarily, energizes the respective PSM manifold isolation valves into the magnetic latch (open). The CLOSE momentary position energizes the valves to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid.

Each manifold fuel and oxidizer valve of a PSM contains a position switch that is in parallel to its respective SM RCS PSM MANF ISOL position talkback indicator located above the respective SM RCS PSM MANF ISOL switch on panel 2. When the position switch in each PSM manifold valve of a PSM is actuated open, the respective PSM MANF ISOL indicator on panel 2 will be gray (same color as the panel) indicating positively that all manifold valves of that PSM are open in respect to fluid flow. When the position switch in a PSM manifold valve of a PSM is actuated closed, the respective PSM MANF ISOL indicator on panel 2 will be barber pole (diagonal lines) indicating that one or all manifold valves of that PSM are closed in respect to fluid flow.

The manifold fuel and oxidizer valves of a single PSM are normally open in respect to fluid flow. IF PSM 1 and 2 are installed, PSM 1 MANF fuel and oxidizer valves will be normally open and PSM 2 MANF fuel and oxidizer valves will be normally closed.

2.5.2.2.7 SM RCS Propellant Storage Module Quad Propellant Isolation Valves

Each propellant storage module quad propellant fuel and oxidizer isolation low ΔP valve contains two solenoids: one that is energized momentarily to magnetically latch the valve open; and the remaining solenoid is energized momentarily to unlatch the magnetic latch, and spring pressure and propellant pressure closes the valve.

The propellant storage module propellant fuel and oxidizer isolation valves of a quad are controlled by the respective SM RCS PSM PRPLNT quad switch on panel 2. The switch for a quad, positioned to OPEN, momentarily, energizes the respective quad SM RCS PSM PRPLNT fuel and oxidizer valve into the magnetic latch (open). The CLOSE momentary position energizes the valves to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid.

Each propellant storage module propellant fuel and oxidizer isolation valve of a quad contains a position switch that is in series to its respective SM RCS PSM PRPLNT talkback indicator located above the respective SM RCS PSM PRPLNT quad switch on panel 2. When the position switches in the propellant fuel and oxidizer isolation valve of a quad are closed, the respective SM RCS PSM PRPLNT talkback indicator on panel 2 is gray (same color as the panel) indicating positively that both valves of that quad are open in respect to fluid flow. When the position switch in either fuel and oxidizer valve of a quad are actuated open, the respective SM RCS PSM PRPLNT quad indicator will be barber pole (diagonal lines) indicating that either valve or both valves of that quad are closed in respect to fluid flow.

The propellant storage module propellant fuel and oxidizer isolation valves of a quad are normally closed. The propellant storage module propellant fuel and oxidizer isolation valves of a quad are opened, when desired, allowing the PSM to supply propellants to the respective quad engine cluster.

2.5.2.2.8 Distribution Plumbing

Propellant distribution from a PSM is routed through the PSM MANF ISOL valves into the PSM manifolds. The PSM fuel and oxidizer manifolds are routed to the respective quads and SM RCS PSM PRPLNT quad isolation valves. When the SM RCS PSM PRPLNT quad isolation valves are opened, the PSM manifold propellants are distributed into the quad fuel and oxidizer lines, thus to the cluster of four engines. The PSM manifolds are connected into each quad manifold downstream of the quad primary and secondary isolation valves.

The cluster of four engines in a given quad are normally supplied from the respective quad propellant system. When the respective quad propellant supply is depleted, a PSM could then be utilized to supply propellants to that cluster of engines.

The accumulators installed in each quad fuel and oxidizer line allow the PSM propellant supply to support the cluster of SM RCS engines in either the pulse mode or steady-state operation.

2.5.2.2.9 Propellant, In-Line Filters

An in-line filter is installed in the fuel and oxidizer line of each quad.

The in-line filters are installed to prevent any particles from flowing into the engine injector valves, thus, the engine injector.

2.5.2.2.10 Accumulators

An accumulator is installed in the fuel and oxidizer line of each quad. The accumulators dampen engine valve dynamics and maintain quad manifold pressure above a predetermined level with propellants in the lines. The accumulators allow a PSM to support the SM RCS engine clusters in either a pulse mode or steady-state operational mode.

2.5.2.3 Engine Assemblies

The service module reaction control system engines are radiation cooled, pressure fed, bipropellant thrust generators which can be operated in either the pulse or steady state mode. (These modes are defined as a firing duration of less than one second, and one second or more, respectively.)

Each engine has a fuel and oxidizer injector solenoid control valve. The injector solenoid control valves control the flow of propellants by responding to electrical commands (automatic or manual) generated by the reaction jet engine ON-OFF control assembly or direct manual RCS respectively. Each engine contains an injector head assembly which directs the flow of each propellant from the injector solenoid control valves to the combustion chamber where the propellants atomize and ignite by hypergolic reaction, producing thrust. A filter is incorporated at the inlet of each fuel and oxidizer solenoid injector valve. An orifice is installed in the inlet of each fuel and oxidizer solenojd injector valve that meters the propellant flow to obtain a nominal 2:1 oxidizer-fuel ratio by weight.

2.5.2.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer)

The propellant solenoid injector valves utilize two coaxially wound coils, one for automatic and one for direct manual operation. The automatic coil is used when the thrust command originates from the reaction jet engine ON-OFF control assembly which is the electronic circuitry that selects the required automatic coils to be energized for a given maneuver. The direct manual coils are used when the thrust command originates at the rotation control (direct manual mode), direct ullage pushbutton, SPS abort or the SM jettison controller (figure 2.5-11).

The solenoid valves are spring-loaded closed and energized open.

The reaction time of the valves are illustrated in figures 2.5-12 and 2.5-13.

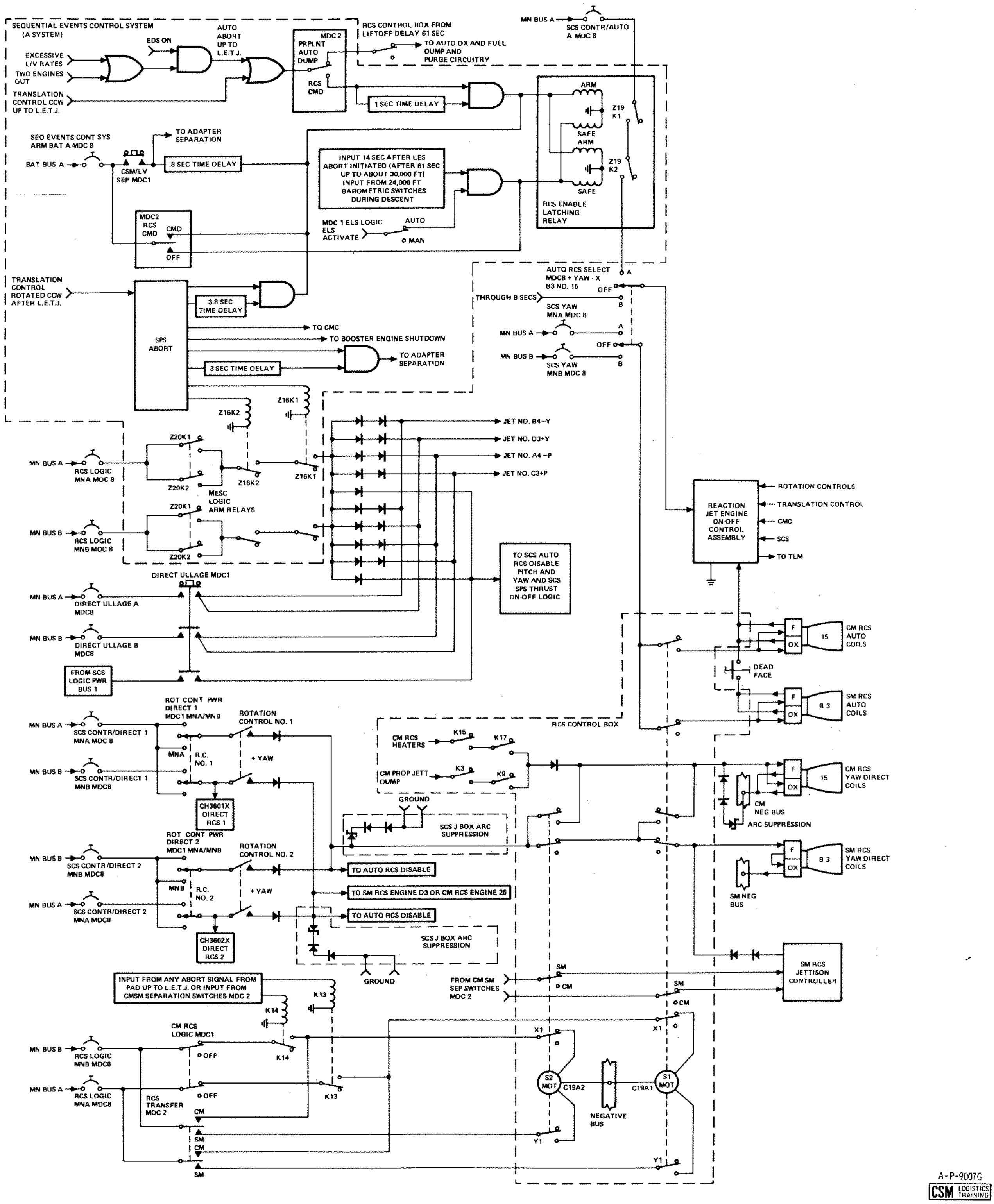


Figure 2.5-11. Simplified CSM RCS Electrical Control

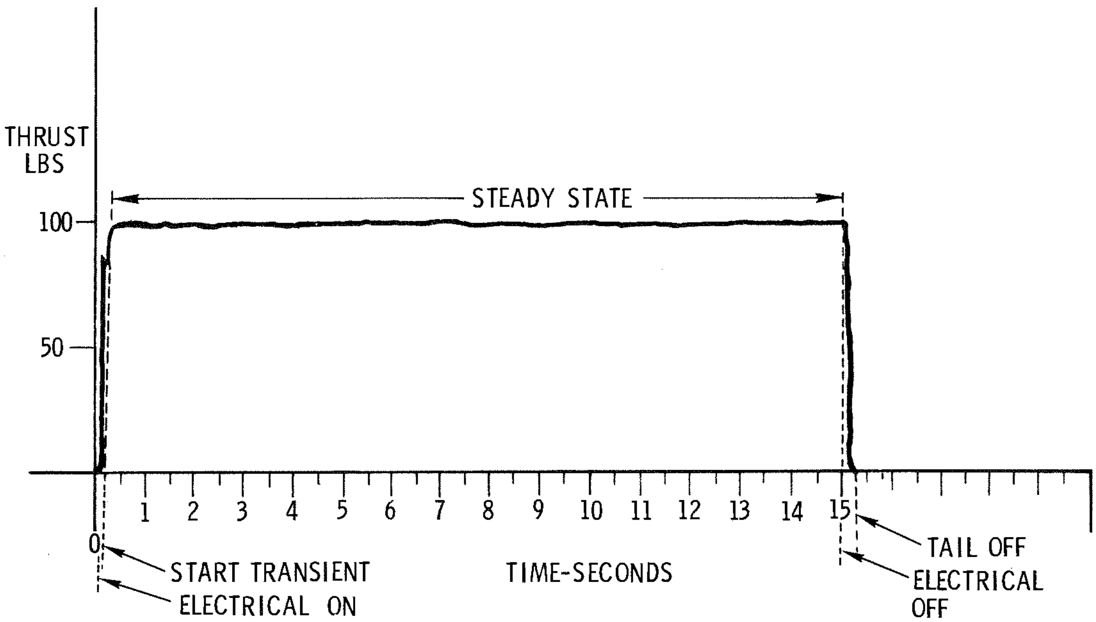


Figure 2.5-12. SM RCS Steady State Operation - Typical

Figure 2.5-12 illustrates a thrusting duration of 15 seconds (steady state). The electrical on signal is received within either the automatic (normal) or manual direct coils of the engine injector valves. At 14 seconds after the receipt of the thrust on signal, the automatic or manual direct coils are de-energized and the injector valves spring-load closed. However, due to the valve lag and residual propellant flow downstream of the injector valves, thrust output continues until the residuals have burned which establishes the cutoff transient.

Figure 2.5-13 illustrates the minimum pulse width electrical signal that can be provided to the automatic coils of the injector valves from the reaction jet engine ON-OFF control assembly. Sequence of operation is described in the subsequent steps:

a. A time of 12 to 18 milliseconds will elapse before the reaction jet engine ON-OFF control assembly can electrically provide a command off signal to the automatic coils of injector valves on the engine.

b. When the automatic coils of injector valves receive the electrical on signal, injector valves are energized to open position.

c. The fuel injector valve automatic coil energizes to the fully open position in approximately 7 milliseconds, and the oxidizer injector valve automatic coil energizes to the fully open position in approximately 9 milliseconds, establishing an approximate 2-millisecond fuel lead. This is accomplished by varying the resistance of the automatic coils in the fuel and oxidizer injector valve.

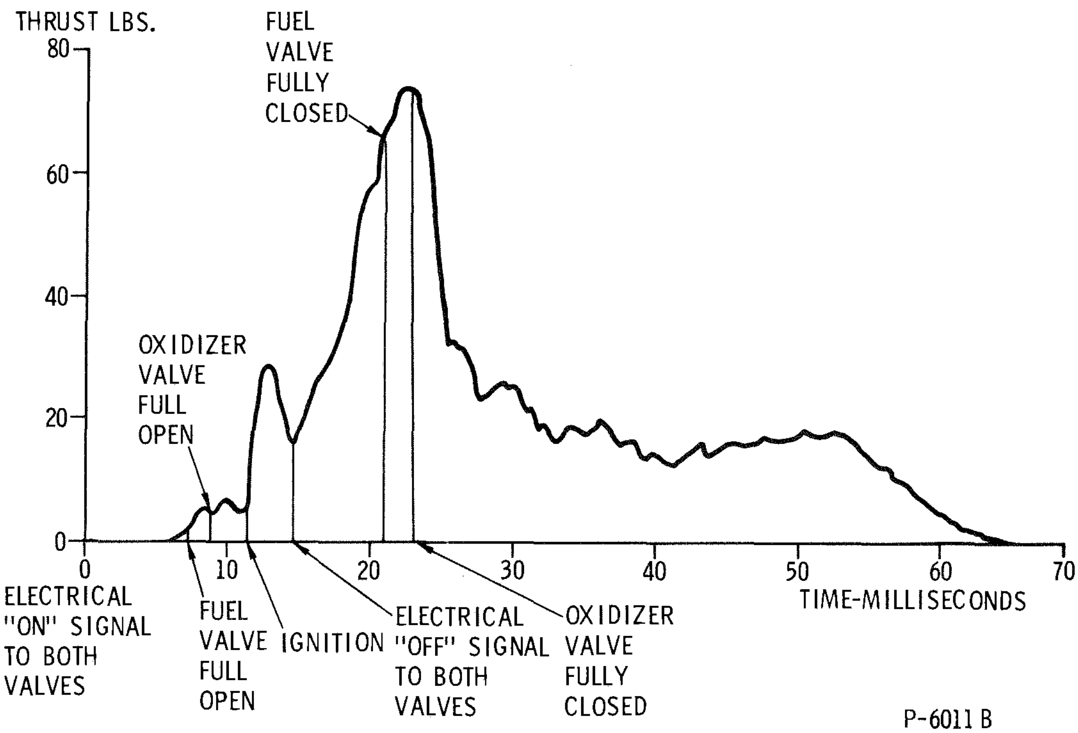


Figure 2.5-13. SM RCS Engine Minimum Total Impulse - Typical

d. The propellants start to flow from the injector valves as soon as they start to open to the premix igniter; however, the fuel will lead the oxidizer by 2 milliseconds.

e. The propellants flow into the premix igniter and the combustion chamber which creates some pressure, gas velocity, and thrust in the combustion chamber even though it is very small because the engine is operating in a space environment.

f. The pressure, gas velocity, and thrust continue to increase slightly until the valves reach the full open position.

g. At approximately 12-1/2 milliseconds, the propellants ignite producing a spike of thrust. At 12 milliseconds minimum, the electrical signal is removed from the automatic coils of the injector valves.

h. The engine thrust continues very erratic until the valves become de-energized and spring-load closed.

i. At approximately 7 milliseconds after the electrical off signal on the fuel valve and approximately 8 milliseconds on the oxidizer valve, the injector valves are fully closed.

j. The residual propellants, downstream of the injector valves, continue to flow into the combustion chamber, decreasing until complete thrust decay of 0 pounds occurs at approximately 65 milliseconds.

k. In order to determine the total impulse for this time span of operation (figure 2.5-13), everything under the entire thrust curve must be integrated.

The automatic coils are electrically connected in parallel from the reaction jet engine ON-OFF control assembly.

The direct manual coils in the fuel and oxidizer injector valves provide a direct backup to the automatic mode of operation. The direct manual coils of the injector valves are electrically connected in series. The reason for the series connection of the manual coils are as follows:

a. To ensure a fuel lead if any heat-soaked back into the direct manual coil windings, which would change the coil resistance and result in an oxidizer lead if the coils were connected in parallel.

b. The series connection from the fuel direct manual coil is positive to negative and to the oxidizer direct manual coil is negative to positive, then to ground. The reverse polarity on the oxidizer coil increases the arc suppression, reducing the arc at the rotation control in the direct RCS mode of operation. The direct manual coil opening time for the fuel injector valve is 26 milliseconds and the oxidizer is approximately 36 milliseconds. Closing time for the fuel and oxidizer direct manual coils is 55±25 milliseconds.

2.5.2.3.2 Injector

The main chamber portion of the injector will allow eight fuel streams to impinge upon eight oxidizer streams (unlike impingement) for main chamber ignition. There are eight fuel holes around the outer periphery of the injector which provide film cooling to the combustion chamber walls. There are eight fuel holes around the premix chamber providing cooling to the premix chamber walls.

The injector contains a premix igniter, and the premix chamber contains a fuel and an oxidizer passage that impinge upon each other (unlike impingement) within the premix igniter chamber. The premix igniter chamber, along with the approximate 2-millisecond fuel lead, provides a smoother start transient primarily in the pulse mode of operation and especially in the area of minimum impulse.

2.5.2.3.3 Combustion Chamber

The combustion chamber is constructed of unalloyed molybdenum which is coated with molybdenum disilicide to prevent oxidation of the base metal. Cooling of the chamber is by radiation and film cooling.

2.5.2.3.4 Nozzle Extension

The nozzle extension is attached to the chamber by a waspolloy nut. The nozzle extension is machined from a cobalt base alloy (stainless steel). The stiffener rings are machined.

2.5.2.3.5 RCS Electrical Heaters

Each of the SM RCS engine housings contains two electrical strip heaters. Each of the heaters contains two electrical elements. The heater elements are controlled by therm-o-switches (figures 2.5-14 and 2.5-15). Positioning the applicable SM RCS HTRS ENGINE PACKAGE switch on panel 5 for a given quad to position 1 supplies 28 vdc to a therm-o-switch. The therm-o-switch is set at a predetermined temperature range and automatically opens or closes the circuit to the heater elements. Positioning the applicable SM RCS HTRS ENGINE PACKAGE switch on panel 5 for a given quad to position 2 supplies 28 vdc to a redundant therm-o-switch that operates at the same predetermined range as in 1 and controls the redundant elements in the redundant heaters. The OFF position of the applicable SM RCS HTRS ENGINE PACKAGE switch or switches on panel 5 for a given quad removes all power from the quad heater circuits.

Each SM RCS quad contains an aluminum rod with a heater installed on the rod. The aluminum rod is installed on the inner side of the respective quad door (figure 2.5-16). Each heater contains two elements. In addition, each SMRCS quad contains a heater on the PSM flex line bracket. Each heater contains two elements. The heater elements are controlled by thermal switches (figure 2.5-15). Positioning the applicable SM RCS HTRS QUAD switch on panel 5 for a given quad to PRIM position supplies 28 vdc to the primary thermal switch, sensors, thus to the heaters. The mercury thermal control sensors are set at a predetermined temperature range and automatically open or close the circuit to the primary heater element. Positioning the applicable SM RCS HTRS QUAD switch on panel 5 for a given quad to SEC position supplies 28 vdc to a secondary thermal switch, sensors, and heater elements. The secondary mercury thermal sensors are set at a slightly higher predetermined temperature range from that of the primaries. The secondary thermal switches and sensors control the secondary heater elements automatically. The OFF position of the applicable SM RCS HTRS QUAD switch on panel 5 for a given quad removes all power from the quad heater circuits.

Heaters are also installed on the propellant storage module. It is noted that propellant storage module 2 may not be installed. Each of the four heaters installed on a PSM contains two elements (figures 2.5-18 and 2.5-15). The heater elements are controlled by thermal switches and sensors. Positioning the applicable SM RCS HTRS PSM switch on panel 5 for a given PSM to PRIM position supplies 28 vdc to the primary thermal switch, sensors, thus the primary heater elements. The mercury thermal sensors are set at a predetermined temperature range and automatically open or close the circuit to the primary heater elements.

Positioning the applicable SM RCS HTRS PSM switch on panel 5 for a given PSM to SEC position supplies 28 vdc to a secondary thermal switch, sensors, and heater elements. The secondary mercury thermal sensors are set at a slightly higher predetermined temperature range from that of the primaries. The secondary thermal switches and sensors control the secondary heater elements automatically. The OFF position of the applicable SM RCS HTRS PSM switch on panel 5 for a given PSM removes all power from the PSM heater circuits.

Figures 2.5-8, 2.5-9, and 2.5-15 illustrate the temperature measurements that may be monitored on panels 101 and 2 to determine proper heater operation.

2.5.2.4 The Quad and Propellant Storage Module Monitoring

The SM RCS quads and propellant storage module tank pressure and the total propellant quantity remaining may be monitored on panel 2 (figures 2.5-7 and 2.5-8). In addition, the fuel and oxidizer manifold pressure of the propellant storage module manifolds may be monitored on the same indicators on panel 2.

Positioning the RCS IND switch on panel 2 to TK PRESS/QTY position, the fuel tank pressure and the total propellant quantity remaining of each quad and propellant storage module are supplied to the RCS INDICATORS rotary switch on panel 2.

Positioning the RCS INDICATORS rotary select switch to SM QUAD A, B, C, or D, the applicable quad fuel tank pressure and the total quantity remaining will be displayed on the panel 2 indicators. Positioning the RCS INDICATORS select switch to PSM 1 or PSM 2 (if installed), the applicable propellant storage module fuel tank pressure and total quantity remaining may be displayed on the panel 2 indicators.

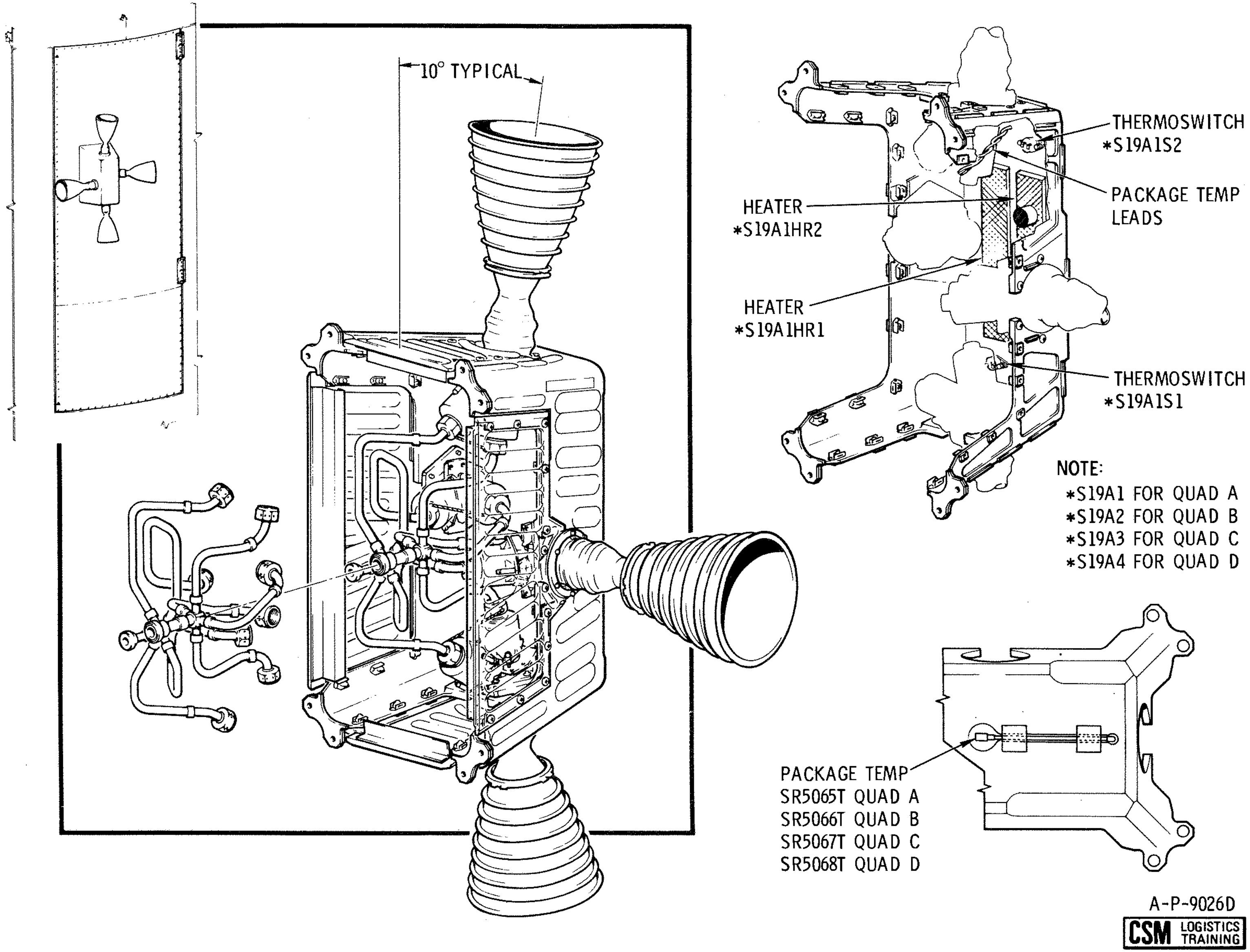


Figure 2.5-14. SM RCS Engine Heaters

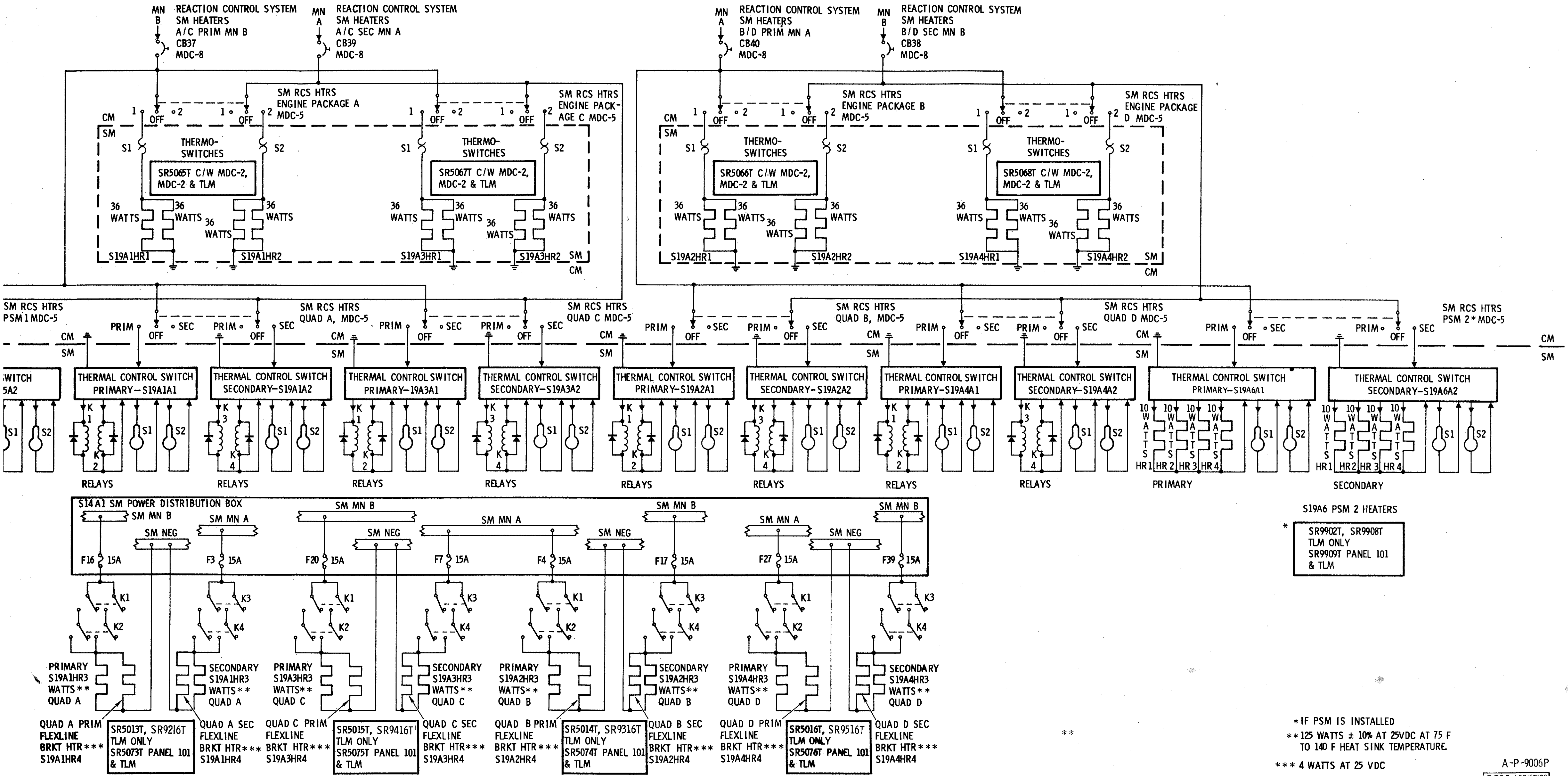
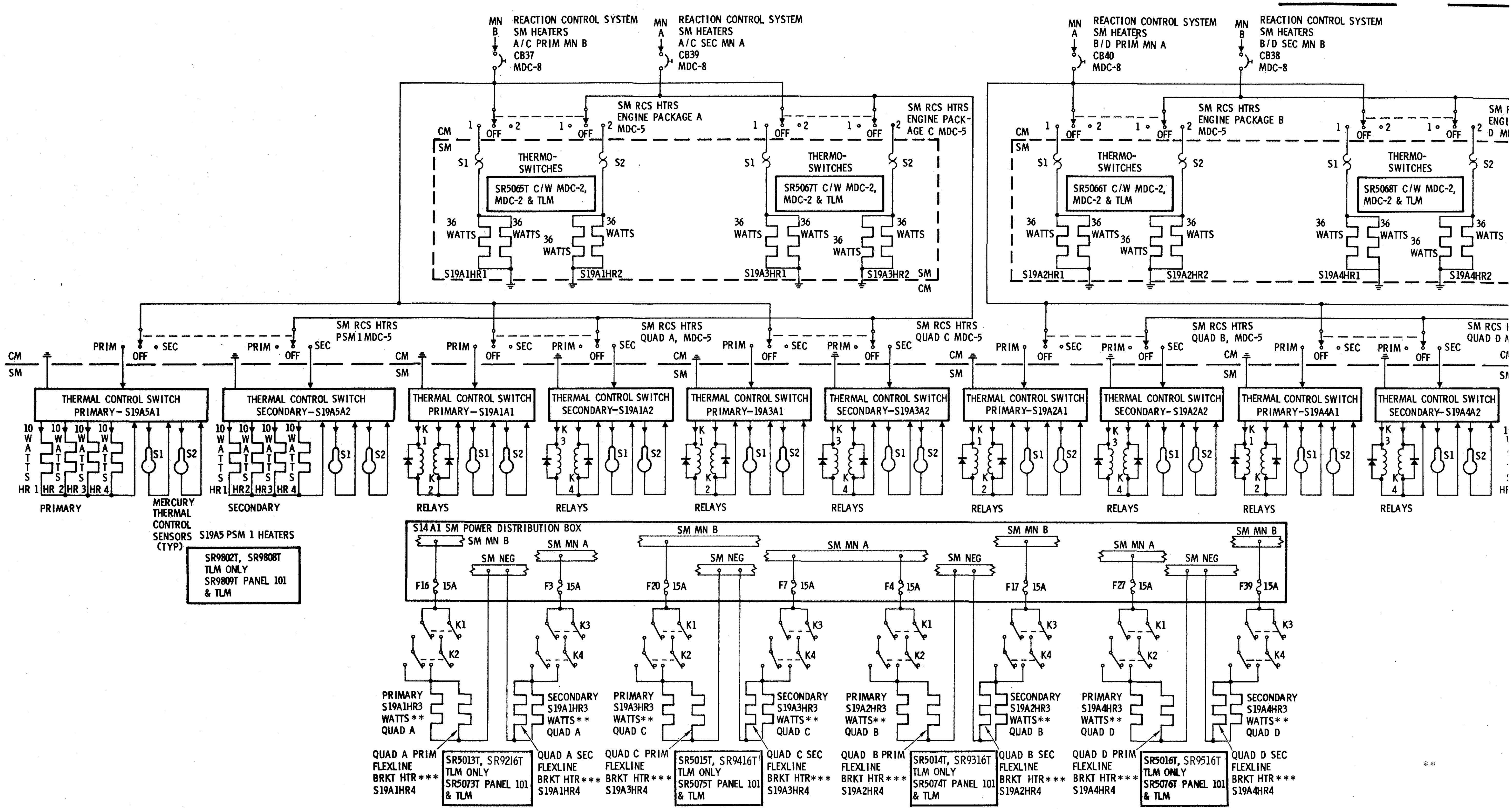


Figure 2.5-15. SM RCS Heaters - Electrical

RCS



MN B
REACTION CONTROL SYSTEM
SM HEATERS
A/C PRIM MN B
CB37
MDC-8
MN A
REACTION CONTROL SYSTEM
SM HEATERS
A/C SEC MN A
CB39
MDC-8
MN A
REACTION CONTROL SYSTEM
SM HEATERS
B/D PRIM MN A
CB40
MDC-8
MN B
REACTION CONTROL SYSTEM
SM HEATERS
B/D SEC MN B
CB38
MDC-8
SM RCS HTRS
ENGINE PACKAGE A
MDC-5
SM RCS HTRS
ENGINE PACK-
AGE C MDC-5
SM RCS HTRS
ENGINE PACKAGE B
MDC-5
THERMO-
SWITCHES
SR5065T C/W MDC-2,
MDC-2 & TLM
SR5067T C/W MDC-2,
MDC-2 & TLM
SR5066T C/W MDC-2,
MDC-2 & TLM
SR5068T C/W MDC-2,
MDC-2 & TLM
36 WATTS
S19A1HR1
S19A1HR2
S19A3HR1
S19A3HR2
S19A2HR1
S19A2HR2
S19A4HR1
S19A4HR2
CM
SM
SM RCS HTRS
PSM 1 MDC-5
SM RCS HTRS
QUAD A, MDC-5
SM RCS HTRS
QUAD C MDC-5
SM RCS HTRS
QUAD B, MDC-5
PRIM
SEC
OFF
THERMAL CONTROL SWITCH
PRIMARY - S19A5A1
THERMAL CONTROL SWITCH
SECONDARY - S19A5A2
THERMAL CONTROL SWITCH
PRIMARY - S19A1A1
THERMAL CONTROL SWITCH
SECONDARY - S19A1A2
THERMAL CONTROL SWITCH
PRIMARY - 19A3A1
THERMAL CONTROL SWITCH
SECONDARY - S19A3A2
THERMAL CONTROL SWITCH
PRIMARY - S19A2A1
THERMAL CONTROL SWITCH
SECONDARY - S19A2A2
THERMAL CONTROL SWITCH
PRIMARY - S19A4A1
THERMAL CONTROL SWITCH
SECONDARY - S19A4A2
10 WATTS
HR 1 HR 2 HR 3 HR 4
PRIMARY
SECONDARY
MERCURY
THERMAL
CONTROL
SENSORS
(TYP)
S19A5 PSM 1 HEATERS
SR9802T, SR9808T
TLM ONLY
SR9809T PANEL 101
& TLM
RELAYS
S14A1 SM POWER DISTRIBUTION BOX
SM MN B
SM MN A
SM NEG
F16 15A
F3 15A
F20 15A
F7 15A
F4 15A
F17 15A
F27 15A
F39 15A
K1
K2
K3
K4
PRIMARY
S19A1HR3
WATTS**
QUAD A
SECONDARY
S19A1HR3
WATTS**
QUAD A
PRIMARY
S19A3HR3
WATTS**
QUAD C
SECONDARY
S19A3HR3
WATTS**
QUAD C
PRIMARY
S19A2HR3
WATTS**
QUAD B
SECONDARY
S19A2HR3
WATTS**
QUAD B
PRIMARY
S19A4HR3
WATTS**
QUAD D
SECONDARY
S19A4HR3
WATTS**
QUAD D
QUAD A PRIM
FLEXLINE
BRKT HTR***
S19A1HR4
SR5013T, SR9216T
TLM ONLY
SR5073T PANEL 101
& TLM
QUAD A SEC
FLEXLINE
BRKT HTR***
S19A1HR4
QUAD C PRIM
FLEXLINE
BRKT HTR***
S19A3HR4
SR5015T, SR9416T
TLM ONLY
SR5075T PANEL 101
& TLM
QUAD C SEC
FLEXLINE
BRKT HTR***
S19A3HR4
QUAD B PRIM
FLEXLINE
BRKT HTR***
S19A2HR4
SR5014T, SR9316T
TLM ONLY
SR5074T PANEL 101
& TLM
QUAD B SEC
FLEXLINE
BRKT HTR***
S19A2HR4
QUAD D PRIM
FLEXLINE
BRKT HTR***
S19A4HR4
SR5016T, SR9516T
TLM ONLY
SR5076T PANEL 101
& TLM
QUAD D SEC
FLEXLINE
BRKT HTR***
S19A4HR4

**

Figure 2

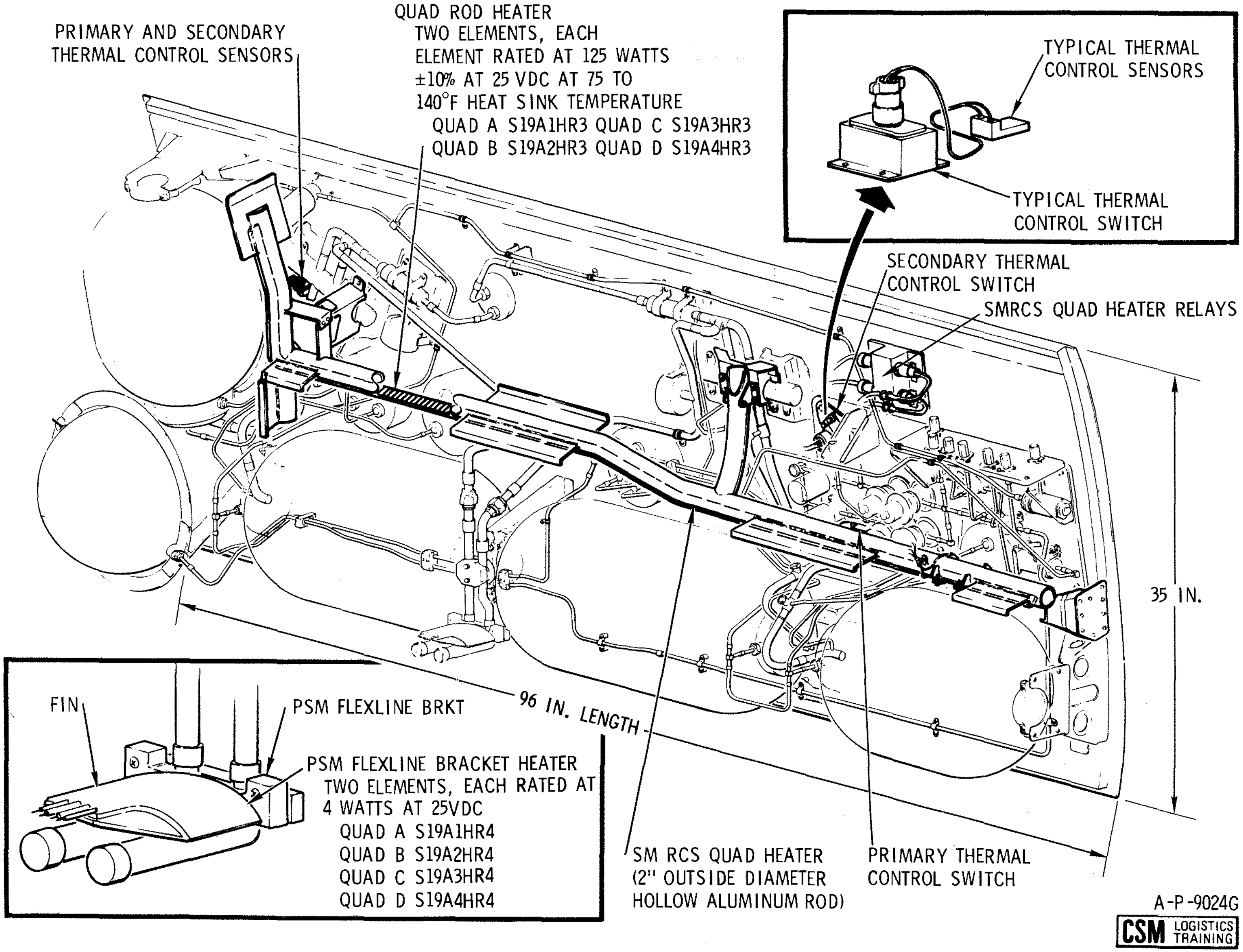


Figure 2.5-16. Typical SM RCS Quad Thermal Control

Figure 2.5-17. Deleted

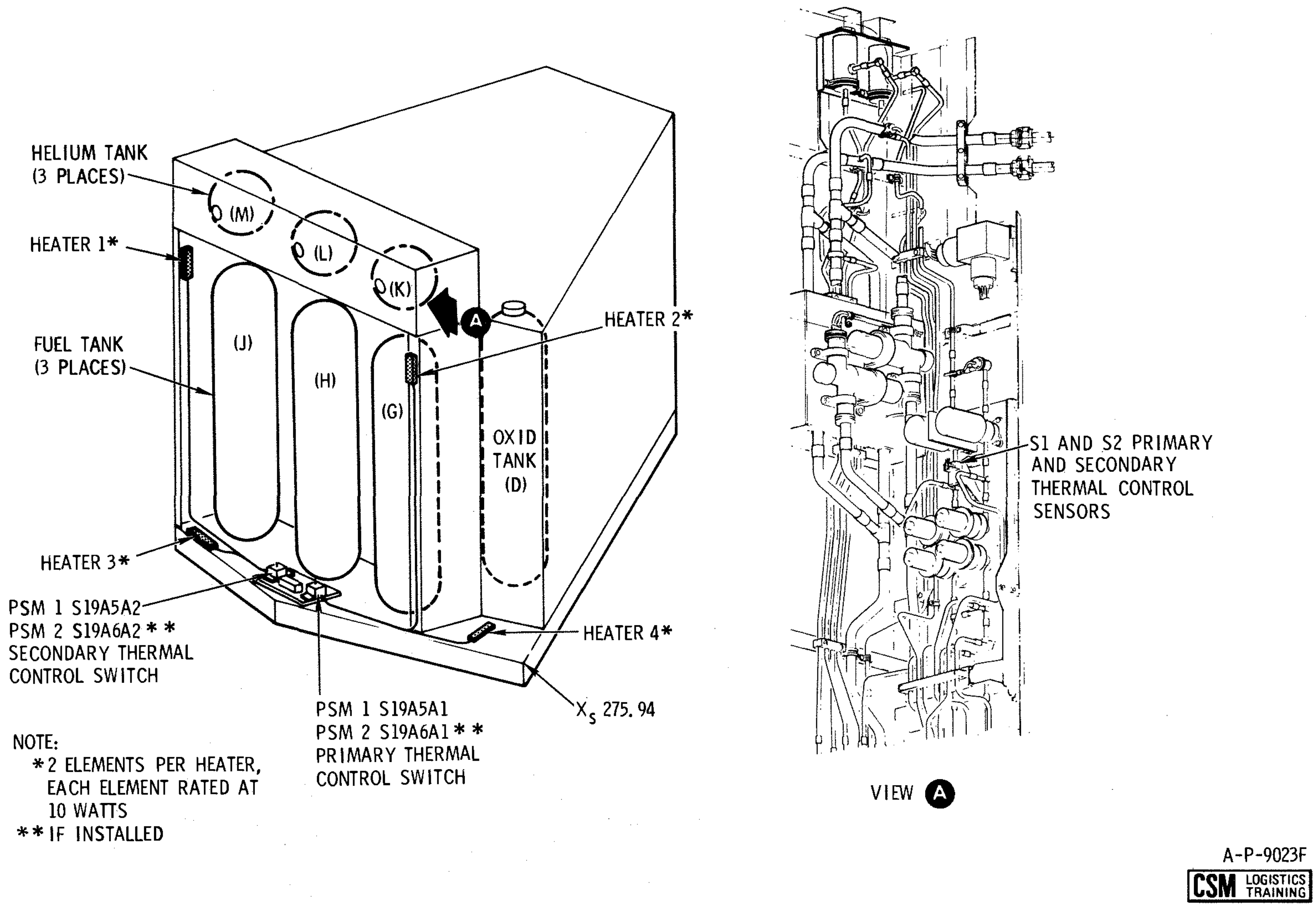


Figure 2.5-18. SM RCS PSM Heater Installation

Positioning the RCS IND switch on panel 2 to MANF PRESS, the propellant storage module fuel and oxidizer manifold pressure is supplied to the RCS INDICATORS rotary switch on panel 2. Positioning the RCS INDICATORS rotary switch to SM QUAD A, B, C, D or PSM 1 or PSM 2 (if installed) the fuel and oxidizer manifold pressure of the PSM manifolds may be displayed on the panel 2 indicators.

It is noted when the RCS INDICATORS rotary switch is positioned to SM QUAD A, B, C, or D, the applicable quad package temperature and helium source pressure will be displayed on the panel 2 indicators. When the RCS INDICATORS rotary switch is positioned to PSM 1 or PSM 2 (if installed), the applicable propellant storage module helium source pressure will be displayed on the panel 2 indicator.

2.5.2.5 Engine Thrusting Logic

In the SM RCS, the main bus cannot supply electrical power to one leg of the AUTO RCS SELECT switches on panel 8 and reaction jet engine ON-OFF control assembly until the contacts of the RCS latching relay are closed (figure 2.5-11). Closing of these contacts for SM RCS control may be energized (closed) by the following operational modes, referred to as SPS abort or normal CSM/LV SEP.

SPS Abort Mode

With the launch escape tower jettisoned, and by rotating the translation control counterclockwise, the following sequence of events occur:

a. Informs the CMC of an SPS abort initiation. The CMC does not utilize this signal.

b. Shuts down the applicable booster.

c. Inhibits the pitch and yaw automatic coils of the SM RCS engines within the reaction jet engine ON-OFF control assembly and provides a signal to the SCS-SPS thrust ON-OFF logic.

d. Initiates an ullage maneuver signal to the required SM RCS engine direct manual coils, as long as the translation control is counterclockwise. The ullage maneuver is terminated when the translation control is returned to the neutral detent.

e. Initiates adapter separation 3 seconds after the SPS abort sequence was initiated. In the event automatic adapter separation did not occur, the CSM/LV SEP pushbutton on panel 1 could be depressed as a backup.

f. Energizes the arm coils of the RCS latching relay 3.8 seconds after the SPS abort was initiated. The reaction jet engine ON-OFF control assembly is now enabled, thus the SM RCS engine automatic coils. If the automatic energizing of the RCS latching relay did not occur, the arm coils could be energized by positioning the RCS CMD switch on panel 2 to RCS CMD, providing a backup. In addition, if the CSM/LV SEP pushbutton on panel 1 is depressed and held approximately 1 second, the arm coils of the RCS latching relays are energized.

The above mentioned sequences may also be utilized as a normal separation sequence from the S-IVB.

Normal CSM/LV Separation Mode

The normal separation of the CSM from the S-IVB may be initiated as follows.

a. Position the RCS CMD switch on panel 2 to the RCS CMD position. This energizes the arm coils of the RCS latching relays. The reaction jet engine ON-OFF control assembly is now enabled, thus, the SM RCS engine automatic coils.

b. Position translation control to +X. This provides commands to the reaction jet engine ON-OFF control assembly, and thus to the required SM RCS engine +X automatic coils. The DIRECT ULLAGE pushbutton on panel 1 depressed could be utilized as a backup.

c. Depress the CSM/LV SEP pushbutton on panel 1. This initiates adapter separation. The CSM/LV SEP pushbutton depressed would also energize the arm coils of the RCS latching relays if held for 1 second.

d. Return translation control to neutral, after CSM/LV SEP, and release CSM/LV SEP pushbutton.

In the event the translation control is unable to provide an ullage maneuver, the DIRECT ULLAGE pushbutton, on panel 1, when pressed and held, provides the direct ullage signal to the direct manual coils of the required SM RCS engines providing a +X translation. This provides a manual direct backup to the translation control for the ullage maneuver. The ullage maneuver is terminated upon release of the DIRECT ULLAGE pushbutton.

In the event the reaction jet engine ON-OFF control assembly is unable to provide commands to the automatic coils of the SM RCS engines, a backup method is provided. This method consists of two ROT CONT PWR DIRECT RCS switches on panel 1 and the two rotation controllers. The ROT CONT PWR DIRECT RCS 1 switch supplies power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch is position to MNA/MNB, main buses A and B supply power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch is positioned to MNA, main bus A supplies power only to rotation control 1. The ROT CONT PWR DIRECT RCS 2 switch supplies power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNA/MNB, main buses A and B supply power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNB, main bus B supplies power only to rotation control 2. When the rotation control is positioned fully to its stops in any direction, the rotation control will energize the required direct manual coils for the desired maneuver and provide an inhibit signal to the SM RCS automatic coils.

If the reaction jet engine ON-OFF control assembly is unable to control the SM RCS engine automatic coils, the automatic translation control of the CSM is disabled. The SM RCS direct ullage (+X translation) capability is still operational.

2.5.3 SM RCS PERFORMANCE AND DESIGN DATA

2.5.3.1 Design Data

The following list is the design data on the SM RCS components.

Helium tanks (10)*	4150±50 psig at 70±5°F during servicing. After servicing 70±10°F, capacity 1.35 lb. Internal volume of 905±10 cubic inches. Wall thickness, 0.135 inch. Weight 11.5 lb, diameter 12.37 in.
Regulator units (12)*	Primary 181±4 psig with a normal lockup of 183±5 psig. Secondary lockup of 187±5 psig. From lockup 185±4 psig maximum. Filter 25 microns nominal, 40 microns absolute at inlet of each regulator unit.
Check valve filters (12)*	40 microns nominal, 74 microns absolute. One at inlet to check valve assembly, one at each test port.
Helium relief valves (12)*	Diaphragm rupture at 228±8 psig, filter 10 microns nominal, 25 microns absolute. Relief valve relieves at 236.5±11.5 psig, reseats at not less than 220 psig. Flow capacity 0.3 lb/min at 248 psig at 60°F. Bleed device closes when increasing pressure reaches no more than 179 psig in the cavity and a helium flow of less than 20 standard cubic centimeters per hour across the bleed device and relief valve assembly combined. The bleed device reopens when decreasing pressure has reached no less than 20 psig.
Propellant storage module oxidizer tanks (10)*	Combined propellant and ullage volume of 215.9 lbs, each. Outside diameter 12.64 in. maximum. Internal volume 4093.0 cubic inches Length 38.819 in. Wall thickness 0.017 to 0.023 in.

*Assumes PSM 2 is installed

Propellant storage module fuel tanks (8)*	Combined propellant and ullage volume of 132.0 lb each. Outside diameter 12.64 in. maximum. Internal volume 4093.0 cubic inches. Length 38.819 in. Wall thickness 0.017 to 0.023 in.
Quad primary fuel tanks (4)	Combined propellant and ullage volume of 69.1 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Internal volume 2257.8 cubic inches. Outside diameter 12.62 in. maximum Length 23.717 in. (+0.060, -0.000) Wall thickness 0.017 in. to 0.022 in. Helium inlet port 1/4 in., fill and drain port 1/2 in.
Quad primary oxidizer tanks (4)	Combined propellant and ullage volume of 137.0 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Internal volume 2848.1 cubic inches Outside diameter 12.62 in. maximum Length 28.558 in. (+0.060, -0.000) Wall thickness 0.017 in. to 0.022 in.
Quad secondary fuel tanks (4)	Combined propellant and ullage volume of 45.2 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Internal volume 1473.0 cubic inches Outside diameter 12.62 in. maximum Length 17.329 in. (+0.040, -0.000) Wall thickness 0.022 in. to 0.027 in.
Quad secondary oxidizer tanks (4)	Combined propellant and ullage volume of 89.2 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Internal volume 1786.6 cubic inches Outside diameter 12.65 in. maximum Length 19.907 in. (+0.040, -0.000) Wall thickness 0.022 in. to 0.027 in.
Quad secondary fuel line pressure transducers (4)	Illuminate caution and warning light on panel 2 (SM RCS A, B, C, D). Underpressure 152±7 psia Overpressure 207±7 psia
Propellant storage module manifold isolation and quad to manifold low ΔP valves (16)*	One filter at inlet and outlet of each valve. 100 microns with propellants flowing in either direction.

*Assumes PSM 2 is installed

RCS

Filters (8)	Upstream of each engine cluster manifold. 5 microns nominal, 15 microns absolute.
Propellant storage module fuel tank press transducers (2)*	Illuminate applicable PSM caution and warning light on panel 2 PSM 1; PSM 2* Overpressure +207±7 psia
Accumulators (8)	Dampen engine valve dynamics and maintain quad manifold pressure above 122 psia with propellants in the lines.
Engine (16)	4000 seconds service life, 2400 seconds continuous, capable of 15,000 operational cycles. Expansion ratio 40 to 1 at nozzle exit. Cooling-film and radiation, injector-type premix ignitor, one on one unlike impingement, 8 fuel annulus for film cooling of premix ignitor, main chamber 8 on 8 unlike impingement, 8 fuel for film cooling of combustion chamber wall. Nozzle exit diameter - 5.6 inches Fuel lead Automatic coils - connected in parallel Manual coils - connected in series Weight - 4.99 lb Length - 13.400 in. maximum
Filters - each injector valve inlet	100 microns nominal, 250 microns absolute
Heaters	Two heaters for each quad engine package. Four heater elements for each quad engine package. 36±3.6 watts per element nominal. Two heaters for each quad. Two heater elements in each heater. Each heater element of quad heater rated at 125 watts ±10 percent at 25 vdc at 75° to 140°F heat sink temperature. Each element of PSM flex line bracket heater on each quad rated at 4 watts at 25 vdc. Four heaters for each PSM. Two heater elements for each PSM heater. 10 watts per element nominal at 25 vdc. Therm-o-switch. Two for each quad engine package. Opens circuit at 134°F, closes circuit at 115°F, minimum spread of 9°F.

*Assumes PSM 2 is installed

	Mercury thermal control sensors. With the applicable SM RCS HTRS QUAD switch and SM RCS HTRS PSM switch on panel 5 in PRIM, the primary mercury thermal control sensors close and open the circuits at approximately 50°F. With the applicable SM RCS HTRS QUAD switch and SM RCS HTRS PSM switch on panel 5 in SEC, the secondary mercury thermal control sensors close and open the circuits at approximately 55°F.
Quad A, B, C, D package temperature transducers (4)	Illuminates caution and warning light on panel 2 (SM RCS A, B, C, D) Temperature above +200±7°F Temperature below +85±7°F

RCS

2.5.3.2 Performance Data

Refer to CSM/LM Spacecraft Operational Data Book SNA-8-B-027 CSM (SD 68-447).

2.5.3.3 SM RCS Electrical Power Distribution

See figure 2.5-19 for electrical power distribution.

2.5.4 SM RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS

Refer to Skylab Operations Handbook, Volume 2.

2.5.5 CM RCS FUNCTIONAL DESCRIPTION

The command module reaction control subsystems provide the impulses required for controlling spacecraft rates and attitude during the terminal phase of a mission.

The subsystems may be activated by the CM-SM SEP switches on panel 2 placed to CM-SM SEP position, or by placing the CM RCS PRESS switch on panel 2 to the CM RCS PRESS position. The subsystems are activated automatically in the event of an abort from the pad up to launch escape tower jettison. Separation of the two modules occurs prior to entry (normal mode), or during an abort from the pad up to launch escape tower jettison.

The CM RCS consists of two similar and independent subsystems, identified as subsystem 1 and subsystem 2. Both subsystems are pressurized simultaneously. In the event a malfunction develops in one subsystem, the remaining subsystem has the capability of providing the impulse required to perform necessary pre-entry and entry maneuvers. The CM RCS is contained entirely within the CM and each reaction engine nozzle is ported through the CM skin. The propellants consist of inhibited nitrogen tetroxide (N_2O_4) used as the oxidizer and monomethylhydrazine (MMH) used as fuel. Pressurized helium gas is the propellant transferring agent.

The reaction jets may be pulse-fired, producing short thrust impulses or continuously fired, producing a steady state thrust level. CM attitude control is maintained by utilizing the applicable pitch, yaw, and roll engines of subsystems 1 and 2. However, complete attitude control can be maintained with only one subsystem.

A functional flow diagram of CM RCS subsystems 1 and 2 is shown in figure 2.5-20. The helium storage vessel of each subsystem supplies pressure to two helium isolation squib valves that are closed throughout the mission until either the CM SM SEP switches on panel 2, or the CM RCS PRESS switch on panel 2 is activated. When the helium isolation squib valves in a subsystem are initiated open, the helium tank source pressure is supplied to the pressure regulators. The regulators reduce the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through series-parallel check valves. The check valves permit helium pressure to the fuel and oxidizer tanks and prevent reverse flow of propellant vapors and/or liquids. A pressure relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressure.

Helium entering the propellant tanks creates a pressure buildup around the propellant positive expulsion bladders, forcing the propellants to be expelled into the propellant distribution lines. Propellants then flow to valve isolation burst diaphragms, which rupture because of the pressurization, and then through the normally open propellant isolation valves. Each subsystem supplies fuel and oxidizer to six engines.

Oxidizer and fuel are distributed to the 12 engines by a parallel feed system. The fuel and oxidizer engine injector valves, on each engine, contain orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel ignite because of the hypergolic reaction. The engine injector valves are controlled automatically by the reaction jet engine ON-OFF control assembly. Manual direct RCS control is provided for rotational maneuvers. The engine injector valves are spring-loaded closed.

CM RCS engine preheating may be necessary before initiating pressurization because of possible freezing of the oxidizer (+11.8°F) upon contact with the engine injector valves. The crew will monitor the oxidizer injector valve temperatures and determine if preheating is required. If preheat is required, the engine injector valve solenoids manual direct RCS coils will be utilized for preheat until acceptable engine temperatures are obtained. The CM RCS HTRS switch, on panel 101, will be utilized to apply power to the engine injector valve direct manual coils for engine preheating.

If an abort sequence is initiated after T +61 seconds up to 30,000 feet (Mode 1B abort) and the crew is advised prior to launch that high head winds could cause CM land impact, the remaining propellants aboard the CM RCS will be burned out through ten of the twelve CM RCS engines, followed by purging of the systems and depleting the helium source pressure.

If head winds are not high enough to cause a land impact, the CM RCS propellants will be retained on board the CM. This would hold true for all aborts above T +61 seconds and a normal entry. Prior to 800 feet, the CM RCS 1 and 2 propellant isolation valves will be closed.

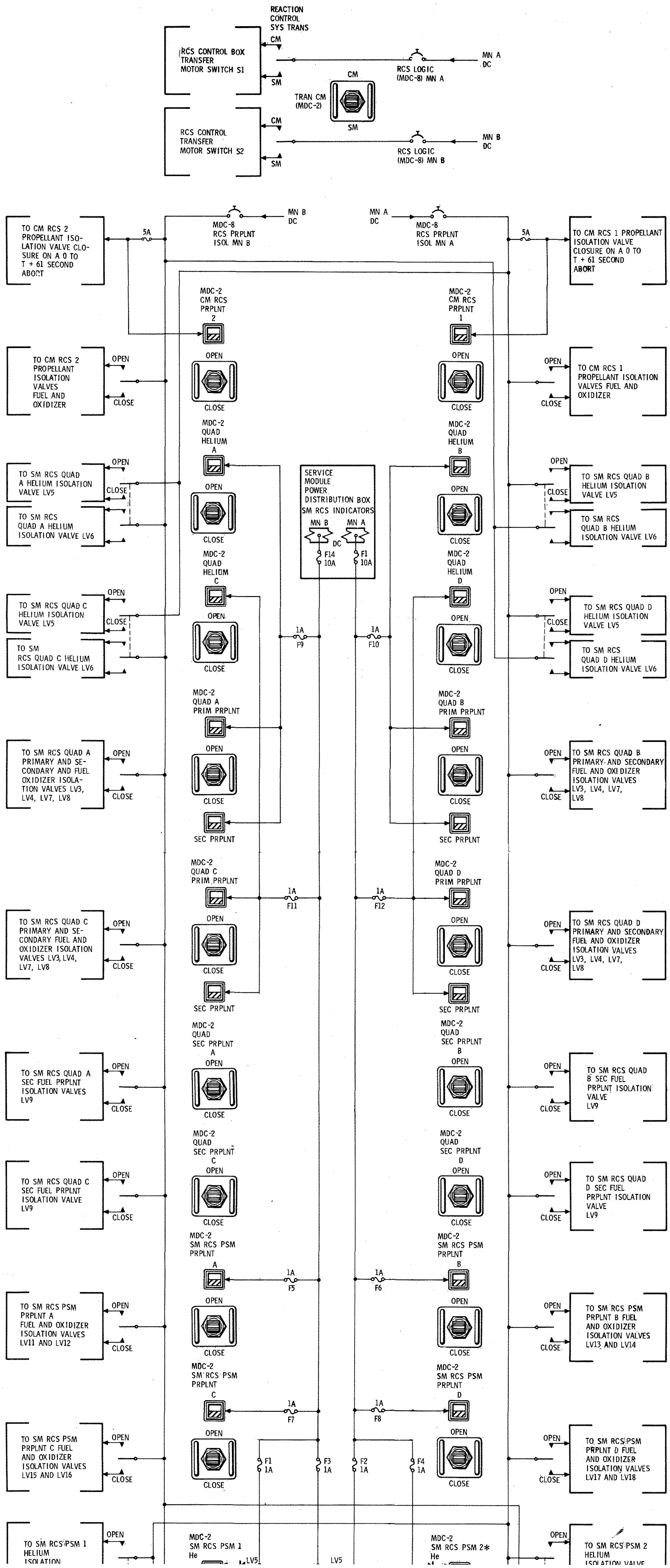
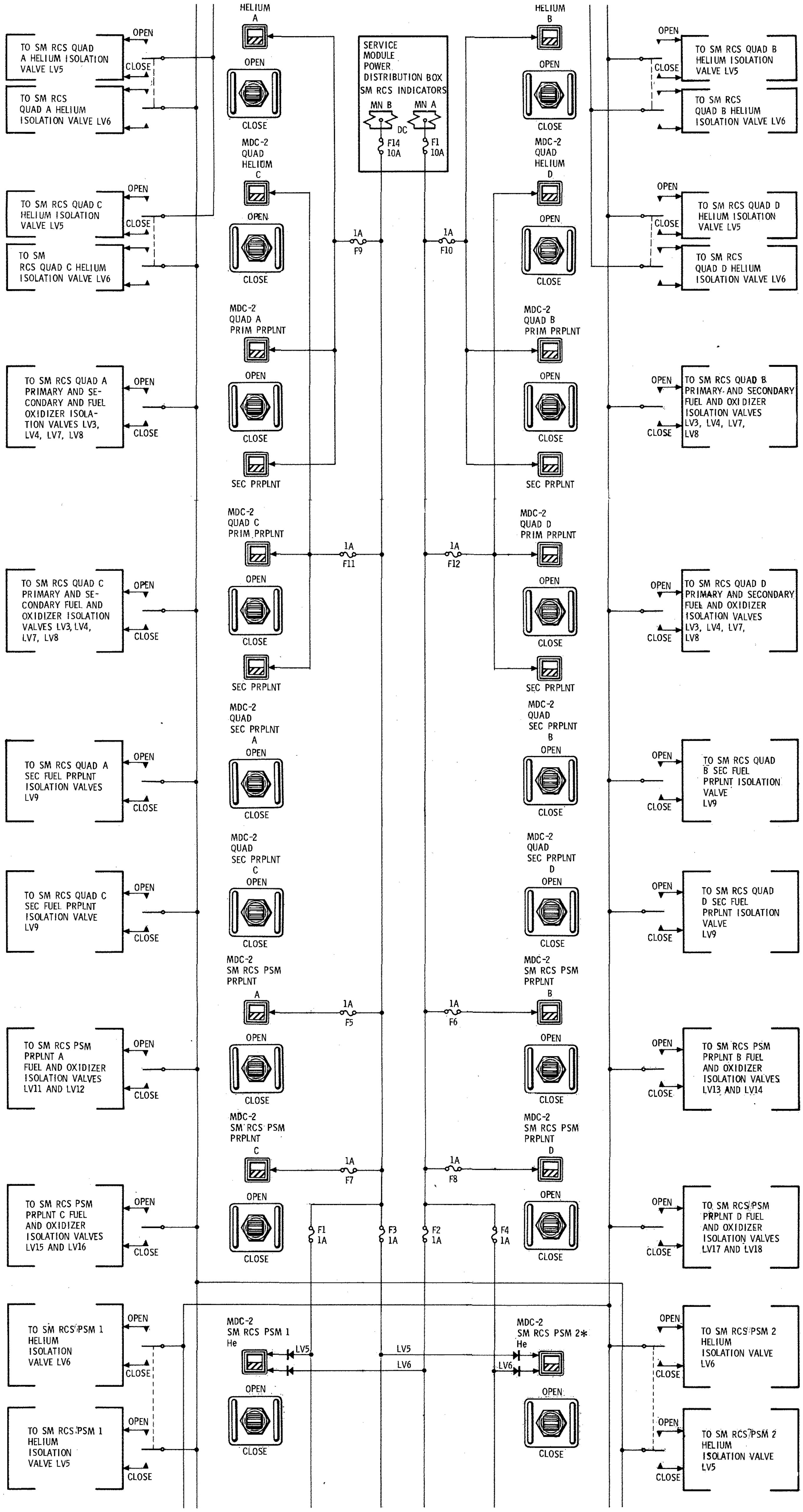
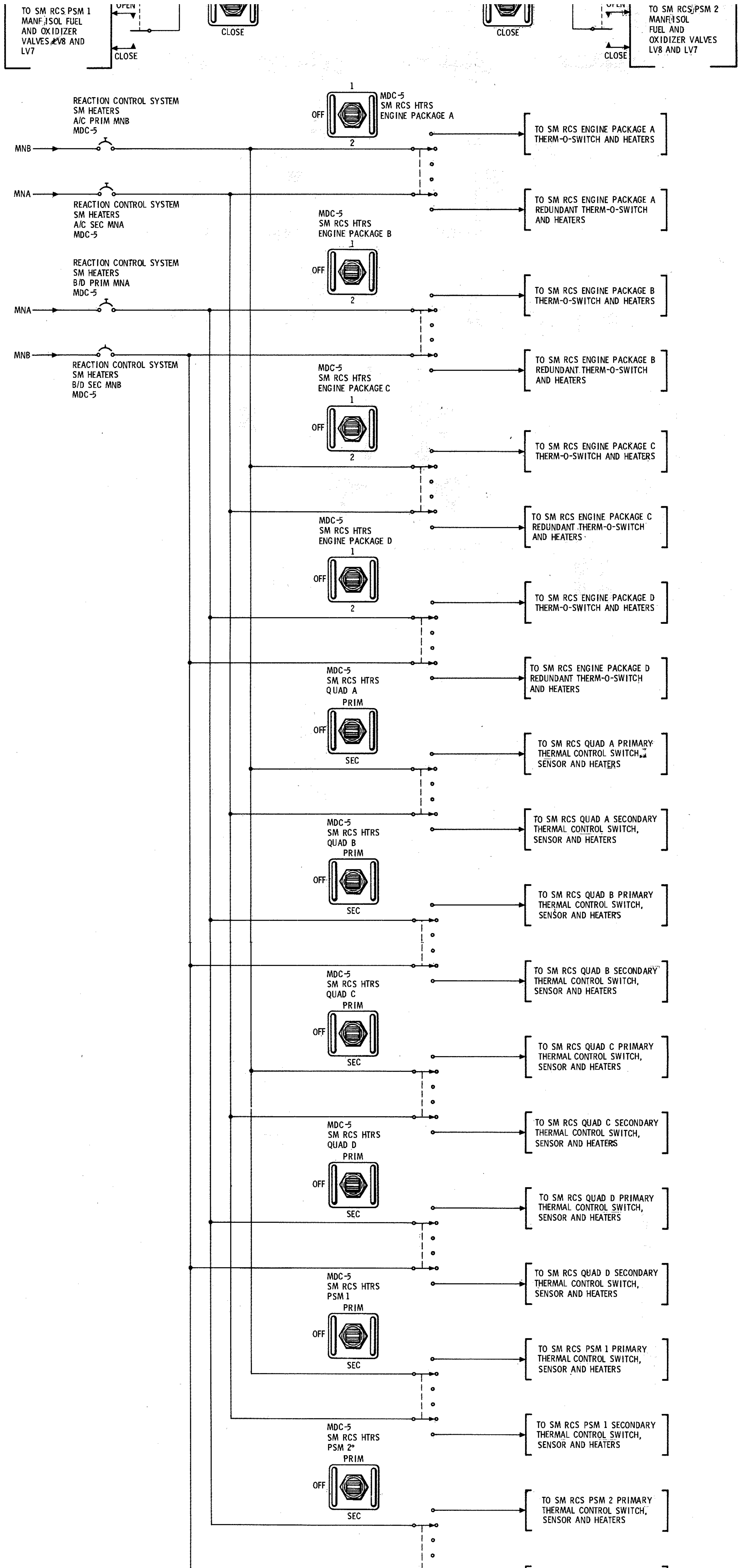


Figure 2.5-19. SM RCS Electrical Power Distribution (Sheet 1 of 2)

on (Sheet 1 of 2)





NOTE:
1. ALL CM RCS, SM RCS QUAD AND PSM ISOLATION VALVES ARE MAGNETICALLY LATCHED OPEN AND SPRING LOADED CLOSED
2. ALL CM RCS, SM RCS QUAD AND PSM ISOLATION VALVES, TALK BACK INDICATORS WILL INDICATE GRAY (POSITIVE OPEN) WHEN VALVES ARE OPEN, BARBER POLE WHEN ANY ONE VALVE IS CLOSED

* IF INSTALLED

A-P-9010N
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Figure 2.5-19. SM RCS Electrical Power Distribution (Sheet 2 of 2)

RCS

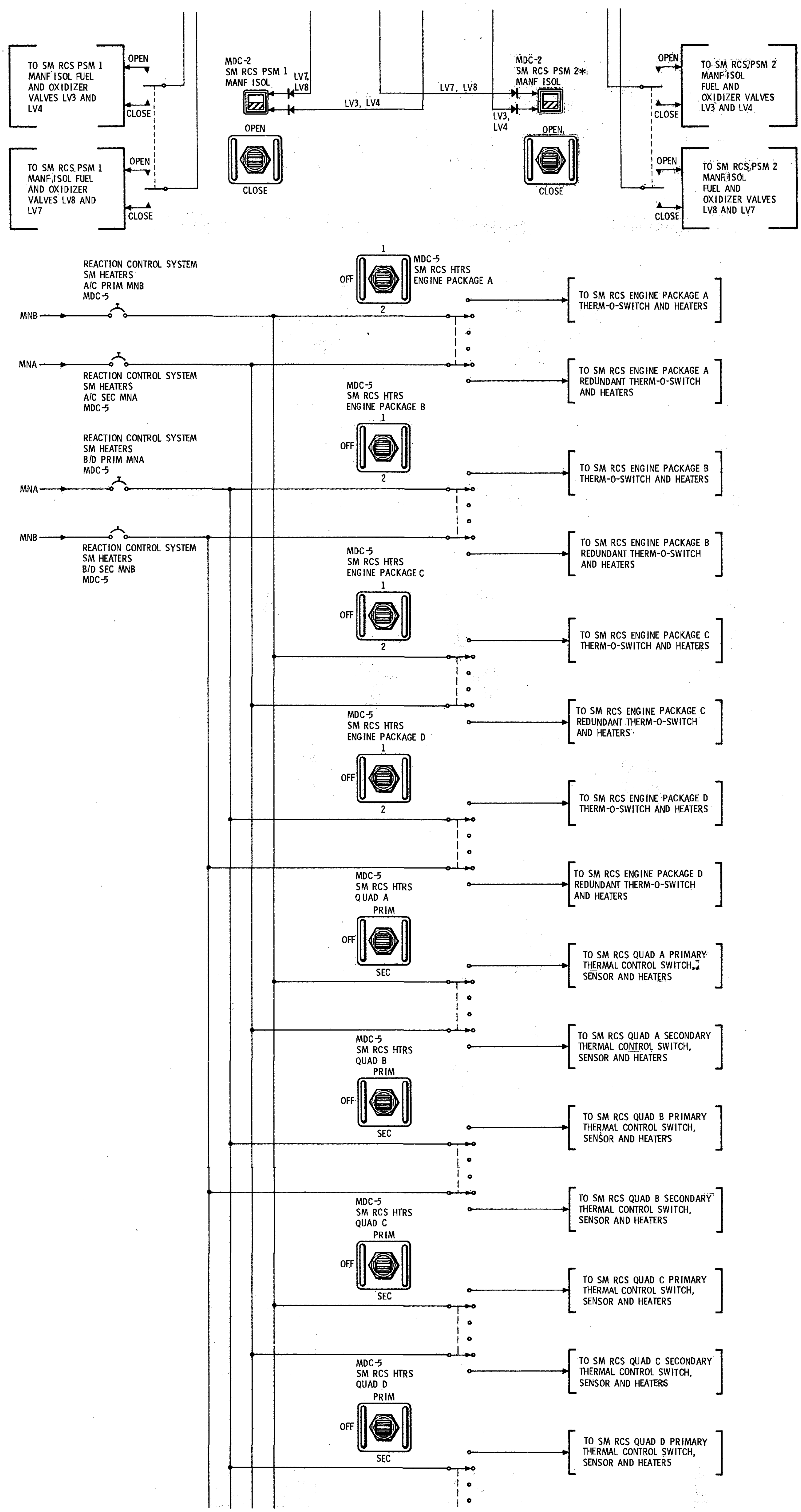
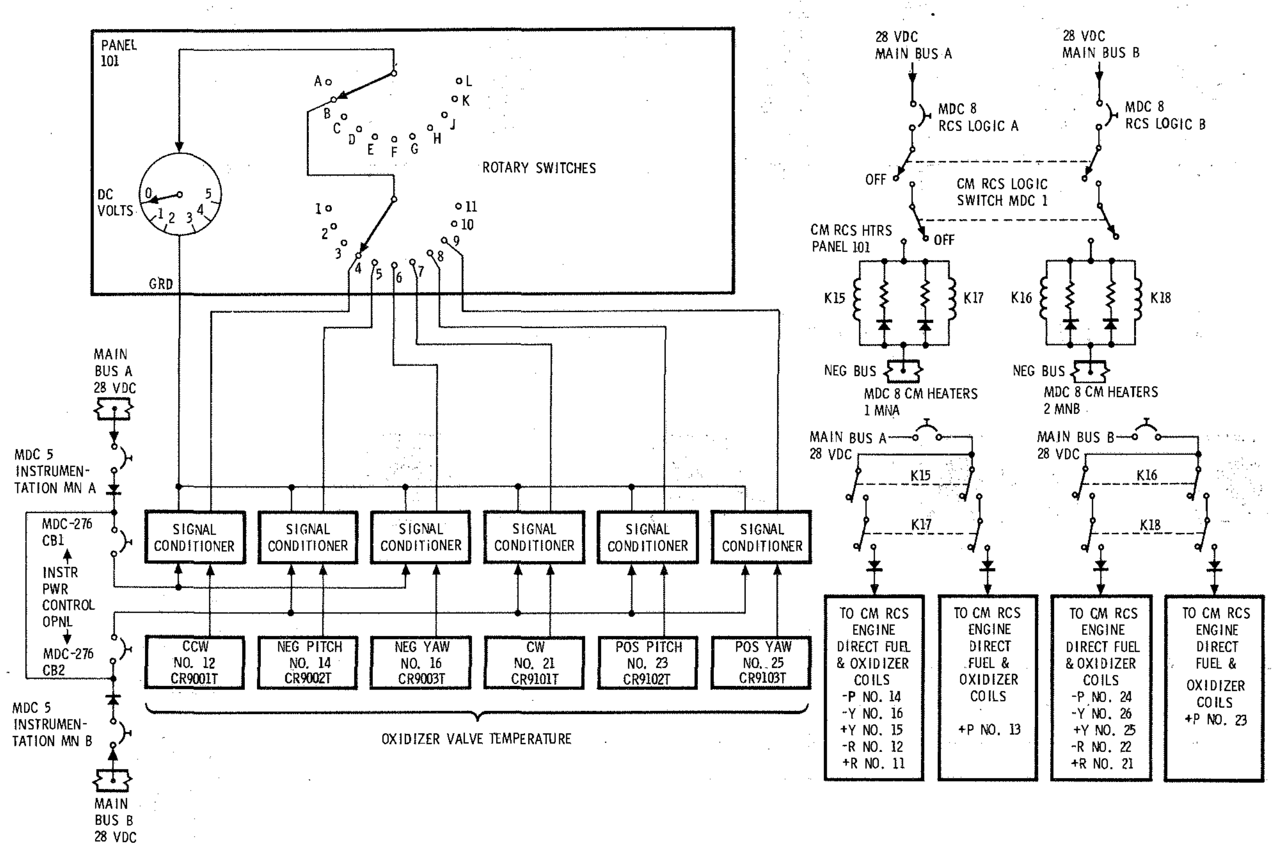


Figure 2.5-19. SM RCS

CM RCS HEATERS ELECTRICAL



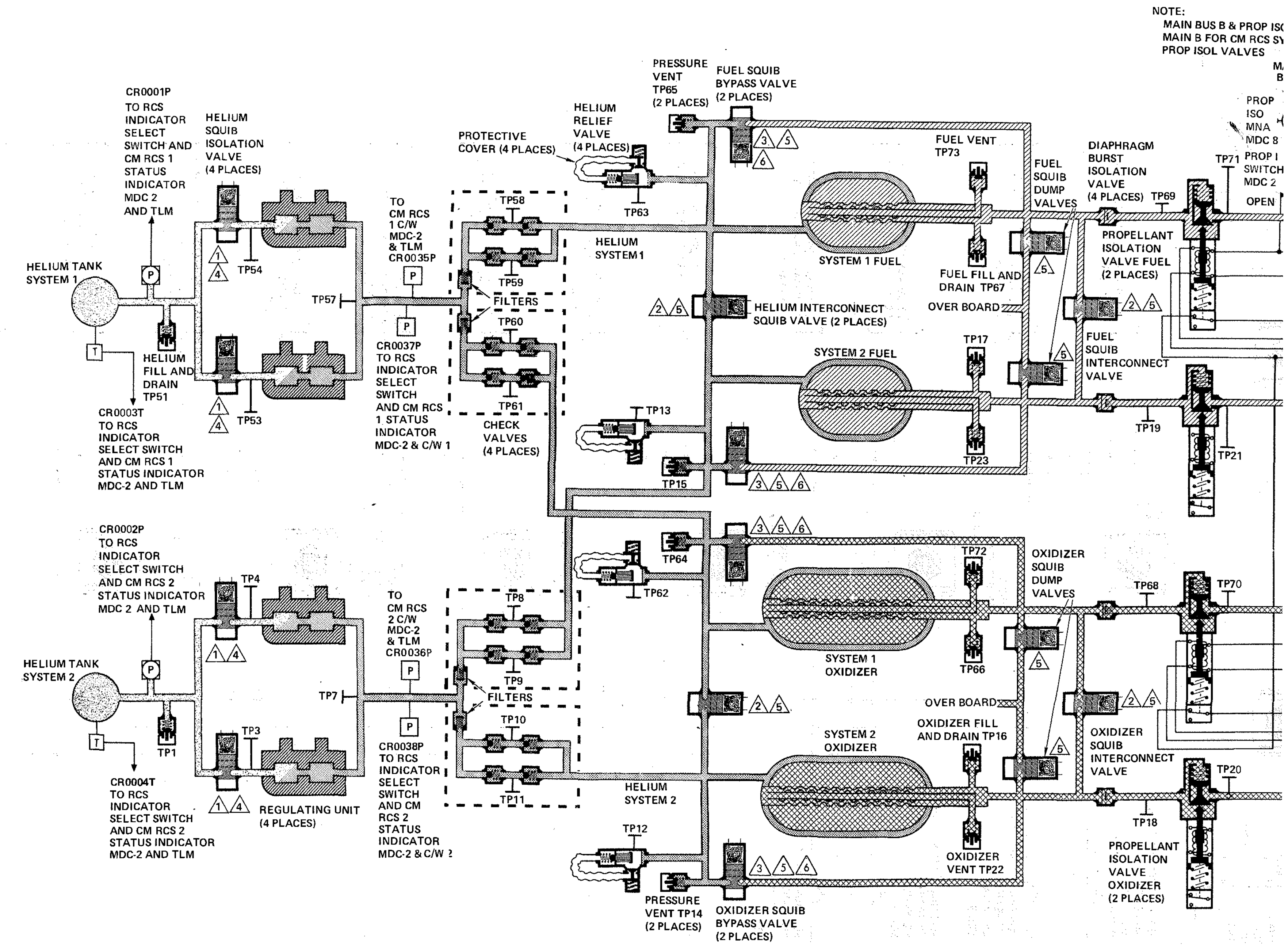
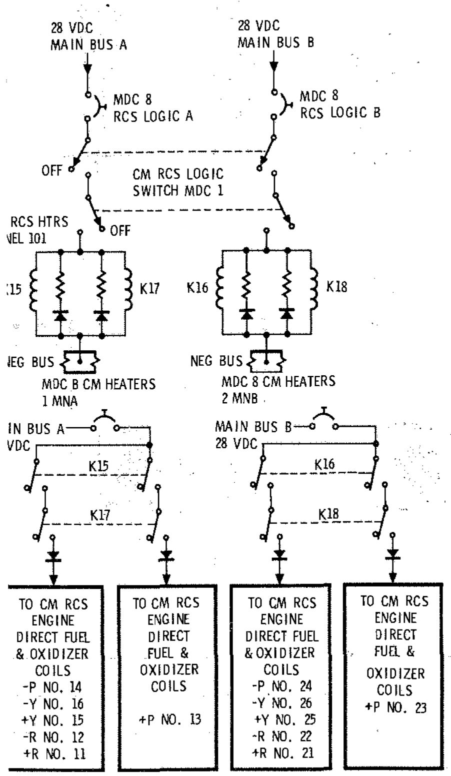
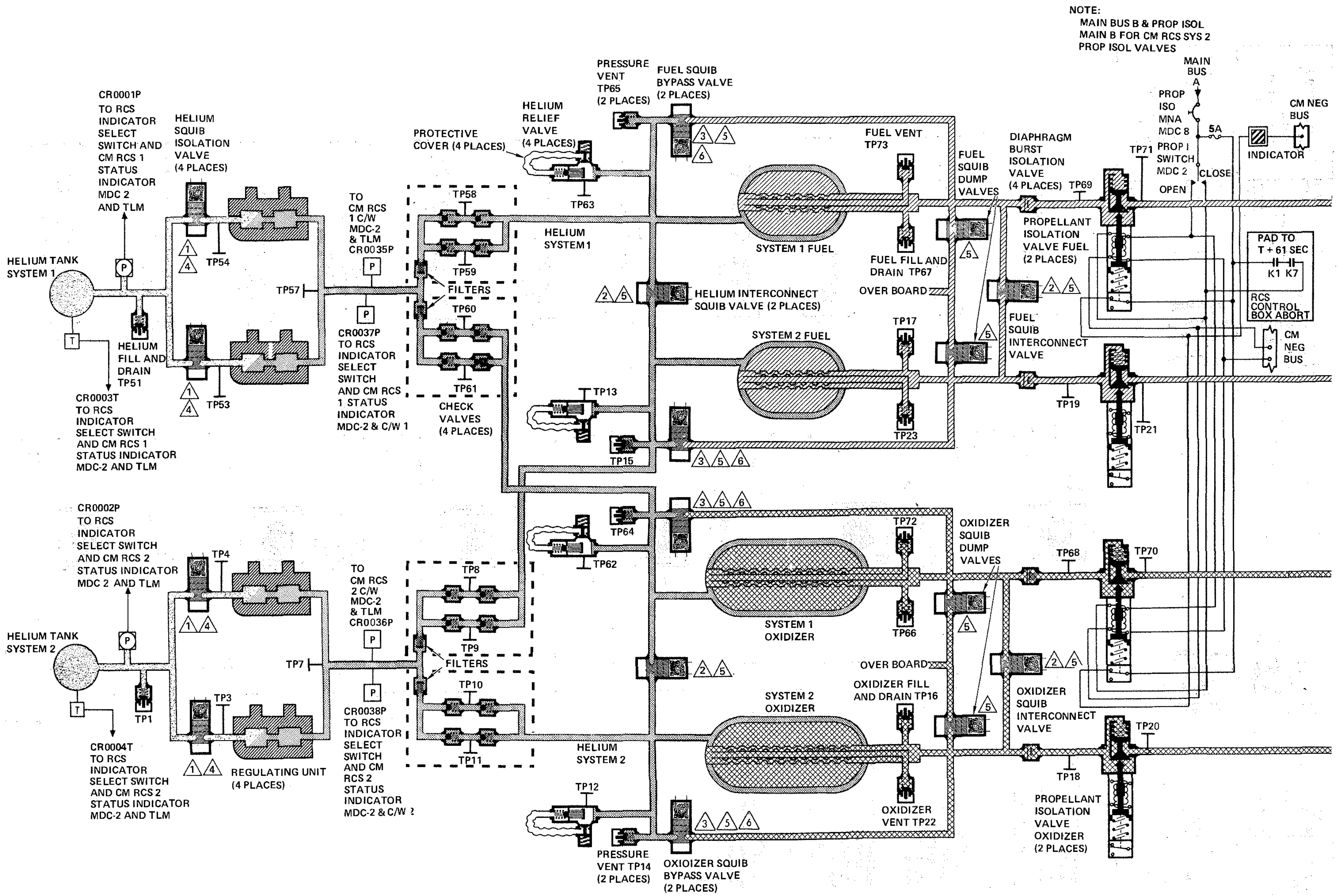


Figure 2.5-20. CM RCS Functional Flow (Sheet 1 of 2)

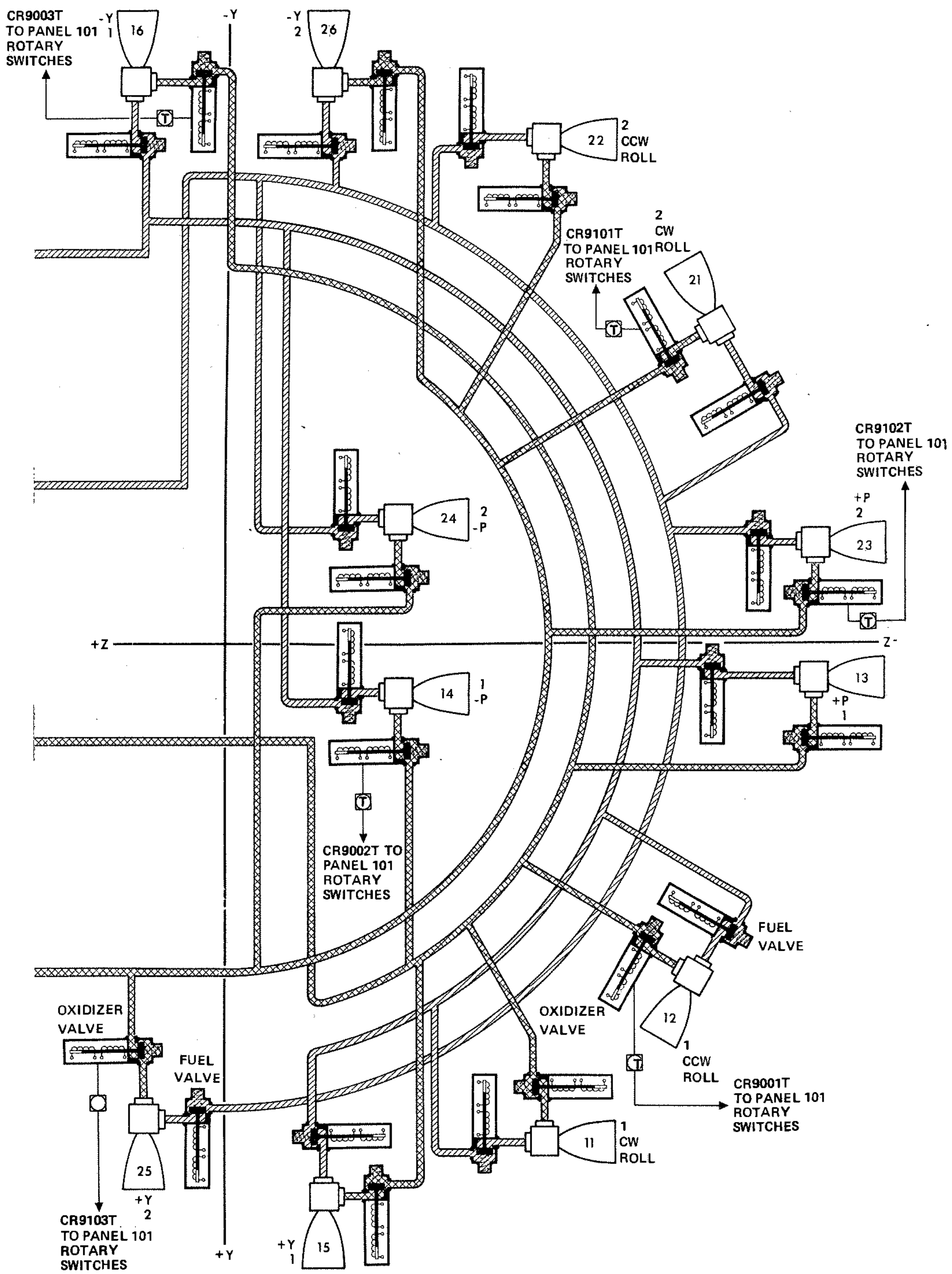
ICAL





Sheet 1 of 2)

RCS



PHASE	SEQUENCE	SQUIB VALVE INDICATION (TOTAL: 16 VALVES)								
		HELIUM ISOLATION (4)	FUEL SIDE HELIUM INTERCONNECT (1)	OXIDIZER SIDE HELIUM INTERCONNECT (1)	FUEL INTERCONNECT (1)	OXIDIZER INTERCONNECT (1)	FUEL TANK BYPASS (2)	OXIDIZER TANK BYPASS (2)	OXIDIZER DUMP (2)	FUEL DUMP (2)
NORMAL ENTRY	1. PRIOR TO CM SM SEPARATION	△1 (NORMAL OR BACKUP) / (BACKUP OR NORMAL) △4								
ABORT AFTER T + 61 SECONDS, CM NO LAND IMPACT	1. SIMULTANEOUS WITH EDS OR MANUAL ABORT INITIATION	△4 (NORMAL) / (BACKUP) △1								
ABORT PAD TO T + 61 SECONDS	1. SIMULTANEOUS WITH EDS OR MANUAL ABORT INITIATION	△4 (NORMAL) / (BACKUP) △1	△5	△5	△5	△5			△5	
	2. ABORT INITIATION PLUS 5 SECONDS.									△5
	3. 13 SECONDS AFTER FUEL DUMP INITIATION						△5	△5		
ABORT AFTER T + 61 SECONDS UP TO 30,000 FT AND POSSIBLE CM LAND IMPACT	1. SIMULTANEOUS WITH EDS OR MANUAL ABORT INITIATION.	△4 (NORMAL) / (BACKUP) △1								
	2. MAIN PARACHUTE DISREEFED		△2	△2	△2	△2				
	3. AFTER PROPELLANT DEPLETION						△3 (NORMAL) / (BACKUP) △6	△3 (NORMAL) / (BACKUP) △6		
ALL SPS ABORTS	SAME AS NORMAL ENTRY									

- [helium pattern] HELIUM
- [oxidizer pattern] OXIDIZER
- [fuel pattern] FUEL
- P PRESSURE TRANSDUCER
- T TEMPERATURE TRANSDUCER
- C/W CAUTION AND WARNING

LEGEND FOR SQUIB VALVE ACTUATION

- △1 CM RCS PRESSURIZE, SWITCH MDC 2
- △2 CM PROPELLANT DUMP SWITCH MDC 1
- △3 CM PROPELLANT PURGE SWITCH MDC 1
- △4 AUTOMATIC (CM SM SEPARATION)
- △5 AUTOMATIC (RCS CONTROL BOX)
- △6 CM RCS HELIUM DUMP PUSHBUTTON, MDC 1

A-P-10003R
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Figure 2.5-20. CM RCS Functional Flow (Sheet 2 of 2)

In the event of an abort from the pad up to T +61 seconds after liftoff, provisions have been incorporated to automatically dump the oxidizer and fuel supply overboard. Then, this is followed by a helium purge of the fuel and oxidizer systems in addition to depleting the helium source pressure.

2.5.6 CM RCS MAJOR COMPONENTS/SUBSYSTEMS DESCRIPTION

The CM RCS is composed of two separate, normally independent subsystems, designated subsystem 1 and subsystem 2. The subsystems are identical in operation, each containing the following four major subsystems:

RCS

- Pressurization
- Propellant
- Rocket engine
- Temperature control system heaters.

2.5.6.1 Pressurization Subsystem

This subsystem consists of a helium supply tank, two dual pressure regulator assemblies, two check valve assemblies, two pressure relief valve assemblies, and associated distribution plumbing.

2.5.6.1.1 Helium Supply Tank

The total high-pressure helium is contained within a single spherical storage tank for each subsystem.

2.5.6.1.2 Helium Isolation (Squib-Operated) Valve

The two squib-operated helium isolation valves are installed in the plumbing from each helium tank to confine the helium into as small an area as possible. This reduces helium leakage during the period the system is not in use. Two squib valves are employed in each system to assure pressurization. The valves are opened by closure of the CM RCS PRESS switch on panel 2 to CM RCS PRESS, or by placing the CM SM SEP switches on panel 2 to CM SM SEP, or upon the receipt of an abort signal from the pad up to the launch escape tower jettison.

2.5.6.1.3 Helium Pressure Regulator Assembly

The pressure regulators used in the CM RCS subsystems 1 and 2 are similar in type, operation, and function to those used in the SM RCS. The difference is that the regulators in the CM RCS are set at a higher pressure than those of the SM RCS.

2.5.6.1.4 Helium Check Valve Assembly

The check valve assemblies used in CM RCS subsystems 1 and 2 are identical in type, operation, and function to those used in the SM RCS.

2.5.6.1.5 Helium Relief Valve

The helium relief valves used in the CM RCS subsystems 1 and 2 are similar in type, operation, and function to those used in the SM RCS. The difference being the rupture pressure of the burst diaphragm in the CM RCS is higher than that of the SM RCS and the relief valve relieves at a higher pressure in the CM RCS than that of the SM RCS.

2.5.6.1.6 Distribution Plumbing

Brazed joint tubing is used to distribute regulated helium in each subsystem from the helium storage vessels to the propellant tanks.

2.5.6.2 Propellant Subsystem

Each subsystem consists of one oxidizer tank, one fuel tank, oxidizer and fuel isolation valves, oxidizer and fuel burst diaphragm isolation valves, and associated distribution plumbing.

2.5.6.2.1 Oxidizer Tank

The oxidizer supply is contained in a single titanium alloy, hemispherical-domed cylindrical tank in each subsystem. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, forcing the oxidizer into the diffuser tube assembly and on out of the tank outlet into the manifold.

2.5.6.2.2 Fuel Tank

The fuel supply is contained in a single titanium alloy, hemispherical-domed cylindrical tank in each subsystem that is similar in material, construction and operation to that of the CM RCS oxidizer tanks. The fuel tanks are the smaller tanks.

2.5.6.2.3 Diaphragm Burst Isolation Valve

The burst diaphragms downstream from each tank are installed to confine the propellants into as small an area as possible throughout the mission. This is to prevent loss of propellants in the event of line rupture downstream of the burst diaphragm or engine injector valve leakage.

When the helium isolation squib valves are initiated open, regulated helium pressure pressurizes the propellant tanks creating the positive expulsion of propellants into the respective manifolds to the burst diaphragms which rupture and allow the propellants to flow on through the burst diaphragm and the propellant isolation valves to the injector valves on each engine. The diaphragm is of the nonfragmentation type, but in the event of any fragmentation, a filter is incorporated to prevent any fragments from entering the engine injector valves.

2.5.6.2.4 Propellant Isolation Shutoff Valves

When the burst diaphragm isolation valves are ruptured, the propellants flow to the propellant isolation valves.

The fuel and oxidizer isolation valves in the SYS 1 fuel and oxidizer lines are both controlled by the CM RCS PRPLNT 1 switch on panel 2. The fuel and oxidizer isolation valves in the SYS 2 fuel and oxidizer lines are both controlled by the CM RCS PRPLNT 2 switch on panel 2. Each propellant isolation valve contains two solenoids, one that is energized momentarily to magnetically latch the valve open, and the remaining solenoid is energized momentarily to unlatch the magnetic latch and spring-pressure and propellant-pressure close the valve. The CM RCS PRPLNT switches on panel 2, positioned to 1 and 2, energize the valves into a magnetic latch (open position of the valves). The CLOSE positions of the CM RCS PRPLNT switches, on panel 2, energize the valves to unlatch the valves from the magnetic latch (closed position of the valves). The center position removes electrical power from either solenoid. The valves are normally open in respect to the fluid flow.

Each valve contains a position switch which is in parallel to one position indicator above the switch on panel 2 that controls both valves. When the position switch in each valve is open, the indicator on panel 2 is gray (same color as the panel) indicating that the valves are in the normal position, providing a positive open valve indication. When the position switch in either valve is closed, the indicator on panel 2 is barber pole (diagonal lines) indicating that either valve, or both valves, are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, runaway thruster, etc.

2.5.6.2.5 Distribution Plumbing

Brazed joint tubing is used to distribute regulated helium to the propellant positive expulsion tanks in subsystems 1 and 2. The distribution lines contain 16 explosive-operated (squib) valves which permit changing the helium and propellant distribution configuration to accomplish various functions within the CM RCS. Each squib valve is actuated by an explosive charge, detonated by an electrical hot-wire ignitor. After ignition of the explosive device, the valve remains open permanently. Two squib valves are utilized in each subsystem to isolate the high-pressure helium supply until CM RCS pressurization is initiated.

If head winds are not high enough to cause a CM land impact on an abort sequence after T +61 seconds up to 30,000 feet, or any abort sequence after T +61 seconds up to launch escape tower jettison, or normal entry, the CM RCS systems 1 and 2 propellant isolation valves will be closed prior to 800 feet on descent. Thus, no squib valves other than the helium pressurization squib valves are initiated open.

RCS

If head winds are high enough to cause a CM land impact on an abort sequence after T +61 seconds up to 30,000 feet, the CM RCS propellants will be burned out through ten of the twelve CM RCS engines, followed by purging of the systems and depleting the helium source pressure. As a result the following squib valves will be initiated open. Two squib valves are utilized to interconnect systems 1 and 2 regulated helium supply which ensures pressurization of both systems during burn and helium purge operations. One squib valve in the oxidizer system permits both oxidizer systems to become common. One squib valve in the fuel system permits both fuel systems to become common. Two squib valves in each system permit helium gas to bypass the propellant tanks allowing helium purging of the propellant system and depletion of the helium source pressure.

If an abort sequence is initiated on the launch pad up to T +61 seconds, the following squib valves are initiated open. Two squib valves are utilized to interconnect system 1 and 2 regulated helium supply ensuring pressurization of both systems. One squib valve in the oxidizer system permits both oxidizer systems to become common. One squib valve in the fuel system permits both fuel systems to become common. Two squib valves in the oxidizer system and two in the fuel system are utilized to dump the respective propellant overboard. Two squib valves in each system permit helium gas to bypass the propellant tanks allowing helium purging of the propellant system and depletion of the helium source pressure through the overboard dumps.

2.5.6.3 <u>Engine Assembly</u>

The command module reaction control subsystem engines are ablative cooled, bipropellant thrust generators which can be operated in either the pulse mode or the steady-state mode.

Each engine has a fuel and oxidizer injector solenoid valve. The injector solenoid control valves control the flow of propellants by responding to electrical commands generated by the reaction jet engine ON-OFF control assembly or by the manual direct RCS mode. Each engine contains an injector head assembly which directs the flow of each propellant from the engine injector valves to the combustion chamber where the propellants atomize and ignite by hypergolic reaction, producing thrust. Estimated engine thrust rise and decay is shown in **figure 2.5-21.**

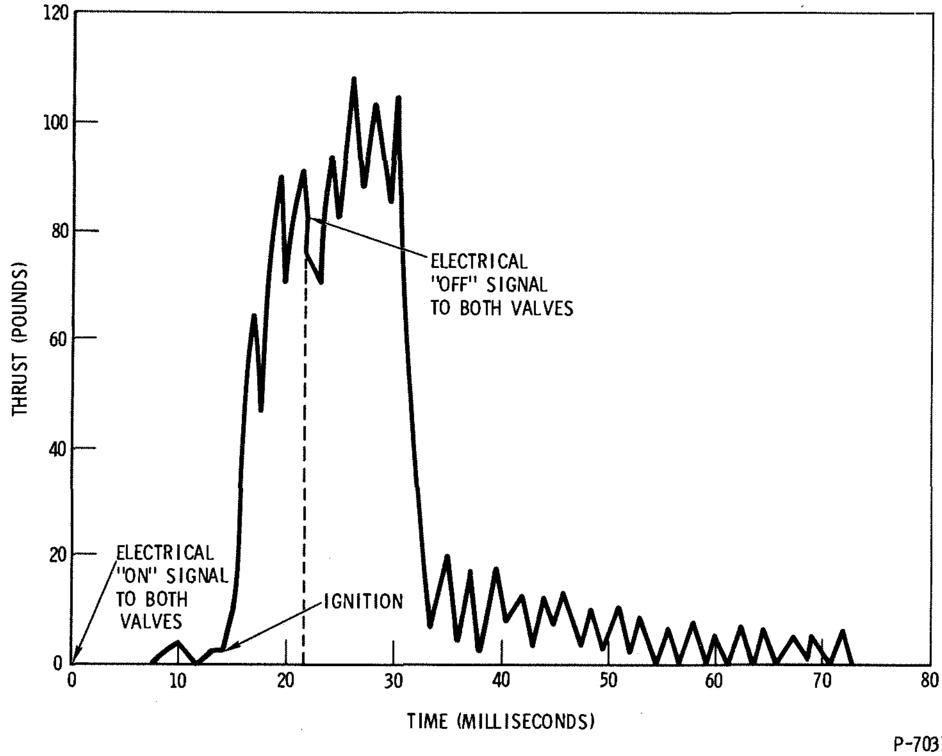


Figure 2.5-21. CM RCS Engine Thrust Rise and Decay Time

2.5.6.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer)

The injector valves utilize two coaxially wound coils, one for automatic and one for manual direct RCS control. The automatic coil is used when the thrust command originates from the reaction jet engine ON-OFF control assembly.

The manual direct RCS coils are used when the thrust command originates at the rotation control (direct RCS).

The engine injector valves are spring-loaded closed and energized open.

The reaction time of the valves, pulse mode of operation, reason for pulse mode, and thrust curve generated by the engine are similar to the SM RCS engines.

The automatic coils in the fuel and oxidizer injector valves are connected in parallel from the reaction jet engine ON-OFF control assembly.

The manual direct RCS coils in the fuel and oxidizer injector valves provide a direct backup to the automatic system. The manual direct RCS coils are connected in parallel from the rotation controls.

The engine injector valve automatic coil opening time is 8±1/2 milliseconds, and closing is 6±1/2 milliseconds. The engine injector valve manual direct RCS coil opening time is 16±3 milliseconds and closing time is 7±3 milliseconds.

2.5.6.3.2 Injector

RCS

The injector contains 16 fuel and 16 oxidizer passages that impinge (unlike impingement) upon a splash plate within the combustion chamber. Therefore, the injector pattern is referred to as an unlike impingement splash-plate injector.

2.5.6.3.3 Thrust Chamber Assembly

The thrust chamber assembly is fabricated in four segments: the combustion chamber ablative sleeve, throat insert, ablative material, asbestos and a fiberglass wrap. The engine is ablative-cooled.

2.5.6.3.4 Nozzle Extension

The CM RCS engines are mounted within the structure of the CM. The nozzle extensions are required to transmit the gasses from the engine out through the structure of the CM. The nozzle extensions are fabricated of ablative material.

2.5.6.3.5 Engine Solenoid Injector Temperature-Control System

A temperature-control system of the CM RCS engine is employed by energizing the manual direct RCS coils on each engine (figure 2.5-20).

Temperature sensors are mounted on the following engine oxidizer injector valves.

- Subsystem 1 counterclockwise roll engine
- Subsystem 1 negative yaw engine
- Subsystem 1 negative pitch engine
- Subsystem 2 positive yaw engine
- Subsystem 2 positive pitch engine
- Subsystem 2 clockwise roll engine.

The temperature transducers have a range from -50° to +250°F. The temperature transducers from the three subsystems 1 and 2 engine oxidizer injector valves provide inputs to the two rotary switches on panel 101, which are located in the lower equipment bay of the command module. With the rotary switches positioned as illustrated in figure 2.5-20, the specific engine injector temperature is monitored as d-c voltage on the 0- to 5-vdc voltmeter on panel 101. The 0 vdc is equivalent to -50°F and 5 vdc is equivalent to +250°F.

A CM RCS HTRS switch located on panel 101 (figure 2.5-20) is placed to the CM RCS HTRS position when any one of the instrumented engines are below +40°F or less. The CM RCS LOGIC switch, on panel 1, must be positioned to CM RCS LOGIC to provide electrical power to the CM RCS HTRS switch on panel 101. When the CM RCS HTRS switch is positioned to CM RCS HTRS, relays are energized, which allow electrical power to be provided from the CM HEATERS circuit breakers 1 MNA and 2 MNB on panel 8, to the direct injector solenoid control valves of the 12 CM RCS engines. The fuel and oxidizer injector solenoid control valve direct coils (of all 12 CM RCS engines) are energized open prior to the pressurization of CM RCS subsystems 1 and 2. If preheat is required, the engine injector valve direct coils will be preheated for 20 minutes or until any instrumented oxidizer injector valve temperature reaches +225°F. The CM RCS HTRS switch on panel 101 is positioned to OFF, allowing the injector solenoid control valve direct coils to de-energize, and the injector solenoid control valves spring-load closed. This will prevent the oxidizer from freezing at the engine injector valves upon pressurization of subsystems 1 and 2, and 20 minutes or +225°F ensures that the engine injector valves will not be overheated.

The CM RCS HTRS switch must be placed to OFF prior to CM RCS pressurization.

The operation of the CM RCS HTRS switch in conjunction with the d-c voltmeter and/or heating time ensures all other engine valves reach the acceptable temperature levels.

If the CM RCS HTRS switch on panel 101 fails to energize the direct coils for the CM RCS preheat, the following backup procedure may be utilized:

a. The CM RCS HTRS switch on panel 101 is placed to OFF.

b. The ROTATION CONTROL POWER DIRECT RCS switch 1 and 2 on panel 1 is placed to OFF.

c. RCS TRANSFER switch on panel 2 is placed to CM.

d. SC CONT switch on panel 1 is placed to SCS.

e. MANUAL ATTITUDE PITCH, YAW, and ROLL switches on panel 1 are placed to ACCEL CMD.

f. A/C ROLL AUTO RCS AUTO RCS SELECT switches on panel 8 are placed to OFF.

g. ROTATION HAND CONTROLS are placed to soft stops for 10 minutes or until any instrumented engine oxidizer injector valve reaches +225°F.

h. If a CM RCS engine temperature that is monitored on panel 1 fails to increase because of a CM RCS engine direct coils failure, the preceding steps a through f are followed, and then the ROTATION HAND CONTROL(S) are placed to soft stop(s) of affected engine for 10 minutes or until any instrumented engine oxidizer injector valve reaches +225°F.

2.5.6.3.6 Engine Thrust ON-OFF Logic

All automatic thrust commands for CM attitude are generated from within the reaction jet engine ON-OFF control assembly. These commands may originate at:

- The rotation controls
- The stabilization and control subsystem
- The command module computer.

In the event the reaction jet engine ON-OFF control assembly is unable to control the automatic coils of the CM RCS engines, a backup method is provided. The backup method consists of two ROT CONT PWR DIRECT RCS switches on panel 1 and the two rotation controllers. The ROT CONT PWR DIRECT RCS 1 switch supplies power only to rotation control 1. When the ROT CONTROL PWR DIRECT RCS 1 switch is positioned to MNA/MNB, main buses A and B supply power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch is positioned to MNA, main bus A supplies power only to rotation control 1. The ROT CONT PWR DIRECT RCS 2 switch supplies power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNA/MNB, main buses A and B supply power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNB, main bus B supplies power only to rotation control 2. When the rotation control is positioned fully to its stops in any direction, the required manual direct RCS coils are energized for the desired maneuver.

When the CM SM SEP switches on panel 2 are placed to CM SM SEP position, the switches automatically energize relays in the RCS control box (figure 2.5-11) (providing the CM RCS LOGIC switch on panel 1 is at CM RCS LOGIC) that transfer the reaction jet engine ON-OFF control assembly automatic, and manual direct RCS inputs from the SM RCS engine to the CM RCS engines automatically. These same functions occur automatically on any LES ABORT providing the CM RCS LOGIC switch on panel 1 is at CM RCS LOGIC.

The transfer motors in the RCS control box are redundant to each other in that they ensure the manual direct RCS inputs are transferred from the SM RCS engines to the CM RCS engines in addition to providing a positive deadface.

The RCS transfer motors may also be activated by the RCS TRNFR switch placed to CM position on panel 2, which provides a manual backup to the automatic transfer. The CM RCS LOGIC switch on panel 1 does not have to be in CM RCS LOGIC position for the manual backup transfer function.

As an example, in the case of the direct manual inputs only to the RCS engines: If the electrical A RCS transfer motor failed to transfer automatically at CM SM SEP (providing the CM RCS LOGIC switch on panel 1 is at CM RCS LOGIC), or by use of the manual RCS transfer switch on panel 2, the electrical B RCS transfer motor would transfer the direct manual inputs from the SM RCS engines to the CM RCS engines, in addition, providing a positive deadface to the SM RCS engines.

The CM RCS subsystems 1 and 2 may be checked out prior to CM SM separation by utilization of the RCS transfer switch on panel 2. Placing the RCS TRANSFER switch to the CM position, the reaction jet engine ON-OFF control assembly and manual direct RCS inputs are transferred to the CM permitting a CM RCS checkout prior to CM SM separation.

2.5.6.4 Propellant Jettison

There are three sequences of propellant jettison. One sequence is employed in the event of an abort while the CSM is on the launch pad and through the first 61 seconds of flight. The second sequence is employed on an abort sequence after T +61 seconds up to 30,000 feet if head winds are high enough to cause land impact of the CM. The third sequence is used if head winds are not high enough to cause a CM land impact on an abort sequence after T +61 seconds up to launch escape tower jettison or normal entry.

The sequence of events before and during a normal entry is as follows:

a. The CM RCS is pressurized by placing the CM SM SEP switches on MDC-2 to CM SM SEP position or by placing the CM RCS PRESS switch on MDC-2 to the CM RCS PRESS position prior to initiating CM-SM separation. The CM RCS PRESS switch or the CM SM SEP switches initiate the helium isolation squib valves in CM RCS subsystems 1 and 2, thus pressurizing both subsystems (figures 2.5-20 and 2.5-22). The CM RCS LOGIC switch on MDC-1 must be placed to CM RCS LOGIC prior to initiating CM/SM separation to provide the automatic RCS transfer function.

b. The CM RCS provides attitude control during entry. At approximately 24,000 feet, barometric switches are activated unlatching the RCS latching relay. This inhibits any further commands from the reaction jet engine ON-OFF control assembly (providing the ELS LOGIC switch on MDC-1 is in AUTO) (figure 2.5-11). The RCS CMD switch MDC-2, positioned to OFF momentarily provides a manual backup to the 24,000 feet barometric switches.

c. Prior to 800 feet on descent, the CM RCS 1 and 2 propellant isolation valves are closed.

The sequence of events involving an abort from the pad up to 61 seconds is as follows:

a. The ABORT SYSTEM PRPLNT DUMP AUTO switch on MDC-2 is placed to the PRPLNT DUMP AUTO position (figures 2.5-11 and 2.5-22) and the CM RCS LOGIC switch on MDC-1 is placed to the CM RCS LOGIC position at the same time in the countdown prior to T +0.

b. The following events occur simultaneously upon the receipt of the abort signal. The command may be generated automatically by the sequential events control system or by manually rotating the translation control counterclockwise:

1. When the abort signal is received, the two squib-operated helium isolation valves in each system are initiated open, pressurizing both systems 1 and 2. Manual backup would be the CM RCS PRESS switch on MDC-2.

2. The squib-operated helium interconnect valve for the oxidizer and fuel tanks is initiated open. If only one of the two squib helium isolation valves was initiated open, both subsystems are pressurized as a result of the helium interconnect squib valve interconnect.

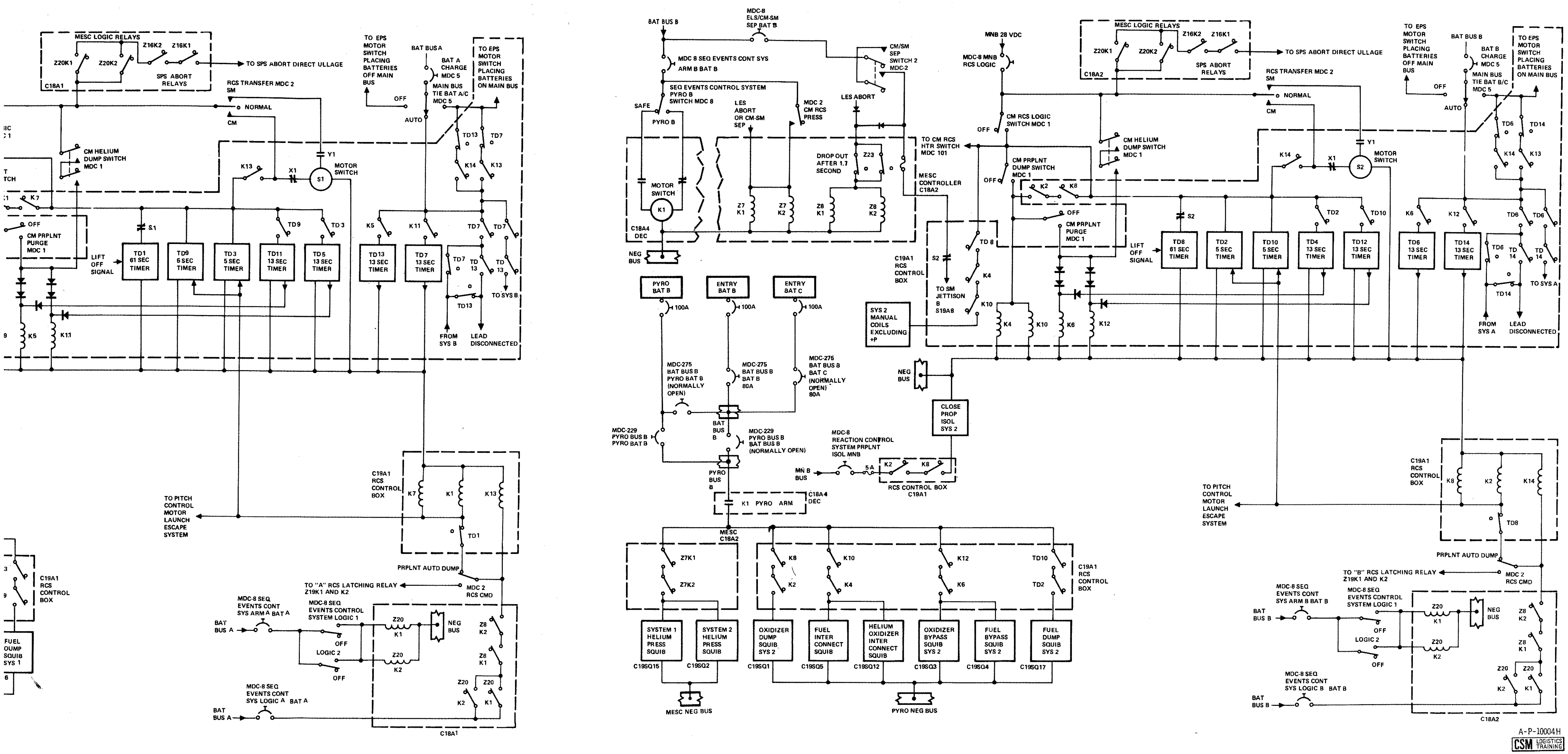
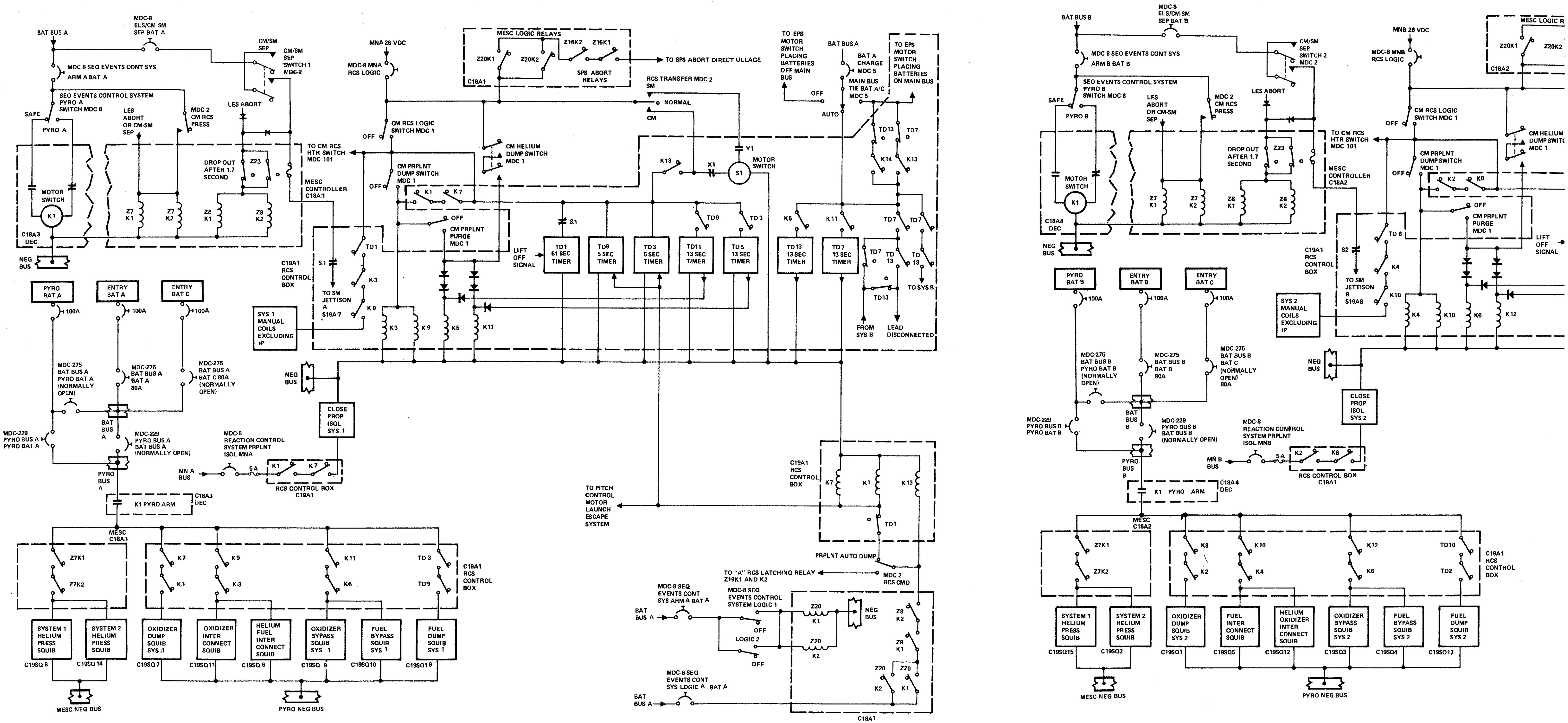


Figure 2.5-22. CM RCS Squib Valve Control



BAT BUS A
MDC-8 ELS/CM SM SEP BAT A
MDC 8 SEQ EVENTS CONT SYS ARM A BAT A
SEO EVENTS CONTROL SYSTEM PYRO A SWITCH MDC 8
SAFE
PYRO A
LES ABORT OR CM-SM SEP
MDC 2 CM RCS PRESS
LES ABORT
CM/SM SEP
CM/SM SEP SWITCH 1 MDC-2
DROP OUT AFTER 1.7 SECOND
Z23
MOTOR SWITCH
K1
C18A3 DEC
Z7 K1
Z7 K2
Z8 K1
Z8 K2
NEG BUS
PYRO BAT A
ENTRY BAT A
ENTRY BAT C
100A
MDC-275 BAT BUS A PYRO BAT A (NORMALLY OPEN)
MDC-275 BAT BUS A BAT A 80A
MDC-275 BAT BUS A BAT C 80A (NORMALLY OPEN)
BAT BUS A
MDC-229 PYRO BUS A PYRO BAT A
MDC-229 PYRO BUS A BAT BUS A (NORMALLY OPEN)
PYRO BUS A
K1 PYRO ARM
C18A3 DEC
MESC C18A1
Z7K1
Z7K2
K7
K1
K9
K3
K11
K6
TD 3
TD9
C19A1 RCS CONTROL BOX
SYSTEM 1 HELIUM PRESS SQUIB
SYSTEM 2 HELIUM PRESS SQUIB
OXIDIZER DUMP SQUIB SYS 1
OXIDIZER INTER CONNECT SQUIB
HELIUM FUEL INTER CONNECT SQUIB
OXIDIZER BYPASS SQUIB SYS 1
FUEL BYPASS SQUIB SYS 1
FUEL DUMP SQUIB SYS 1
C19SQ 8
C19SQ 14
C19SQ7
C19SQ11
C19SQ 6
C19SQ 9
C19SQ10
C19SQ16
MESC NEG BUS
PYRO NEG BUS
TO CM RCS HTR SWITCH MDC 101
MESC CONTROLLER C18A1
MNA 28 VDC
MDC-8 MNA RCS LOGIC
OFF
CM RCS LOGIC SWITCH MDC 1
CM PRPLNT DUMP SWITCH MDC 1
CM PRPLNT PURGE MDC 1
C19A1 RCS CONTROL BOX
S1
TD1
TO SM JETTISON A S19A7
SYS 1 MANUAL COILS EXCLUDING +P
K3
K9
K5
K11
NEG BUS
CLOSE PROP ISOL SYS 1
MDC-8 REACTION CONTROL SYSTEM PRPLNT ISOL MNA
MN A BUS
5A
RCS CONTROL BOX C19A1
MESC LOGIC RELAYS
Z20K1
Z20K2
Z16K2
Z16K1
C18A1
SPS ABORT RELAYS
TO SPS ABORT DIRECT ULLAGE
RCS TRANSFER MDC 2
SM
NORMAL
CM
CM HELIUM DUMP SWITCH MDC 1
K13
X1
Y1
S1
MOTOR SWITCH
LIFT OFF SIGNAL
TD1 61 SEC TIMER
TD9 5 SEC TIMER
TD3 5 SEC TIMER
TD11 13 SEC TIMER
TD5 13 SEC TIMER
TD13 13 SEC TIMER
TD7 13 SEC TIMER
TO EPS MOTOR SWITCH PLACING BATTERIES OFF MAIN BUS
BAT BUS A
BAT A CHARGE MDC 5
MAIN BUS TIE BAT A/C MDC 5
AUTO
TO EPS MOTOR SWITCH PLACING BATTERIES ON MAIN BUS
TD13
TD7
K14
K5
K11
TO SYS B
FROM SYS B
LEAD DISCONNECTED
TO PITCH CONTROL MOTOR LAUNCH ESCAPE SYSTEM
C19A1 RCS CONTROL BOX
PRPLNT AUTO DUMP
TO "A" RCS LATCHING RELAY Z19K1 AND K2
MDC 2 RCS CMD
MDC-8 SEQ EVENTS CONT SYS ARM A BAT A
BAT BUS A
MDC-8 SEQ EVENTS CONTROL SYSTEM LOGIC 1
LOGIC 2
Z20 K1
Z20 K2
Z8 K2
Z8 K1
MDC-8 SEQ EVENTS CONT SYS LOGIC A BAT A
C18A1
BAT BUS B
MDC-8 ELS/CM-SM SEP BAT B
MDC 8 SEO EVENTS CONT SYS ARM B BAT B
SEO EVENTS CONTROL SYSTEM PYRO B SWITCH MDC 8
PYRO B
CM/SM SEP SWITCH 2 MDC-2
C18A4 DEC
PYRO BAT B
ENTRY BAT B
ENTRY BAT C
MDC-275 BAT BUS B PYRO BAT B (NORMALLY OPEN)
MDC-275 BAT BUS B BAT B 80A
MDC-275 BAT BUS B BAT C (NORMALLY OPEN) 80A
MDC-229 PYRO BUS B PYRO BAT B
MDC-229 PYRO BUS B BAT BUS B (NORMALLY OPEN)
PYRO BUS B
K1 PYRO ARM
MESC C18A2
MESC CONTROLLER C18A2
MNB 28 VDC
MDC-8 MNB RCS LOGIC
S2
TO SM JETTISON B S19A8
SYS 2 MANUAL COILS EXCLUDING +P
K4
K10
K6
K12
CLOSE PROP ISOL SYS 2
MDC-8 REACTION CONTROL SYSTEM PRPLNT ISOL MNB
MN B BUS
OXIDIZER DUMP SQUIB SYS 2
FUEL INTER CONNECT SQUIB
HELIUM OXIDIZER INTER CONNECT SQUIB
OXIDIZER BYPASS SQUIB SYS 2
FUEL BYPASS SQUIB SYS 2
FUEL DUMP SQUIB SYS 2
C19SQ15
C19SQ2
C19SQ1
C19SQ5
C19SQ12
C19SQ3
C19SQ4
C19SQ17

Figure 2.

3. The solenoid-operated fuel and oxidizer isolation shutoff valves are closed. This prevents fuel and oxidizer from flowing to the thrust chamber assemblies.

4. The squib-operated fuel and oxidizer interconnect valves are initiated open. If only one of the two oxidizer or fuel overboard dump squib valves was intiated open, the oxidizer and fuel manifolds of each respective system are common as a result of the oxidizer and fuel interconnect squib valve.

5. The squib-operated oxidizer overboard dump valves are initiated open directing the oxidizer to an oxidizer blowout plug, in the aft heat shield of the CM. The pressure buildup causes the pin in the blowout plug to shear, thus blowing the plug and dumping the oxidizer overboard. The entire oxidizer supply is dumped in approximately 13 seconds.

6. The RCS latching relay will not energize in the event of an abort from 0 to +61 seconds because of the position of the PRPLNT DUMP AUTO switch (figures 2.5-11 and 2.5-22). Thus, the reaction jet engine ON-OFF control assembly is not enabled.

7. The CM-SM RCS transfer motor-driven switches are automatically driven upon receipt of the abort signal, transferring the logic circuitry from SM RCS engines to CM RCS engines.

8. Five seconds after abort initiation, the squib-operated fuel overboard dump valves are initiated open and route the fuel to a fuel blowout plug in the aft heat shield of the CM. The pressure buildup causes the pin in the blowout plug to shear, thus blowing the plug and dumping the fuel overboard. The entire fuel supply is dumped in approximately 13 seconds.

9. Thirteen seconds after the fuel dump sequence was started, the fuel and oxidizer bypass squib valves subsystems 1 and 2 are initiated open. This purges the fuel and oxidizer systems out through the fuel and oxidizer overboard dumps, respectively, and depletes the helium source pressure.

During the prelaunch period the MAIN BUS TIE switches on MDC-5 are in the AUTO position. In the event of a pad abort, electrical power is automatically applied to the main buses. Just prior to lift-off the electrical power is applied to the main buses by manually placing the two MAIN BUS TIE switches on MDC-5 to BAT A/C and BAT B/C positions.

The sequence of events if an abort is initiated after T +61 seconds up to 30,000 feet and head winds are high enough to cause land impact of CM is as follows:

a. At 61 seconds after lift-off, as a normal manual function the PRPLNT DUMP AUTO switch on MDC-2 is placed to the auto RCS CMD position. This safes the oxidizer, fuel dump, and purge circuitry (figures 2.5-11 and 2.5-22) and sets up the circuitry for the RCS latching relay.

b. The CM RCS LOGIC switch panel 1 was placed to CM RCS LOGIC prior to T +0.

c. Initiate both helium isolation squib valves in the CM RCS subsystems 1 and 2. Manual backup would be the CM RCS PRESS switch on MDC-2; thus, pressurizing CM RCS subsystems 1 and 2.

d. Automatically drives the CM SM transfer motors from SM RCS engines to CM RCS engines. Manual backup would be the RCS transfer switch on MDC-2 to CM position.

e. Energize the RCS latching relay arming coils one second after receipt of the abort signal. This allows the reaction jet engine ON-OFF control assembly to control the automatic coils of the CM RCS. Manual backup would be the RCS CMD switch on MDC-2.

f. At 24,000 feet, barometric switches energize the RCS latching relay safe coils (providing the ELS LOGIC switch on MDC-1 is in AUTO). This removes electrical power from the reaction jet engine ON-OFF control assembly, thus the CM RCS engines. Manual backup would be the RCS CMD switch on MDC-2 to OFF.

g. At approximately main parachute line stretch as a normal manual function, the CM RCS PRPLNT-DUMP switch on MDC-1 is placed to the DUMP position. This function initiates the following simultaneously. (CM RCS LOGIC switch on MDC-1 must be placed to CM RCS LOGIC to provide electrical power to the DUMP switch.) (See figures 2.5-11 and 2.5-22.)

1. Initiates the two helium interconnect squib valves.
2. Initiates the fuel interconnect squib valves.
3. Initiates the oxidizer interconnect squib valve.
4. The fuel and oxidizer injector valve direct manual coils are energized on all of the CM RCS engines excluding the two + pitch engines. The propellants are jettisoned by burning the propellants remaining through 10 of the 12 engines. The length of time to burn the remaining propellants will vary, depending upon the amount of propellants remaining in the fuel and oxidizer tanks at 24,000 feet. If an entire propellant load remained, as an example, a nominal burn time would be 88 seconds through 10 of the 12 engines. In the worst case of only 5 of the 12 engines (direct manual coils energized), a nominal burn time would be 155 seconds.

h. Upon completion of propellant burn, the CM PRPLNT PURGE switch on MDC-1 is placed to the PURGE position as a normal manual function (the CM PRPLNT-DUMP switch supplies electrical power when placed to DUMP position to the PURGE switch). When the PURGE switch is placed to PURGE, the switch initiates the four helium bypass squib valves. This allows the regulated helium pressure to bypass each fuel and oxidizer tank, purging the lines and manifolds out through 10 of the 12 engines, as well as depleting the helium source pressure. Purging requires approximately 15 seconds (until helium depletion).

i. In the event of a CM RCS LOGIC switch and/or CM PRPLNT DUMP switch failure on MDC-1, the remaining propellants may be burned by placing ROT CONT PWR DIRECT RCS switch 1 on MDC-1 to either MNA/MNB or MNA, and/or ROT CONT PWR DIRECT RCS switch 2 on MDC-1 to either MNA/MNB or MNB. Then positioning the two rotation controllers to CCW, CW, -Y, +Y, and -P (excluding +P) position. This will energize the direct fuel and oxidizer injector solenoid valve coils of 10 of the 12 CM RCS engines and burn the remaining propellants. At the completion of propellant burn the CM RCS HELIUM DUMP pushbutton on MDC-1 would be pressed initiating the four bypass squib valves. This allows the regulated helium pressure to bypass each fuel and oxidizer tank. This purges the lines and manifolds out through 10 of the 12 engines as well as depleting the helium source pressure providing the two rotation controllers are positioned to CCW, CW, -Y, and -P (excluding +P).

j. In the event the CM RCS LOGIC and CM PRPLNT DUMP switches on MDC-1 function correctly and the PURGE switch fails, the CM RCS HELIUM DUMP pushbutton on MDC-1 would be pressed, initiating the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, purging the lines and manifolds out through 10 of the 12 engines as well as depleting the helium source pressure.

k. Upon completion of purging, the direct manual coils of the CM RCS engine injector valves will be de-energized by placing the CM RCS LOGIC switch on MDC-1 to OFF, or by placing the CM PRPLNT DUMP switch on MDC-1 to OFF. The CM RCS 1 and 2 PRPLNT switches on MDC-2 will also be placed to the OFF position momentarily closing the fuel and oxidizer propellant isolation valves. These functions will be accomplished prior to impact.

The sequence of events involving an abort after T +61 seconds up to launch escape tower jettison and head winds not high enough to cause a CM land impact is as follows:

a. At 61 seconds after liftoff, as a normal manual function, the PRPLNT DUMP AUTO switch on MDC-2 is placed to the auto RCS CMD position. This safes the oxidizer, fuel dump, and purge circuitry (figures 2.5-11 and 2.5-22), and sets up the circuitry for the RCS latching relay.

b. The CM RCS LOGIC switch (panel 1) was placed to CM RCS LOGIC prior to T +0.

c. Both helium isolation squib valves in the CM RCS subsystems 1 and 2 are initiated. Manual backup would be the CM RCS PRESS switch on MDC-2, thus pressurizing CM RCS subsystems 1 and 2.

d. The CM SM transfer motors are automatically driven from SM RCS engines to CM RCS engines. Manual backup would be the RCS transfer switch on MDC-2 to CM position.

e. The RCS latching relay is energized one second after receipt of the abort signal. This allows the reaction jet engine ON-OFF control assembly to control the automatic coils of the CM RCS. Manual backup would be the RCS CMD switch on MDC-2.

f. At 24,000 feet, barometric switches energize the RCS latching relay safe coils (providing the ELS LOGIC switch on MDC-1 is in AUTO). This removes electrical power from the reaction jet engine ON-OFF control assembly, thus the CM RCS engines. Manual backup would be the RCS CMD switch on MDC-2 to OFF.

g. Before 800 feet on descent, the CM RCS systems 1 and 2 propellant isolation valves are closed.

2.5.7 CM RCS PERFORMANCE AND DESIGN DATA

2.5.7.1 Design Data

The following list contains data on the CM RCS components:

Helium tanks (2)	4150±50 psig at 70° ±5°F during servicing; after servicing 70° ±10°F. Capacity 0.57 lb, inside diameter 8.84 in., wall thickness 0.105 in., internal volume of 356±5 cu in. at 4150±50 psig, and weight 5.25 lb.
Helium isolation squib valve filter	Removes 98 percent of all particles whose two smallest dimensions are greater than 40 microns. Removes 100 percent of all particles whose two smallest dimensions are greater than 74 microns.
Regulator units (4)	Primary 291±6 psig. Lockup pressure maximum of 302 psig. Secondary - 293.5±8.5 psig lockup 308 psig maximum. Filter 25 microns nominal, 40 microns absolute at inlet of each regulator unit.
Check valve filters	40 microns nominal, 74 microns absolute. One at each inlet to check valve assembly, one at each test port.

RCS

SYSTEMS DATA

Helium manifold pressure transducer (4)	Illuminates caution and warning lights on panel 2 (CM RCS 1 or 2). After helium isolation squib valve actuation. Underpressure 260±12 psia Overpressure 315±12 psia
Helium relief valves (4)	Diaphragm rupture at 340±8 psi. Filter 10 microns nominal, 25 microns absolute. Relieve at 346±14 psig. Reseat at no less than 327 psig. Flow capacity 0.3 lb/min at 60°F and 346±14 psig. Bleed device closes when increasing pressure has reached no more than 179 psig in the cavity, and a helium flow of less than 20 standard cubic centimeters per hour across the bleed device and relief valve assembly combined. The bleed device reopens when decreasing pressure has reached no less than 20 psig.
Fuel tanks (2)	Combined propellant and ullage volume of 45.2 lb initially at 65°F at 150 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Internal volume 1473.0 cubic inches Outside diameter 12.62 in. maximum Length 17.329 in. (+0.040, -0.000) Wall thickness 0.022 to 0.027 in.
Oxidizer tank (2)	Combined propellant and ullage volume of 89.2 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Internal volume 1786.6 cubic inches Outside diameter 12.65 in. maximum Length 19.907 in. (+0.040, -0.000) Wall thickness 0.022 to 0.027 in.
Valve isolation burst diaphragm (4)	Rupture at 241±14 psig within 2 seconds after rupture pressure is reached at any temperature between 40° to 105°F. Filter 75 microns nominal, 100 microns absolute.
Engine	200-second service life, 3000 operational cycles Expansion ratio 9 to 1 Cooling Ablation

	Injector type	16 on 16 splash plate
	Combustion chamber-refrasil ablative sleeve and graphite base throat insert. Automatic and manual coils connected in parallel.	
	Weight	8.3 lb
	Length	11.65 in. maximum
	Nozzle exit diameter	2.13 in.
	Nozzle extensions	ablative refrasil
Oxidizer blowout plug	Pin shears at approximately 200 psi	
Fuel blowout plug	Pin shears at approximately 200 psi	

RCS

2.5.7.2 Performance Data

Refer to CSM/LM Spacecraft Operational Data Book SNA-8-D-027 CSM (SD 68-447).

2.5.7.3 CM RCS Electrical Power Distribution

See figure 2.5-23 for electrical power distribution.

2.5.8 CM RCS OPERATION LIMITATIONS AND RESTRICTIONS

Refer to Skylab Operations Handbook, Volume 2.

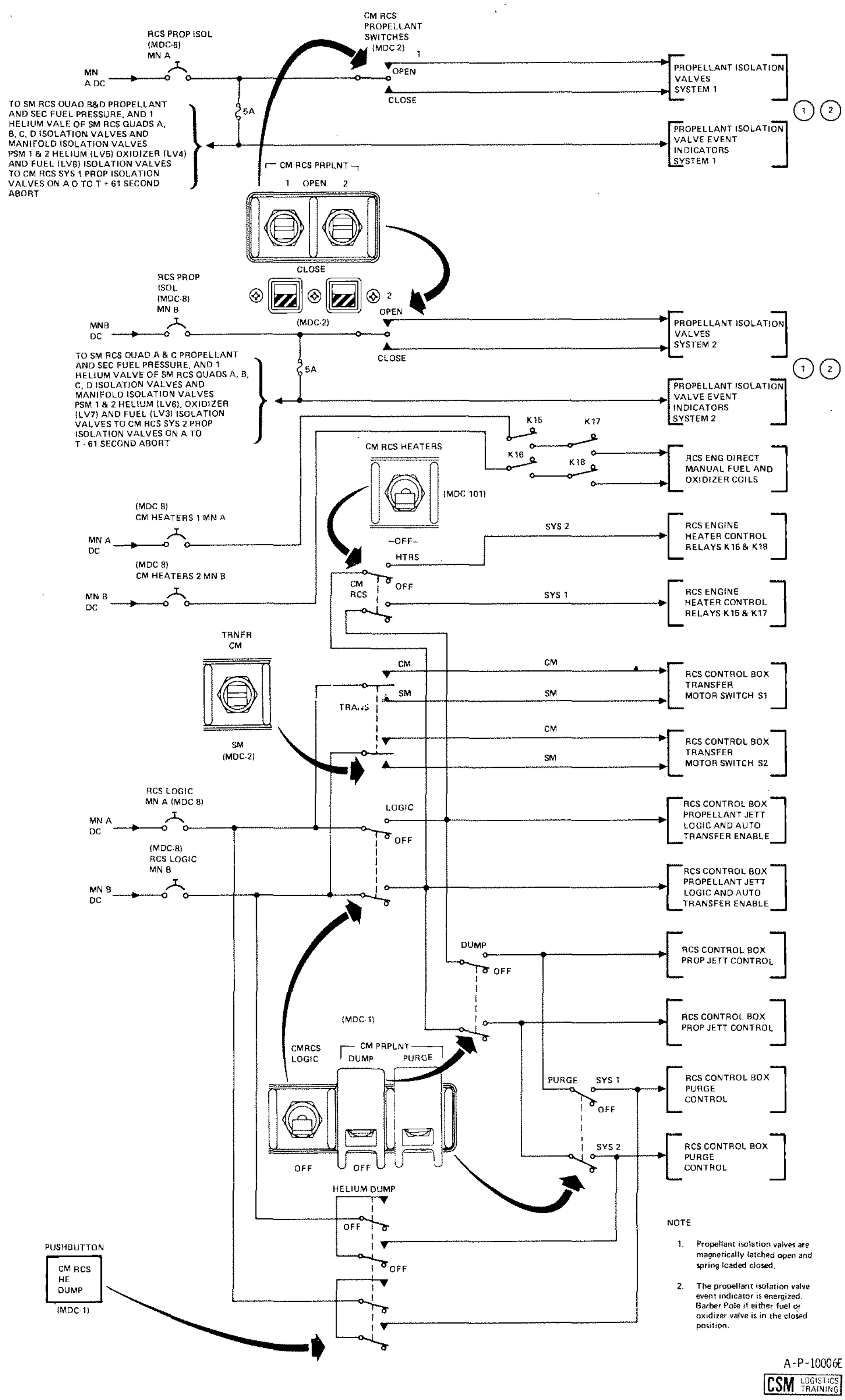


Figure 2.5-23. CM RCS Electrical Power Distribution

SECTION 2

SUBSECTION 2.6

ELECTRICAL POWER SYSTEM

2.6.1 INTRODUCTION

The electrical power subsystem (EPS) consists of the cryogenic storage, equipment required to supply electrical energy sources, power generation and controls, power conversion, and power distribution to the CSM buses. Equipment beyond the buses is not considered a part of this subsystem. Power is supplied by components aboard the CSM until fuel cell shutdown. Subsequent earth orbit d-c power is supplied by the orbital assembly. D-C power is transferred from the orbital assembly to the CSM through a tunnel umbilical.

The EPS is functionally divided into four major categories:

Energy storage:	Cryogenic storage, entry and postlanding batteries, pyrotechnic batteries, descent battery pack
Power generation:	Fuel cell powerplants
Power conversion:	Inverters, battery charger
Power distribution:	D-C and a-c buses, controls, sensing circuits.

EPS

In general, the CSM electrical power system operates in several configurations. The first configuration, from boost until docking, utilizes two fuel cell powerplants supplemented by two entry/postlanding batteries as d-c supplies. The second configuration, during the early docked period, utilizes only the two fuel cell powerplants for supplying dc. Just prior to fuel cell shutdown, the third configuration is assumed in which the orbital assembly, utilizing a solar array/battery arrangement, supplies all CSM d-c power through a manually connected umbilical. The fourth configuration, with two of three descent batteries and three entry/postlanding batteries, is used after separation from the orbital assembly for deorbit. The final two are the normal Apollo configurations assumed during entry and for postlanding. Ac will normally be supplied by two inverters during all mission phases.

2.6.2 FUNCTIONAL DESCRIPTION

2.6.2.1 Energy Storage

The primary source of energy for the CSM power generating system is the cryogenic storage subsystem (CSS) which provides fuel (H_2) and oxidizer (O_2) to the power generation units (fuel cells). Two hydrogen and two oxygen tanks are located in bay IV of the service module (SM). The two fuel cells are also located in bay IV. O_2 remaining in the SM tanks after fuel cell shutdown will provide a partial supply to the orbital assembly and subsequently also be used for deorbit. Fuel cells will be shut down after H_2 depletion. CM tanks will supply the oxygen during entry.

Automatic or manual control is available for operation of individual cryogenic tank repressurization circuits. Automatic repressurization, by addition of heat from heaters, is dependent on energy demand by the fuel cells and/or the environmental control subsystem. Manual control of heaters and the H_2 fans can be used when necessary.

A secondary source of energy storage is provided by eight batteries. Five identical silver oxide-zinc rechargeable batteries are located in the command module. Three of these are defined as entry and postlanding (E&PL) batteries, while the other two are defined as pyrotechnic batteries. Two of the three E&PL batteries supply sequencer logic power when necessary, and supplemental CSM power during peak power periods. All three E&PL batteries simultaneously supply power required for entry. The two pyrotechnic batteries are used to provide energy for operation of individual pyrotechnic circuits throughout all mission phases. In the event of battery failures, a cross coupling capability is available to use the E&PL batteries for powering pyrotechnic circuits or for use of the pyrotechnic batteries to power the E&PL circuits. Postlanding loads are powered by any of the five batteries, in any configuration necessary to satisfy the demand. The descent battery pack, consisting of three 500 AH silver oxide-zinc batteries, supplies the majority of d-c power required for deorbit in place of the shutdown fuel cells.

2.6.2.2 Power Generation

The two fuel cell powerplants, generating power through an electrochemical reaction of H_2 and O_2, supply d-c power to CSM systems until fuel cell shutdown. Normally, each fuel cell is connected to a separate main d-c bus. After fuel cell shutdown, CSM power is supplied by the solar array/battery arrangement on the orbital assembly through tunnel umbilicals which are connected prior to fuel cell shutdown. Control circuits in the CM are used to complete the power transfer operation.

Manual switch control is provided for selecting the fuel cells or descent batteries as primary d-c power sources. Additional controls are provided to connect the SM power sources to the main d-c buses and manual and/or automatic control for power source isolation in case of malfunctions.

2.6.2.3 Power Conversion

Primary d-c power is converted to ac by two of the three available solid-state static inverters, each of which can provide 115/200-volt 400-cps 3-phase a-c power up to 1250 volt-amperes. A-C power is connected by motor switch controls to two a-c buses for distribution to the a-c loads. One inverter has the capability of supplying all spacecraft a-c power and can power both buses, however, each bus will be powered by a separate inverter. Provisions are available for inverter isolation in the event of malfunctions. Inverter outputs cannot be phase-synchronized; therefore, interlocked motorized switching circuits and switching control design prevents the connection of two inverters to the same bus.

A second conversion unit, the battery charger, assures keeping the three entry and postlanding and two pyro batteries in a fully charged state. It is a solid state device utilizing dc through the main d-c buses and ac from the inverters to develop charging voltage.

2.6.2.4 Power Distribution

Distribution of SM d-c power is accomplished via two redundant main d-c buses in the service module which are connected to two redundant buses in the command module through a SM deadface, the CSM umbilical, and a CM deadface. For contingency operation while docked, a CM main dc bus intertie capability is provided by two circuit breakers on panel 250. Additional buses provided are; a d-c bus for servicing experiments; a flight bus for servicing inflight telecommunications equipment; two battery buses for distributing power to sequencers, gimbal motor controls, and servicing the battery relay bus for power distribution switching; and a flight and postlanding bus for servicing some communications equipment and the postlanding loads.

During docked operation, all batteries will be completely disconnected from all CSM systems. Circuit breakers provide the capability of disconnecting the battery buses from the batteries, and instead, connecting the main d-c buses as supplies to the battery buses. A power umbilical, controls, and circuit protection are provided for power transfer from the OWS to the CM main d-c buses when required. Separate circuit protection and an electrical connector have been provided to be used with a drag through umbilical on a contingency basis. A suppressor filter is incorporated in each of the power transfer circuits to CM main d-c buses A & B.

Three-phase ac is distributed via two redundant a-c buses, providing bus selection through switches in most of the a-c operated circuits.

A d-c sensing circuit monitors voltage on each main d-c bus, and an a-c sensing circuit monitors voltage on each a-c bus. The d-c sensors provide an indication of an undervoltage by illuminating a warning light. The a-c sensors illuminate a warning light when high- or low-voltage limits are exceeded, and activate an automatic disconnect of the inverter from the a-c bus during an overvoltage. A-C overload conditions are displayed by illumination of an overload warning light, an automatic disconnect of the inverter from the overloaded bus, and are accompanied by a low voltage light. Additional sensors monitor SM power source overload and reverse current conditions providing an automatic disconnect, together with visual indications of the disconnect, whenever either condition is exceeded.

Switches, meters, lights, and talkback indicators are provided for controlling and monitoring all functions of the EPS.

2.6.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION

The subsequent paragraphs describe the cryogenic storage subsystem and each of the various EPS components.

2.6.3.1 Cryogenic Storage

The cryogenic storage subsystem supplies oxygen to the EPS and ECS and hydrogen to the EPS. The physical data of the cryogenic storage subsystem are as follows:

SYSTEMS DATA

Weight of Usable Cryogenics (lb/tank)		Design Storage Pressure (psia)	Minimum Allowable Operating Pressure (psia)	Approximate Flow Rate at Min dq/dm (+145°F environment) (lb/hr-2 tanks)	Approximate Quantities at Minimum Duty Cycle of Repressurization Circuits (per tank)
O_2	(Dependent on fill and pad off-loading)	900±35	150 865 (EVA & IVA)	1.71	45 to 25%
H_2		245 (+15, -20)	100	0.140	53 to 33%

Initial pressurization from fill to operating pressures is accomplished by GSE. After attaining operating pressures, the cryogenic fluids are in a single-phase condition, therefore completely homogeneous. This avoids sloshing which could cause sudden pressure fluctuations, possible damage to internal components, and prevents positive mass quantity gauging. The single-phase expulsion process continues at nearly constant pressure and increasing temperature above the 2-phase region. Relief valves provide overpressure relief, check valves provide tank isolation, and individual fuel cell shutoff valves provide for isolation of malfunctioning power plants. Filters extract particles from the flowing fluid to protect pressure relief valves and the ECS and EPS components. The pressure and fluid temperature transducers provide indications of the thermodynamic state of the fluid. A capacitive probe measures quantity of fluid remaining in the tanks. O_2 heater temperature sensing is provided as a precautionary measure to detect possible overheating of the tank structure.

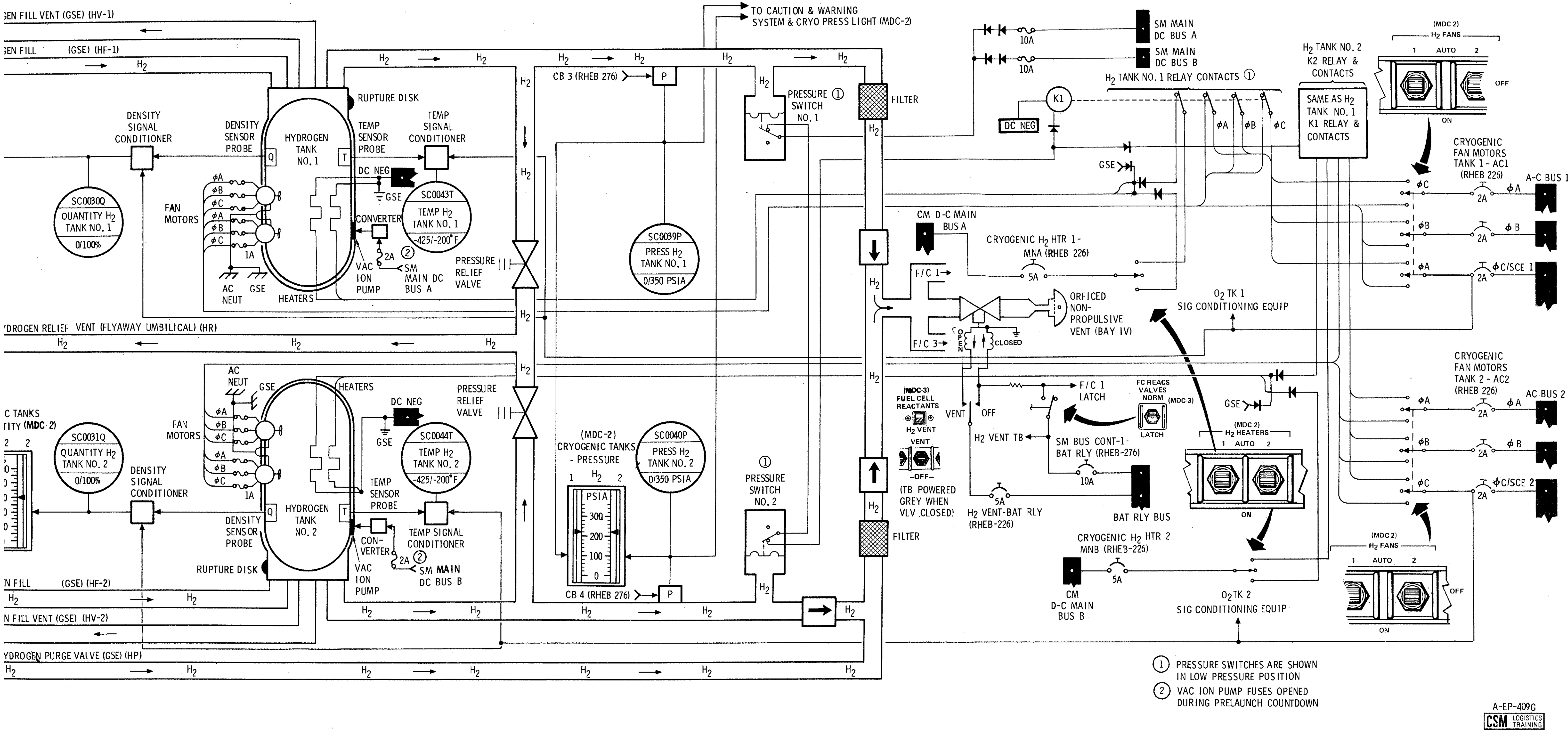
Cryogenic quantity is managed so O_2 quantity is at a level to provide the flow required for an IVA should it be necessary after the initial docking. H_2 quantity is managed to provide maximum fuel cell operation until H_2 depletion, while retaining sufficient O_2 to satisfy the requirement for an IVA, for repressurizing the CM repress package, and for orbit return and the required reserve. Fuel cell shutdown will occur after H_2 is depleted to 5 percent, after which the remainder will be vented overboard through a nonpropulsive vent. O_2 remaining after fuel cell shutdown, and prior to temperature stabilization, can be vented into the CM and thus into the orbital assembly, or overboard through a nonpropulsive vent in the CM hatch.

It is estimated there will be approximately 105 pounds of O_2 remaining at fuel cell shutdown which is estimated to occur at 356 hours GET. There will be approximately 54 pounds of usable O_2 remaining when the fluid temperature stabilizes with ambient, thus terminating pressure buildup because of heat leak. Approximately one pound will be required for the repress package in the CM and 2 pounds is allocated for leakage, thus 51 pounds will be available for orbit return use in the CM. Estimated orbit return requirement is six pounds.

To satisfy the aforementioned requirements, tanks will be filled to 100 percent. Fuel cell usage on the pad and off-loading will be managed to provide 82 percent H_2 and 73 percent O_2 at launch.

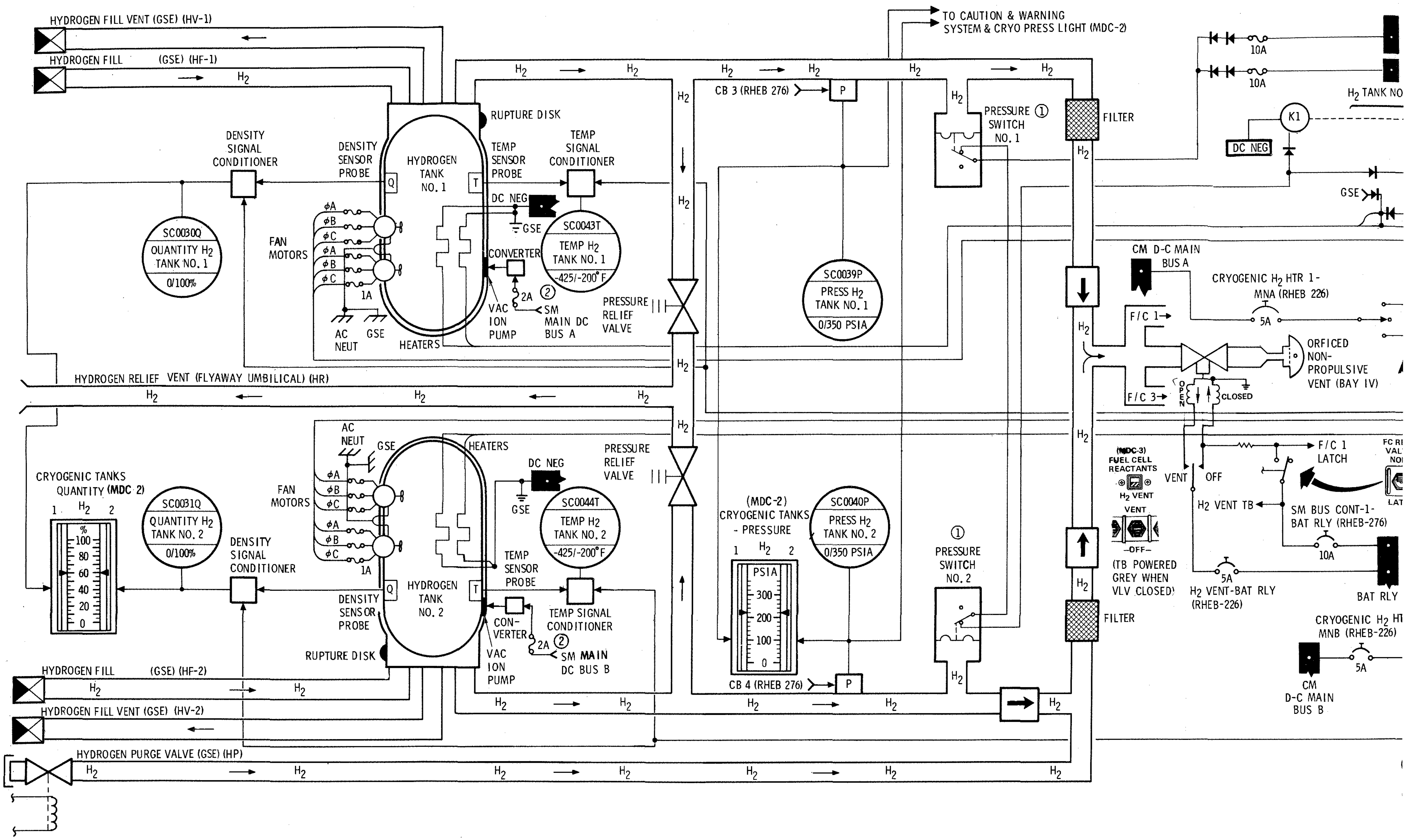
2.6.3.1.1 Hydrogen Storage

Two parallel d-c heaters in each hydrogen tank supply the heat necessary to maintain design pressure (figure 2.6-1). Two parallel 3-phase a-c



EPS

Figure 2.6-1. Hydrogen Storage System


HYDROGEN FILL VENT (GSE) (HV-1)
HYDROGEN FILL (GSE) (HF-1)
TO CAUTION & WARNING SYSTEM & CRYO PRESS LIGHT (MDC-2)
RUPTURE DISK
DENSITY SIGNAL CONDITIONER
DENSITY SENSOR PROBE
HYDROGEN TANK NO. 1
TEMP SENSOR PROBE
TEMP SIGNAL CONDITIONER
CB 3 (RHEB 276)
PRESSURE SWITCH NO. 1
FILTER
10A
H_2 TANK NO
K1
DC NEG
GSE
SC0030Q QUANTITY H_2 TANK NO. 1 0/100%
FAN MOTORS
SC0043T TEMP H_2 TANK NO. 1 -425/-200° F
CONVERTER
SC0039P PRESS H_2 TANK NO. 1 0/350 PSIA
CM D-C MAIN BUS A
CRYOGENIC H_2 HTR 1-MNA (RHEB 226)
5A
F/C 1
F/C 3
ORFICED NON-PROPULSIVE VENT (BAY IV)
OPEN
CLOSED
AC NEUT
HEATERS
VAC ION PUMP
SM MAIN DC BUS A
PRESSURE RELIEF VALVE
HYDROGEN RELIEF VENT (FLYAWAY UMBILICAL) (HR)
(MDC-3) FUEL CELL REACTANTS
H_2 VENT
VENT
OFF
F/C 1 LATCH
H_2 VENT TB
SM BUS CONT-1-BAT RLY (RHEB-276)
CRYOGENIC TANKS QUANTITY (MDC 2)
SC0031Q QUANTITY H_2 TANK NO. 2 0/100%
SC0044T TEMP H_2 TANK NO. 2 -425/-200° F
(MDC-2) CRYOGENIC TANKS - PRESSURE
SC0040P PRESS H_2 TANK NO. 2 0/350 PSIA
PSIA
PRESSURE SWITCH NO. 2
(TB POWERED GREY WHEN VLV CLOSED)
H_2 VENT-BAT RLY (RHEB-226)
BAT RLY
HYDROGEN TANK NO. 2
CON-VERTER
SM MAIN DC BUS B
RUPTURE DISK
CB 4 (RHEB 276)
CRYOGENIC H_2 HT MNB (RHEB-226)
CM D-C MAIN BUS B
HYDROGEN FILL (GSE) (HF-2)
HYDROGEN FILL VENT (GSE) (HV-2)
HYDROGEN PURGE VALVE (GSE) (HP)

Figure

circulating fans are used to circulate the fluid to maintain a uniform density and decrease the effects of stratification. A typical heater and fan installation is shown in figure 2.6-2.

Repressurization of the system can be automatically or manually controlled by selection with the H_2 control switches on panel 2. Automatic operation is used in the heater circuits. The fan circuits are generally operated manually, but are in AUTO during the docked period while fuel cells are used for CSM power. The automatic mode is designed to give a single-phase hydrogen flow into the fuel cell feed lines at design pressures. Automatic operation is controlled through a pressure switch/relay arrangement. As pressure in the tanks decreases, the pressure switch in each tank is closed to energize the relays which close contacts in the power circuits. Both tanks decrease in pressure before the circuits are energized. When either tank reaches the upper operating pressure limit, that respective pressure switch opens to de-energize the relays, thus opening the circuits to both tanks. The circuits energize at 225 psia minimum and de-energize at 260 psia maximum. The most accurate quantity readout will be acquired shortly after the fans have stopped stopped. During all other periods partial stratification may degrade quantity readout accuracy.

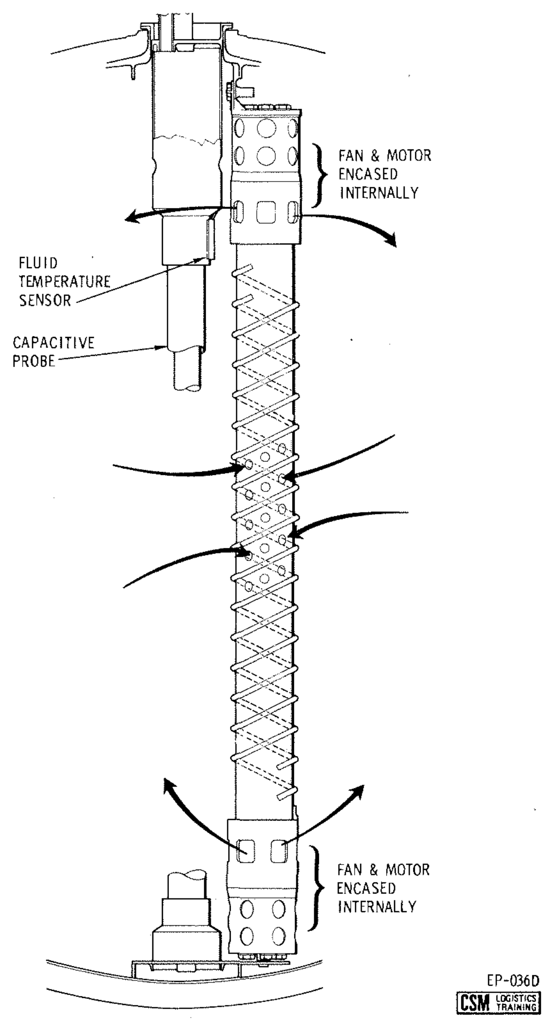


Figure 2.6-2. H_2 Quantity Measurement and Pressurization Devices

The manual mode of operation bypasses the pressure switches, and supplies power directly to the heaters and/or fans through the individual control switches. It can be used in case of automatic control failure.

Tank pressures and quantities are monitored on meters located on panel 2. The caution and warning system (CRYO PRESS) will alarm when pressure in either tank exceeds 270 psia or falls below 200 psia. Since a common lamp is provided, reference must be made to the individual pressure meters (panel 2) to determine the malfunctioning tank. Pressure, quantity, and fluid temperature of each tank are telemetered to STDN.

The hydrogen tanks have vac-ion pumps installed, with power source protection provided by a fuse in each line. The vac-ion pumps are used on the launch pad to maintain the integrity of the vacuum between the inner and outer tank shells, thus maintaining heat leak into the fluid at design levels. The fuses are pulled prior to launch; therefore, the circuits are not active during flight.

Power source protection for the heater, fan and signal conditioning equipment circuits is provided by circuit breakers on panel 226 in the RHEB. Five-amp circuit breakers protect the heater circuits. H_2 HTR-1-MNA provides protection in the tank 1 heater circuit, and H_2 HTR-2-MNB protects the tank 2 heater circuit. Two-amp circuit breakers, CRYOGENIC FAN MOTORS - TANK 1 - AC1-ØA, ØB, and ØC/SCE, protect each phase of the tank 1 fan motor circuits, and the TANK 2 - AC2-ØA, ØB, and ØC/SCE, protect each phase of the tank 2 fan motor circuits. In addition, a one-amp fuse is located in each phase line of each fan motor circuit. The ØC/SCE circuit breakers also provide protection in the quantity and fluid temperature measuring circuits of each tank.

Should an overpressure condition occur in the hydrogen tanks, venting will occur through the individual tank relief valves which are designed to open at a pressure between 273 and 283 psig with full flow occurring 2 pounds above the cracking pressure. The valves reseat at 268 psig minimum. The overboard vent is in the flyaway umbilical connector located in sector I of the service module.

Fuel cell operation will continue until hydrogen is depleted to 5 percent quantity. After completion of power transfer from the workshop to the CSM, the fuel cells will be shut down and the remaining hydrogen will be vented overboard through the H_2 vent valve and an orificed nonpropulsive vent located in the vicinity of the hydrogen shelf in bay IV (figure 2.6-1). The vent is designed to allow flow of 0.2 lb/hr at 225 psia and 0°F nozzle temperature. Control of the vent valve is provided by the FUEL CELL REACTANTS - H_2 VENT switch on panel 3. The talkback provides a striped indication when the vent valve is open. Circuit protection is provided by the 5 amp H_2 VENT - BAT RLY circuit breaker on panel 226.

The necessity for dumping the remaining hydrogen is predicated on the fracture mechanics of the hydrogen storage tanks at hydrogen temperatures above 0°F and pressures above 115 psi. If the H_2 vent fails, hydrogen disposal will be performed by continuing fuel cell operation. H_2 heaters and fans will be turned off, hydrogen system inputs to the C&W will be inhibited, and both fuel cells will be operated until H_2 pressure decreases to 200 psia. The pressure decrease will take approximately 30 hours. After the pressure decrease, workshop power will be supplied to main bus A and FC1 will be shut down. Single fuel cell operation will be continued until

H_2 pressure decreases to 90 psia, which should take approximately 24 hours. After reaching 90 psia, workshop power will be supplied to main bus B, FC3 will be shut down, and the cryogenic system will be configured for quiescent mode operation.

The ability to sustain hydrogen pressure and flow is a factor of the amount of heat required versus the amount that can be provided by heaters, fan motors, and heat leak. Since heat leak characteristics of each tank vary slightly, the flow each tank can provide will also vary to a small degree. On SC 116 and 118, heat input from heaters, fan motors and heat leak into a H_2 tank is approximately 87.3 Btu/hr (17.2 watt heaters supply 58.7 Btu, 7.2 watt fan motors supply 24.6 Btu, and heat leak supplies 4 Btu). These wattage figures take into consideration the line loss between the power source and the operating component. SC 117 and 119 fan motors have been increased in size to 27w per motor; therefore fan motor heat input is increased to 184.3 Btu and the overall heat input capability increases to 247 Btu/hr.

2.6.3.1.2 Oxygen Storage

Three heaters in each oxygen tank supply the heat necessary to maintain design pressure (figure 2.6-3). Two of the heaters are on a parallel circuit, while the third heater is powered separately.

EPS

Repressurization of the system can be automatically or manually controlled by switch selection on panel 2. The automatic mode is designed to give a single-phase oxygen flow into the fuel cell and ECS feed lines at design pressure. The pressure switch/relay arrangement operates similarly to the hydrogen system. In AUTO, the heater circuits are energized at 865 psia minimum and de-energized at 935 psia maximum. O_2 quantity readings may be partially degraded because of the greater probability of stratification, since there are no circulation fans.

The manual mode by-passes the pressure switches and supplies power directly to the heaters through the individual control switches. It can be used in case of automatic control failure.

Circuit protection for the tank heaters is provided by circuit breakers on panel 226. A 10-amp circuit breaker, O_2 HTRS-100W-1-MNA, protects the circuit to the parallel heaters in tank 1, and the 5-amp 50W-1-MNB circuit breaker protects the single heater circuit. A 10-amp circuit breaker, O_2 HTRS-100W-2-MNB protects the parallel heater circuit in tank 2, and the 5-amp 50W-2-MNA circuit breaker protects the single heater circuit. Each of the three heater circuits is further protected by a 5-amp fuse. Selection of automatic or manual modes, or heater shutdown, is accomplished by the O_2 HEATERS - 1 and 2 switches on panel 2.

Using the circuit breakers on panel 226, single- dual- or three-heater operation is available. The heaters are 50-watt elements at 28 vdc; however, the actual wattage is lower because of the line loss between the main d-c bus and the heater element. With the main d-c buses at 28 vdc, the single heater in each tank will provide 37.7 watts (129 Btu/hr), and the parallel heater will provide 96.2 watts (328 Btu/hr). The three-heater total is 133.9 watts (457 Btu/hr). Heat leak during the undocked period will be approximately 24 Btu/hr at a 70°F ambient bay temperature. During the docked period, heat leak will be approximately 15 Btu/hr at an approximate ambient bay temperature of 20°F. Fuel cell operation or shutdown results in a small temperature difference in the bay, thus has a small effect on heat leak.

Conversion of heater energy into pressure is not a direct function of heater output and specific heat input, since there is considerable influence by the heat transfer characteristics between the heater and pressurant. Convection is the major factor influencing heat distribution, with conduction having considerably less effect. The degree of convection is a function of g level and fluid density, each of these affecting buoyancy of the heated fluid. Although the g force is very low, it has a pronounced effect on the heat distribution process. A higher g level increases convection, which more efficiently transfers heat from around the heater probe to the bulk fluid. A decrease in g level decreases convection, and heat is retained in the fluid adjacent to the heater probe. Fluid density also influences heat transfer to the extent that at greater densities a larger amount of heat is absorbed per volume since the mass is greater. By virtue of the greater expansion per volume of fluid, a larger amount of heat is transferred. These heat transfer characteristics apparently change at densities equivalent to a 70 percent quantity or less, as the thermophysical properties of the fluid tend to stabilize resulting in decreased heat transfer and increasing heater temperature. Generally, heater temperature becomes critical at densities corresponding to quantities below 55 percent; therefore, two-heater operation is recommended below a quantity of 55 percent, and single-heater operation below 20 percent. Between 55 percent and 75 percent quantities, two-heater operation will satisfy all mission demands.

During extremely low g levels resulting in reduced convection, as the heater operates through several repressurization cycles, there is a reduction in the density of the fluid around the probe. This results in lower heat transfer to the adjacent bulk fluid; is reflected in higher heater temperature and creates a condition which can result in a partial pressure collapse. The small volume of warmer fluid around the probe provides a substantial portion of the pressure in the tank. A g force imparted to the vehicle can cause a partial pressure collapse by virtue of mixing the larger bulk of cold, dense fluid with the smaller volume of warm, lower density fluid around the probe. The mixing transfers some of the energy from the warm fluid to the cold fluid, but the energy available is insufficient to maintain pressure since the specific heat required by the denser fluid is much greater. This results in a partial pressure collapse requiring extended operation of the heaters to provide the required energy for repressurizing.

The above principles are not of major consideration in dealing with nominal oxygen demand of approximately 2 lb/hr (1 lb/hr/tank). However. they should be considered for periods of higher demand, since tank quantity (density) also is a major factor in determining expulsion rates and the ability to maintain pressure.

On Skylab, the period of greatest oxygen demand will occur after docking with the SWS, should there be a requirement to activate an unpressurized MDA/AM. Oxygen demand at this time will be on the order of 9.3 to 10.4 lb/hr with 1.4 lb/hr supplied to the fuel cells and 7.9 to 9.0 lb/hr to the IVA suit station. Environmental control system (ECS) design is such that oxygen tank No. 2 has to supply the bulk of the suit flow. Since expulsion rates are also governed by density (quantity), tank quantities will have to be managed to realize a satisfactory condition for supplying suit demand at

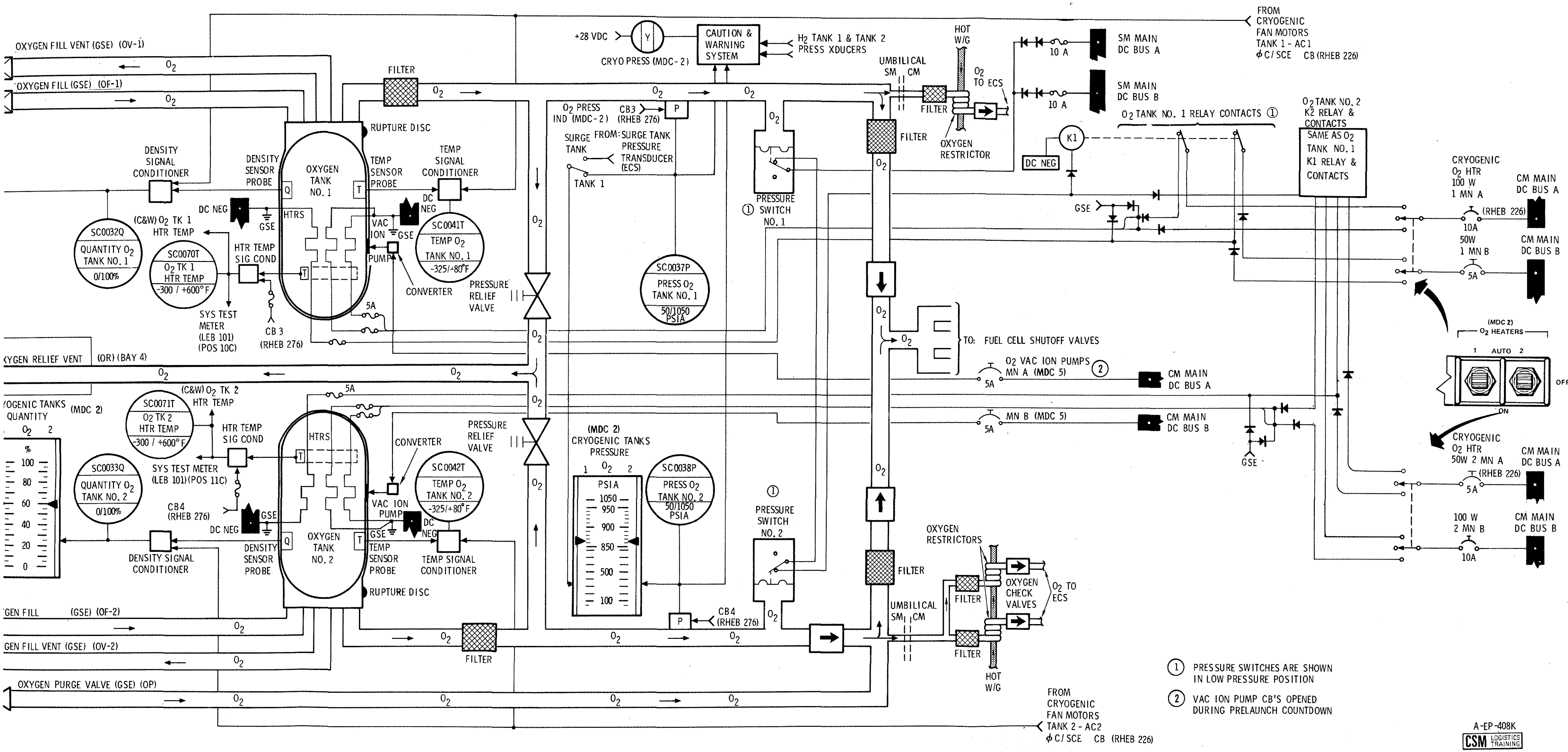
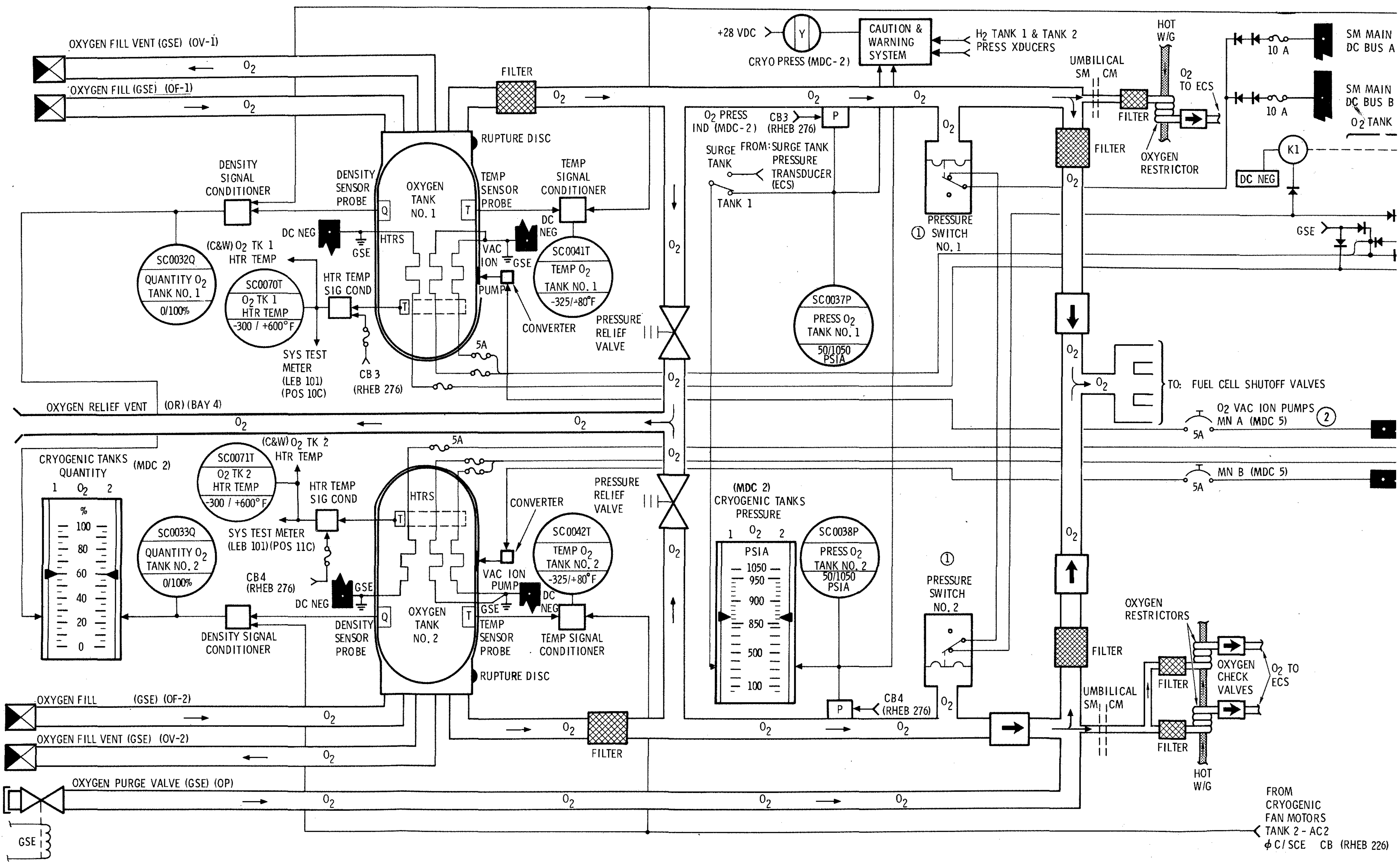


Figure 2.6-3. Oxygen Storage System


OXYGEN FILL VENT (GSE) (OV-1)
OXYGEN FILL (GSE) (OF-1)
O_2
FILTER
RUPTURE DISC
DENSITY SIGNAL CONDITIONER
DENSITY SENSOR PROBE
OXYGEN TANK NO. 1
TEMP SENSOR PROBE
TEMP SIGNAL CONDITIONER
DC NEG
GSE
HTRS
VAC ION PUMP
CONVERTER
SC0032Q QUANTITY O_2 TANK NO. 1 0/100%
(C&W) O_2 TK 1 HTR TEMP
SC0070T O_2 TK 1 HTR TEMP -300 / +600°F
HTR TEMP SIG COND
SYS TEST METER (LEB 101) (POS 10C)
CB 3 (RHEB 276)
5A
SC0041T TEMP O_2 TANK NO. 1 -325/+80°F
PRESSURE RELIEF VALVE
OXYGEN RELIEF VENT (OR) (BAY 4)
+28 VDC
CRYO PRESS (MDC-2)
CAUTION & WARNING SYSTEM
H_2 TANK 1 & TANK 2 PRESS XDUCERS
O_2 PRESS IND (MDC-2)
CB3 (RHEB 276)
SURGE TANK
FROM: SURGE TANK PRESSURE TRANSDUCER (ECS)
TANK 1
SC0037P PRESS O_2 TANK NO. 1 50/1050 PSIA
PRESSURE SWITCH NO. 1
HOT W/G
UMBILICAL SM CM
O_2 TO ECS
FILTER
OXYGEN RESTRICTOR
10 A
SM MAIN DC BUS A
SM MAIN DC BUS B
O_2 TANK
K1
DC NEG
GSE
TO: FUEL CELL SHUTOFF VALVES
O_2 VAC ION PUMPS MN A (MDC 5)
MN B (MDC 5)
CRYOGENIC TANKS QUANTITY (MDC 2)
%
100
80
60
40
20
0
(C&W) O_2 TK 2 HTR TEMP
SC0071T O_2 TK 2 HTR TEMP -300 / +600°F
SC0033Q QUANTITY O_2 TANK NO. 2 0/100%
SYS TEST METER (LEB 101)(POS 11C)
CB4 (RHEB 276)
DENSITY SIGNAL CONDITIONER
OXYGEN TANK NO. 2
SC0042T TEMP O_2 TANK NO. 2 -325/+80°F
(MDC 2) CRYOGENIC TANKS PRESSURE
PSIA
1050
950
900
850
500
100
SC0038P PRESS O_2 TANK NO. 2 50/1050 PSIA
PRESSURE SWITCH NO. 2
OXYGEN RESTRICTORS
OXYGEN CHECK VALVES
OXYGEN FILL (GSE) (OF-2)
OXYGEN FILL VENT (GSE) (OV-2)
OXYGEN PURGE VALVE (GSE) (OP)
FROM CRYOGENIC FAN MOTORS TANK 2 - AC2 φC/SCE CB (RHEB 226)

Figur

the required time. It appears that quantity levels between 55 percent and 80 percent will meet the suit demand, with near optimum performance at 75 percent quantity. The present flight plan schedules MDA/AM entry at 21 hours after lift-off. As previously explained, the cryogenic system is managed on the launch pad so O_2 quantity is at the proper level to satisfy these requirements.

Oxygen tank pressures and quantities are monitored on meters located on panel 2. Heater temperatures can be monitored on position 10C and 11C of the system test meter on panel 101. The C&W (O_2 TK 1 HTR TEMP, O_2 TK 2 HTR TEMP) will alarm when heater temperature exceeds 356°F. The caution and warning (CRYO PRESS) will alarm when pressure in either tank exceeds 950 psia or falls below 800 psia. Since this lamp is common to the H_2 and O_2 tanks, reference must be made to the individual pressure meters (panel 2) to determine the malfunctioning tank. The HTR TEMP and CRYO PRESS signals are also monitored by the C&W memory unit for transient indications, and can be inhibited on panel 201. Pressure, quantity, fluid temperature, and heater temperature of each tank are telemetered to the STDN.

EPS

The oxygen tank vac-ion pumps are used to maintain the integrity of the vacuum between the inner and outer shells, thus maintaining heat leak into the fluid at the design level. Power source protection is provided by two 5-amp circuit breakers on panel 5, O_2 VAC ION PUMPS - MNA for tank 1 and MNB for tank 2. The breakers are opened just prior to lift-off, and closed if required during the mission. The STDN will determine if circuit breaker closure is required.

During other than docked operation, an overpressure in either or both tanks will be vented through the respective relief valve and the overboard vent in bay IV. The relief valves vent at a pressure between 983 and 1008 psig, with full flow occurring approximately 2 pounds above the cracking pressure. Minimum reseat pressure is 965 psig.

During docked operation, after fuel cell shutdown, excess oxygen will be used to supplement the orbital assembly environment or in the event of an overpressure it will be vented overboard. This is provided for by units manually coupled to panel 603 which has two oxygen outlets. One of the couplings consists of three selectable orifices which operate in conjunction with a 100 psi regulator to allow flow into the CM. The three selectable flow rates are 9, 13, or 17 lb/day. The other coupling is mated with a hose to a nonpropulsive vent installed in the CM cabin hatch. It is fitted with a 900±25 psia relief valve which will maintain tank pressures within acceptable limits if the selectable orifices are unable to accommodate the oxygen expulsion rate. The nonpropulsive vent will allow a flow of 2 to 5 lbs/hr.

2.6.3.2 Batteries

Eight storage batteries are incorporated in the EPS. Five of the batteries are located in the CM lower equipment bay. Three of the five are the E/PL batteries, and the other two are used as pyro batteries. The remaining three, which are the descent batteries, are located in bay 1 of the SM and are for CSM use during earth orbit return until CM/SM separation for entry, after which they power the necessary SM circuits.

Three rechargeable entry and postlanding batteries (A, B, and C) power CM systems after CM/SM separation. Prior to CM/SM separation, these batteries provide a secondary source of d-c bus power while the fuel cells or descent batteries are the primary source. The entry and postlanding batteries are used for the following purposes:

- Provide CM power after CM/SM separation
- Supplement fuel cell or descent battery power during peak load periods
- Provide power during emergency CSM operations
- Provide power for EPS control circuitry when required
- Provide sequencer logic power when required
- Provide power for recovery aids during postlanding
- Entry battery A or B can be used as backup to power the respective pyro circuit
- Battery C can be used as backup for entry battery A and/or B.

Each of the CM batteries is mounted in a vented plastic case and consists of 20 silver oxide-zinc cells connected in series. The cells are individually encased in plastic containers which contain relief valves that open at 30±10 psig, venting during an overpressure into the battery case. The five cases are vented overboard through a common manifold, a pressure relief valve, the manual BATTERY VENT valve (RHEB-252), and the ECS waste water dump line.

The 8 psid pressure relief valve is physically located behind panel 252. It is in series between the battery vent manifold and the manually operated BATTERY VENT valve on RHEB 252. The manual valve will be opened during prelaunch and will remain open except for water dumping. After launch, when the line bleeds down, the system test meter (position 2B) will always indicate approximately 2 vdc which is equivalent to 8 psi.

Each of the five CM batteries is rated at 40 ampere-hours (AH) minimum and delivers this at a current output of 25 amps for 60 minutes and a subsequent output of 2 to 5 amps for the remainder of the rating. Generally, 40 AH is used for mission in-flight planning and 45 AH for postlanding planning. Open circuit voltage is 37.1 volts dc.

During boost, only batteries A and B are connected to the main d-c buses for supplemental power. Battery C is isolated during prelaunch by opening the MAIN A-BAT C and MAIN B-BAT C circuit breakers (panel 275). Battery C therefore provides a backup for main d-c bus power in case of failure of battery A or B. The MAIN A- and MAIN B-BAT C circuit breakers are closed prior to an SPS deorbit and 12 minutes before entry during an RCS deorbit. All three batteries are used for entry. After docking and SWS activation, the batteries are completely disconnected from spacecraft systems.

Battery C, through circuit breakers BAT BUS A-BAT C and BAT BUS B-BAT C (panel 275), can be used to power the respective battery bus in the event of failure of entry battery A or B. These circuit breakers are normally open until a failure of battery A or B occurs.

The two pyrotechnic batteries which are identical to the E/PL batteries, supply power to initiate ordnance devices in the SC. They are isolated from the rest of the EPS to prevent the high-power surges in the pyrotechnic system from affecting the EPS and to ensure source power when required. Entry and postlanding battery A or B, can be used as source power for initiating pyro circuits in the respective A or B pyro system if either pyro battery fails. This can be performed by opening the PYRO BUS A (B) - PYRO BAT A (B) circuit breaker and closing the PYRO BUS A (B) - BAT BUS A (B) circuit breaker (panel 229). Conversely, a pyro battery can be used to power a battery bus and main d-c bus in case of failure of batteries A and C or B and C. This is performed by opening the BAT BUS A (B) - BAT A (B) and BAT C circuit breakers and closing the BAT BUS A (B), PYRO BAT A (B) circuit breaker (panel 275). Pyro batteries A & B can be recharged through the respective BATTERY CHARGE - A or B circuit. This is performed by opening the BAT BUS A (B) - BAT A (B) circuit breaker (panel 275), opening the PYRO BUS A (B) - BAT BUS A (B) circuit breaker (panel 229), opening the BAT RLY BUS - BAT A (B) circuit breaker (panel 5), closing the BAT BUS A (B) - PYRO BAT A (B) circuit breaker (panel 275), and positioning the BATTERY CHARGE switch (panel 3) to the respective A or B position.

Performance characteristics of the batteries are as follows:

EPS

Battery	Rated Capacity per Battery	Open Circuit Voltage (nominal)	Nominal Voltage (on load)	Minimum Voltage	Ambient Battery Temperature
Entry and Postlanding, A, B, and C (3); and Pyro A and B (2)	40 amp-hrs	37.1 vdc	28 vdc (25 amps load)	27 vdc (25 amps load)	50° to 110°F
Descent	500 amp-hrs	37.1 vdc	28.5 vdc (60 amps load)	28.0 vdc after first 5 minutes (35 to 60 amps load)	30° to 80°F

The descent battery pack consists of three 500 AH silver oxide-zinc storage batteries each weighing approximately 250 pounds. Each battery consists of 20 cells, each cell containing a relief valve to allow venting into a volume in the case. The case relief valve provides venting at pressures above 10 psig and reseats at 5 psig. Each battery contains a temperature sensor located within the maximum temperature area. Monitoring of the batteries is provided by a voltage measurement which is monitored in the CM through the SM SOURCE positions of the DC INDICATORS switch, and the DC VOLTS meter (panel 3). Current monitoring is provided through the same selector switch and the DC AMPS meter. The switch positions always provide a battery voltage reading; however, the current reading of power sources 1 and 3 is dependent on whether the fuel cells or descent batteries (1 and 3) have been selected. Position 2 will always provide an indication of descent battery 2 status. Descent battery voltage and temperature, and fuel cell or descent battery current are telemetered to the STDN. The 1500 AH total will provide for a maximum 18-hour earth orbit return period. Descent battery 1 and 3 or FC 1 and 3 selection is provided by switches on panel 5. Descent battery 2 can be directly coupled to the main d-c buses with the bus tie switches on panel 3.

2.6.3.3 Fuel Cell Power Plants

Each of the two Bacon-type fuel cell power plants is individually coupled to a heat rejection (radiator) system, the hydrogen and oxygen cryogenic storage systems, a water storage system, and a power distribution system. A typical power plant schematic is shown in figure 2.6-4.

The power plants generate d-c power on demand through an exothermic chemical reaction. The by-product water is fed to a potable water storage tank in the CM where it is used for astronaut consumption and for cooling purposes in the ECS, or into a SM H_2O tank. Tank selection can be made by correct positioning of the POTABLE TANK INLET on panel 352 and the SM H_2O TK INLET control on panel 2. The amount of water produced is equivalent to the power produced which is relative to the reactant consumed.

REACTANT CONSUMPTION AND WATER PRODUCTION

Load (amps)	O_2 lb/hr	H_2 lb/hr	H_2O lb/hr	cc/hr
0.5	0.0102	0.001285	0.01149	5.21
1	0.0204	0.002570	0.02297	10.42
2	0.0408	0.005140	0.04594	20.84
3	0.0612	0.007710	0.06891	31.26
4	0.0816	0.010280	0.09188	41.68
5	0.1020	0.012850	0.11485	52.10
6	0.1224	0.015420	0.13782	62.52
7	0.1428	0.017990	0.16079	72.94
8	0.1632	0.020560	0.18376	83.36
9	0.1836	0.023130	0.20673	93.78
10	0.2040	0.025700	0.2297	104.20
15	0.3060	0.038550	0.34455	156.30
20	0.4080	0.051400	0.45940	208.40
25	0.5100	0.064250	0.57425	260.50
30	0.6120	0.077100	0.68910	312.60
35	0.7140	0.089950	0.80395	364.70
40	0.8160	0.10280	0.91880	416.80
45	0.9180	0.11565	1.03365	468.90
50	1.0200	0.12850	1.1485	521.00
55	1.1220	0.14135	1.26335	573.10
60	1.2240	0.15420	1.3782	625.20
65	1.3260	0.16705	1.49305	677.30
70	1.4280	0.17990	1.6079	729.40
75	1.5300	0.19275	1.72275	781.50
80	1.6320	0.20560	1.83760	833.60
85	1.7340	0.21845	1.95245	885.70
90	1.8360	0.23130	2.06730	937.90
95	1.9380	0.24415	2.18215	989.00
100	2.0400	0.25700	2.2970	1042.00

FORMULAS:

$O_2 = 2.04 \times 10^{-2}$ I $\qquad$ H_2O = 10.42 cc/amp/hr

$H_2 = 2.57 \times 10^{-3}$ I $\qquad$ $H_2O = 2.297 \times 10^{-2}$ lb/amp/hr

EPS

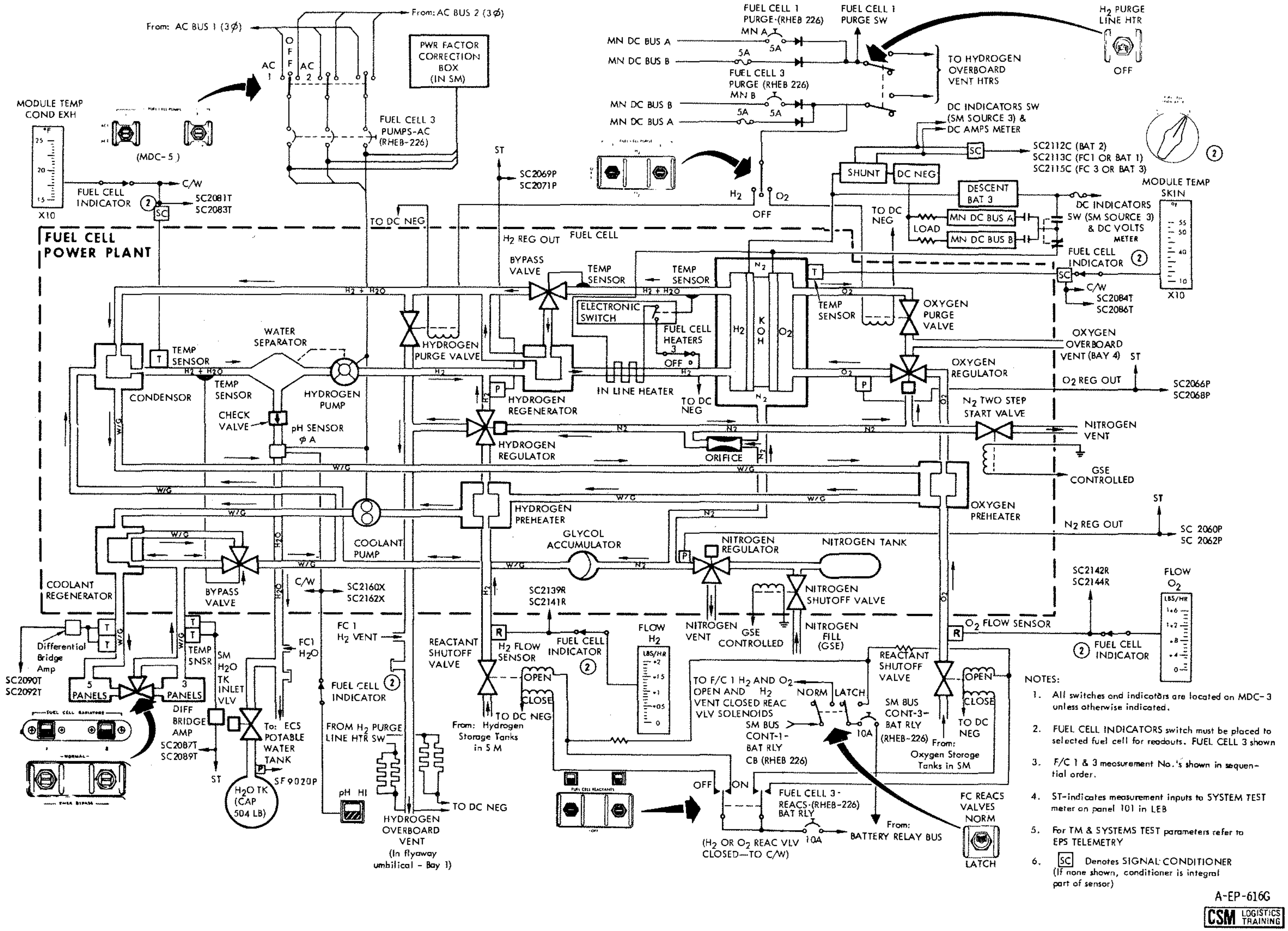


Figure 2.6-4. Fuel Cell Schematic

2.6.3.3.1 Component Description

Each power plant consists of 31 single cells connected in series and enclosed in a metal pressure jacket. The water separation, reactant control, and heat transfer components are mounted in a compact accessory section attached directly above the pressure jacket.

Power plant temperature is controlled by the primary (hydrogen) and secondary (glycol) loops. The hydrogen pump, providing continuous circulation of hydrogen in the primary loop, withdraws water vapor and heat from the stack of cells. The primary bypass valve regulates flow through the hydrogen regenerator to impart exhaust heat to the incoming hydrogen gas. Flow is regulated in accordance with skin temperature. The exhaust gas flows to the condenser where waste heat is transferred to the glycol; the resultant temperature decrease liquifying some of the water vapor. The motor-driven centrifugal water separator extracts the liquid and feeds it through a pH sensor to the potable water tank in the CM or the SM water tank. The cool gas is then pumped back to the fuel cell through the primary regenerator by a motor-driven vane pump, which also compensates for pressure losses due to water extraction and cooling. Waste heat, transferred to the glycol in the condenser, is transported to the radiators located on the fairing between the CM and SM, where it is radiated into space. Individual controls (FUEL CELL RADIATORS, panel 3), can bypass 3/8 of the total radiator area for each power plant. Radiator area is varied dependent on power plant condenser exhaust and radiator exit temperatures which are relevant to loads and space environment. Internal fuel cell coolant temperature is controlled by a condenser exhaust sensor, which regulates flow through a secondary regenerator to maintain condenser exhaust within desired limits. When either condenser exhaust or radiator exit temperature falls below limits (150° and -30°F respectively), the respective FUEL CELL RADIATORS switch is positioned to EMERG BYPASS to decrease the radiator area in use, thus decreasing the amount of heat being radiated. Since the power plants are relatively close in load sharing and temperature operating regimes, the effect on the other power plant must be monitored.

Use of the bypass should be minimal because of power plant design to retain heat at low loads and expel more heat at higher loads. The bypass is primarily intended for use after failure of one power plant. Heat radiation effects on the single power plant may require use of the bypass for the one remaining power plant.

Water tank selection for storage of fuel cell water is performed by operating the POTABLE and WASTE TANK INLET valves on panel 352 and the SM H_2O TK control on panel 2. Cb H_2O/URINE DUMP HTR MNA provides protection for the SM H_2O tank valve circuit. The SM tank has a capacity of 504 pounds. SM water tank pressure is monitored only by the STDN.

Reactant valves for fuel cells 1 and 3 provide the interface between the power plants and cryogenic system. They are opened during prelaunch and closed only after a power plant malfunction necessitating its permanent isolation from the d-c system, or during fuel cell shutdown. Control is provided by the FUEL CELL REACTANTS - 1 and 3 switches on panel 3 together with the associated talkback indicators which indicate striped when an O_2 or H_2 valve closes. The H_2 VENT switch, and associated talkback indicator, provides control of the H_2 vent valve which is used to evacuate the hydrogen tanks after fuel cell shutdown. Venting is provided through an orificed nonpropulsive vent on the exterior of bay IV. The talkback indicates striped when the H_2 vent valve is open. The orificed vent (0.2 lb/hr) precludes a large flow, thus preventing any effect on the fuel cells due to any inadvertent opening of the vent valve while the power plants are operating. Prior to launch and SIVB separation, the FC REACS VALVES switch (panel 3) is placed to the LATCH position. This applies a holding voltage to the open solenoids of the H_2 and O_2 reactant valves of the power plants, and to the closed solenoid of the H_2 vent valve. This voltage is required during these periods to prevent inadvertent closure of the reactant valves, or opening of the vent valve due to shock or high vibration. With the holding voltage applied, the reactant valves cannot be closed by use of the REACTANTS switches (panel 3). The FC REACS VALVES switch is positioned to NORMAL after earth orbit insertion and after completion of SIVB separation. The respective FUEL CELL REACTANTS talkback indicator (panel 3) and FC 1 or 3 caution and warning light (panel 2) will be activated if either of the power plant H_2 or O_2 reactant valves close because of shock or vibration or if the valves are closed by use of the REACTANTS switches. During any illumination of the FC 1 or FC 3 caution and warning lights, the FUEL CELL REACTANTS - 1 or 3 talkback indicators should be checked first to determine if the caution/warning alarm was caused by valve closure. The valve (H_2) must be opened in approximately 25 seconds to preclude fuel cell failure.

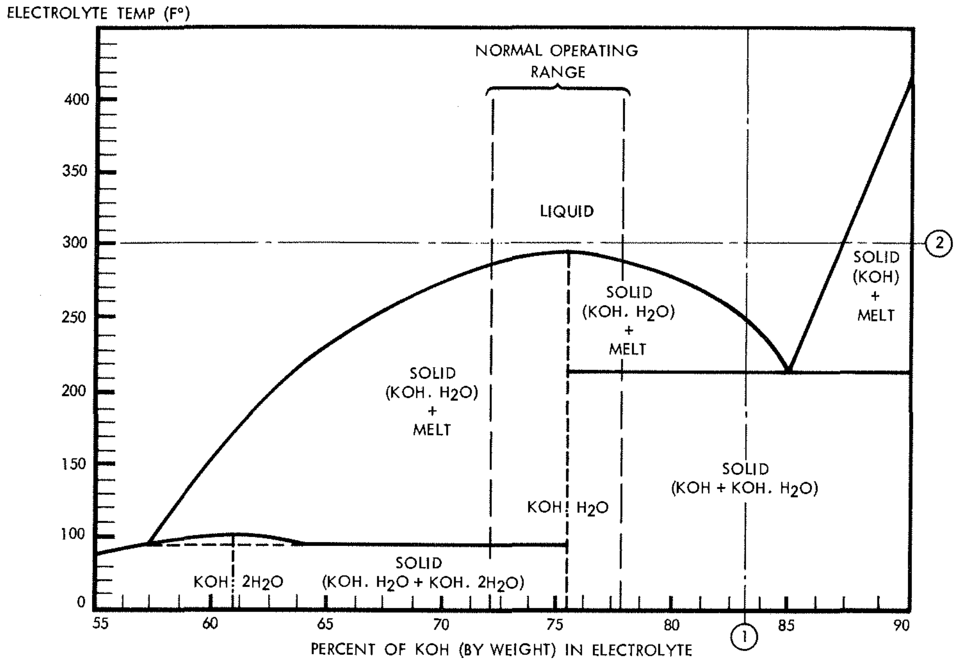
H_2 gas is individually stored in each power plant at 1500 psia and regulated to a pressure of 54±3 psia. Output of the regulator pressurizes the electrolyte in each cell, the coolant loop through an accumulator, and is coupled to the O_2 and H_2 regulators as a reference pressure.

Oxygen, supplied to the power plants at 900±35 psia, absorbs heat in the lines, absorbs additional heat in the preheater, and reaches the oxygen regulator in a gaseous form at temperatures above 100°F. The differential regulator reduces oxygen pressure to 9.0 psia above the N_2 reference, thus supplying it to the fuel cell stack at 63.0±2 psia. Within the porous oxygen electrodes, the O_2 reacts with the H_2O in the electrolyte and the electrons provided by the external circuit to produce hydroxyl ions ($O_2 + 2H_2O + 4e = 4OH^-$).

Hydrogen, supplied to the power plants at 245 (+15, -20) psia, is heated in the same manner as the oxygen. The differential hydrogen regulator reduces the pressure to 9.0 psia above the reference N_2, thus supplying it in a gaseous form to the fuel cells at 63.0±2 psia. The hydrogen reacts in the porous hydrogen electrodes with the hydroxyl ions in the electrolyte to produce electrons, water vapor, and heat ($2H_2 + 4OH^- = 4H_2O + 4e$ + heat). The nickel electrodes act as a catalyst in the reaction. The water vapor and heat is withdrawn by the circulation of hydrogen gas in the primary loop, and the electrons are supplied to the load.

Each of the 31 cells comprising a power plant contains electrolyte which on initial fill consists of 83 percent potassium hydroxide (KOH) and 17 percent water by weight. The power plant is initially conditioned to increase the water ratio, and during normal operation, water content will vary between 23 and 28 percent, operating at the lower percentage during higher load conditions (higher skin temperature) due to the increase in vapor pressure. At this ratio, the electrolyte has a critical temperature of 300°F (figure 2.6-5). It solidifies at an approximate temperature of 220°F. Power plant electrochemical reaction becomes effective at the critical temperature. Bringing power plants to critical temperature is performed by GSE and cannot be performed from SC power sources. Placing a load on the power plant will maintain it above the critical temperature. The automatic in-line heater circuit can maintain power plant temperature at 385°F with no additional loads applied. It will provide a 4.5 to 6 amp load on the power plant and is not dependent on the main d-c buses.

Purging is a function of power demand and gas purity. O_2 purging requires 2 minutes and H_2 purging 80 seconds. A hydrogen purge is preceded by activation of the H_2 PURGE LINE HTR switch (panel 3) 20 minutes prior to the purge. The purge cycle is determined by the mission power profile and gas purity as sampled after spacecraft tank fill. Figures 2.6-6 and 2.6-7 can be used to calculate the 0.25 volt degradation purge cycles. The period between purge cycles can be extended with a slightly greater voltage degradation. A degradation purge can be performed if power plant output decreases approximately 3 to 5 amps below VIT curve characteristics during g sustained operation. The O_2 purge has more effect during this type of purge, although it would be followed by an H_2 purge if recovery to normal was not realized after performing an O_2 purge. If the pH talkback indicator (panel 3) is activated, a hydrogen purge will not be performed on the fuel cell with the high pH. This prevents the possibility of clogging the hydrogen purge vent line which is common to both fuel cells. To decrease contamination around the assembly, present plans schedule an H_2 purge every 96 hours, and an O_2 purge every 48 hours. Purges will be adjusted by 24 hour increments, so as not to exceed fuel cell degradation of 0.5 vdc.



NOTES: 1. Percent (83) of KOH in electrolyte at initial fill.
2. Critical temperature (300°F) of electrolyte at which electrochemical reaction begins, on initial start-up of fuel cell.

SM-2A-883B

Figure 2.6-5. KOH H_2O Phase Diagram

2.6.3.3.2 Fuel Cell Loading

The application and removal of fuel cell loads causes the terminal voltage to decrease and increase, respectively. A decrease in terminal voltage, resulting from an increased load, is followed by a gradual increase in fuel cell skin temperature which causes an increase in terminal voltage. Conversely, an increase in terminal voltage, resulting from a decreased load, is followed by a gradual decrease in fuel cell skin temperature which causes a decrease in terminal voltage.

The range in which the terminal voltage is permitted to vary is determined by the high- and low-voltage input design limits of the components being powered. For most components, the limits are 30 volts dc and 24 volts dc. To remain within these design limits, the d-c bus voltage must be maintained between 31.0 and 25.5 volts dc. To compensate for cyclic loads, it is recommended sustained bus voltage be maintained between 26.0 and 30.0 volts dc. Bus voltage is maintained within prescribed limits by the application of entry and postlanding batteries during large load increases (power up). Load increase or decrease falls well within the limits of power supply capability and, under normal conditions, should not require other than normal checklist procedures.

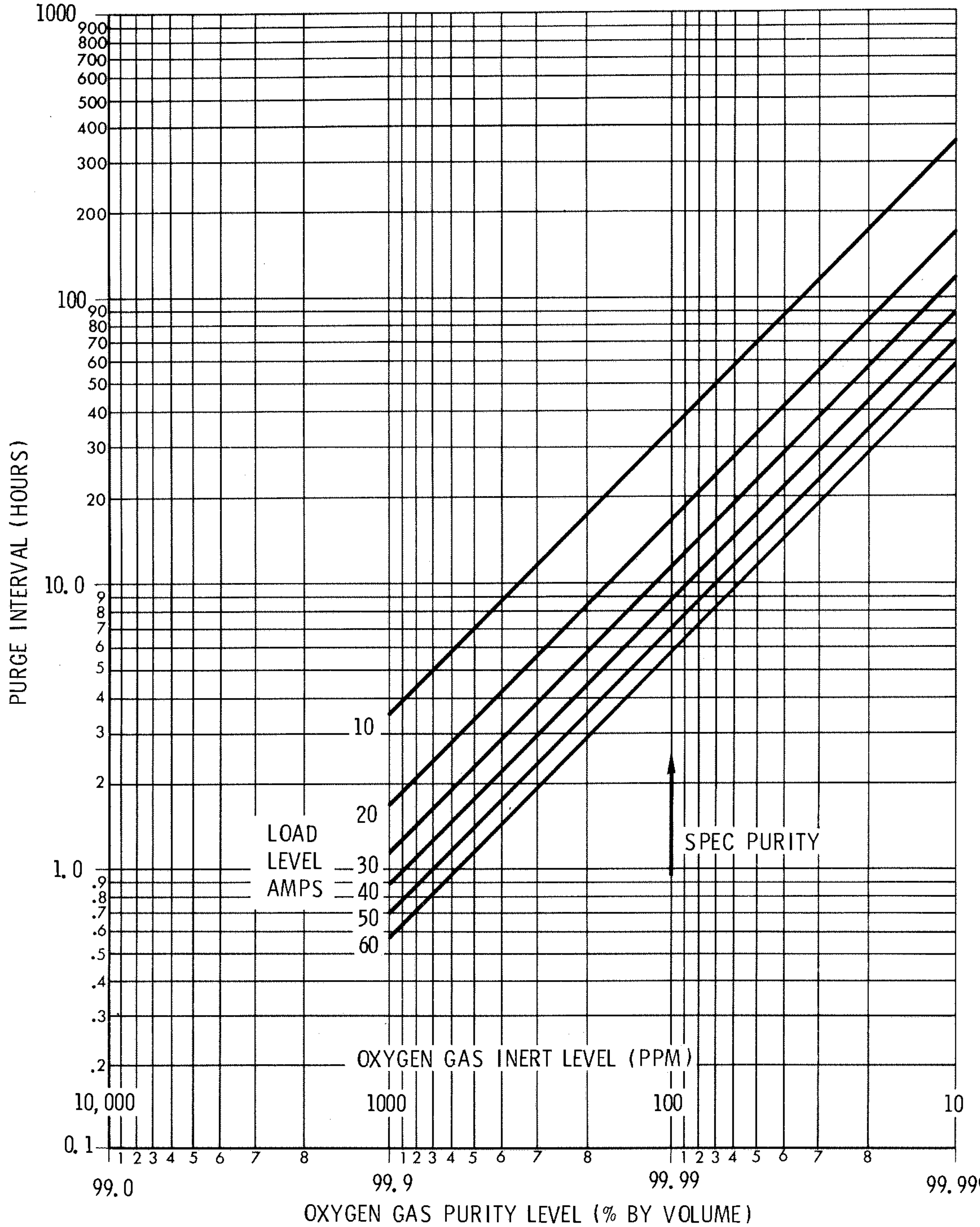


Figure 2.6-6. Oxygen Gas Purity Level (Percent by Volume)

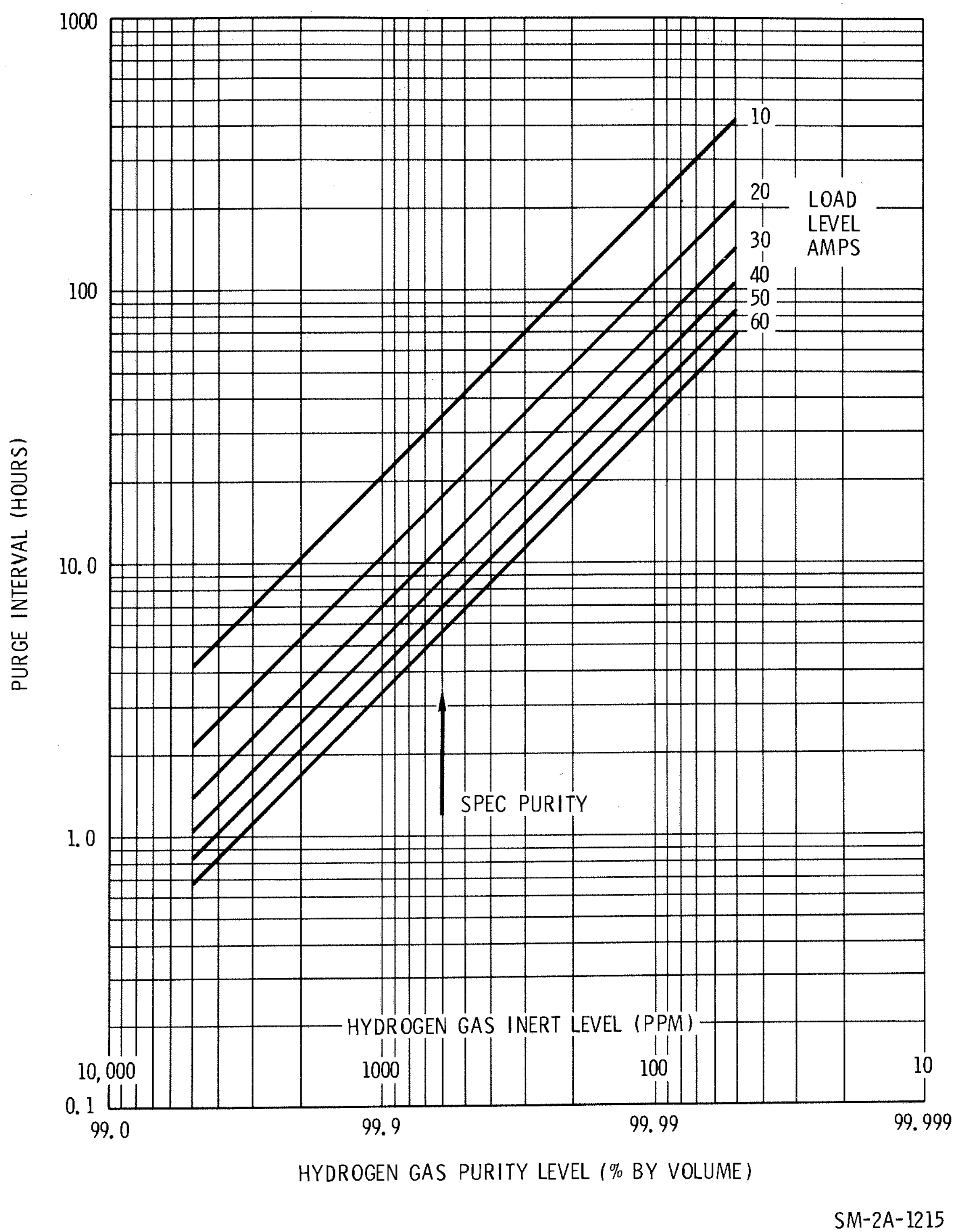


Figure 2.6-7. Hydrogen Gas Purity Level (Percent by Volume)

EPS

Power Up. Powering up spacecraft systems is performed in one continuous sequence providing the main bus voltage does not decrease below 25.7 volts. If bus voltage decreases to this level, the power up sequence can be interrupted for the time required for fuel cell temperatures to increase with the resultant voltage increase, or entry batteries can be connected to the main buses thus reducing the fuel cell load. In most cases, powering up can be performed in one continuous sequence; however, when starting from an extremely low spacecraft load, it is probable that a power up interruption or earlier battery coupling may be required. The greatest load increase occurs while powering up for a delta V maneuver.

Power Down. Powering down spacecraft systems is performed in one continuous sequence providing the main bus voltage does not increase above 31.0 volts. In powering down from relatively high to low spacecraft load levels, the sequence may have to be interrupted for the time required for fuel cell temperature, and as a result bus voltage, to decrease.

Fuel Cell Disconnect. If the requirement arises to maintain a powerplant on open circuit, temperature decay would occur at an average rate of approximately 6°/hr., with the automatic in-line heater circuit activating at a skin temperature of 385°F and maintaining powerplant temperature at 385°F. In-line heater activation can be confirmed by a 4.5- to 6-amp indication as observed on the d-c amps meter (panel 3) with the d-c indicator switch positioned to the open circuited fuel cell position. Reactant valves should remain open, and fuel cell pumps should be kept operating during all open circuit operation.

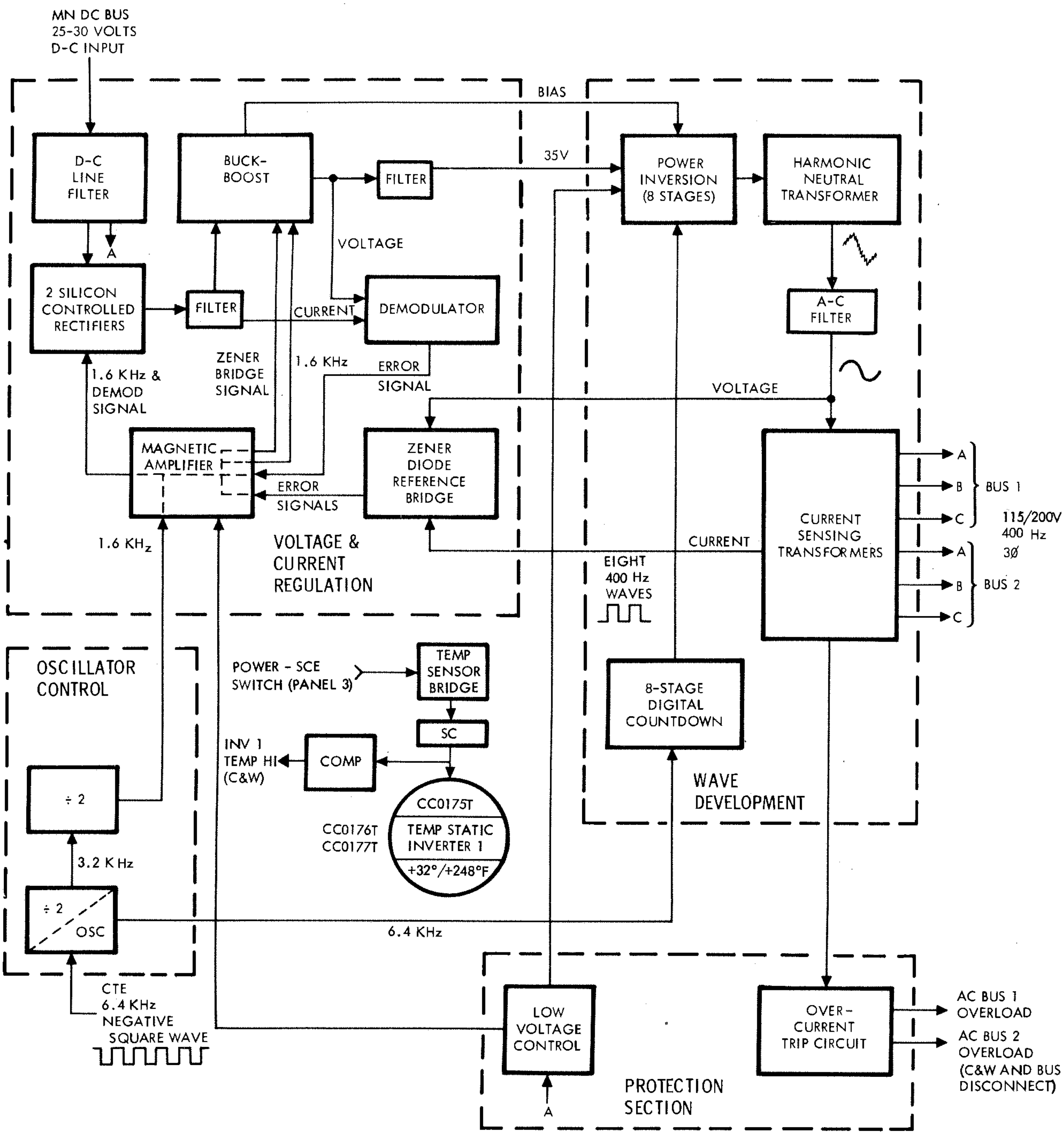
Closing of reactant valves during a power plant disconnect is dependent on the failure experienced. If power plant failure is such as to allow future use, i.e., shutdown due to partially degraded output, it is recommended the reactant valves remain open to provide a positive reactant pressure. The valves should be closed after power-plant skin temperature decays below 300°F. The reactant valves are closed during initial shutdown, if the failure is a reactant leak, an abnormally high regulator output pressure, or complete power-plant failure. Reactant valve closure will activate the respective FC caution and warning light, requiring reset of the caution and warning master alarm circuits.

Fuel Cell Shutdown. The fuel cells may be shut down at any time after SWS activation or after hydrogen depletion. After completion of the power transfer operation the H_2 vent is opened to validate its operation. Subsequently fuel cell heaters and pumps are turned off and the reactant valves are closed. When SKIN TEMP decays to less that 200°F, the electrolyte (KOH) becomes solidified, and the hydrogen and oxygen purge valves will be opened to relieve internal fuel cell pressures. Fuel cell shutdown could be required due to exceeding the capacity of the SM water tank prior to hydrogen depletion.

2.6.3.4 Inverters

Each inverter (figure 2.6-8) is composed of an oscillator, an eight-stage digital countdown section, a d-c line filter, two silicon-controlled rectifiers, a magnetic amplifier, a buck-boost voltage regulator, a demodulator, two d-c filters, an eight-stage power inversion section, a harmonic neutralization transformer, an a-c output filter, current sensing transformers, a Zener diode reference bridge, a low-voltage control, and an overcurrent trip circuit. The inverter normally uses a 6.4-kHz square wave synchronizing signal from the central timing equipment (CTE) which maintains inverter output at 400 Hz. If this external signal is completely lost, the free running oscillator within the inverter will provide pulses that will maintain inverter output within ±7 Hz. The internal oscillator is normally synchronized by the external pulse. The subsequent paragraphs describe the function of the various stages of the inverter.

EPS



NOTE: Unless otherwise specified:
1. Inverter 1 is shown.
2. A denotes input voltage to low voltage control from D-C line filter

A-EP-304B

CSM LOGISTICS TRAINING

Figure 2.6-8. Inverter Block Diagram

EPS

The 6.4-kHz square wave provided by the CTE is applied through the internal oscillator to the eight-stage digital countdown section. The oscillator has two divider circuits which provide a 1600-Hz signal to the magnetic amplifier.

The eight-stage digital countdown section, triggered by the 6.4-kHz signal, produces eight 400-Hz square waves, each mutually displaced one pulse-time from the preceding and following wave. One pulse-time is 156 microseconds and represents 22.5 electrical degrees. The eight square waves are applied to the eight-stage power inversion section.

The eight-stage power inversion section, fed a controlled voltage from the buck-boost regulator, amplifies the eight 400-Hz square waves produced by the eight-stage digital countdown section. The amplified square waves, still mutually displaced 22.5 electrical degrees, are next applied to the harmonic neutralization transformer.

The harmonic neutralization section consists of 31 transformer windings on one core. This section accepts the 400-Hz square-wave output of the eight-stage power inversion section and transforms it into a 3-phase 400-Hz 115-volt signal. The manner in which these transformers are wound on a single core produces flux cancellation which eliminates all harmonics up to and including the fifteenth of the fundamental frequency. The 22.5-degree displacement of the square waves provides a means of electrically rotating the square wave excited primary windings around the 3-phase, wye-connected secondary windings, thus producing the 3-phase 400-Hz sine wave output. This 115-volt signal is then applied to the a-c output filter.

The a-c output filter eliminates the remaining higher harmonics. Since the lower harmonics were eliminated by the harmonic neutral transformer, the size and weight of this output filter was reduced. Circuitry in this filter also produces a rectified signal which is applied to the Zener diode reference bridge for voltage regulation. The amplitude of this signal is a function of the amplitude of a-c output voltage. After filtering, the 3-phase 115-volt a-c 400-Hz sine wave is applied to the a-c buses through individual phase current-sensing transformers.

The current-sensing transformers produce a rectified signal, the amplitude of which is a direct function of inverter output current magnitude. This d-c signal is applied to the Zener diode reference bridge to regulate inverter current output; it is also paralleled to an overcurrent sensing circuit.

The Zener diode reference bridge receives a rectified d-c signal, representing voltage output, from the circuitry in the a-c output filter. A variance in voltage output unbalances the bridge, providing an error signal of proper polarity and magnitude to the buck-boost regulator via the magnetic amplifier. The buck-boost regulator, through its bias voltage output, compensates for voltage variations. When inverter current output reaches 200 to 250 percent of rated current, the rectified signal applied to the bridge from the current sensing transformers is of sufficient magnitude to provide an error signal causing the buck-boost regulator to operate in the same manner as during an overvoltage condition. The bias output of the buck-boost regulator, controlled by the error signal, will be varied to correct for any variation in inverter voltage or a beyond tolerance increase in current output. When inverter current output exceeds 250 percent of rated current, the overcurrent sensing circuit is activated.

The overcurrent sensing circuit monitors a rectified d-c signal representing current output. When total inverter current output exceeds 250 percent of rated current, this circuit will illuminate an overload lamp in 15±5 seconds. If current output of any single phase exceeds 300 percent of rated current, this circuit will illuminate the overload lamp in 5±1 seconds. The AC BUS 1 OVERLOAD and AC BUS 2 OVERLOAD lamps are in the caution/warning matrix on panel 2. The same signals will initiate an automatic inverter disconnect from the overloaded a-c bus.

D-C power to the inverter is supplied from the main d-c buses through the d-c line filter. The filter reduces the high frequency ripple in the input, and the 25 to 30 volts dc is applied to two silicon-controlled rectifiers.

The silicon-controlled rectifiers are alternately set by the 1600-Hz signal from the magnetic amplifier to produce a d-c square wave with an on-time of greater than 90 degrees from each rectifier. This is filtered and supplied to the buck-boost regulator where it is transformer-coupled with the amplified 1600-Hz output of the magnetic amplifier, to develop a filtered 35 volts dc which is used for amplification in the power inversion stages.

The buck-boost regulator also provides a variable bias voltage to the eight-stage power inversion section. The amplitude of this bias voltage is controlled by the amplitude and polarity of the feedback signal from the Zener diode reference bridge which is referenced to output voltage and current. This bias signal is varied by the error signal to regulate inverter voltage and maintain current output within tolerance.

The demodulator circuit compensates for any low-frequency ripple (10 to 1000 Hz) in the d-c input to the inverter. The high-frequency ripple is attenuated by the input filters. The demodulator senses the 35-volt d-c output of the buck-boost regulator and the current input to the buck-boost regulator. An input d-c voltage drop or increase will be reflected in a drop or increase in the 35-volt d-c output of the buck-boost regulator, as well as a drop or increase in current input to the buck-boost regulator. A sensed decrease in the buck-boost regulator voltage output is compensated for by a demodulator output, coupled through the magnetic amplifier to the silicon-controlled rectifiers. The demodulator output causes the SCRs to conduct for a longer time, thus increasing their filtered d-c output. A sensed increase in buck-boost regulator voltage output, caused by an increase in d-c input to the inverter, is compensated for by a demodulator output coupled through the magnetic amplifier to the silicon-controlled rectifiers causing them to conduct for shorter periods; thus producing a lower filtered d-c output to the buck-boost regulator. In this manner, the 35-volt d-c input to the power inversion section is maintained at a relatively constant level irrespective of the fluctuations in d-c input voltage to the inverter.

The low-voltage control circuit samples the input voltage to the inverter and can terminate inverter operation. Since the buck-boost regulator provides a boost action during a decrease in input voltage to the inverter, in an attempt to maintain a constant 35 volts dc to the power inversion section and a regulated 115-volt inverter output, the high boost required during a low-voltage input would tend to overheat the solid-state buck-boost regulator. As a precautionary measure, the low-voltage control will terminate inverter operation by disconnecting operating voltage to the magnetic amplifier and the first power inversion stage when input voltage decreases to a level between 16 and 19 volts dc.

A temperature sensor with a range of +32° to +248°F is installed in each inverter. The inverter 1 sensor provides an input to the C&WS which will illuminate a light at an inverter overtemperature of 190°F. Inverters 2 and 3 are not monitored by the C&WS. The three inverter temperatures are telemetered to STDN, which will provide monitoring of inverters 2 and 3 temperatures.

2.6.3.5 Battery Charger

A constant voltage, solid-state battery charger (figure 2.6-9) is located in the CM lower equipment bay. The BATTERY CHARGER selector switch (panel 3) controls power input to the charger, as well as connecting the charger output to the selected battery (figure 2.6-9). When the BATTERY CHARGER selector switch is positioned to A, B, or C, a relay (K1) is activated completing circuits from a-c and d-c power sources to the battery charger, and connecting charger output to the selected battery.

The battery charger is supplied 25 to 30 volts from both main d-c buses and 115 volts 400-Hz 3-phase from either of the a-c buses. All three phases of ac are used to boost the 25- to 30-volt d-c input and produce 40 volts dc for charging. In addition, phase A of the ac is used to supply power for the charger circuitry. The logic network in the charger, which consists of a two-stage differential amplifier (comparator), Schmitt trigger, current sensing resistor, and a voltage amplifier, sets up the initial condition for operation. The first stage of the comparator is in the on mode, with the second stage off, thus setting the Schmitt trigger first stage to on with the second stage off. Maximum base drive is provided to the current amplifier which turns the switching transistor to the on mode. With the switching transistor on, current flows from the transformer rectifier through the switching transistor, current sensing resistor, and switch choke to the battery being charged. Current lags voltage because of switching choke action. As current flow increases, the voltage drop across the sensing resistor increases, and at a specific level sets the first stage of the comparator to off and the second stage to on. The voltage amplifier is set off to reverse the Schmitt trigger to first stage off and second stage on. This sets the current amplifier off, which in turn sets the switching transistor off. The switching transistor in the off mode terminates power from the source, causing the field in the choke to continue collapsing, discharging into the battery, then through the switching diode and the current sensing resistor to the opposite side of the choke. As the EMF in the choke decreases, current through the sensing resistor decreases, reducing the voltage drop across the resistor. At some point, the decrease in voltage drop

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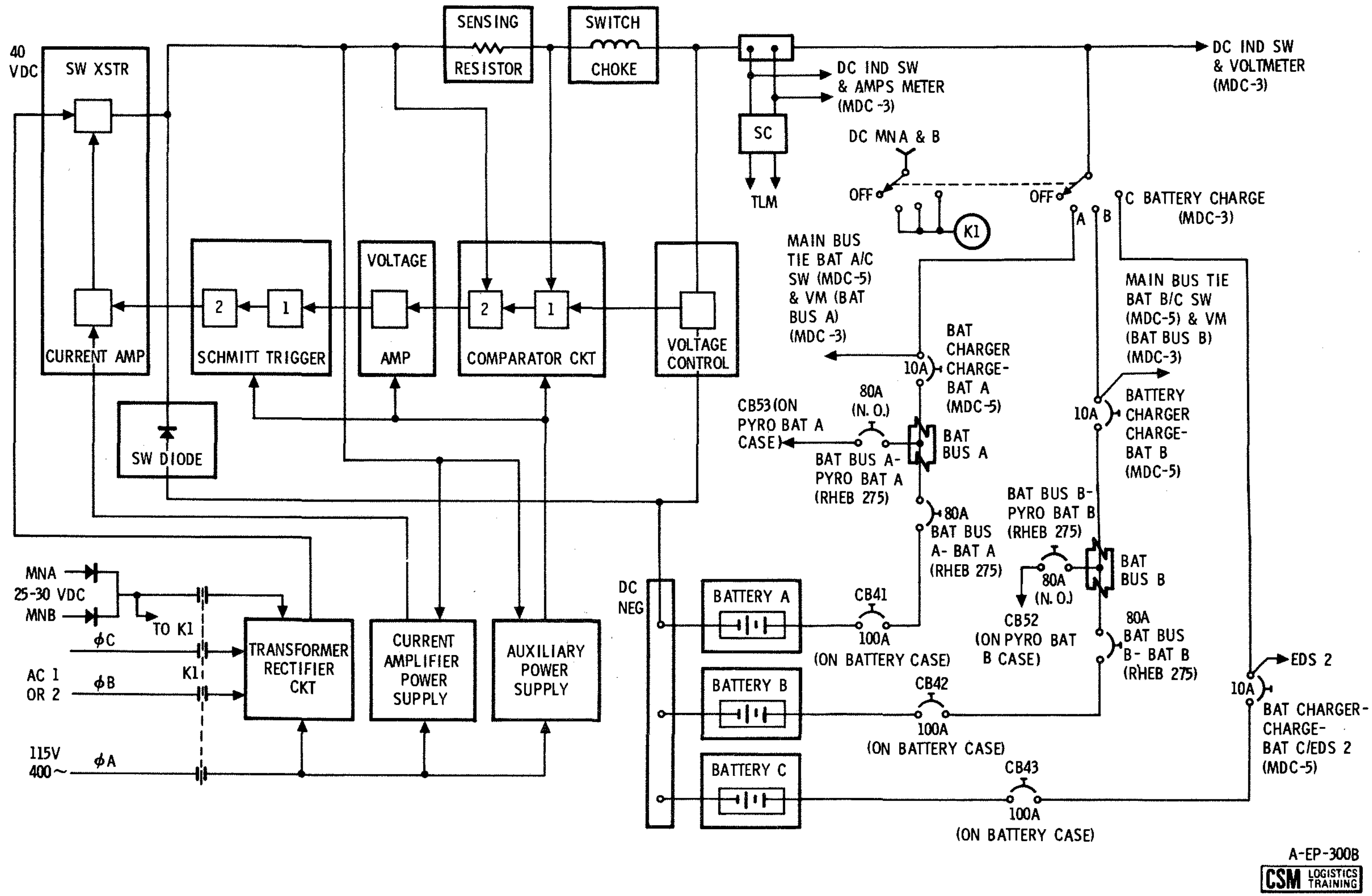

Figure 2.6-9. Battery Charger Block Diagram

across the sensing resistor reverses the comparator circuit, setting up the initial condition and completing one cycle of operation. The output load current, because of the choke action, remains relatively constant except for the small variation through the sensing resistor. This variation is required to set and reset the switching transistor and Schmitt trigger through the action of the comparator.

Battery charger output is regulated by the sensing resistor until battery voltage reaches approximately 37 volts. At this point, the biased voltage sensor circuit is unbiased, and in conjunction with the sensing resistor provides a signal for cycling the battery charger. As battery voltage increases, the internal impedance of the battery increases, decreasing current flow from the charger. At 39.8 volts, the battery is considered fully charged. Recharging the batteries until battery amp hour input equates amp hours previously discharged from the battery, or when battery bus voltage reads 39.5 vdc, assures sufficient battery capacity for mission completion. The STDN will monitor this function. If there is no contact with the STDN, battery charging is terminated when the voltmeter indicates 39.5 vdc with the battery charger connected and the DC INDICATORS switch (panel 3) set to the BAT CHARGER or the respective BAT BUS A or B position.

Charger voltage is monitored on the DC VOLTS METER (panel 3). CURRENT output is monitored on the inner scale of the DC AMPS meter (panel 3) by placing the DC INDICATORS switch (panel 3) to the BAT CHARGER position. Battery charger current output is telemetered to the STDN.

Recharge of a battery immediately after it is exposed to any appreciable loads requires less time than recharge of a battery commencing 30 minutes or more after it is disconnected from these loads. Therefore, it is advantageous to connect batteries to the charger as soon as possible after they are disconnected from the main buses since this decreases overall recharge time. Batteries will be recharged during the initial docked period and subsequently prior to undocking if required.

Present mission rules allow recharge of descent batteries if necessary. Descent battery recharge can be performed if the total battery capacity has been depleted to the point requiring this contingency operation. The charging can be performed through the BAT A or B position requiring disconnect of all loads from the battery and main d-c buses through which the charging is performed. In order to realize approximately a 1 amp/hr recharge capability, descent battery depletion of approximately 100 amp hours must have occurred.

2.6.3.6 Power Distribution

D-C and a-c power distribution to components of the EPS is provided by two redundant buses in each system. A single-point ground on the spacecraft structure is used to eliminate ground loop effects. Sensing and control circuits are provided for monitoring and protection of each system.

2.6.3.6.1 Dc Power Distribution

Distribution of d-c power (figure 2.6-10) is accomplished with a two-wire system and a series of interconnected buses, switches, circuit breakers, and isolation diodes. The d-c negative buses are connected to

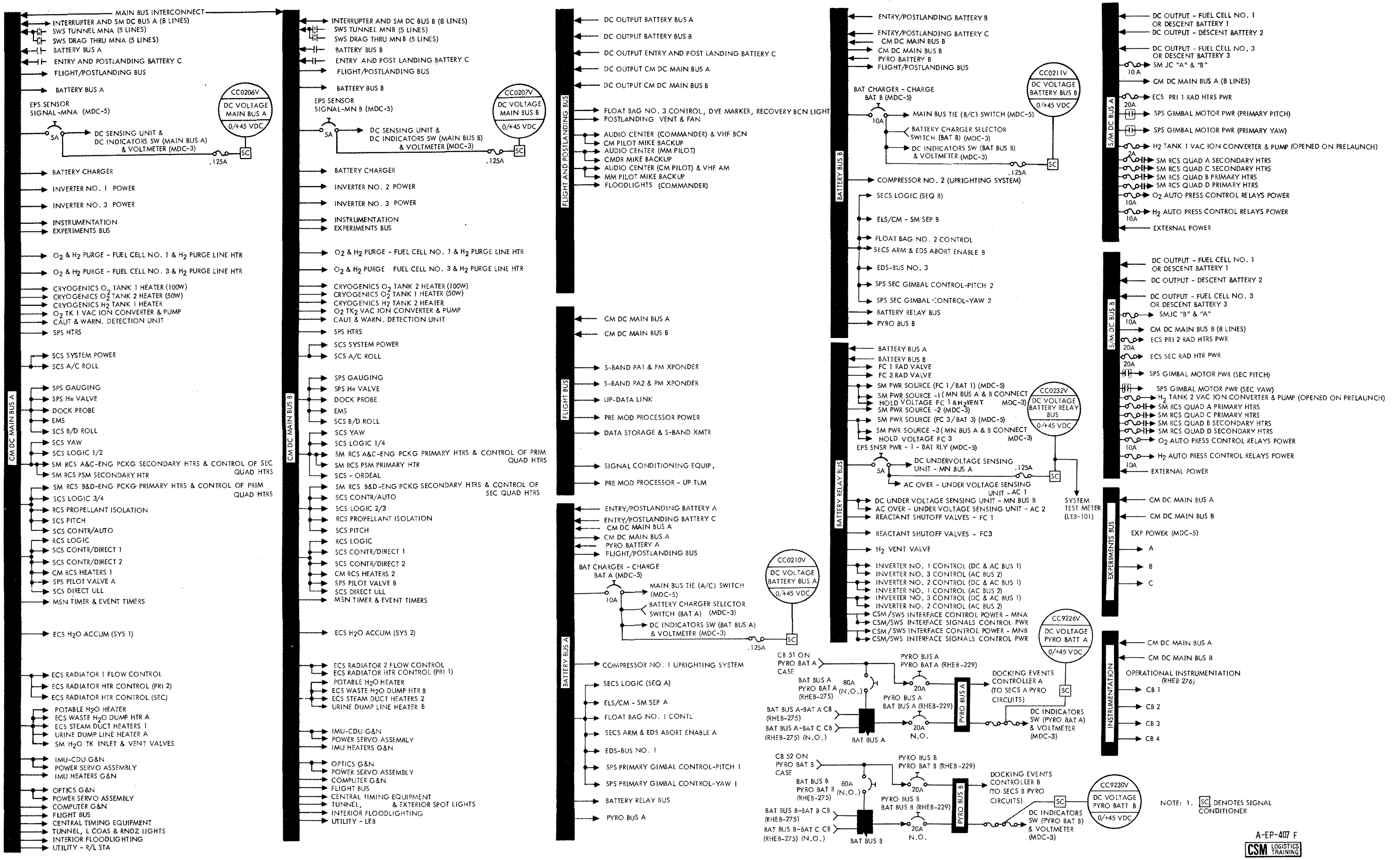

Figure 2.6-10. D-C Power Distribution

EPS

the vehicle ground point (VGP). The CM VGP will be used as the common ground when the orbital assembly is supplying power to the CSM. The buses consist of the following:

- Two main d-c buses (A and B), powered by the two fuel cells, or the OWS, or the descent batteries, and/or entry and postlanding batteries A, B, and C. A bus interconnect is provided for contingency operation in the event of a failure of one OWS bus.
- Two battery buses (A and B), each powered by its respective entry and postlanding battery A and B, or during docked operation through the main d-c buses by closing the BAT BUS A - MAIN A and BAT BUS B - MAIN B cbs (panel 275) and through isolation diodes, and disconnecting the entry batteries. Battery C can power either or both buses if batteries A and/or B fail. Pyro battery A can power battery bus A and pyro battery B can power battery bus B in the event two E/PL batteries fail (A and C or B and C).
- Battery relay bus, powered through the individual battery buses and isolation diodes.
- Flight and postlanding bus, powered through both main d-c buses and diodes, or directly through battery buses A and B and battery C, through dual diodes.
- Flight bus, powered through both main d-c buses and isolation diodes.
- Experiments bus, powered through both main d-c buses and isolation diodes.
- Instrumentation power supplied through both main d-c buses and isolation diodes.
- Pyro buses, isolated from the main electrical power system when powered by the pyro batteries. A capability is provided to connect an entry battery to the A or B pyro system in case of loss of a pyro battery.
- SM jettison controllers, powered by the fuel cell power plants or descent batteries, and completely isolated from the main electrical power system until activated during CM/SM separation.

Fuel cell or descent battery power is available from service module power sources. The fuel cells are used on the launch pad, during boost, and during orbital operation until shutdown. Fuel cell 1 and 3 or descent battery 1 and 3 selection is performed with the SM PWR SOURCE switches on panel 5 (figure 2.6-11). The power source to d-c main bus connection is performed with the SM PWR SOURCE - MAIN BUS A-1, 2, 3 and MAIN BUS B-1, 2, 3 switches (panel 3). The number 2 switches control the connection of descent battery 2 only. The desired fuel cell configuration, during their use, is to have fuel cell 1 connected to d-c main bus A and fuel cell 3 to d-c man bus B, while descent battery connection is battery 1 to d-c main bus A and battery 3 to d-c main bus B. Battery 2 will provide a backup for additional power if required.

Battery recharge is performed during the early orbital period; however, entry and pyro batteries A & B can be recharged during any period prior to an SPS deorbit by disconnecting the respective battery bus from the main d-c bus, connecting the desired battery to the respective battery bus and enabling the battery charger. After the determination to remain in orbit, the proper CM bus configuration is assumed. The battery buses are connected to draw power through the CM main d-c buses, and the CM batteries are disconnected from all loads. This is performed by closing the BAT BUS A - MAIN A and BAT BUS B - MAIN B circuit breakers, and opening the BAT BUS A - BAT A and BAT BUS B - BAT B circuit breakers on panel 275. Just prior to fuel cell shutdown, the power transfer (SWS to CSM) operation is completed with the switches and circuit breakers on panels 230, and the controls in the OWS. The fuel cells are disconnected from the main d-c buses and total shutdown is completed approximately 24 hours later. All subsequent orbital operation is conducted with the CSM powered by the OWS.

A drag-thru umbilical is provided for contingency operation in the event of failure of the normal tunnel power umbilical. It is capable of handling a dual-bus 2200-watt power transfer load similar to the tunnel umbilical. It is intended to be used separately; however, it can be used with the tunnel umbilical if a failure of one of the workshop buses occurs. In order to maintain all CSM systems operational, the A or B transfer circuits (tunnel and drag-thru umbilicals) can provide the total 2200-watt power transfer capability. The MAIN BUS INTERCONNECT - MNA and MNB cbs (panel 250) (figure 2.6-11) are closed to provide power to both CSM main buses.

EPS

A transient suppression filter network is incorporated in the SWS to CSM MNA and MNB power supply lines. The filter is active irrespective of whether the tunnel or drag-through power umbilical is used. The filter network is electrically located between the motor operated switch contacts and two 100-amp circuit breakers on panel 274 (figure 2.6-11). These circuit breakers are closed during all mission phases.

The transfer back to CSM power, prior to orbit return, is performed by selecting descent batteries 1 and 3 with the SM PWR SOURCE switches (panel 5) and connecting the descent batteries to the d-c main buses (figure 2.6-11). Descent battery 1 is connected to d-c main bus A, and battery 3 to d-c main bus B with the SM PWR SOURCE switches (panel 3). The SWS interface is terminated after the entry batteries and battery buses are reconfigured for normal operation. The three entry/postlanding batteries are connected to the d-c main buses for an SPS deorbit burn and subsequent entry. If an RCS deorbit is performed, the three entry batteries are not connected to the d-c main buses until 12 minutes prior to entry. The batteries are not required for an RCS deorbit, and are connected 12 minutes prior to entry to condition them (temperature increase) for the entry phase.

During the periods that fuel cells or descent batteries are used, overload-reverse current circuits provide power source protection. Overload conditions above 75 amps and for specific time envelopes will automatically disconnect the power sources from the overloaded bus. A reverse current condition above 4 amps will result in an automatic disconnect of the power source after a minimum period of 1 second. Either of these disconnect conditions will be accompanied by illumination of the SM PWR DISCONN caution/warning lamp (panel 2), and the appropriate talkback indicator above the main bus control switches on panel 3.

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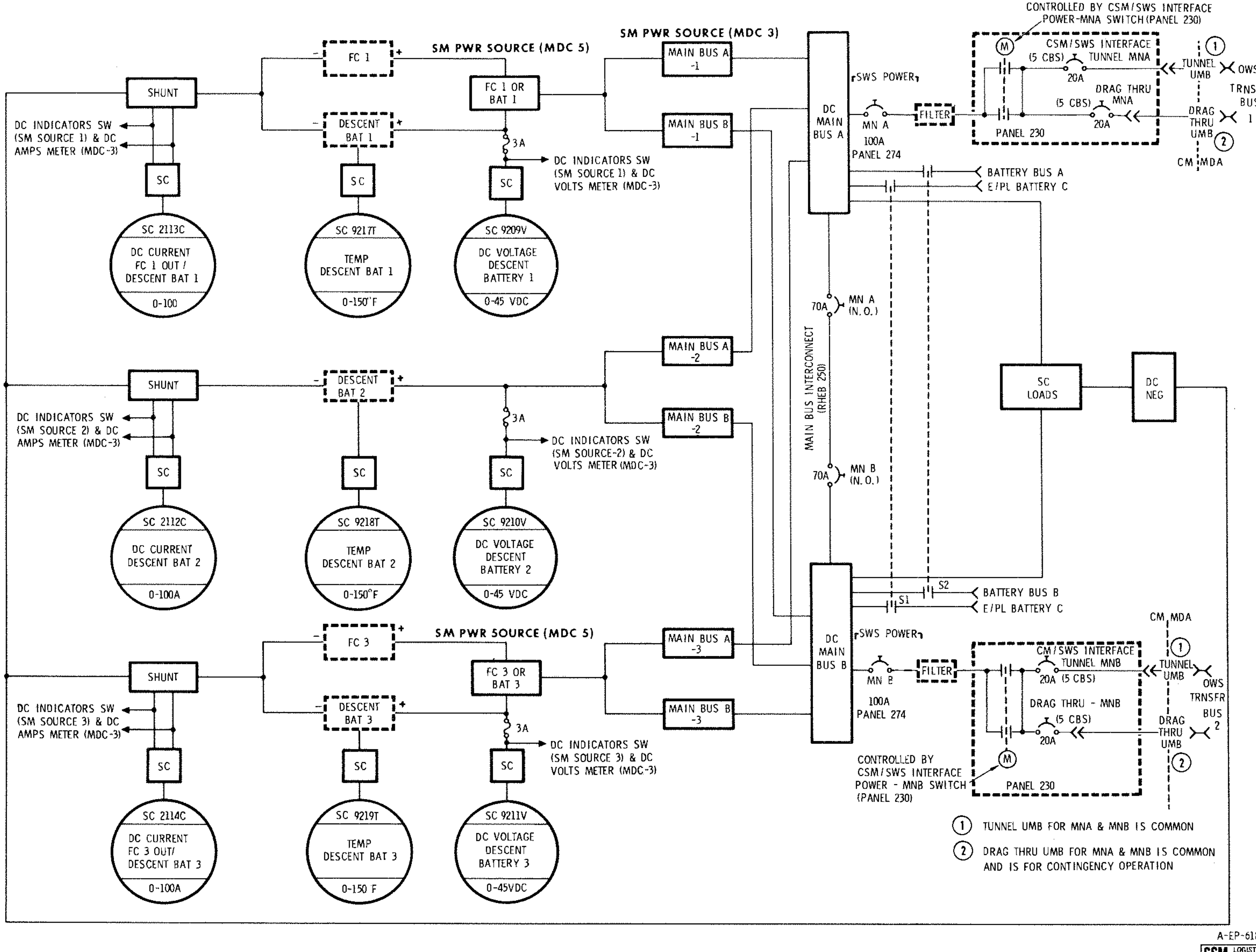

Figure 2.6-11. D-C Main Bus Power Sources and Descent Battery Telemetry

D-C undervoltage sensing circuits (figure 2.6-12) are provided to indicate main d-c bus low-voltage conditions during all periods. A sustained or transient CM main d-c bus voltage of 25.6±.1 vdc or less will illuminate the applicable undervoltage light in the C&W matrix (panel 2). Operation of the appropriate RESET switch (panel 3) determines a transient or sustained condition and the procedures to be followed. The DC INDICATORS switch and DC VOLTS meter (panel 3) provide the capability of checking voltage of each descent battery, each CM main d-c bus, the battery charger, battery buses A and B, battery C, and pyro batteries A and B. The same switch and the DC AMPS meter (panel 3) provide the capability of checking current output of the SM source (fuel cells or descent batteries), E&PL batteries A, B, and C, battery charger, and pyro batteries A and B.

During high power demand or emergencies, supplemental power to the main d-c buses can be supplied from E/PL batteries A and B via the battery buses and directly from battery C (figure 2.6-13). During entry, spacecraft power is provided by the three entry and postlanding batteries which are connected to the main d-c buses prior to an SPS deorbit burn. Placing the MAIN BUS TIE switches (panel 5) to BAT A/C and BAT B/C provides this function after closing the MAIN A-BAT C and MAIN B-BAT C circuit breakers (RHEB-275). The switches are manually placed to OFF after closing the FLIGHT/POST LANDING BUS-BAT A, BAT B, and BAT C circuit breakers (panel 5) during main chute descent. The AUTO position of the main bus tie switches provides an automatic connection of the entry batteries to the main d-c buses at CM/SM separation, and is used only on the launch pad after the spacecraft is configured for a LES pad abort until just prior to lift-off.

EPS

Each of the two battery buses (A and B) supplies power to individual sequential circuits, gimbal motor controls, float bag inflation controls and compressors, through diodes to the battery relay bus, and to the flight and postlanding bus when required. During orbital docked operation, power is supplied to the battery buses through the main d-c buses. This is performed by closing the BAT BUS A-MAIN A and BAT BUS B-MAIN B circuit breakers, and opening the BAT BUS A-BAT A and BAT BUS B-BAT B circuit breakers on panel 275. Battery recharge is completed prior to the battery bus power transfer but can also be performed later with proper circuit breaker manipulation, as explained previously. The battery buses will exhibit a lower voltage during the docked period since power is derived through the main d-c buses instead of directly from the entry batteries.

The battery relay bus, powered through both battery buses and isolation diodes, distributes power to the SM PWR SOURCE - main bus control circuits and talkback indicators (panel 3), SM PWR SOURCE selection circuits (panel 5), a-c sensing units, inverter control circuits (panel 3), fuel cell reactant and radiator valves and control circuits (panel 3), and the H_2 vent valve control. The relay bus, monitored by the MSFN through telemetry and on position 3B of the system test meter (LEB-101), will indicate a lower voltage during the period the CSM is supplied power from the SWS, as opposed to the higher voltage derived from the entry battery configuration.

The flight and postlanding bus, powered through both main d-c buses and isolation diodes until approximately 600 feet altitude, distributes power to the intercom during flight. At 600 feet altitude, the main d-c buses are deactivated, and power to the flight and postlanding bus is provided through the two battery buses (A and B) and directly from battery C

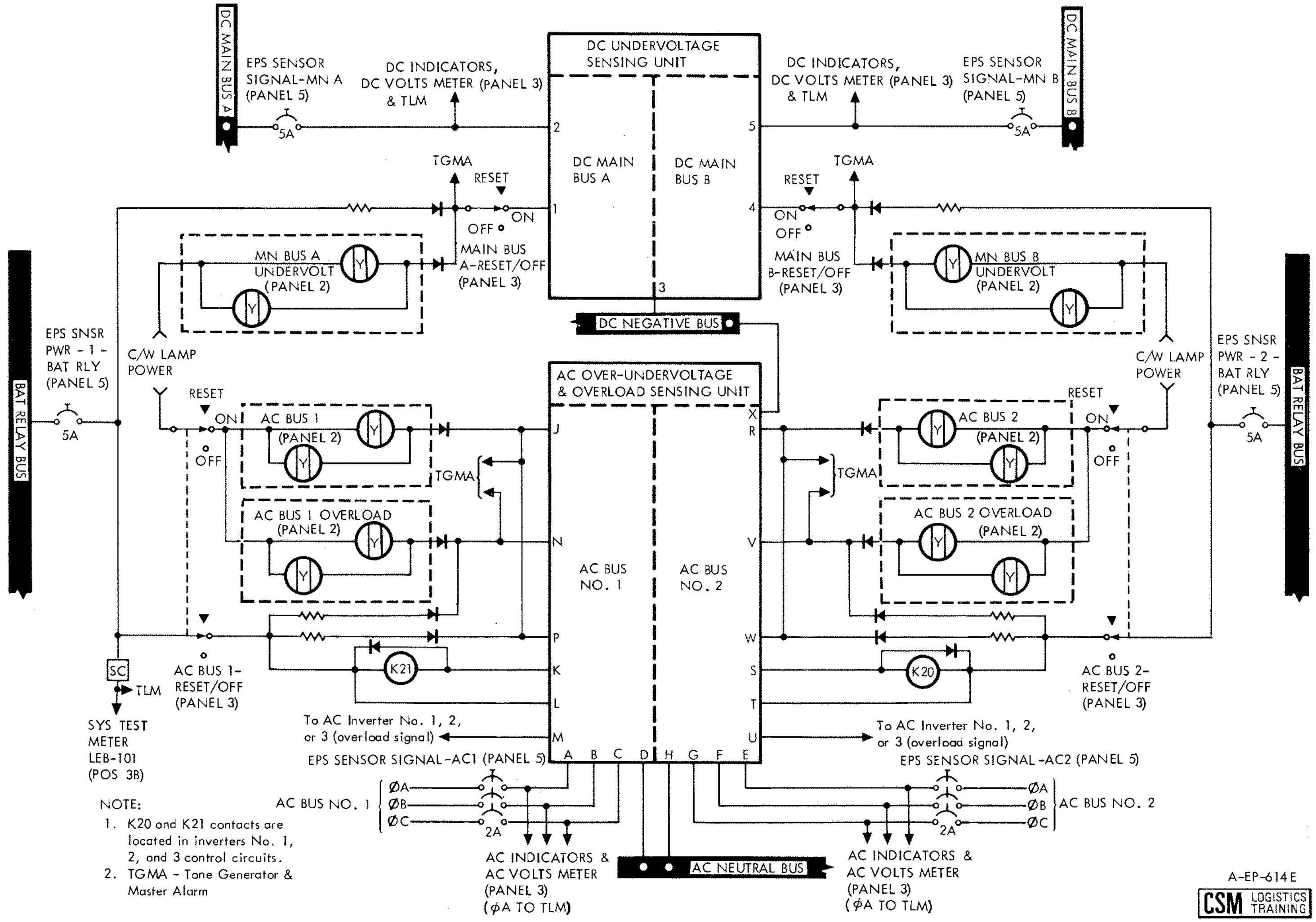

Figure 2.6-12. D-C and A-C Voltage Sensing

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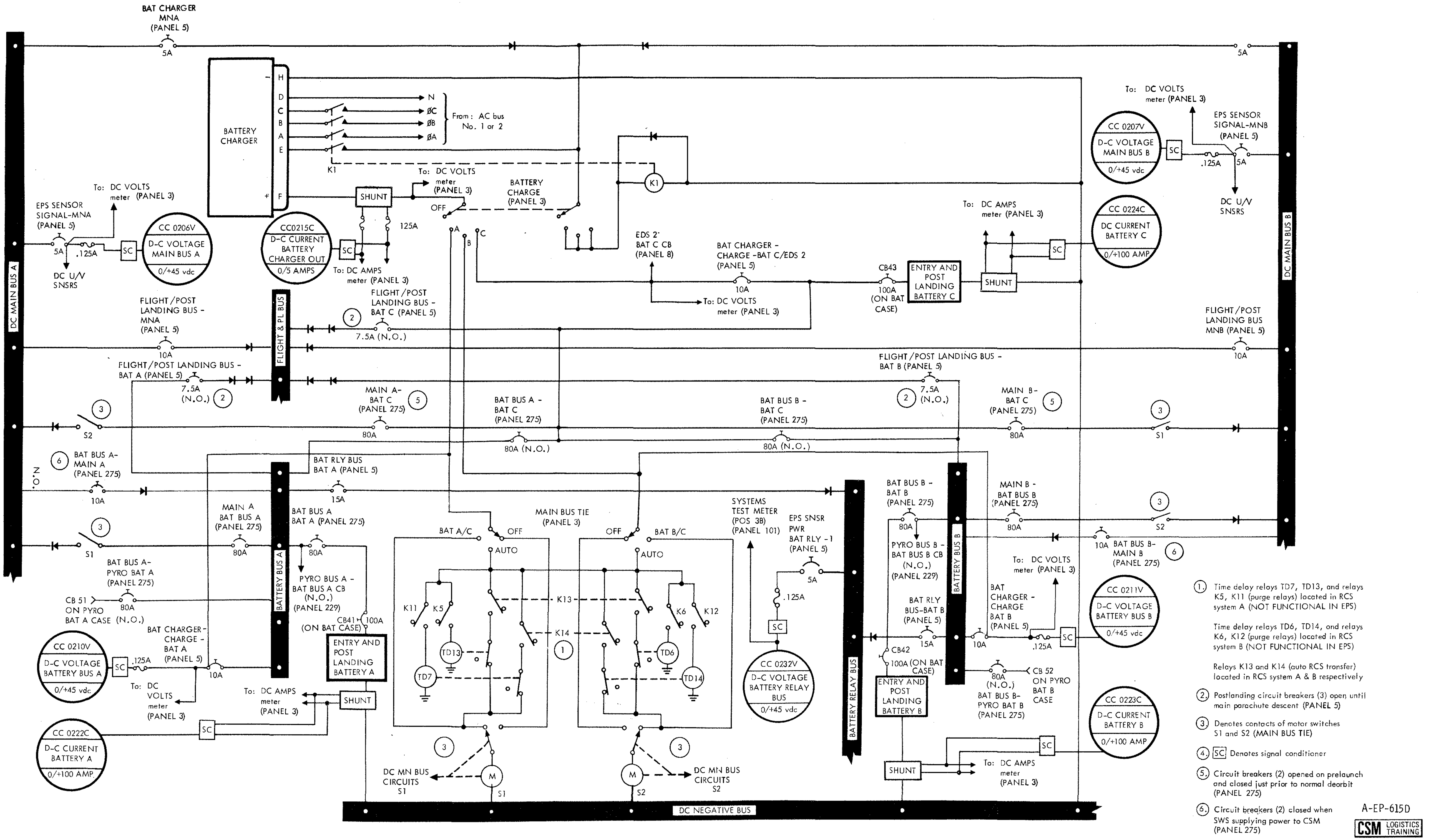


Figure 2.6-13. Battery Charger and CM D-C Control Circuits

through dual isolation diodes in each circuit by closing the appropriate circuit breakers on panel 5. Power is distributed to the intercom, commander's floodlights, float bag 3 control, and other postlanding circuits.

The flight bus, powered through both main d-c buses and isolation diodes, distributes power to the in-flight communications equipment.

The experiments bus, powered through the main d-c buses and isolation diodes, distributes power to three experiments circuit breakers (A, B, and C) on panel 5.

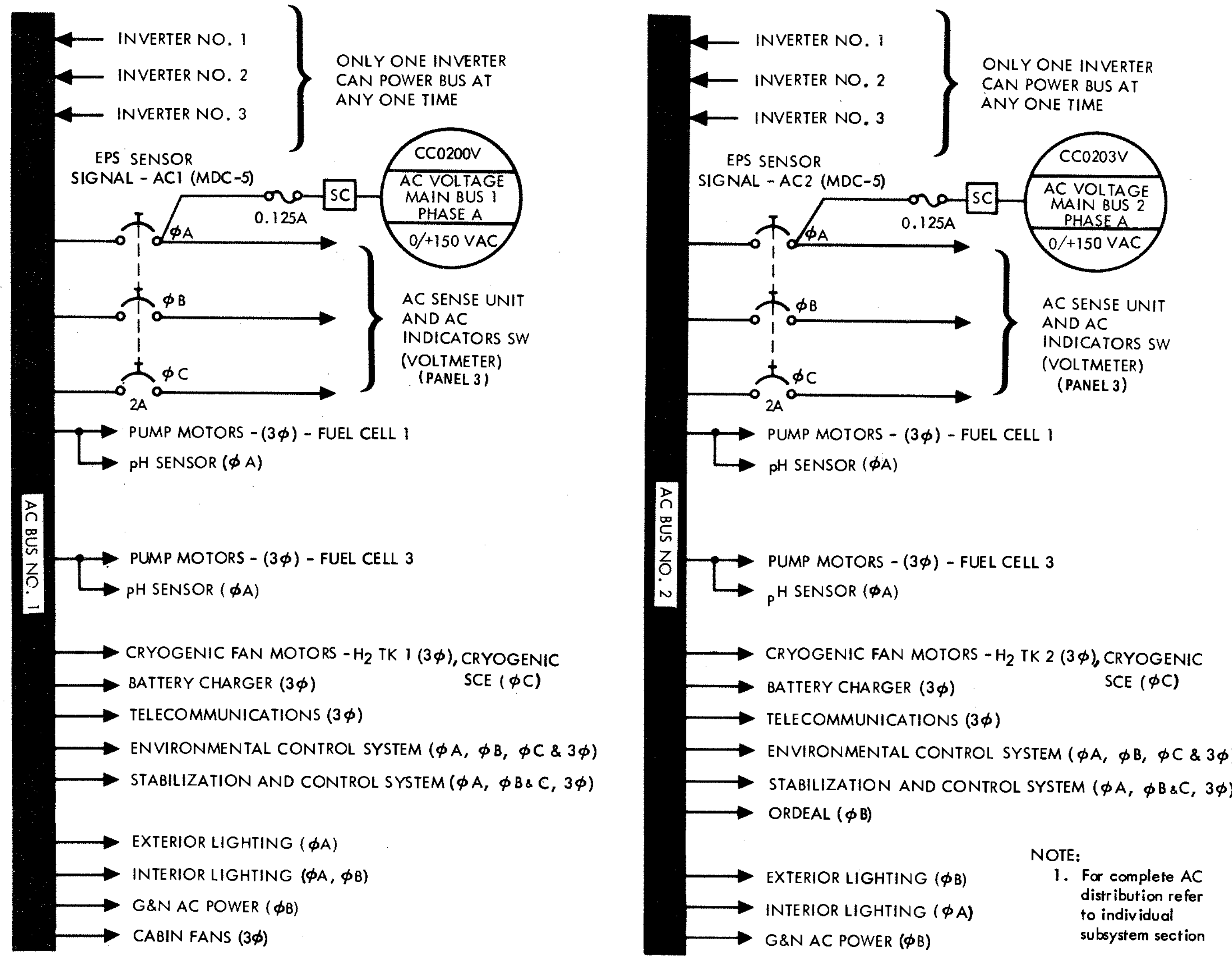
Instrumentation power is supplied through the main d-c buses and isolation diodes to four instrumentation circuit breakers on panel 276.

The redundant pyro buses are isolated from the main electrical power system when powered by the pyro batteries. As a backup, entry battery A can be connected to pyro bus A, and entry battery B can be connected to pyro bus B through battery buses A and B respectively. The respective pyro bus and logic bus are not isolated from each other in the backup configuration since both are powered by the same battery.

2.6.3.6.2 Ac Power Distribution

Distribution of a-c power (figure 2.6-14) is accomplished with a four-wire system via two redundant buses, a-c bus 1 and a-c bus 2. The a-c neutral bus is connected to the vehicle ground point. A-C power is provided by two of the solid-state 115/200-volt 400-Hz 3-phase inverters. Two-inverter operation, one on each a-c bus, is used during all mission phases. Single inverter operation can be used anytime it is necessary to conserve power. D-C power is routed to the inverters through the main d-c buses. Inverter No. 1 is powered through d-c main bus A, inverter No. 2 through d-c main bus B, and inverter No. 3 through either d-c main bus A or B by switch selection. Each of these circuits has a separate circuit breaker and a power control motor switch. D-C power circuit breakers are located on panel 250. Control switches for applying power to the motor switches are located on panel 3. Circuit breakers protecting the control circuits are located on panel 5. All three inverters are identical and are provided with temperature sensors that supply the signals for telemetry. Inverter 1 temperature is monitored by the caution/warning system, while inverters 2 and 3 are not. The light indicator, in the caution/warning group on panel 2, illuminates at 190°F to indicate an overtemperature condition in inverter 1. Inverter output is routed through a series of control motor switches to the a-c buses. Six control switches (panel 3) provide power to motor switches which operate contacts to connect or disconnect the inverters from the a-c buses. Inverter priority is 1 over 2, 2 over 3, and 3 over 1 on any one a-c bus. For example, inverter 2 cannot be connected to the bus until the inverter 1 switch is positioned to OFF. Also, when the inverter 3 switch is positioned to ON, it will take inverter 1 off the bus before the inverter 3 connection will be performed. The motor switch circuits are designed to prevent connecting two inverters to the same a-c bus at the same time. On each bus, if all three switches are activated to on, the bus will be unpowered, as all inverters are disconnected. Most a-c loads can receive power from either a-c bus through bus selector switches. In certain instances of redundant components, one is powered through one a-c bus, while the other is powered

ELECTRICAL POWER SYSTEM



A-EP-617E

CSM LOGISTICS TRAINING

Figure 2.6-14. A-C Power Distribution

through the opposite a-c bus. In some instances, single-phase power is used, while in others all three phases are used. In one case, in the stabilization and control subsystem, two-phase power is used. Over-undervoltage and overload sensing circuits (figure 2.6-12) are provided for each bus. An automatic inverter disconnect is effected during an over-voltage or overload. A-C bus voltage fail and overload lights in the caution/warning group (panel 2) provide a visual indication of voltage or overload malfunctions. Monitoring voltage of each phase on each bus is accomplished by selection with the AC INDICATORS switch (panel 3). Readings are displayed on the AC VOLTS meter (panel 3). Phase A voltage of each bus is telemetered to STDN stations.

Several precautions should be taken during any inverter switching. The first precaution is to completely disconnect the inverter being taken out of the circuit whether due to inverter transfer or malfunction. The second precaution is to ensure that no more than one switch on AC BUS 1 or AC BUS 2 (panel 3) is in the up position at the same time. The first precaution is necessary to assure positive power transfer since power to any one inverter control motor switch is routed in series through the switches of the other inverters. The second precaution is necessary to prevent total loss of ac on a bus, since positioning all three bus switches to ON (up) disconnects all inverters from that bus. A third precaution must be exercised to preclude a motor switch lockout when d-c power to inverter 3 is being transferred from d-c main bus A to d-c main bus B, or vice versa. The AC INVERTER 3 switch (panel 3) should be held in the OFF position for one second when performing a power transfer operation from one main d-c bus to the other.

EPS

2.6.3.6.3 Rescue Vehicle

Rescue capability will be provided during limited periods of each of the three visits to the SWS. S/C 117 (Skylab III) is the rescue vehicle for S/C 116 (Skylab II). S/C 118 (Skylab IV) is the rescue vehicle for Skylab III. S/C 119 is the rescue vehicle for Skylab IV.

A mod kit is available for converting a vehicle for a rescue mission. There will be no variance in the EPS when a vehicle will be performing a rescue mission. The rescue vehicle may dock at the axial or radial port of the MDA depending on the configuration available which will be dictated by the circumstances warranting a rescue mission.

When docked at the axial port, CSM power may be derived from the two fuel cells onboard the CSM, or should the power requirement increase because of an extended docked period necessitating use of additional heaters, descent battery 2 may be used together with the two fuel cells. If the situation warrants, the fuel cells may be put on open circuit, and SWS power can be supplied through the CSM/MDA power umbilical.

Docking at the radial port precludes availability of SWS power because the power transfer connection is at the axial port. Therefore, increased loads would have to be supplied by the two fuel cells, and if necessary, augmented with descent battery 2. A radial docking is time-constrained by thermal effects on the CSM because of location of the port in conjunction with assembly attitude.

2.6.4 PERFORMANCE AND DESIGN DATA

2.6.4.1 A-C and D-C Data

A-C and d-c performance and design data for the EPS is as follows:

AC

Phases	3
Displacement	120±2 degrees
Steady-state voltage	115.5 (+1, -1.5) vac (average 3 phases)
Transient voltage	115 (+35, -65) vac
Recovery	To 115±10v within 15 ms, steady state within 50 ms
Unbalance	2 vac (worst phase from average)
Frequency limits	
Normal (synchronized to central timing equipment)	400±3 Hz
Emergency (loss of central timing equipment)	400±7 Hz
Wave characteristics (sine wave)	
Maximum distortion	5 percent
Highest harmonic	4 percent
Crest factor	1.414±10 percent
Rating	1250 va

DC

Steady-state voltage limits	
Normal	29±2.0 vdc
Minimum CM bus	26.0 vdc (allows for cyclic loads)
Maximum CM bus	31.0 vdc
Maximum Precautionary CM bus	30.0 vdc (allows for cyclic loads)
During postlanding and preflight checkout periods	27 to 30 vdc
Ripple voltage	1v peak to peak

2.6.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS

2.6.5.1 Fuel Cell Powerplants

Fuel cell power plants are designed to function under atmospheric and high-vacuum conditions. Each must be able to maintain itself at sustaining temperatures and minimum electrical loads at both environment extremes. To function properly, fuel cells must operate under the following limitations and restrictions:

External nonoperating temperature	-20° to +140°F
Operating temperature inside SM	+30° to +145°F
External nonoperating pressure	Atmospheric
Normal voltage	27 to 31 vdc
Minimum operating voltage at terminals	
Emergency operation	20.5 vdc at 2295 watts (gross power level)
Normal operation	27 vdc
Maximum operating voltage at terminals	31.5 vdc
Fuel cell disconnect	
Overload	75 amperes no trip, 112 amperes disconnect after 25 to 300 seconds
Maximum reverse current	1 second minimum before any disconnect
Minimum sustaining power/fuel cell power plant (with in-line heater OFF)	420 watts

In-line heater power (sustains F/C skin temp above 385°F min)	160 watts (4.5 to 6 amps)
Maximum gross power under emergency conditions	2295 watts at 20.5 vdc min
Nitrogen pressure	50.2 to 57.5 psia (54 psia, nominal)
Reactant pressure	
Oxygen	57.9 to 67.95 psia (63.0 psia, nominal)
Hydrogen	57.9 to 67.6 psia (63.0 psia, nominal)
Reactant consumption/fuel cell power plant	
Hydrogen	PPH = Amps x (2.57×10^{-3})
Oxygen	PPH = Amps x (2.04×10^{-2})
Minimum skin temperature for self-sustaining operation	+385°F
Minimum skin temperature for recovery in flight	+360°F
Maximum normal skin temperature	+455°F
Maximum absolute skin temperature	+500°F
Approximate external environment temperature range outside SC (for radiation)	-260° to +400°F
Fuel cell power plant normal operating temperature range	+385° to +440°F
Condenser exhaust normal operating temperature	+150° to +175°F
Purging nominal frequency	Dependent on mission load profile and reactant purity after tank fill
O_2 purge duration	2 minutes
H_2 purge duration	80 seconds
Additional flow rate while purging	
O_2	Up to 0.6 lb/hr
H_2.	Up to 0.75 lb/hr (nominal 0.67 lb/hr)

EPS

2.6.5.2 Cryogenic Storage Subsystem

The cryogenic storage subsystem must be able to meet the following requirements for proper operation of the fuel cell power plants and the ECS:

Minimum usable quantity (100% fill)	
Oxygen	320 lb
Hydrogen	28 lb (Actual availability will be dependent on launch pad procedures.)
Temperature at time of fill	
Oxygen	-297°F (approx)
Hydrogen	-423°F (approx)
Operating pressure range	
Oxygen	
Normal	865 to 935 psia
Minimum for F/C operation	150 psia
Minimum for EVA or IVA	865 psia
Hydrogen	
Normal	225 to 260 psia
Minimum	100 psia
Temperature probe range	
Oxygen	-325° to +80°F
Hydrogen	-425° to -200°F
Pressure relief valve operation	
Crack pressure	
Oxygen	983 psig min
Hydrogen	273 psig min
Full flow, maximum relief	
Oxygen	1010 psig max
Hydrogen	285 psig max
Reseat pressure	
Oxygen	965 psig min
Hydrogen	268 psig min

2.6.5.3 Additional Data

Additional data about limitations and restrictions may be found in the CSM Spacecraft Operational Data Book MSC-01549, Vol III.

SYSTEMS DATA

2.6.6 SYSTEMS TEST METER

The SYSTEMS TEST meter and the alphabetical and numerical switches, located on panel 101, provide a means of measuring various parameters within the SC, or verifying certain parameters displayed only by event indicators. The following EPS instrumentation can be measured using the SYSTEMS TEST meter, the respective switch positions, the range of each sensor, and normal operating parameters.

Measurement Description and TLM Number	Switch Positions		Sensor Range	Nominal	
	Numerical Select	Alphabetical Select		System	Test Meter Range (volts)
Fuel Cell 1					
N_2 Reg Press SC2060P	1	A	0 to 75 psia	50-58 psia	3.4-3.8
O_2 Reg Press SC2066P	2	A	0 to 75 psia	55-67 psia	3.7-4.5
H_2 Reg Press SC2069P	3	A	0 to 75 psia	55-67 psia	3.7-4.5
Rad Out Temp SC2087T	4	A	-50 to +300°F	-10 to +90°F	0.6-2.0
Fuel Cell 3					
N_2 Reg Press SC2062P	5	A	0 to 75 psia	50-58 psia	3.4-3.8
O_2 Reg Press SC2068P	6	A	0 to 75 psia	55-67 psia	3.7-4.5
H_2 Reg Press SC2071P	7	A	0 to 75 psia	55-67 psia	3.7-4.5
Rad Out Temp SC2089T	8	A	-50 to +300°F	-10 to +90°F	0.6-2.0
Bat Compt Press CC0188P	2	B	0 to 20 psia	8 ± 1 psia	1.75-2.25
Bat Rly Bus DC Volts CC0232V	3	B	0 to 45 vdc	30.5 to 37.0 vdc (undocked) 25.2 to 29.0 vdc (docked)	3.4-4.1 2.8-3.3
O_2 Tk 1 Htr Temp SC0070T	10	C	-300 to +600°F	<356°F	<3.6
O_2 Tk 2 Htr Temp SC0071T	11	C	-300 to +600°F	<356°F	<3.6

For a complete listing of all system test meter measurements, refer to Section 3.0, Controls and Displays.

EPS

Full scale conversion of the previously listed measurements to the SYSTEMS TEST meter indications is listed in the following chart.

NOTE

Brackets denote nominal ranges.

Systems Test Meter Display	N_2,O_2,H_2 Pressure (psia)	EPS Radiator Outlet Temperature (°F)	Battery Manifold Pressure (psia)	Battery Relay Bus (vdc)	O_2 Tank Heater Temperature (°F)
0.0	0	-50	0.00	0	-300
0.2	3	-36	0.80	1.8	-264
0.4	6	-22	1.60	3.6	-228
0.6	9	-8	2.40	5.4	-192
0.8	12	+6	3.20	7.2	-156
1.0	15	+20	4.00	9.0	-120
1.2	18	+34	4.80	10.8	-84
1.4	21	+48	5.60	12.6	-48
1.6	24	+62	6.40	14.4	-12
1.8	27	+76	7.20	16.2	+24
2.0	30	+90	8.00	18.0	+60
2.2	33	+104	8.80	19.8	+96
2.4	36	+118	9.60	21.6	+132
2.6	39	+132	10.40	23.4	+168
2.8	42	+146	11.20	25.2 (DOCKED)	+204
3.0	45	+160	12.00	27.0	+240
3.2	48	+174	12.80	28.8 (UNDOCKED)	+276
3.4	51 (N_2)	+188	13.60	30.6	+312
3.6	54	+202	14.40	32.4	+348
3.8	57 (H_2 & O_2)	+216	15.20	34.2	+384
4.0	60	+230	16.00	36.0	+420
4.2	63	+244	16.80	37.8	+456
4.4	66	+258	17.60	39.6	+492
4.6	69	+272	18.40	41.4	+528
4.8	72	+286	19.20	43.2	+564
5.0	75	+300	20.00	45.0	+600

2.6.7 COMMAND MODULE INTERIOR LIGHTING

The command module interior lighting system (figure 2.6-15) furnishes illumination for activities in the couch, lower equipment bay and tunnel areas, and back-lighted panel lighting to read nomenclature, indicators, and switch positions. Tunnel lighting is provided on SC which will be concerned with tunnel activity.

Floodlighting for illumination of work areas is provided by use of fluorescent lamps. Integral panel and numerics lighting is provided by electroluminescent materials. Tunnel lights are incandescent. Pen flashlights are provided for illuminating work areas which cannot be illuminated by the normal spacecraft systems, such as under the couches.

Electroluminescence (EL) is the phenomena whereby light is emitted from a crystalline phosphor (Z_NS) placed as a thin layer between two closely spaced electrodes of an electrical capacitor. One of the electrodes is a transparent material. The light output varies with voltage and frequency and occurs as light pulses, which are in-phase with the input frequency. Advantageous characteristics of EL for spacecraft use are an "after-glow" of less than one second, low power consumption, and negligible heat dissipation.

EPS

2.6.7.1 Floodlight System

The interior floodlight system consists of six floodlight fixture assemblies and three control panels (figure 2.6-16). Each fixture assembly

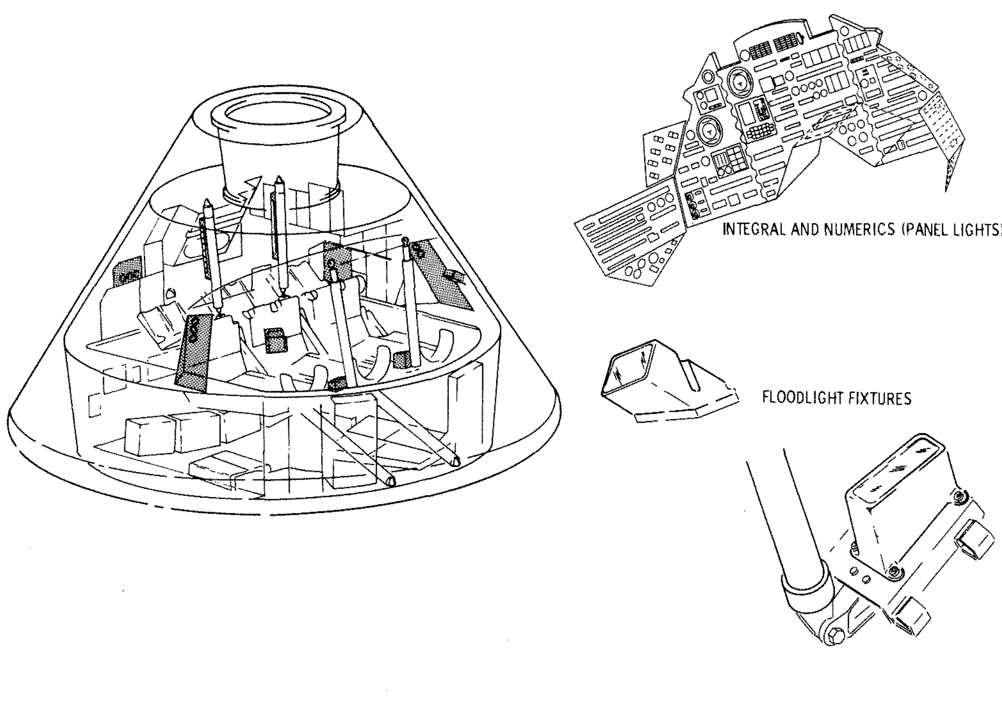


Figure 2.6-15. CM Interior Lighting

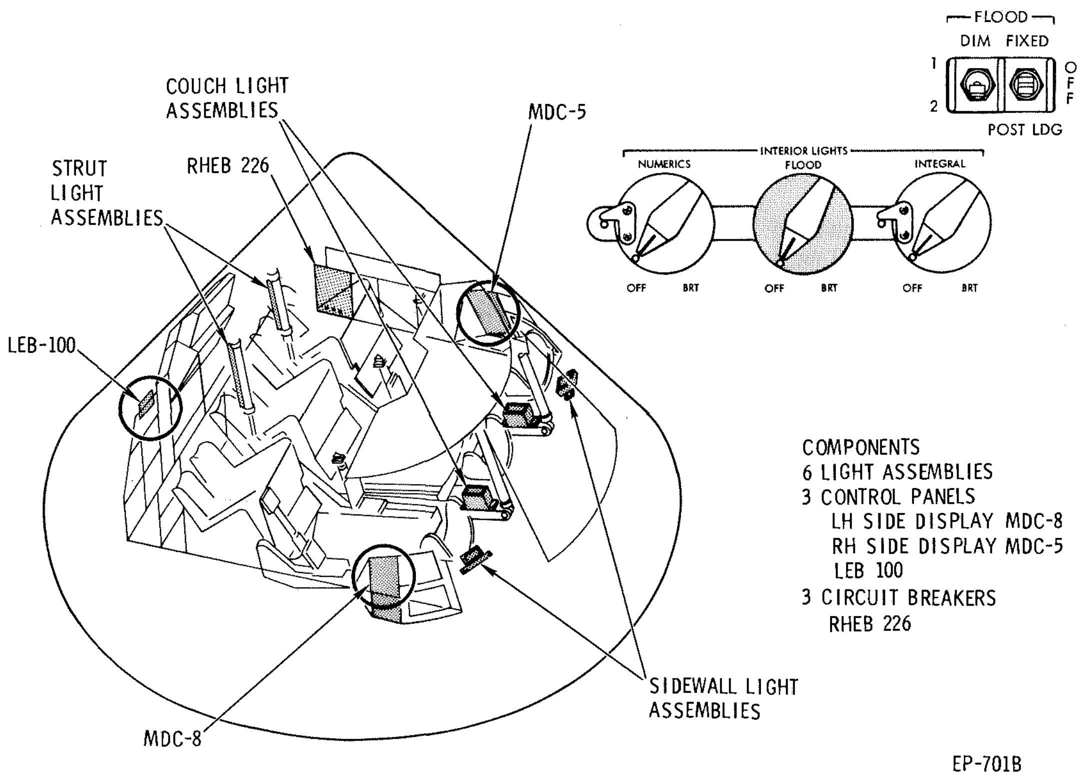


Figure 2.6-16. CM Floodlight Configuration

contains two fluorescent lamps (one primary and one secondary) and converters. The lamps are powered by 28 vdc from main d-c buses A and B (figure 2.6-17). This assures a power source for lights in all areas in the event either bus fails. The converter in each floodlight fixture converts 28 vdc to a high voltage pulsating dc for operation of the fluorescent lamps.

Floodlights are used to illuminate three specific areas: the left main display console, the right main display console, and the lower equipment bay. Switches on panel 8 provide control of lighting of the left main display console area. Switches on panel 5 provide control of lighting of the right main display console area. Switches for control of lighting of the lower equipment bay area are located on panel 100. Protection for the floodlight circuits is provided by the LIGHTING - FLOOD - MNA, MNB and FLT/PL circuit breakers on panel 226.

Each control panel has a dimming (DIM-1-2) toggle switch control, a rheostat (FLOOD-OFF-BRT) control, and an on/off (FIXED-OFF) toggle switch control. The DIM-1 position provides variable intensity control of the primary flood lamps through the FLOOD-OFF-BRT rheostat, and on-off control of the secondary lamps through the FIXED-OFF switch. The DIM-2 position provides variable intensity control of the secondary lamps through the FLOOD-OFF-BRT rheostat, and on-off control of the primary lamps through the FIXED-OFF switch. When operating the primary lamps under variable

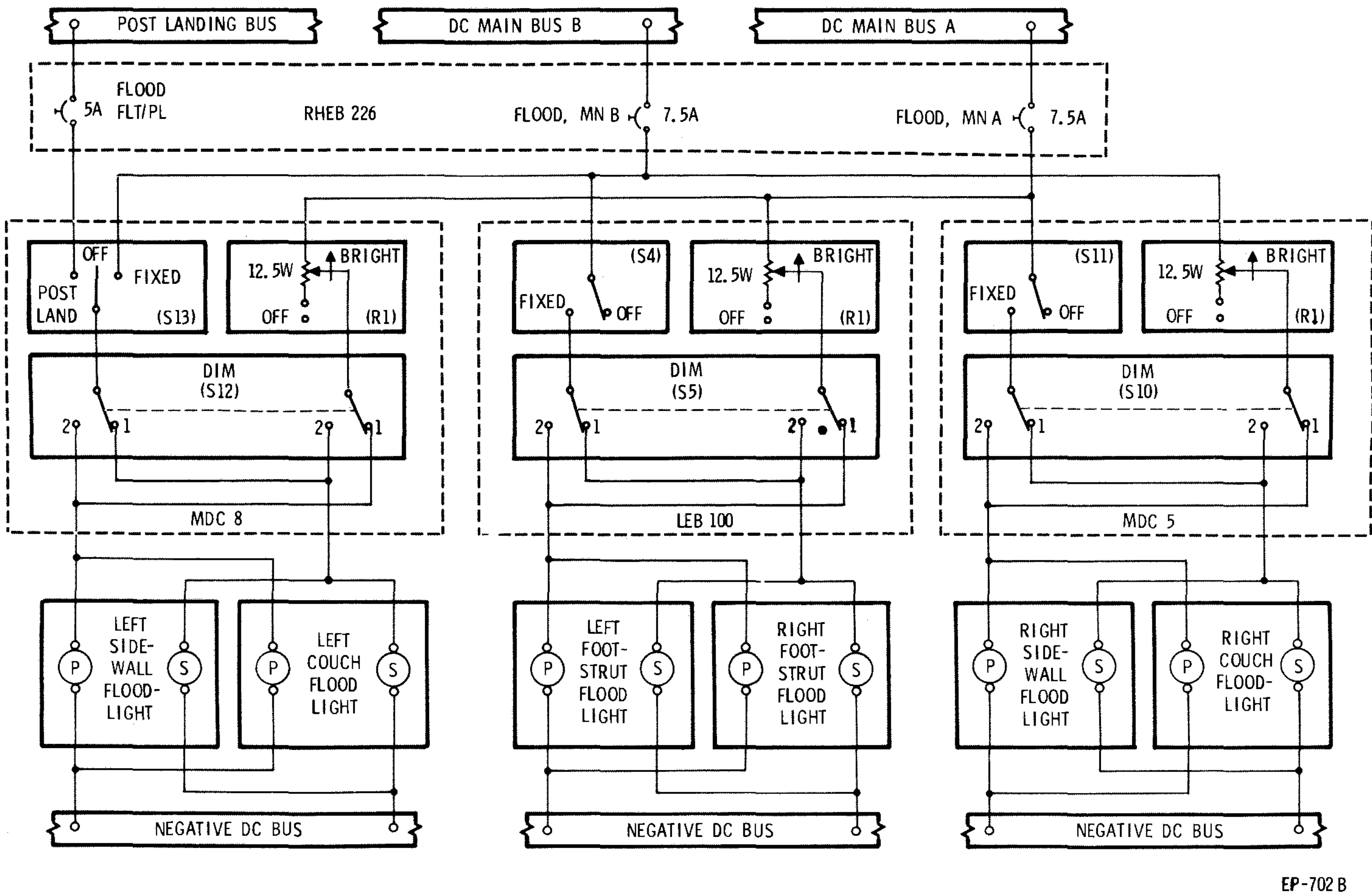


Figure 2.6-17. CM Floodlight System Schematic

intensity control (DIM-1 position), turnon of the lamps is acquired after the FLOOD-OFF-BRT rheostat is moved past the midpoint. In transferring variable intensity control to the secondary lamps, the FLOOD-OFF-BRT rheostat should first be rotated to the OFF position before placing the DIM switch to the DIM-2 position. The rheostat is then moved to the full bright setting and should remain in this position unless dimming is desired. Dimming of the secondary flood lamps should not be used unless dimming control of the primary floodlights is not available. Dimming of the secondary lamps results in approximately a 90-percent reduction in lamp life. The range of intensity variation is greater for the primary than the secondary floodlights. The DIM 1-2 switch on panel 100 is three-position, with a center (off) position.

The commander's control panel (panel 8) has a POST LANDING-OFF-FIXED switch which connects the flight and postlanding bus to his floodlights (figure 2.6-17). The POST LANDING position provides single intensity lighting to the commander's primary or secondary lamps as selected by the DIM-1 or DIM-2 position respectively. It is for use during the latter stages of descent after main d-c bus power is disconnected, and during postlanding.

2.6.7.2 Integral Lighting System

The integral lighting system controls the EL lamps behind the nomenclature and instrument dial faces on all MDC panels, and on specific panels in the lower equipment bay, left-hand equipment bay and right-hand equipment bay (figures 2.6-18 and 2.6-19). The controls (figure 2.6-18) are rotary switches controlling variable transformers powered through the appropriate a-c bus. Each rotary control switch has a mechanical stop which prevents the switch being positioned to OFF. Disabling of a circuit because of malfunctions is performed by opening the appropriate circuit breaker on panel 226. The INTEGRAL switch on panel 8 controls the lighting of panels 1, 7, 8, 9, 15, and the DSKY and mission timer and FDAI on panel 2. The INTEGRAL switch on panel 5 controls the lighting of panels 3, 4, 5, and 6, 16, and the majority of panel 2. The INTEGRAL switch on panel 100 controls the lighting of panels 10, 100, 101, 122, the DSKY lights on panel 140, and panels 225, 226, 229, 230, 275, and 306. Intensity of the lighting can be individually controlled in each of the three areas.

2.6.7.3 Numerics Lighting System

Numerics lighting control is provided over all electroluminescent digital readouts. The NUMERICS rotary switch on panel 8 controls the intensity of numerals on the DSKY and mission timer on panel 2, and through the FUNCTION switch on the EMS panel, the range and delta V indicators of the entry monitor system on panel 1. The switch on panel 100 controls the intensity of the numerals on the LEB-140 DSKY and the mission timer on panel 306. Protection for the integral and numerics circuits is provided by the LIGHTING-NUMERICS/INTEGRAL-LEB AC 2, L MDC AC 1, and R MDC AC 1 circuit breakers on panel 226. A 1/8-amp fuse provides additional protection in each circuit to the mission timer numerics on panels 2 and 306. The fuses provide for retention of the remaining EL circuits controlled by the panel 8 and LEB 100 switches in case of a short in the respective mission timer circuit. The circuit breakers are used to disable a circuit in case of a malfunction. The L MDC AC 1 circuit breakers also power the EMS roll attitude and scroll incandescent lamps through the FUNCTION switch on the EMS panel of MDC-1.

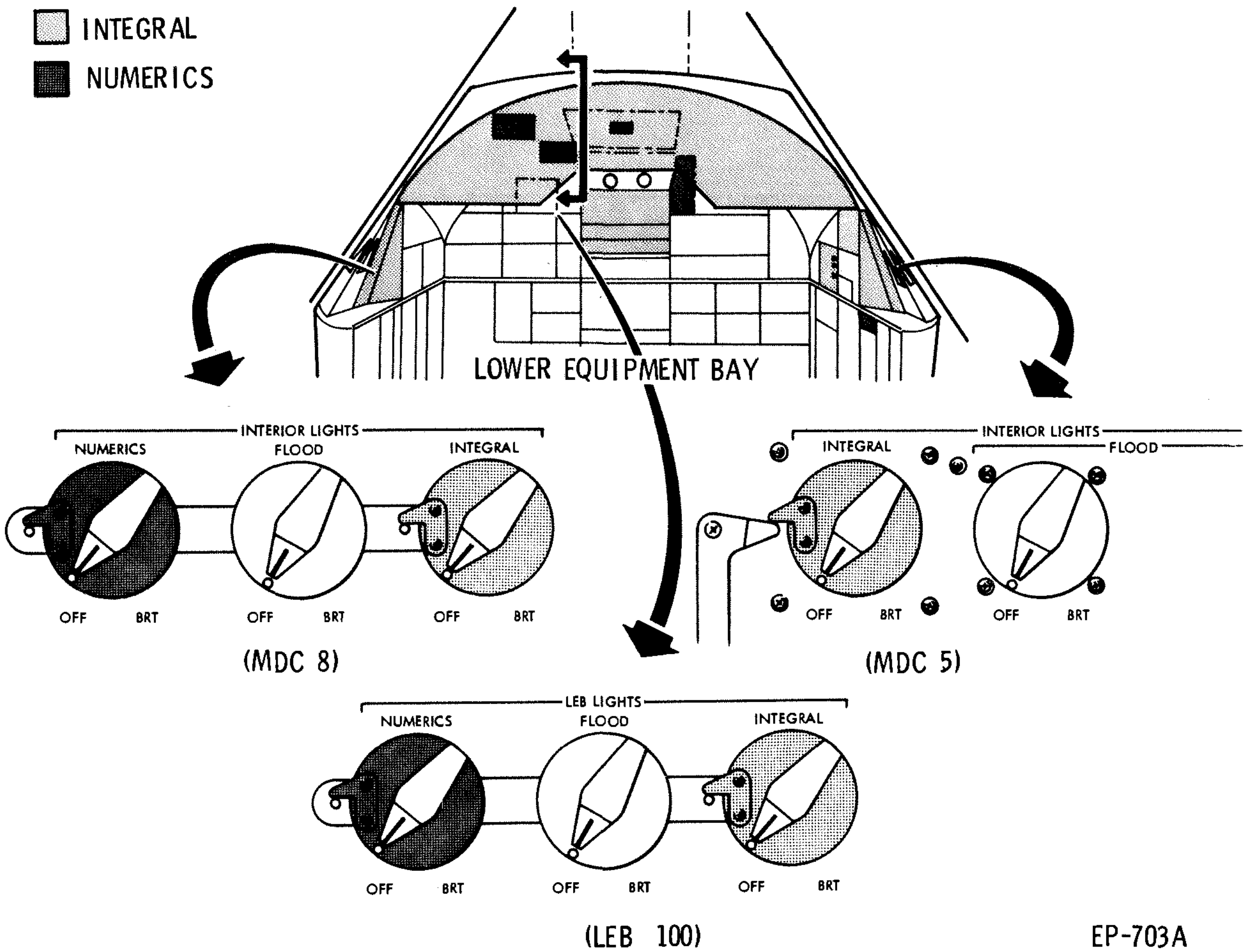


Figure 2.6-18. CM Integral/Numerics Illumination System

2.6.7.4 Tunnel Lighting

The six light fixtures in the CM tunnel provide illumination for tunnel activity during docking and undocking. Each of the fixtures, containing two incandescent lamps, is provided 28 vdc through a TUNNEL-LIGHTS-OFF switch on panel 2 (figure 2.6-20). Main d-c bus A distributes power to one lamp in each fixture, and main d-c bus B to the other lamp. Protection is provided by the LIGHTING/COAS/TUNNEL/SPOT DOOR MNA and MNB circuit breakers on panel 226.

EPS

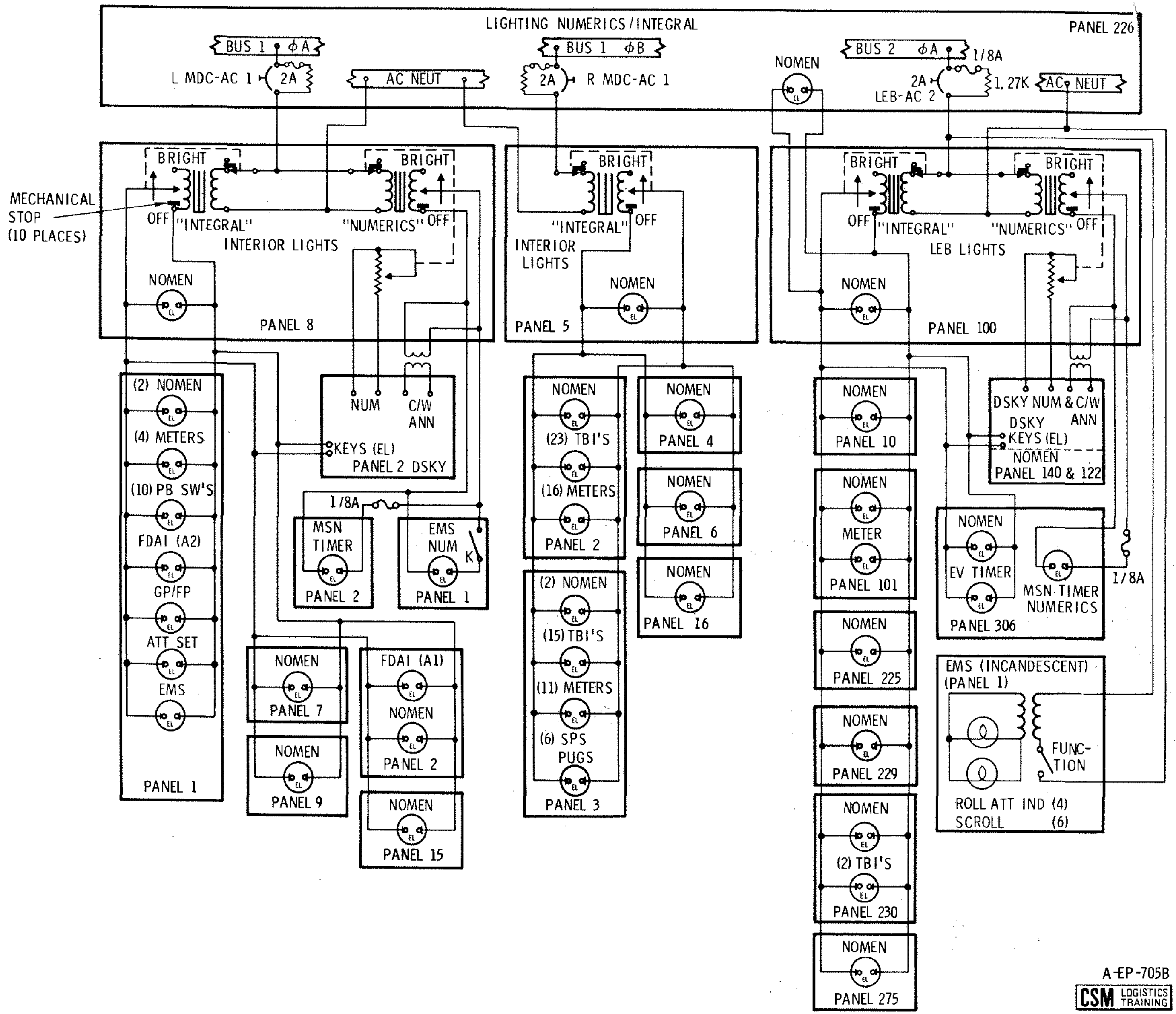


Figure 2.6-19. Integral and Numerics Panel Lighting Schematic

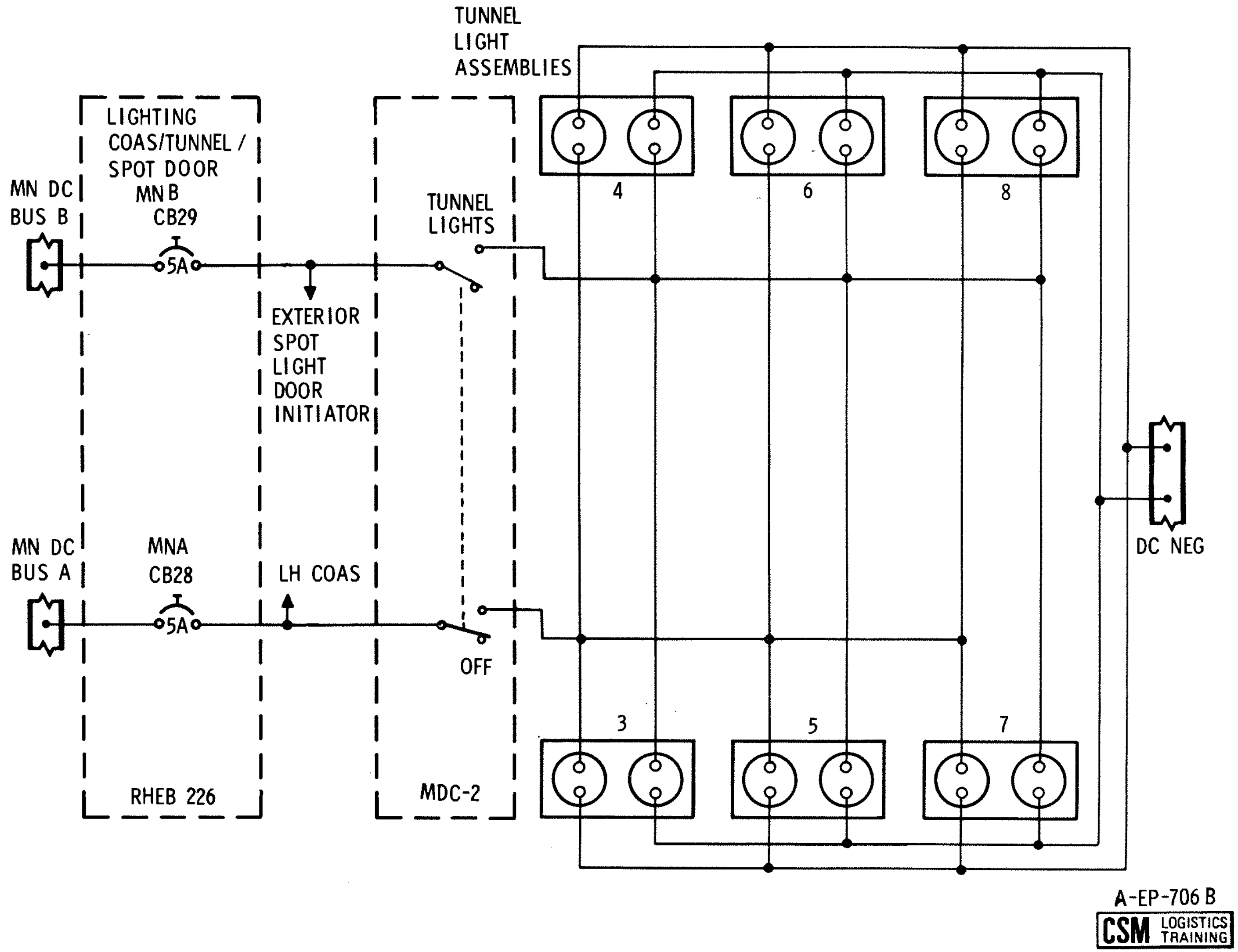


Figure 2.6-20. Tunnel Lighting Schematic

EPS

SECTION 2

SUBSECTION 2.7

ENVIRONMENTAL CONTROL SYSTEM (ECS)

2.7.1 INTRODUCTION

The environmental control system (ECS) is designed to provide the flight crew with a conditioned environment that is both life-supporting, and as comfortable as possible. The ECS is aided in the accomplishment of this task through an interface with the electrical power system, which supplies oxygen and potable water. The ECS also interfaces with the electronic equipment of the several CSM systems, for which the ECS provides thermal control, and with the waste management system to the extent that the water and the urine dump lines can be interconnected in case one of the dump nozzles becomes clogged.

The ECS is operated continuously during undocked mission phases, and with the exception of the primary glycol system, is shut down during docked operations. The functions of atmosphere control and water management are provided by the orbital assembly while docked. During undocked operations the system provides the crew with the following three major functions:

- Spacecraft atmosphere control
- Water management
- Thermal control.

Control of the spacecraft atmosphere consists of regulating the pressure and temperature of the cabin and suit gases; maintaining the desired humidity by removing excess water from the suit and cabin gases; controlling the level of contamination of the gases by removing CO_2, odors, and particulate matter; and ventilating the cabin after landing.

Water management consists of collecting, sterilizing, and storing the potable water produced in the fuel cells, and delivering chilled and heated water to the crew for metabolic consumption, and disposing of the excess potable water by either transferring it to the waste water system, storing it in the SM water tank, or by dumping it overboard. Provisions are also made for the collection and storage of waste water (extracted in the process of controlling humidity), delivering it to the glycol evaporators for supplemental cooling, and dumping the excess waste water overboard.

Thermal control consists of removing the excess heat generated by the crew and the spacecraft equipment, transporting it to the cabin heat exchanger (if required), and rejecting the unwanted heat to space, either by radiation from the space radiators, or in the form of steam by boiling water in the glycol evaporators.

Five subsystems operating in conjunction with each other provide the required functions:

- O_2 subsystem
- Pressure suit circuit (PSC)
- Water subsystem
- Water-glycol subsystem
- Postlanding ventilation (PLV) subsystem.

The oxygen subsystem controls the flow of oxygen within the command module (CM); stores a reserve supply of oxygen for use during entry and emergencies; regulates the pressure of oxygen supplied to the subsystem and PSC components; controls cabin pressure in normal and emergency (high flow-rate) modes; controls pressure in the water tanks and glycol reservoir; provides for PSC purge via the DIRECT O_2 valve; and supplies oxygen at high flow rates for intravehicular activity, through an IVA station.

The pressure suit circuit provides the crew with a continuously conditioned atmosphere. It automatically controls suit gas circulation, pressure, and temperature; and removes debris, excess moisture, odors, and carbon dioxide from both the suit and cabin gases.

The water subsystem (potable section) collects and stores potable water; delivers hot and cold water to the crew for metabolic purposes; and augments the waste water supply for evaporative cooling. The waste water section collects and stores water extracted from the suit heat exchanger, and distributes it to the water inflow control valves of the evaporators, for evaporative cooling when required.

The water-glycol subsystem provides cooling for the PSC, the potable water chiller, and the spacecraft equipment; and heating or cooling for the cabin atmosphere.

The postlanding ventilation subsystem provides a means for circulating ambient air through the command module cabin after landing.

2.7.2 FUNCTIONAL DESCRIPTION

The environmental control system operation begins during preparation for launch and continues until docking operations are completed. The system is restarted approximately one day prior to separation from the workshop, and is operated through entry. The following paragraphs describe the operating modes and the operational characteristics of the ECS from the time of crew insertion to recovery. (Refer to figure 2.7-1 for the following descriptions.)

2.7.2.1 Spacecraft Atmosphere Control

During prelaunch operations the SUIT CIRCUIT RETURN VALVE is closed; and the DIRECT O_2 valve is opened slightly (approximately 0.2 pound per hour flow rate) to provide an oxygen purge of the PSC.

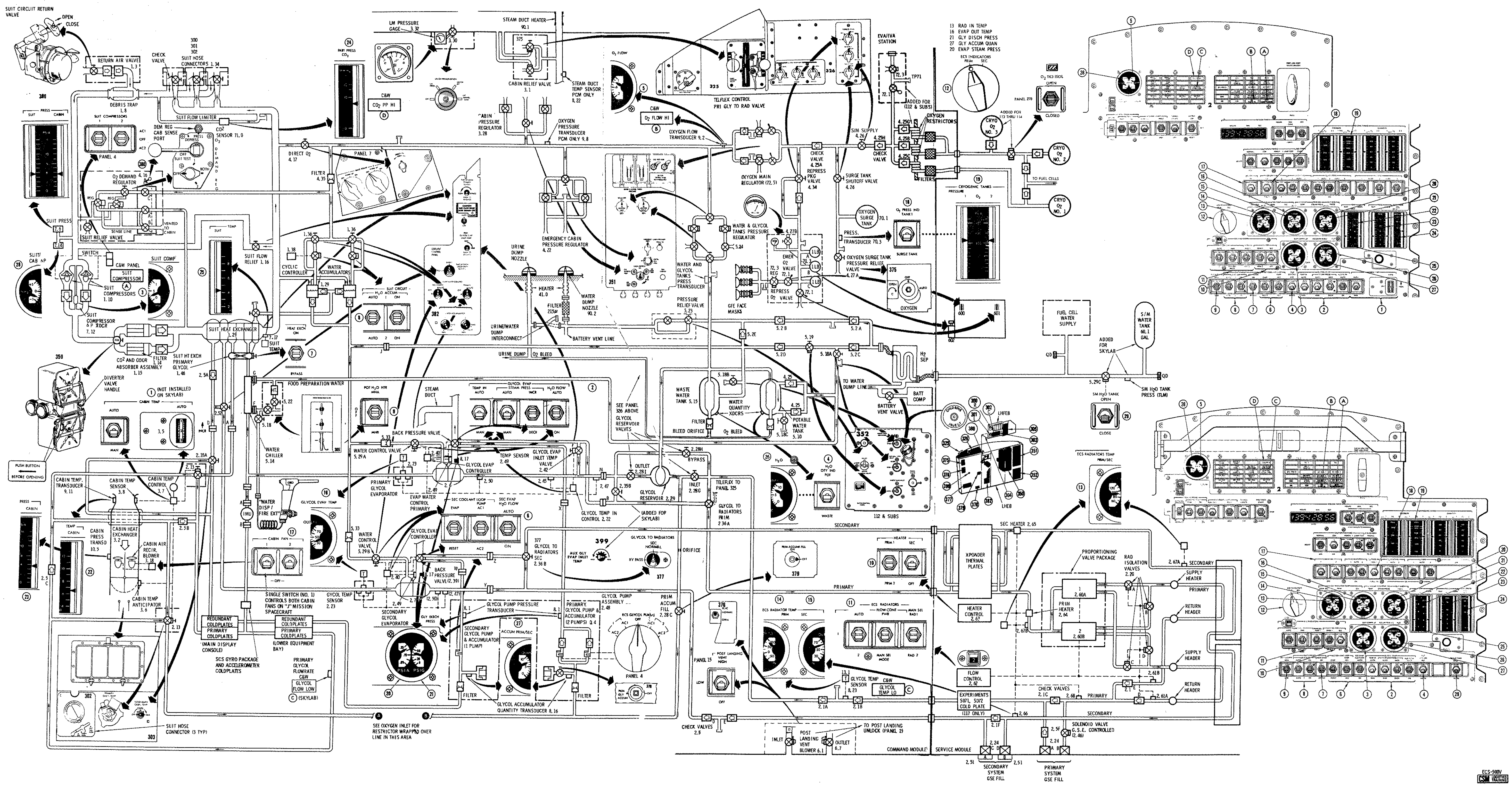


Figure 2.7-1. Environmental Control System Schematic

ECS

Prior to prime crew insertion, the O_2 flowrate is increased to 0.6 pound per hour. This flow is in excess of that required for metabolic consumption and suit leakage, results in the PSC being pressurized slightly above the CM cabin. The slight overpressure prevents the cabin gases from entering the PSC.

Any changes made in the pressure or composition of the cabin gas during the prelaunch period are controlled by the ground support equipment through the purge port in the CM side hatch.

As soon as the crew connects into the PSC, the suit gas becomes contaminated by CO_2, odors, moisture, and is heated. The gases are circulated by the suit compressor through the CO_2 and odor absorber assembly where a portion of the CO_2 and odors is removed; then through the heat exchanger, where they are cooled and the excess moisture is removed. Any debris that might get into the PSC is trapped by the debris trap or on felt pads on the upstream side of each filter cartridge.

When the crew is partially suited or in a shirtsleeve environment, they contaminate the cabin gases. Since the contaminants can only be removed in the PSC, the crew must necessarily configure the PSC to allow for an adequate flow of gas out of the PSC into the cabin and back into the PSC through the suit return hoses and the SUIT CIRCUIT RETURN VALVE in order to provide the required scrubbing. This can be accomplished for the "partially suited" mode by disconnecting and installing cap screens on the return hoses and opening the SUIT CIRCUIT RETURN VALVE. For the shirtsleeve mode, it can be accomplished by disconnecting the inlet hoses and placing the flow control valve in the CABIN FLOW position in addition to the preceding steps.

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During the ascent, the cabin remains at sea level pressure until the ambient pressure decreases a nominal 6 psi. At that point the CABIN PRESSURE RELIEF valve vents the excess gas overboard, maintaining cabin pressure at 6 psi above ambient. As the cabin pressure decreases, a relief valve in the O_2 DEMAND REGULATOR vents excess suit gases into the cabin to maintain the suit pressure slightly above cabin pressure.

Sometime after attaining orbit, it will be necessary to close the DIRECT O_2 valve to conserve oxygen. After the DIRECT O_2 valve is closed, make-up oxygen for the PSC is supplied by the DEMAND REGULATOR when the SUIT CIRCUIT RETURN VALVE is closed or from the cabin via the cabin pressure regulator when the SUIT CIRCUIT RETURN VALVE is open.

During undocked operations, the cabin pressure is maintained at a nominal 5 psia by the cabin pressure regulator, at flow rates up to 1.3 pounds of oxygen per hour. In the event a high leak rate develops, the EMERGENCY CABIN PRESSURE regulator will supply oxygen at high flow rates to maintain the cabin pressure above 3.5 psia for more than 5 minutes, providing the leak is effectively no larger than a 1/2-inch hole.

During docked operations, spacecraft atmosphere control is provided by equipment in the orbital assembly (OA). The CM oxygen main regulators are shut off to prevent the cabin pressure regulator from interacting with the OA pressure regulating system. Provision is made for venting oxygen into the CM cabin from the cryogenic storage tanks after the electrical power system fuel cells have been shut down.

A gas interchange duct is installed in the CM tunnel to provide circulation of filtered gas from the MDA to the CM cabin. The return flow of gases from the cabin to the MDA is through the CM tunnel. Temperature control of the spacecraft atmosphere during the docked mode is passive.

When depressurized operations are performed, the suit circuit pressure is maintained above 3.5 psia by the O_2 DEMAND REGULATOR; the cabin pressure regulator shuts off automatically to prevent wasting oxygen.

If the crew is to be suited during entry, the SUIT CIRCUIT RETURN VALVE is closed, isolating the suit circuit from the cabin; the O_2 DEMAND REGULATOR then controls suit pressure. Cabin pressure is maintained during the descent by the cabin pressure regulator until the ambient pressure rises to a maximum of 0.9 psi above cabin pressure. At that point the cabin relief valve will open, allowing ambient air to flow into the cabin. As the cabin pressure increases, the O_2 DEMAND REGULATOR admits oxygen into the suit circuit to maintain the suit pressure slightly below the cabin, as measured at the suit compressor inlet manifold.

After landing, when the CM is floating upright in the water, the cabin can be ventilated with ambient air by means of the postlanding vent system.

2.7.2.2 Water Management

In preparing the spacecraft for the mission, the potable and waste water tanks are partially filled to ensure an adequate supply for the early stages of the mission. In the process of generating electrical power, the fuel cells also produce potable water. This water is pumped into the potable water tank. Bacterial control is provided by chlorine and buffer injection. A portion of the water is chilled and made available to the crew through the drinking fixture and the food preparation unit. The remainder is heated, and is delivered through a separate valve on the food preparation unit during pre-docked operations. After the oxygen MAIN REGULATORS have been closed, the CABIN REPRESS valve is opened to create a flow path between the cabin and the water tanks which will prevent bladder pressure from decreasing below approximately 5 psia. Water is no longer available for consumption or as an evaporant until the tanks are repressurized. While docked, water for drinking and food preparation is available in the workshop. Water for metabolic consumption during the post-docked period, through entry, is stored in the return water containers.

From the time the crew connects into the suit circuit, and during all undocked operations, the water accumulator pumps are extracting water from the suit heat exchanger and pumping it into the waste water tank. This water is delivered to the glycol evaporators when supplemental cooling is required.

2.7.2.3 Thermal Control

Thermal control is provided by two water-glycol coolant loops (primary and secondary). During prelaunch operations, ground servicing equipment cools the water-glycol and pumps it through the primary loop, providing cooling for the electrical and electronic equipment, and the suit and cabin heat exchangers. The cold water-glycol is also circulated through the reservoir to make available a larger quantity of coolant for use as a heat sink during the ascent. Additional heat sink capability is obtained by selecting maximum cooling on the CABIN TEMP selector, and placing both cabin fans in operation. This cold soaks the CM interior structure and equipment. Shortly before launch, one of the primary pumps is placed in operation, the pump in the ground servicing unit is stopped, and the unit is isolated from the spacecraft system.

During the ascent the radiators will be heated by aerodynamic friction. To prevent this heat from being added to the CM thermal load, the PRIMARY GLYCOL TO RADIATORS valve is placed in the PULL TO BYPASS position at approximately 135 seconds before launch. The coolant then circulates within the CM portion of the loop.

The heat that is generated in the CM, from the time that the ground servicing unit is isolated until the spacecraft reaches 110K feet, is absorbed by the coolant and the prechilled structure. Above 110K feet it is possible to reject the excess heat by evaporating water in the primary glycol evaporator.

After attaining orbit the reservoir is isolated from the loop to maintain a reserve quantity of coolant for refilling the primary loop in case of loss of fluid by leakage. The PRIMARY GLYCOL TO RADIATORS valve is placed in the position (control pushed in) to allow circulation through the radiators and the radiator outlet temperature sensors. If the radiators have cooled sufficiently (radiator outlet temperature is less than the inlet) they will be kept on-stream; if not, they will be bypassed until sufficient cooling has taken place. After the radiators have been placed on-stream, the glycol temperature control is activated (GLYCOL EVAP TEMP IN switch in AUTO); and the CABIN TEMP selector valve is positioned as desired.

After docking has been completed, the primary glycol system is configured for single radiator panel operation. The isolation valves for the radiator panel facing the sun are closed. This action also removes power from the radiator flow proportioning system, which results in the total flow being routed to the "dark-side" radiator panel.

The primary and secondary glycol evaporators are dried out to minimize the growth of bacteria in the evaporator wicking material during the docked mode. Prior to undocking, both evaporators are re-serviced with water and configured to provide supplemental cooling when required.

The primary loop provides thermal control for CSM systems throughout the mission unless a degradation of system performance requires the use of the secondary loop, which would then be operated in the evaporative mode only.

Several hours before CM-SM separation the system valves are positioned so that the primary loop provides cooling for the cabin heat exchanger, the entire coldplate network, and the suit heat exchanger. The CABIN TEMP control valve is placed in the MAX COOL position, and both cabin fans are turned on to cold-soak in the CM interior structure.

Prior to separation the PRIMARY GLYCOL TO RADIATORS, and the GLYCOL TO RADIATORS SEC valves are placed in the BYPASS position to prevent loss of coolant when the CSM umbilical is cut. From that time (until approximately 110K feet spacecraft altitude) cooling is provided by water evaporation.

2.7.3 OXYGEN SUBSYSTEM

The ECS shares the oxygen supply with the electrical power system. Approximately 640 pounds of oxygen are stored in two cryogenic tanks located in the service module. Heaters within the tanks pressurize the oxygen to 900 psig for distribution to the using equipment. Oxygen is delivered to the CM through two separate supply lines. The line from the No. 1 cryo O_2 tank is connected to a single inlet restrictor assembly. The line from the No. 2 cryo O_2 tank branches into two lines, each of which is connected to an inlet restrictor assembly. Each assembly contains a filter, a capillary line, and a spring-loaded check valve. The filters provide final filtration of gas entering the CM. The capillaries which are wound around the hot glycol line, serve two purposes; they restrict the total O_2 flow rate to 12.0 pounds per hour maximum, and they heat the oxygen entering the CM. The check valves serve to isolate the two cryo O_2 tanks, and to prevent loss of oxygen after CSM separation. Downstream of the check valves the three lines are connected together, forming an oxygen supply manifold.

One outlet line from the manifold is connected to the IVA STATION inlet port (panel 603).

The IVA STATION (figure 2.7-2), panel 603, contains the O_2 SUPPLY valve, a pressure regulator (900 psi to 100+5 psi), and the following connectors: UMB O_2 (TP72), UMB ELEC (P1), CCU (j1), CRYO VENT VALVE (TP71), and an electrical connector (J2) on the underside of the panel. During IVA operations, the cable from panel 604 is connected to J2 to supply 28 vdc power to the UMB ELEC connector. The CCU (crewman communication umbilical) for the IVA crewman is mated with the CCU connector on panel 603. (This connects the IVA crewman's communications panel to the UMB ELEC connector.) The IVA umbilical is connected between the crewman's suit and the UMB O_2 and the UMB ELEC connectors. The O_2 supply valve is placed in the ON position and the switch on panel 604 is turned to ON. The IVA crewman now receives oxygen from the UMB O_2 connector, and is connected to the communications, bioinstrumentation, and electrical power systems through the UMB ELEC connector. A pressure gauge is connected to TP71 to provide a means for monitoring the input pressure to the oxygen regulator.

At some time during docked operations it will be necessary to relieve the excess pressure that will develop in the cryogenic oxygen storage tanks. To accomplish this the excess oxygen is vented either into the CM cabin or overboard. Oxygen is vented into the cabin by one of two methods, either

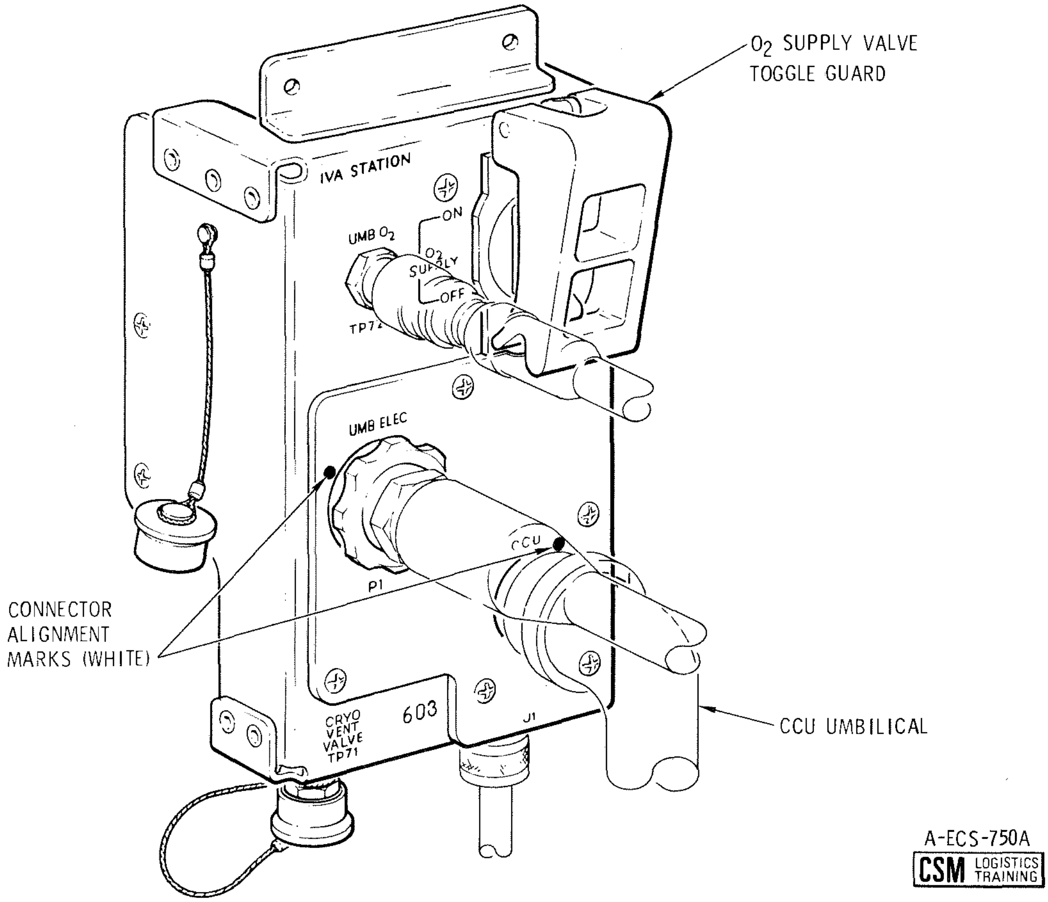

Figure 2.7-2. IVA Station

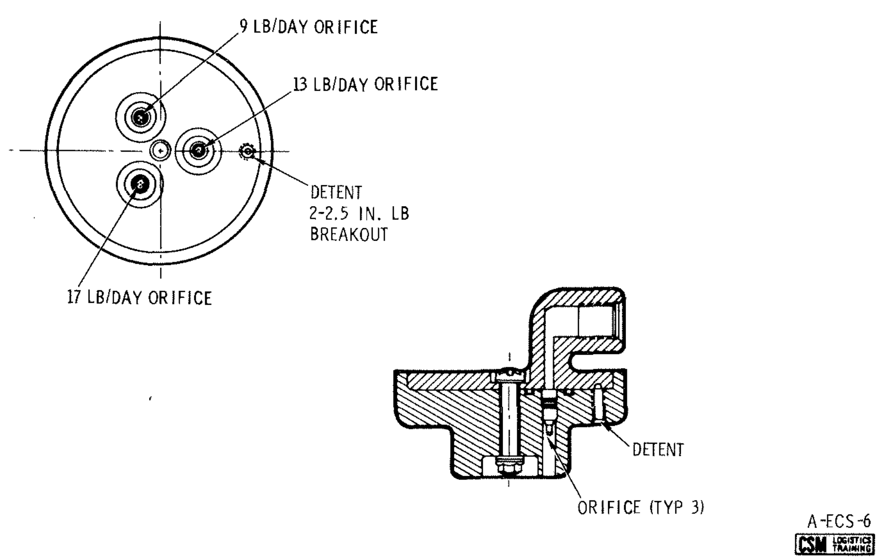

Figure 2.7-2A. Polychoke Assembly

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through the polychoke (figure 2.7-2A) or through the cryo vent valve (figure 2.7-3). The polychoke assembly consists of three selectable orifices (flowrates of 9 pounds, 13 pounds, 17 pounds per day), and a quick-disconnect fitting. The polychoke is installed on the UMB O_2 connector in the 13-pound-per-day setting, and the O_2 cryo vent valve is installed on panel 603 at TP71, and the O_2 cryo vent hose (figure 2.7-4) is installed between the vent valve and the nonpropulsive dump nozzle in the side hatch. The O_2 SUPPLY valve is turned to ON and oxygen is permitted to flow at the 13-pound-per-day rate as long as the oxygen flow through the MDA pressure regulator is less than 4 pounds per day, but greater than zero flow. If the MDA flowrate is greater than 4 pounds per day, increase the polychoke setting; if zero and the oxygen partial pressure is increasing, reduce the polychoke setting. If the cryo O_2 storage tanks pressure rises above 900 psi, during venting operations, the excess oxygen will be vented overboard. When the cryo O_2 storage tanks pressure drops to 850 psi, reduce the polychoke setting. When the lowest setting has been reached and the cryogenic tanks pressure is less than 850 psi, remove the polychoke assembly and the O_2 cryo vent hose. Allow the O_2 cryo vent valve to relieve oxygen into the cabin until the O_2 cryo storage tanks temperature stabilizes at approximately 0°F; then remove the valve.

The other line from the manifold is routed to a spring-loaded check valve, and then to the OXYGEN S/M SUPPLY valve (panel 326). The check valve prevents loss of oxygen from the surge tank and repress package tanks, in the event of a failure of the equipment or plumbing upstream of the check valve. The S/M SUPPLY valve is normally open throughout the mission; it is closed prior to CSM separation, to back up the check valves in preventing loss of oxygen.

The outlet of the S/M SUPPLY valve is connected in parallel to the OXYGEN-SURGE TANK valve (panel 326) and to a check valve on the OXYGEN CONTROL PANEL (panel 351). The SURGE TANK valve is normally open during flight, and is closed only when it is necessary to isolate the surge tank from the system. The surge tank stores approximately 3.7 pounds of oxygen at 900 psig for use during entry, and for augmenting the SM supply when the operational demand exceeds the flow capacity of the inlet restrictors. The OXYGEN SURGE TANK PRESSURE RELIEF and shutoff valve on panel 375 prevents overpressurization of the surge tank, and provides a means for shutting off the flow in case of relief valve failure. The relief valve operates at 1045 ± 25 psid. A pressure transducer puts out a signal proportional to surge tank pressure, for telemetry and for display to the crew. This signal shares the indicator used for displaying O_2 CRYOGENIC TANK #1 PRESSURE. The signal source is selected by the O_2 PRESS IND switch, which is located beneath the indicator on panel 2. The outlet of the check valve (on the OXYGEN CONTROL PANEL) is connected to both the OXYGEN-REPRESS PKG valve on panel 326, and the MAIN REGULATOR on panel 351.

The REPRESS PKG valve is used for controlling the flow of oxygen to and from the cabin repressurization package. The package consists of three 1-pound capacity oxygen tanks connected in parallel; a toggle-type fast acting REPRESS O_2 valve on panel 601 for dumping oxygen into the cabin at very high flowrates; a toggle valve and regulator on panel 600 for supplying oxygen to the emergency O_2 face masks; a relief and shut-off valve on panel 602 to protect the package against overpressurization; and a direct-reading pressure gauge on panel 602 for monitoring package and pressure when the REPRESS PKG valve is closed. (More accurate pressure indication can be had by placing the REPRESS PKG valve in the FILL position and monitoring SURGE TANK pressure.) Opening the REPRESS O_2 valve, with the REPRESS PKG valve in the FILL

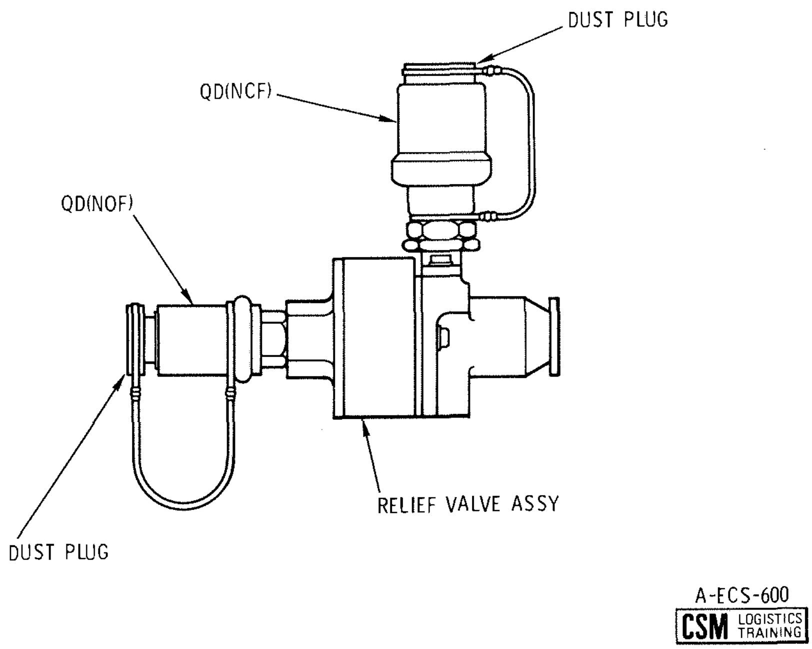

Figure 2.7-3. CSM O_2 Cryo Vent Valve

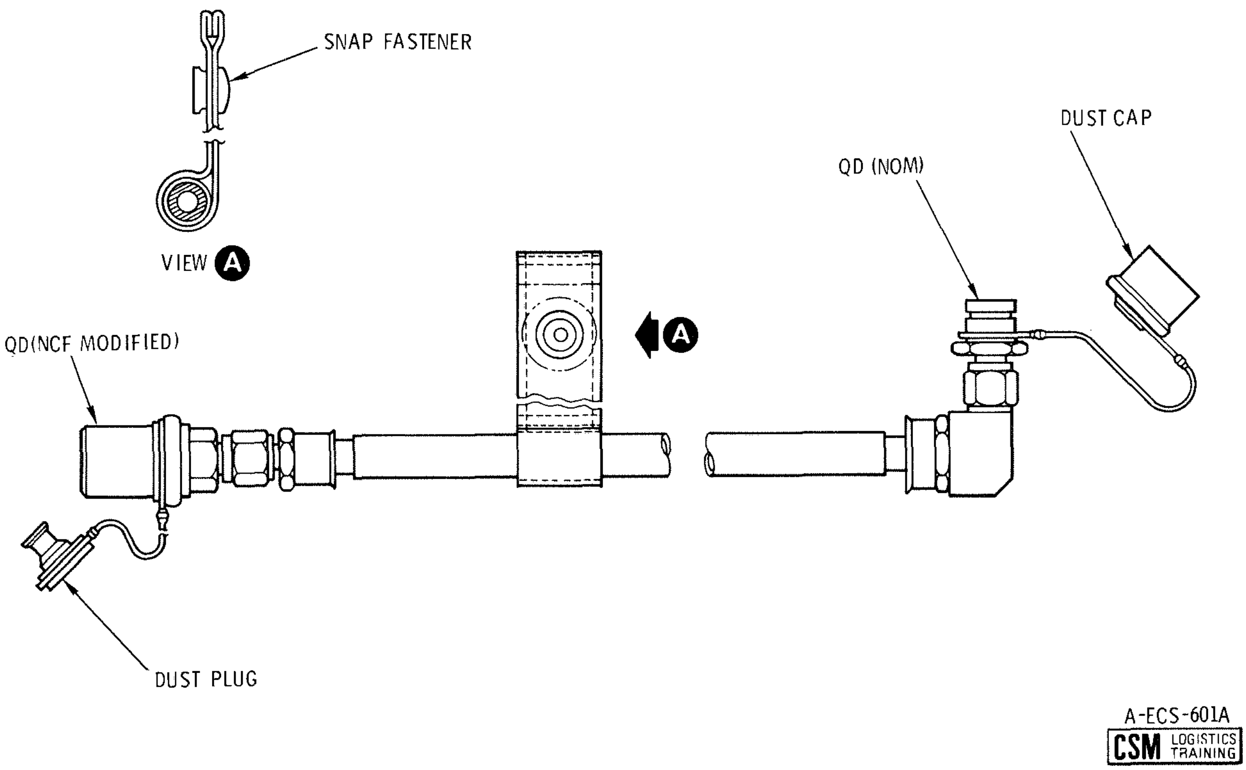

Figure 2.7-4. CSM O_2 Cryo Vent Hose

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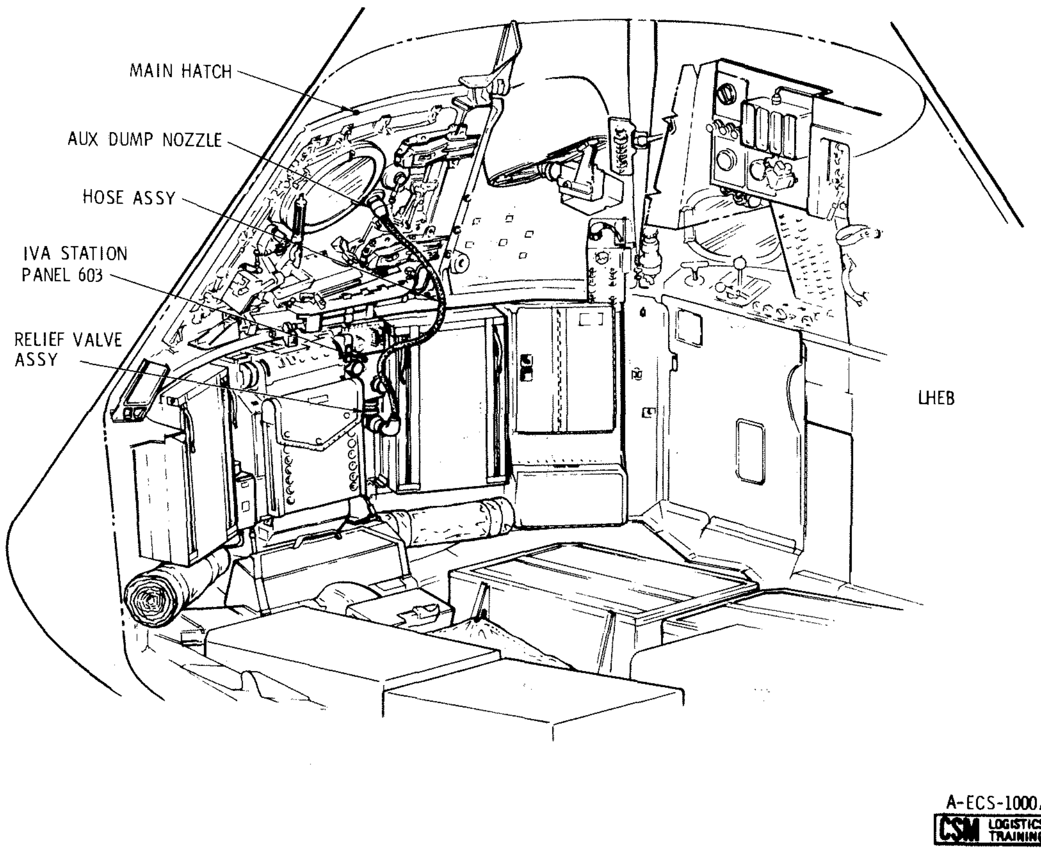

Figure 2.7-5. CSM O_2 Cryo Vent (overboard)

position, will dump both the package tanks and the surge tanks at a rate that will pressurize the command module from 0 to 3 psia in 1 minute. When the REPRESS PKG valve is in the ON position, the package tanks augment the surge tank supply for entry and emergencies. The package tanks are filled by placing the REPRESS PKG valve to the FILL position, the O_2 PRESS IND switch (panel 2) to the SURGE TANK position, and monitoring surge tank pressure on the CRYOGENIC TANKS PRESSURE O_2 1 indicator. When the indicator reads 900±35 psi, both the surge tank and package tanks are full.

The MAIN REGULATOR reduces the supply pressure to 85-110 psig for use by the subsystem components. The regulator assembly is a dual unit which is normally operated in parallel. Two toggle valves at the inlet to the assembly provide a means of isolating either of the units in case of failure, or for shutting them both off. Integral relief valves limit the downstream pressure to 140 psig maximum. The output of the MAIN REGULATOR passes through a flowmeter, then is delivered to the WATER & GLYCOL TANKS PRESSURE regulator, the cabin pressure regulator, EMERGENCY CABIN PRESSURE regulator (all on panel 351), the O_2 DEMAND REGULATOR (panel 380), the DIRECT O_2 valve (panel 7), and the WATER ACCUMULATOR valves (panel 382). Oxygen flow to these components is blocked during docked operations.

The output of the flowmeter is displayed on the O_2 FLOW indicator (panel 2), which has a range of 0.2 to 1.0 pound per hour. Nominal flow for metabolic consumption and cabin leakage is approximately 0.43 pound per hour. Flow rates of 1 pound per hour or more with a duration of 16.5±1.5 seconds will illuminate the O_2 FLOW HI light on the caution and warning panel (panel 2). The warning is intended to alert the crew to the fact that the oxygen flow rate is greater than is normally required. It does not necessarily mean that a malfunction has occurred, since there are a number of flight operations in which a high-oxygen flow rate is normal. These cases will be noted, when applicable, in the descriptions that follow. A pressure transducer at the outlet of the MAIN REGULATOR provides data for telemetry only.

The WATER & GLYCOL TANKS PRESSURE regulator assembly (panel 351) is a dual unit, normally operating in parallel, which reduces the 100-psi oxygen to 20±2 psig (relative to cabin) for pressurizing the positive expulsion bladders in the waste and potable water tanks, and in the glycol reservoir. Integral relief valves limit the downstream pressure to 25±2 psi above cabin pressure. INLET and OUTLET SELECTOR valves are provided for selecting either or both regulators and relief valves, or for shutting the unit off. When changing the position of the selector valves for the purpose of isolating a malfunctioning unit, it is necessary to place both selector valves in the same position in order to eliminate the possibility of cross-feeding oxygen through the outlet selector valve if it is left in the normal position. If a cross-selection is made (inlet selector to 1; outlet selector to 2, or vice versa), flow through the assembly is blocked.

The cabin pressure regulator controls the flow of oxygen into the cabin to make up for depletion of the gas because of metabolic consumption, normal leakage, or for repressurization. The assembly consists of two absolute pressure regulators operating in parallel, and a manually operated CABIN REPRESS valve. The regulator is designed to maintain cabin pressure at 5±0.2 psia at flow rates up to 1.4 pounds per hour (O_2 FLOW HI light on). Losses in excess of this value will result in a continual decrease in cabin pressure. When cabin pressure falls to 3.5 psia minimum, the regulator will automatically shut off to prevent wasting the oxygen supply. Following depressurization, the cabin can be repressurized by manually opening the CABIN REPRESS valve. The CABIN REPRESS valve will flow a minimum of 6 pounds per hour. The O_2 FLOW HI light will be on.

The EMERGENCY CABIN PRESSURE regulator provides emergency protection for the crew in the event of a severe leak in the cabin. The assembly consists of two absolute pressure regulators, either of which can handle the maximum flow rate, and a selector valve for selecting either or both of the regulators, or for shutting the unit off. The regulator valve starts to open when cabin pressure decreases to 4.6 psia; and at 4.2 psia the valve is full-open, flooding the cabin with oxygen. The regulator can supply oxygen to the cabin at a flow rate of 0.67 pound per minute minimum (O_2 FLOW HI light on), to prevent

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rapid decompression in case of cabin puncture. The regulator is capable of providing flow rates which will maintain cabin pressure above 3.5 psia for a period of 5 minutes, against a leakage rate equivalent to 1/2-inch-diameter cabin puncture. The regulator is normally used during shirtsleeve operations, and is intended to provide time for donning pressure suits before cabin pressure drops below 3.5 psia. During pressure suit operations, the regulator is shut off to prevent unnecessary loss of oxygen in case of unplanned cabin depressurization.

The O_2 DEMAND REGULATOR supplies oxygen to the suit circuit whenever the suit circuit is isolated from the cabin (return air SHUTOFF VALVE closed), and during depressurized operations. It also relieves excess gas to prevent overpressurizing the suits. The assembly contains redundant regulators; a single relief valve for venting excess suit pressure; an inlet selector valve for selecting either or both regulators; and a SUIT TEST valve for performing suit integrity tests.

Each regulator section consists of an aneroid control, and a differential diaphragm housed in a reference chamber. The diaphragm pushes against a rod connected to the demand valve; the demand valve will be opened whenever a pressure differential is sensed across the diaphragm. In operation, there is a constant bleed flow of oxygen from the supply into the reference chamber, around the aneroid, and out through the control port into the cabin. As long as the cabin pressure is greater than 3.75 psia (nominal), the flow of oxygen through the control port is virtually unrestricted, so that the pressure within the reference chamber is essentially that of the cabin. This pressure acts on the upper side of the diaphragm, while suit pressure is applied to the underside of the diaphragm through the suit sense port. The diaphragm can be made to open the demand valve by either increasing the reference chamber pressure, or by decreasing the sensed suit pressure.

The increased pressure mode occurs during depressurized operations. As the cabin pressure decreases, the aneroid expands. At 3.7 psia the aneroid will have expanded sufficiently to restrict the outflow of oxygen through the control port, thus increasing the reference chamber pressure. When the pressure rises approximately 3-inch H_2O pressure above the sensed suit pressure, the demand valve will be opened.

Decreased pressure mode occurs whenever the suit circuit is isolated from the cabin, and cabin pressure is above 5 psia. In the process of respiration, the crew will exhale carbon dioxide and water vapor. In circulating the suit gases through the CO_2 and odor absorber, and the suit heat exchanger, the CO_2 and water are removed. The removal reduces the pressure in the suit circuit, which is sensed by the regulator on the underside of the diaphragm. When the pressure drops approximately 3-inch H_2O pressure below cabin, the diaphragm will open the demand valve.

The regulator assembly contains a poppet-type relief valve which is integral with the suit pressure sense port. During operations where the cabin pressure is above 3.75 psia, the relief valve is loaded by a coil spring which allows excess suit gas to be vented whenever suit pressure rises to 2- to 9-inch H_2O above cabin pressure. When the cabin pressure decreases to 3.75 psia, the reference chamber pressure is increased by the throttling effect of the expanding aneroid. The reference chamber pressure is applied, through ducts, to two relief valve loading chambers which are arranged in tandem above the relief valve poppet. The pressure in the loading chambers acts on tandem diaphragms which are forced against the relief valve poppet. The relief value of the valve is thus increased to 3.75 psia plus 2- to 9-inch H_2O.

The SUIT TEST valve provides a means for pressurizing and depressurizing the suit circuit, at controlled rates, for performing suit integrity tests. Placing the SUIT TEST valve in the PRESS position supplies oxygen through a restrictor to pressurize the suit circuit to a nominal 4 psi above cabin, in not less than 75 seconds. The maximum time required for pressurizing or depressurizing the suits depends upon the density of the suit and cabin gases at the time the test is performed. It will take a longer time to perform the pressurizing or depressurizing during prelaunch than in orbit because of the higher density of the gas at sea level pressure. Placing the SUIT TEST valve in the DEPRESS position will depressurize the suits in not less than 75 seconds. Moving the SUIT TEST valve from the PRESS position to OFF will dump the suit pressure immediately. Also, if any one of the three suits is vented to cabin, while the SUIT TEST valve is in the PRESS position, all three suits will collapse immediately. This is due to the restrictor in the pressurizing port, which prevents the O_2 DEMAND REGULATOR from supplying the high oxygen flow rate required for maintaining the pressure in the other two suits.

The DIRECT O_2 valve on panel 7 is a screw-actuated poppet valve capable of metering oxygen into the suit circuit of flow rates from 0 to 0.67 pound per minute (at 85 psig inlet pressure). The control end of the poppet valve is connected to a bellows assembly, which provides both the internal seal and the force required for closing the valve. When the knob is rotated counterclockwise, the screw mechanism moves inward contacting a follower on the bellows assembly forcing the poppet valve off its seat, thus opening the valve. When the knob is rotated clockwise the screw moves outward allowing the bellows assembly to close the valve. Because there is no mechanical connection between the screw and the bellows assembly, the valve will actually be closed before the screw mechanism has been rotated to the extreme clockwise position. Under average operating conditions, it will require approximately 30-degree rotation counterclockwise from the extreme clockwise position to crack the valve open.

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2.7.4 PRESSURE SUIT CIRCUIT

The pressure suit circuit (PSC) is a circulating gas loop which provides the crew with a continuously conditioned atmosphere throughout the mission. The gas is circulated through the PSC by two centrifugal compressors, which are controlled by individual switches on panel 4. Normally only one of the compressors is operated at a time; however, the individual switches provide a means for connecting either or both of the compressors to either a-c bus.

A differential pressure transducer connected between the compressor inlet and outlet manifolds provides a signal to the SUIT COMPR ΔP indicator (panel 2); to telemetry; and to the caution and warning system, which will illuminate the SUIT COMPRESSOR light at a ΔP of 0.22 psig or less. Another differential pressure transducer connected between the compressor inlet manifold and the cabin, provides a signal to the SUIT-CAB ΔP indicator (panel 2); and to telemetry. An absolute pressure transducer connected to the compressor inlet manifold provides a signal to the PRESS SUIT indicator (panel 2); and to telemetry.

The gas leaving the compressor flows through the CO_2 and odor absorber assembly. The assembly is a dual unit containing two absorber elements in separate compartments with inlet and outlet manifolds common to both. A diverter valve in the inlet manifold provides a means of isolating one compartment or the other (without interrupting the gas flow) for the purpose of replacing a spent absorber. An interlock mechanism between the diverter valve handle and the cover handles is intended to prevent opening both compartments at the same time. A pressure interlock device on each canister cover extends a pin into a slot in the cover handle whenever the internal pressure is one psi above cabin pressure. A manual bleed valve on each canister cover provides a means of bleeding down the canister pressure so the cover can be opened in a depressurized cabin. The absorber elements contain lithium hydroxide and activated charcoal for removing carbon dioxide and odors from the suit gases. Orlon pads on the inlet and outlet sides trap small particles and prevent absorbent materials from entering the gas stream.

From the filter the gas flows through the suit heat exchanger where the gases are cooled and the excess moisture is removed. The heat exchanger assembly is made up of two sets of broad flat tubes through which the coolant from the primary and secondary loops can be circulated. The coolant flow/bypass is controlled by two valves located on the coolant control panel (382). The SUIT HT EXCH PRIMARY GLYCOL valve is a motor-driven valve with manual override; the motor is controlled by the SUIT CIRCUIT-HEAT EXCH switch on panel 2. The SUIT HT EXCH SECONDARY GLYCOL valve must be positioned manually. The space between the tubes forms passages through which the suit gases flow. The coolant flowing through the tubes absorbs some of the heat from the suit gases. As the gases are cooled to about 55°F, the excess moisture condenses out and is removed from the heat exchanger by one or both of a pair of water accumulator pumps.

The water accumulators are piston-type pumps, which are actuated by oxygen pressure (100 psi) on the discharge stroke, and by a return spring for the suction stroke. The oxygen flow is controlled by the two WATER ACCUMULATOR selector valve assemblies located on the coolant control panel 382. Each valve assembly contains a selector valve, a solenoid valve, and an integral bypass. When the selector valve is in the RMTE position, oxygen flow is controlled by the solenoid valve; when in the MAN position, the oxygen flows through the bypass directly to the pump. The solenoid valve can be controlled automatically by signals from the central timing equipment by placing the SUIT CIRCUIT-H_2O ACCUM switch (panel 2) in either AUTO 1 or AUTO 2. In the automatic mode the central timing equipment signal will cause one of the accumulators to complete a cycle every 10 minutes. If it becomes necessary to cycle the accumulators at more frequent intervals the solenoid valve can be controlled manually by placing the AUTO switch in the OFF position, and placing the adjacent H_2O ACCUM switch to the ON position for either No. 1 or 2 accumulator. When exercising manual control, either by means of the switch or the selector valve, it is necessary to hold that particular control on for 10 seconds then return it to the OFF position.

During docked operations, while the atmosphere is controlled by equipment in the OA, the suit circuit and water accumulator operations are stopped. Prior to undocking, the suit circuit and accumulator operation is resumed.

The cool gas (55°F nominal) flows from the heat exchanger through the suit flow limiters and the flow control valves, into the suits. The suit temperature is measured at the heat exchanger outlet, and is displayed on the SUIT TEMP indicator (panel 2) and telemetered.

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A suit flow limiter is installed in each suit supply duct to restrict the gas flow rate through any one suit. The flow limiter is a tube with a Venturi section, sized to limit flow to 0.7 pound per minute. The limiter offers maximum resistance to gas flow through a torn suit, when cabin pressure is near zero psia. the O_2 demand regulator will supply oxygen at a flow rate of 0.67 pound per minute minimum (for at least 5 minutes) to maintain pressure in the circuit while the torn suit is being repaired.

The flow control valves (panels 300, 301, 302) are part of the suit hose connector assembly. These valves provide a means for adjusting gas flow through each suit individually, and are fully modulating from OFF to the FULL FLOW position. When operating in a shirtsleeve environment with the inlet hose disconnected from the suit, placing the flow control valve in the CABIN FLOW position will allow approximately 12 cubic feet of suit gas per minute to flow into the cabin.

A suit flow relief valve is installed between the suit heat exchanger outlet and the compressor inlet, and is intended to maintain a relatively constant pressure at the inlets to the three suits by relieving transient pressure surges. The SUIT FLOW RELIEF valve control (panel 382) provides a means for manually closing the valve by placing the control in the OFF position. Placing the control in AUTO removes the restraint and allows the valve to operate as a relief valve. There is no provision for manually opening the valve. It is planned to place the control in the OFF position for the duration of the mission to ensure maximum flow through the SUIT CIRCUIT.

The gas leaving the suits flows through the debris trap assembly, into the suit compressor. The debris trap is a mechanical filter for screening out solid matter that might otherwise clog or damage the suit compressors. The trap consists of a stainless steel screen designed to block particles larger than 0.040 inch, and a bypass valve which will open at a differential pressure of 0.5 inch H_2O in the event the screen becomes clogged.

The SUIT CIRCUIT RETURN VALVE (panel 381) is installed on the debris trap upstream of the screen. The valve consists of two flapper-type check valves, and a manual shutoff valve, all in series. The manual valve provides a means for isolating the suit circuit from the cabin manually by means of a remote control located on panel 381. This is done to prevent inducting cabin gases into the suit circuit, in the event the cabin gases become contaminated.

The valve is located at the suit compressor inlet manifold, which is normally 1 to 2 inches of water pressure below cabin pressure. The differential pressure causes cabin gases to flow into the suit circuit when the manual valve is open. The reconditioned cabin gases are recirculated through the suits and/or cabin. During emergency operation, the check valve prevents gases from flowing into the depressurized cabin from the suit circuit.

A CO_2 sensor is connected between the suit inlet and return manifold. The output signal is delivered to the PART PRESS CO_2 indicator (panel 2); to telemetry; and to the caution and warning system. At a CO_2 partial pressure of 7.6 mm Hg, the CO_2 PP HI light on panel 2 will be illuminated.

2.7.5 WATER SUBSYSTEM

The water subsystem consists of two individual fluid management networks which control the collection storage, and distribution of potable and waste water. The potable water is used primarily for metabolic purposes. The waste water is used solely as the evaporant in the primary and secondary glycol evaporators. Although the two networks operate and are controlled independently, they are interconnected in a manner which allows potable water to flow into the waste system under certain conditions described below.

Potable water produced in the fuel cells is pumped into the CM at a flow rate of approximately 1.5 pounds per hour. The water flows through the hydrogen separator to a check valve on the WATER CONTROL PANEL (352) and to the inlet ports of the POTABLE TANK INLET and WASTE TANK INLET valves (panel 352). The hydrogen separator consists of a series of tubes (made of 25 percent silver and 75 percent palladium), encased in a can which is vented to space, through which the water flows. Hydrogen, in both the dissolved and free states, passes through the walls of the tubing into the can and flows overboard. The separator is installed in the right-hand equipment bay behind the waste management panel, and is connected into the system through flexible hoses and quick-disconnects, which are accessible through a door at the bottom of panel 252. The check valve at the inlet prevents loss of potable water after CM-SM separation.

The POTABLE TANK INLET is a manual shutoff valve used for preventing the flow of fuel cell water into the potable system in the event the fuel cell water becomes contaminated. The pH HI talkback (panel 3) shows a "barber pole" when the water pH factor exceeds a value of 9.

The WASTE TANK INLET is an in-line relief valve, with an integral shutoff valve. The relief valve allows potable water to flow into the waste water tank whenever the potable water pressure is 6 psi above waste water pressure. This pressure differential will occur when the fuel cells are pumping water, and either the potable water tank is full, or the POTABLE TANK INLET valve is closed; or when the waste water tank is completely empty and the glycol evaporators are demanding water for cooling. In the latter case, the water flow is only that quantity which is demanded. The shutoff valve provides a means of blocking flow in case the relief valve fails. If such a failure occurs, potable water can flow through the valve (provided the potable water pressure is higher than the waste), until the two pressures are equal. Reverse flow is prevented by a check valve downstream of the WASTE TANK INLET valve.

In the event that both water tanks are full at the time the fuel cells are pumping, the excess potable water will be dumped overboard through the PRESSURE RELIEF valve on panel 352. However, automatic dumping through the relief valve is not desirable because the pumps in both the potable and waste water systems discharge water intermittently, rather than in a steady stream. Dumping water through the relief valve in spurts results in some flash-freezing, which could result in a temporary blockage of the dump line. To preclude this the PRESSURE RELIEF valve has been modified by removing the poppet of one of the two relief valves, so that it can be used as a dump valve, to dump water in a steady stream. Prior to docking, the waste water tank quantity will be maintained below 75 percent by manually dumping the excess water. This means that normally an ullage will be maintained to receive the potable water, instead of dumping it overboard. After docking, the water produced by the fuel cells will be used to fill the potable tank to 100 percent and the waste tank to 75 percent. Water produced from this point until the fuel cells are shut down will be stored in the SM water tank.

Water flows from the control panel to the potable water tank, the FOOD PREPARATION WATER unit (panel 305), and the water chiller. Chilled water is delivered to the FOOD PREPARATION WATER unit, and to the drinking water dispenser through the DRINKING WATER SUPPLY valve (panel 304).

The water chiller cools and stores 0.5 pound of potable water for crew consumption. The water chiller is designed to supply 6 ounces of 50°F water every 24 minutes. The unit consists of an internally baffled reservoir containing a coiled tube assembly which is used as the coolant conduit. The baffles are used to prevent the incoming hot water from mixing with and raising the temperature of the previously chilled water.

The FOOD PREPARATION WATER unit heats potable water for use by the crew, and allows manual selection of hot or cold potable water. The cold potable water is supplied by the water chiller. The unit consists of an electrically heated water reservoir and two manually operated metering valves. The insulated reservoir has a capacity of 1.9 pounds of water. Thermostatically controlled heating elements in the reservoir heat the water and maintain it at 154°F nominal. The two metering valves dispense either hot or cold water, in 1-ounce increments, through a common nozzle. The hot water delivery rate is approximately 10 ounces every 30 minutes.

The DRINKING WATER SUPPLY valve on panel 304 provides a means for shutting off the flow of water to the drinking water dispenser (water pistol), in case of a leak in the flex hose.

After docking, the potable water is used only for the evaporators. Water for metabolic purposes is supplied by the workshop while docked, and from sterile containers in the CSM during the post-docked period through recovery.

The waste water and potable water is stored in positive expulsion tanks, which with the exception of capacity, are identical in function, operation, and design. The positive expulsion feature is obtained by an integrally supported bladder, installed longitudinally in the tank. Water collector channels, integral with the tank walls, prevent water from being trapped within the tank by the expanding bladder. Quantity transducers provide signals to the H_2O QUANTITY indicator on panel 2. The signal source is selected by the H_2O QTY IND switch located below and to the right of the indicator on panel 2.

Waste water extracted from the suit heat exchanger is pumped into the waste water tank, and is delivered to the EVAP WATER CONTROL-PRIMARY and -SECONDARY valves on panel 382. When the tank is full, excess waste water is dumped overboard through the water PRESSURE RELIEF valve. The EVAP WATER CONTROL valves consist of a manually operated inlet valve and a solenoid valve. When the inlet valves are in AUTO, the solenoid valves control water flow to the evaporators. The PRIMARY solenoid valve is controlled automatically when the GLYCOL EVAP-H_2O FLOW switch (panel 2) is in AUTO, and manually when the switch is ON. The SECONDARY solenoid valve is controlled automatically when the SEC EVAP H_2O FLOW switch is in AUTO and manually when the switch is ON.

2.7.6 WATER-GLYCOL COOLANT SUBSYSTEM

The water-glycol coolant subsystem consists of two independently operated closed coolant loops. The primary loop is operated continuously throughout the mission, unless damage to the equipment necessitates shutdown. The secondary loop is operated at the discretion of the crew, and provides a backup for the primary loop. Both loops provide cooling for the suit and cabin atmospheres, the electronic equipment, and a portion of the potable water supply. The primary loop also serves as a source of heat for the cabin atmosphere when required.

2.7.6.1 Coolant Flow

The coolant is circulated through the loops by pumping unit consisting of two pumps, a full-flow filter, and an accumulator for the primary loop; and a single pump, filter, and accumulator for the secondary loop. The purpose of the accumulators is to maintain a positive pressure at the pump inlets by accepting volumetric changes due to changes in coolant temperature. If the primary accumulator leaks, it can be isolated from the loop by means of the PRIM GLY

ACCUM valve (panel 378). Then the reservoir must be placed in the loop to act as an accumulator. Accumulator quantity is displayed on the ACCUM PRIM/SEC indicator on panel 2. (The signal source is selected by the ECS INDICATORS rotary switch on panel 2.) The primary pumps are controlled by the ECS GLYCOL PUMPS rotary switch on panel 4. The secondary pump is controlled by a three-position toggle switch SEC COOLANT LOOP-PUMP on panel 2, which allows the pump to be connected to either a-c bus.

The output of the primary pump flows through a passage in the evaporator steam pressure control valve to de-ice the valve throat. The coolant next flows through the GLYCOL TO RADIATORS-PRIM valve (panel 377), through the radiators, and returns to the CM. The GLYCOL TO RADIATORS-PRIM valve is placed in the BYPASS position; prior to launch to isolate the radiators from the loop, and prior to CM-SM separation to prevent loss of coolant when the CSM umbilical is cut. During space operations the valve is in the NORMAL position.

Coolant returning to the CM flows to the GLYCOL RESERVOIR valves (panel 326). From prelaunch until after orbit insertion, the reservoir INLET and OUTLET valves are open and the bypass valve is closed, allowing coolant to circulate through the reservoir. This provides a quantity of cold coolant to be used as a heat sink during the early stage of launch. After orbit insertion, the reservoir is isolated from the primary loop (by opening the BYPASS valve, and closing the INLET and OUTLET valves) to provide a reserve supply of coolant for refilling the loop in the event a leak occurs. Refilling is accomplished by means of the PRIM ACCUMR FILL valve (panel 379). Prior to entry, the reservoir may be placed in the loop if required.

The coolant flow from the evaporator divides into two branches. One branch carries a flow of 33 pounds per hour to the inertial measurement unit (IMU), and into the coldplate network. The other branch carries a flow of 167 pounds per hour to the water chiller, then through the SUIT HI EXCH PRIMARY GLYCOL valve (panel 382) and the suit heat exchanger to the PRIMARY CABIN TEMP control valve (panel 303).

The PRIMARY CABIN TEMP control valve routes the coolant to either the cabin heat exchanger or to the coldplate network. The valve is positioned by means of a control on the face of the valve. The valve is so constructed that in the cabin full cooling mode, the flow of coolant from the suit heat exchanger (167 pounds per hour) is routed first through the cabin heat exchanger and then through the thermal coldplates where it joins with the flow (33 pounds per hour) from the IMU. In the cabin full heating mode, the total flow (200 pounds per hour) is routed through the thermal coldplates first, where the water-glycol absorbs heat; from there it flows through the cabin heat exchanger. In the intermediate valve positions, the quantity of cool or warm water-glycol flowing through the heat exchanger is reduced in proportion to the demand for cooling or heating. Although the amount of water-glycol flowing through the cabin heat exchanger will vary, the total flow through the thermal coldplates will always be total system flow. A flow transducer at the outlet of the coldplate network provides data for telemetry, and an input signal to the caution and warning system. The GLYCOL FLOW warning light will illuminate when the flow rate decreases below 135 lbs/hr. An orifice restrictor is installed between the cabin temperature control valve and the inlet to the coldplates. Its purpose is to maintain a constant flow rate through the coldplates by reducing the heating mode flow rate to that of the cooling mode flow rate. Another orifice restrictor, located in the coolant line from the IMU, maintains a constant flow rate through this component regardless of system flow fluctuations. The total flow leaving the PRIMARY CABIN TEMP valve enters the primary pump and is recirculated.

The output of the secondary pump flows through a passage in the secondary evaporator steam pressure control valve for de-icing the valve throat. The coolant next flows through the GLYCOL TO RADIATORS-SEC valve (panel 377), through the radiators, and returns to the CM. The GLYCOL TO RADIATORS-SEC valve is placed in the bypass position, prior to CM-SM separation to prevent loss of coolant when the CSM umbilical is severed. After returning to the CM the coolant flows through the secondary evaporator, the SUIT HT EXCH SECONDARY GLYCOL valve, and the suit heat exchanger to the SECONDARY CABIN TEMP control valve (panel 303). The SECONDARY CABIN TEMP control valve regulates the quantity of coolant flowing through the cabin heat exchanger in the cooling mode (there is no heating capability in the secondary loop). The coolant from the secondary cabin temp control valve and/or the cabin heat exchanger then flows through redundant passages in the coldplates for the flight critical equipment and returns to the secondary pump inlet.

2.7.6.2 Glycol Temperature Control

The heat absorbed by the coolant in the primary loop is transported to the radiators where a portion is rejected to space. If the quantity of heat rejected by the radiators is excessive, the temperature of the coolant returning to the CM will be lower than desired (45°F nominal). If the temperature of the coolant entering evaporator drops below a nominal 43°F, the mixing mode of temperature control is initiated. The automatic control (GLYCOL EVAP-TEMP IN switch ON) opens the PRIMARY GLYCOL EVAP INLET TEMP valve (panel 382), which allows a sufficient quantity of hot coolant from the pump to mix with the coolant returning from the radiators, to produce a mixed temperature at the inlet to the evaporator between 43° and 48°F.

While docked, the CSM systems are in a quiescent mode of operation, and are adding little heat to the coolant. Therefore, it is desirable to operate the primary glycol system at a higher temperature than normally to reduce condensation in the CM. To accomplish this, a switch (GLY EVAP TEMP IN, panel 163) and a resistor have been added to the automatic control circuit to permit operating at either a 45°F (normal) or a 60°F (high) evaporator inlet temperature. Also, an orifice has been installed in the AUX GLY EVAP INLET TEMP valve to limit its maximum flow capacity. To change from 45° to 60°F operating level, the auxiliary temp in valve is opened fully, and the switch on panel 163 is placed in the HI position. To change from 60° to 45°F for earth resources experiments, it is only necessary to change the switch position back to NORMAL. Prior to undocking, the auxiliary valve is closed and the switch placed to NORMAL.

There is no mixing mode in the secondary loop. If the temperature of the coolant returning from the secondary radiator is lower than 45°F nominal, the secondary radiator inlet heater will be turned on to maintain the outlet temperature between 42° and 48°F.

If the radiators fail to radiate a sufficient quantity of heat, the coolant returning to the CM will be above the desired temperature. When the temperature of the coolant entering the evaporator rises to 48° to 50.5°F, the evaporator mode of cooling is initiated. The glycol temperature control (GLYCOL EVAP-STEAM PRESS switch, AUTO position) opens the steam pressure valve allowing the water in the evaporator wicks to evaporate, using some of the heat contained in the coolant for the heat of vaporization. A glycol temperature sensor at the outlet of the evaporator controls the position of the steam pressure valve to establish a rate of evaporation that will result in a coolant outlet temperature between 40° to 43°F (an evaporator outlet temperature range of 38° to 45° is acceptable for a period of one hour following a transition from the mixing mode of glycol temperature control to the evaporative mode). The evaporator wicks are maintained in a wet condition by the wetness control (GLYCOL EVAP-H_2O FLOW switch, AUTO position), which uses the wick temperature as an indication of water content. As the wicks become dryer, the wick temperature increases and the water control valve is opened. As the wicks become wetter, the wick temperature decreases and the water valve closes. The evaporative mode of cooling is the same for both loops, except that backup control for the primary loop has a separate switch for controlling the steam pressure valve manually. The PRIM GLYCOL EVAP INLET TEMP valve can be positioned manually when the TEMP IN switch is in the MAN position. The steam pressure valve can be controlled remotely by placing the STEAM PRESS switch to the MAN position, and using the INCR/DECR switch to position the valve. The water control valve can be opened remotely by placing the H_2O FLOW switch to ON. The secondary steam pressure is controlled automatically when the SEC COOLANT LOOP switch is in the EVAP position; placing the switch in RESET causes the control to close the secondary steam pressure valve. The OFF position removes power from the control. The SEC EVAP H_2O FLOW switch AUTO position permits automatic control at water flow. The ON position opens the water valve directly; the OFF position opens the H_2O control circuits.

2.7.6.3 ECS Radiator Control

Each coolant loop includes a radiator circuit. The primary radiator circuit consists basically of two radiator panels, in parallel with a flow-proportioning control for dividing the flow between them, and a heater control for adding heat to the loop. The secondary circuit consists of two parallel tubes utilizing some of the area of both panels, and a heater control for adding heat to the loop.

The radiator panels are an integral part of the SM skin and are located on opposite sides of the SM (panel 1 in bays 2 and 3; panel 2 in bays 5 and 6). With the radiators being diametrically opposite, it is possible that one primary panel may "see" deep space while the other "sees" the sun, earth, or moon. These extremes in environments, provide for large differences in panel efficiencies and outlet temperatures. The panel seeing deep space can reject more heat than the panel receiving external radiation; therefore, the overall efficiency of the subsystem can be improved by increasing the flow to the cold panel. The higher flow rate reduces the transit time of the coolant through the radiator, which decreases the quantity of heat radiated.

Flow through the radiators is controlled by a dual flow-proportioning valve assembly, four radiator isolation valves, and a solid-state electronic controller. The flow-proportioning valve assembly consists of two vane-type proportioning valves each driven by an individually controlled torque motor. The assembly has a common inlet port, and each of the valves has two outlet ports, one going to the supply lines for radiator panel No. 1, and the other going to panel 2. A radiator isolation valve is installed between each of the valve outlet ports and the supply line for each of the radiator panels. The controller not only contains the circuits for controlling the position of the flow-proportioning valves, it also contains radiator isolation valve selection logic, a failure-sensing logic, and redundant power supplies.

Power is supplied to the controller through the two FLOW CONT switches in the ECS RADIATORS switch group on panel 2. Placing the PWR-MAN SEL MODE switch in the PWR position routes d-c power to the AUTO-1-2 switch, which is used for selecting the operating mode of the controller. When the AUTO-1-2 switch is placed in the AUTO position, and the PWR-MAN SEL MODE switch is in PWR, 28 vdc is applied to the No. 1 power supply of the controller through the internal automatic transfer circuit. The output of the power supply goes to the No. 1 operational amplifier which controls the No. 1 flow-proportioning valve; the failure sensing logic circuit, which controls the electrical state of the auto transfer circuit; and to the control circuit for the four radiator isolation valves, which will position the valves for operation on the No. 1 flow-proportioning system. Three temperature sensors are located in the outlet line from each of the primary radiator panels. The first pair of sensors are connected to the temperature bridge of the No. 1 operational amplifier, the second pair to the No. 2 amplifier, and the third pair to the failure-sensing logic amplifier.

During operation, if a difference in radiator panel outlet temperature occurs, the flow-proportioning valve will be positioned to increase the coolant flow to the cooler radiator panel. At a temperature differential of 10°F the flow-proportioning valve will be "hard over," diverting approximately 95 percent of the flow to the cold radiator. The failure-sensing logic is monitoring radiator panel outlet temperatures and the magnitude and polarity of the flow-proportioning valve torque motor current. If a temperature differential of 15°F occurs, and the torque motor current is less than 90 percent of maximum or of the wrong polarity, the failure-sensing logic will trigger the automatic transfer circuit. The transfer from the No. 1 to the No. 2 system is effected by removing the input power from the No. 1 power supply and applying power to the No. 2 power supply. The output of the No. 2 power supply then causes the radiator isolation valves to be positioned for operation with the No. 2 flow-proportioning valve, and applies power to the No. 2 operational amplifier. The failure-sensing logic does not operate with the No. 2 system.

When the AUTO-1-2 switch is in the 1 or 2 position, power is applied to the corresponding power supply, which will set up the system for operation as described previously, except for the failure sensing and transfer circuits. Transfer in this case is by means of the AUTO-1-2 switch.

In situations where the radiator inlet temperature is low and the panels have a favorable environment for heat rejection, the radiator outlet temperature starts to decrease and thus the bypass (flow through **the PRIM GLYCOL EVAP INLET TEMP valve) ratio starts to increase. As** more flow is bypassed, the radiator outlet temperature decreases until the minimum desired temperature would be exceeded. To prevent this from occurring, an in-line heater upstream of the radiator is automatically turned on when radiator mixed outlet temperature drops to -15° and remains on until -10°F is reached. The controller provides only on/off heater control which results in a nominal 450 watts being added to the coolant each time the heater is energized. Power for the controller comes from the ECS RADIATORS HEATER switch in the PRIM 1 or PRIM 2 position. Switching to the redundant heater system is accomplished by the crew.

If the radiator outlet temperature falls below the desired minimum, the effective radiator surface temperature will be controlled passively by the selective stagnation method. The two primary circuits are identical, each consisting of five tubes in parallel. The two panels, as explained in the flow proportioning control system, are in parallel with respect to each other. The five parallel tubes of each panel have manifolds sized precisely to provide specific flow-rate ratios in the tubes, numbered 1 through 5. Tube 5 has a lower rate than tube 4, and so on, through tube 1 which has the higher flow. It follows, that for equal fin areas the tube with the lower flow rate will have a lower coolant temperature. Therefore, during minimum CM heat loads, stagnation begins to occur in tube 5 as its temperature decreases; for as its temperature decreases, the fluid resistance increases, and the flow rate decreases. As the fin area around tube 5 gets colder, it draws heat from tube 4 and the same process occurs with tube 4. In a fully stagnated condition, there is essentially no flow in tubes 3, 4, and 5, and some flow in tubes 1 and 2, with most of it in tube 1.

When the CM heat load increases and the radiator inlet starts to increase, the temperature in tube 1 increases and more heat is transferred through the fin towards tube 2. At the same time, the PRIM GLYCOL EVAP INLET TEMP valve starts to close and force more coolant to the radiators, thus helping to thaw the stagnant portion of the panels. As tube 2 starts to get warmer and receives more flow, it in turn starts to thaw tube 3, etc. This combination of higher inlet temperatures and higher flow rates quickly thaws out the panel. The panels automatically provide a high effectiveness (completely thawed panels operating at a high-average fin temperature) at high-heat loads, and a low effectiveness (stagnated panels operating at a low-average fin temperature) at low-heat loads.

The secondary radiator consists of two tubes which are an integral part of the ECS radiator panel structure. Each tube is purposely placed close to the hottest primary radiator tubes (i.e., the number 1 tube on each panel) to keep the water-glycol in the secondary tubes from freezing while the secondary circuit is inoperative. The "selective stagnation" principle is not utilized in the secondary radiator because of the "narrower" heat load range requirements. Because of the lack of this passive control mechanism, the secondary ECS circuit is dependent on the heater control system at low-heat loads and the evaporator at high-heat loads for control of the water-glycol temperature.

The secondary heater control receives power through the ECS RADIATORS HEATER switch in the SEC position. The secondary heaters differ from the primary in that they can be operated simultaneously. When the secondary outlet temperature reaches 45°F, the No. 1 heater comes on, and at 42°F the No. 2 heater comes on; at 44°F No. 2 goes off, and at 45°F No. 1 goes off.

2.7.7 ELECTRICAL POWER DISTRIBUTION

The electrical power required for the operation of the environmental control system is 28 volts dc and 115/200-volt 400-cycle 3-phase ac. The larger motors of the system utilize 200-volt 3-phase power, whereas the smaller motors and control circuits operate from a single phase of the ac at 115 volts. Except for the postlanding ventilation system, those components using 28 volts dc will receive power from the fuel cells before CSM separation and from batteries after separation. The post-landing ventilation system will operate from batteries, exclusively. (See figure 2.7-6, sheets 1, 2, and 3.)

2.7.8 ECS PERFORMANCE AND DESIGN DATA

The following table provides performance and design data for system components that operate automatically without direct control. Components that operate in response to crew control are described in Skylab, Volume 1, section 3. Components are identified by the AiResearch item number and nomenclature.

ENVIRONMENTAL CONTROL

Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
1.8	Debris trap	ECU	Mechanical filter with integral bypass	Prevents debris from entering the suit compressors.	Filtration = 0.04 in. Pressure drop = 0.25 in. H_2O max. Bypass valve cracks at 0.5 in. H_2O max.
1.10	Suit compressor	ECU	Centrifugal blower (2)	Circulates gases through the suit circuit.	Normal Operation = 35 cfm with 0.38 psi pressure rise at 5 psia; 33.6 cfm with 0.27 psi pressure rise at 3.5 psia.
1.29	Suit heat exchanger	ECU	2 pass, suit gas to water-glycol heat exchanger, and water separator	Cools suit gas and removes excess water to control humidity.	Cooling = 2100 Btu/hr total minimum.
1.31	Suit flow limiter	LHFEB	Venturi tube (3)	Limits the flow of gas to any one suit in case a suit becomes torn in a depressurized cabin.	Choked flow = 0.7 lb/minute O_2 max. at 3.5 psia and 70°F.
2.6 (2.7)	Primary (secondary) glycol evaporators	ECU	Evaporative heat exchanger (2)	Cools water-glycol by evaporation of waste water into low-pressure steam with minimum water carryover into steam duct.	Heat transfer = 7620 Btu/hr. Steam water content = 1 percent max.
2.20	Space radiator isolation valves	S/M	Electrically actuated, rotary shut-off valve (4)	Controlled by flow-proportioning controller, or by flow control switches to isolate space radiators.	Actuation time = 17 sec max. for full rotational stroke. Power req. = 8 va max. at 115 v, 1Ø, 400 cps.

Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
2.29	Glycol reservoir	LHEB	Tank with oxygen-pressurized bladder for W/G expulsion at zero G	Contains reserve supply of W/G; substitutes for failed accumulator.	Capacity = 8.2 lb W/G at 70°F.
2.39	Back pressure valve	ECU	Electrically actuated pinch valve	Controls "steam" pressure in W/G evaporator.	Actuation time = 58 sec max. full closed to full open. Power req. = 8 va (0.07a) at 115 v.
2.48	Glycol pumping unit	LHEB	Centrifugal impeller motor driven through magnetic coupling (two primary, one secondary)	Circulates W/G through the primary and/or secondary coolant loops.	Inlet press = 7.5 psig. Pump ΔP = 34 psid with 200-240 lb/hr flow rate. Power requirements - 115v, 3Ø, 400 cps, 52 W max.
3.2	Cabin heat exchanger	LHFEB	Plate fin, sandwich construction, cabin gas-to-water glycol heat exchanger	Used to control cabin gas temperature.	Heat transfer rate: Primary heating = 236 Btu/hr. Primary cooling = 892 Btu/hr. Secondary cooling = 1132 Btu/hr.
3.28	Cabin pressure regulator	LHEB 351	Two flow-limited, absolute pressure regulators with integral repressurization valve	Maintain cabin at normal pressure (nonemergency) and shut-off during depressurized cabin (emergency).	Hi pressure lock-up = 5.2 psia nominal. Control range = 5.2 to 4.8. Total range = 5.2 to 3.5 psia. Demand flow = 0.7 lb/hr each.
4.25	Hi press O_2 check	LHEB	Spring-loaded umbrella	Allows O_2 flow in one direction only.	Flow = 0.75 lb/min at 5 psid.

Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
4.35	O_2 filter	LHEB	Mechanical	Provides filtering for O_2 supply to water accumulators and demand regulator.	10 microns nominal. 25 microns absolute.
5.10	Potable water tank	Aft Compartment	Cylindrical tank with pressurized bladder	Stores drinking water.	Capacity = 36 + 3, -0 lb H_2O at 150°F.
5.14	Water chiller	ECU	Heat exchanger	Utilizes 45° W/G to cool drinking water.	W/G flow = 167 lb/hr. W/G temp 45°F Water in = 150°F. Water out = 55°F max. With above inlet conditions and 6 fl oz H_2O withdrawn in 10 sec. max. at 24 min intervals.
5.15	Waste water tank		Cylindrical tank with pressurized bladder	Stores water for evaporative cooling.	Capacity = 56 + 3, -0 lb H_2O at 150°F.
5.29	Evaporator water control valves (primary and secondary)	LHEB 382	Normally closed solenoid valve in series with two-way selector valve	Controls water flow to primary and secondary W/G evaporators.	Flow capacity 24 lb/hr H_2O at 0.5 psid Power requirement = 6 va at 28 vdc.
5.33	Water filter (primary and secondary)	LHEB ECU	Filter cartridge plus bypass valve that opens for clogged cartridge	Filters waste water at inlet to primary and secondary W/G evaporators.	Filtration - = 10 microns absolute Bypass relief = 3 psid

SYSTEMS DATA

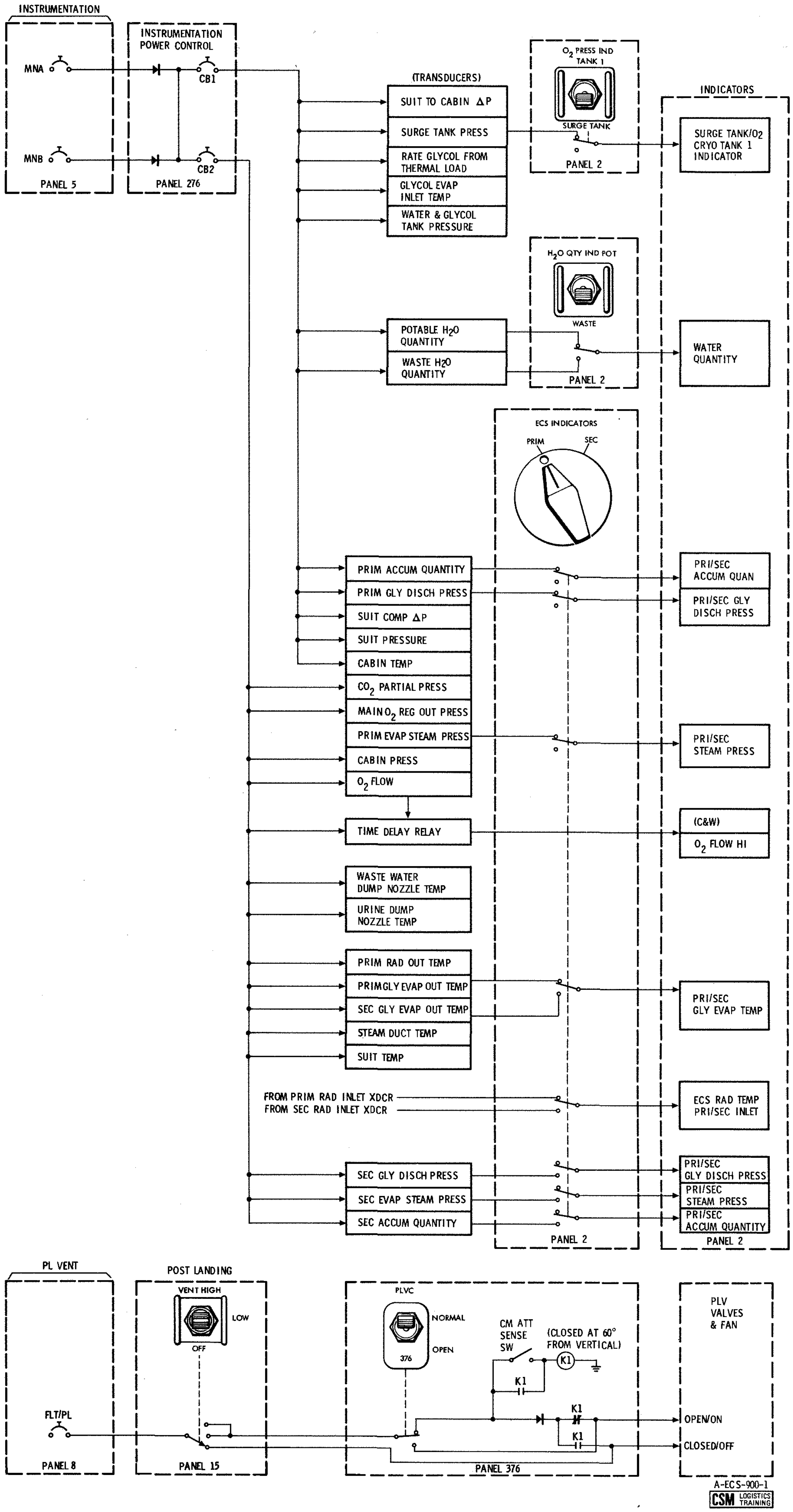


Figure 2.7-6. Skylab ECS Power Distribution (Sheet 1 of 3)

ENVIRONMENTAL CONTROL

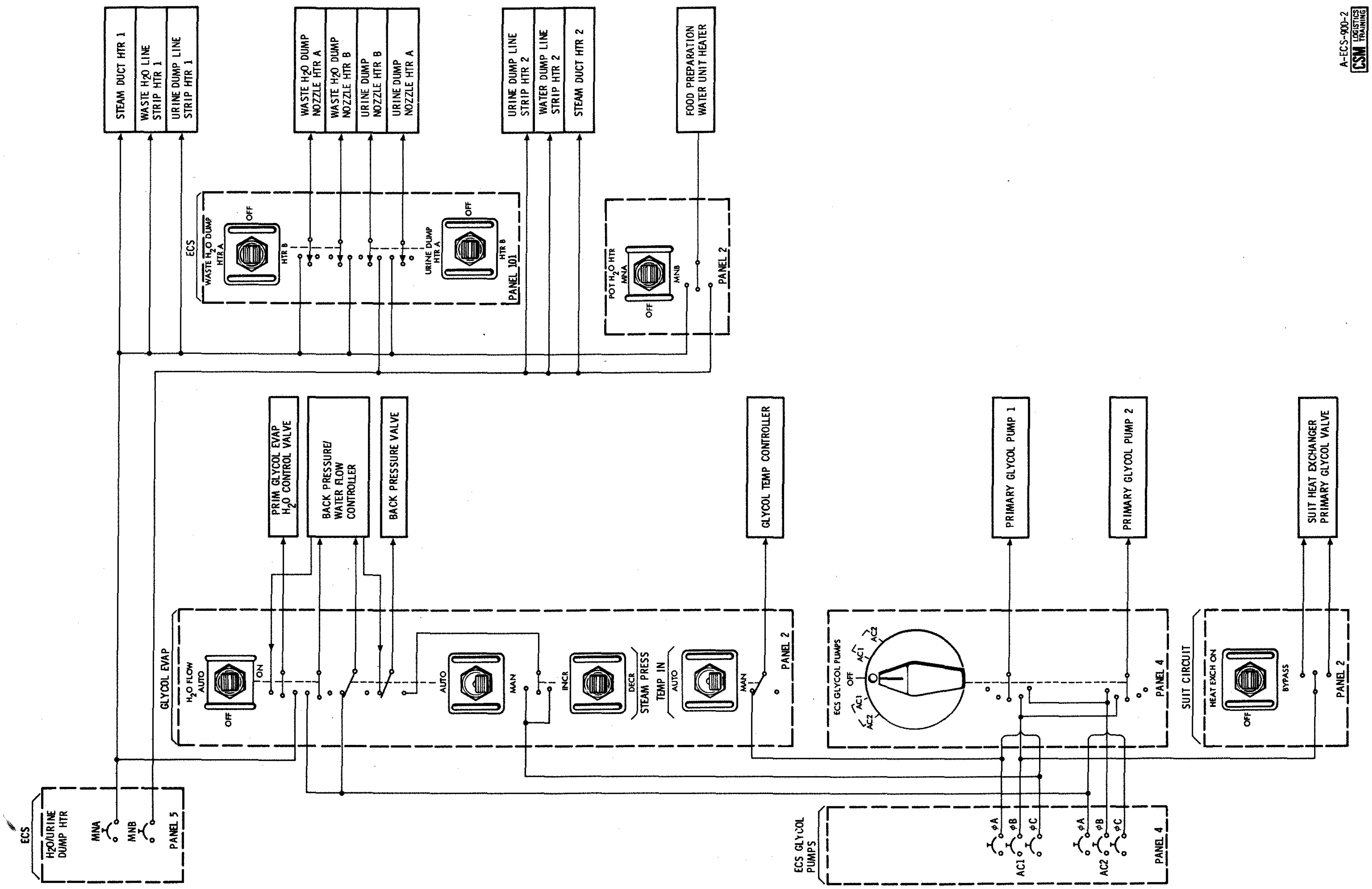


Figure 2.7-6. Skylab ECS Power Distribution (Sheet 2 of 3)

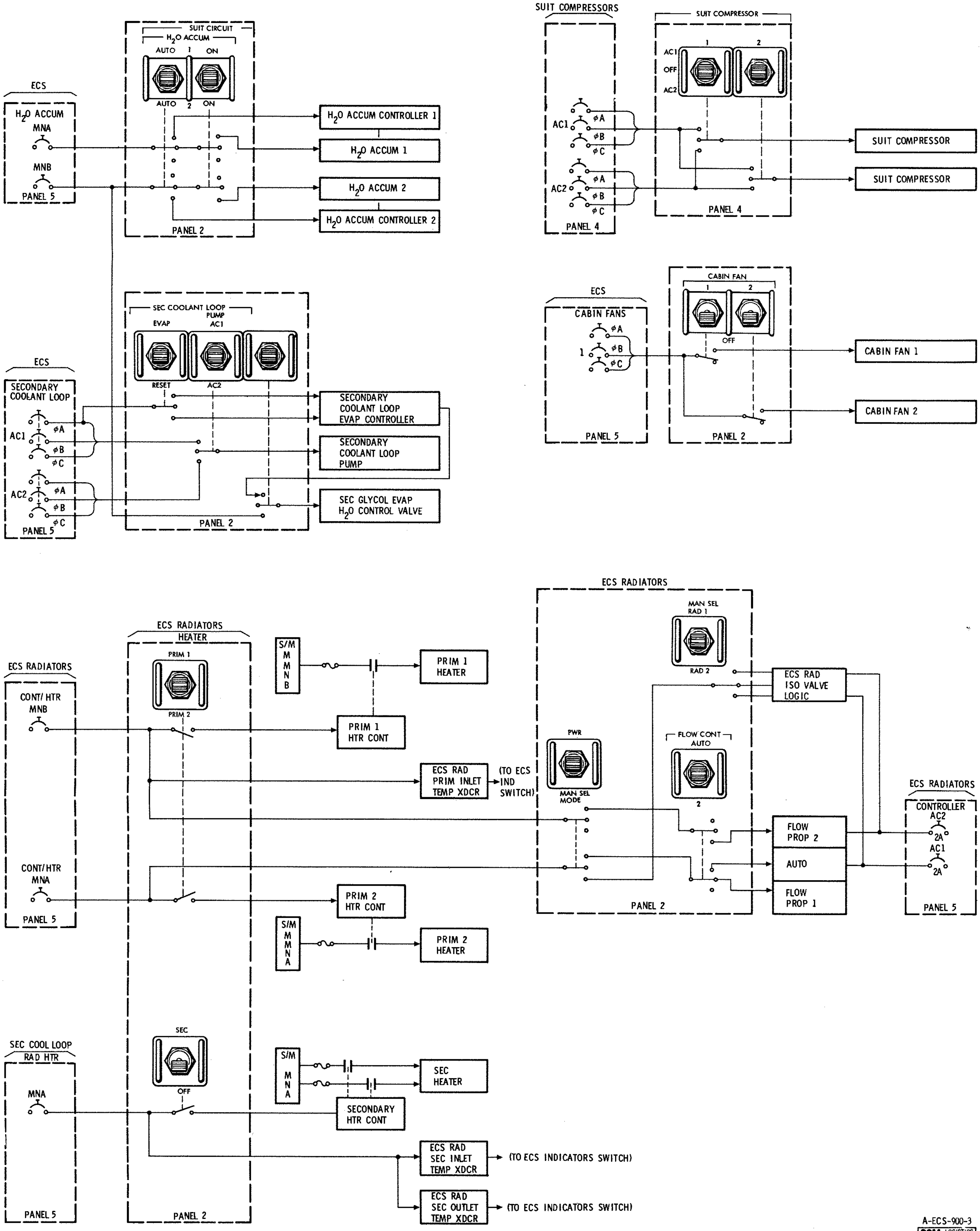


Figure 2.7-6. Skylab ECS Power Distribution (Sheet 3 of 3)

SECTION 2

SUBSECTION 2.8

TELECOMMUNICATION SYSTEM

2.8.1 INTRODUCTION

The communications subsystem is the only link between the spacecraft and the spacecraft tracking and data network (STDN). In this capacity, the communications subsystem provides the STDN flight controllers with data through the pulse code modulation (PCM) telemetry system for monitoring spacecraft parameters, subsystem status, crew biomedical data, event occurrence, and scientific data. The communications subsystem has data reception capability from the STDN for operation of spacecraft functions. The communications subsystem, through its STDN link, serves as a primary means for the determination of spacecraft position in space and rate of change in position. The communication subsystem provides CSM to SWS range data by means of a separate ranging system. As a voice link, the communications subsystem gives the crew the added capability of comparing and evaluating data with STDN computations. It also provides for voice between crew members in the CSM and SWS. Through the use of the television camera, crew observations and public information can be transmitted in real time to STDN. The subsystem provides voice outputs and inputs for SWS voice storage on the CSM recorder and for CSM voice storage on the CSM recorder for later playback, to avoid loss because of an interrupted communication link. CSM telemetry may also be recorded simultaneously with voice. Direction finding aids are provided for postlanding location, and rescue by ground personnel.

T/C

The following list summarizes the general telecomm functions:

Provide voice communication between

- Astronauts via the intercom in CSM and SWS
- CSM and STDN via the unified S-band equipment (USBE) and in orbital and recovery phases via the VHF/AM
- CSM and intravehicular astronaut (IVA) via the CSM intercom system
- CSM and SWS-EVA via the CSM intercom system
- CSM and launch control center (LCC) via PAD COMM
- CSM and recovery force swimmers via swimmers umbilical
- Astronauts and the voice log via intercomm to the data storage equipment

Provide data to the STDN of

- CSM system status
- Astronaut biomedical status
- Astronaut activity via television
- Scientific experiments - real time and delayed
- IVA biomed status

Provide update reception and processing of

- Digital information for the command module computer (CMC)
- Digital time-referencing data for the central timing equipment (CTE)
- Real time commands to remotely perform switching functions in three CM systems

Facilitate ranging between

- STDN and CSM via the USBE transponder
- CSM and SWS via the VHF/AM ranging system

Provide recovery aid

- VHF beacon for location

Provide a time reference for all time-dependent spacecraft subsystems except the guidance and navigation subsystem.

2.8.2 FUNCTIONAL DESCRIPTION

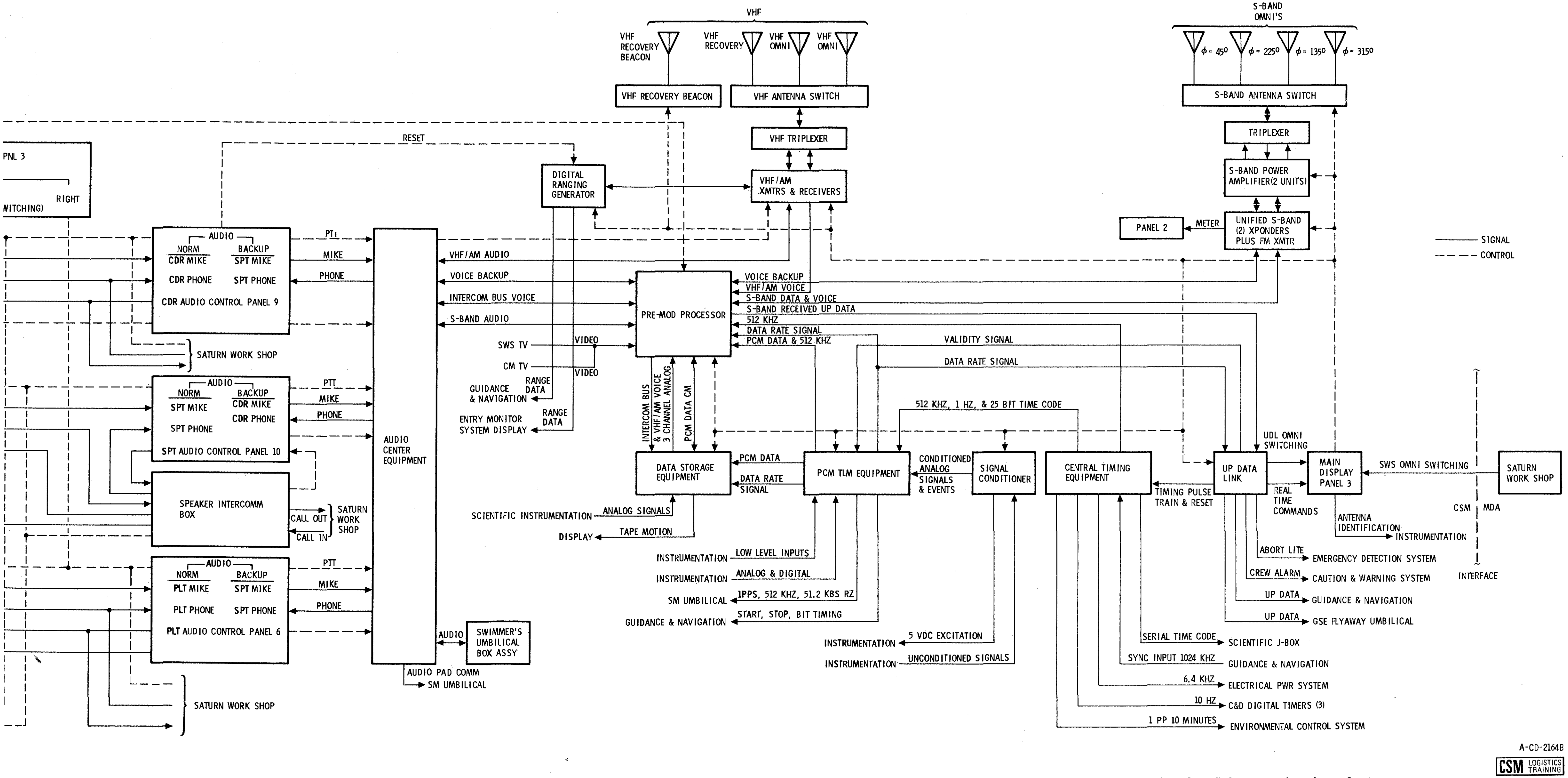
The functional description of the telecommunications system is divided into four parts: intercommunications equipment, data equipment, radio frequency equipment, and antenna equipment. All of these functional groups of equipment interface with each other to perform the system tasks. In the functional descriptions of these parts, such interfaces will be apparent. The equipment that falls into each group is shown in figure 2.8-1.

2.8.2.1 Intercommunications Equipment

2.8.2.1.1 General

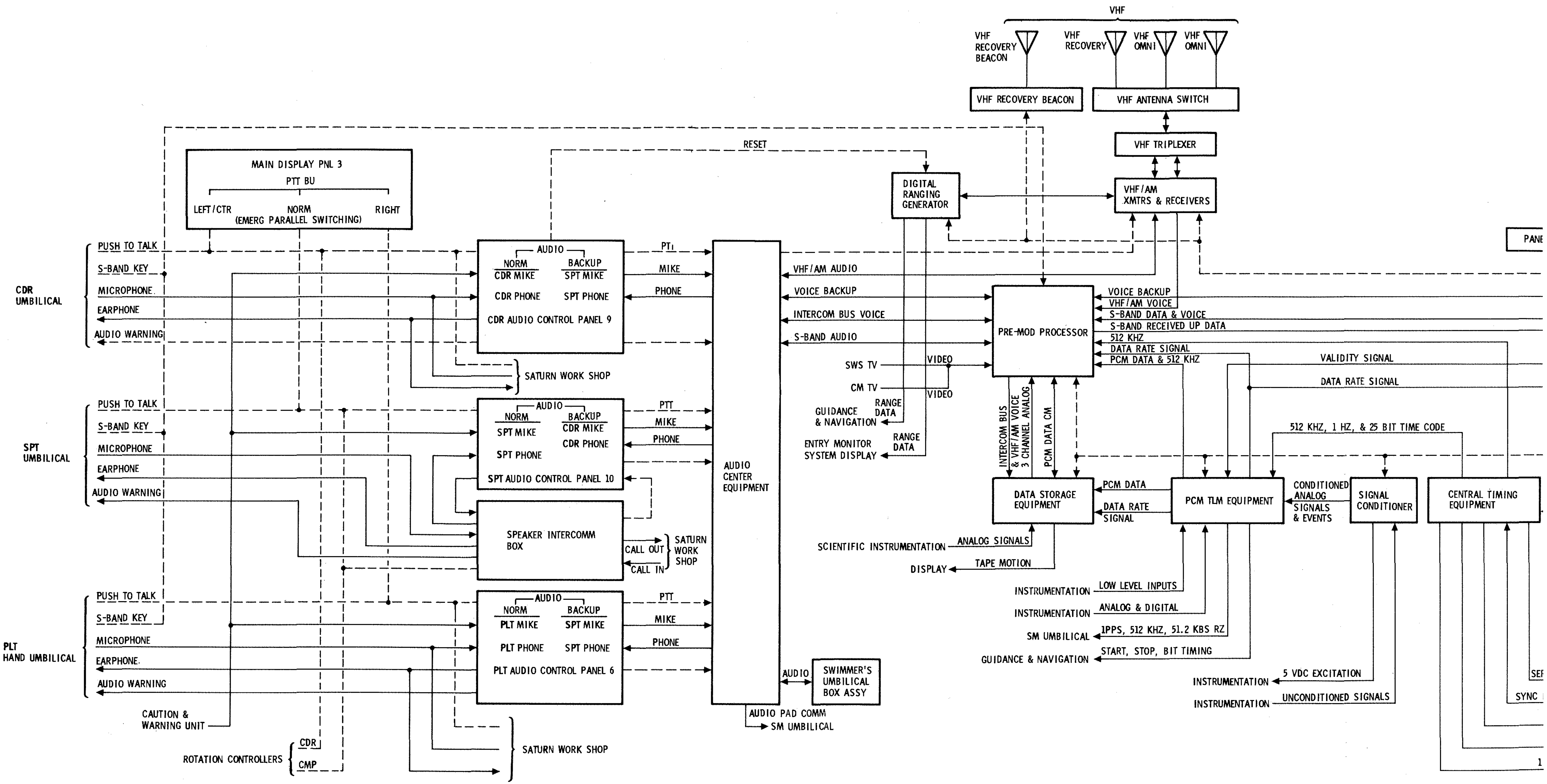
The functions performed by the intercommunications equipment can be summarized as providing the means for each astronaut to interface or isolate himself to or from the

- Intercomm for astronaut-to-astronaut communications in CM and SWS
- Voice annotation for scientific experiments
- Pad communications for astronaut-to-launch controi center communications



T/C

Figure 2.8-1. Telecommunications System


VHF
VHF RECOVERY BEACON
VHF RECOVERY
VHF OMNI
VHF OMNI
VHF RECOVERY BEACON
VHF ANTENNA SWITCH
VHF TRIPLEXER
VHF/AM XMTRS & RECEIVERS
DIGITAL RANGING GENERATOR
RESET
MAIN DISPLAY PNL 3
PTT BU
LEFT/CTR
NORM (EMERG PARALLEL SWITCHING)
RIGHT
CDR UMBILICAL
PUSH TO TALK
S-BAND KEY
MICROPHONE
EARPHONE
AUDIO WARNING
AUDIO
NORM
BACKUP
CDR MIKE
SPT MIKE
CDR PHONE
SPT PHONE
CDR AUDIO CONTROL PANEL 9
PTT
MIKE
PHONE
SATURN WORK SHOP
SPT UMBILICAL
SPT MIKE
CDR MIKE
SPT PHONE
CDR PHONE
SPT AUDIO CONTROL PANEL 10
SPEAKER INTERCOMM BOX
CALL OUT
CALL IN
SATURN WORK SHOP
PLT HAND UMBILICAL
PLT MIKE
PLT PHONE
PLT AUDIO CONTROL PANEL 6
CAUTION & WARNING UNIT
ROTATION CONTROLLERS
CDR
CMP
AUDIO CENTER EQUIPMENT
AUDIO
SWIMMER'S UMBILICAL BOX ASSY
AUDIO PAD COMM
SM UMBILICAL
VHF/AM AUDIO
VOICE BACKUP
INTERCOM BUS VOICE
S-BAND AUDIO
SWS TV
CM TV
VIDEO
VIDEO
GUIDANCE & NAVIGATION
RANGE DATA
ENTRY MONITOR SYSTEM DISPLAY
RANGE DATA
PRE-MOD PROCESSOR
VOICE BACKUP
VHF/AM VOICE
S-BAND DATA & VOICE
S-BAND RECEIVED UP DATA
512 KHZ
DATA RATE SIGNAL
PCM DATA & 512 KHZ
VALIDITY SIGNAL
DATA RATE SIGNAL
512 KHZ, 1 HZ, & 25 BIT TIME CODE
INTERCOM BUS & VHF/AM VOICE 3 CHANNEL ANALOG
PCM DATA CM
DATA STORAGE EQUIPMENT
PCM DATA
DATA RATE SIGNAL
PCM TLM EQUIPMENT
CONDITIONED ANALOG SIGNALS & EVENTS
SIGNAL CONDITIONER
CENTRAL TIMING EQUIPMENT
PANE
SCIENTIFIC INSTRUMENTATION
ANALOG SIGNALS
DISPLAY
TAPE MOTION
INSTRUMENTATION
LOW LEVEL INPUTS
INSTRUMENTATION
ANALOG & DIGITAL
SM UMBILICAL
1PPS, 512 KHZ, 51.2 KBS RZ
GUIDANCE & NAVIGATION
START, STOP, BIT TIMING
INSTRUMENTATION
5 VDC EXCITATION
INSTRUMENTATION
UNCONDITIONED SIGNALS
SER
SYNC
1

Figure

- Crew call to astronauts in SWS
- VHF/AM for astronaut-to-STDN communications
- USBE for astronaut-to-STDN communications
- Data storage equipment for a voice log (via intercomm)
- Swimmers umbilical during recovery (via intercomm).

2.8.2.1.2 Equipment

The equipment that falls into the intercommunications grouping is listed as follows:

- Personal communications assembly
- T-adapter cable
- Communications cable
- Audio control panels (panels 6, 9, 10)
- Audio center
- Swimmers umbilical cable
- Speaker box
- Audio hardlines to SWS (control umbilicals A and B).

2.8.2.2 Data Equipment

2.8.2.2.1 General

The functions of the data equipment can be summarized as providing

- Information gathering and telemetering of critical spacecraft and astronaut parameters
- Conditioning of instrumentation inputs for compatibility with the telemetry equipment
- Storage and playback capabilities of CSM telemetering data, voice log, and scientific parameters
- Decoding and distributing of up-data to the proper switching or information receiving systems
- Frequency and/or time code signals to other spacecraft equipment.

2.8.2.2.2 Equipment

The equipment that falls under the data grouping is as follows:

- Central timing equipment (CTE)
- Signal conditioning equipment (SCE)
- Pulse code modulation (PCM) telemetering equipment
- Television (TV) camera
- Data Storage Equipment (DSE)
- Up-data link (UDL) equipment
- Scientific J-box

T/C

2.8.2.3 Radio Frequency Equipment

2.8.2.3.1 General

The functions performed by the RF equipment can be summarized as the transmission and reception of

- Voice information between

  SWS and STDN
  CM and STDN
  CM and recovery forces

- Telemetering data

  Between CM and STDN
  From IVA to CM to STDN

- Television from CM to STDN

- Television from SWS to STDN

- Ranging and beacon (BCN) information

  Pseudo-random noise ranging signals from STDN to CM to STDN
  Double doppler ranging signals from STDN to CM to STDN
  VHF ranging signals from CM to SWS to CM
  VHF beacon signals from CM to recovery forces

2.8.2.3.2 Equipment

As shown in figure 2.8-1, the equipment that falls into the radio frequency grouping is

- VHF/AM transceivers A and B
- Digital ranging generator
- Unified S-band equipment (primary and secondary transponders and FM transmitter)
- S-band power amplifiers (primary and secondary)
- VHF beacon
- Premodulation processor.

T/C

.8.2.4 Antenna Equipment

The antenna equipment can be divided into three groups: VHF antennas and ancillary equipment, S-band antennas and ancillary equipment, and beacon antenna. Their overall function is to propagate and receive RF signals from and to the RF equipment. The ancillary equipment includes three RF switches and two triplexers (figures 2.8-2 and 2.8-3).

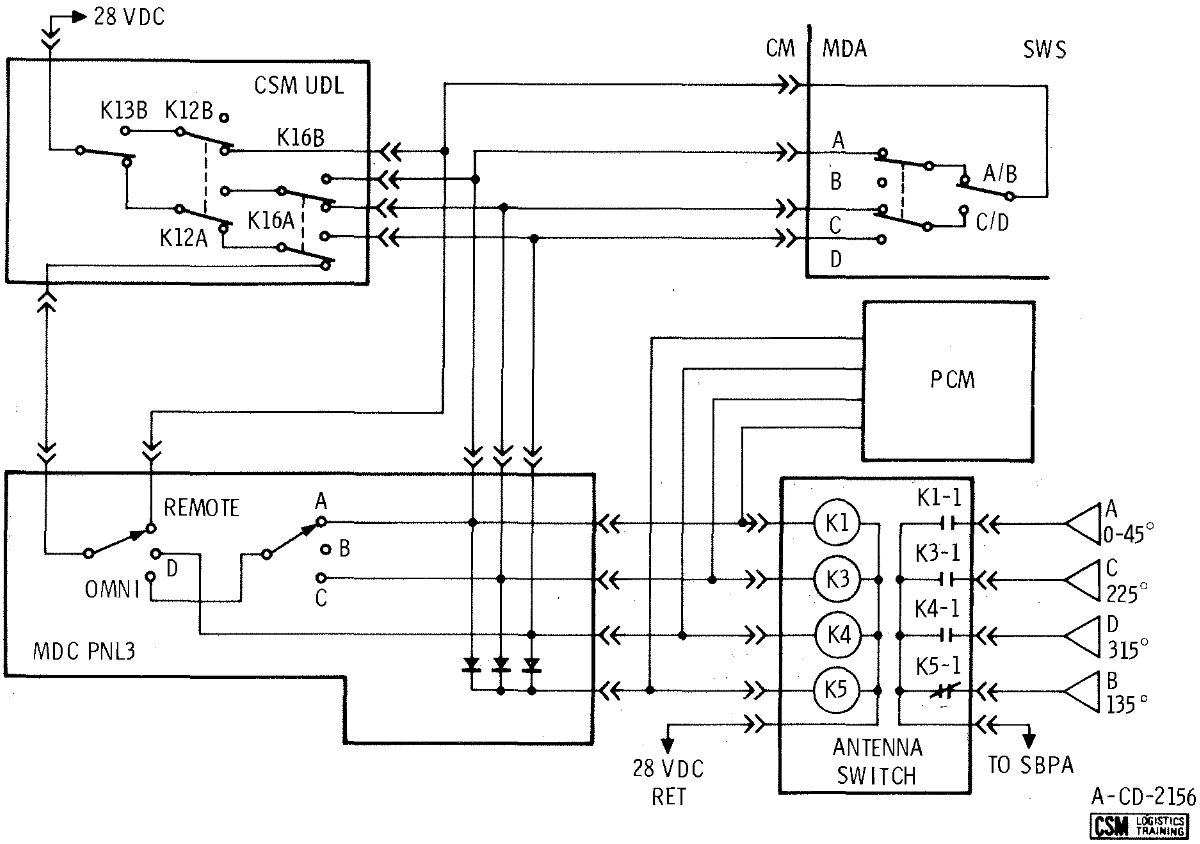


Figure 2.8-2. S-Band Antenna Switching

2.8.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION

The following descriptions will follow the functional divisions established in the previous section. In many instances, however, when an operational mode is being explained, interfacing equipment of another division will be discussed to present a complete picture.

2.8.3.1 Intercommunication Equipment

2.8.3.1.1 Personal Communications Assembly (Comm Carrier)

As shown in figure 2.8-4 the personal communications assembly (comm carrier) contains redundant earphones and microphones. The comm carrier can be worn with the space suit, flight coveralls, or constant wear garment. When used with the space suit, the comm carrier is interfaced with an integral wiring harness in the suit. A T-adapter cable is required when the comm carrier is worn with the flight coveralls or just the constant wear garment to interface the headset with the comm cable.

Three lightweight headsets are also available for use in the CM. They have a single earphone and microphone with a lightweight head clamp and connecting cable.

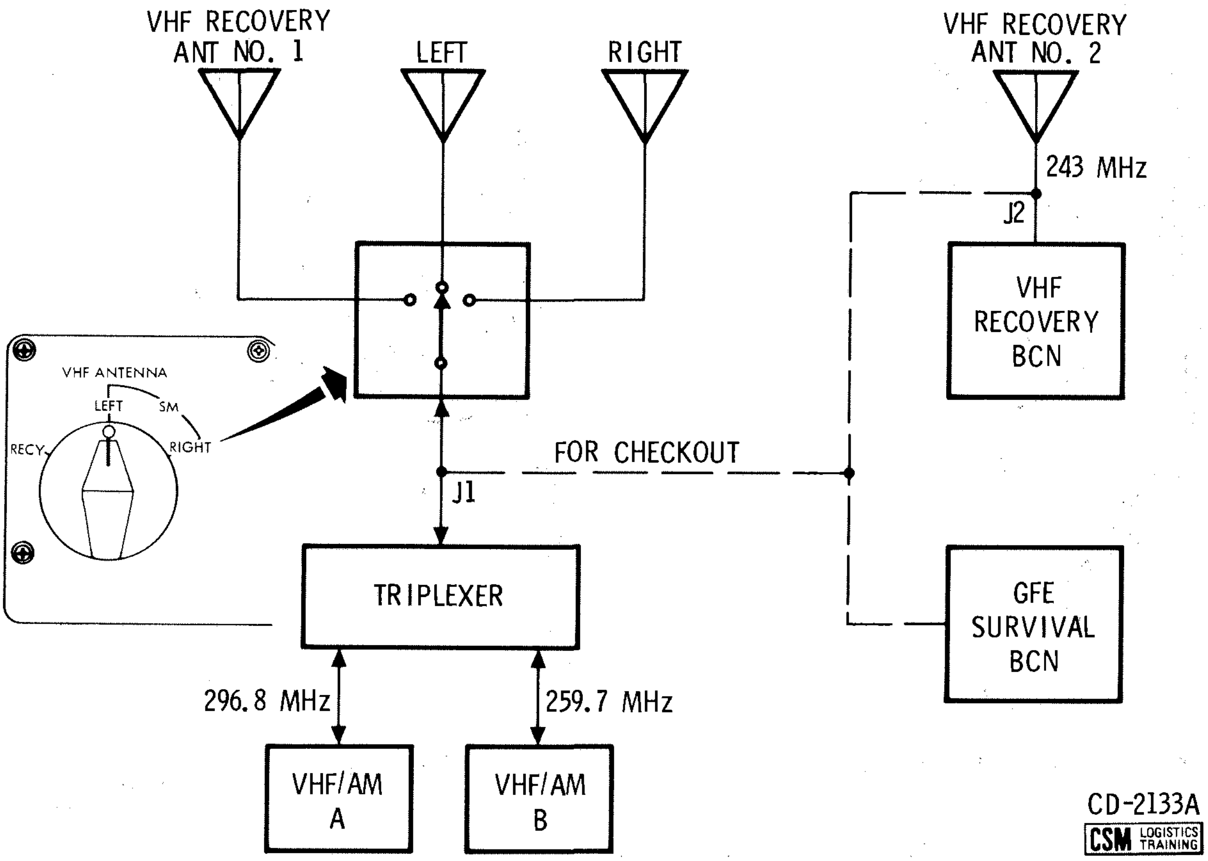


Figure 2.8-3. VHF/AM Antenna Switching

T/C

2.8.3.1.2 T-Adapter Cable (Figure 2.8-5)

The T-adapter cable is used when the astronaut is wearing his flight coveralls or just his constant wear garment to connect the personal communications assembly and biomed preamplifiers to the comm cable. An integral cable assembly performs this function when the astronaut is in his space suit so no T-adapter is necessary. Besides handling the audio signals to and from the comm carrier, the T-adapter must handle 16.8 volts needed by the microphone preamps and biomed preamps. The output of the biomed preamps is also routed to the comm cable.

2.8.3.1.3 Communications Cable (Electrical Umbilical Assembly)

The comm cable has several functions not the least of which is providing the path for audio signals to and from the comm carrier. It also provides the necessary path for the 16.8 volts required by the microphone preamps in the comm carrier and the biomed preamps. The output from the biomed preamps also is carried by the comm cable.

Separate from, but related to the audio signals from the comm carrier are the control functions of the comm cable control head. This control head contains a self-centering rocker switch which, when depressed on one side or

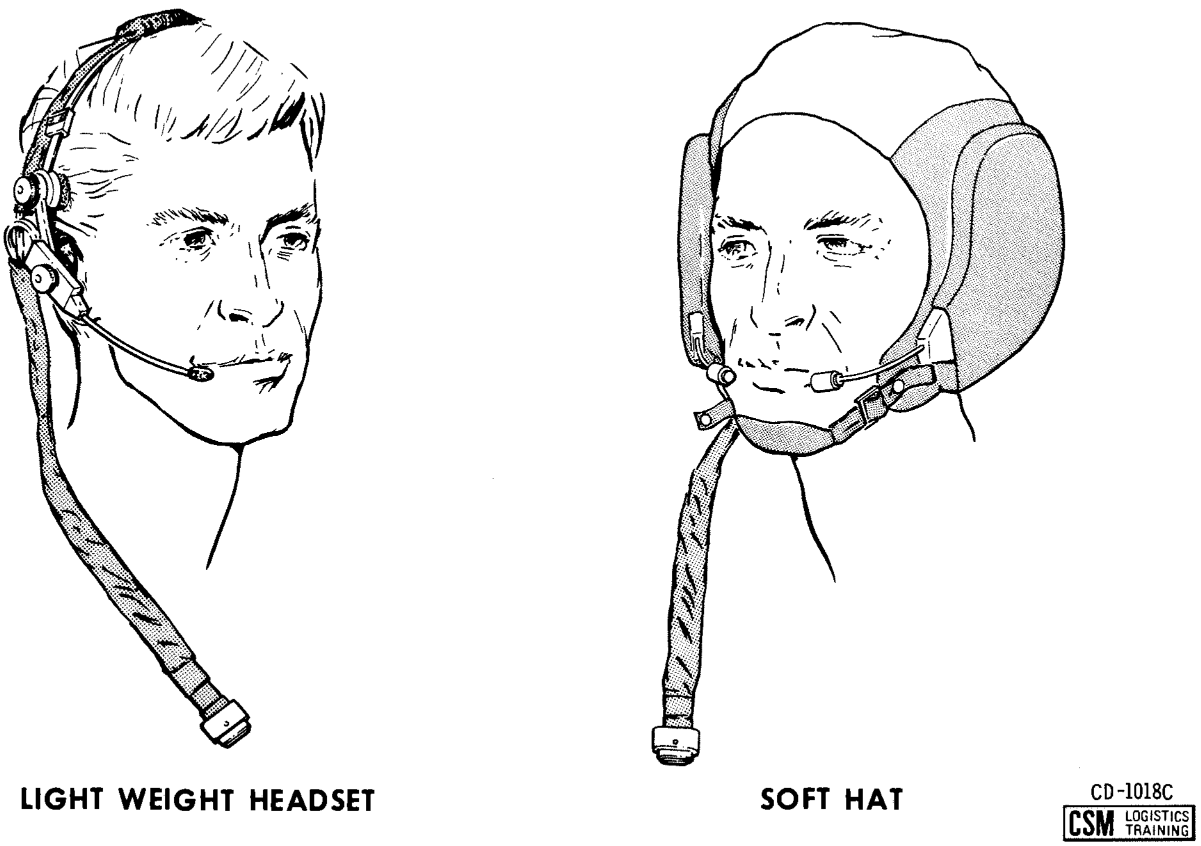


Figure 2.8-4. Personal Communications Assembly

the other, initiates specific functions in the intercommunications equipment. The I'COM side of the rocker switch is depressed when the intercommunications equipment is configured in the manual (PTT) mode of operation and communications over just the intercom is desired. The XMIT side of the rocker switch can be used for two different functions. Normally it is used to enable communications over the intercom and RF equipment in any of the three operational modes of the intercommunications equipment. The XMIT side of the rocker switch can also be used as a sending key in the S-band key mode of operation.

Figure 2.8-5 shows the comm cables interface with the connectors on the left-hand forward equipment bay (below panel 301) and the T-adapter cable.

2.8.3.1.4 Audio Center Equipment

The audio center equipment accomplishes the necessary audio signal amplification and switching to provide the capability of the following:

- Intercommunication between the three astronauts in the CM
- Intercommunication between one or more astronauts in the CM and up to two astronauts in the SWS docked to the CM

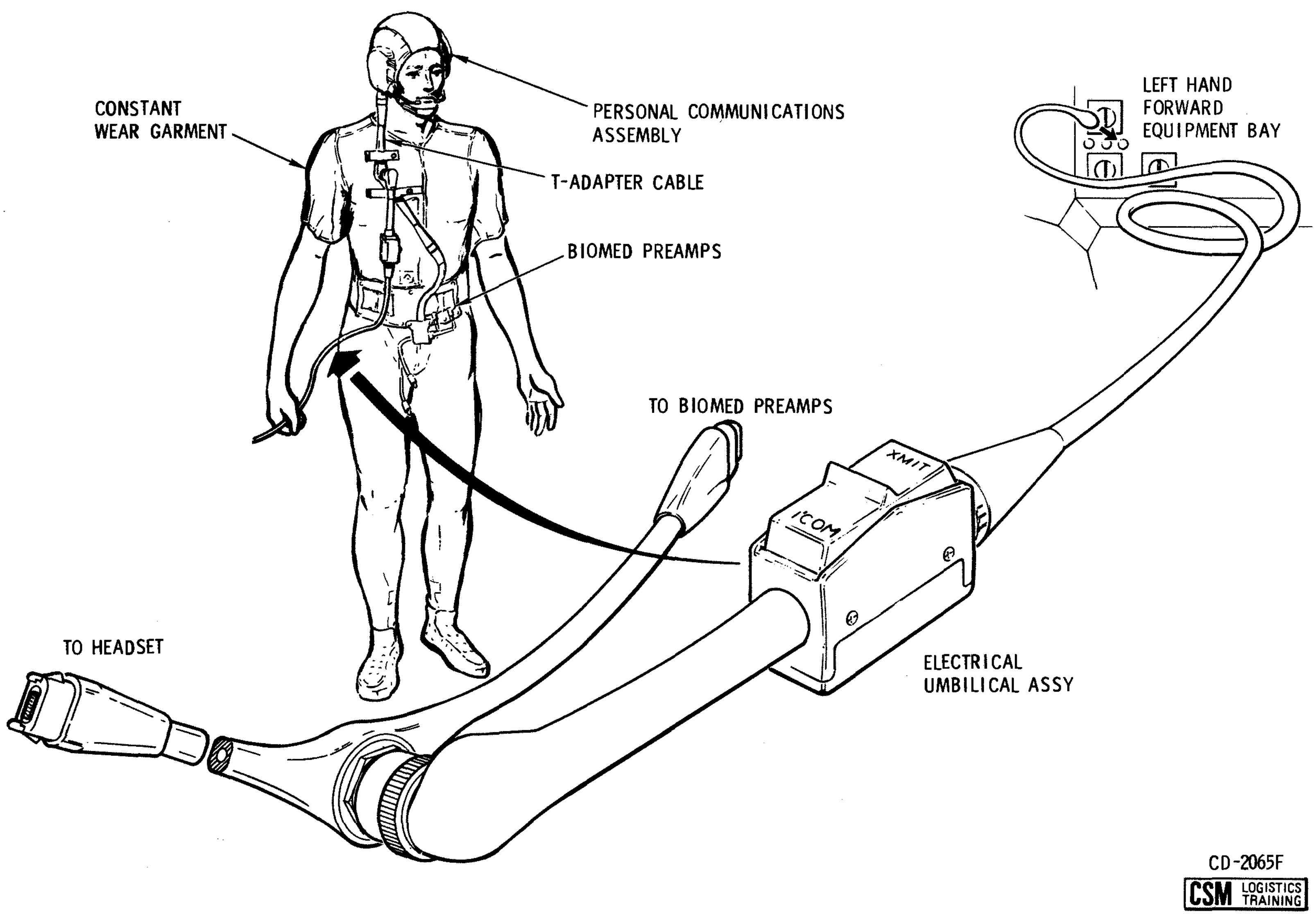


Figure 2.8-5. Communications Cable

- Communication between ground and one or more astronauts in the CM and up to two astronauts in the SWS docked to CSM via the CSM VHF/AM and S-band radio frequency links

- CM voice annotation and CM and SWS intercom voice storage on the CM recorder

- CM voice annotation on the recorder external to the CM

- Intercommunications, via external hardlines, with ground personnel during ground checkout and with recovery personnel during postlanding operations

- Intercommunications via the speaker box in the CM.

The audio center equipment consists of three audio stations, one for each astronaut. Each station has the capability of accommodating a second astronaut for emergency operation. Control of audio amplification levels and selective switching of functions is remotely accomplished within the CM, except that the capability is provided for the push-to-talk function to be also exercised externally to the CM through the CM docking ring interface.

The audio center equipment consists of three electrically identical sets of circuitry which provide parallel selection, isolation, gain control, and amplification of all voice communications. Each set of circuitry contains the following components (figure 2.8-6):

- Isolation pad, diode switch, and gain control for each receiver input, and intercom channel

- Isolation pad and diode switch for each transmitter modulation output and intercom channel

- An earphone amplifier and a microphone amplifier

- Voice-operated relay (VOX) circuitry with externally controlled sensitivity.

The equipment operates with three remote control panels to form three audio stations, each providing an astronaut with independent control of all common functions. Each station has the capability of accommodating a second astronaut for emergency operation. Provision is made in each station to enable voice transmission over any or all transmitters by means of a voice-operated relay (VOX) circuit or push-to-talk (PTT) circuit. A "hot mike" is so incorporated as to maintain continuous inter-crew communication using the INTERCOM/PTT mode, and to require PTT operation for eternal transmission. Enabling a TRANSMIT function also enables the corresponding RECEIVE function. Sidetone is provided in all transmit modes.

Audio signals are provided to and from the VHF/AM transmitter-receiver equipment. USBE (via the PMP), the PAD COMM, and intercom bus. The PAD COMM, intercom bus, and all transmitter-receiver equipments are common to all three stations.

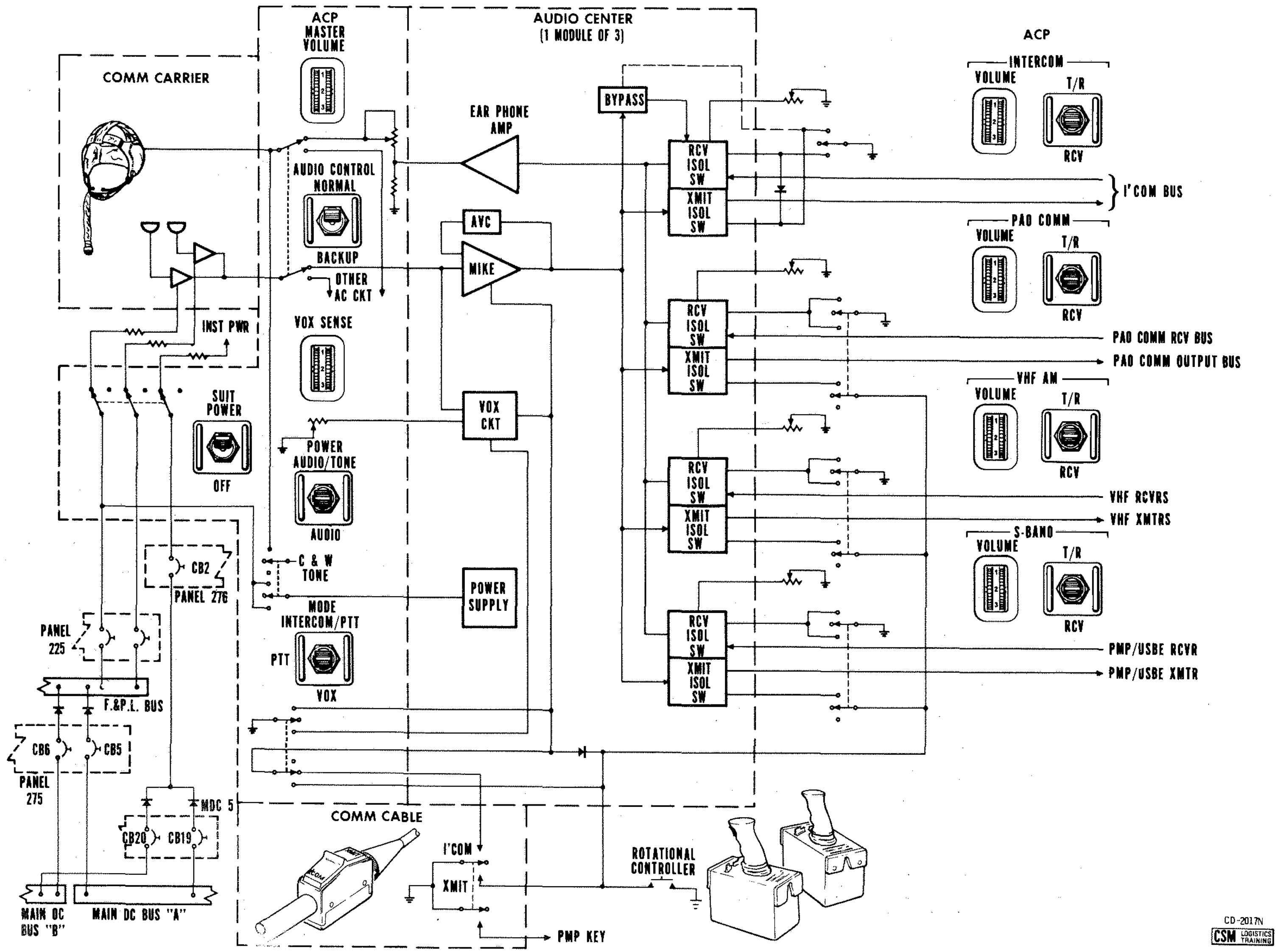


Figure 2.8-6. Audio Center

T/C

Inputs and outputs are controlled by the VHF/AM, S-BAND, PAD COMM, and INTERCOM switches on the audio control panels. Each of these switches has three positions: T/R, OFF, and RCV. Setting any of the switches to T/R permits transmission and reception of voice signals over its respective equipment, RCV permits reception only, and OFF disables the input and the output. The POWER switch of each station, in either AUDIO/TONE or AUDIO, energizes the earphone amplifier to permit monitoring. The AUDIO/TONE position also enables the audible crew alarm to be heard, if triggered, at the respective SC station. Each SC station can be isolated from the alarm by selecting the AUDIO or OFF position. The operation of the microphone amplifier in each station is controlled by the VOX keying circuit or the PTT pushbutton on the comm cable or on the rotation controller. The VOX circuit is energized by the VOX position of the MODE switch on each audio control panel. When energized, the VOX circuit will enable both the intercom and accessed transmitter keying circuits. The INTERCOM/PTT position permits activation of the PAD COMM, VHF/AM, and S-band voice transmission circuits by the PTT key while the intercom is on continuously. The PTT position permits manual activation of the intercom or intercom and transmitter keying circuits by depression of the I'COM or XMIT side of the communication cable switch, respectively.

Six potentiometer controls are provided on each audio control panel: VOX SENS, PAD COMM, S-BAND, INTERCOM, VHF/AM, and MASTER VOLUME. The VOX SENS control is used to adjust the sensitivity of the VOX circuitry, determining the amplitude of the voice signal necessary to trigger the VOX keying circuit. The PAD COMM, S-BAND, VHF/AM, and INTERCOM volume controls are used to control the signal levels from the respective units to the input of the earphone amplifier. The MASTER VOLUME controls the level of the amplified signal going to the earphones.

The intercom bus connects to the recovery interphone (swimmer umbilical) and the premodulation processor which in turn routes the signal to the data storage equipment for recording.

An AUDIO CONTROL switch on each audio control panel allows the astronaut to access himself to the normal audio center circuits for that station, or through a selection of the BACKUP position, access himself to the audio control panel and audio center of another station. In the BACKUP position, CDR is accessed to SPT panel and audio center, while BACKUP for SPT accesses him to CDR panel and audio center. PLT is accessed to SPT panel and audio center if he selects the BACKUP mode. (See figure 2.8-7 for switching details.)

A SUIT POWER switch on each panel controls application of power to the respective astronauts personal communications assembly microphone preamplifiers and the biomed preamplifiers contained in his constant wear garment.

SPT is accessed to the speaker box if he selects the SPEAKER position of the SPEAKER HEADSET switch on panel 98. Figure 2.8-8 shows the speaker box, panel 98, and the various switches used for its operation. The self-centering rocker switch has the identical function as that of the comm cable control head when depressed to the I'COM or XMIT position. The control for the speaker box is a three-position switch, spring-loaded to the ON position from the momentary CALL position. The ON position applies power to the speaker box whereas the SLEEP position removes all power from the

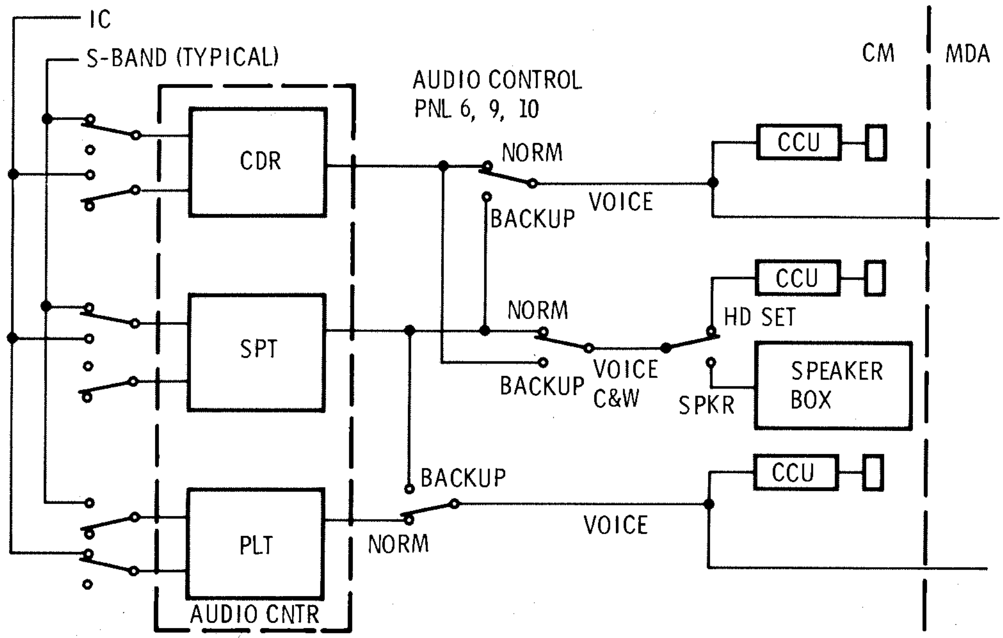


Figure 2.8-7. Audio Circuitry

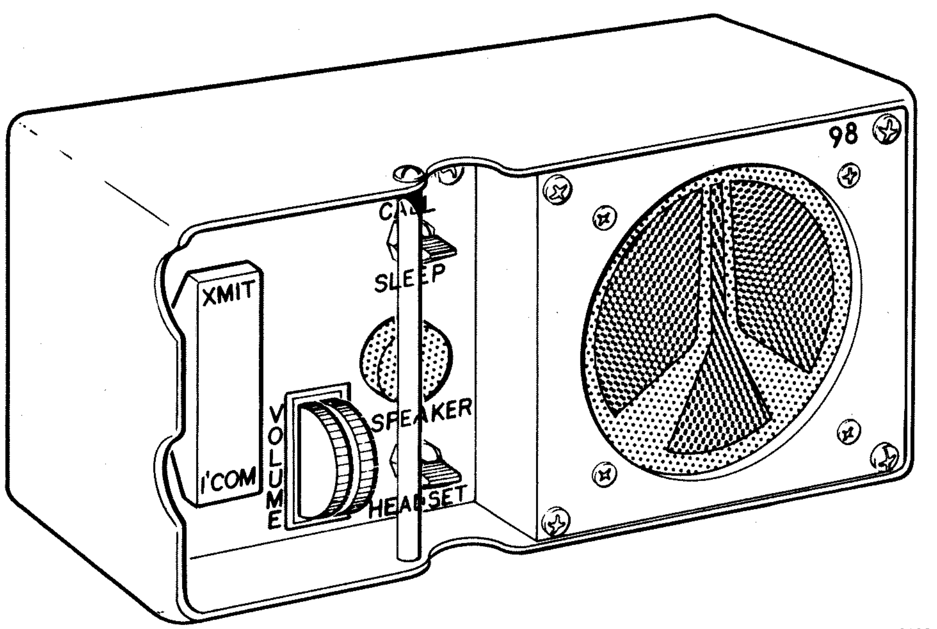


Figure 2.8-8. Speaker Box

speaker box but allows call capabilities from SWS. The CALL position allows intercommunications between the astronaut in the CM and the astronauts in the SWS. A volume control, speaker, and microphone are mounted directly on the speaker box.

A PTT BU switch on panel 3 allows the astronauts to use their own communications cable control head for the PTT mode of operation when configured in the backup mode of operation of the AUDIO CONTROL switch. The LEFT/CTR position parallels CDR and SPT PTT functions while the RIGHT position parallels SPT and PLT PTT functions. See figure 2.8-9 for switching details.

It is important to note that most signal processing done by the audio center is of preparatory nature. In order for any audio signal to be transmitted or received, the RF equipment must be in the proper operational mode.

2.8.3.1.5 CSM/SWS Telecommunication and Caution and Warning Interfaces

Figure 2.8-9A illustrates the interfaces between the CSM telecommunication system and the SWS telecommunication system through the tunnel umbilicals.

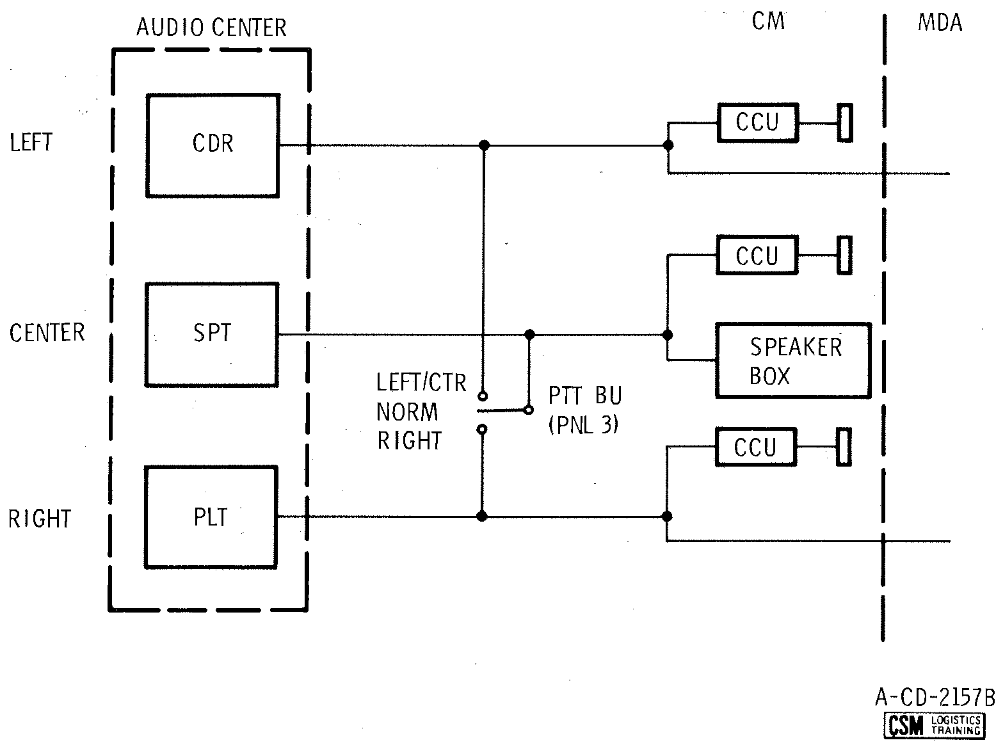


Figure 2.8-9. PTT Circuitry

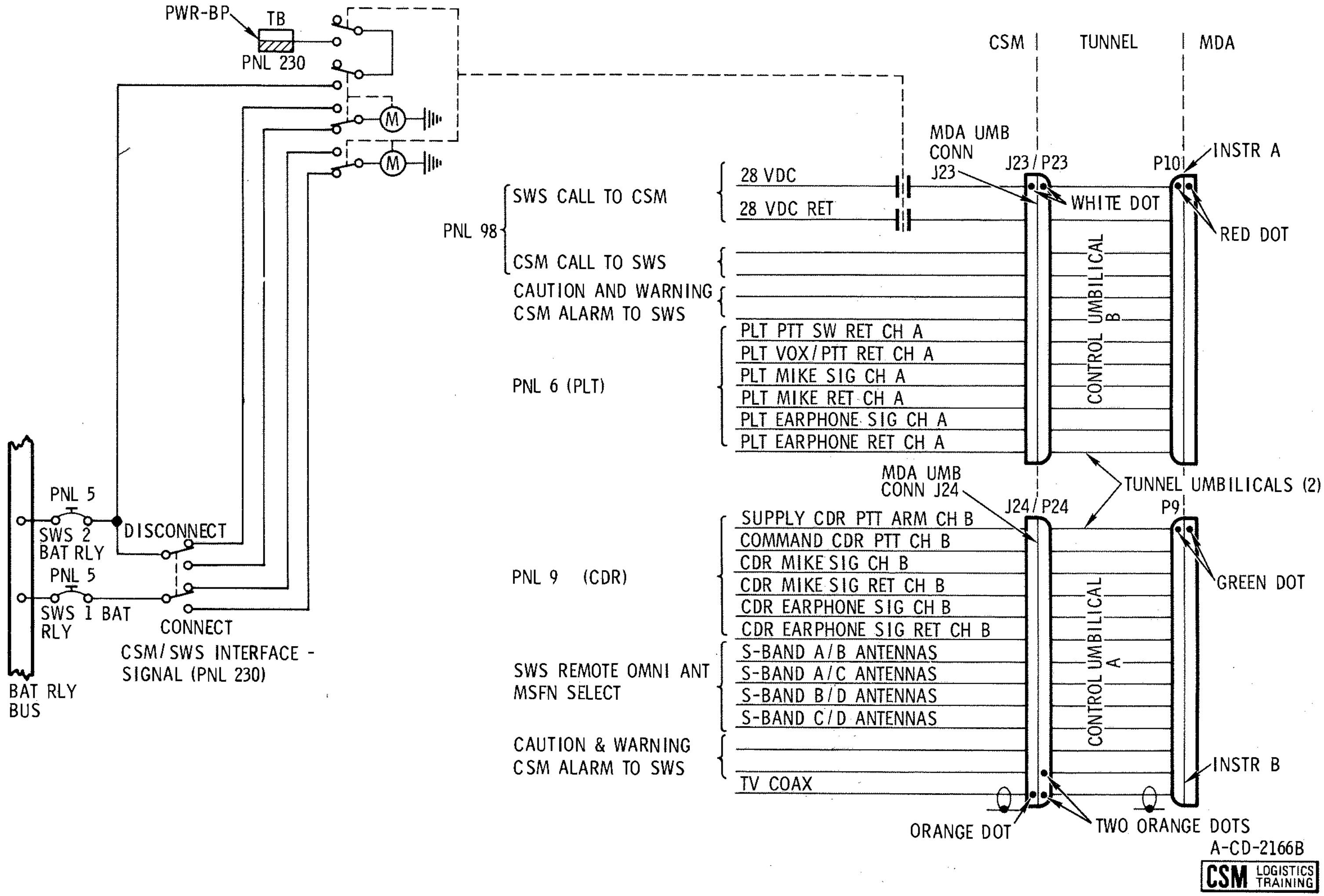


Figure 2.8-9A. CSM/SWS Telecomm/Caution and Warning Interface

T/C

Tunnel control umbilical B contains channel A microphone and earphone signals. In addition, umbilical B contains the SWS call to CSM and CSM call to SWS signals. The caution and warning CSM alarm signal is routed through both control umbilicals A and B for redundancy purposes.

Tunnel control umbilical A contains channel B microphone and earphone signals. In addition, umbilical A contains the SWS remote S-band omni-antenna STDN select lines and the TV coax which contains SWS video information.

The SWS call to CSM signal consists of a 28 vdc and a d-c return line. These control lines are closed by motor switch contacts. The motor switch is activated by the CSM/SWS INTERFACE - SIGNAL switch on panel 230 in the CONNECT position.

2.8.3.1.6 Swimmers Umbilical Cable

The swimmers umbilical cable is deployed with the dye marker in the recovery phase of the mission. It provides a hard-line connection to the spacecraft intercom bus for the recovery force swimmers. Actual deployment is accomplished by activating the guarded DYE MARKER switch on panel 8 which provides 28 vdc to a pyrotechnic actuator.

2.8.3.2 Intercommunication System Interfaces

Figure 2.8-10 illustrates the interfaces between the intercommunications group and the other telecommunications equipment.

A function not too obvious is CM/SWS voice log recording and playback. The intercom bus of the audio center is connected through the premodulation processor to the data storage equipment (DSE). Any time the DSE is recording, the conversation on the intercom bus will be recorded as well, in some instances, as the received voice from the VHF/AM equipment. There are no provisions to monitor this recorded voice in the SC.

2.8.3.3 Data Equipment

2.8.3.3.1 Instrumentation Equipment Group

The SC instrumentation equipment consists of various types of sensors and transducers for providing environmental, operational status, and performance measurements of the SC structure, operational systems, and experimental equipment. The outputs from these sensors and transducers are conditioned into signals suitable for utilization by the SC displays, presentation to the PCM TLM equipment, or both. In addition, various digital signals are presented to the PCM TLM equipment, including event information, guidance and navigation data, and a time signal from the CTE.

Many of the signals emanating from the instrumentation sensors are of forms or levels which are unsuitable for use by the SC displays or PCM TLM equipment. Signal conditioners are used to convert these signals to forms and levels which can be utilized. Some signals are conditioned at or near the sensor by individual conditioners located throughout the SC. Other signals are fed to the signal conditioning equipment (SCE), a single electronic package located in the lower equipment bay. (Refer to paragraph 2.8.3.3.5 for signal conditioning equipment.) In addition to conditioning many of the signals, the SCE also supplies 5-volt d-c excitation power to some sensors. The SCE can be turned on or off with the POWER-SCE switch on panel 3. This is the only control that the crew can exercise over instrumentation equipment for operational and flight qualification measurements. These two instrumentation groups are discussed in paragraphs 2.8.3.3.2 and 2.8.3.3.3. A scientific J-box is used to connect the scientific experiments to the PCM TLM equipment. STDN has control over the experiments through the J-box because of interface between the J-box and the UDL equipment.

2.8.3.3.2 Operational and Flight Qualification Instrumentation

Operational measurements are those which are normally required for a routine mission and include three categories: in-flight management of the SC, mission evaluation and system performance, and preflight checkout of the SC. The operational instrumentation sensors and transducers are capable of making the following types of measurements: pressure, temperature, flowrate, quantity, angular position, current, voltage, frequency, RF power, and "on-off" type events.

Flight qualification measurements may vary between SC, depending on mission objectives and state-of-hardware development. These measurements will be pulse-code modulated along with the operational measurements and transmitted to the STDN.

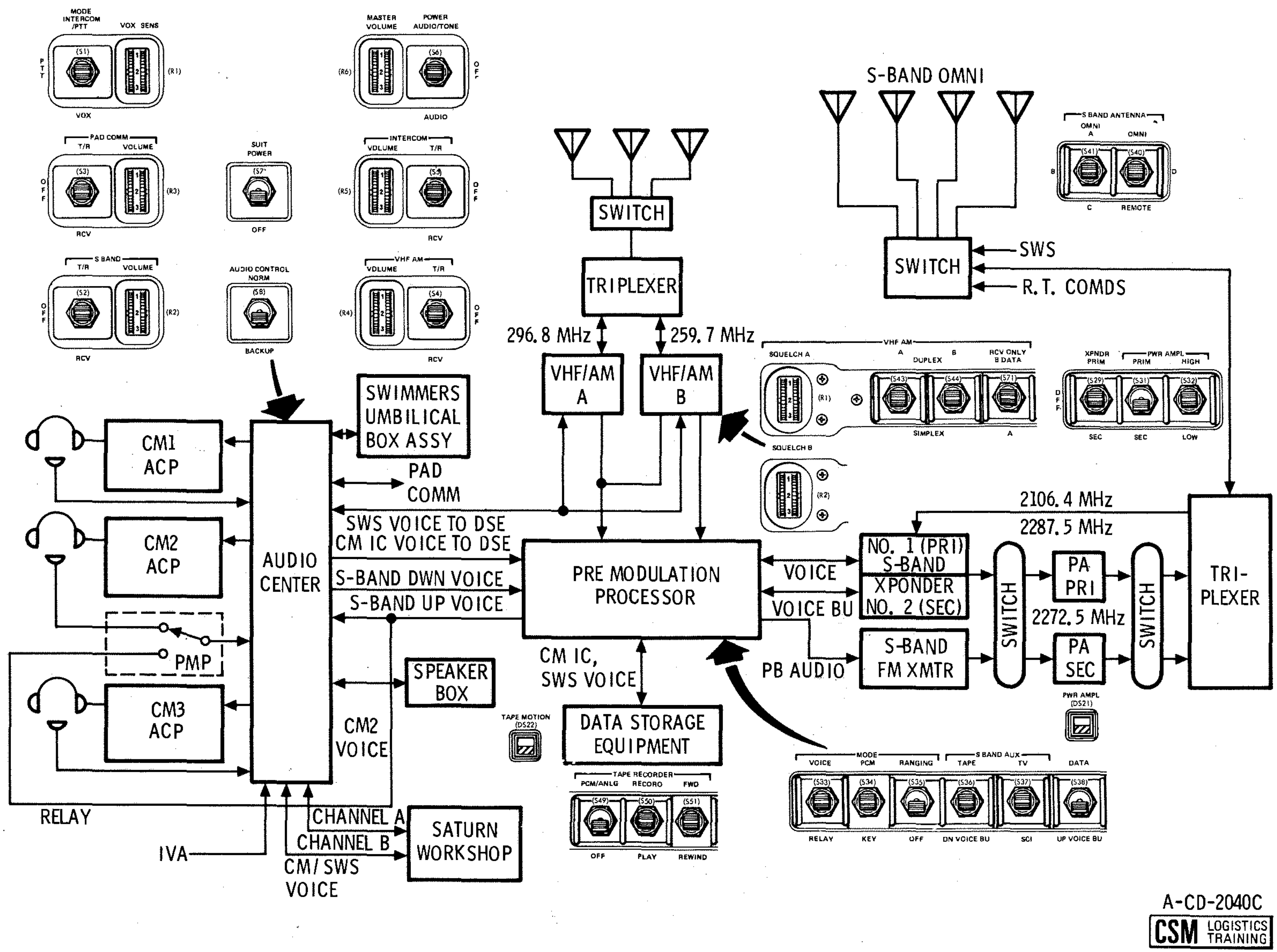


Figure 2.8-10. Audio Interfaces

2.8.3.3.3 Data Equipment Interfaces

Figure 2.8-11 illustrates the major interfaces between the units that make up the data equipment and their interfaces with the RF equipment group.

2.8.3.3.4 Central Timing Equipment (CTE)

The CTE provides precision square-wave timing pulses of several frequencies to time-correlate all SC time-sensitive functions. It also generates and stores the real-time day, hour, minute, and second mission elapse time (MET), in binary-coded decimal (BCD) format for transmission to the STDN. (See figure 2.8-12.)

In the primary or normal mode of operation, the command module computer (CMC) provides a 1024-kc sync pulse to the CTE. This automatically synchronizes the CTE with the CMC and provides a stability of $\pm 2 \times 10^{-6}$ parts in 14 days. In the event of sync pulse failure, the CTE automatically switches to the secondary mode of operation with no time lapse and operates using its own crystal oscillator at a stability reduced to $\pm 2.2 \times 10^{-6}$ parts in 5 days.

The CTE requires approximately 20 watts of 28-vdc power for its two redundant power supplies. Each one is supplied from a different power source and through separate circuit breakers. These circuit breakers, CENTRAL TIMING SYS-MN A and - MN B on panel 225, provide the only external means of control for the CTE. The two power supplies provide paralleled 6-volt d-c outputs, either one of which is sufficient to power the CTE.

The timing signals generated by the CTE, and their applications, are listed in the CTE outputs charts.

CTE OUTPUTS

Signal	Destination	Purpose
512-kc sq wave	PCM	Sync of internal clock
512-kc sq wave	PMP	Modulating signal for S-band emergency key transmission and subcarrier development
6.4-kc sq wave	EPS inverters (3)	Sync of 400-cycle a-c power
10-cps sq wave	Digital event timer and mission timer	Pulse digital clock
1-cps sq wave	PCM	PCM frame sync
1 pulse per 10 minutes	ECS	Discharge water from astronaut suit
25-bit parallel time code output	PCM	Time correlation of PCM data
Serial time code output (3)	NA	Not used for Skylab

TELECOMMUNICATION SYSTEM

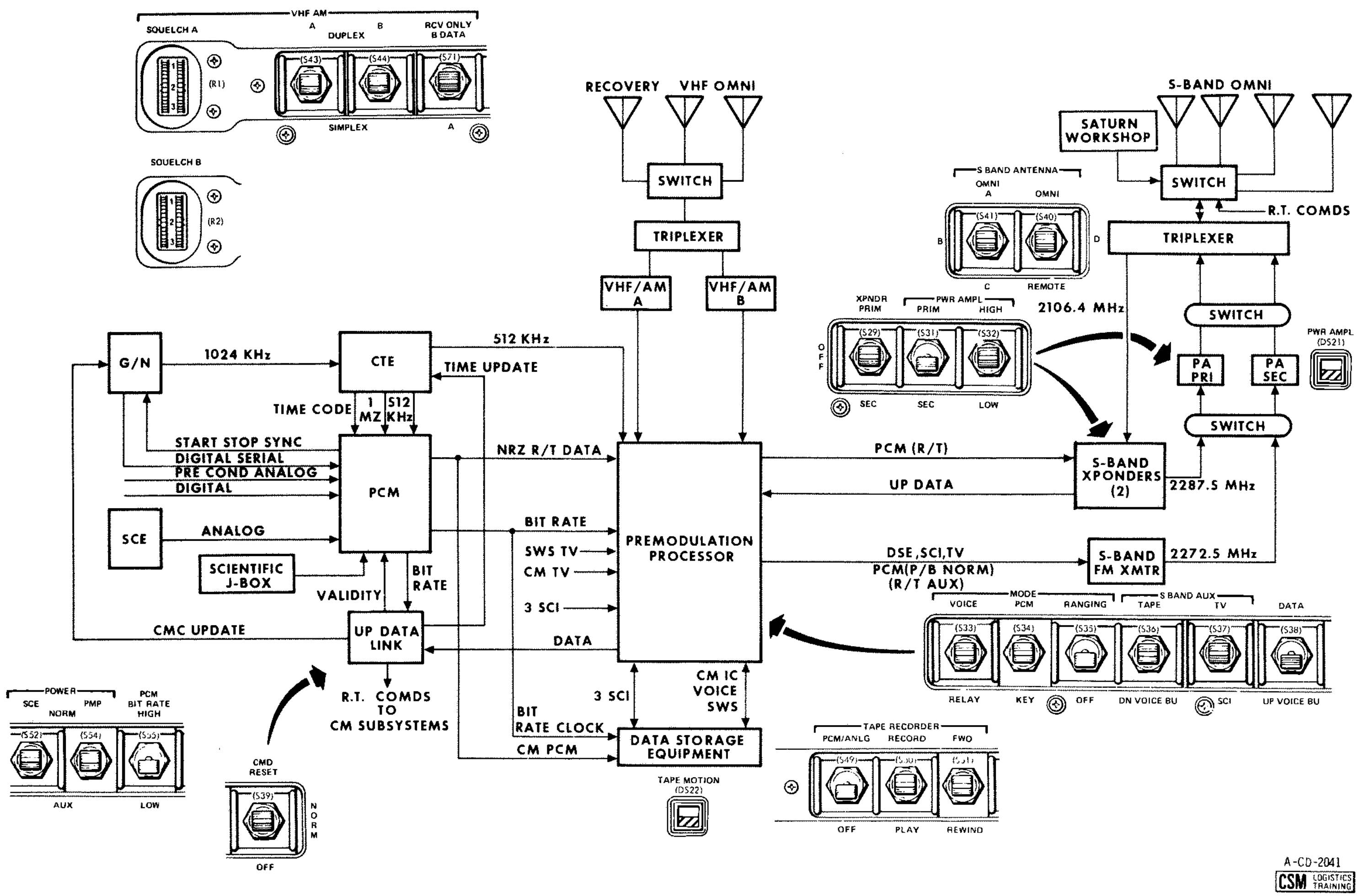


Figure 2.8-11. Data Interfaces

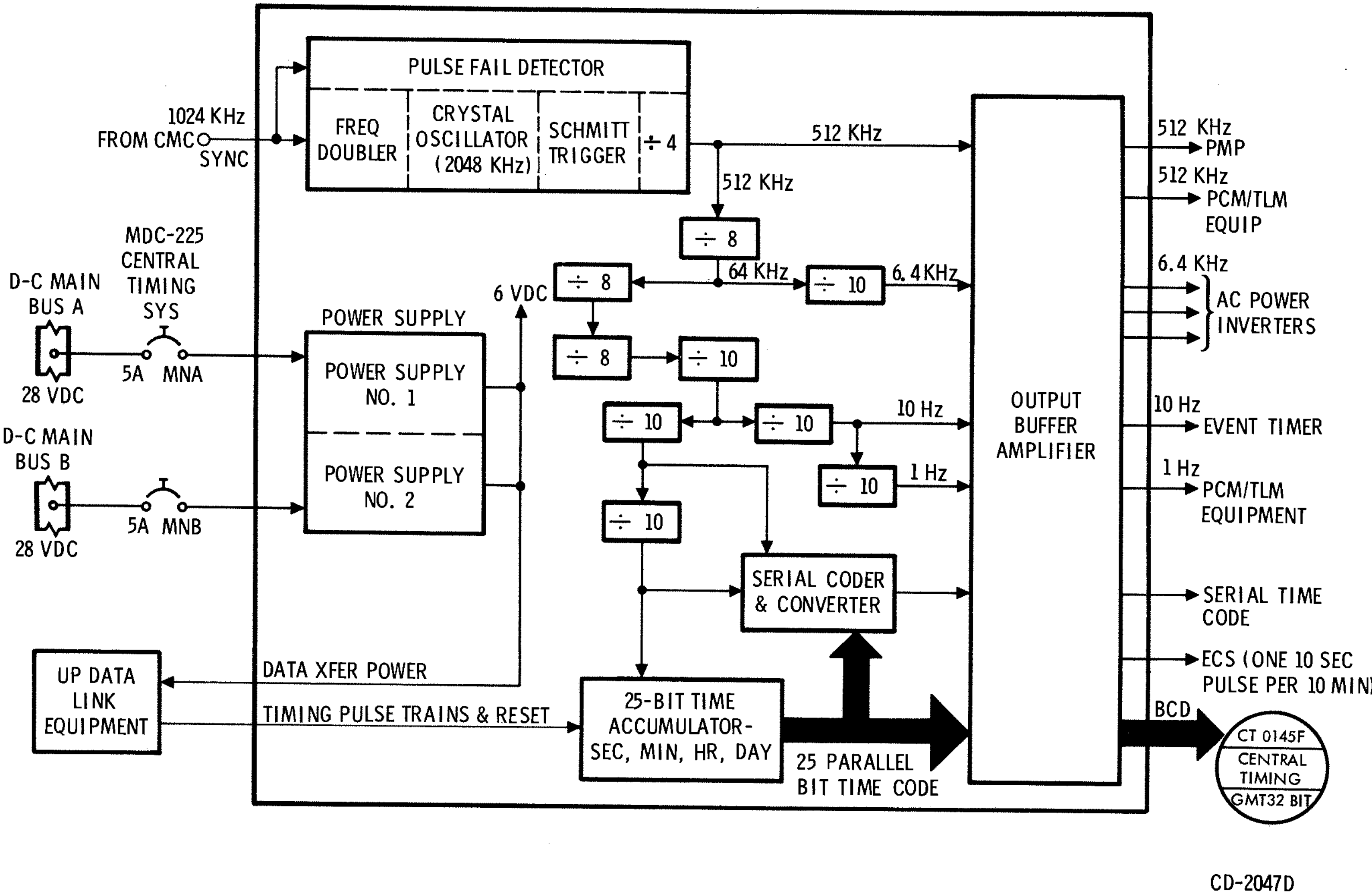


Figure 2.8-12. Central Timing Equipment

2.8.3.3.5 Signal Conditioning Equipment (SCE)

The signal conditioning equipment (SCE) is contained in a single electronics package located in the LEB. (See figure 2.8-13.) Its functions are to convert various kinds of unconditioned signals from the instrumentation equipment into compatible 0- to 5-volt d-c analog signals, and to provide excitation voltages to some of the instrumentation sensors and transducers.

The SCE contains the following modules:

- DC differential amplifier assembly
- DC differential bridge amplifier assemblies
- AC to DC converter assembly
- DC active attenuator assembly
- Power supply +20 vdc, -20 vdc, +10 vdc, +5 vdc
- Redundant power supply - +20 vdc, -20 vdc, +10 vdc, +5 vdc.

The only external control for the SCE is the three-position SCE switch on panel 3. The NORMAL position energizes the primary power supply and an error detection circuit. If the primary power supply voltages go out of

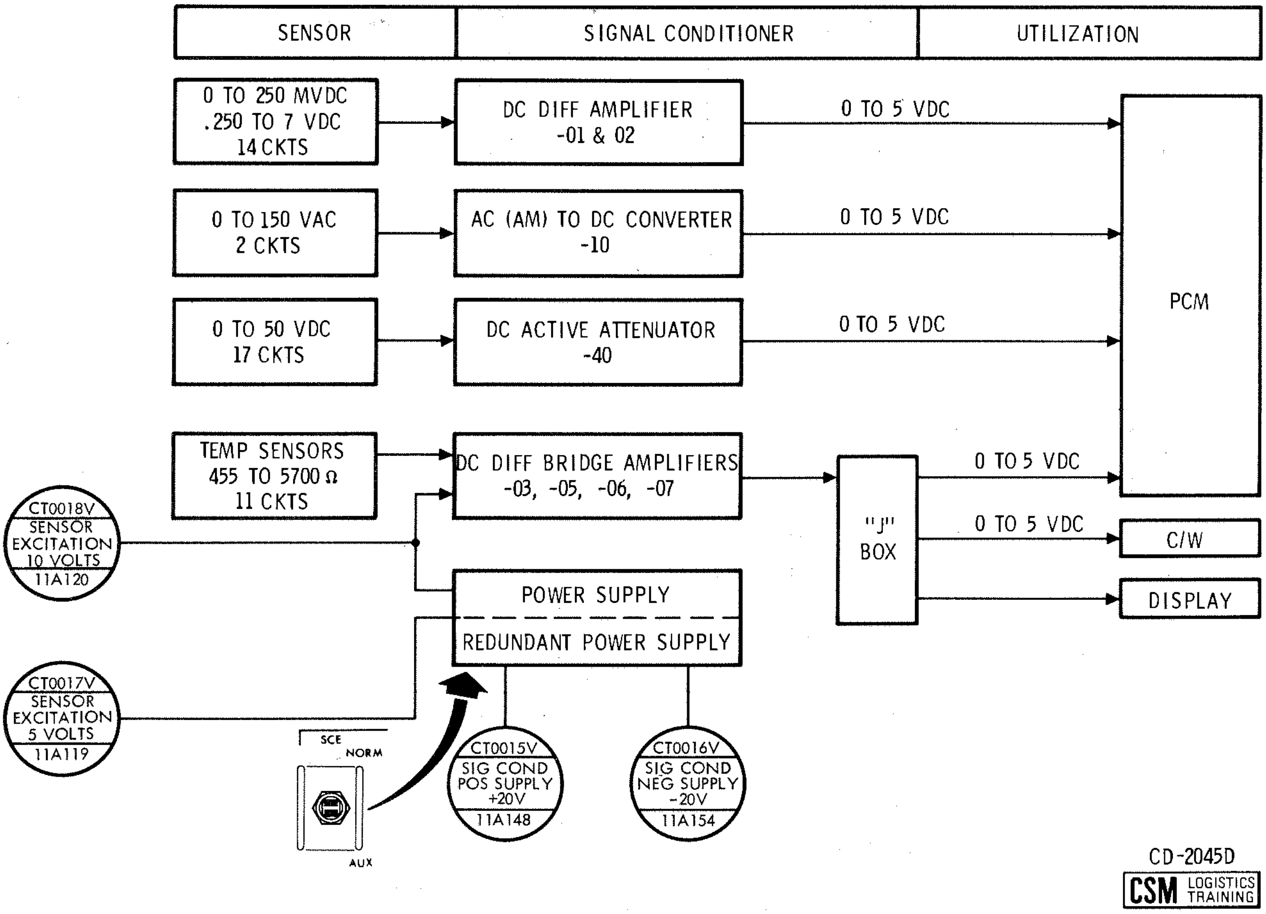


Figure 2.8-13. Signal Conditioning Equipment

tolerance, the error detection circuit automatically switches the SCE to the redundant power supply. The SCE will not automatically switch back to the primary once it has switched to the redundant unless power is interrupted.

The AUX position provides for manual switching between the power supplies. This is accomplished by repeated selection of the AUX position.

The SCE requires 28-volt d-c power input and consumes about 35 watts.

Figure 2.8-13 shows graphically the input and outputs of the SCE and its redundant power supply.

2.8.3.3.6 Pulse-Code Modulation Telemetry (PCM TLM) Equipment

The function of the PCM TLM equipment (figure 2.8-14) is to convert TLM data inputs from various sources into one serial digital output signal. This single-output signal is routed to the PMP for transmission to the STDN or to the DSE for storage. The PCM TLM equipment is located in the lower equipment bay. Input signals to the PCM TLM equipment are of three general types: high-level analog, parallel digital, and serial digital.

Two modes of operation are possible: the high (normal) bit-rate mode of 51.2 kilobits per second (kbps) and the low (reduced) bit-rate mode of 1.6 kbps. Operational mode is selected by placing the PCM BIT RATE switch on panel 3 to HIGH or LOW, as applicable. When the switch is in the LOW position, the high-PCM bit-rate can be commanded by the STDN via the UDL equipment. The PCM requires about 21 watts of 3-phase 115/200-volt 400-cps a-c power. Internal signal flow of the PCM is shown in figure 2.8-14.

The analog multiplexer can handle 365 high-level analog inputs in the high-bit-rate mode. Four of these signals, 22A1-4, are sampled at 200 SPS; 16 signals, 12A1-16, are sampled at 100 SPS; 15 signals, 51A1-15, are sampled at 50 SPS; 180 signals, 11A1-180, are sampled at 10 SPS; and 150 signals, 10A1-150, are sampled at 1 SPS.

T/C

These analog signals are gated through the multiplexer, the high-speed gates, and are then fed to the coder. In the coder, the 0- to 5-volt analog signal is converted to an 8-bit binary digital representation of the sample value. This 8-bit word is parallel-transferred into the digital multiplexer where it is combined with 38 external 8-bit digital parallel inputs, and 5 internal ones, to form the majority of the output format.

The external digital parallel inputs fall into three groups. The first group contains two 8-bit word inputs sampled at 200 S/S at the high-bit rate only. The second group contains a single 8-bit word input sampled at 50 S/S at the high-bit rate and 10 S/S at the low-bit rate. The third, and largest, group contains 35 eight-bit word inputs sampled at 10 S/S at the high-bit rate and one S/S at the low-bit rate. The remaining inputs to the digital multiplexer are internal and come from the coder, sync format, and programmer of the PCM.

This digital parallel information is parallel-transferred into the output register where it is combined with the command module computer digital serial input, and then dumped serially into the data transfer buffer. From here the information is passed on to the premodulation processor for preparation for transmission over the RF equipment.

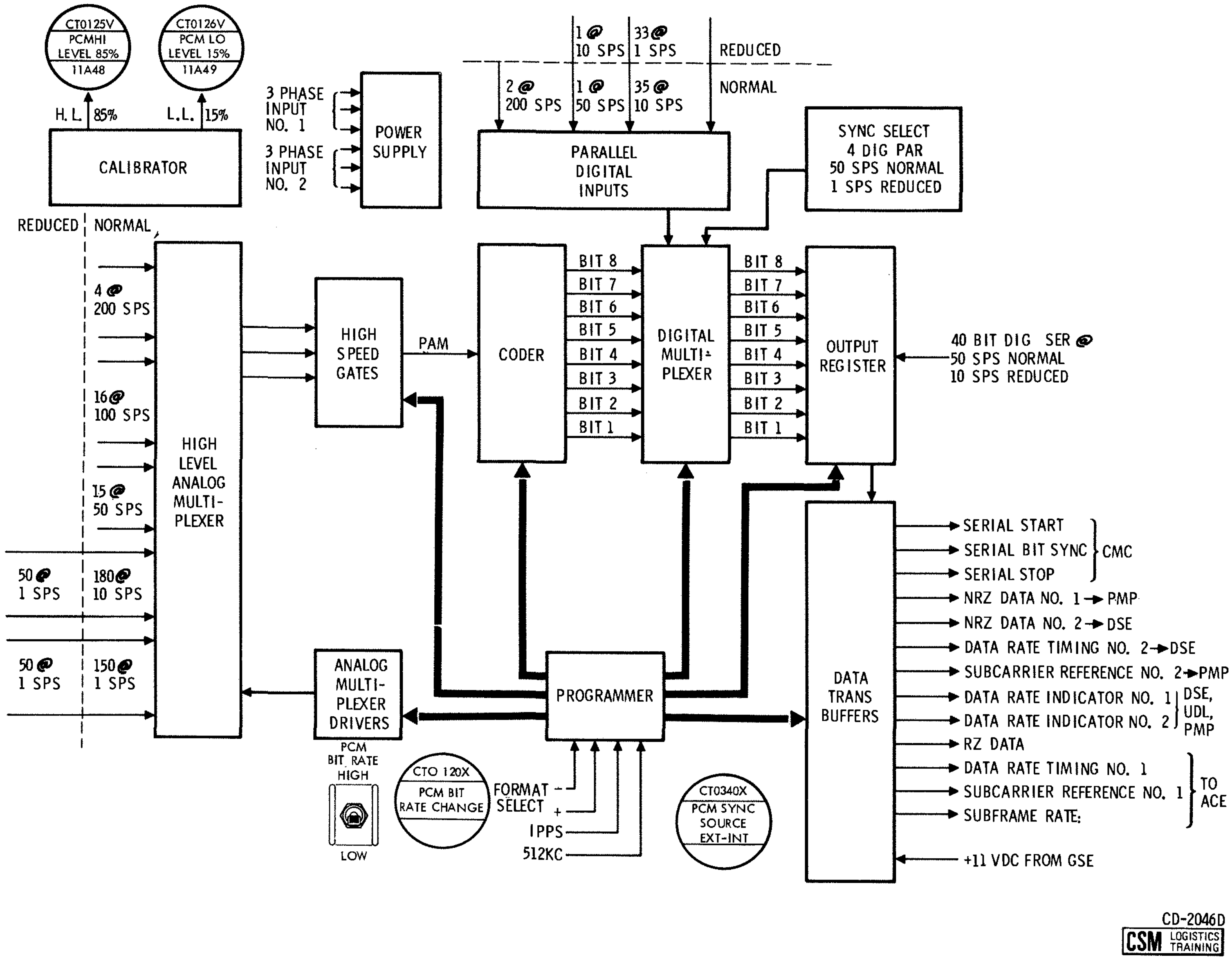


Figure 2.8-14. PCM Block Diagram

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Figures 2.8-15 and 2.8-15A deleted.

The PCM receives 512-kc and 1-cps timing signals from the central timing equipment. If this source fails, the PCM programmer uses an internal timing reference. The timing source being used is telemetered. Two calibration voltages are also telemetered as a confidence check of the PCMs overall operation.

The PCM requires about 21 watts of 3-phase 400-cycle power for its redundant power supplies.

2.8.3.3.7 Television (TV) Equipment

The color TV equipment consists of a small, portable color TV camera that is hand-held. One of the camera's functions is to acquire real-time color video information for transmission to the STDN. The camera's function is its use during rendezvous and docking operations, formation flight (undocking), experiment operations, workshop tour, systems housekeeping, and EVA.

A TV monitor is used with the color TV camera for astronaut viewing of TV operations so that f-stop, light level, zoom position and focus can be properly accomplished. See figure 2.8-16 for details of camera and monitor. The camera can be used in the SWS by the proper selection of the TV SOURCE - SWS/CM switch on panel 3.

The camera is controlled by an XMITT/STANDBY switch and an automatic light control switch on the back. Power is supplied to the cameras XMITT/STANDBY switch through CB13 located on RHEB-225 when the S-BAND AUX TAPE/DN VOICE BU switch (panel 3) is in the OFF position and the S-BAND AUX TV/SCI switch (panel 3) is in the TV position. Power required by the camera is 23 watts at 28 volts dc. Power required by the monitor is 2.5 watts at 28 volts dc.

T/C

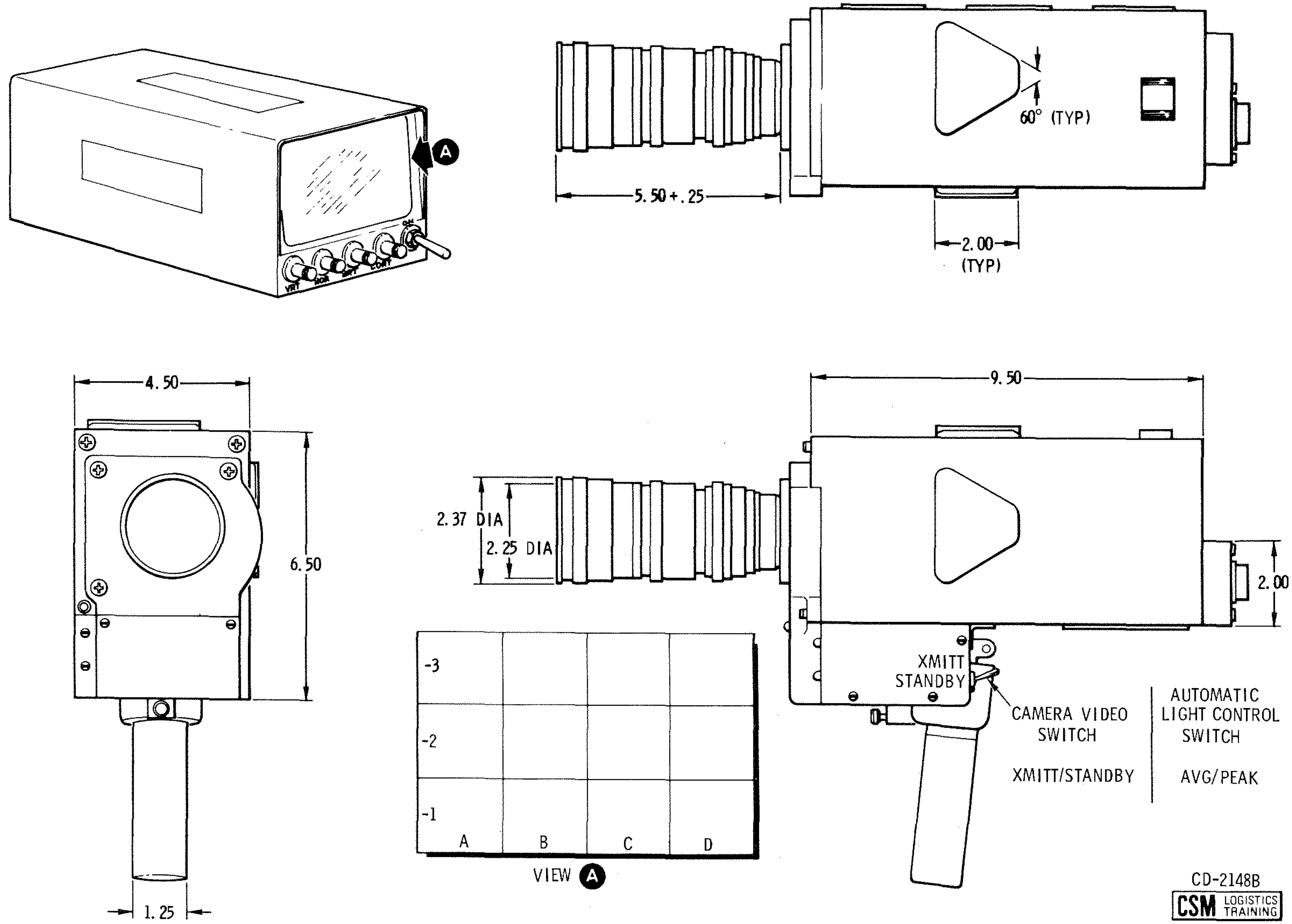


Figure 2.8-16. Color TV Camera and Monitor

The composite video signal is sent from the camera to the premodulation processor where it is then sent to the S-band FM transmitter and its associated power amplifier for transmission to the STDN and to the SM umbilical for hardline communications before lift-off.

2.8.3.3.8 Data Storage Equipment (Figure 2.8-17)

The data storage equipment provides for the storage of data for delayed playback and/or recovery with the spacecraft. Information is recorded during powered flight phases, and when out of communication, is then played back (dumped) when over selected S-band stations.

- Location: lower equipment bay.

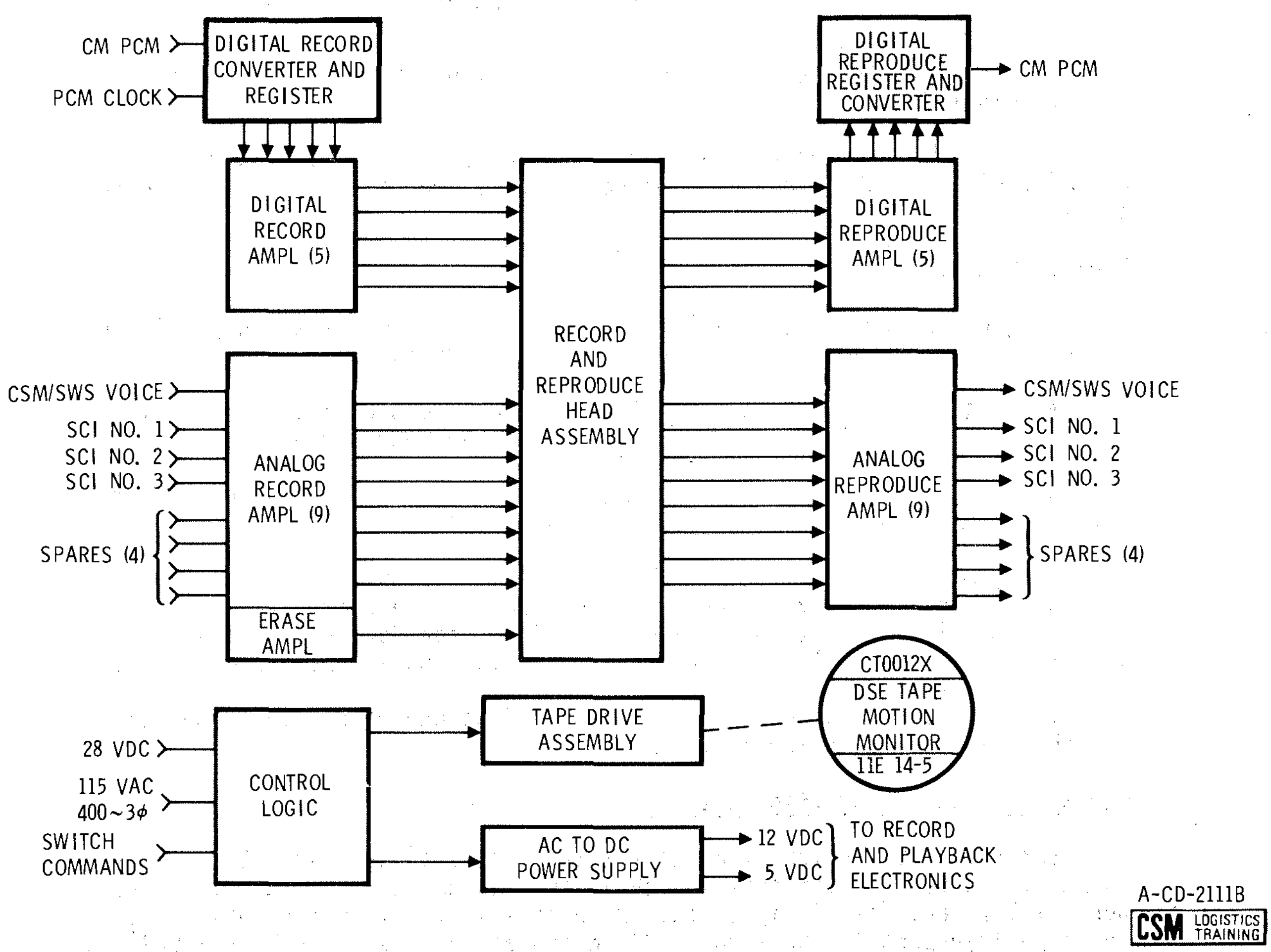


Figure 2.8-17. Data Storage Equipment

T/C

Electrical Power Requirements

- Voltage input: 115-vac 3-phase 400-cps and 28-vdc
- Power input: 40 watts nominal, 70 watts maximum (3 seconds).

Tape Transport Characteristics

- Tape speeds: 3.75, 15, and 120 ips
- Operational stability: Stable in less than 5 seconds
- Single directional: A rewind mode is provided
- Automatic selection: Tape speed determined by data rate
- Remote control: Complete remote operation possible via up-data link
- 2250 feet of tape giving record times of 2 hours at 3-3/4 ips and 30 minutes at 15 ips.

Channels. Fourteen parallel tracks: four CM PCM digital data, and one of digital clock, one CM/SWS voice, three scientific data, and five spare tracks.

Digital Channels

a. Input parameters, serial to parallel conversion of the digital input is performed by the data storage equipment electronics:

- Single serial NRZ, 51.2 kbs data train, and one 51.2-kc digital timing signal, recorded speed at 15 inches per second
- Single serial NRZ, 1.6 kbs data train, and one 1.6-kc digital time signal, recorded at 3.75 inches per second

b. Output parameters, parallel to serial conversion of the digital output, are performed by the data storage equipment electronics.

c. The playback rate of CM PCM is 51.2 kbs for data recorded at 3.75 ips or 15 ips. Playback speeds are 120 ips and 15 ips respectively.

The various operational capabilities and attendant switching positions are shown in the following list.

Operational Switching (Figure 2.8-18)

External +28 vdc from the FLT BUS is applied to the TAPE RECORDER - FWD/REWIND switch. With this switch in the REWIND position, the tape transport will reverse at 120 ips. The FWD position of this switch will also run the tape transport in the forward direction at 120 ips if PLAY or RECORD is not selected. The FWD position of the TAPE RECORDER - FWD/REWIND switch supplies the excitation to the RECORD/PLAY switch in the FWD position. In the RECORD position, the record and erase circuitry is enabled and power is applied to the PCM BIT RATE-HIGH/LOW switch. The recording speed in the HIGH position is 15 ips and in the LOW position the speed is 3.75 ips. In the PLAY position, the reproduce circuitry is enabled and power is applied to the automatic speed control circuit. The PCM/ANLG/OFF switch is not used for Skylab.

	RECORD			PLAYBACK			
Panel 3 Switches	3-SCIs	CSM PCM	SWS CSM Voice	3-SCIs	CSM PCM	SWS CSM Voice	REWIND
S-BAND AUX TAPE	Normally off	Normally off	Normally off	TAPE	TAPE	TAPE	Normally off
S-BAND AUX TV	Off or TV	N/A	N/A	Tape sw override	Tape sw override	Tape sw override	N/A
VHF/AM A	Normally SIMPLEX	Normally SIMPLEX	Normally SIMPLEX	N/A	N/A	N/A	N/A
VHF/AM RCV only	N/A	N/A	Off	N/A	N/A	N/A	N/A
TAPE RECORDER/ PCM/ANLG (NOT USED)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TAPE RECORDER/ RECORD	RECORD	RECORD	RECORD	PLAY	PLAY	PLAY	Normally off
TAPE RECORDER/ FWD	FWD	FWD	FWD	FWD after REWIND	FWD after REWIND	FWD after REWIND	REWIND
PCM BIT RATE	N/A	High or low	N/A	N/A	N/A	N/A	N/A

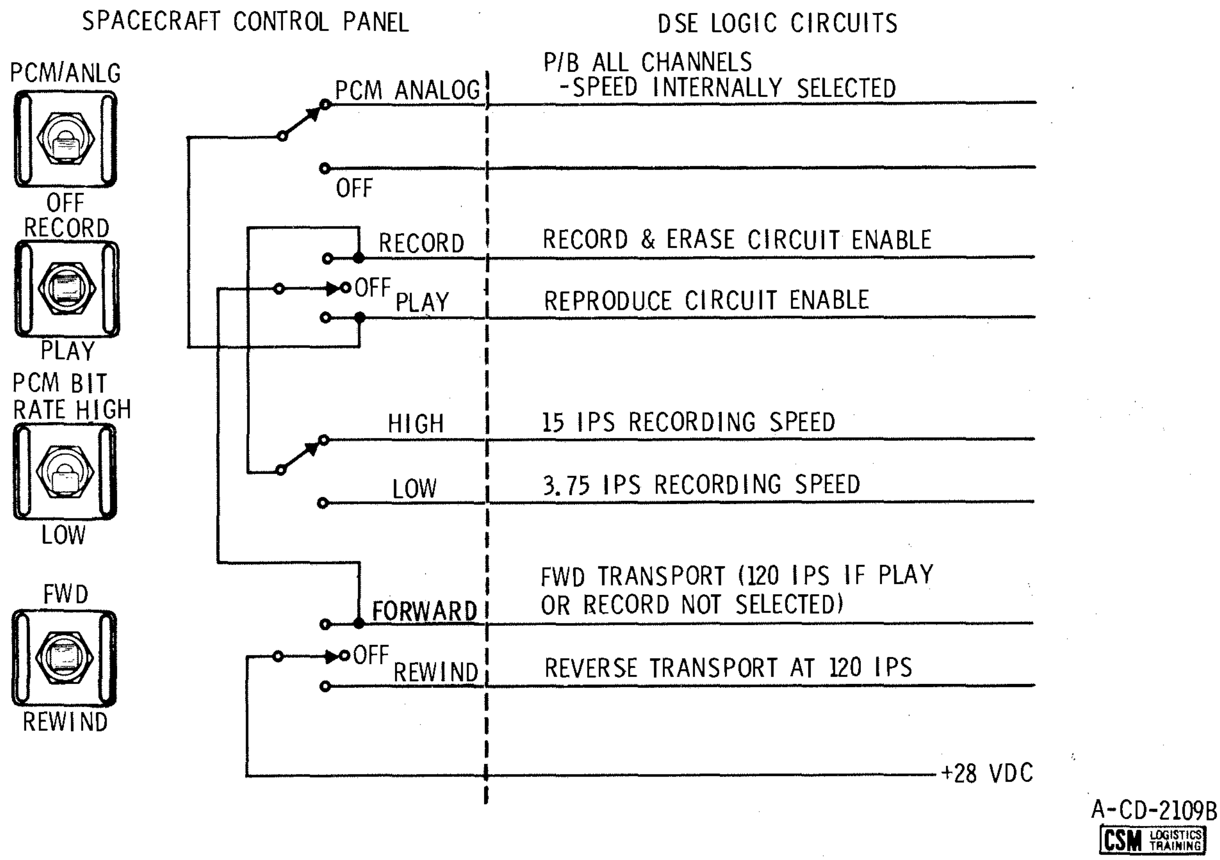


Figure 2.8-18. DSE Simplified Switching Circuits

All of the preceding switching functions may be accomplished by the use of real-time commands from the STDN through the up-data (UDL) equipment.

2.8.3.3.9 Up-Data Link (UDL) Equipment

The function of the UDL equipment is to receive, verify, and distribute digital updating information sent to the SC by the STDN at various times throughout the mission to update or change the status of operational systems. The UDL (figure 2.8-19) consists of detecting and decoding circuitry, a buffer storage unit, output relay drivers, and a power supply. The UDL provides the means for STDN to update the CMC, the CTE, and to select certain vehicle functions. Up-data information is transmitted to the SC as part of the 2-kmc S-band signal. When this signal is received by USBE receiver, the 70-kc subcarrier containing the up-data information is extracted and sent to the up-data discriminator in the PMP. The resulting composite audio frequency signal is routed to the sub-bit detector in the UDL which converts it to a serial digital signal. The digital output from the sub-bit detector is fed to the remaining UDL circuitry which checks and stores the digital data, determines the proper destination of the data, and transfers it to the appropriate SC system or equipment. The UDL has four controls; two are on panel 3

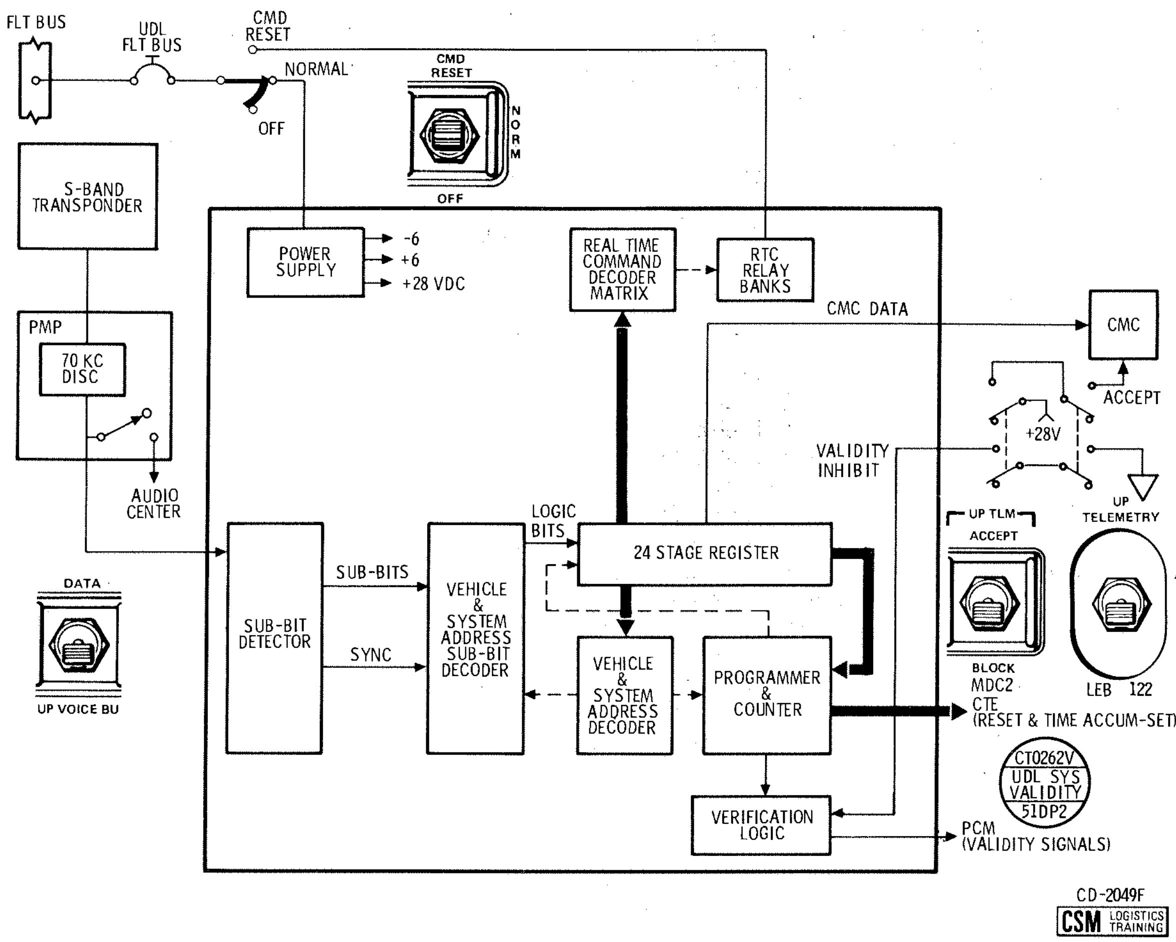


Figure 2.8-19. Up-Data Link Equipment

under the UP-TLM bracket, the third is on panel 2, and the fourth is on panel 122. The first, a two-position switch, is the DATA-UP VOICE BU switch. In the DATA position, the 70-kc subcarrier information is routed to the UDL equipment for normal processing. The UP VOICE BU position routes the 70-kc subcarrier information to the UDL equipment and audio centers, thus providing an alternate path for voice information to be sent in case of failure of the 30-kc subcarrier discriminator.

The second switch is the CMD RESET/NORMAL/OFF switch. The center, NORMAL, position applies power to the UDL and permits normal operation. The upward position performs a real-time command reset function and keeps power applied to the power supply. This resets all RTC relays except those relays affecting the system A abort light and the crew alarm, so the affected equipment will resume the operational mode dictated by their control switches on the panel 3. The OFF position removes the power from the UDL equipment. The UDL consumes about 12 watts of 28-vdc power.

The third control, on panel 2 by the DSKY, is labeled UP-TLM ACCEPT-BLOCK. This two-position switch blocks or routes the UDL message in the command module computer.

The fourth control, on panel 122, is labeled UP-TLM ACCEPT-BLOCK. This two-position switch is in series with the UP-TLM ACCEPT-BLOCK switch on panel 2 and performs the same function.

The following list gives the real-time commands and their functions. Some functions require multiple separate commands.

SKYLAB UDL REAL-TIME COMMANDS

Real-Time Commands	Functions	
01	Abort light (system A) On	
00	Abort light (system A) Off	
07	Abort light (system B) On	
06	Abort light (system B) Off	
05	Crew alarm on	
04	Crew alarm off	
17	Initiate experiment (clock update) on	SC 117 only
16	Initiate experiment (clock update) off	SC 117 only
03	Experiment data playback	SC 117 only
02, 13	Experiment data realtime	SC 117 only
02, 12	Experiment data realtime/playback off	SC 117 only
02	Experiment data playback off	SC 118 only
03	Experiment data playback	SC 118 only
10, 14	G&N ACE hardline disconnected	
11, 15	G&N ACE hardline connected	
22, 27	S-band ranging on	
23	S-band ranging off	
22, 26	*Astronaut control (S-band ranging)	
32, 37	S-band PCM mode on	
33, 37	S-band PCM mode off	
32, 36	*Astronaut control (S-band PCM mode)	
42, 47	S-band P.A. high on	
43, 46	S-band by-pass mode	
43, 47	S-band P.A. low on	
42, 46	*Astronaut control (S-band P.A. mode)	
62, 67	Tape recorder - record mode	
63, 66	Tape recorder - off mode	
63, 67	Tape recorder - playback mode	
62, 66	*Astronaut control (tape recorder playback/record selection)	
72, 77	Tape recorder - transport forward	
73, 76	Tape recorder - power off	
73, 77	Tape recorder - transport rewind	
72, 76	*Astronaut control (tape transport)	
65	PCM data rate low	
64, 71	PCM data rate high	
64, 70	*Astronaut control (PCM data rate)	
41, 45	S-band tape mode	
41, 44	S-band tape off	
40, 51	S-band back-up down voice	
40, 50	*Astronaut control (S-band)	

*Resets previously set relays so that equipment returns to mode shown on control panels.

SYSTEMS DATA

Real-Time Commands	Functions
75, 60, 54	D OMNI antenna ON
74, 60, 54	Astronaut control (S-band antenna)
55, 60 75	A OMNI antenna ON
55, 61	B OMNI antenna ON
55, 60, 74	C OMNI antenna ON
54, 61	Remote
20	E/PS - electronics power off
21	E/PS - electronics power on
52	TV off
53	TV on
12	E/PS - detector power off
13	E/PS - detector power on

T/C

2.8.3.4 RF Electronics Equipment Group

The RF electronics equipment group includes all T/C equipment which functions as RF transmitters or receivers. The antennas used by this equipment are mentioned only briefly in this paragraph. (Refer to paragraph 2.8.3.5 for more information on the antennas.)

2.8.3.4.1 VHF/AM Transmitter-Receiver Equipment (Figure 2.8-20)

The VHF/AM transmitter-receiver equipment provides the capability for the following:

- Two-way voice communications with STDN and recovery forces
- Ranging with the SWS

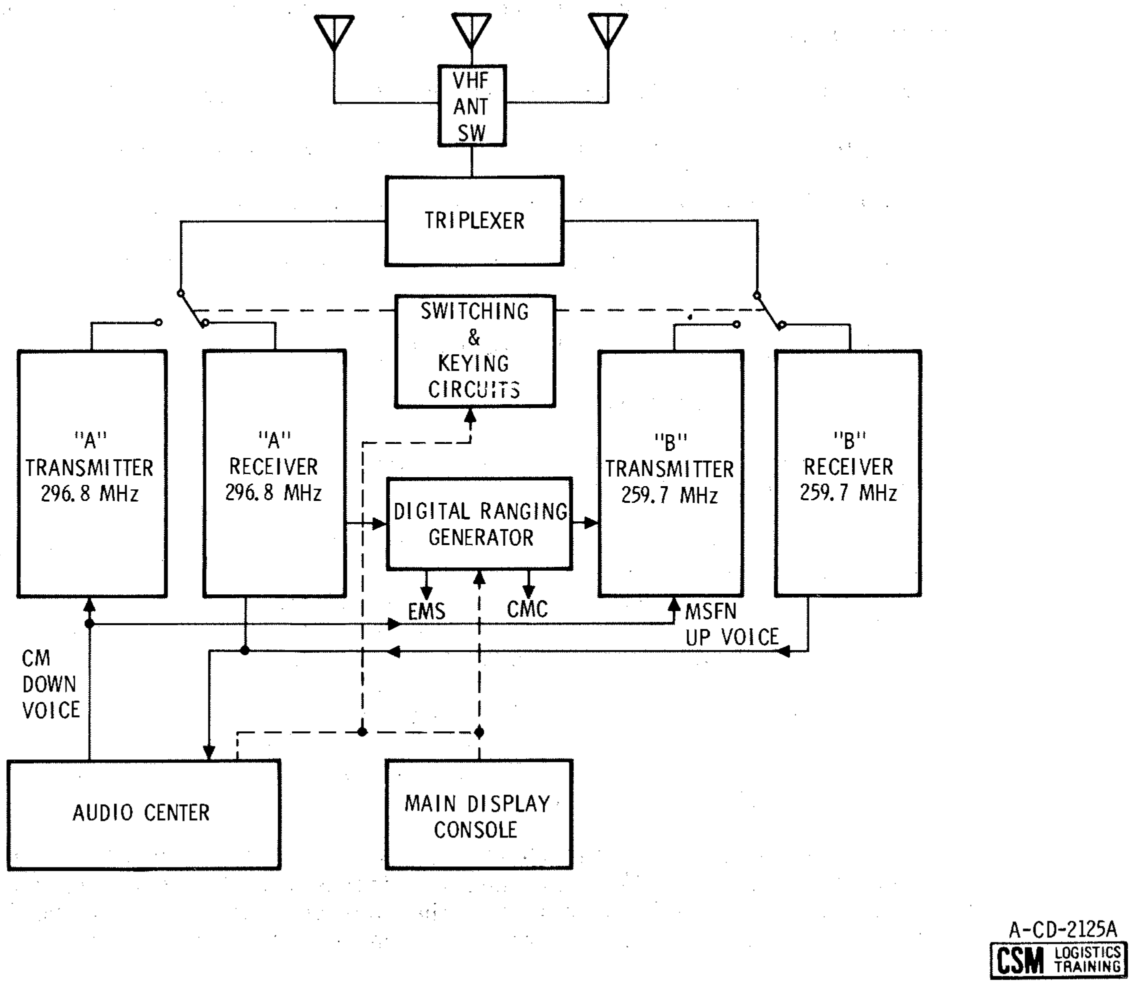


Figure 2.8-20. VHF-AM Block Diagram

T/C

The equipment is contained in a single enclosure consisting of 11 subassemblies, 2 coax relays, and 2 bandpass filters mounted within a three-piece hermetically sealed case in the lower equipment bay.

The equipment group provides two independent VHF/AM transmitters and two independent VHF/AM receivers. One transmitter and receiver will provide for transmission and reception of voice communications on a preassigned frequency of 296.8 mc. One transmitter and receiver will provide for transmission of voice communications or reception of voice communications and data on a preassigned frequency of 259.7 mc. Complete isolation of the receiver circuits up to the final common outputs is provided. A short or open on any output will not degrade the other outputs.

Various modes of operation are possible in both the simplex and duplex configurations.

- Simplex A - Transmit and receive on 296.8 mc for voice only
- Simplex B - Transmit and receive on 259.7 mc for voice only
- Duplex A - Transmit on 296.8 mc and receive on 259.7 mc for voice
- Duplex B - Transmit on 259.7 mc and receive on 296.8 mc for voice and ranging
- Receive A - Receive on 296.8 mc only
- Receive B - Receive on 259.7 mc only

These modes may also be used as a backup VHF recovery beacon transmitting on 296.8 or 259.7 mc.

The VHF/AM transmitter-receiver is controlled by the VHF-AM controls on panel 3 of the main display console (S43, S44, and S71). The DUPLEX-off-SIMPLEX switches activate the receivers and transmitters by applying 28-volt d-c power. About 6 watts of power are required in these modes with the transmitter in standby and about 36 watts when keyed. In the OFF position, no power will be supplied to the equipment. The RCV ONLY B DATA/OFF/A switch activates the receivers only. When the A position is selected, about 2 watts of 28-volt d-c power are supplied to the 296.8-mc receiver. When the B DATA position is selected, about 2 watts of 28-volt d-c power are supplied to the 259.7-mc receiver.

After being selected, the VHF/AM transmitters can be enabled either by voice-operated relay (VOX) or by manually depressing the XMIT switch on the comm cable or rotational controller. The squelch control varies the level of squelch sensitivity and is located on panel 3 of the main display console.

The transmitters and receivers interface with the main display console (power control), the audio center (audio inputs, outputs and PTT functions), and the triplexer (RF inputs and outputs). The equipment is connected through the triplexer and antenna control switch to either of the VHF omniantennas in the service module or the VHF recovery antenna No. 1 in the command module.

2.8.3.4.2 Digital Ranging Generator (VHF Ranging)

The function of the VHF ranging system is to aid the rendezvous of the CSM with the SWS. This system uses the existing VHF/AM equipment, and incorporates the use of a digital ranging generator (DRG).

- Location: Lower Equipment Bay
- Electrical Power Requirements
  Voltage input: 28 vdc
  Power input: 25 watts
- Mechanical Characteristics:
  Weight: 7.0 pounds
  Volume: 200 cubic inches (approximately)

The DRG generates a tone for transmission over the VHF/AM 259.7-mc transmitter, and receives the turn-around range tone from the SWS via the VHF/AM 296.8-mc receiver. A range tracker in the DRG will compute the range by comparing the difference between the transmitted and received tone, and display this range, real-time, on the entry monitoring system (EMS). In addition, the range data will also be sent to the command module computer (CMC), at a rate of once a minute, initiated by a command from the CMC. This information will be displayed on the DSKY. Both displays will be shown in units of 1/100-nautical mile.

This system is activated by turning on the VHF RANGING switch on panel 3. This switch applies +28-vdc power to the DRG, as well as applying a ground to the keying circuit to key the VHF/AM 259.7-mc transmitter, for ranging tone transmission. If the TRACKER alarm light on the DSKY comes ON, this indicates that the data on the DSKY is incorrect. At the same time the display on the EMS will be reset to read zero. To restart ranging, the VHF RANGING - RESET-NORMAL switch, on the commander's audio center panel, is put to RESET, the acquisition phase is started, and tracking will be established.

T/C

2.8.3.4.3 Unified S-Band Equipment (USBE)

The USBE (figure 2.8-21) consists of two transponders, an FM transmitter, and power supply contained in a single electronic package in the lower equipment bay. The USBE will be used for voice communications, tracking and ranging, transmission of PCM data, and reception of up-data. The USBE also provides the sole means for transmission of TV.

The USBE tracking method employed is the two-way or double-doppler method. In this technique, a stable carrier of known frequency is transmitted to the SC where it is received by the phase-locked receiver, multiplied by a known ratio, and then re-transmitted to the STDN for comparison. Because of this capability, the USBE is also referred to as the S-band transponder.

For determining SC range, the STDN phase-modulates the transmitted carrier with a pseudo-random noise (PRN) binary ranging code. This code is detected by the SC USBE receiver and used to phase-modulate the carrier transmitted to the STDN. The STDN receives the carrier and measures the amount of time delay between transmission of the code and reception of the

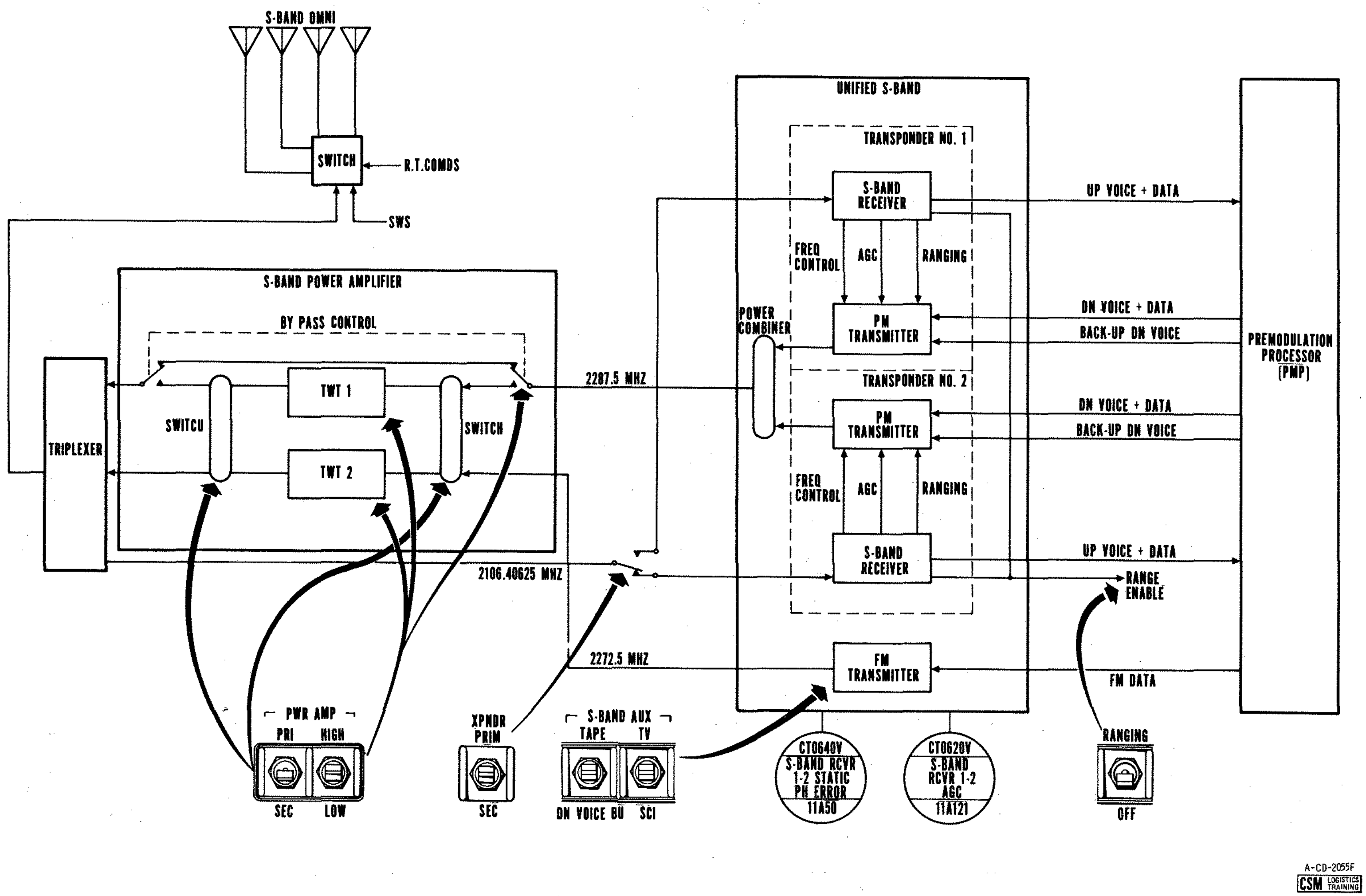


Figure 2.8-21. Unified S-Band Equipment

same code, thereby obtaining an accurate measurement of range. Once established, this range can be continually updated by the double-doppler measurements discussed earlier. The STDN can also transmit up-data commands and voice signals to the SC USBE by means of two subcarriers: 70 kc for up-data and 30 kc for up-voice.

The USBE transponder is a double-superheterodyne phase-lock loop receiver that accepts a 2106.4-mc, phase-modulated RF signal containing the up-data and up-voice subcarriers, and a pseudo-random noise (PRN) code when ranging is desired. This signal is supplied to the receiver (figure 2.8-22) via the triplexer in the S-band power amplifier equipment and presented to three separate detectors: the narrow band loop phase detector, the narrow band coherent amplitude detector, and the wide band phase detector. In the wide band phase detector, the 9.531-mc IF is detected; and the 70-kc up-data and 30-kc up-voice subcarriers are extracted, amplified, and routed to the up-data and up-voice discriminators in the PMP equipment. Also, when operating in a ranging mode, the PRN ranging signal is detected, filtered, and routed to the USBE transmitter, as a signal input to the phase modulator. In the loop-phase detector, the 9.531-mc IF signal is filtered and detected by comparing it with the loop reference frequency. The resulting d-c output is used to control the frequency of the 19.0625-mc voltage-controlled oscillator (VCO). The output of the VCO is used as the reference frequency for receiver circuits as well as for the transmitter.

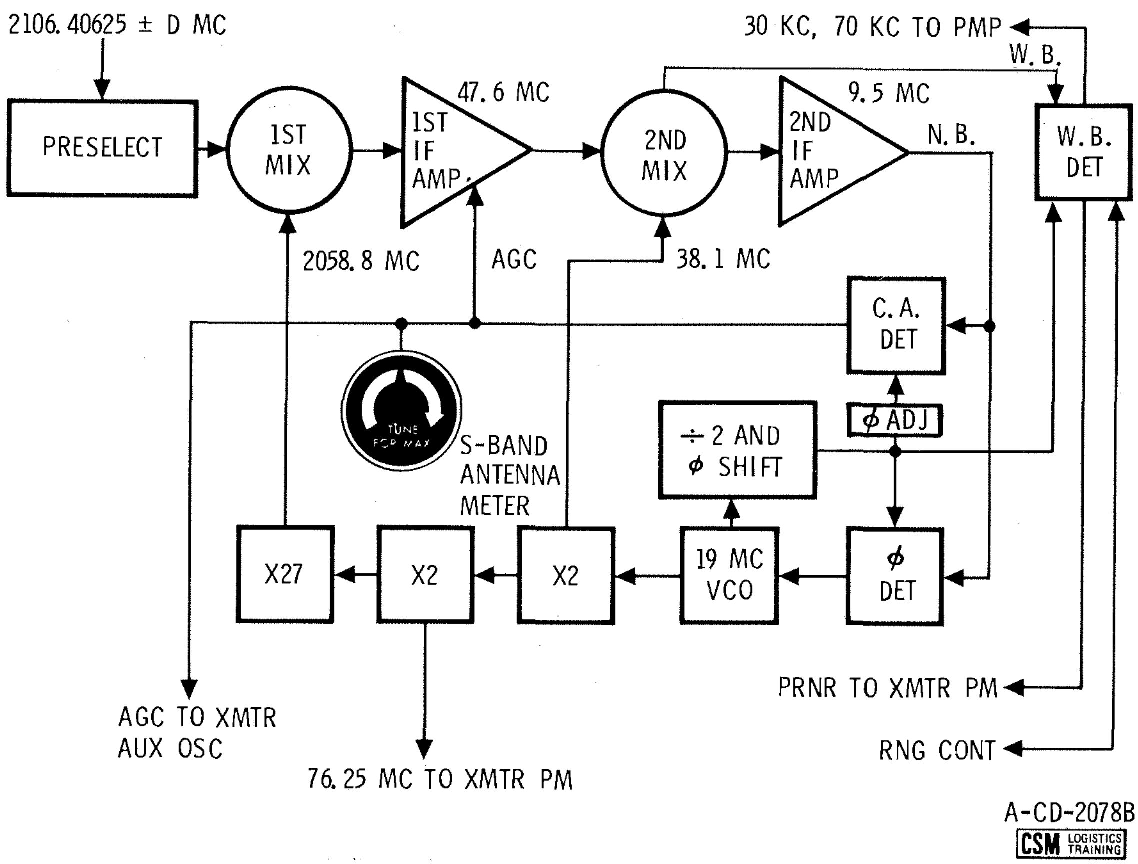


Figure 2.8-22. S-Band Receiver

T/C

The coherent amplitude detector (CAD) provides the automatic gain control (AGC) for receiver sensitivity control. An additional function of the CAD is to select the auxiliary oscillator to provide a stable carrier for the transmitter, whenever the receiver loses lock. The AGC circuitry also supplies a signal to the S-BAND ANT S-meter located on the lower right on panel 2. A received relative signal strength is indicated by this meter.

The USBE transponders are capable of transmitting a 2287.5-mc phase-modulated signal. The initial transmitter frequency is obtained from one of two sources: the VCO in the phase-locked USBE receiver or the auxiliary oscillator in the transmitter. Selection of the excitation is controlled by the CAD. If ranging has been selected, the up-link information is routed from the receiver wide band detector to the phase modulator in the transponder transmitter (figure 2.8-23). The phase modulator also can receive premodulated CSM voice and PCM data from the PMP in a normal mode or backup voice in event of a malfunction. The phase modulator signal is amplified to 3 watts by a power amplifier and sent into a X30 variactor multiplier, where much of this power is dissipated. The final power output through the power combiner is about 250 mw. About 20 watts of 3-phase 400-cycle a-c power and 2 watts of 28-vdc power are required by each transponder.

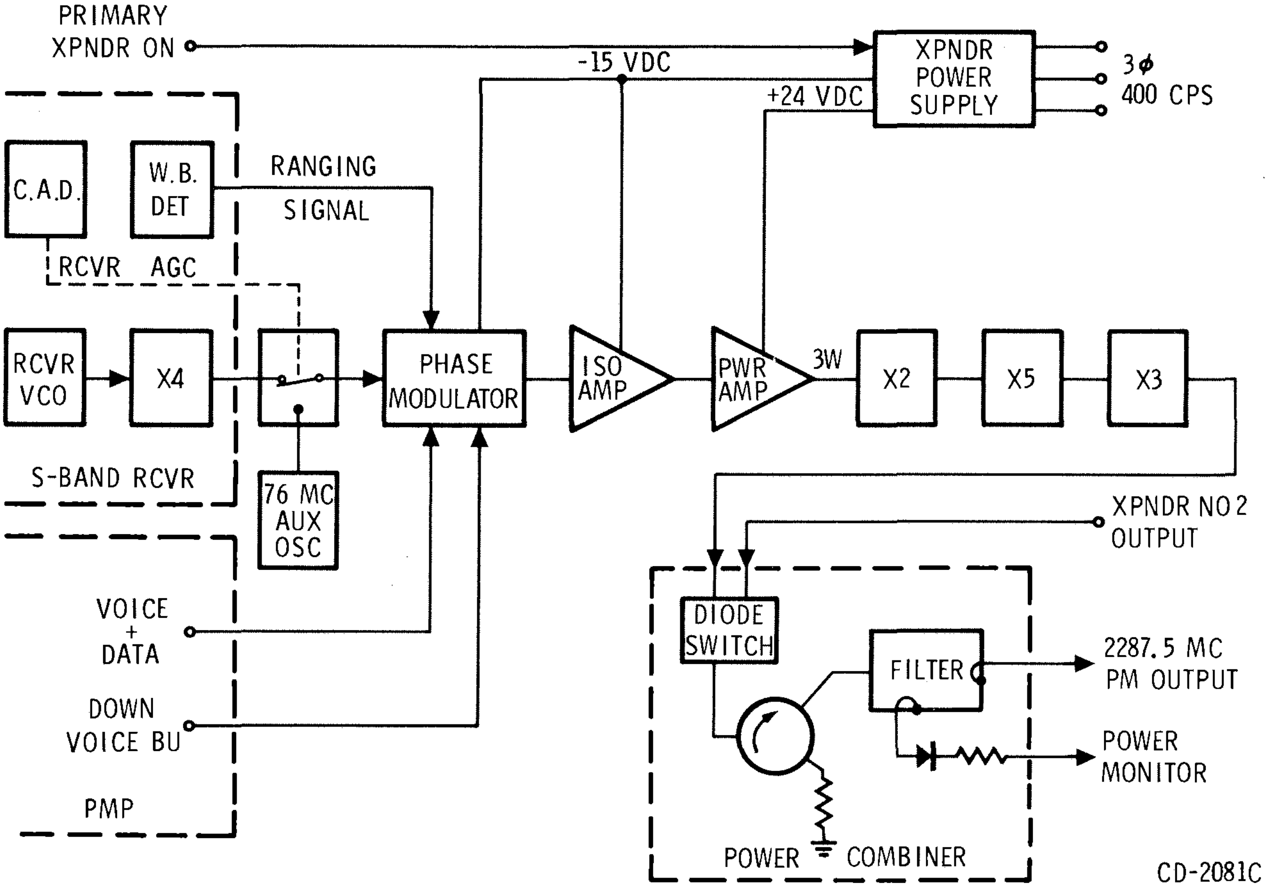


Figure 2.8-23. S-Band PM Transmitter

The USBE also contains a separate FM transmitter which operates at 2272.5 mc (figure 2.8-24). This separate S-band transmitter permits time-shared scientific, television, or playback data to be sent to the STDN while voice, real-time data, and ranging are being sent simultaneously via the transponder. The transmitter VCO receives modulation from the FM mixer or TV output of the PMP. The frequency modulator signal passes through two stages of amplification and then is sent through three multipliers, X2, X3, and X5 respectively. A ferrite circulator is used on the output of the final multiplier to preclude reflected power from feeding back and degrading the signal. The output power is approximately 100 mw. The USBE FM transmitter requires about 8 watts of 3-phase 400-cycle a-c power and 1 watt of 28-vdc power.

Operational configurations of the USBE are controlled by the S-band switches on panel 3. Individual functions are described in the Controls and Displays, section 3, while control circuits involved with the USBE are shown in figure 2.8-25.

2.8.3.4.4 S-Band Power Amplifier Equipment

The S-band power amplifier (PA) equipment (figure 2.8-26) is used to amplify the RF output from the USBE transmitters when additional signal strength is required for adequate reception of the S-band signal by STDN. The amplifier equipment consists of a triplexer, two traveling-wave tubes for amplification, power supplies, and the necessary switching relays and control circuitry. The S-band PA is contained in single electronics package located in the lower equipment bay. Each power amplifier requires about 15 watts of warmup, 45 watts at low-power and 90 watts at high-power of 3-phase 400-cycle a-c power and about 2.5 watts of 28-vdc power.

T/C

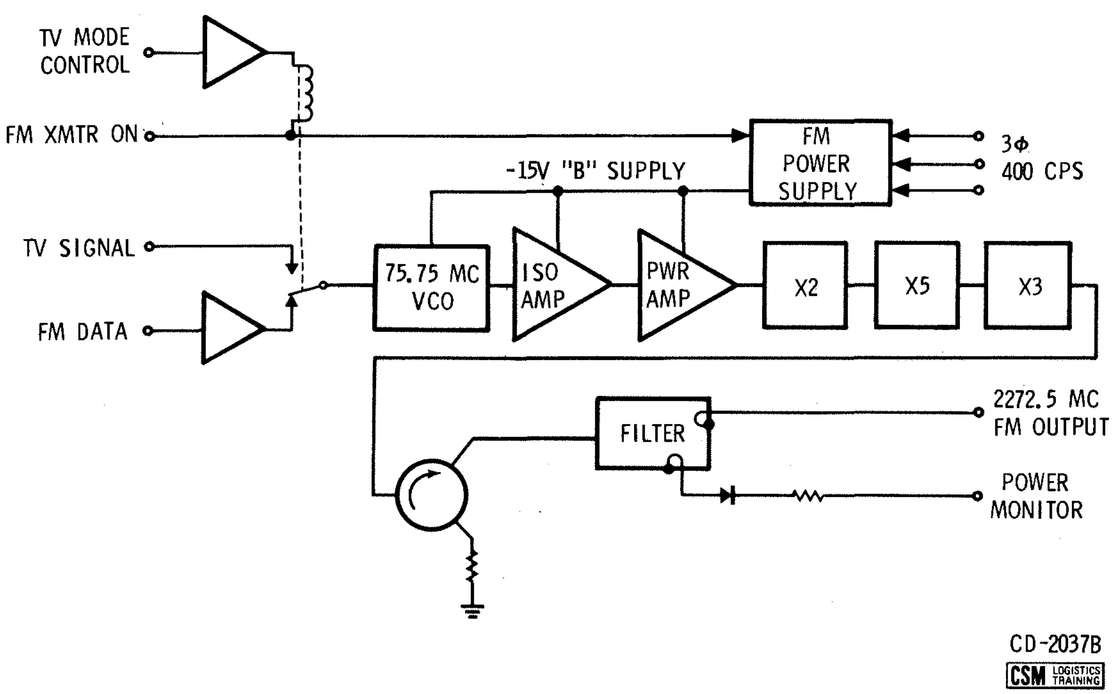


Figure 2.8-24. S-Band FM Transmitter

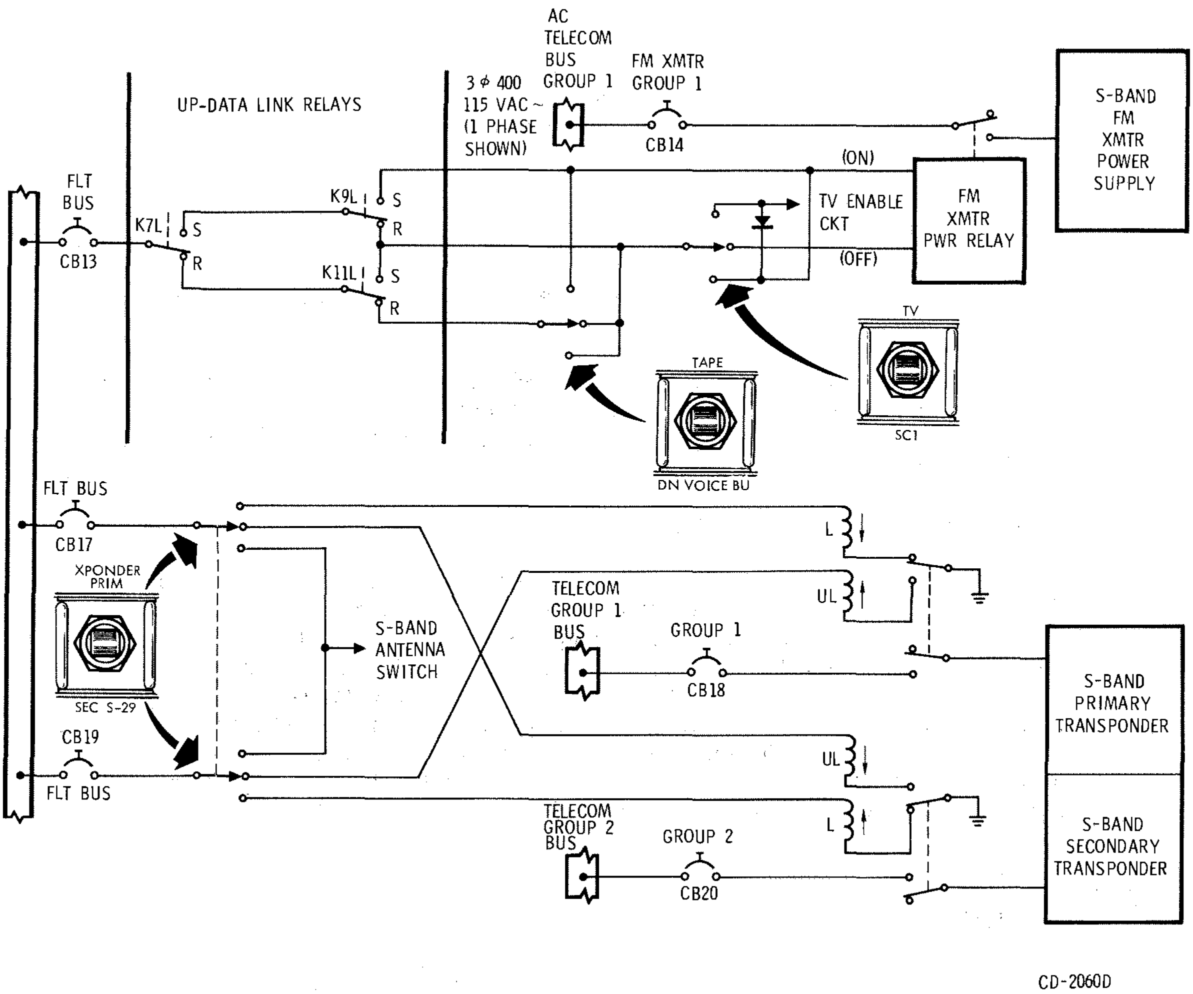
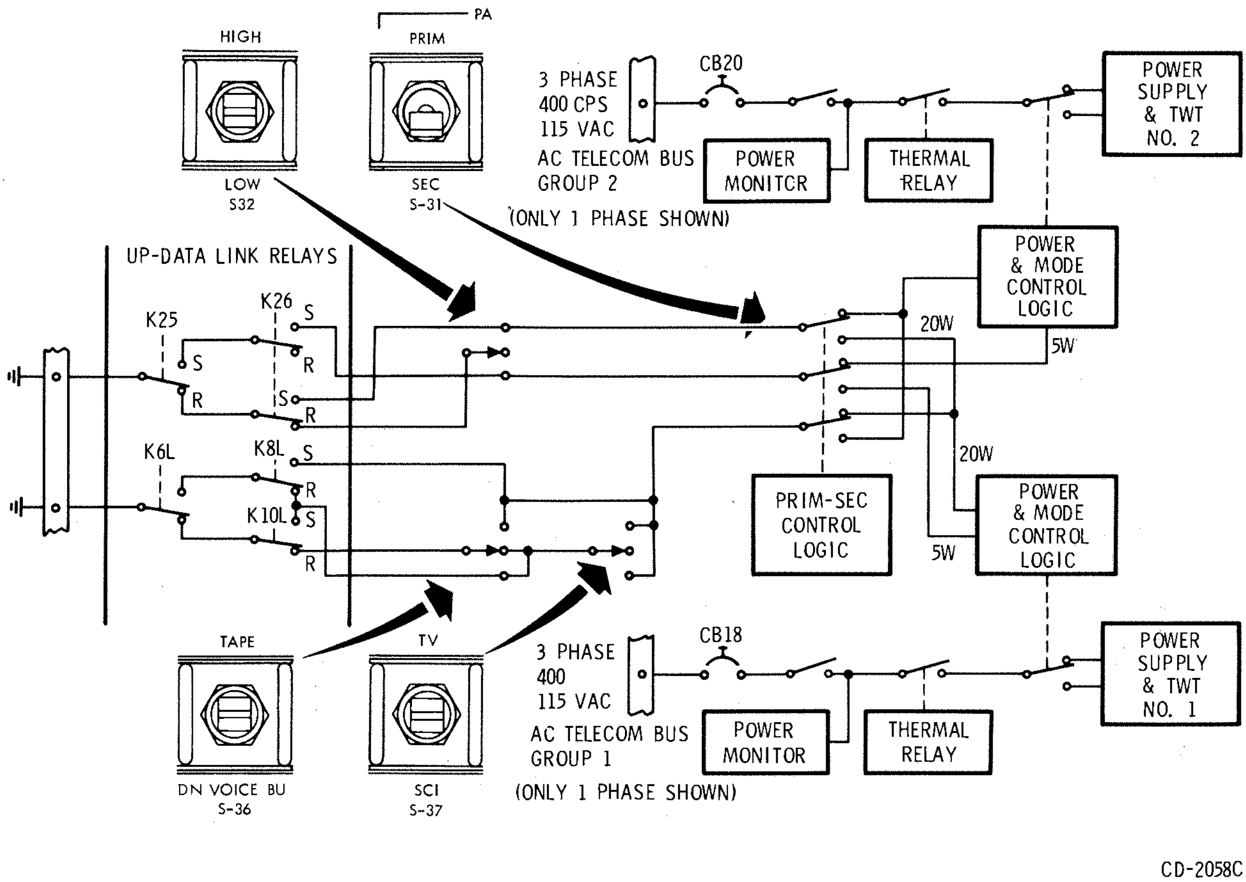


Figure 2.8-25. Unified S-Band Switching

All received and transmitted S-band signals pass through the S-band PA triplexer. The 2106.4-mc S-band carrier, received by the SC, enters the S-band PA triplexer from the S-band antenna equipment. The triplexer passes the signal straight through to the USBE receiver. The 2287.5-mc output signal from the USBE transponder enters the S-band PA where it is either bypassed directly to the triplexer and out to the S-band antenna equipment, or amplified first and then fed to the triplexer. There are two power amplifier modes of operation, low power and high power. The high-power mode is automatically chosen for the power amplifier connected to the FM transmitter.

Power for the power amplifier comes from the telecomm group circuit breakers 1 and 2. Separate 3-phase 115-volt 400-cps power sources are employed to drive each traveling wave tube and its attendant power supply. Figure 2.8-26 shows the controlling circuits involved with power distribution to the power amplifier.



T/C

Figure 2.8-26. S-Band Power Amplifier Control and Power Switching

2.8.3.4.5 Premodulation Processor Equipment

The premodulation processor (PMP) equipment provides the interface connection between the airborne data-gathering equipment and the RF electronics. The PMP accomplishes signal modulation and demodulation, signal mixing, and the proper switching of signals so that the correct intelligence corresponding to a given mode of operation is transmitted. These modes, which are listed in this section, are shown on the S-band operational spectrum (figure 2.8-27). The PMP uses a maximum power of 12.5-watts at 28-volt dc.

Voice

Command Module Normal S-Band Down Voice. The input voice signal from the audio center equipment is pre-emphasized, clipped, and frequency modulates the 1250-kc voice VCO. The voice subcarrier may be transmitted with the PCM/PM 1024-kc subcarrier for PM transmission via the USBE (unified S-band equipment).

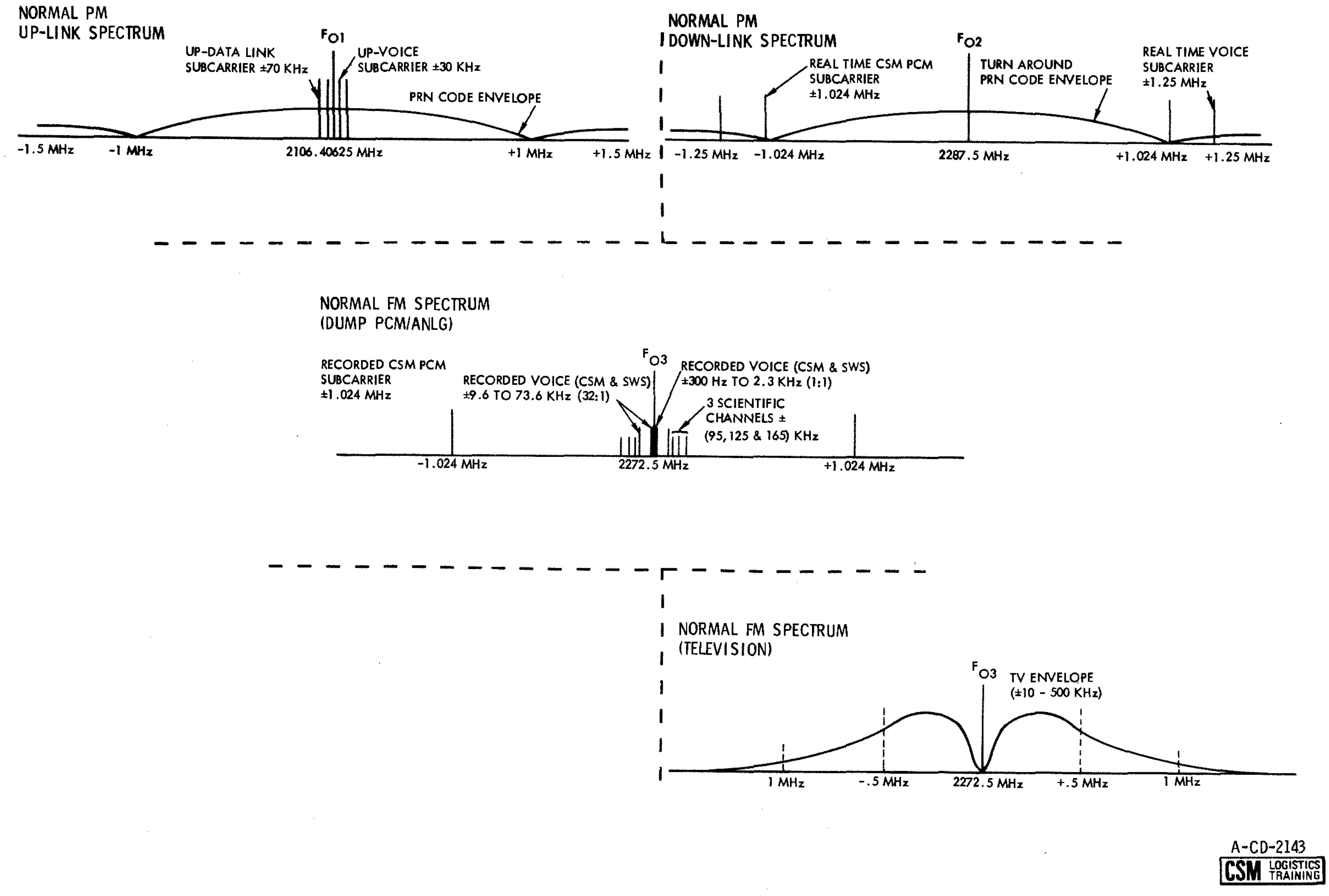


Figure 2.8-27. S-Band Operational Spectrums

Command Module Backup S-Band Down Voice. The input voice signal from the audio center equipment is pre-emphasized and clipped. The voice signal is then routed directly to the USBE, bypassing the voice modulator, for base band phase-modulation (PM) on the S-band carrier transmission to STDN.

STDN to CSM S-Band Normal Up-Voice. The STDN up-voice is PM/FM voice via S-band. The received, frequency-modulated 30-kc subcarrier from the USBE is bandpass-filtered and demodulated in the PMP. The output voice signal is low-pass filtered and routed to the audio center equipment input.

STDN to CM S-Band Backup Up-Voice. The STDN backup up-voice is PM/FM voice via S-band. The STDN voice is switched from the 30-kc subcarrier to the 70-kc subcarrier and mixed with the up-data. This bypasses the up-voice detector in the PMP.

CSM/SWS INTERCOM PLAYBACK. The playback-to-record ratio may be either 32:1 or 1:1 dependent upon the CSM PCM recorded bit rate. The input signal from the DSE is limited, filtered, and frequency-multiplexed with the three scientific subcarriers and stored PCM data on the 1024-kc subcarrier for FM transmission via the USBE.

Command Module Television. The CSM television camera input signal is a direct output signal to the USBE for FM base band transmission. An additional isolation amplifier attenuator circuit is provided for output to the spacecraft umbilical. SWS television is also available to the USBE FM transmitter by proper switching of the TV SOURCE switch on panel 3.

Real-Time Telemetry

Command Module PCM Data. The CSM PCM data input signal biphase modulates the 1024-kc subcarrier. The subcarrier is filtered and mixed with the voice 1250-kc subcarrier. The output signal phase-modulates (PM) the carrier for transmission via the USBE.

T/C

STDN to CSM S-Band Up-Data. The up-data signal is processed the same as up-voice except the subcarrier center frequency is 70 kc and the output is routed to the up-data link decoder.

Scientific Analog Data. Three real-time scientific analog telemetry inputs frequency-modulate three subcarrier oscillators. The three real-time subcarrier signals are mixed and the composite signal frequency-modulates the S-band carrier for FM transmission via the USBE.

Recorded Telemetry

CM PCM Stored Data. The CSM stored PCM TLM data biphase modulates the auxiliary 1024-kc subcarrier. This subcarrier is mixed with the playback of scientific data and CSM/SWS INTERCOM voice for modulation of the S-band FM modulator and transmission to STDN.

Scientific Stored Analog Data. The stored scientific analog data frequency-modulates three subcarrier oscillators (SCO). The SCOs are frequency-multiplexed with the stored PCM/TLM 1024-kc subcarrier and the INTERCOM voice playback signal. The composite signal frequency-modulates the S-band equipment.

CM to STDN Emergency Key. To provide a keyed output for emergency key communications, the 512-kc CTE clock input may be keyed by depressing the XMIT side of the rocker switch located on the astronaut's comm cable. The key closure controls a gated amplifier from which the keyed signal is routed to the USBE. A 400-cps sidetone is also keyed by the PTT. This signal is mixed into the PMP up-voice output circuitry and routed through the audio center to the earphones. The S-BAND-T/R switch on the audio control panel is set to T/R or REC.

Redundancy

CM Backup S-Band Down Voice. The CM voice input is pre-emphasized, clipped, and routed directly to the S-band for PM transmission, bypassing the PMP voice modulator.

CM Auxiliary PCM Telemetry Subcarrier Modulator. The real-time PCM TLM input may be switched by S54 (AUX position) to the auxiliary biphase modulator with the output being switched to the PMP PM mixer output for S-band PM transmission and to the FM mixer output for S-band FM transmission.

STDN to CM S-Band Backup Up-Voice. The STDN voice is placed on the 70-kc up-data subcarrier. This enables the use of the 70-kc subcarrier for time-shared voice and data.

Auxiliary Power Supply. The PMP has redundant switchable regulator power supplies to provide power to all PMP circuitry. When switch S54 is in the AUX position, the auxiliary +18-volt d-c regulator is in use. Also the auxiliary 1.024-mc biphase modulator which normally handles stored CM PCM data is switched to handle real-time CM PCM data.

PMP Operational Modes and Output Levels. Output signals are provided in combinations and levels as described in the following. Control panel switches, used to achieve the various modes, are illustrated in the schematic (figure 2.8-28).

Primary Power Control. When S54 switch is in the NORMAL position, power is supplied to all PMP circuitry from the normal +18-volt regulator. When switch S54 is in AUX position, auxiliary +18-volt regulator is used. Also the auxiliary 1.024-mc biphase modulator which normally handles stored CM/PCM data is switched to handle real-time CM/PCM data.

Scientific Data Output to DSE. The three R/T scientific analog data signals are supplied to the DSE through the PMP except when switch S37 is in the SCI position.

When S37 is in the SCI position, the three R/T scientific analog data signals are applied directly to the FM mixer in the PMP for transmission via the S-band FM transmitter.

Intercom Voice Output to DSE. The intercom voice output is supplied for DSE recording at all times power is applied to the PMP.

Up-Voice and Up-Data Output. When switch S38 is in the DATA position, the up-voice signal from the 30-kc demodulator is supplied as an output to the audio center. The 70-kc demodulator supplies an up-data output to the up-data link decoder.

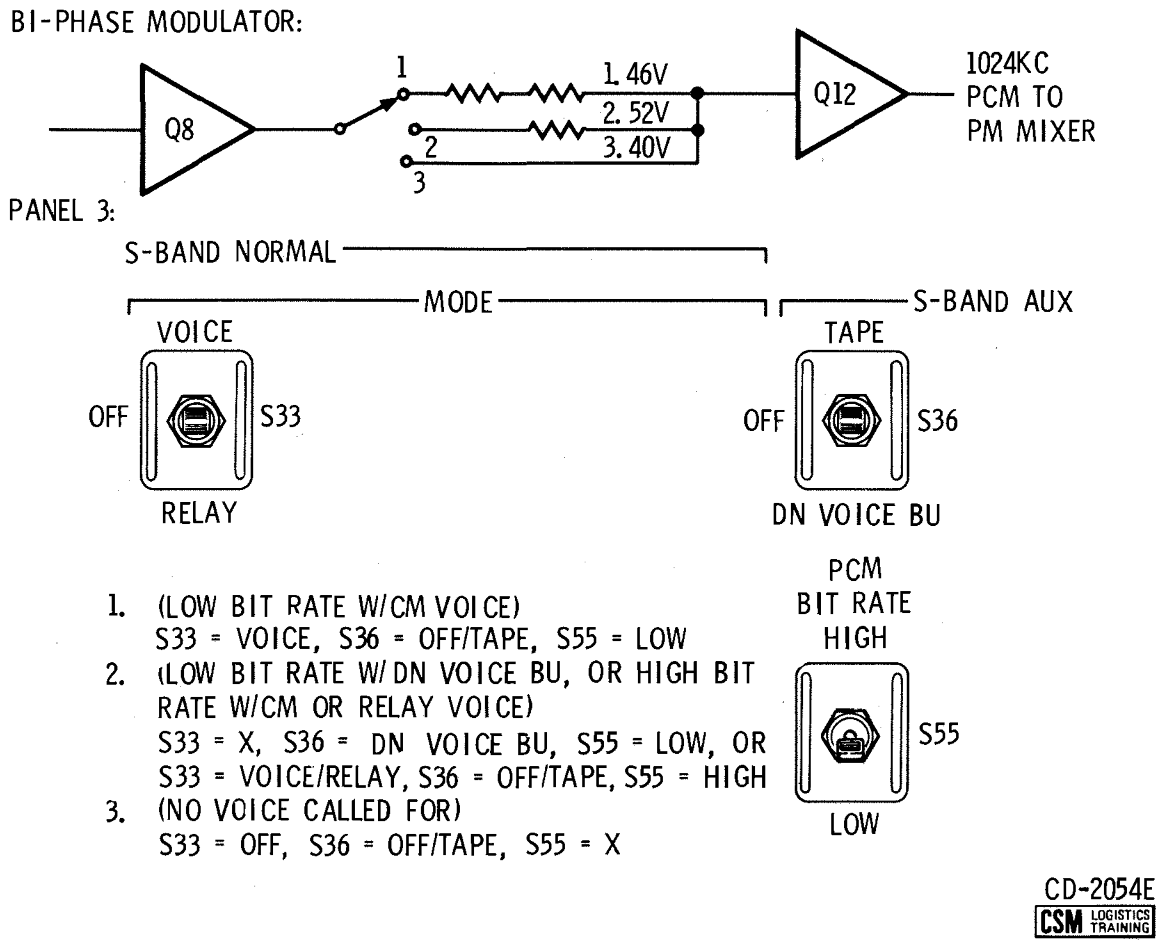


Figure 2.8-28. PMP Data Modulation Levels

When switch S38 is placed in the UP VOICE BU position, the 70-kc demodulator output is switched to the up-voice output terminals, as an output to the audio center.

Television Signal Output. The television signal input is provided as a direct output. Coaxial terminals having 100-ohm ±5 percent impedance are used. This channel will pass frequencies from dc to 500 kc with no more than 0.5-db attenuation.

A TV umbilical output is also provided through an isolation amplifier. Output voltage is no greater than the TV input signal and is no less than 1 volt peak-to-peak, for a 1.9-volt peak-to-peak input signal at 1000 cps. Frequency response in the band from 10 cps to 500 kc is no more than 3 db below the peak response. This output is protected against open or short circuit conditions.

FM Output. Signals supplied to the FM terminals for transmission on USBE are

- Real-time scientific data
- Stored CM SWS voice

- Stored scientific data
- Stored CM PCM data
- Television
- Auxiliary real-time CM PCM data.

These signals are selected by appropriate combinations of switches S36, S37, and S49.

PM Output. Subcarriers are selected by suitable configurations of switches. Subcarriers selected for phase modulation of the USBE are

- 1.024-mc biphase-modulated by real-time CM PCM data
- 1.25-mc VCO frequency-modulated by CM voice and SWS voice
- 512-kc emergency key signal.

These signals are selected by appropriate combinations of switches S33, S34, S36, and S44. Switch positions and the output level of each subcarrier are shown on figure 2.8-27.

The overall functions of the PMP are summarized in figure 2.8.29.

2.8.3.4.6 VHF Recovery Beacon Equipment

The VHF recovery beacon equipment (figure 2.8-30) provides line-of-sight direction-finding capabilities to aid in locating the SC during the recovery phase of the mission. The 3-watt beacon signal emitted is an interrupted 243-mc carrier, modulated by a 1000-cps square wave. The signal is transmitted for 2 seconds, then interrupted for 3 seconds.

Manual control of the equipment is provided by the RECOVERY - VHF-BCN, two-position ON/OFF switch on panel 3. The beacon requires a maximum of 10 watts of 28-vdc power.

The output of the VHF recovery beacon equipment is fed to VHF recovery antenna No. 1, which is deployed automatically when the main chutes are deployed.

2.8.3.5 Antenna Equipment Group

The antenna equipment group contains all the SC antennas and ancillary equipment used in the T/C system. For the antenna locations, see figure 2.8-31.

2.8.3.5.1 VHF Omniantenna Equipment

The VHF omniantennas and ancillary equipment consist of two VHF scimitar antennas, a VHF triplexer, a VHF antenna switch, an RF switch and the necessary signal and control circuits. The function of this equipment is to provide capabilities for radiation and pickup of RF signals in the VHF spectrum. The VHF/AM transceivers, which work through this equipment, operate at 296.8 mc and 259.7 mc. Provisions are also made for the checkout of the Apollo survival radio through this equipment.

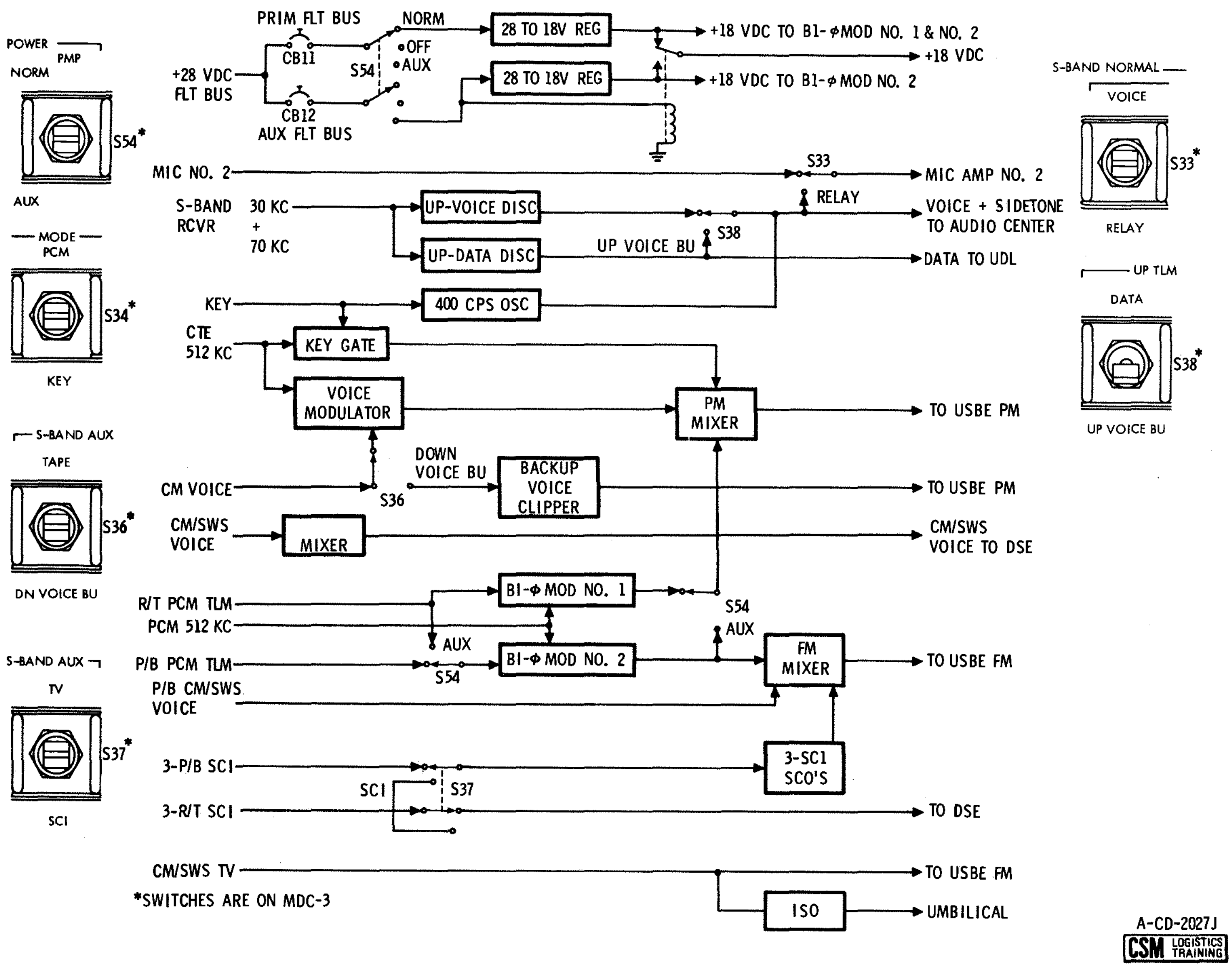


Figure 2.8-29. PMP Block Diagram

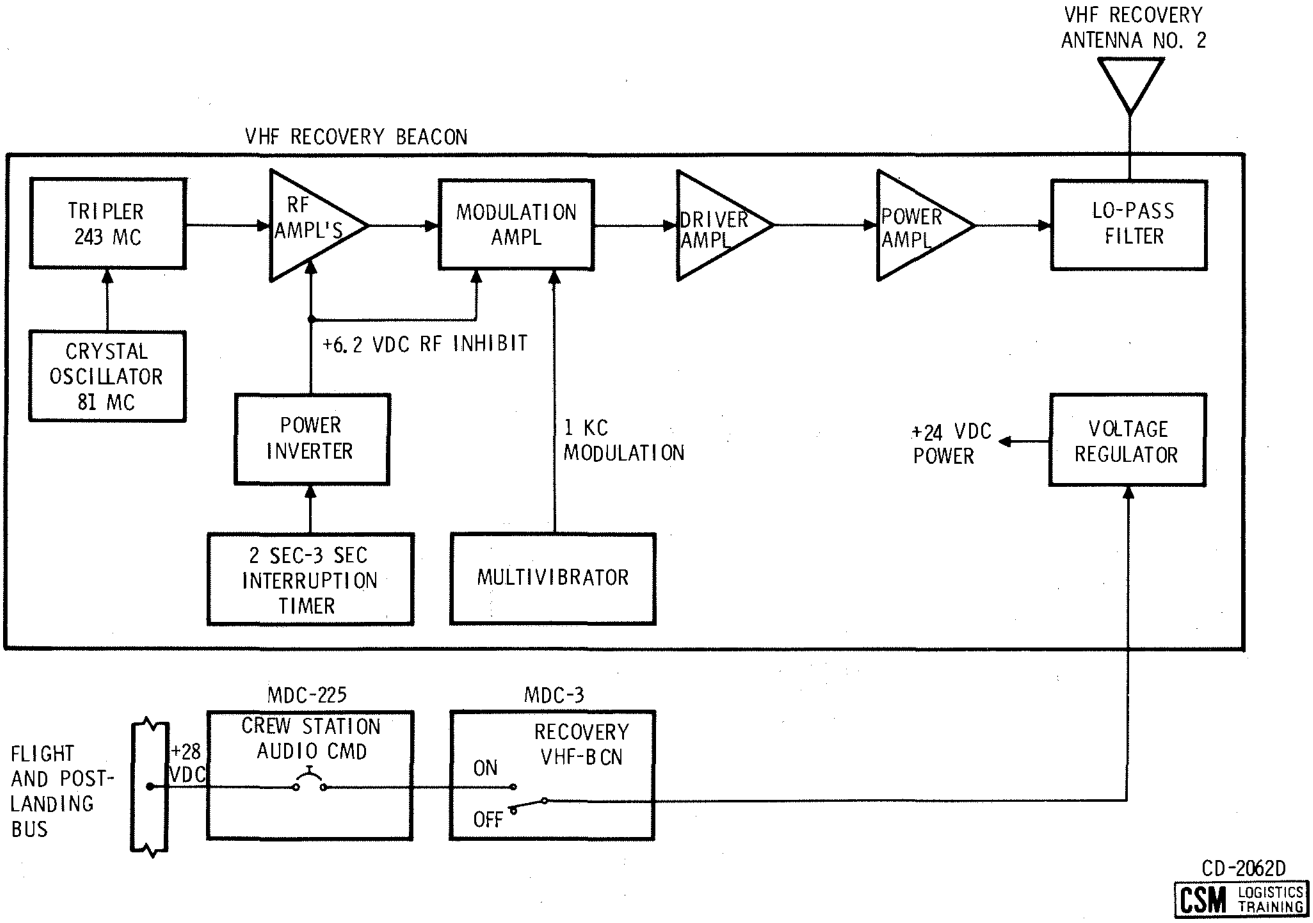


Figure 2.8-30. VHF Recovery Beacon Equipment

The VHF triplexer is a passive, three-channel filtering device which enables three items of VHF transmitting and receiving equipment to utilize one VHF antenna simultaneously. The three-channel filters are composed of two tuned cavities each, which function as bandpass filters. No power is required by the device and there are no external controls.

The VHF scimitar antennas, shown in figure 2.8-32, are omniantennas with approximately hemispherical radiation patterns. Because of its characteristic shape, this type of VHF antenna is called a scimitar.

These two VHF antennas are located on opposite sides of the service module. One is located near the +Y axis and is called the right VHF antenna, the other is located near the -Y axis and is called the left VHF antenna. Because of their approximate hemispherical radiation patterns, full omnidirectional capabilities can be obtained only by switching from one antenna to the other. This is accomplished with the VHF ANTENNA remote control switch on panel 3 for VHF communications.

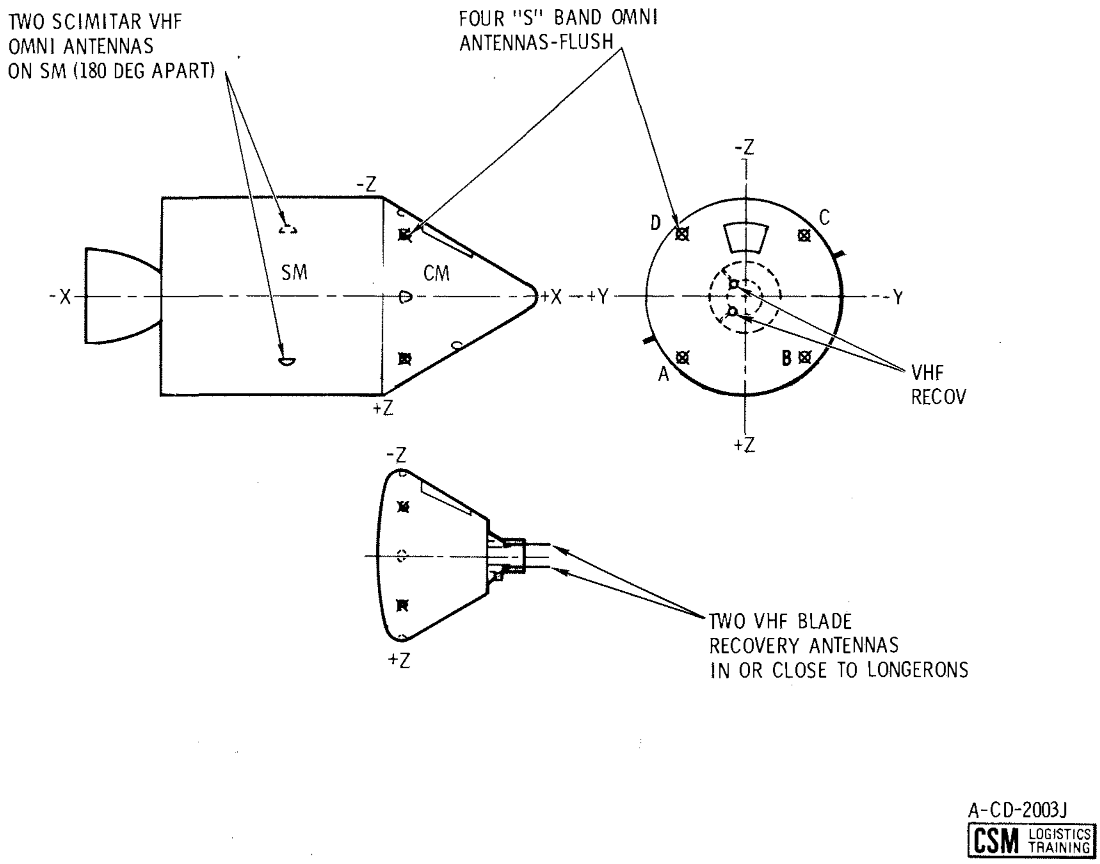


Figure 2.8-31. Antenna Locations

T/C

2.8.3.5.2 S-Band Omniantennas

The function of the four S-band omniantennas is to transmit and receive all S-band signals during the near-earth operational phase. Locations are shown in figure 2.8-30 at X_C = 20.766 and 45 degrees off the +Z, -Y, -Z and +Y axis.

The antennas are flush-mounted, right-hand polarized helical, and in a loaded cavity. They are rated at 15 watts cw at 2100 to 2300 mc. The antennas are manually selected in the CSM and remotely selected by STDN through the SWS DCS system. STDN can also, through interface with the CSM UDL equipment, select any one of the four antennas. (See figure 2.8-2.)

2.8.3.5.3 VHF Recovery Antenna Equipment

There are two VHF recovery antennas, No. 1 and No. 2, stowed in the forward compartment of the SC. Each antenna consists of a quarter-wave stub, 11 inches long, and a ground plane. They are automatically deployed 8 seconds after main parachute deployment, during the descent phase of the mission. (See figures 2.8-33 and 2.8-34.)

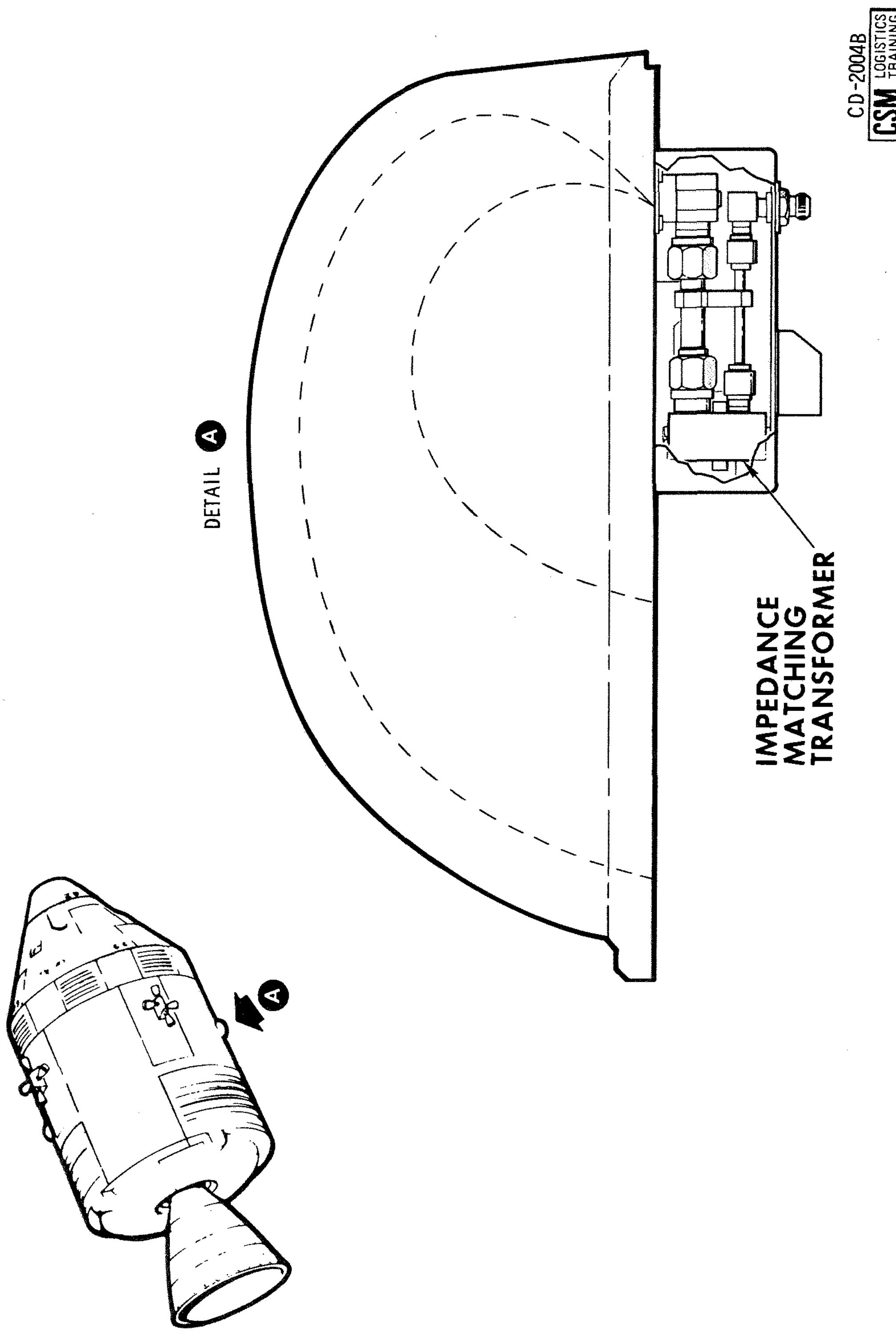


Figure 2.8-32. Scimitar Antenna

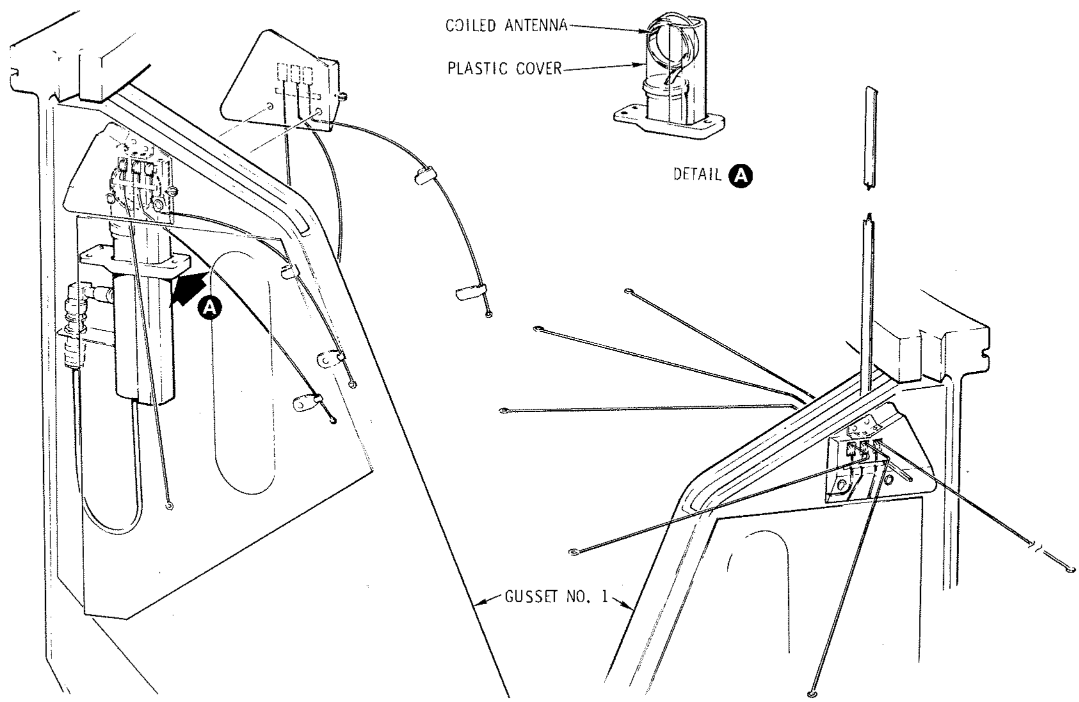


Figure 2.8-34. VHF Recovery Antenna No. 2

2.8.4.2 PMP

When UP TLM/UP VOICE BU is chosen, the output of the data discriminator is sent to both the audio center and the up-data link equipment.

Low-bit rate PCM data can be transmitted with DN VOICE BU. If only VOICE transmission is desired, the PCM switch must be at OFF and the PCM BIT RATE switch must be at HIGH for the best circuit margins.

Selection of the AUX PMP power supply precludes the transmission of recorded data from the data storage equipment. Real-time PCM is available for transmission over both the S-band transponder and FM transmitter in this mode.

To transmit real-time PCM over the FM transmitter, S-BAND AUX TAPE and PMP AUX POWER should be selected.

2.8.4.3 DSE

Selection of the record speed in the DSE is made by the PCM BIT RATE HIGH-LOW switch. If PCM BIT RATE HIGH is selected, the record speed would be 15 ips. A PCM BIT RATE LOW selection changes the record speed to 3-3/4 ips.

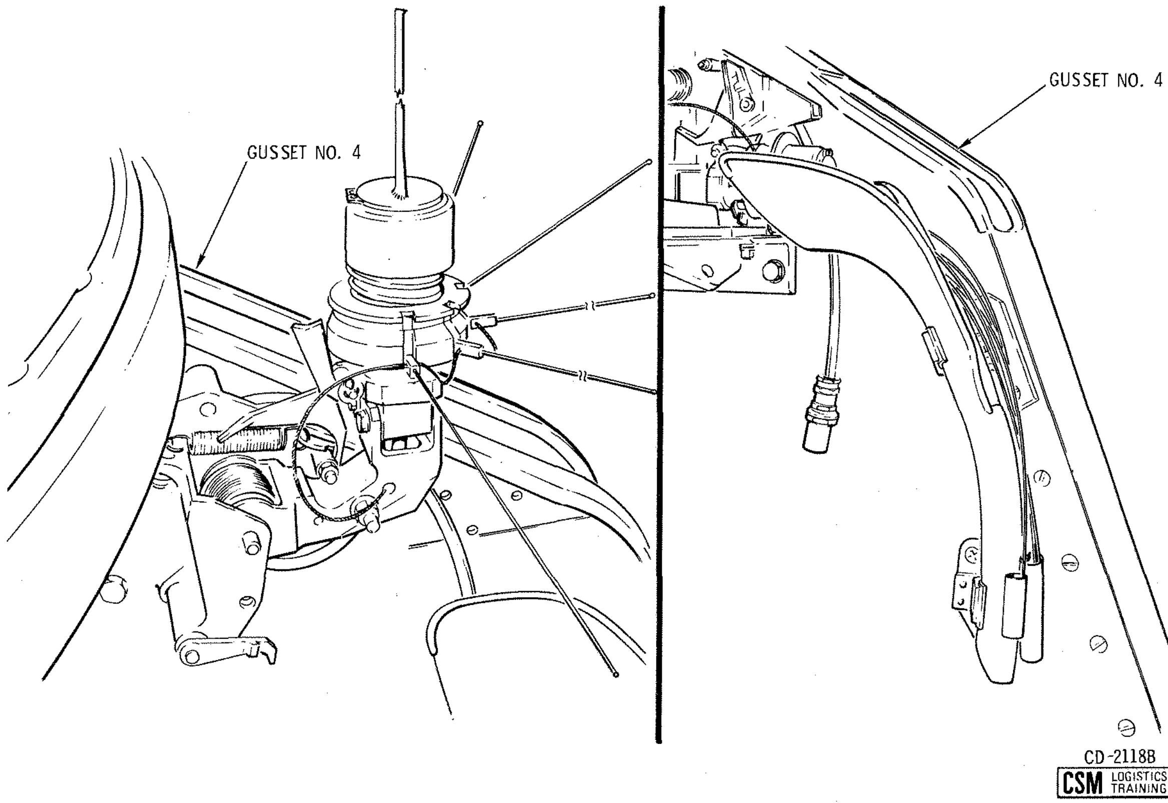


Figure 2.8-33. VHF Recovery Antenna No. 1

VHF recovery antenna No. 2 is connected to the VHF recovery beacon equipment. VHF recovery antenna No. 1 is to be used with the VHF/AM transmitter-receiver equipment and is connected to the VHF antenna switch with a coaxial cable. An access hatch is provided to allow either of the VHF recovery antennas to be used with the GFE survival transceiver. This requires that the coaxial cable from one of the antennas be manually disconnected at the triplexer and reconnected to the survival transceiver.

T/C

2.8.3.6 Electrical Power Distribution

Electrical power distribution for the intercommunication, data, instrumentation, RF and antenna equipment is summarized in figure 2.8-36. In most cases, the power circuit for each piece of equipment was covered in the respective functional description. The majority of the circuit breakers for the telecommunication system are located on panel 225.

2.8.4 OPERATIONAL LIMITATIONS AND RESTRICTIONS

2.8.4.1 VHF-AM

Simultaneous selection of DUPLEX A and B gives the same operation as selection of SIMPLEX A and B.

Selection of the DUMP speed is automatically made by the DSE electronics through monitoring of the bit rate on the recorded CM PCM CLOCK track. High-bit rate PCM is dumped at 15 ips (1:1) while low-bit rate PCM is dumped at 120 ips (32:1). A failure of the speed select electronics causes automatic dumping at 120 ips.

2.8.4.4 USBE

The S-BAND NORMAL-XPONDER switch, when switched between PRI and SEC, should be held momentarily in the center (off) position to allow the internal power relay to follow the desired configuration change.

2.8.4.5 VHF RANGING

The VHF RNG - RESET-NORM switch on audio control panel 9 must be held in the reset position at least 1 second when the acquisition phase is started to ensure SWS RTTA lock-up.

2.8.5 SKYLAB RESCUE VEHICLE CONFIGURATION

The Skylab rescue vehicle configuration provides communications for a two-crewman launch and five-crewman return. (See figure 2.8-35.)

Two CCU adapters are used to mate directly with the standard CM CCUs at the CM bulkhead interface. One CCU adapter is used to connect the right couch (flight crewman) to the lower right couch (rescued crewman) while the second CCU adapter is used to connect the center couch (rescued crewman) to the lower left couch (rescued crewman). The left couch contains only the standard CCU for the flight crewman. The lower right couch and lower left couch have modified CCUs which do not contain biomedical instrumentation, audio warning, and S-band emergency key.

For further information, refer to Crew Equipment Section, 2.12.11.6.

T/C

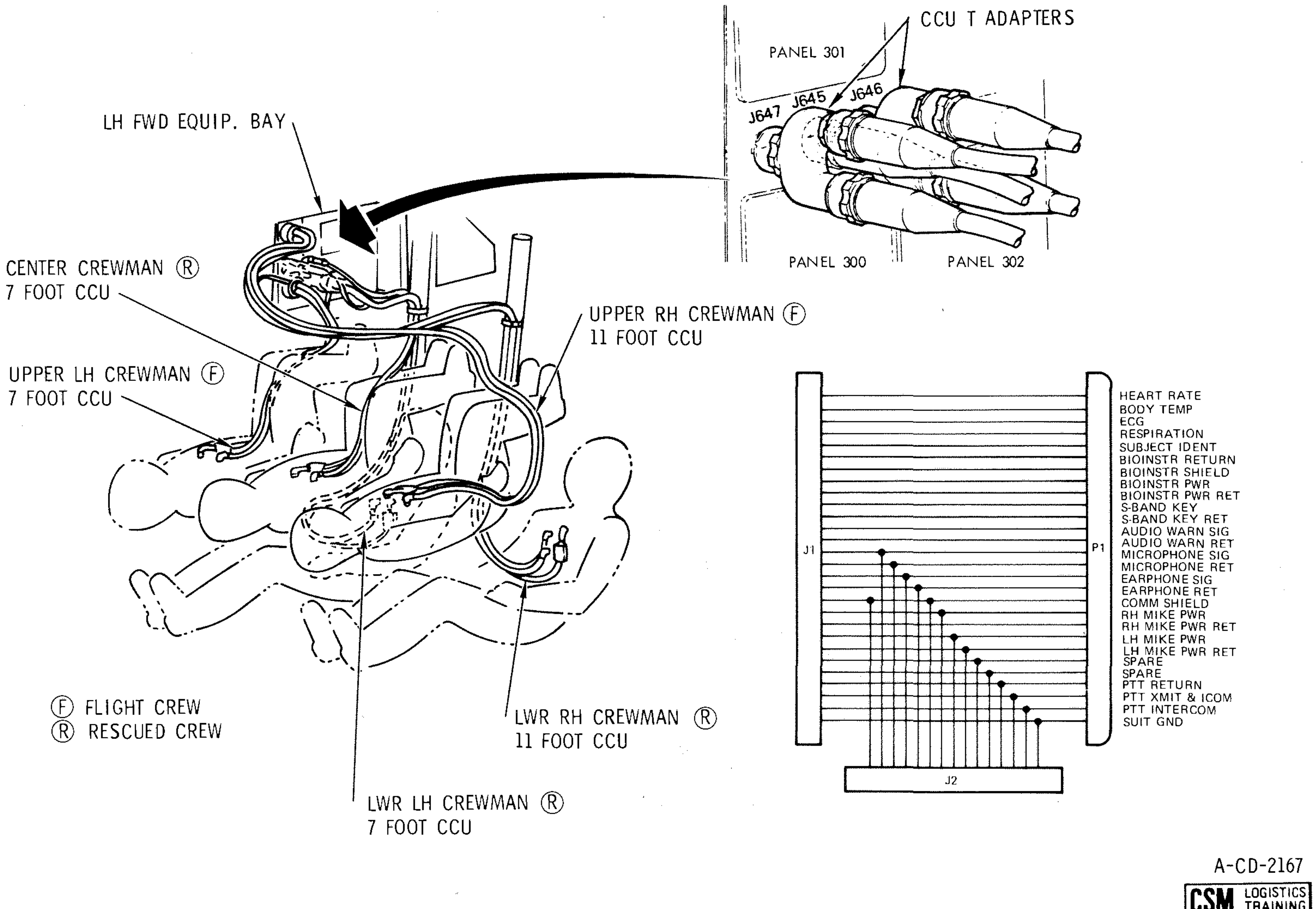


Figure 2.8-35. Telecomm CCU Rescue Flight Return Configuration

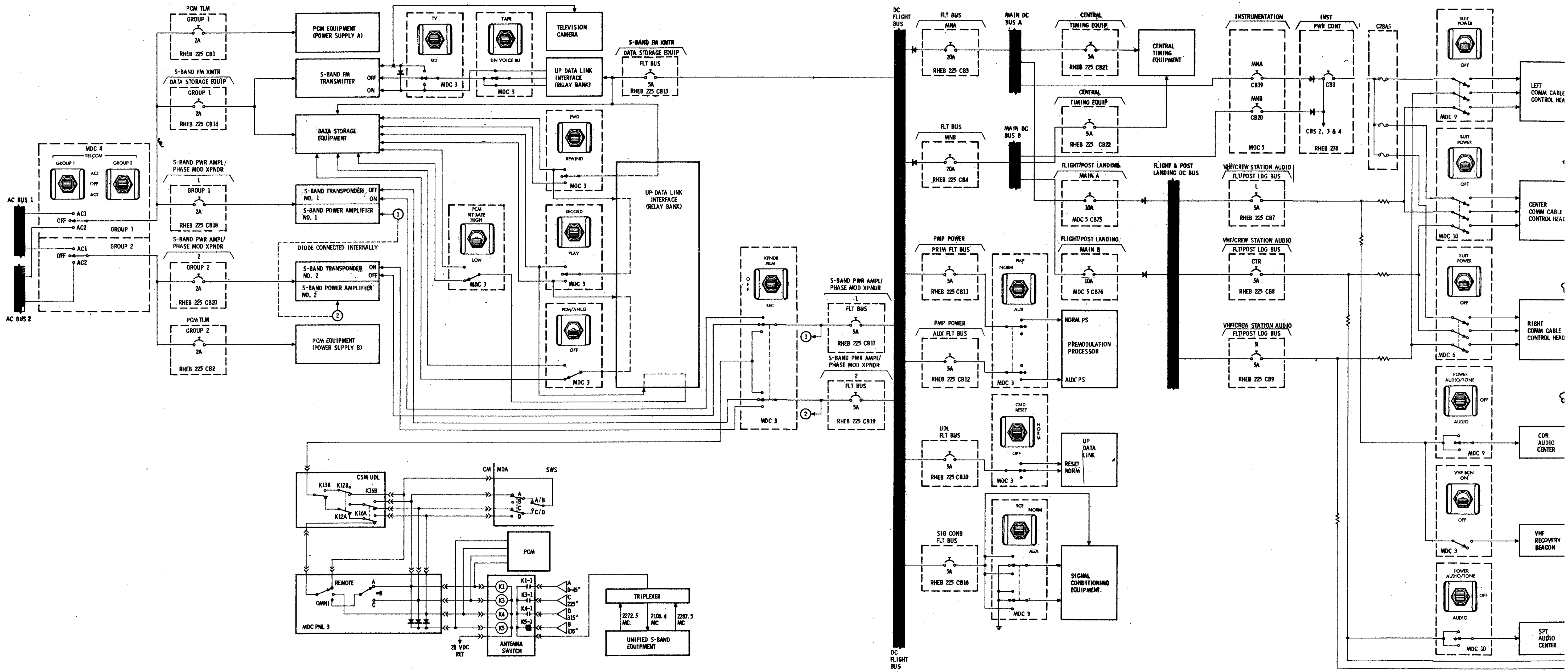
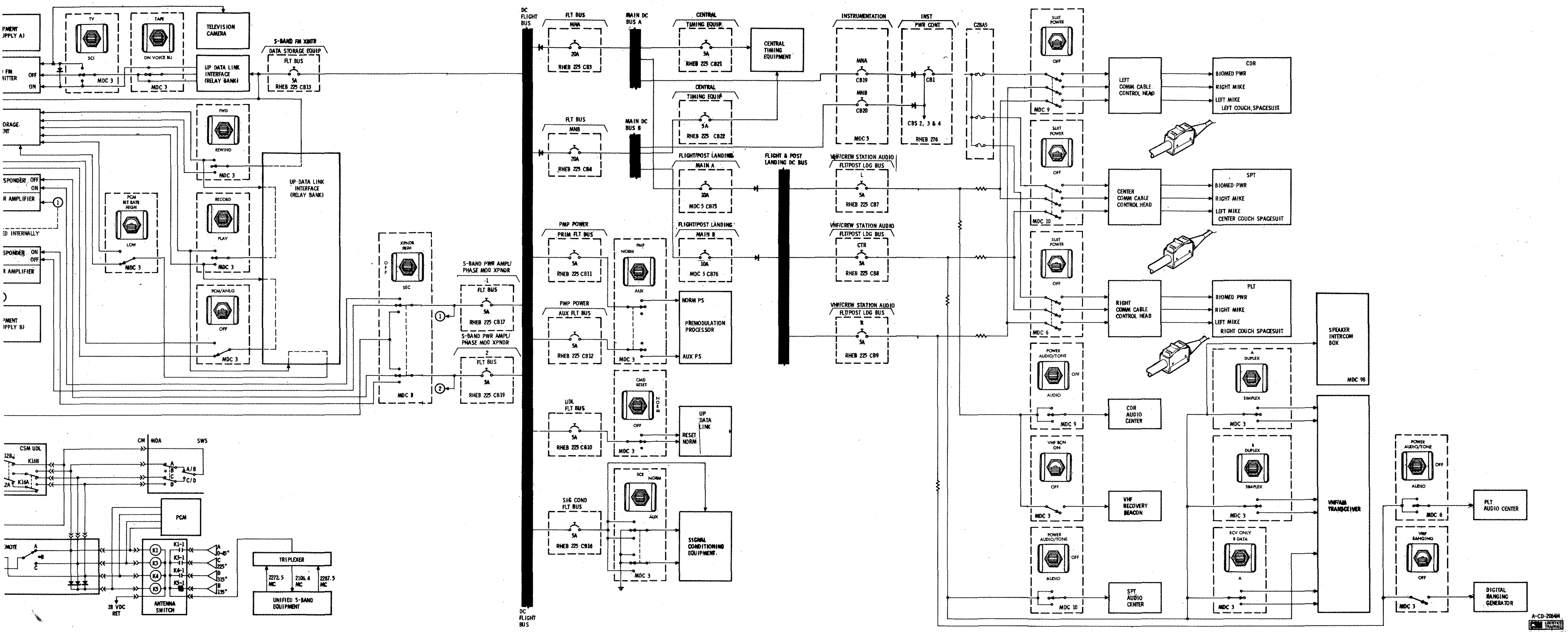


Figure 2.8-35



T/C

Figure 2.8-35. Telecommunications Power Distribution

SECTION 2

SUBSECTION 2.9

SEQUENTIAL SYSTEMS

2.9.1 INTRODUCTION

Flight crew safety is the paramount consideration in design and development of all Apollo/Saturn systems and procedures. However, complexity dictates the need for automation that can be utilized in the event of contingency malfunctions prior to achievement of orbital insertion. Sequential systems are incorporated to satisfy this vital requirement.

During the launch and earth ascent phase of a mission, critical emergency conditions are possible. This is at a time when human reflexes may be impaired because acceleration forces, vibration and high noise level can impose physical limitations on the crew members.

The need is apparent for a system that will monitor time-critical emergency conditions during periods of launch vehicle (LV) powered flight. The need is also apparent for a system that will automatically sequence events required for the safe removal and recovery of a crew from a malfunctioning LV (aborted mission). To satisfy these needs, the basic functions of sequential systems are sensing, sequencing, escape, and recovery.

Four major subsystems of sequential systems are incorporated for the performance of these basic functions: emergency detection subsystem (EDS) for sensing, sequential events control subsystem (SECS) for sequencing, launch escape subsystem (LES) for escape, and earth recovery subsystem (ERS) for recovery.

Many sequential operations of the Apollo spacecraft (SC) are activated or accomplished using electro-explosive (pyrotechnic) devices. These are basically defined as those explosive components that are ignited electrically. The SECS, which is the nucleus of sequential systems, is several control circuits which are integrated for the initiation of pyrotechnic devices.

Certain discrete sequential operations, other than those activated or accomplished using pyrotechnic devices, are also necessary for the successful completion of a nominal mission; therefore, portions of sequential systems incorporate electro-mechanical automation.

Functional requirements of sequential systems are achieved by integrating several Apollo/Saturn subsystems. Figure 2.9-1 illustrates the SECS interface with the following subsystems:

- Displays and controls
- Emergency detection (EDS)
- Electrical power (EPS)

- Stabilization and control (SCS)
- Reaction control (RCS)
- Docking (DS)
- Telecommunications (T/C)
- Earth recovery (ERS)
- Launch escape (LES)

2.9.2 EMERGENCY DETECTION SUBSYSTEM

The EDS monitors critical parameters associated with LV powered flight. It is basically a LV system, that interfaces with command module (CM) portions of sequential systems, in the launch vehicle instrument unit (LV-IU). Emergency conditions are displayed to the crew on panel 1 to indicate the necessity for abort action (figure 2.9-2).

2.9.2.1 Automatic Initiation of Abort

An additional provision of the EDS is automatic initiation of an abort in the event of certain extreme time-critical conditions, these are:

- Loss of thrust on two or more engines on the first stage of the LV.
- Excessive vehicle angular rates around any of the pitch, yaw, or roll axes.

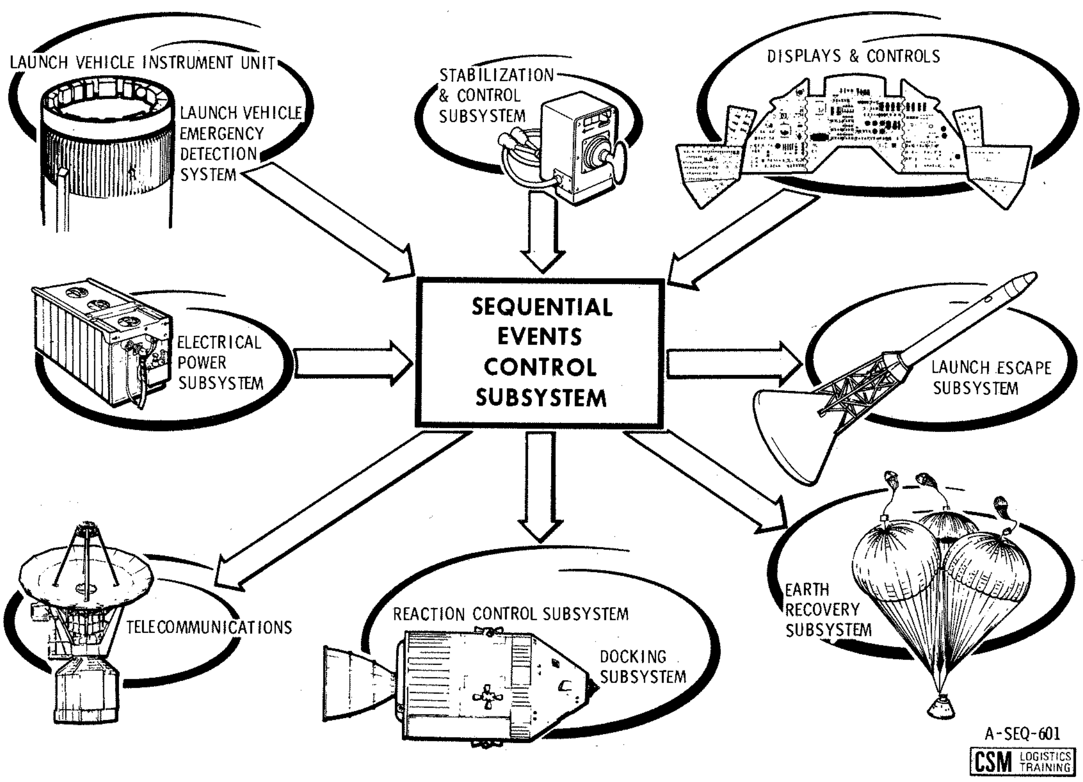


Figure 2.9-1. Sequential Systems Interface

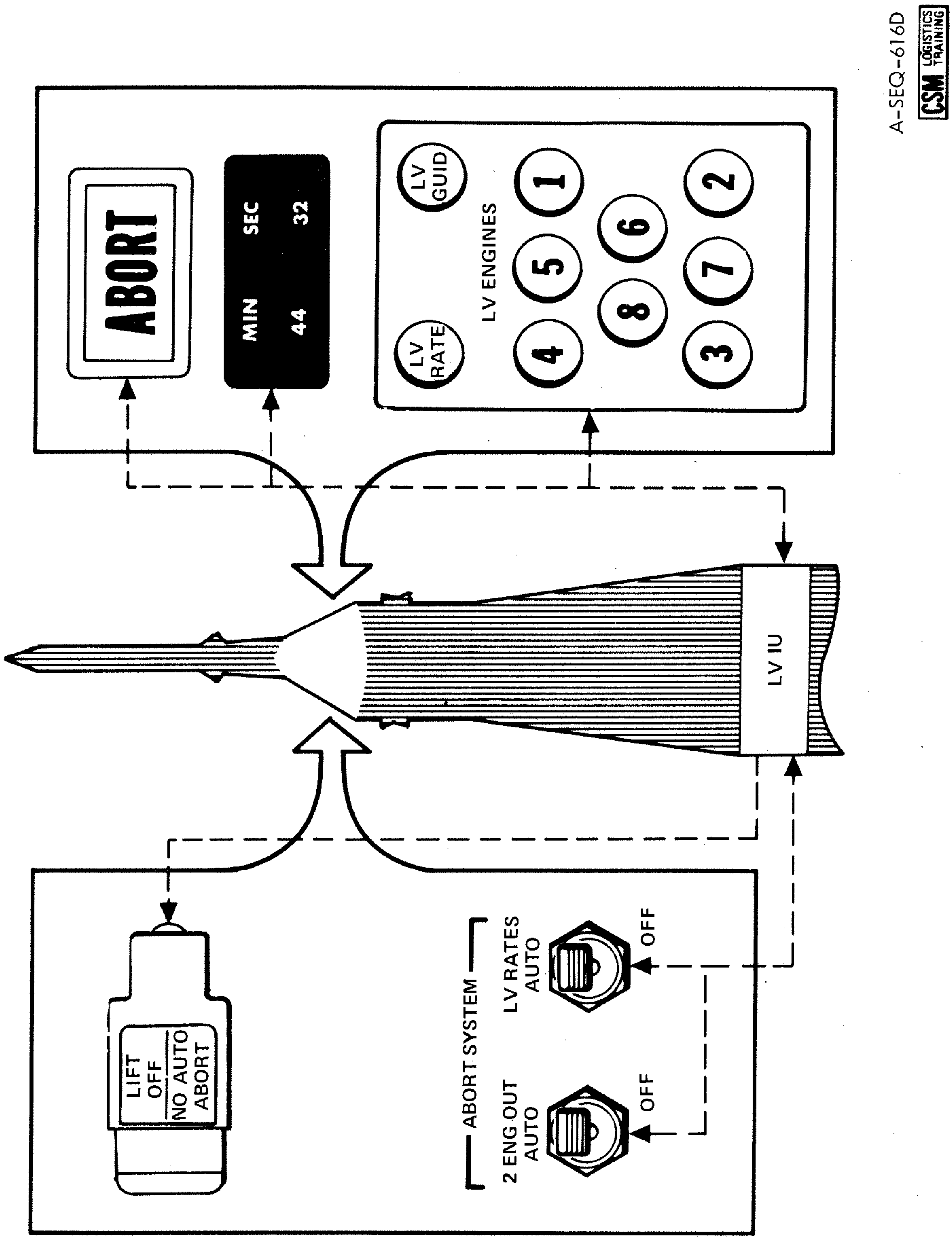


Figure 2.9-2. EDS Interface With CM

SEQ

2.9.2.2 EDS Automatic Abort Activation and Deactivation

EDS automatic abort circuits in the CM are activated automatically at lift-off and deactivated automatically at launch escape tower (LET) jettison. Switches are provided on the MDC to deactivate the entire automatic abort capability or the 2 ENG OUT and LV RATES portions of the system independently (figures 2.9-2 and 2.9-46). Deactivation of the two automatic abort parameters is also accomplished automatically in the LV-IU just prior to inboard engine cutoff (IECO). This automatic inhibit is in addition to the manual (procedural) deactivation by the flight crew.

2.9.2.3 EDS Power Sources

Electrical power for the EDS in each Saturn stage is supplied by batteries within that stage only. Each stage contains two or more batteries which supply power for separate buses. No electrical connection is made from a power source in one stage to a power source in any other stage. However, power and ground returns from each stage are supplied to special power and ground return buses in each of the other stages. Power from these special buses is then used for the transmission of EDS signals to the respective stages that originally supplied the power.

Power for the EDS circuits in the CM is supplied by CM entry and postlanding batteries. As is the case between stages of the Saturn vehicle, power and ground returns are provided between the CM and the LV-IU.

2.9.2.4 (Deleted)

Figure 2.9-3. Deleted

2.9.2.5 LV ENGINES Lights (Panel 1)

SEQ

A cluster of eight yellow lights display LV ENGINES status (figure 2.9-2). These lights are numbered and oriented the same as the first-stage booster engines. Status of the single S-IVB stage engine is monitored by the light which is designated number 1. Each of the eight displays includes two bulbs which are integral parts of redundant systems. Operation of the lights is analogous to the operation of automotive oil pressure indicators. If the parameter (fluid pressure which is interpreted engine thrust) is below tolerance, the light illuminates; if the parameter is at or above nominal the light is extinguished.

Observation of this display will enable the crew to monitor staging sequences in addition to time-critical emergency conditions. The event timer will be used in conjunction with this display when normal sequences are monitored.

2.9.2.6 LV GUID Light (Panel 1)

A single red light (figure 2.9-2) is used to indicate failure of the LV guidance system. Two bulbs are included in the fixture for redundancy, and illumination of either or both of these indicates a failure. A discrete signal from the LV-IU stable platform is the stimulus for illumination.

2.9.2.7 LV RATE Light (Panel 1)

A single red light (figure 2.9-2) is used to indicate an excessive rate condition around any of the pitch, roll, or yaw axes. Two bulbs are included in the fixture for redundancy, and illumination of either or both of these indicates excessive rates. Redundant signals are transmitted from the LV-IU to illuminate this light.

2.9.2.8 LIFT-OFF Light (Panel 1)

A white light (figure 2.9-2) illuminates at lift-off when discrete redundant signals from the LV-IU are transmitted to the CM. Two bulbs are included in the fixture for redundancy.

2.9.2.9 NO AUTO ABORT Light (Panel 1)

A red light (figure 2.9-2) illuminates to warn that the automatic abort initiate circuits are not operable. If an abort is required when this light is illuminated, it must be manually initiated. Two bulbs are included in the fixture for redundancy. Normally a discrete lift-off signal from the LV-IU will cause the SECS automatic abort initiate circuits to be switched to a state of operational readiness. When this happens, relay logic in the SECS inhibits illumination of the light.

2.9.2.10 Auto Abort Enable Switch

The LIFT OFF and NO AUTO ABORT lights are combined in an illuminated pushbutton (IPB) which is a guarded switch and is armed by an alternate battery bus power source. Illumination of the red NO AUTO ABORT light is an indication that complete enabling of both redundant SECS systems has not been established on the prime battery bus power source. In this event, the IPB should be depressed momentarily to manually switch the SECS automatic abort initiate circuits to a state of operational readiness.

2.9.2.11 ABORT Light (Panel 1)

The ABORT light (figure 2.9-2) is a red lamp assembly containing four bulbs that provide high-intensity illumination. Two bulbs are in system A, and two are in system B of the SECS. Operation of this light is independent of the sensing parameters of the Saturn LV-EDS. A discrete signal from either the LV-IU or via the SC updata link illuminates the light. Each of these signals originates from one of two sources: the range safety or launch control center (LCC) in the case of the signal from the IU, or the manned spaceflight control center (MSCC) or LCC in the case of the SC updata link signal.

2.9.2.12 (Deleted)

2.9.3 SEQUENTIAL EVENTS CONTROL SUBSYSTEM

The SECS is an integrated subsystem consisting of ten controllers which are installed in the command and service modules (CSM). Hybrid circuits, consisting of relay-logic and solid-state components, are incorporated for the initiation of pyrotechnic devices. In several instances control of electromechanical systems is required in conjunction with the utilization of explosive components and the SECS includes this capability. Switches are incorporated for manual intervention (backup and override) in most of the automated sequences; switches are also incorporated for the manual initiation of automated sequences, when time critical emergency conditions do not exist. The ten integrated controllers are:

- Two master events sequence controllers (MECS)
- Two service module jettison controllers (SMJC)
- One reaction control system controller (RCSC)
- Two docking events controllers (DEC)
- Two earth-landing sequence controllers (ELSC)
- One pyro continuity verification box (PCVB)

SEQ

The relationship of these controllers and their sources of electrical power are illustrated in figure 2.9-4. Eight batteries and two fuel cells supply electrical power. The SMJC is powered by the descent batteries; however, entry and postlanding battery power is used for the start signal. The remaining controllers of the SECS are powered by entry and postlanding batteries and pyrotechnic batteries.

2.9.3.1 SECS Design Criteria

The basic electrical design criteria for pyrotechnic systems are rigidly specified in the Air Force Eastern Test Range Manual, Range Safety

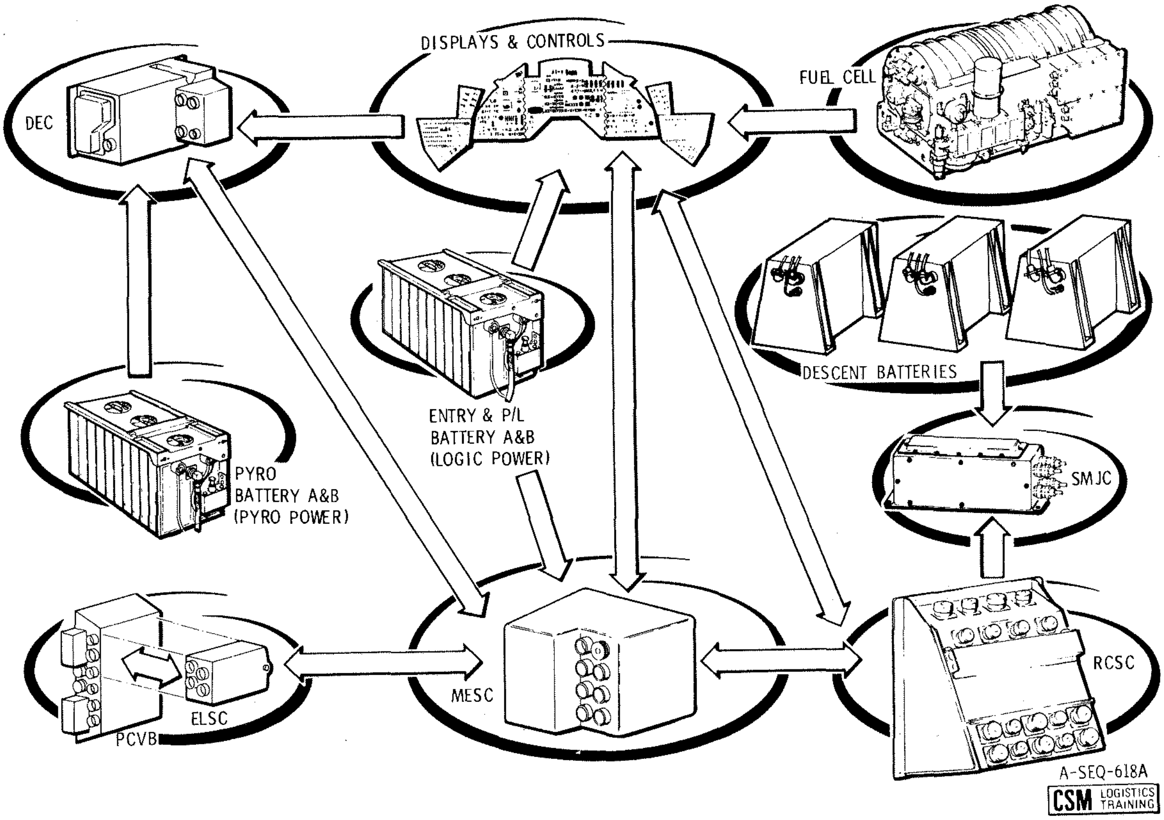


Figure 2.9-4. SECS Major Components

Manual, AFETRM 127-1 (10 September 1965). In addition to the design criteria specified in this manual, the following requirements are satisfied:

- The electroexplosive devices are electrically shorted until they are fired to prevent inadvertent ignition.
- At least two individually operated switching circuits are incorporated between the initiators and their pyrotechnic battery terminals. These are arming switches and firing switches which are illustrated in figure 2.9-5.
- Electrical power for the logic control circuits of the pyrotechnic firing circuits is supplied from a source other than pyrotechnic buses.
- All logic and pyrotechnic firing circuits are at least dual redundant.
- All logic timing circuits will fail in the T = ∞ mode.

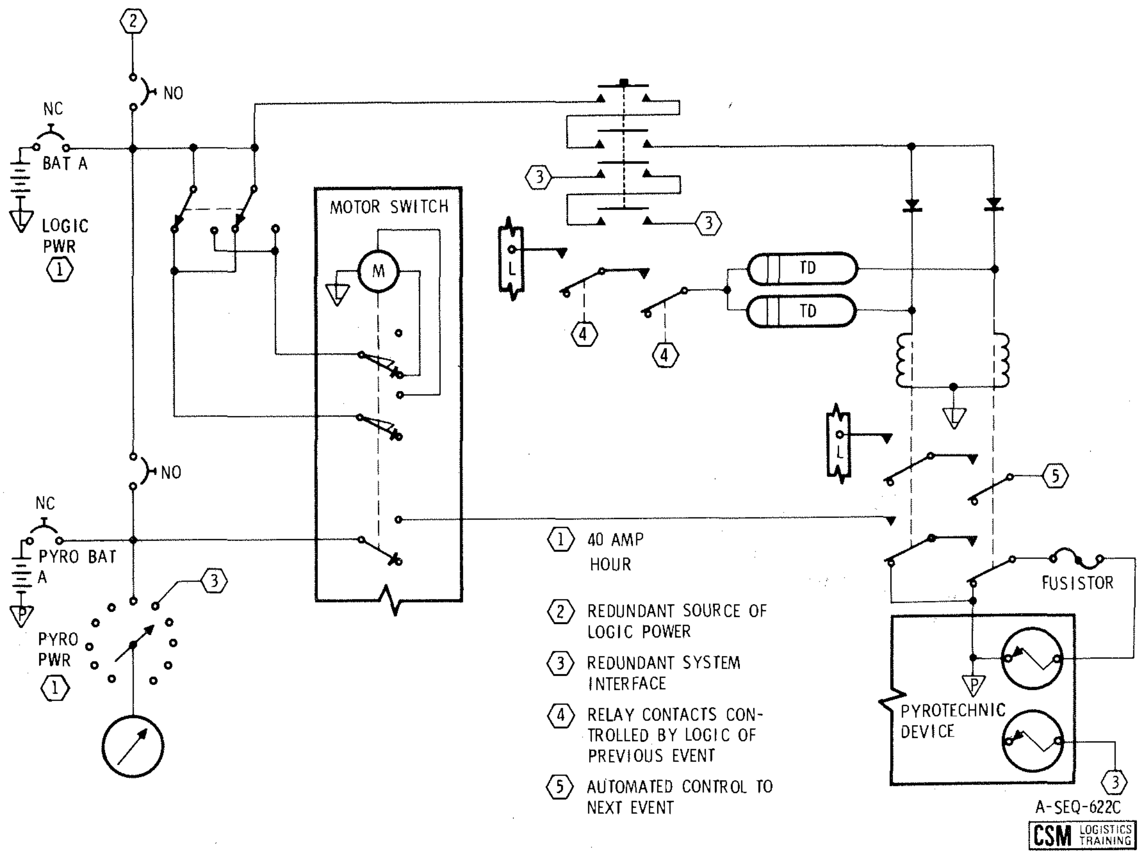


Figure 2.9-5. Typical SECS Circuits, Logic and Pyro

- Fusistors are located in series with the output contacts of the firing relays. Thus individual protection of each pyrotechnic firing circuit will prevent a current leakage path on any given firing line. A continual discharge of pyrotechnic battery power is impossible in this circuit design. These fusistors are specially designed to withstand high acceleration and vibration levels. The resistance value of these devices is 0.95 to 1.10 ohms at 25°C. The time-current operating characteristics are reflected in the following tabulation:

Amperes	Seconds
20.0	0.03 to 0.17
10.0	0.20 to 1.20
8.0	0.30 to 8.00
7.0	0.40 to 20.00

- To minimize RF pickup, the electrical leads from the firing relay contacts are twisted (20 twists per 12 inches) and are shielded. The shield is grounded at the firing relay interface and at the case of the initiator. Full 360-degree shielding is provided between the shield and the initiator case.

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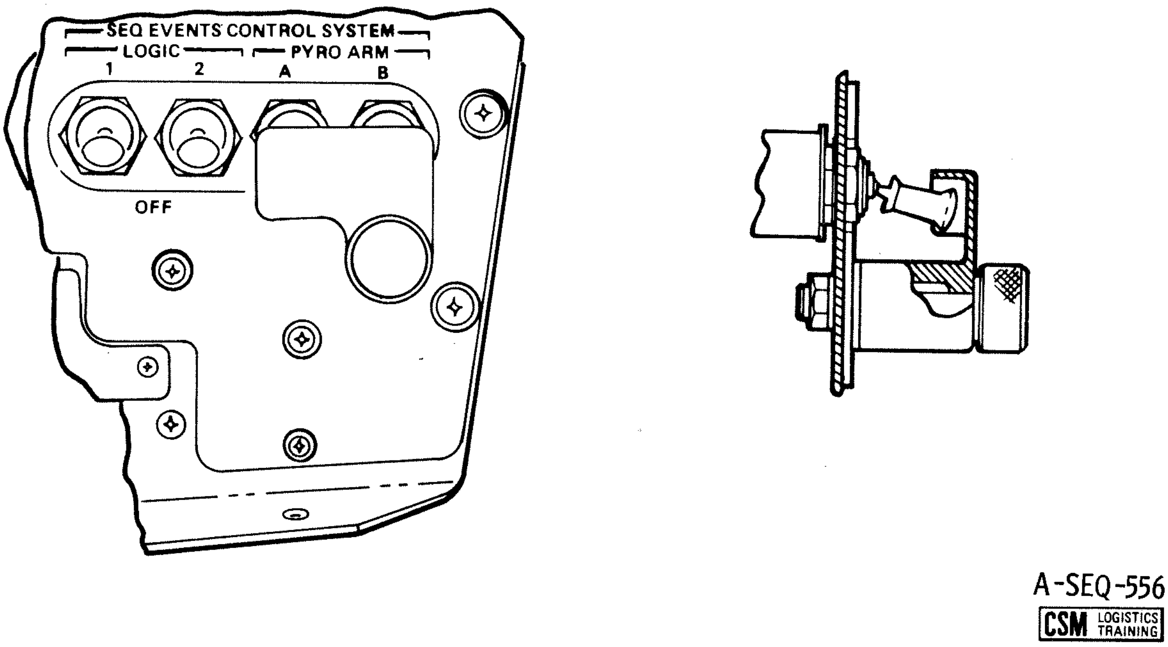

Figure 2.9-6. Pyro Arm Switch Guard

- The arm/safe function of the pyrotechnic circuit is controlled by a positive mechanical lock to prevent movement from the safe to the armed position. The device for this purpose is illustrated in figure 2.9-6.

Dual redundancy with manual backup is employed in the design of the SECS critical circuits. This ensures that in all cases the effects of a component failure, in prime failure mode, will not prevent system operation or cause inadvertent operation of the system.

The SECS is capable of performing the proper sequencing of events, initiating functions, and providing monitoring capabilities that are reflected in the following chart:

Flight Period	Controllers Used	Events Sequenced
Ascending	MESC	LES abort, escape tower jettison, SPS abort
Entry	MESC, ELSC, SMJC, RCSC, PCVB	CM-SM separation, deploy parachutes
LES abort	MESC, ELSC, RCSC, PCVB	LES motor fire, PC motor fire, deploy canard surfaces, deploy parachutes
Adapter separation and SPS abort	MESC	Separation of adapter from SM

Flight Period	Controllers Used	Events Sequenced
Docking	DEC, MESC	Probe retract
Emergency departure	DEC, MESC	CM docking ring separation
SM jettison	SMJC, MESC	CM-SM separation

Logic d-c power for the master event sequence controller, the earth landing system controller, and the CM reaction control subsystem controller is supplied by the entry and postlanding batteries through buses A and B located in the CM.

The electrical power for the firing of all ordnance initiators is supplied by the pyrotechnic batteries located in the CM. These batteries are isolated from the main electrical system with provision for in-flight recharging.

To assure operation of all functions controlled by the SECS, the design is fail-safe in all respects and the sequencers are designed as dual redundant subsystems. An exception to the dual redundant subsystem concept is in the control of certain pyrotechnically actuated valves within the CM RCS.

Redundant internal wiring is used where a loss of a single lead would cause premature initiation of a major function or loss of control of function.

Timing requirements are held within ±5 percent maximum under all conditions specified herein with the exception of the time delays associated with the earth landing sequence controller which has a maximum tolerance of +10, -0 percent. Time delays are arranged in pairs and wired with inputs in parallel and outputs in series, or similar provisions made to minimize the possibility of function initiation occurring before the specified time delay.

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Pyrotechnic circuits are the only electrical load connected to the pyrotechnic power bus and are not powered from the logic bus. Pyrotechnic circuits and logic circuits are electrically and physically isolated from one another and their wiring routed separately where possible.

2.9.3.2 SECS Equipment

Four controllers (MESC, ELSC, DEC, and PCVB) of the SECS are located in the right-hand equipment bay (RHEB) of the CM (figure 2.9-7).

Installation of the redundant SMJC controllers on the forward bulkhead of the SM in sector 2 is illustrated in figure 2.9-8. The fuel cells, which supply power for the SMJC, are also located in the SM.

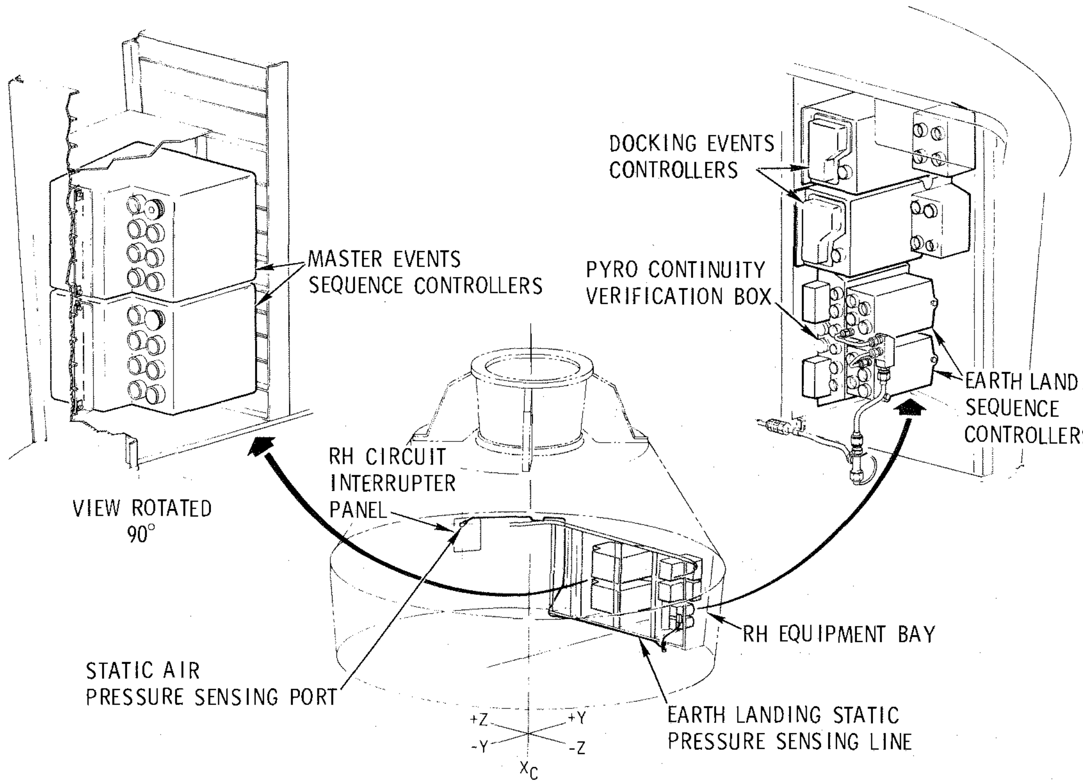

Figure 2.9-7. MESC, ELSC, DEC, and PCVB Locations

The location of the RCS controller in the aft equipment bay of the CM is illustrated in figure 2.9-9.

The SECS receives manual and/or automatic signals and performs control functions for normal mission events or aborts. The manual signals are the result of manipulating switches on the MDC or rotating the commander's primary translation hand control counterclockwise, which is the prime control for a manual abort. Automatic abort initiate signals are generated by the EDS. The origin of signals and functions of the sequential systems are described in paragraphs 2.9.7 and 2.9.8.

2.9.4 PYROTECHNIC SUBSYSTEM

Vehicle requirements dictate the need for one-shot, high-energy, quick-response systems for rocket motor ignition, physical separations, and deployment of earth recovery devices. Initiators, igniters, detonators,

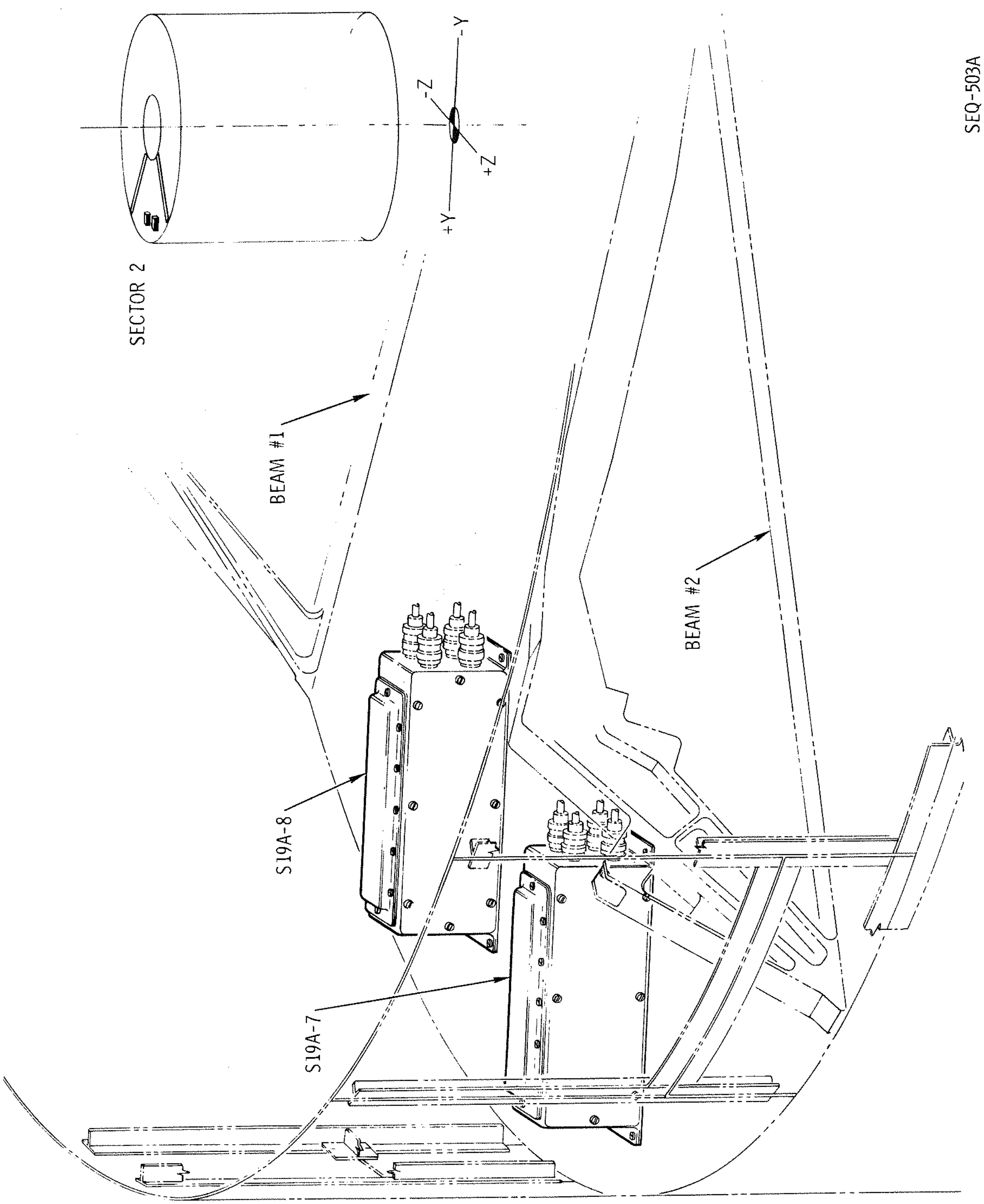

Figure 2.9-8. SMJC Location

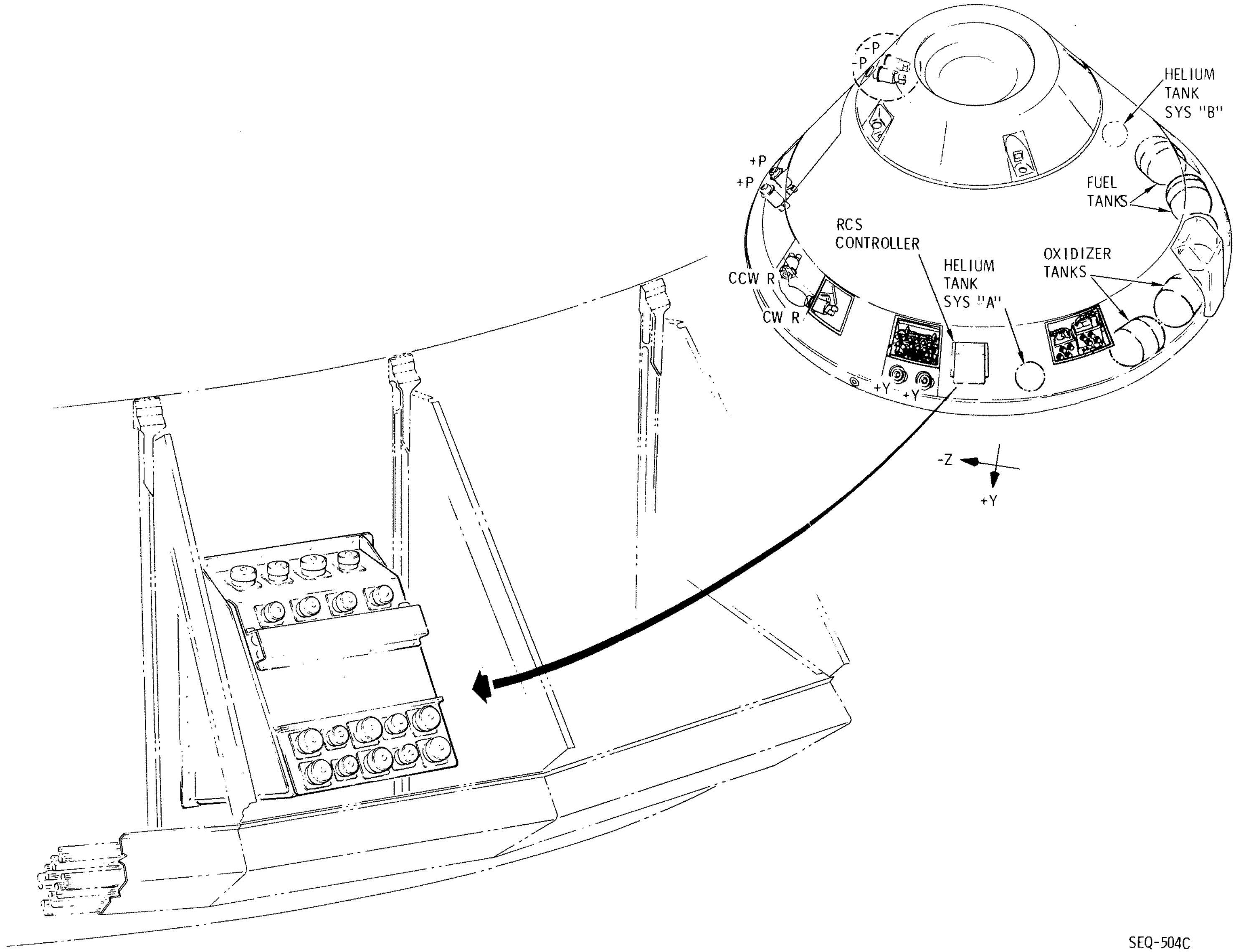

Figure 2.9-9. RCSC Location

pressure cartridges, detonating cords, linear-shaped charges and reefing line cutters were selected to support these needs. These are used for performing the following system functions:

Function	Subsystem
LE motor ignition	LES
PC motor ignition	LES
TJ motor ignition	LES
LE tower release	LES
Canard deployment	LES
Forward heat shield jettison	ERS
Drogue chute deployment	ERS
Drogue chute release	ERS
Pilot chute deployment	ERS
Main chute release	ERS
Main and drogue chute disreefing	ERS
Deployment of recovery aids	ERS
CM/SM separation	SM structure
structural	SM structure
umbilical	CM and SM structure
Electrical cable deadfacing	CM structure
Electrical cable deadfacing	SLA structure
SM-SLA separation	SLA structure
structure	SLA structure
umbilical	SLA structure
deadfacing	SLA structure
Propellant pressurization	CM-RCS
Propellant dump	CM-RCS
MDA separation	Docking subsystem
MDA docking probe retraction	Docking subsystem

2.9.4.1 Installation of Pyrotechnic Devices

Pyrotechnic devices are not an integral part of the vehicle structure and are installed during the various vehicle buildup staging periods; the devices are located in the following SC and LV areas:

System or Device	Area
LET separation device	External to CM forward heat shield
LES igniters	External to CM in launch escape assembly
ERS parachute and recovery aid deployment devices	External to CM and beneath the forward CM heat shield
CM-SM separation system	External to CM and between CM aft heat shield and SM forward bulkhead

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System or Device	Area
CSM-LV separation	External to CSM and in the SLA adapter
CM RCS valves	External to CM inner structures and internal to CM outer structural shell
CM-DS separation	External to CM and beneath the CM apex cover

2.9.4.2 Initiators

The single bridgewire Apollo standard initiator (SBASI) is used to initiate all electrically sequenced Apollo spacecraft ordnance devices and subsystems. This device has a primary ignition charge that is ignited by electrically heating a bridgewire. The primary charge ignites the main charge of the initiator, which, in turn, generates high-temperature gasses sufficient to initiate the main charge of a specialized explosive device (figure 2.9-10).

Each initiator has one pair of pins, electrically connected internally by a one-ohm resistance bridgewire. It is standard Apollo practice to use two initiators for each pyrotechnic application for redundancy. It is a one-watt, one-ampere, no-fire cartridge, with a single bridgewire and a ceramic header contained in a stainless-steel body. A flange-type washer provides a hermetically sealed interface when the initiator is permanently mated with ordnance devices. The all-fire current of the initiator is 3.5 amperes, and a safety factor is provided in the electrical system which provides 5.0 amperes to the bridgewire of each initiator. The approximate output of 150 calories is produced.

The initiator functions as the single interface between the logic subsystem and the spacecraft ordnance subsystem. High reliability and economy are achieved when one type of initiator is used as a standard. The initiator acts as the primer, in most applications, for the main explosive charge (figure 2.9-11).

The body of the SBASI forms an electrical connector, which includes a keying concept, that precludes adjacent pyrotechnic devices or systems from being interchanged during installation (figure 2.9-12).

2.9.4.3 Igniters

The Apollo standard igniter assemblies (figure 2.9-13) are used for the launch escape, tower jettison, and pitch control motors. The igniter provides controlled ignition of boron-potassium pellets which are contained in pellet baskets. Because of their large size, the tower jettison and launch escape motors require a large quantity of gas and hot particles for propellant ignition. The additional ignition energy required is supplied by a pyrogen unit, which is ignited by the boron-potassium nitrate pellets. Two igniters per motor are incorporated for redundancy.

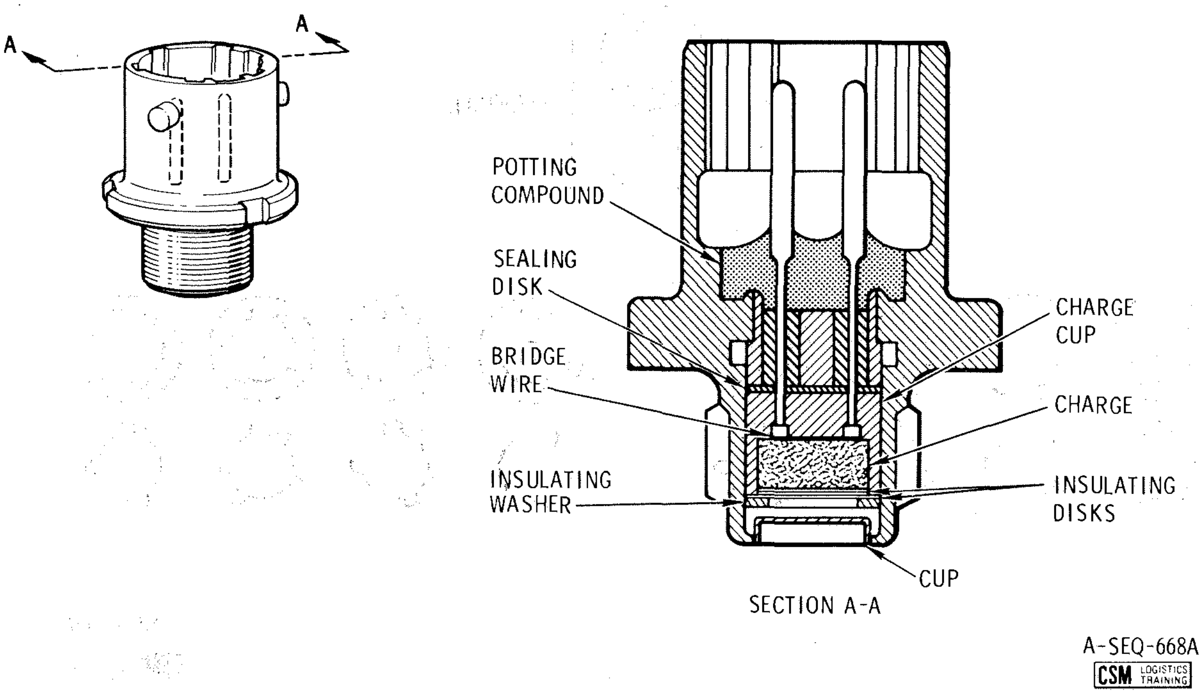

Figure 2.9-10. Single Bridgewire Apollo Standard Initiator

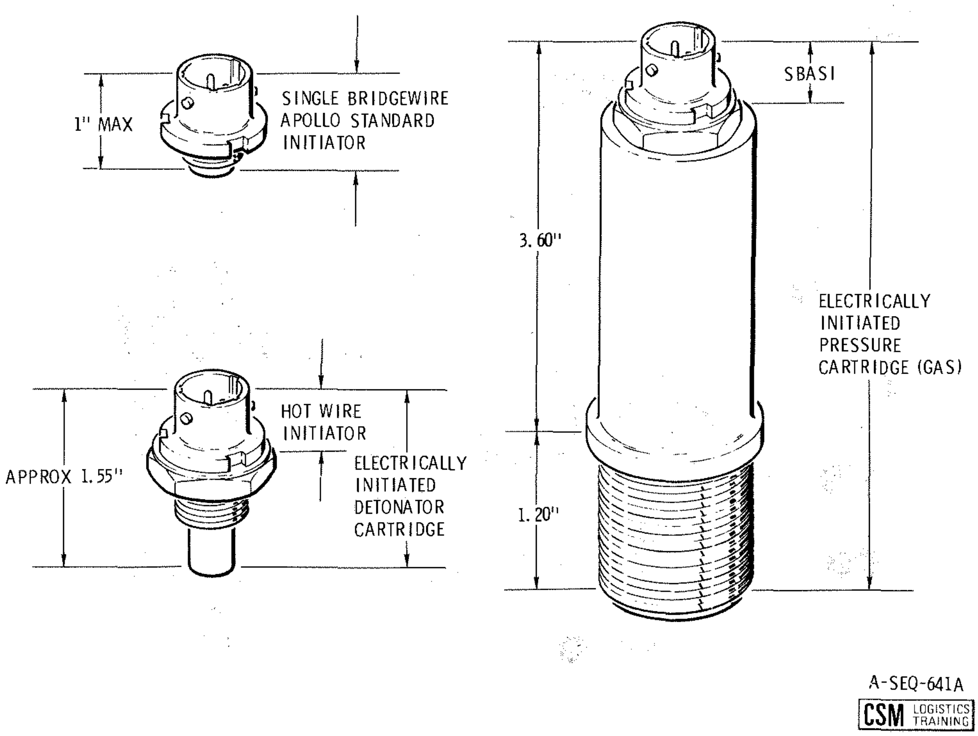

Figure 2.9-11. Electrical Hotwire Initiator and Associate Assemblies

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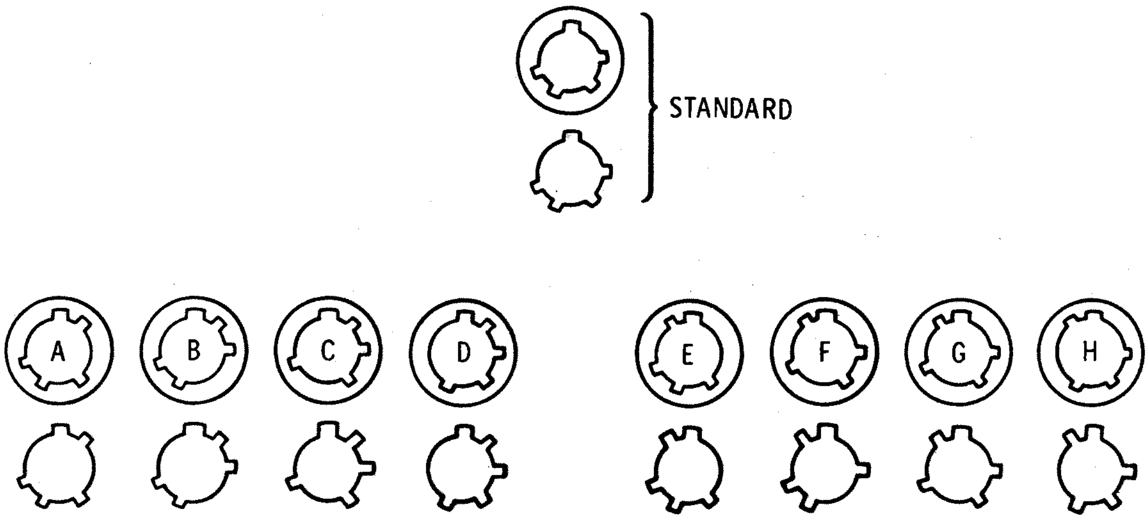

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Figure 2.9-12. Skylab Standard Initiator Noninterchangeability Keying Concept

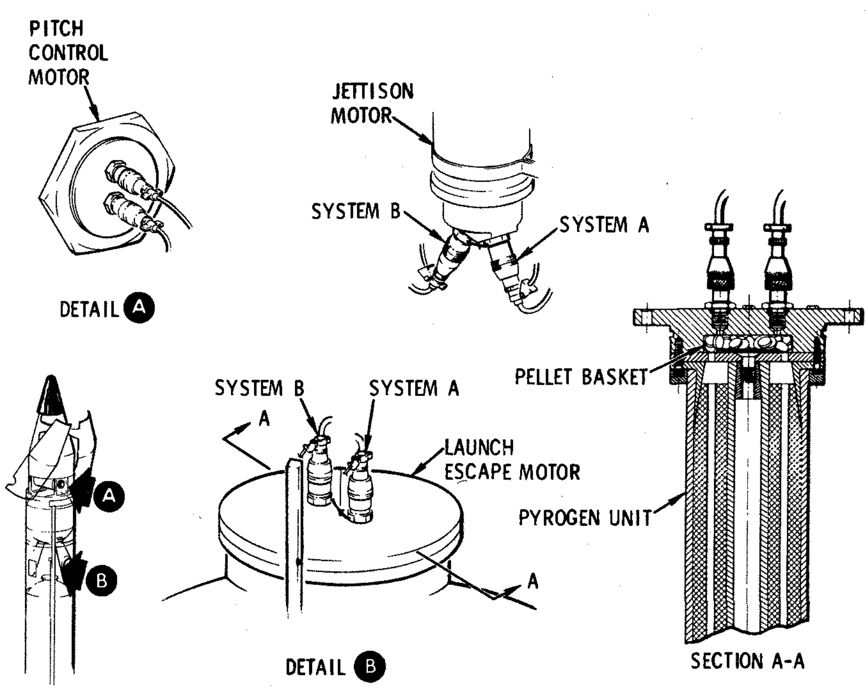

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Figure 2.9-13. LES Igniters

2.9.4.4 Apollo Standard Detonator

The standard detonator is used throughout the Apollo ordnance subsystem. The SBASI acts as the igniter for the detonator and is welded to the detonator body. The detonator cartridge (figure 2.9-14) consists of an explosive charge composed of lead azide and cyclotrimethylenetrinitramine (RDX). Detonators may affect certain functions by themselves or they may affect sympathetic detonation of other pyrotechnic or ordnance devices by concussion. These other devices are flexible linear-shaped charges (usually assembled into cutting assemblies), mild detonating cords, and confined detonating cords.

2.9.4.5 Long-Reach Detonator

The long-reach detonator is used only in the docking ring separation system. It is used to place the main charge out of reach of the standard detonator and contains high-temperature-resistant explosive (HNS) so it can operate satisfactorily at temperatures to 270°F. Figure 2.9-15 illustrates the long-reach detonator.

2.9.4.6 Pressure Cartridges

The pressure cartridge assembly (gas generator) is the electrically initiated hotwire type. The SBASI is used to initiate the burning of a

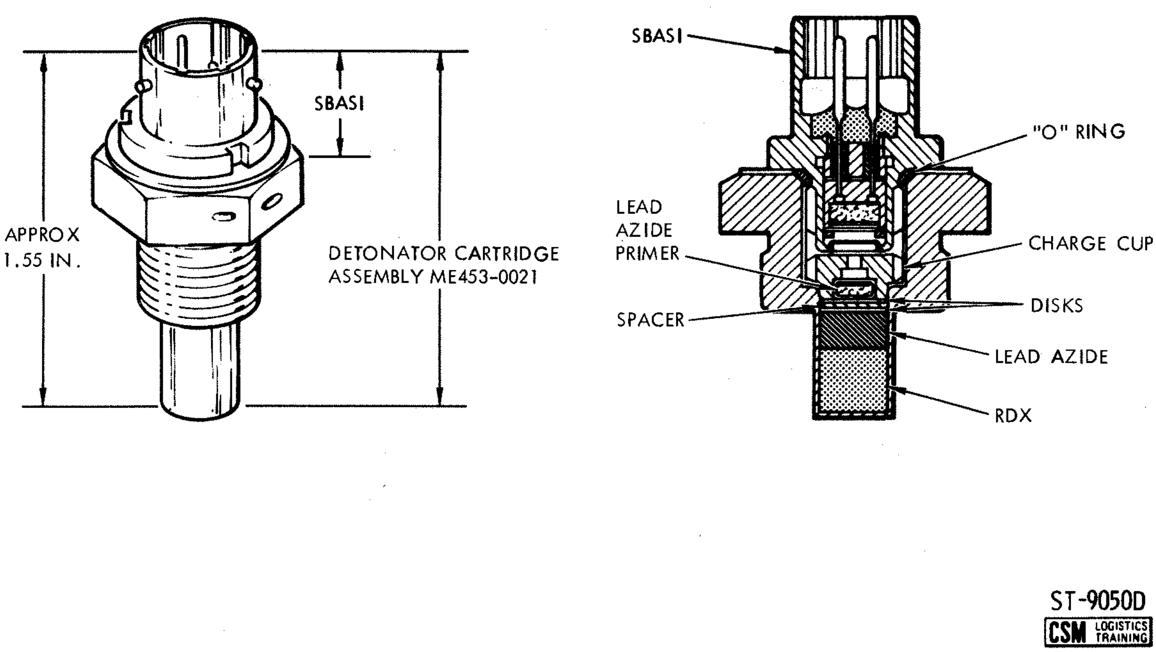

Figure 2.9-14. Detonator Cartridge Assembly

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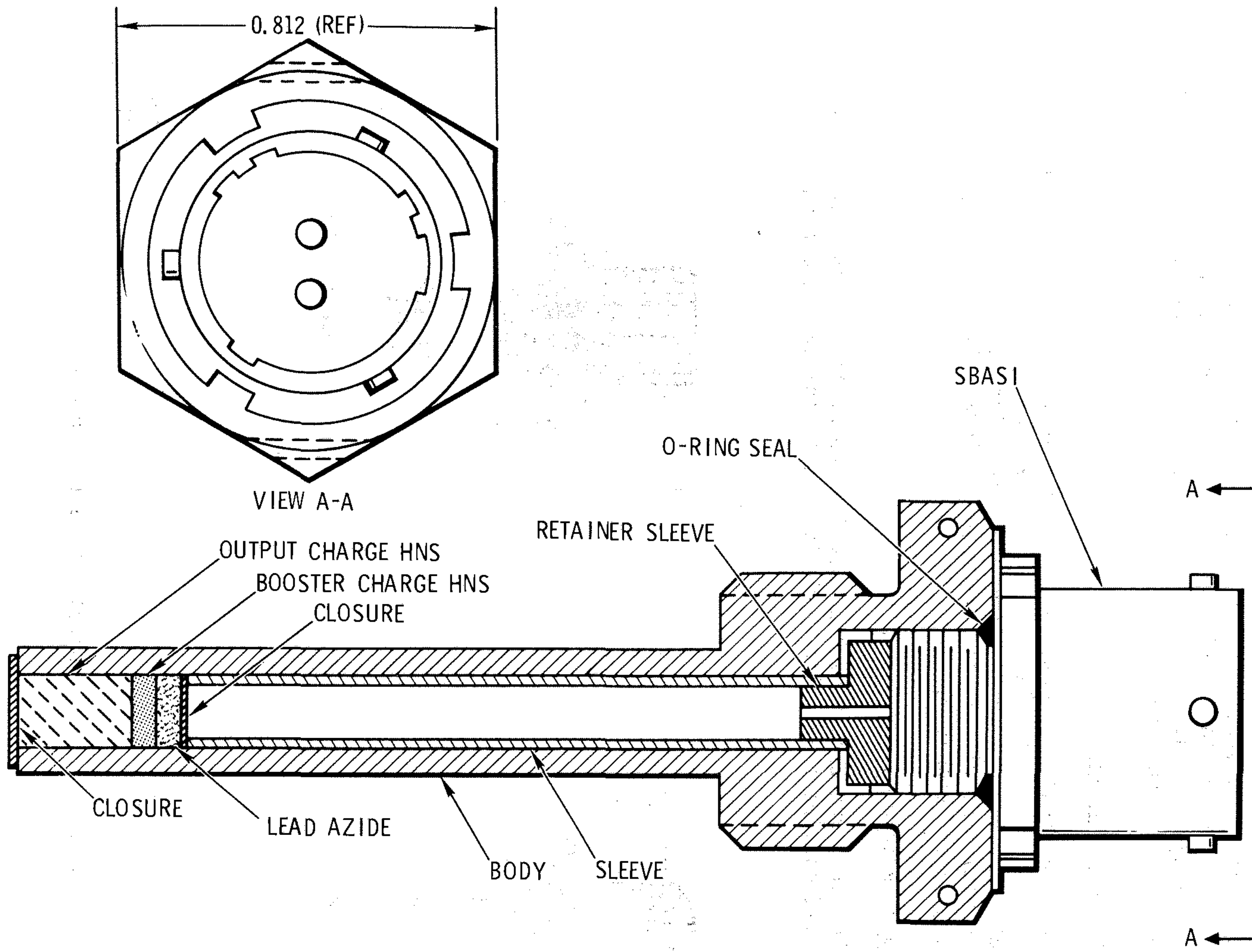

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CSM LOGISTICS TRAINING

Figure 2.9-15. Long-Reach Detonator

booster charge of powder which in turn ignites the main charge of pellets. The fast burning of these pellets generates gas pressure according to the number of pellets in the assembly. Cartridge types are reflected in the following chart.

Type	Application	Function
I	Drogue mortar	Mortar ejects the drogue parachute for spacecraft deceleration.
II	Pilot mortar	Mortar ejects the pilot parachutes which pull out the main parachutes for earth landing, and the drag parachute for the apex cover.
IV	5/8-inch valve	Cartridge used to operate valve.
200	Electric circuit interrupter	Dead-faces electrical circuitry in SM and CM.
100	1/4-inch valve	Cartridge (initiator plus adapter) is used to operate valve.
V15-590220	Canard deployment	Cartridge provides thruster power to deploy canards.
V36-596006	Drogue disconnect	Cartridge drives guillotine to sever drogue parachute riser.
V36-596007	Main parachute disconnect	Cartridge drives guillotine to sever main parachute riser.
VI	Heat shield	Cartridge device jettisons the heat shield covering the parachute compartment at the apex of the CM (figure 2.9-16).

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2.9.4.7 Explosive-Train-Initiated Pressure Cartridge

The spacecraft lunar module adapter (SLA) panel thrusters are operated by a through-bulkhead, explosive-train-initiated pressure cartridge (figure 2.9-17). This pressure cartridge differs from the conventional pressure cartridge in that a solid bulkhead within the cartridge body prevents any back pressure. The explosive train charge initiates the detonator charge which transmits the detonation wave through the solid bulkhead. This wave is of sufficient intensity to ignite the primer or receptor charge without rupturing the bulkhead. The receptor charge then ignites an intermediate charge which ignites the propellant or gas-producing grains.

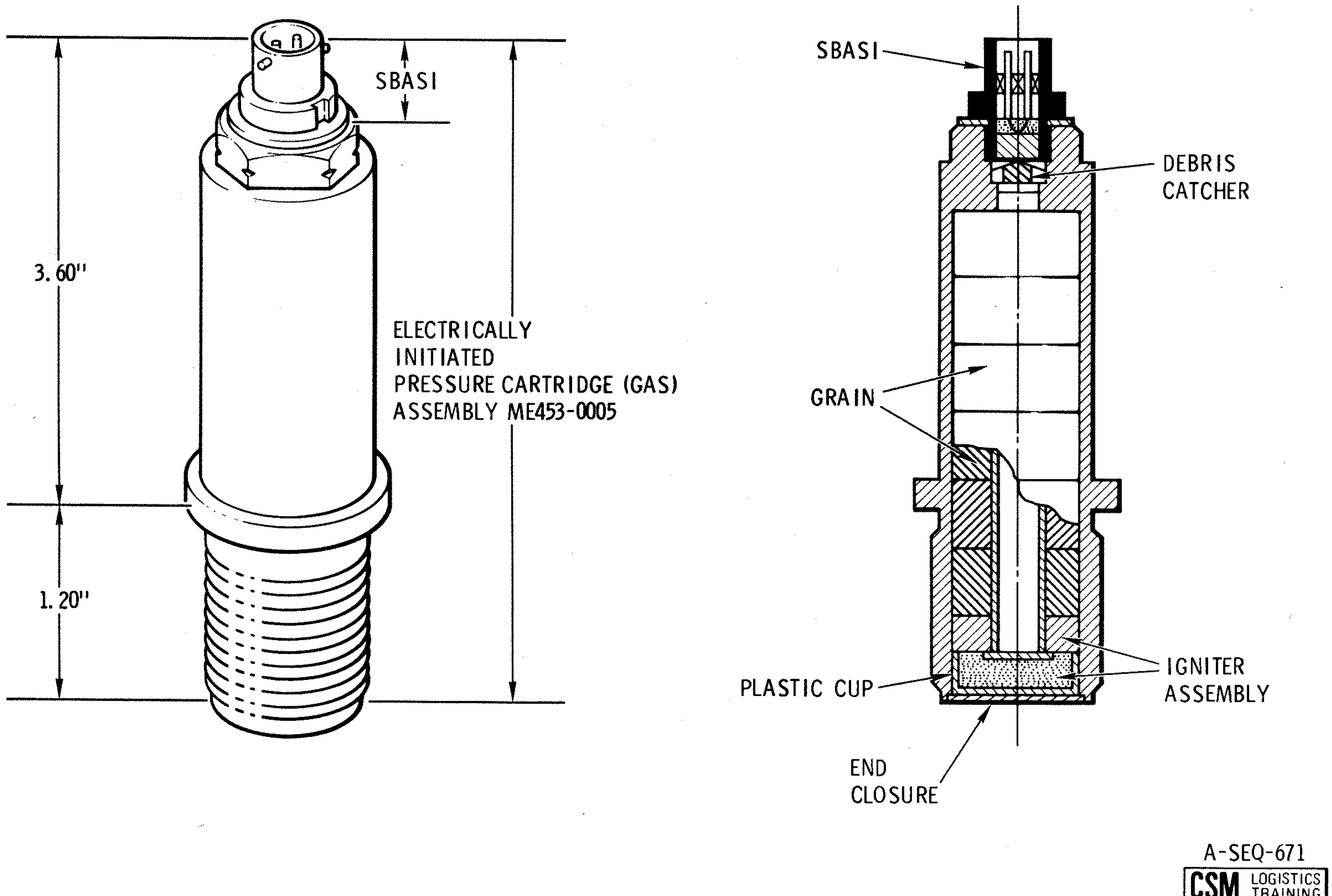

Figure 2.9-16. Type VI Pressure Cartridge

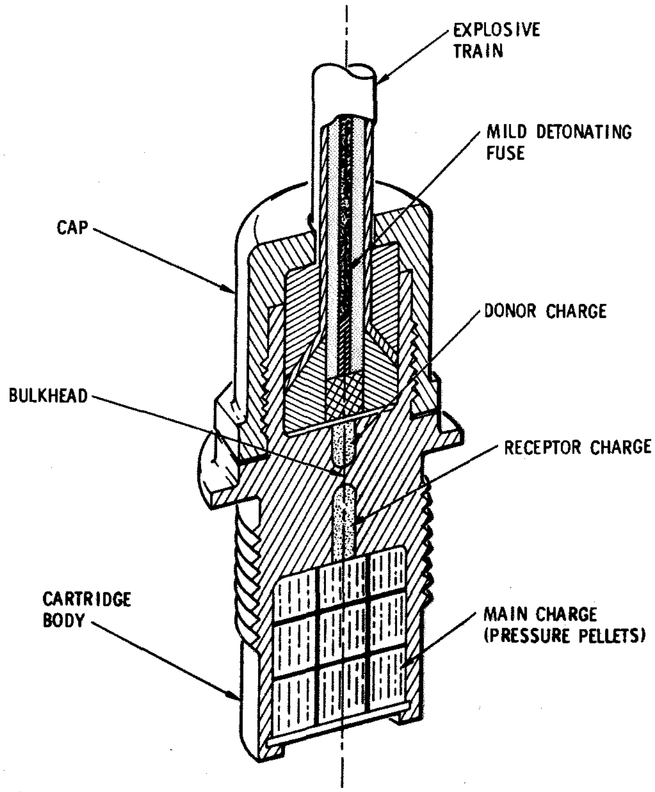

Figure 2.9-17. Explosive-Train-Initiated Pressure Cartridge

2.9.4.8 Confined Detonating Cord

The confined detonating cord (figure 2.9-18) has a core made up of a mild detonating fuse covered with several layers of plastic tubing, fiber-glass matting, and nylon covers. It is used to transfer a detonation wave between two or more small booster charges. The detonation is completely contained by the insulation buildup. Because the detonation is small and completely contained, the confined detonating cord may be routed in close proximity to sensitive electronic telemetering instruments or structural members, or through crowded areas, without damage.

2.9.4.9 Explosive Train

Detonating cords are also used to break splice plates and to transfer detonation from one junction to another. This cord (figure 2.9-18) is a seamless, continuous lead or silver sheath surrounding an explosive cord.

The Apollo explosive train charge is a detonating cord designed with accompanying booster explosive charges to transfer the detonation across junctions.

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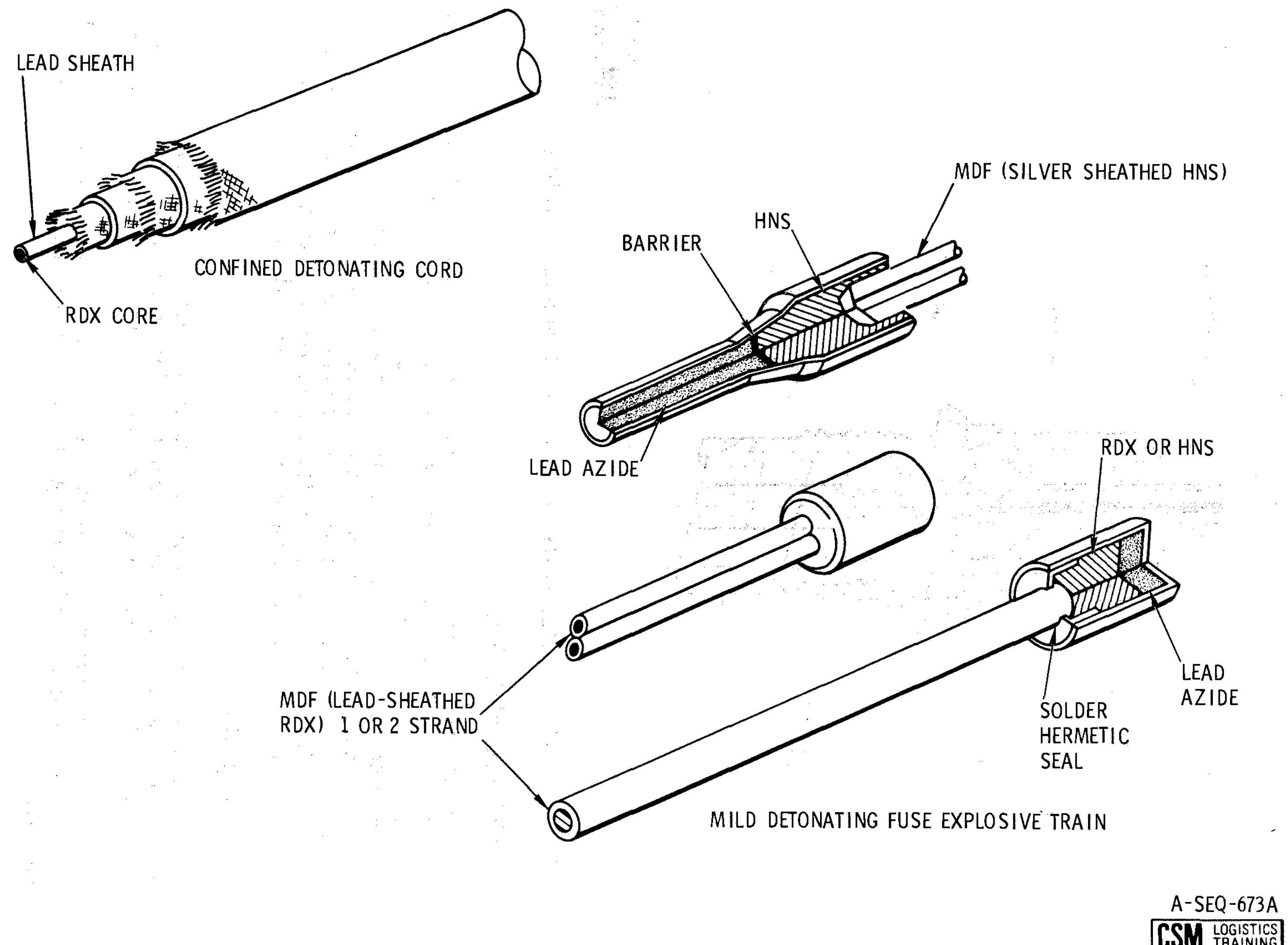

Figure 2.9-18. Detonating Cords

2.9.4.10 Mild Detonating Fuse

Mild detonating fuse (MDF) cord is formed by filling a lead antimony tube with explosive (virgin RDX for the Apollo program) and drawing down to required grain-weight-per-foot. Wall thickness will vary depending on core weight; overall diameter is approximately 0.070 inch.

The MDF for the docking ring separation system is fabricated to withstand the higher temperatures encountered in this system. It is a silver sheath with HNS.

2.9.4.11 Linear-Shaped Charges

A linear-shaped charge (LSC) is a seamless, continuous metal sheath surrounding a continuous column of explosive. It is shaped to utilize the Munroe effect and to penetrate materials in a predictable manner. The metal-covered charge can be formed into intricate shapes. The shape charge used in Apollo systems (figure 2.9-19) consists of a silver sheath and an explosive core of HNS.

The cutting ability of LSC is an inverse function of the square root of the density of the material to be cut. A much greater thickness of magnesium than of steel can be cut with a given size. Also, for each type of LSC and given target, there is an optimum spacing between charge and target at which maximum penetration into the target can be achieved.

The tension tie cutters utilize LSC fabricated into components with a lead azide booster charge on each end. Increased reliability is obtained. The boostered LSC and detonators are used on the CM/SM separation system. The CM is secured to six compression pads on top of the SM. Three of the pads contain tension ties that hold the CM tightly to the SM. The boostered LSC, designated BLSC, is used to cut these tension ties.

2.9.4.12 Reefing Line Cutters

The reefing line cutter assembly (figure 2.9-20) is initiated mechanically rather than electrically. A lanyard-operated firing pin is used to ignite the time-delay train. After the train has burned for the required time, it ignites a small powder charge which drives a cutting blade against the anvil and severs the reefing line.

Reefing line cutters are used to control parachute shock loading during inflation. They are also used in the deployment of recovery devices during descent.

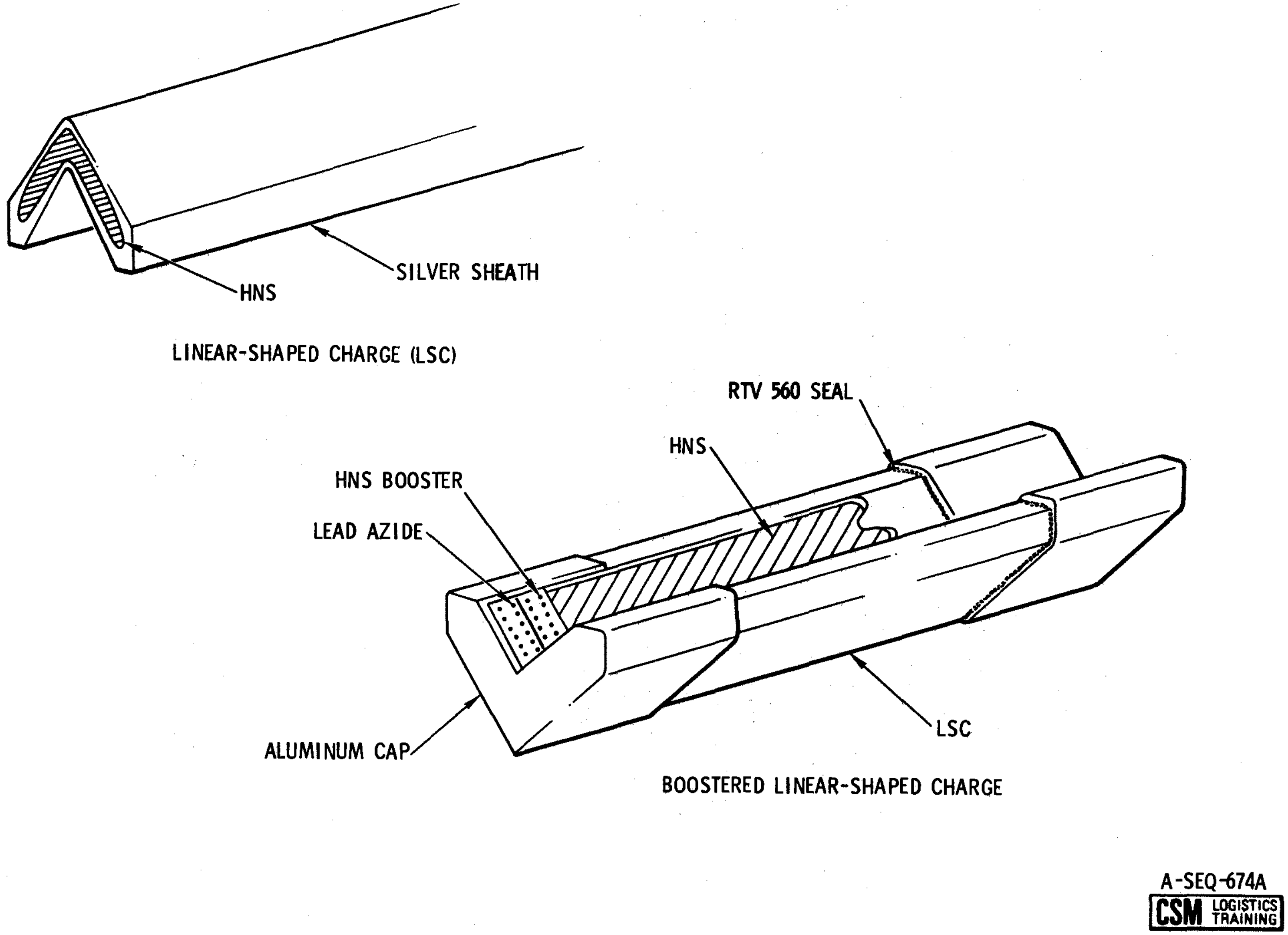

Figure 2.9-19. Linear-Shaped Charge

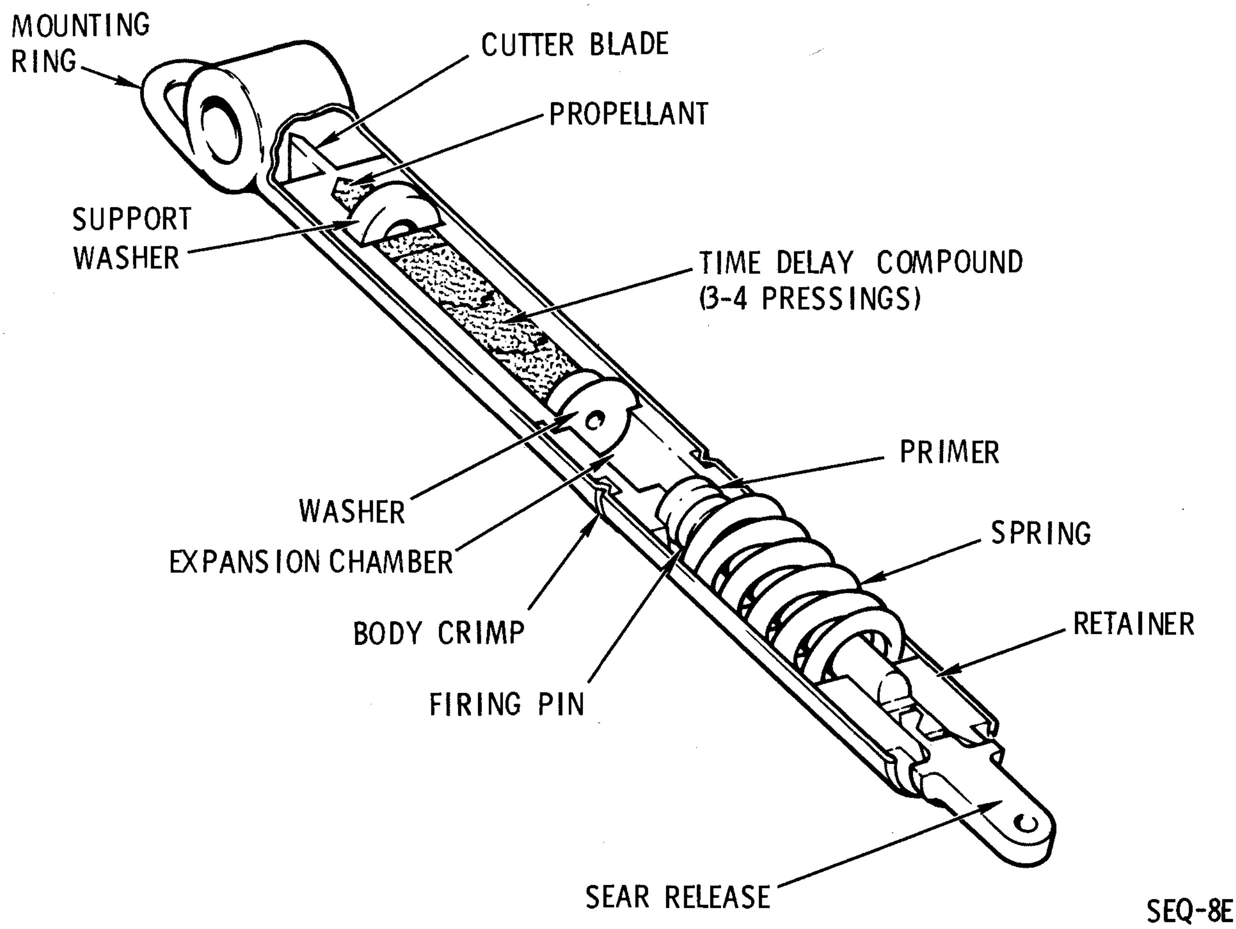

Figure 2.9-20. Reefing Line Cutter

2.9.4.13 Design Criteria for Pyrotechnic Subsystem

The pyrotechnic system is designed to meet the range safety requirements specified in AFETRM 127-1. It is designed to achieve a high degree of reliability with respect to operation and function. In order to achieve reliability of operation, a dual initiation capability is designed into each pyrotechnic device. In addition, each device is initiated by an independent redundant electrical system. Each electrical system is powered by an independent power source, with provisions for switching to main vehicle power if the main pyrotechnic power source should become inoperative. To further enhance system and component reliability, primary initiation sources such as initiators, detonators, and pressure cartridges have been standardized.

To assure proper sequence of operation and to protect against inadvertent operations, a centralized control system is used. Pyrotechnic devices are controlled by the SECS.

The SBASI will not ignite or be degraded when subjected to 1 ampere or 1 watt for five minutes minimum and will not ignite or be degraded when subjected to a 25,000-volt discharge from a 500-pf capacitor between the connector pins and the body. The insulation resistance between any pin and the body is greater than two megohms at a potential of 250 volts dc. The SBASI fires when subjected to any current above 3.5 amperes and up to the delivery capability of the firing battery.

Figure 2.9-21. Deleted

The initiator is capable of performing without degradation of performance after being subjected to the no-fire test at 165°F or the static discharge test at ambient temperature when the all-fire current is applied. In addition, the SBASI can withstand a minimum of 25 applications of 50 milliamperes through its bridgewire for one minute without degradation. The SBASI is equipped with a Government-approved shorting plug which shunts all connector pins together and to the initiator body. The initiator functions without degradation of performance after having been exposed to all combined environments occurring during a mission; for this requirement, the initiator is assumed to be mounted externally to the spacecraft without protection other than that afforded by the mating electrical connector and the next higher output and assembly.

All high-explosive materials are from newly manufactured batches. RDX will be supplied as GFE. Where high-temperature explosives other than RDX are required, explosives are GFE or obtained from a Government-approved source.

All high-explosive charges such as LSC and MDF are mounted in suitable charge holders separable from structural elements. Charge holders are designed to protect the explosive trains, to minimize and/or direct back-blast, and to permit ease of installation at the launch site. The explosive charge is sealed from exposure at atmospheric and mission environments. Explosive trains consisting of more than one integrally assembled component have boostered interfaces.

2.9.5 LAUNCH ESCAPE SYSTEM

The LES is used in the event of an emergency arising from a malfunction in the LV or other systems affecting flight crew safety. It is used to abort the mission by separating the CM from the LV and the service module (SM). The LES is operational from the time of launch complex access arm withdrawal until shortly after second-stage booster ignition. Following second-stage booster ignition, the launch escape tower (LET) is jettisoned from the command/service module (CSM) LV combination.

The major components of the LES are rocket motors, LET structure, structural skirt, tower separation mechanism, boost protective cover, canards, nose cone and Q-Ball (figure 2.9-23).

2.9.5.1 Launch Escape Vehicle

The launch escape vehicle (LEV) consists of the LET attached to the CM. Acceleration vector alignments and center-of-gravity excursions are illustrated in figure 2.9-24.

2.9.5.2 LES Rocket Motors

The launch escape motor (LEM), the pitch control motor (PCM), and the tower jettison motor (TJM), respectively, provide primary propulsion, trajectory shaping, and LET jettison capabilities. These are solid rocket motors with propellants consisting of case-bonded star grain employing polysulfide ammonium perchlorate formulations.

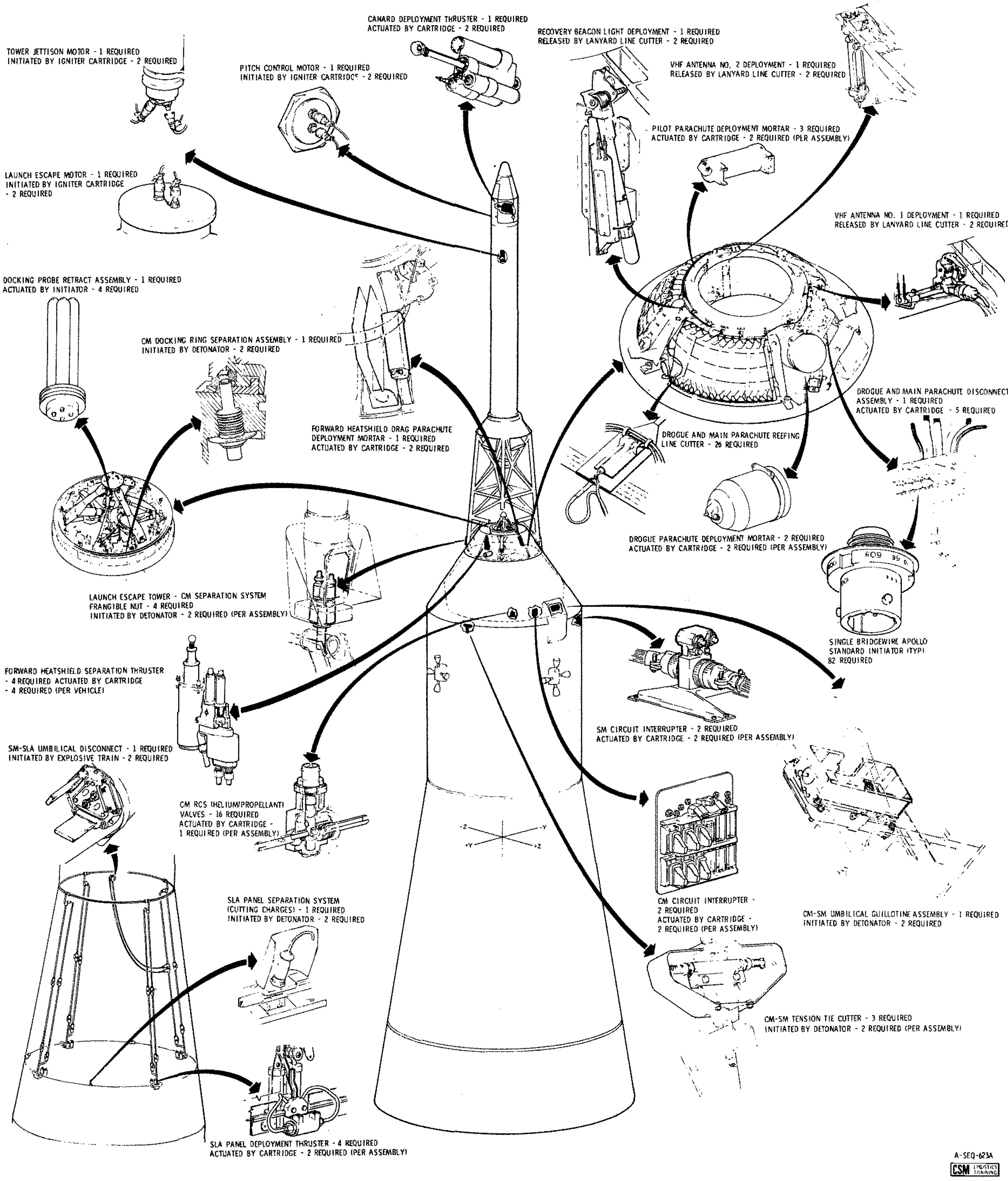

Figure 2.9-22. Skylab CSM Pyrotechnics

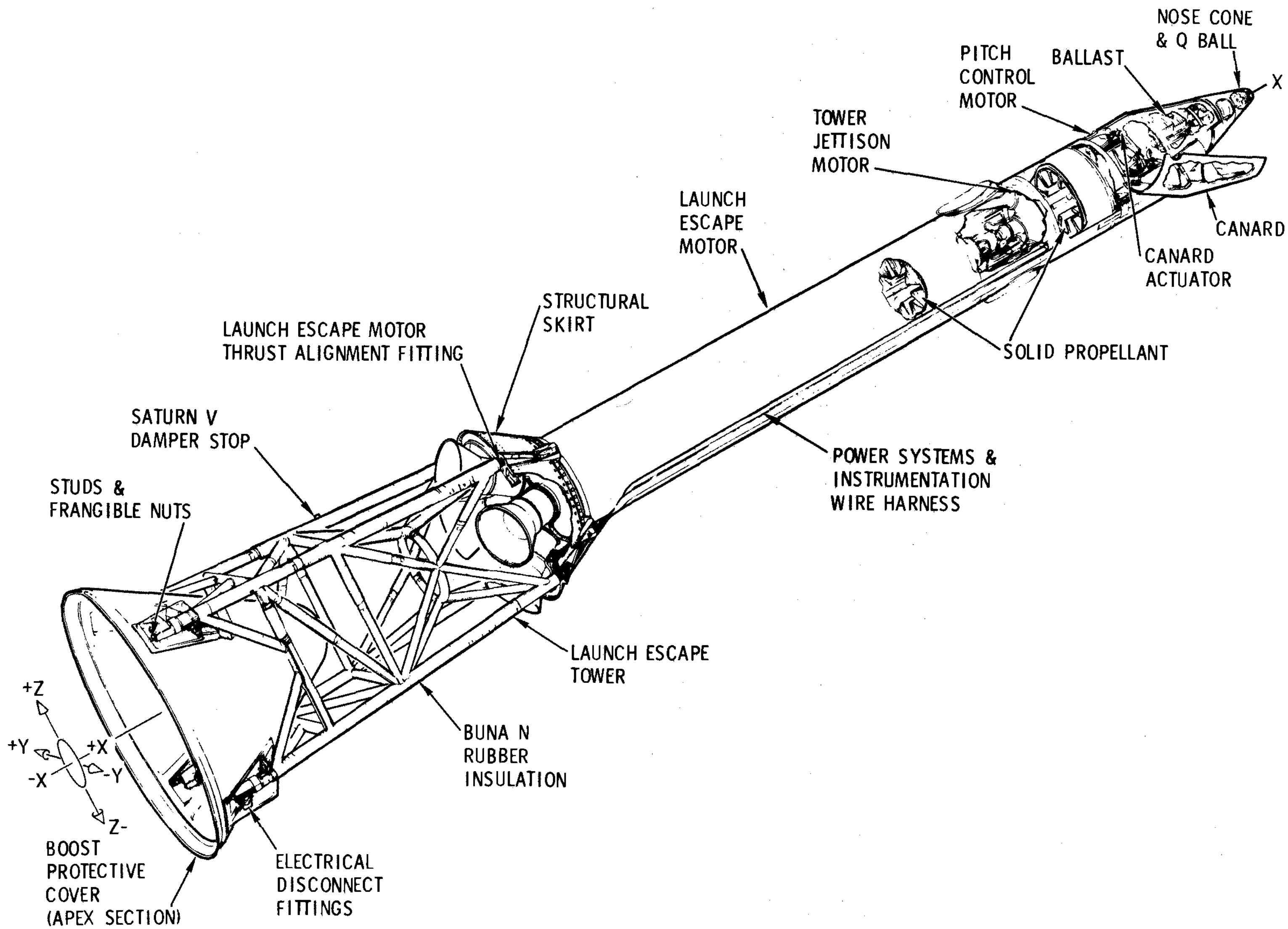

Figure 2.9-23. Launch Escape Tower Assembly

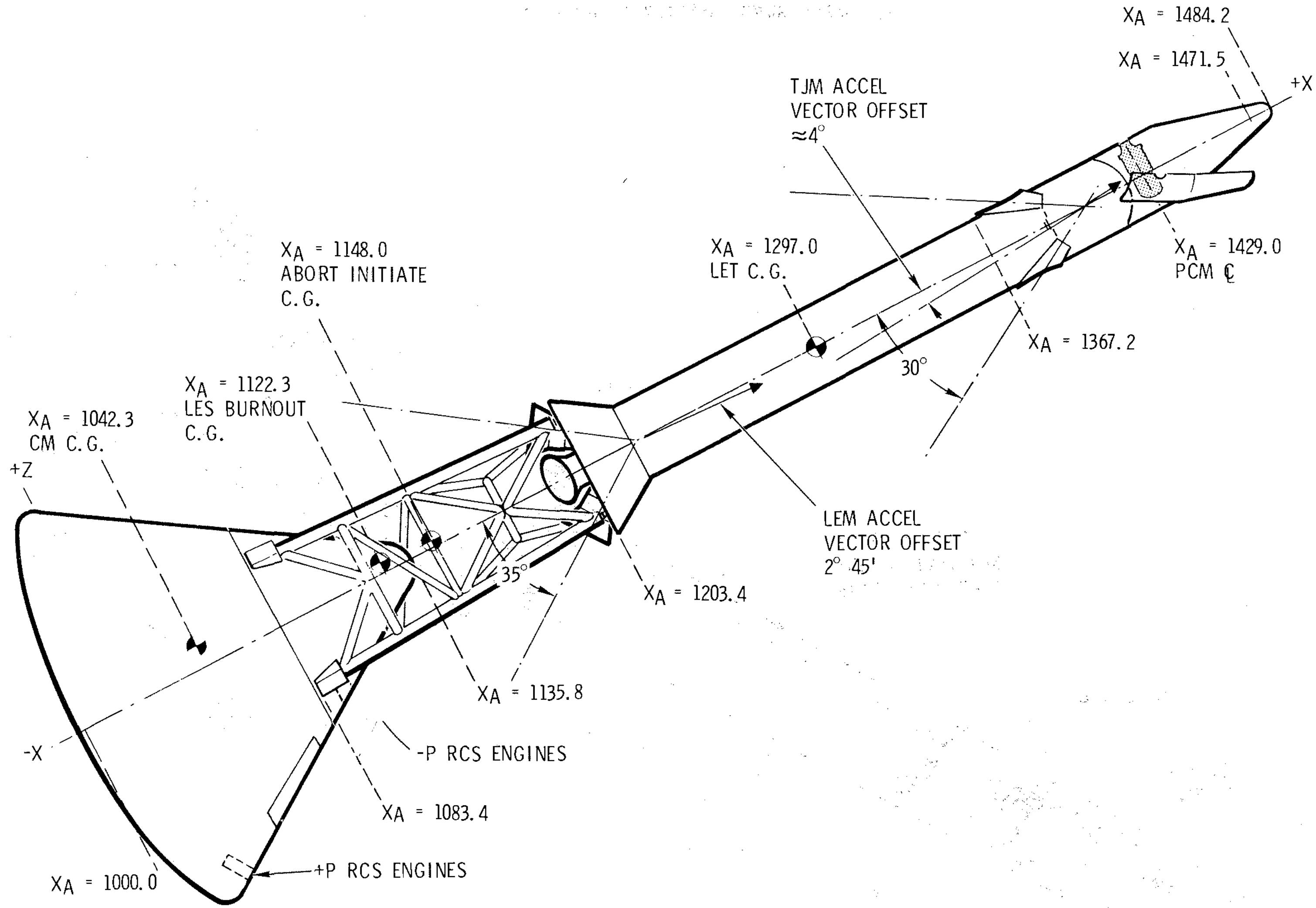

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Figure 2.9-24. Launch Escape Vehicle Centers of Gravity

The TJM delivers sufficient thrust, under normal mission conditions, to effect adequate separation of the LET from the CM while the latter is undergoing acceleration by the second-stage booster. Under abort conditions, the TJM delivers sufficient thrust for adequate separation of the LET from the CM after LEM burnout.

The LEM delivers sufficient thrust for the safe removal of the crew from a malfunctioning LV.

The PCM, in conjunction with the LEM, is employed to place the LEV in the correct flight attitude for a successful escape during mode 1A aborts.

2.9.5.2.1 Tower Jettison Motor

The tower jettison motor (figure 2.9-25) is a solid propellant motor providing LES jettison capability and includes the items sepcified.

The motor case assembly is fabricated from Inconel. The forward end of the case incorporates provisions for attachment to the canard support structure.

The motor case liner provides a satisfactory bond to the propellant grain and to the motor case. The case liner is TED-100L and has the following formulation:

Ingredient	Parts by Weight (%)
TPE-8104 PROPELLANT	
NH_4 ClO_4	72.00
LP-33 (fuel/binder)	18.81
Para-quinone dioxime	1.39
Sulphur	1.00
Iron oxide	2.00
TP-908 plasticizer	2.09
Diphenyl quanidine	0.70
Aluminum	2.00
TED-100L LINER FORMULATION	
LP-3	72.04
Para-quinone dioxime	4.80
Diphenyl quanidine	0.50
MgO	2.99
Sulphur	0.22
Thermax	19.45

The aft closure dome of the tower jettison motor is fabricated from Inconel, and is attached to the motor case assembly by means of a bolted flange. The dome contains provisions for the attachment of two canted exhaust nozzles and the igniter assembly.

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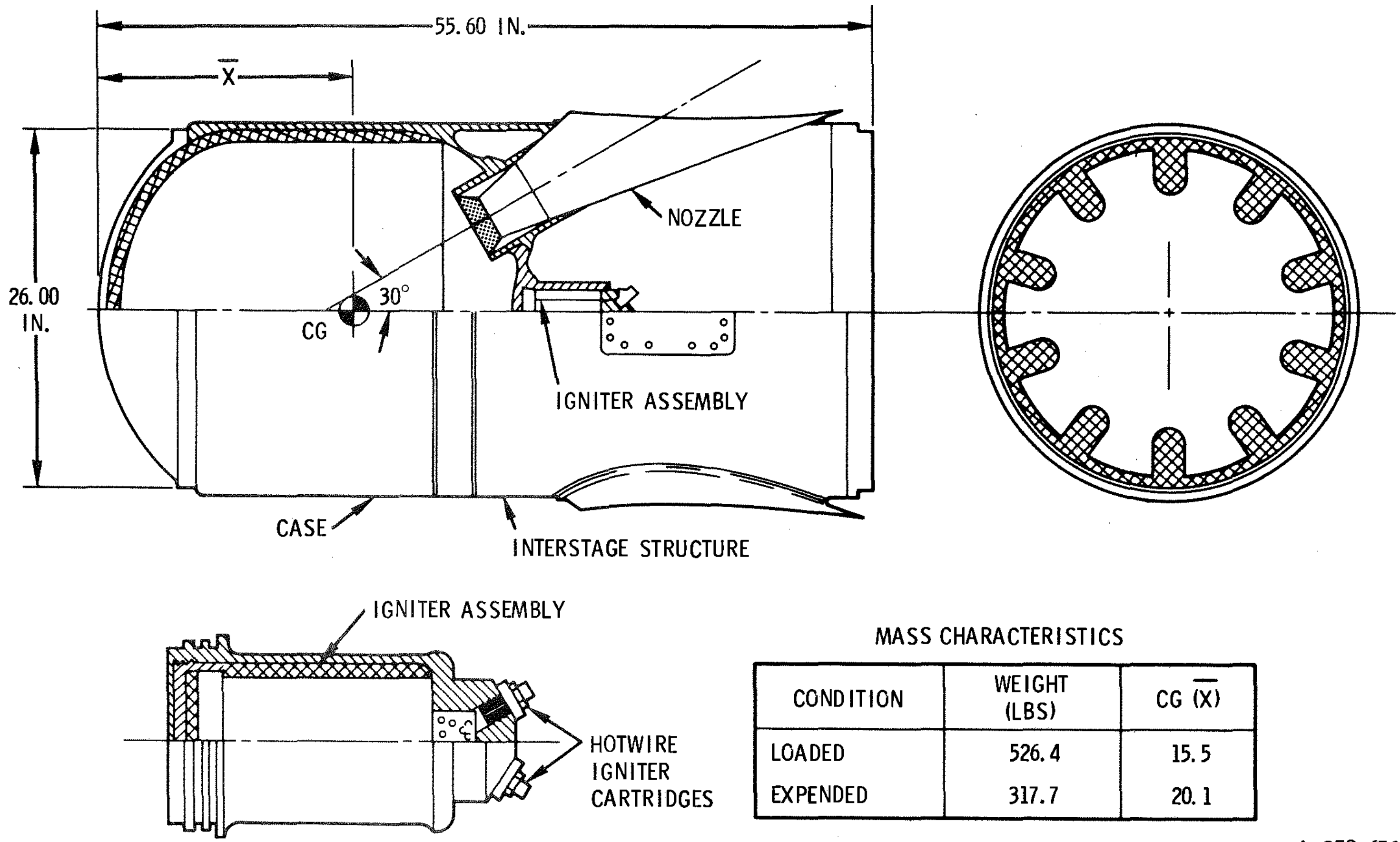


MASS CHARACTERISTICS

CONDITION	WEIGHT (LBS)	CG (X̄)
LOADED	526.4	15.5
EXPENDED	317.7	20.1

Figure 2.9-25. Tower Jettison Motor Configuration (Nominal)

A case-bonded propellant charge having a 10-point internal burning star configuration is employed. The propellant grain does not require addition of auxiliary grain supports, inert slivers, or other similar provisions to achieve its design objectives. The propellant is TPE-8104.

The resultant average thrust over the burning time, when measured at sea-level conditions and with the propellant grain as the noted temperatures, is within the following limits:

140°F = 31,200 to 36,000 pounds

70°F = 29,400 to 33,900 pounds

20°F = 28,000 to 32,400 pounds

A typical thrust versus time trace is presented in figure 2.9-26.

The thrust rise time from time zero (time of firing current application to the time at which the thrust reaches 90 percent of F_i (ignition thrust) is between 75 and 150 milliseconds.

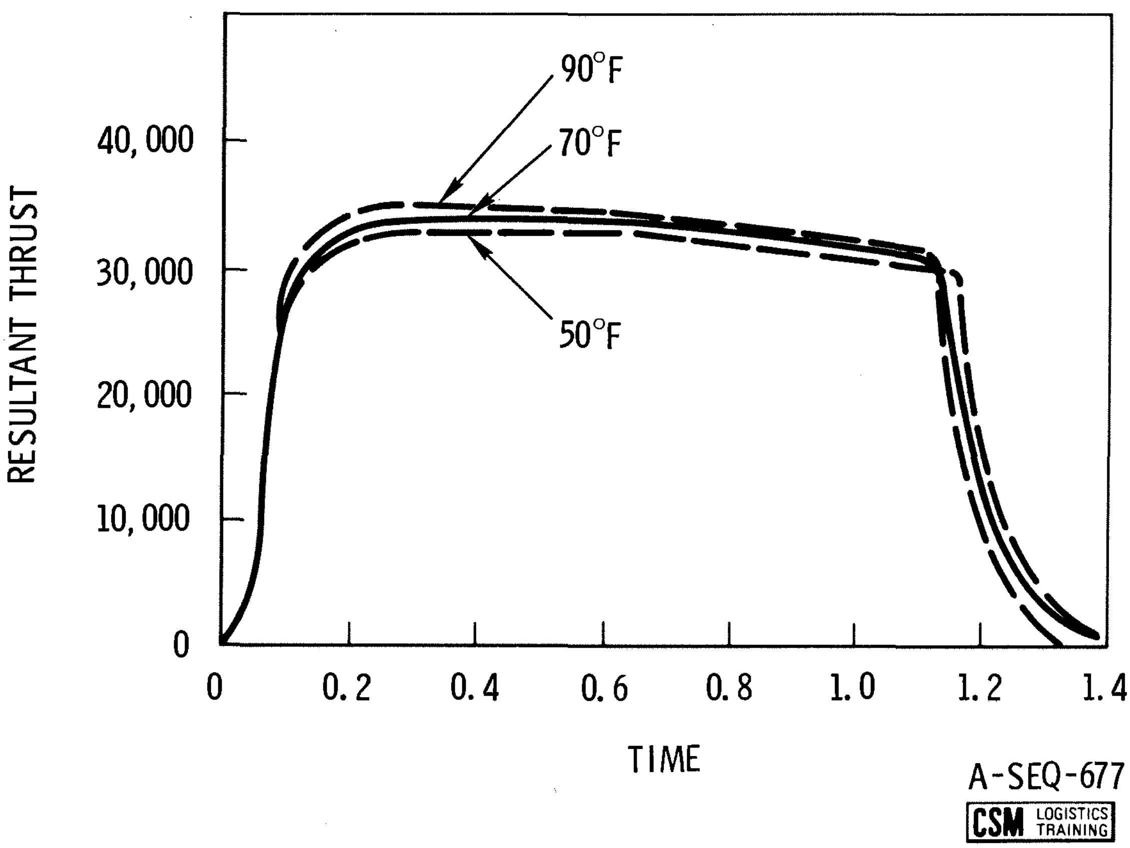


Figure 2.9-26. Tower Jettison Motor Typical Thrust Characteristics (For All Altitudes)

The resultant total impulse over the action time and at sea-level conditions, and with the propellant grain at the noted temperature, is within the following limits:

140°F = 35,900 to 37,700 pound-seconds

70°F = 35,800 to 37,600 pound-seconds

20°F = 35,700 to 37,500 pound-seconds

The motor performs satisfactorily at maximum and minimum uniform soak temperatures of 140°F and 20°F, respectively.

The resultant thrust vector offset is between 3.0 degrees and 4.5 degrees at sea level conditions. For motors operating in a vacuum, the maximum allowable thrust vector offset shall be 5.0 degrees. The offset is in the X-Z plane of the motor and produces a thrust component in the +Z direction. A capability for adjustment of thrust axis is not provided; appropriate dimensions and manufacturing tolerances are employed to provide the specified alignment characteristics.

The propellant grain is ignited by an igniter assembly mounted in the aft closure dome concentric with the motor centerline. The igniter assembly employs a gas-producing unit, utilizing a boron-potassium nitrate booster charge. The igniter assembly uses TPE-8104 propellant (identical to the motor propellant) as its main propellant charge. The igniter assembly employs redundant igniter cartridges.

The igniter cartridge is identical with that used in the launch escape motor igniter assembly, except that the thread size and SBASI connector indexing are noninterchangeable.

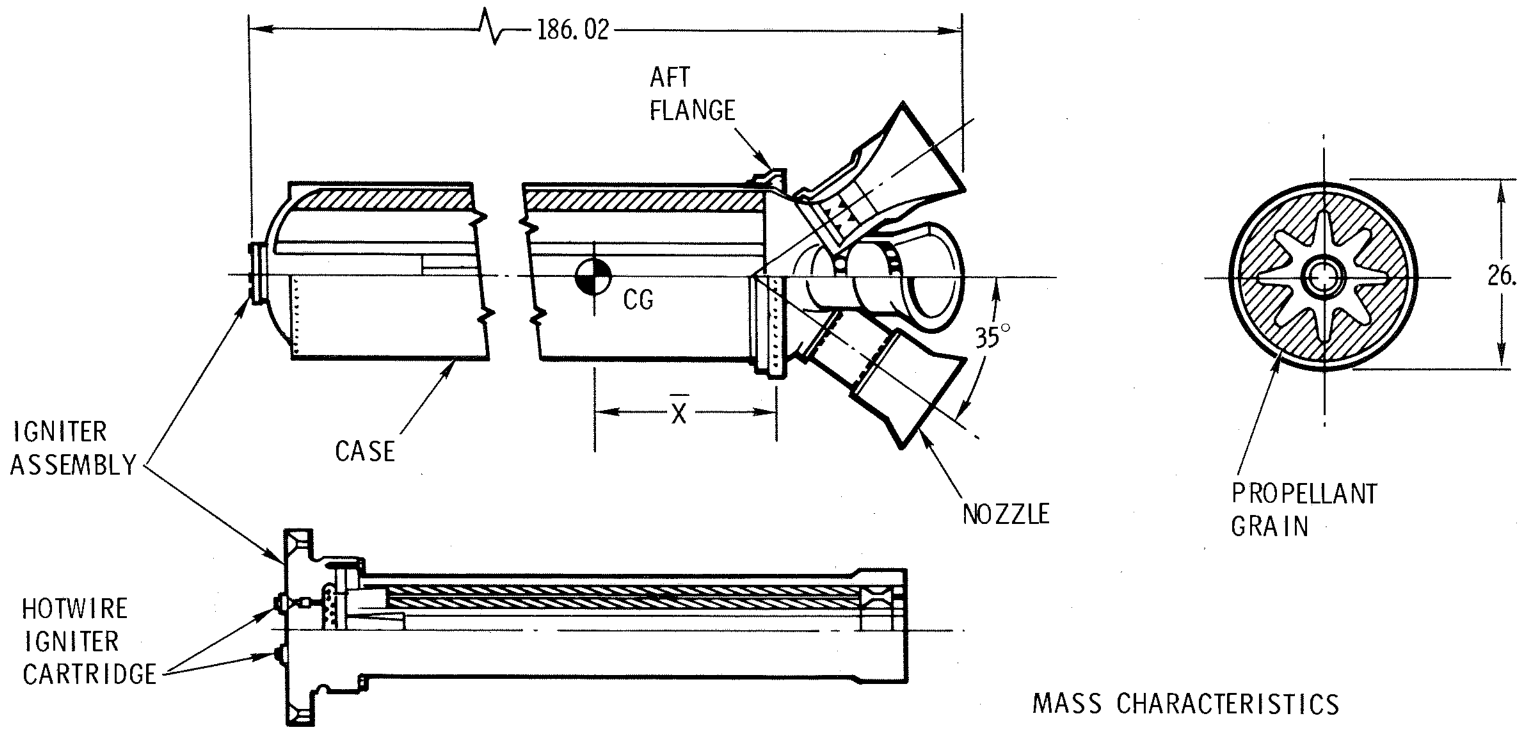
The exhaust nozzle of the tower jettison motor is attached to the aft closure dome flanges with suitable fasteners. The nozzles are constructed of SAE 4130 steel or equivalent, and inserts fabricated from ATJ graphite or equivalent material are used in the nozzle throat area.

A nozzle closure is provided that will protect the propellant from the effects of moisture, aerodynamic heating, and contaminants. The nozzle closure is designed to withstand a minimum internal pressure of 55 psig. The maximum closure blowout pressure determined by cold-gas testing does not exceed 150 psia.

2.9.5.2.2 Launch Escape Motor

The launch escape motor (figure 2.9-27) is a solid propellant motor providing primary propulsion for mission abort and includes the items in the following subsections.

The motor case assembly is fabricated of Inconel. The assembly includes a cylindrical mounting flange at its forward end for the mounting of the tower jettison motor.



MASS CHARACTERISTICS

CONDITION	WEIGHT (LBS)	CG ($\overline{X}$)
LOADED	4774	64.2
EXPENDED	1610	47.2

A-SEQ-678
CSM LOGISTICS TRAINING

Figure 2.9-27. Launch Escape Motor Configuration (Nominal)

The aft closure dome of the launch escape motor is fabricated of Inconel and is attached to the case assembly by means of a bolted flange. The dome contains provisions for the attachment of four canted exhaust nozzles, for mating with the structural skirt, and for mounting the motor case assembly. Provisions are made on the surface of the dome for alignment purposes. The surface incorporates a precision pilot hole and three threaded mounting holes for attachment of alignment tooling.

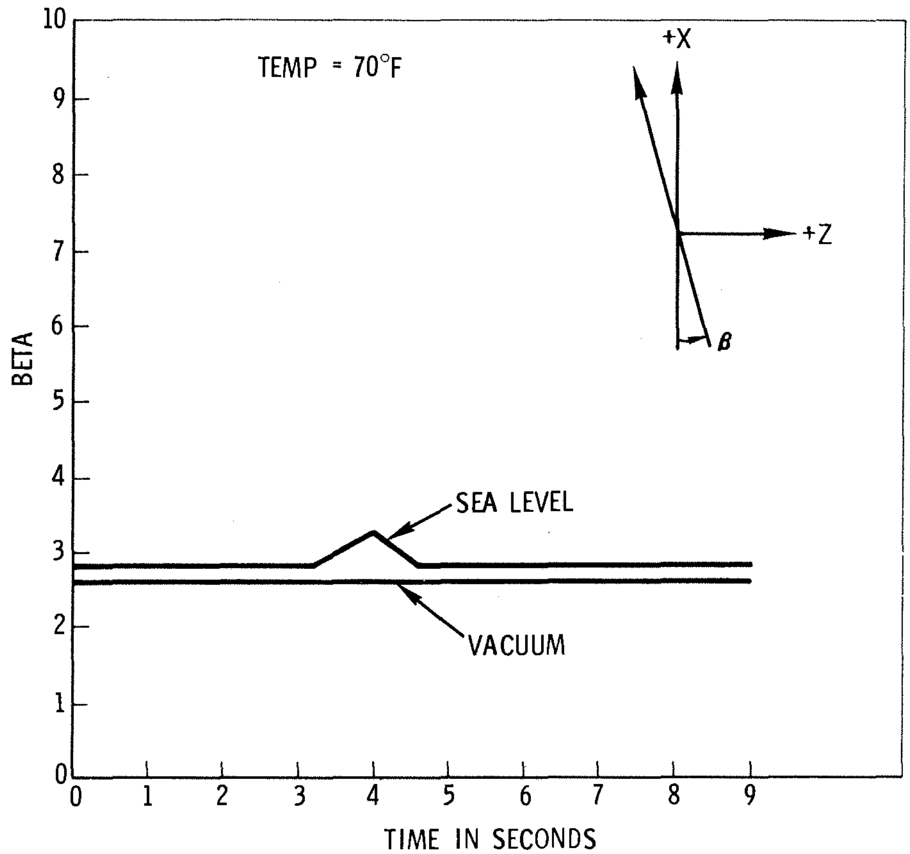
The launch escape motor employs four nozzles secured to the aft closure dome. Each nozzle incorporates a throat insert of ATJ graphite. Each nozzle exit cone is made of molded silica cloth-phenolic resin and is secured to the nozzle outer shell in a reliable manner.

Each of the four nozzles has a centerline cant angle of 35 degrees ± 15 minutes as measured from the mean nozzle centerline to the mean geometric motor centerline. The nominal resultant thrust centerline of the rocket motor is oriented 2 degrees 45 minutes to the mean geometric motor centerline, with the nominal thrust centerline and the motor centerline forming the pitch plane. The maximum angular deviation of thrust from this nominal thrust centerline during the time of motor burning to propellant web burnout, and excluding the ignition phase (first 0.200 second), is ± 15 minutes of solid angle. During this same period, the average roll moment induced by nozzle alignment, internal ballistics, or any other cause does not exceed 200 feet-pounds. The effective thrust vector deflection is obtained by off-sizing of the respective nozzle throat diameters. Nominal thrust vector angle during motor burning is shown in figure 2.9-28.

A case-bonded propellant charge having an internal eight-point star grain configuration is employed. The propellant is GCR-231 and has the following formulation:

Ingredient	Parts by Weight (%)
LAUNCH ESCAPE MOTOR AND PITCH CONTROL MOTOR	
NH_4ClO_4	72.00
LP-33 (fuel/binder)	5.53
LP-205 (fuel/binder)	16.57
Para-quinone dioxime	1.00
S	0.10
MgO	0.80
Fe_2O_3	2.00
Al powder	2.00

The motor propellant grain is ignited by an igniter assembly mounted on the forward end of the motor case assembly concentric with the motor centerline. The igniter assembly employs a gas-producing unit that utilizes a boron-potassium nitrate booster charge. The igniter assembly uses GCR-231 propellant (identical to the motor propellant) as its main propellant charge. The igniter is oriented in the launch escape motor so that the initiator installation bosses in the igniter head can lie in the plane formed by the aft closure index pin and the motor centerline. Matching scribe marks on the launch escape motor case flange and igniter



A-SEQ-679

CSM LOGISTICS TRAINING

Figure 2.9-28. Launch Escape Motor Typical Thrust Vector Alignment Characteristic

headcap are used to ensure this orientation. The igniter headcap contains threaded mounting holes for installation of electrical wiring brackets by the contractor. The igniter employs redundant hot-wire igniter cartridges.

The igniter cartridge consists of a booster charge and the single bridgewire Apollo standard initiator (SBASI) assembled in a hermetically sealed unit. The cartridge is separable from the igniter assembly and is capable of being installed on the launch pad. The thread size and SBASI electrical connector indexing of this cartridge is non-interchangeable with that used in the tower jettison motor.

The case liner provides a satisfactory bond to the propellant grain and the motor case assembly; it is LPL-106C and has the following formulation:

LPL-106C LAUNCH ESCAPE MOTOR LINER	
LP 3A	70.17
Para-quinone dioxime	4.47
Diphenyl quanidine	1.00
MgO	3.36
Carbon black	21.00

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Gaskets, O-rings, and nozzle weather seals are provided to protect the interior of the rocket motor and the propellant from the effects of moisture and contamination for the storage life of the motor. Maximum seal blowout pressure does not exceed 180 psi and minimum blowout pressure is not less than 55 psi.

Typical thrust during motor burning is shown in figure 2.9-29.

a. The maximum vacuum thrust for a grain temperature of 120°F does not exceed 200,000 pounds.

b. The minimum sea-level thrust for a grain temperature of 20°F is not less than 121,000 pounds between 0.2 and 2.0 seconds.

c. The average thrust at a pressure altitude of 36,000 feet and a grain temperature of 70°F is not less than 147,250 pounds between 0.12 and 2.0 seconds.

The thrust rise time from time zero (time of firing current application) to the time at which the thrust reaches 90 percent of F_i (ignition thrust) is between 50 and 120 milliseconds.

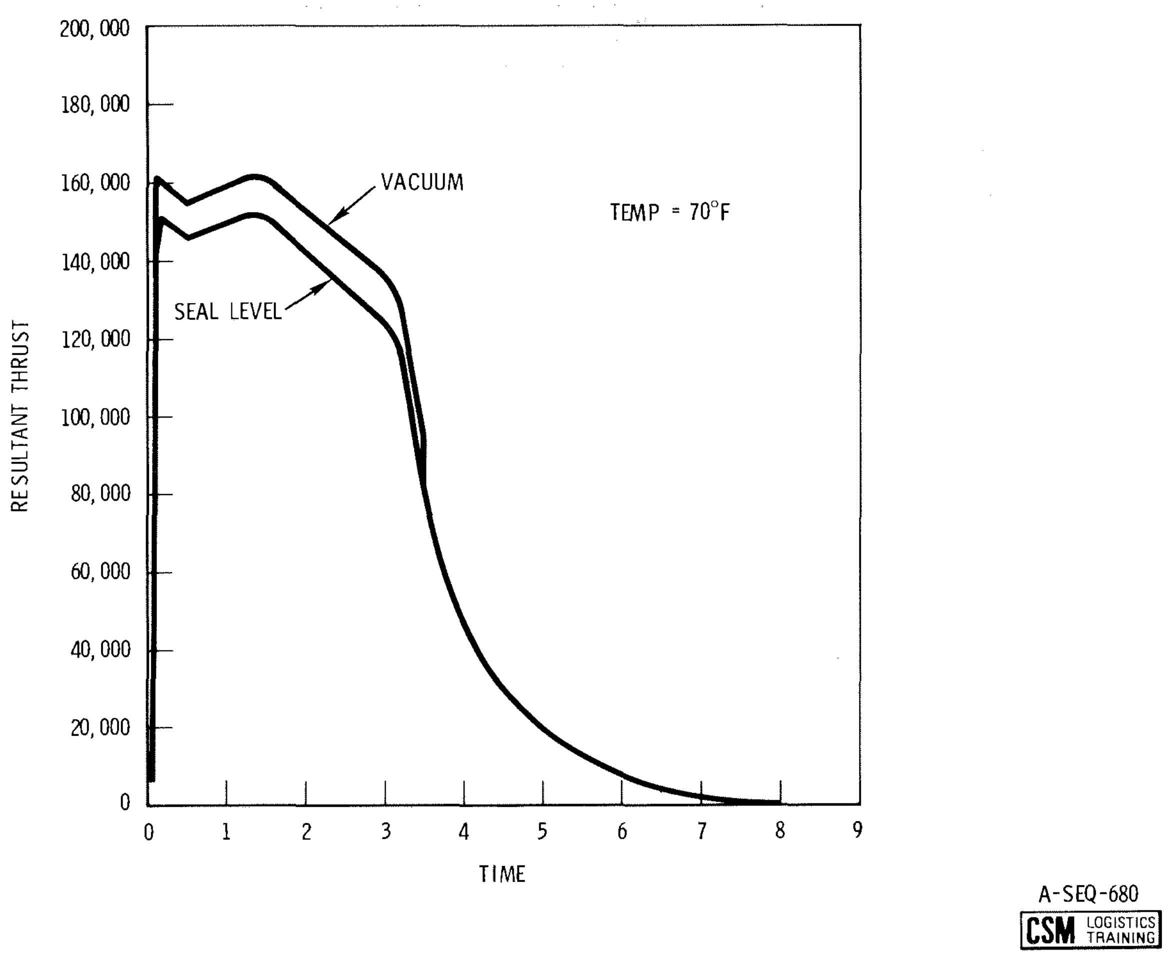

Figure 2.9-29. Launch Escape Motor Typical Thrust Characteristics

The minimum delivered total impulse is 515,000 pound-seconds. The minimum delivered total impulse between 0.12 and 2.00 seconds is 233,064 pound-seconds.

The motor performs satisfactorily at maximum and minimum uniform soak temperatures of 120°F and 20°F, respectively.

The launch escape motor provides an alignment surface on the aft closure dome for alignment to the CM center of gravity. The surface incorporates a precision pilot hole and three threaded mounting holes for attachment of alignment tooling.

The motor meets the performance requirements specified herein when subjected to the following temperature environments:

a. Air transportation: -20°F minimum to +140°F maximum for 8 hours

b. Ground transportation: -20°F minimum to +140°F maximum for 2 weeks

c. Storage: +25°F minimum to +105°F maximum for 5 years

d. Launch base area: +25°F minimum to 105°F maximum air temperature for 30 days, plus solar radiation of 360 Btu/ft^2/hr for a 6-hour period each day.

2.9.5.2.3 Pitch Control Motor

The pitch control motor (figure 2.9-30) is a solid-propellant rocket motor used for trajectory shaping during mode 1A aborts.

The motor case assembly is fabricated from heat-treated high-strength steel. The motor case incorporated provisions for mounting the pitch control motor horizontally within the canard support enclosure. The forward closure dome assembly of the pitch control motor is fabricated from heat-treated high-strength steel. The forward closure dome assembly is integral with the motor case assembly. The forward dome assembly contains provision for the igniter assembly.

The aft closure dome of the pitch control motor is fabricated from Inconel, and is suitably attached to the case assembly. The aft dome and nozzle assembly is of single-piece construction.

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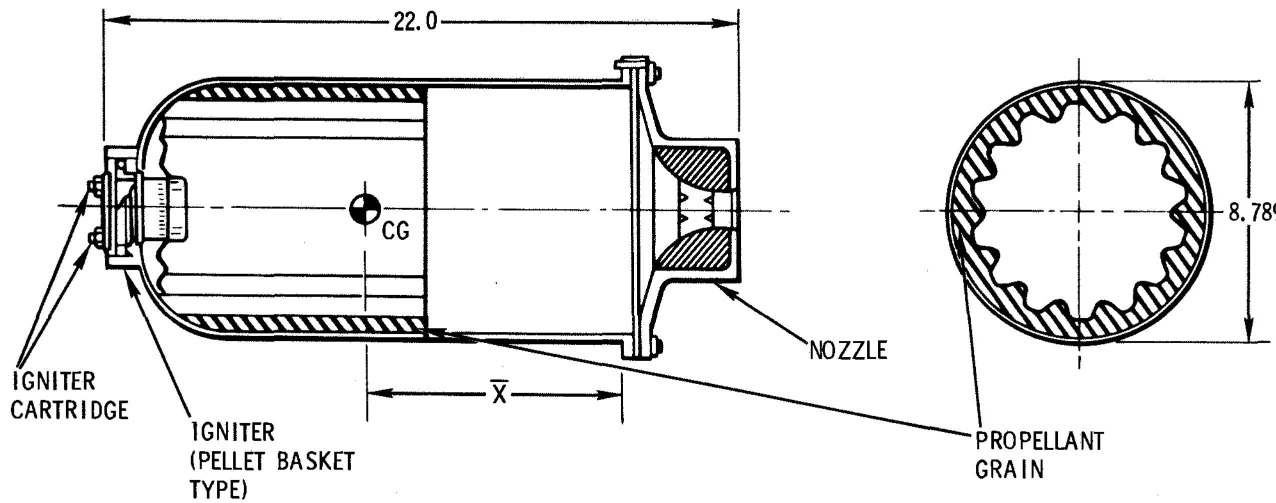
The propellant grain of the pitch control motor is a 14-point star configuration. The propellant is GCR-231 which is the same as the propellant used in the LEM (paragraph 2.9.5.1.2). The propellant grain does not require the additions of auxiliary grain supports, inert slivers, or other similar provisions to achieve its design objectives.

The propellant grain is ignited by an igniter assembly mounted in the forward closure dome concentric with the motor centerline. The igniter uses a boron-potassium nitrate charge. The igniter assembly employs redundant igniter cartridges that are identical to those used in the launch escape motor and are designed for installation on the launch pad.

Gaskets, O-rings, and nozzle weather seals are used to protect the interior of the rocket motor and the propellant from the effects of moisture and contamination. The nozzle seals maintain their integrity over the range of external atmospheric pressure specified for service usage. Maximum seal blowout pressure does not exceed 180 psi, and the minimum blowout pressure is greater than 55 psi.



MASS CHARACTERISTICS

CONDITION	WEIGHT (LBS)	CG ($\bar{X}$)
LOADED	49.1	6.2
EXPENDED	40.2	7.3

A-SEQ-681

CSM LOGISTICS TRAINING

Figure 2.9-30. Pitch Control Motor (Nominal)

The thrust level does not exceed 4,000 pounds. Typical thrust during motor burning is shown in figure 2.9-31.

Web burning time is not less than 0.5 second nor more than 0.7 second.

The thrust rise time from zero (time of firing current application) to the time at which thrust reaches 80 percent of maximum is between 60 and 120 milliseconds.

The total delivered impulse of the pitch control motor is 1750 pound-seconds ±3 percent at 70°F and sea-level pressure. The criterion of motor design is that the performance of the motor be capable of modification to deliver a value of total impulse anywhere within the range of 1550 pound-seconds to 3000 pound-seconds.

The total delivered tailoff impulse from web burnout to end of burning is not more than 500 pound-seconds.

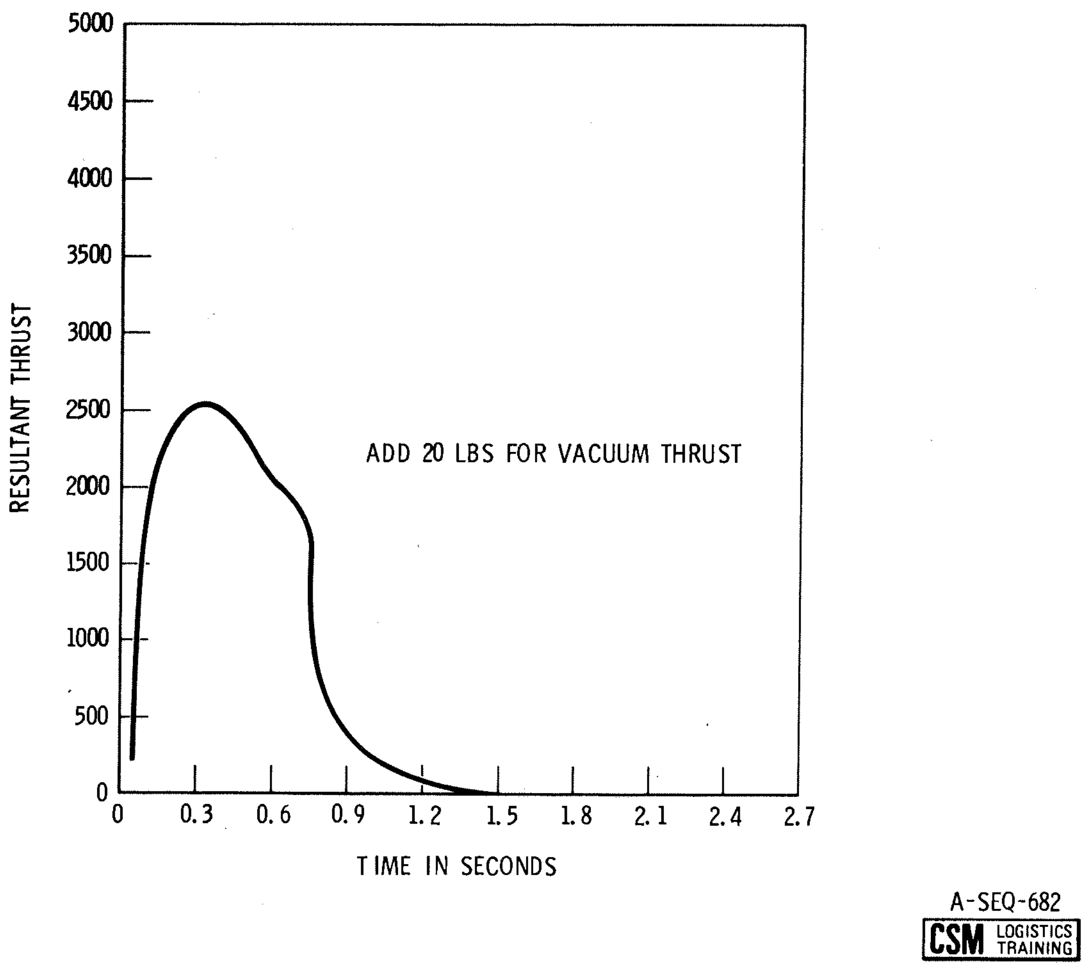


Figure 2.9-31. Pitch Control Motor Typical Thrust History

The nozzle has a centerline angle of zero degrees as measured from the mean motor centerline. The angular deviation of the thrust axis from the mean motor centerline is not more than 30 minutes of solid angle.

The motor performs satisfactorily at a maximum and a minimum uniform soak temperature of 140°F and 20°F, respectively.

2.9.5.3 LET Structure

The launch escape tower transmits launch escape motor thrust to the CM and supports the forward section of the boost protective cover. The tower is made from 6Al-4V titanium tubes that are welded at the joints. The entire structure is insulated for protection from flame impingement of the motors and aerodynamic heating. The tower attaches directly to the CM inner structure and the base of each tower leg by means of studs and frangible nuts.

2.9.5.4 Structural Skirt

The structural skirt distributes the loads from the four tower attachment points to the launch escape motor and serves as an aerodynamic fairing for escape motor nozzles. A ring integral with the forward end of the skirt mates with a flange on the motor aft closure.

Tower legs are attached to structural members near the perimeter of the skirt. Primary structures are of 6Al-4V titanium.

2.9.5.5 Tower/Command Module Separation System

The tower/CM separation system consists of four frangible nuts, one located in each leg of the tower structure (figure 2.9-32). Each nut incorporates redundant detonators. The detonators are capable of being installed on the launch pad. Structural fittings provide for torquing of the attachment device to ensure adequate preloads for tower retention. Apollo standard detonators are the explosive components of the nut assembly. Component fragmentation is controlled so that fragments resulting from explosive separation will be retained sufficiently by the tower legs to prevent impact of particles that could damage the spacecraft or booster. Each explosive nut assembly is capable of sustaining an ultimate load of 95,000 pounds in pure tension at an ambient temperature of 70°F. The separation function of the explosive nut is accomplished by either of the detonators acting alone. Failure of one detonator to effect separation does not prevent the other detonator from performing its function.

The same electrical signal that initiates the frangible nuts also ignites the TJM when the LET is jettisoned either during a normal mission or subsequent to a LET abort (figure 2.9-33).

2.9.5.6 Boost Protective Cover

The boost protective cover (BPC) protects the CM thermal coating from the boost heating environment and from launch escape jettison motor exhaust products, and protects the CM windows from sooting or erosion because of

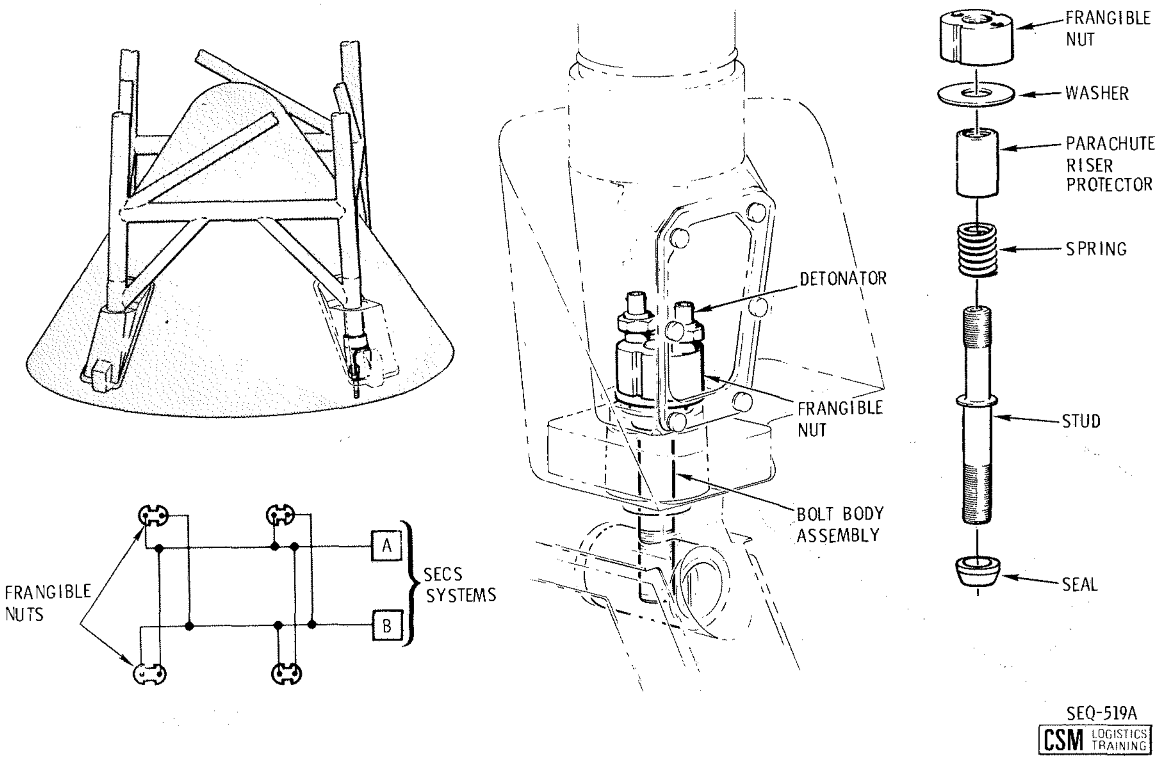


Figure 2.9-32. Tower Separation System

launch escape motor or tower jettison exhaust products. The BPC consists of a composite structural shell which is contoured to fit the external lines of the conical section of the CM. The BPC consists of a section of "hard" construction at the apex end of the cover and a section of pliable, or "soft," construction over the remaining area. The BPC is attached to the launch escape tower and is jettisoned along with the LES at the end of first-stage boost. An entry hatch, docking window, RCS motor ports, a venting fixture, and means for assembly and attachment of the complete cover are provided.

2.9.5.7 Canards

This system consists of two canard surfaces, a fairing surface, a support structure (or housing), a canard retention mechanism, an actuating mechanism for deployment, and associated switching circuitry. The canards reorient the launch escape vehicle in a heat-shield-forward attitude to allow satisfactory deployment of the parachute system.

Canards are deployed in an elapsed time of less than 0.3 second during extreme environmental conditions and a tower-forward stable flight attitude.

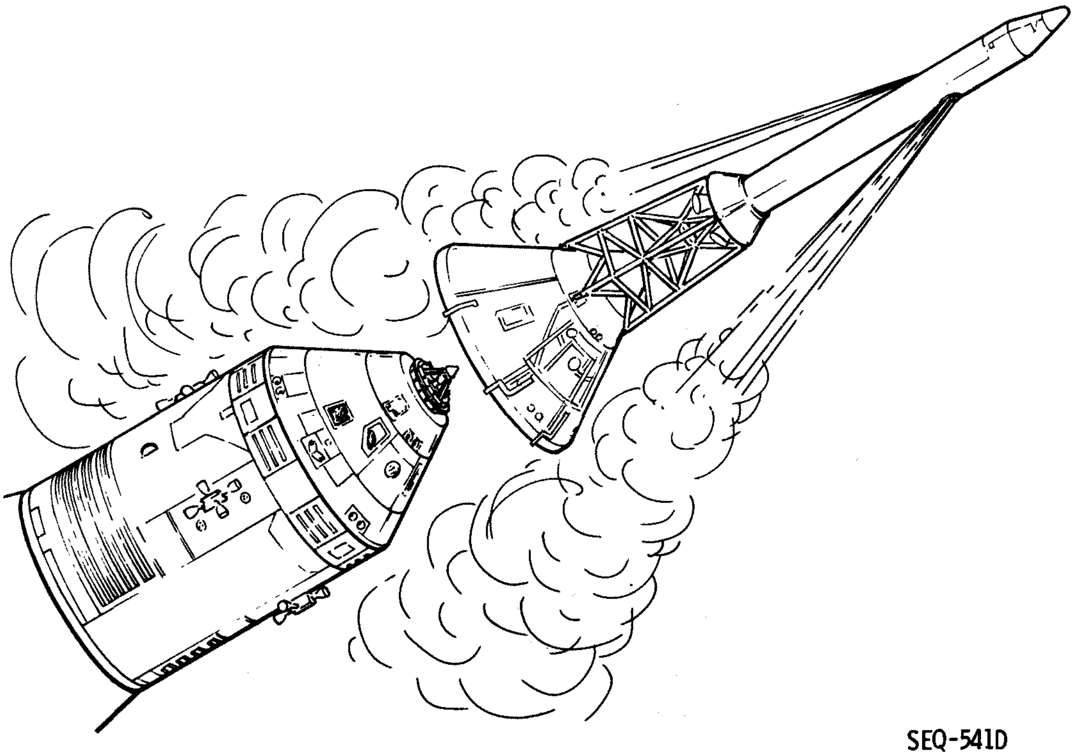


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Figure 2.9-33. Normal Tower Jettison

The canards perform after exposure to temperatures between -20°F or +140°F for 15 days. The canard system is designed to perform satisfactorily while being subjected to temperatures encountered during normal boost and aborted entry phases of the AAP mission.

The canard surface geometry is developed by removing 100-degree arc segments from a cone-cylinder geometrical configuration which extends approximately from the tower jettison motor structural interface to the nose cone interface, comprising a total length of approximately 48 inches and an area of 5.8 square feet per canard. The centerline of the cylindrical portion of the canard surface is oriented with an incidence angle of approximately 30 degrees relative to the vehicle X-Y plane and at a yaw angle and an incidence angle relative to the vehicle X-Z plane as determined by structural design considerations. Each canard surface is constructed of Inconel-X and PH15-7 Mo series steels and includes two lateral hinge ribs, one lateral deployment attach point rib, and the necessary lateral and longitudinal support stringers.

The canard support structure is of semimonocoque construction. The structure encloses and provides mounting capability for ballast, the pitch control motor, the canard actuating mechanism, and necessary wiring. Interfaces with the Q-ball and the tower jettison motor are compatible with the requirements of these items (figure 2.9-23).

A fairing surface is attached to the support structure filling the 160-degree arc segment of the support structure which is not occupied by the canard surfaces or hinges. The fairing surface is removable to allow access to the interior for maintenance and adjustment of Canard hardware, pitch control motor, and wiring.

The canard actuating mechanism (figure 2.9-34) consists of a pyrotechnic-powered linkage capable of locking the canard surfaces in the retracted position during normal missions to LES jettison altitude and during the first 11 seconds of an abort. The mechanism is also capable of extending the canard surfaces 115 degrees about their hinge lines, snubbing the loads, and locking the canards in the deployed position when the launch escape vehicle is at any angle of attack following abort. The canard thruster employs redundant, hermetically sealed, pyrotechnic cartridges.

2.9.5.8 Nose Cone and Q-Ball

The LET nose cone is, in effect, a fairing for the EDS Q-Ball (paragraph 2.9.2.4).

2.9.5.9 Ballast

A compartment for ballasting the launch escape system is provided (figure 2.9-23). A fixture with capability for attaching up to 960 pounds of ballast is provided and is located in the forward region of the canard support structure. The amount of ballast to be included is flexible and is determined for each end item on the basis of vehicle center-of-gravity location and aerodynamic stability requirements.

The LET structure is designed for loads arising from a tumbling or oscillating LEV. However, tumbling or excessive oscillations of the LEV are avoided by increasing LEV stability (by adding ballast) when such motions result in increased CM structural weight to withstand LES motor plume impingement pressures.

The LET/CM structure is designed for loads arising from abort at the maximum abort altitude. The LET/CM is capable of sustaining loads incurred during canard deployment at dynamic pressure/Mach number conditions occurring 11.0 seconds after abort initiation. The LET/CM combination is designed for loads arising during entry with canards deployed following an abort initiated prior to normal LET jettison (maximum of approximately 320,000 feet).

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2.9.5.10 LES Aborts

LES aborts are categorized under three operating modes (figure 2.9-35):

Mode 1A Aborts initiated from the time of launch complex access arm withdrawal until T +61 seconds (approximately 23,000 feet).

Mode 1B Aborts initiated between T +61 seconds and T +1 minute 50 seconds (approximately 100,000 feet).

Mode 1C Aborts initiated from T +1 minute 50 seconds to tower jettison (approximately 251,000 feet).

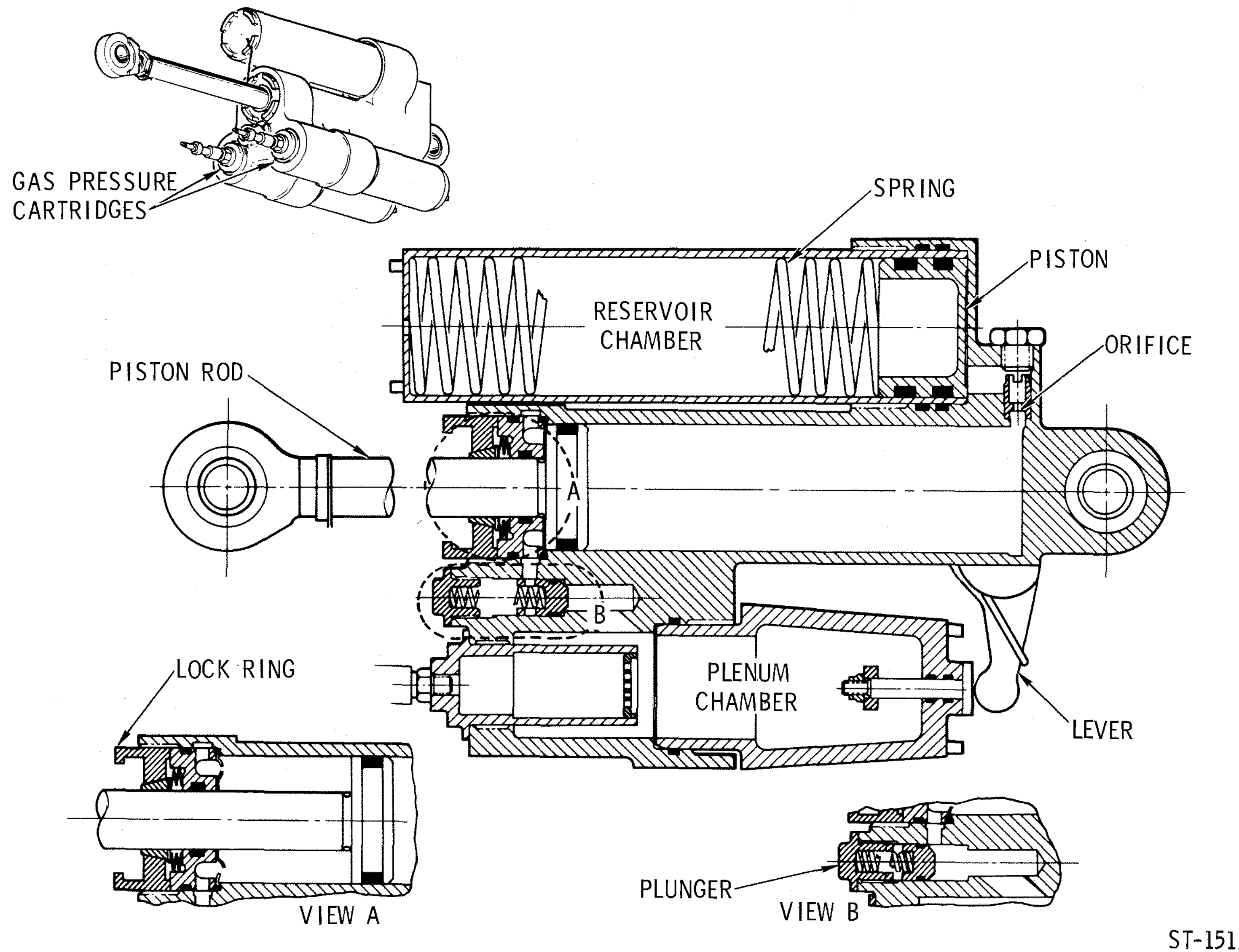

Figure 2.9-34. Canard Actuating Mechanism

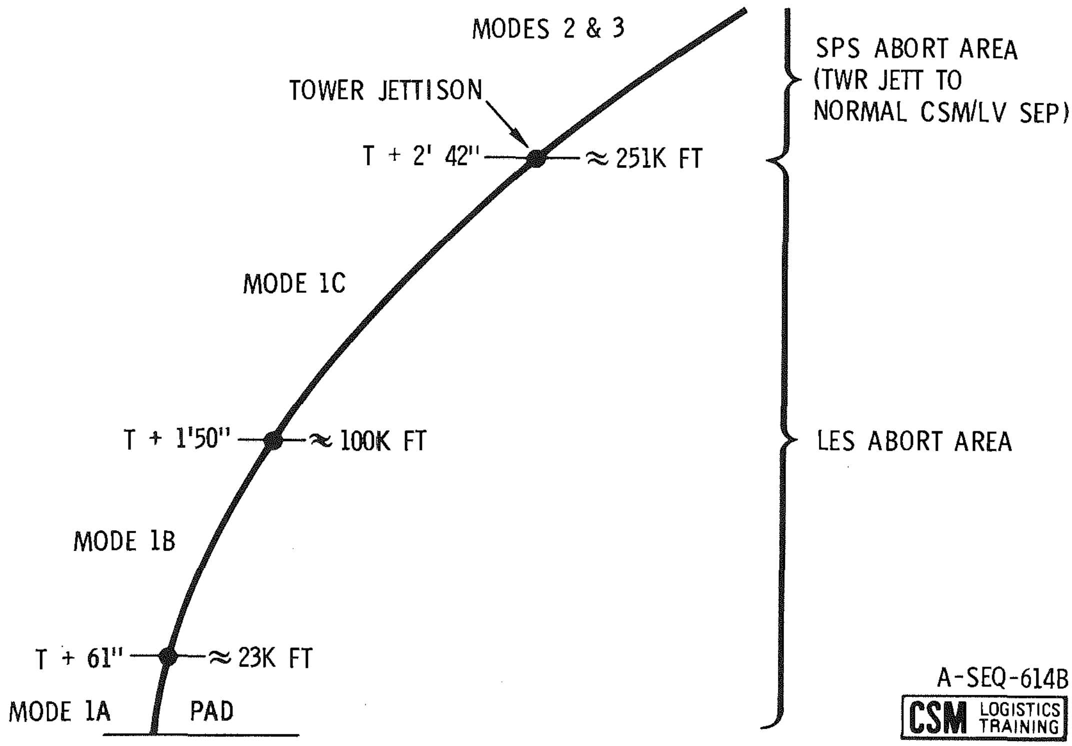

Figure 2.9-35. Abort Designations, Launch and Earth Ascent Phase

The CM RCS provides launch escape vehicle damping during high-altitude aborts and empties propellant tanks prior to impact in a Mode 1A abort. For abort initiation below approximately 23,000 feet, the dumping sequence for oxidizer and fuel is automatically initiated 5.0 seconds following abort initiation. Purging of the tanks, valves, and lines is automatically initiated 18.0 seconds following abort initiation. With aborts initiated above approximately 23,000 feet, the RCS/SCS is activated at abort initiation (in a damping mode of operation) if the manual RCS/SCS switch is placed in the active position. The system remains in operation until the LET is jettisoned on descent to 24,000 feet, at which time the RCS is automatically deactivated.

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2.9.5.11 Abort Below 100,000 Feet Altitude

LES aborts are initiated either manually or automatically on receipt of a signal from the emergency detection system. Automation requirements for mode 1A aborts include simultaneous initiation of the launch escape and pitch control motors together with CM-to-SM tension tie pyrotechnics. If an abort is initiated after approximately T +40 seconds, booster thrusting is automatically terminated. The pitch control motor and the launch escape motor provide thrust for approximately 0.6 second and 4.0 seconds, respectively. At T +61 seconds, the pitch control motor firing circuits, together with automatic propellant dumping circuits, are disabled by time-delay relay logic and/or a crew-operated switch. During mode 1B aborts the pitch control produces a large pitching moment of relatively short duration which aids in both pad abort range capability and lateral separation from the booster flight path at higher altitudes. During and immediately following motor burning, the launch escape vehicle continues to separate from the booster. After a delay of 11.0 seconds following abort initiation, canard surfaces are deployed, effecting destabilization of the launch escape vehicle in the tower-forward attitude and a turnaround to the heat-shield-forward flight attitude results. After a delay of 3.0 seconds (or on descent to approximately 24,000 feet), the launch escape system and docking mechanism are jettisoned by simultaneous ignition of the jettison motor, tower leg frangible nuts, and docking ring separation pyrotechnics. The apex cover is jettisoned 0.4 second later. The boost protective cover, which is permanently attached to the tower structure, is jettisoned along with the LET. After a delay of 2.0 seconds, to permit separation of jettisoned components, the two drogue parachute mortars are ignited and the drogues are deployed. The drogues decelerate the CM and damp oscillations incurred during the turnaround. The drogues are disconnected and main parachute deployment is initiated 12.0 seconds after drogue deployment (or on descent to the altitude required for baroswitch closure). A manual switch is provided to allow delaying main parachute deployment so as to minimize wind drift toward the launch pad area.

2.9.5.12 Abort Above 100,000 Feet Altitude

Following initiation of aborts above approximately 100,000 feet, the launch escape motor propels the LEV away from the LV. The CM RCS may be utilized manually as soon as practical following abort to provide a positive (+) LEV body axis pitch rate. The canard subsystem is deployed 11 seconds after abort initiation. The LES is retained during descent until jettison at approximately 24,000 feet by baroswitches. Following this event, the ERS sequence is identical to that for abort at lower altitudes, where LET jettison is initiated by baroswitches.

2.9.5.13 LET Jettisoning

During a normal mission, the LET is jettisoned manually after completion of launch vehicle second-stage ignition and staging. Normal system operation consists of simultaneous ignition of tower leg frangible nuts and the tower jettison motor. The LET, with boost protective cover attached, is pulled clear of the booster's flight path. A lateral separation distance of 150 feet assures a minimum miss distance.

2.9.5.14 Backup LET Jettison

In the event of a jettison motor malfunction, the launch escape motor can be initiated to accomplish LET jettison without impairing the capability for safe crew recovery.

2.9.5.15 Subsystem Functions

A capability for manual initiation of the following abort functions is provided. The requirements for automatic and manually sequenced functions are:

- Emergency detection subsystem (EDS) auto abort enabling
- Abort sequence initiation (hand controller)
- LET jettison, initiate tower jettison motor and tower leg frangible nuts
- Backup mode LET jettison, ignite launch escape motor and pitch control motor
- Forward heat shield (apex cover) jettison, ignite forward heat shield thrusters, and tower jettison motor
- Canard deployment
- Earth landing system activation
- Drogue deployment
- Main parachute deployment
- Inhibit automatic deployment of main parachute

Signals are provided to external equipment to denote failure when corrective action is possible. The functions listed are cause for a signal to be provided:

- Failure of the tower to separate
- EDS auto abort enabling light

2.9.5.16 Subsystem Performance Characteristics

Critical abort performance requirements such as defining pad escape, launch escape vehicle damping, high-Q region, and maximum and minimum entry altitude mode information are detailed in the following subsections.

2.9.5.16.1 Pad Escape

For escape prior to or shortly after lift-off, the LES separates the CM from the launch vehicle and propels the CM to an adequate height for ERS operation and to sufficient range to minimize wind drift-back. The plane of the abort trajectory is fixed nominally in a down range direction. The minimum altitude requirement for aborts from a nominal launch vehicle (zero attitude change and zero degrees per second attitude rate) is 3000 feet at apogee. This minimum altitude must be compatible with safe parachute operation (2300 to 2800 feet).

2.9.5.16.2 Malfunction at Liftoff

Abort capability is provided for critical launch vehicle malfunctions which occur with liftoff.

2.9.5.16.3 Separation From Thrusting Booster at Low Altitude

A capability is provided for separating from a thrusting booster at altitudes where range safety considerations prohibit thrust termination at abort initiation. The minimum capability includes separation from a thrusting booster following abort until approximately 40 seconds after liftoff. At higher altitude, booster thrust is terminated automatically at abort initiation.

2.9.5.16.4 Earth Recovery System Sequencing

Earth recovery subsystem sequencing is coupled with the LES abort sequencing functions as required to provide a continuous, automatic sequence of events from abort initiation through completion of recovery system deployment.

2.9.5.16.5 CM SCS/RCS

The CM SCS/RCS is compatible with the following requirements:

a. Launch escape vehicle damping is provided following aborts initiated above 10,000 feet.

b. The crew participates in modulating the SCS/RCS to provide means for orientation of the LEV following LES abort above 10,000 feet. Procedures to accomplish orientation and alignment of the LEV for entry are provided for cases in which on-board rate displays are employed.

2.9.5.16.6 Abort at High Dynamic Pressure

The LES is capable of performing its function at the maximum dynamic pressure incurred during boost, with abort initiated prior to structural breakup of the launch configuration.

A minimum separate rate at maximum dynamic pressure is characterized by a requirement for attaining a separation distance of 350 feet at 3 seconds following CM-SM separation. A minimum miss distance of 800 feet is provided for the case of abort at zero-degree angle of attack and stable flight of the booster. The term miss distance is defined as the distance between vehicles at a time when the LES crosses a plane which contains the booster and is perpendicular to the booster's flight path. In addition, the LES is capable of achieving separation and avoiding recontact with the launch vehicle under combined conditions of off-nominal booster trajectory and LES performance characteristics.

2.9.5.16.7 Transition Altitude Abort Region

The maximum altitude for low-mode abort and the minimum altitude for high-mode aborts overlap the nominal transition altitude by a minimum of 5000 feet.

The canards are aerodynamically effective in eliminating tower-forward trim conditions, provide aerodynamic damping during entry, prevent an excessive acceleration environment, and provide satisfactory conditions for recovery system deployment following abort at the highest altitude at which the system is employed. For LES aborts initiated above 100,000 feet, the crew may initiate the proper tumbling rates through utilization of the CM/RCS/SCS.

2.9.5.16.8 Maximum LES Abort Altitude

The maximum altitude for LES abort is compatible with (1) completion of second-stage ignition and separation of jettisoned components and (2) achieving a dynamic pressure condition permitting utilization of a SM abort. A minimum capacity includes the following parameters:

Altitude	320,000 feet
Mach number	8.0
Dynamic pressure	0.5 to 1.0 psf

2.9.5.16.9 Structural Loads

The LES/CM structure is designed to withstand the aerodynamic, dynamic, and thermal conditions associated with first-stage boost, abort, and staging. The LEV only is capable of withstanding the structural loads associated with an abort under any of the conditions listed below.

Condition	Altitude (ft)	Angle of Attack (deg)	Degrees per Second
I	20,000	±22	±5
II	35,000	±15	±5
III	60,000	±20	±5
IV	80,000	±15	±5

2.9.6 EARTH RECOVERY SUBSYSTEM

The ERS parachutes are protected throughout a mission by the forward heat shield (apex cover) until descending to an altitude of approximately 24,000 feet. The forward heat shield is then jettisoned to uncover the parachutes for subsequent deployment during the descent phase. Jettisoning of the forward heat shield is automated by time-delay relay logic during aborts.

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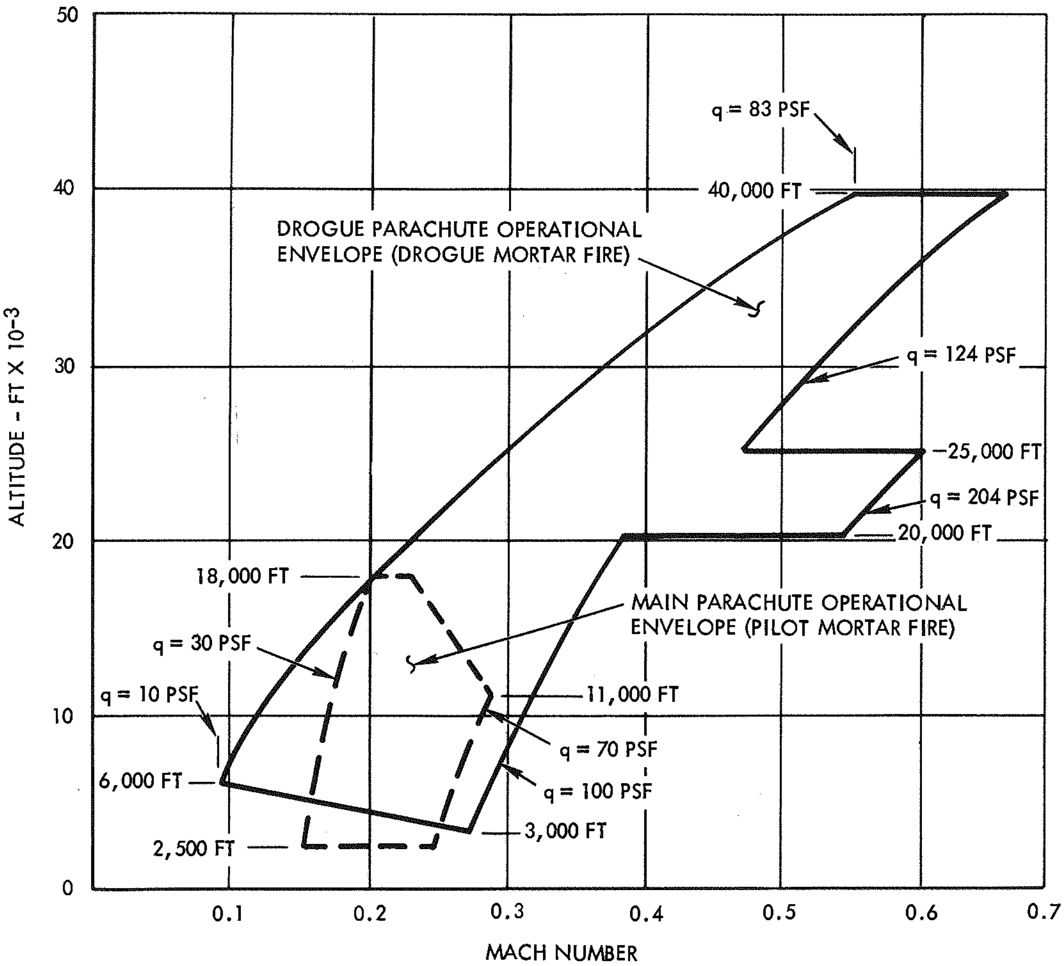


Figure 2.9-36. Parachute Design Envelope

The recovery parachute subsystem provides the means to decelerate and safely land a 13,000-pound descending weight (13,500-pound total weight) command module following entry from terrestrial orbit or mission abort conditions, and is capable of controlling the descent and landing of the command module as follows:

a. The two drogue parachutes are capable of deployment and operation under all entry and abort conditions as defined in figure 2.9-36.

b. The most critical case (worst-case operational requirements) for the CM angles of attack, rotational rates, and flight path angles at drogue parachute initiation for entry and abort conditions are reflected in the following chart.

SYSTEMS DATA

Conditions at Drogue Mortar Fire	q (PSF)	γ (deg)	α (deg)	h (feet)	Roll P (deg/sec)	Pitch Q (deg/sec)	Yaw R (deg/sec)
Pad abort							
Minimum altitude	90	-23	340	2,440	10	-35	-10
Maximum altitude	20	60	180	6,300	1	20	2
Nominal altitude	60	-5	200	3,600	3	7	2
Low-altitude abort							
500-foot abort	66	-12	20	3,800	10	-35	-10
1000-foot abort	60	-5	40	5,000	5	-20	-5
1500-foot abort	50	+2	60	6,000	5	-20	-5
Medium-altitude abort							
10,000-foot abort	50	64	130	18,000	2	42	-1
20,000-foot abort	80	55	140	30,230	1	80	0
30,000-foot abort	100	42	150	38,000	2	90	-1
High-altitude aborts							
≈42 K	204	-90	30	*23,700	±30	-180	±10
	190	-90	124	*23,700	±30	-60	±15
	190	-90	160	*23,700	±30	-100	±10
	187	-90	140	*23,700	±30	40	±10
Emergency condition (Max Q)	204	-90	30	**40,000	±30	-180	±10
Entry nominal	124	-70	165	23,700	±10	±10	±10

NOTE: In pad or low-altitude abort, pilot mortar fire must be manually initiated when the altitude on a descent trajectory reaches 2500 feet. Pilot mortar fire may take place above this altitude.

* 23,700-foot altitude based on nominal baroswitch operation with minimum venting lag.

** Drogue phase bypassed; pilot parachutes manually deployed.

c. Deployment of the two drogue parachutes brings the vehicles within the landing parachute operational envelope defined in figure 2.9-36. The drogue parachutes reduce the command module attitude to an oscillatory, or stable, aft-heat-shield-forward condition and reduce velocity to a point which assures proper deployment and operation of the main landing parachutes within the respective operational envelope.

d. Either of the two drogue parachutes, when deployed within the drogue parachute operational envelope, will decelerate the command module into the operational envelope for the main parachutes as defined in figure 2.9-36.

e. The main landing parachutes are capable of deployment and operation under the conditions defined in figure 2.9-36. Any two of the three main parachutes are sufficient to reduce the command module rate of descent to a maximum of 38 feet per second at sea level on a standard day. The parachute design loads are reflected in the following chart:

Application	Parachute Design Loads	Attachment Fitting Design Loads	
		3σ	Worst on Worst
Single Drogue	17,200 lb	17,200 lb *10,200 lb *12,000 lb	18,520 lb *10,200 lb 21,000 lb
Two Drogue	34,400 lb	34,400 lb *20,400 lb	37,040 lb *20,400 lb
Single Main Parachute	24,700 lb	-	-
Three Main Parachutes	37,500 lb	37,500 lb *37,000 lb	49,000 lb *40,500 lb
Drogue Motor Pilot Motor	13,000 lb 6,000 lb		

*Values are normal entry all other values are high-altitude abort.

2.9.6.1 Ground Impact

Ground impact is not a design condition; however, ground impact may occur during low-altitude abort.

On ground impact, the outer and inner structures deform to absorb part of the vehicle's kinetic energy during the first milliseconds of impact. The ground deformation absorbs a part of kinetic energy. The crew couch attenuates accelerations, maintaining the crew system within crew tolerance limits and must be capable of operations throughout the impact maneuver. The spacecraft, dependent upon slope of ground, vertical velocity, horizontal velocity, and attitude in direction of travel, may roll over several times before finally coming to rest.

All ground impacts are emergency impacts and under some circumstances crew emergency limits are exceeded.

2.9.6.2 Water Impact

On water impact, the vehicle displaces a mass of water to absorb part of the kinetic energy. Depending on sea conditions and vehicle descent parameters, the vehicle pitches or yaws or may roll over, and may stabilize in either of two positions. Upon operation of the uprighting subsystem, if required, the CM will float in the apex-up attitude. The normal egress hatches are then clear of the water. The operation of the crew couch attenuating system is the same as stated for ground impact.

The envelope of water impact design conditions based upon Monte Carlo results is shown in figure 2.9-37. Drop testing has shown that the tangential-velocity-versus-contact-angle envelope is critical for the forward section of the CM. The normal velocity-versus-contact-angle envelope is critical for the aft section of the CM. The tangential-velocity-versus-contact-angle envelopes, together with the appropriate normal velocity, are critical for the side and torus portions of the CM. The crew nominal impact limits will not be exceeded for more than approximately 10 percent of water impact. Within the limits of this criterion, the crew emergency tolerance limits will not be exceeded.

2.9.6.3 Parachute System Equipment

The parachute system (figure 2.9-38) consists of two independent drogue parachutes that are mortar-deployed, a cluster of three main landing parachutes which are deployed by three independently mortar-deployed pilot parachutes, one guillotine-type parachute disconnect assembly consisting of two drogue disconnects and three main parachute disconnects.

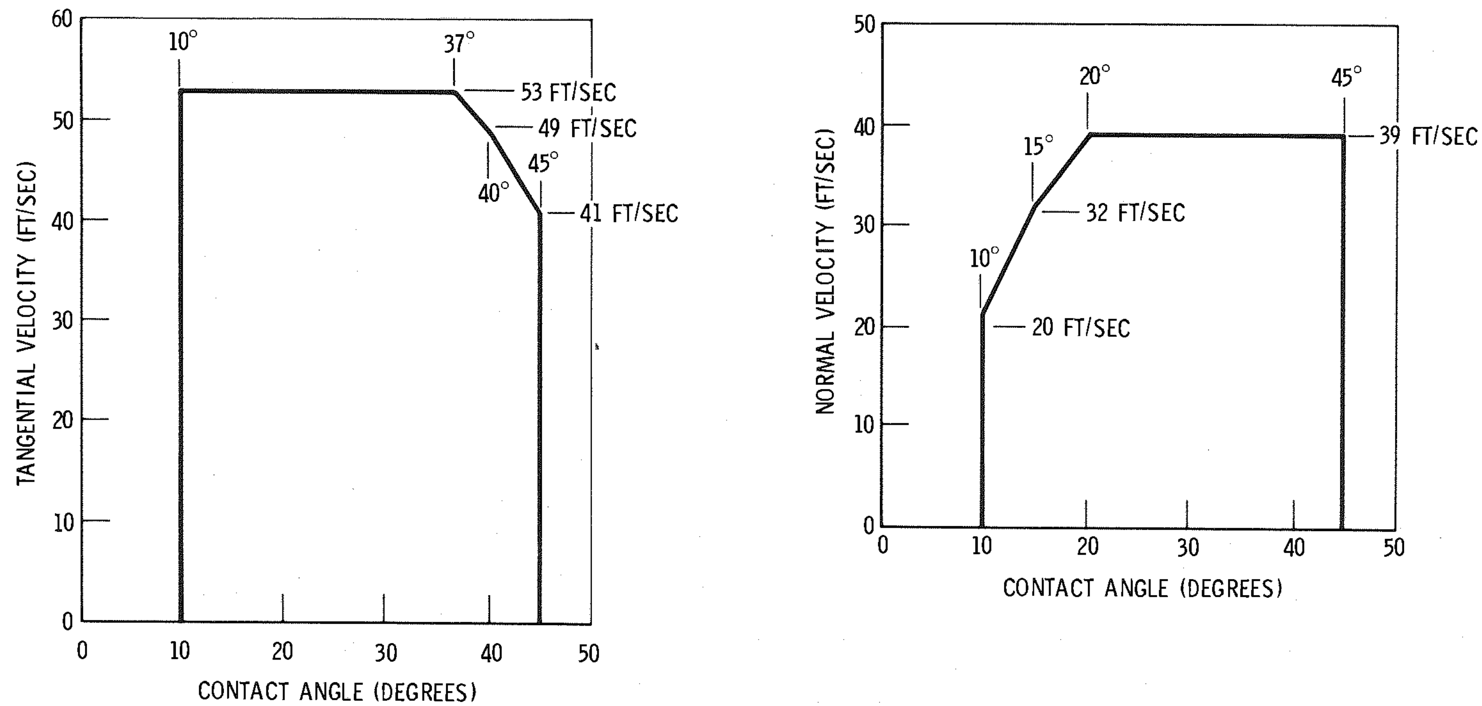
2.9.6.3.1 Drogue Parachutes

The two drogue parachutes (figure 2.9-39) are of a conical FIST-type ribbon design of 16.5-foot nominal diameter and are attached to the CM through the drogue disconnect fitting. Dual reefing systems consisting of two reefing lines, each with two reefing line cutters, are incorporated in each canopy. Reefed diameter and duration are such that the total load (with two drogues performing) on the CM will not exceed 40,000 pounds. The drogues are designed to operate throughout the drogue operational envelope defined in figure 2.9-36. The two drogues parachutes are independently mortar-deployed in a manner to preclude entanglement or interference with each other or with the CM structure.

The drogue parachute deployment bag encloses and protects the drogue parachute and riser while contained in the drogue mortar and during ejection. The deployment bag controls the parachute and riser to ensure orderly deployment of the parachute into the airstream.

The drogue parachute riser is of sufficient length to place the drogue parachute in a favorable position with respect to the airflow around the CM. The riser design incorporates resistance to heat, abrasion, and cutting.

The drogue parachute mortar, containing one drogue parachute and riser packed into the drogue deployment bag, together with two pyrotechnic cartridges, ejects the drogue parachute assembly into the airstream to ensure positive deployment of the drogue parachute. The maximum force exerted on the CM structure by firing of the drogue mortar will not exceed 18,000 pounds. The pyrotechnic cartridges are installed to provide sympathetic ignition.



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CSM LOGISTICS TRAINING

Figure 2.9-37. Water-Impact Design Envelope

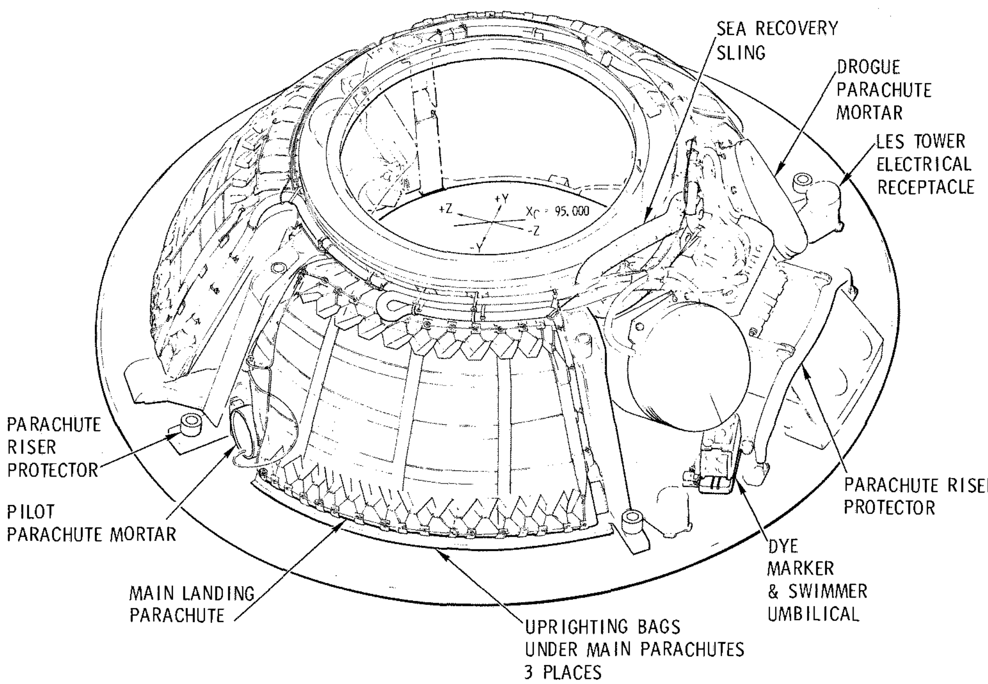

Figure 2.9-38. ERS Equipment

The drogue mortar pyrotechnic cartridges provide the necessary propulsive force to eject the drogue parachute package a distance consistent with the deployment requirements of the drogue parachute. Each of the two cartridges provides one-half the energy required to deploy the drogue parachute package. The cartridge is a hermetically sealed assembly.

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The drogue disconnect assembly provides for the simultaneous disconnect of the drogue parachutes. Fragments resulting from the disconnect operation are contained or so directed as to have no adverse effects on the parachute system or CM structure.

2.9.6.3.2 Pilot Parachutes

The pilot parachute system includes three independent pilot parachute mortars. These mortars are simultaneously initiated, positively deploying the respective pilot parachutes into the airstream in such a manner as to individually deploy the main parachutes.

The pilot parachute (figure 2.9-39) is of a ring-slot design 7.2 feet in nominal diameter. Each pilot parachute is permanently attached to the apex of the main parachute it extracts.

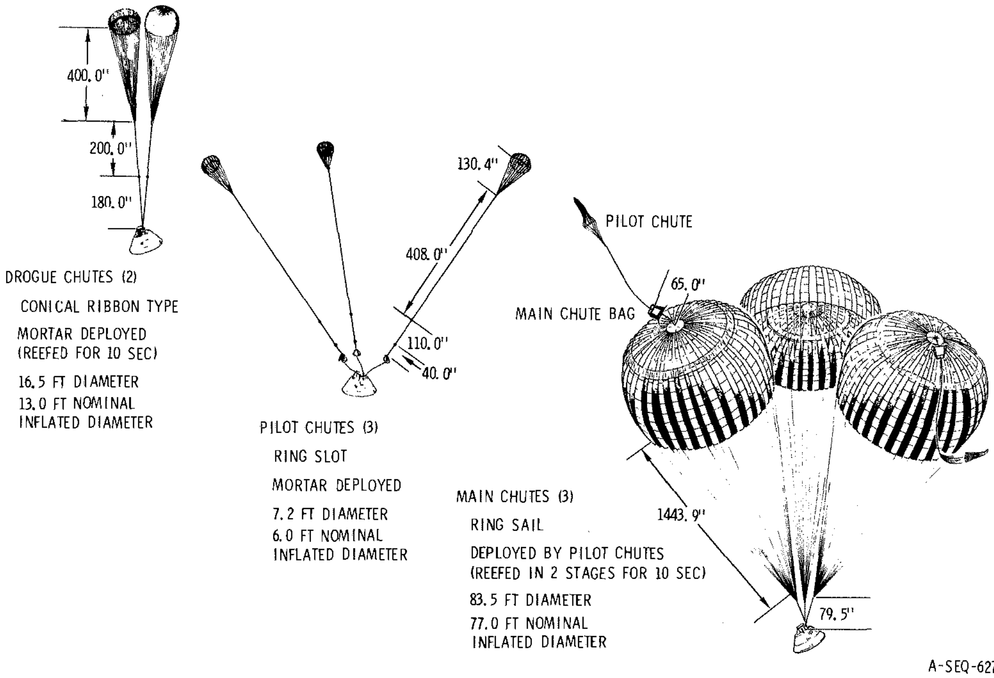

Figure 2.9-39. Earth Recovery Subsystem Parachutes

The pilot parachute deployment bag contains and protects the pilot parachute prior to and during ejection from the pilot mortar and suitably controls the deployment of the pilot parachute riser and pilot parachute.

The pilot parachute riser retains the pilot parachute during deployment and operation. The riser is of sufficient length to place the pilot parachute in a favorable position with respect to the airflow around the CM. The riser design incorporates resistance to heat, abrasion and cutting.

The pilot parachute mortar assembly contains and ejects one pilot parachute upon signal from electrical control circuits. The maximum force exerted on the CM structure by firing the pilot parachute mortar will not exceed 6000 pounds. The pilot mortar pyrotechnic cartridges are installed to provide sympathetic ignition.

2.9.6.3.3 Main Parachutes

The main parachute assembly (figure 2.9-39) consists of the main parachute and parachute riser. The main parachute is of a ring-sail design and operates in a cluster of three parachutes. Dual reefing systems are used in the first stage and a single-reefing system is used for the second-reefing stage. Each reefing line has two cutters. Reefing ratios and durations are selected to preclude the possibility of three sigma parachute fitting loads in excess of 37,500 pounds at a recovery weight of 13,000 pounds.

The descent rates for a 13,000-pound CM recovery weight will not exceed 38 feet per second at sea level with two main chutes deployed, or 31.5 feet per second at sea level with three main chutes deployed.

The main parachute deployment bag contains and protects the main parachute and riser prior to and during extraction from the vehicle and ensures orderly deployment of the parachute and riser.

The main parachute riser is of sufficient length to place the main parachute in a favorable position relative to the airflow around the CM. The riser design incorporates resistance to heat, abrasion, and cutting.

Two-stage reefing is employed to keep the main parachute peak loads at values compatible with the operational requirements. Dual reefing systems are used for the first stage and a single-reefing system is used for the second-reefing stage. The failure of one reefing line cutter to function on either of the reefing lines does not prevent the severance of that reefing line. Each cutter operates at loads consistent with dynamic pressure conditions at deployment. The first- and second-stage reefing lines and cutters are color-coded to provide a means of readily distinguishing first-stage hardware from second-stage hardware.

The main parachute disconnects are incorporated into the design of the vehicle attach fittings. They are mounted on the side of the crew transfer tunnel in the center of the -Z compartment. The main parachutes are disconnected from the CM by manual initiation. Redundancy of pyrotechnic initiation is provided.

2.9.6.4 Earth Landing Sequence Controllers

The earth landing sequence controllers (ELSC) are two of the ten SECS controllers (paragraph 2.9.3). Each ELSC:

- Is capable of performing the proper sequencing of events, initiating functions, providing monitor capability in the parachute subsystem, and of withstanding a minimum of 100 full-load cycles.
- Contains a separate logic circuit including baroswitches, time delays, and switching devices as necessary to achieve the proper sequence of events.
- Contains a separate pyrotechnic circuit (sequenced by the logic circuit) for initiation of pyrotechnic devices.
- Provides crossover and lock-in provisions to ensure assembly function.
- Contains provisions for manual override of selected functions.
- Contains provisions for test monitoring of selected functions.
- Contains provisions for telemeter monitoring of selected functions.
- Is designed to minimize single-point failure.

2.9.6.5 Sequence of Events

Each ELSC functions as shown in figure 2.9-40 wherein separate logic and pyrotechnic circuits are shown. The logic circuit initiates the proper sequence of pyrotechnic functions or signals to related equipment. The logic circuit is divided into two segments, high- and low-altitude. Provisions are made to ensure operation of both system A and system B high-altitude logic circuits upon closing of the high-altitude baroswitch set (BS1 and BS2) in either logic system. These provisions also ensure continuation of the high-altitude logic systems once initiated.

The high-altitude circuit functions as follows:

a. The first logic power input arms high-altitude baroswitches BS1 and BS2. BS1 and BS2 open and close in a band range defined by opening at a pressure no lower than 5.97 inches of mercury (approximately 38,500-foot standard air altitude) and closing at a pressure no higher than 11.61 inches of mercury (approximately 24,000-foot standard air altitude).

b. When BS1 and BS2 close, simultaneous logic functions are generated to:

1. Provide a logic signal to the master events sequence controller.
2. Arm time-delay switches TD1 and TD2 of 2.0 seconds (+0.2, -0.0).

c. Following the 2-second delay, when TD1 and TD2 operate, a logic function is generated to:

1. Provide pyro function to deploy the drogue parachute.
2. Provide a switch closure signal to indicate event occurrence through telemetry and hardline monitors.

The low-altitude circuit functions as specified below:

a. The second circuit, for low altitude, is armed simultaneously with the high-altitude circuit. The logic function is the arming of time-delay switches TD3 and TD4 of 14.0 (+1.4, -0) seconds.

b. Following the 14-second time delay, TD3 and TD4 arm baroswitches BS3 and BS4. BS3 and BS4 open and close in a band range defined by opening at a pressure no lower than 15.00 inches of mercury (approximately 18,000-foot standard air altitude) and closing at a pressure no higher than 20.58 inches of mercury (approximately 10,000-foot standard air altitude).

c. When BS3 and BS4 close, simultaneous logic functions are generated to provide:

1. Pyrotechnic function to release drogue chutes.
2. Pyro function to deploy pilot chute 1.
3. Pyro function to deploy pilot chute 2.
4. Pyro function to deploy pilot chute 3.
5. Switch closure signal to indicate event occurrence through telemetry and hardline monitors.
6. Logic power to arm pilot switch for main chute disconnect.

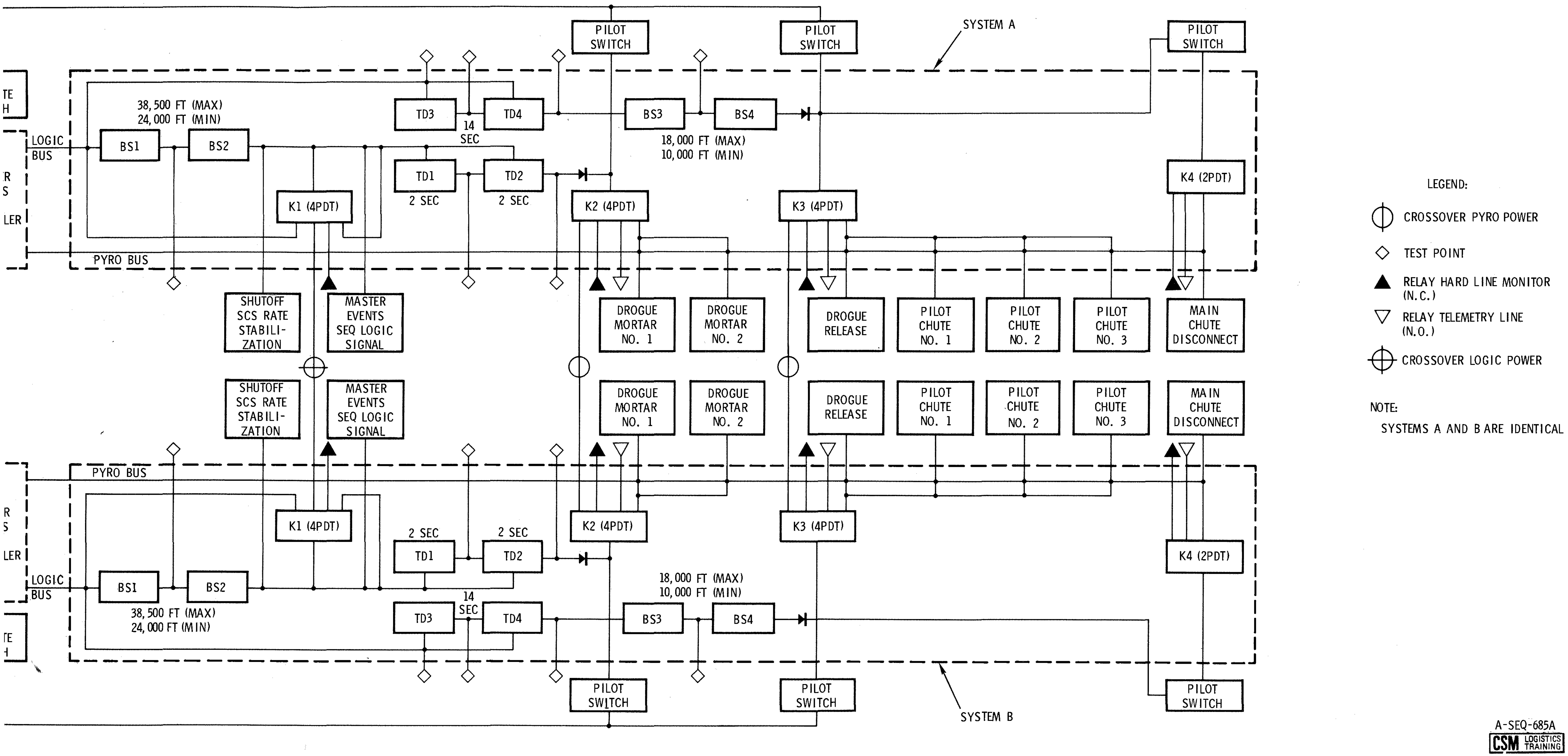

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Figure 2.9-40. Earth Landing Sequence Controller Functional Diagram

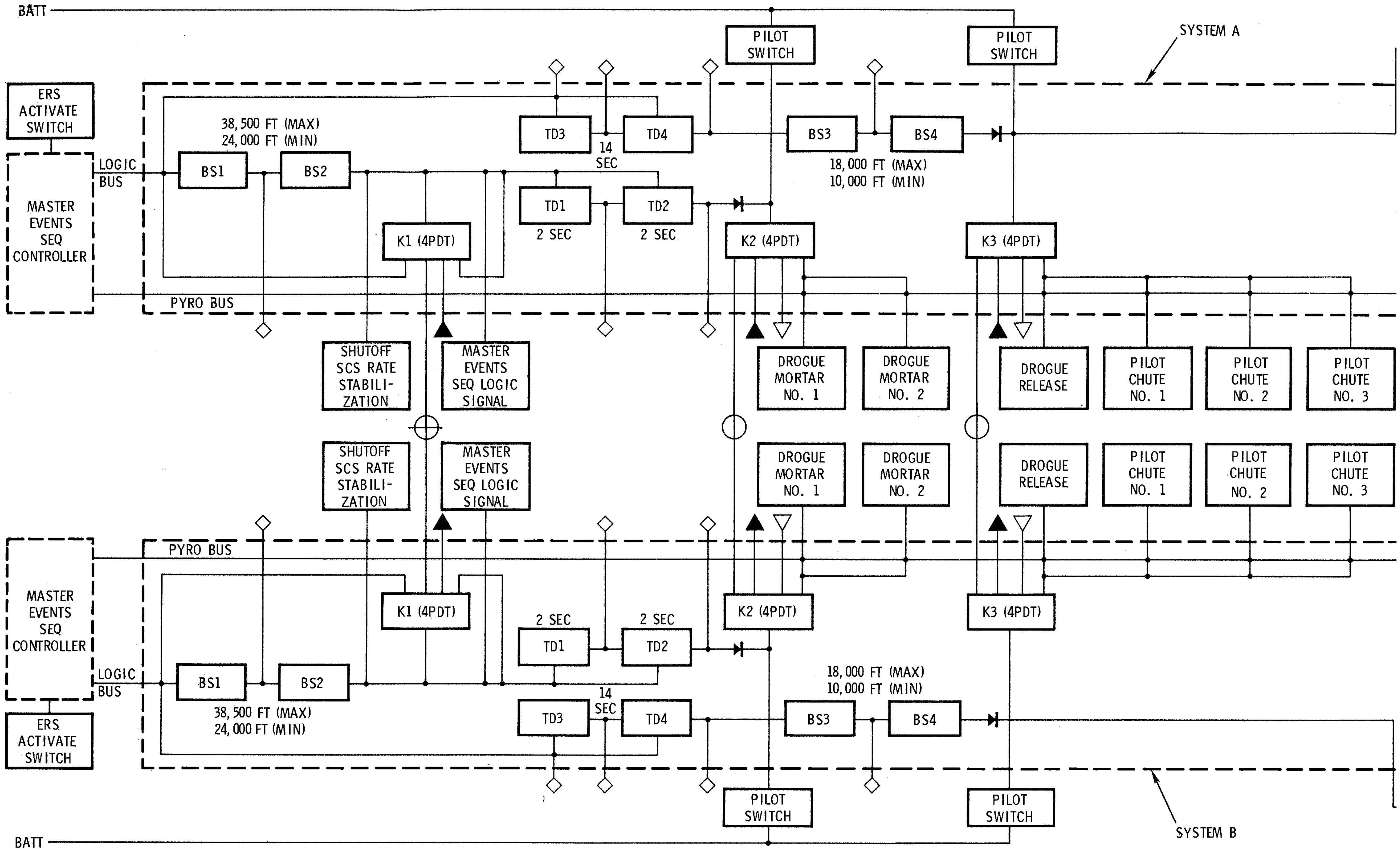

Figure 2.9-40. Earl

2.9.6.6 ELSC Electrical Design

The two ELSC units are operated in parallel. There are electrically separate logic, pyrotechnic, and instrumentation circuits in each unit. Power is supplied by batteries for each circuit and each ELSC is fabricated in accordance with the following electrical design requirements:

- There is complete electrical separation of the two ELSC units. Any failure of one unit does not affect satisfactory operation of the other unit.
- The pyrotechnic battery provides a maximum open-circuit voltage of 37 volts. The nominal working power is 23 volts at 75 amperes.
- The pyrotechnic circuitry includes a shunt across each ordnance device circuit prior to firing. The firing circuit operation simultaneously removes this shunt.
- The pyrotechnic bus is protected from the effects of a pyrotechnic device "after-firing" short. This protection is provided by a suitable device capable of disconnecting the shorted pyrotechnic from the pyrotechnic bus within the minimum time between successive functions within the sequence logic circuit.
- Crossover circuitry is provided as required to coordinate the two units, compensate for normal component tolerances, and ensure simultaneity of system functions.
- The logic battery has a design voltage range from 27 to 37 volts. The sequencer logic circuit is capable of operation from an input voltage of 28 volts (+6, -2) (considering a 3-volt line drop).
- Logic, pyrotechnic, and instrumentation circuit ground returns are separate. The chassis is not to be used as a ground return for these circuits. Shield circuits are grounded at the pyrotechnic devices.
- Time-delay switches are arranged in pairs and either wired with their inputs in parallel and their outputs in series or fitted with similar provisions to minimize the possibility of function initiation occurring before the termination of the specified time delay.
- Electronic switching units containing operating contacts, when used in the sequencer or inertia switch, are not operated by the stresses generated by environmental conditions specified herein. Contacts (or points) in the closed conditions, in either the unenergized position or the energized position, remain closed, and the open contacts in either position remain open during environmental stress. There is no deviation from these requirements of sufficient duration to fire a standard Apollo pyrotechnic device with 32 volts applied to the pyrotechnic bus, disrupt the operation of the ERS time delay units with a voltage of either 26 or 34 volts on the logic bus, or cause interference or undergrounding problems.

2.9.6.7 ELSC Instrumentation

The instrumentation circuitry supplies information indicating the operation of both the logic and pyrotechnic circuits:

- Hardline Monitor: For each function, the ELSC provides individual indications that the pyrotechnic firing devices are in a safe condition. The monitor is obtained through a normally closed set of contacts in each switching device.
- Sequence of Operations Monitor: For each function, the ELSC provides individual switch closure operations for use on the instrumentation bus, in order to monitor sequence of operations. The monitor is obtained, through a normally open set of contacts in each switching device.
- Sequence Control Static Pressure Source: A static pressure source provides ambient air within the forward compartment for the ELSC. Internal connections are provided within the ELSC to the various baroswitches. The outlet from the ELSC is a standard adapter fitting. Filters or other suitable barriers are provided on the static outlets from the ELSC in order to prevent dust or other foreign matter from entering the ELSC. The filters do not cause sufficient lag between ambient pressure and the interior of the ELSC to affect sequencer performance.

2.9.6.8 Forward Heat Shield Separation and Retention System (FHSS)

The system, as illustrated in figure 2.9-41, secures the forward heat shield to the CM until the time prescribed for initiation of the earth-landing sequence of events and at that time jettisons the heat shield without recontact with the CM or the parachute system. The system consists of the following equipment items:

- Jettison thrusters (four)
- Pyrotechnic gas generators (two)
- Pyrotechnic cartridges (four)
- High-pressure gas transmission lines and associated equipment
- Drag chute and mortar assembly and two cartridges.

2.9.6.8.1 Attachment

The FHSS attaches the forward heat shield to the CM inner structure and maintains integrity of thermal protection at the interface between the forward heat shield and the CM under all conditions.

2.9.6.8.2 Retention Loading

Coil-type compression springs are employed in the jettison thrusters to produce a sufficient contact pressure between mating surfaces of the forward heat shield and the CM outer structure.

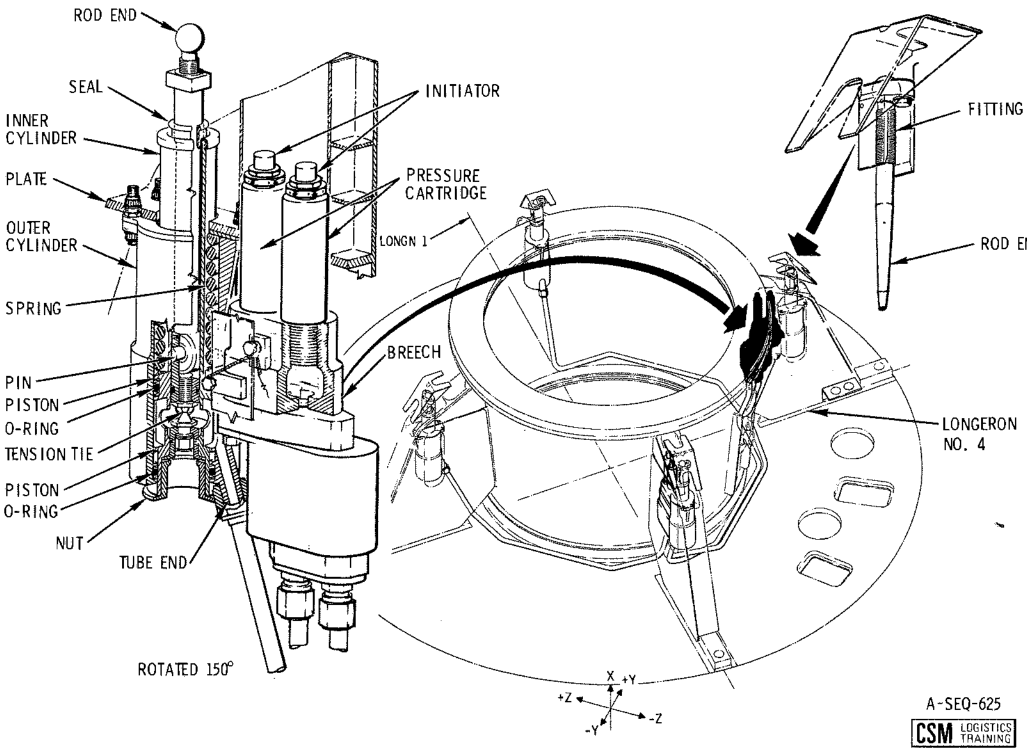

Figure 2.9-41. Forward Heat Shield Separation System

2.9.6.8.3 Differential Thermal Expansion

The FHSS provides for the maximum net differential thermal expansion between the inner CM structure and the forward heat shield while maintaining the requirements of this specification.

2.9.6.8.4 Jettison

Thrusters jettison the forward heat shield upon command with the CM oriented at attitudes encountered during both normal descent and LES abort modes. The drag chute augments the thrusters to assure adequate separation from the spacecraft and the deploying drogue parachutes.

2.9.6.8.5 Redundancy

Redundancy of FHSS separation is obtained by the use of two propellant cartridges per thruster system initiated by independent, redundant, SECS's. Operation of either of the SECSs causes a satisfactory jettison function. The drag parachute is deployed by a single mortar utilizing dual cartridges initiated by redundant signals.

2.9.6.8.6 Thruster Energy Requirements

The gas generator-propellant cartridge assembly is configured to produce sympathetic ignition of the second (trailing) cartridge in each thruster system. The FHSS is jettisoned at an exit velocity to assure safe separation when one electrically ignited system plus one sympathetically ignited cartridge of the second system operate. The drag chute augments the thrusters to assure adequate separation from the spacecraft and the deploying drogue parachutes.

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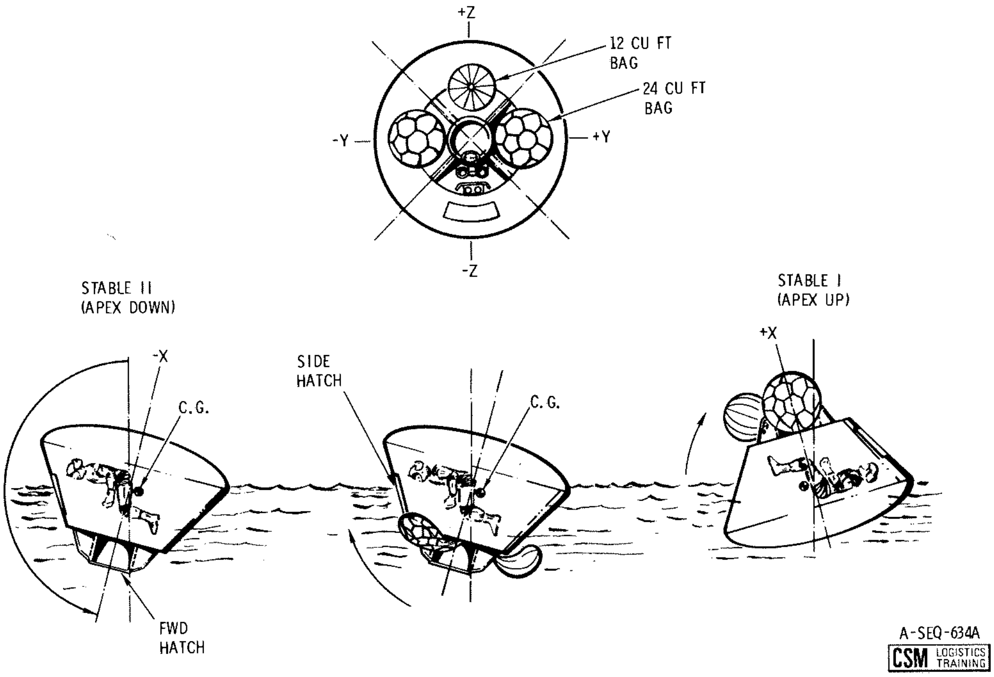

Figure 2.9-42. Uprighting Subsystem, 3 Flotation Bag System

2.9.6.9 Uprighting and Stabilization

The CM uprighting subsystem consists of three air bags packed into containers and located in the forward compartment (figure 2.9-42) of the vehicle, and a means of inflating the bags upon demand. Inflation is accomplished by two electric air compressors located in the aft compartment of the vehicle outside the crew compartment. Each bag is controlled by a solenoid-operated control valve, and pressure relief valves are incorporated into the system to provide protection against over inflation of the air bags. Check valves are used to prevent loss of pressure due to a compressor line failure.

The uprighting compressors operate when the appropriate flotation bag control switches on the left-hand display console are positioned to FILL. With both compressors operating, the air flow is not less than 6.0 standard cubic feet per minute (scfm).

Each solenoid valve actuates to the FILL, OFF, or VENT position when the corresponding switch on the left-hand display console is positioned. In the FILL position, the valve passes the full flow of both compressors to the bag fill ports. In the VENT position, the valve passes a flow of 0.20 ± 0.02 scfm when a pressure of 1.0 psig is applied to the respective flotation bag. Each bag relief valve bypasses sufficient flow overboard from both the compressors to limit the pressure at the respective ball fill port to between 3.0 and 5.5 psig. The electrical schematic is shown in figure 2.9-43.

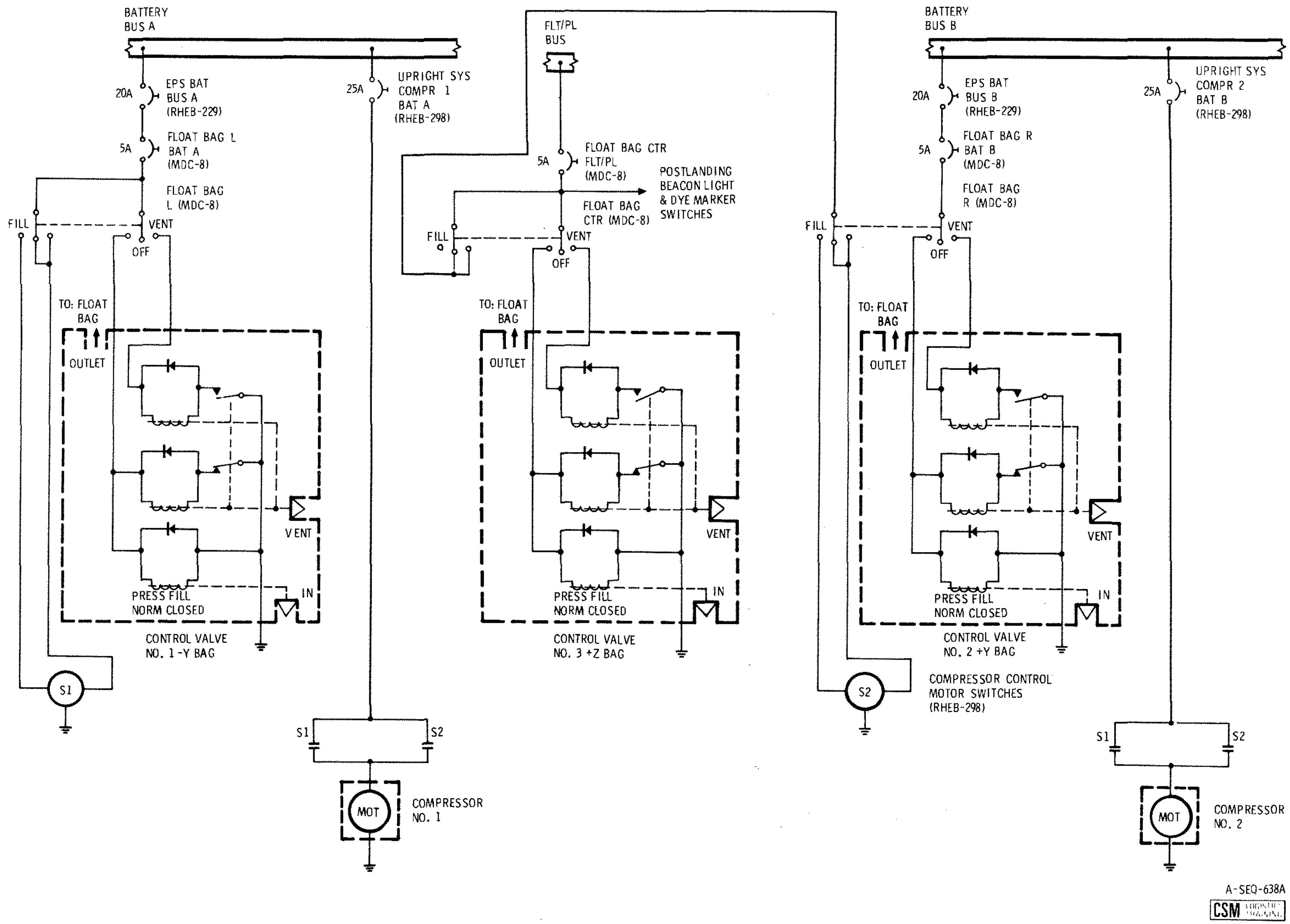

Figure 2.9-43. Uprighting Subsystem Electrical Schematic

2.9.6.10 Recovery Aids

Recovery aids (figure 2.9-44) are also installed in the proximity of ERS parachutes, they are sea recovery sling, uprighting flotation bags, swimmer umbilical and sea dye marker, VHF recovery antennas, and flashing beacon light. The recovery antennas and flashing beacon light are deployed automatically; the uprighting flotation bags and swimmer umbilical, which includes the sea dye marker, are deployed by the flight crew as required (manual switching exclusively). The sea recovery sling is removed from its stowed position by recovery forces.

2.9.7 FUNCTIONAL DESCRIPTION

The origin of signals and functions of the sequential systems are illustrated in figure 2.9-45. Launch escape system (LES) aborts may be executed from the launch pad, or during ascent, until launch escape tower (LET) jettison. Prior to lift-off, LES abort signals are initiated by manual control only because the automatic abort circuits of the EDS are activated at lift-off. Thereafter LES aborts may be initiated by manual control or by automatic control during the period that the EDS automatic abort circuits are active. LES aborts are categorized as modes 1A, 1B, and 1C aborts. Service propulsion system (SPS) aborts are categorized as modes 2 and 3 aborts and may be initiated after the LET has been jettisoned. No provisions are made to initiate SPS aborts automatically.

2.9.7.1 Normal Mission Functions

In addition to control for aborts, sequential systems provide for the monitoring of vital LV parameters and control for other essential mission functions as follows:

a. Sensing and displaying LV status:
    1. Thrust OK lights for all booster engines
    2. Angular rates excessive
    3. IU guidance failure
    4. LV propellant tank pressures
    5. Angle of attack.
b. Receiving and displaying abort requests from ground stations.
c. Jettisoning of the LET:
    1. Initiate ordnance devices that separate the LET from the CM
    2. Ignite TJM.
d. Separation of the CSM from the S-IVB stage:
    1. Enable controller reaction jet on/off assembly which provides automatic control of SM RCS engines. (Enable SM RCS/SCS.)
    2. Initiate ordnance devices that separate the SLA:
        (a) Initiate cutting and deployment of SLA panels
        (b) Separate SC/LV umbilical
e. Docking probe retraction.
f. Separation of the docking ring.
g. Separation of the CM from the SM.
    1. Start SMJC:
        (a) Lock up fuel SM power to SMJC.
        (b) Start -X jets of SM RCS.
        (c) Start +roll jets of SM RCS.
        (d) Stop +roll jets of SM RCS.
        (e) Stop -X jets of SM RCS.

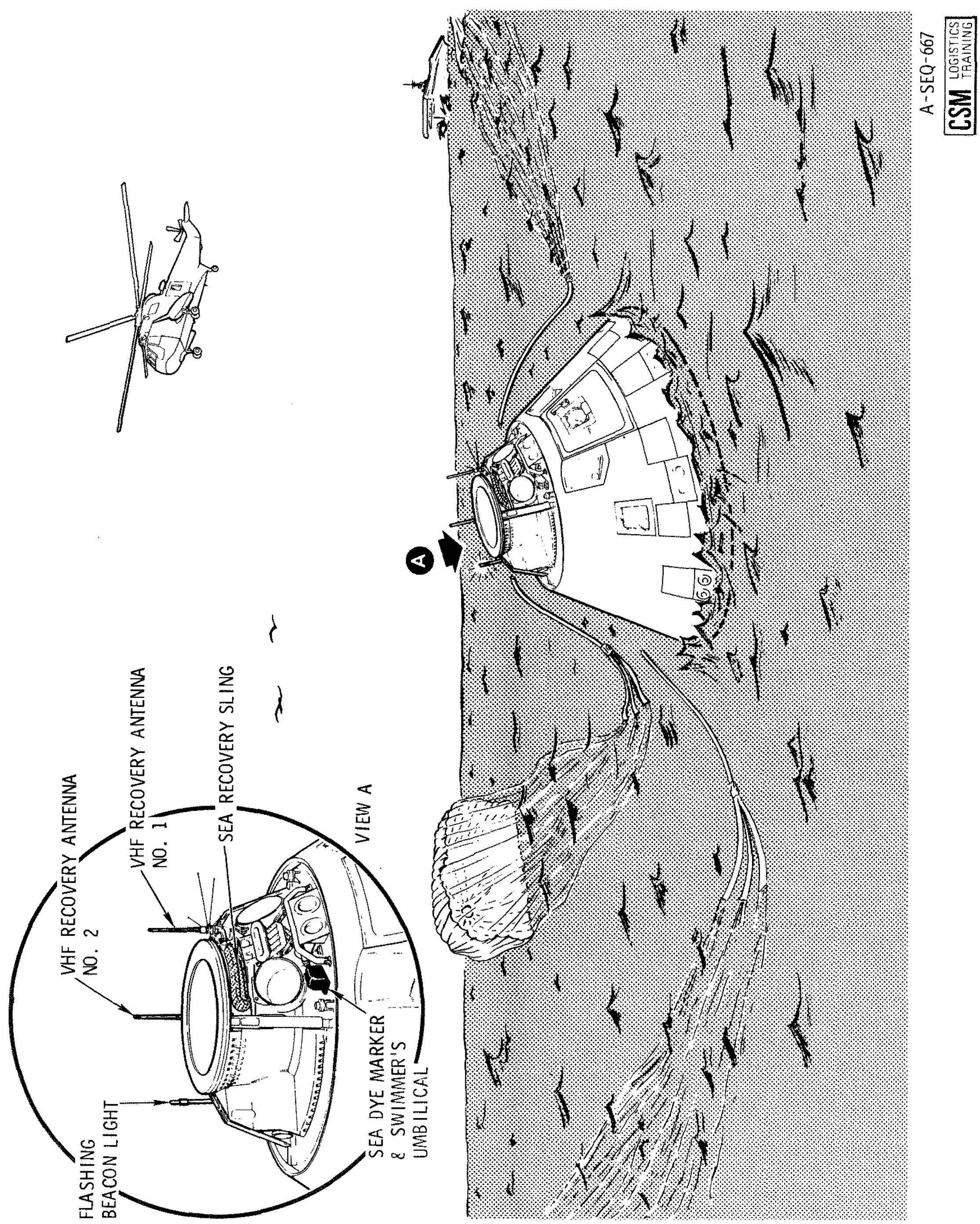

Figure 2.9-44. ERS Recovery Aids

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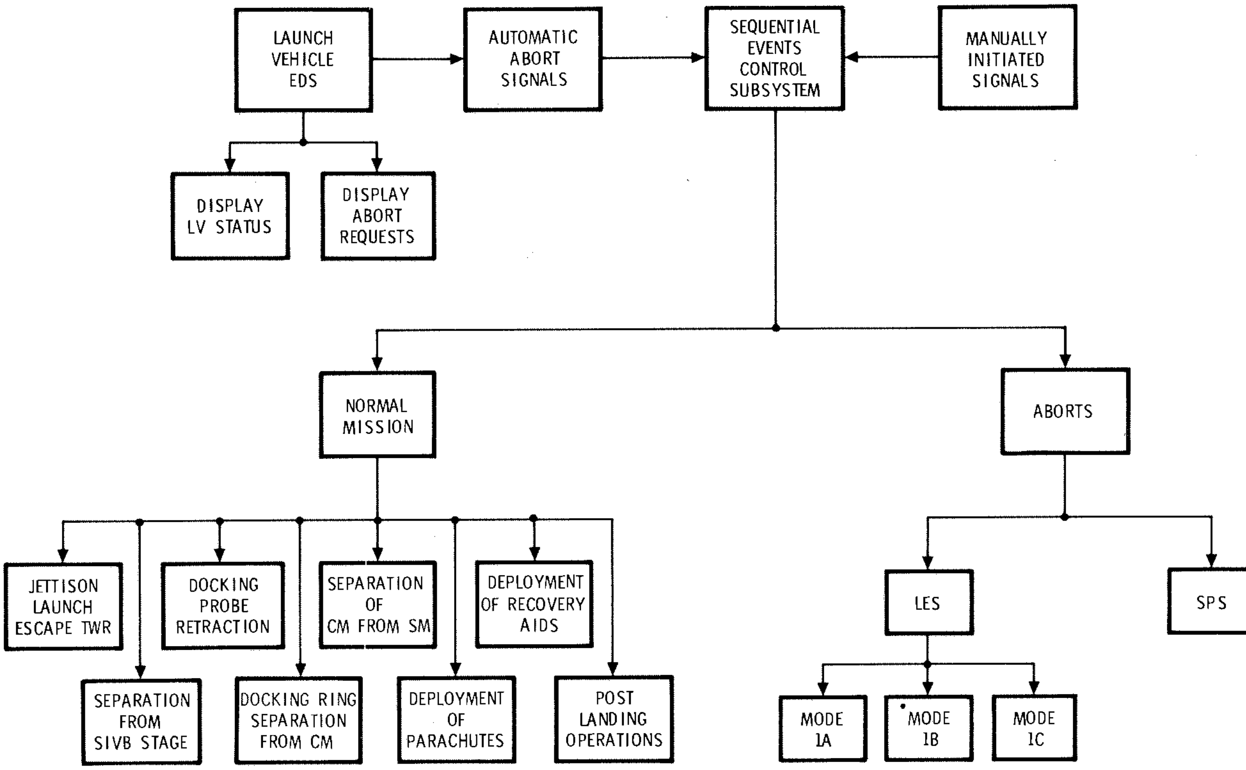

Figure 2.9-45. Sequential Systems Functional Block Diagram

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2. Deadface CM-SM umbilical power.
3. Pressurize CM RCS.
4. Transfer electrical power from SM RCS engines to CM RCS engines and deadface SMJC start signal.
5. Transfer entry and postlanding battery power to main d-c buses (main bus tie).
6. Initiate separation ordnance devices:
   (a) CM-SM tension ties
   (b) CM-SM umbilical guillotine.
7. Deadface CM-SM separation pyro power (pyro cutout).

h. Deployment of ERS parachutes:
1. Activate ELSC.
2. Disable controller reaction jet on/off assembly which inhibits automatic control of CM RCS engines (disable CM RCS/SCS).
3. Jettison apex cover.
4. Deployment of apex cover drag parachute.
5. Deployment of drogue parachutes.
6. Release of drogue parachutes.
7. Deployment of pilot parachutes of the main parachutes.

i. Deployment of recovery devices:
1. Two VHF antennas
2. One flashing beacon light.

j. Burning of CM RCS propellants and pressurant.

k. Postlanding functions:
1. Release of main parachutes.
2. Uprighting subsystem in case of Stable II attitude.

2.9.7.2 Mode 1A Abort

The functions of a mode 1A abort are as follows:

a. Relay booster engine cutoff (BECO) signal to the IU.
b. Reset and start the commander's event timer.
c. Separation of the CM from the SM:
   1. Deadface CM-SM umbilical power.
   2. Pressurize CM RCS.
   3. Transfer electrical control from SM RCS engines to CM RCS engines.
   4. Transfer entry and postlanding battery power to main d-c buses (main bus tie).
   5. Initiate separation ordnance devices:
      (a) CM-SM tension ties
      (b) CM-SM umbilical guillotine.
   6. Fire LEM and PCM.
   7. Start automated rapid propellant dump (CM RCS propellant and pressurant jettison):
      (a) Initiate oxidizer dump.
      (b) Initiate interconnect of A and B fluid systems.
      (c) Close propellant shutoff valves.
      (d) Initiate fuel dump.
      (e) Initiate helium dump (purge).
d. Deploy canards.
e. Deployment of ERS parachutes:
   1. Activate ELSC.
   2. Disable controller reaction jet on/off assembly which inhibits automatic control of CM RCS engines (disable CM RCS/SCS).
   3. Jettison LET.
   4. Separate docking ring.
   5. Jettison apex cover.
   6. Deployment of apex cover drag parachute.
   7. Deployment of drogue parachutes.
   8. Release of drogue parachutes.
   9. Deployment of pilot parachutes of the main parachutes.
f. Deployment of recovery devices:
   1. Two VHF antennas.
   2. One flashing beacon light.
g. Postlanding functions:
   1. Release of main parachutes.
   2. Uprighting subsystem in case of Stable II attitude.

2.9.7.3 Modes 1B and 1C Aborts

The functions of the modes 1B and 1C aborts are the same as those of a mode 1A abort with the following exceptions:

a. Firing of the PCM is inhibited.
b. Automated rapid propellant jettisoning is inhibited.

c. Enable controller reaction jet on/off assembly which provides automatic control of CM RCS engines (enable CM RCS/SCS).

2.9.7.4 Modes 2 and 3

The functions of the sequential systems portion of an SPS abort are as follows:

a. Relay BECO signal to the IU.
b. Reset and start commander's event timer.
c. Initiate CSM direct ullage (+X translation).
d. Relay signal to SCS to inhibit pitch and yaw rate stabilization.
e. Separate CSM from the LV:
    1. Initiate ordnance devices that separate SLA:
        (a) Initiate severance and deployment of SLA panels.
        (b) Separate SC/LV umbilical.

f. Enable controller reaction jet on/off assembly which provides automatic control of SM RCS engines (enable SM RCS/SCS).

2.9.8 OPERATIONAL DESCRIPTION

In most Apollo applications, premature operation of an ordnance system is hazardous to the crew and could cause loss of mission objectives. Identification and correction of single points of failure, therefore, are prime objectives in the SECS circuit concept. Elimination of single failures is accomplished by the addition of series contacts (dual) in each firing circuit. The probability of premature operation of an ordnance device has been greatly reduced by the utilization of series elements. On the other hand, the reliability of the firing network to operate has been reduced. The overall firing circuit reliability is enhanced by the use of redundant firing circuits. Each circuit is independent of the other with each output controlling its own ordnance component. Each of these redundant circuits is contained in independent systems which are designated systems A and B. Figure 2.9-5 illustrates one of the redundant systems of a typical firing network. This illustration also shows that some control circuits for sequential events utilize the same circuit concept.

Figure 2.9-46 illustrates the operation and functions of the integrated sequential systems and zone references to this illustration are used in subsequent paragraphs. This is an operational/functional diagram and should not be misconstrued as an electrical schematic since many details of the electrical system are not included, i.e., ground returns are not shown except for the clarification of unique circuits. Also, initiator firing circuits are not complete in the operational/functional diagram. Figure 2.9-5 illustrates that normally closed contacts of firing relays are utilized to short the initiator to ground and that all initiator firing circuits are protected with fusistors. All initiators are grounded by relay logic and fusistors are incorporated even though the operational/functional diagram does not illustrate this feature. Generally, only one of the redundant systems is illustrated, which in this instance is system A; however, the redundant system is included when the two are not identical or for clarification. Numerous crossover networks are illustrated where vital functions are concerned; in these instances, systems A or B components will activate and/or initiate the discrete requirements. Interface with other systems is limited to the effect the interfacing system has on sequential systems.

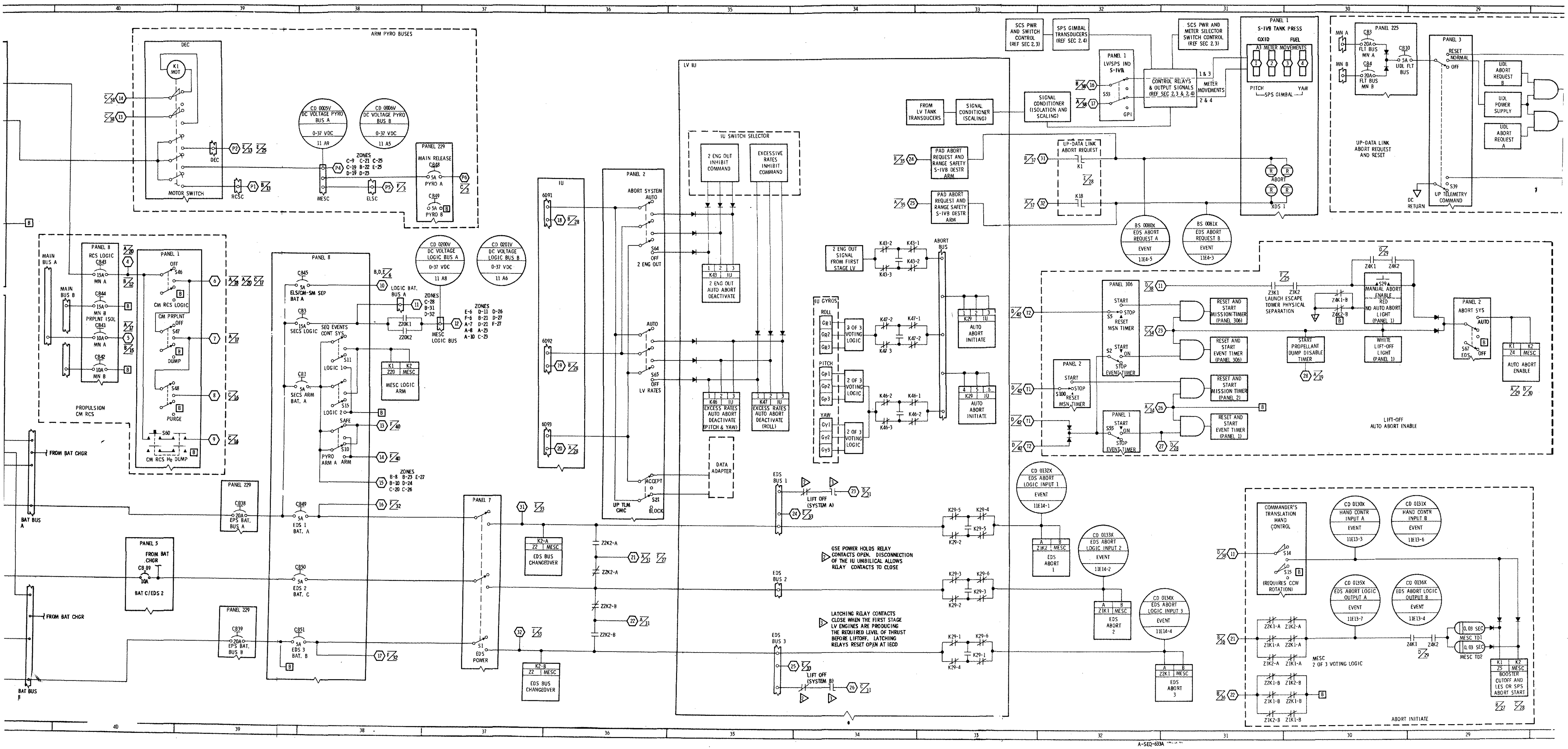


Figure 2.9-46. Sequential Systems Operational/Functional Diagram (Sheet 1 of 3)

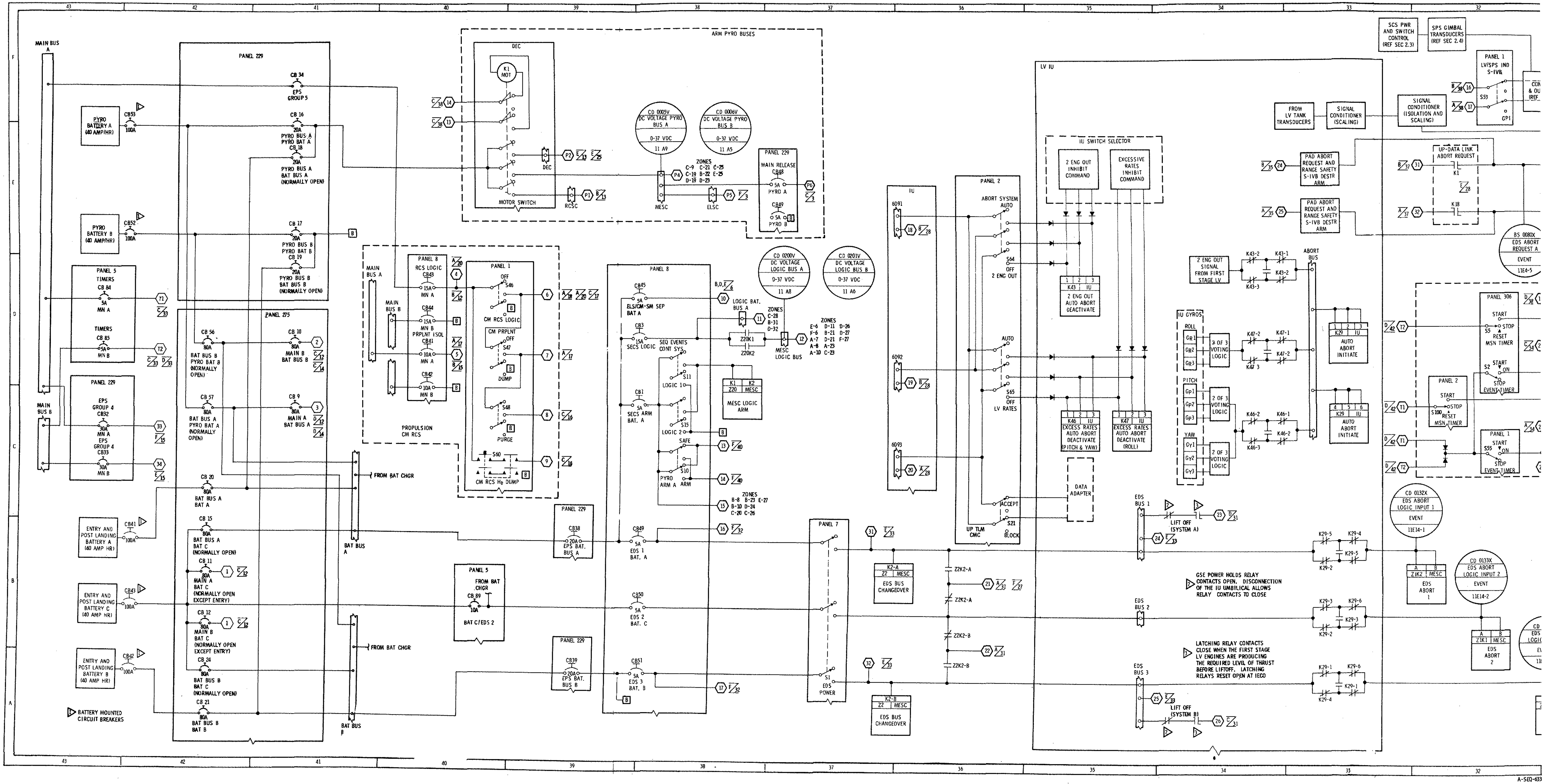


Figure 2.9-46. Sequ

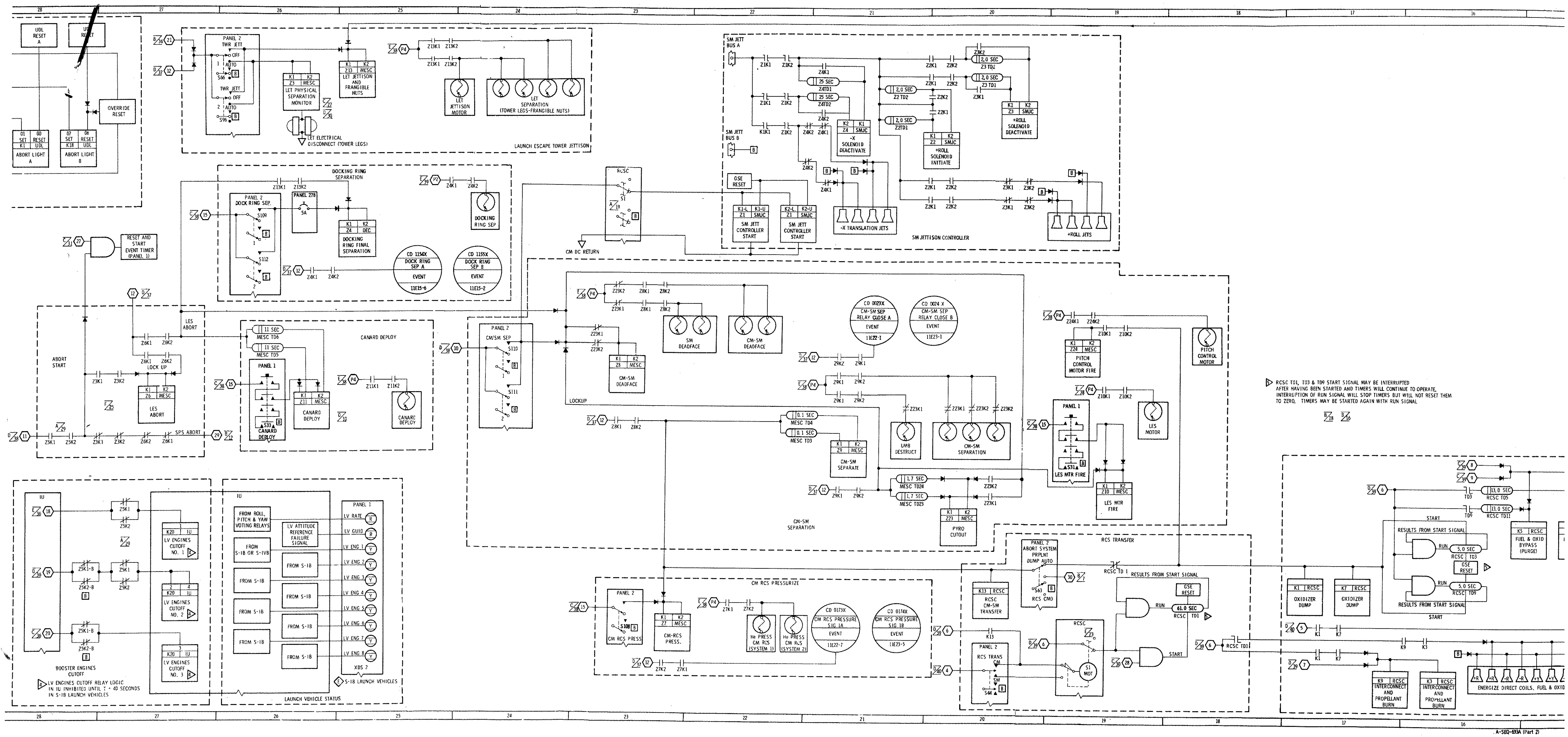
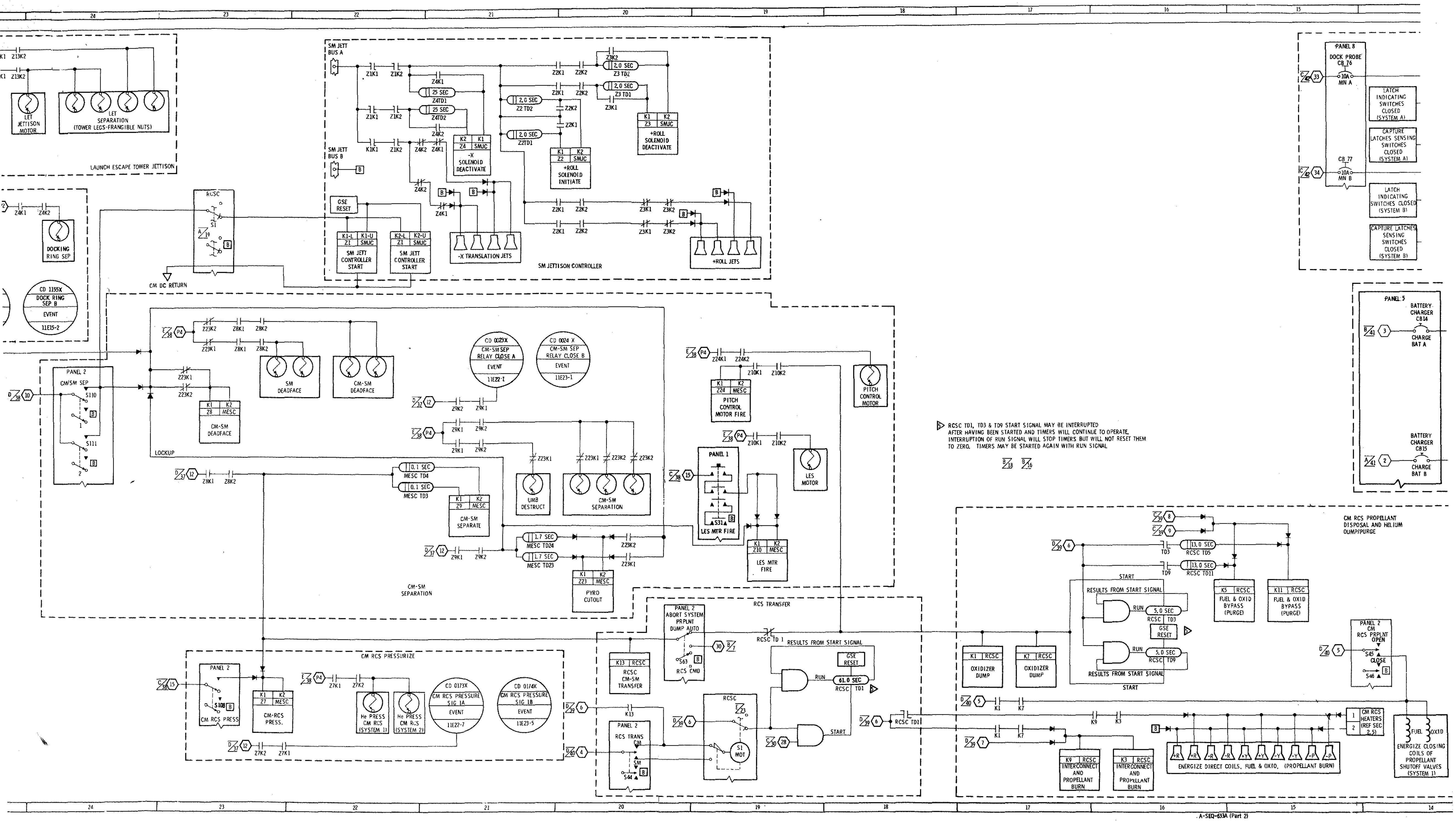


Figure 2.9-46. Sequential Systems Operational/Functional Diagram (Sheet 2 of 3)



unctional Diagram

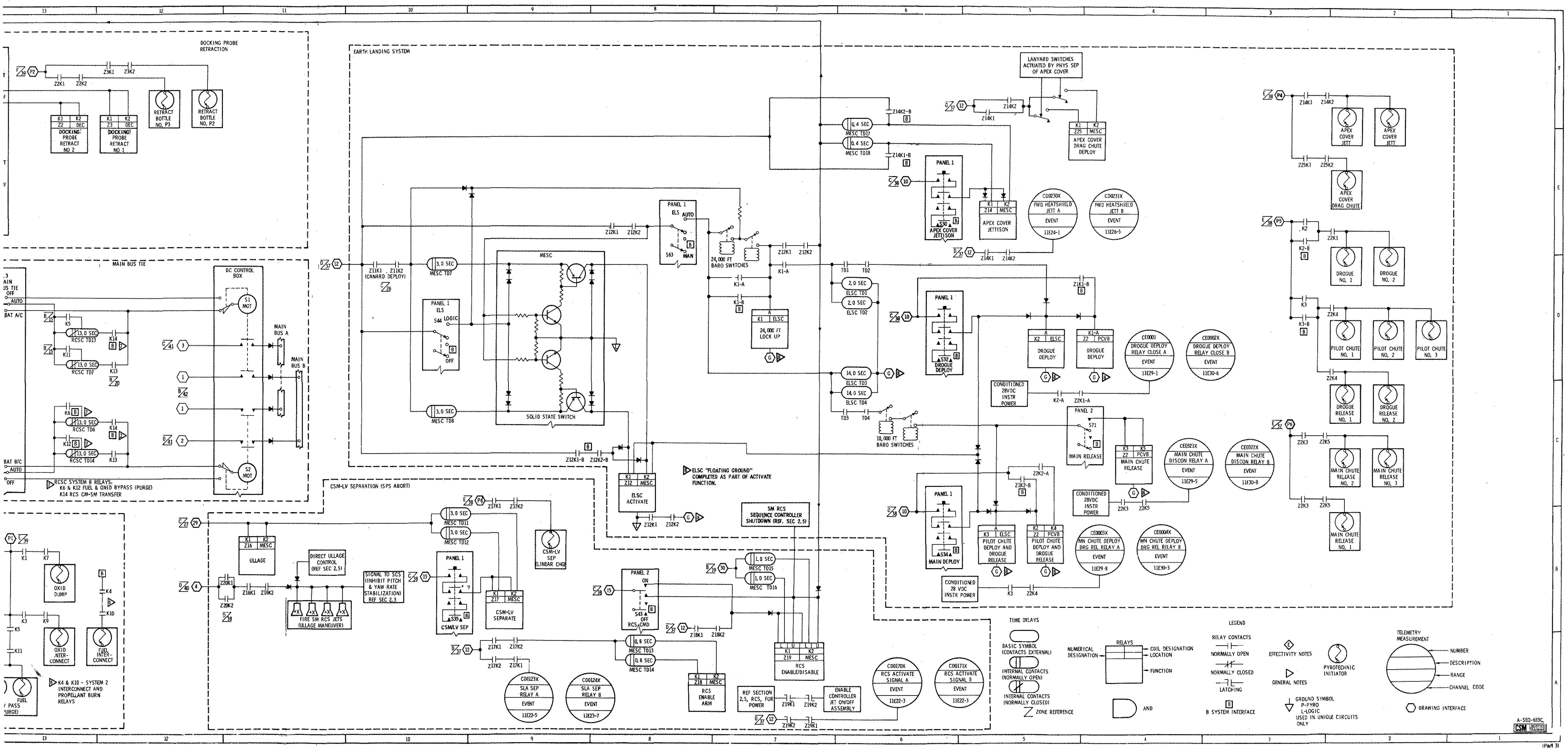


Figure 2.9-46. Sequential Systems Operational/Functional Diagram (Sheet 3 of 3)

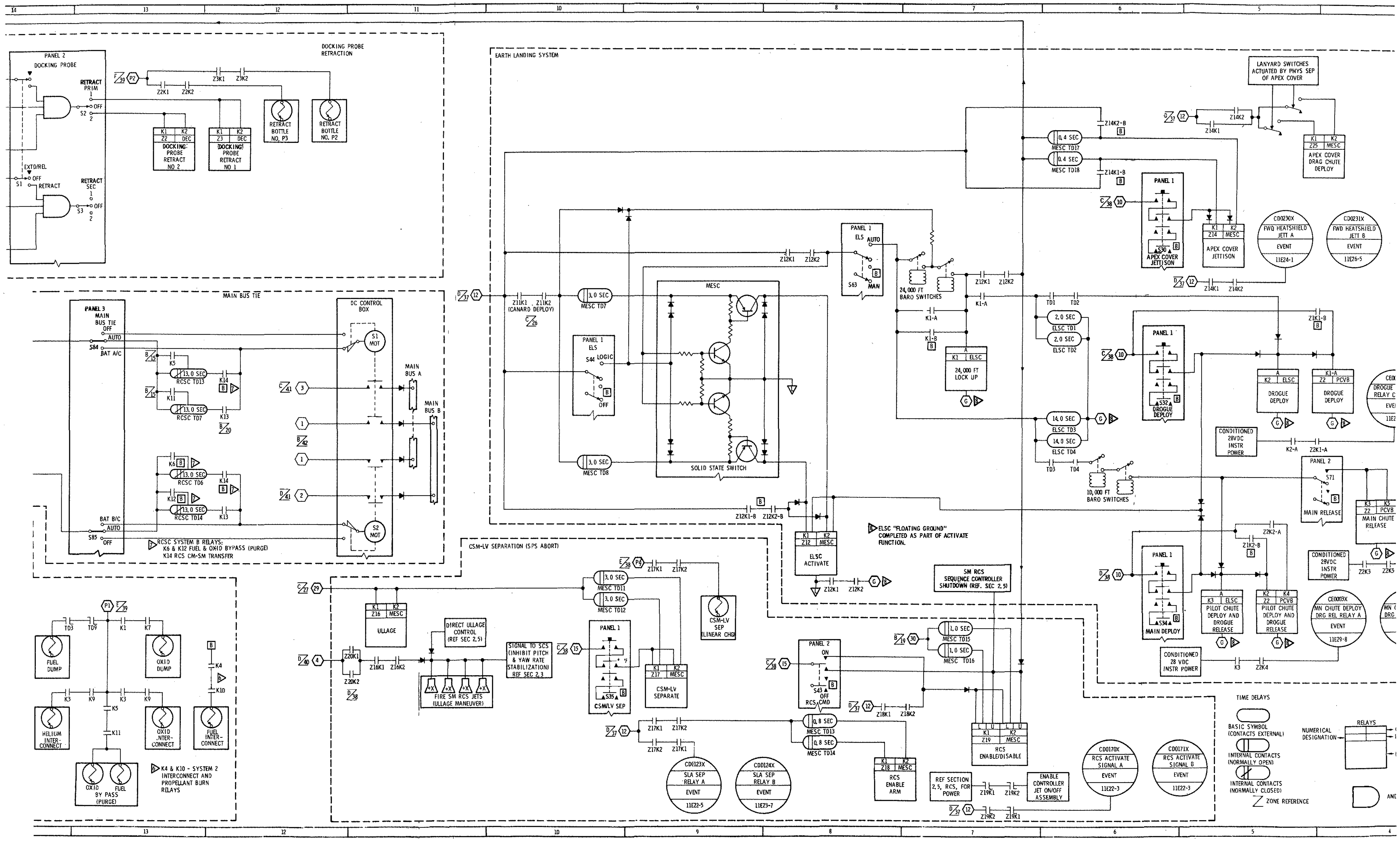


Figure 2.9-46. Sequ

2.9.8.1 Logic Power (Zones 42, 43-A, and -B)

The source of logic power for sequential systems is entry and postlanding batteries A, B, and C which are described in section 2.6, Electrical Power. Utilization of the circuit breakers (Panels 5, 229, and 275) in these power circuits is also described in the electrical power section.

2.9.8.1.1 Arming Sequential Systems Logic Circuits (Zones 38 and 39-C and -D)

Three circuit breakers are utilized in the system A sequential systems logic arming circuits, and their counterparts (not illustrated) are utilized in the system B circuits. The system A circuit breakers are ELS/CM-SM SEP BAT A (CB 45), SECS LOGIC (CB 3), and SECS ARM BAT A (CB 1). The SEQ EVENTS CONT SYS LOGIC switches 1 and 2 (S11 and S15) are two pole lever-lock switches and their function is SECS logic arming. When either of these switches is closed, the MESC LOGIC ARM relays will be energized in systems A and B and the MESC logic buses of both systems will be armed.

2.9.8.2 Pyro Power (Zones 41 through 43-E and -F)

Normally the source of pyro power is pyro batteries A and B; however, entry and postlanding batteries may be used as backup sources of pyro power. Closure of PYRO BUS A PYRO BAT A and PYRO BUS B PYRO BAT B circuit breakers (CB 16 and 17), zone 41-E, will complete battery power circuits to pyro systems A and B. If the voltage of either of the pyro batteries should be too low for crew safety, entry battery power may be utilized. Opening the appropriate PYRO BUS PYRO BAT circuit breaker and closing the appropriate PYRO BUS BAT BUS circuit breaker (CB 18 or 19), zones 41-D and -E, will execute the selection of backup power.

2.9.8.2.1 Arming Pyro Buses (Zones 37 through 40-E and -F)

The system A SECS pyro buses are armed with a motor switch in the DEC primarily for power conservation. When the motor is driven to either position, power is not required to hold the switch contacts in the selected position. The PYRO ARM A switch (S10), zone 38-C, is used to control the DEC motor switch (K1), zones 39, 40-E, and -F. Contacts of the motor switch control power to the DEC, RCSC, and MESC pyro buses. Pyro power for the ELSC is derived from the MESC pyro bus.

SEQ

2.9.8.2.2 Main Parachute Release (Zone 37-E)

Two circuit breakers are incorporated in the pyro power systems of the main parachute release circuits. These circuit breakers are unique because they are, in effect, safety switches to prevent a premature main parachute release. Closure of MAIN RELEASE, PYRO A and/or PYRO B circuit breaker(s) (CB 48 or CB 49), should be accomplished immediately following splashdown only.

2.9.8.3 EDS Bus Changeover (Zones 36, 37-A, and -B)

Battery C provides an alternate power source to the MESC voting logic, zone 31-A, and the TWR JETT switches, zone 27-F. These circuits are normally powered by entry batteries A and B. This is accomplished by the EDS bus changeover circuits in each MESC. Closure of the EDS POWER switch (S1), zones 37-A and -B, energizes EDS CHANGEOVER relays. When these relays are energized, battery A is coupled to system A and battery B is coupled to system B. In the event of a power failure in either system A or B, the relay logic will automatically switch out the dead battery and couple battery C to the system which had a power failure.

2.9.8.4 MESC Auto Abort Voting Logic

When the EDS power is turned ON, three hot wire loops are established between the CM and LV. Power from the EDS buses 1, 2, and 3 energize the EDS ABORT relays 1, 2, and 3 in the MESC, zones 31 and 32-A and -B. The three legs of EDS bus power are through three matrices of relay contacts of the AUTO ABORT INITIATE relays, zones 33-A through -D. When an automatic abort is initiated in the IU the EDS ABORT relays in the MESC are de-energized, this constitutes three abort votes in the MESC. The MESC 2 of 3 voting logic is illustrated with matrices of EDS ABORT relay contacts, zones 30 and 31-A.

2.9.8.5 LV Auto Abort Logic

The EDS will automatically initiate an abort signal when two or more first stage engines are out, zone 34-D, or when LV excessive rates are sensed by gyros in the IU, zones 34-C and -D. These abort signals will arm an ABORT BUS which will energize AUTO ABORT INITIATE relays, zones 33-C and -D. When the AUTO ABORT INITIATE relays in the IU are energized, the auto abort voting relays in the MESC are de-energized. Three matrices of relay contacts, each of which constitutes 2 of 3 voting logic, are in the abort signals to the ABORT BUS and the functions of these relays are automatic abort deactivate, zones 34-C and -D. The source of power to energize the AUTO ABORT DEACTIVATE relays is in the IU, zones 36-C, -D and -E, and may be controlled by switches in the CM. If the 2 ENG OUT switch (S64), zone 36-E, is placed in the OFF position, the 2 ENG OUT AUTO ABORT DEACTIVATE relays will be energized and the 2 engines out signal from the first stage will be inhibited from initiating an abort. If the LV RATES switch (S65), zone 36-D, is placed in the OFF position, the EXCESSIVE RATES AUTO ABORT DEACTIVATE relays will be energized and the abort signals from the IU gyros will be inhibited from initiating an abort.

2.9.8.6 Lift-Off

The lift-off originated in the IU, zones 34-A and -C, is the result of two L/V events:

a. Thrust commit activates lift-off enable circuitry when the first stage LV engines are producing the required level of thrust.

b. Disconnection of the IU umbilical will drop out lift-off holding circuits, which, in turn will switch the lift-off signal power to the CSM. The umbilical will be disconnected at the instant of actual lift-off.

If the appropriate circuit breakers and switches are in the configuration intended for a nominal launch the lift-off signal will initiate five events, zones 29 through 32-C and -D

a. Reset and start event and mission timers (two each).
b. Start the automatic PROPELLANT DUMP DISABLE timer.
c. Illuminate the white LIFT OFF light.
d. Provide power to illuminate the red NO AUTO ABORT light in the event the MESC automatic abort circuits are not enabled.
e. Enable the MESC automatic abort circuits by energizing the AUTO ABORT ENABLE relays.

2.9.8.6.1 Event Timers, Panels 1 and 306

Digital display is controlled by four toggle switches. Manual switching enables the following control:

- Reset, count up mode, count down mode.
- Start, stop.
- Individual slewing of units and tens of minutes.
- Individual slewing of units and tens of seconds.

Operational characteristics:

- Maximum readout 59 minutes 59 seconds.
- Requires d-c spacecraft power for operation. Removal of power will stop timer. When power is again applied, timer will not start counting but will remain as when power was removed. Must be started manually.
- Readout progresses through discrete one second iterations in responses to pulses from the CTE.
- Automatic reset to zero and start counting at lift-off. The timer on panel 1 will reset to zero and start counting if an abort is initiated.
- If reset switch is triggered while timer is running, the display will reset to zero and the timer will stop.
- When running (up or down mode), counting will continue through 00 00 after reaching the maximum readout.
- Center position of all switches is the normal run position.

SEQ

2.9.8.6.2 Mission Timers (GFE), Panels 2 and 306

Digital display controlled by four toggle switches. Manual switching enables the following control:

- Start, stop and reset (start position normal for lift-off and run).
- Individual slewing of the units and tens of minutes and seconds.
- Individual slewing of the units of hours. One switch position is used to slew tens and hundreds of hours.

Operational characteristics:

- Maximum readout 999 hours, 59 minutes, 59 seconds.
- Count-up mode only.
- Automatically reset to zero and start counting at lift-off.
- Must be running to accept discrete lift-off signal.
- When slewing minutes and seconds, tens and units must be slewed separately.

- When slewing hours, the transition from tens to hundreds is automatic. Units must be slewed separately.
- Readout progresses through discrete one second iterations in response to pulses from CTE.
- Internal oscillator permits continued operation if CTE pulses are interrupted. Tuning fork light indicates this situation.
- Requires a-c and d-c spacecraft power for operation. Removal of power will stop timer; when power is again applied, timer will start. In this instance the displayed time will not indicate mission elapsed time.
- If reset switch is triggered while timer is running, the display will reset to zero and the timer will continue to run.

2.9.8.7 Launch Escape Tower Physically Attached

One requirement for enabling the circuits that will automatically initiate an abort is to have the LET physically attached to the CM. Another requirement is logic power to the circuits associated with tower attachment. The power may be from the EDS bus changeover circuits or from the MESC LOGIC bus. The LET PHYSICAL SEPARATION MONITOR relays, zone 26-F, have ground wires routed through the tower legs. One pair of contacts of these relays is in the holding circuit to the AUTO ABORT ENABLE relays, zone 31-D. Automatic initiation of an abort is impossible after the tower has been jettisoned because the AUTO ABORT ENABLE relays will have been de-energized.

2.9.8.8 Auto Abort Enable

The last requirement for an abort initiate signal to be automated is to have the MESC automatic abort circuits enabled. If the EDS switch (S67), zone 29-D, is in the AUTO position, a lift-off signal from the IU will enable these circuits. Relay logic in the automatic abort enable circuits are designed to establish holding circuits on battery bus power. These holding circuits are required to maintain the automatic abort circuits in an enabled state since the lift-off signals are discontinued from the IU at IECO. For the holding circuits to be established, power must be made available from the SECS LOGIC CB3, and the LET must be physically attached and electrically mated. Normally closed contacts of the system B AUTO ABORT ENABLE relays are installed in the negative return of the red NO AUTO ABORT light. When the automatic abort circuits are enabled, the red NO AUTO ABORT light will not be illuminated. The LIFT OFF and NO AUTO ABORT lights are combined in an illuminated pushbutton (IPB) which is the only illuminated switch in this group. Illumination of the red light would be the indication that complete enabling of both systems had not been established. If the white LIFT OFF light should not illuminate at lift-off, the most probable cause would be a failure of both lift-off signals in the IU. In this event, the IPB should be depressed momentarily to allow the automatic abort circuits to be enabled from the alternate battery bus power source; neither of the lights would be illuminated in this instance.

2.9.8.9 Normal Ascent

Figure 2.9-47 illustrates a typical ascent profile of S-IB launch vehicles.

At T +61 seconds, the PRPLNT switch (S63), zone 20-B, will be changed from the DUMP AUTO position to the RCS CMD position. The DUMP AUTO contacts of the switch are in series with contacts of the PROPELLANT DUMP DISABLE timer which was started at lift-off. Additional information relative to this time delay and procedural switching is included in section 2.5, RCS.

2.9.8.10 Launch Vehicle Status (Zones 25 and 26-A and -B)

The electrical circuits that provide illumination power and control the LV status lights are in the IU. The LV RATE light will illuminate when LV roll, pitch, or yaw rates are in excess of predetermined limits. To indicate loss of attitude reference in the IU guidance unit, the red LV GUID and the LV RATE lights illuminate during first stage boost, only LV GUID will illuminate after staging. The yellow LV ENGINES lights illuminate when a respective LV operating engine is developing less than the required thrust output. The engine lights provide four cues: (1) ignition, (2) cutoff, (3) engine below thrust, and (4) physical stage separation.

2.9.8.11 Abort Request Light (Zone 31-E)

Two bulbs are in system A, and two are in system B. The ABORT light is illuminated if an abort is requested by launch control center for a pad abort or an abort during lift-off via up-data link (UDL). The ABORT light can be illuminated after lift-off by the range safety officer transmitting a

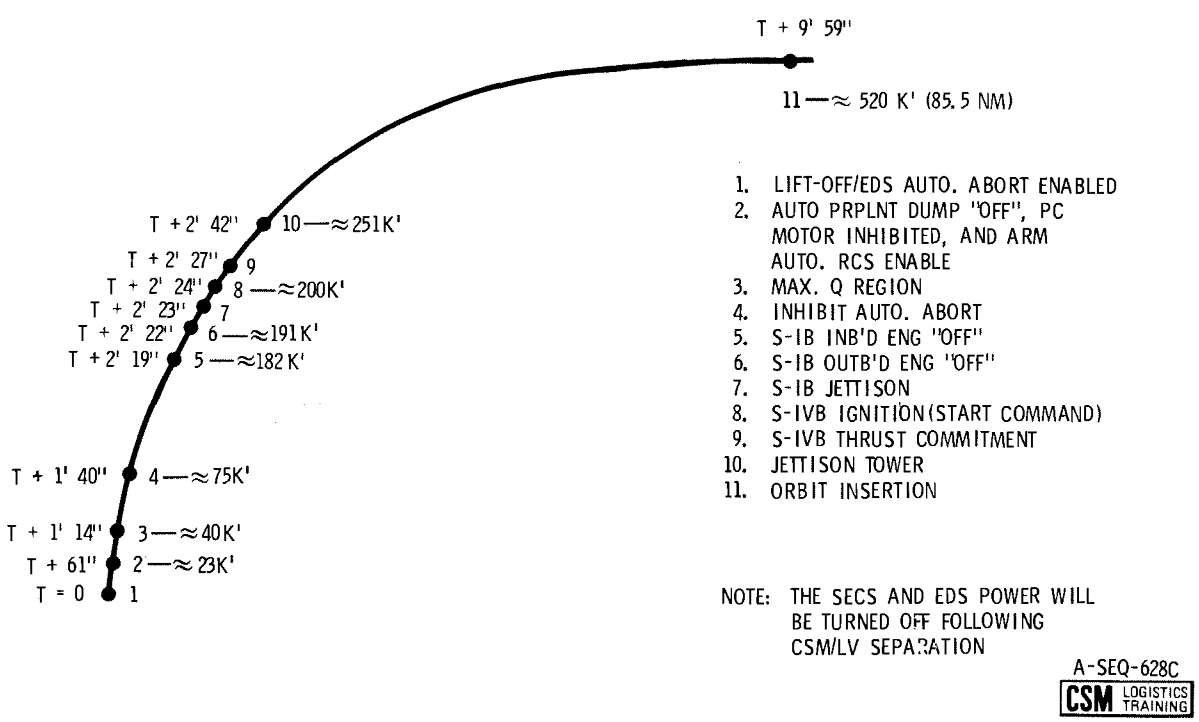


Figure 2.9-47. Typical Event Profile, Normal Ascent Saturn IB LV

DESTRUCT ARM COMMAND, zone 33-E. An abort may also be requested via UDL from the manned space flight network (MSFN). The ABORT lamps, systems A and/or B may be extinguished by UDL reset commands; however, the flight crew can extinguish the lamps in system B only with the UP TELEMETRY COMMAND switch (S39), zones 27 through 30-E and -F.

2.9.8.12 Launch Vehicle Tank Pressure Monitor

A time-shared display is used to indicate LV propellant tank pressures and SPS gimbal position, zones 30 through 33-E and -F. The LV/SPS IND selector switch (S53), zone 32-F, is used to select the parameters to be displayed. Meter movement selector switches and operational power circuits are included in section 2.3.

2.9.8.13 Angle of Attack Monitor (Zones 35 through 37-E and -F)

A Q-ball (figure 2.9-3) mounted above the LES motors, provides an electrical signal input to the LV AOA/SPS P_c indicator and an electrical signal input to ground control via telemetry.

2.9.8.14 EDS Automatic Abort Deactivate

The entire automatic abort capability or a portion of the circuits may be deactivated by the flight crew prior to staging. If the EDS switch (S67), zone 29-D, is switched to the OFF position, the entire EDS automatic abort capability will be deactivated. If the 2 ENG OUT switch (S64) and/or LV RATES switch (S65) are switched to the OFF position, the appropriate automatic abort parameter will be deactivated. Automated switching in the IU SWITCH SELECTOR, zone 35-E, will also deactivate the two automatic parameters as a part of the staging sequence.

2.9.8.15 Extinguish LIFT OFF and NO AUTO ABORT Lights

Just before IECO, the LIFT OFF ENABLE INHIBIT relay contacts in the IU are opened, zones 34-A and -C. This interrupts EDS bus power which is required to illuminate the lamps of the LIFT OFF and NO AUTO ABORT displays. If the EDS switch (S67) is used to deactivate the EDS automatic abort circuits, the NO AUTO ABORT lamps will have been illuminated and will be extinguished at this time. When the EDS bus power is interrupted by this IU relay logic, the mission and event timers, which were started at lift-off, will continue to operate because of internal holding circuits in these units.

2.9.8.16 Launch Escape Tower Jettison

After staging, the LET is jettisoned. Normally, both of the TWR JETT switches (S66 and S96), zone 26-F, will be used to initiate this function; however, either one of the switches will initiate systems A and B tower jettison circuits. Each of these switches, No. 1 and 2, are double pole switches and system A logic or EDS changeover power will enable one of the poles of each switch. Moreover, one pole of each switch will activate the circuits of system A and the other pole system B. Utilization of the event timer will enable the crew to jettison the LET at the correct time. If the

TJM should fail to ignite, an alternate method may be used to jettison the LET. The LES MOTOR FIRE switch (S31), zone 19-C, will ignite the LEM which is flight-qualified to jettison the LET. If this alternative should be necessary, it is vital that the detonators of the frangible nuts shall have been initiated before the LES MOTOR FIRE switch is depressed. The TWR JETT switches are the only controls that will initiate the detonators of the frangible nuts.

2.9.8.17 Separation of the Spacecraft From the Launch Vehicle

The next function that sequential systems will be utilized to perform is CSM/LV separation. Closing the CSM/LV SEP switch (S35), zone 10-B, will energize the CSM-LV SEPARATE relays, which will fire initiators of the explosive trains that sever the SLA panels. The same explosive train will separate the CSM/LV umbilical.

2.9.8.18 Enable Automated Control of the SM RCS

The CSM-LV SEPARATE relay will, in addition to initiating the explosive train, energize the RCS ENABLE ARM relays, zone 8-A, which, in turn, will energize the latching coils of the RCS ENABLE/DISABLE relays, zone 7-A. This relay logic will enable the controller reaction jet on/off assembly which couples the SCS jet selection logic and SM RCS, section 2.5, RCS.

2.9.8.19 Docking Probe Retraction

This system is designed for two retractions with backup for each. Since there are four retraction cylinders, however, four retractions are possible under ideal circumstances.

The DOCK PROBE RETRACT PRIM and/or SEC switches (S2 and S3), zones 13-E and -F, are armed when four conditions are satisfied as follows:

a. The appropriate buses are energized and the appropriate circuit breakers are closed, zones 15-E and -F.

b. The EXTEND/REL switch (S1), zones 14-E and -F, is in the RETRACT position.

c. The latch indicating switches in the docking ring latches are closed (system A and/or B as required).

d. The capture latches sensing switches are closed (probe head latched in MDA drogue).

When these conditions are satisfied, the DOCK PROBE RETRACT switches may be utilized to energize the DOCKING PROBE RETRACT No. 1 and 2 relays as required. Contacts of these relays will fire the initiators and retraction will be executed.

2.9.8.20 Docking Ring Separation

Logic power through the momentary contacts of either of the DOCK RING SEP switches (S109 or S112), zone 26-D, will energize the DOCKING RING FINAL SEPARATION relays in the DEC. These are the firing relays for the ordnance which severs the docking ring from the CM tunnel.

2.9.8.21 Nominal Pre-entry, Entry, and Descent

Arming the SECS is the first requirement of the sequential systems preparatory to a nominal entry and descent. If mission rules require a checkout of the CM RCS prior to CM/SM separation, it is vital that electrical control of the RCS be placed in the SM RCS configuration prior to initiating the separation. Figure 2.9-48 illustrates a typical pre-entry, entry, and descent profile.

2.9.8.22 CM/SM Separation Control

When either of the CM/SM SEP switches (S110 or S111), zones 24-C and -D are closed, battery bus power will start the automated sequence of CM/SM separation. Each of these switches, No. 1 and 2, is a double-pole switch with one pole controlling system A components and the other pole controlling system B components. When either or both of these switches are utilized for CM/SM separation, they should be held closed for approximately 0.1 of a second to allow the time-delay relay logic to function properly.

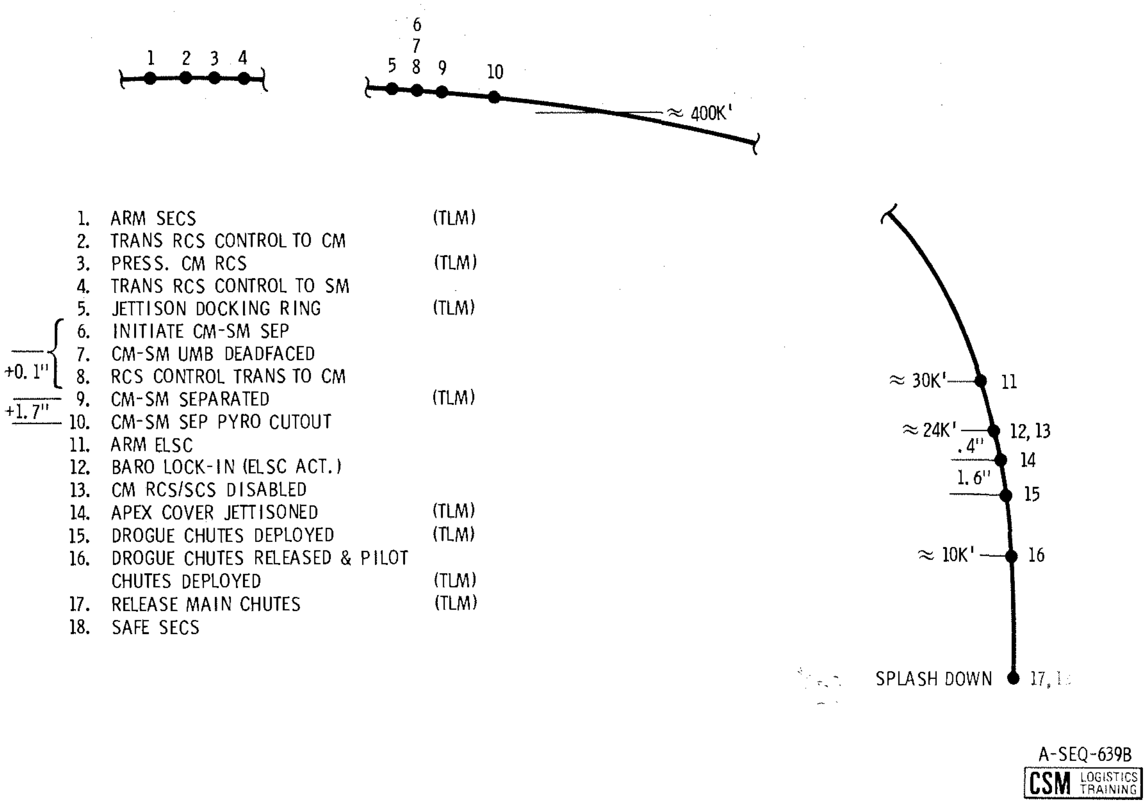


Figure 2.9-48. Typical Event Profile, Normal Pre-entry, Entry and Descent

SEQ

2.9.8.23 Jettisoning the SM (Zones 19 through 22-E and -F)

A manually initiated CM/SM separation signal will start the SMJC with battery bus power through contacts of the RCSC motor switch (S1), zone 23-E. The motor switch must be in the SM control position for the start signal to activate the SMJC. Latching relays are utilized to couple SM electrical power to the SMJC and to energize the coils of the SM RCS -X engines. SM power to the SMJC is through contacts of motor switches, zones 23-E and -F, which are described in section 2.6, Electrical Power. The control circuits in the SMJC constitute a crossover network; either system A or B will energize the coils of both of the SM RCS redundant engine systems. The +roll engines will be started 2.0 seconds after the SMJC is started and will operate for 2.0 seconds. The -X translation engines will burn for 25.0 seconds.

2.9.8.24 Deadfacing the CM-SM Umbilical

Closure of either of the CM/SM SEP switches will energize the CM/SM DEADFACE relays to the MESC, zone 23-C. These relays are utilized to initiate the ordnance devices of the CM-SM electrical circuit interrupter and the SM circuit interrupter. These relays may be considered as pilot relays to the automation of other CM-SM separation functions which includes interface with the CM-RCS.

2.9.8.25 Separation of the CM From the SM

When the CM-SM SEPARATE relays in the MESC are energized after a time delay of 0.1 second, ordnance devices required for CM-SM separation are initiated. These are the guillotine blades of the CM-SM umbilical assembly and three tension ties between the CM and SM structures. The time delay is required in this circuit because the guillotine blades will cut wires which were deadfaced.

2.9.8.26 Pyro Cutout

The pyro cutout circuits are incorporated to eliminate the possibility of draining pyro power through wiring which may have one or two strands shorted by umbilical blades, or any other high resistance short. Fusistors afford protection against "dead shorts". The pyro cutout relays, zone 20-B, are energized 1.7 seconds after the CM-SM separate relays. Contacts of the pyro cutout relays are in the logic circuits to the CM-SM deadface relays, zone 23-D. Contacts of the pyro cutout relays are also in the pyro circuits to the initiators that are expended in the separation sequence, zones 20 through 23-C and -D. This relay logic is an arc suppression system since electrical energy is removed from initiator firing relay contacts at the time they return to their normal state. When the CM/SM SEP switch is released it will return to its normally open state and all relays in this logic, including the pyro cutout relays, will be de-energized.

2.9.8.27 CM RCS Interface

Any time a CM-SM separation signal is initiated in the MESC, a signal is automated for the initiation of two CM RCS functions. These are:

a. Fluid systems pressurization, zones 21 through 23-A and -B. The system 1 CM-RCS press relay logic provides firing circuits to one of the helium squib isolation valves in each of the redundant fluid systems of the CM RCS (section 2.5, RCS).

b. Transfer electrical control from the SM RCS to the CM RCS, zones 18 through 20-A and -B. RCS CM-SM transfer relay logic in the RCSC will drive the transfer motor switch to the SM position. Moreover, contacts of the motor switch are utilized to deadface the SMJC start signal, zone 23-E. There is a time delay of approximately 50 milliseconds in this deadfacing function which is explained as the time it takes the motor switch contacts to change state.

2.9.8.28 Main Bus Tie

Relay logic of the RCSC, zones 11 through 13-C and -D, will couple entry and postlanding batteries A, B and C to the main buses providing certain circuit breakers and switches of the electrical power system (section 2.6) are in the correct position for this automation.

2.9.8.29 Arm ELSC

Closure of the ELS LOGIC switch (S44), zone 10-D, will complete logic power circuits to redundant transistorized switches in the MESC. These solid state switches function as a pair of AND gates, each of which requires two inputs to emit. One of the inputs is satisfied when the logic power circuits are completed.

2.9.8.30 Activate ELSC

Logic power circuits to the ELSC, including ground returns for the components in this controller, are not completed until the ELSC activate relays in the MESC are energized, zone 8-C. The solid state switches control the logic power required to energize these relays. Assuming that the ELS switch (S63), zone 8-E, is in the AUTO position, closure of the 24,000 ft baro switches will satisfy the second input to the solid state switches. Logic power in this instance is derived from a point between the ELS LOGIC switch and the solid state switches. It is wired, through a resistor, to a point between the redundant baro switches. Both baro switches will be closed at the same time, and the reduced logic power, because of the resistor, will be sufficient to trigger the solid state switches; however, the reduced logic power is not sufficient to energize relay coils of the ELSC. When the ELSC activate relays are energized, another crossover network is established; system B relay logic will establish holding circuits to the system A relays; moreover, system B relay logic can energize system A relays.

2.9.8.31 <u>24,000 ft Baro Switch Lock Up</u>

In addition to activating the ELSC, closure of the 24,000 ft baro switches will energize the 24,000 ft lock up relay in the ELSC, zone 7-D. This relay logic, together with the system B counterpart, will establish logic power holding circuits which bypass the 24,000 ft baro switches.

2.9.8.32 <u>Disable CM RCS/SCS</u>

A signal is relayed to the unlatching (disable) coils of the RCS/SCS enable relay, zone 7-A, when the ELSC is activated. This relay logic disables the controller reaction jet on/off assembly (section 2.5, RCS).

2.9.8.33 <u>Apex Cover Jettison</u>

When the ELSC has been activated, the first function that will be automated is apex cover jettison (figure 2.9-49). The apex cover jettison relays in the MESC are energized after a time delay of 0.4 second, zones 5 and 6-E. The holding circuits of these firing relays are one of the numerous crossover networks. In addition to initiating the ordnance devices, this relay logic will also arm lanyard-actuated switches, zone 5-F, which are used to deploy the apex cover drag parachute. The lanyard pulls holding

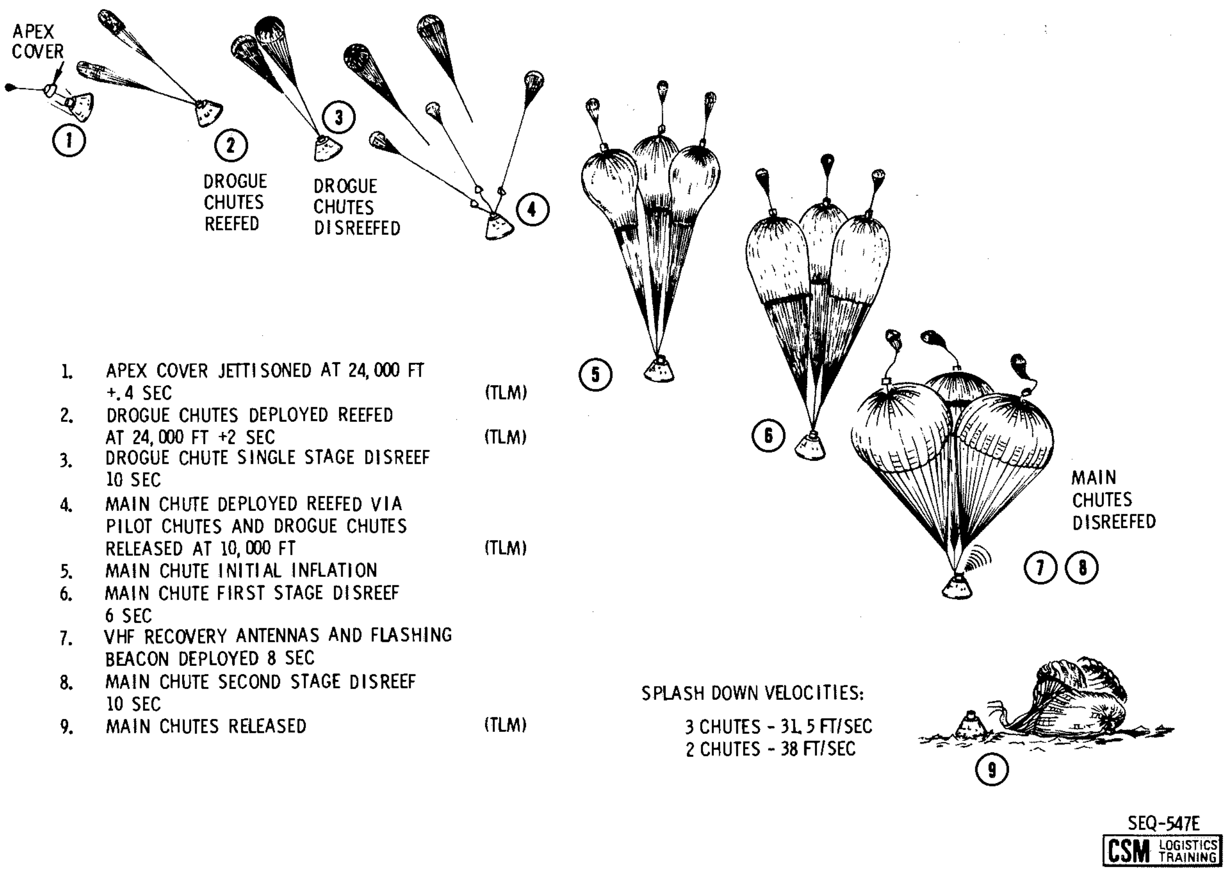


Figure 2.9-49. Earth Landing System, Normal Sequence

pins from the switches which, because of spring loading, will close circuits. Closure of these switches will energize the drag parachute deploy relays in the MESC which initiate the drag parachute mortar.

2.9.8.34 Deployment of Drogue Parachutes

The drogue igniter relays in the ELSC and PCVB, zones 4 and 5-D, are energized by ELSC activate relay logic after a time delay of 2 seconds. Another crossover is established in this relay logic wherein the systems A and B PCVB relays cross-couple each other with holding circuits. Moreover, each system initiates ordnance devices of both systems.

2.9.8.35 Deployment of Main Parachutes and Release of Drogues

Closure of the 10,000 ft baro switches, zone 6-C, will energize the pilot chutes and drogue release relays in the ELSC and the PCVB. The PCVB relays in this logic are also cross-coupled, systems A and B, into crossover holding circuits. The ordnance initiator circuits are also arranged into a crossover network.

2.9.8.36 Burning of the CM RCS Propellants

Switches in the CM RCS, zones 40-C and -D, are used to energize the direct coils of ten CM RCS jets, zones 15 and 16-A. The correct utilization of these switches is described in section 2.5, RCS.

2.9.8.37 Release of Main Parachutes

Closure of the MAIN RELEASE switch (S71), zones 4 and 5-C, will energize the main chute release relays in the PCVB. These relays are used to initiate ordnance which will drive cutter chisels through the main parachute risers. It should be noted that circuit breakers are incorporated in the pyro circuits for main parachute release, paragraph 2.9.8.2.2.

2.9.8.38 Aborts

Abort signals may be initiated manually by rotating the commander's translation hand control counterclockwise into a detent. Two cam-operated micro switches, zone 31-B, are included in the control. Battery bus power through these switches will energize the booster cutoff and LES or SPS abort start relays in the MESC, zone 29-A. These relays may also be energized by an EDS automatic abort signal through 30-millisecond time delays. The reason for the time delays is to insure against spurious signals initiating an abort. EDS bus changeover power is utilized to energize the booster cutoff and LES or SPS abort start relays in the event of an EDS automatic abort. Any abort signal will automate two functions which are common to all abort sequences as follows:

a. BECO, zones 27 and 28-A and -B, is inhibited by IU relay logic until T +40 seconds in the S-IB LV configuration because of range safety requirements.

b. Reset and start the commander's event timer, zone 27-D. It is necessary for the EVENT TIMER START switch (S56), zone 32-C, to be in the center ON position for this function to be automated.

2.9.8.39 Abort Start (Zones 27 and 28-C and -D)

Two pairs of LET physical separation monitor relay contacts are in the abort start relay logic. One pair is normally closed and the other is normally open. The state of these contacts at the time an abort is initiated will determine whether an LES or SPS abort is automated in sequential systems. When the booster cutoff and LES or SPS abort start relays are energized, the LES abort relays may or may not be energized. If they are energized an LES abort will be started, if not, an SPS abort will be started.

2.9.8.40 LES Abort Start

Initially the sequential events of all LES aborts are identical. In addition to the functions that are common to all aborts, separation of the CM from the SM is automated. The automated CM/SM separation sequence is the same as the manually initiated separation sequence described under nominal pre-entry, entry, and descent with two exceptions which are:

- The SMJC is not started when the separation sequence is started by a LES abort signal, zone 24-D.
- In an LES abort the CM/SM separation sequence includes the firing of the LEM, zones 18 through 21-C.

2.9.8.41 Mode 1A Abort

A mode 1A abort (figure 2.9-50) is initiated prior to the expiration of the propellant dump disable timer (TD1) in the RCSC, zone 18-B. This time-delay relay logic is started at lift-off provided two conditions are satisfied. These are:

- The RCSC motor switch (S1), zone 19-A, must be in the SM RCS control position (as illustrated).
- The CM RCS LOGIC switch (S46), zone 40-D, must be in the CM RCS LOGIC position.

A pair of latching contacts, which are closed when the timer is reset by GSE, are in series with the DUMP AUTO contacts of the PRPLNT switch (S63), zone 20-B. When this switch is in the DUMP AUTO position, and before the timer contacts are opened, the requirements peculiar to a mode 1A abort may be automated. These are:

- The PCM is fired by the same relay logic that ignites the LEM, zone 19-D. Logic power for energizing the PCM firing relays is derived through the closed contacts of the propellant dump disable timer, zone 19-B.
- The oxidizer dump relays, zone 17-B, are energized immediately with an abort initiate signal resulting in four CM RCS functions: (1) closure of the propellant shutoff valves, zone 14-A; (2) energization of the interconnect and propellant burn relays, zones 16 and 17-A; (3) initiation of the oxid dump squib valves, zone 13-B; (4) initiation of the helium and oxid interconnect squib valves, zones 13 and 14-A. The fuel interconnect squib valve is initiated by the B system relay logic of the SECS.

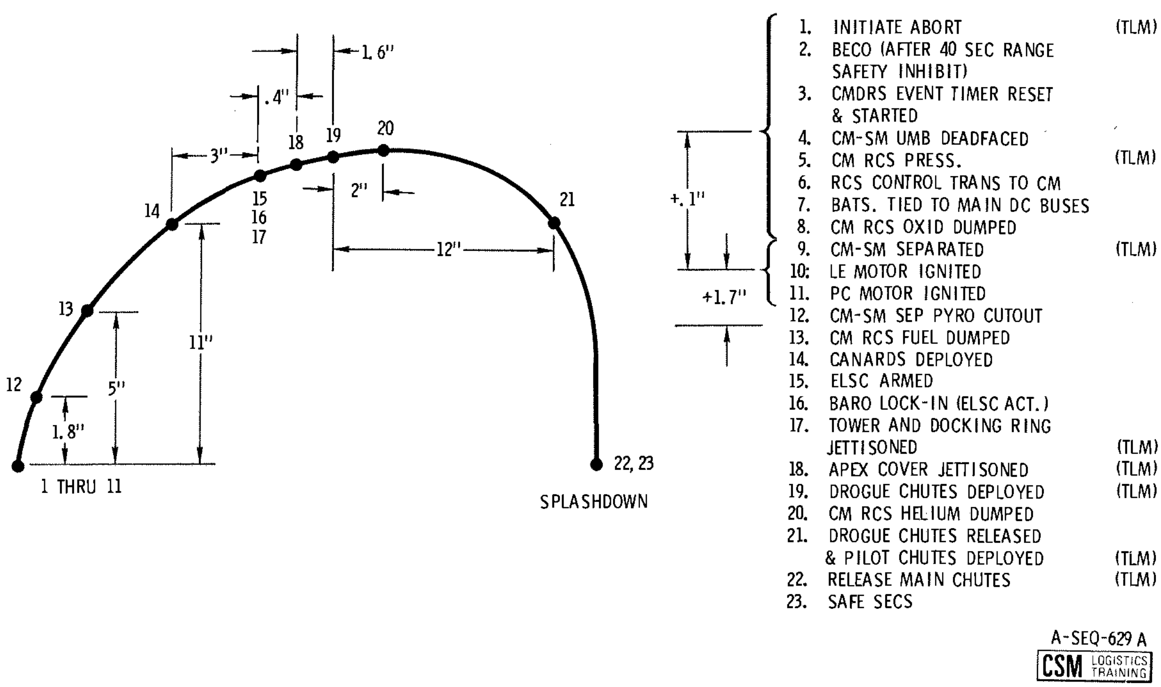


Figure 2.9-50. Typical Event Profile, Mode 1A Abort

- Five seconds after the abort initiate signal, the fuel dump squib valve, zone 14-B, is initiated by time-delay relay logic in the RCSC, zone 16-B.
- Thirteen seconds later, or 18 seconds after the abort initiate signal, the fuel and oxid bypass relays are energized, zone 15-B. This time-delay relay initiates the squib valves which will purge the CM RCS fluid systems in addition to depleting the pressurant, zone 13-A.

2.9.8.42 Canard Deploy and ELSC Arm

Eleven seconds after the initiation of any LES abort, canard deployment is automated, zones 25 and 26-C and -D. This relay logic will also arm the ELSC, zone 10-D. Contacts of the canard deploy relay are incorporated parallel to the ELS LOGIC switch (S44) which must be in the OFF position during the launch and ascent phases of a mission.

2.9.8.43 ELSC Operation

Functions of the ELSC may be initiated by baro switches, time-delay relay logic, or direct manual control. Baro switches are opened and closed by aneroid cells and are calibrated to close at approximately 24,000 and 10,000 feet during a nominal entry. During a nominal launch and ascent the 10,000-foot baro switches will open at approximately 18,000 feet and the 24,000-foot baro switches will open at approximately 40,000 feet. This is the result of several variables which include spacecraft velocity, attitude, and atmospheric conditions. During a mode 1A abort, for example, closure of canard deploy relay contacts, zone 10-D, will not only arm the ELSC but will also activate it because the 24,000-foot baro switches will be closed in this instance. When the ELSC activate relays, zone 8-C, are energized, a signal will be relayed from a point starting at zone 7-D to the LET jettison and frangible nuts relays, zone 25-F. This results in automatic LET jettison and, if the spacecraft

SEQ

is equipped with a docking probe, docking ring separation, zones 24 through 26-D and -E. Also, when the ELSC activate relays are energized, a signal will be relayed from a point starting at zone 7-E to the unlatching coils of the RCS enable/disable relays, zone 7-A. This disables automatic control of the CM RCS. Time-delay relay logic is incorporated in the integrated MESC and ELSC, zones 6-C through -E, to automate the required functions at the lower altitudes before the baro switches are opened. The apex cover jettison relays, zone 5-E, will be energized 0.4 second after the ELSC is activated. Drogue igniter relays, zones 4 and 5-D, will be energized 2.0 seconds after the ELSC is activated, or 1.6 seconds after the apex cover is jettisoned. Pilot chutes and drogue release relays, zone 5-B, will be energized 14.0 seconds after the ELSC is activated, or 12.0 seconds after the drogue parachutes are deployed. If the ELS switch (S63), zone 8-E, is placed in the MAN position, the automated functions of the integrated MESC and ELSC will be disabled. This switching inhibits the solid state switches which prevents activation of the ELSC. In the event of a worst case abort, automatic deployment of parachutes could result in landing in an unsafe area and direct manual control of ELS functions would be required. The direct manual switches, zones 6-B through -E, may be used to jettison the apex cover, deploy drogue parachutes, release drogue parachutes, and deploy the pilot parachutes of the main parachutes.

2.9.8.44 LES Abort Mode Switchover

A configuration change is made in a portion of the SECS when the PRPLNT switch (S63), zone 20-B, is placed in the RCS CMD position. Normally this switching is concurrent with the expiration of the propellant dump disable timer. Requirements peculiar to a mode 1A abort are inhibited at this time and the requirements of any other mode abort, or a normal mission, will be automated as a part of the CM/SM separation sequence. When the latching coils of the RCS enable/disable relays are energized, zone 7-A, the controller jet on/off assembly is enabled. This makes automatic control of the CM RCS possible (section 2.5, RCS).

2.9.8.45 Mode 1B Aborts

Mode 1B aborts may be categorized according to the altitude at which the abort is initiated. Figure 2.9-51 illustrates the profile of an abort initiated after abort mode switchover and before reaching an altitude of approximately 30,000 feet. Figure 2.9-52 illustrates the profile of an abort initiated between the approximate altitudes of 30,000 and 100,000 feet. Part of the ELSC functions (items 14 through 19, figure 2.9-51) are automated by time-delay relay logic during mode 1B aborts initiated at the lower altitudes. All of the ELSC functions are automated by normal baro switch operation (items 14 through 19, figure 2.9-52) during mode 1B aborts initiated at the higher altitudes. Manually initiated requirements during descent and postlanding functions of mode 1B aborts are the same as during a nominal descent.

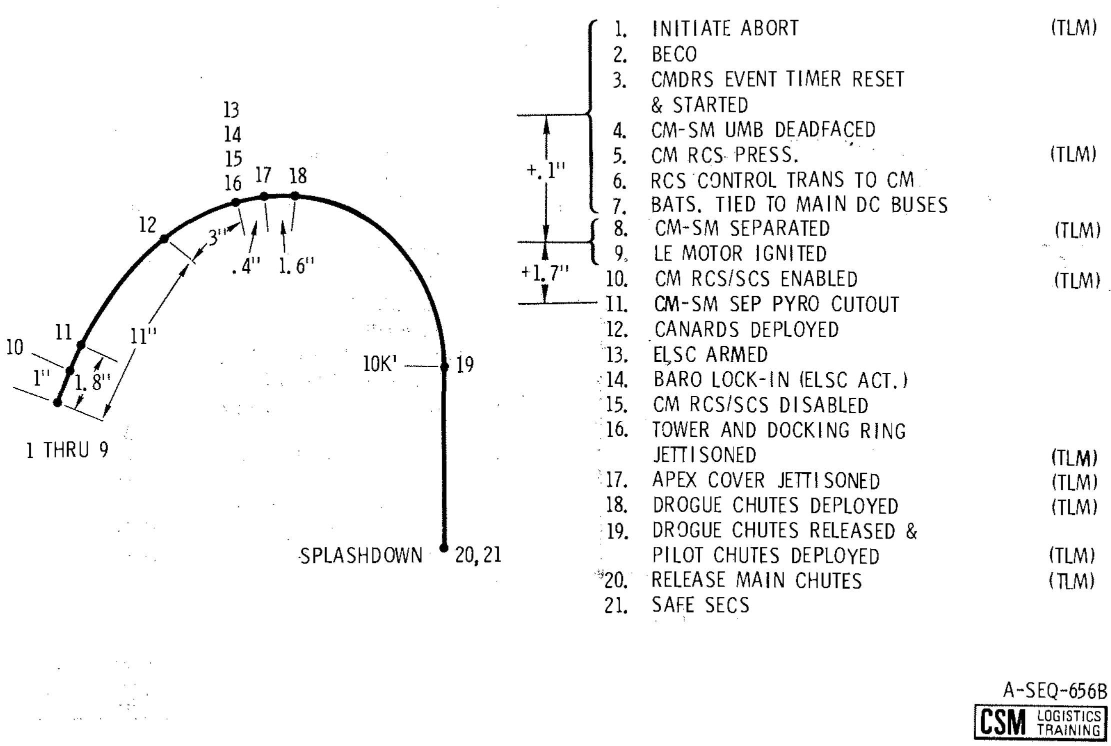


Figure 2.9-51. Typical Event Profile, Mode 1B Abort
T +61 Sec to ≈30,000 Feet

2.9.8.46 Mode 1C Abort

Mode 1C aborts (figure 2.9-53) are initiated at a time when the velocity of the LV is higher than the trim point of the canards. This is between an approximate altitude of 100,000 feet and normal LET jettison. The crew has the prerogative of jettisoning the LET shortly after the abort is initiated and utilizing the CM RCS for orientation similar to nominal entry maneuvers; or allowing the canards to orient the LEV when the free fall velocity is reduced to the trim point. If the latter option is elected there is a slight probability of an apex forward capture and violent rotational rates when the canards become effective aerodynamically. This slight probability can be avoided by imparting energy to the falling LEV. The CM RCS may be utilized to maintain a +pitch rate and this should be in excess of 5°/sec. There is no upper limit of rates since the CM RCS is limited under these flight conditions. Automation of ELSC functions during parachute descent and postlanding functions are the same as a normal descent.

2.9.8.47 SPS Abort

Sequential systems functions during an SPS abort are designed to separate the CSM from the LV with automation conducive to utilization of the SPS if required. Firing the SPS is not a function of the sequential

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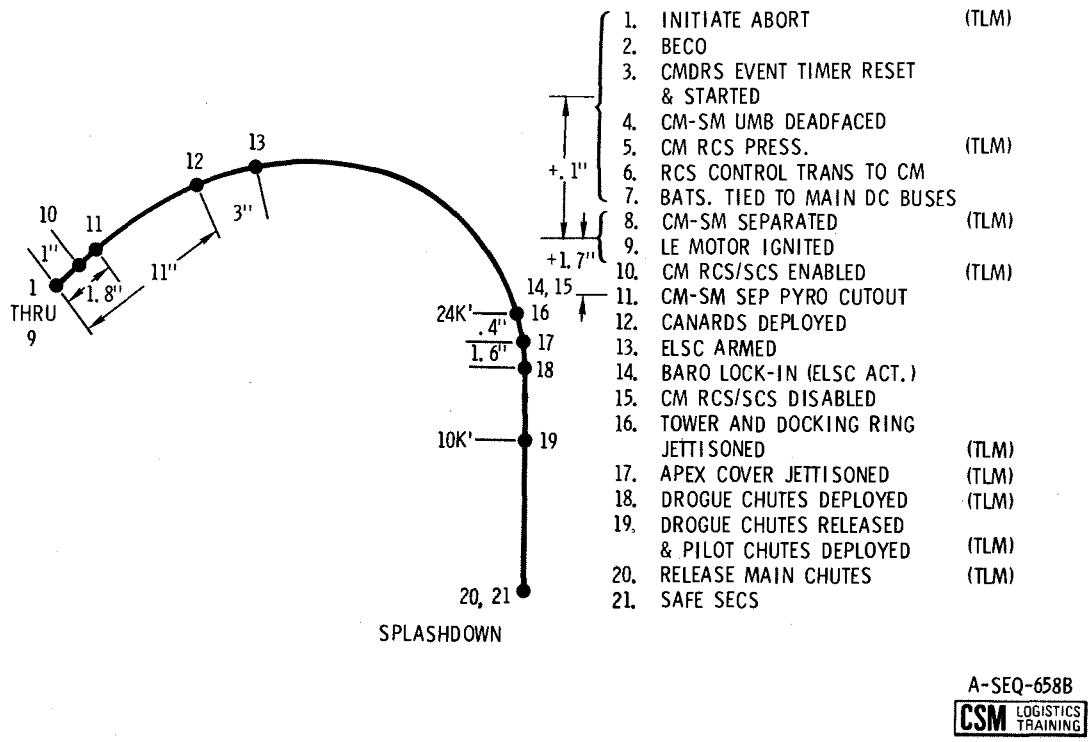
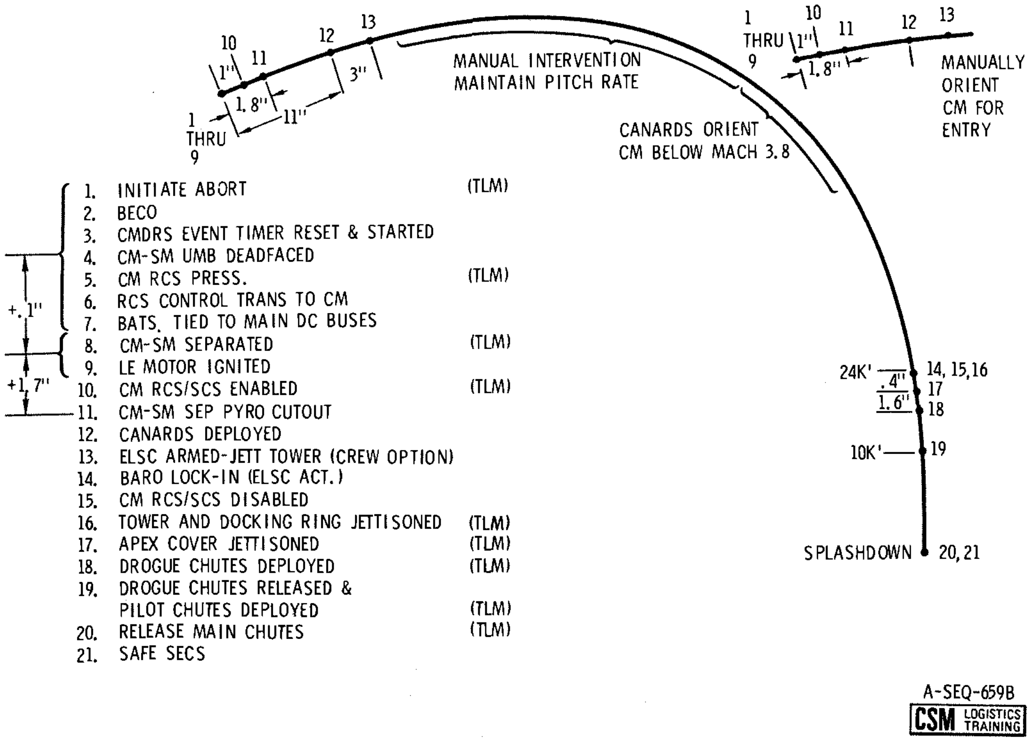


Figure 2.9-52. Typical Event Profile, Mode 1B Abort 30,000 Feet to 100,000 Feet

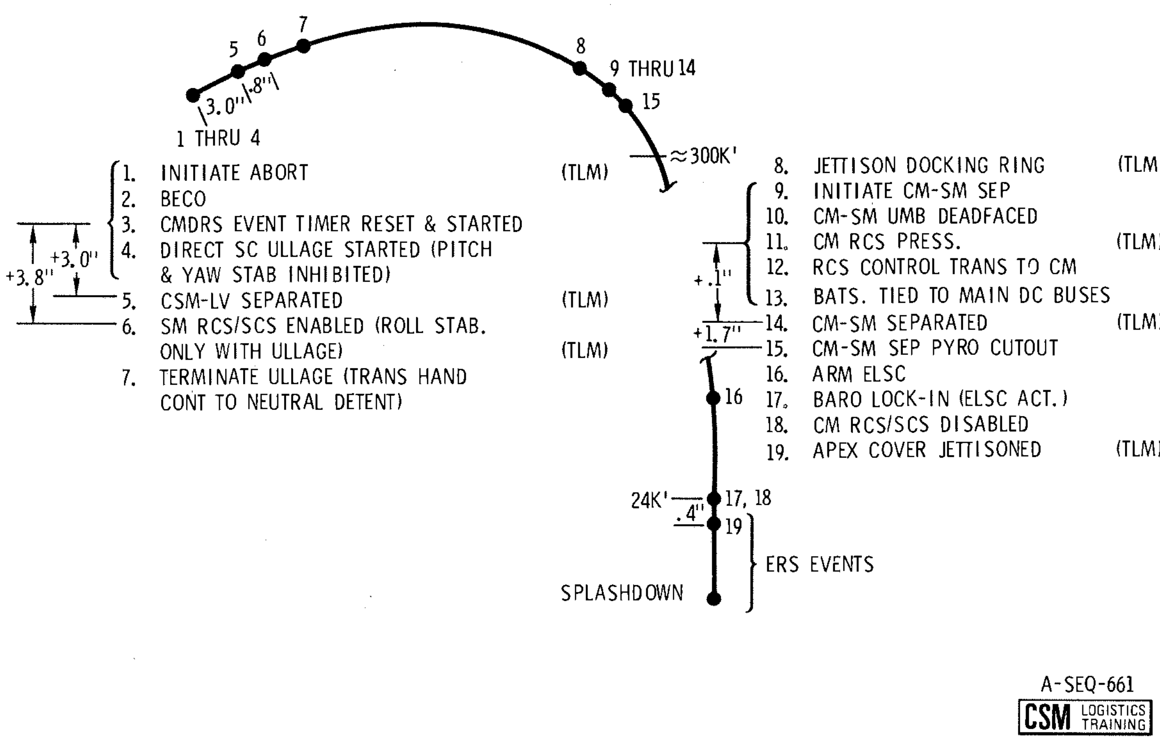
systems. The way this propulsion system is utilized, if it is utilized, is contingent on maneuvering requirements for a safe recovery. Sequential systems automation is the same in all SPS aborts, figure 2.9-54. This type abort may be initiated any time after the LET is jettisoned until the CSM is separated from the LV. All SPS aborts must be initiated manually because the EDS automatic abort capability is lost when the LET is jettisoned. Moreover, jettisoning of the LET results in configuration change in the abort start circuits. Ullage relays in the MESC, zone 11-B, are energized when the abort is initiated and the +X translation engines of the SM RCS are fired. The same signal that fires the engines also inhibits pitch and yaw rate stabilization in the SCS. CSM-LV separate relays, zone 9-B, are energized after a time delay of 3.0 seconds and the CSM will be separated from the LV RCS enable arm relays, zone 8-A, are energized after a time delay of 0.8 second and automated control of the SM RCS will be enabled. It will be necessary to separate the docking ring at some time conducive to the situation. CM/SM separation and descent operations are the same as during a normal entry.

SYSTEMS DATA



1. INITIATE ABORT (TLM)
2. BECO
3. CMDRS EVENT TIMER RESET & STARTED
4. CM-SM UMB DEADFACED
5. CM RCS PRESS. (TLM)
6. RCS CONTROL TRANS TO CM
7. BATS. TIED TO MAIN DC BUSES
8. CM-SM SEPARATED (TLM)
9. LE MOTOR IGNITED
10. CM RCS/SCS ENABLED (TLM)
11. CM-SM SEP PYRO CUTOUT
12. CANARDS DEPLOYED
13. ELSC ARMED-JETT TOWER (CREW OPTION)
14. BARO LOCK-IN (ELSC ACT.)
15. CM RCS/SCS DISABLED
16. TOWER AND DOCKING RING JETTISONED (TLM)
17. APEX COVER JETTISONED (TLM)
18. DROGUE CHUTES DEPLOYED (TLM)
19. DROGUE CHUTES RELEASED & PILOT CHUTES DEPLOYED (TLM)
20. RELEASE MAIN CHUTES (TLM)
21. SAFE SECS

Figure 2.9-53. Typical Event Profile, Mode 1C Abort



1. INITIATE ABORT (TLM)
2. BECO
3. CMDRS EVENT TIMER RESET & STARTED
4. DIRECT SC ULLAGE STARTED (PITCH & YAW STAB INHIBITED)
5. CSM-LV SEPARATED (TLM)
6. SM RCS/SCS ENABLED (ROLL STAB. ONLY WITH ULLAGE) (TLM)
7. TERMINATE ULLAGE (TRANS HAND CONT TO NEUTRAL DETENT)
8. JETTISON DOCKING RING (TLM)
9. INITIATE CM-SM SEP
10. CM-SM UMB DEADFACED
11. CM RCS PRESS. (TLM)
12. RCS CONTROL TRANS TO CM
13. BATS. TIED TO MAIN DC BUSES
14. CM-SM SEPARATED (TLM)
15. CM-SM SEP PYRO CUTOUT
16. ARM ELSC
17. BARO LOCK-IN (ELSC ACT.)
18. CM RCS/SCS DISABLED
19. APEX COVER JETTISONED (TLM)

Figure 2.9-54. Typical Event Profile, SPS Abort

SEQ

2.9.9 SEQUENTIAL SYSTEMS DATA AND TELEMETRY MEASUREMENTS

Part numbers are included in the tabulated data to facilitate the acquisition of additional data should it be required.

2.9.9.1 SECS Data

Master Events Sequence Controller (MECS) — 2 each

Part No.:	ME901-0567
Mfrd by:	Autonetics, Anaheim, Calif.
Dimensions:	14 x 14 x 18 inches
Weight:	38 pounds
No. of electrical receptacles:	8 each
Relays:	Babcock, 4 pole 42 nonlatching and 2 latching 10 amps continuous current rating
Z1K1, Z1K2, and Z2K1	EDS Auto. Abort Voting
Z2K2	EDS Bus Changeover
Z3K1 and 2	Escape Tower Physical Separation
Z4K1 and 2	EDS Auto. Abort Enable
Z5K1 and 2	Booster Cutoff and Abort Initiate
Z6K1 and 2	LES Abort Lockup
Z7K1 and 2	CM RCS Pressurize
Z8K1 and 2	CM-SM Umbilical Deadface
Z9K1 and 2	CM-SM Separation
Z10K1 and 2	Launch Escape Motor Fire
Z11K1 and 2	Canard Deploy
Z12K1 and 2	ELS Activate
Z13K1 and 2	Tower Jettison
Z14K1 and 2	Apex Cover Jettison
Z16K1 and 2	Direct Ullage
Z17K1 and 2	SLA Separation
Z18K1 and 2	RCS Enable Arm
Z19K1 and 2 (latching)	RCS Enable/Disable (latching)
Z20K1 and 2	SECS Logic Bus Arming
Z23K1 and 2	CM-SM Sep Pyro Cutoff
Z24K1 and 2	Pitch Control Motor Fire
Z25K1 and 2	Apex Cover Drag Parachute
Time Delays:	Parko, resistance-capacitance-transistor type, 18 each
TD1 and 2	0.03 sec Booster Cutoff
TD3 and 4	0.1 sec CM-SM Separation
TD5 and 6	11.0 sec Canard Deploy
TD7 and 8	3.0 sec ELS Activate
TD11 and 12	3.0 sec SLA Separate
TD13 and 14	0.8 sec RCS Enable Arm
TD15 and 16	1.0 sec RCS Enable/Disable
TD17 and 18	0.4 sec Apex Cover Jettison
TD23 and 24	1.7 sec CM-SM Sep Pyro Cutoff

Docking Events Controller (DEC)		2 each
Part No.:	ME476-0035	
Mfrd by:	Autonetics, Anaheim, Calif.	
Dimensions:	11.5 x 6 x 8.5 inches	
Weight:	12 pounds	
No. of electrical receptacles:	5 each	
Motorswitch:	Kinetics, 9 pole 1 each powered during transfer only 15 amps continuous current rating	
K1	SECS Pyro Bus Arming	
Relays:	Babcock, 4 pole 7 nonlatching and 1 latching 10 amps continuous current rating	
Z1K1 (latching) and Z1K2	SLA Separation Initiate	
Z2K1 and 2	Docking Probe Retract No. 2	
Z3K1 and 2	Docking Probe Retract No. 1	
Z4K1 and 2	Docking Ring Final Separation	
Time Delays:	Parko, resistance-capacitance-transistor type, 2 each	
TD1 and 2	0.03 sec LM-SLA Sep Initiate	
Earth Landing Sequence Controller (ELSC)		2 each
Part No.:	ME901-0001	
Mfrd by:	Northrop-Ventura, Newbury Park, Calif.	
Dimensions:	7 x 4.5 x 3 inches	
Weight:	5 pounds	
No. of electrical receptacles:	4 each	
Relays:	Filters, 4 pole 4 nonlatching 5 amps continuous current rating	
K1	Baroswitch Lock-in	
K2	Drogue Parachute Deploy	
K3	Drogue Parachute Release and Pilot Parachute Deploy	
K4	Not used	
Time Delays:	General Time, resistance-capacitance-transistor type, 4 each	
TD1 and 2	2.0 sec Drogue Parachute Deploy	
TD3 and 4	14.0 sec Pilot Parachute Deploy	

SEQ

Pyro Continuity Verification Box (PCVB) 1 each

Part No.:	V16-540130
Mfrd by:	Space Division, North American Rockwell Corporation, McAlester, Oklahoma
Dimensions:	10.5 x 7 x 3 inches
Weight:	10 pounds
No. of electrical receptacles:	8 each
Relays:	Babcock, 4 pole 10 nonlatching (2 modules, 5 each) 10 amps continuous current rating
Z2K1	Sys A Drogue Parachute Deploy
Z2K2	Sys A Drogue Parachute Release and Pilot Parachute Deploy Lockup
Z2K3	Sys A Main Parachute Release
Z2K4	Sys A Drogue Parachute Release and Pilot Parachute Deploy
Z2K5	Sys A Main Parachute Release
Z1K1	Sys B Drogue Parachute Deploy
Z1K2	Sys B Drogue Parachute Release and Pilot Parachute Deploy Lockup
Z1K3	Sys B Main Parachute Release
Z1K4	Sys B Drogue Parachute Release and Pilot Parachute Deploy
Z1K5	Sys B Main Parachute Release

Reaction Control System Controller (RCSC) 1 each

Part No.:	V36-447520
Mfrd by:	Space Division, North American Rockwell Corporation, McAlester, Oklahoma
Dimensions:	15 x 13 x 9 inches
Weight:	35 pounds
No. of electrical receptacles:	18 each
Motorswitches:	Kinetics, 22 pole 2 each powered during transfer only 5 amps continuous current rating
S1 and 2	Sys 1 and 2 CM-SM RCS Transfer
Relays:	Babcock, 4 pole 18 nonlatching 10 amps continuous current rating
K1 and 7	Sys 1 Oxidizer Dump Valves
K2 and 8	Sys 2 Oxidizer Dump Valves
K3 and 9	Sys 1 Helium and Oxidizer Interconnect Valves
K4 and 10	Sys 2 Helium and Oxidizer Interconnect Valves

K5 and 11	Sys 1 Fuel and Oxidizer Bypass Valves
K6 and 12	Sys 2 Fuel and Oxidizer Bypass Valves
K13 and 14	Sys 1 and 2 CM-SM RCS Transfer
K15 and 17	Sys 1 CM RCS Heaters
K16 and 18	Sys 2 CM RCS Heaters

Time Delays: Eagle-Signal, resistance-capacitance-transistor type, 14 each

TD1 and 8	42.0 sec Sys 1 and 2 Propellant Dump Inhibit
TD3 and 9	5.0 sec Sys 1 Fuel Dump
TD2 and 10	5.0 sec Sys 2 Fuel Dump
TD5 and 11	13.0 sec Sys 1 Helium Dump
TD4 and 12	13.0 sec Sys 2 Helium Dump
TD7 and 13	13.0 sec Sys 1 Main DC Bus OFF
TD6 and 14	13.0 sec sys 2 Main DC Bus OFF

Service Module Jettison Controller (SMJC) 2 each

Part No.:	ME901-0569
Mfrd by:	Autonetics, Anaheim, Calif.
Dimensions:	13.5 x 5.25 x 5.75 inches
Weight:	8 pounds
No. of electrical receptacles:	4 each
Relays:	Babcock, 4 pole 4 nonlatching and 2 latching 10 amps continuous current rating
Z1K1 and 2 (latching)	SMJC Activate/-X Translation
Z2K1 and 2	Positive Roll Initiate
Z3K1 and 2	Positive Roll Deactivate
Time Delays:	Parko, resistance-capacitance-transistor type, 4 each
Z2 TD1 and 2	2.0 sec Roll Initiate
Z3 TD1 and 2	5.5 sec Roll Deactivate
Z4 TD1 and 2	25.0 sec -X Translation Deactivate

2.9.9.2 LES Data

Launch Escape Motor

Mfrd by:	Lockheed Propulsion, Redlands, Calif.
Dimensions:	26-inch diameter, 15.5 feet long, incl nozzles and igniter
Propellant:	8 point star grained solid using a polysulphide ammonium perchlorate formulation

SEQ

Resultant Thrust:	147,000 pounds force (lbf.) nominal at 70°F and sea-level barometric pressure
Burn Time:	Total of 8 sec of which the greatest portion of the total impulse is delivered in the first 3.5 to 4.0 sec
Nozzle Cant Angle:	4 nozzles each canted 35 degrees off the motor centerline
Nozzle Insert I.D.:	-Y and +Y = 5.2 inches, -Z = 4.8 inches, and +Z = 5.6 inches
Resultant Thrust Vector:	2.75 degrees offset of motor centerline

Pitch Control Motor

Mfrd by:	Lockheed Propulsion, Redlands, Calif.
Dimensions:	9-inch diameter, 22 inches long incl nozzle and igniter
Propellant:	14 point star grained solid using a polysulphide ammonium perchlorate formulation
Resultant Thrust:	2,850 pounds force (lbf.) nominal at 70°F and sea-level barometric pressure
Burn Time:	0.6 ± 0.1 sec
Resultant Thrust Vector:	Coincidental with motor centerline

Tower Jettison Motor

Mfrd by:	Thiokol Chemical, Elkton, Md.
Dimensions:	26-inch diameter, 55.5 inches long
Propellant:	10 point star grained solid using a polysulphide ammonium perchlorate formulation
Resultant Thrust:	32,000 pounds force (lbf.) nominal at 70°F and sea-level barometric pressure
Burn Time:	1.1 ± 0.06 sec
Nozzle Cant Angle:	2 nozzles each canted 30 degrees off the motor centerline
Nozzle Insert I.D.:	-Z = 3.5 inches and +Z = 3.2 inches
Resultant Thrust Vector	4.0 degrees offset of motor centerline

2.9.9.3 ERS Data

Apex Cover Drag Parachute		1 each
Mfrd by:	Northrop-Ventura, Newbury Park, Calif.	
How Deployed:	Mortar	
Type:	Ring Slot	
No. of Rings:	9	
No. of Gores:	12	
No. of Suspension Lines:	12	
Dimensions:	7.2-foot diameter	
Weight:	10 pounds incl mortar	
Drogue Parachutes		2 each
Mfrd by:	Northrop-Ventura, Newbury Park, Calif.	
How Deployed:	Mortar	
Type:	Conical Ribbon	
No. of Ribbons:	36	
No. of Gores:	20	
No. of Suspension Lines:	20	
Dimensions:	16.5 foot diameter	
Weight:	50 pounds incl mortar	
Reefing:	Single stage, 10 sec from line stretch plus a permanent skirt band	
Pilot Parachutes		3 each
Mfrd by:	Northrop-Ventura, Newbury Park, Calif.	
How Deployed:	Mortar	
Type:	Ring Slot	
No. of Rings:	9	
No. of Gores:	12	
No. of Suspension Lines:	12	
Dimensions:	7.2 foot diameter	
Weight:	9 pounds incl mortar	
Main Landing Parachutes		3 each
Mfrd by:	Northrop-Ventura, Newbury Park, Calif.	
How Deployed:	Pilot parachutes	
Type:	Ring Sail	
No. of Rings:	12	
No. of Gores:	68	
No. of Suspension Lines:	68	
Dimensions:	83.5 foot diameter	

SEQ

Weight:	136 pounds
Reefing:	Two stage, 6 and 10 sec from line stretch

NOTE

All weights quoted which include a mortar do not include the weight of the dual gas pressure cartridges in the breech.

2.9.9.4 URS Data

Uprighting Subsystem Control Box — 1 each

Part No.:	V36-452170
Mfrd by:	Space Division, North American Rockwell Corporation, McAlester, Oklahoma
Dimensions:	4 x 11.75 x 12 inches
Weight:	10 pounds
No. of electrical receptacles:	2 each
Motorswitches:	Kinetics, 4 pole 3 each powered during transfer only 75 amps continuous current rating on two main contacts
S1, S2, and S3	Flotation bag 1, 2, and 3 fill/vent control valve control

2.9.9.5 Pyrotechnic Subsystem Data

QUANTITIES OF SECS CONTROLLED PYROTECHNIC DEVICES ON THE APOLLO SPACECRAFT

Launch Escape Tower	
Canard Thruster	2
Pitch Control Motor	2
Tower Jettison Motor	2
Launch Escape Motor	2
Tower Separation System	8
CM Forward Compartment and Docking Subsystem	
Docking Probe Retraction Bottles	4
* Docking Ring Separation System	2
* Apex Cover Separation System (thrusters)	4
Apex Cover Separation System (drag chute)	2
* Drogue Parachute Deployment Mortars	4
* Pilot Parachute Deployment Mortars	6
* Parachute Disconnect Mechanism	10

CM Aft Compartment

* Helium Isolation Valves	4
* Oxidizer and Fuel Dump Valves	4
* Oxidizer, Fuel, and Helium Interconnect Valves	4
* Oxidizer and Fuel Bypass Valves	4
* Circuit Interrupters	4
CM-SM Umbilical Guillotine	2

SM Forward Compartment

Circuit Interrupters	4
CM-SM Separation System	6

Spacecraft LM Adapter

SLA Separation System	2
	82

*Denotes pyrotechnic devices recovered on CM.

Reefing Line Cutters

Drogue Parachutes, 8 each; Main Landing Parachutes, 18 each; VHF Recovery Antennas, 4 each; and Recovery Flashing Beach, 2 each. Total of 32.

2.9.9.6 Launch Escape System Ordnance

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
Canard Cartridge	V15-590220-81	LES Canard Deploy	F01-590230	2
Igniter	ME453-0014-0013	1. LES Motor Ignition 2. PC Motor Ignition	F01-100406 F01-100406	2 2
Igniter	ME453-0014-0014	TJ Motor Ignition	F01-100406	2
Detonator	ME453-0021-0007	Separate Frangible Nut	F01-100403	8
Frangible Nut	ME114-0013-0002	Holds Tower to CM	01-100402	4

SEQ

SYSTEMS DATA

2.9.9.7 Earth Recovery System Ordnance

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
Heat Shield Cartridge	ME453-0005-0046	Forward Heat Shield Separation	V36-596171	4
Pilot Chute Cartridge	ME453-0005-0093	1. Deploys Drag Chute for FHS Separation 2. Deploys Pilot Chute for Main Chute Deploy	V36-596171	2 6
Drogue Chute Cartridge	ME453-0005-0091	Deploys Drogue Chute	V36-596172	4
Drogue Chute Disconnect Cartridge	V36-596006-51	Disconnect Drogue Chutes	V36-596172	2
Main Chute Disconnect Cartridge	V36-596007-51	Disconnect Main Chutes	V36-596172	3
Line Cutter	ME182-0004-0001	Releases Recovery Aids	V36-576002	6
Reefing Line Cutters (6 sec)	Northrop Ventura NV58516-60	Main Chute Disreef	V36-576002	12
Reefing Line Cutter (10 sec)	NV58517-100	Main Chute Disreef	V36-576002	6
Reefing Line Cutter (10 sec)	NV58517-100	Drogue Chute Disreef	V36-576002	8

2.9.9.8 Command Module Ordnance

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
Initiator	SEB26100001-256	Docking Probe Retract	F01-100406	4
Docking Ring Explosive Train	V36-596030-21	Separate Docking Ring	V36-596173	2
Docking Separation Detonator	ME453-0025-0003	Initiates Docking Ring Explosive Train	V36-596173	2
CI Cartridge	ME453-0005-0252	Operates Circuit Interrupter	F01-100406	4

SYSTEMS DATA

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
RCS Cartridges	ME453-0005-0121 ME453-0005-0122	Operates Reaction Control System Valves	F01-100406 F01-100406	8 2
	ME453-0005-1034 ME453-0005-1034			5 1
Guillotine	V37-590020	Severs CSM Umbilical	V37-590006	1
Detonator	ME453-0021-0007	Initiates Guillotine	F01-100406	2
L.H. Circuit Interrupter	V36-597008	Dead-face CSM Umbilical	V36-444201	1
R.H. Circuit Interrupter	V36-597014	Dead-face CSM Umbilical	V36-444201	1

2.9.9.9 Service Module Ordnance

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
Tension Tie Cutter	ME453-0032	Severs Tension Tie CM to SM	F01-100407	6
Detonator	ME453-0021-0007	Initiates Tension Tie Cutter	F01-100407	6
CI Cartridge	ME453-0005-0054	Initiates Circuit Interrupter	F01-100406	4

2.9.9.10 SM/SLA Ordnance

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
Umbilical Disconnect	V24-590230	Disconnects Umbilical SLA to SM	F01-590006	1
Confined Detonating Cord	ME320-0001-0002	Initiates Umbilical Disconnect	F01-590006	2
Explosive-Initiated Pressure Cartridge	ME901-0595-0001	Deploys SLA Panels	F01-100431	8
Explosive Tube Assembly	ME901-0689-0001 ME901-0689-0002	Initiates Explosive-Initiated Pressure Cartridge	F01-100431	4 4
Detonator	ME453-0021-0008	Initiates SLA Panel Deployment and Separation System	F01-100431	2

SEQUENTIAL SYSTEMS

SEQ

2.9.9.11 SLA Explosive Train Charge Holders in Separation System

Nomenclature	Part Number	Function	Installation Drawing	No. Per S/C
Forward Circumferential	V24-590010-71 V24-590010-81	The explosive train charge holders' position. The explosive trains on the several splice plates are interconnected. Upon initiation of the detonator, splices are severed.	F01-100431	2 2
Aft Circumferential	V24-590288-11 V24-590288-21			4 4
Forward Inner Longitudinal	V24-590017 V24-590026-11 V24-590026-21			2 1 1
Aft Inner Longitudinal	V24-590330			4
Center Inner Longitudinal	V24-590333-11 V24-590333-21 V24-590334			1 1 2
Forward Outer Longitudinal	V24-590032			4
Aft Outer Longitudinal	V24-590331			4
Center Outer Longitudinal	V24-590332			4
Booster Crossovers	V24-590120 V24-590121 V24-590144 V24-590122-31			4 4 4
Panel Ejectors (Mechanical)	V24-590301	Jettison SLA Panels	F01-100428	8

2.9.9.12 Apollo Ordnance Explosives and Their Composition

Part No.	Name	ICC Class	Content
ME453-0014-0013, 0014	Igniter	C	246 mg of SOS No. 109 powder
ME453-0005-0091	Drogue Cartridge	C	90 mg of Hi-temp, 4.75 grams of Hercules 5250.95, 250 mg of SOS No. 109 powder
ME453-0005-0093	Pilot Cartridge	C	450 mg of Hi-temp, 1.05 grams of Hercules 5250.95, 100 mg of SOS No. 109 powder

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SYSTEMS DATA

Part No.	Name	ICC Class	Content
ME453-0005-0034, 1034, 0054	RCS Cartridge	C	90 mg of Hi-temp powder
ME453-0005-0046	Forward Heat Shield Cartridge	C	45.6 grams (Al. 10%, $KClO_4$ 75%, Epoxy 15%)
ME453-0005-0121, 0122	RCS Cartridge	C	122 mg of SOS No. 108 powder
ME453-0005-0252	Circuit Interrupter Cartridge	C	475 mg of Hi-temp powder
V15-590220-81	Canard Cartridge	C	33.0 grams of Hercules 5250.6, 1.0 gram of Unique powder
V36-596006-51	Drogue Release Cartridge	C	10.0 grains of Hi-temp powder
V36-596007-51	Main Chute Release Cartridge	C	34.6 grains of Hi-temp powder
ME901-0595-0001	Explosive Initiated Cartridge	C	92 mg of PETN, 8.0 grams B-KNO_3 pellets
ME901-0689-0001, 0002	Explosive Tube Assembly	C	2 cords, each of 5 grains per foot of RDX, 12 inches long. Booster output, 0.166 grams PETN; input, 0.105 mg of PbN_6, 380 mg of RDX
ME320-0001-0002	Confined Detonating Cord	C	15-foot length RDX, 2 grains/foot. Booster (each end); 1.1 grains RDX
ME320-0001-0001	Confined Detonating Cord	C	1.5-foot length RDX, 2 grains/foot. Booster (each end); 1.1 grains RDX
ME320-0001-0003	Confined Detonating Cord	C	22-foot length RDX, 2 grains/foot. Booster (each end); 1.1 grains RDX.
V37-590020 1. ME453-0026-4001	CSM Umbilical Guillotine Explosive Train Charge	C	Each of 4 blades; two 9.73-inch lengths RDX, 20 grains/foot. Booster (each end); 0.377 grams RDX.
2. ME453-0026-5001	CSM Umbilical Guillotine Explosive Train Charge	C	Each of 2 crossovers; one 12.7-inch length RDX, 5 grains/foot. Booster (each end); 0.14 grams PbN_6, 0.35 grams RDX.

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SEQ

SYSTEMS DATA

Part No.	Name	ICC Class	Content
3. ME453-0026-6001	CSM Umbilical Guillotine Explosive Train Charge	C	Each of 3 transfer boosters; one 51-inch length RDX, 20 grains/foot; 0.16 grams PbN_6; 0.135 grams RDX; output 0.42 grams RDX.
V24-590230 ME901-0612-3001	SM-SLA Umbilical Disconnect, Explosive Train Charge	C	Each of 2 trains; one 2.18-inch length RDX, 15 grains/foot. Each of 1 booster for each train: 0.195 grams RDX
ME453-0032	Boostered Flexible Linear-Shaped Charge	A	Two 4.59-inch lengths HNS, 100 grains/foot. Booster (each end); 0.125 grams PbN_6.
ME453-0021-0007, 0008	Detonator	C	327 mg PbN_6, 0.400 grams RDX
ME453-0025-0003	Detonator, Long Reach	C	230 mg HNS II, 150 mg PbN_6
SLA Panel Separation Explosive Trains			
V24-590010-71 ME901-0612-1001	Forward Circumferential Explosive Train	C	Two 129.9-inch strands RDX, 7 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-950010-81 ME901-0612-1001	Forward Circumferential Explosive Train	C	Two 129.9-inch strands RDX, 7 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590288-11 ME901-0612-0007	Aft Circumferential Explosive Train	C	Two 91.71-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590288-21 ME901-0612-0006	Aft Circumferential Explosive Train	C	Two 91.71-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590017 ME901-0612-0015	Forward Inner Longitudinal Explosive Train	C	Two 126-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-950026-11 ME901-0612-0015	Forward Inner Longitudinal Explosive Train	C	Two 126-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX

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SYSTEMS DATA

Part No.	Name	ICC Class	Content
V24-590026-21 ME901-0612-0015	Forward Inner Longitudinal Explosive Train	C	Two 126-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590330 ME901-0612-	Aft Inner Longitudinal Explosive Train	C	Two 20.06-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590334 ME901-0612-	Center Inner Longitudinal Explosive Train	C	Two 110.19-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590333-11 ME901-0612	Center Inner Longitudinal Explosive Train	C	Two 110.19-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590032 ME901-0612-0016	Forward Outer Longitudinal Explosive Train	C	Two 125.08-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590331 ME901-0612	Aft Outer Longitudinal Explosive Train	C	Two 24.14-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590120 ME901-0612-2003	Booster, Outer Splice	C	1.25 inch, 0.090 grams PbN_6, 0.192 grams RDX
V24-590121 ME901-0612-2003	Booster, Inner Splice	C	1.125 inch, 0.090 grams PbN_6, 0.192 grams RDX
V24-590122-31 ME901-0612-2002	Booster, Lower Crossover	C	1.438 inch, 0.090 grams PbN_6, 0.260 grams RDX
V24-590144 1. ME901-0612-2002 2. ME901-0612-2003	Booster, Forward Circular Splice	C	2 each 1.125 inch, 0.090 grams PbN_6, 0.260 grams RDX 1 each 1.438 inch, 0.090 grams PbN_6, 0.260 grams RDX
V24-590333-21 ME901-0612-	Center Inner Longitudinal Trains	C	Two 110.19-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590332 ME901-0612	Center Outer Longitudinal Trains	C	Two 104.28-inch strands RDX, 5 grains/foot. Booster (each end); 95 mg PbN_6, 381 mg RDX
V24-590327 ME901-0612	Booster Holder	C	1.125 inch, 0.090 grams PbN_6, grams RDX

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SYSTEMS DATA

Part No.	Name	ICC Class	Content
V24-590335 ME901-0612	Booster Holder	C	1.125 inch, 0.090 grams PbN_6, 0.192 grams RDX
SEB 261-000001	SBASI	C	122 mg of SOS No. 108 powder
ME182-0004-0001	Recovery Aid Line Cutter	C	Each cutter: 1398 mg of 8-sec-delay mixture consisting of 21.85% Zr-Ni, Type II (70% Ni, 30% Zr) 4.15% Zr-Ni, Type I (30% Ni, 70% Zr), 60% barium chromate and 15% potassium chlorate. Blade charge - 75 mg. Hercules Unique Pwdr. Primer - M42, Ignition mix - 195 mg AIA-MILP - 22264
NV58517-100 (Northrop-V)	Drogue Parachute Line Cutter	C	
NV58516-60 (Northrop-V)	Main Parachute Line Cutter	C	
NV58517-100 (Northrop-V)	Main Parachute Line Cutter	C	

2.9.9.13 Telemetry Measurement ID

Meas. ID	Description	Switch or Relay No.	Channel Code
	LAUNCH ESCAPE SYSTEM		
CD0005V	DC Voltage Pyro Bus A	K1	11A9
CD0006V	DC Voltage Pyro Bus B	K1	11A5
CD0023X	CM-SM Sep Relay Close A	Z9	11E22-1
CD0024X	CM-SM Sep Relay Close B	Z9	11E23-1
CD0123X	SLA Separation Relay A	Z17	11E22-5
CD0124X	SLA Separation Relay B	Z17	11E23-7
CD0130X	Hand Controller Input A	Manual Abort	11E13-3
CD0131X	Hand Controller Input B	Manual Abort	11E13-6
CD0132X	EDS Abort Logic Input No. 1	EDS POWER	11E14-1
CD0133X	EDS Abort Logic Input No. 2	EDS POWER	11E14-2
CD0134X	EDS Abort Logic Input No. 3	EDS POWER	11E14-4
CD0135X	EDS Abort Logic Output A	Z1K1, Z1K2, & Z2K1	11E13-7
CD0136X	EDS Abort Logic Output B	Z1K1, Z1K2, & Z2K1	11E13-4
CD0170X	RCS Activate Signal A	Z19 (latched)	11E22-3
CD0171X	RCS Activate Signal B	Z19 (latched)	11E23-3
CD0173X	CM RCS Pressurize Signal A	Z7	11E22-7
CD0174X	CM RCS Pressurize Signal B	Z7	11E23-5
CD0200V	DC Voltage Logic Bus A	Z20	11A8
CD0201V	DC Voltage Logic Bus B	Z20	11A6
CD0230X	Forward Heatshield Jettison A	Z14	11E24-1
CD0231X	Forward Heatshield Jettison B	Z14	11E26-5
CD1154X	Docking Ring Sep Relay Sys A	Z4	11E15-6
CD1155X	Docking Ring Sep Relay Sys B	Z4	11E15-7

SYSTEMS DATA

Meas. ID	Description	Switch or Relay No.	Channel Code
CREW SAFETY SYSTEM			
BS0080X	EDS Abort Request A	UDL	11E4-5
BS0081X	EDS Abort Request B	UDL	11E4-3
CS0150X	Master Caution Warning ON		11E4-6
LS0200H	Angle of Attack (Vector Sum Output)		11A51
CS0220T	Temp Docking Probe		10A22
EARTH LANDING SEQUENCE CONTROLLER			
CE0001X	Drogue Deploy Relay Close A	K2 & Z2K1	11E29-1
CE0002X	Drogue Deploy Relay Close B	K2 & Z1K1	11E30-6
CE0003X	Main Chute Deploy-Drogue Rel Relay A	K3 & Z2K4	11E29-8
CE0004X	Main Chute Deploy-Drogue Rel Relay B	K3 & Z1K4	11E30-3
CE0321X	Main Chute Disconnect Relay A	Z2K3 & Z2K5	11E29-5
CE0322X	Main Chute Disconnect Relay B	Z1K3 & Z1K5	11E30-8

2.9.10 OPERATIONAL LIMITATIONS AND RESTRICTIONS

Since sequential systems include numerous controls for manual backup and/or intervention of automated functions, and since several of the functions are time-critical, certain precautions should be observed. Moreover, considerable versatility has been designed into the systems, such as alternate electrical power selection. Serious damage could result if correct procedures are not followed.

2.9.10.1 Alternate Selection of Logic Power

It would be possible to couple a defective battery to a good one, and serious damage to the electrical power supply could result if certain circuit breakers are not utilized properly. The BAT BUS A BAT C and BAT BUS B BAT C circuit breakers (CB9 and CB10), zone 42-A and B, are included in the system to enable the utilization of ENTRY AND POST LANDING BATTERY C in the event of a power failure in either of the ENTRY AND POST LANDING BATTERIES A or B. If the contingency of alternate power utilization should occur, the defective battery should be isolated before the appropriate BAT BUS A BAT C or BAT BUS B BAT C circuit breaker is closed. Additional information on this subject is included in section 2.6, Electrical Power.

2.9.10.2 Alternate Selection of Pyro Power

If the pyro power circuit breakers are not utilized properly, serious damage to the electrical supply could result. The potential hazard is the same as described in paragraph 2.9.9.1 except in this instance the electrical power of the PYRO Systems, zones 41 through 43-D and -E, is concerned. The PYRO BUS A BAT BUS A and PYRO BUS B BAT BUS B circuit breakers (CB45 and CB47) are included in the system to be used in the event of a failure of PYRO BATTERY A or B. If such a power failure should occur, the appropriate PYRO BUS A PYRO BAT A or PYRO BUS B PYRO BAT B circuit breaker (CB44 or CB46) should be opened before coupling the appropriate ENTRY AND POST LANDING battery to the PYRO power system.

SEQ

2.9.10.3 Control for Arming Pyro Systems

Logic battery power is required to arm or safe PYRO buses. It is therefore necessary to close the SECS ARM BAT A circuit breakers (CB1), and/or its counterpart in system B, zone 39-C, before the motor switch (K1) in the DEC, zones 39 and 40-E and -F, can be operated to energize or de-energize the PYRO buses. This feature is designed into the system for power conservation during a mission when the docking probe is being used. The procedures for the utilization of logic power for control of PYRO power will consequently differ somewhat during the various phases of a mission.

2.9.10.4 Status of Logic and Pyro Buses

It will be necessary for the flight crew to verify the status of LOGIC and PRYO buses, i.e., armed or safe, through the MSFN. Displays for this status are not included in the CM.

2.9.10.5 Utilization of Controls for CSM/LV Separation

When the CSM/LV SEP switch is used, it should be held closed for approximately one second (0.8 second minimum) for the time-delay-relay logic to perform as it was designed.

2.9.10.6 Utilization of Controls for CM/SM Separation

When the CM/SM SEP switches are used, they must be held closed for 0.1 of a second for the time-delay-relay logic to perform as it was designed.

2.9.10.7 Manual Control of ELSC Functions

Under certain entry conditions, erratic aerodynamic damping coefficients, wind gusts, and shears, the CM may become unstable. If this should occur, the apex cover and drogue parachutes may be manually deployed early. This will stabilize and keep the CM in the proper descending attitude. See figure 2.9-36 for the drogue deployment design envelope. The following precautions should be observed:

a. Manual initiation of drogue parachute deployment should never be accomplished above 40,000 feet during entry.

b. The CM RCS must be turned off prior to apex cover jettison.

c. Manual initiation of apex cover jettison must not be executed with the LET attached.

d. Manual initiation of drogue parachute deployment must not be executed with the apex cover on the vehicle.

e. Manual initiation of main parachute deployment must not be executed prior to drogue deployment.

f. Manual initiation of main parachute deployment must be accomplished above 2500 feet.

g. Two circuit breakers are incorporated in MESC PRYO circuits to the main parachute release ordnance devices. These circuit breakers should not be closed until after the CM has landed.

h. It is impossible to release the main parachutes with the ELS switch in the MAN position. This switch must be in the AUTO position and the 14-second time delays in the ELSC (TD 3 and TD 4), zone 6-C, expired before the MAIN RELEASE switch is armed.

SECTION 2

SUBSECTION 2.10

CAUTION AND WARNING SYSTEM

2.10.1 INTRODUCTION

The caution and warning subsystem (C&WS) (figure 2.10-1) monitors selected parameters of various CM and SM systems. Malfunction or system identification is provided, together with aural and visual alerting, so that corrective action may be taken. Additional alerting circuits to the SWS are provided during the period the CSM is docked to the workshop and the CM is unmanned.

2.10.2 MAJOR COMPONENT DESCRIPTION

The caution and warning subsystem consists of the following circuits and controls.

2.10.2.1 Circuit Protection

Two circuit breakers (C/W - MNA and MNB) on panel 5 provide power input source protection. One-amp fuses, located in each of two power input lines to the inhibit and the SWS alarm relay circuits, provide isolation of the caution detection unit (CDU) from short circuit failures in these circuits.

2.10.2.2 CAUTION/WARNING Control Switches (Panel 2)

- NORMAL/BOOST/ACK. Three maintaining positions provide selection of one of three modes of operation.
- CSM/CM. Two maintaining positions provide selection of status light activation by inputs from the CM and SM or only from the CM.
- POWER. Three maintaining positions (1, center off, 2) provide selection of primary or alternate power supplies in the CDU and the Memory/Tone Amplifier (M/TA) units with a center position for terminating power.
- LAMP TEST. Two momentary positions (1, 2) used to perform lamp continuity checks of the panel 2 status lights and the MASTER ALARM switch lights on panels 1 and 3.
- C/W MEMORY. The switch has two momentary positions (RESET, RECALL). The RESET position is for activating and clearing the memory functions. The RECALL position is for recalling signals stored by the memory unit.

C&WS

2.10.2.3 Inhibit Panel (Panel 201)

Thirty-nine two-position (ENABLE, INHIBIT) maintaining switches for enabling or inhibiting signal inputs to status lights which do not have an inhibit capability on other panels.

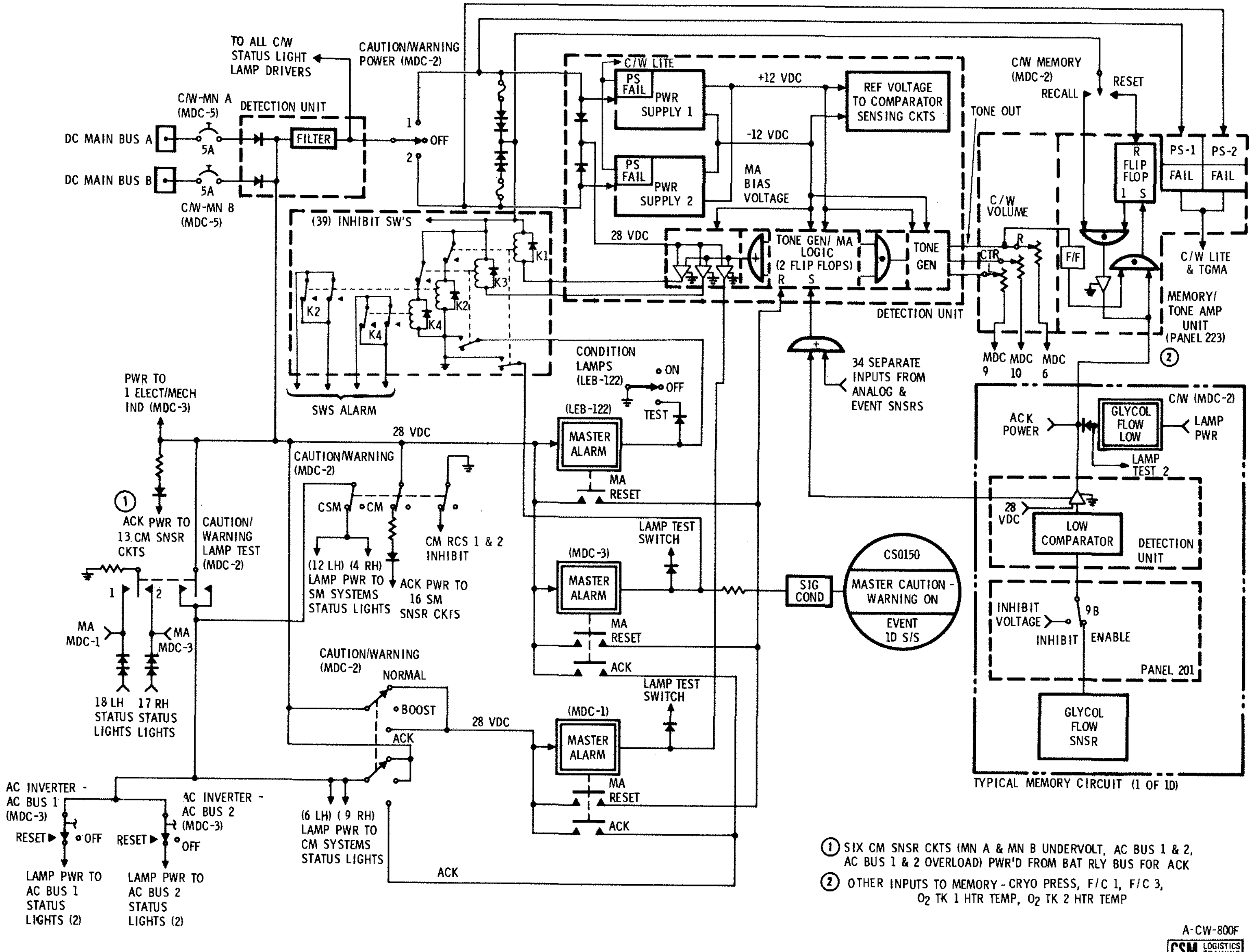


Figure 2.10-1. Caution and Warning Schematic

2.10.2.4 C/W Volume (Panel 223)

Three screwdriver adjustments for regulating tone volume to each of the three individual headsets.

2.10.2.5 GUIDANCE/NAVIGATION-LIGHTS Circuit Breakers (Panel 5)

Two circuit breakers (AC1, AC2) provide power source protection in circuits supplying power to status lights (PGNC, CMC, ISS) on panel 122.

2.10.2.6 G/N LTS Switch (Panel 100)

Three maintaining positions (AC1, OFF, AC2) provide selection of power sources for operation of status lights on panel 122.

2.10.2.7 CONDITION LAMPS Switch (Panel 122)

Three maintaining positions (ON, OFF, TEST) for operation and test of the three (panel 122) status lights, and for test of the MASTER ALARM switch light on this panel.

2.10.2.8 POWER Switches (Panels 9, 10, 6)

Three maintaining positions (AUDIO/TONE, OFF, AUDIO) for selecting or isolating tone input to each individual crew position headset.

2.10.3 FUNCTIONAL DESCRIPTION

The following is a functional description of the C&WS and its various modes of operation.

2.10.3.1 Power Control

The two C/W circuit breakers (panel 5) are dioded, requiring closure of either breaker for system operation. Normally both breakers are closed. The POWER switch (panel 2) allows selection of either of two power supplies in the CDU simultaneously with either of two power supplies in the M/TA unit. Normally this switch is in the 1 position.

The CDU power supply, providing a +12 vdc and a -12 vdc output, is used for operation of comparator, logic, and tone generator circuits. The M/TA power supply provides a 14 vdc and 5 vdc output. The 14 vdc output is used for operation of both the memory and tone amplifier circuits, and supplies power to the 5 vdc supply which is used only for operation of the memory circuits.

2.10.3.2 Mode Selection and Lamp Test

The NORMAL/BOOST/ACK and CSM/CM switches (panel 2) provide mode selections, while the LAMP TEST switch provides an illumination test of the status and master alarm lights on the main display console.

2.10.3.2.1 Mode Selection

a. The C&WS can be operated in any one of three modes with the NORMAL/BOOST/ACK switch. The NORMAL or ACK modes can be used when desired except on the launch pad after pyro arm until orbit insertion at which time the BOOST mode is used.

In the NORMAL position, receipt of a malfunction or out of limits signal illuminates the appropriate status light in the matrix (panel 2) and the three red MASTER ALARM switch lights (panels 1, 3, 122). In conjunction with the MASTER ALARM switch lights, circuits in the CDU generate an audio tone. The tone consists of 750 and 2000 Hz signals modulated at 2.5 Hz. This is supplied through the tone amplifier (controlled by adjustments on panel 223) and the individual communications controls (POWER switches on panels 9, 10, 6) to the individual headsets, and to the panel 98 speaker when it is activated. Depressing either of the three MASTER ALARM switch lights extinguishes them, discontinues the audio tone, and resets the switch light and audio tone circuits for activation by a subsequent signal input. The status light will remain illuminated as long as the malfunction or out of limits condition exists.

The ACK position can be used to extinguish a continuously illuminated status light, or when it is desirable to retain darkness adaptation and not have illumination of a status light. In this mode, a signal from a monitored measurement will illuminate only the red MASTER ALARM switch lights and activate the audio tone. Depressing and holding the panel 1 or 3 switch light will illuminate the appropriate status light and reset the master alarm and audio tone circuits. Releasing the switch light will extinguish all associated lights. Depressing the panel 1 or 3 switch light again will reilluminate the status light, as long as the out of limits condition exists. In the ACK mode, the panel 122 MASTER ALARM switch light will only reset the master alarm and audio tone circuits, and will not illuminate the applicable panel 2 status light. The ACK mode is primary for operation during the docked period when the CM is not inhabited.

When the CM C&WS is triggered by a malfunction or out of limits condition, two discrete signals are provided to the SWS caution/warning system. These activate a status light (CSM), the master alarm lights and warning audio tone in the SWS. Upon crew member entry into the CM, the MASTER ALARM is reset to disable the input to the SWS, and the NORMAL/BOOST/ACK switch is positioned to NORMAL prior to any further analysis of the situation.

The BOOST mode is selected on the launch pad at the time the pyro systems are armed, and is retained throughout liftoff and boost until after earth orbit insertion. This mode completely deactivates the panel 1 MASTER ALARM switch light to prevent confusion with the red ABORT light on the same panel. Therefore, during the above periods, only the panel 3 MASTER ALARM switch light will be available to provide the required responses while the crew members are in their couches. The remainder of the C&WS functions the same as in normal operation.

b. The CSM/CM switch (panel 2) enables, for triggering by a monitored signal, or deactivates all SM associated lights in the C&WS. The CSM position is selected for all phases of flight until entry. At CM-SM separation, a number of SM status lights will be illuminated together with the master alarm switch lights and activation of the audio tone circuit. Illumination of the lights provides a means of checking umbilical severance, since certain lights are enabled due to signal decrease. After activation of the circuits by the separation, the master alarm/audio tone circuit is reset, and positioning of the CSM/CM switch to the CM position extinguishes all the SM status lights, leaving only the CM status lights active. In the CSM position, the two CM RCS signals are inhibited to prevent lamp illumination since the CM RCS is not pressurized with the SM attached.

This switch is also used to determine validity of the CSM/SWS caution and warning interface. After control umbilical connection and SWS activation, this switch is positioned to CM, which allows the CM RCS 1 & 2 signals to trigger the CM C&WS and provide an input to the SWS caution warning circuits. This illuminates the CM RCS 1 & 2 lights and the MASTER ALARM lights, as well as activating the audio tone in the CM. The CM signals will in turn activate the workshop CSM and MASTER ALARM lights, as well as the warning audio tone.

2.10.3.2.2 Lamp Test

The LAMP TEST-1/2 switch (panel 2) is used to test the C&W lamps on the main display panels. Position 1 tests the left C&W matrix and the panel 1 MASTER ALARM switch light. The panel 1 switch light will not test with the NORMAL/BOOST/ACK switch in the BOOST position. Position 2 tests the right C&W matrix and the panel 3 MASTER ALARM switch light. The CSM/CM switch must be in the CSM position to perform a lamp test of all the status lights, otherwise only the CM status lights can be tested. The AC BUS 1 and 2 RESET switches (panel 3) must be in the ON (center) position to test the AC BUS 1 & 2 and AC BUS 1 & 2 OVERLOAD status lights. The LEB master alarm switch light is tested by positioning the panel 122 CONDITION LAMPS switch to TEST. The LEB C&W status lights (CMC, ISS, PGNC) and the MASTER ALARM switch light (panel 122) can be tested by using EXTENDED VERB 35 on the DSKY. This will also activate the audio tone into the headsets. Termination of VERB 35, due to relay time out, extinguishes the three status lights. Depressing the MASTER ALARM switch light extinguishes the three master alarm lights and discontinues the audio tone.

2.10.3.3 Memory/Tone Amplifier (M/TA) Unit

This unit consists of a memory section and a tone amplifier section. Both of these operate from one of two common internal power supplies which are activated by positioning the CAUTION/WARNING - POWER switch to 1 or 2, and momentarily positioning the C/W - MEMORY switch to RESET.

C&WS

2.10.3.3.1 Power

A 14 vdc power supply provides power for memory and tone amplifier operation. A 5 vdc supply, functioning from the 14 vdc supply, provides power only for memory operation, as well as providing the power failure signal for illuminating the C/W status light. The C/W MEMORY switch has to be positioned to RESET any time there is reselection of caution warning power with the POWER - 1/2 switch. This is necessary in order to enable the tone amplifier, thus retaining operation of the tone output irrespective of the fact that memory operation may not be desired.

2.10.3.3.2 Memory Section

The memory section consists of ten logic circuits providing a capability of retaining in memory any number of the ten available channels. Presently, six of the ten channels are used. These are CRYO PRESS, F/C 1, F/C 3, O_2 TK 1 HTR TEMP, O_2 TK 2 HTR TEMP, and GLYCOL FLOW LOW. The prime purpose of the memory is for use during the period the CSM is docked with the SWS and the CM is unmanned. Since the status lights indicate only a prevailing out of limits condition, the memory will retain for recall any transient out of limits occurrence of the monitored parameters which has cleared prior to crew member entry into the CM. A crew member, upon entry into the CM due to a CSM alarm in the SWS, will initially depress the panel 1 or 3 MASTER ALARM to reset the alarm circuits including the input to the SWS. The NORMAL/BOOST/ACK switch will then be positioned to NORMAL and troubleshooting performed of the system(s) with status light indications. If there are no status light indications, the C/W MEMORY switch is held in RECALL, which will illuminate the status light(s) identifying the parameter which provided the transient response. If a status light was previously illuminated, after troubleshooting, the C/W MEMORY switch is positioned to RECALL to determine if there were any other responses. Performing the recall operation will not activate the master alarm or SWS indicators. Positioning the C/W MEMORY switch to RESET will clear all the signals from memory and re-institute original monitoring.

2.10.3.3.3 Tone Amplifier

Three screwdriver adjustable controls are provided on panel 223. Each of the crew tone signals has its own screwdriver adjustment for regulating the volume of the C&W tone supplied to the respective headset when the C&W system is energized. In addition, each audio control panel (9, 10, 6) has a POWER-AUDIO/TONE, OFF, AUDIO switch for allowing or isolating the tone input to the respective headset. Panel 9 controls the left-hand couch, panel 10 controls the center couch, and panel 6 controls the right-hand couch audio inputs.

2.10.3.4 Inhibit Unit

This unit provides a capability of inhibiting continuous inputs to C&W status lights which monitor several measurements, inputs which are nuisance triggering a C&W status light, and also for inhibiting signals from systems which have been deactivated, such as the H_2 tanks after H_2 depletion. This, for example, retains use of the CRYO PRESS light for monitoring the O_2 tanks. The inhibit switches are located on panel 201. A decal is provided to correlate the switches with the C&W input signals which activate the status lights. Signal identification of each inhibit switch is shown in the following chart.

SYSTEMS DATA

	A	B	C	D
1	CREW ALERT	INV 1 TEMP HI	O_2 TK 1 HTR TEMP	O_2 TK 2 HTR TEMP
2	CRYO PRESS (O_2 TK 1 PRESS)	CRYO PRESS (O_2 TK 2 PRESS)	CRYO PRESS (H_2 TK 1 PRESS)	CRYO PRESS (H_2 TK 2 PRESS)
3	FC 1 (TEMP COND EXH)	FC 1 (TEMP SKIN)	FC 1 (pH HI)	FC 1 (REAC VLV CLOSED)
4	FC 3 (TEMP COND EXH)	FC 3 (TEMP SKIN)	FC 3 (pH HI)	FC 3 (REAC VLV CLOSED)
5	SM RCS A (FUEL TK PRESS)	SM RCS A (PKG TEMP)	SM RCS B (FUEL TK PRESS)	SM RCS B (PKG TEMP)
6	SM RCS C (FUEL TK PRESS)	SM RCS C (PKG TEMP)	SM RCS D (FUEL TK PRESS)	SM RCS D (PKG TEMP)
7	SM RCS PSM 1 (FUEL TK PRESS)	Unassigned	SPS PRESS (OXID PRESS)	SPS PRESS (FUEL PRESS)
8	PITCH GMBL 1	PITCH GMBL 2	YAW GMBL 1	YAW GMBL 2
9	CO_2 PP HI	GLYCOL FLOW LOW	O_2 FLOW HI	SUIT COMPRESSOR
10	BMAG 1 TEMP	BMAG 2 TEMP	CMC	ISS

2.10.3.5 SWS Interface

Any input to the CM C&WS will alert crew members in the workshop by activating the caution/warning in the workshop. This portion of the SWS caution/warning consists of a status light (CSM), MASTER ALARM lights and a warning tone. It is activated by discrete signals operating in conjunction with two of the master alarm switch lights in the CM. Individual signals are supplied through each of the control umbilicals into the workshop. Reset of the CM master alarm resets the input to the CSM alarm in the SWS.

2.10.3.6 Panel 122 Status Lights and Master Alarm Light

The three G&N status lights (PGNS, CMC, ISS) operate from an independent power source which is associated with the G&N system. The G/N LTS - AC1/AC2 switch (panel 100) controls power for these circuits, with power source protection provided by the GUIDANCE NAVIGATION - AC1 and AC2 circuit breakers (panel 5). The CMC and ISS status lights function in parallel with similar status lights in the matrix on panel 2. Detailed operation of these circuits is provided in section 2.1.

2.10.3.7 Power Supply Failure Detection

The C/W status light monitors failure of the CDU power supply as well as the M/TA power supply. Failure of either the +12 vdc or -12 vdc CDU power will illuminate the light. In the M/TA, loss of the 5 vdc power illuminates the light; however, the 5 vdc power supply is dependent on the internal 14 vdc power supply; therefore, it can fail independently. A failure of the 14 vdc power supply illuminates the status light because of the loss of the dependent 5 vdc supply.

Failure of the CDU power supply results in the loss of 15 status light indicators, partial loss of two other status light indicators and loss of the audio tone. Failure of the M/TA 5 vdc supply results in loss of the memory functions but retention of the audio tone, while failure of the 14 vdc supply results in loss of the memory and audio tone functions.

The response to an initial failure is to position the CAUTION/WARNING - POWER switch to the alternate power supply, and the C/W MEMORY switch to RESET. Should a second failure be indicated, determination of which power supply failed should be performed in order to retain optimum operation of the C&WS. Retention of CDU operation is primary. Since, with a M/TA 5 vdc supply failure, retention of tone with the CDU is possible, determination should be made to retain this capability.

Reception of an audio tone after a C/W status light indication reflects an operational CDU power supply and an operational 14 vdc M/TA power supply. This is an optimum condition under a second power supply failure situation and should by retained. If there is no audio response on one power selected position, the alternate position should be checked. Lack of an audio tone on both power positions indicates failure of the CDU supply or the 14 vdc M/TA supply. Therefore, determination has to be made whether either CDU is operational. This is performed by depressing and releasing the panel 1 or 3 MASTER ALARM switch light. If the MASTER ALARM lights remain extinguished, the 14 vdc M/TA supply has failed. This is the optimum condition under this type of failure and should be retained. If the MASTER ALARM lights re-illuminate, the CDU supply has failed requiring a check of the alternate power position to determine if that CDU supply is operational.

If both CDU power supplys are inoperative, the MASTER ALARM switch lights will remain illuminated continuously with a continuous input to the SWS caution/warning, and also a loss of monitoring certain CSM parameters. Therefore, it is recommended the CAUTION/WARNING - POWER switch be positioned to center (off) and the CSM light in the SWS be inhibited.

Under this set of conditions, the following CSM status lights will remain functional: BMAG 1 TEMP, BMAG 2 TEMP, PITCH GMBL 1, YAW GMBL 1, PITCH GMBL 2, YAW GMBL 2, FC1 and FC3 (reactant valve closed input only), AC BUS 1, AC BUS 2, SM PWR DISCONNECT, AC BUS 1 OVERLOAD, AC BUS 2 OVERLOAD, CMC, CREW ALERT, MN BUS A UNDERVOLT, MN BUS B UNDERVOLT, ISS, and O_2 FLOW HI. With the NORMAL/BOOST/ACK switch in NORMAL or BOOST, these lights will illuminate upon receipt of a malfunction signal. The pH talk back indicator will also be operational. The MASTER ALARM lights, audio tone, CSM alarm in the SWS and caution/warning PCM will not be functional. With the switch in ACK, the unilluminated panel 1 or 3 MASTER ALARM switch lights would have to be depressed to illuminate any of the above status lights. The following status lights will be inoperative: CO_2 PP HI, O_2 TK 1 HTR TEMP, O_2 TK 2 HTR TEMP, CRYO PRESS, GLYCOL FLOW LOW, CM RCS 1, CM RCS 2, SM RCS PSM 1, SM RCS A, SM RCS B, SM RCS C, SM RCS D, FC1 and FC3 (skin temp, cond exh temp, pH inputs only), INV 1 TEMP HI, SPS PRESS, C/W, and SUIT COMPRESSOR.

2.10.4 OPERATIONAL LIMITATIONS AND RESTRICTIONS

2.10.4.1 Crew Alert Status Light

The CREW ALERT light is normally activated and deactivated by up-data link commands from MSFN stations. Activation of this status light also activates the master alarm/audio tone circuits. The circuit can also be deactivated by inhibit switch 1A on panel 201.

2.10.4.2 Caution/Warning Power

Whenever the CAUTION/WARNING-POWER switch (panel 2) is moved through the OFF position to either power supply position, the master alarm is activated, requiring a reset. Also, switching from one power supply to the other with no power supply failure may cause the C/W status light to flicker as the switch traverses through the OFF position. Each power change requires restart of the memory unit power supply by activating the C/W MEMORY switch to RESET.

Failure of both C&W detection unit (CDU) power supplies results in loss of the CM audio tone circuit, continuous illumination of the MASTER ALARM lights, continuous alarm signals to the SWS, continuous alarm output to PCM, and loss of the status lights listed in paragraph 2.10.3.6.

2.10.4.3 Normal/Boost/Ack Switch

In the BOOST position the panel 1 MASTER ALARM switch light will not function, therefore, the panel 3 MASTER ALARM switch light is used exclusively to reset the master alarm/audio tone circuits.

2.10.5 SYSTEM STATUS LIGHT DATA

The following list provides the lamp trigger values and associated information for all status lights on panel 2.

SYSTEMS DATA

System Status Lights	Trigger Values	Other Indications (Lights, Gauges, Meters, etc.)	CM or SM	Remarks
BMAG 1	1. Any BMAG <168°F 2. Any BMAG >172°F	None	CM	If activated, the BMAG POWER switch should be left in WARM UP until light is extinguished.
BMAG 2	Same as BMAG 1		CM	
CO_2 PP HI	At 7.6 mm Hg	PART PRESS CO_2 meter (panel 2)	CM	
PITCH GMBL 1	Overcurrent conditions dependent on time and temperature.	Excessive current can be detected on DC AMPS meter with DC INDICATORS sw on SM SOURCE 1, 2 or 3	SM	
YAW GMBL 1	Same as PITCH GMBL 1	Same as PITCH GMBL 1	SM	
PITCH GMBL 2	Overcurrent conditions dependent on time and temperature.	Same as PITCH GMBL 1	SM	
YAW GMBL 2	Same as PITCH GMBL 2	Same as PITCH GMBL 1	SM	
CRYO PRESS	1. Tank 1 O_2 <800 psia 2. Tank 1 O_2 >950 psia	CRYOGENIC TANKS - PRESSURE-O_2-1 meter (panel 2)	SM	Cryo press signal provided to memory.
	3. Tank 2 O_2 - same as tank 1 O_2	CRYOGENIC TANKS - PRESSURE-O_2-2 meter (panel 2)	SM	
	4. Tank 1 H_2 <200 psia 5. Tank 1 H_2 >270 psia	CRYOGENIC TANKS - PRESSURE-H_2-1 meter (panel 2)	SM	
	6. Tank 2 H_2 - same as tank 1 H_2	CRYOGENIC TANKS - PRESSURE-H_2-2 meter (panel 2)	SM	
GLYCOL FLOW LOW	Primary glycol flow <135 lbs/hr		CM	Glycol flow low signal provided to memory.

CAUTION AND WARNING SYSTEM

SYSTEMS DATA

System Status Lights	Trigger Values	Other Indications (Lights, Gauges, Meters, etc.)	CM or SM	Remarks
CM RCS 1	1. He manf press <260 psia 2. He manf press >330 psia	CM RCS - PRESS-MANF meters (panel 2)	CM	Light functional only when CAUTION/ WARNING - CSM-CM switch is in CM position.
CM RCS 2	Same as CM RCS 1		CM	
SM RCS PSM 1	Fuel tank press >215 psia	SM RCS-FUEL TK PRESS meter (panel 2)	SM	
SM RCS A	1. Pkg temp <75°F 2. Pkg temp >205°F	SM RCS - TEMP PKG meter (panel 2)	SM	
	3. Sec fuel press <145 psia 4. Sec fuel press >215 psia	SM RCS - PRESS-SEC-FUEL meter (panel 2)		
SM RCS B	Same as SM RCS A	Same as RCS A	SM	
SM RCS C	Same as SM RCS A	Same as RCS A	SM	
SM RCS D	Same as SM RCS A	Same as RCS A	SM	
FC 1	1. Skin temp <360°F Skin temp >475°F	FUEL CELL - MODULE TEMP-SKIN meter (panel 3)	SM	FC 1 signal provided to memory.
	2. Cond exh <150°F Cond exh >175°F	FUEL CELL - MODULE TEMP-COND EXH meter (panel 3)		Meter reads 155°F at 150°F
	3. At pH factor >9	pH HI event talk back indicator (panel 3). FC1 or 3 input selected by FUEL CELL INDICATOR sw (panel 3)		Event indicator (elec/mech) pH HI, is activated at lamp trigger value.
	4. H_2 or O_2 reactant valve closed	FUEL CELL REACTANTS talkback indicator (panel 3)		
FC 3	Same as FC 1		SM	FC 3 signal provided to memory.
INV 1 TEMP HI	At >190°F	None	CM	

C&WS

SYSTEMS DATA

System Status Lights	Trigger Values	Other Indications (Lights, Gauges, Meters, etc.)	CM or SM	Remarks
O_2 TK 1 HTR TEMP	At >356°F	Position 10C on system test meter (panel 101)	SM	O_2 tk 1 and 2 htr temp signals are provided to memory.
O_2 TK 2 HTR TEMP	At >356°F	Position 11C on system test meter (panel 101)	SM	
SPS PRESS	1. Fuel tk He press <157 psia	SPS PRPLNT TANKS - PRESS-FUEL meter (panel 3)	SM	
	2. Fuel tk He press >200 psia			
	3. Ox tk He press - same as fuel tank He press	SPS PRPLNT TANKS - PRESS-OXID meter (panel 3)		
AC BUS 1	1. At <95±3 vac	AC VOLTS meter (panel 3)	CM	
	2. At >130±2 vac			Overvoltage automatically disconnects inverter from bus.
AC BUS 2	Same as AC BUS 1		CM	
SM PWR DISCON	1. Forward current >75 amps (time for disconnect decreases with current increase)	DC INDICATORS - SM SOURCE 1, 2, 3 and DC AMPS meter (panel 3)	SM	
	2. Reverse current >4 amps for 1 to 10 seconds			
AC BUS 1 OVERLOAD	1. 3Ø at 27 amps for 15±5 seconds	AC VOLTS meter and excessive dc current on DC AMPS meter with DC INDICATORS on SM SOURCE 1, 2 or 3 (panel 3)	CM	Auto disconnect of inverter from bus.
	2. 1Ø at 11 amps for 5±1 seconds			
AC BUS 2 OVERLOAD	Same as AC BUS 1 OVERLOAD	Same as AC BUS 1 OVERLOAD	CM	Auto disconnect of inverter from bus.

SYSTEMS DATA

System Status Lights	Trigger Values	Other Indications (Lights, Gauges, Meters, etc.)	CM or SM	Remarks
CMC	1. Loss of prime power 2. Scaler fail - if scaler stage 17 fails to produce pulses 3. Counter fail - continuous requests or fails to happen following increment request 4. SCADBL - 100 pps scaler stage >200 pps 5. Parity fail - accessed word, whose address is octal 10 or greater, contains even number of ones 6. Interrupt too long or infrequent - 140 to 300 ms 7. TC trap - too many TC or TCF instructions, or TCF instructions too infrequent 8. Night watchman - computer fails to access address 67 within 64 milli-sec to 1.92 seconds 9. V fail - 4v supply >4.4v 4v supply <3.6v 14v supply >16.0v 14v supply <12.5v 28v supply <22.6v 10. If oscillator stops 11. Stand by	CMC light illuminated (LEB-122) RESTART & PGNS lights illuminated if restart and standby exist in CMC	CM	Items 5 through 11 will cause restart in the CMC.

C&WS

SYSTEMS DATA

System Status Lights	Trigger Values	Other Indications (Lights, Gauges, Meters, etc.)	CM or SM	Remarks
CREW ALERT	Activated by real-time command from MSFN through the UDL	None	N/A	System status light is extinguished by ground command or INHIBIT switch (panel 201)
MN BUS A UNDERVOLT	At 25.60±0.1 vdc	DC INDICATORS switch and DC VOLTS meter (panel 3)	CM	
MN BUS B UNDERVOLT	At 25.60±0.1 vdc	DC INDICATORS switch and DC VOLTS meter (panel 3)	CM	
ISS	1. IMU fail a. IG servo error >2.9 mr for 2 seconds b. MG servo error >2.9 mr for 2 seconds c. OG servo error >2.9 mr for 2 seconds d. 3200 cps <50% e. 800 cps wheel supply <50%	ISS light illuminated (LEB-122)	CM	IMU fail signal inhibited by CMC when in coarse align mode.
	2. PIPA fail a. No pulse during 312.5-ms period b. If both + and - pulses occur during 312.5-ms period c. If no + and - pulses occur between 1.28 to 3.84 seconds	PIPA fail will also illuminate PGNC lights and PROGRAM light on DSKY	CM	PIPA fail signal inhibited by CMC except during CMC controlled translation or thrusting.
	3. CDU fail a. CDU fine error >1.0v rms b. CDU coarse error >2.5v rms c. Read counter limit >160 cps d. Cos (θ - ψ) <2.0v e. +14 vdc supply <50%		CM	CDU fail signal inhibited by CMC during CDU zero mode.

CAUTION AND WARNING SYSTEM

SYSTEMS DATA

System Status Lights	Trigger Values	Other Indications (Lights, Gauges, Meters, etc.)	CM or SM	Remarks
C/W	1. Caution detection unit power supply a. At <+11.7 or >+13.9 vdc (for +12 vdc power) b. At <-11.7 or >-13.9 vdc (for -12 vdc power)	None	CM	C/W light monitors caution detection unit and 5 vdc memory unit power supplies
	2. Memory/Tone amp power supplies (14 vdc and 5 vdc) a. Loss of 5 vdc power supply (dependent on 14 vdc supply)	None	CM	
O_2 FLOW HI	1.0 lb/hr for 16.5 sec	O_2 FLOW meter (panel 2)	CM	
SUIT COMPRESSOR	ΔP across inlet and outlet <0.22 psia	SUIT COMPR ΔP meter (panel 2)	CM	

C&WS

SECTION 2

SUBSECTION 2.11

MISCELLANEOUS SYSTEMS DATA (CSM EXPERIMENTS)

2.11.1 INTRODUCTION

During the Skylab missions, many experiments are performed aboard the orbital assembly. The categories are Engineering and DOD (MXXX or DXXX), Medical (MXXX), Scientific (SXXX), and Technological (TXXX). Only those experiments that are located and performed aboard the Apollo CSM are described in this section. The effectivity for each experiment is designated in the description.

The description of the experiments will contain the objective, physical description of the experiment module, power interface and requirements, controls and displays, effectivity, general procedures, and crew involvement. For a detailed description and operations for each experiment, refer to the Skylab Experiments Handbook; for crew operational procedures, refer to Volume II of this Skylab Operations Handbook.

2.11.2 D008 RADIATION IN SPACECRAFT (Figure 2.11-1)

The D008 experiment, Radiation in Spacecraft, is effective on SKYLAB 2 (CSM 116). The objectives of D008 are to test advanced active and passive dosimetry instruments and techniques, provide experimental tests of theoretical computer codes, and to accumulate information of the command module interior radiation environment.

The equipment consists of one active dosimeter (5.25 pounds, 7.12 by 5 by 4 inches) and one passive dosimeter (0.50 pound, 6 by 1.56 inches) mounted on a pallet in the upper equipment bay. Four additional passive dosimeters are located in the crew compartment. The sensing head of the active dosimeter is removable for remote sensing and draws 1.5 watts.

The active dosimeter will operate through the entire mission. When performing the prelaunch procedures, power will be applied as the EXP PWR circuit breaker (CB23) is closed (in) and the SCI INST switch on RHEB panel 227 is in the PWR position. The crewman will survey 14 predetermined locations of his body and the CSM interior on four separate occasions. In-flight requirements are data recording and transmission during six revolutions per day (45 minutes per revolution) for 14 days when passing through the South Atlantic Anomaly and cosmic radiation.

The five passive dosimeters require no crew action and will be recovered during the postretrieval period.

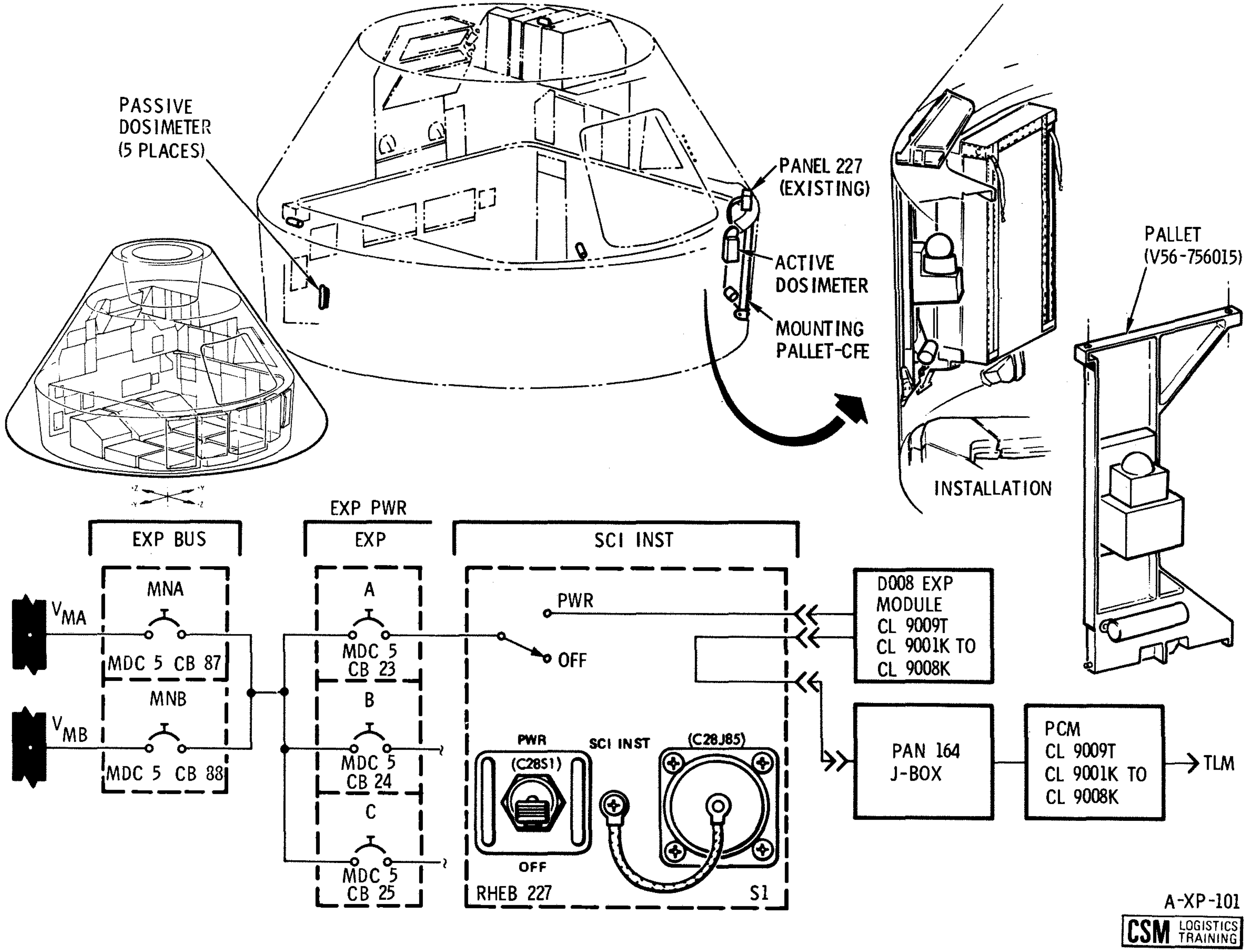


Figure 2.11-1. D008 Radiation in Spacecraft

2.11.3 S015 ZERO G SINGLE HUMAN CELL (Figure 2.11-2)

The S015 experiment, Zero G Single Human Cell, is effective on SKYLAB 2 (CSM 116). The objective is to observe the influence of zero gravity on living human cells and tissue cultures.

The S015 equipment module is 15.5 by 9.05 by 6.5 inches, weighs 24 pounds, and is located in stowage compartment B-6. The module subsystems are a microscope camera and a cytochemical experiment. The module subsystems require 28 vdc, and draw an average of 16 watts, and must be powered throughout the mission.

Upon installation of the experiment module in the CSM, the EXP PWR C circuit breaker (CB25) on MDC 5 is closed (in) and switch S1 on LEB panel 164 is placed to ON. Power will remain on throughout the 28 day mission as the switch S1 is not accessible to the crew. The crewman must check indicator lamps daily; label, rinse, and fix biopack No. 1 at the end of the 4th day; label, rinse, and fix biopack No. 2 at the end of the 10th day.

The S015 equipment module will be recovered during the postretrieval period.

2.11.4 S071/S072 CIRCADIAN RHYTHM, POCKET MICE AND VINEGAR GNAT (Figure 2.11-3)

S071 and S072, Circadian Rhythm of Pocket Mice and Vinegar Gnats, are effective on SKYLAB 3 (CSM 117). The objective of S071 is to determine if the circadian rhythm and activity of pocket mice is affected when in a zero g, constant temperature, and darkness environment. The objective of S072 is to determine if vinegar gnat pupae hatch cycle occurs at periods other than 24 hours in a zero g, constant temperature, and darkness environment.

The S071/072 module is 40 by 24 by 20 inches, weighs 243 pounds, and is installed in the service module bay 1. It contains three subassemblies: the S071 tank with six pocket mice implanted with biotelemeters which transmit activity indicating temperatures; the S072 with four compartments of 180 vinegar gnat pupae with optical eclosion sensors; and the Circadian Data System that is the electrical/electronic interface between the CSM and the PCM. The power required for the S071/S072 module is a maximum of 120 watts for 20 days, and 95 watts for the remainder. Primary control of the module data system is by UDL commands. Secondary or backup control is from RHEB panel 277.

S072 is powered throughout the first 20 days of the mission and S071 power is terminated after 28 days of the mission. The crew will turn the power switches off on RHEB panel 277 when requested by ground control.

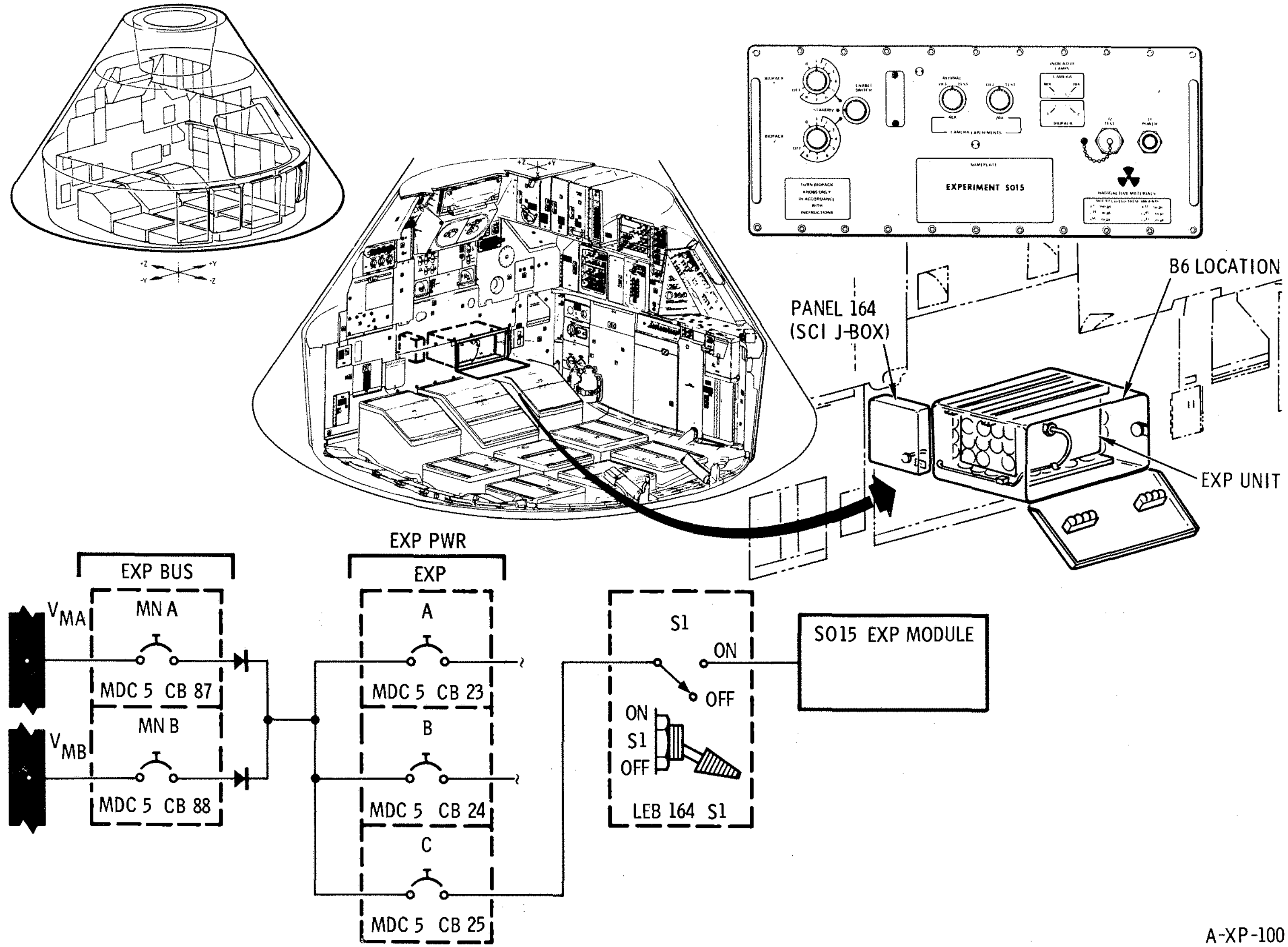


Figure 2.11-2. S015 Zero g Single Human Cell Experiment

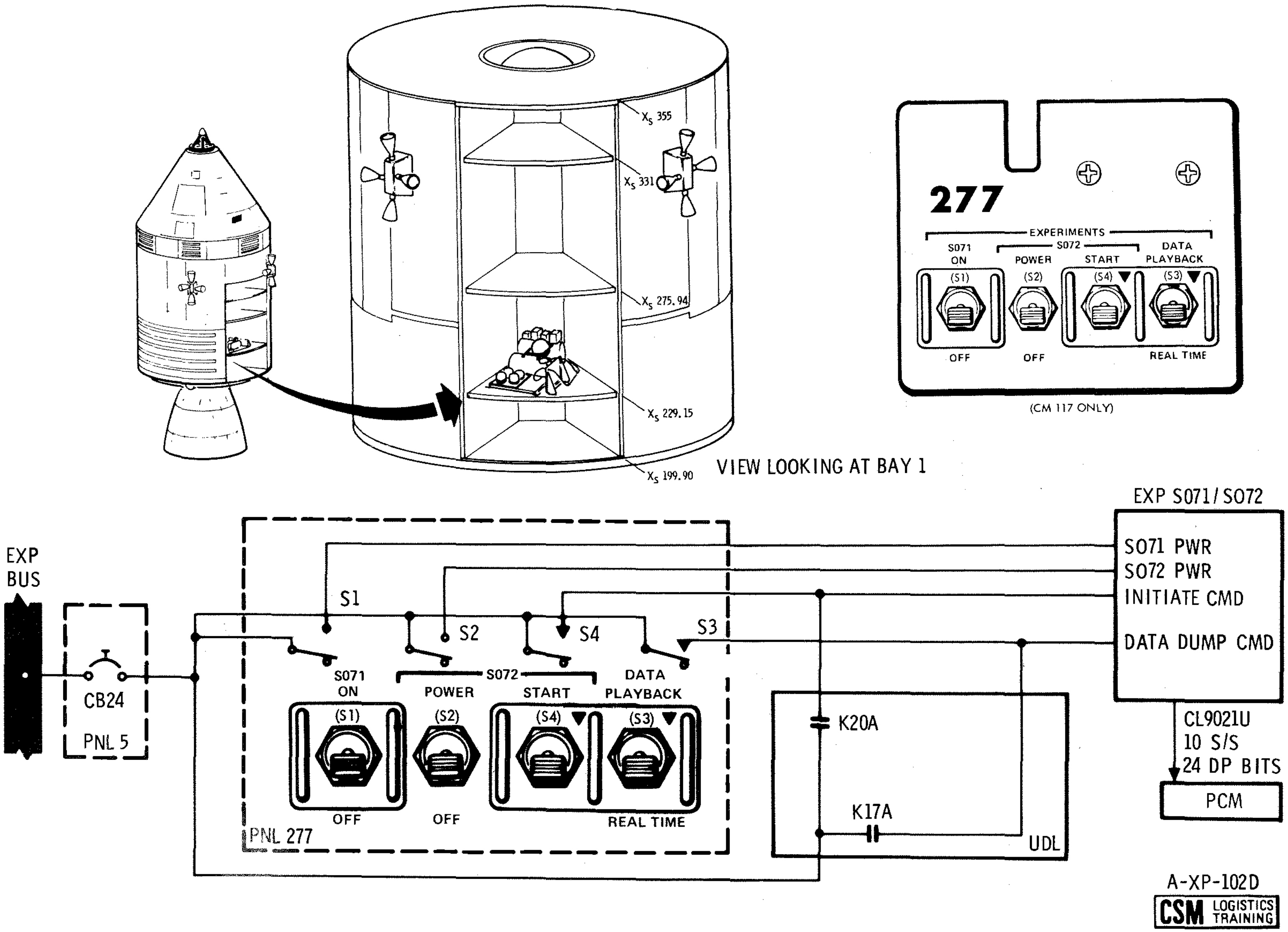


Figure 2.11-3. S071/S072 Circadian Rhythm of Pocket Mice and Vinegar Gnat Experiment

2.11.5 ELECTRON PROTON SPECTROMETER (E/PS)

2.11.5.1 General Specifications

Experiment Objectives:

To monitor electron and proton flux at specific energy levels about the CSM particularly as the CSM passes through the South Atlantic Anomaly.

Power Requirements:

	Detectors	Electronics	Heaters
Peak	1.4 watts	15.6 watts	6 watts

Temperature Range:

Nomenclature	Measurement Point	Survival	Operate
Detectors		-58° to +122°F	-58° to +50°F
Electronics		-58° to +150°F	-13° to +122°F

Field-of-View:

180° spherical acceptance angle.

Data System Interface:

Measurement Identification	Measurement Description	Samples per Second
SK9075K	Electron Proton Spectrometer Data (See figure 2.11-4 for format.)	10

The following listing details the housekeeping parameter shown in figure 2.11-4.

SYSTEMS DATA

Measurement ID	Prime Frame No.	House keeping ID BIT 2	House keeping ID BIT 3	Measurement	Range	Accuracy
SK9111T	1A	0	0	Package temp	-50° to +50°C	±1.5°C
SK9112V	2A	0	0	Detector 1 noise	0 to 100 Kev	±10 Kev
SK9113C	3A	0	0	Detector 1 leakage	0.05μA to 20μA	±0.05μA
SK9122T	4A	0	0	Detector plate temp	-50° to +50°C	±1.5°C
SK9114V	5A	0	1	Detector 2 noise	0 to 100 Kev	±10 Kev
SK9115C	6A	0	1	Detector 2 leakage	0.05μA to 20μA	±0.05μA
SK9123V	7A	0	1	+5 volt monitor	0 to +10 volts	±5 mv
SK9116V	8A	0	1	Detector 3 noise	0 to 100 Kev	±10 Kev
SK9117C	9A	1	0	Detector 3 leakage	0.05μA to 20μA	±0.05μA
SK9125V	10A	1	0	+8 volt monitor	0 to +10 volts	±5 mv
SK9126V	11A	1	0	-8 volt monitor	*	*
SK9128V	12A	1	0	+25 volt monitor	0 to +55 volts	±27 mv
SK9129V	13A	1	1	350 volt monitor	0 to 505 volts	±250 mv
SK9127V	14A	1	1	-15 volt monitor	*	*
SK9124V	15A	1	1	-5 volt monitor	*	*
SK9130V	16A	1	1	Discrim ref mon	0 to 6.002 volts	±3 mv
SK9111T	1B	0	0	Package temp	-50° to +50°C	±1.5°C
SK9118V	2B	0	1	Detector 4 noise	0 to 100 Kev	±10 Kev
SK9119C	3B	1	0	Detector 4 leakage	0.05μA to 20μA	±0.05μA
SK9122T	4B	1	1	Detector plate temp	-50° to +50°C	±1.5°C
SK9120V	5B	0	0	Detector 5 noise	0 to 100 Kev	±10 Kev
SK9121C	6B	0	1	Detector 5 leakage	0.05μA to 20μA	±0.05μA
SK9123V	7B	1	0	+5 volt monitor	0 to +10 volts	±5 mv
SK9131X	8B	1	1	Heater monitor	On/off	*
SK9131X	9B	0	0	Heater monitor	On/off	*
SK9125V	10B	0	1	+8 volt monitor	0 to +10 volts	±5 mv
SK9126V	11B	1	0	-8 volt monitor	*	*
SK9128V	12B	1	1	+25 volt monitor	0 to +55 volts	±27 mv
SK9129V	13B	0	0	350 volt monitor	0 to 505 volts	±250 mv
SK9127V	14B	0	1	-15 volt monitor	*	*
SK9124V	15B	1	0	-5 volt monitor	*	*
SK9130V	16B	1	1	Discrim ref mon	0 to 6.0020 volts	±3 mv

CSM EXPERIMENTS

MISC

WORD LOCATION →

PRIME FRAME NUMBER ↓	1	2	3	4	5	6	7	8	9	10	11	12	13
1	PRIME FRAME SYNC	DET 1 ELEC	DET 1 PROT	DET 2 ELEC	DET 2 PROT	DET 3 ELEC	HOUSE KPG 1A	DET 3 PROT	DET 4 ELEC	DET 4 PROT	DET 5 PROT	DET 5 PROT	HOUSE KPG 1B
2							2A						2B
3							3A						3B
4							4A						4B
5							5A						5B
6							6A						6B
7							7A						7B
8							8A						8B
9							9A						9B
10							10A						10B
11							11A						11B
12							12A						12B
13							13A						13B
14							14A						14B
15							15A						15B
16	PRIME FRAME SYNC	DET 1 ELEC	DET 1 PROT	DET 2 ELEC	DET 2 PROT	DET 3 ELEC	16A	DET 3 PROT	DET 4 ELEC	DET 4 PROT	DET 5 PROT	DET 5 PROT	16B

← 13 SECONDS →

MAIN FRAME = 208 SECONDS

A-XP-108

CSM LOGISTICS TRAINING

Figure 2.11-4. Electron Proton Spectrometer Main Frame Format

Sensitivity Range:

Detector No.	Electrons (Mev) (threshold energy)	Protons (Mev)
1	0.45	10 to 20
2	1.22	20 to 40
3	2.38	30 to 50
4	3.90	40 to 80
5		80 to 120
		>120

Operational Modes:

The various modes in which the E/PS can be configured are described in the following matrix.

Mode	Power Switch	UDL Command		Remarks
		Electric Power	Detector Power	
Off	OFF	OFF	OFF	No power applied to E/PS.
Standby 1	ON	OFF	OFF	Power applied to E/PS heater only.
Standby 2	ON	ON	OFF	Power applied to heater and electronics circuits. Selected housekeeping measurements provide data.
Operate	ON	ON	ON	Power applied to detectors. Total system is operational.

Operating Time Requirements:

The E/PS shall be configured to the Operate mode prior to launch and shall remain in this mode for the duration of the mission. Any requirement to operate the E/PS in either Standby 1 or Standby 2 mode shall be based on real time ground decisions.

2.11.5.2 Experiment Description

The E/PS provides the capability to monitor radiation about the CSM in real time for the duration of the mission. The updata link command feature enables the Operate, Standby 1 and Standby 2 modes to be selected from the ground after the power switch is thrown in the CSM. The electron and protron flux about the South Atlantic Anomaly is of particular interest.

MISC

2.11.5.3 Equipment Description (figure 2.11-5)

The E/PS is mounted on the adapter between the CM and SM. It has five solid state detectors whose output pairs into ten separate level discriminators (figure 2.11-6). The output of each of these discriminators in turn is fed into a 24-stage counter. The number of events within each counter is periodically shifted into the digital data compressor where the **seven** most significant bits plus a **five** bit scale count and single bit word sink is assembled for subsequent processing in the digital multiplexer. (See figure 2.11-7 for word formats.) Besides the compressed counts from each of the channel counters, there are thirty-one analog housekeeping measurements inserted into the overall format. (See figure 2.11-4.) A listing of these parameters is included in the data interface paragraph.

The updata link switching capability allows individual control of power to the detector and low voltage power supplies.

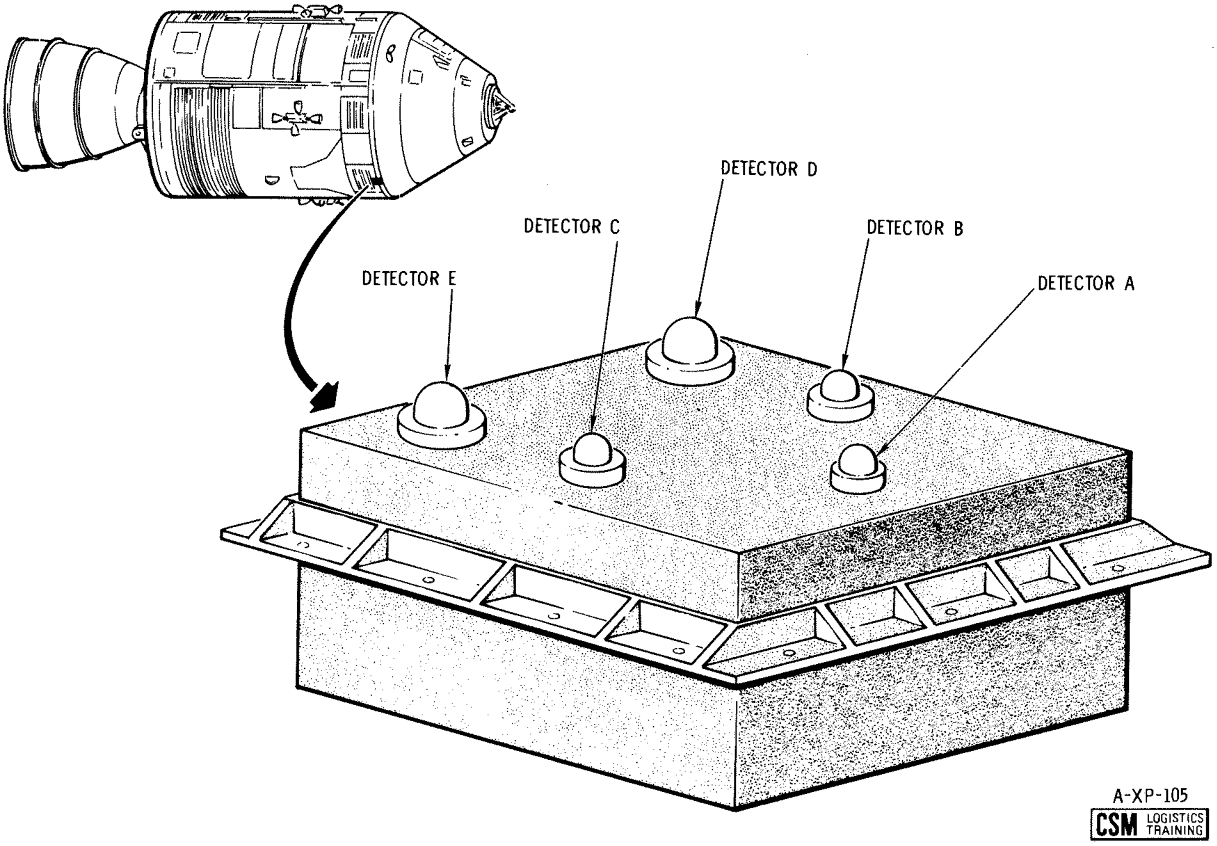


Figure 2.11-5. Electron-Proton Spectrometer

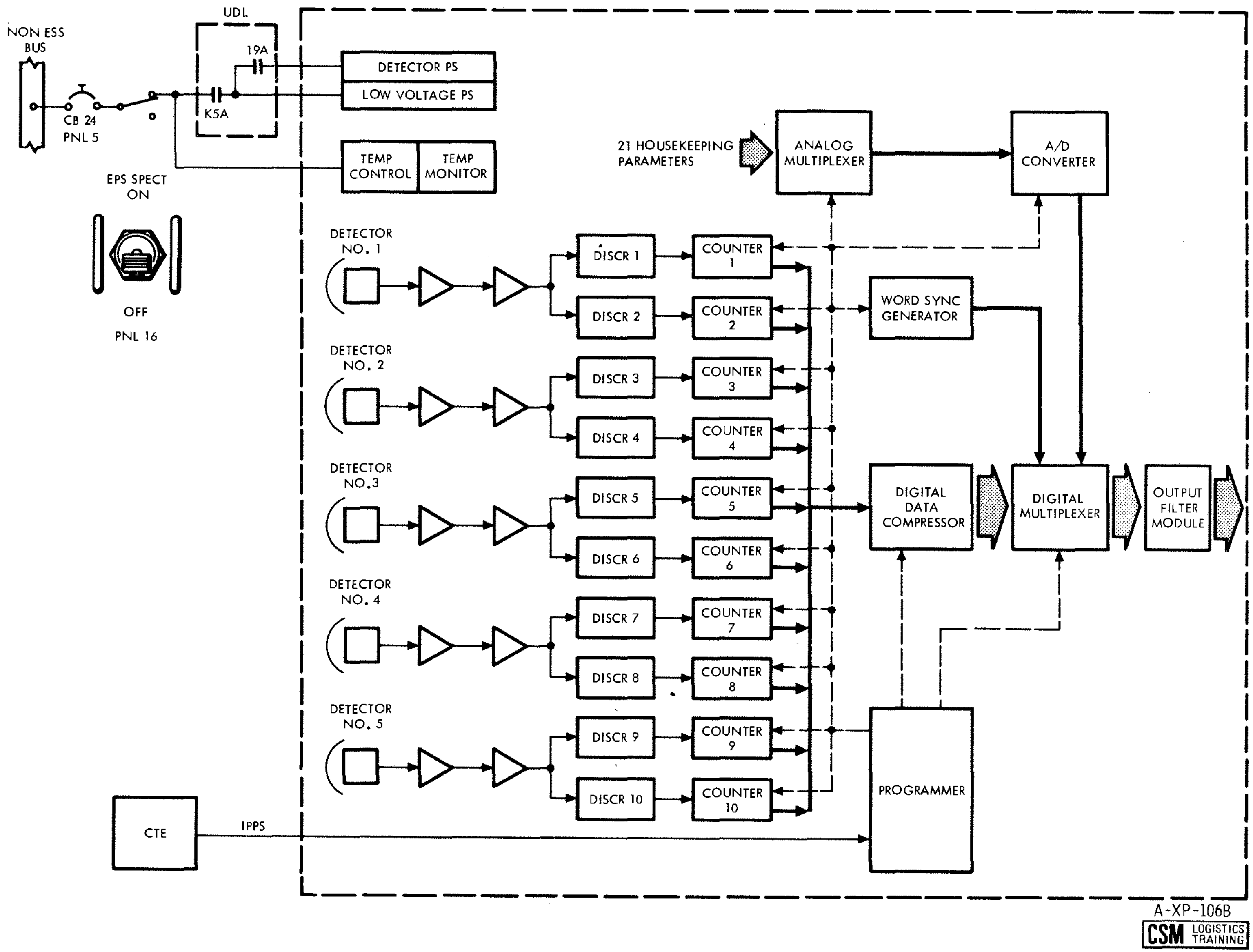
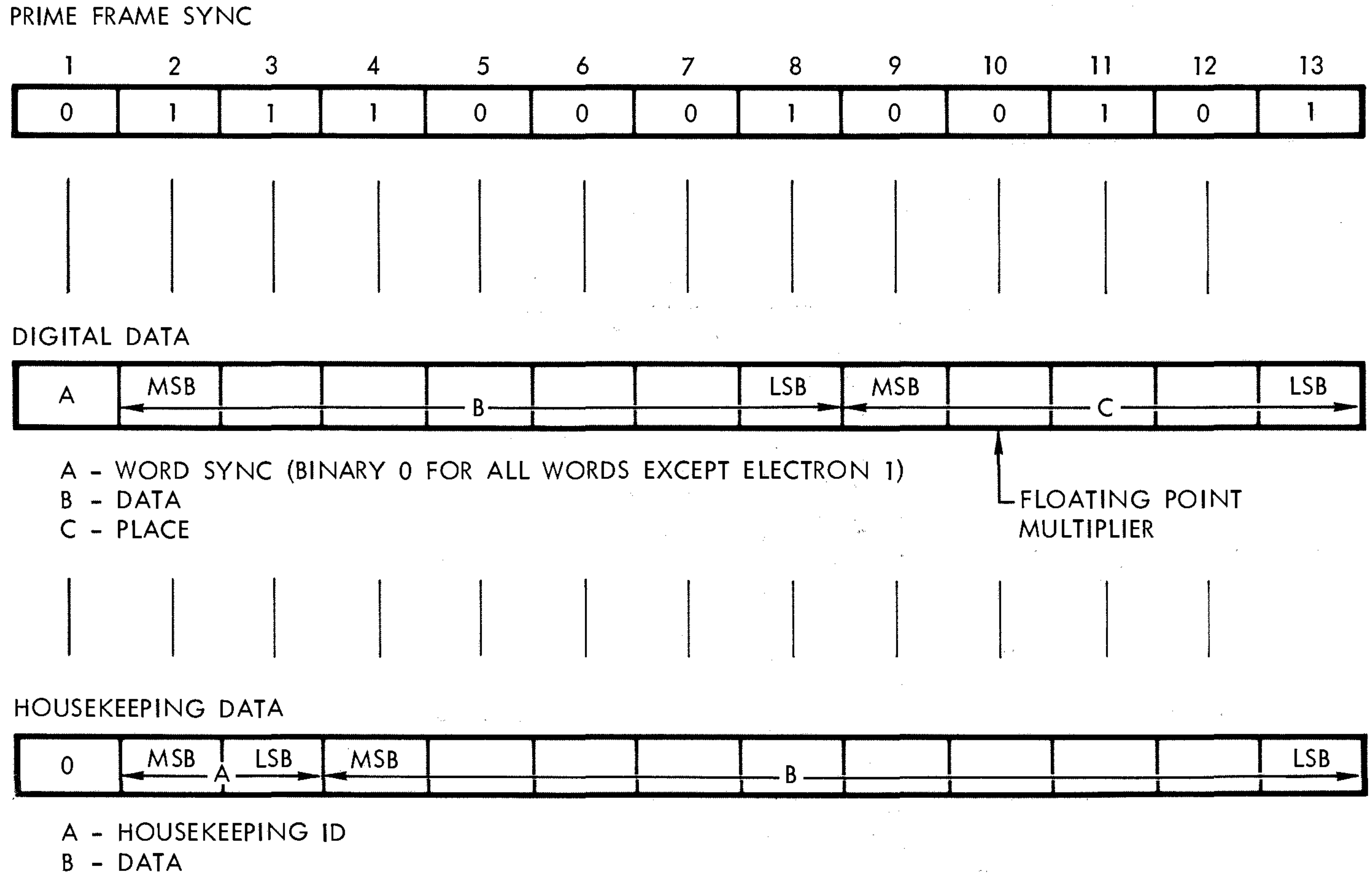


Figure 2.11-6. Electron Proton Spectrometer Functional Block Diagram

MISC



A-XP-107A
CSM LOGISTICS TRAINING

Figure 2.11-7. Electron Proton Spectrometer Digital Word Format

SECTION 2

SUBSECTION 2.12

CREW PERSONAL EQUIPMENT

2.12.1 INTRODUCTION

This section contains the description and operation of Contractor- and NASA-furnished crew personal equipment and miscellaneous stowed equipment that is not described in other sections of the handbook. All major items are identified as Contractor-furnished equipment (CFE) or Government-furnished (NASA) property (GFP - synonymous with GFE).

A brief outline of the arrangement of this section is as follows:

A. Stowage item lists (paragraph 2.12.1.1)
B. Spacesuit and related equipment (paragraph 2.12.2)
    1. A7L B spacesuit
        a. Bioinstrumentation
        b. Fecal containment system (FCS)
        c. Urine collection and transfer assembly (UCTA)
        d. Constant wear garment (CWG)
        e. Flight coveralls
        f. Protective garment, hypotensive, pressure assembly
        g. Communications carrier
        h. CWG electrical adapter
        i. Communication cable with control head
        j. Pressure garment assembly (PGA)
            (1) Donning and doffing
            (2) Operational modes
        k. Miscellaneous personal equipment
    2. Oxygen hose assembly (paragraph 2.12.2.2.1)
        a. Coupling and screen caps
    3. EMU maintenance kit
    4. Integrated thermal micrometeoroid garment (ITMG)
    5. Liquid cooled garment (LCG)
    6. IVA umbilical (paragraph 2.12.2.4)
C. G-load restraints (paragraph 2.12.3.1)
    1. Crewman restraint harness
    2. Handholds
    3. Hand bar
    4. Heel restraints
D. Zero-G restraints (paragraph 2.12.3.2)
    1. Hand straps
    2. G&N station restraint
    3. Sleep station restraints
    4. Flight data restraints
    5. Restraint straps
    6. Utility straps
    7. Probe straps
E. Internal sighting and illumination aids (paragraph 2.12.4.1)
    1. Window shades
    2. Internal view mirrors

CPE

3. Crewman optical alignment sight (COAS)
4. Window markings
5. Telescope sun filters

F. External sighting and illumination aids (paragraph 2.12.4.2)
   1. Docking spotlight

G. Mission operational aids (paragraph 2.12.5)
   1. Flight data file
   2. Crewman toolset
      a. Description and use
   3. Cameras (paragraph 2.12.5.3)
      a. 16 mm data acquisition camera (DAC)
      b. 70 mm Hasselblad electric camera (HEC)
   4. Automatic spotmeter (paragraph 2.12.5.3.3)
   5. Accessories and miscellaneous equipment (paragraph 2.12.5.4)
      a. Temporary stowage bags
      b. Pilots preference kit (PPK)
      c. Fire extinguisher
      d. Oxygen masks
      e. Tape roll
      f. Two-speed timer
      g. Accessory bag
      h. Headrest pad
      i. Grounding cable
      j. Insulation blanket
      k. Polychoke oriface
      l. O_2 Vent and hose
      m. Probe activation cable
      n. CB activation device
   6. D-C utility receptacles (paragraph 2.12.5.5)

H. Crew life support (paragraph 2.12.6)
   1. Crew water (paragraph 2.12.6.1)
      a. Drinking water
      b. Return water containers
      c. Food preparation water
      d. Gas separator cartridge
   2. Food system (paragraph 2.12.6.2)
      a. Types
      b. Stowage
      c. Contingency feeding
   3. Waste management system and supplies (paragraph 2.12.6.3)
      a. General description (paragraph 2.12.6.3.1)
      b. Urine subsystem (paragraph 2.12.6.3.2)
         (1) Urine transfer system (UTS)
         (2) Hose and filter
         (3) Operation
      c. Fecal subsystem (paragraph 2.12.6.3.3)
   4. Personal hygiene

I. Medical supplies and equipment (paragraph 2.12.7)
   1. Bioinstrumentation harness assembly
   2. Medical accessories kit
   3. IMSS resupply and return system

J. Radiation monitoring and measuring equipment (paragraph 2.12.8)
   1. Dosimeters
   2. Radiation survey meter (RSM)

K. Stowage (paragraph 2.12.9)
   1. Containers
   2. Aft bulkhead lockers
   3. Decals
   4. Launch/return aft bulkhead stowage configuration
   5. Stowage drawings
   6. CG control

L. Postlanding recovery aids (paragraph 2.12.10)
   1. Postlanding ventilation (PLV) ducts
   2. Swimmer umbilical and dye marker
   3. Recovery beacon
   4. Snagging line
   5. Survival kits
      a. Rucksack 1
      b. Rucksack 2

M. Rescue vehicle
   1. Crew couches and harness assemblies
   2. Experiment return pallet assembly
   3. Urine chiller tie-down assembly
   4. Ballast assemblies
   5. Oxygen umbilicals and hose connectors
   6. Crew communication umbilicals and tee adapters
   7. Emergency oxygen masks and hose connectors
   8. Postlanding ventilation air direction ducts
   9. Probe and drogue modifications

2.12.1.1 Skylab Crew Equipment Stowage Items

On the following pages is an alphabetical listing of the Skylab crew and miscellaneous equipment, stowed at launch and returned or transferred, that will be described in this section. Only items to be returned and are not described are listed in paragraph 2.12.9.4.

The listings apply to SL-2 (CSM-116) only, but the majority of the equipment will also be on SL-3 (CSM-117)* and SL-4 (CSM-118)*.

CPE

*Refer to Skylab stowage list

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Adapter, CWG electrical T w bag		X	4	4	12 x 3 x 2	203	0.4	2.12.2
Adapter, urine hose to UCTA		X	1	1	4.5 x 2 x 1.5	0058	0.2	2.12.6
Bag, accessory		X	3	3	15 x 10D	0014	0.31	2.12.5
Bag, gas separator cart	X		1	0	10 x 1.7D		0.1	2.12.6
Bag, helmet stowage		X	3	3	9.3 x 9.3 x 2.5	0014	0.71	2.12.2
Bag, PGA stowage	X		3	3	33 x 22 x 0.5	1032	1.5	2.12.2
Bag, probe stowage	X		1	0	12 x 12 x 4	1048	2.3	2.12.3
Bag, TV mount	X		1	0	9 x 5D		0.2	2.12.5
Bags, temp stowage	X		3	1	36 x 13 x 1	1047	1.7	2.12.5
Bag, waste stowage	X		1	1	14.5 x 10 x 9		2.0	2.12.6
Battery, HEC		X	*	*	1.9 x 1.4D	0127	0.3	2.12.5
Battery, spotmeter		X	*	*	2.1 x 1.5D	0134	0.2	2.12.5
Bladder assembly, centrifical system	X		3	3		0600	0.84	2.12.6
Bulb, COAS spare	X		1	1	0.8 x 0.6	1053	0.02	2.12.4
Cable, docking probe aux	X		1	0	108	1056	0.2	2.12.6
Cable assembly, B/U waste dump	X		1	0	12	1081	0.2	2.12.5
Cable, CM short power (DAC)		X	1	0	112 x 0.50	113	0.23	2.12.5
Cable, grounding	X		1	0	4D x 1.5	1128	0.1	2.12.5
Camera, color TV and accessories		X	*	0	4.5 x 6.64 x 11.39 (TV camera only)	1201	*	2.8 (TLCM)
Camera, 70 mm electric Hasselblad		X	1	1	5 x 5 x 4	120	3.1	2.12.5

*Refer to Skylab stowage list

CPE

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Camera, 16 mm data acquisition (DAC)		X	1	0	6.4 x 5.4 x 4.8	100	1.8	2.12.5
Canister, film		X	*	1	8.7 x 8.6 x 7.5	301	15.34	2.12.5
Cap, aux dump (B/U) nozzle pressure	X		1	0	1 x 1.25D		0.20	2.12.6
Cap, hose screen, w bag	X		3	0		1149	0.20	2.12.2
Cassette, 16 mm DAC		X		28	6.5D x 1	0103	1.2	2.12.5
Chlorination items	X		*	0				2.7
Clamps, UCTA		X	3	3	3 x 2.5 x 0.5	0013	0.03	2.12.2
Clip, data card		X	6	6	1.9 x 2.25 x 0.95	0168	0.10	2.12.5
COAS	X		1	1				2.12.4
Comm cable (CCU)	X		2	2	87	1003		
Comm cable (CCU) (1 spare)	X		2	2	133	1006	3.6	2.12.2
Communication carrier (snoopy helmet)		X	3	3	5 x 5 x 5	0023	1.5	2.12.2
Container, aux dump WMS B/U	X		1	1	5.8 x 5 x 1.8	1183	0.4	2.12.6
Container, cryo atmos cont vlv & hose	X		1	0	11 x 6D		0.3	2.12.5
Container, DAC mount	X		1	0	6.5 x 6 x 1.5	1176	0.9	2.12.5
Container, ESE tape		X	0	8	13.5D x 2.1	0314	2.8	2.12.5
Container, CM food		X	1	1		0209	4.2	2.12.7
Container, IVA umb	X		1	0	17 x 12 x 8	1174	1.0	2.12.2
Container, MDA umb	X		1	0	19 x 5D	1172	0.3	2.12.5
Container, MO 71/73	X		6	6		1300		2.12.9
Container, PCU	X		2	0		1170		2.12.2
Container, PGA elec conn cover	X		1	0	6.25 x 4.8 x 3.5		0.30	2.12.2

*Refer to Skylab stowage list

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Container, 70 mm film mag	X		1	1	7 x 4 x 3.5	121	0.4	2.12.5
Container, 16 mm film mag	X		7	7	5.8 x 3.8 x 3	1182	0.3	2.12.5
Container, SOP	X		2	0		1171		2.12.2
Container, urine filter	X		1	1	5.5 x 2.75 x 1.75	1166	0.2	2.12.6
Container, urine hose	X		1	0	12 x 5 x 4	1179	0.54	2.12.6
Container, UTS	X		1	1	6 x 3 x 3	0036	0.5	2.12.6
Contingency resupply	X		2	0	12 x 12 x 6	245	25.0	
Control head (CCU) w bag	X		1	1	11.6 x 2.8 x 2.2	1002	1.1	2.12.2
Coupling, oxygen hose w bag	X		3	0	3 x 2.16D	1022	0.6	2.12.2
Cover, PGA elec conn protective		X	3	0	1.5 x 1.5D	0202	0.2	2.12.3
Coveralls, flight		X	3	3	13 x 6.5 x 4	0078 0079	2.8	2.12.2
Curtain, debris closeout	X		1	1	36 x 10 x 0.25	1168	0.7	2.12.3
Dosimeters, passive		X	9	9	2.5 x 1.8 x 0.25	0700	0.01	2.12.8
Dosimeters, personal		X	7	7	3.1 x 2.2 x 0.8	0701	0.38	2.12.8
Ducts, PLV w bag	X		3	3	3D x 1	1028	0.10	2.12.10
Eartube, universal		X	3	0	3 x 0.25	1200	0.01	2.12.2
Exerciser, inflight		X	1	0	8 x 3.5D	165	1.4	2.12.5
Fecal/vomitus return bundle		X	0	*		0600		2.12.9
Fecal/vomitus bag, contingency		X	18	12	15.1 x 9.2 x 0.2	0600	0.83	2.12.6

*Refer to Skylab stowage list

CREW PERSONAL EQUIPMENT

CPE

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Filter, high density sun (sextant)		X	2	2	3D X 1	0906	0.13	2.12.4
Filter, urine w bag	X		2	1	4.31 x 1.35D	1024	0.5	2.12.6
Fire extinguisher	X		1	1	9 x 5D	1013	7.5	2.12.5
Flight data file, launch		X	1			184	40.0	2.12.5
Flight data file, return		X		1		184	33.5	2.12.5
Food set, 12 man day		X	1	0		0209	30.0	2.12.6
Food set, 3 man day		X	1	1		0209	7.5	2.12.6
Fuse, DAC		X	1	0	1.7 x 1.20 x 0.5	0162	0.01	2.12.5
Garment, constant wear (CWG)		X	6	3	12 x 5 x 1	080	0.78	2.12.2
Garment, liquid cooled		X	3	0	12.5 x 10 x 3.5	0002	4.48	2.12.2
Gas separator cartridge		X	1	0	6 x 1.5D	0073	0.65	2.12.6
Gloves, EVA (pr)		X	3	0	10 x 6 x 2	0020	2.7	2.12.2
Harness assy, bio-instrumentation		X	3	3	10.9 x 4.6 x 1.0	0201 0202	1.1	2.12.7
Headrest, pad		X	3	3	7 x 4 x 3	0057	1.06	2.12.5
Headset, lightweight		X	3	3	6D x 2	1200	0.6	2.12.2
Heel restraint (pr)		X	3			0004 0005	1.8	2.12.5
Heel restraint bag	X		1	0	8 x 5 x 4		0.3	2.12.3
Hook, snagging line w bag	X		1	1	8 x 6 x 2		1.5	2.12.10

*Refer to Skylab stowage list

CREW PERSONAL EQUIPMENT

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Hose, cryovent valve	X		1	0	60 x 0.5	1151	0.9	2.7 (ECS)
IMSS, res & return sys		X	1	1	11.5 x 10.5 x 6.0	0244	17.2	2.12.7
Kit, data card		X	1	1	10.75 x 8.25 x 2	0170	1.50	2.12.5
Kit, EMU maintenance		X	1	1	5.8 x 4.4 x 2.8	0018	0.58	2.12.2
Kit, Medical access		X	1	1	9.0 x 5.8 x 5	0245	3.5	2.12.7
Kit, pilot's preference		X	3	3	9 x 4 x 2	0166	0.5	2.12.5
Lens, 18 mm Kern (16 mm DAC)		X	1	0	2.78 x 2.71D	0117	0.71	2.12.5
Lens, 75 mm Kern (16 mm cam)		X	1	0	3.68 x 2.74D	106	0.85	2.12.5
LiOH canisters	X		10	2	7.3 x 7.3 x 5.2	1057	5.0	2.7 (ECS)
Life vest		X	3	3	15 x 4 x 2	0025	2.4	2.12.2
Lockers, A1-A3, A5, A7	X		*	*			*	2.12.9
Magazines, 70 mm HEC camera film		X	3	1	3.5 x 3.4 x 3.9	121	1.4	2.12.5
Magazines, 16 mm DAC		X	2	7	5.4 x 3.7 x 0.9	107	1.0	2.12.5
Masks, oxygen w hose		X	3	3	10.3 x 8.3 x 4.8	0016	3.0	2.12.5
Mirror, 16 mm camera right angle		X	1	0	2.2 x 2.14D		0.16	2.12.5
Mount, TV camera	X		1	0	8.75 x 4.38 x 2.6		1.0	2.12.5
Mount, 16 mm DAC	X		1	0	5 x 3 x 2.85	1031	0.9	2.12.5
Otolith test goggles		X	0	1	8 x 6 x 4	0213	0.76	2.12.9
Oxygen hose (CCU)	X		2	2	72 x 3D	1015	7.8	2.12.2
Oxygen hose (CCU)	X		1	1	118 x 4D	1016	11.0	2.12.2
PCU (Part of ALSA)		X	2	0	18.2 x 9.45 x 8.86	0007	26.29	2.12.2
Pencil		X	3	3	5.07 x 0.4D	0155	0.05	2.12.2

*Refer to Skylab stowage list

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Penlights		X	3	3	5.16 x 1.03D	0027	0.34	2.12.2
Pen, marker		X	3	3	5.2 x 0.55D	0154	0.028	2.12.2
Pens, data recording		X	3	3	5.21 x 0.52D	0153	0.05	2.12.2
Polychoke, orifice assembly	X		1	1		1075	0.5	2.12.5
Pouch, food retainer		X	2	2	10 x 4 x 1		0.20	2.12.6
Pouch, temp stow	X		2	0	15 x 12 x 1.00		0.4	2.12.3
Power pack, DAC		X	1			0137	4.3	2.12.5
QD, aux dump (B/U) nozzle	X		1	0	4 x 1D		0.30	2.12.6
QD, water (waste) panel	X		1	0	4.5 x 1D		0.30	2.12.6
Radiation survey meter		X	1	0	9.78 x 2.32D		1.58	2.12.8
Restraint, sleep station	X		3		21 x 4D	1007	3.6	2.12.3
Restraints, flight data (clips, hooks, snaps, bungees)	X		35	0		1156 1161		2.12.3
Ring sight		X	1	0	1.2D x 0.8	1201	0.08	2.12.5
Roll on cuff assembly		X	3	3	2.5 x 2.5 x 1	0037	0.06	2.12.6
Scissors (large)		X	3	3	8.25 x 2 x 2	0030	0.46	2.12.2
Secondary oxygen pack (SOP)		X	2	0	15.5 x 11.3 x 5.5	0009	44.1	2.12.2
Shades, rendezvous window	X		2	2	0.38 x 8.12 x 14.25	1009 1010	1.2	2.12.4
Shade, side hatch	X		1	1	10D x 0.38	1012	1.4	2.12.4
Shades, side window	X		2	2	13.5 x 13.5 x 0.38	1011	1.7	2.12.4

*Refer to Skylab stowage list

CREW PERSONAL EQUIPMENT

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Sight, crew optical alignment (COAS) w filter	X		1	1	8.9 x 4.5D	1052	1.5	2.12.4
Spacesuit, EV		X	3	3			45.4	2.12.2
Spacesuit, helmet		X	3	3	11.25 x 12D	0023	2.68	2.12.2
Spotmeter, automatic		X	1	0	6.3 x 4.17 x 3.86	0133	1.75	2.12.5
Straps, utility	X		15	15	12.8 x 1 x 0.1	1043	0.03	2.12.3
Strap, CCU	X		1	1		1064	0.04	2.12.3
Straps, center couch stow	X		2	0	4 x 2 x 1.5	1085	0.3	2.12.3
Straps, control cable	X		4	4	11 x 1 x 0.1		0.04	2.12.3
Straps, probe stowage	X		2	0	4 x 2 x 1.8	1087	0.3	2.12.3
Sunglasses with pouch		X	3	3	6 x 1.72 x 5.5	0151	0.11	2.12.2
Survival rucksack 1		X	1	1	20.5 x 7.4 x 6.8	0011	35.5	2.12.10
Survival rucksack 2		X	1	1	20.5 x 7.2 x 7	0012	19.9	2.12.10
Tape reel, EREP mag		X	4	4	12.5D x 1.2	0314	8.25	2.12.5
Tape (roll)		X	1	1	5.3D x 1	0157	0.88	2.12.5
Timer, two speed		X	1	1	2.7D x 2	0163	0.5	2.12.5
Tissue dispensers		X	4	4	8.5 x 5 x 3	0082	1.36	2.12.6
Toolset, inflight	X		1	1	12.5 x 4D	1000	5.4	2.12.5
Towels, utility (pack)		X	3	3	12 x 7 x 1.5	0083	0.8	2.12.6
Umbilical, IVA	X		1	0	12 x 12 x 12	1150	33.0	2.12.2
Urine collection & transfer assembly		X	6	6	12 x 12 x 2	0028	0.4	2.12.2

*Refer to Skylab stowage list

CPE

SYSTEMS DATA

Item	CFE	GFP	Launch Qty	Return Qty	Dimensions (inches)	Item No.	Wt Each (lb)	Paragraph
Urine hose	X		1	1	120 x 1D		1.30	2.12.6
Urine transfer system (UTS)		X	3	3	8.5 x 3 x 2.5	0036	0.8	2.12.6
UTS receiver		X	1	1	1.8 x 1.5	0086	0.07	2.12.6
Valve, cryovent atmos control	X		1	0	5.5 x 5.0 x 2	1151	1.3	2.7 (ECS)
Verb/noun list panel indicator		X	1	1		0911	0.2	
Watch with watchband		X	3	3		0149	0.33	2.12.2
Water supply system, return mission	X		*	1	9 x 7 x 7	1139	7.0	2.12.6
Water metering dispenser		X	1	0	7.8 x 0.5 x 2.5	0010	1.13	2.12.6

*Refer to Skylab stowage list

2.12.2 SPACESUITS (Figure 2.12-1)

A spacesuit is an enclosed unit that provides a crewman with a life supporting atmosphere and protective apparel in a space environment. It will be considered in two conditions, intravehicular and extravehicular.

2.12.2.1 Spacesuit Assembly

The intravehicular spacesuit is depicted in figure 2.12-1. The intravehicular condition has two subconditions, unsuited and suited. In the unsuited condition or "shirtsleeve environment," the crewman breathes the oxygen in the spacecraft cabin and wears a bioinstrumentation harness, a communication soft hat for communication, a constant wear garment (CWG) for comfort, flight coveralls for warmth, and booties for zero-g restraint. A CWG adapter is used to connect the communications soft hat (CSH) and the bioinstrumentation harness signals to the communications cable. The comm cable attaches to connectors between panels 300 and 301 to complete the signal flow to the audio center.

In the suited condition, the crewman wears his bioinstrumentation harness, a communication soft hat, a CWG, a pressure garment assembly (PGA) and breathes oxygen within the garment. An oxygen hose assembly delivers the oxygen to the suit and returns it to the ECS. The comm cable connects directly to the PGA for telecommunications signal flow. In this condition there are two ECS modes of operation, ventilated and pressurized.

In the extravehicular (EV) condition, the apparel is called the extravehicular mobility unit (EMU) and consists of a fecal containment system, a urine collection and transfer assembly (UCTA), the bioinstrumentation harness assembly, a liquid-cooled garment (LCG), communications soft hat, extravehicular (EV) gloves, a portable life support system (LSS), oxygen purge system (OPS), an extravehicular visor assembly (EV visor), and associated equipment contained on or within the EMU.

The spacesuit is covered with an integrated thermal micrometeoroid garment (ITMG) (paragraph 2.12.2.2.5).

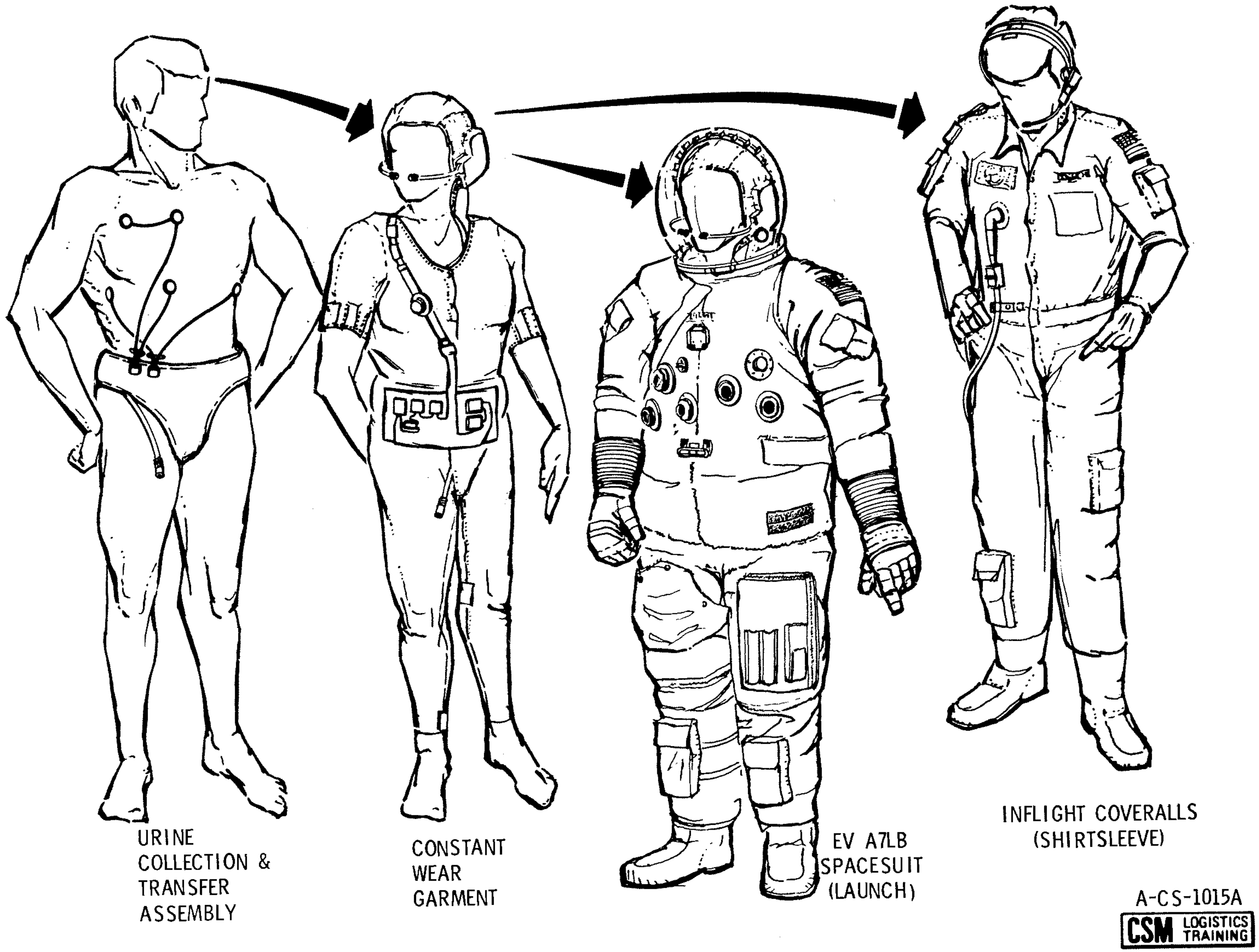


Figure 2.12-1. Spacesuits

2.12.2.1.1 Bioinstrumentation Harness and Biomed Belt (Figure 2.12-2)

The bio-belt (figure 2.12-2) supports four signal conditioners, a dc-dc power converter, and a subject identification module. The bio-belt is a rectangular section of woven teflon cloth which features pockets and restraining strap/snap flap combinations for retaining the above modules. The restraints are configured for module alignment with and attachment to the bio-harness. Each module is color coded as an aid to identification. The dc-dc power converter (red) and the cardiotachometer (CTM) signal conditioner (green) are located on the left side (as worn) of the bio-belt. The electrocardiograph (ECG) signal conditioner (blue), the impedance pneumograph (ZPN) signal conditioner (yellow), the body temperature measuring (TEM) signal conditioner (black), and the subject identification (SID) module (white) are located on the right side of the bio-belt. The bio-belt attaches to either the liquid cooling garment (LCG) or the constant wear garment (CWG) by means of snap fasteners. When the belt is transferred between LCG and CWG, the color-coded electrode harnesses are disconnected at the modules, and the modules are retained in the belt connected to the bio-harness. The bio-harness need not be disconnected from the belt. The electrodes, which are attached to the crewman's skin, are not removed to change garments.

The bio-harness (figure 2.12-2) interfaces with the four signal conditioners (ECG, ZPN, CTM, and TEM), the dc-to-dc converter, and the SID module. The main branch mates with the suit electrical harness through a 15-pin connector. The harness consists of twisted, shielded wire pairs and a terminal block encased as a woven teflon jacket.

2.12.2.1.2 Fecal Containment System

The fecal containment system (FCS) is a chemically treated underpant worn under the LCG during periods of extravehicular activity (EVA). In the event of an uncontrolled bowel movement, the chemicals in the underpant will neutralize the feces. At launch and entry, the fecal containment systems are stowed.

2.12.2.1.3 Urine Collection and Transfer Assembly and UCTA Clamps

The urine collection and transfer assembly (UCTA) functions to transfer the urine from the suited crewman to the suit during emergency urinations. This condition could occur during a "hold" on the launch pad or EVA.

The UCTA consists of a belt, roll-on (external catheter), and a tube leading to the spacesuit urine collection bladder around the right thigh.

The UCTA is donned over the fecal containment system in the EV condition. When doffing the UCTA, the UCTA clamps are used to seal urine in the tube to prevent leakage into the crew compartment. The urine in the UCTA can be drained while it is in the spacesuit or after it is removed. For the procedure, refer to paragraph 2.12.6

2.12.2.1.4 Constant Wear Garment (CWG) (Figure 2.12-2)

The CWG is used as an undergarment for the PGA and provides warmth for the crewman while unsuited in the shirtsleeve environment. As an additional purpose, this garment provides an attach point for the biomed belt.

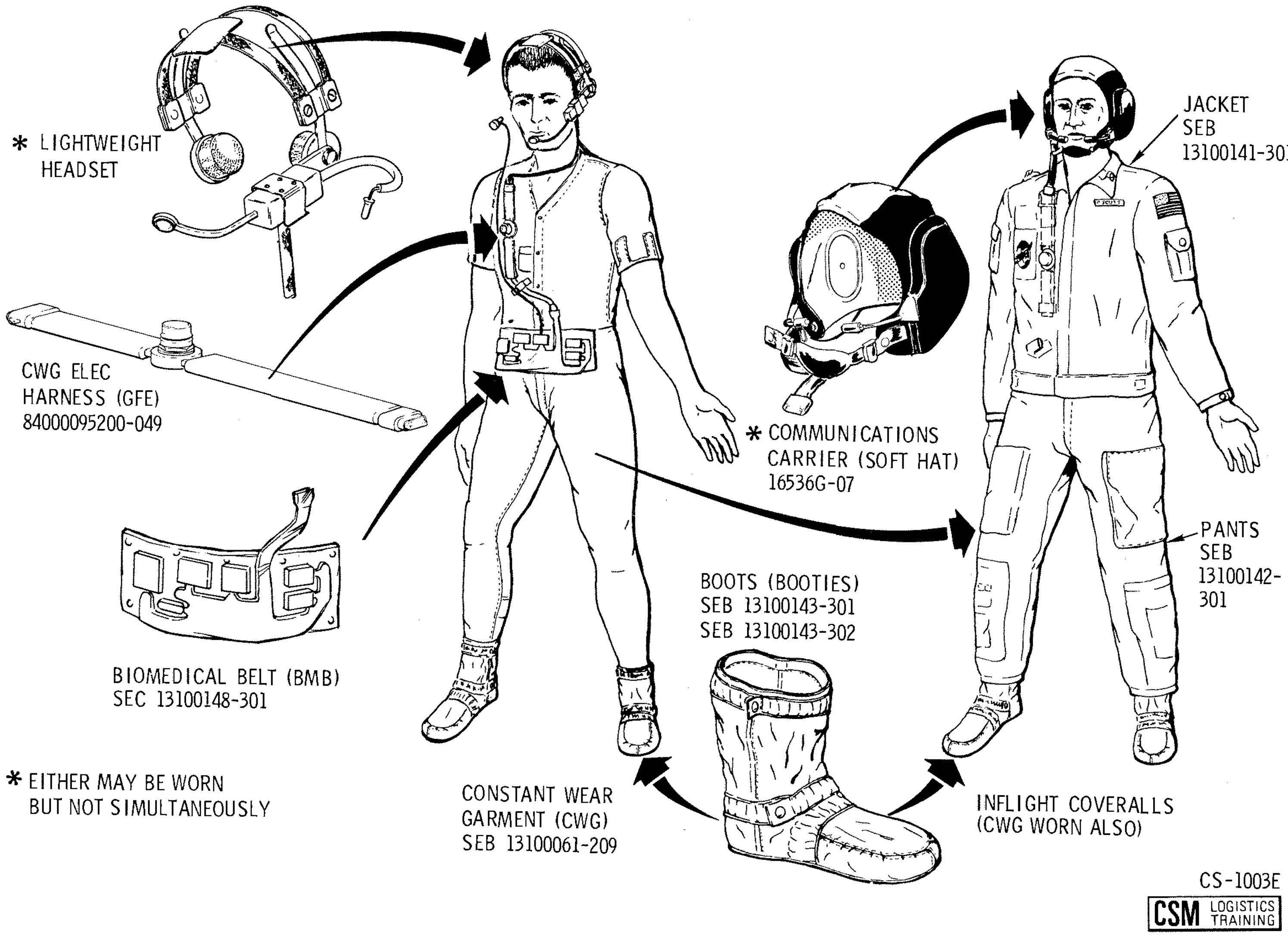


Figure 2.12-2. Shirtsleeve Environment Intravehicular Apparel

The CWG is a porous cloth, one-piece garment similar to long underwear. It has a zipper from the waist to the neck for donning and doffing. An opening in front is for urination and one in the rear for defecation. There are snaps at the mid-section to attach the biomed belt with signal conditioners, and pockets for film packet passive dosimeters at the ankles, thighs, and chest. It also has integral socks.

Three CWGs will be worn aboard by the crew with three being stowed in a locker, allowing one CWG change each.

2.12.2.1.5 Flight Coveralls (Figure 2.12-2)

The flight coveralls help keep the CWG clean, provide additional crewman warmth, and provide stowage for miscellaneous personal equipment while in a shirtsleeve environment. It is a two-piece garment and is stowed at launch and entry. Accessories include a pair of booties with Velcro patches on the soles for restraint.

2.12.2.1.6 Protective Garment, Hypotensive, Pressurized Assembly (PGHPA)

This garment (figure 2-12-3) extends from the ankles to the abdomen. It applies graduated mechanical pressure to the lower torso via a capstan pressure system which extends on the outside of each leg from the ankle up to a point level with the crotch. Mounted on the left frontal thigh area is a 0 to 300 mm Hg pressure gage, a hand bulb and pressure relief valve. These units allow the astronaut to pressurize the assembly to reduce cardiovascular changes during the entry and recovery phases of the mission. These garments are individually sized to each crewman to ensure comfort and mobility in both the pressurized and nonpressurized conditions.

2.12.2.1.6A Communication Soft Hat, Lightweight Headset, and Eartube (Figure 2.12-2)

The communication soft hat is worn at all times in the PGA, for the purpose of communications. Alternate names for it are communications carrier (comm carrier) or "Snoopy" helmet.

The comm soft hat has two earphones and two microphones, with voice tubes on two mounts that fit over the ears. The hat or helmet is cloth and has lacing to adjust the fit to the individual crewman. A chin strap secures the hat to the head. A small pocket on the inside near the right temple will hold a passive dosimeter film packet. An electrical cable with a 21-socket connector will connect to the CWG adapter or PGA.

The lightweight headset is a single microphone and earpiece held on the head by a head band. It can be used in place of the comm soft hat while in a shirtsleeve environment.

The universal ear tube attaches to the lightweight headset earphone. The ear tube is a short length of plastic tube with an ear fitting that conducts sound from the earphone to the ear. It is stowed in a pocket of the inflight coverall.

2.12.2.1.7 Constant Wear Garment Electrical Adapter (Figure 2.12-2)

Communications and bioinstrumentation signals are transmitted to the communications cable by the CWG electrical adapter; it is used when in the shirtsleeve environment.

The CWG electrical adapter has a 61-socket connector pull in the middle and two pigtails, one with a 9-pin connector and one with a 21-pin connector.

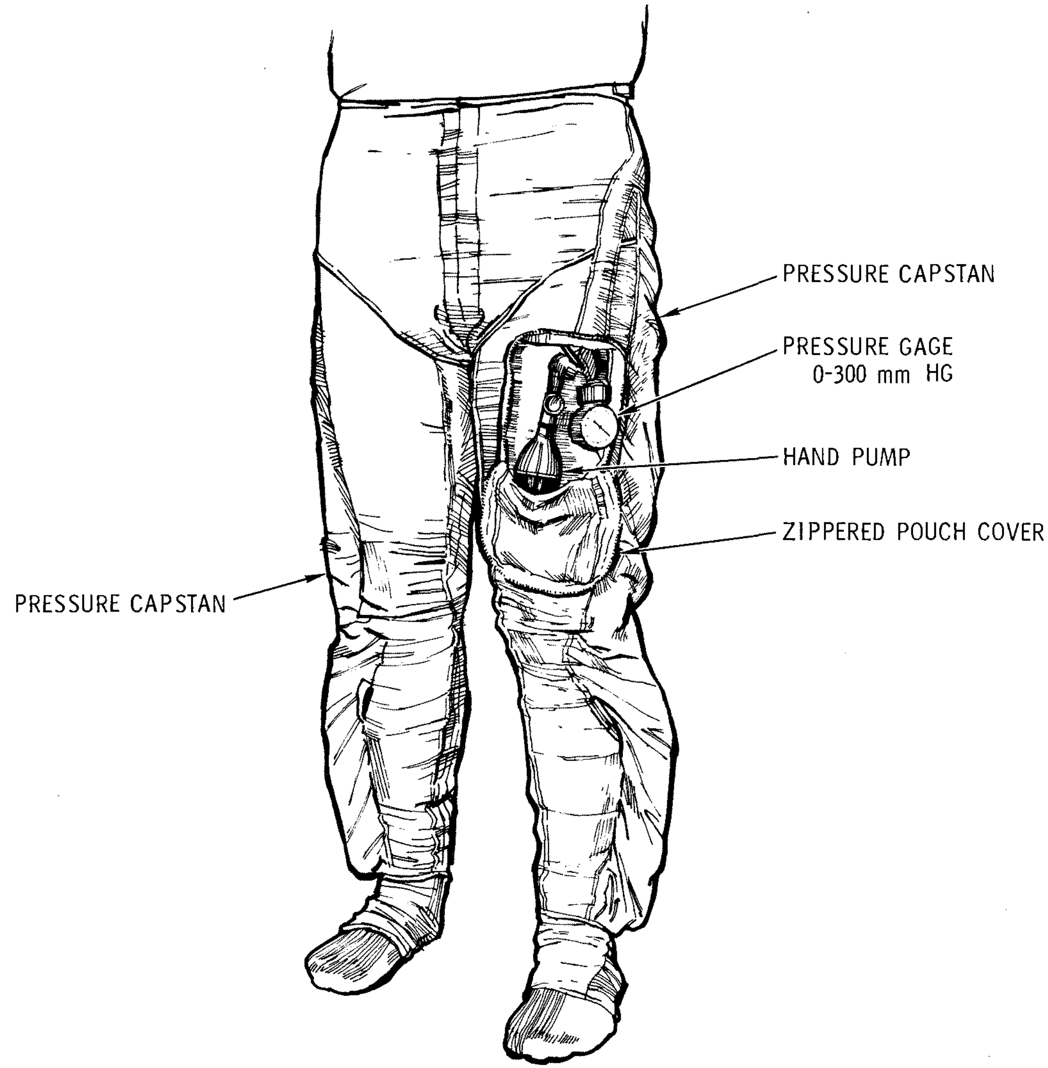


Figure 2.12-3. Protective Garment, Hypotensive, Pressure Assembly (PGHPA)

There are three CWG electrical adapters, plus a spare, which are stowed when not in use.

2.12.2.1.8 Communications Cable With Control Head

The communications cable, or comm cable, transmits voice communications and bioinstrumentation signals from the adapters and crew to the spacecraft bulkhead connectors. It also carries electrical power and the caution and warning (C/W) system audible alarm signal. Another name for the comm cable is the crewman communications umbilical (CCU).

The comm cable consists of a control head and a cable. The control head has a 61-pin connector, a rocker switch and a 37-pin connector. The cable has a 37-pin connector at one end and a 37-pin connector with a lanyard pull at the spacecraft bulkhead end. The cables for the CM 1 and CM 2 are 87 inches long. The CM 3 cable is 133 inches in length, which allows it to be used for crew transfer through the tunnel into the MDA. One spare control head and cable (133 inches) is carried in the event of a malfunction.

For further information and use of the comm cable, refer to section 2.8.

2.12.2.1.9 Pressure Garment Assembly (PGA) (Figure 2.12-1)

The major component of the spacesuit is the PGA. The A7L PGA provides a mobile life support chamber that can be pressurized separately from the cabin inner structure in case of a leak or puncture. The PGA consists of a helmet, gloves, and torso and limb assembly. It requires an oxygen hose for oxygen and electrical cable for telecommunications.

The torso has a neck ring for securing the helmet and wrist rings for securing the gloves. It is constructed of Beta cloth (a fiberglass-type material). A double zipper runs from the crotch area along the back to the neck ring for donning and doffing. Snaps are located on the upper chest for securing the life vest. The right wrist area has a pressure gage with a range of 2 to 5 psia. Two cables run laterally from the chest, around the biceps, to the spine as an anti-ballooning device, and are attached and detached at the chest. Two adjustment straps restraining the neck ring are located in the front (sternal area) and rear (spinal area).

On the right chest area is a 61-pin telecommunications connector. When not in use and during stowage, the connector is protected by a PGA electrical connector protective cover. The inside telecommunications harness splits to a 9-pin connector (bioinstrumentation) and a 21-pin connector (communications). On the left chest area is a connector for the PLSS liquid system. Inside, it has a supply hose and a return hose with connectors that connect to the liquid-cooled garment (LCG) when worn in place of the CWG.

Two sets of oxygen hose connectors are located on the left- and right-lower rib cage area. A set consists of a blue supply connector and red return connector. The left connector set is normally for the PLSS hoses and the right set for the CM ECS hoses, but the oxygen hose connectors will fit either set. To prevent an alien object from entering and damaging a spacesuit O_2 hose connector, a PGA gas connector plug (figure 2.12-1) is inserted when an O_2 connector is not in use. The gas connector plugs are color coded red and blue to match the O_2 connectors. To insert, the plug is fitted into the connector and pressed until it clicks. It mechanically locks in place. To remove, the plug is unlocked by pressing the gold lockpin, then lifting the locking tabs, rotating the locking ring, and pulling the plug.

A urine collection system (UCS) is located on the right leg. A UCTA tube connects to a capped quick-disconnect on the right thigh. There are six additional UCS stowed in A6.

Leg pockets are placed in accordance with the defined locations. These are used to contain the numerous personal items. Additional pockets are strapped on the legs to hold other miscellaneous items. The boots are integral to the torso and the soles have Velcro patches for restraint. The boot heels have partial steel plates to wedge in the couch footpan cleats for restraining the feet. The gloves secure to the wrist ring with a slide lock and rotate by means of a ball bearing race.

The helmet is a plastic bubble. It secures to the torso neck ring with a slide lock. A slot channel at the rear of the neck ring receives oxygen from the torso ventilation duct and directs it to a one-half-inch-thick foam plastic manifold. The manifold lays on the aft quarter of helmet, terminating at the top. Numerous slits in the manifold direct the oxygen across the face, purging the helmet of carbon dioxide. On the left side, near the mouth, is a feed port and a feed port cover. A contingency feeding valve adapter is provided with the food set and will attach to the feed port to provide a method of emergency nourishment. Only liquids will pass through.

Additional subassemblies or accessories are donning lanyards for doffing/donning a neck dam for restricting water during postrecovery CM egress, and strap-on leg pockets for scissors, checklists, and data lists.

After docking activities, the spacesuit and helmet may be stowed. The PGA stowage bag is approximately 40 inches long and 22 inches wide with a bottom and a lanyard closure, duffle bag style (figure 2.12-4). It will stow one PGA with gloves.

The PGA helmet stowage bag is made of Beta cloth. The "dome" end is closed, and the open end has a draw string for closure. Four straps with snaps are attached for restraints. At launch, the helmet bags are collapsed and stowed. When the helmet is doffed it is placed in a helmet bag, the draw strings are tied and attached to the right- and left-hand equipment bays by the snaps on the straps. For suited entry, the helmet bags are again collapsed and stowed. In the event of an unsuited entry, the helmet bags are placed over the helmets and stowed. In the event of a suited entry without helmets and gloves, the helmets with helmet bag covers are stowed in a PGA bag and lashed to an aft bulkhead locker.

PGA Donning and Doffing. In the event the command module inner structure loses pressure, the ECS can maintain a pressure of 3.5 psia for 15 minutes to allow the crewmen to don their PGAs. Time will vary depending on rate of leakage.

To don the PGA, the legs and arms are cleared of obstructions, the zippers are run to the neck ring with lanyards attached and oxygen hoses connected. The legs are placed in the boots and legs of the torso and the bioinstrumentation and communication harness is connected. The arms are placed in torso arms and the head through neck ring. The lanyard connected to the inner zipper and outer zipper to crotch is pulled, closing the stress relieving and pressure seals. The shoulder cables are connected and locked.

The helmet is donned by connecting it to torso neck ring and rotating the neck ring lock. The donning is completed by putting the gloves on and locking. The ECS suit flow regulator is adjusted.

To doff the PGA, the gloves and helmet are removed, the crotch to the neck ring is unzipped, and neck and arms are withdrawn. The bioinstrumentation and communication harness are disconnected, and the legs are removed from the torso.

Operational Modes. In the suited condition, there are two modes, the normal or ventilated and pressurized. In both cases, the helmet is on and locked.

In the ventilated mode, sometimes referred to as vented, the cabin is pressurized at 5 psi and the suit is 5.072 psi, or a positive pressure differential of 2 inches of water in the suit to maintain a gas-tight seal. This condition allows comfort and maximum mobility for the crewman. The flow rate through the suit will be approximately 7 to 11 cubic feet per minute..

The oxygen is delivered by the oxygen supply hose, routed to the helmet and midsection to be purged to the extremities, and returned via ventilation tubes to the midsection return connector and oxygen hose.

In the event the cabin pressure decreases to 3.5 psia or lower, the ECS will maintain 3.7 psia in the PGA. This mode is pressurized, and the

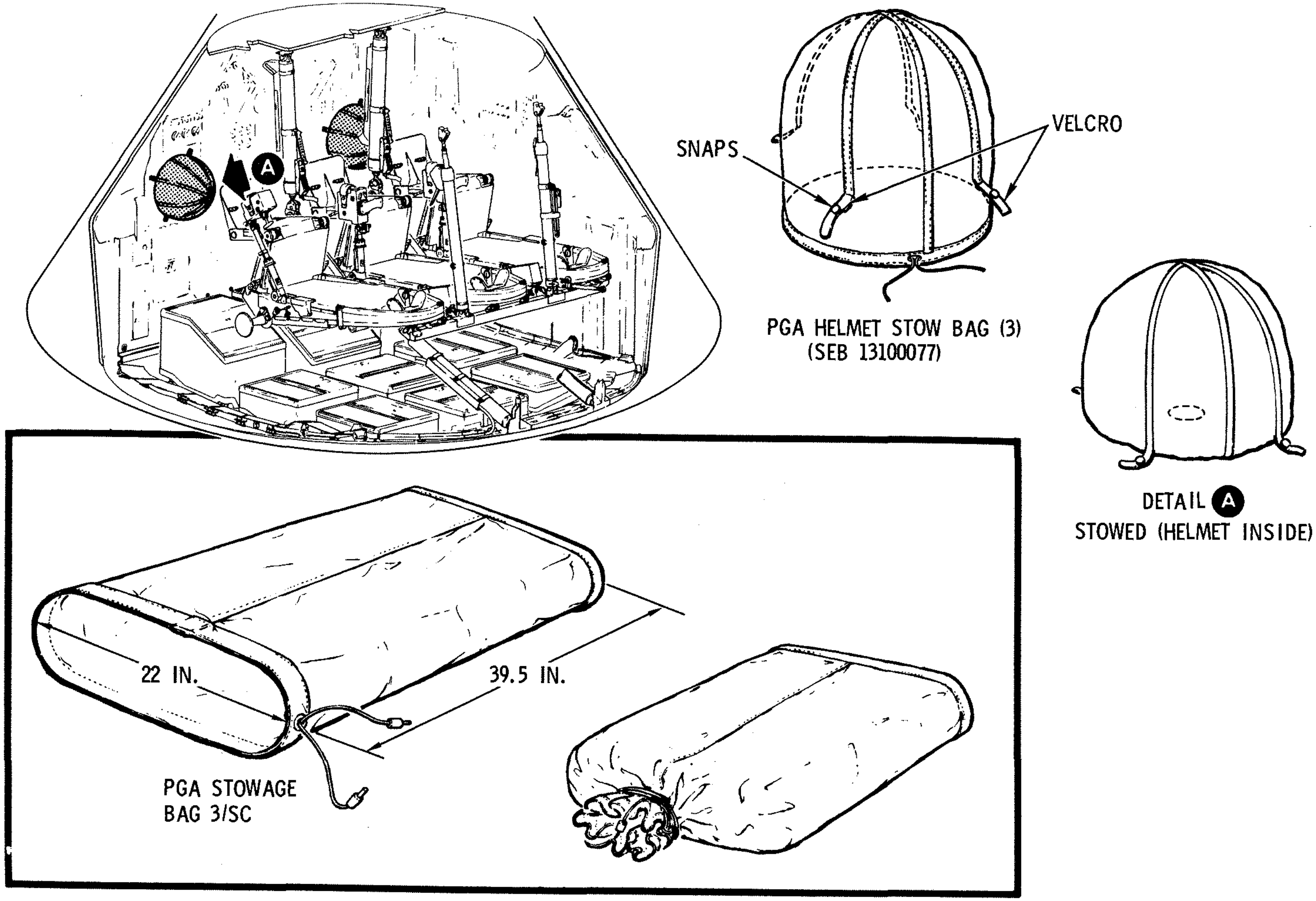


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Figure 2.12-4. Skylab PGA and Helmet Stowage Bags flow rate will be more than 12.33 pounds per hour and less than 17 pounds per hour. The crewmen will have to overcome the pressurized balloon effect, and mobility will be more restricted than the vented mode.

Miscellaneous Personal Equipment (Figures 2.12-5 and 2.12-6). Personal items of equipment that are used many times and must be immediately accessible are stowed in spacesuits, pockets or attachable pockets. These items must also be transferred to the flight coveralls after doffing the spacesuit. The following is the nomenclature and description of these items.

- Penlight - Small, two-cell unit used for portable lighting
- Sunglasses with pouch
- Personal Radiation Dosimeter - A cigarette package-shaped unit, battery-powered dosimeter which indicates accumulated dosage (rads) by its register readout
- Chronograph With Watchband - "Accutron Astronaut" watch featuring sweep second hand, stopwatch control, and changeable time zone dial
- Marker Pen - Felt-tip pen used for marking sanitation bag assemblies, refuse bags, and log book
- Pencil
- Data Recording Pens - Pressurized ball point pens for writing
- Scissors - Surgical scissors, used for cutting food bags, pouches, etc.
- Life Vest - Attached to PGA during boost and entry; during the remainder of the mission, stows in U2 after helmet bags and accessory bags have been removed.
- Slide Rule - Standard slide rule, 6 inches long, aluminum
- Motion Sickness Bag - A plastic emesis bag in a small wrapper
- Pockets, Attachable - Pockets with straps that attach to the legs for storing checklists, scissors, and miscellaneous items.

2.12.2.2 Spacesuit Related Equipment

2.12.2.2.1 Oxygen Hose Assembly (Figure 2.12-7)

The oxygen hose assembly conducts oxygen to the PGA under pressure from the ECS, and returns contaminated oxygen from the suit to the ECS. A secondary use is to deliver oxygen from the ECS to the cabin atmosphere.

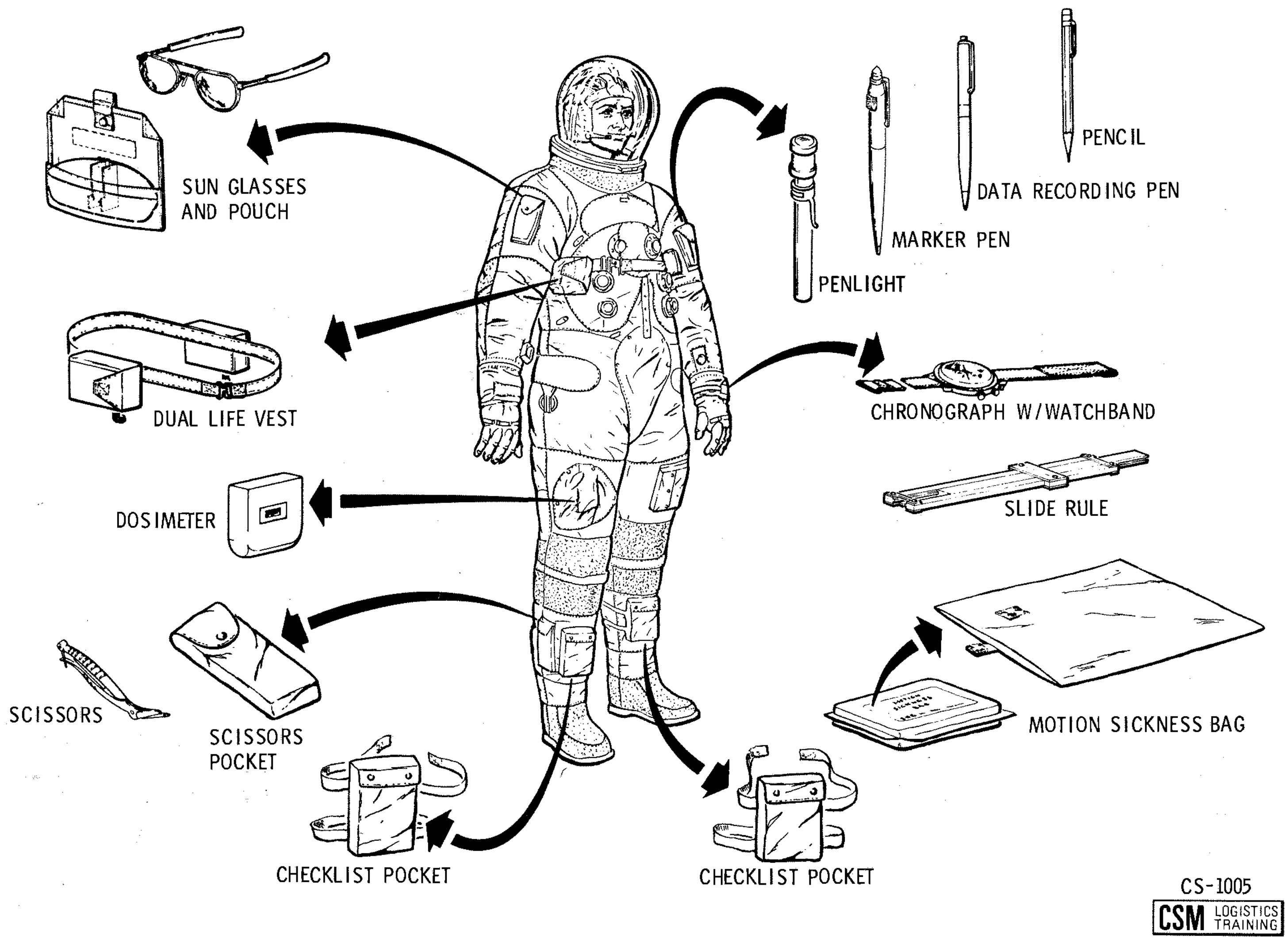

Figure 2.12-5. Spacesuit Personal Equipment

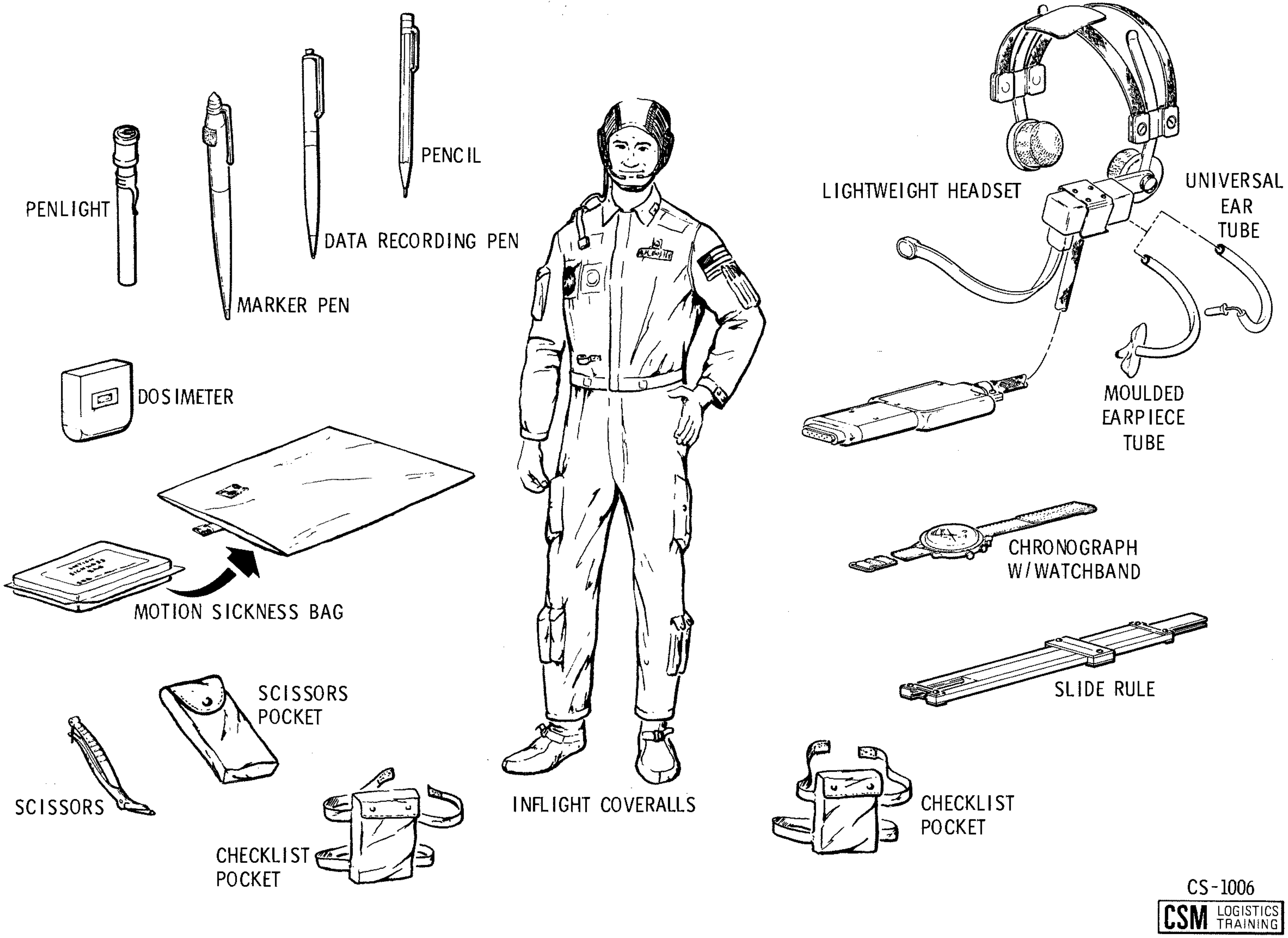

Figure 2.12-6. Inflight Coveralls Personal Equipment

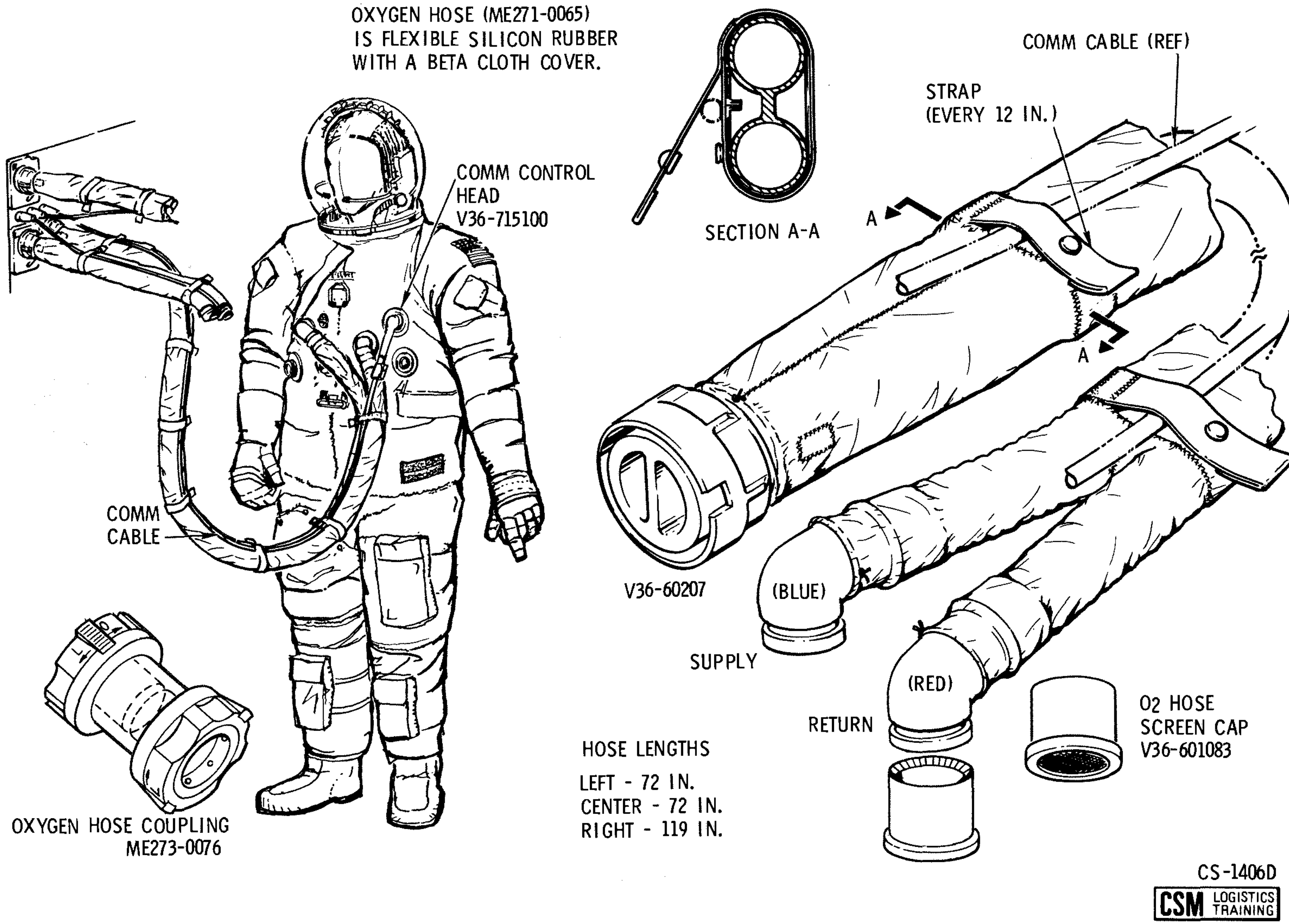

Figure 2.12-7. Oxygen Hose Assembly and Accessories

The oxygen hoses are flexible silicone rubber hoses with a convoluted wire reinforcement and 1.25-inch inside diameter. Each assembly has two hoses, a double "D" section and connector at the ECS end, and two separate nozzles at the suit end (supply and/or return). The supply nozzle is blue and the return nozzle is red to match the spacesuit oxygen hose connector colors. The assembly is covered with Beta cloth and the hoses are fastened together with keepers every 12 inches. Also, at 12-inch intervals along the hose, cloth straps with fasteners for securing the comm cable are provided. When coupled together as a unit, the hose and cable is referred to as an umbilical assembly.

The hoses for the left and center crewmen are 72 inches long and the right crewman's hose is 119 inches in length.

When the oxygen hose is not connected to the PGA, the ECS end will remain attached to the valve at the left-hand forward equipment bay and the oxygen hose will be stowed. Straps on the CM structure will aid in routing the hoses across the forward bulkhead and right-hand forward equipment bay.

2.12.2.2.2 Oxygen Hose Coupling (Figure 2.12-7)

During the shirtsleeve environment, to prevent fresh oxygen from returning through the exhaust or the return end of the O_2 hose while the suit circuit return valve is open, a coupling is placed over the return end. It is a 5-inch aluminum tube with a web seal in the middle and hose connectors at each end. During an EVA, both nozzles (supply and return) are plugged into the coupling connectors, thus sealing both nozzles.

2.12.2.2.3 Oxygen Hose Screen Caps (Figure 2.12-7)

In the shirtsleeve environment, the crew compartment oxygen returns to the ECS suit loop through the suit circuit return valve which has a screen cover functioning as a preliminary debris trap. The screen has to be cleaned periodically but the task is difficult because of obstructions. By placing the screen caps on the oxygen return nozzles (red), placing the flow control valves on panels 300, 301, and 302 in the CABIN FLOW position, the return oxygen is split between the oxygen hoses and the suit circuit return valve. The oxygen is screened for debris at the cap screens, which is accessible and easy to clean but also greatly reduces the flow. Therefore, the oxygen hose screen caps are used to delay the cleaning of the suit circuit return valve. A screen cap on an oxygen return hose nozzle (red) can also be used for vacuuming debris in the crew compartment.

The screen cap is a fluorel tube with a monel screen (No. 30 mesh) at one end and an internal ridge at the other. It slides over the return nozzle and engages a groove to retain it. There are three screen caps per spacecraft.

When the screen cap becomes clogged with debris, it can be cleaned by using a small piece of utility tape to blot the screen. The tape can be inserted in a utility bag, food bag, or waste bag for disposal.

2.12.2.2.4 EMU Maintenance Kit

In the event the spacesuit PGA O-rings are damaged, they can be replaced by use of the EMU maintenance kit. The kit is approximately 8 by 6 by 1.5 inches and weighs 0.50 pound. There is one kit aboard the CM, stowed in a compartment (R13) in the right-hand equipment bay (RHEB).

2.12.2.2.5 Integrated Thermal Micrometeroid Cover

The cover, or integrated thermal micrometeoroid cover (ITMG) consists of an outer protective layer with scuff patches at the knees and elbows, seven alternating layers of Beta cloth (micrometeoroid protection) and silverized mylar (thermal protection), and a liner. The ITMG is also laced on the PGA for the mission.

2.12.2.2.6 Liquid Cooled Garment (LCG) (Figure 2.12-1)

The LCG is worn in place of the CWG when a crewman performs an EVA. The LCG contains small plastic tubes (0.125-inch diameter) sewn to a netting that covers the crewman's body. Water circulates through these plastic tubes absorbing body heat. The water is transported to the ALSA which controls water flow and expells the heat. The LCG has a thin cloth lining that prevents the hands and feet from entangling the plastic tubes when donning.

The LCGs are fully charged, packed singly or in pairs in a Beta cloth bag, weigh 5 pounds each, and are stowed. When donning, they must be connected to the EV spacesuit multiple water connector. When the LCG is not in use, it must be disconnected, doffed, folded, and stowed.

2.12.2.3 Deleted.

2.12.2.4 <u>IVA Umbilical</u>

The IVA umbilical is a 45-foot electropneumatic umbilical with a tether connection on both ends for stress relief of the input and output connectors. The basic electrical function of the umbilical is to connect the astronaut life support assembly (ALSA) to the spacecraft power and telecommunications systems. The umbilical also supplies 100 psi O_2 at a flow up to about 13 pounds/hour to the ALSA. Figure 2.12-7A shows the electrical and pneumatic connections to the IVA umbilical at panel 603 on the CM upper equipment bay. Figure 2.12-7B details the connection of the umbilical to the ALSA while figure 2.12-7C shows a simplified schematic of the systems joined by the IVA umbilical.

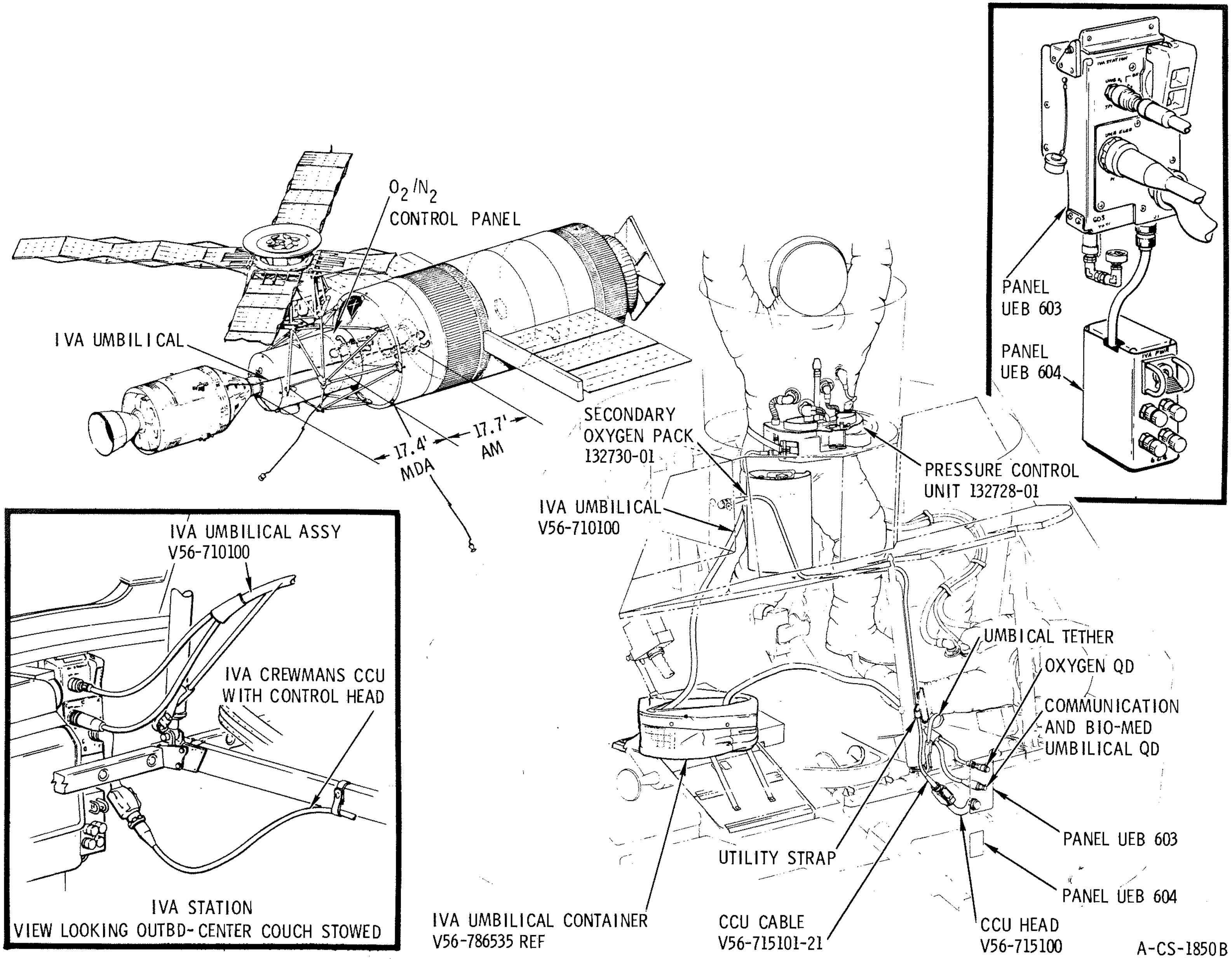

Figure 2.12-7A. IVA Operations

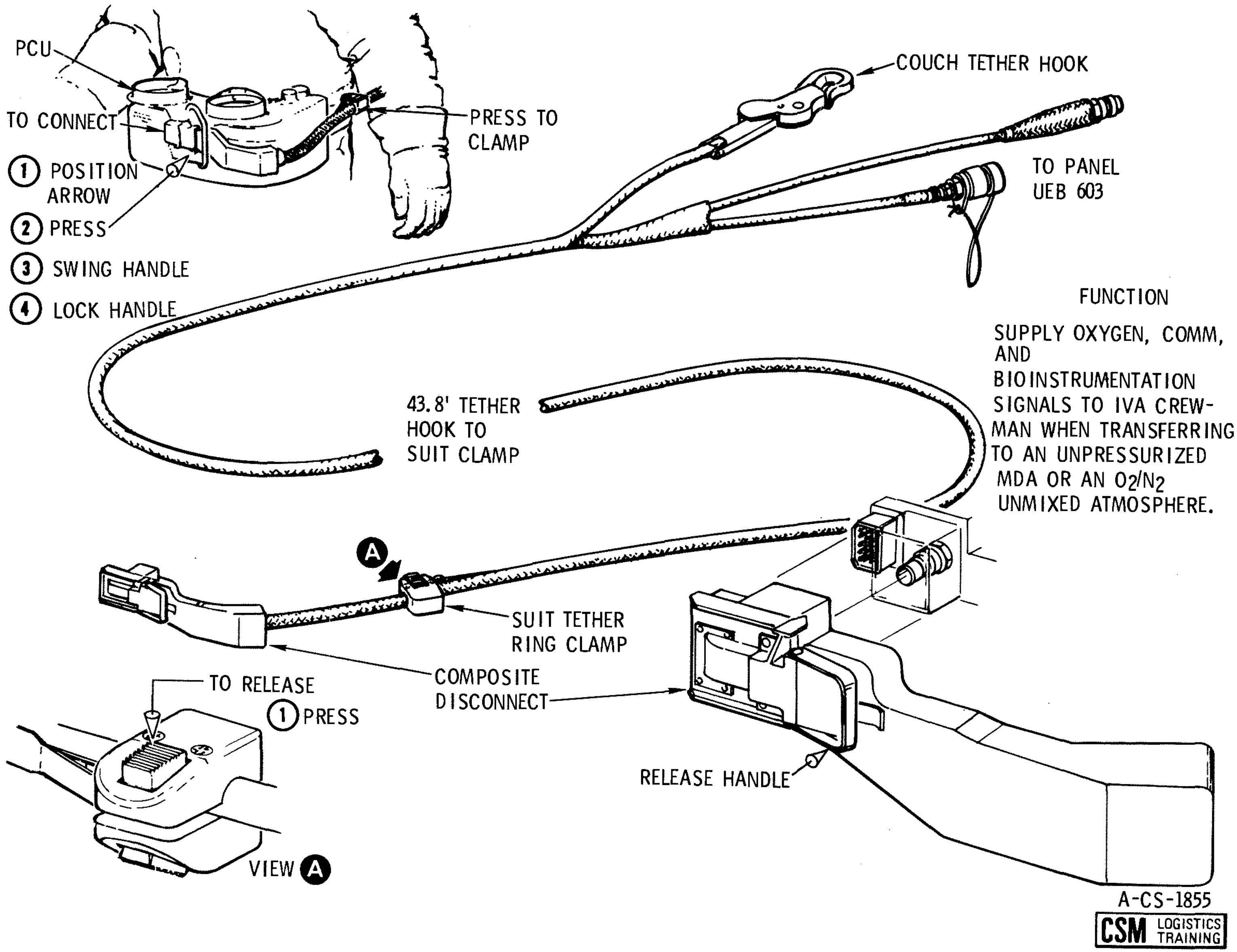

Figure 2.12-7B. IVA Umbilical

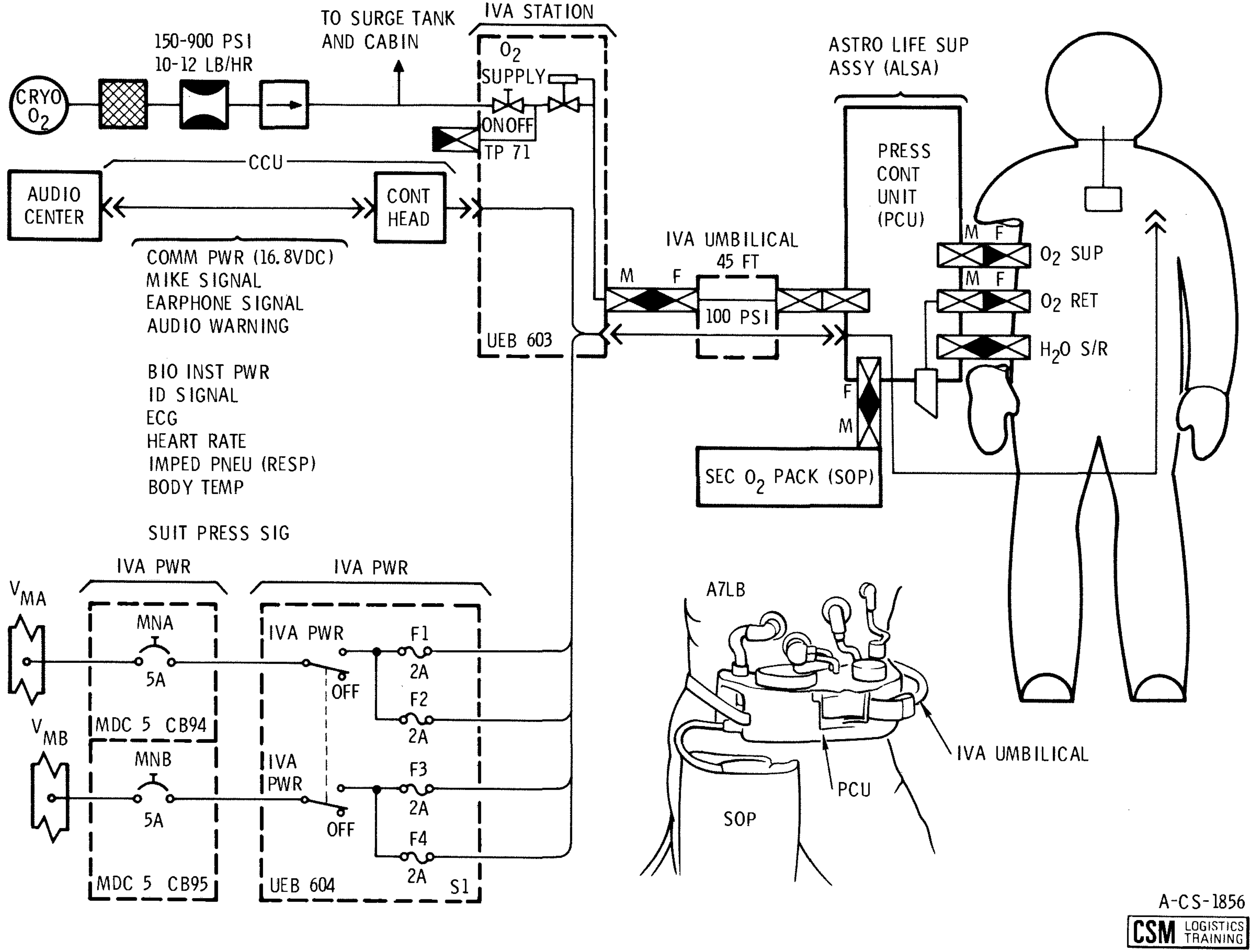

Figure 2.12-7C. IVA Umbilical - ALSA Schematic

2.12.3 CREWMAN RESTRAINTS

2.12.3.1 "g" Load Restraints

2.12.3.1.1 Crewman Restraint Harness (Figure 2.12-8)

There are three restraint harnesses per spacecraft, one for each crewman. The harnesses are attached to the crew couches. The restraint harness consists of a lap belt and two shoulder straps interfacing the lap belt at the buckle. The lap belt straps are connected to the seat pan and back pan. This configuration provides adequate hip support. The shoulder straps are connected to shoulder beam of the couch.

The lap belt buckle is a lever-operated three-point release mechanism. By pulling a lever, the shoulder straps and right-lap belt strap will be released. The strap ends are equipped with snaps which may be fastened to mating snaps on the couch and struts when not in use. The restraint harness buckle can be restrained when not in use by attaching it to the translation or rotation control with the buckle stow straps (figure 2.12-8). This also prevents the buckles and attachments from floating free during zero-g and striking a crewman or equipment.

Operation. The harness will be on and locked during all maneuvers when g-loads are expected at launch, delta V, docking, entry, and landing The harness can be tightened and loosened readily by adjusting the length of the strap. The hand grip is pulled to tighten. To loosen, the adjuster is rotated, allowing it to unlock and the strap can be lengthened.

2.12.3.1.2 Handholds (Figure 2.12-9)

The function of the handholds is to aid the crew in maneuverability. The handholds are aluminum handles bolted to the longerons. There are two handholds, one on each longeron by the side windows, located close to the MDC.

2.12.3.1.3 Hand Bar (Figure 2.12-9)

The hand bar is located on the MDC near the side hatch and has two positions, stowed and extended. A lever at one end releases the detent for moving from one position to the other. The hand bar furnishes a place to hold when ingressing or egressing from the CM side hatch. It will support the weight of a suited astronaut in 1 g. In zero g during extravehicular activity or transfer, the hand bar can also be used for ingressing or egressing through the side hatch.

2.12.3.1.4 Heel Restraints (Figure 2.12-9)

During the CM landing, the legs and feet of the crewman may jostle about unless restrained to the couch footpan. If in the spacesuit, the boot heels and couch footpan interconnect and restrain the feet and legs. However, if entry and landing is in shirtsleeves, or in-flight coveralls, the feet are held to the couch footpans by heel restraints.

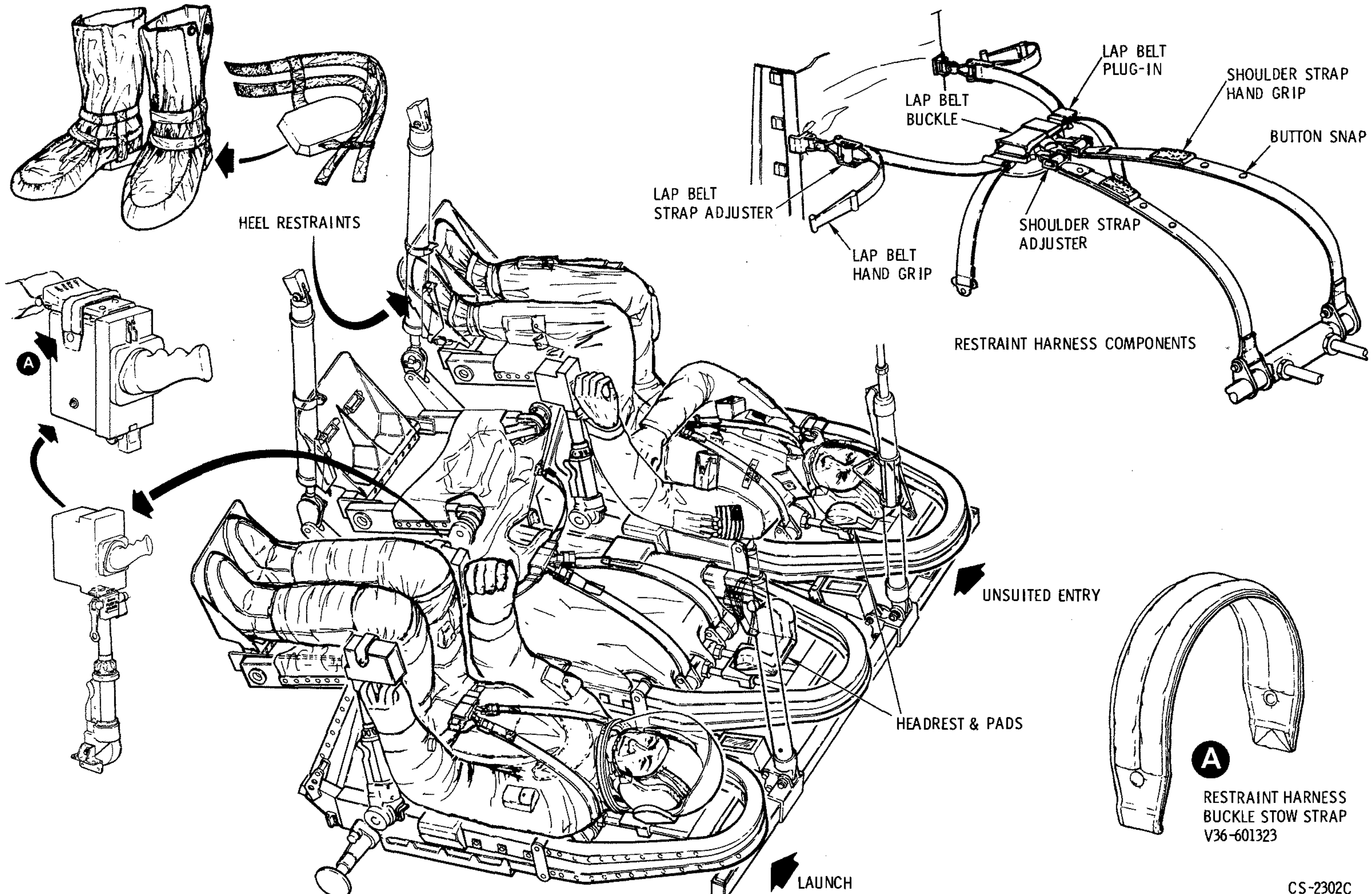

Figure 2.12-8. Crewman Restraint Harness and Heel Restraints

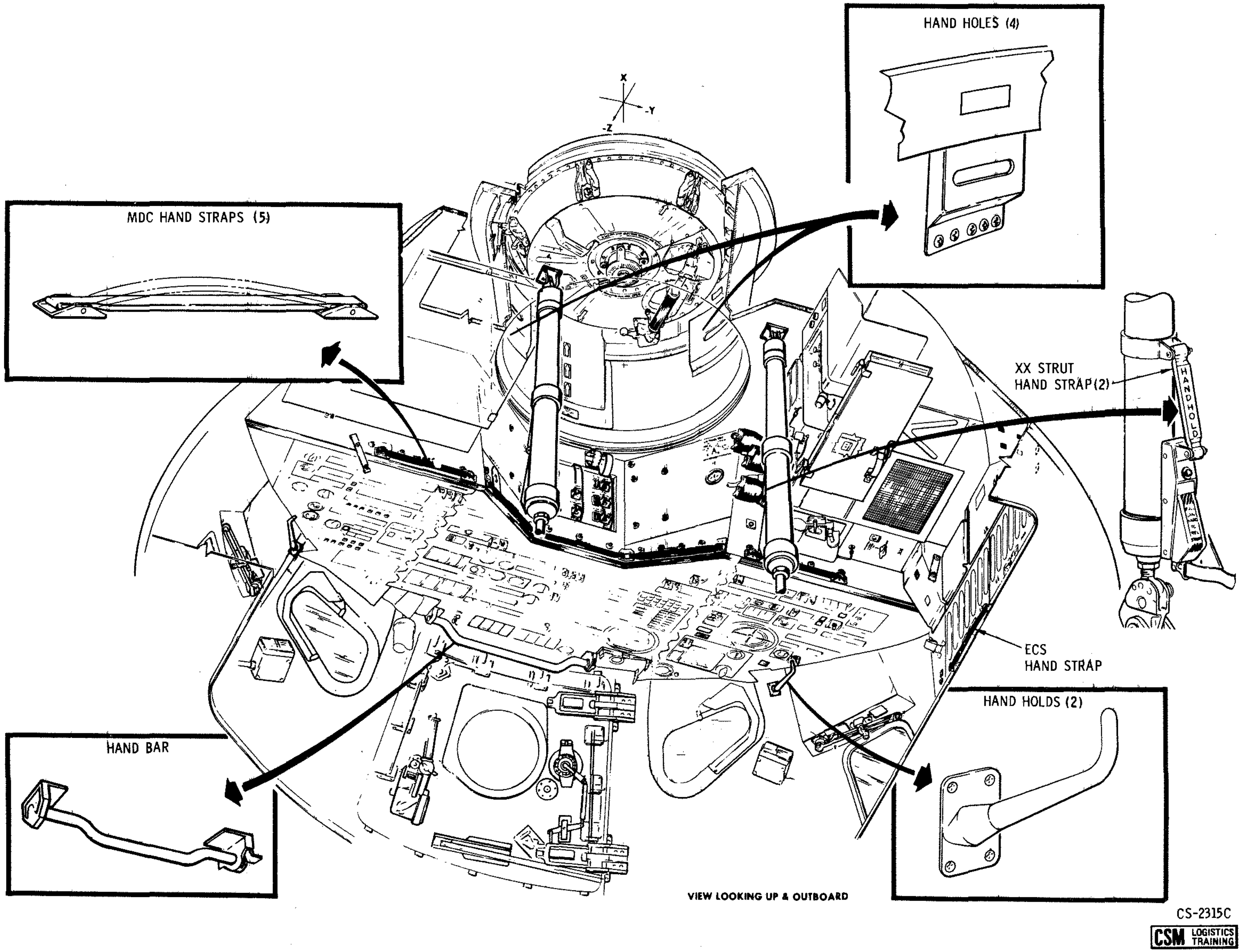

Figure 2.12-9. Handholds, Hand Straps and Hand Bar

The heel restraints are hollow aluminum blocks that attach to the heels of the crewman's booties by means of straps and Velcro. The restraints connect to the footpan in the same manner as the spacesuit booties. Three sets of heel restraints are stowed in a bag.

2.12.3.2 Zero-G Restraint

2.12.3.2.1 Hand Straps (Figure 2.12-9)

The hand straps serve as a maneuvering aid during a g-load or zero-g condition.

The hand straps are of molded fluorel reinforced with nomex tape and are attached by brackets at each end. There are five hand straps behind the MDC and one on the left-hand equipment bay over the ECS filter access panel and one each on the foot X-X struts. These straps lie flat against the structure when not in use.

2.12.3.2.2 Guidance and Navigation Station Restraint

The astronaut will restrain himself in the center couch at the G&N station by positioning the couch to a 170-degree hip angle and restraining his feet in the couch footpans.

2.12.3.2.3 Sleep Station Restraints (Figure 2.12-10)

The crewmen's sleeping positions will be in the right couch and under the left and right couch with the head toward the LEB. Each crewman will be restrained in position by a crewman sleep station restraint.

The three restraints are Beta fabric, lightweight sleeping bags 64 inches long, with zipper openings for the torso and 7-inch-diameter neck openings. The two sleep restraints under the couches are supported by two longitudinal straps that attach to lockers A7 and A9 on one end (LEB), and to the CM inner structure at the other end. To restrain the head end, an additional strap on each side attaches to the stowage locker brackets. The third restraint for the right couch is just the sleeping bag with no straps.

During the mission and shirtsleeve environment, a crewman can unzip the restraint and slide in with his flight coveralls on. However, if an emergency exists, and the crew are in their spacesuits, they will be too large to enter the sleep restraint. In that case, the crewman will lie on top of the restraint and hold himself in place by the strap around the middle of the sleep restraint.

The sleep restraints will be rolled and strapped against the side wall and aft bulkhead at launch. When needed, they will be unrolled and attached to lockers A7 or A9 near the LEB or placed in the right couch.

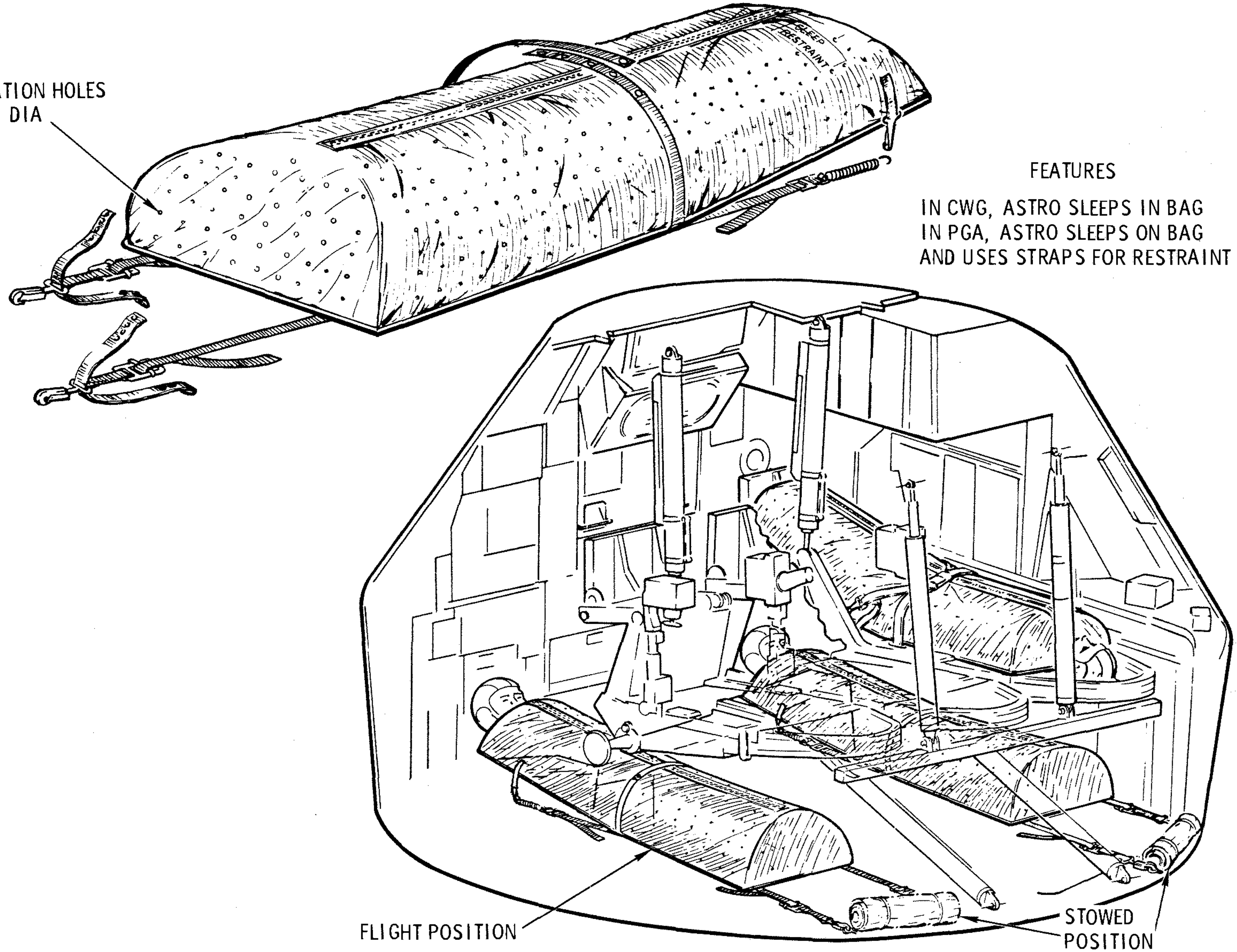

Figure 2.12-10. Sleep Station Restraints

2.12.3.2.4 Flight Data Restraints (Figure 2.12-11)

The purpose of the flight data restraint, or bungee system, is to position and retain the flight data charts, maps, and manuals so the crew can view them during the mission. The system includes long and short data retention snap assemblies (bungees), long and short data retention hook assemblies (bungees), data card clips, food door clips, data book spring clips, temporary stowage pouches, and a debris closeout with pockets.

The bungees (retention snap and hook assemblies) are 0.25-inch-diameter steel springs, the "short", 4 inches long and the "long", 8 inches long. The short will stretch to 14 inches and the long will stretch to 34 inches for use. At each end of the bungee spring, a 3-inch length of Beta cloth with a female snap or clip and a snap is attached. The snap-type bungees attach to bonded male snaps (studs) on the panels or closeouts so they lie parallel and close to the panel. The hook-type bungees hook on doors or switchwickets, whichever is the most useful. The manuals or charts are slid between the bungee spring and the panel and will stay in place.

A data card clip is a small, steel clip with a female snap on the rear. It attaches to a male stud on the panels or closeouts and holds data cards.

A female snap on the data book spring-clip fastens to any one of numerous male studs on the panels. The spring-clip allows a rapid exchange of manuals or data.

The number of restraints may vary from spacecraft to spacecraft. The following list is approximate:

Snap bungees, short	6
Snap bungees, long	6
Hook bungees, short	2
Hook bungees, long	2
Data card clip	8
Data book spring-clip	8

To verify the number, refer to the spacecraft stowage drawing or stowage list.

Two small, temporary stowage pouches 15 inches in length with female snaps that attach to studs in the crew compartment, are Beta cloth with a bungee-type closure, and have a small plastic viewing window. The bungees, clips, and adapter plates are stowed in the pouches prior to use.

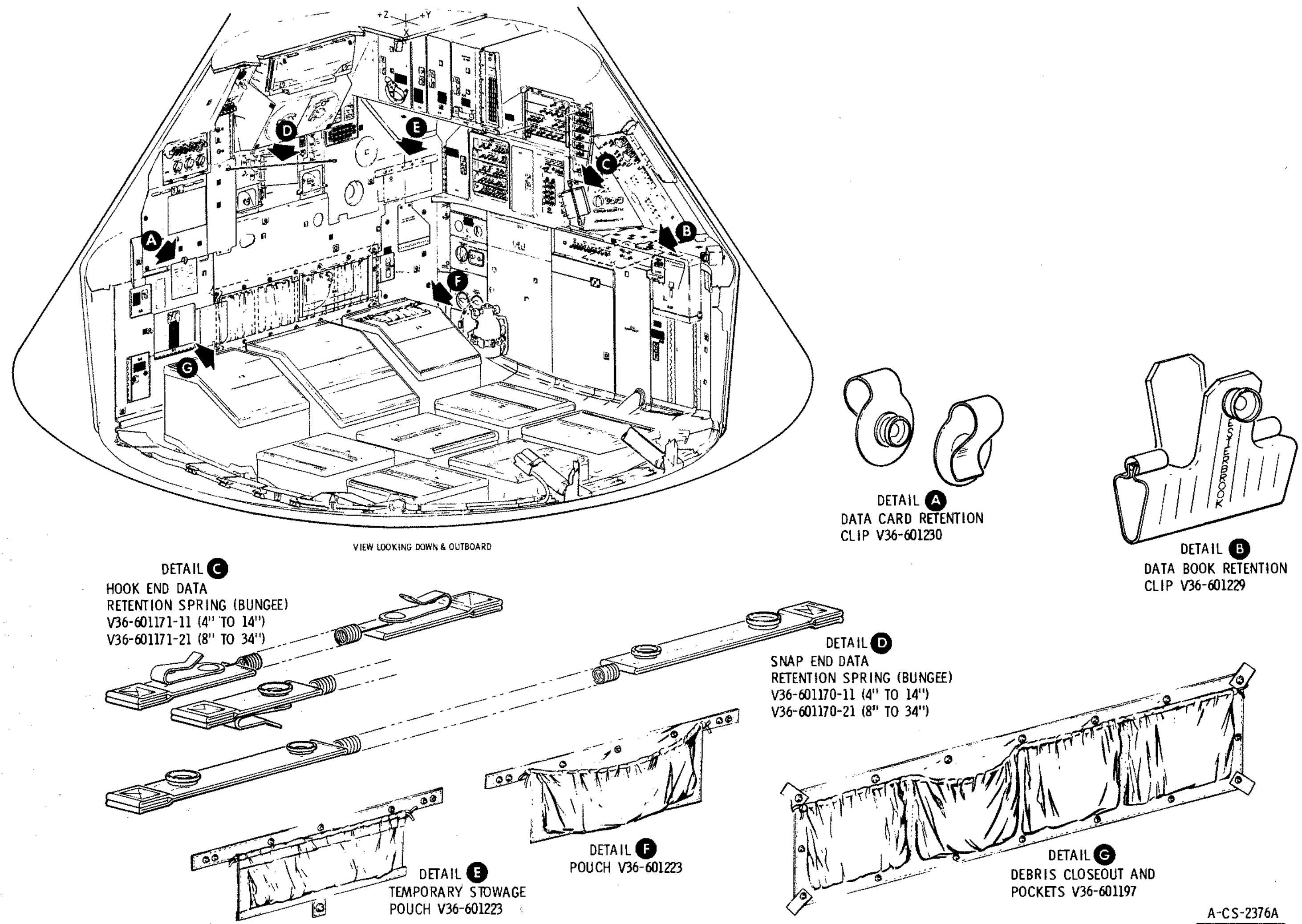

Figure 2.12-11. Skylab Flight Data Restraints

The debris closeout with pockets has two purposes: restricting debris from entering the gaps and, is the flight data temporary stowage position after removing the data from the compartment. The closeout is 42 inches long, has 4 pockets, is Beta cloth, and attaches to the LEB with snaps. When the temporary stowage pouches are not being used, they can be stowed in the closeout pockets with the flight data.

2.12.3.2.5 Restraint Straps

There are a number of straps used for restraint purposes during zero g. The couch, probe, control cable, and cable routing straps have specific uses, whereas the utility straps have numerous uses. Most of the straps are made of Beta cloth and use snaps as a restraining method. The snaps have a male (stud) and female (socket) component.

Control Cable Straps (Figure 2.12-12). The rotation control cables exit the junction box on the aft bulkhead and are routed along the ZZ attenuator struts to the couch side stabilizer beams. The control cables are held to the ZZ struts by the control cable straps, two on each strut. The straps are 1 inch wide and 11 inches long. Each has four snaps, a pair to snap around the strut and a pair to hold the cable.

Center Couch Stow Straps. During the preparation for EVA, the center couch is removed from its center position and stowed under the left couch. The center couch is restrained to the left couch by the two center couch stow straps.

The upper center couch stow strap routes around the headrest support bars and connects to itself. It is 24 inches long, has a D-ring at one end, a center flat rubber bungee section, and a snap-hook at the other end.

The lower center couch stow strap routes through two holes in the center couch body support at the seatpan. It is 43 inches long, has a 12-inch bungee section, and a hook at each end which attaches to D-rings on the left couch body support near the seatpan. When not in use, the straps are stowed.

Cable Routing Straps (Figure 2.12-12). The cable routing strap is 5.5 inches long with a back-to-back socket and stud at one end and a socket at the other end. The socket/stud attaches to studs bonded on the structure and when the socket is attached to the strap stud/socket, it forms a loop. This facilitates routing the TV camera cable and the translation control cable. When not in use, the straps are left attached to a wall stud.

Probe Stow Straps (Figure 2.12-13). The two probe stow straps are identical. They are 26 inches long with a snap hook at one end, a right angle hook at the other, and a 6-inch bungee section. The probe is stowed by positioning it under the seatpan with the probe pointing outboard. The right angle hook is attached around the lap belt connector on the seatpan by pressing the hook lever. The straps are routed around the ends of the probe and the hook end is snapped to the D-rings on the right couch. When not in use, the probe straps are stowed.

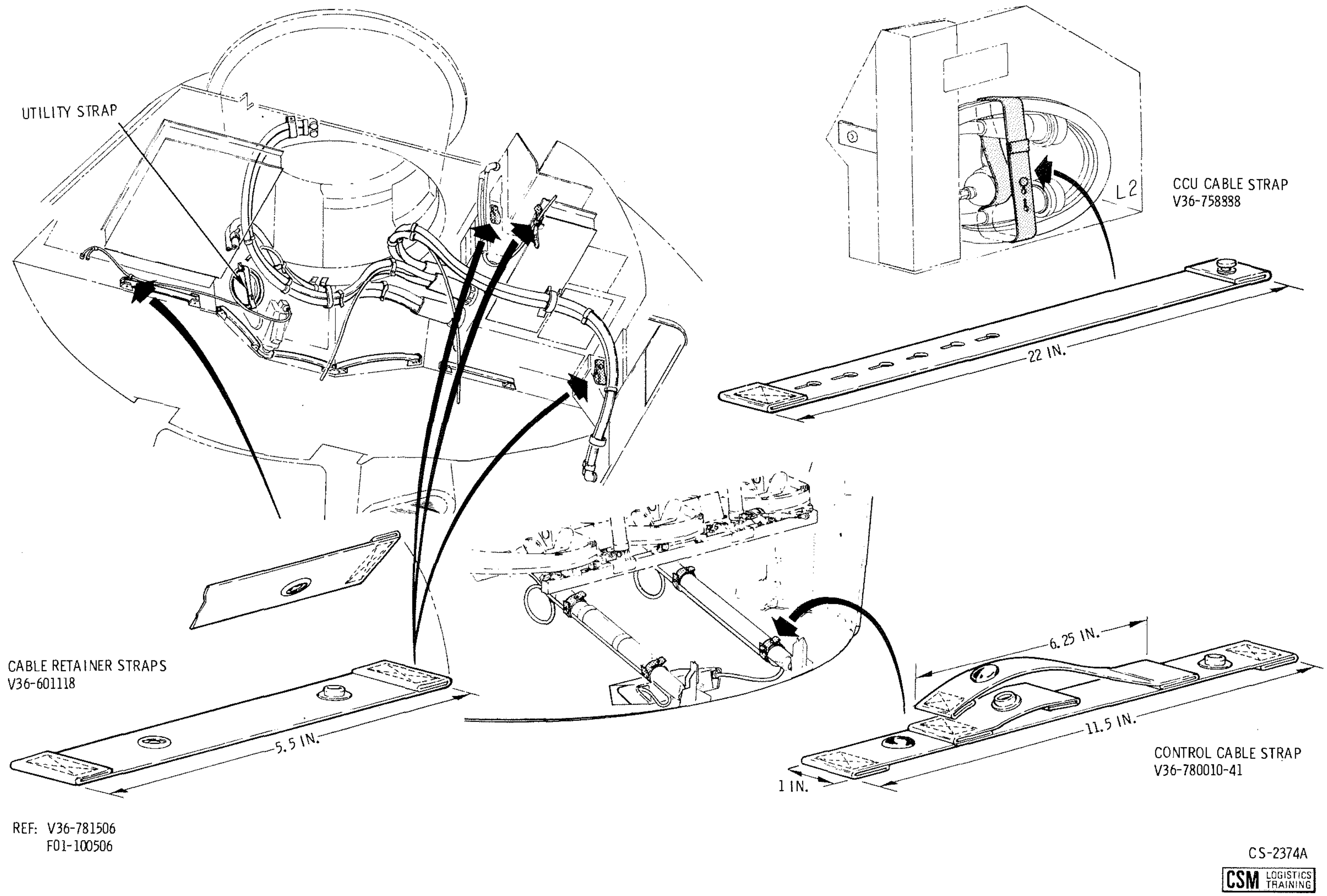

Figure 2.12-12. Special Straps

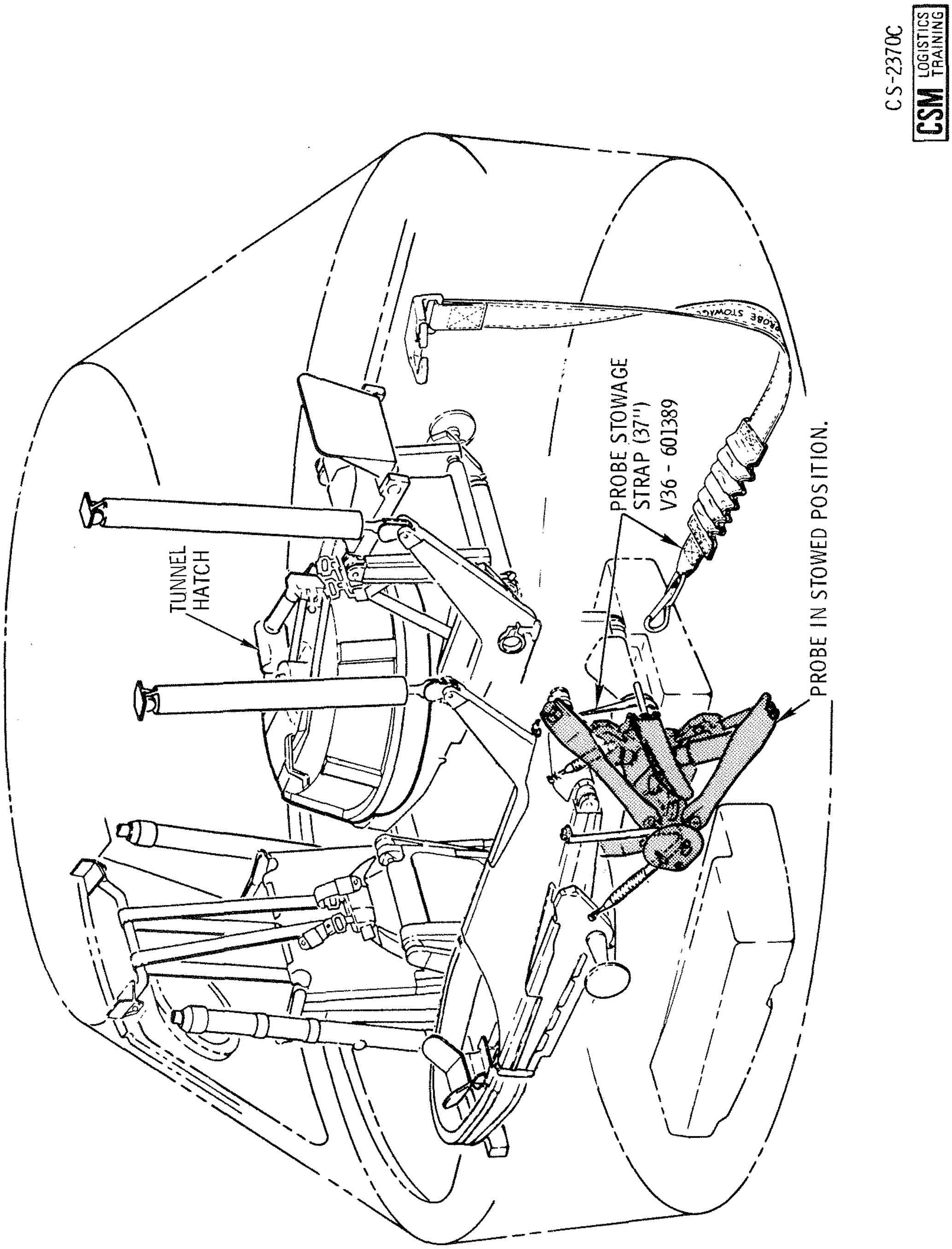

Figure 2.12-13. Probe and Drogue Stowage Straps

Utility Straps (Figure 2.12-14). The utility straps are named for their versatility. They are used for holding looped straps and cables in stowage lockers or compartments and for restraining other equipment to the structure during the mission.

The utility straps are 12.5 inches long with two studs and two sockets positioned so as to form two loops when snapped. One loop will wrap around a piece of equipment and the other loop will wrap around a structure or will attach to the structure by the snap.

2.12.3.2.6 Velcro and Snaps Retainer Locations (Figure 2.12-15)

There are numerous 1-inch square patches of Velcro located in the crew compartment. They are bonded to the structure and control panels in accordance with crew and crew support requirements. Each CM has a Velcro and Snaps Map designating the location of all retainers. The drawing number is V36-6300XX, the XX being the CM numerical designation plus 4. Example, the Velcro and Snaps Map for CM 116 will be V36-630120. Only the LEB is shown in figure 2.12-15 as it is typical.

2.12.3.2.7 Probe Stowage Bag (CSM 116 only)

The probe stowage bag is provided to protect the probe from MDA humidity during stowage. The bag is stowed in Locker A3 at launch, used to stow the CSM probe, and left stowed in the MDA after use.

The probe stowage bag is Beta cloth, 32 inches long, 26 inches in diameter, and has a sealed zipper for entry into the bag.

2.12.3.2.8 Deleted

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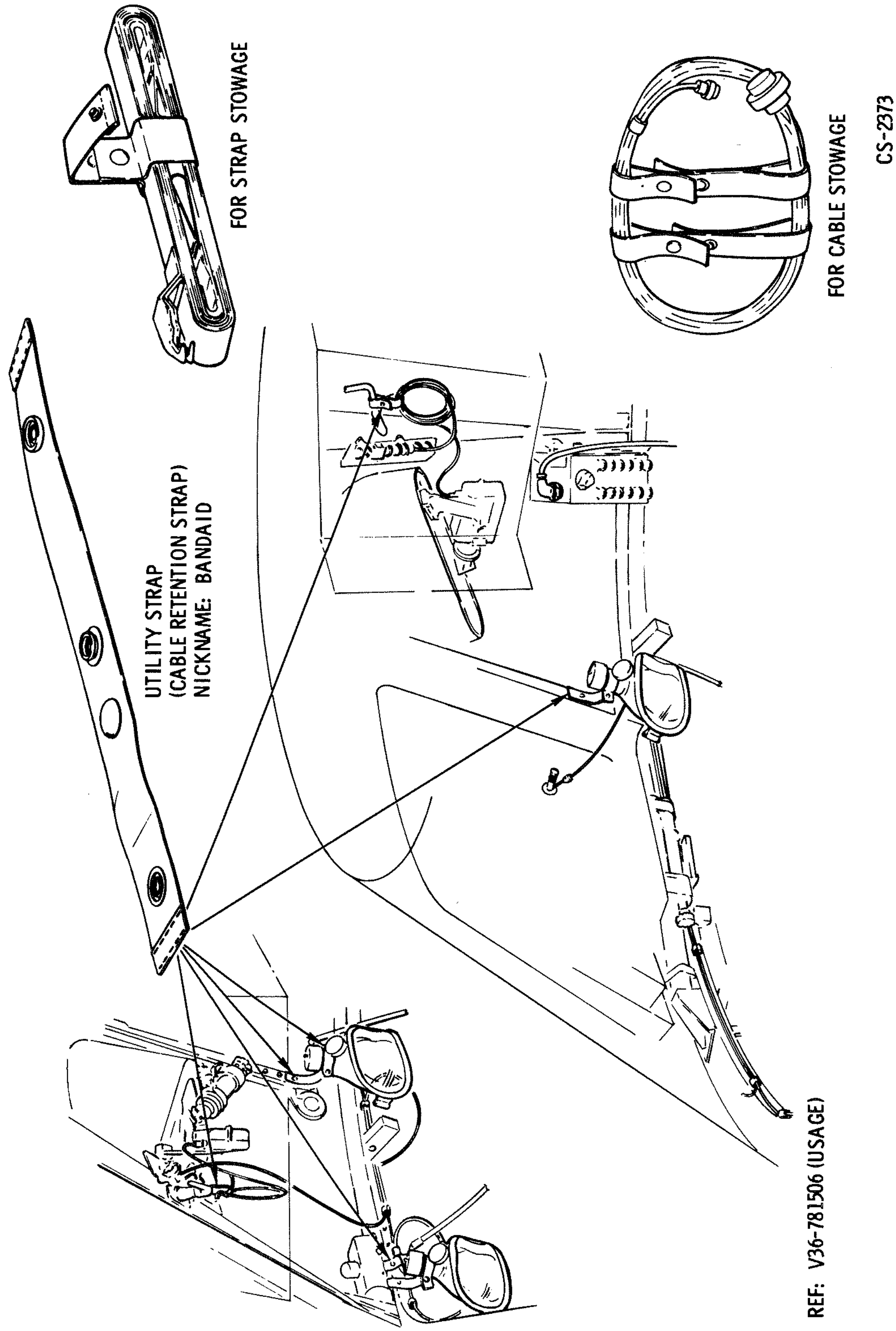

Figure 2.12-14. Utility Straps

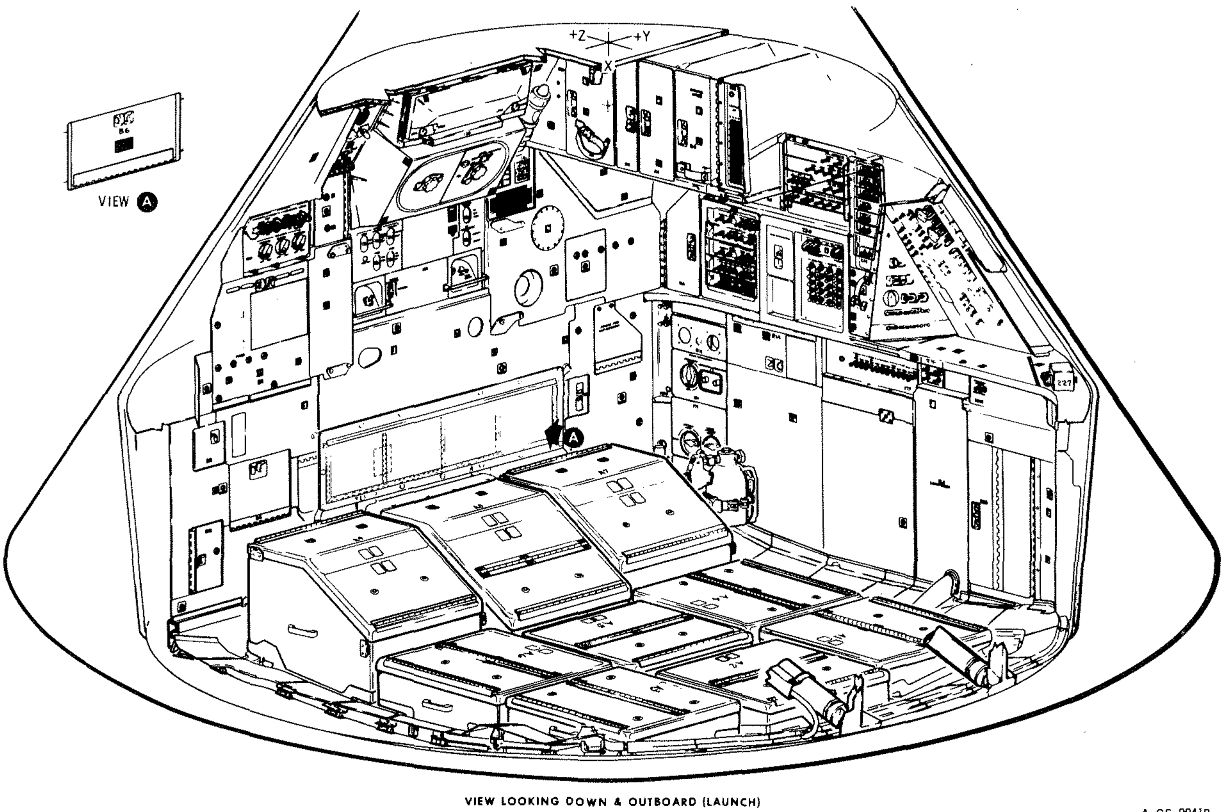

Figure 2.12-15. Velcro and Snaps Locations

2.12.4 SIGHTING AND ILLUMINATION AIDS

Sighting and illumination aids are those devices, lights, or visual systems that aid the crew in the accomplishment of their operational mission. This handbook describes the internal sighting aids first and the external second. The crew compartment floodlights and panel lighting are described in the electrical power system section, 2.6, of this handbook.

2.12.4.1 Internal Sighting and Illumination Aids (Figure 2.12-16)

Internal sighting and illumination aids include window shades for controlling incoming light, internal viewing mirrors, the crewman optical alignment sight for docking and aiming the data acquisition camera, window markings for monitoring entry, a monocular, and some miscellaneous items such as floodlight glareshields, MDC glareshades, and an eyepatch.

2.12.4.1.1 Window Shades (Figure 2.12-17)

The CSM has five windows: two triangular-shaped rendezvous windows, two square-shaped side windows, and a hatch window. Periodically, the light coming through these windows has to be restricted. This is accomplished by window shades (figure 2.12-17).

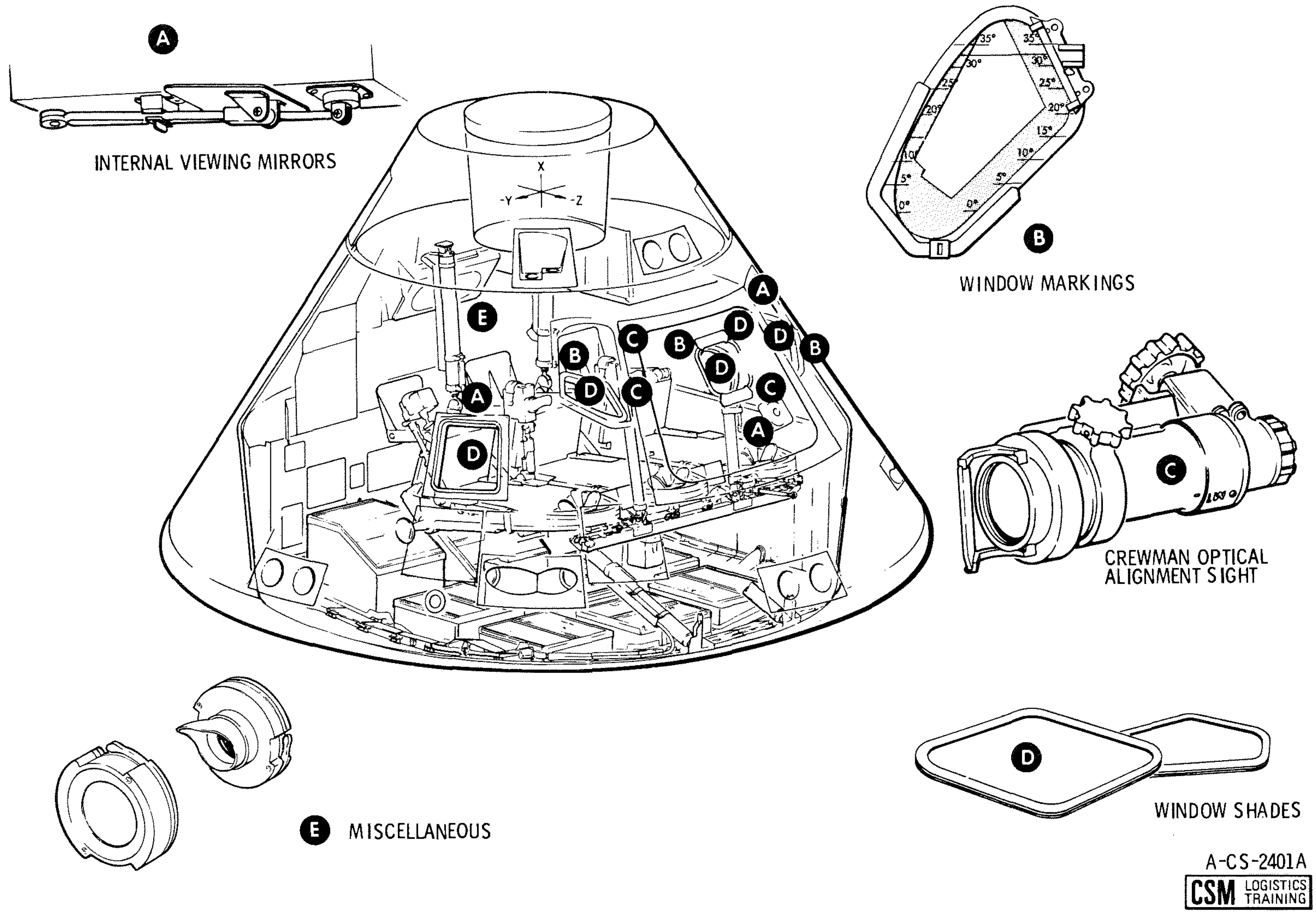

Figure 2.12-16. Skylab Internal Sighting and Illumination Aids

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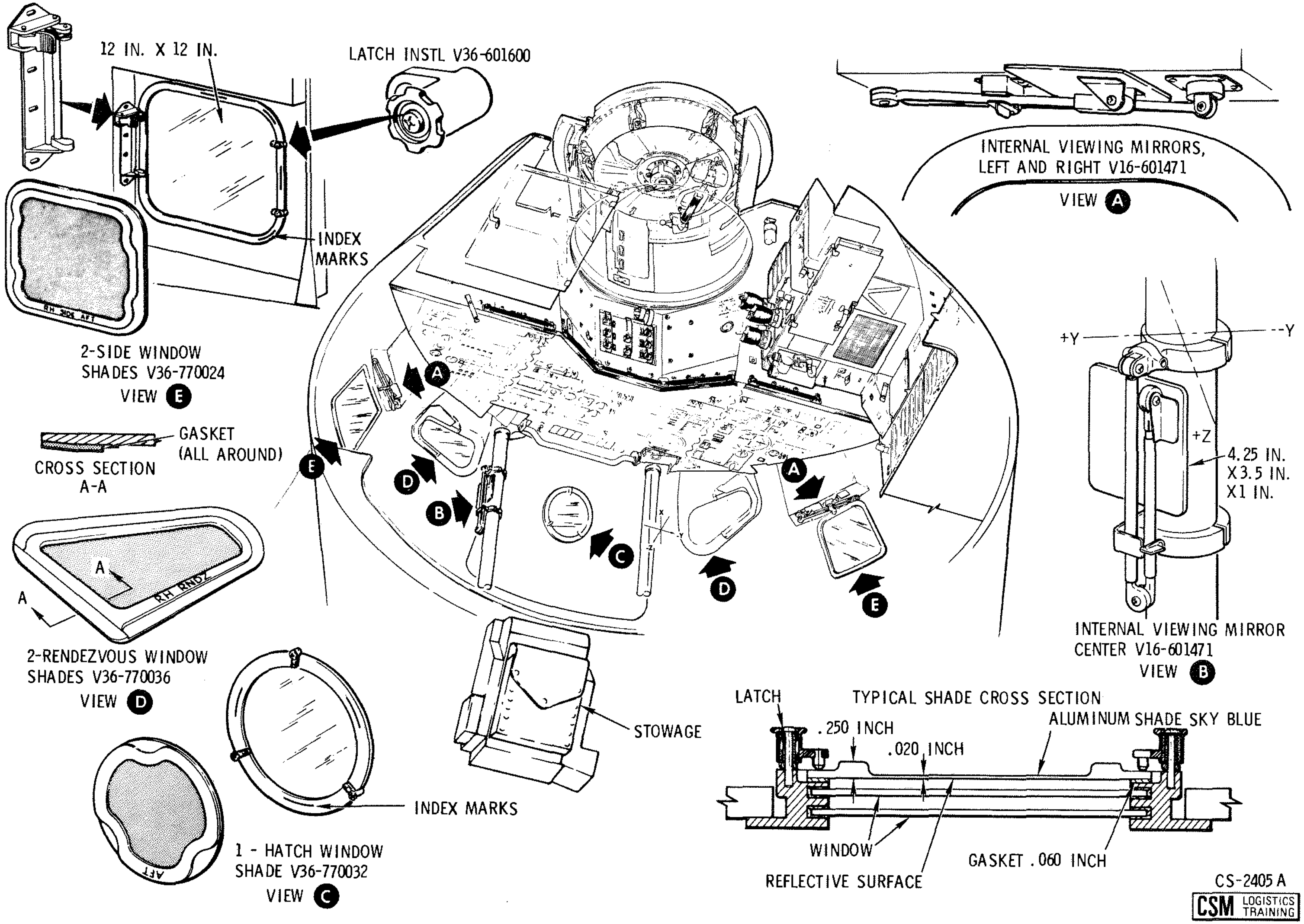

Figure 2.12-17. Window Shades and Mirrors

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The window shades are aluminum sheets held on by wing latches. The shades are 0.020-inch thick with a frame of 0.250 inch. The shade has a gasket on the light side which seats against the window. Each window frame has three wing latches, or two latches and a clip, that restrain the shade on the window. The shades are stowed in a stowage bag in the upper equipment bay.

2.12.4.1.2 Internal Viewing Mirrors (Figure 2.12-17)

When the astronaut is in a pressurized spacesuit on the couch, his field of vision is very limited. He can see only to the lower edge of the main display console (MDC), thus "blanking out" his stomach area where his restraint harness buckling and adustment takes place. The function of the internal viewing mirrors is to aid the astronaut in buckling and adjusting the restraint harness, and locating couch controls and spacesuit connectors.

There are three mirrors, one for each couch position. The mirrors for the left and right astronaut are mounted on the side of the lighting and audio control console above the side viewing window and fold. The center astronaut's mirror is mounted on the right X-X head attenuator strut.

The mirror assembly consists of a mounting base, a two-segmented arm, and a mirror. The mirror is rectangular (4.25 by 3.5 inches), flat stainless steel with a polished surface. The two-segmented arm allows a reach of approximately 22 inches from the mount. The arms have swivel joints with a friction adjustment to position the mirrors in the desired angles. The friction is adjusted with tool R, a No. 10 torque set driver. The mirrors are locked in position by a clamp during boost and entry.

2.12.4.1.3 Crewman Optical Alignment Sight (COAS) (Figure 2.12-18)

The primary function of the crewman optical alignment sight (COAS) is to provide range and range rate to the CM during the docking maneuver. The closing maneuver, from 150 feet to contact, is an ocular kinesthetic coordination of the astronaut controlling the CM with economy of fuel and time.

A secondary function of the sight is to provide the crewman a fixed line-of-sight attitude reference image which, when viewed through the rendezvous window, appears to be the same distance away as the target. This image is boresighted (by means of a sight mount) parallel to the centerline (X-axis of the CM) and perpendicular to the Y-Z plane.

COAS Description. The crewman optical alignment sight (COAS) is a collimator device, similar to the aircraft gunsight, weighing approximately 1-1/2 pounds, is 8 inches long and requires a 28-vdc power source. The COAS consists of a lamp with an intensity control, reticle, barrel-shaped housing, mount, combiner assembly, and a power receptacle. The reticle consists of a 10-degree circle (figure 2.12-18), vertical and horizontal cross hairs with 1-degree marks, and an elevation scale (on the side) of -10 to +31.5 degrees. The elevation scale is seen through an opening or window.

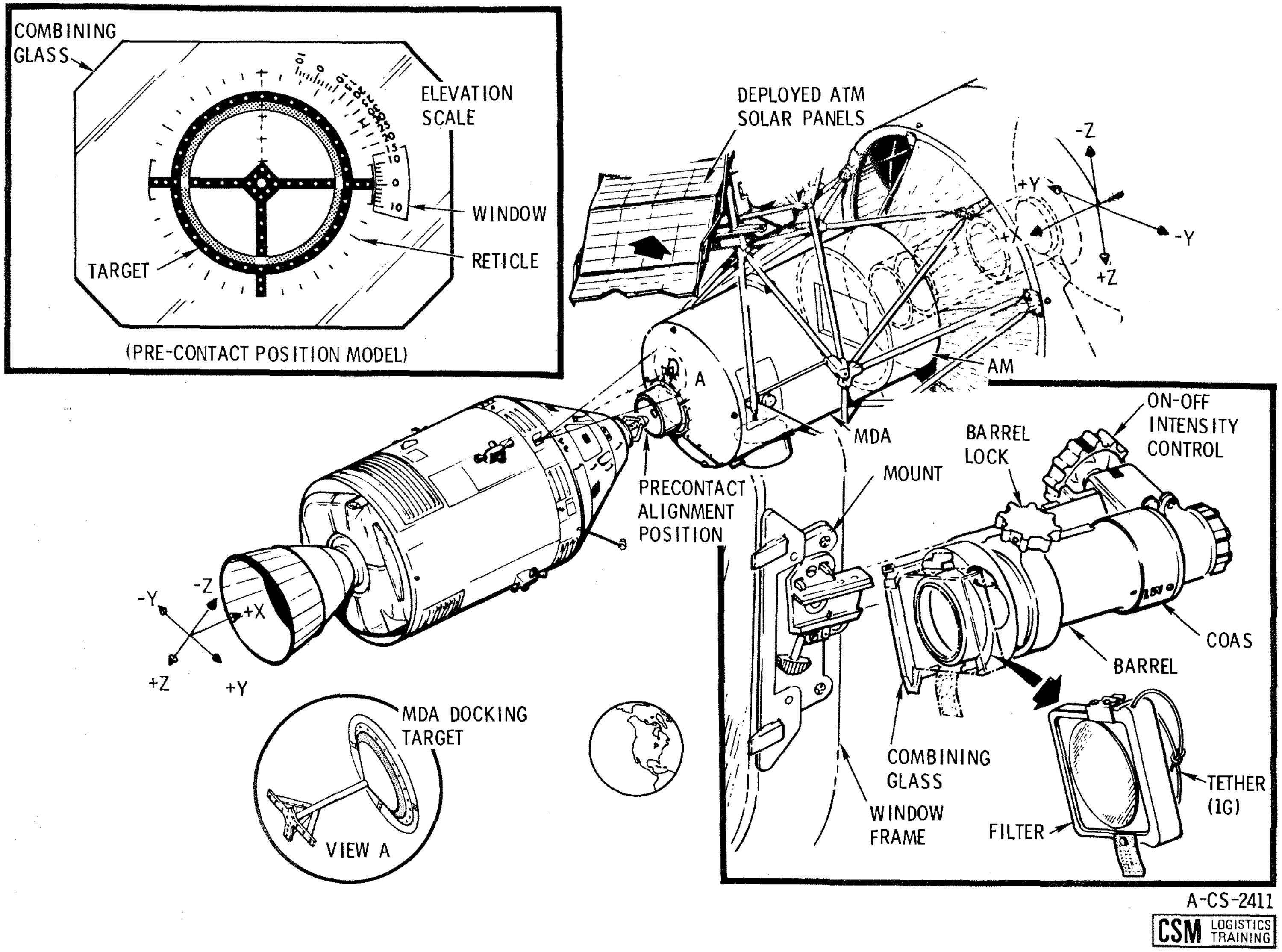

Figure 2.12-18. Crewman Optical Alignment Sight System

The COAS is stowed in a mount by the left side window at launch and entry, and other periods as the mission requires. A spare lamp (bulb) is stowed in U3. The COAS is mounted in the left rendezvous window when used for docking.

COAS Operation. The receptacle is de-energized by placing the switch on panel 16 (right) or 15 (left) to the OFF position. COAS is installed on the rendezvous window mount and the circuit is energized by placing switch to ON.

The barrel index is matched with LW by unlocking the barrel lock and rotating the barrel until the detent seats. There may be a little play when the detent seats. To duplicate the boresighted condition, the barrel must be snugged or rotated against the detent. The direction of rotation is on the sidewall near each COAS mount.

To turn the lamp on, the intensity control is turned clockwise until the reticle appears on the combiner glass at the required brightness. The actual usage and visual presentations are discussed in paragraph 2.13.

Additional Uses. While photographing activities or scenes outside the spacecraft with the 16 mm data acquisition camera, the COAS is used to orient the spacecraft and aim the camera. The camera is mounted in the right window at a 90-degree angle to the X-axis, and will be shooting out the right rendezvous window, via a right-angle mirror assembly.

A constant angle on a star during a differential velocity maneuver (MTVC) can be maintained by use of the elevation scale. The barrel lock is lifted and turned so the barrel can be rotated, and will hold in an intermediate position by friction. The elevation will be read on the elevation scale using the horizontal line of the reticle as the index.

2.12.4.1.4 Window Markings (Figure 2.12-19)

The left-rendezvous window, right-rendezvous and hatch window frames have markings to aid the crew in monitoring the entry maneuver, and also function as a visual reference for orientation during a manually controlled entry. After service module separation, the CM will be oriented to a bottom forward entry attitude with the crew's heads and Z-axis pointing down. The X-axis will make an angle of approximately 31.7 degrees with the aft horizon during the initial entry, so as the CM 1 views the horizon through the left rendezvous window, it will appear to touch the 31.7-degree mark. During the entry roll program, the actual roll can be approximated by markings on the hatch window frame that have been precalculated by computers.

Being a method that requires a fixed-eye position to avoid parallax, the 80th-percentile crewman eye position is used; his eyes are 15 inches aft of the 31.7-degree mark on the inner rendezvous windows. If a crewman is other than the 80th percentile, he will have to adjust his head/eye position.

Left Rendezvous Window Markings. The left rendezvous window has marks that are yellow epoxy ink applied externally on the glass for CM 1's viewing. The index marks are located every 5 degrees from -5 degrees to +35 degrees.

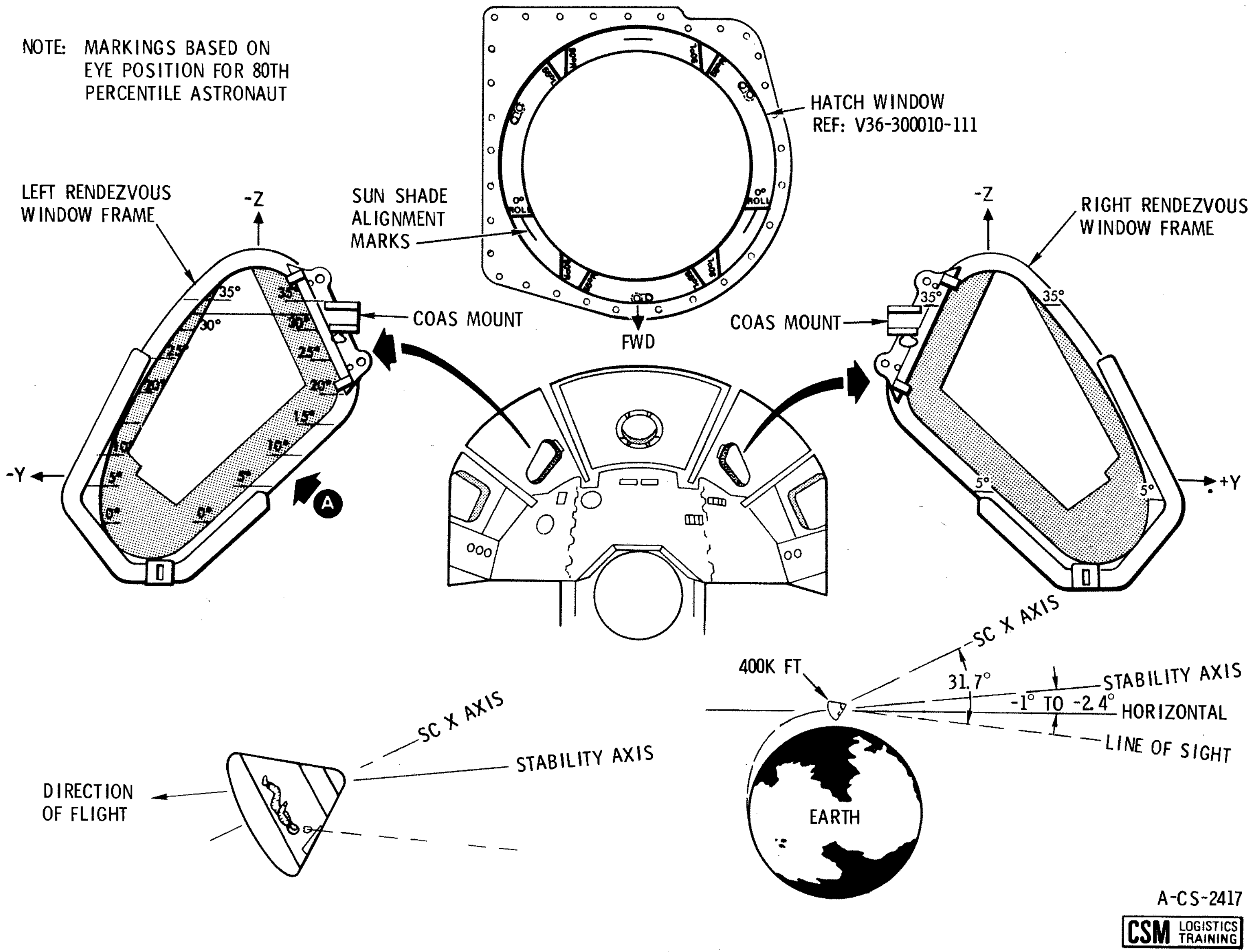

Figure 2.12-19. CM Window Markings

Center (Hatch) Window Frame Markings. Entry begins at 400,000 feet (75 miles). When .05 g is sensed, the G&N system computes the entry path to land at a certain location. The entry involves rolling the command module to control the lift vector. The CM 2 in the center couch can monitor the entry roll program. At 400,000 feet, the horizon will appear across the 0° ROLL marks. As the CM is rolled, there are 55° R&L, 90° R&L roll marks to compare to the horizon and estimate roll. The black roll marks are located on the hatch window frame.

Right Rendezvous Window Frame Markings. The CM 3 will also monitor the entry but in a limited degree. The right rendezvous window frame only has the 5° and 35° markings in black.

2.12.4.1.5 Telescope Sun Filters (Figure 2.12-20)

When sighting the G&N telescope toward the sun, the sun rays are attenuated by the use of the telescope sun filters. There are two sun filter assemblies, one that is used on the long eyepiece for suited operations, and one that is used on the standard (short) eyepiece for unsuited or shirtsleeve operations.

The standard eyepiece sun filter is 3 inches in diameter, 0.6 inch thick, and has an eyeguard or eyecup. The long eyepiece sun filter is 3.5 inches in diameter and 0.9 inch thick. Both filters have similar mechanisms for attachment. They are rocker-arm levers 180 degrees apart, that seat a shoe in a groove on the eyepiece.

To install the standard eyepiece sun filter, the eyepiece eyeguard must be removed by unscrewing and stowing. Then, the filter is aligned to the eyepiece, the levers are pressed, the eyepiece is slid on, the levers are released, and the shoes are seated. The long eyepiece filter installs directly on the long eyepiece in the same manner.

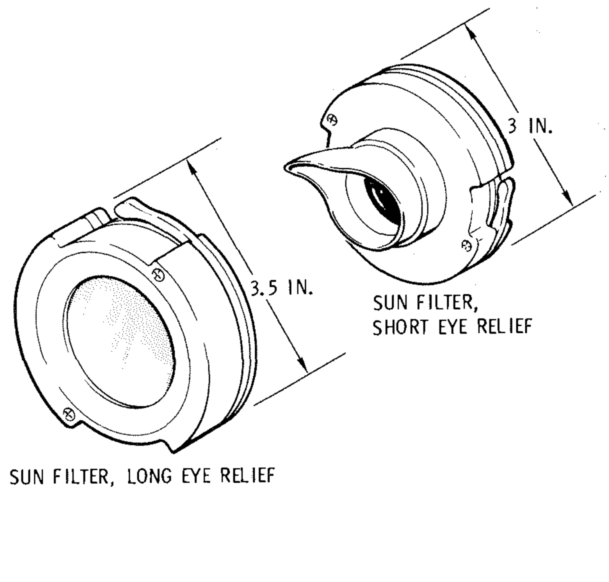

Figure 2.12-20. Miscellaneous Internal Sighting and Illumination Aids

2.12.4.2 External Sighting and Illumination Aids

External illumination aids are those devices or lights located on the exterior surface of the CSM that furnish the visual environment to perform operational activities.

2.12.4.2.1 Docking Spotlight (Figure 2.12-22)

During the docking phase of the mission, the CSM translates forward toward the multiple docking adapter (MDA). During the translation toward the MDA, it is desirable to light the MDA so the proper perspective is maintained and excessive maneuvering is decreased, thus minimizing SM RCS propellant usage. The lighting of the MDA is accomplished by use of the docking spotlight.

The spotlight is mounted behind the left rendezvous window on the door of a concealed compartment in the CM/SM fairing. The door is spring-loaded to the deployed position and is held flush by a pin extended from an actuator. To deploy the spotlight/door, on panel 16 the SPOTLIGHT switch is placed in the ON position. The spotlight door initiator/actuator receives 28 vdc, its pin-retention wire melts, pulling the spring-loaded pin and releasing the door. The spring-loaded door swings to the deployed position and is held there by a hinge-brace. As the switch is placed in the ON position, it simultaneously applies 115 vac to the spotlight, turning it on.

When docking has been completed and the spotlight is no longer needed, the switch is placed in the OFF position, removing power from the spotlight. The compartment door remains open, or deployed, for the remainder of the mission. If the spotlight is required again, the switch is placed in the ON position.

The circuit breakers for the spotlight are on panel 226. The a-c circuit breaker is labeled SPOTLIGHT-AC2 and the d-c circuit breaker is labeled COAS/TUNNEL SPOT DOOR-MNB.

Paragraphs 2.12.4.2.2 through 2.12.4.2.5 deleted.

Figures 2.12-21 and 2.12-23 deleted.

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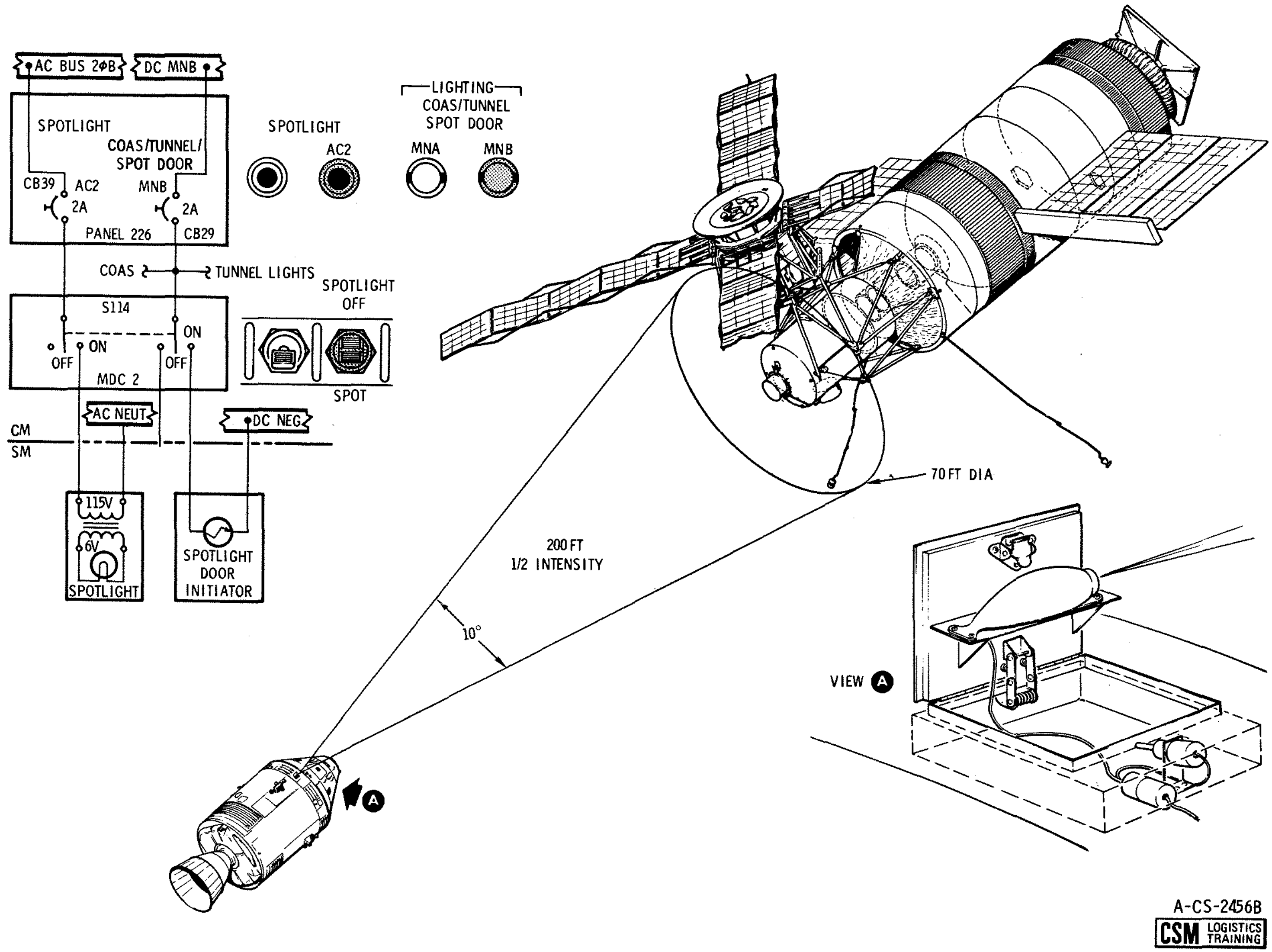


Figure 2.12-22. Docking Spotlight

Figures 2.12-24, 2.12-25, and 2.12-26 Deleted.

All information deleted from pages 2.12-49 through 2.12-54.

2.12.5 MISSION OPERATIONAL AIDS

Mission operational aids are those stowed devices, apparatus, and paraphernalia the crew utilizes to perform the required mission. Normal, backup, and emergency requirements are accomplished by these items. Miscellaneous items that are not related to other spacecraft systems or subsystems are also included and described in this category.

2.12.5.1 Flight Data File (Figure 2.12-28)

The flight data file is a mission reference data file that is available to the crewmen within the command module. The file contains checklists, manuals, charts, and data card kit. It weighs approximately 40 pounds.

2.12.5.1.1 Data File Clip

The data file clip function is to attach the handbooks to the structure for accessibility. It is a metal clamp (clipboard-type) with a patch of Velcro on one side.

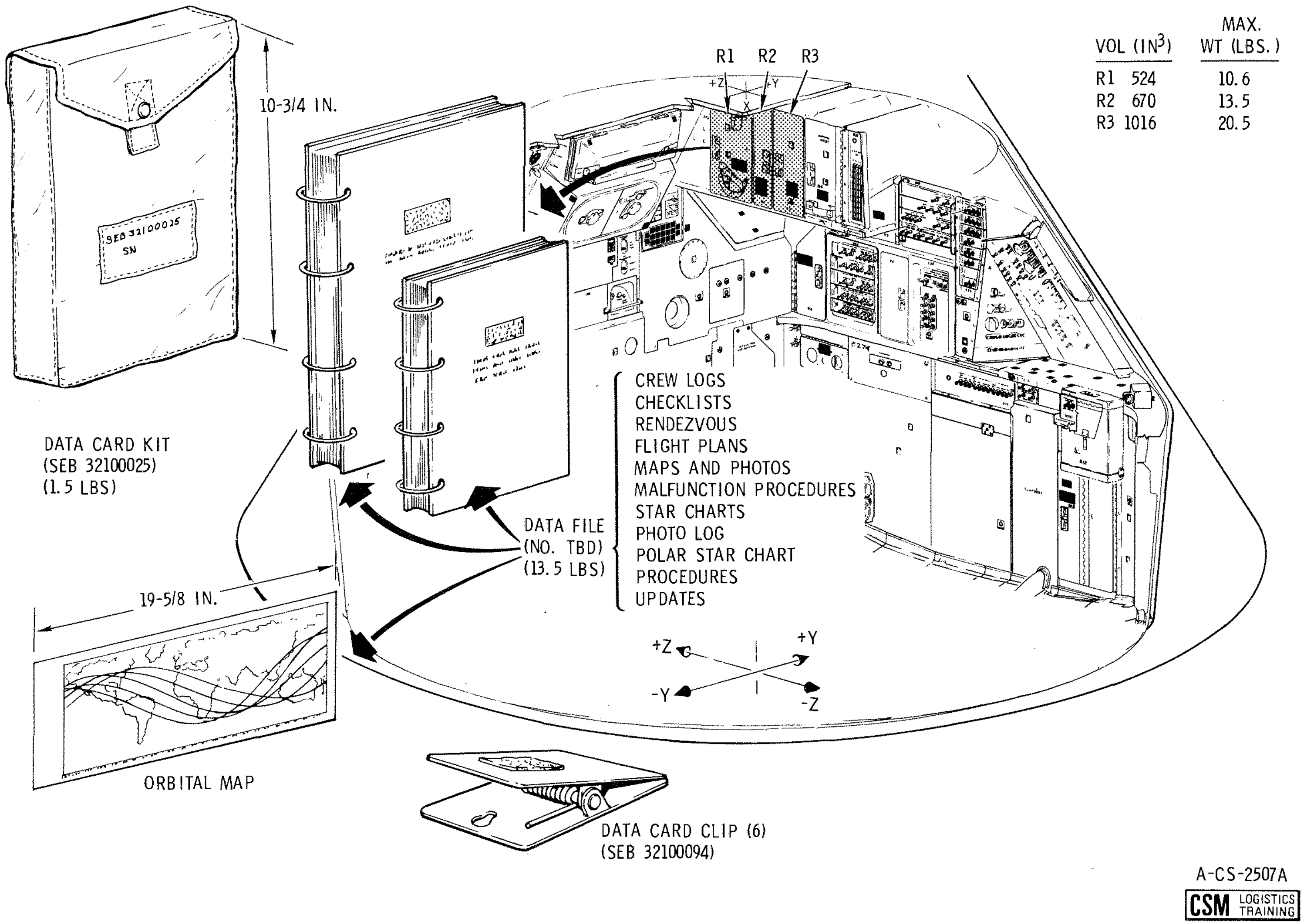
2.12.5.2 Crewman Toolset (Figure 2.12-29)

2.12.5.2.1 General

The crewman toolset provides multipurpose tools and/or attachments for mechanical actuations and valve adjustments. The toolset contains the following items: a pouch, an emergency wrench, an adapter handle, an adjustable end wrench, a U-joint driver, a torque set driver, a CPC driver, three jack screws, a 20-inch tether, a midget rachet wrench, two sockets, and #6, #8, and #10 torque set drivers. Each tool has a tether ring and is designated with a letter of the alphabet. All tools are capable of being used with a PGA gloved hand.

The adapter handle (tool E) is most often used. Therefore, if the tool required is other than tool E, a placard will indicate the correct tool and the direction of rotation. For specific tool usage, refer to the tool usage chart that follows.

Figure 2.12-27. Deleted



	VOL (IN^3)	MAX. WT (LBS.)
R1	524	10.6
R2	670	13.5
R3	1016	20.5

Figure 2.12-28. Flight Data File

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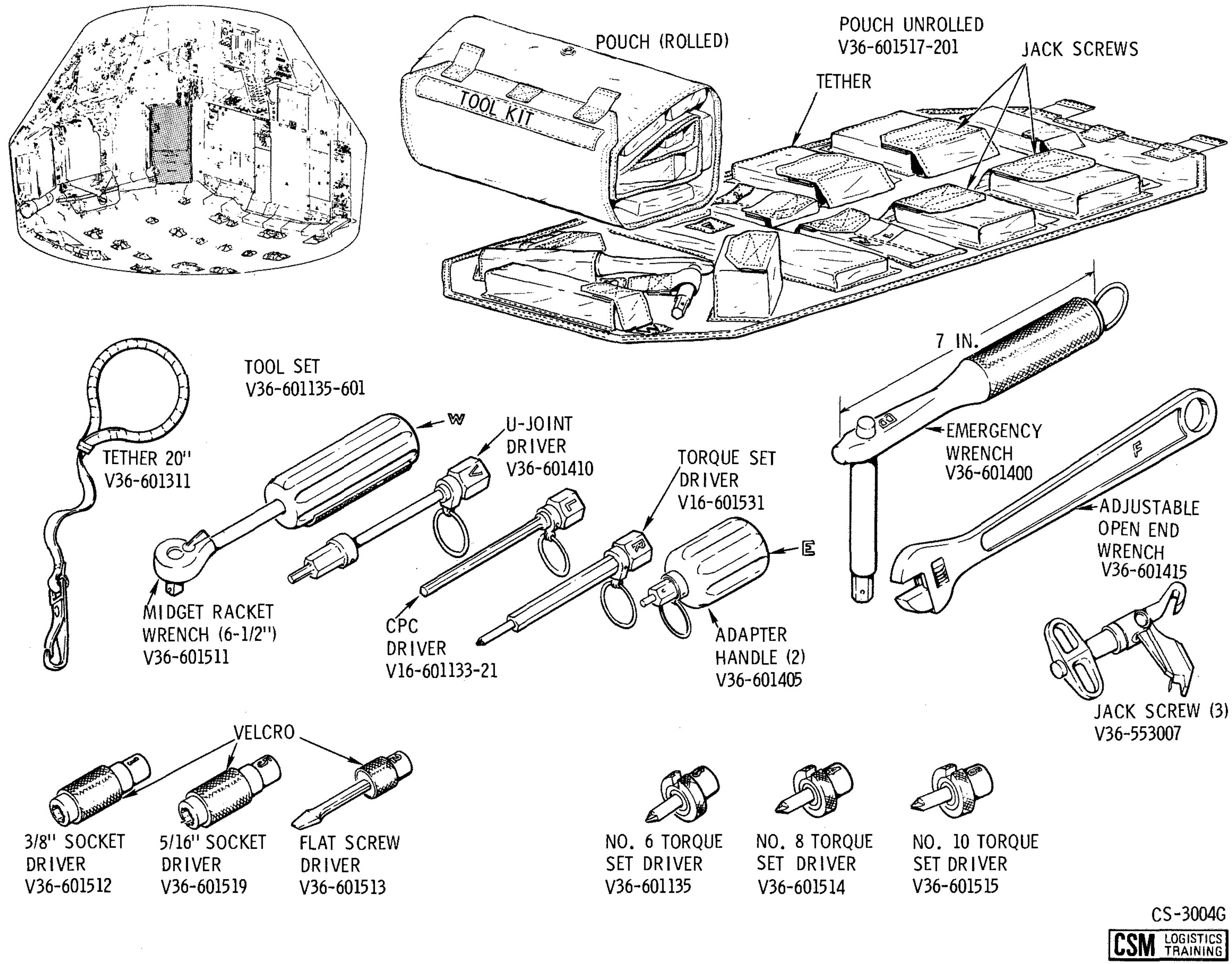

Figure 2.12-29. Crewman Toolset

Crewman Toolset Usage Chart

E = Emergency, or Backup, Tool Usage
P = Primary Tool Usage

Function	Small Drive Tip	Large Drive	Emer Wrench	Adap Handle (2)	Adj End Wrench	Torque Set Driver	U-Joint Driver	Midget Ratchet	3/8" Socket	1/4" Screw Driver	NR 8 Torque Set	NR 10 Torque Set	5/16 Socket	NR 6 Torque Set
Tool Designator			B	E	F	R	V	W	1	2	3	4	5	6
A. Environmental Control System														
1. Open/close ECS valves on oxygen, water, coolant control, girth shelf ECS, LHEB ECS panels, and TUNNEL VENT valve.	X			P										
2. Operate secondary cabin temperature valve (LHFEB).	X			P										
3. Operate CM/tunnel MDA PRESSURE EQUALIZATION valve (from MDA side).		X	P											
4. Unlatch/latch fasteners of access panel and cove to gly evap temp cont (LHEB).	X			P										
5. Unlatch/latch fasteners of access panel to cabin atmosphere recirc system (LHFEB).	X			P										
6. Position PRIM ACCUM FILL valve OPEN/CLOSE.	X			P										
7. Open hatch dump valve (from outside EVA).		X	P											
8. Unlatch/latch fasteners of access panel to waste water line filter.				P										
B. Guidance and Control System														
1. R/R G&N handles (2) on G&N panel (LEB).	X			P										
2. Adjust scanning telescope shaft and trunnion axis (emergency mode) (LEB Panel 121).	X			E			E							
3. Open/close EMS pot GTA cover and adjust EMS pot on MDC-1 during prelaunch checklist by backup crew.	X			P										
C. Mechanical Systems - Inside CM														
1. Install/remove survival beacon connector (5/8) hex.	X				P									
2. Any drive screw or fastener with a 5/32" internal hex.	X			P										

CPE

Crewman Toolset Usage Chart

E = Emergency, or Backup, Tool Usage
P = Primary Tool Usage

Function	Small Drive Tip	Large Drive	Emer Wrench	Adap Handle (2)	Adj End Wrench	Torque Set Driver	U-Joint Driver	Midget Ratchet	3/8" Socket	1/4" Screw Driver	NR 8 Torque Set	NR 10 Torque Set	5/16 Socket	NR 6 Torque Set
Tool Designator			B	E	F	R	V	W	1	2	3	4	5	6
3. Adjust mirror U-joints.				P		P								
4. Manually remove forward tunnel hatch latch pivot pin.					E			E		E				
5. Tighten lightweight headset mic boom.								E		E				
6. Adjust window shade latches.								E		E				
7. Backup for "R" tool.								E			E	E		
8. Manually release docking ring latches										E				
D. Mechanical Systems - Unified Hatch														
1. R/R bell crank.		X	E											
2. Operate unified hatch latch drive (from inside).		X	E											
3. Isolate latch linkage.		X	E											
4. Actuate latches (backup adjustment 11/16 flats).					E									
5. Disconnect/remove hinges.		X	E											
E. Probe and Tunnel Equipment														
1. Remove nuts and bolts from ends of shock struts (emergency probe collapse and removal).					E			E	E					
2. Remove fairings from docking ring latches (prior to manual release of docking ring latches).								E			E	E		
3. Remove extension latch solenoid for installation of manual extend latch release mechanism.														P
4. Remove pressure equalization valve from tunnel hatch in case of malfunction.													P	
F. Miscellaneous														
1. Adjust crewman headset earphone volume.								P		P				

2.12.5.2.2 Toolset Description and Use

Tools B, E, and V have small 5/32-inch and large 7/16-inch hex drives similar to allen-head wrenches. The small drive is primarily used for mechanical fastener and ECS valve operation. The large drive is used for large torque requirements and connecting to drivers. Drivers, such as tools L, R, and V, have 7/16-inch hex sockets that receive the large drives.

Toolset Pouch. The toolset pouch is a tool retention device made of Beta cloth. The pouch has pockets with retention flaps and Velcro tabs. For zero-g stowage, it has Velcro hook patches so it can be attached to the CM structure. For launch and entry stowage, it rolls and fits into a stowage locker. The pouch will stow all of the tools. However, a crewman may elect to stow the adapter handle E in the spacesuit or in a more accessible compartment.

Tool B - Emergency Wrench. The emergency wrench is 6.25 inches long with a 4.25-inch drive shaft. The drive shaft has a large drive only. The wrench is capable of applying a torque of 1475 inch-pounds, and has a ball-lock device to lock it in a socket. It is essentially a modified allen-head L-wrench.

Tool E - Adapter Handle. The adapter handles (2) are approximately 3.5-inches long and 1.5-inches in diameter. Each has a large and small drive and fits all drivers. A ball detent will assist in maintaining contact with the drivers. It is used similarly as a screwdriver. One is located in the toolset and the other is stowed in L2.

Tool F - End Wrench. There is one adjustable end wrench per toolset, a 10-inch crescent wrench. The end wrench is used for installation and removal of the survival beacon connector and emergency activation of the hatch latches.

Tool L - Cold Plate Clamp Driver. The CLP driver is 5 inches long with a 7/32-inch hex at one end and the 7/16-inch socket at the other. It is used to remove the waste water servicing plug on the water panel (panel 352) in preparation for partial dump of waste water tank.

Tool R - Torque Set Driver. The torque set driver is 4 inches long with a 7/16-inch socket at one end, a shaft in the center, and a No. 10 torque set screwdriver at the other end. It is used primarily to adjust the mirror universal joints that may come out of adjustment during vibration loads.

Tool V - U-Joint Driver. The U-joint driver has a 7/16-inch driver socket at one end and a universal joint with a small and a large hex drive at the other end. The U-joint driver will rotate up to an angle of 30°. It is used to gain access to the hard to get at fasteners.

NOTE

The following five tools (W, 1, 2, 3, 4, 5, 6) are referred to as docking probe tools but their capability is greater than emergency probe disassembly. The tools are all modified snap-on tools and have Velcro patches for restraint. The attachment tools have 1/4-inch drive sockets.

CPE

Tool W - Midget Ratchet Wrench. The midget ratchet wrench is 6.62 inches long, has a 1/4-inch drive with an R/L ratchet controlled by a pawl on one end, and a 1-inch cylindrical handle on the other. The handle has a 2-1/2-inch length of Velcro hook for restraint. Its function is to drive attachment tools 1, 2, 3, and 4.

Tool 1 - 3/8-Inch Socket. Tool 1 is 2 inches long, has a 1/4-inch drive socket on one end, and a 3/8-inch, 12-point socket on the other. It is used to remove the nuts from the bolts that retain the shock strut to the probe supports.

Tool 2 - Screwdriver. A 1/4-inch flat screw driver 2.8 inches long is tool No. 2. It is used to torque any slotted screws or bolts and those listed in the tool usage chart.

Tools 3, 4, and 6 - Number 8, 10, and 6 Torque Set Drivers. The torque set drivers are 1.6 inches long. The No. 6, 8, and 10 indicate the No. 6, 8, and 10 torque set tips. They are used to remove No. 6, 8, and 10 torque set screws (some of which are listed in the tool usage chart) and as a backup for tool R, the 5-inch torque set driver.

Tool 5 - 5/16-Inch Socket. Tool 5 is 2 inches long, has a 1/4-inch drive socket on one end, and a 5/16-inch, 12-point socket on the other. It is used to remove the pressure equalization valve on the tunnel hatch.

Tether. The tether is a strap 14 inches long with a snap hook at one end and a loop at the other. The hooks can be snapped into the tool tether ring to secure it to the crewman when he is moving about the CM.

Jackscrew. The jackscrew (3) is approximately 4 inches long with a wing nut on one end. The opposite end has a trunnion, about which a lever rotates, and through which a hook shaft slides. When the wing nut is turned clockwise, it draws the hook shaft into the barrel.

In the event the side hatch is deformed and the hatch latch mechanism will not engage the hatch frame, the jackscrew is used to draw the hatch to the position the latch mechanism will engage. If the latch will not engage, the screwjacks will hold the hatch closed so that it will withstand the thermal load of entry. However, it may not be pressure-tight.

To use the jackscrew, engage the lever into the three catches on the hatch frame (two on right, one on left). Next, engage the hook into the three catches on the hatch and screw the wing nut clockwise, taking care to tighten evenly in increments. That is, a couple of turns on one jackscrew, then a couple on the next jackscrew (next clockwise position), etc., until the hatch is snug.

2.12.5.3 Cameras

Two basic types of operational cameras and associated accessories are furnished to facilitate in-flight photography: a 16 mm cine/pulse camera and a 70 mm still camera. Photography assignments vary from mission to mission and hardware requirements vary accordingly. Spacecraft crew equipment stowage lists reflect camera equipment configuration. Typical mission photography task assignments include the following: synoptic terrain and weather studies, docking, crew operations, crew

EVA, and targets of opportunity. Some flights will provide for specific scientific experiments and will require specialized equipment. A brief description of the two basic operational cameras and their accessories follows.

2.12.5.3.1 16 mm Data Acquisition Camera (Figure 2.12-30)

The data acquisition camera is a modified movie camera and is an improved version of the earlier Gemini-type 16 mm sequence camera equipped with new-type external film magazines which greatly enhance the photographic capabilities. Primary use of the camera will be to obtain sequential photographic data during manned flights. It will be used for documentary photography of crew activity within the CM and for recording scenes exterior to the spacecraft. Bracketry installations at each rendezvous window facilitate use of the camera for CSM-MDA docking photography to recording engineering data. Camera modes of operation (frame rates) are variable as follows: time, 1 frame per second (fps), 6 fps, 12 fps, and 24 fps. Shutter speeds are independent of frame rate and include 1/60 second, 1/125 second, 1/250 second, 1/500 second and 1/1000 second. Camera power is obtained from spacecraft electrical system via panel-mounted 28-vdc utility receptacles. Camera operation is manually controlled by an ON-OFF switch located on the front of the camera. Camera weight, less film magazine, is 1.8 pounds. When bracket-mounted at either spacecraft rendezvous window, the camera line of sight is parallel ($\pm$2 degrees) to vehicle X-axis. Camera accessories include a power cable, film magazines, lenses, right angle mirror, and a ring sight, which are described in the following paragraphs. The remote control cable, described with the 70 mm electric Hasselblad camera accessories, can also be used with the 16 mm data acquisition camera.

Power Cable. The power cable provides the necessary connection between the spacecraft electrical power system and the 16 mm camera. The cable is approximately 108 inches long and weighs approximately 0.23 pound. Utility receptacles, 28 vdc, are located on spacecraft panels 15, 16, and 100.

16 mm Film Magazine. Film for each mission is supplied in preloaded film magazines that may be easily installed and/or removed from the camera by a gloved crew member. Film capacity is 130 feet of thin base film. Total weight of magazine with film is approximately one pound. Magazine run time versus frame rate is from 87 minutes at one fps second to 3.6 minutes at 24 fps. Each magazine has a "film remaining" indicator plus an "end of film" red indicator light. Quantity and type of film supplied is determined by mission requirements.

16 mm Film Magazine Container. To be supplied at a later date.

16 mm Film Cassette. The film cassettes are launched in the OWS and are part of the return equipment. There is 400 feet of film per cassette.

Lenses. Two lenses of different focal length, which are provided for use on the 16 mm camera, are described herewith.

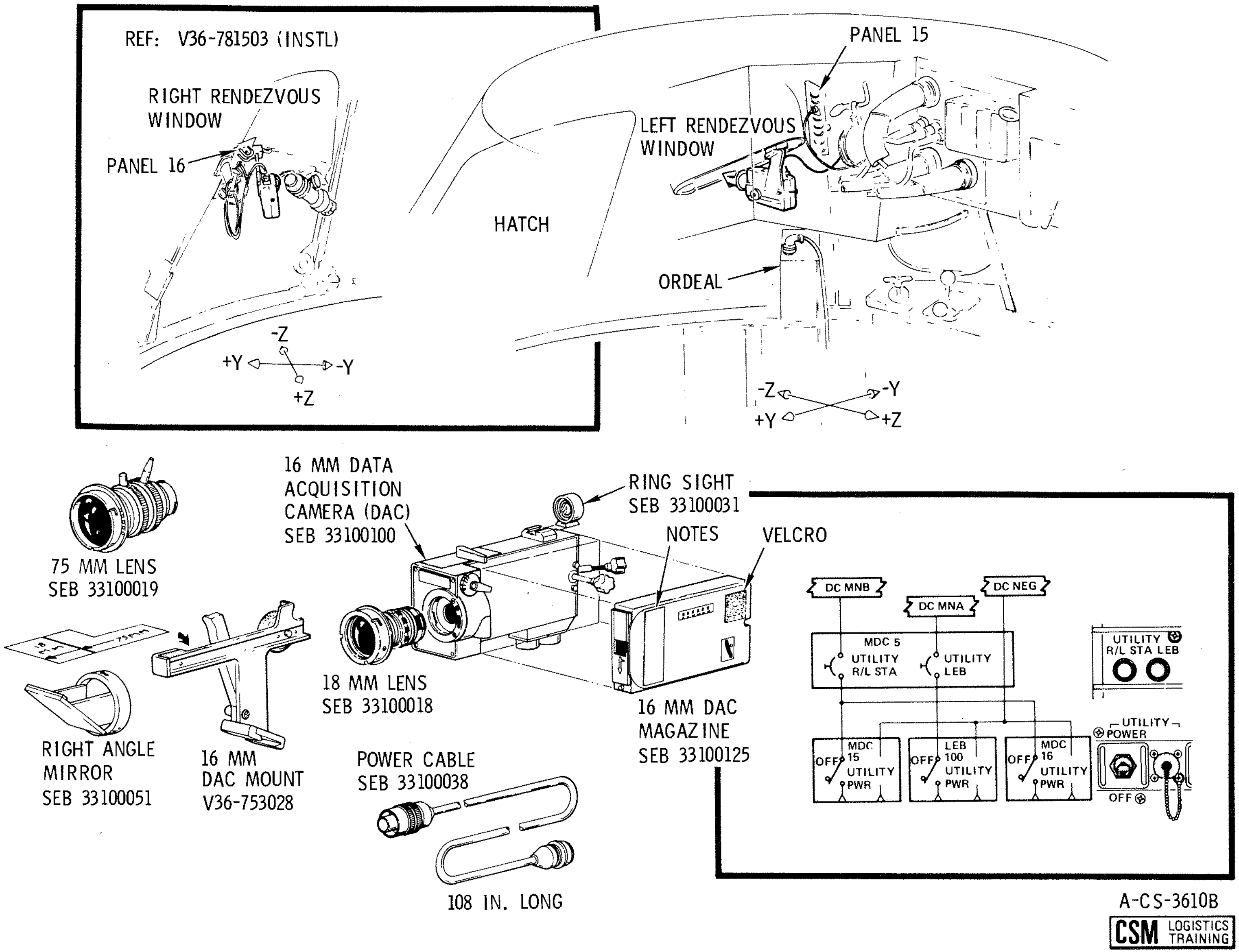

Figure 2.12-30. 16 mm Data Acquisition Camera (DAC)

18 mm Kern -- (SEB 33100018) the newest 18 mm lens model for general photography of intravehicular and extravehicular activities. It is slightly larger and longer than the former lens and is distinguished by its two spike-like handles for setting the f stop and distance with the gloved hand. This improved lens has larger numbers for ease in reading from within the EV spacesuit.

75 mm Kern -- (SEB 33100019) the newest 75 mm lens model for DAC telephotos. This lens is similar in appearance to the new 18 mm lens and has two handles for f stop and distance, gloved hand settings, and larger printed numbers. It also has a sun shade.

Right Angle Mirror. This accessory, when attached to the bracket-mounted 16 mm camera and lens, facilitates photography through the spacecraft rendezvous windows along a line of sight parallel to vehicle X-axis with a minimum of interference to the crewmen. It adapts to the 18 mm, 75 mm, and 200 mm lenses by means of bayonet fittings.

Data Acquisition Camera Mount. This device facilitates in-flight mounting of the 16 mm camera at spacecraft left or right rendezvous windows during zero "g". The mount is a quick-disconnect hand-grip that may be attached to a dovetail adapter at either rendezvous window. The camera attaches to the mount by means of a sliding rail and a friction lock screwed against the camera by a knob. Two marked locating stops are provided for correct positioning of the camera at a window, one for the 18 mm lens and one for the 75 mm lens. Mount alignment is such that installed camera/lens line of sight is parallel to spacecraft X-axis, ±1 degree.

DAC Fuse. One spare fuse is furnished in the data card kit in Volume R3.

16 mm Camera Operation. The camera mount (grip) is removed from stowage and attached to dovetail at appropriate rendezvous window. The 16 mm camera and accessories are unstowed as required. The selected lens is attached. A right-angle mirror is installed on lens (optional). A ring sight is installed on camera for hand-held use (optional). A film magazine is installed on camera. The correct exposure is determined. The lens aperture and focus are set. The camera mode (frame rate) and shutter speed are set. The power cable is installed on camera. The camera is installed in the mount (optional) at window. On spacecraft panels 15 and 16, UTILITY POWER receptacle switch is in OFF position. Camera power cable is mated to appropriate receptacle. Switch is placed to POWER position and green operate light on camera is illuminated steadily for approximately 3 seconds to indicate electrical circuit operation. Filming operation can be started by pressing the operate button (switch) on front of camera. To stop, operate button is pressed again.

The DAC camera equipment is stowed at launch and stowed in the MDA prior to CSM undocking.

DAC Mount Container. A draw-string Beta bag is provided for stowage in Volume B8 under a strap.

2.12.5.3.2 70 mm Hasselblad Electric Camera (HEC) and Accessories (Figure 2.12-31).

The 70 mm camera is primarily used for high-resolution still photography, and is hand-held and manually operated. The standard lens is an 80 mm f/2.8. Some specific uses of the camera are as follows:

- Verify landmark tracking
- Record Saturn IVB separation
- Photograph disturbed weather regions (hurricanes, typhoons, etc.), debris collection on the spacecraft windows, SLA separation, MDA/OW during rendezvous and docking, terrain of geological and oceanographic interests, and other space equipment in orbit
- Act as a backup to the 16 mm sequence camera
- Record in-cockpit operation, e.g., normal positions of suited crewmen.

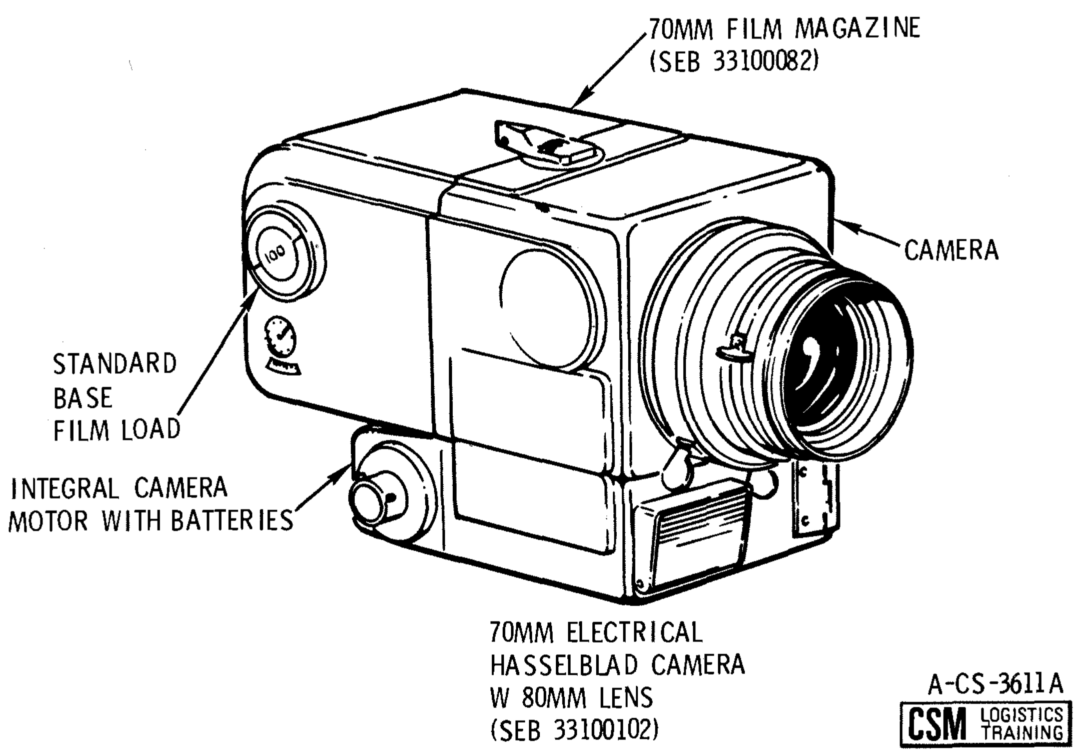

Figure 2.12-31. 70 mm Hasselblad Electric Camera and Cassette

The 70 mm Hasselblad camera is electrically operated. The increased ease of operation and improved photographic quality distinguish this camera from the earlier model still camera. A built-in 6.25-vdc battery-powered, electric-motor-driven mechanism advances the film and cocks the shutter whenever the actuation button is pressed. An accessory connector permits remote camera operation and shutter operation indication for time correlation. All accessories for the earlier model camera, except film magazines, may be used on the electric camera. Weight of the camera, with 80 mm lens and 2 batteries, without film magazine, is 4.04 pounds. The camera accessories are herewith described.

80 mm f/2.8 Lens. Standard or normal lens for the 70 mm camera with 2-1/4 x 2-1/4-inch film format. Used for general still photography when a wide angle or telephoto view is not required. Focuses from 3 feet to infinity. Has built-in shutter with speeds from 1 second to 1/500 second. Field of view, each side, is approximately 38 x 38 degrees.

HEC Batteries. Four batteries are provided for use with the HEC. They each weigh 0.330 pound and are 1.92 inches long with a 1.4-inch diameter.

70 mm Film Magazine Container. To be supplied at a later date.

2.12.5.3.3 Automatic Spotmeter (Figure 2.12-32)

This meter replaces the earlier model spotmeter and greatly enhances the crewman's ability to obtain accurate exposure information with a minimum of expended time and effort. The unit is a completely automatic CdS reflectance light meter with a very narrow angle of acceptance (one degree). The meter scales are automatically rotated to indicate the correct camera shutter speed/lens aperture values for the selected photographic subject. Brightness range is from 0.32 to 5000 foot-lamberts, with an extended range to 20,000 foot-lamberts by use of accessory neutral density filter. ASA range is from 3 to 25,000 and the weight of meter is 1.9 pounds.

2.12.5.3.4 Deleted

2.12.5.4 Accessories and Miscellaneous Equipment (Figure 2.12-33)

2.12.5.4.1 Temporary Stowage Bags

The temporary stowage bags are used for temporary stowage of small items and permanent stowage of dry refuse or "trash."

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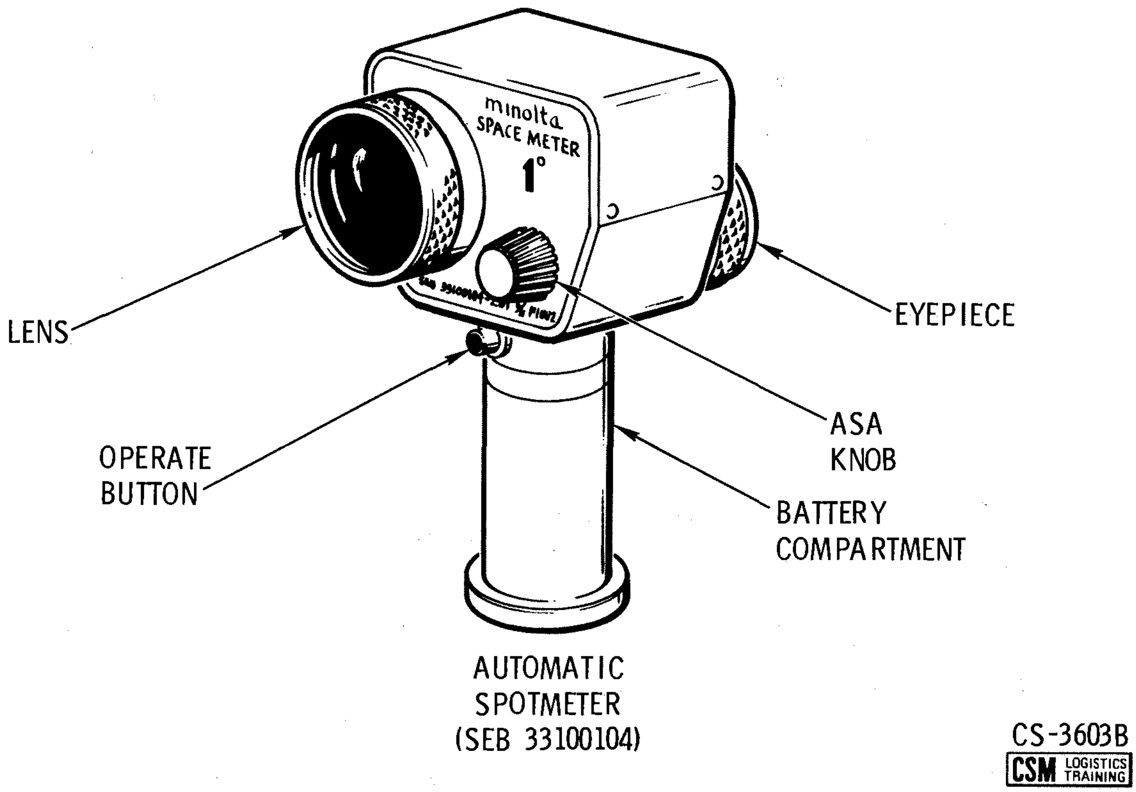

Figure 2.12-32. Spotmeter

The waste bag, nicknamed the "VW" bag, is a two-pocket unit. The outer pocket is deep, about 3 feet by 1 foot by 3 inches and is held shut by a bar spring. The inner pocket is flat, about 1 by 1 foot and is held shut by a rubber bungee. The bags are attached to the girth shelf and LEB by snaps.

The outer bag is for dry uncontaminated waste matter and the inner bag serves as temporary stowage for small items.

There are three waste bags, one for each crewman. The CM 1 bag attaches to the left girth shelf, the CM 3 to the right girth shelf, and the CM 2, the LEB. They are stowed in a stowage locker (U1) at launch and entry.

2.12.5.4.2 Pilot's Preference Kits (Figure 2.12-33)

The pilot's preference kits are small Beta cloth containers 7 x 4 x 2 inches, and weigh 0.5 of a pound. Each crewman will pack a kit with personal equipment or equipment of his choice.

2.12.5.4.3 Fire Extinguisher (Figure 2.12-33)

A fire in the cabin, or behind the closeout or protection panels, is extinguished by a small fire extinguisher. One fire extinguisher, mounted on the RHEB, is provided.

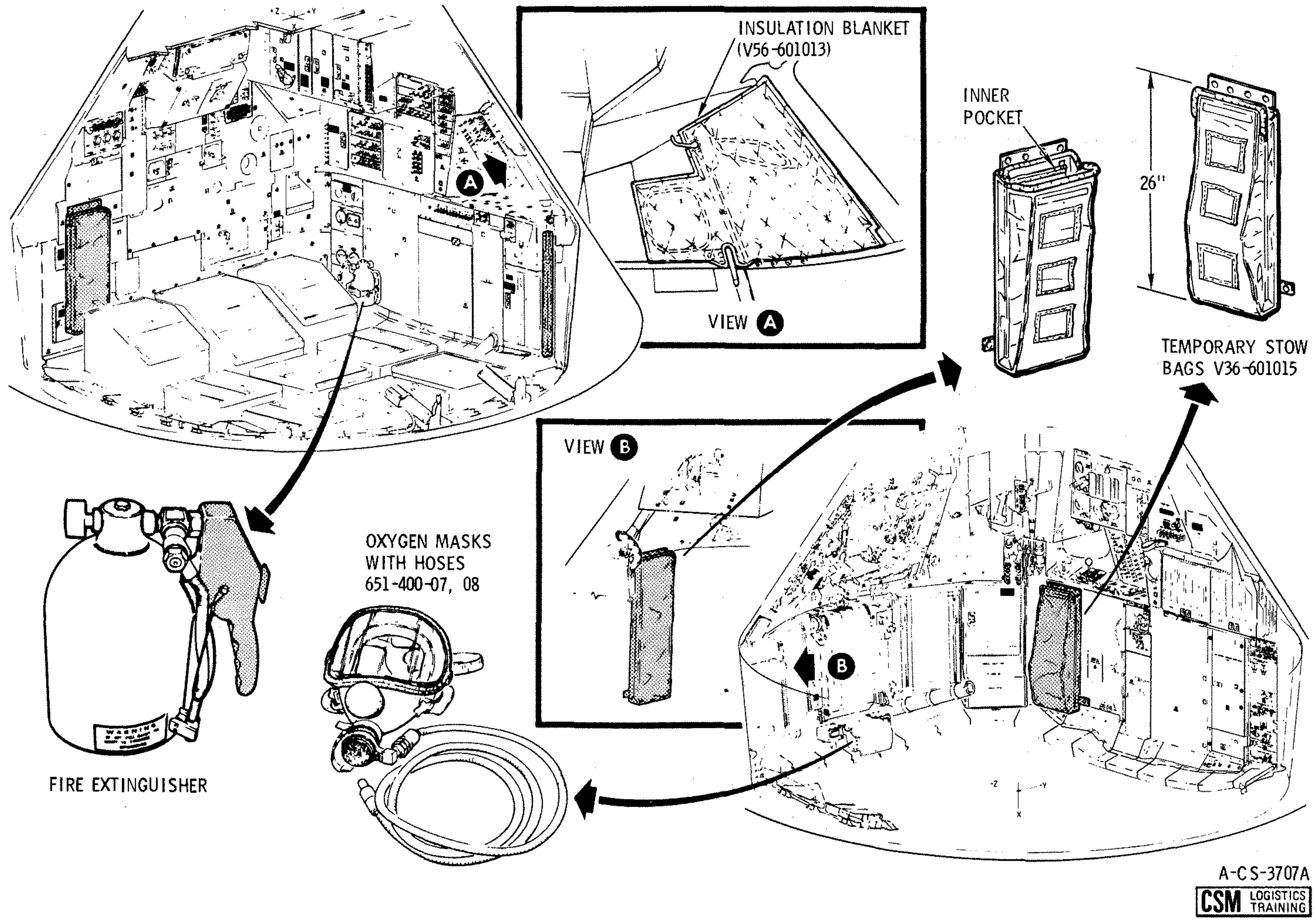

Figure 2.12-33. Accessories and Miscellaneous Equipment (Sheet 1 of 3)

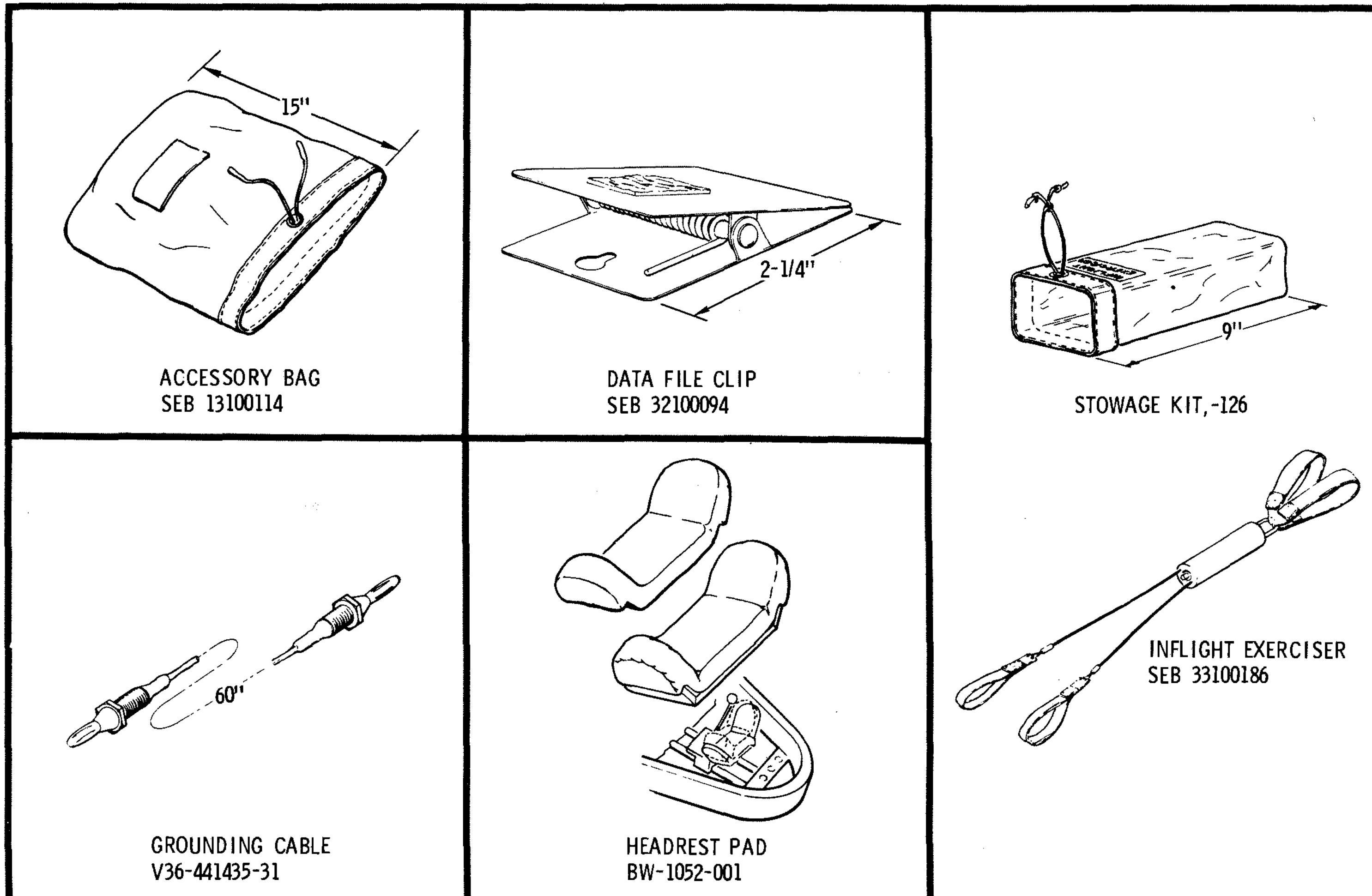

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Figure 2.12-33. Accessories and Miscellaneous Equipment (Sheet 2 of 3)

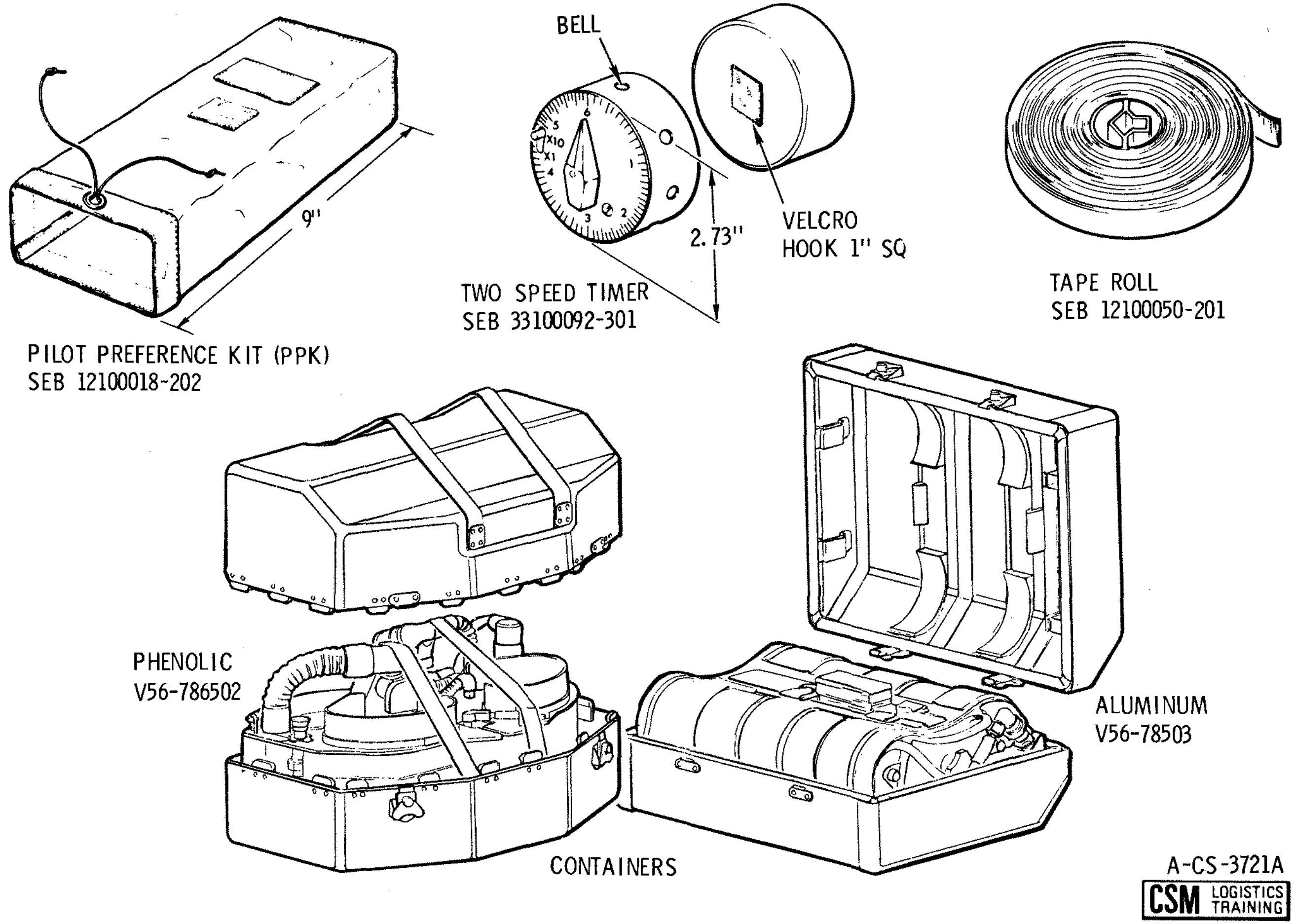

Figure 2.12-33. Accessories and Miscellaneous Equipment (Sheet 3 of 3)

The extinguisher weighs 7.7 pounds and is about 10 inches high with a 7-inch nozzle and handle. The tank body is a cylinder with a dome, and is made of stainless steel. The extinguishing agent is an aqueous gel (hydroxymethyl cellulose) which expells 2 cubic feet of foam for approximately 30 seconds under 250 psi at 140°F. The expulsion agent is Freon and is separated from the gel by a polyethylene bellows. The nozzle, handle, and actuator button are insulated against sparking. As a safety measure against overheating, a disk will rupture between 350 and 400 psi, allowing the gel to expel. A temperature indicating "temp-plate" near the label has four dots that turn black at temperatures of 110°, 120°, 130°, and 140°F respectively for the purpose of evaluating usability prior to flight.

To operate, the safety pin in the handle is pulled, the extinguisher is pointed at the fire or inserted in a FIRE PORT, and the button is pressed.

2.12.5.4.4 Oxygen Masks (Figure 2.12-33)

In the event of smoke, toxic gas, or hostile atmosphere in the cabin during the shirtsleeve environment, three oxygen masks are provided for emergency breathing.

The mask is a modified commercial type (GFP) with headstraps to hold it on. A utility strap is attached to the mask muzzle for in-flight stowage. The oxygen is supplied at 100 psi through a flexible hose from the emergency oxygen/repressurization unit on the upper equipment bay by actuating the emergency oxygen valve handle on panel 600. The mask has a demand regulator that supplies oxygen when the crewman inhales.

The three masks are stowed in a Beta cloth bag on the aft bulkhead below and aft of the emergency oxygen/repressurization unit. The masks are removed by pulling the center tape loop handle to disengage the snap fasteners restraining the cover. For in-flight accessibility, the oxygen masks may be stowed along the girth ring near the side hatch by attaching its utility strap snap socket to a stud.

2.12.5.4.5 Tape Roll (Figure 2.12-33)

A 6-inch diameter roll of 1-inch wide tape is provided for utility purposes.

2.12.5.4.6 Two-Speed Timer (Figure 2.12-33)

The two-speed timer is a two-mode kitchen timer. It is used by the crew to time short period events such as fuel cell purge. The face markings are 0 to 6. The two modes are 6 minutes and 60 minutes and are set by positioning a lever on the face to X1 or X10. To operate, the mode is set, the pointer is turned to the desired time setting. An alarm bell will ring when the time elapses.

2.12.5.4.7 Accessory Bag (Figure 2.12-33)

There are three accessory bags stowed in the PGA helmet bags at launch. They will be used for utility purposes. The bags are Beta cloth, flat (15 x 10 inches) and the open end has a drawstring closure.

2.12.5.4.8 Headrest Pad (Figure 2.12-33)

During an unsuited entry, the crew will need pads on the couch headrest to ease landing impact to the head and to raise the head to the helmeted eye position. Therefore, there are three headrest pads stowed at launch that are attached to the couch headrests at entry.

The headrest pads are 5 x 13 x 2 inches and are a black fluorel sponge. They have pockets on the ends to slip over the headrests and restrain them.

2.12.5.4.9 Grounding Cable (Figure 2.12-33)

Static electricity is generated by crew activity in the crew compartment. The CO_2 canisters must be grounded when removing them from the stowage locker or compartment to the ECS filter. The canisters have a jack in the center to receive a plug when removing and replacing the canisters.

The grounding cable is 60 inches long with a plug at each end. It is stowed at launch. When in use, is grounded by inserting one plug in a jack on locker A3. The opposite end inserts into the CO_2 canister jack.

2.12.5.4.10 Deleted

2.12.5.4.11 Insulation Blanket (Figure 2.12-33)

After docking, the atmosphere interchange duct (AID) is pulled through and attached to the right side of the tunnel and crew compartment to circulate conditioned OWS atmosphere through the command module. To prevent moisture from condensing on the upper equipment bay or sidewall on the right side, insulation blankets are bonded and attached to the structure.

Low density fluorel blankets, 1/4 inch thick, are bonded to the upper equipment bay sidewall from station X_C = 14 to 42 (girth ring) and from longeron number 3 to 4. They will be covered by stowage lockers and bags U1, U2, U3, U4, and the oxygen repressurization package.

A removable insulation blanket is stowed in the MDA to be used in each command module. The blanket is a thermal insulation (fluorel sponge) material 1/4 inch thick covered with fabric and edged with Velcro pile. It will cover the right side of the upper equipment bay from the hatch frame to panels 5 and 6 and from the girth shelf to panel 3, thus covering the right side and rendezvous windows (4 and 5). The structure has a continuous Velcro pile strip for attaching the blanket.

The insulation blanket is stowed in the MDA. After docking, MDA pressurization, and probe/hatch removal, the blanket is unstowed from the MDA, and attached to the CM structure. During the preparation for return phase, the blanket is detached from the CM and stowed in the MDA.

2.12.5.5 DC Utility Receptacles (Figure 2.12-34)

The crew compartment has three electrical utility receptacles of 28 volts dc. The receptacles are disbursed for accessibility and are located near the left side window (panel 15), the right side window (panel 16), and on the lower equipment bay panel 100. Each outlet or receptacle has an adjacent UTILITY switch with a POWER and OFF position. The circuit breakers for the utility outlets are on panel 5 and are marked UTIL R/L STA MNA for panels 15 and 16, and UTIL LEB MNB for panel 100.

2.12.5.6 Polychoke Orifice

The polychoke orifice is a variable flow restrictor with three different calibrated orifices. It is mounted on the IVA station panel 603 (Figure 2.12-34A), and permits manual to selection of a maximum O_2 venting rate into the CM crew compartment. When not in use the polychoke orifice is stored in compartment A3.

2.12.5.7 Oxygen Vent Valve and Hose Assembly

The oxygen vent valve and hose assembly allows excessive cryo tank pressure to be vented through the auxiliary dump nozzle in the CM side hatch. The vent valve is mounted below the IVA station panel 603 (Figure 2.12-34A) and is connected to the auxiliary dump nozzle by the hose assembly. Both the hose assembly and vent valve are stored in a bay in container A3.

2.12.5.8 Auxiliary Docking Probe Cable

The auxiliary docking probe cable is used to bypass specific circuits in the docking events controller and permit probe retraction without capture latch activation in contingency docking operations. The cable is used to connect the docking events controller in the RHEB to the utility connector in panel 16. The auxiliary docking probe cable is stowed in L2. For single astronaut operation, connection to panel 15 instead of panel 16 is desirable so the back-up waste dump cable, stored in A3, is joined to the auxiliary docking probe cable to provide the necessary additional length.

2.12.5.9 Circuit Breaker Activation Device

The circuit breaker activation device is a lanyard and hinged striker assembly which allows the astronaut to close two circuit breakers in the docking ring jettison circuit in case of an abort in the launch sequence. The lanyard hooks over the right hand-hold at the top of the MDC and runs down to the hinged activation device on panel 277. A quick-release pin in the hinge permits removal and storage of the device after launch.

2.12.6 CREW LIFE SUPPORT

2.12.6.1 Crew Water

2.12.6.1.1 Drinking Water Subsystem (Figure 2.12-35)

The source of cold water for drinking and food preparation is the potable water tank via the water chiller. The line is then routed to the cold water valve of the FOOD PREPARATION WATER tank, and has a maximum

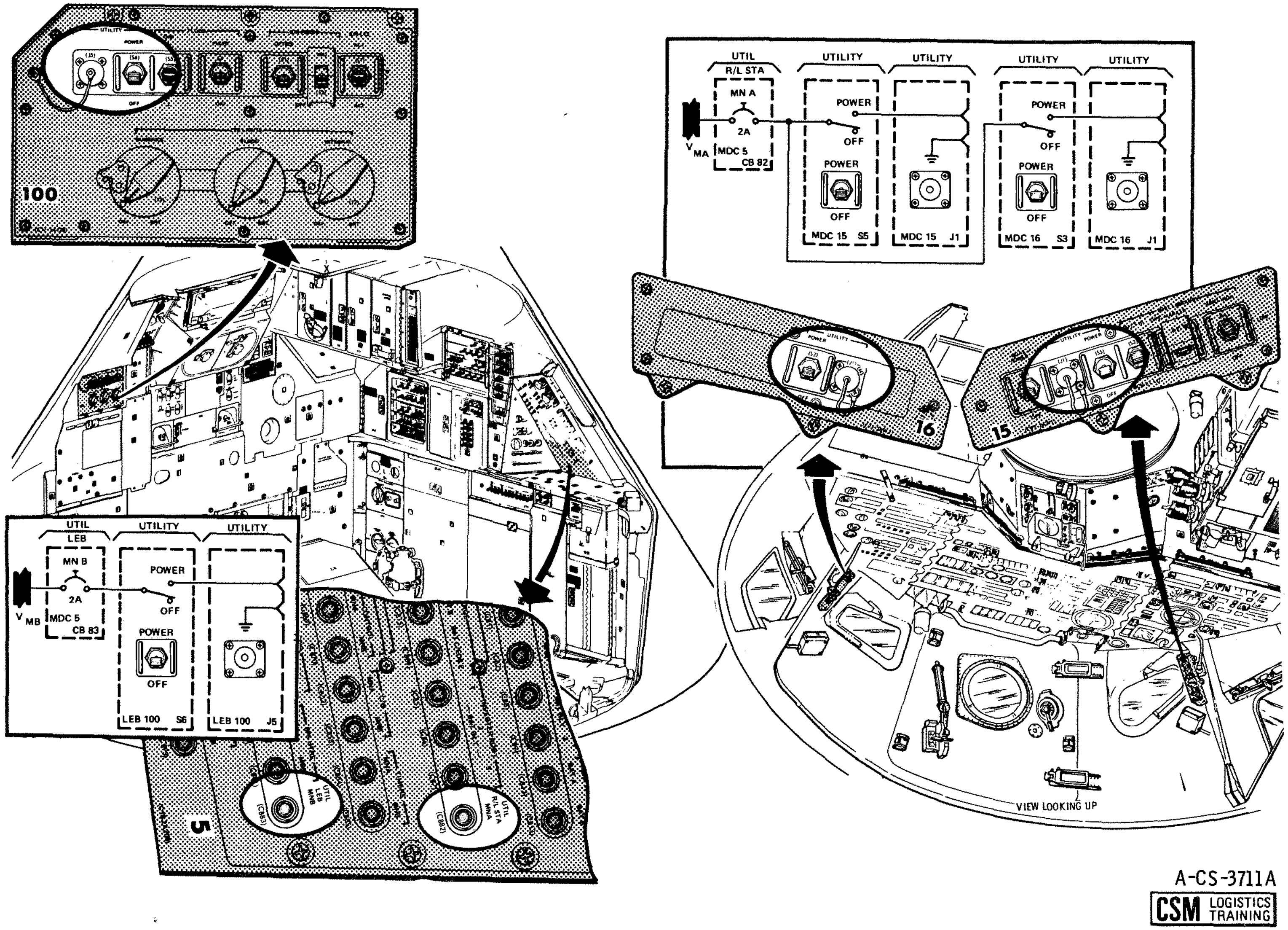

Figure 2.12-34. Skylab Utility Receptacles (28 vdc)

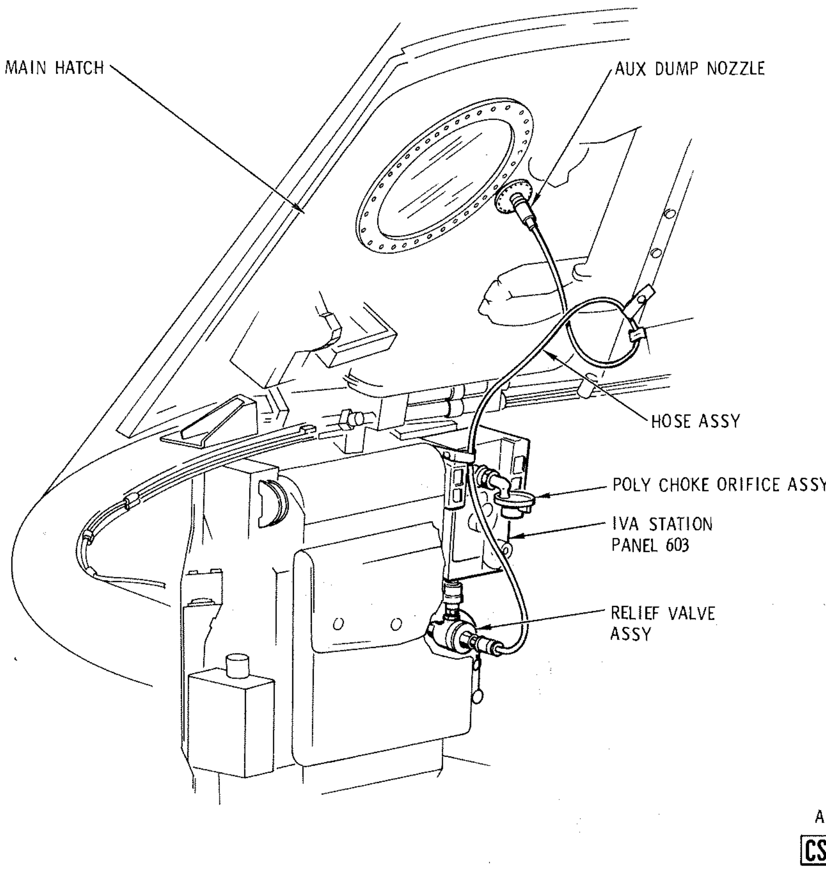

Figure 2.12-34A. Polychoke Orifice, Oxygen Vent Valve and Hose Assembly

pressure of 48 psi, a minimum pressure of 18 psig, and a nominal working pressure of 22 to 27 psig. The crewman drinking water line is teed off, and routed through a shutoff valve to the water dispenser located beneath the main display panel structure.

The water dispenser assembly consists of an aluminum mounting bracket, a coiled viton rubber hose with a QD, and a water dispenser in the form of a lever-actuated pistol. The water pistol delivers approximately 8 milliliters of water per second (ml/s) when actuated. It has a QD at the bottom of the handle for connecting to the coiled hose. The handle contains a fire extinguishing valve that delivers water at the rate of 38 ml/s in a 60-degree cone when actuated. The pistol is identical to the MDA water pistol.

The uncoiled hose will reach 108 inches, and when the pistol is returned to the mount, the hose will re-coil into the housing. The pistol is stored in the mounting bracket and is held in place by a retainer lever.

Operational Use. The shutoff valve on panel 304 is opened after orbit insertion to activate the system using the adapter handle (Tool E). The shutoff valve will be open for the entire mission unless the pistol or dispenser assembly develops a leak, or malfunctions. To use, the pistol nozzle is placed in the mouth and the actuator lever pressed. In the event the drinking water contains gas, a gas separator cartridge is attached to the barrel.

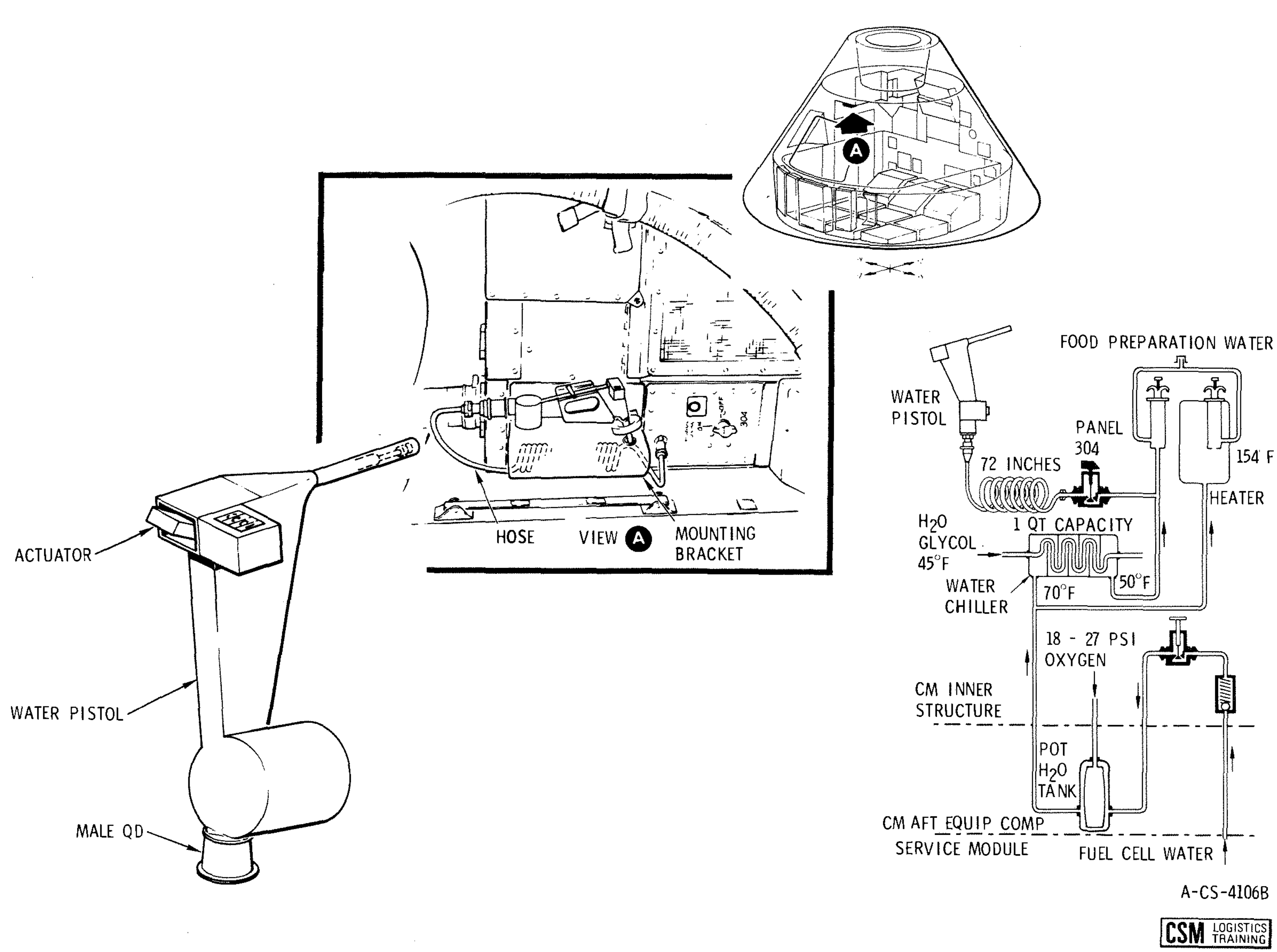

Figure 2.12-35. Drinking Water Subsystem

2.12.6.1.2 Return Water Containers (Figure 2.12-35)

During the return phase of the mission, the fuel cells will not be operating; therefore, the potable water tank will not be supplied with water. Additional water will be needed. Nine water return containers, each containing 8 pounds of water, will be stowed in the workship at launch. Each returning crewman will have one container for the return phase water consumption.

Each return water container will be filled from the OWS food preparation table with 6 pounds of water. A water nozzle and valve is at the using end to fit a food bag or to go directly into the mouth. The valve is opened by rotating about 90 degrees and water is forced through the nozzle by compressing the container. The container should not be extended as oxygen will be drawn in. A cloth handle is attached to the using end for restraint.

In the event the spacesuits must be worn, a helmet feed-through adapter is contained in a small pocket on the using end. The adapter attaches to the container nozzle by threads and the extended adapter nozzle will insert into the helmet feed-through part after removing the cover.

2.12.6.1.3 Food Preparation Water (Figure 2.12-36)

The food preparation water is metered from the FOOD PREPARATION WATER supply on the LHFEB (panel 305), and is used to reconstitute the food. It meters cold water at 50°F and hot water at 154°F to 1-ounce aliquots.

There are two syringe-type valves, and a water nozzle with a protective cover and lanyard. The hot water tank capacity is 38 ounces (slightly more than a quart) and is heated by 25- and 20-watt calrod heaters controlled by three thermostats. The thermostats are powered through the H_2O URINE DUMP HTR, MNA or MNB circuit breakers on panel 5 and the POT H_2O HTR switch on panel 2 (lower center). The POT H_2O HTR switch has 3 positions: MNA, OFF, and MNB.

To operate, the nozzle protective cover is removed by pulling. The food bag is secured, and the protective cover is cut from the food bag valve. The food bag valve is pushed on the water nozzle, and the food bag valve is opened. The syringe handles are pulled and released (1 cycle) as many times for as many ounces of water needed. When finished, the food bag valve is pulled off the nozzle and the cover is replaced.

2.12.6.1.4 Gas Separator Cartridge (Figure 2.12-37)

The swallowing of water with excessive gas is uncomfortable. During the production of water by the fuel cells, hydrogen is in solution and under a pressure of 64 psi which is partially removed by the hydrogen gas separator prior to entering the potable water tank. As the pressure is reduced to 25 psi in the potable water tank, the hydrogen and oxygen gases increase in volume and migrate through the bladder. Further reduction of pressure at the water pistol outlet to 5 psi frees more of the hydrogen and oxygen from solution. The function of the gas separator cartridge is to separate the hydrogen and oxygen from the drinking water and food preparation water and vent it into the crew compartment. A gas separator cartridge with an inlet plug and outlet cap and a stowage bag are provided. The gas separator cartridge has a set screw to hold it on the pistol barrel.

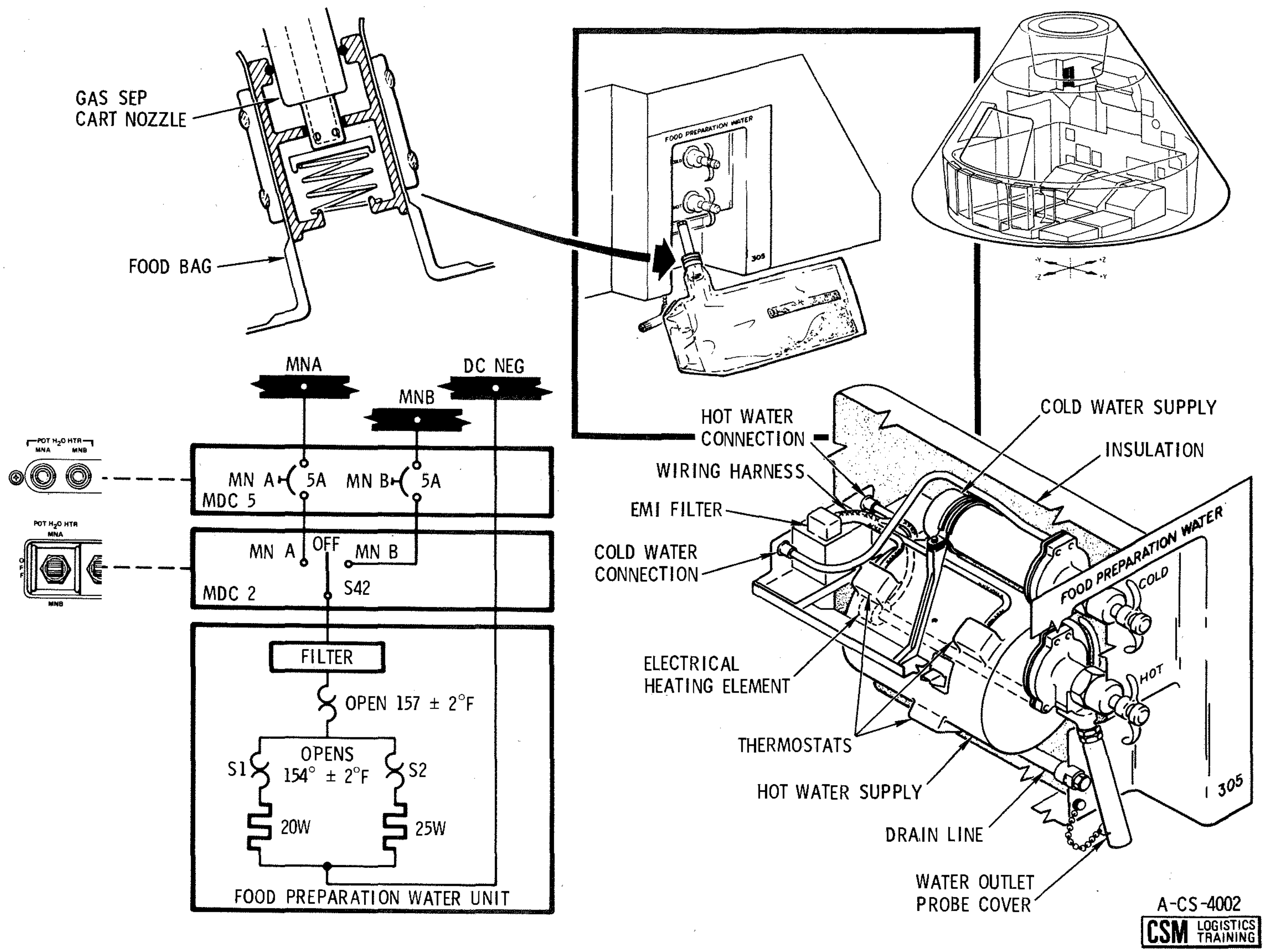

Figure 2.12-36. Food Preparation Water

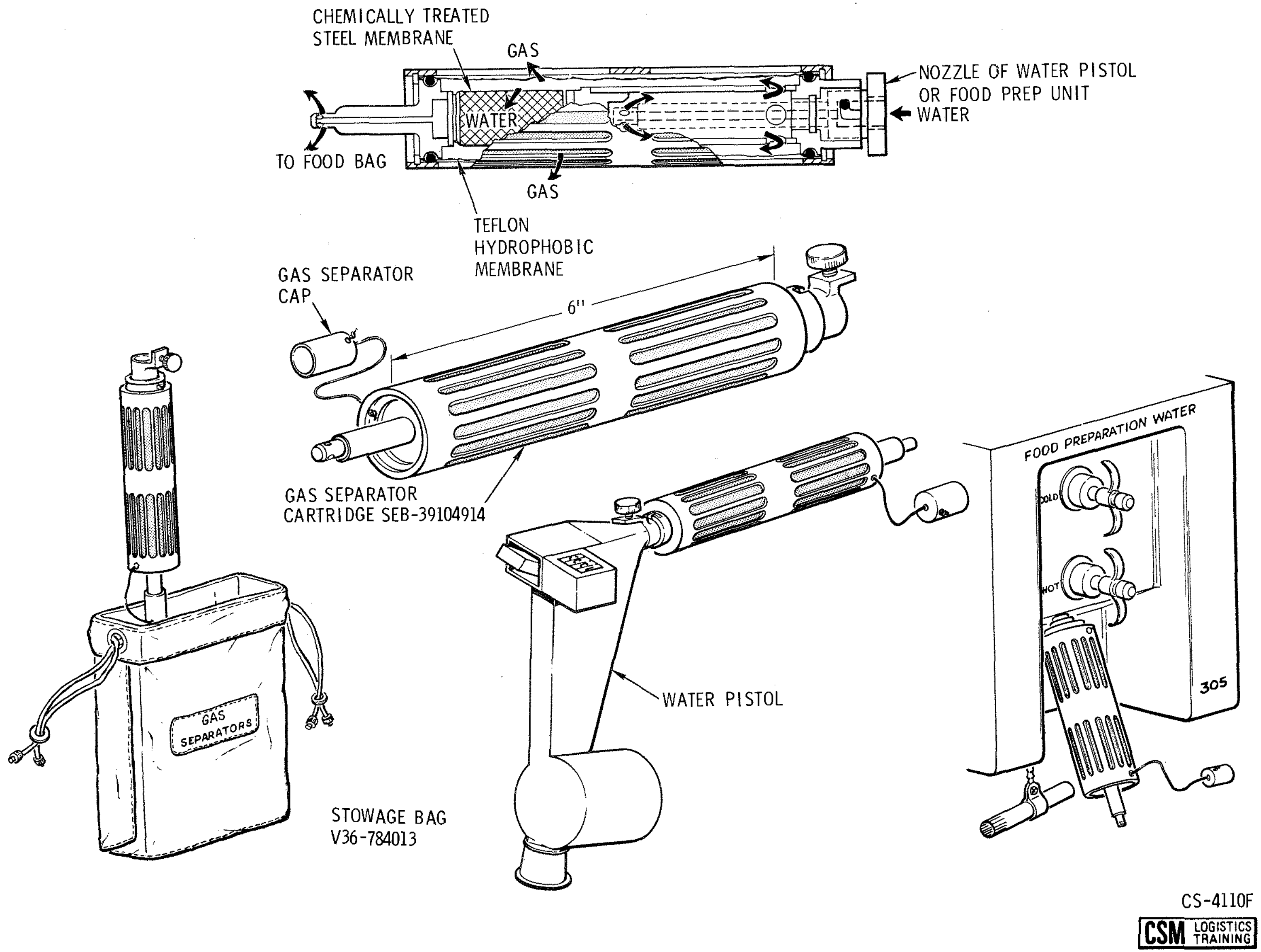

Figure 2.12-37. Gas Separator Cartridge, Contingency Use

The gas separator cartridge is a cylinder 6 inches long with a female (inlet) fitting at one end and a nozzle (outlet) at the other end. The inlet fitting has a bayonet key and will fit and lock to the the food preparation water nozzle on panel 305 or the water pistol barrel. The separator outlet nozzle will interface with a food bag or can be inserted in the mouth for drinking. The inlet plug and outlet cap seal the separator during stowage and are tethered to the separator cartridge.

Water from the pistol or food preparation water unit enters the inner chamber and is routed through holes in the upper end into the outer chamber. The water flows along a teflon hydrophobic membrane that allows gas to permeate the membrane and pass through slots in the cylinder wall. At the outlet end the water passes through a hydrophilic stainless steel fine mesh screen chemically treated to transmit water readily. The water then flows through the outlet nozzle.

Operation. The separator membrane has to be pre-wet before using. A separator cartridge is attached to the water pistol barrel by rotating and pushing slowly. Caution should be exercised when handling the separator as getting the outside surface of the membrane wet will cause it to leak and lose its effectiveness as a gas separator. When seated, the water pistol actuator is triggered in short bursts until water is observed at the outlet nozzle. Ten minutes for membrane wetting is allowed. The gas separator is carefully removed from the water pistol by twisting and pulling. The food preparation water nozzle cover is removed and the pre-wet separator is slid onto the nozzle. The bayonet key is engaged to the nozzle studs and turned, to lock on the separator. The food preparation water unit is then ready for use. Care must be taken when filling a food bag, to ensure the bag is not folded or the sides stuck together and from excessive filling as a slight backpressure will result in water breakthrough of the membrane and destroy its effectiveness as a gas separator. After each use, water on the exterior of the separator should be dried with a tissue (handy wipe).

2.12.6.2 Food System (Figure 2.12-38)

The food furnishes a balanced diet of approximately 2500 calories per day to each crew member and is contained in food sets or separate packages. The food sets are stowed in two prepacked food boxes for compartment L3. Oral hygiene assemblies for brushing the teeth and spoons for eating are also included.

There are several forms of food such as freeze-dried food in bags, wet packs, dried fruit packs, beverages in bags, bread packs, and canned food.

Wet packs are frankfurters or a meat and gravy combination such as ham, turkey, and beef. They are packaged in aluminum dishes with a peel-away cover and are eaten with a spoon.

Standard dried fruits are vacuum-packed in plastic bags for ease in cutting open.

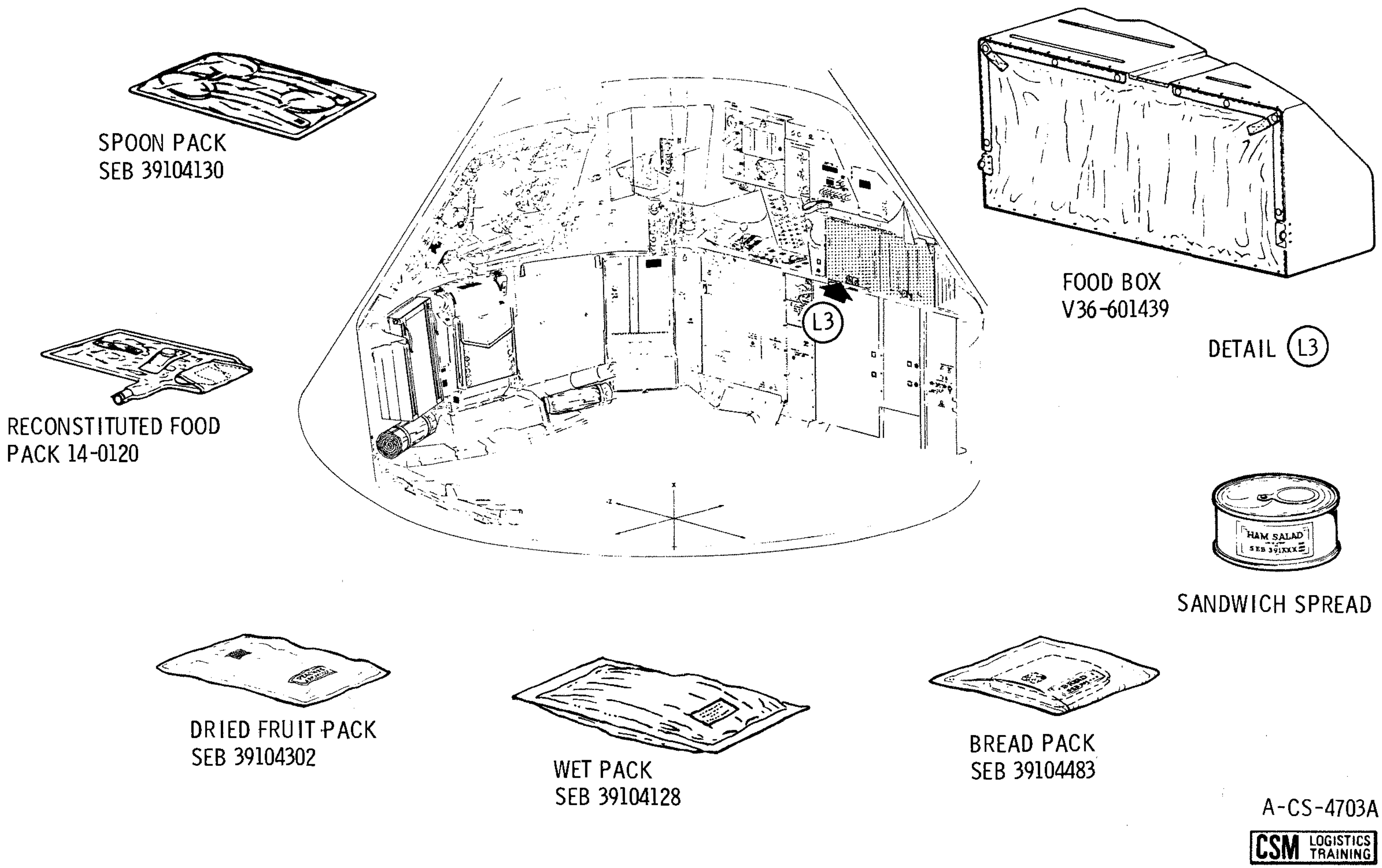

Figure 2.12-38. Food System

Freeze-dried beverages and fruit juices are packaged in the same type of plastic bags as the freeze-dried food. They can be used for supplementary liquid meals in emergencies.

Bread is vacuum-packed in plastic bags and is spread with ham, chicken, or tuna salad from cans which have plastic, snap-off lids.

The freeze-dried food is usually a meat combination dish, soup, or combination salad and is vacuum-packed in plastic bags. The food bag has a one-way poppet valve through which the food preparation water supply or gas separator nozzle is inserted. The bag has a second valve through which the food passes into the mouth. Approximately one-half of the food is packaged in Kel F plastic bags to make one meal for each astronaut. There are meal bags for breakfast, lunch, and dinner. Cleansing cloths are also included for each meal. The meal bags have red, white, and blue patches to identify them for the individual crewman.

The freeze-dry food is reconstituted by adding hot or cold water through the one way valve on the food bag neck. It is then kneaded by hand for approximately 3 to 5 minutes. When reconstituted, the neck is cut off with scissors and placed in the mouth. A squeeze on the bag forces food into the mouth. When finished, a germicide tablet, attached to the bag, is slipped through the mouthpiece into the bag to prevent fermentation and gas. The bag is then rolled as small as possible, taped, and returned to the food stowage compartment.

2.12.6.2.1 Food Stowage (Figure 2.12-38)

Food is stowed in the food stowage compartment in the left-hand equipment bay (LHEB). The food stowage compartment offers approximately 2500 cubic inches of food storage volume, which is sufficient for a 5-day mission.

The LHEB food compartment (L3) has two doors. Each door has a squeeze latch and is hinged at the top. The fiberglass food box has a Beta cloth cover attached with snaps.

2.12.6.2.2 Contingency Feeding System

In the event the cabin is depressurized, the crew will be in their spacesuits and pressurized. Feeding will therefore have to be through the helmet feed port with use of the contingency feeding adapter. However, the backpressure from the spacesuit into the food bag may rupture the bag so it must have a protective cover--the food restraint pouch. Only fluids, primarily fruit drinks and punches will be drunk under these conditions as the solid food is too large to pass through the adapter.

The contingency feeding adapter and food restraint pouch are in a Kel F package and stowed in the LHEB food compartment L3.

Food Restraint Pouch. The food restraint pouch is a strong nylon bag that fits over the food bag and prevents its rupture. While it contains the food bag, it can be compressed, forcing drinks from the bag, through the adapter into the mouth of the crewman.

Contingency Feeding Adapter. Nicknamed the "pon" tube, the contingency feeding adapter is a tube-like device that inserts into, and opens, the food bag valve. It also inserts through the PGA helmet feed-through port and into the crewman's mouth.

2.12.6.3 Waste Management System and Supplies

The function of the waste management system (WMS) is to control and/or dispose of crew waste solids, liquids, and waste stowage gases. The major portion of the system is located in the RHEB. The basic requirements of the system are ease of operation, accessible supplies, collection and stowage of feces, urine collection and overboard dump, removal of urine from the PGA, urination while in the couches, venting of waste stowage gases, and vacuuming waste liquids overboard. The WMS contains a urine, fecal, waste stowage vent, and vacuum subsystem with their associated supplies and equipment.

2.12.6.3.1 General Description (Figure 2.12-39)

The WMS contains a urine transfer system (UTS), urine hose, a vacuum fitting, a fecal collection device, fecal stowage bag, a WMS panel with two QDs, a control valve, a waste stowage vent valve, a urine dump line with a special dump nozzle and an auxiliary dump nozzle. Opening the control valve on the WMS panel subjects the system to a 5-psi differential pressure, crew compartment to space. The dump nozzle contains an exit orifice of 0.055 inch that restricts gas flow to a maximum of 0.4 cfm and liquid flow to 1 pound per minute. The gas flow is limited to prevent excessive loss of cabin oxygen during system usage. To prevent the formation of ice at the dump nozzle, which could block flow, the dump nozzle contains two 5.7-watt heaters controlled from panel 101 (LEB). A switch selects the dump nozzle heater to be enabled. Two 2-watt strip heaters are on the urine line just inboard of the nozzle and are operating continuously.

The battery vent/waste water dump subsystem parallels the urine dump line. It routes outgassing and emergency relief of fluids from the batteries to the WMS panel (252), through the battery vent valve to the ECS water panel 352 where the waste water vent line T's into it. From panel 352, it is routed through a 215-micron filter on the aft bulkhead, through a penetration fitting in the sidewall, to the waste water dump nozzle. The temperatures of both dump nozzles (0 to 100°F) are telemetered to earth to provide an indication of impending nozzle freezing. In the event that either dump nozzle freezes or clogs, the dump lines can be interconnected. To interconnect, the door below panel 252 is opened, exposing a flex line connected to a stowage QD. The flex line is disconnected and connected to the QD 2 inches to the right marked TO WASTE WATER NOZZLE. The interconnecting allows fluids to flow out the "open" (unrestricted) dump nozzle.

The battery vent line contains a pressure transducer that has a readout on the SYSTEMS TEST meter (position 4A) on panel 101 (LEB). A periodic check of the battery vent line pressure will indicate freezing or clogging of the waste water dump nozzle. (This is not likely to occur if the waste water tank is drained periodically.) The BATTERY VENT valve (panel 252) is placed in the VENT position, thus sensing the battery vent and waste water

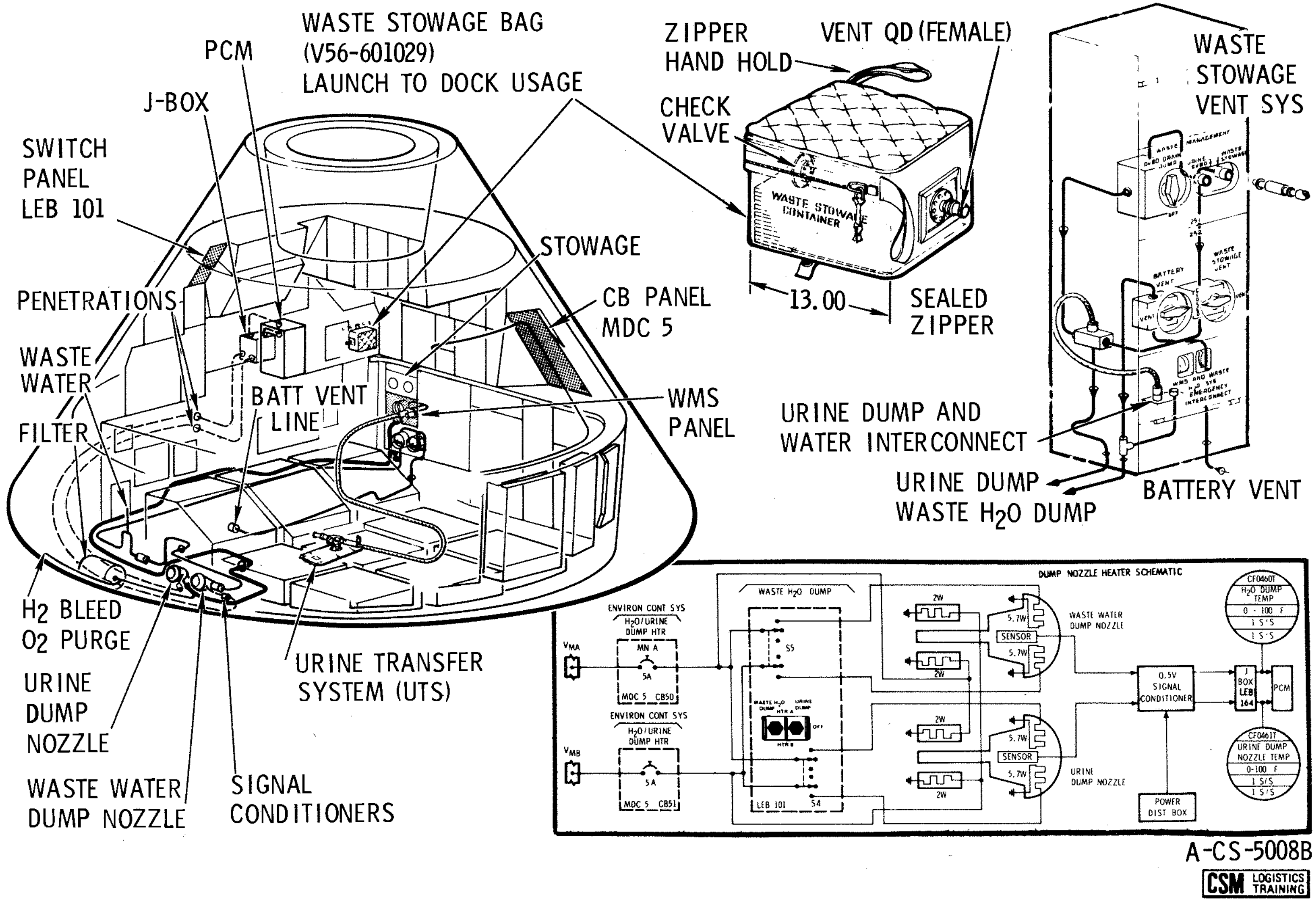

Figure 2.12-39. Skylab Waste Management System

dump line. Plugging of the nozzle will be indicated by a rise in pressure. If the waste water dump nozzle becomes plugged, the urine dump line is interconnected and the urine dump nozzle is checked. The cabin nitrogen purge (vacuum) fitting is inserted into the WMS panel QD, the lines (5 psi) are pressurized by opening the OVBD DRAIN valve (to DUMP), the valve is closed, and the battery vent line pressure is monitored. If the pressure drops to zero, the urine line and nozzle are clear. If the system remains pressurized, both nozzles are plugged. The auxiliary dump system should then be used and is described in subsequent paragraphs.

2.12.6.3.2 Urine Subsystem (Figure 2.12-40)

The Skylab mission requirements for the urine subsystem differ sharply with that of previous missions. Nominally, all urine is stored for later processing on the OWS or at a ground facility. Urine will be dumped only in a contingency situation which prevents docking with the OWS or similar occurrences in which the MSFN feels dumping is advisable.

Nominally, urine will be collected in the urine collection and transfer assemblies (UCTA) in the launch and pre-docking phase of the mission. Additional urine storage is provided by the three bladder assemblies stowed under the crew couch seat pans. The urine transfer system (UTS) and the urine hose and filter are on board to facilitate operation in the contingency mode. Their use will be covered along with the units used in a nominal operational mode.

Use of the Bladder Assemblies in the CM. These units are stowed under each crew couch seat pan and are utilized by the crew when an alternate method of urine collection is desired other than that provided by the UCTAs. A urine transfer system (UTS) receiver with attached roll-on cuff is connected to the bladder assembly inlet port, and the valve opened just prior to use. After connection, the valve is closed, UTS receiver removed, and the bladder is stowed.

Urine Transfer System (UTS). The components of the urine transfer system (UTS) are a roll-on, receiver, valve with a manifold, collection bag, and a 3/8-inch quick-disconnect (QD). The roll-on is a rubber tube that functions as an external catheter between the penis and the receiver/valve. The roll-on is used approximately one day (5 to 6 urinations) and then replaced. Additional roll-ons are stowed. The roll-on attaches to the urine receiver. The receiver is a short tube that contains a low-pressure differential check valve (0.038 psi), a low pressure differential bypass valve, and screws onto the valve manifold. The collection valve has two positions, OPEN and CLOSED, and allows urine to flow into the manifold. The other end of the valve manifold has a 3/8-inch QD and the collection bag throat is teed into the manifold. The urine collection bag is rectangular in shape with a capacity of approximately 1200 ccs. Each crewman will have his personal UTS for sanitary reasons.

Urine Hose and Filter. Current mission requirements call for urine to be stored. However, the urine hose and filter are provided for contingency situations where urine can be dumped overboard. The flexible urine hose will withstand a 5-psi differential pressure and is supple to facilitate easy routing and handling at zero g. The spacesuit urine QD is located approximately 20 inches from the urine QD and is teed into the hose. The flexible hose is covered with Beta cloth. The panel QD end of the hose connects to

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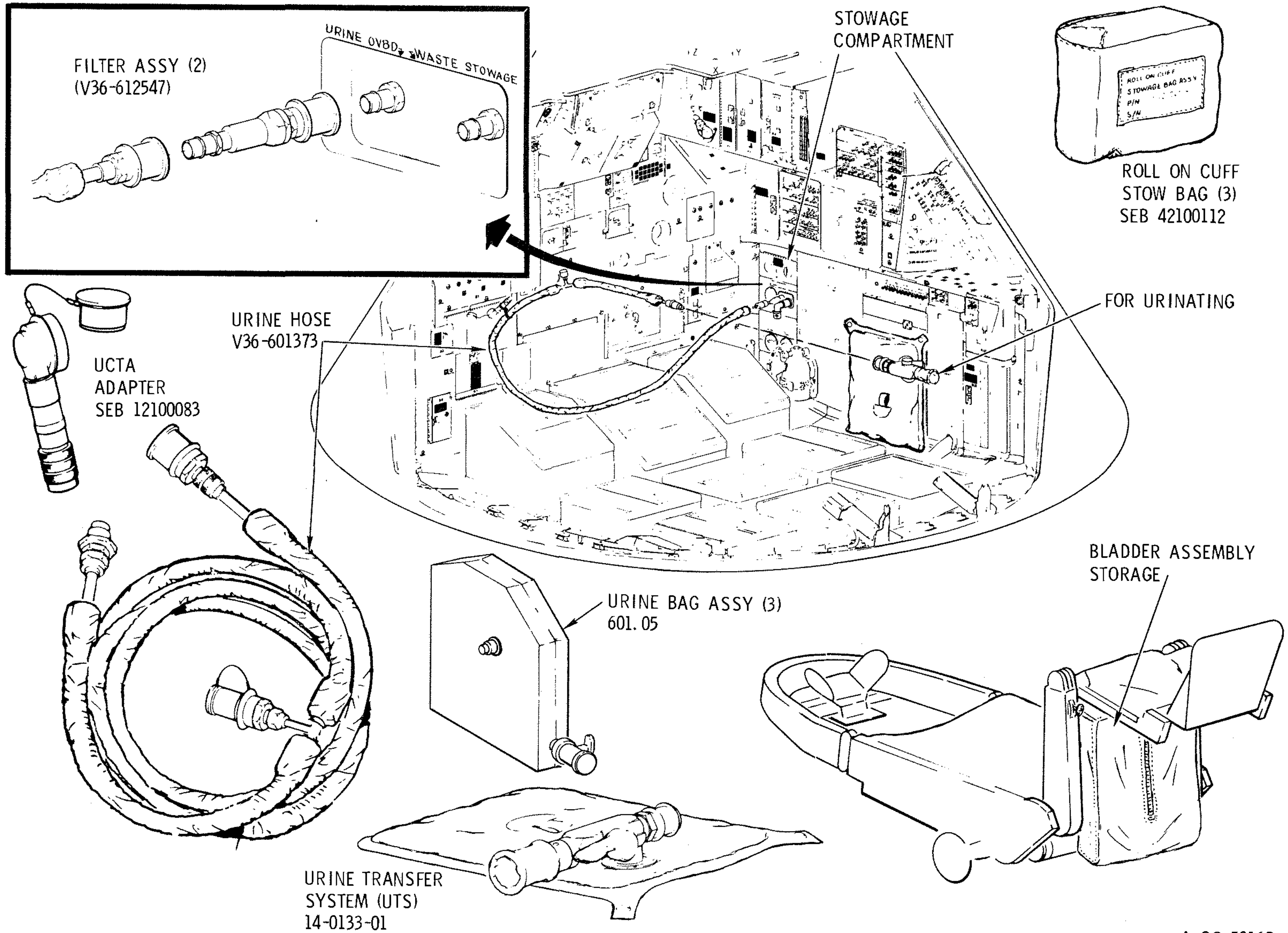


Figure 2.12-40. Skylab Urine Subsystem Components

a 215-micron (0.009 inch) filter with a QD which mates with the waste management system (WMS) panel QD. The urine is filtered to prevent clogging the 0.055-inch orifice in the urine dump nozzle. In the event the OVBD (overboard) DRAIN valve leaks, the panel QD can be disconnected to prevent loss of oxygen.

Operation. Urine can be dumped in one of the following ways: urinating and dumping simultaneously, urinating and dumping separately, or draining (dumping) the spacesuit urine collection and transfer assembly (UCTA). There is also an auxiliary dump method which will be described later.

One of the two urine dump nozzle heaters should be on at all times during the mission. The URINE DUMP HTR switch, on panel 101 of the LEB, has three positions: HTR A, HTR B, and OFF. HTR A or HTR B is selected. The circuit breakers for this switch are the DUMP LINE HTR MNA/MNB circuit breakers on panel 348 (upper left).

Draining the UCTA While in the Spacesuit. To drain the spacesuit urine collection and transfer assembly (UCTA) through the spacesuit urine transfer QD, the UTS or urine receptacle is connected to the hose, and the hose to the panel QD. Then the hose spacesuit urine QD is connected to the spacesuit urine transfer QD. The OVBD DRAIN valve is positioned to DUMP. The hose internal pressure is then zero and the spacesuit pressure of 5 psi compresses the UCTA bladder, forcing the urine into the urine hose and overboard dump line. When the bladder has been emptied, the UTS or urine receptacle valve is opened for approximately a minute to purge the urine hose and line. After closing the UTS or urine receptacle valve, the urine hose is disconnected from the spacesuit and UTS or urine receptacle and stowed.

Draining the UCTA After Removal From Spacesuit. It is difficult to drain the UCTA while it is attached to a stowed spacesuit. Therefore, the UCTA is removed from the suit by verifying the roll-on is clamped and the UCTA QD is disconnected. The urine hose to UCTA adapter is a small tube with a urine hose QD on one end and a UCTA QD on the other. (The UCTA adapter is attached to the urine hose for mission stowage by a strap.) The adapter is connected to the UCTA and the hose spacesuit urine QD. The UTS or urine receptacle assembly is attached to the urine hose, and the OVBD DRAIN valve and the UTS or receptacle valve are opened. Gas will now flow through the urine hose. The UCTA is compressed gently to force urine into the urine hose. When the UCTA is empty, the 60-second purge is allowed before the UTS or receptacle valve and OVBD DRAIN valve are closed. The UCTA is disconnected from the adapter and attached to the spacesuit.

2.12.6.3.3 Fecal Subsystem (Figure 2.12-41)

The fecal subsystem consists of a fecal collection assembly, tissue dispensers, waste stowage bladder, and a waste stowage vent subsystem.

The fecal collection assembly is a plastic bag in which the feces is collected. It is approximately 13 inches long with a 10-inch flange opening which has an adhesive surface.

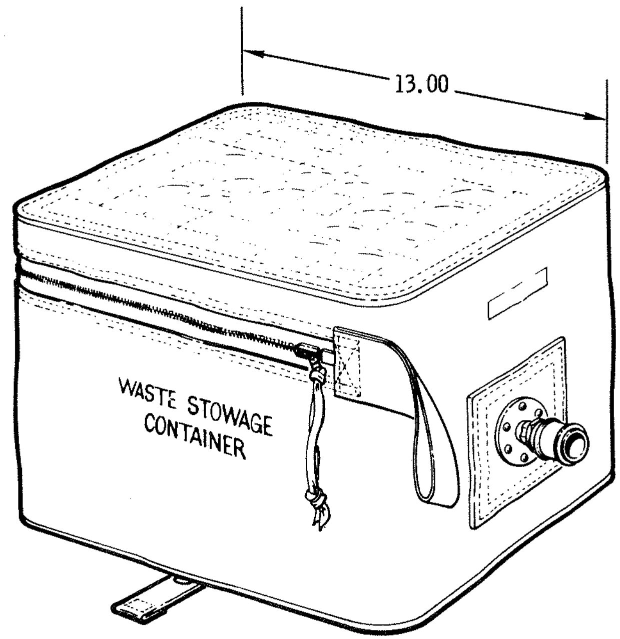
The tissue dispensers contain tissue (Kleenex) for wiping, are approximately 8 x 4 x 3 inches, and weigh approximately one-half pound each. They are stowed in an aft bulkhead locker, and one dispenser is attached to the back of the center couch footpan so it will be available for use.

The waste stowage bag provides stowage for used fecal collection assemblies or processed fecal collection assemblies. It is 9 by 10 by 13 inches (0.68 cubic feet), constructed from a silicon rubber coated fabric, has a female vent QD, a check valve, a sealed zipper, and snap tabs for temporary stowage.

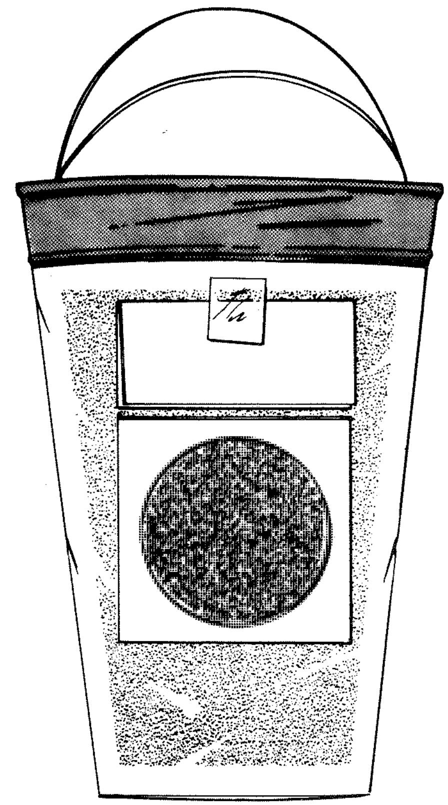
The waste stowage (bag) vent subsystem consists of the urine hose, QD on RHEB panel 251, and the WASTE STOWAGE VENT valve on RHEB panel 252. It vents into the urine overboard dump line.

After orbit insertion, the waste stowage bag is unstowed and attached to the right-hand equipment bay near panel 251 for easy access and is ready for use. When needed, a fecal collection assembly is retrieved from the fecal bag container, Locker A5, and protector strips covering the stomaseal on the flanges are removed. The flange is pressed to the buttocks and defecation is performed. When finished, the fecal bag is removed, tissue is used to wipe, and a wet cleansing cloth is used to clean. The gas is gently forced out of the bag, and the flange opening is sealed. The FE bag is placed in the waste stowage bladder without folding or rolling.

In the event a fecal collection assembly ruptures and fecal odors are emitted from the waste stowage bag, the urine hose is attached to the WASTE STOWAGE QD and the bag vent QD. Periodically the odors are vented overboard by placing the WASTE STOWAGE VENT valve on panel 252 to the VENT position. The waste stowage bladder check valve allows crew compartment oxygen to purge the bladder.



WASTE STORAGE CONTAINER
V56-601029 1154.00.00



CONTIGENCY FECAL/VOMITUS BAG
1B79450-1 0600.13.03

A-CS-5018
CSM LOGISTICS TRAINING

Figure 2.12-41. Fecal Subsystem

Prior to entry, the waste stowage bag and contents are detached from the RHEB and stowed in an aft bulkhead locker.

Contingency Fecal/Vomitus Bag. To be supplied at a later date.

2.12.6.4 Personal Hygiene (Figure 2.12.42)

Personal hygiene items consist of an oral hygiene assembly, utility towels, and wet and dry cleansing cloths.

2.12.6.4.1 Oral Hygiene Set - Cleansing of Teeth

The maintenance of oral health in space flight requires aids which will cleanse the mouth of food debris and bacterial plagues. These aids are provided each crew member on an individual basis according to his needs. The oral hygiene set consists of a toothbrush and consumable toothpaste or ingestible gum. The required set is stored in the first-day food stowage compartment B1, to be used for the entire mission.

2.12.6.4.2 Wet Cleansing Cloth

Wet cleansing cloths are used for postmeal and postdefecation hygiene. The cloths are 4 x 4 inches, folded into a 2-inch square and sealed in plastic. They are saturated with a germicide and water.

The cloths for postmeal cleansing are stored, along with the dry cleansing cloth, in the food containers for easy accessibility. The postdefecation cloths are part of the fecal collection assembly.

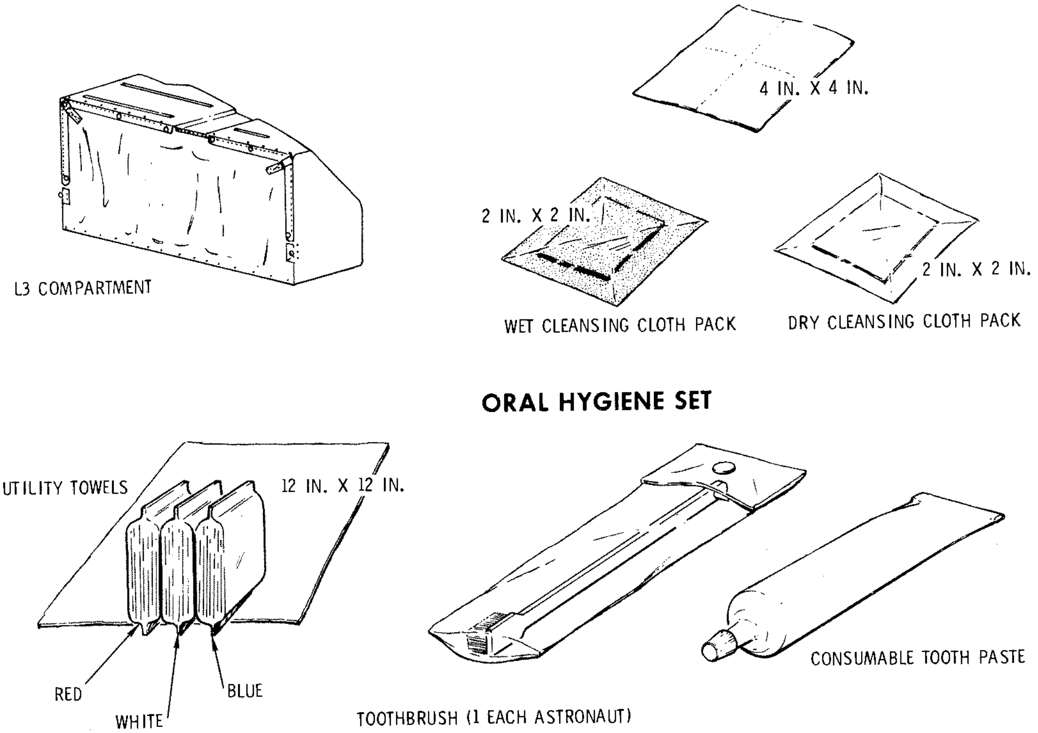


Figure 2.12-42. Personal Hygiene Items

2.12.6.4.3 Dry Cleansing Cloth

The dry cleansing cloths are alternated with the wet cleansing cloths for postmeal cleanup. They are the same size and texture; however, they do not contain water and a germicide. They are also packaged with the food.

The wet and dry cleansing cloths will be placed in the food packages and be part of the "Food Set."

2.12.6.4.4 Utility Towels

The towels are used for utility cleanup and use. They are 12 x 12 inches and similar to a washcloth, are sterile, and are packaged in plastic containers. The containers have Velcro patches and stow in an aft bulkhead locker.

2.12.6.4.5 Tissue Dispensers

The tissue dispensers contain tissues (Kleenex) for utility-wipe and clean-up purposes. The dispenser consists of a container and tissues. The container is Beta cloth, approximately 9 x 4 x 2 inches, weights 1.4 pounds with tissues, and has Velcro patches for restraint during the mission. Approximately four dispensers are stowed in B1 compartment at launch and two on return.

2.12.7 MEDICAL SUPPLIES AND EQUIPMENT

The medical equipment is used to monitor current physiological condition of the crewmen, and to furnish medical supplies for treatment of crewmen in-flight medical emergencies.

The medical equipment is subdivided into two functional types: monitoring equipment and emergency medical equipment. The monitoring equipment consists of personal biomedical sensors assembly and a bio-medical signal conditioner instrument assembly. The emergency medical equipment is contained in the medical accessories kit in Volume R13. This kit also contains spares for the bioinstrumentation equipment and harnesses.

The command module also transports medical supplies to and from the orbital workshop (OWS) in-flight medical support system (IMSS) in the IMSS resupply and return system. The IMSS has four modules A, B, C, and D, to be resupplied.

2.12.7.1 Bioinstrumentation Harness Assembly (Figure 2.12-43)

The current physical condition is of great importance to the mission monitoring flight surgeon. The heartbeat, by electrocardiograph (ECG), the heart rate, by the cardiotachometer (CTM), the body temperature by the (TEM) signal conditioner, and the respiration, via impedance pneumograph (ZP), are monitored throughout the mission. The ECG, TEM, CTM, and ZP can be telemetered simultaneously for all three crewmen.

The bioinstrumentation harness is the crewman's personal harness consisting of a sensors assembly and signal conditioner assemblies.

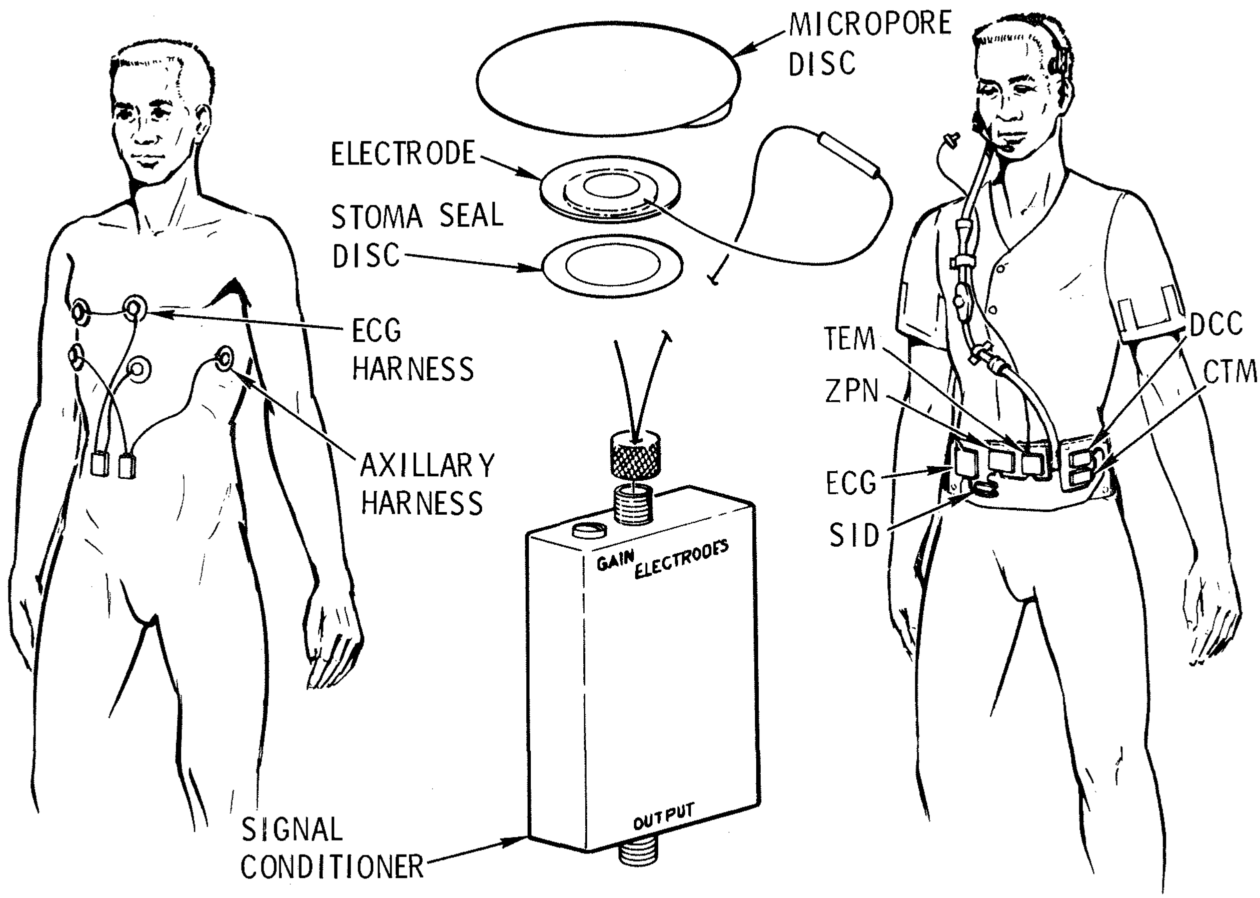


Figure 2.12-43. Bioinstrumentation Harness

2.12.7.1.1 Personal Biomedical Sensors Instrument Assembly

The personal biomedical sensors instrument assembly consists of five or more electrodes (silver chloride), signal wire, and accessories, such as paste and application tape.

The sensors (electrodes) are attached to the body of the astronaut, using paste and tape, at areas of sparse muscles (to reduce artifact level), and remain throughout the mission. The sensor assembly consists of two harnesses, an EKG harness attached to the breastbone and an axillary harness attached to ribs near the armpits. The harnesses terminate in connectors that attach to the signal conditioners.

2.12.7.1.2 Biomedical Signal Conditioner Assembly

Because of their weak signal level, the sensor signals have to be amplified before being telemetered. Thus the function is performed by the signal conditioners.

The signal conditioners are 2.3 x 0.46 x 1.5 inches and weigh about 55 grams. They operate through a signal range of plus to minus 5 volts and are powered by a dc-to-dc converter which requires 16.8 vdc. This input power is supplied through the SUIT POWER switch on each of the audio control panels (panels 6, 9, 10). There are four signal conditioners (ECG, TEM, CTM, and ZP), the Subject Identification Module (SID), and the dc-to-dc converter.

The signal conditioners fit into pockets in the bioinstrumentation belt which snaps on the CWG at the stomach. Wire leads connect to the sensors, which act as an electrode for the ECG and ZP conditioners. The difference of resistance between two electrodes is measured. Muscle activity (breathing) changes the skin resistance and this change is amplified and transmitted to the telemetry system. The body temperature input comes from an ear probe fitted to the astronauts right ear. Each signal conditioner has an output connector that attaches to the harness leading to the CWG adapter or spacesuit harness.

2.12.7.1.3 Bioinstrumentation Accessories or Spares

Spares are located in the medical accessories kit. The kit has spare electrodes, micropore discs, electrolyte paste, stomaseal disks, and a sternal and axillary harness.

2.12.7.2 Medical Accessories Kit (Figure 2.12-44)

The medical supplies are oral drugs, injectable drugs, dressings, topical agents, and eyedrops. The contents of the medical kit are as follows:

- Oral Drugs and Pills
  - Pain capsules
  - Stimulant
  - Antibiotic
  - Motion sickness
  - Diarrhea
  - Decongestant
  - Aspirin
- Injectable Drugs
  - Pain injectors
  - Motion sickness injectors
- Dressings
  - Compress bandage
  - Band-Aids
- Topical Agents
  - Skin cream
  - Antibiotic ointment
- Eye Drops
- Nasal Emollient
- EKG harness
- Axillary harness
- Electrode Assemblies
- Thermometer
- Ph paper
- UCTA roll-ons

The kit is contained in a Beta cloth case (9 by 5.8 by 5 inches) with a cloth closure and weighs approximately 3.5 pounds. Inside are leaves with pockets and pouches in which the contents are stowed. The medical accessories kit is stowed in the RHEB in compartment R13.

In the event the astronauts have to evacuate the command module during the recovery phase, the medical accessories kit will be removed from stowage Volume R13 and carried overboard into the liferafts.

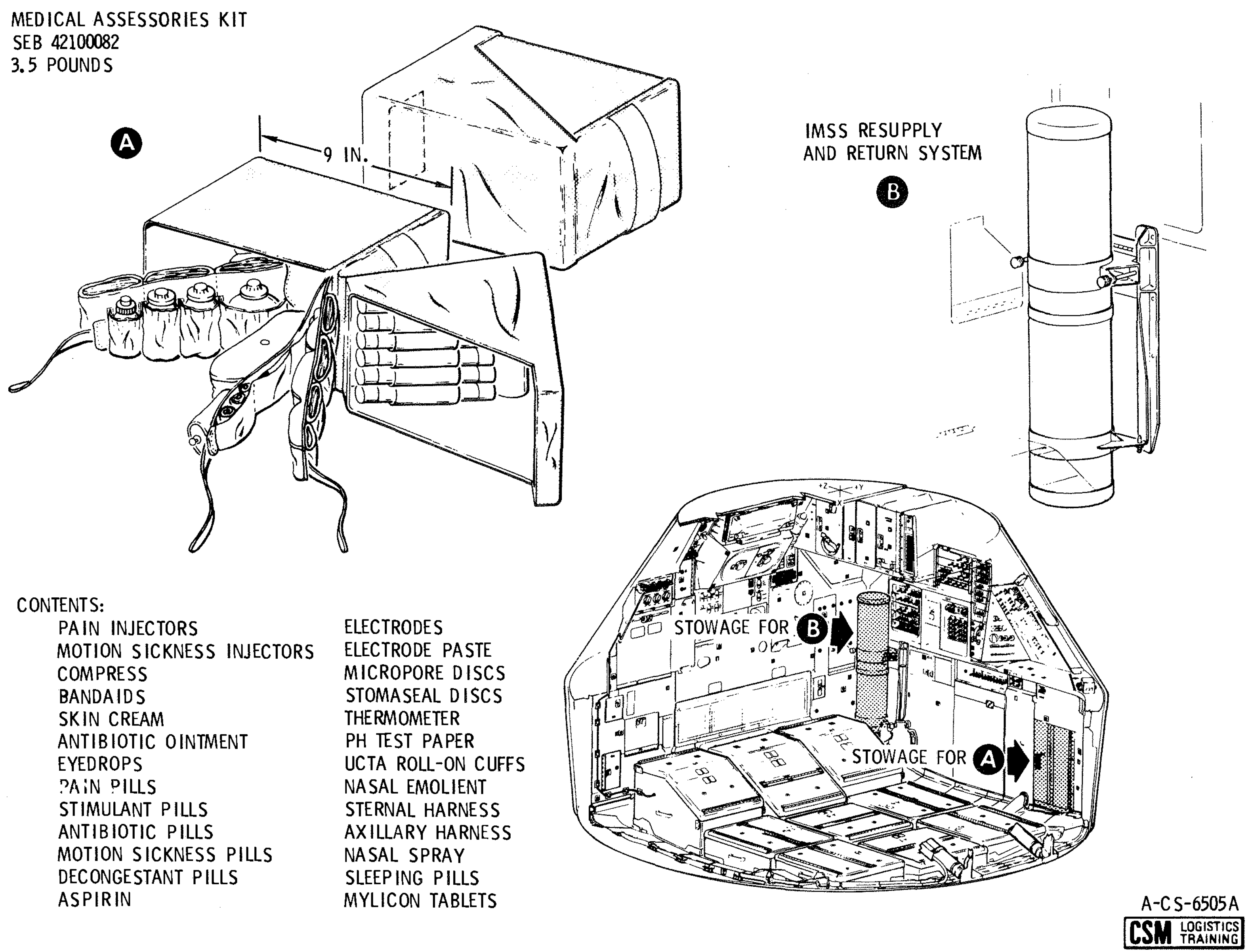


Figure 2.12-44. Medical Accessories Kit

2.12.7.3 IMSS Resupply and Return System (Figure 2.12-44)

Each Skylab CM will launch and return with an IMSS resupply and return system. The system contains the programmed and requested supplies for the IMSS modules. The case is 11.5 by 10.5 by 6.0 inches and will weigh approximately 10.2 pounds when packed.

2.12.8 RADIATION MONITORING AND MEASURING EQUIPMENT (Figure 2.12-45)

The system devices that measure the radiation accumulated dose received by the crew are the passive dosimeters and the personal radiation dosimeters, while the Van Allen Belt dosimeter and the radiation survey meter monitor the ambient strength of the radiation field. In addition, the nuclear particle detection system measures the particle flux of the radiation field.

2.12.8.1 Passive Dosimeters

Four passive dosimeters (film packs) are worn by each crewman in the form of film packs which are processed in the laboratory after recovery to determine total dosage received. The dosimeters are located inside the communication hat by the temple and in CWG pockets on the chest, the thigh, and the ankle. When CWGs are changed, the film packs must be respectively switched (figure 2.12-45).

2.12.8.2 Personal Radiation Dosimeter (PRD)

Each crewman wears one personal radiation dosimeter which is battery-powered and the size of a package of cigarettes. The PRDs register readout indicates the accumulated dosage received by the crewman during the mission. The PRD is worn on the PGA or flight coveralls at all times. There are additional dosimeters stowed in Volume B1.

2.12.8.3 Radiation Survey Meter (RSM)

The radiation survey meter is used to determine the magnitude of the immediate radiation field. It is a flashlight-like, self-contained unit about 10 inches long and 2 inches in diameter. The RSM has an ON-OFF switch, direct readout dial calibrated in rads/hr, and is battery powered and manually operated.

The RSM is clamped in a bracket-mounted on the G&N signal conditioning panel.

2.12.8.4 Deleted

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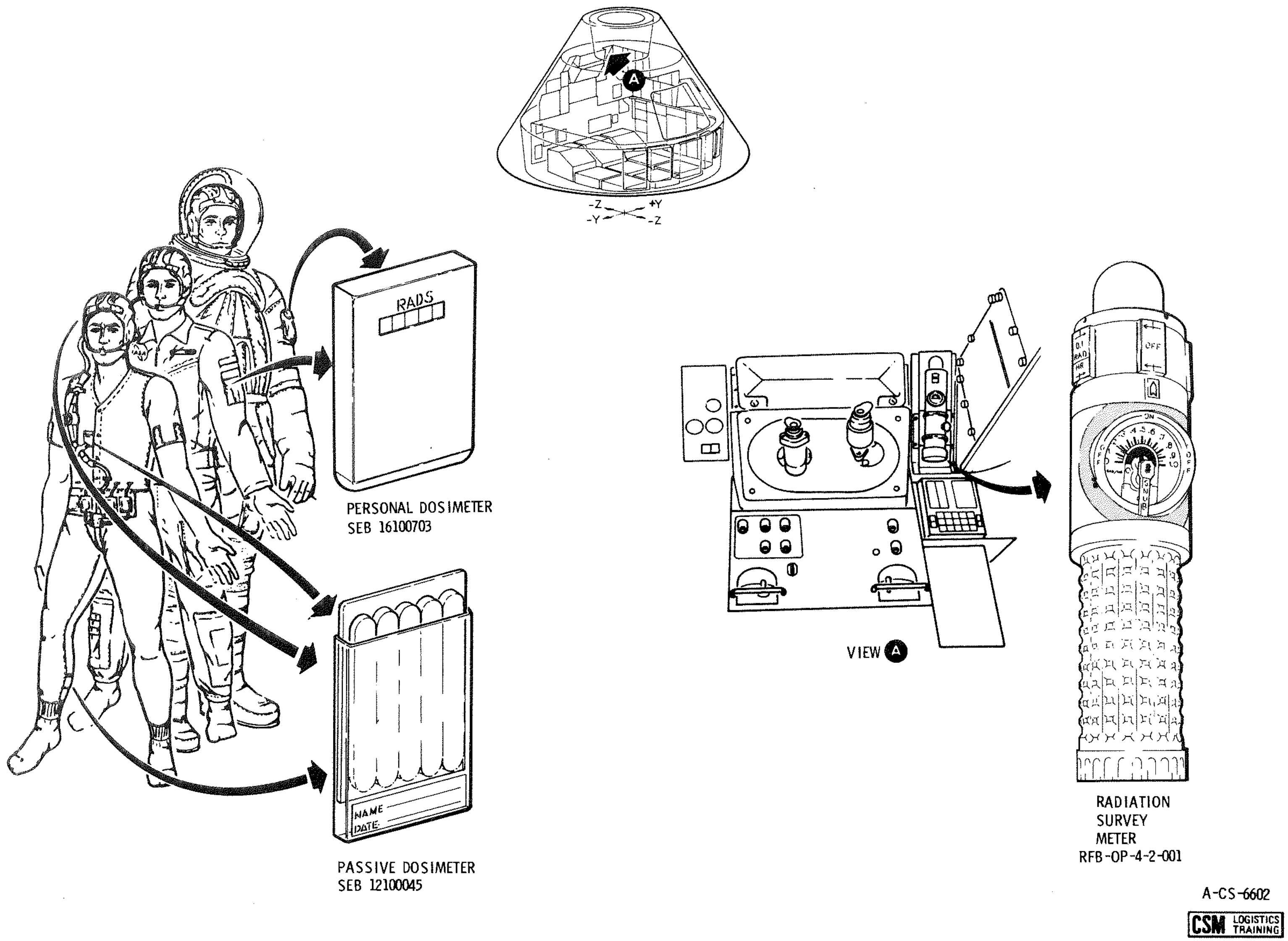

Figure 2.12-45. Radiation Monitoring and Measuring Equipment

2.12.9 STOWAGE

The numerous activities of the crew make housekeeping very necessary. All equipment must be stowed at launch and entry, and provisions made to restrain loose equipment during the mission zero g conditions.

The stowage system function is to provide an accessible stowage position for portable mission equipment. Its features are (1) standardized locations for same or similar items; (2) minimized in-flight equipment relocation; (3) simplification of in-flight handling and stowage; (4) maximum space utilization; and (5) flexibility in reconfiguration during g orbit, quiescent, and return mission phases. The system utilizes stowage compartments and lockers with dual-use cushions, labeled stow straps and containers identifying the launch and return position of the item, removable and replaceable lockers, and decals identifying launch and return configuration.

Movable or loose equipment is placed in containers and stowed in compartments and lockers located in the equipment bays, on the aft bulkhead, or sidewalls. The compartments have load bearing doors, internal foam cushions, or boxes to hold and position equipment. On the aft bulkhead and upper equipment bay, rigid aluminum lockers or reinforced Beta cloth cases (lockers) are provided for stowage.

Patches of Velcro hook are conveniently located on the CM interior structure for stowage of loose equipment, which also have patches of Velcro pile. Mechanical fasteners (snaps, straps, etc.) are also used for mission restraint. Additional details of Velcro and snaps are described in paragraph 2.12.3.

2.12.9.1 Stowage Containers

Crew equipment to be stowed may be one item (i.e., film magazine), or a group of related items (i.e., WMS/BU components). The function of stowage containers is to furnish padding, restraint, and environmental protection to its contents while making it operationally convenient to use.

2.12.9.1.1 Container Types

Each container is typed in accordance with its descriptive term to aid identification and reduce confusion. The container types are, from the smallest to the largest, bags, satchels, pouches, cases and sacks. They are fabricated of Beta cloth, a fire retardant material.

A bag is a small tubular container closed out at one end and a drawstring closure on the other end.

A bag with a handle or handling strap is a satchel.

A pouch is a single pocket or a group of pockets sewn on a cloth panel that can be rolled and secured with snaps or Velcro. The pockets have flap or bungee closures.

Cases are reinforced fabric containers with rectangular shaped ends and a lid which is zippered or flap type closure.

A sack is a large bag with a drawstring closure - similar to the PGA sack.

CPE

2.12.9.1.2 Container Labels

Beta cloth tape labels (sometimes called I.D. patches) are sewn on all containers designating the nomenclature, launch and return or off loading stowage of the item. For example, "UCTA CLAMPS R11 LAUNCH & RETURN" is the label on the UCTA clamps pouch indicating the clamps and pouch are stowed in R11 for launch and return. However, the chlorine ampules and buffers case has the label "CHLORINE EQUIPMENT - B7 LAUNCH - OFFLOAD", indicating the case with equipment is launched in B7 compartment and offloaded into the workshop prior to CM-OA separation.

2.12.9.2 Deleted

2.12.9.3 Aft Bulkhead Stowage Lockers (Figure 2.12-46)

The aft bulkhead has support fittings for one fixed and eight removable lockers arranged in three rows of three lockers per row. When standing on the aft bulkhead near the LEB and facing the side hatch, the lockers in the row nearest the hatch are designated A1, A2, and A3 from left to right. The center row is designated A4, A5, and A6 from left to right and the lockers in the row nearest the LEB are designated A7 through A9. Locker A8 is attached with Calfax fasteners to fittings on the aft bulkhead and normally is not removed during the mission. The other lockers are removable in order to replace them entirely or repackage them in the workshop. The lockers are constructed of aluminum with some steel working parts.

Lockers A1 through A6 are opened from the top by double panel doors with a squeeze latch. The panel with the latch must be opened 90 degrees (right angle) to release the second panel. When opened 180 degrees, patches of Velcro will hold the two panels together. Lockers A7 and A9 each have two single panel doors and A9 has a single panel door and a double panel door with latches for each door.

Lockers A4 and A6 each contain four LiOH canisters in a removable frame. Riveted to each door panel are spring retainers which make it necessary to put approximately 5 pounds pressure on the panel to lock it down (capture it).

Items and equipment stowed in lockers and compartments are supported by micro-syl cushions or placed in fabric containers and retained by straps. There are launch-return and dual-purpose types of cushions. Removable cushions are restrained by snaps. The retainer strap fasteners are buckles, buttonholes, or snaps. Launch cushions are off-loaded into the OWS and the vacated space utilized for return stowage. Hard containers with return items are strapped in lockers. Other return items are placed in fabric bags before being strapped in lockers.

All removable lockers except A7 have single handles on one side for maneuvering through the orbital assembly.

2.12.9.3.1 Locker Removal

Protruding from the corners of the locker bottoms are four lugs (tongues) with holes. The removable lockers are attached to the aft bulkhead by four shear pins, one of which extends/retracts and is spring-loaded to the extended position. The lock pin handle detents at two positions: down-pin extended (engaged) and up-pin retracted. All lockers, except A2

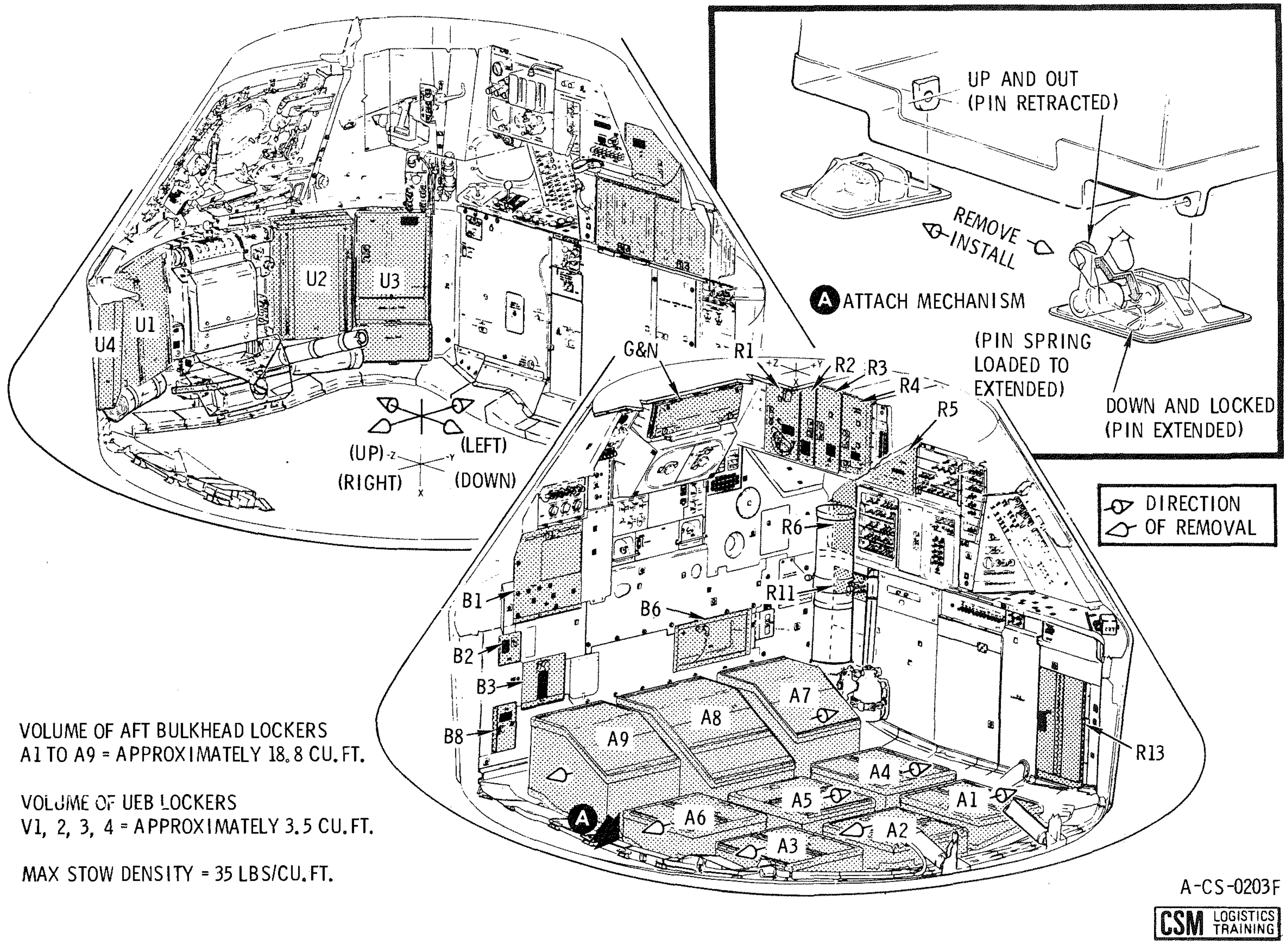

Figure 4.12-46. Skylab Stowage Compartments and Lockers

and A5 remove by retracting the locking pin and sliding 3/4 inch outboard, to disengage from the pins, and lifting. A2 is removed by sliding to the left (toward A3) and A5, by sliding to the right (toward A4). Any removable locker can be removed or replaced independently.

2.12.9.3.2 Locker Replacement

To replace a locker, verify the lock pin is retracted (handle up and detented), and the pins are clear. To aid alignment during replacement, white guide lines are on the aft bulkhead and the lockers sides at the three shear pins. The locking lever area is not marked.

2.12.9.3.3 Top Loading (Figure 2.12-46)

Stowage attachments for low density return packages such as MO 71/73 return container are provided on lockers A1 through A6 by four tie rings located on the side near the corners of each locker. The tie rings swivel in two axes and are sized to thread 1-inch webbing and double D-ring buckles.

The MO 71/73 sample return containers are 17 by 13 by 6.5 inches, fabricated of Beta cloth, double-celled with a zippered closure at each end. Two 65-inch straps, each of which has a double D-ring buckle, are attached diagonally to the bottom of each cell for lashing to the lockers with tie rings. The processed MO 71/73 fecal vomitus sample bags are placed in each cell, the zipper closed, and the container positioned on the locker. The return container straps are threaded through the tie-down rings, placed diagonally across the top of the container, threaded through the strap D-ring buckles, and secured with two half hitches.

In the event the unit that replaces a locker for return stowage has no tie-down, as in the case of the S082 film canisters, two bellyband tie straps per canister (unit) are provided. A bellyband is of 1-inch webbing, 58-inches long, has two tie rings, a double D-ring buckle and four 6-inch fluorel sponge friction pads. Prior to canister replacement, the bellyband is passed around the film canister girth parallel to its door, positioning the friction pads on the corners, and secured by threading through the double D-ring buckle and typing with two half hitches. Top positioning of the bellyband double D-ring buckle permits adjustment after the canister is installed on the aft bulkhead.

Top loading is then accomplished utilizing the two tie rings on the bellyband.

2.12.9.3.4 Locker and Compartment Decals

Each stowage volume, compartment, or locker has a decal identifying all stowage items within as per launch. The stowage decals are aluminum foil, dyed black, with white printing, and are bonded to the compartment or locker in a conspicuous location.

Stowage items within a locker or compartment that change location or are added during the mission are identified with a gold decal. This includes items that are returned from the orbital assembly (OA), returned from the SM, or reshuffled for entry stowage. For entry stowage, some compartments and lockers have a black decal only, indicating no change. Other compartments and lockers will have a black and gold decal indicating a change of stowage for entry.

2.12.9.4 Launch/Return Aft Bulkhead Stowage Configuration

At launch, lockers A1 through A9 will be installed and locked in their respective positions on the aft bulkhead.

Prior to undocking, during the preparation for return, selected aft bulkhead lockers are removed and replaced with return canisters or repacked with experiment data payloads. Numerous items of crew equipment that are not needed for re-entry are off-loaded and placed in the Skylab OWS. These items can be identified from the chart in paragraph 2.12.1.1 by a zero in the Return Qty column. Return packages are lashed on top of selected lockers. The following listing indicates the launch and return stowage configuration for SL 2, 3, and 4. After undocking, access to aft bulkhead lockers is not required. Stowed items required on the return mission phase should be stowed in areas of easy access such as the left, right, and lower equipment bay compartments (Figure 2.12-46A).

Locker	Vol (cu ft)	Wt (lb)	Max Payload (lb)	Launch	Return		
				SL 2,3, & 4	SL 2 (CSM 116)	SL 3 (CSM 117)	SL 4 (CSM 118)
A1	1.3	10.9	45.5	A1	S082 Helmet/gloves Press garm	S082 Helmet/gloves Press garm	S082 Helmet/gloves Press garm
A2	1.7	11.2	59.5	A2	A2 fec/vom samples	S082 fec/vom samples	A2 fec/vom samples
A3	1.3	10.9	45.5	A3	S082 fec/vom samples	S082 fec/vom samples	S082 fec/vom samples
A4	1.9	12.9	66.5	A4	A4 Helmet/gloves Press garm	A4 Helmet/gloves Press garm	A4 Helmet/gloves Press garm
A5	2.1	12.8	73.5	A5	A5 fec/vom samples	S082 fec/vom samples	A5 fec/vom samples
A6	1.9	12.9	66.5	A6	A6 Helmet/gloves Press garm	A6 Helmet/gloves Press garm	A6 Helmet/gloves Press garm
A7	3.4	17.5	119	A7	Urine freezer	Urine freezer	Urine freezer
A8	5.4	21.6	189	A8	A8	A8	A8
A9	3.3	17.4	115.5	A9	A9	A9 fec/vom samples (3)	A9 fec/vom samples (3)

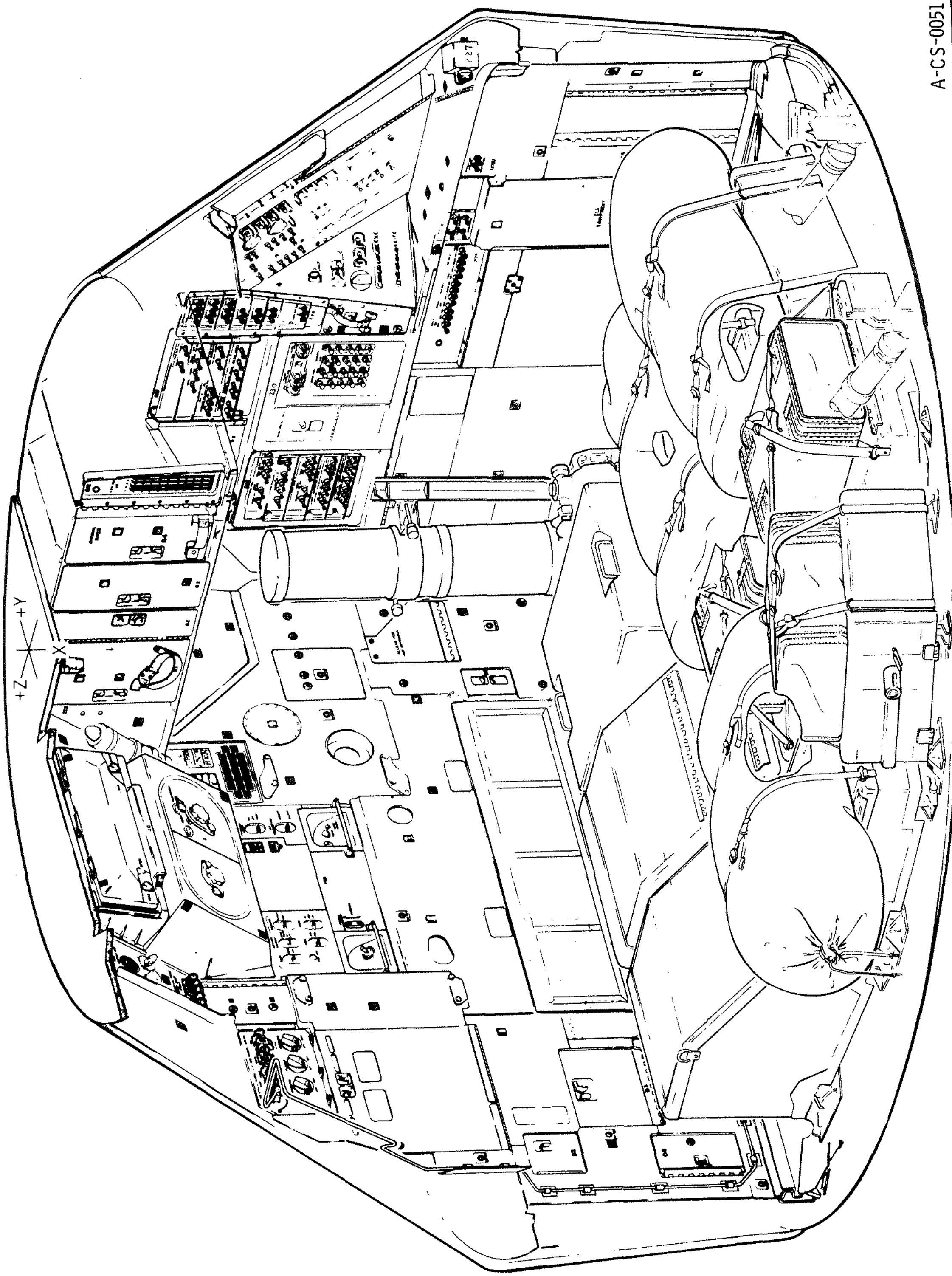

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Figure 2.12-46A. Skylab Return Stowage Configuration

2.12.9.5 Spacecraft Stowage Drawings

Stowage differs from spacecraft to spacecraft because of mission requirements. Each spacecraft is stowed for launch in accordance with its field installation stowage drawing and stowage list. The stowage list officially installs items on the spacecraft. The stowage drawing specifically indicates where the item will be stowed, by compartment, locker, sub-compartment, and position. The stowage drawing is an engineering perspective illustration, the bill of material conforming to the stowage list. The stowage drawing number is F04-1005XX, the XX being the last two digits of the command module designator CM-1XX. For instance, Skylab 2, using CM 116, has a stowage drawing of F04-100516.

During the MDA activation, OWS activation, CSM deactivation, experiment transfer, CM activation, and OA deactivation mission phases, major items and cables are unstowed and installed in accordance with an in-flight stowage and cable routing drawing (V56-7815XX). The XX are the last two digits of the command module designator, CM-1XX. For example, the in-flight stowage drawing for Skylab 4, using CM 118, is V56-781518.

2.12.9.6 CG Control and Nonnormal Return Stowage

In the event of an emergency mission termination after docking, and time does not permit normal return stowage configuration, or additional equipment is to be returned, the following information is of value when stowing the crew compartment aft bulkhead.

The command module CG must be maintained to assure entry stability and the L/D ratio greater than 0.280 and less than 0.365. Therefore, the aft bulkhead must be stowed so any weight shift is toward the LEB and not toward the hatch or, any positive weight change should be toward the +Z direction. Shifts in the + or -Y direction have little affect on the CG. That is, when returning for entry and the AB lockers are not stowed according to the return stowage configuration, or some lockers on the +Z side of the aft bulkhead are empty, these lockers must be stowed as similar to launch configuration as possible. Excessive equipment or experiments are stowed toward the LEB or +Z side of the Y-axis. Postlanding stability is also maintained when conforming to the preceding stowage management.

2.12.10 POSTLANDING RECOVERY AIDS

The postlanding recovery of the crew and CM may last 48 hours. The recovery aids will assist the crew in signaling the recovery forces and survival.

2.12.10.1 Postlanding Ventilation (PLV) Ducts (Figure 2.12-47)

Shortly after landing, the POST LDG VENT VALVE UNLOCK handle in the upper center of panel 2 is pulled, unlocking the PLV valves on the forward bulkhead. Then the POSTLANDING - VENT HIGH switch on panel 15 is positioned to VENT HIGH, forcing air into the CM cabin. The PLV ducts are unstowed and distributed. The crew installs the PLV ducts on the PLV manifold. Each crew member places a head strap around the back of his head, and lies in his couch. The PLV ducts direct the flow of incoming air to the crewmen. The right- and center-couch crewmen use the short ducts and the left-couch crewman uses the long duct.

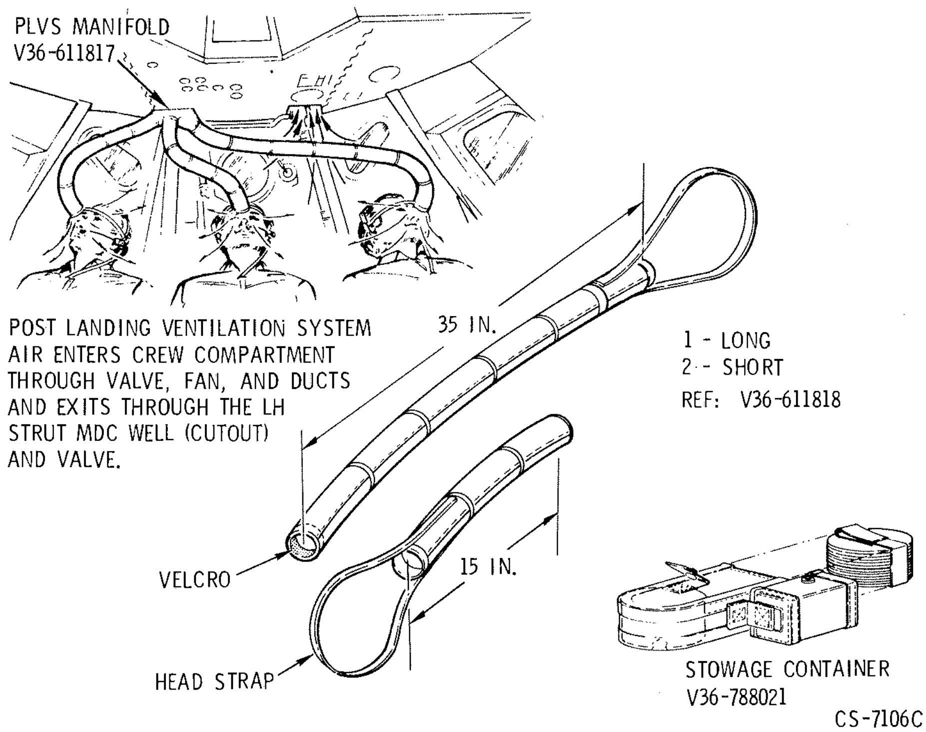

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Figure 2.12-47. Postlanding Ventilation Ducts

The ducts are 3.25 inches in diameter, 15 inches or 35 inches long, and are made of cloth with stiffeners every 5 inches. One end has a head strap and the other end an internal circumferential strip of Velcro for attaching to the PLV manifold. The ducts compress, accordian style, into small volumes that are stowed easily.

2.12.10.2 Swimmer Umbilical and Dye Marker (Figure 2.12-48)

For daylight visual acquisition during the recovery phase, dye marker is deployed. The CM equipment consists of a dye marker and swimmer umbilical deployment mechanism located on the forward bulkhead and a power control.

The swimmer umbilical and dye marker is spring-loaded and held by a hot wire actuator pin. When the crew determines that the dye marker is required, the DYE MARKER switch is activated to the DYE MARKER position. The POSTLANDING switches are located on panel 15. The DYE MARKER switch is the center switch of the three POSTLANDING switches. The circuit breaker is on panel 8 and marked FLOAT BAG - CTR - FLT/PL. The current melts the actuator hot wire, retracting the pin and releasing the dye marker umbilical. It falls in the sea on the end of the 12-foot swimmer umbilical; the dye colors 1000 square feet of sea for 12 hours. When the pararescue personnel arrive, they uncap the swimmer umbilical and plug in a jack, connecting their headset-microphone to the audio center intercomm system, allowing them to communicate with the crew.

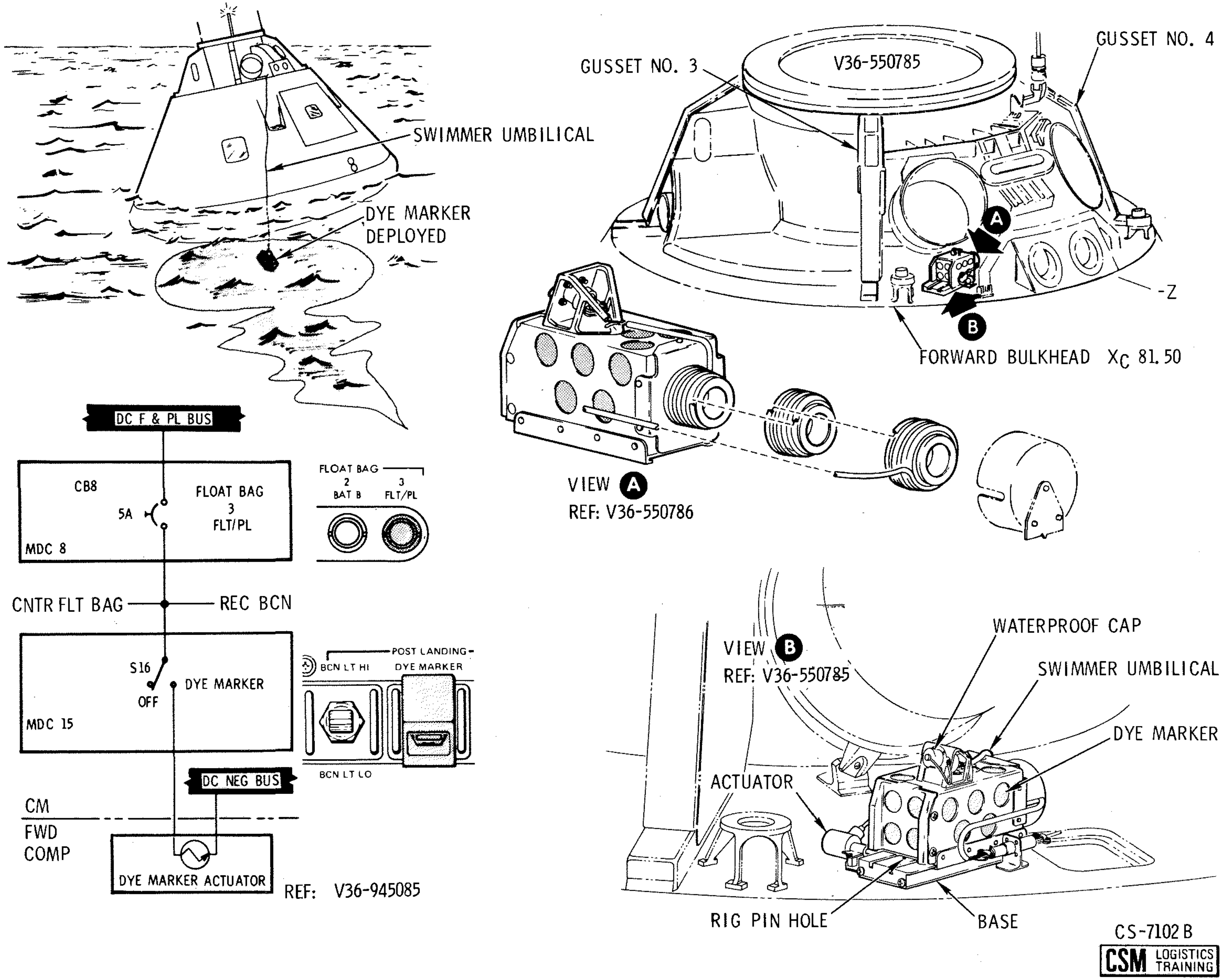

Figure 2.12-48. Swimmer Umbilical and Dye Marker

2.12.10.3 Recovery Beacon (Figure 2.12-49)

In the event that crew and CM recovery are not effected during daylight, there is a visual acquisition method for night operations. The CM equipment consists of a flashing light (or beacon) located near the tunnel that is turned on by the crew when needed.

Deployment of the beacon begins when the main parachute deploys. A lanyard, attached to the main chute risers, actuates two reefing line cutters that sever a cord holding the recovery beacon arm in the stowed position. A spring rotates the arm in an upright (deployed) position and a latch locks it in place.

The CM has a dual mode recovery beacon and the d-c power source is the SC flight and postlanding bus. The POSTLANDING - BCN LT switch is located on panel 15. Its circuit breaker is labeled FLOAT BAG - CTR - FLT/PL and is located on panel 8.

For CM visual acquisition, the BCN LT switch is placed in the LO position. The beacon will flash with a high intensity once every 4 seconds or 15 flashes per minute (FPM). In the low (LO) mode, the operating time is two 12-hour periods or 2 nights.

When the pararescue team is ready for deployment the request for the high rate will be made. The BCN LT switch is then placed in the HI position. The beacon will flash with a low intensity twice every second or 120 FPM. In the high (HI) mode, the operating time is 4 hours.

2.12.10.4 Snagging Line (Figure 2.12-50)

In the event the CM lands beyond the recovery force helicopter range, a recovery aircraft will drop an aircraft delivered drift reduction system consisting of a recovery equipment package and a parachute at each end of 840 feet of floating line. The crew will deploy a snagging line hook through the side hatch pressure equalization valve port after removing the valve. The snagging line is restrained by a plate bolted to the port. When the CM drifts to the floating line the line will either slide up the CM and catch around the upper deck or will move under the CM to be snagged by the snagging line hook. Once the line is snagged the parachutes act as sea anchors and the CM drift speed is retarded.

2.12.10.5 Survival Kit (Figure 2.12-51)

The survival kits function is to provide the equipment necessary for 48-hour crew survival in the water after landing. There are some items that can be used inside the CM such as the water and desalter kits.

The survival kit is stowed in the RHFEB structure in two rucksacks. To remove, the SURVIVAL KITS door is opened and the rucksacks are pulled inboard. The rucksacks have an interconnecting mooring lanyard, and a man-line lanyard.

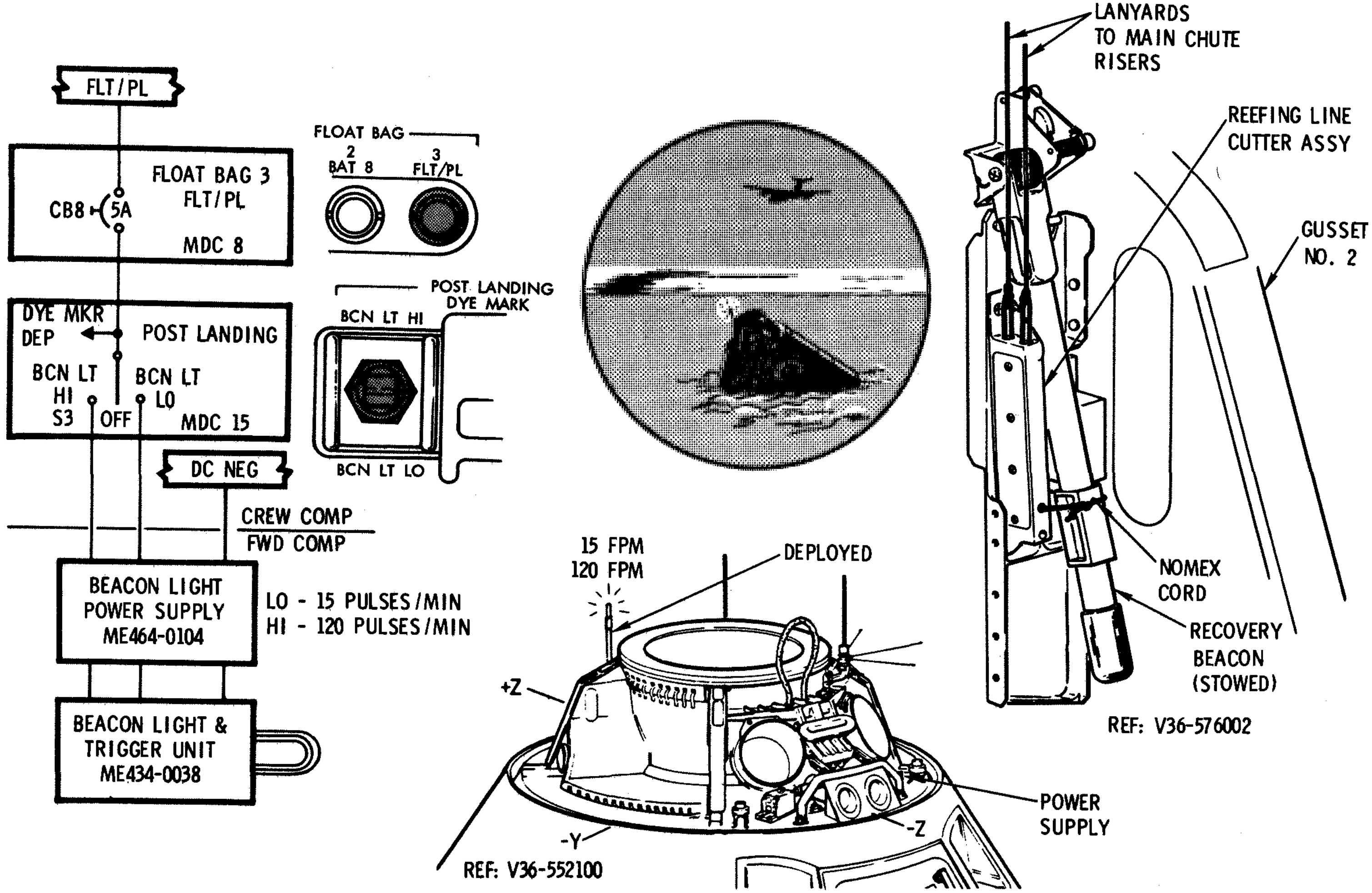

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Figure 2.12-49. Recovery Beacon

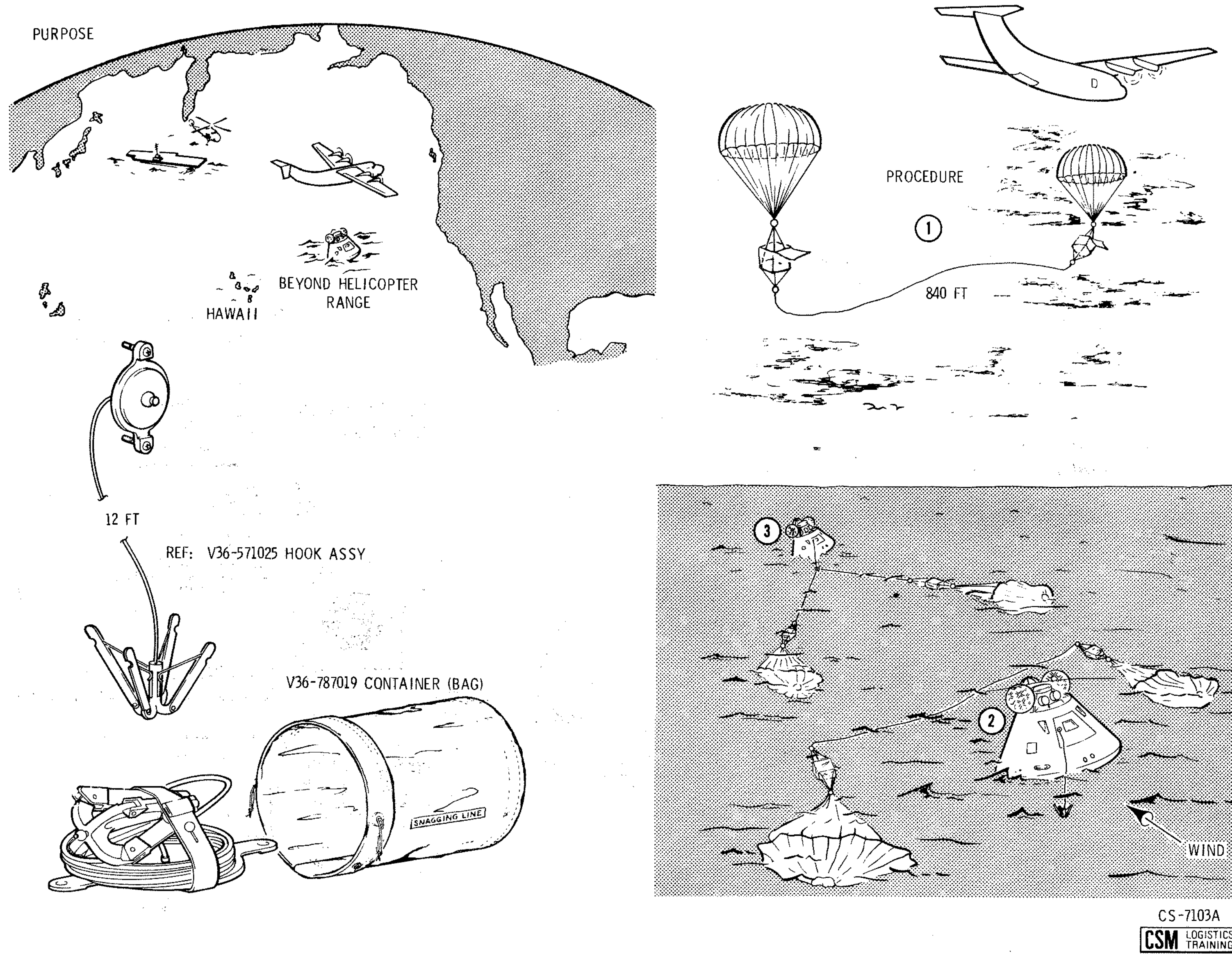

Figure 2.12-50. Snagging Line

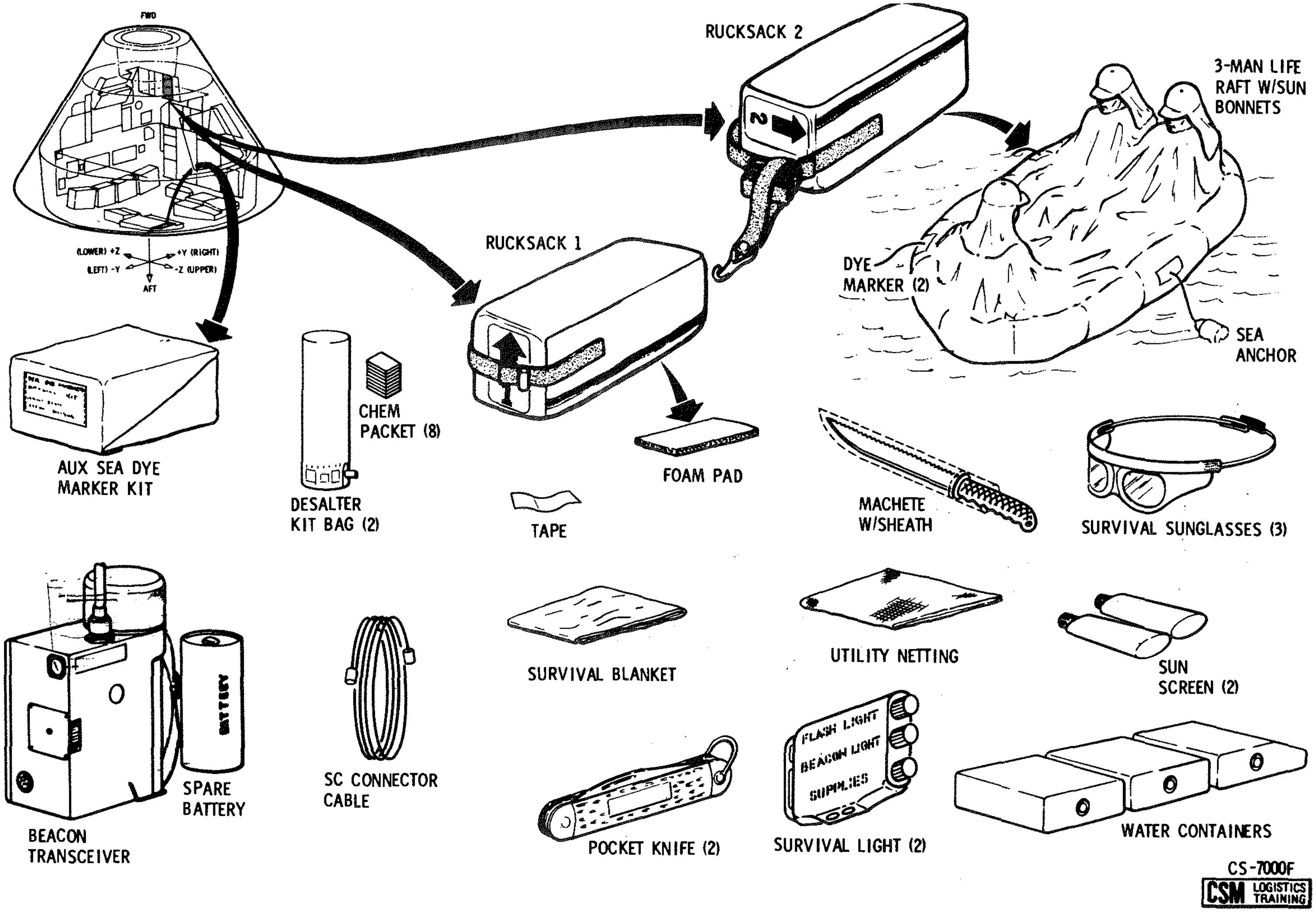

Figure 2.12-51. Survival Kit

2.12.10.5.1 Rucksack 1

The rucksacks are cloth bags with a zipper for opening, and a strap for handling. Rucksack I contains the following equipment.

Skylab Survival Radio. The Skylab survival radio is hand-held, battery-powered, and fix-tuned to a VHF frequency of 243 MHc. The radio consists of a transmitter-receiver assembly, a battery pack, an antenna, spacecraft connector cable, and a spare battery pack. The transceiver and battery pack are assembled in a water-proof unit 7-7/8 by 4-3/4 by 2-1/2 inches and weigh 4 pounds.

The radio has a VO, BCN, and OFF mode switch, a push-to-talk switch, a speaker-microphone, and a voltage meter. The voice (VO) mode is AM with a 100-nautical-mile range and the beacon (BCN) mode transmits a wail from 300 to 1000 Hz and has a 195-nautical-mile range. The transmitter output is protected against damage due to accidental shorting of the antenna or submergence in salt water.

The batteries are a mercury-cell type, 16.2 volts, and will operate the radio for 24 hours each at 30-percent transmit, 70-percent receive. The antenna is a quarter-wavelength, teflon-coated, flexible blade, 13 inches long, and connects to the top of the radio with a type TNC plug. By removing the antenna, the survival radio can be connected to the CM VHF antenna by use of the spacecraft connector cable.

Survival Light Assemblies. The survival light is a three-units-in-one device as it contains three compartments. The whole device is waterproof. The controls for the lights are on the bottom.

The first unit is a flashlight. The second unit is a strobe light for night signaling. The third unit is a waterproof compartment containing a fish hook and line, a sparky kit (striker and pith balls), needle and thread, and whistle. The top of the unit is a compass. On one side is a folding signal mirror.

Desalter Kits. The desalter kits contain a desalter process bag, desalter tablets, and bag repair tape. The desalter bags are plastic with a filter at the bottom. Approximately one pint of water is put into a bag and one tablet added. After one hour, drinking water may be taken through a valve on the bottom of the bag.

Machetes. The two machetes are protected with a cloth sheath. The knives are very thin with razor edges. The back edge is a saw.

Sunglasses. For protection of the eyes against the sun and glare, three sunglasses are included. They are a polarized plastic sheet with Sierra Coat III, a gold coating that reflects heat and radio waves.

Water Cans. For drinking water there are three aluminum cans, with drinking valve, each containing approximately 5 pounds of water.

Sun Lotion. Two containers of sun lotion are for protection of the skin.

2.12.10.5.2 Rucksack 2

Rucksack 2 contains the flotation gear in the form of a three-man life raft with an inflation assembly and CO_2 cylinder. In addition, it contains a sea anchor, dye marker, lanyards, and a sunbonnet for each crewman.

2.12.11 RESCUE VEHICLE CONFIGURATION

The general rescue vehicle concept provides a modification kit that will allow a standard Skylab command module to be fitted for a two-man launch and five-man return configuration. Along with the necessary crew support equipment modifications will be provisions for return of the maximum possible experiment equipment from the Skylab vehicle. Figure 2.12-52 shows some of the major features of the five-man return configuration.

2.12.11.1 Rescue Couches and Harness Assembly

Two specifically designed couches are fitted under the existing right and left couches of the CM. Figure 2.12-53 shows the general configuration of these couches and how, through special adapters, they utilize existing stowage attach points. The rescue couches consist of a shock attenuated back pan assembly, a rigid leg support assembly, their attendant adapter fittings, and the modified restraint harness.

The back pan assembly provides the required crew protection through a six-element PYRELL shock attenuation system. The inset in figure 2.12-53 shows the arrangement of these attenuators. A system of torque rods and sway bars are designed to assure even compression of the attenuator elements on both sides of the couch.

The leg support assembly has seven positions and is adjusted to any one prior to launch. It is configured to provide the required foot and calf support to the specific astronaut assigned to that couch.

The restraint harness fitted to the rescue couch adds three additional straps to the standard restraint harness. Figure 2.12-54 shows the +Z center strap and its adapter plate which integrates it with the standard Apollo harness. Two thigh straps have been added to secure the astronaut in the -Z direction. It should be noted that the rescue couch harness has a three-point release system.

2.12.11.2 Experiment Return Pallet Assembly

When the CM is fitted for a rescue mission, the majority of the storage area on the aft bulkhead is allocated to the rescue couches. The experiment return pallet accommodates a selected experiment payload from Skylab. Figure 2.12-55 shows the return pallet in its launch and return configuration. The unit consists of two aluminum frames that mount to existing aft bulkhead mounting fixtures, a hinged close-out panel which limits shifting of the stowed articles in the -Z direction, and a beta cloth cover which straps to the frame and facilitates tie-down of the stowed articles.

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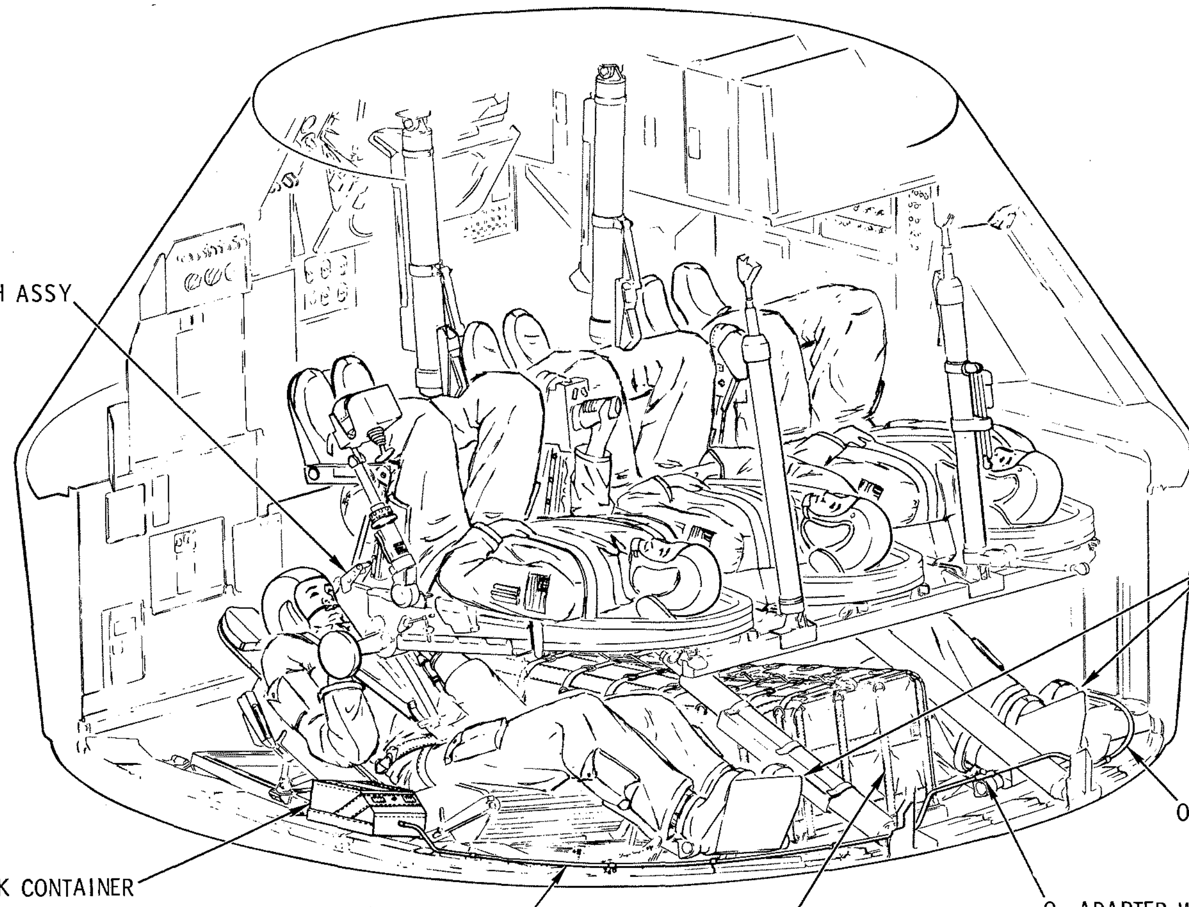

Figure 2.12-52. Rescue Vehicle Return Configuration

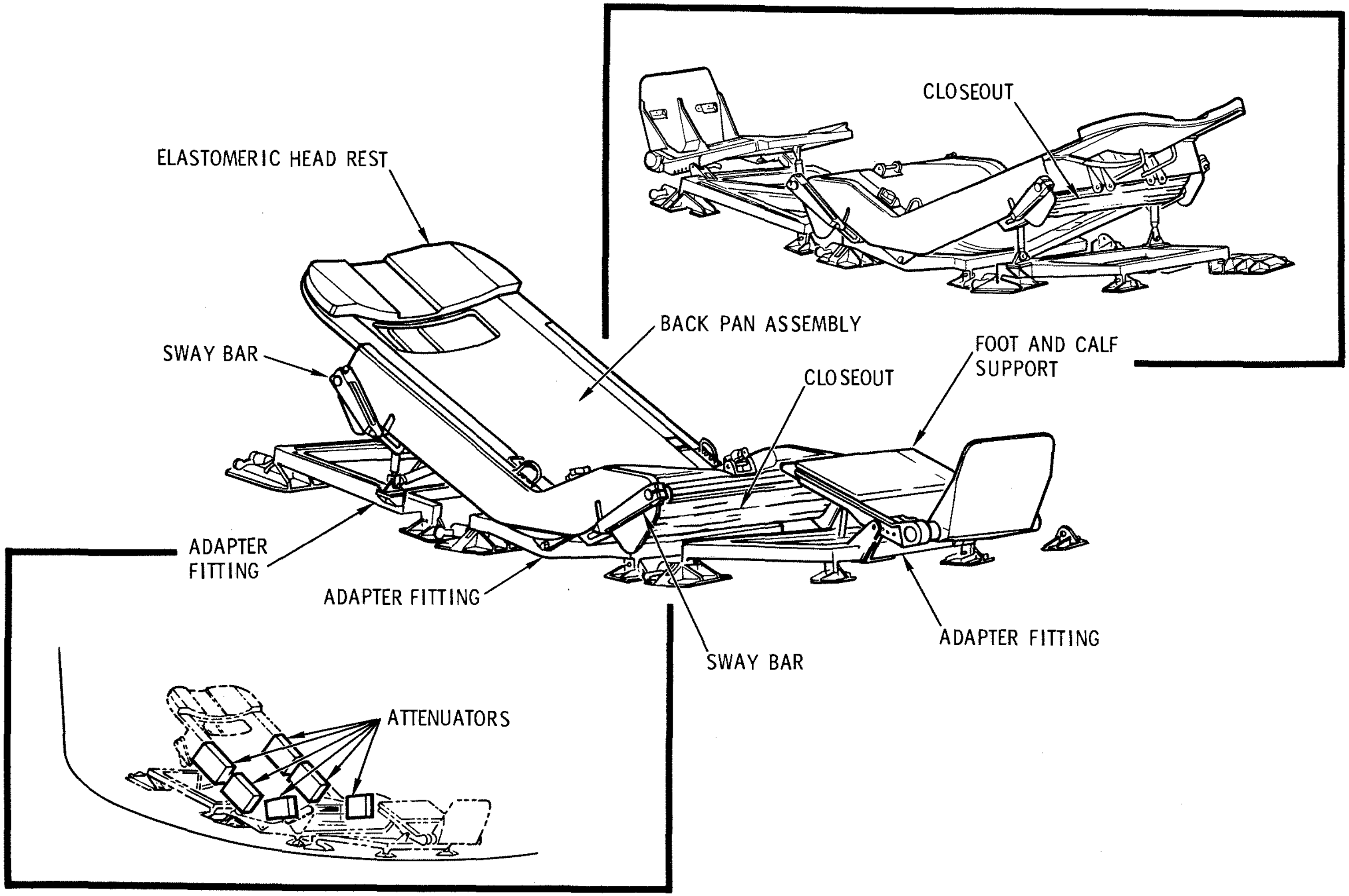

Figure 2.12-53. Rescue Vehicle Couch Assembly

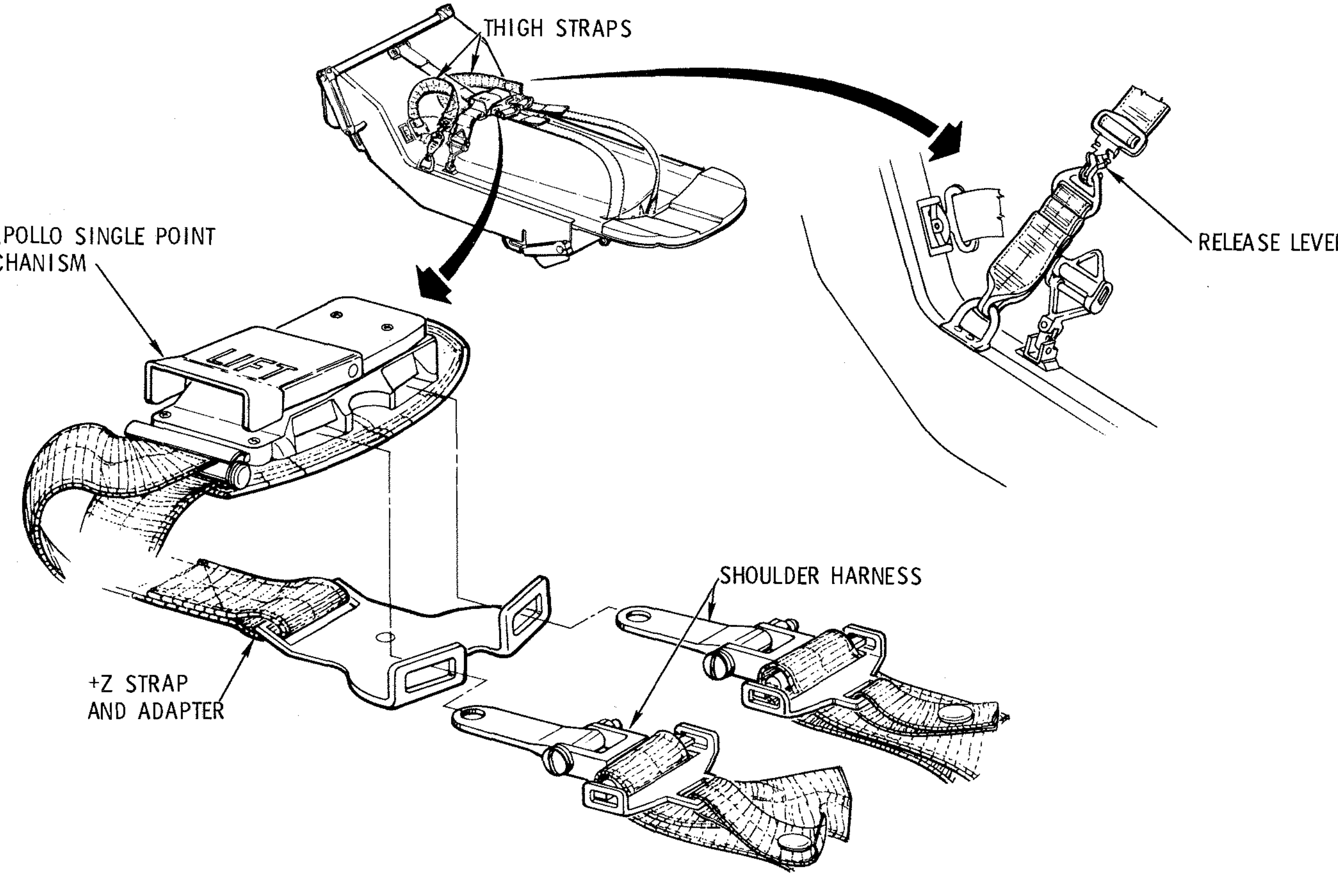

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Figure 2.12-54. Rescue Vehicle Couch Restraint Harness

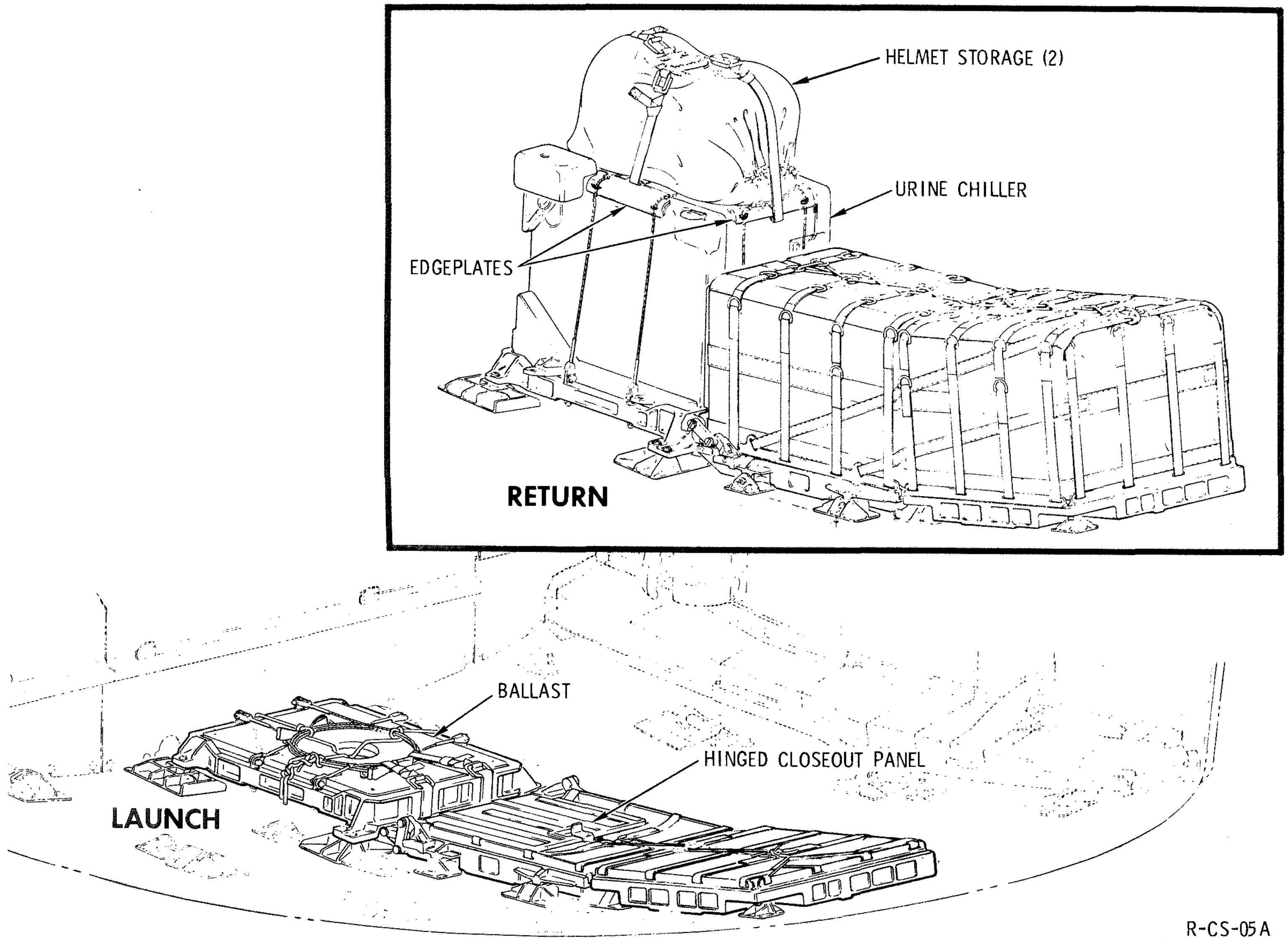

Figure 2.12-55. Rescue Vehicle Experiment Return Pallets

2.12.11.3 Urine Chiller Tie-Down Assembly

One of the experiment payloads to be returned on the rescue vehicle is the MO 71/73 urine chiller. The urine chiller tie-down assembly is shown in figure 2.12-55 in its launch and return configuration. The unit basically consists of an aluminum frame that mounts to existing mounting fixtures on the aft bulkhead and a series of cables, straps, and edge plates to facilitate tie-down of the urine chiller. Return stowage of two spacesuit helmets is provided on top of the urine chiller and is also shown in figure 2.11-55. Note also that during launch, a ballast assembly is stowed on the frame.

2.12.11.4 Ballast Assemblies

In order to trim the rescue vehicles CG in the two-man launch configuration, two ballast assemblies were added. One unit is strapped to the center couch and weighs 220 pounds. The second unit is tied down in the urine chiller adapter frame (figure 2.12-55) and weighs 200 pounds. Both ballast assemblies will be transferred to the SWS after docking.

2.12.11.5 Oxygen Umbilicals and Hose Adapters

The five-man return configuration of the rescue vehicle necessitated the special oxygen umbilicals shown in figure 2.12-56. Note that two of the three hose assemblies have been converted to feed two separate crewmen while the left couch umbilical remains single. During the launch phase of the mission the three unused umbilicals are closed off through use of the O_2 umbilical couplings shown in figure 2.12-56.

2.12.11.6 Crew Communication Umbilicals and T Adapter

Two additional crew communication umbilicals (CCU) and their attendant T adapters have been provided in the rescue vehicle to allow all five astronauts to use the intercomm and PTT functions of the Skylab CSM telecommunications system. Basically, the T adapter parallels the center and right couches with the lower left and lower right rescue couches, respectively. Functional switching for setting up the crew's interface with the telecommunications system is also paralleled with the SPT and the lower left crewman sharing panel 10 and the PLT and lower right crewman using panel 6. The lower right and upper right crewmen will have 11-foot CCUs, while the other three crewmen will have 7-foot CCUs.

2.12.11.7 Emergency Oxygen Masks and Hose Connectors

Figure 2.12-52 shows the location of the two additional emergency oxygen masks provided for the two astronauts in the rescue couches. The supporting hose, O_2 adapter, and TEC connect to TP 27 of the ECS.

2.12.11.8 Post Landing Ventilation Air Direction Ducts

Two of the three ducts have been lengthened to provide fresh air to the astronauts in the rescue couches after splashdown. The ducts have been lengthened to 90 and 130 inches.

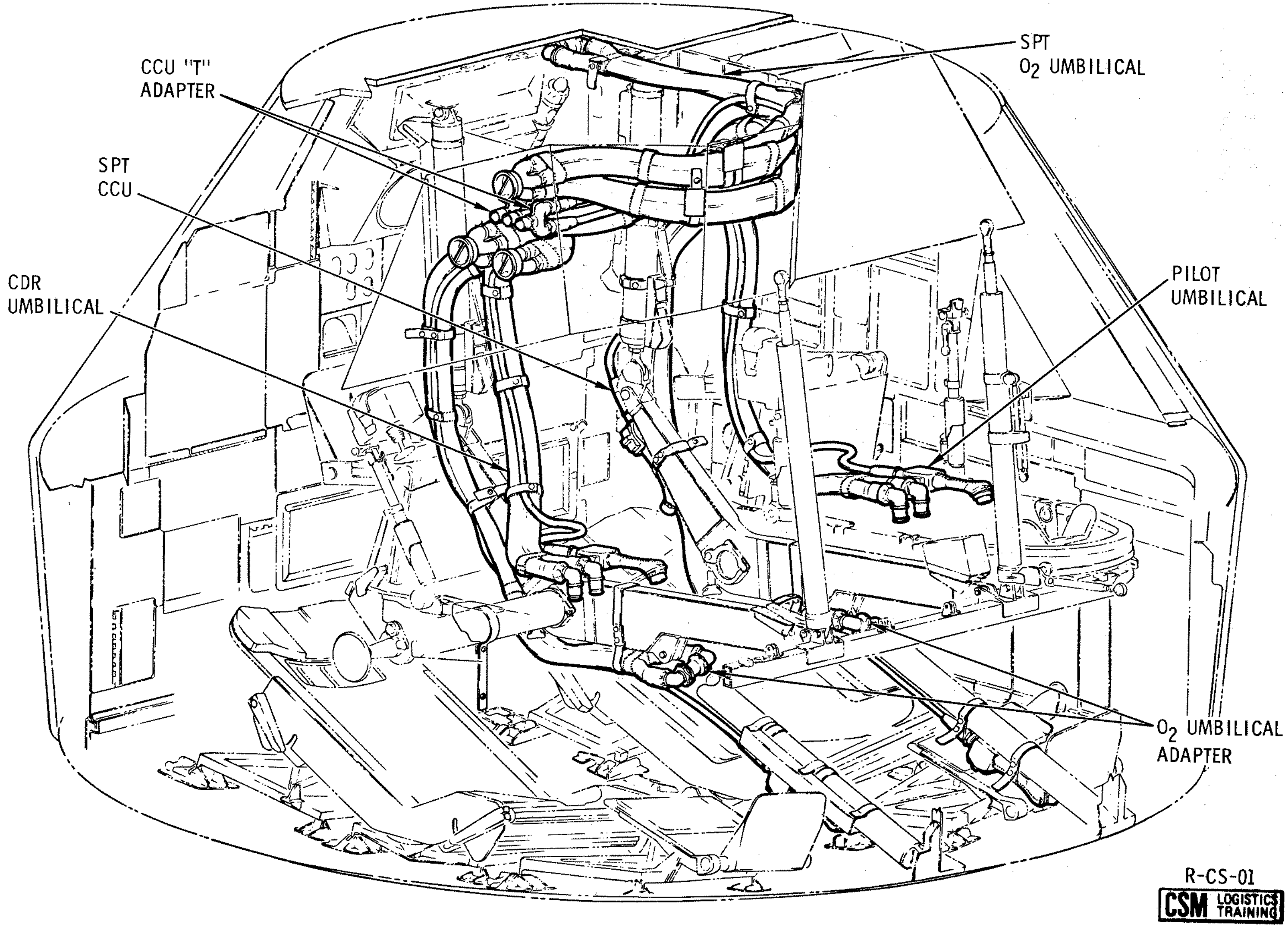

Figure 2.12-56. Rescue Vehicle O_2 and Communication Umbilicals

2.12.11.8A Rescue Vehicle PGA Stowage

Figure 2-12-56A shows the placement of the five pressure garment assemblies in their respective stowage bags. The doffing of the spacesuits will be accomplished after crew transfer from the orbital laboratory and prior to entry. Entry will normally be in a unsuited condition.

2.12.11.9 Probe and Drogue Modifications

In order to provide the capability to jettison the disabled CSM from the axial port of the MDA, a special tripod drogue and a modified probe assembly are used. Both units plus a special docking ring latch release tool are shown in figure 2.12-57. The probe is modified by the astronaut by removing the electrical solenoid actuator from the right side of the extend latch release mechanism and replacing it with a manual release mechanism. Note the manual release mechanism is equipped with a safety locking pin and a lanyard for remote operation of the release mechanism.

To jettison the disabled CSM, the astronaut first installs the modified docking probe and tripod drogue. The probe is preloaded and all but three docking ring latches released from the MDA side of the interface via the special latch release tool. At this point the astronauts get into a hard-suited condition and the MDA is depressurized. The final three latches are released and one astronaut will initiate the jettison by removing the safety locking pin from the manual release mechanism, pushing in the release button at the hand of the probe with aid of a B tool and pulling the lanyard that releases the extend latch to the probe. The subsequent probe extension will impart a nominal 0.5-foot-per-second delta V to the jettison of CSM.

Subsequent to CSM jettison, the tripod drogue is replaced with the docking drogue, the MDA hatch closed, and the MDA repressurized.

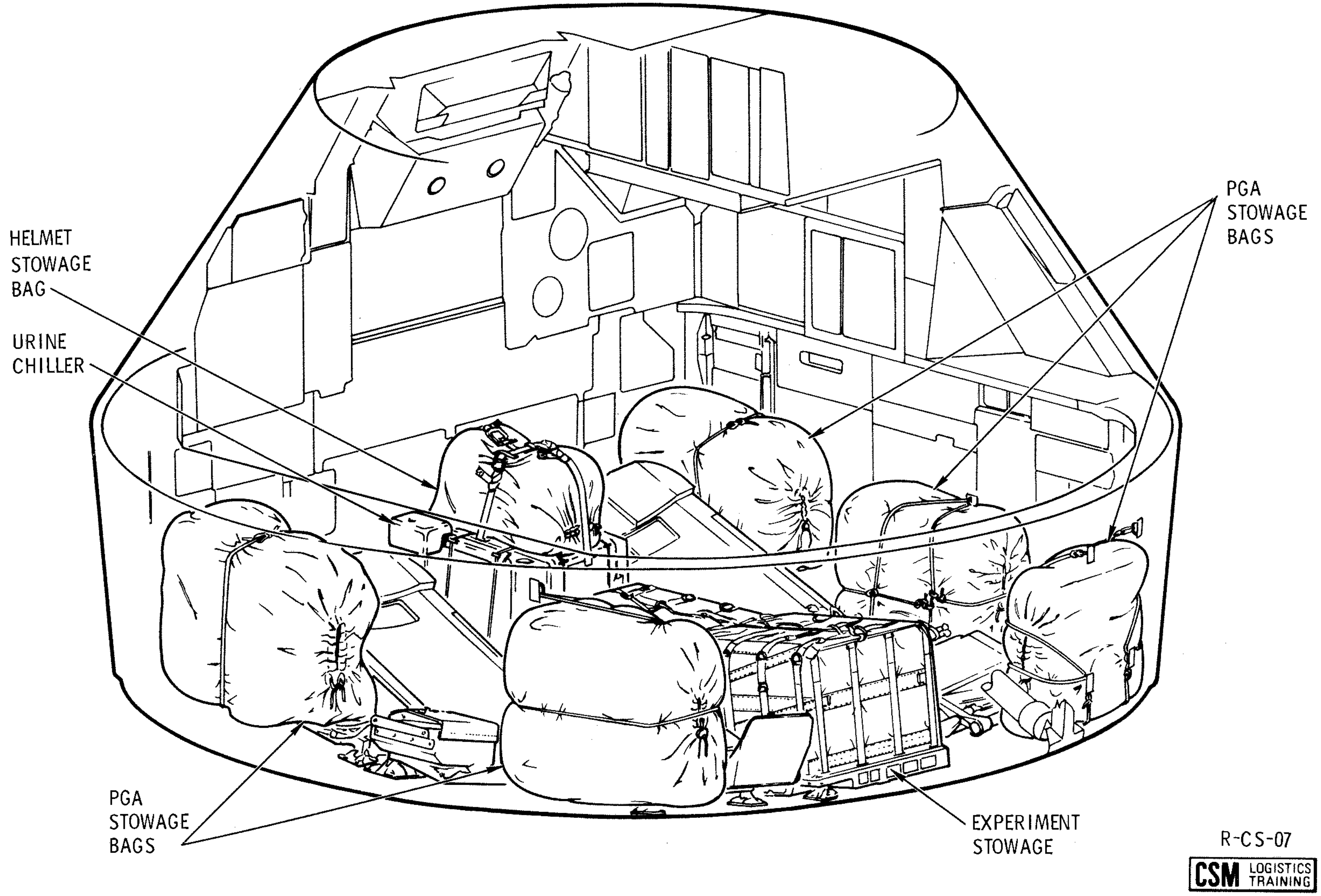

Figure 2.12-56A. Rescue Vehicle PGA Return Stowage

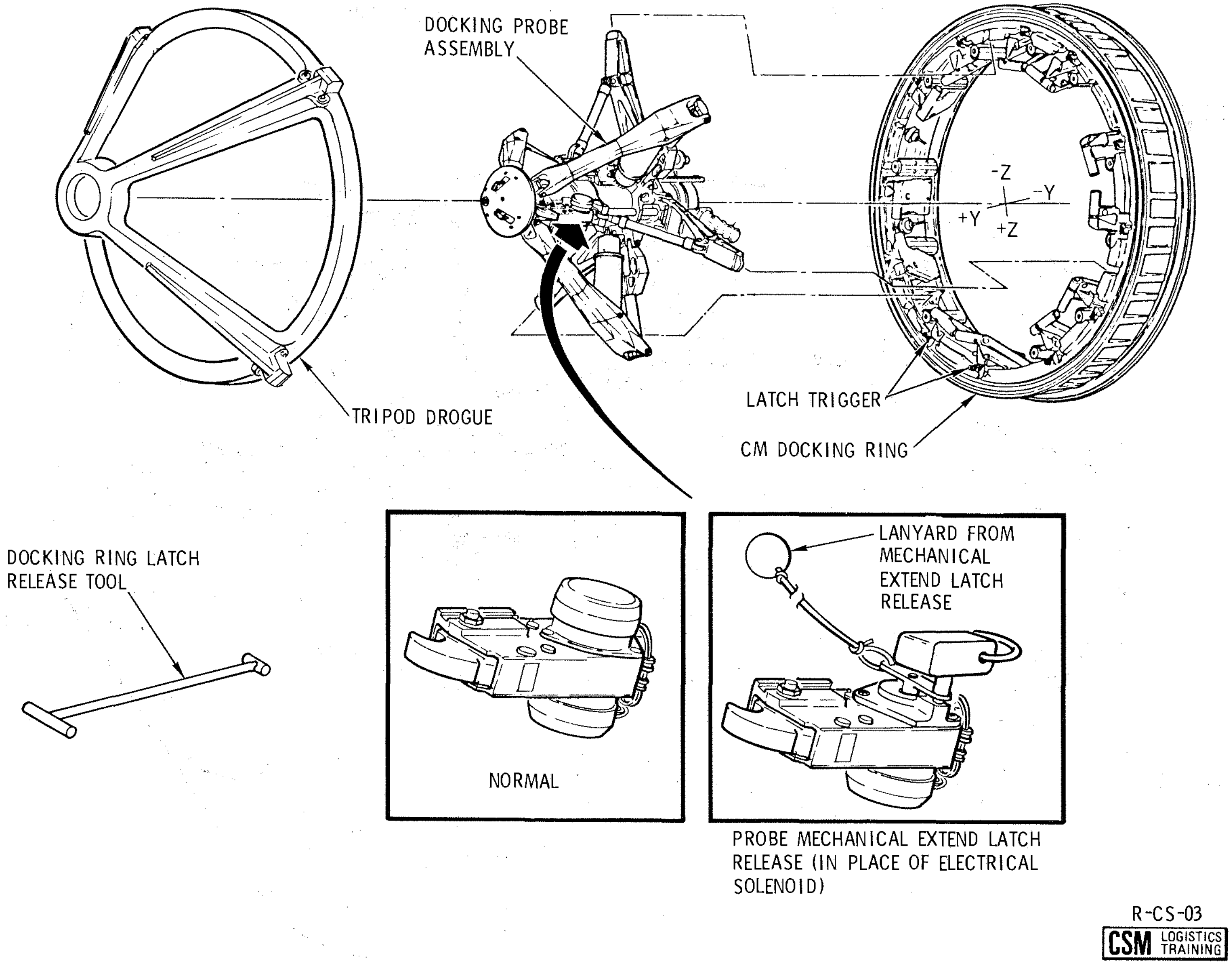

Figure 2.12-57. Rescue Vehicle Probe and Drogue Modifications

SECTION 2

SUBSECTION 2.13

DOCKING AND TRANSFER

2.13.1 INTRODUCTION

This section identifies the physical characteristics of the docking system and the operations associated with docking and transfer.

2.13.1.1 Docking Operational Sequence

The following illustrations and text describe the general functions that are performed during docking.

The docking probe is extended during one of the orbits used to check out the spacecraft systems. After system checks are complete, the SPS engine is ignited to rendezvous with orbital workshop (OWS) (figure 2.13-1).

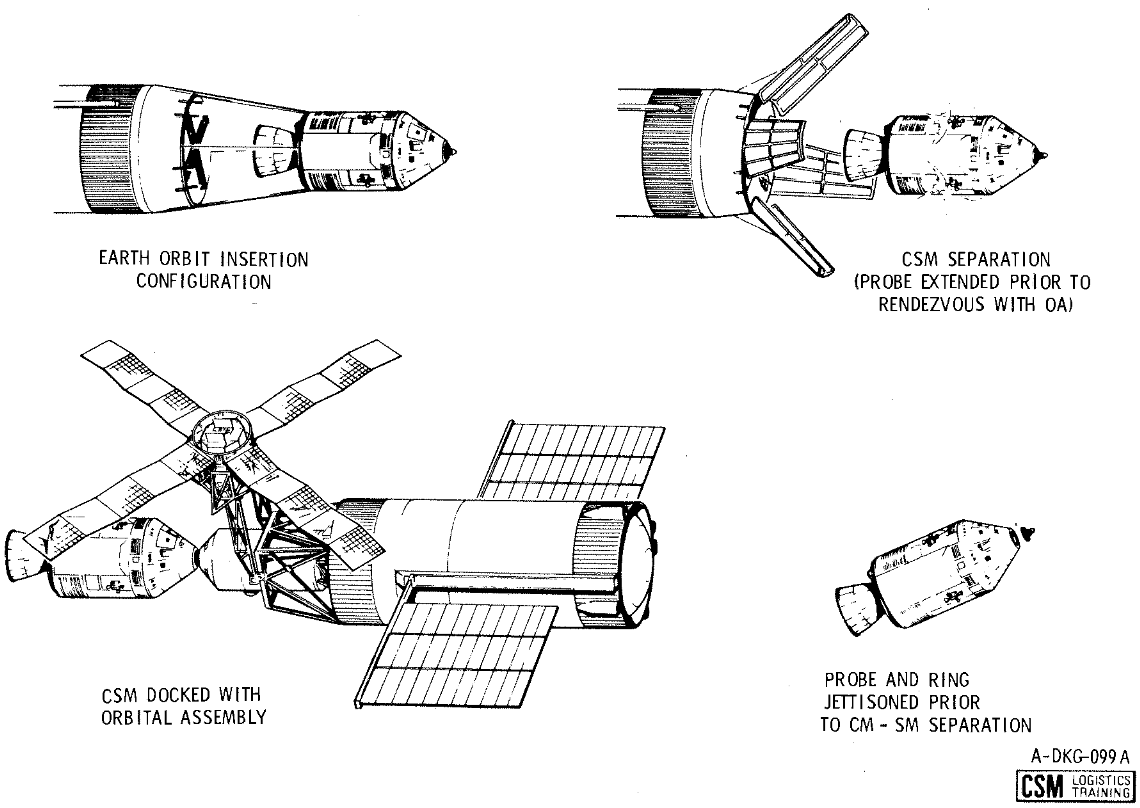

Figure 2.13-1. CSM/OWS Docking Operational Phases

DCT

With the probe extended, docking is achieved by maneuvering the CSM close enough to the MDA so that the extended probe engages the drogue on the MDA. When the probe engages the drogue through the capture latches, the probe retract system is activated to pull the MDA and the CSM together. Upon retraction, the MDA tunnel ring activates the 12 automatic latches and effects a pressure seal between the modules through the two seals in the CM docking ring face. After the vehicles are docked (figure 2.13-1), the pressure in the tunnel is equalized from the CM through the equalization valve. The CM tunnel hatch is removed, and the actuation of all 12 latches is verified.

Any latches not automatically actuated are cocked and actuated manually by the crewman. The probe and drogue assembly are removed and temporarily stowed in CM. The MDA pressure hatch is opened providing a passageway between the two modules and the MDA is activated. This completed, umbilicals (two control and one power) are retrieved from stowage and connected to their respective connectors in the CM docking ring and MDA tunnel. An atmosphere interchange duct (stowed in MDA), used to transfer atmosphere from the MDA into the CM, is also installed at this time. The probe and drogue are transferred for stowage in the MDA. The probe is stowed in a moisture-proof bag. An insulation blanket (stowed in MDA) is installed in CM to prevent condensation from forming on CM sidewalls. (Refer to section 2.12 for description of bag and blanket.)

After completing the schedule experimental tasks, the OWS is prepared for orbital storage. The crew transfers back to the CSM and begins preparation for the separation of the CSM from the MDA.

The atmosphere interchange duct is removed, the umbilicals are disconnected, and the drogue and probe are installed. The automatic docking latches are cocked and the tunnel hatch is installed. After venting the tunnel, the probe is extended and the CSM is separated from the OWS (figure 2.13-1).

Prior to CM-SM separation the docking probe and docking ring are jettisoned (figure 2.13-1).

2.13.2 FUNCTIONAL DESCRIPTION

The docking system is a means of connecting and disconnecting the CSM/MDA during a mission and of providing for intravehicular transfer between the CSM and MDA.

The crew transfer tunnel, or CSM/MDA interlock area, is a passageway between the CM forward bulkhead and the MDA pressure hatch. The hatch relationship with the docking hardware is shown in figure 2.13-2. For descriptive purposes that portion of the interlock area above the CM forward bulkhead to the docking interface surface is referred to as the CM tunnel. That portion of the interlock outboard of the MDA pressure hatch extending to the docking interface surface is referred to as the MDA tunnel. The CM tunnel incorporates the CM tunnel hatch, probe assembly, docking ring and seals, umbilical connections, and the automatic docking latches. The MDA tunnel contains a pressure hatch, drogue support fittings, drogue assembly, drogue locking mechanism, and umbilical connections.

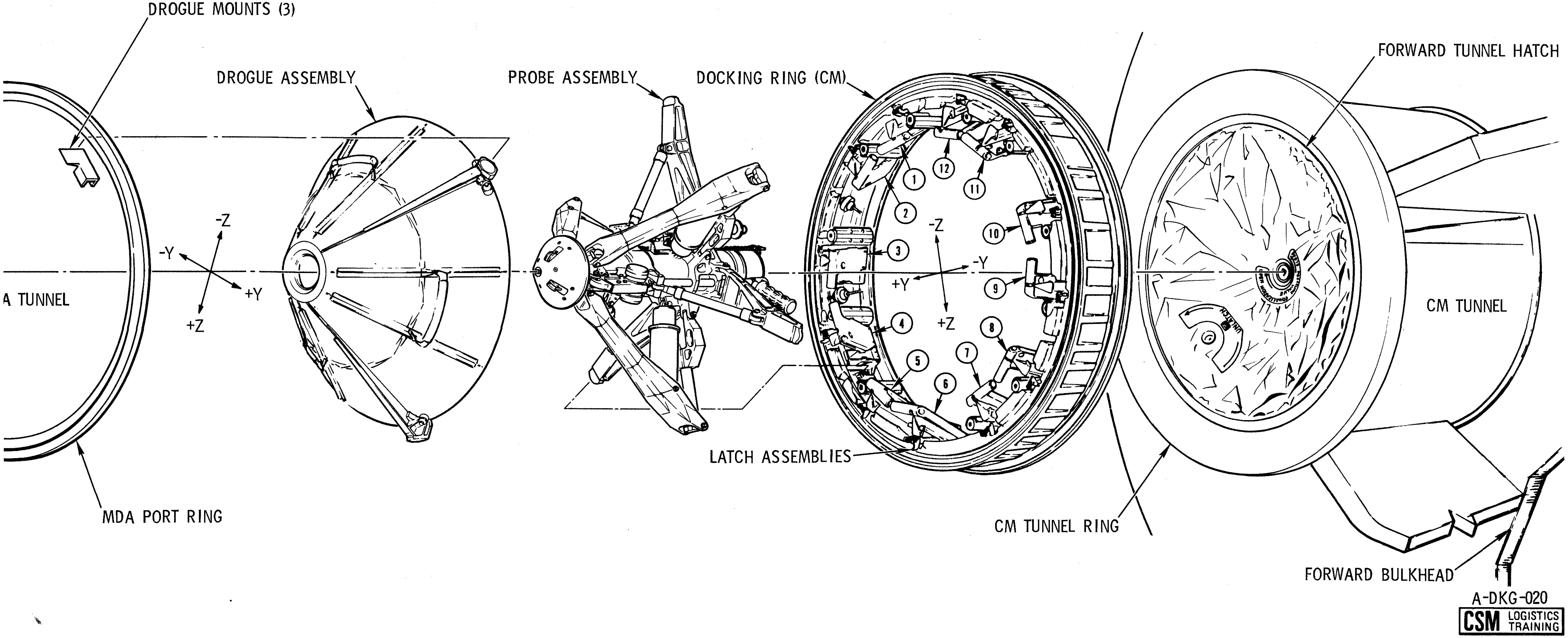

Figure 2.13-2. Docking System - Major Assemblies

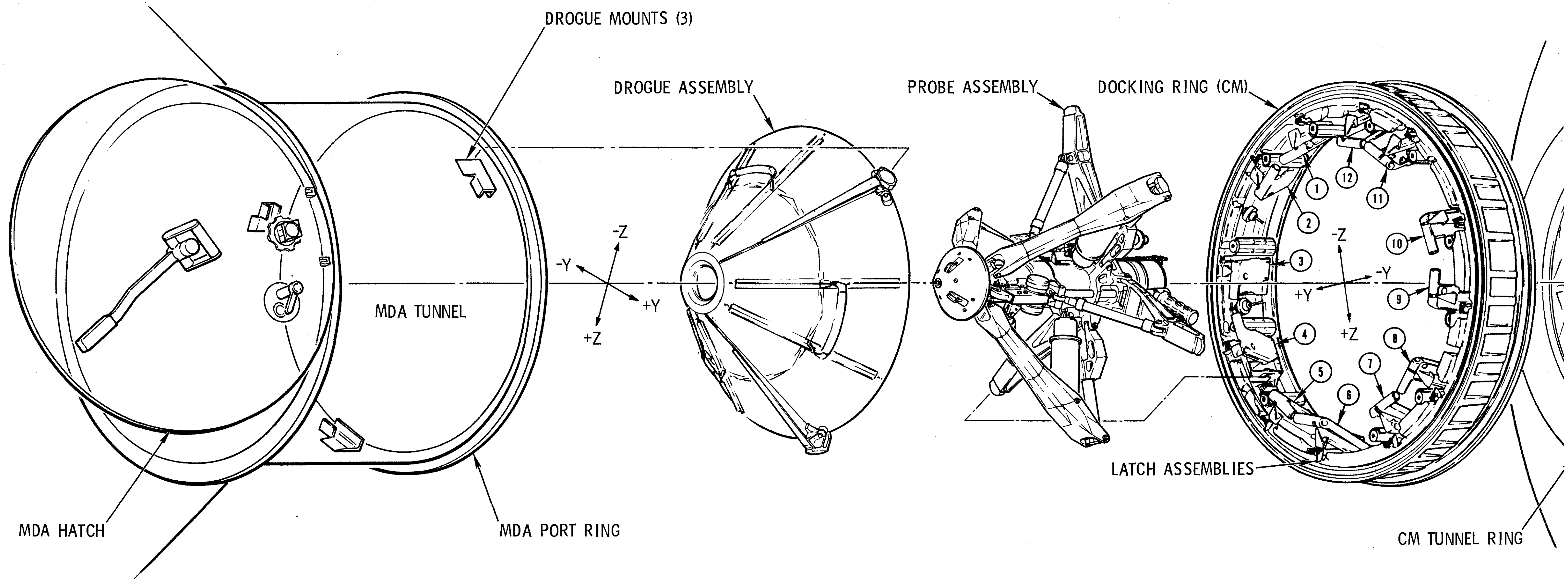
DROGUE MOUNTS (3)
DROGUE ASSEMBLY
PROBE ASSEMBLY
DOCKING RING (CM)
-Z
-Y
+Y
+Z
MDA TUNNEL
1
2
3
4
5
6
7
8
9
10
11
12
LATCH ASSEMBLIES
MDA HATCH
MDA PORT RING
CM TUNNEL RING

Figure 2.13-

2.13.3 COMPONENT DESCRIPTION

2.13.3.1 CM Docking Ring

The docking ring is bolted to the forward ring of the CM tunnel. The docking ring is capable of withstanding all interface loads and maintains the docked alignment of the modules.

The docking ring also serves as a support for the probe, the 12 automatic docking latches, a pyrotechnic charge, passageway for the electrical harness, and the two interface seals. A continuous wire passageway and attachment covers are provided in the docking ring. The passageway is covered by a protective cover with an opening to allow the individual harnesses and lines to enter or exit the passageway. The two concentric interface seals will enable pressurization of the tunnel and vented spacesuit operation within the tunnel. The docking seals are round and hollow; the inner seal is vented to the crew compartment pressure, and the outer seal is vented to ambient pressure. The seals are of sufficient size to allow for maximum warpage/waviness gap between the flanges. To remove the docking ring and attached hardware after CSM/MDA final separation a mild detonating fuse (MDF) is fired to sever the docking ring. The charge is initiated by a switch on the main display console (MDC) within the CM.

If a launch escape system abort is initiated, the docking ring is automatically severed when the tower is jettisoned. The probe and ring will be pulled away by the use of a tension tie that is attached between the boost protective cover (BPC) and the probe head (figure 2.13-2A).

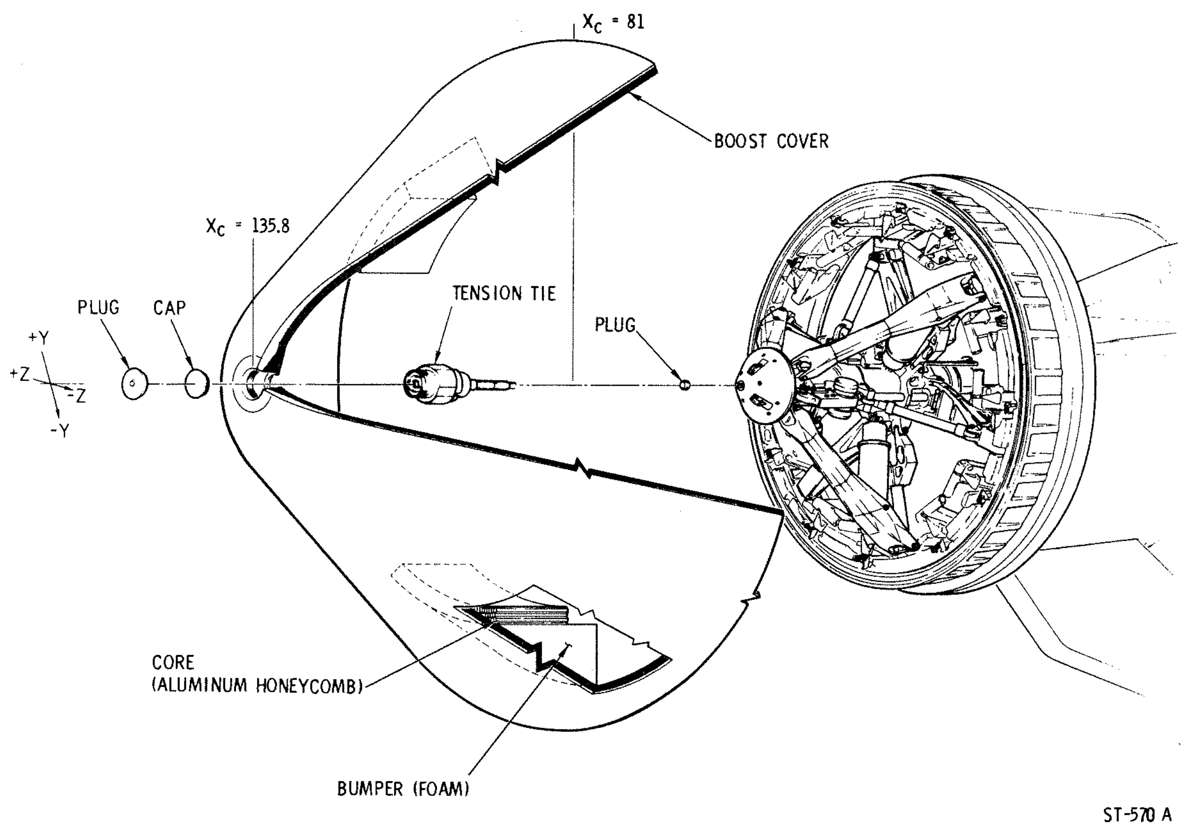

Figure 2.13-2A. BPC and Probe Tension Tie

DCT

2.13.3.2 Docking Latches (Figure 2.13-3)

Twelve automatic docking latches are equally spaced about the inner periphery of the docking ring. When latched, they provide a means of effecting structural continuity and pressurization capability between the CSM and MDA in the docked configuration. The docking latches automatically self-seek and engage the MDA docking flange back surface upon activation of the latch trigger mechanism when making contact with the MDA docking flange. Should a latch be inadvertently triggered, the latch components will not prevent a successful MDA and CM docking and sealing operations. A red button will protrude out of the handle indicating an unlocked condition. Any three latches located approximately 120 degrees apart engaged and latched hold the CSM and MDA together with the tunnel pressurized. The individually triggered latch may later be rearmed and released manually by the crewman for CM to MDA engagement. The latch mechanism exerts a preload or hook pulling force of 2700 pounds minimum. This preload force retracts the hook, seats the hook on the back of the MDA docking flange, accommodates for flange warpage/waviness and compresses the docking seals. Release of the latches is accomplished by the crewman pulling each individual latch handle for a double throw. Fairings are installed in the area between the latches providing a smooth inner mold line.

2.13.3.3 Docking Probe Assembly

The primary function of the docking probe assembly is to provide initial vehicle CSM/MDA coupling and attenuate impact energy imposed by vehicle

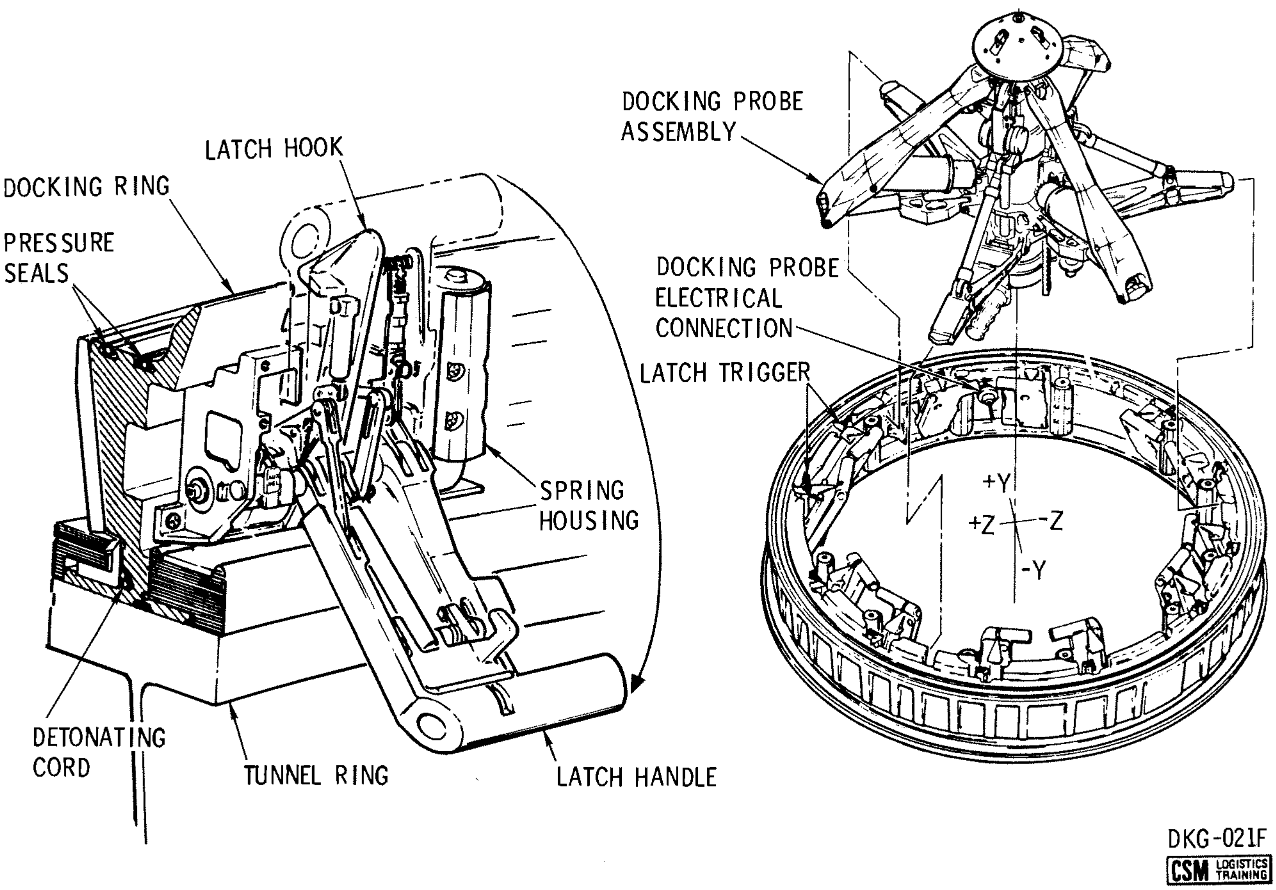

Figure 2.13-3. Automatic Docking Latches

contact. The docking probe assembly (figures 2.13-4 and 2.13-5) consists of a central body, probe head and capture latches, pitch arms and tension linkages, shock attenuators, ratchet assembly, support structure, extension latch and preload torque shaft, probe retraction system, probe electrical umbilicals, and the electrical circuitry necessary to accomplish the functions described herein (figure 2.13-22). The docking probe may be folded for removal and stowage and is capable of being removed from either end of the crew transfer tunnel. A fixed steady handle is provided for a permanent probe secondary handling point.

2.13.3.3.1 Support Structure

The probe is tripod-mounted to the docking ring by a support structure attached to the outer collar of the probe. The supports are designed to collapse (fold) to allow removal of the probe from either module. (See figure 2.13-4.) Collapse of the probe consists of reducing the diameter of the three mount legs to approximately 24-3/4 inches in diameter making the probe small enough for passage. This is accomplished by unlatching the

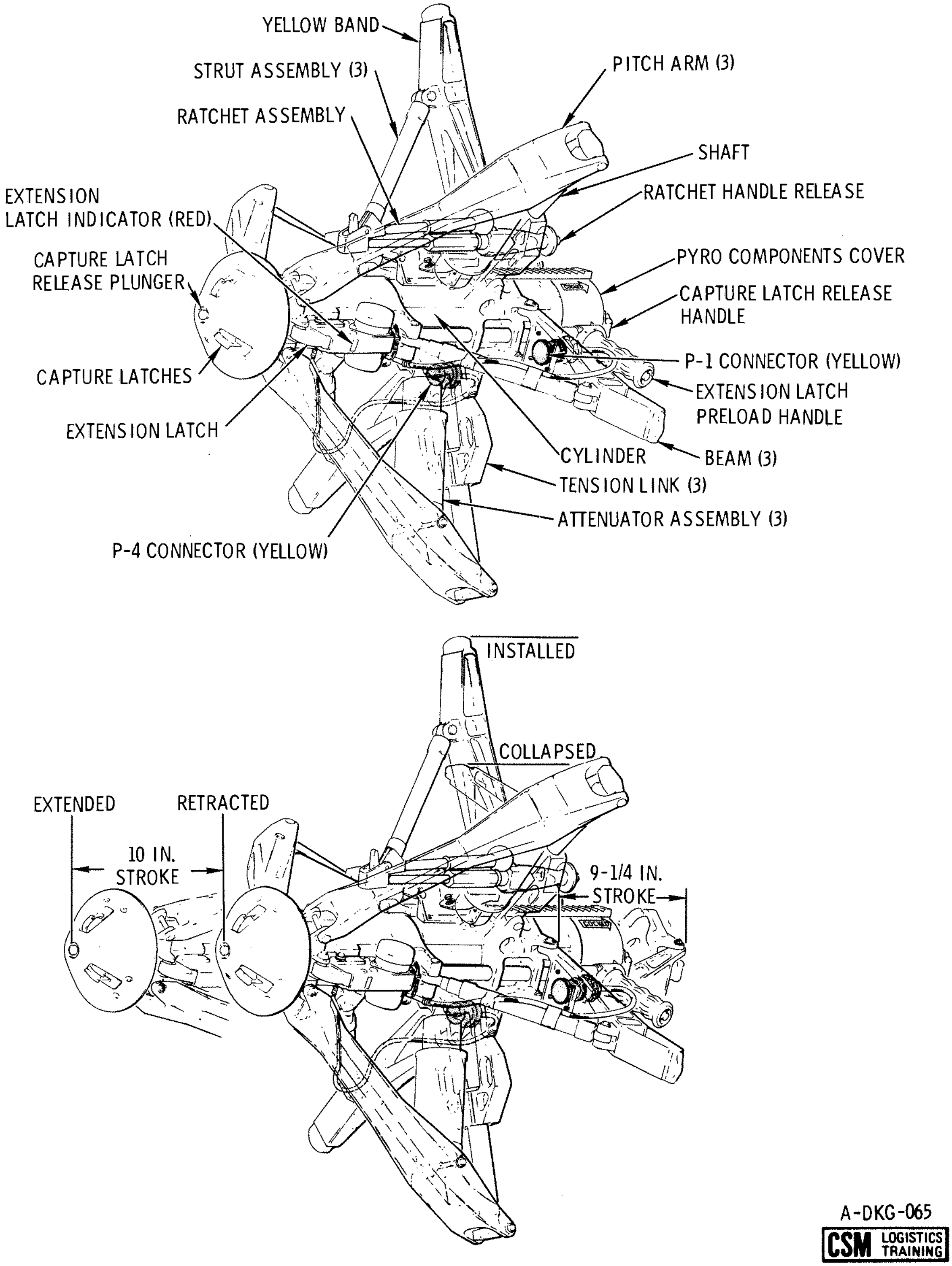

Figure 2.13-4. Docking System Probe Assembly

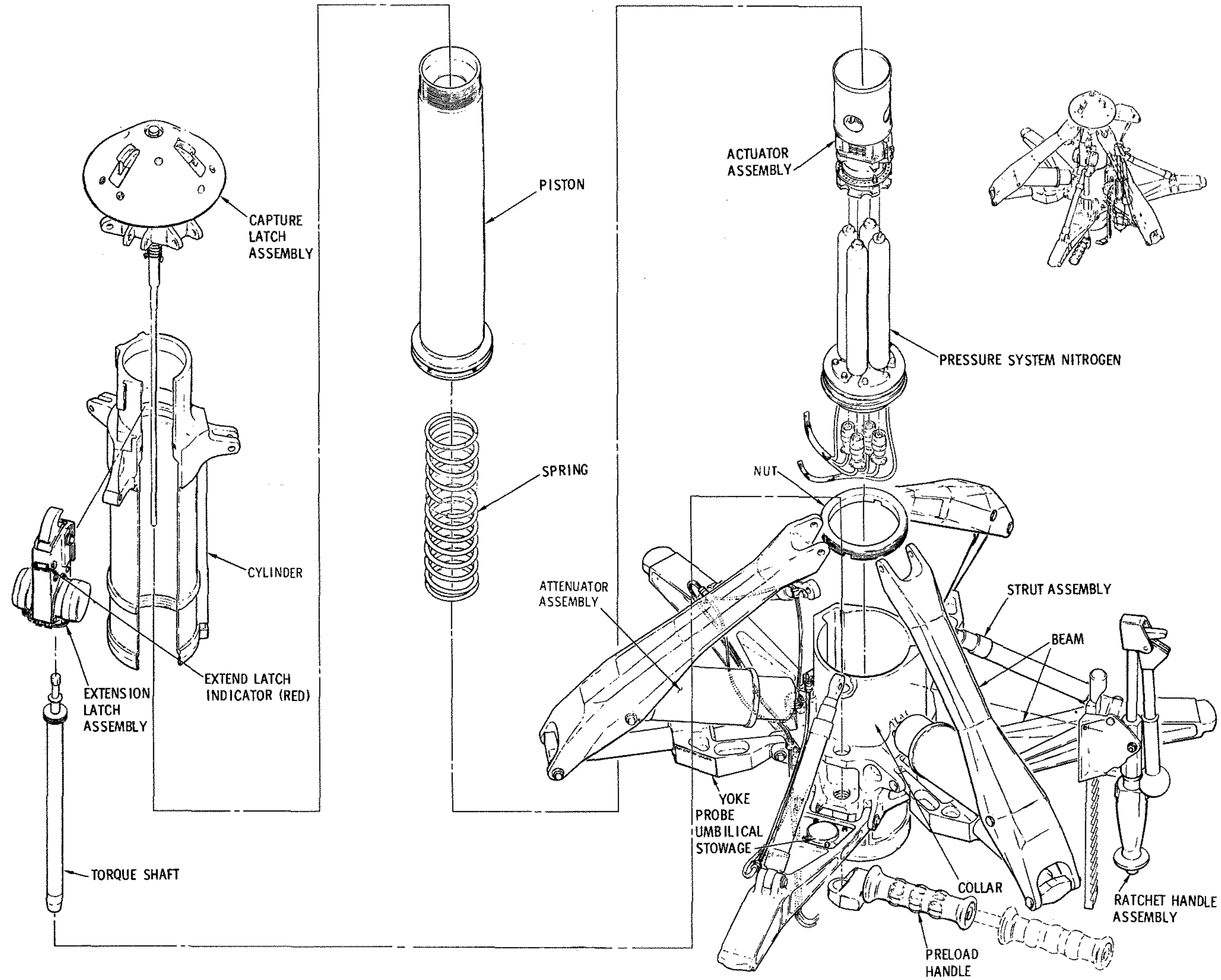

Figure 2.13-5. Exploded View - Probe Assembly

collar with the ratchet handle and allowing the collar to slide aft approximately 9-1/4 inches on the probe cylinder. Connected between each support leg and the probe cylinder is a semi-rigid strut assembly (figure 2.13-4.) The strut assemblies contain Bellville washers which help in attenuating the high lateral loads. The washers are concave in shape and are arranged to provide a rigid strut in tension and a high rate of spring action in compression. One of the support legs is marked yellow to correspond with a matching color on the docking ring socket fairing. The probe installation support strut is stowed on the yellow support beam, whereas the other two support legs contain stowage receptacles for the probe umbilicals.

2.13.3.3.2 Pitch Arms and Tension Linkages

The pitch arms make contact with the drogue surface during the probe retraction cycle if the CM and MDA tend to jacknife. The tension links transmit the pitch arm loads and torque loads to the probe outer cylinder during an axial displacement. Together the pitch arms and tension linkage induce the required kinematics causing compression of the shock attenuators, attenuating the loads necessary to meet the docking requirements (figure 2.13-4).

2.13.3.3.3 Shock Attenuators

The shock attenuators are piston, variable-orifice, fluid-displacement-type units (figure 2.13-6). The attenuators are attached to the probe assembly so that all axial loads or side loads are attenuated to or below the required level for the docking mechanism. The attenuator cylinders are filled with a Orinite 70 fluid at a temperature of $70°\pm3°F$. With the piston assembly extended, a mixture of argon and helium gas is inserted through a plug located under the rod end. The gas is injected with the aid of a hypodermic needle to a pressure of 30 ± 3 psig at $70°\pm5°F$. The purpose for pressurizing with gas is to provide an air spring and pressure for attenuator extension. This stored energy within the attenuators causes the collar assembly to move aft when released, pulling the support structure from its mount.

2.13.3.3.4 Probe Body - Extension Latch Assembly

The probe body consists of an inner (piston) and outer cylinder, sized to allow a 10-inch maximum travel of the inner cylinder (figure 2.13-5). Attached to the probe body is an extension latch which engages and retains the probe in the fully retracted position (figure 2.13-7). The large coil spring located within the inner cylinder extends the probe upon release of the extension latch.

Located within the preload torque shaft is a spring allowing the extend latch to be free-floating and self-locking. This assures automatic capture of the probe piston by the extension latch when the probe retracts. An indicator is provided to indicate a fully engaged latch. The indicator (red) protruding above the housing shows that the hook has not fully engaged the roller on the probe piston. If this situation exists, the extend latch assembly can be altered by applying a CCW ratchet torque extending the latch assembly until the hook engages and the indicating pin retracts.

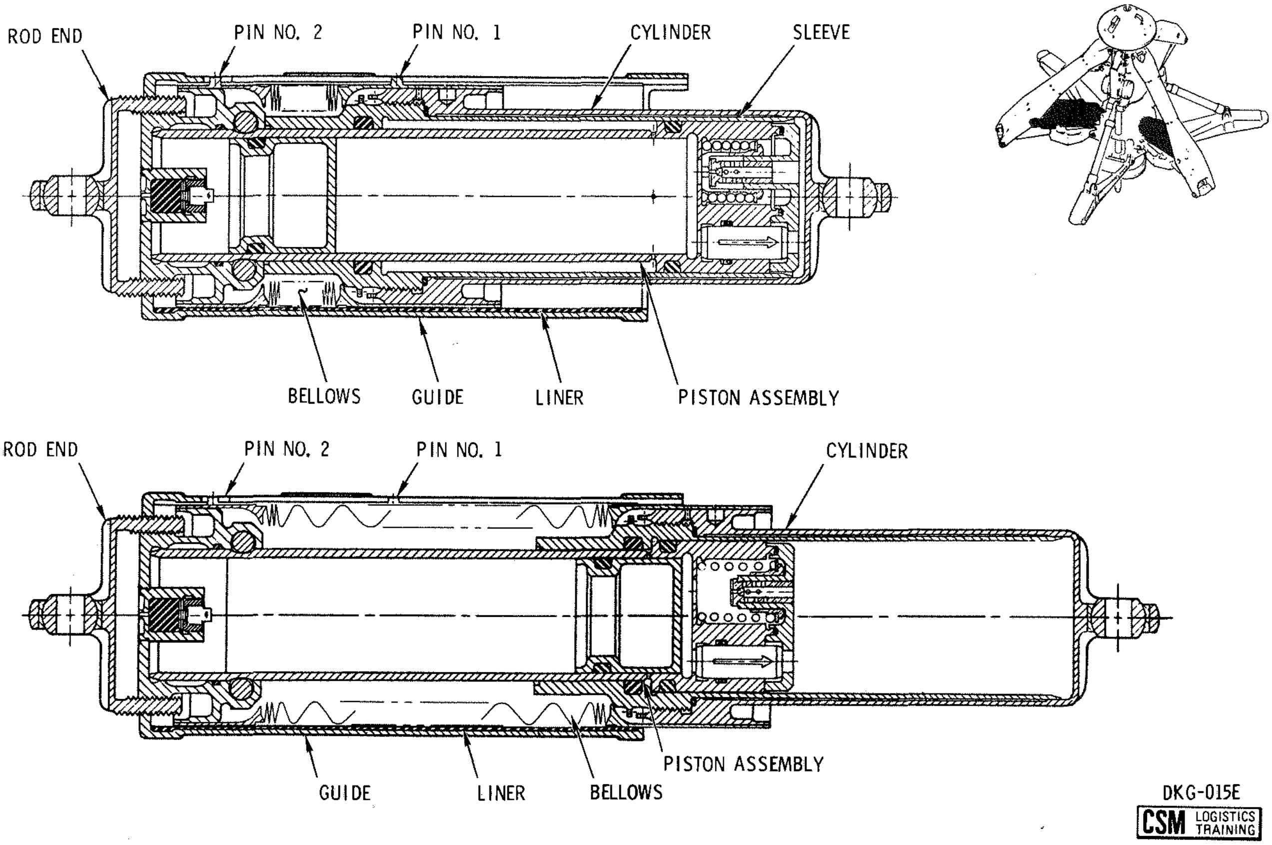

Figure 2.13-6. Docking Probe Attenuator Assembly

2.13.3.3.5 Probe Head - Capture Latches

The probe head is self-centering and is gimbal-mounted to the piston of the probe assembly (figure 2.13-8). It houses the capture latches and is designed so that the probe head deflects toward the drogue socket through all contact attitudes within the design parameters. The capture latches automatically engage the drogue socket when the probe head centers and bottoms in the drogue. The capture latches are capable of remote and manual release from the CM side and manual release from the MDA side. Release of the capture latches permits withdrawal or insertion of the probe head assembly. Electrical release is accomplished by switching power to motors within the probe body (figure 2.13-5) causing the torque shaft to rotate and allow release of the latches. Manual release of the capture latches from the CM side is accomplished by a built-in release knob and handle on the CM side of the probe. (See figure 2.13-9.) To unlock the release handle, the lock (view D) must be rotated CCW. To unlock the capture latches, the capture latch release knob and handle are pulled aft 1/2 inch and rotated 180 degrees CW. This can be accomplished only with the probe piston in the retract position. When the probe is being

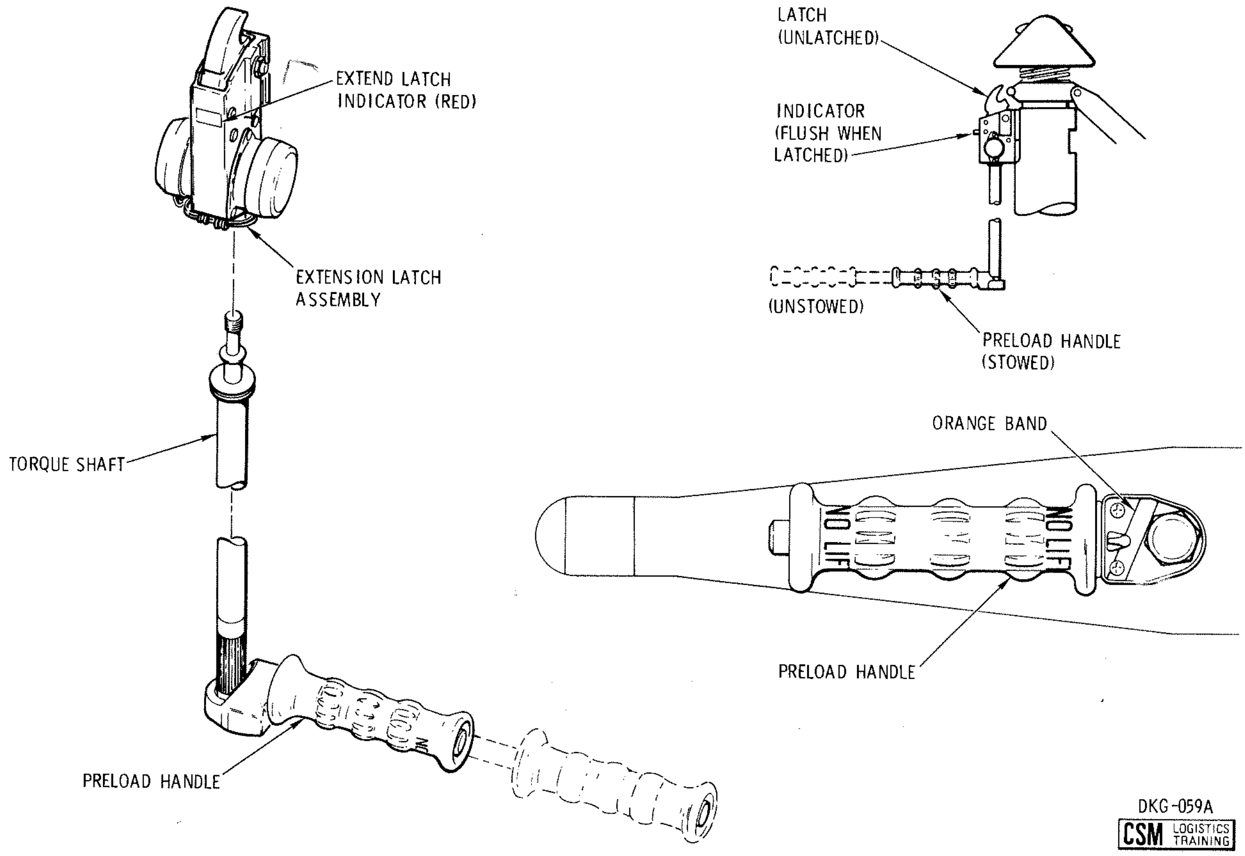

Figure 2.13-7. Extension Latch Assembly

collapsed, the probe collar contacts the release handle, which in turn telescopes and remains operable with the probe installed or folded. (See figure 2.13-10.) The capture latch release handle must be rotated 150° CCW to an indicating arrow to make the capture latches "cocked." This means the capture latches capture when all three latches have penetrated the drogue ring simultaneously.

If the retracted position is selected on the RETRACT EXTD/REL switch located on panel 2 (figure 2.13-22), capture latch engagement closes a switch within the probe, so that selection of the RETRACT/PRIM or SEC-1 or 2 starts operation of the retraction mechanism.

2.13.3.3.6 Ratchet Assembly

The integrated ratchet assembly assist in installing and removing the probe assembly, and performs the ratcheting operation that slides the collar forward or aft, extending or collapsing the probe pitch and support arms (figure 2.13-11). The ratchet assembly will lock/unlock the sliding collar by pivoting the handle away from the probe centerline either from the CM or MDA side. The jack handle is stowed and locked by a lug which engages the handle on the CM side. A release button is provided on the CM handle and a trigger release on the MDA handle to unlock the ratchet assembly.

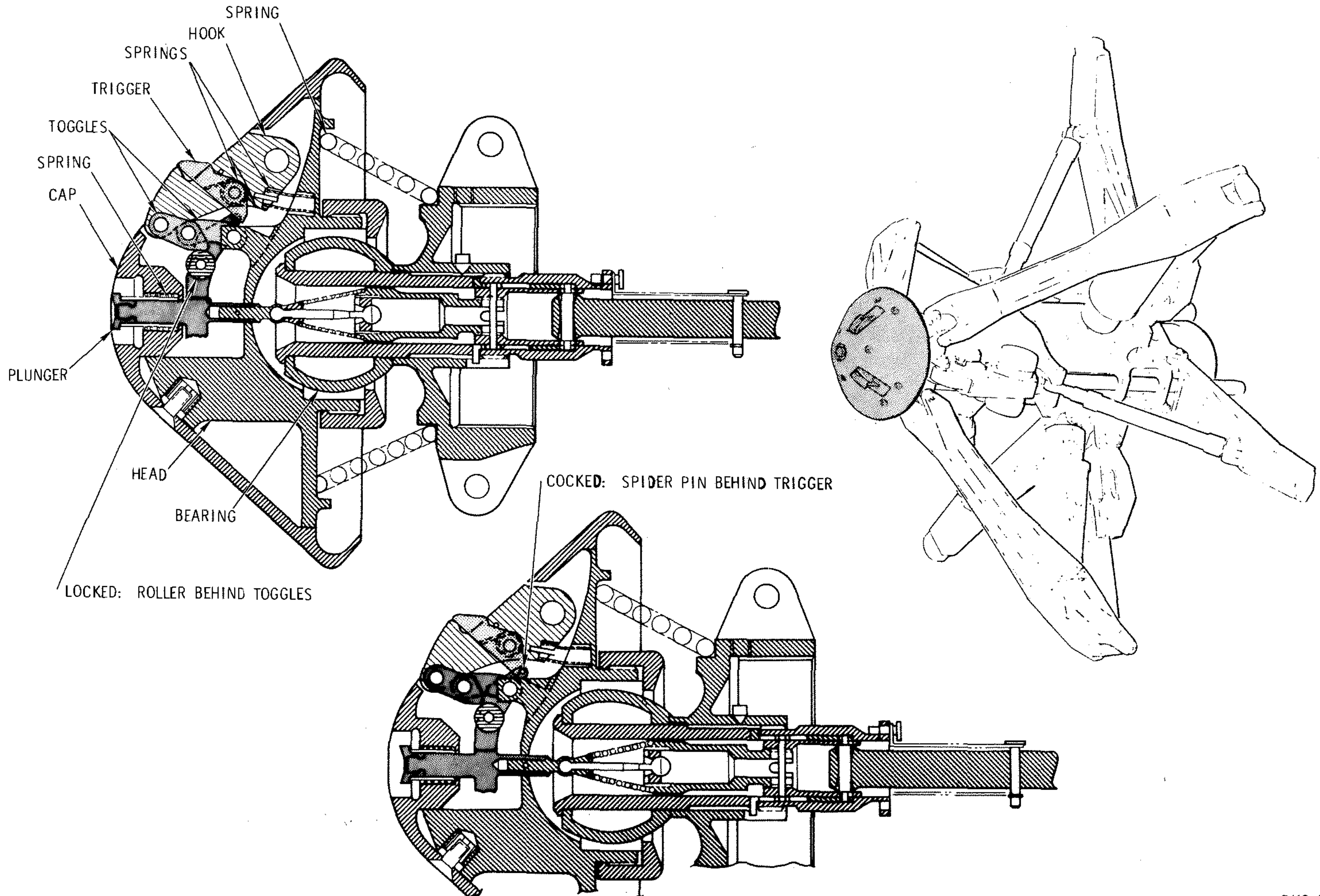

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Figure 2.13-8. Probe Capture Latch Assembly

Figure 2.13-12 shows the various ratchet handle positions for probe removal and installation. View A shows the jack handle and ratchet assembly in the locked and stowed position.

View B shows the 30-degree stroke required to unlock the sliding collar from the CM side. To unlock the sliding collar from the CM side, the jack handle is grasped at the CM end, the slide release button is depressed, and the handle is pulled all the way aft. Secondly, the handle is pushed forward to the first detent and the handle is swung out 30 degrees from the probe centerline. In the last 5 degrees of pivoting, the pawls are lifted from the rack, the collar slides aft, and the probe collapses because of the spring and attenuators stored energy.

View C shows the unlocking operation from the MDA side. First, the release button on the MDA side of the jack handle is depressed and pushed aft to the first detent. Second, the foldable lever is slowed by pulling on the handle knob and rotating the lever upward against the stop. Third, the handle assembly is rotated inboard until the collar is released. The

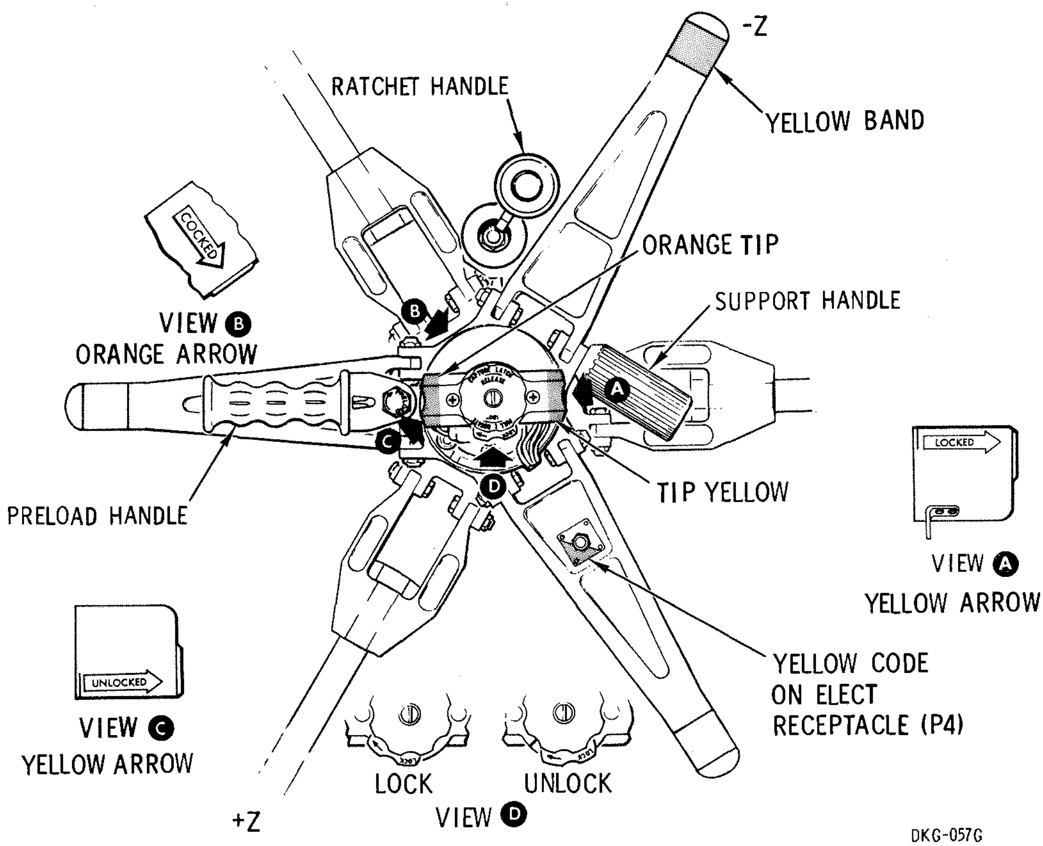


Figure 2.13-9. Aft View Docking Probe

knob is held again until the probe folds. This capability exists; however, there should be no requirement for this operation during any of the Skylab missions.

View D shows the 25-degree stroke used when installing the probe. After the probe is locked in the drogue, the support strut located on the support beam is unstowed, and positioned against the ledge on the tunnel hatch seal ring. The jack handle is pulled to its extreme aft position. The support handle is grasped with the left hand and with the right hand the probe collar is jacked forward extending the support legs into the three support sockets in the CM docking ring. While the handle is being pumped, a thrust load on the tunnel ring is maintained through the support strut. The maximum push force on the handle should not exceed 60 pounds for the working stroke of 25 degrees. Installation is complete when the collar uncovers a cross-hatched area on the probe conduit. To ensure the operator that the pawls are seated in the rack, a pawl indicator is located on the ratchet mechanism. (See figure 2.13-11.) Operation is complete when the indicating button is flush with the housing.

With the probe installed, the handle is stowed by holding it parallel with the centerline of the probe and by depressing the button release while thrusting the handle toward the probe head. The socket of the handle locks on a lug and prevents further handle movement.

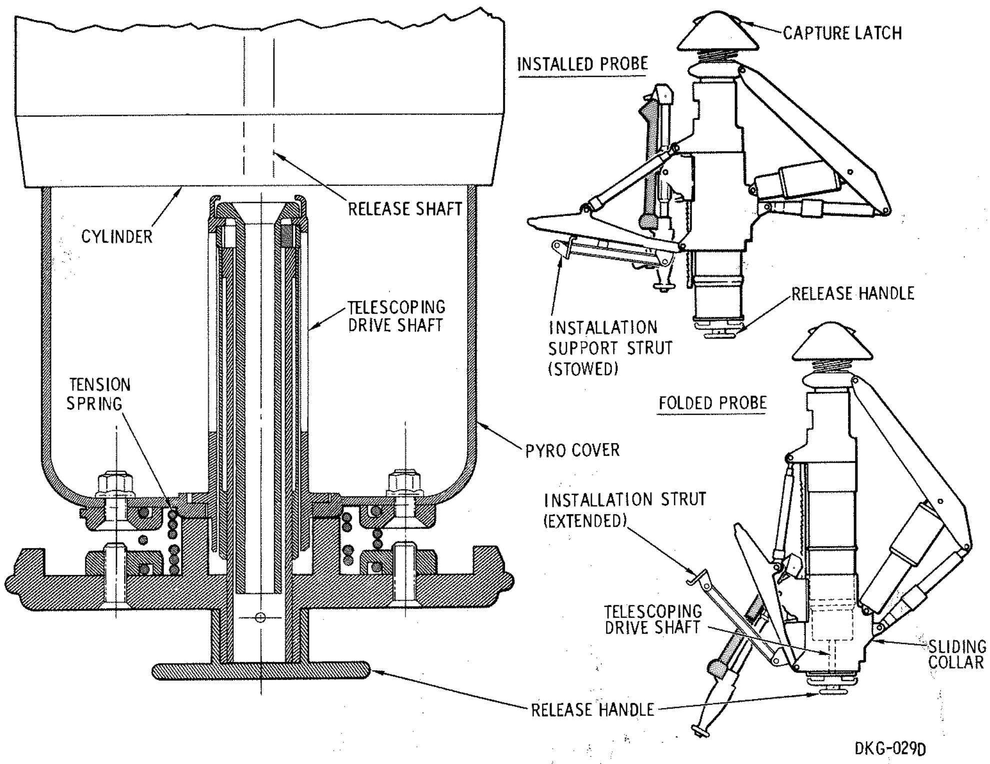


Figure 2.13-10. Capture Latch Release

2.13.3.3.7 Retraction System

The retraction system consists of nitrogen gas pressure from four hermetically sealed bottles located inside the probe body (figure 2.13-13). Gas pressure is released when the piercing piston punctures the seal on the bottle. The pyrotechnic initiators are activated by a crewman within the CM placing the RETRACT/PRIM-SEC to position 1 or 2 (figure 2.13-22). Releasing the nitrogen gas causes the probe piston to retract. The retraction force is sufficient to draw the modules together, compress the interface seals, and allow engagement of the automatic locking latches.

The residual gas will be bled off manually by the astronaut in order not to restrict probe movement during the next extension. Pressure release is accomplished by a manual relief valve located as part of the gas manifold. This valve is opened by depressing a red thumb button on the aft end of the probe. The button and pyro components are protected from handling damage by a protective cover.

2.13.3.3.8 Probe Umbilicals

Two microdot connectors and harness assemblies are provided for probe instrumentation and probe logic power. The connectors are installed in the docking ring so they are visible and can be demated and mated from either the CM side or the MDA side of the combined vehicles (figure 2.13-14).

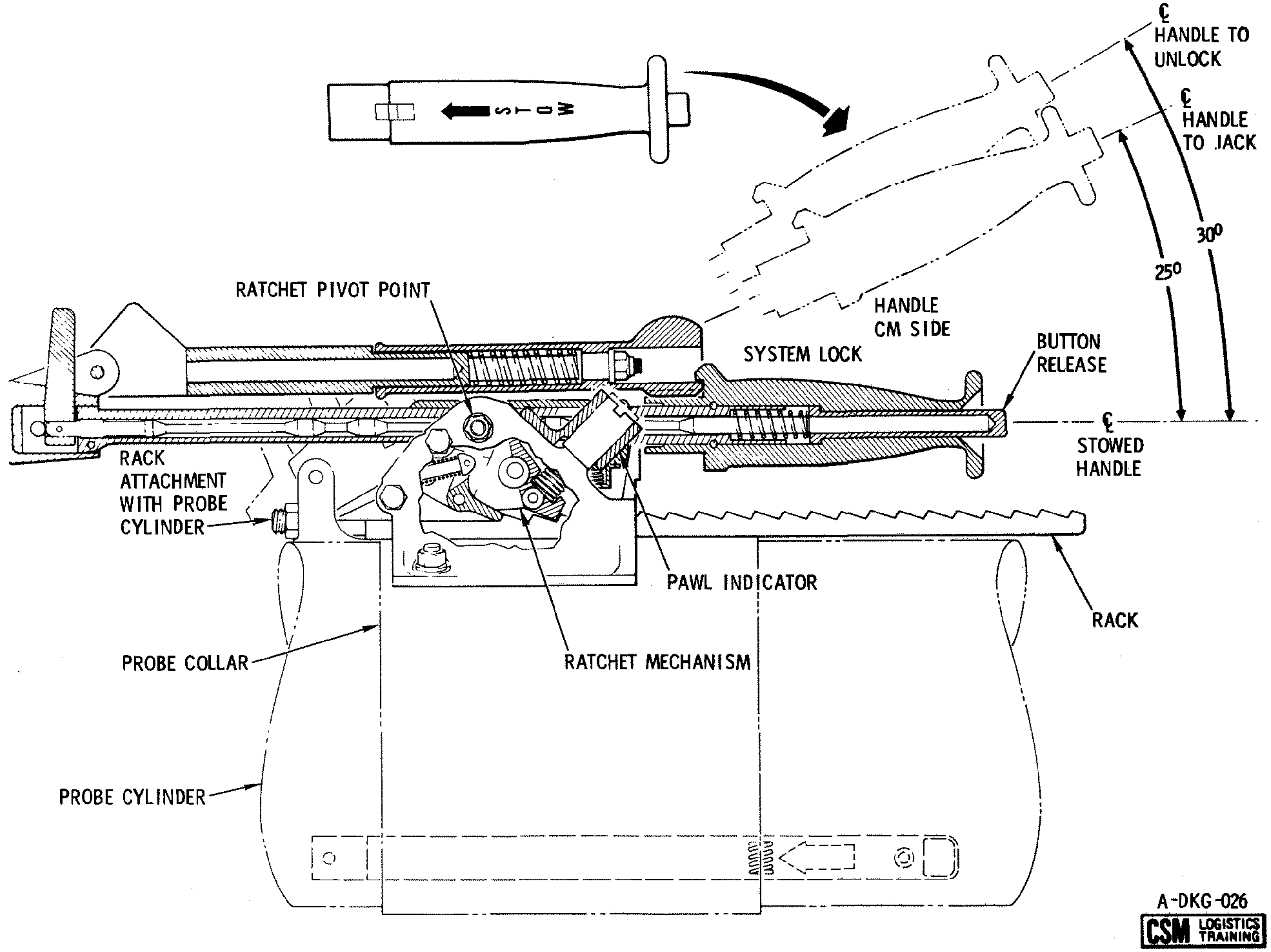


Figure 2.13-11. Integrated Ratchet Assembly

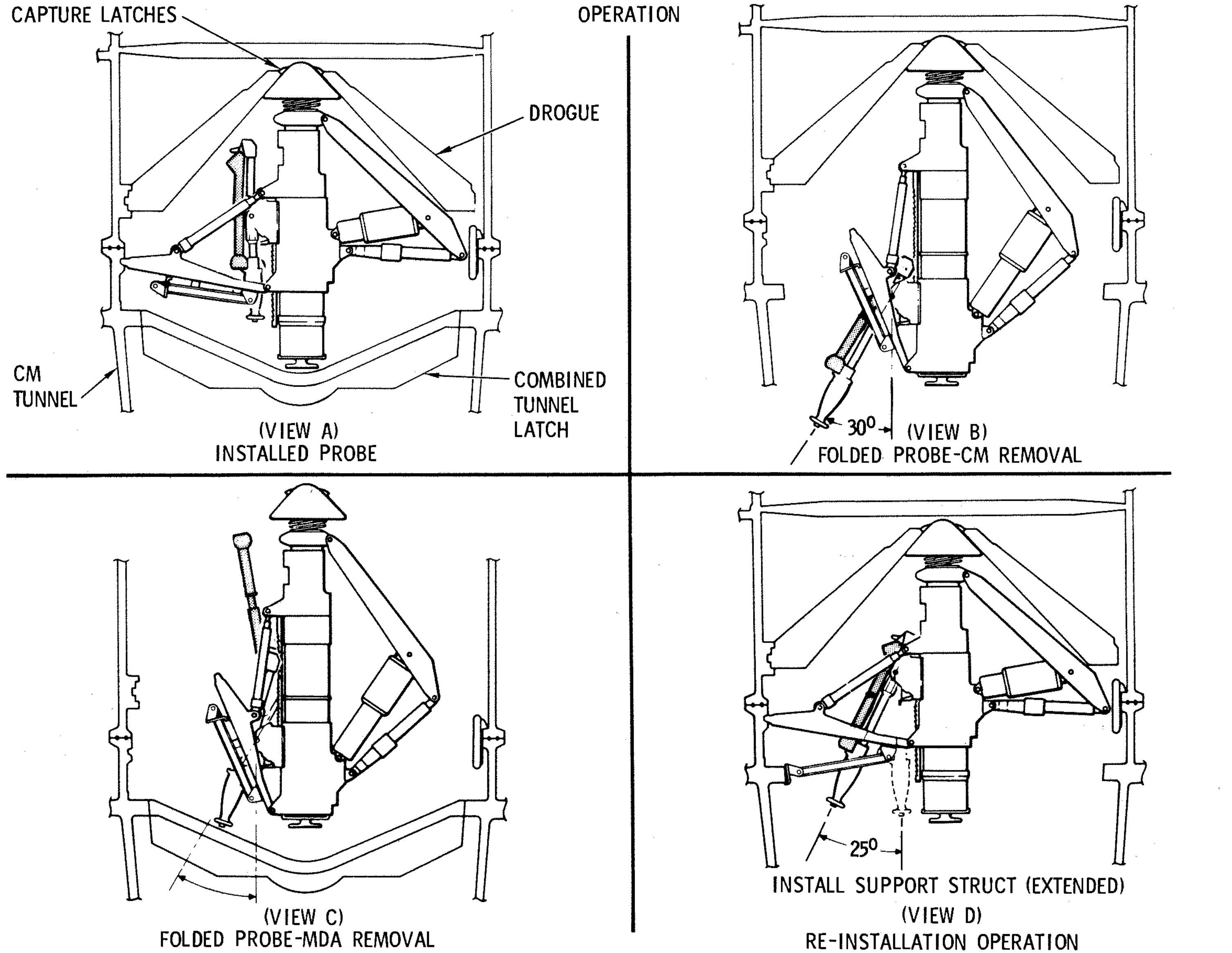


Figure 2.13-12. Integrated Ratchet Assembly Operation

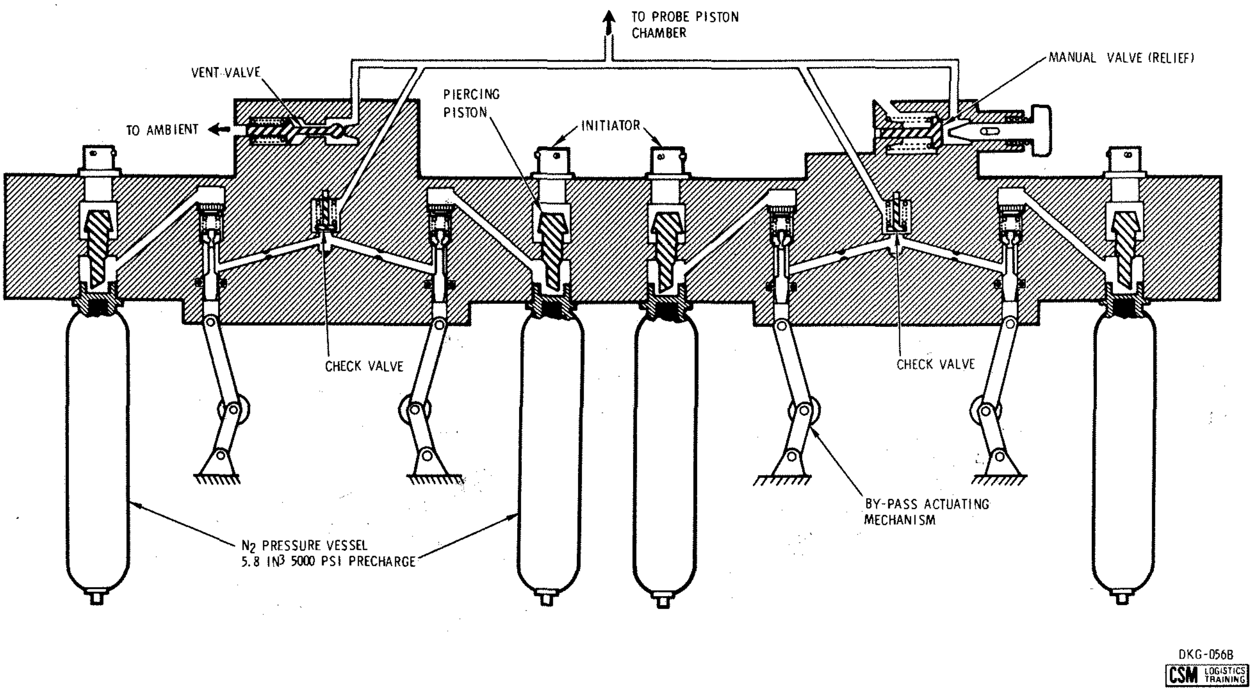


Figure 2.13-13. Probe Retraction System

The connectors utilize a notched handle that provides a positive grip for twist and pull action. Part of the connector and the probe harness may protrude into the tunnel when the probe is installed, but when the probe is removed, the fixed portion of the connector is covered by a hinged protective cover. This provides a smooth surface for crewman passage through the tunnel. When disconnecting or reconnecting the probe electrical connectors from the CM side, the EXT/REL-OFF-RETRACT switch should be in the OFF position, and CB2 on panel 276 open, to assure that no instrumentation power exists.

2.13.3.4 Drogue Assembly

The drogue assembly consists of an internal conical surface facing the CM, a support structure and mounting provisions that interface with three mounts in the MDA tunnel. One of the tunnel mounts contains a locking mechanism to secure the drogue and prevent it from turning during the docking maneuvers. Unlocking and removing the drogue may be accomplished from either end of the crew transfer tunnel. To aid in handling, three handles are provided on the MDA side (figure 2.13-15).

2.13.3.5 Vehicle Umbilicals and Interchange Duct

Three umbilicals are installed between the CM docking ring and the MDA tunnel. The umbilicals are retrieved from stowage in the CM and are connected to their respective receptacles (figure 2.13-15A). Two of the umbilicals are for control circuits and one is for power transfer from MDA to CM. An additional umbilical is available for a backup power umbilical. This is a pull-through umbilical and is used in the event that the normal power umbilical should fail.

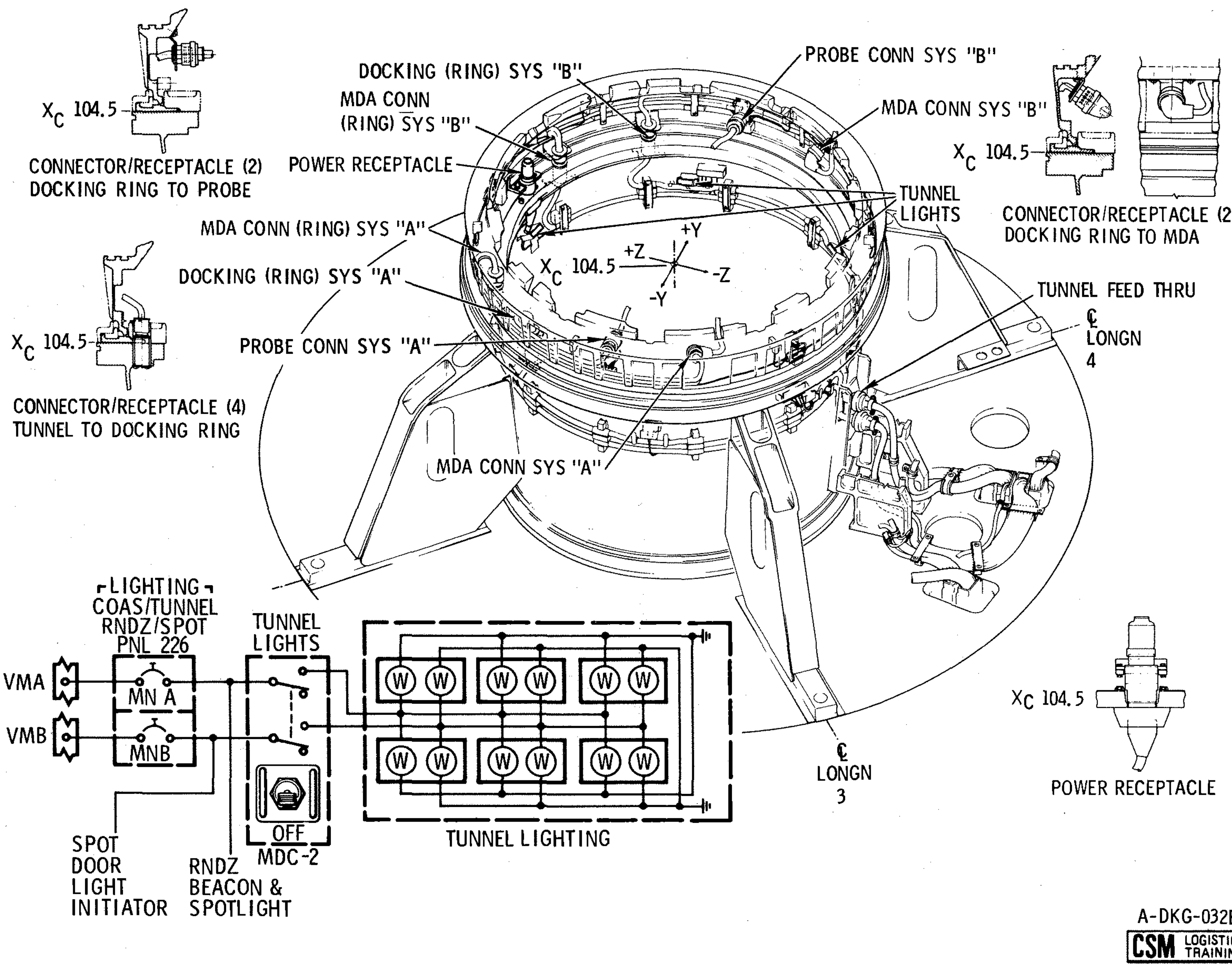


Figure 2.13-14. Tunnel Lighting and Electrical System

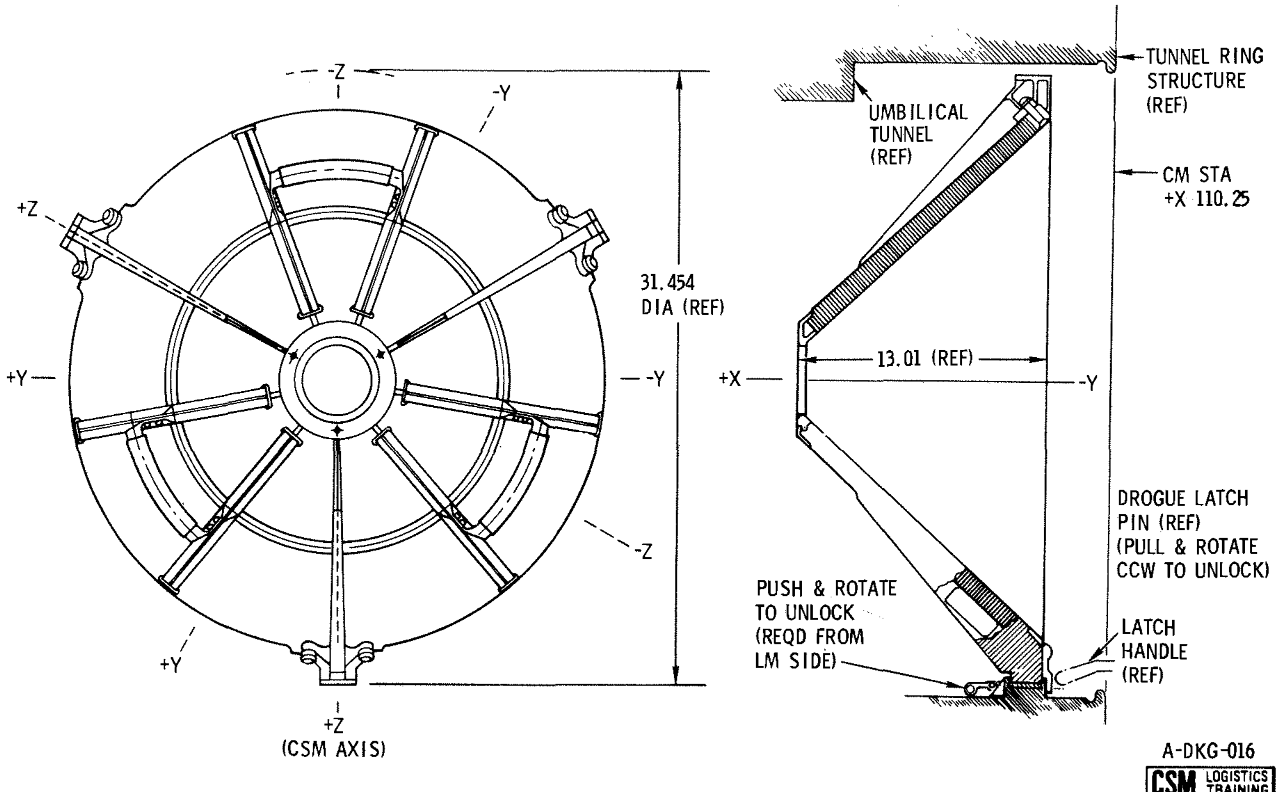


Figure 2.13-15. Drogue Assembly

The air interchange duct is stowed in the MDA and is installed in the tunnel as shown in figure 2.13-15A. Controlled atmosphere from the MDA is circulated through the CM via this duct during the docked configuration.

2.13.3.6 CM Tunnel Hatch

The hatch in the CM tunnel enables crew access to the interface and may be used for emergency egress after postlanding. (See figure 2.13-16.) The hatch is removable only into the crew compartment. The reinforced flange on the forward tunnel ring prevents an outward removal. The hatch is retained at the forward end of the CM tunnel by six separate jointed latches whose linkage is driven by an actuating handle from within the crew compartment. A drive is provided on the outside opposite the actuating handle drive, permitting hatch removal by using the B tool of the in-flight toolset. A pressure equalization valve, which can be opened or closed from either side, is provided on the hatch. This valve is used to equalize pressure in the tunnel and MDA prior to hatch removal.

A single activating handle is provided to open or close the hatch. This actuating handle is an integral part of the gear box and requires only one hand for operation. Manipulating the actuating handle will extend or retract the six latches (figure 2.13-17). The operating distance of the handle is approximately 80 degrees. The working stroke to operate the latches is only 60 degrees. The handle has a three-position selector L-N-U (Latch-Neutral-Unlatch). A sturdy aluminum cover supporting the insulation and covering the latches is provided to minimize the possibility of condensation and ice formation.

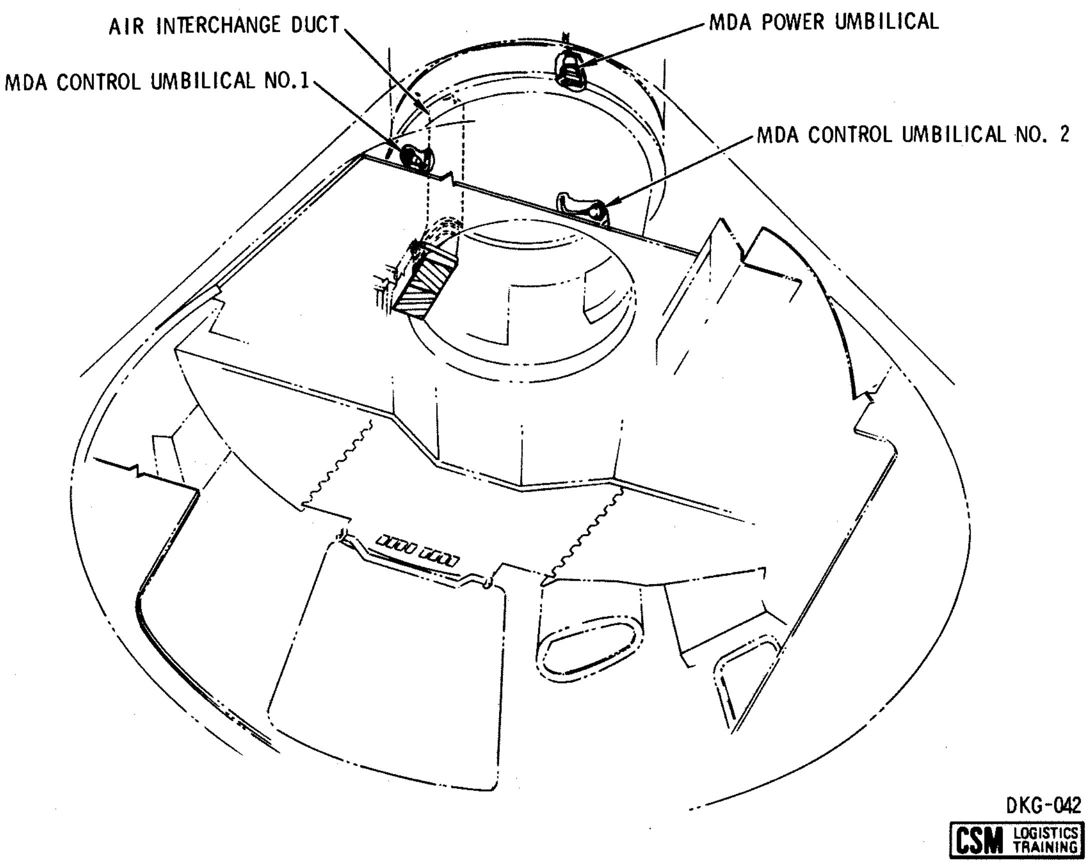


Figure 2.13-15A. MDA Connections to CM

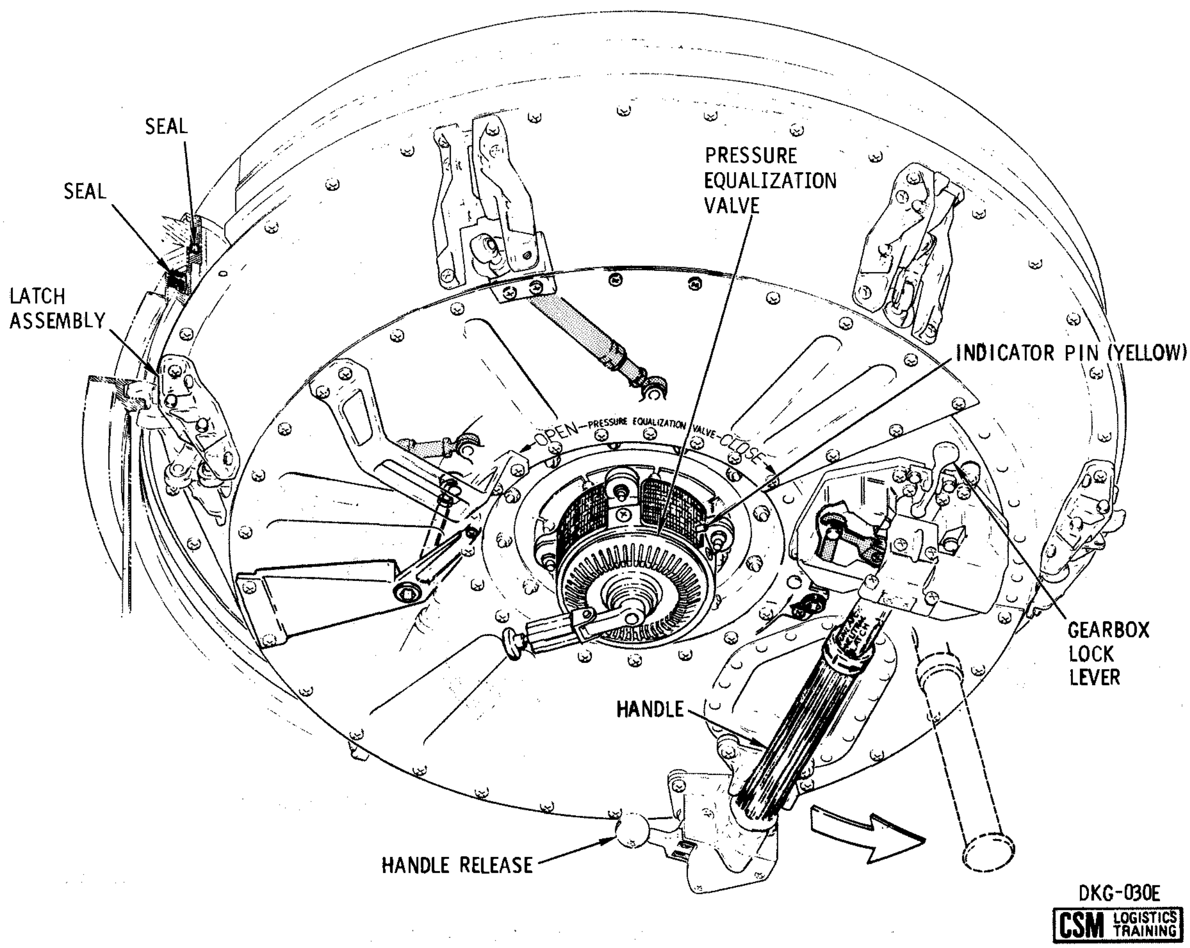


Figure 2.13-16. CM Tunnel Hatch

An auxiliary means of latching is provided to operate the latches should the gear box or actuating handle fail. To use this means of latching, the gear box is disconnected, and the ring is rotated to engage the latches. To open the hatch from the outside, the B tool is inserted in the drive opposite the gear box and rotated CCW. Total rotational travel necessary to retract the latches is 167 degrees with the first 30 degrees disconnecting the gear box.

2.13.3.7 MDA Pressure Hatch

The MDA pressure hatch is hinged to open into the MDA. Six rollers, attached to a spider linkage, are utilized to hold the hatch in the closed position. Operation of the handle either extends or retracts the rollers into or from a slot in the lower ring of the MDA tunnel. Incorporated into the hatch is a pressure equalization valve which can be operated from either side and a dual pressure indicator which is visible on either side of the hatch. Once crew transfer takes place from CSM to MDA, the hatch should remain open until the termination of the crew activities in the workshop and the crew transfers back to the CSM.

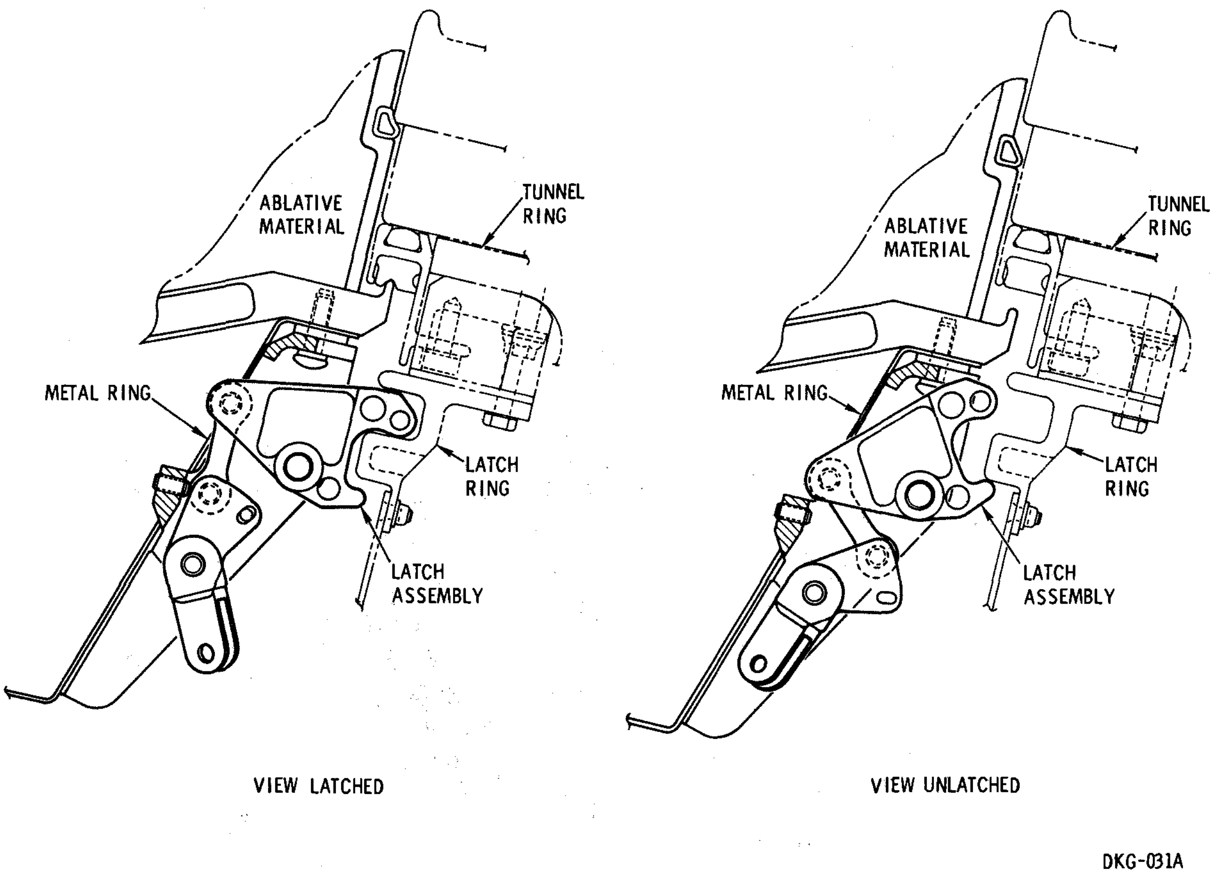


Figure 2.13-17. Tunnel Hatch Mechanism

2.13.3.8 Tunnel and MDA Pressurization

The pressurization components are necessary to equalize pressure in the tunnel area after the CSM has docked to the MDA. The MDA is pressurized upon a signal from MSFN after orbit insertion. The components for pressurizing the tunnel and the MDA (if necessary) from the CM are covered in the following paragraphs. Figure 2.13-18 shows these components and their location.

2.13.3.8.1 CM Pressure Equalization Valve

A pressure equalization valve is installed in the center of the CM forward tunnel hatch to equalize pressure between the CM cabin and the MDA tunnel. The valve may be operated from either side. A hand crank is attached for opening the valve from the CM side. The handle has a 45- and 90-degree position. The handle placed in either position unlocks the valve. (See figure 2.13-19.) Approximately five turns retract (open) or extend (close) the valve. The B tool is used to open the valve from the MDA side. An indicating pin is attached to the valve showing the operator the valve position. A green and yellow color painted on the valve body coinciding with the pin indicates open or closed.

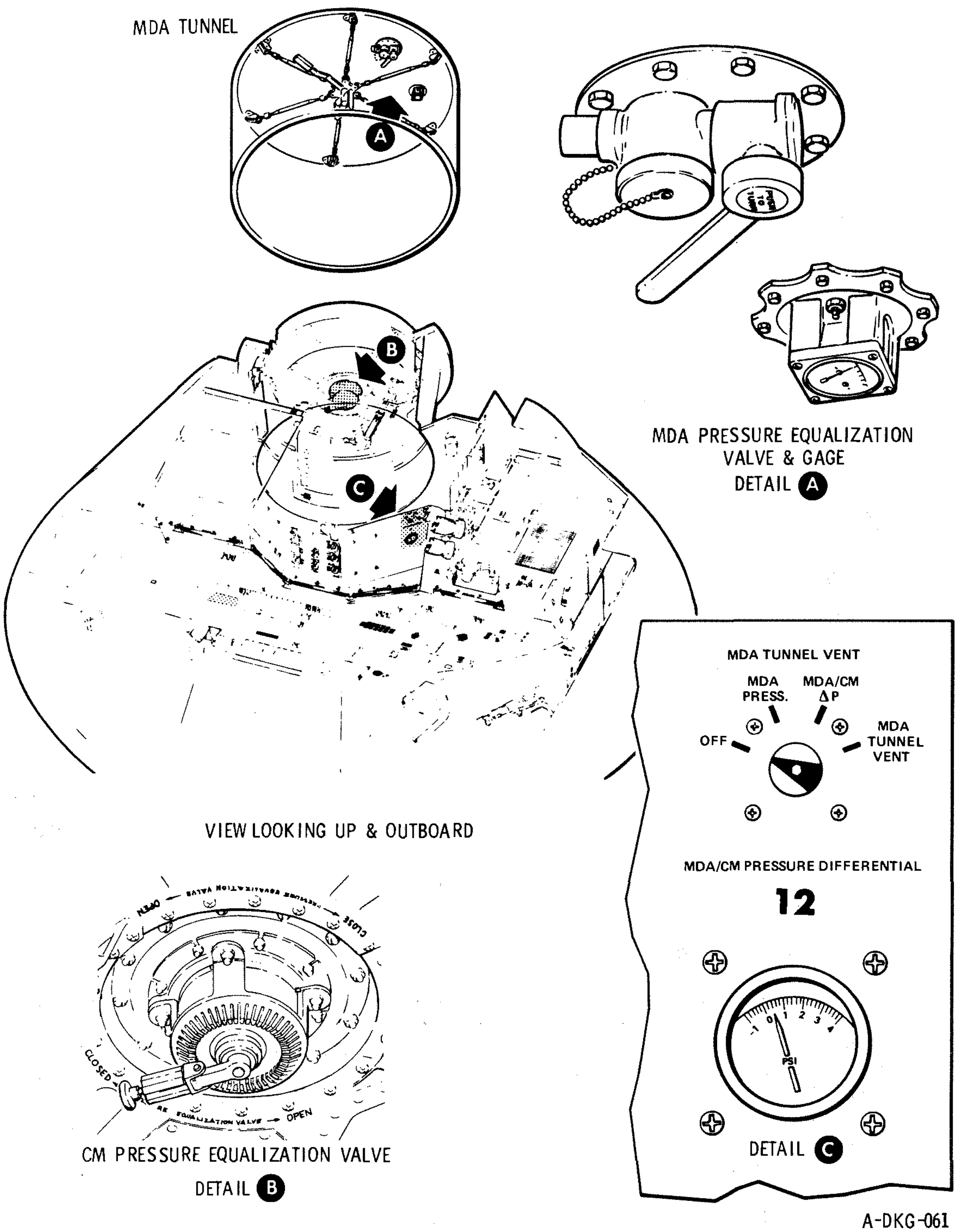


Figure 2.13-18. Pressurization System Components

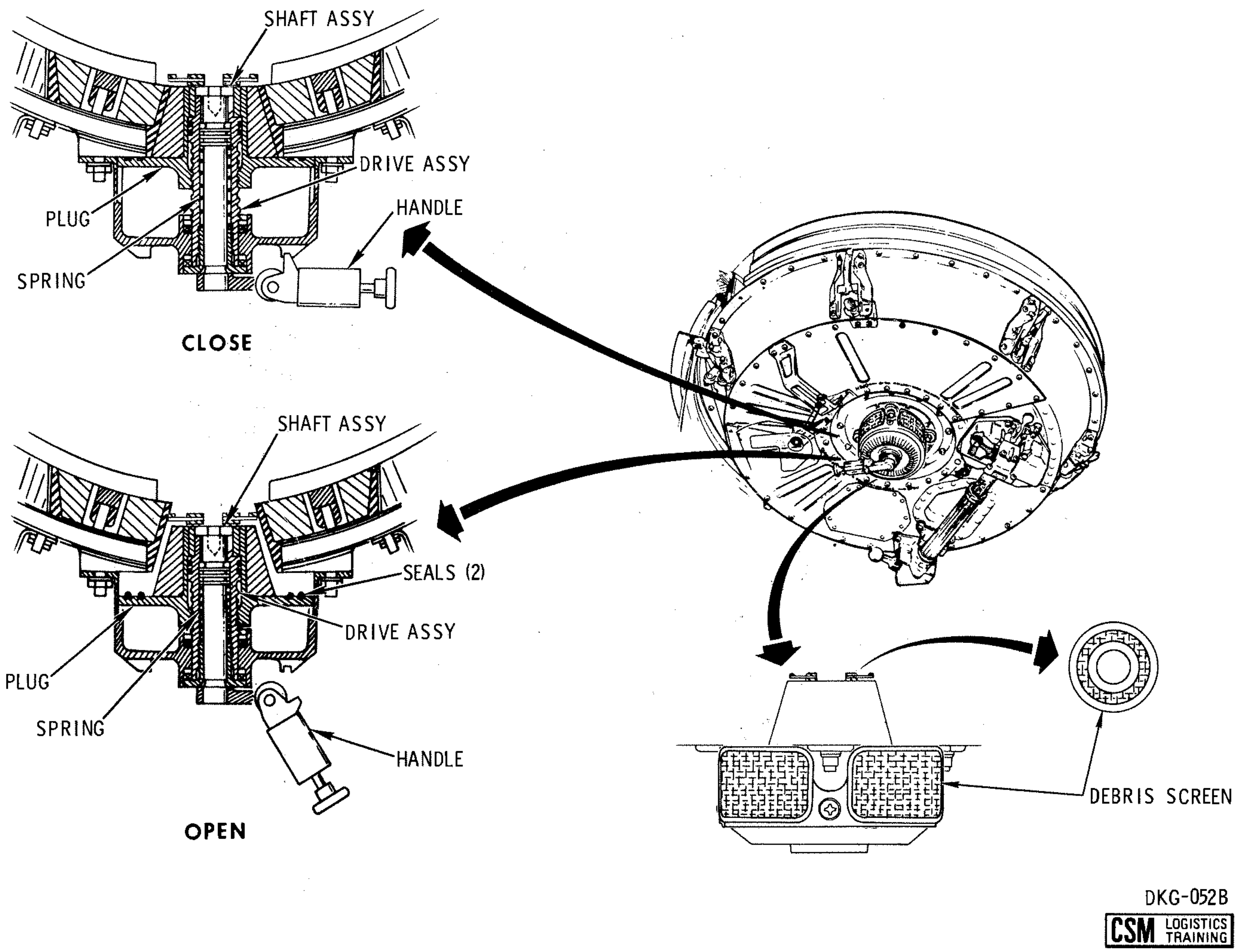


Figure 2.13-19. CM Hatch - Pressure Equalization Valve

2.13.3.8.2 MDA Tunnel Pressure Sensing and Vent System

The MDA/tunnel vent valve is a four-way manually operated valve located adjacent to the tunnel entry. (See figure 2.13-20.) Tool E is used to operate the valve which is accessible to a crewman at the lower equipment bay. A differential pressure gage, together with the vent valve, is capable of verifying pressure equalization between CM cabin and MDA tunnel. Position 1 isolates the system. This position prevents any airflow from the cabin to the MDA/CM tunnel ring interface. Position 2 opens the 1/4-inch line to the MDA/CM ring interface. This position may be used as a backup to the pressure equalization valve in the hatch. Placing the valve in position 3 opens the 1/4-inch line to the MDA tunnel and ΔP gage monitoring the pressure differential between the CM cabin and MDA tunnel. When the valve is in position 4 the MDA tunnel will be vented to ambient. This position checks and verifies the sealing capabilities of the two hatches. After venting, a check to see that the tunnel remains evacuated may be made by placing the valve back in position 3.

2.13.3.8.3 MDA Pressure Equalization Valve

The MDA pressure equalization valve is located in the MDA hatch (figure 2.13-18, View A). The valve is capable of being operated from either side of the hatch to equalize pressure between the tunnel and MDA before the hatch is opened. To operate the valve, the center of the valve must be depressed before the handle can be turned to open the valve.

2.13.3.9 Docking System Electrical Mechanical Schematic

Figure 2.13-22 shows schematically the overall electrical and mechanical operation of the docking system hardware.

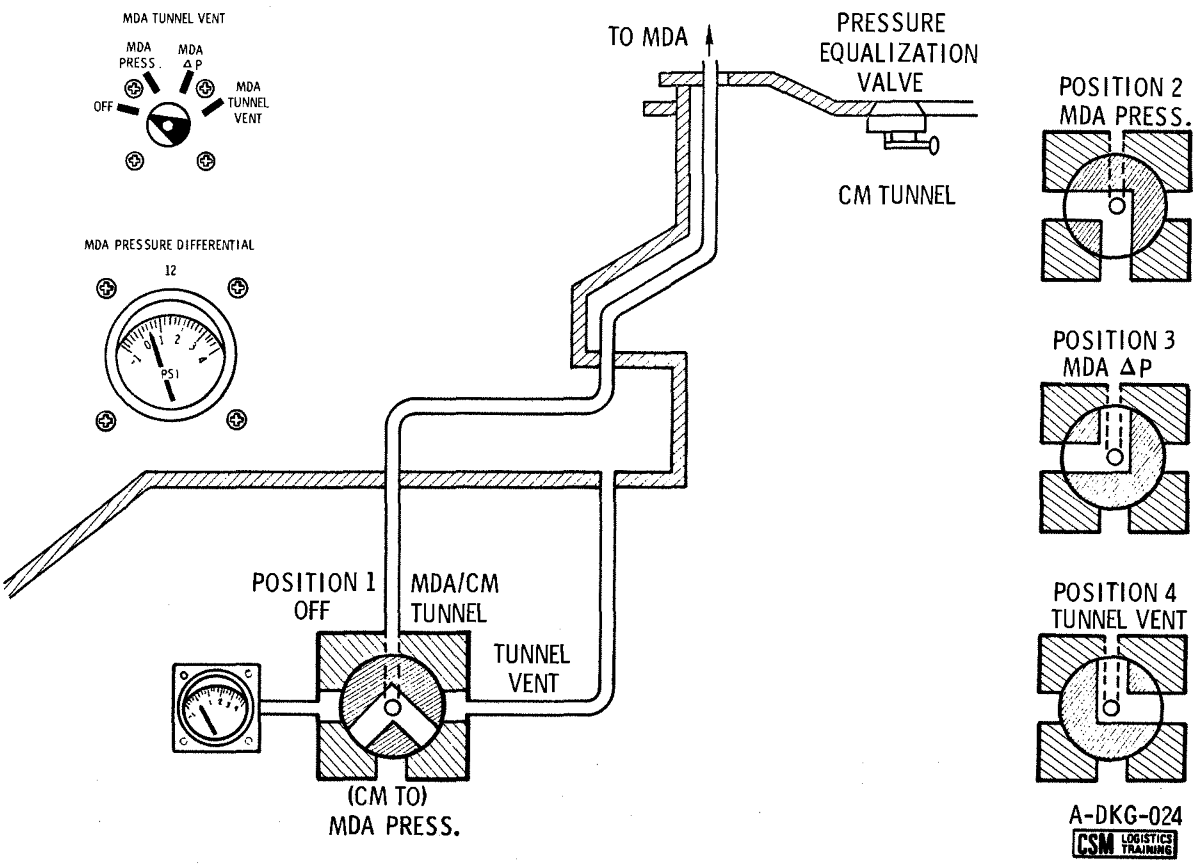


Figure 2.13-20. MDA-Tunnel Pressure Sensing and Vent System Schematic

Figure 2.13-21. Deleted

DCT

2.13.4 PERFORMANCE AND DESIGN DATA

2.13.4.1 Design Data

2.13.4.1.1 Docking Latches

Latch Description	Notes
Trigger set at 0.110 in.	Clearance between the rings.
Latch reach 0.165 in.	
Minimum requirements 2700 lb at 0.65 in.	Greater the translation distance the higher the load applied.
No-back engages 0 to 0.007 in.	Governed by number of teeth on the ratchet.
Latch stiffness 66,000 lb/in.	Linear stretch in the hook.
Latch loading	

2.13.4.1.2 Docking Probe

Probe Description	Notes
Weight	
83 lb	
Size	
Installed 24 in.	Capture latch release handle to probe head.
Extended 34 in.	10-in. piston stroke.
Folded 31 in.	Collar slid all the way aft.
Internal Spring	
Piston extended 70 lb	Spring force variance governed by length of stroke.
Piston retracted 130 lb	
Strut Assembly	Bellville washers (concave)
Piston extended 240 lb	Force variance governed by number of washers and how they are stacked (static).
Piston retracted 8000 lb	
Attenuators	Fluid filled
Piston extended 60 lb	Force variance governed by stored gas pressure (static).
Piston retracted 300 lb	

2.13.4.1.3 Probe Pressure System

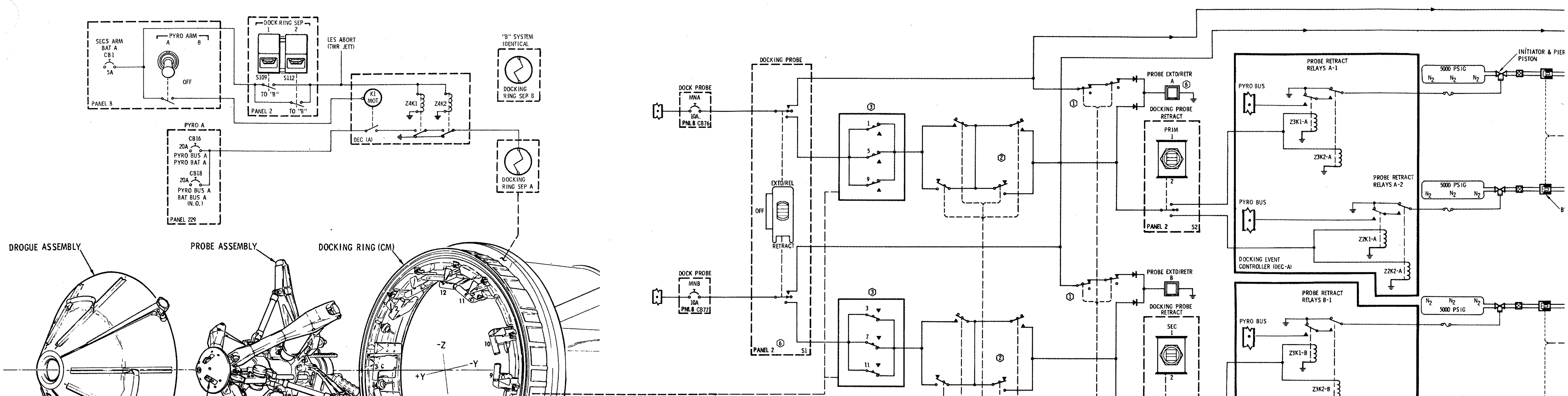
Pressure System Description	Notes	
Manual Valve (Relief) and Automatic Relief Valve	Manually opened from back of probe (red button)	
	Cracking pressure	350 psig*
	Full flow pressure	450 psig
	Reseat pressure	300 psig
	**Cracking pressure could occur when two bottles are discharged simultaneously.*	
Flow Passages	0.093 minimum diameter	
Primary Orifice	Flow area 0.005 diameter	
Secondary Orifice	Flow area 0.013 diameter. This area effective when bypass valve is open.	
Vent Valve	Open pressure	15.0 psig
	Closing pressure	15 to 20 psig
	N_2 is vented into the probe cylinder.	
Filter	5 micron (nominal)	
N_2 Pressure Vessel	5000 psi precharge 5.8 $in.^3$	
	Bottles are checked by weight	

2.13.4.2 Performance Data

Refer to CSM/LM Spacecraft Operational Data book SNA-8-D-027 CSM (SD 68-447).

2.13.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS

Refer to Volume 2 of the SOH and its malfunction procedures.



(1) EXTEND INDICATING SWITCHES OPEN WHEN PISTON HAS EXTENDED 9.25 INCHES

(2) SWITCHES CLOSE WHEN CAPTURE LATCHES ARE IN THE LOCKED POSITION (PROBE LOCKED TO MDA DROGUE) - (LAST 16° to 18° OF SHAFT ROTATING CW)

(3) SWITCHES OPEN WHEN AUTOMATIC DOCKING LATCHES ARE ACTUATED (DOCKING RINGS APPROXIMATELY .1 INCH APART)

(4) SWITCHES OPEN REMOVING POWER FROM SOLENOIDS WHEN SHAFT EXTENDS 0.75 INCHES

(5) SWITCHES CLOSE ACTIVATING CAPTURE LATCH RELEASE MOTOR WHEN SHAFT EXTENDS 0.75 INCHES (EITHER MOTOR ROTATES SHAFT UNLOCKING CAPTURE LATCHES)

(6) TALKBACK INDICATION "A" SYSTEM (B WOULD BE IDENTICAL)

SWITCH POSITION EXT / REL - RETRACT	PROBE POSITION RETRACTED	INTERMEDIATE	EXTENDED		REMARKS
EXT / REL (MOMENTARY)	(barber pole) →	(barber pole) →	GRAY →	RELEASE SW →	FAILURE TO HOLD SW WILL ALLOW CAPTURE LATCHES TO RECAPTURE MDA BEFORE SEPARATION TAKES PLACE
OFF	GRAY	GRAY	GRAY		
RETRACT	GRAY ← DOCKING LATCHES ACTIVATED	(barber pole) ←	MDA CAPTURED (barber pole) ← PROBE WILL RETRACT IF PRIM 1 OR 2 BOTTLE IS SELECTED	MDA NOT CAPTURED GRAY	

Figure

Mission________ Basic Date 1

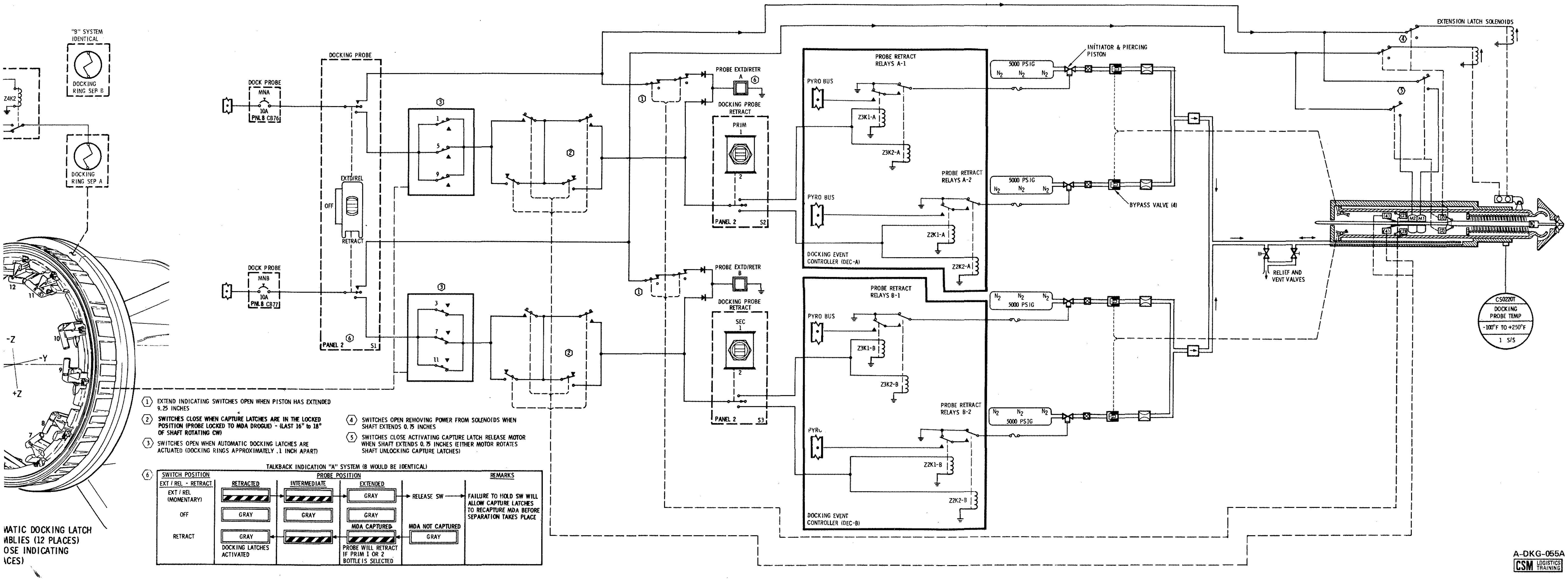


Figure 2.13-22. Mechanical Schematic

SECTION 3

CONTROLS AND DISPLAYS

3.1 INTRODUCTION

This section identifies each control and display in the command module. It lists each panel, reference designator, system, nomenclature and position, related function, circuit breaker, power source and associated explanatory data.

Panel numbers are those numbers appearing on the panel illustrations preceding each tabulated list. Panel illustrations are of a fold-out type and are located at the front of the tabulated information for each panel. This facilitates correlation between panel description and panel illustration.

The following is a detailed explanation of the data presented in the tabulated list.

Panel	Identifies panel by number
Reference Designator	Reflects reference designator as shown on engineering drawings. (Reference designators are not shown on spacecraft panels.)

REFERENCE DESIGNATORS

(A)	Subsystem unit
(CB)	Circuit breaker
(DS)	Indicator - electromechanical
(J)	Receptacle/Jack
(M)	Meter
(R)	Rheostat or potentiometer
(S)	Switch
(T)	Variable transformer
(V)	Valve
(XDS)	Annunciator light
(LM)	Left side of meter

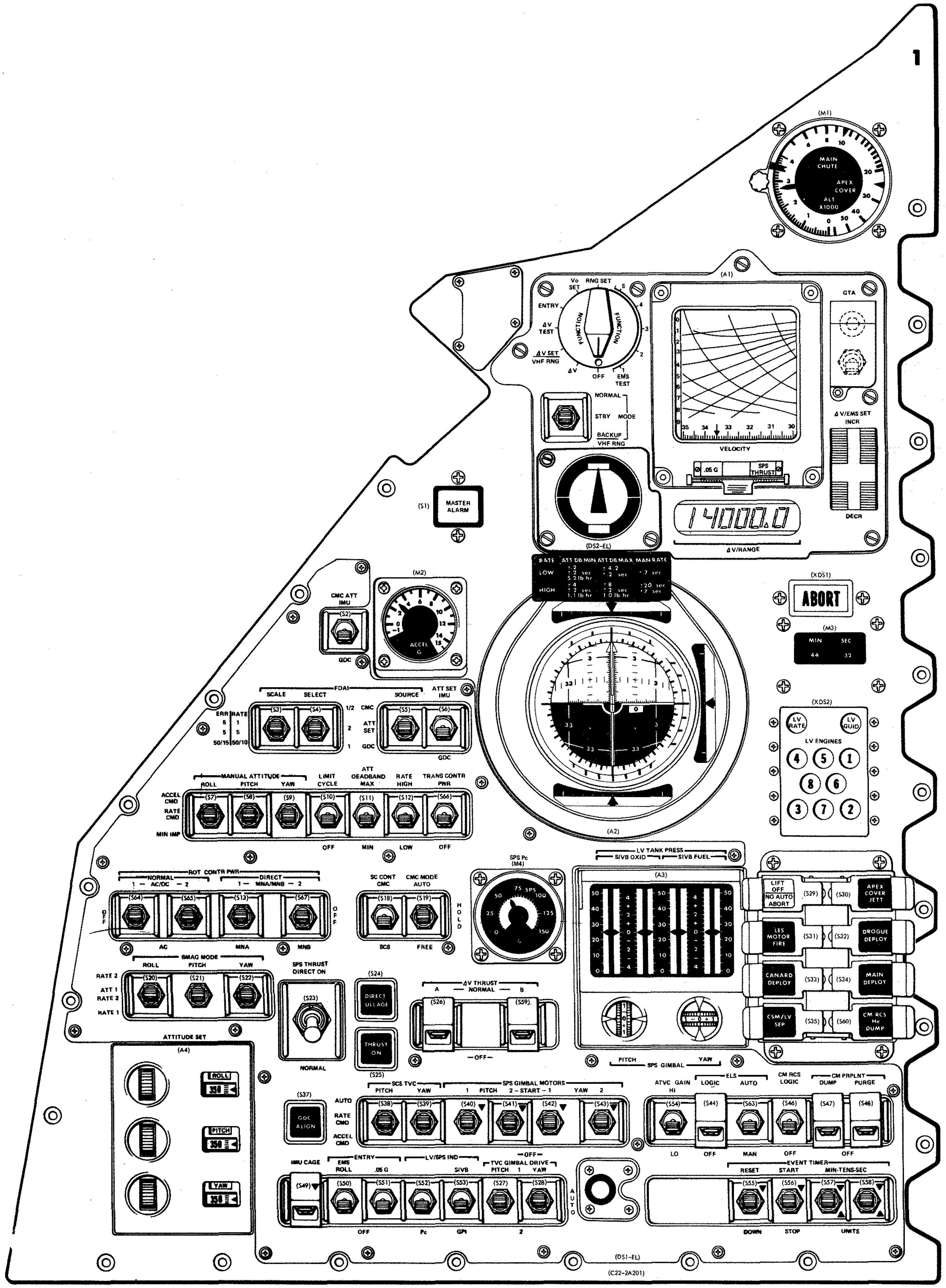
(RM)	Right side of meter
▼	Denotes momentary switch position and does not appear on panels.
System	Designates the specific associated system

SYSTEMS

C/W	Caution and warning system
DKG	Docking system
ECS	Environmental control system
EPS	Electrical power system
EXP	Experiments
G&N	Guidance and navigation system
MISC	Miscellaneous systems
RCS	Reaction control system
SCS	Stabilization and control system
SEQ	Sequential systems
SPS	Service propulsion system
TLCM	Telecommunications

Nomenclature and position	Gives the exact nomenclature of a particular control or display and its position. In the absence of a placard/nomenclature, a functional name is assigned in parenthesis ( ).
Function	Describes the function of each control in each selected position.
Circuit breaker	Gives the name and location of the circuit breaker(s) for circuit protection and controlling power to each display and control.
Power Source	Identifies the immediate bus or source supplying power to each control or display.
Remarks	Other data in support of description of the control or display.

PANEL 1


1
(M1)
MAIN CHUTE
APEX COVER
ALT X1000
(A1)
ENTRY
Vo SET
RNG SET
FUNCTION
ΔV TEST
ΔV SET VHF RNG
ΔV
OFF
EMS TEST
NORMAL
STBY
MODE
BACKUP VHF RNG
VELOCITY
.05 G
SPS THRUST
GTA
ΔV/EMS SET INCR
DECR
14000.0
ΔV/RANGE
(DS2-EL)
(S1)
MASTER ALARM
(M2)
CMC ATT IMU
(S2)
GDC
ACCEL G
(XDS1)
ABORT
(M3)
MIN
SEC
(XDS2)
LV RATE
LV GUID
LV ENGINES
FDAI
SCALE
SELECT
SOURCE
ATT SET IMU
CMC
ATT SET
GDC
MANUAL ATTITUDE
ROLL
PITCH
YAW
LIMIT CYCLE
ATT DEADBAND MAX
RATE HIGH
TRANS CONTR PWR
ACCEL CMD
RATE CMD
MIN IMP
OFF
MIN
LOW
(A2)
ROT CONTR PWR
NORMAL
DIRECT
AC
MNA
MNB
SC CONT CMC
CMC MODE AUTO
SCS
FREE
HOLD
SPS Pc (M4)
LV TANK PRESS
SIVB OXID
SIVB FUEL
(A3)
BMAG MODE
RATE 2
ATT 1 RATE 2
RATE 1
SPS THRUST DIRECT ON
DIRECT ULLAGE
THRUST ON
NORMAL
ΔV THRUST
ATTITUDE SET
(A4)
ROLL
PITCH
YAW
LIFT OFF NO AUTO ABORT
APEX COVER JETT
LES MOTOR FIRE
DROGUE DEPLOY
CANARD DEPLOY
MAIN DEPLOY
CSM/LV SEP
CM RCS He DUMP
PITCH
SPS GIMBAL
YAW
GDC ALIGN
SCS TVC
SPS GIMBAL MOTORS
AUTO
RATE CMD
ACCEL CMD
ATVC GAIN HI
ELS LOGIC
AUTO
CM RCS LOGIC
CM PRPLNT DUMP
PURGE
LO
MAN
IMU CAGE
ENTRY
EMS ROLL
.05 G
LV/SPS IND
SIVB
TVC GIMBAL DRIVE
EVENT TIMER
RESET
START
MIN-TENS-SEC
DOWN
STOP
UNITS
(DS1-EL)
(C22-2A201)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A1	SCS	(ENTRY MONITOR SUBSYSTEM)				
			DELTA V/RANGE	a. Provides numerical readout of either range to go or ΔV remaining, depending on position of FUNCTION switch. b. Provides thrust off command to RJEC ON-OFF for SCS configuration. c. Provides readout of CSM-SWS ranging during rendezvous.	EMS MNA & MNB (Panel 8)	EPS GROUP 4 MNA and MNB (Panel 229)	The two circuit breakers both supply power to EMS. They are separated by diodes. a. Drive signal originates in EMS electronics and logic. b. Readout units are nautical miles (range) and feet per second (ΔV).
			(ROLL STABILITY IND)	Indication roll attitude (lift vector orientation). (Refer to Remarks.)		EPS GROUP 4 MNA and MNB (Panel 229) Requires SCS AC1 and AC2 CBs SYSTEM main buses A and B	Drive signal for RSI is obtained from the yaw-GDC channel. The signal is enabled when the ENTRY - EMS ROLL switch is up. a. Pointer on RSI should be (if not presently) directed toward lamp that is lit. b. Drive signal from corridor verification circuitry in EMS electronics.
			.05 G	Provides, when illuminated, an indication of deceleration greater than .05 G.		EPS GROUP 4 MNA and MNB (Panel 229)	
			(GV PLOT)	Provides a display of acceleration (G-scribe) versus velocity (VELOCITY scroll) during entry.			
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A1 (Cont)	SCS	(LIFT REQUIRED UP)	If lit, approximately 10 seconds after .05 G light comes on, indicates deceleration $\geq$.262 G.	EMS MNA & MNB (Panel 8)		
			(LIFT REQUIRED DOWN)	If lit, approximately 10 seconds after .05 G light comes on, indicates deceleration $\leq$.262 G.			
			SPS THRUST	When lit, indicates ground on low side of SPS bipropellant solenoid control valves and SPS relays with ΔV THRUST NORMAL switches A&B OFF or in A and B position.		EPS GROUP 4 MNA and MNB (Panel 229)	RJEC ON-OFF logic circuitry normally supplies ground to SPS bipropellant solenoid control valves and SPS relays.
			FUNCTION (EMS SELECT 12 POSITION)				a. Function switch is used to select desired EMS operating function. b. Mode switch will be used in conjunction with FUNCTION switch where required.
			OFF	Deactivates EMS except for SPS THRUST ON light and roll stability indicator.			
			EMS TEST				
			1	Tests EMS for deceleration <.05 G. Enables scroll slewing. (No lamps illuminated.)			
			2	Deceleration >.05 G. (.05 G lamp should illuminate.)			
			3	Deceleration <.262 G. a. .05 G lamp illuminates immediately. b. Ten seconds later bottom lamp on RSI is illuminated. c. Enables slewing of ΔV/RANGE display to 58.0.			
			...continued				

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A1 (cont)	SCS	4	EMS system test. a. ΔV/RANGE display drives to zero ±0.2 in 10 seconds. b. VELOCITY scroll drives right to left. c. G scribe drives down to 9 g in 10 seconds. d. .05 G lamp on.	EMS MNA & MNB (Panel 8)		
			5	Deceleration >.262 G. a. Illuminates .05 G lamp immediately. b. Ten seconds later top lamp on RSI is illuminated. c. G scribe drives up to 0.28±0.1 G. d. Enables slewing scroll to 37,000 fps.			
			RNG SET	Enables slewing ΔV/RANGE display to initial condition using EMS/ΔV SET switch. G scribe drives vertically to 0±0.1 G.			
			Vo SET	Enables slewing VELOCITY scroll to initial condition using EMS/ΔV SET switch.			
			ENTRY	Operational position for EMS entry display functions.			
			ΔV TEST	Verifies correct operation of: a. SPS THRUST lamp. b. ΔV display (and countdown electronics). (See ΔV SET position.) c. Thrust off command.			

...continued

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A1 (Cont)	SCS	ΔV SET/VHF RNG	a. Enables use of EMS/ΔV SET switch to slew ΔV/RANGE display to initial condition for ΔV TEST and SPS thrust monitoring. b. Provides VHF ranging information for ΔV/RANGE display in conjunction with MODE switch.	EMS MNA & MNB (Panel 8)		
			ΔV	Correct position for SPS thrust monitoring (ΔV display).			
			GTA				
			(ON)	Bias signal used in ground tests to nullify Earth's gravitation.			GTA switch cover cannot be closed when switch is ON.
			(OFF)	Bias signal is removed.			
			MODE				
			NORMAL	Normal position for ENTRY, ΔV, and TEST positions.			
			STBY	Inhibits operation in all but ΔV SET/VHF RNG, RNG SET, and Vo SET positions of FUNCTION switch.			
			BACKUP/VHF RNG	a. A manual backup to automatic .05 G trigger circuits that starts scroll drive and RANGE integrator display drive circuits. Also backup to TVC MODES for velocity monitoring.			
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A1 (Cont)	SCS		b. Does not permit negative acceleration spikes into countup circuits. c. Enables VHF ranging information to be displayed on ΔV/RANGE display if FUNCTION switch is in ΔV SET VHF RNG.	EMS MNA & MNB (Panel 8)		
			ΔV/EMS SET				
			INCR	a. Drives ΔV/RANGE display in positive (increasing) direction. b. Slews velocity scroll up to 1 inch in positive (increasing) direction. (See ΔV/RANGE display and FUNCTION switch.)			The two circuit breakers supply power to EMS. They are separated by diodes.
			DECR	Used to slew VELOCITY scroll right to left. Drive ΔV/RANGE display in negative direction (decreasing).			
1	A2	SCS	(FLIGHT DIRECTOR ATTITUDE IND)				
			(Rate Indicators)				
			(Top)	Display of roll rate.	Refer to Remarks, Power.	AC bus 1	a. Power 1. Rate and error meters are servo-metric. The pot reference voltages comes from EDA power supply, which obtains phase A power from AC1 circuit breaker through FDAI/GPI POWER switch.
			(Far right)	Display of pitch rate.			
			(Bottom)	Display of yaw rate.			
			(Attitude error indicators)				
			(Top below roll rate indicator)	Display of roll error or desired roll attitude.			
			...continued				

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A2 (Cont)	SCS			Refer to Remarks, Power.	AC bus 1	2. Power to motors is obtained from EDA which obtains a-c power from FDAI/GPI POWER switch supplied from AC1 circuit breaker, 28 vdc, bus A from SCS SYSTEM MNA circuit breaker is also used.
			(Right - left of pitch rate indicator)	Display of pitch error or desired pitch attitude.			b. Rate 1. Indicator consists of triangular marker with scale marked at 0, ±1/5, ±2/5, ±3/5, ±4/5, and full scale. Full-scale value depends on position of FDAI-SCALE switch.
			(Bottom - above yaw rate indicator)	Display of yaw error or desired yaw attitude.			
			(Euler angle indicator ball gimbal angle repeater)				
			(Great semicircles)	The great semicircle under index indicates pitch Euler attitude.			2. Drive signals are obtained from EDA which obtains rate information from BMAGs in GA-2 or GA-1. BMAGs in GA-1 will supply rate when selected by BMAG MODE switches.
			(Small circles)	Small circle under index indicates yaw Euler attitude.			3. Indicators are fly-to displays.
			(Roll bug and scale)	Indicates roll Euler attitude or, after .05 G, indicates roll stability attitude "IF DRIVEN BY GDC." (Back-up to RSI)			c. Error 1. Indicator consists of needle-type pointer and scale marked as follows: (a) Roll scale marked at 0, ±1/2 and full scale. (b) Pitch and yaw marked at 0, ±1/3, ±2/3, and full scale. (c) Full scale value depends on position of FDAI-SCALE switch.
			...continued				

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A2 (Cont)	SCS					2. Drive signals are obtained from EDA. Input (source) to EDA is selectable among the following: (a) G&N CDUs (b) BMAGs in GA-1 (c) ATTITUDE set resolvers. 3. FDAI-SELECT, FDAI-SOURCE, and/or ATT SET switches determine which source is selected. 4. Indicators are fly-to displays (except ASCP-IMU source). d. Ball 1. Signals to motor come from servo amp in EDA. Signal source is either IMU or GDC as selected by panel switches. (See FDAI-SELECT, FDAI-SOURCE, and/or ATT SET switches.)
1	A3	SCS	LV TANK PRESS SIVB OXID SIVB FUEL ...continued	 Indicates SIVB oxidizer pressure on redundant readouts, providing LV/SPS IND switch on Panel 1 is in SIVB position, until CSM separates from SIVB. Indicates SIVB fuel pressure on redundant readouts until CSM separates from SIVB, providing LV/SPS IND switch on Panel 1 is in SIVB position.	 STAB CONT SYSTEM AC1 and AC2 (Panel 8) EDS 1 BAT A AND EDS 3 BAT B (Panel 8) and FDAI/GPI POWER switch (Panel 7)	 AC bus 1 or 2 EPS BAT BUS A AND B (Panel 229)	 Time-shared to monitor LV tank pressure and SPS gimbal angles.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A3 (Cont)	SCS	SPS GIMBAL				
			PITCH	Provides manual pitch trim input commands to respective engine gimbal position servos for alignment of SPS engine thrust axis through SC CG, prior to SPS thrusting in SCS modes only.	STAB CONT SYSTEM TVC AC1, AC1 and AC2 (Panel 8) STABILIZATION CONTROL SYSTEM ECA/TVC AC2 (Panel 8) and TVC SERVO POWER 1 & 2 switches (Panel 7)	AC bus 1 or 2	Provides display and manual control of gimbaled SPS engine thrust axis orientation with respect to SC body axes when in the SCS ΔV mode. Pitch indicator and thumbwheel are calibrated in 0.5° increments from -4.5° to +4.5°. Reading of 0° corresponds to pitch actuator position null offset of +2° to +Z thrust vector during SPS thrusting periods.
			YAW	Provides manual yaw trim input commands to respective engine gimbal position servos for alignment of SPS engine thrust axis through SC CG, prior to SPS thrusting in SCS modes only.			Yaw thumbwheel is calibrated in 0.5° increments from -4.5° to +4.5°. Reading of 0° corresponds to yaw gimbal actuator position null offset of +1° to +Y thrust vector during SPS thrusting periods.
			(GPI)	Indicates SPS engine gimbal position on redundant readouts for pitch and yaw in respective CSM pitch and yaw (body) axes respectively, providing LV/SPS IND switch on Panel 1 is in GPI position.	STAB CONT SYSTEM AC1 and AC2 (Panel 8) and FDAI/GPI POWER switch (Panel 7)	AC bus 1 or 2	Yaw and pitch indicators are calibrated in 0.5° increments from -4.5° to +4.5°. Reading of 0° corresponds to yaw gimbal actuator position null offset of +1° to +Y thrust vector during SPS thrusting periods. Reading of 0° corresponds to pitch gimbal actuator position null offset of +2° to +Z thrust vector during SPS thrusting periods.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	A4	SCS	ATTITUDE SET (CONTROL) ROLL (thumbwheel and display) PITCH (thumbwheel and display) YAW (thumbwheel and display)	Rotating thumbwheel positions shaft of a resolver to electrical equivalent of angle readout on display adjacent to thumbwheel.	N/A	N/A	ATTITUDE SET resolvers are used for functions listed under ATT SET switch and GDC ALIGN pushbutton.
1	M1	SEQ	(ALTIMETER)	Indicates pressure altitude of command module up to 60,000 feet. Cue markers at 10,000 feet (MAIN CHUTE) and 24,000 feet (APEX COVER) are utilized during normal entry to enable crew to monitor ERS equipment.	N/A	N/A	Altimeter is monitored to verify deployment of drogue and main parachutes at proper altitude. Adjustable reference marker on dial is set prior to launch. Marker is used as reference for manual deployment of main parachutes during low altitude LES aborts.
1	M2	MISC	ACCEL G	Mechanical device for measuring G-forces along the SC X-axis.	N/A	N/A	
1	M3	MISC	(EVENT TIMER)	Digital event timer provides crew with means of monitoring and timing events. Event timer will start automatically when lift-off occurs.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	Timer located on Panel 1 will reset and restart automatically if any abort occurs. Scale: 59 min 59 sec.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	M4	SPS	SPS P_c	SPS P_c: Indicator displays SPS chamber pressure in percent from chamber pressure transducer on injector of engine.	INSTRUMENTATION POWER CONTROL CB4 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	Indicator range: 0 to 150%. P_c range: 0 to 150% which correlates with 0 to 150 psia chamber pressure.
1	S1	C/W	MASTER ALARM	Red light illuminates to alert crewman in LH couch of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on Panel 2.	C/W MNA & MNB (Panel 5)	DC main buses A and B	MASTER ALARM lights on Panels 1, 3, and 122 are simultaneously illuminated and audio alarm tone is sent to each headset when any C/W light illuminates. Disabled by positioning CAUTION/WARNING-NORMAL-BOOST-ACK sw (Panel 2) to BOOST position. CAUTION/WARNING switch (Panel 2) is set to BOOST during ascent phase only, preventing this MASTER ALARM switch-light from illuminating in order to avoid confusion with adjacent red ABORT light. Switch-light loses its reset function during this time. MASTER ALARM switch-light contains integral pushbutton switch. Pressing switch-light will reset master alarm circuit, extinguishing MASTER ALARM lights and shutting off audio alarm.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S2	SCS	CMC ATT IMU	a. Required in logic that enables body to Euler transformation in GDC. b. Enables motor excitations to either or both FDAI balls, if FDAI/GPI POWER switch is not OFF. (See FDAI/GPI POWER switch on Panel 7.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA 1/2-MNA & 1/4-MNB circuit breakers summed through diodes. (Panel 8)	DC main buses A and B	Switch has redundant poles and output contacts. IMU position contacts are tied together through isolation diodes. SCS LOGIC BUS 4 supplies power to one pole. The other is supplied from SCS LOGIC BUS 1.
			GDC	Not used.			
1	S3	SCS	FDAI SCALE ERR / RATE				
			5 / 1	Full scale on attitude error indicators (3) of both FDAI's is 5 degrees. Full scale on rate indicators is 1 deg per sec.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			5 / 5	Logic signal to EDA that selects signal flow gains so that full scale on rate indicators (3) of both FDAIs is 5 deg per sec. Attitude error full scale equals 5 degrees.			
			50/15 / 50/10	Logic signal to EDA that selects gains so that full scale indications on both FDAIs are: a. Roll error - 50 deg. b. Roll rate - 50 deg per sec. c. Pitch and yaw error - 15 deg.			Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			...continued	...continued			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S3 (Cont)	SCS		d. Pitch and yaw rate - 10 deg per sec.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 1/4-MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNB (Panel 229)	
1	S4	SCS	FDAI SELECT				
			1/2	Logic signal to EDA that selects specific sources for both FDAIs. Sources for each FDAI are: a. FDAI No. 1 IMU - CDU - BMAGs in GA-2. (See BMAG MODE switch.) b. FDAI No. 2 GDC - BMAGs in GA-1 - BMAGs in GA-2 (if BMAG MODE switch(es) are in ATT 1/RATE 2 position).	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 1/4-MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNB (Panel 229)	Logic power is obtained from SCS logic power circuit breakers. NOTE: FDAI-SOURCE switch has no function when this position is selected.
			2	Logic signal to EDA that inhibits signals to FDAI No. 1. Signal sources for FDAI No. 2 depends on positions of FDAI-SOURCE and/or ATT SET switches, excluding rate source. (See BMAG MODE switch.)			
			1	Logic signal to EDA that inhibits signals to FDAI No. 2. Signal sources for FDAI No. 1 depends on positions of FDAI-SOURCE and/or ATT SET switches, excluding rate source. (See BMAG MODE switch.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA & MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7) (applicable to switch positions 2 & 1).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S5	SCS	FDAI SOURCE				NOTE: This switch has no function if FDAI-SELECT switch is in the 1/2 position.
			CMC	Logic signal to EDA that selects IMU-attitude and CDU-error for display on that (1 or 2) FDAI switch selected. (Refer to note applying to SOURCE switch.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			ATT SET	Logic signal to EDA that selects the attitude set source for error display on FDAI. Source for total attitude (ball drive) is determined by position of ATT SET switch. (Refer to note applying to SOURCE switch.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA & MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC PWR 2/3 switch (Panel 7).
			GDC	Logic signal to EDA that selects GDC-attitude and BMAG-error for display on that FDAI selected. (Refer to note applying to SOURCE switch.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA & MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
1	S6	SCS	ATT SET IMU	Total attitude signals from IMU are routed to resolvers in ATTITUDE SET control panel to generate Euler errors. These error signals can be displayed on FDAI error needles if selected. (See FDAI-SOURCE and FDAI-SELECT switches.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).

...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S6 (Cont)	SCS	GDC	a. Same concept as for IMU position except total attitude signals are obtained from GDC and Euler errors are transferred to body errors in GDC. b. This position is necessary for GDC alignment. (See GDC ALIGN pushbutton.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 1/4-MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S7	SCS	MANUAL ATTITUDE				
			ROLL				
			ACCEL CMD	a. Logic signal to RJEC ON-OFF that disables CMC and/or ECA (SCS) control of RCS. b. Logic signal to ROLL BMAG (attitude) uncage logic in ECA that inhibits uncaging of BMAG if SPS engine is not thrusting. c. Enables input to minimum impulse circuits from roll breakout switches in RC (2).	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			RATE CMD				
			MIN IMP	Logic signal to ECA that: a. Disables roll switching amplifier outputs. b. Enables input to minimum impulse circuits from roll breakout switches in RC (2). c. Inhibits uncaging of BMAG if SPS engine is not thrusting.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S8	SCS	MANUAL ATTITUDE PITCH ACCEL CMD	a. Logic signal to RJEC ON-OFF that disables CMC and/or ECA (SCS) control of RCS. b. Logic signal to pitch BMAG (attitude) uncage logic in ECA that inhibits uncaging of BMAG if SPS engine is not thrusting. c. Enables input to minimum impulse circuits from pitch breakout switches in RC (2).	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			RATE CMD				
			MIN IMP	Logic signal to ECA that: a. Disables pitch switching amplifier outputs. b. Enables input to minimum impulse circuits from pitch breakout switches in RC (2). c. Inhibits uncaging of BMAG if SPS engine is not thrusting.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S9	SCS	MANUAL ATTITUDE YAW ACCEL CMD	a. Logic signal to RJEC ON-OFF that disables CMC and/or ECA (SCS) control of RCS. b. Logic signal to YAW BMAG (attitude) uncage logic in ECA that inhibits uncaging of BMAG if SPS engine is not thrusting.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			...continued	...continued			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S9 (Cont)	SCS		c. Enables input to minimum impulse circuits from yaw breakout switches in RC (2).	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	
			RATE CMD				
			MIN IMP	Logic signal to ECA that: a. Disables yaw switching amplifier outputs. b. Enables input to minimum impulse circuits from yaw breakout switches in RC (2). c. Inhibits uncaging of BMAG if SPS engine is not thrusting.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S10	SCS	LIMIT CYCLE				
			(LIMIT CYCLE)	Enables pseudo-rate feed back circuits in ECA.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			OFF	Inhibits pseudo-rate feedback circuits in ECA.			
1	S11	SCS	ATT DEADBAND				
			MAX	(Refer to Remarks.)			A ±4-degree electrical deadband is normally part of ECA attitude control loops. This deadband is in addition to switching amplifier deadband and can be removed. (See MIN position this switch.)

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Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S11 (Cont)	SCS	MIN	Switches (relays) the additional (±4 degrees) electrical deadband out of ECA attitude control loop in all three axes.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S12	SCS	RATE				
			HIGH	Logic signal to ECA that: a. Selects low signal gains in both rate and attitude channels in all axes (roll, pitch, and yaw). b. Selects higher signal gain in roll manual control loop. (Refer to Remarks.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	a. Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches. b. In HIGH position ECA is configured for: 1. Switching amplifier deadband (all axes): Rate ±2 deg per sec; Attitude ±4 deg 2. Maximum proportional rate command capability: Pitch and yaw ±7 deg per sec; Roll ±20 deg per sec.
			LOW	(Refer to Remarks.)			In LOW position ECA is configured for: a. Switching amplifier deadband (all axes): Rate ±0.2 deg per sec; Attitude ±0.2 deg b. Maximum proportional rate command capability (all axes) ±0.7 per sec.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S13	SCS	ROT CONTR PWR				See (S64), (S65), and (S67).
			DIRECT-1				
			MNA/MNB	Applies 28 vdc, MNA and MNB to direct switches in rotation control 1.	STABILIZATION CONTROL SYSTEM CONTR/ DIRECT-1 MNA, MNB (Panel 8)	EPS GROUP 5 MNA and MNB (Panel 229)	
			OFF	Removes 28 vdc from direct switches in rotation control 1.			
			MNA	Applies 28 vdc, MNA, to direct switches in rotation control 1.	STABILIZATION CONTROL SYSTEM CONTR/ DIRECT-1 MNA (Panel 8)	EPS GROUP 5 MNA (Panel 229)	
1	S18	SCS	SC CONT				
			CMC	a. Logic signal to ECA, RJEC ON-OFF, and TVSA logic circuits. Inhibits SCS control functions "IF TC IS NOT CLOCKWISE ($\overline{CW}$)."	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
				b. Logic signal to normally closed clockwise switch in TC. Signal from TC to CMC and PSA (28 vdc).	N/A	G/N POWER IMU switch (Panel 100)	+28 vdc discretes to CMC channel 31 bit 15 and PSA to enable TVC mode.
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S18	SCS	SCS	Logic signal (28 vdc) to ECA and RJEC ON-OFF to enable SCS functions in RJEC ON-OFF.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
1	S19	G/N	CMC MODE	Controls CSM RCS and DOCKED digital autopilot modes. Provides discretes to CMC.	N/A	CMC	
			AUTO	Enables RCS and DOCKED digital autopilot AUTO MODE.			
			HOLD	Enables RCS and DOCKED digital autopilot HOLD MODE.			Input channel 31, bit 13.
			FREE	Enables RCS and DOCKED digital autopilot FREE MODE.			Input channel 31, bit 14.
1	S20	SCS	BMAG MODE				
			ROLL				
			RATE 2	a. Sends 28 vdc to signal conditioner. b. Rate cages BMAG in GA-1, but rate output is not utilized. Logic circuits in ECA, EDA, and GDC, select rate signals from BMAG in GA-2 for control, display, and GDC drive.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			ATT 1 RATE 2	a. Sends 28 vdc to signal conditioner. b. Enables logic circuits in ECA, EDA, and GDC so that: 1. BMAG in GA-2 supplies rate signals for control and display, and GDC update.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			...continued	...continued			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S20 (Cont)	SCS		2. BMAG in GA-1 can provide attitude error signals for control and display. (See FDAI SOURCE and SELECT switches.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 3 MNA GROUP 1 MNB (Panel 229)	
			RATE 1	Rate cages (electrically) BMAG in GA-1 and enables logic circuits in ECA, EDA, and GDC so that this BMAG supplies the rate information for control and display, and drives the GDC.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S21	SCS	BMAG MODE PITCH RATE 2	a. Sends 28 vdc to signal conditioner. b. Rate changes BMAG in GA-1, but rate output is not utilized. Logic circuits in ECA, EDA, and GDC in GA-2 for control, display, and GDC drive.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			ATT 1 RATE 2	a. Sends 28 vdc to signal conditioner. b. Enables logic circuits in ECA, EDA, and GDC so that: 1. BMAG in GA-2 supplies rate signals for control and display, and GDC update. 2. BMAG in GA-1 can provide attitude error signals for control and display. (See FDAI-SOURCE and SELECT switches on Panel 1).	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC BUS 2/3 switch (Panel 7).
			...continued				

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S21 (Cont)	SCS	RATE 1	Rate cages (electrically) BMAG in GA-1, and enables logic circuits in ECA, EDA, and GDC so that this BMAG supplies rate information for control and display, and drives the GDC.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S22	SCS	BMAG MODE YAW				
			RATE 2	a. Sends 28 vdc to signal conditioner. b. Rate cages BMAG in GA-1 but rate output is not utilized. Logic circuits in ECA, EDA, and GDC, select rate signals from BMAG in GA-2 for control, display, and GDC drive.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			ATT 1 RATE 2	a. Sends 28 vdc to signal conditioner. b. Enables logic circuits in ECA, EDA, and GDC so that: 1. BMAG in GA-2 supplies rate signals for control and display, and GDC update. 2. BMAG in GA-1 can provide attitude error signals for control and display. (See FDAI-SOURCE and SELECT switches on Panel 1.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S22 (Cont)	SCS	RATE 1	Rate cages (electrically) BMAG in GA-1 and enables logic circuits in ECA, EDA, and GDC so that this BMAG supplies rate information for control and display, and drives GDC.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S23	SCS	SPS THRUST				
			DIRECT ON	When ΔV THRUST NORMAL-A and ΔV THRUST NORMAL-B switches are placed in NORMAL position, applies power to THRUST DIRECT ON switch. The SPS THRUST DIRECT ON provides a ground to energize SPS relays and solenoid control valves of SPS system A and ground to energize SPS relays and solenoid control valves of SPS system B. Also illuminates SPS THRUST light on EMS.	ΔV THRUST NORMAL-A switch or ΔV THRUST B switch in position (Panel 1)	N/A	Two-position toggle switch lever locked in either position.
			NORMAL	Removes ground from SPS relays and solenoid control valves and SPS THRUST light on EMS is not lit.	ΔV THRUST NORMAL-A switch or ΔV THRUST-B switch in NORMAL position (Panel 1)	N/A	The ΔV THRUST NORMAL-A and -B switch to OFF provides thrust-off command by removing power to SPS relays and solenoids.
1	S24	SCS	DIRECT ULLAGE ...continued	Provides a backup capability for initiating ullage (+X translation) prior to SPS burns. ...continued	STABILIZATION CONTROL SYSTEM DIRECT ULL MNA & MNB (Panel 8)	EPS GROUP 5 MNA and MNB (Panel 229)	Momentary-contact pushbutton switch which must be held engaged until ullage is completed.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S24	SCS		a. Energizes injector valve direct coils of four +X SM RCS engines. MNA for SM RCS B4 & D3, MNB for A4 & C3. b. Disengages automatic attitude hold capability in pitch and yaw axes. c. Provides logic signal to SCS thrust ON-OFF logic. This signal or normal +X translation must be present for a normal SCS SPS thrust ON.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Translation control provides normal capability for initiating ullage.
1	S25	SCS	THRUST ON	Switch actuation applies SPS-thrust-on command to SCS ΔV modes thrust-on logic, which energizes SPS relays and solenoid control valves. When pressed, a lock-up circuit in SCS logic locks command in, thus pushbutton is not depressed throughout SPS thrusting period.	STABILIZATION CONTROL SYSTEM LOGIC PWR 1/4-MNB LOGIC PWR 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Pushbutton momentary contact-type switch does not contain a light. Used in SCS ΔV modes. Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
1	S26	SCS	ΔV THRUST A-NORMAL ...continued	Receives power from SPS PILOT VLVS MNA circuit breaker and applies enabling power to SPS relays and solenoid control valves that are controlled by SPS thrust ON-OFF logic A. Receives power from SPS He VALVE MNA circuit breaker, and applies power to injector prevalve A. ...continued	SERVICE PROPULSION SYSTEM PILOT VLVS A-MNA (Panel 8) SERVICE PROPULSION SYSTEM He VALVE MNA (Panel 8)	EPS GROUP 5 MNA (Panel 229) EPS GROUP 4 MNA (Panel 229)	Two-position toggle switch guarded to OFF position. See (S59).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S26 (Cont)	SCS	OFF	Removes power from thrust ON-OFF logic, from SPS relays and solenoid control valves, and de-energizes injector prevalve A.			Provides backup thrust OFF command to any ΔV mode of operation by removing power from SPS relays, solenoid control valves, and thrust ON-OFF logic.
1	S27	SCS	TVC GIMBAL DRIVE				
			PITCH				
			1	Allows only clutch commands to be applied to primary channel of gimbal actuator.	N/A	Not wired.	Permits checkout of primary gimbal motor and primary channel. If overcurrent is sensed on primary gimbal motor there is no switchover to secondary channel. If translation control is rotated clockwise, there is no switchover to secondary channel.
			AUTO	Allows primary gimbal motor overcurrent relay to control clutch commands to primary or secondary channel. Allows translation control, when rotated clockwise, to switch clutch commands from primary system to secondary system.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Permits checkout of secondary gimbal motor and secondary channel. Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			2	Allows only clutch commands to be applied to secondary channel of gimbal actuator.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S28	SCS	TVC GIMBAL DRIVE YAW				
			1	Allows only clutch commands to be applied to primary channel of gimbal actuator.	N/A	Not wired.	Permits checkout of primary gimbal motor and primary channel. If overcurrent is sensed on primary gimbal motor, there is no switch-over to secondary channel. If translation control is rotated clockwise, there is no switchover to secondary channel.
			AUTO	Allows primary gimbal motor overcurrent relay to control clutch commands to primary or secondary channel. Allows translation control when rotated clockwise to switch clutch commands from primary system to secondary system.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/4-MNB LOGIC BUS 1/2-MNA (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	Permits checkout of secondary gimbal motor and secondary channel. Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			2	Allows only clutch commands to be applied to secondary channel of gimbal actuator.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
1	S29	SEQ	LIFT OFF/NO AUTO ABORT ...continued	White light illuminates at lift-off and will be extinguished at commencement of first stage staging during ascent phase.	EDS 1 BAT A & 3 BAT B (Panel 8)	Battery buses A and B when EDS POWER switch (Panel 7) is (ON).	LIFT OFF/NO AUTO ABORT switch-light combination should be pressed if LIFT OFF light does not illuminate at lift-off. Mission and event timers failing to reset and start in addition to no lift-off light is an indication of no lift-off signal which means the 61-second auto propellant dump time delay has not started.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S29 (Cont)	SEQ		Switch-light will illuminate red at lift-off if either of LV-EDS auto abort systems has not been automatically enabled.	EDS 1 BAT A & 3 BAT B (Panel 8)	Battery buses A and B when EDS POWER switch (Panel 7) is (ON).	If red light illuminates at lift-off, astronaut will press switch-light which will electrically enable LV-EDS automatic abort system. If light still does not go out, it indicates that one or both of dual redundant EDS systems is not enabled. In this event, crew must be prepared to initiate an abort manually, if necessary.
1	S30	SEQ	APEX COVER JETT	Backup switch to jettison CM apex cover.	ELS/CM SM SEP BAT A & BAT B (Panel 8)	Battery buses A and B	Push-type switch to jettison CM apex cover if automatic system fails during abort or earth recovery after normal mission.
1	S31	SEQ	LES MOTOR FIRE	a. Backup switch to jettison LES tower in event tower jettison motor failed to ignite. b. Backup switch to fire launch escape motor on LES abort.	SEQ EVENTS CONT SYS ARM B BAT B (Panel 8)	Battery buses A and B	LES motor is normally (automatically) fired by SECS approximately 0.1 second following abort initiation. It may be used for backup for tower jettison motor only after normal means of LET jettison has failed. This is assuming that LET separation nuts are fractured.
1	S32	SEQ	DROGUE DEPLOY	Backup switch to deploy drogue parachute.	ELS/CM SM SEP BAT A & BAT B (Panel 8)	Battery buses A and B	Push-type switch. Drogue parachutes will normally (automatically) deploy 2 seconds after 24,000-foot baro switches close.
1	S33	SEQ	CANARD DEPLOY	Backup switch to deploy canard if it does not deploy automatically during abort.	SEQ EVENTS CONT SYS ARM B BAT B (Panel 8)	Battery buses A and B	Push-type switch. Canard will normally (automatically) deploy 11 seconds after LES abort initiation.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S34	SEQ	MAIN DEPLOY	Backup switch to deploy main parachutes on normal descent phases. Switch for main parachute deployment on aborts, if optional usage is desired.	ELS/CM SM SEP BAT A & BAT B (Panel 8)	Battery buses A and B	Push-type switch. Main parachutes will normally (automatically) deploy when 10,000-foot baro switches close during descent. Switch may also be used to initiate manual deployment of main parachutes subsequent to aborts.
1	S35	SEQ	CSM/LV SEP	a. Switch for normal CSM/LV separation during ascent phase of mission. (Refer to SLA separation mechanism in section 2.) b. Backup switch for CSM/LV separation if it does not separate automatically during SPS abort. (Refer to SPS abort procedures.)	SEQ EVENTS CONT SYS BAT A & ARM B BAT B (Panel 8)	Battery buses A and B	Push-type switch to separate SLA when SPS abort cannot be initiated with CM 1 translation hand control.
1	S37	SCS	GDC ALIGN (Depressed)	Logic signal to GDC that enables ATTITUDE SET CONTROL PANEL output to drive GDC. (Refer to Remarks.)	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 1/4-MNB (Panel 8)	EPS GROUP 1 MNA Group 3 MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches. NOTE: To obtain meaningful input to GDC (when aligning), ATT SET switch must be in GDC position.
1	S38	SCS	SCS TVC PITCH AUTO ...continued	Logic signal (28 vdc) to ECA and TVSA logic circuits. This position must be selected if SCS AUTO TVC control in PITCH is desired, either as backup to CMC or as primary selection.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S38 (Cont)	SCS	RATE CMD	Logic signal to ECA that must be present if MTVC-RATE CMD TVC control is desired in PITCH, either as backup to CMC or as primary selection.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
			ACCEL CMD	Logic signal to ECA. Similar to above functions but inhibits rate (BMAG) signals.			
				NOTE: RATE CMD & ACCEL CMD are supplied by LOGIC BUS 3.			
1	S39	SCS	SCS TVC				
			YAW				
			AUTO	Logic signal (28 vdc) to ECA and TVSA logic circuits. This position must be selected if SCS AUTO TV control in YAW is desired, either as backup to CMC or as primary selection.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			RATE CMD	Logic signal to ECA that must be present if MTVC-RATE CMD TV control is desired in YAW, either as backup to CMC or as primary selection.			Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).
			ACCEL CMD	Logic signal to ECA. Similar to above functions but inhibits rate (BMAG) signals.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S40	SPS	SPS GIMBAL MOTORS 1-PITCH				Three-position toggle switch with upper (START) position spring-loaded to return switch to center position when released.
			START	Energizes motor switch in applicable overcurrent relay, which applies +28 vdc to applicable gimbal actuator drive motor.	SERVICE PROPULSION SYSTEM 1 PITCH BAT A (Panel 8)	EPS BAT BUS A (Panel 229)	Battery bus A for PITCH 1 motor switch and overcurrent relay, MN BUS A for gimbal motor PITCH 1. Start position provides gimbal motor starting capability.
			(CENTER)	Applies +28 vdc to overcurrent sensing circuitry in applicable overcurrent relay.			Center position provides for overcurrent sensing. During primary channel operation, an overcurrent will automatically cause power to be removed from primary drive motor, and applicable GMBL DR FAIL status indicator illuminates (Panel 2). With TVC GMBL DR switches in AUTO, clutch commands are switched to secondary channel.
			OFF	Energizes motor switch in applicable overcurrent relay which removes +28 vdc from current sensing circuitry and gimbal actuator drive motor.			During ascent, when GIMBAL MOTORS switches (4) are OFF, engine positioning is maintained by application of quiescent current (60 +10, -5 ma) to the electromagnets of extend and retract clutches when TVC SERVO POWER 1 and 2 switches (Panel 7) are in AC1/MNA or AC2/MNB positions.
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S40 (Cont)	SPS					During secondary operation, if overcurrent is sensed, automatically power is removed from secondary drive motor and applicable GMBL DR FAIL status indicator illuminates (Panel 2).
1	S41	SPS	SPS GIMBAL MOTORS 2-PITCH				Three-position toggle switch with upper (START) position spring-loaded to return switch to center position when released.
			START	Energizes motor switch in applicable overcurrent relay, which in turn applies +28 vdc to applicable gimbal actuator drive motor.	SERVICE PROPULSION SYSTEM PITCH 2 BAT B (Panel 8)	EPS BAT BUS B (Panel 229)	Battery bus B for PITCH 2 motor switch and overcurrent relay MN BUS B for gimbal motor PITCH 2. Start position provides gimbal motor starting capability.
			(CENTER)	Applies +28 vdc to overcurrent sensing circuitry in applicable overcurrent relay.			Center position provides for overcurrent sensing. During primary channel operation, an overcurrent will automatically cause power to be removed from primary drive motor, and applicable GMBL DR FAIL status indicator illuminates (Panel 2). With TVC GMBL DR switches in AUTO, clutch commands are switched to secondary channel.
			OFF	Energizes motor switch in applicable overcurrent relay which removes +28 vdc from the current sensing circuitry and gimbal actuator drive motor.			During ascent, when GIMBAL MOTORS switches (4) are OFF, engine positioning is maintained by application of quiescent current (60 +10, -5 ma) to the electromagnets of extend and
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S41 (Cont)	SPS					retract clutches when TVC SERVO POWER 1 and 2 switches (Panel 7) are in AC1/MNA or AC2/MNB positions. During secondary operation, if overcurrent is sensed, automatically power is removed from secondary drive motor. The applicable GMBL DR FAIL status indicator illuminates (Panel 2).
1	S42	SPS	SPS GIMBAL MOTORS 1-YAW START	Energizes motor switch in applicable overcurrent relay, which in turn applies +28 vdc to applicable gimbal actuator drive motor.	SERVICE PROPULSION SYSTEM 1 YAW BAT A (Panel 8)	EPS BAT BUS A (Panel 229)	Three-position toggle switch with upper (START) position spring-loaded to return switch to center position when released. Battery bus A for YAW 1 motor switch and overcurrent relay, MN BUS A for gimbal motor YAW 1. Start position provides gimbal motor starting capability.
			(CENTER) ...continued	Applies +28 vdc to overcurrent sensing circuitry in applicable overcurrent relay.			Center position provides for overcurrent sensing. During primary channel operation, an overcurrent will automatically cause power to be removed from primary drive motor, and applicable GMBL DR FAIL status indicator illuminates (Panel 2). With TVC GMBL DR switches in AUTO, clutch commands are switched to secondary channel. ...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S42 (Cont)	SPS	OFF	Energizes motor switch in applicable overcurrent relay which removes +28 vdc from the current sensing circuitry and gimbal actuator drive motor.			During ascent, when GIMBAL MOTORS switches (4) are OFF, engine positioning is maintained by application of quiescent current (60 +10, -5 ma) to the electromagnets of extend and retract clutches when TVC SERVO POWER 1 and 2 switches (Panel 7) are in AC1/MNA or AC2/MNB positions. During secondary operation, if overcurrent is sensed, automatically power is removed from secondary drive motor. The applicable GMBL DR FAIL status indicator illuminates (Panel 2).
1	S43	SPS	SPS GIMBAL MOTORS 2-YAW START	Energizes motor switch in applicable overcurrent relay, which in turn applies +28 vdc to applicable gimbal actuator drive motor.	SERVICE PROPULSION SYSTEM YAW 2 BAT B (Panel 8)	EPS BAT BUS B (Panel 229)	Three-position toggle switch with upper (START) position spring-loaded to return switch to center position when released. Battery bus B for YAW 2 motor switch and overcurrent relay MN BUS B for gimbal motors YAW 2. Start position provides gimbal motor starting capability.
			(CENTER) ...continued	Applies +28 vdc to overcurrent sensing circuitry in applicable overcurrent relay.			Center position provides for overcurrent sensing. During primary channel operation, an overcurrent will automatically cause power to be removed from primary drive motor, and applicable GMBL DR FAIL status indicator illuminates (Panel 2). With TVC GMBL DR switches in AUTO, clutch commands are switched to secondary channel. ...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S43 (Cont)	SPS	OFF	Energizes motor switch in applicable overcurrent relay which removes +28 vdc from the current sensing circuitry and gimbal actuator drive motor.			During ascent, when GIMBAL MOTORS switches (4) are OFF, engine positioning maintained by application of quiescent current (60 +10, -5 ma) to electro-magnets of extend and retract clutches when TVC SERVO POWER 1 and 2 switches (Panel 7) are in AC1/MNA or AC2/MNB positions. During secondary operation, if overcurrent sensed, automatically power removed from secondary drive motor. The applicable GMBL DR FAIL status indicator illuminates (Panel 2).
1	S44	SEQ	ELS				
			LOGIC	Provides battery voltage to ELS logic and circuitry. Circuitry is automatically armed during LES abort if ELS-AUTO/MAN switch (Panel 2) is in AUTO position.	ELS/CM SM SEP BAT A & BAT B (Panel 8)	SECS logic buses A and B	Logic switch is placed in up position during entry or after SPS abort to arm ELS logic circuitry. This circuitry is armed automatically during LES aborts. ELS is controlled by baro switch closure and time-delay relays after being armed. See (S63).
			OFF	Removes battery voltage from ELS logic circuitry.			Switch should never be placed to up position during launch and ascent. LES tower, apex cover, and parachutes could be jettisoned.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S46	RCS	CM RCS LOGIC				
			(CM RCS LOGIC)	Applies power to CM PRPLNT DUMP switch on Panel 1. Applies power to 0- to 61-second time delays (from liftoff). If an abort is initiated during this time, automatically initiates rapid oxidizer dump followed 5 seconds later by rapid fuel dump, and followed 13 seconds later by purge. Applies power to relay contact points that are closed upon receipt of an abort signal (from 0 to tower jettison) or on CM SM separation which applies power automatically to RCS transfer motors. Applies power to the CM RCS HTRS switch (Panel 101).	REACTION CONTROL SYSTEM RCS LOGIC MNA & MNB (Panel 8)	EPS GROUP 5 MNA and MNB (Panel 229)	Two-position toggle switch. Switch must be in up position before power is available to CM PRPLNT DUMP, PURGE, and CM RCS HTRS switches, and circuitry controlling automatic transfer of engine firing commands from SM RCS to CM RCS engines.
			OFF	Remove power from CM PRPLNT DUMP and PURGE switches and CM RCS HTRS switch as well as RCS logic circuitry for automatic RCS transfer.			
1	S47	RCS	CM PRPLNT	Enabled by CM RCS LOGIC switch.	CM RCS LOGIC switch (Panel 1)	REACTION CONTROL SYSTEM RCS LOGIC MNA and MNB (Panel 8)	Guarded two-position toggle switch (activates explosive-operated valves). During normal entry, switch is placed to DUMP (up) position in event of possible CM land impact at main parachute line stretch. Remaining
			DUMP	Energizes relays to energize 10 CM RCS engine-injector valves direct coils for propellant burn.			
			...continued	...continued	...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S47 (Cont)	RCS	 OFF	Initiates two helium interconnect squib valves, one fuel interconnect squib valve, and one oxidizer interconnect squib valve. De-energizes relays removing power from CM RCS engine-injector valve direct coils allowing valves to close.			propellants are then burned off through 10 of the 12 RCS engines (excluding +P). Dump switch not utilized in 0 to 61 second aborts (from lift-off), except as a possible backup to initiate interconnect squib valves.
1	S48	RCS	CM PRPLNT PURGE OFF	Energizes relays required to initiate the two fuel and two oxidizer bypass squib valves for purge. De-energizes relays.	CM PRPLNT DUMP switch (Panel 1)	REACTION CONTROL SYSTEM RCS LOGIC MNA and MNB (Panel 8)	Guarded two-position toggle switch. Switch manually set to up position after CM RCS propellant burn has been completed in event of possible CM land impact. (approximately 88 seconds after activation of DUMP switch, for 10-engine burn and 155 seconds for 5-engine burn) to deplete the helium source pressure as well as purge the system. (Purge operation approximately 14 seconds.) CM RCS LOGIC and CM PRPLNT DUMP switches must both be in up position before purge operation can be initiated. Switch will not be utilized in 0 to 61 second aborts (from lift-off), except as a possible backup to initiate squib valves.
1	S49	G&N	IMU CAGE (IMU CAGE) (OFF)	Provides power to cage the platform with all three gimbal angles at 0°. Removes d-c power from the cage relays.	GUIDANCE/ NAVIGATION IMU MNA & MNB (Panel 5)	DC main buses A and B	Guarded spring-loaded switch. Power routed through G/N power switch (panel 100) in IMU position. Energizes the cage relays in the power servo assembly.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S50	SCS	ENTRY				
			EMS ROLL	Sends logic signal to GDC that enables yaw channel to drive RSI on EMS display.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 1/4-MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			OFF				
1	S51	SCS	ENTRY				
			.05 G	Provides logic signal (28 vdc) to ECA and GDC logic circuits to enable: a. Roll rate to yaw rate coupling in yaw control electronics. b. Electrical rate caging of BMAGs in GA-1. c. Summing roll and yaw rate BMAG signals in GDC to obtain roll stability attitude for display on RSI and FDAI. d. Disabling of pitch input to GDC and the yaw GDC output and the body to Euler transformation. e. The functions in c and d will not occur if GDC ALIGN pushbutton is pressed.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA LOGIC BUS 1/4-MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNB (Panel 229)	Logic power is routed directly from Panel 8 circuit breakers to Panel 1 switches.
			OFF	Sends logic signal to EDA to inhibit roll and yaw rate BMAG summing in EDA yaw rate signal flow.	STABILIZATION CONTROL SYSTEM LOGIC BUS 1/2-MNA LOGIC BUS 2/3-MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNB (Panel 229) EPS GROUP 1 MNA GROUP 3 MNB (Panel 229)	Logic power is supplied to Panel 1 switches from SCS LOGIC BUS circuit breakers via LOGIC POWER 2/3 switch (Panel 7).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S52	SPS	LV/SPS IND				Two-position toggle switch which enables crew to select input to SPS P_c indicator. Switch is placed in P_c position prior to lift-off.
			P_c	Connects output of SPS engine combustion chamber pressure sensor to SPS P_c indicator.			
1	S53	SCS	LV/SPS IND	Provides display and control of S-IVB tank pressures or SPS gimbal position.	EDS 1 BAT A & EDS 3 BAT B (Panel 8)	EPS BAT BUS A and B (Panel 229)	Two-position toggle switch which allows crew to monitor S-IVB tank pressures or GPI. Placed in SIVB position prior to lift-off. Placed to GPI after separation from S-IVB or earlier if desired.
			SIVB	Applies power to relays allowing S-IVB oxid/S-IVB fuel pressures to be displayed on LV fuel tank pressure meter.			FDAI/GPI POWER switch (Panel 7) must be on for the display to respond correctly; both positions make entire displays active.
			GPI	Removes power from relays allowing SPS yaw and pitch gimbal position to be displayed on redundant SPS gimbal position meters.			SPS gimbal position will be displayed if proper power and switches are positioned.
1	S54	SCS	ATVC GAIN				
			HI	Enables low mass body-bending filter in SCS auto TVC control loop.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA 2/3-MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S54 (Cont)	SCS	LO	Enables hi mass body-bending filter in SCS auto TVC control loop. Allows GPI thumbwheel authority for backup TVC control in the event of AC2 bus failure.	STABILIZATION CONTROL SYSTEM LOGIC BUS 3/4-MNA 2/3-MNB (Panel 8)		
1	S55	MISC	EVENT TIMER RESET (CENTER) DOWN	 ET will reset to zero and stop counting. ET will count up when running or slewing. ET will count down when running or slewing.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	
1	S56	MISC	EVENT TIMER START (CENTER) STOP	 Starts event timer. No function. Stops event timer.	TIMERS MNA & (Panel 5)	DC main buses A and B	Event timer starts automatically when lift-off occurs. The switch is momentary on towards START position and maintained on in other two positions. Timer will reset and start counting up if any abort is initiated.
1	S57	MISC	EVENT TIMER MIN TENS (CENTER) UNITS	 Runs MIN indicating drum in tens. No function. Runs MIN indicating drum in units.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S58	MISC	EVENT TIMER				Control switches provide means of running event timer to any desired setting and are spring-loaded to center position. Indicating drums can be run up or down, depending on position of RESET/DOWN switch.
			SEC				
			TENS	Runs SEC indicating drum in tens.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	
			(CENTER)	No function.			
			UNITS	Runs SEC indicating drum in units.			
1	S59	SCS SPS	ΔV THRUST				
			B-NORMAL	Receives power from SPS PILOT VLVS MNB circuit breaker, and applies enabling power to SPS relays and solenoid control valves that are controlled by SPS thrust ON-OFF logic B.	SERVICE PROPULSION SYSTEM PILOT VLVS B-MNB (Panel 8)	EPS GROUP 5 MNB (Panel 229)	Two-position toggle switch guarded to OFF position. See (S26).
				Receives power from SPS He VALVE circuit breaker MNB, and applies power to injector prevalve B.	SERVICE PROPULSION SYSTEM He VALVE MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	
			OFF	Removes power from thrust ON-OFF logic, from SPS relays and solenoid control valves, and de-energizes injector prevalve B.			Provides backup thrust OFF command to any ΔV mode of operation by removing power from SPS relays, solenoid control valves, and thrust ON-OFF logic.
1	S60	RCS	CM RCS He DUMP	Utilized as back-up to CM PRPLNT PURGE switch.	REACTION CONTROL SYSTEM RCS LOGIC MNA & MNB (Panel 8)	EPS GROUP 5 MNA and MNB (Panel 229)	
			(pressed)	Energizes relays required to initiate the two fuel and two oxidizer bypass squib valves for purge.			Pushbutton guarded switch which provides backup capability for initiating helium purge operation in event of CM PRPLNT PURGE switch failure (Panel 1).
			(released)	De-energizes relays.			

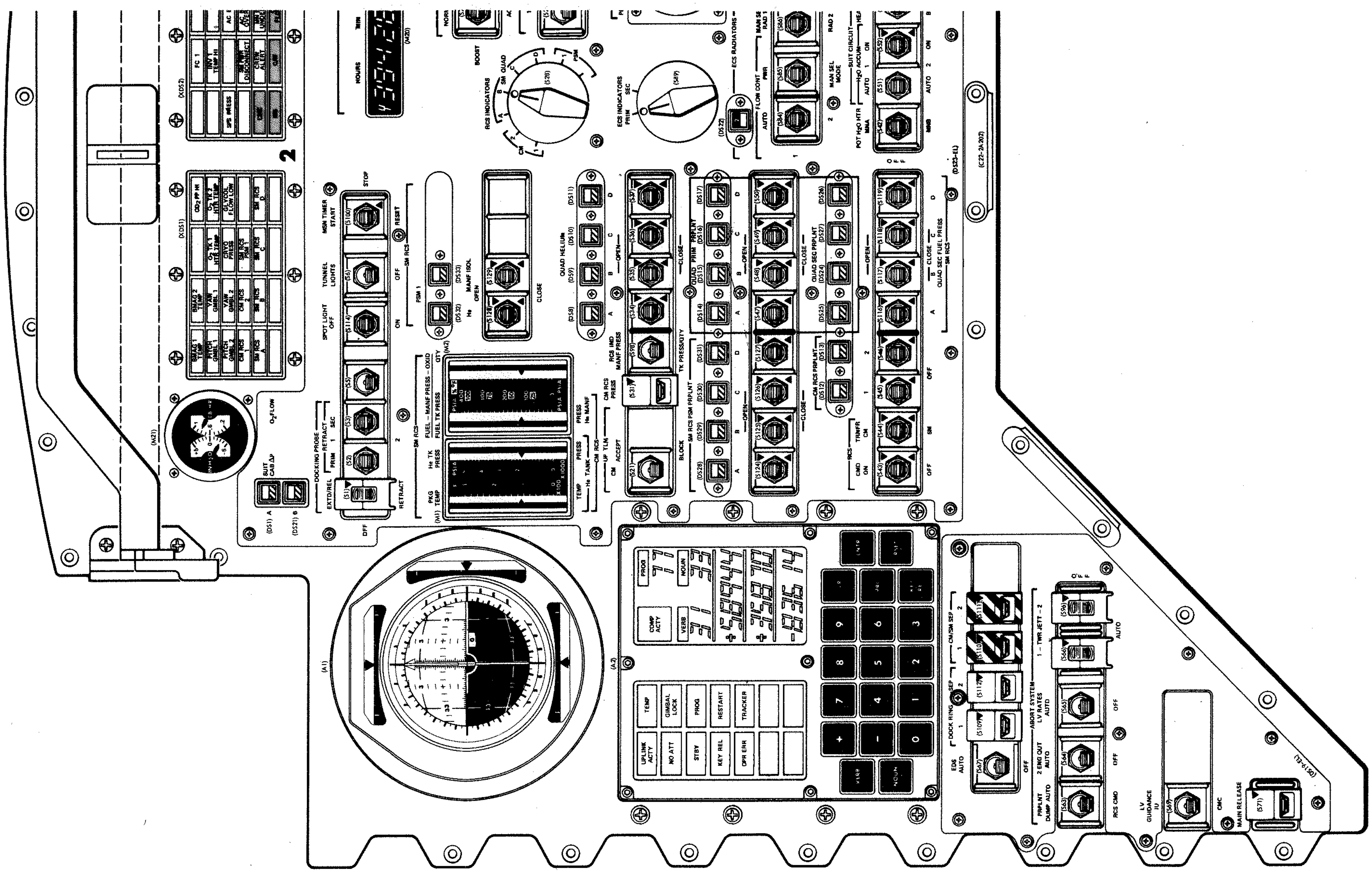
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S63	SEQ	ELS				
			AUTO	a. Prepares ELS for automatic activate during LES abort. b. Allows ELS to function automatically during descent of CM.	ELS/CM SM SEP BAT A & BAT B (Panel 8)	SECS logic buses A and B	NOTE: See (S44). Switch may be set to MAN position after drogue parachute deployment during abort initiated prior to 61 seconds after lift-off. Main parachutes must be deployed manually with MAIN DEPLOY pushbutton (Panel 1) after switch is set to MAN position. If main parachutes are deployed manually, ELS switch must be set back to AUTO to allow main parachute 14-second time delays to arm MAIN RELEASE switch.
			MAN	Disconnects logic arming circuitry from ELS controller.			
1	S64	SCS	ROT CONTR PWR				See (S13), (S65), and (S67).
			NORMAL-1				
			AC/DC	Applies 28 vdc MNA and MNB to breakout switches in rotation control 1 through armed/locked switch.	STABILIZATION CONTROL SYSTEM CONTR/ AUTO MNA & MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
				Applies 26v AC1 from ECA to rotation control transducer.	STAB CONT SYSTEM AC1 (Panel 8)	AC bus 1	Enables when SCS ELECTRONICS PWR SW (S5) is in ECA or GDC/ECA position (Panel 7).
			OFF	Removes d-c and a-c voltage to switches and transducer.			
			AC	Only AC1 applied to rotation control transducer.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S65	SCS	ROT CONTR PWR				See (S13), S64), and (S67).
			NORMAL-2				
			AC/DC	Applies 28 vdc MNA and MNB to breakout switches in rotation control 2 through armed/locked switch.			
				Applies 26v AC2 from ECA to rotation control transducer.	STABILIZATION CONTROL SYSTEM ECA/TVC AC2 (Panel 8)	AC bus 2	Enables when SCS ELECTRONICS PWR SW (S5) is in ECA or GDC/ECA position (Panel 7).
			OFF	Removes d-c and a-c voltage to switch and transducer.			
			AC	Only AC2 applied to rotation control transducer.			
1	S66	SCS	TRANS CONTR				
			PWR	Applies 28 vdc, MNA and MNB to ±X, ±Y, ±Z translational control switches through CM-SM transfer motor switches.	STABILIZATION CONTROL SYSTEM CONTR/ AUTO MNA & MNB (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
			OFF	Removes 28 vdc from translational control switches.			
1	S67	SCS	ROT CONTR PWR				See (S13), (S64), and (S65).
			DIRECT-2				
			MNA/MNB	Applies 28 vdc, MNA and MNB to direct switches in rotation control 2.	STABILIZATION CONTROL SYSTEM CONTR/ DIRECT-2 MNA & MNB (Panel 8)	EPS GROUP 5 MNA and MNB (Panel 229)	
			OFF	Removes 28 vdc from direct switches in rotation control 2.			
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	S67 (Cont)	SCS	MNB	Applies 28 vdc, MNB, to direct switches in rotation control 2.	STABILIZATION CONTROL SYSTEM CONTR/ DIRECT-2 MNB (Panel 8)	EPS GROUP 5 MNB (Panel 229)	
1	XDS1	SEQ	ABORT (LIGHT)	Illuminates red to indicate that abort has been requested by range safety officer or ground control.	EDS 1 BAT A & EDS 3 BAT B (Panel 8)	Battery buses A and B when EDS POWER switch is (ON) (Panel 7)	Light serves to alert crew of emergency situation where abort is required immediately. Light is backup to voice communications from ground control. Redundant bulbs are controlled by redundant commands through UDL, real-time command system.
1	XDS2	SEQ	LV ENGINES	Provides LV status.	N/A	IU battery buses	When engine lights are lit in engine light annunciator assembly on Panel 1, care should be taken to avoid body contact as assembly can exceed temperature of 150°F after extended period of illumination.
			LV RATE	Illuminates red when LV angular rates exceed predetermined limits.			When used in conjunction with angle-of-attack display and FDAI, will indicate necessity for manual abort initation. Light illuminates when automatic abort is initiated because of excessive rates.
			LV GUID	Illuminates red to indicate loss of attitude reference in LV guidance system.			
			...continued				

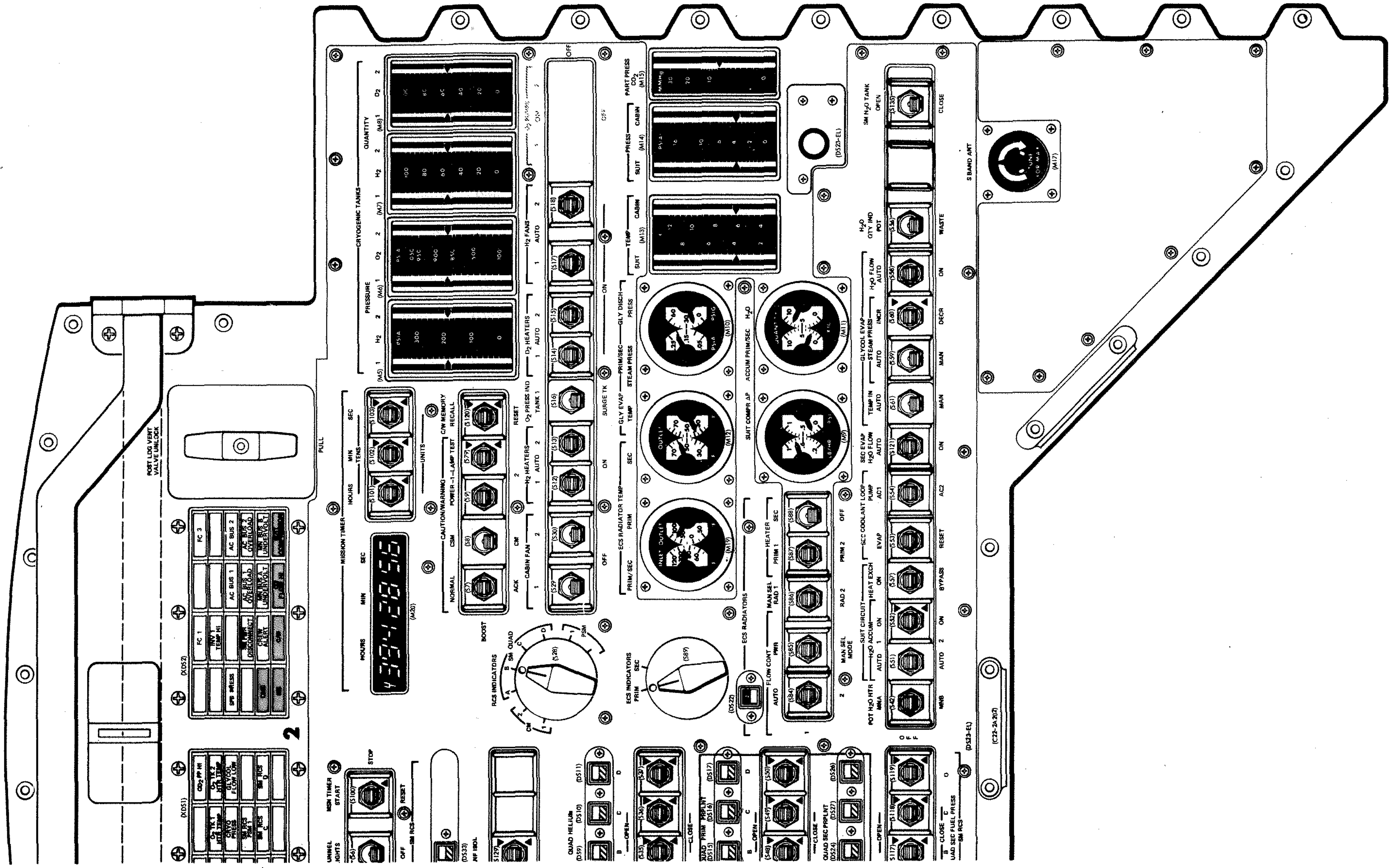
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	XDS2 (Cont)	SEQ	(LV ENGINE) 1	Illuminates yellow to indicate when No. 1 engine of first stage or the single second stage engine of SIB LV is operating below its predetermined level of thrust.	N/A	IU battery buses	Lights are used to indicate LV engine status. Unless inhibited, automatic abort will be initiated with any two first-stage engine lights illuminating. Lights are monitored for possibility of having to manually initiate abort after auto abort capability has been inhibited. Staging sequence may also be monitored by these lights.
			(LV ENGINE) 2	Illuminates yellow to indicate when No. 2 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.
			(LV ENGINE) 3	Illuminates yellow to indicate when No. 3 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.
			(LV ENGINE) 4	Illuminates yellow to indicate when No. 4 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.
			(LV ENGINE) 5	Illuminates yellow to indicate when No. 5 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.
			(LV ENGINE) 6	Illuminates yellow to indicate when No. 6 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
1	XDS2 (Cont)	SEQ	(LV ENGINE) 7	Illuminates yellow to indicate when No. 7 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.
			(LV ENGINE) 8	Illuminates yellow to indicate when No. 8 engine of first stage of SIB LV is operating below its predetermined level of thrust.			See remarks LV ENGINE 1.



PANEL 2
(LEFT SIDE)

CONTROLS AND DISPLAYS



PANEL 2
(RIGHT SIDE)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	A1	SCS	(FLIGHT DIRECTOR ATTITUDE IND)		Refer to Remarks column, power.	AC bus 2	a. Power 1. Rate and error meters are servo-metric. The pot reference voltages comes from EDA power supply, which obtains Phase A power from SCS AC2 circuit breaker through FDAI/GPI POWER switch. 2. Power to motors is obtained from EDA which obtains a-c power from FDAI/GPI POWER switch supplied from SCS AC2 circuit breaker. 28 VDC bus B from STABILIZATON CONTROL SYSTEM-SYSTEM MNB circuit breaker is also used. b. Rate 1. Indicator consists of triangular marker with scale marked at 0, ±1/5, ±2/5, ±3/5, ±4/5, and full scale. Full scale value depends on position of FDAI-SCALE switch.
			(Rate indicators)				
			(Top)	Display of roll rate.			
			(Far right)	Display of pitch rate.			
			(Bottom)	Display of yaw rate.			
			(Attitude error indicators)				
			(Top - below roll rate indicator)	Display of roll error.			
			(Right - left of pitch rate indicator)	Display of pitch error.			
			(Bottom - above yaw rate indicator)	Display of yaw error.			
			...continued				...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	A1 (Cont)	SCS	(Euler angle indicator ball gimbal angle repeater) (Great semicircles) (Small circles) (Roll bug and scale)	 Great semicircle under index indicates pitch Euler attitude. Small circle under index indicates yaw Euler attitude. Indicates roll Euler attitude or, after .05 G, indicates roll stability attitude, if driven by GDC.	Refer to Remarks column, power.	AC bus 2	2. Drive signals are obtained from EDA which obtains rate information from BMAGs in GA-2, normally. BMAGs in GA-1 will supply rate when selected by BMAG MODE switches. 3. Indicators are fly-to displays. c. Error 1. Indicator consists of needle-type pointer and scale marked as follows: (a) Roll scale marked as 0, ±1/2, and full scale. (b) Pitch and yaw marked at 0, ±1/3, ±2/3, and full scale. Full-scale value depends on position of FDAI-SCALE switch. 2. Drive signals are obtained from EDA. Input (source) to EDA is selectable from the following: (a) G&N CDUs (b) BMAGs in GA-1 (c) Attitude set resolvers FDAI-SELECT, FDAI-SOURCE, and/or ATT SET switches determine which source is selected. ...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	A1 (Cont)	SCS					3. Indicators are fly-to displays. d. Ball 1. Signals to motor come from servo amp in EDA. Signal source is either IMU or GDC as selected by panel switches. (See FDAI-SELECT, FDAI-SOURCE, and/or ATT SET switches.)
2	A2	G&N	(DSKY)				
			(Keyboard)		N/A	N/A	
			CLR	Pressing clear button will blank register being loaded.			
			ENTR	This informs CMC that assembled data is complete and/or execute desired function.			
			KEY REL	Release DSKY displays initiated by keyboard action so that information supplied by a CMC program may be displayed.			
			NOUN	Sets computer to accept next two digits as noun code.			Pressing noun button will initially blank noun window.
			RSET	Extinguishes status lamps that are controlled by CMC.			In those areas where error or malfunction exists, pressing reset switch will not extinguish status lamps.
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	A2 (Cont)	G&N	PRO	Informs routine requesting operators response that operator wishes requesting routine to proceed without further inputs from operator; or places CMC in standby mode when pressed, upon request from CMC.			
			VERB	Sets computer to accept next two digits as verb code.			Pressing verb button will initially blank verb window.
			+	Denotes data to follow has positive decimal value.			
			-	Denotes data to follow has negative decimal value.			
			0 through 9	Switches 0 to 9 used to enter data, address codes, and action request codes into CMC.			
			(REGISTER)				
			COMP ACTY (light)	CMC is engaged in computation.	N/A	N/A	
			NOUN (light and display)	A two-digit display, indicating code selected.			On-board data provides definition of PROGRAM and NOUN digits.
			PROG (light and display)	A two-digit display, indicating number of program (major mode) presently in progress.			
			(REGISTER 1 - display)	Displays contents of selected register or memory location. First component of extended-length data word, if applicable.			Displays may be selected manually or by CMC program.
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	A2 (Cont)	G&N	(REGISTER 2 - display)	Displays contents of selected register or memory location. Second component of extended data word, if applicable.			
			(REGISTER 3 - display)	Displays contents of selected register or memory location. Third component of extended data word, if applicable.			
			VERB (light and display)	A two-digit display, indicating verb code selected.			On-board data provides definition of VERB digits.
			(STATUS LIGHTS)				
			GIMBAL LOCK	Gimbal lock-light will illuminate under computer control whenever the middle gimbal angle of the platform exceeds 70 degrees.			Illumination of lights warns of pending gimbal lock condition.
			KEY REL	Internal CMC program needs DSKY circuits to continue program. Crew keystroke is made when internal flashing display is currently on DSKY (exceptions: PRO, ENTR, RSET). Crew makes keystroke on top of his selected monitor verb.			Request for operator to press KEY REL pushbutton.
			NO ATT	Light will illuminate whenever inertial subsystem is not in mode to provide attitude reference.			
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	A2 (Cont)	G&N	OPR ERR	Light will illuminate when illegal keyboard entry is made into CMC.			
			PROG	Light illuminates when the internal program detects computation difficulties.			
			RESTART	Light will be illuminated whenever computer goes into restart program.			
			STBY	Light will be illuminated whenever computer sub-system is in standby mode of operation.			
			TEMP	Light will illuminate whenever temperature of stable platform deviates more than $\pm 5^{\circ}$F from nominal.			Indicates out-of-tolerance temperature, plus or minus, on stable platform.
			TRACKER	Light will illuminate whenever there is failure of one of optical CDU.			
				Data good discrete not present after reading range from VHF DATA LINK.			
			UPLINK ACTY	CMC is receiving data link information by up-telemetry.			
2	DS1	DKG	(PROBE EXTD/RETR)				
			A	Striped-line display indicates probe in motion. Gray display indicates completed movement.	DOCK PROBE MNA (Panel 8)	DC main bus A	Probe indicating switches will open at full extend or retract positions.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS8	RCS	SM RCS QUAD HELIUM A	Indicates gray (positive open) when both quad A helium 1 and 2 isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power MNB - SM power distribution box.	DC main bus B	
2	DS9	RCS	SM RCS QUAD HELIUM B	Indicates gray (positive open) when both quad B helium 1 and 2 isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power MNA - SM power distribution box.	DC main bus A	
2	DS10	RCS	SM RCS QUAD HELIUM C	Indicates gray (positive open) when both quad C helium 1 and 2 isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power MNB - SM power distribution box	DC main bus B	
2	DS11	RCS	SM RCS QUAD HELIUM D	Indicates gray (positive open) when both quad D helium 1 and 2 isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power MNA - SM power distribution box	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS12	RCS	CM RCS PRPLNT 1	Indicates gray (positive open) when both CM RCS 1 fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
2	DS13	RCS	CM RCS PRPLNT 2	Indicates gray (positive open) when both CM RCS 2 fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
2	DS14	RCS	SM RCS QUAD PRIM PRPLNT A	Indicates gray (positive open) when both quad A primary fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNB power distribution box	DC main bus B	
2	DS15	RCS	SM RCS QUAD PRIM PRPLNT B	Indicates gray (positive open) when both quad B primary fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNA power distribution box	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS16	RCS	SM RCS QUAD PRIM PRPLNT C	Indicates gray (positive open) when both quad C primary fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNB power distribution box	DC main bus B	
2	DS17	RCS	RM RCS QUAD PRIM PRPLNT D	Indicates gray (positive open) when both quad D primary fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNA power distribution box	DC main bus A	
2	DS21	DKG	(PROBE EXTD/RETR) B	Striped-line display indicates probe in motion. Gray display indicates completed movement.	DOCK PROBE MNB (Panel 8)	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS22	ECS	ECS RADIATORS				
			(GRAY)	Indicates flow proportioning control No. 1 is in operation.	N/A	N/A	
			2	Indicates flow proportioning control No. 2 is in operation.		Radiator controller No. 2 power supply ON	
2	DS24	RCS	SM RCS QUAD SEC PRPLNT B	Indicates gray (positive open) when both quad B secondary fuel and oxidizer valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNA power distribution box	DC main bus A	
2	DS25	RCS	SM RCS QUAD SEC PRPLNT A	Indicates gray (positive open) when both quad A secondary fuel and oxidizer valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNB power distribution box	DC main bus B	
2	DS26	RCS	SM RCS QUAD SEC PRPLNT D	Indicates gray (positive open) when both quad D secondary fuel and oxidizer valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNA power distribution box	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS27	RCS	SM RCS QUAD SEC PRPLNT C	Indicates gray (positive open) when both quad C secondary fuel and oxidizer valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNB power distribution box	DC main bus B	
2	DS28	RCS	SM RCS PSM PRPLNT A	Indicates gray (positive open) when both PSM A propellant fuel and oxi-dizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNB power distribution box	DC main bus B	
2	DS29	RCS	SM RCS PSM PRPLNT B	Indicates gray (positive open) when both PSM B propellant fuel and oxi-dizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNA power distribution box	DC main bus A	
2	DS30	RCS	SM RCS PSM PRPLNT C	Indicates gray (positive open) when both PSM C propellant fuel and oxi-dizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNB power distribution box	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS31	RCS	SM RCS PSM PRPLNT D	Indicates gray (positive open) when both PSM D propellant fuel and oxidizer isolation valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power - SM MNA power distribution box	DC main bus A	
2	DS32	RCS	SM RCS PSM 1 He	Indicates gray (positive open) when both PSM 1 helium (LV5 and LV6) valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power LV5 SM MNB, LV6 SM MNA - SM distribution box	DC main bus B LV5 (fused) DC main bus A LV6 (fused)	
2	DS33	RCS	SM RCS PSM 1 MANF ISOL	Indicates gray (positive open) when the four PSM 1 manifold isolation propellant valves are open. Indicates barber pole when any one of the valves are closed.	SM RCS INDICATOR power LV3, LV4 SM MNA, LV7, LV8 SM MNB - SM power distribution box	DC main bus A (fused) (LV4) fuse, (LV3) oxidizer DC main bus B (fused) (LV8) fuel, (LV7) oxidizer	
2	DS34	RCS	SM RCS PSM 2 He	Indicates gray (positive open) when the four PSM 2 helium (LV5 and LV6) valves are open. Indicates barber pole when either valve is closed.	SM RCS INDICATOR power LV5 SM MNB, LV6 SM MNA - SM distribution box	DC main bus B LV5 (fused) DC main bus A LV6 (fused)	DS34 is not shown on Panel 2; if installed, this function is applicable.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	DS35	RCS	SM RCS PSM 2 MANF ISOL	Indicates gray (positive open) when the four PSM 2 manifold isolation propellant valves are open. Indicates barber pole when any one of the valves are closed.	SM RCS INDICATOR power LV3, LV4 SM MNA, LV7, LV8 SM MNB - SM power distribution box	DC main bus A (fused) (LV4) fuel, (LV3) oxidizer DC main bus B (fused) (LV8) fuel, (LV7) oxidizer	DS35 is not shown on Panel 2; if installed, this function is applicable.
2	M1	RCS	SM RCS PKG TEMP (LM)	Indicates SM RCS QUADS A, B, C, or D package temperature dependent on RCS INDICATORS select switch position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (for SM RCS QUADS A & C) CB4 (for SM RCS QUADS B & D) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			He TK PRESS (RM)	Indicates SM RCS QUADS, A, B, C, or D or PSM 1, 2 if installed helium source pressure dependent on RCS INDICATORS switch position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (for SM RCS QUADS A & C and PSM 1) CB4 (for SM RCS QUADS B & D and PSM 2 if installed) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M1 (Cont)	RCS	CM RCS (LM) He TANK TEMP	Indicates CM RCS 1 or 2 helium tank temperature dependent upon RCS INDICATORS select switch position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB1 for CM RCS 1 CB2 for CM RCS 2 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			CM RCS (RM) He TANK PRESS	Indicates CM RCS 1 or 2 helium source pressure dependent on RCS INDICATORS switch position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB1 for CM RCS 1 CB2 for CM RCS 2 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
2	M2	RCS	SM RCS FUEL - MANF PRESS (LM)	Indicates SM RCS PSM fuel manifold pressure if RCS IND switch is in MANF PRESS position, dependent upon RCS INDICATORS switch position is in SM QUADS A, B, C, or D, or PSM 1 or 2 position (if installed).	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			FUEL TK PRESS (LM)	Indicates SM RCS QUADS A, B, C, or D secondary fuel pressure or PSM 1 or 2 if installed fuel tank pressure if RCS IND switch is in TK PRESS/QTY position, dependent upon RCS INDICATORS switch position is in SM QUADS A, B, C, or D, or PSM 1 or 2 position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (for SM RCS QUADS A & C and PSM 1) CB4 (for SM RCS QUADS B & D and PSM 2 if installed) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M2 (Cont)	RCS	OXID-MANF PRESS (RM)	Indicates SM RCS PSM oxidizer manifold pressure if RCS IND switch is in MANF PRESS position, dependent upon RCS INDICATORS switch position is in SM QUADS A, B, C, or D, or PSM 1 or 2 positions (if installed).	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			QTY	Indicates SM RCS QUADS A, B, C, or D, quantity or PSM 1 or 2 if installed quantity if RCS IND switch position is in TK PRESS/QTY position, dependent upon RCS INDICATOR switch position is in SM QUADS A, B, C, or D or PSM 1 or 2 position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (for SM RCS QUADS A & C and PSM 1) CB4 (for SM RCS QUADS B & D and PSM 2 if installed) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
			CM RCS (LM)				
			He MANF PRESS	Indicates CM RCS 1 or 2 helium manifold pressure if RCS INDICATORS switch is in CM 1 or 2 position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB1 for CM RCS 1 CB2 for CM RCS 2 (Panel 276)	INSTRUMENTATION main buses A and B (Panel 5)	Will indicate approximately 95 to 105 psia until system is completely pressurized.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M5	EPS	CRYOGENIC TANKS PRESSURE H_2 1 (LM)	Displays H_2 tank No. 1 pressure and is used as follows: a. Determine tank heater performance. b. Detect leaks.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (Panel 276)	DC main buses A & B	Displays for H_2 tanks No. 1 and No. 2 operate prior to CSM separation only. Indicator function is controlled by pressure transducers located in H_2 tanks No. 1 and No. 2 outlet lines. Transducers are also connected to C&WS, operating CRYO PRESS light on Panel 2 and to T/M. H_2 operating range is 225 to 260 psia. Alarm trigger values are 200 psia low and 270 psia high.
			2 (RM)	Displays H_2 tank No. 2 pressure and is used as follows: a. Determines tank heater performance. b. Detect leaks.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (Panel 276)	DC main buses A & B	
2	M6	EPS	CRYOGENIC TANKS PRESSURE O_2 1 (LM)	Displays pressure of O_2 tank No. 1 or ECS surge tank as selected by O_2 PRESS IND switch (Panel 2) and is used as follows: a. Determine tank heater performance. b. Detect leaks. c. Verify surge tank pressure.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (Panel 276)	DC main buses A & B	With O_2 PRESS IND switch at TANK 1, indicator function is controlled by pressure transducer located in O_2 tank No. 1 outlet line. Transducer also connected to C&WS, operating CRYO PRESS light on Panel 2. O_2 operating range is 865 to 935 psia. Alarm trigger values are
			...continued				...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M6 (Cont)	EPS					800 psia low and 950 psia high. With O_2 PRESS IND switch at SURGE TANK position, indicator displays signal from ECS surge tank pressure transducer.
			2 (RM)	Displays O_2 tank No. 2 pressure and is used as follows. a. Determine tank heater performance. b. Detect leaks.	INSTRUMENTATION POWER OPERATIONAL CB3 (Panel 276)	DC main buses A and B	Indicator function is controlled by pressure transducer located in O_2 tank No. 2 outlet line.
2	M7	EPS	CRYOGENIC TANKS QUANTITY H_2				
			1 (LM)	Displays quantity (% remaining) of H_2 in tank No. 1.	CRYOGENIC CIRCULATION - TANK 1-AC1-ØC/SCE (Panel 226)	AC bus 1 ØC	H_2 QUANTITY display range is 0 to 100%.
			2 (RM)	Displays quantity (% remaining) of H_2 in tank No. 2.	CRYOGENIC CIRCULATION - TANK 2-AC2-ØC/SCE (Panel 226)	AC bus 2 ØC	H_2 QUANTITY display range is 0 to 100%.
2	M8	EPS	CRYOGENIC TANKS QUANTITY O_2				
			1 (LM)	Displays quantity (% remaining) of O_2 in tank No. 1.	CRYOGENIC CIRCULATION - TANK 1-AC1-ØC/SCE (Panel 226)	AC bus 1 ØC	O_2 QUANTITY display range is 0 to 100%.
			2 (RM)	Displays quantity (% remaining) of O_2 in tank No. 2.	CRYOGENIC CIRCULATION - TANK 2-AC2-ØC/SCE (Panel 226)	AC bus 2 ØC	O_2 QUANTITY display range is 0 to 100%.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M9	ECS	SUIT COMPR ΔP	Displays differential pressure between compressor inlet and outlet manifolds.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB1 (Panel 276)	DC main buses A and B	Indicator range 0-1 psi XDCR range 0-25 in. H_2O output signal to meter, PCM, and caution and warning system.
2	M10	ECS	PRIM/SEC				
			STEAM PRESS (LM)	Provides indication of steam pressure in water-glycol evaporator.	INSTRUMENTATION POWER CONTROL OPERATIONAL (PRIM 1 EVAP STEAM PRESS) CB1 (SEC/EVAP STEAM PRESS) CB2 (Panel 276)	DC main buses A and B	Range +0.05 to 0.25 psia. Transducer output signals selected by ECS INDICATORS PRIM/SEC switch on Panel 2.
			GLY DISCH (RM)				
			PRESS	Displays primary or secondary water-glycol pump output pressures.	INSTRUMENTATION POWER CONTROL OPERATIONAL (PRIM GLY PUMP PRESS) CB1 (SEC GLY PUMP PRESS) CB2 (Panel 276)	DC main buses A and B	Meter range +0 to +60 psig. Transducer output signals selected by ECS INDICATORS PRIM/SEC switch on Panel 2.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M11	ECS	ACCUM PRIM/SEC (LM)	Provides quantity indication of water-glycol in primary and secondary accumulators.	INSTRUMENTATION POWER CONTROL OPERATIONAL (ACCUM/PRIM) CB1 (ACCUM/SEC) CB2 (Panel 276)	DC main buses A and B	Transducer output signal selected by ECS INDICATORS PRIM/SEC switch on Panel 2.
			H_2O (RM)	Provides quantity indication of waste water tank or potable water tank as selected by H_2O IND switch.	TBD	DC main buses A and B	Capacity of waste tank is 56 lb and potable tank is 36 lb. Meter range 0 to 100 percent.
2	M12	ECS	ECS RADIATOR TEMP				
			SEC OUTLET (LM)	Displays water-glycol temperature at OUTLET of secondary space radiators.	ECS SECONDARY COOLANT LOOP HTR CONTR MNA (Panel 5)	DC main bus A	Indicator range 30° to 70°F. Temperature sensor transducers output 0 to 5 vdc. Supply power to temperature sensing and readout through ECS RAD HTRS selector switch. OFF or SEC signal goes to PCM.
			GLY EVAP				
			TEMP OUTLET (RM)	Provides temperature indication of water-glycol at outlet of PRIM/SEC water-glycol evaporator.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB2 (Panel 276)	DC main buses A and B	Range +30 to +70°F. Transducer output signals selected by ECS INDICATORS PRIM/SEC switch on Panel 2.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M13	ECS	TEMP SUIT (LM) CABIN (RM)	 Provides temperature indication of suit circuit inlet atmosphere. Provides temperature indication of cabin atmosphere.	INSTRUMENTATION POWER CONTROL OPERATIONAL (SUIT TEMP) CB2 (CABIN TEMP) CB1 (Panel 276)	DC main buses A and B	
2	M14	ECS	PRESS SUIT (LM) CABIN (RM)	 Provides pressure indication of suit circuit atmosphere. Provides pressure indication of cabin atmosphere.	INSTRUMENTATION POWER CONTROL OPERATIONAL (SUIT PRESS) CB1 (CABIN PRESS) CB2 (Panel 276)	DC main buses A and B	Pressure measured at compressor inlet. Range +0 to +16 psia. Normal suit circuit operating range indications are as follows: 14.7 psia during prelaunch, 4.7 to 5.3 psia during normal flight mode, and 3.75±0.25 psia during emergency flight mode. Pressure transducer located inside LHFEB. Range +0 to 16 psia. Normal cabin operating range indications are as follows: 14.7 psia during prelaunch, 4.7 to 5.3 psia during normal space flight, and 0.0 psia during emergency space flight.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M15	ECS	PART PRESS CO_2	Provides partial pressure indication of CO_2 in suit circuit atmosphere.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB2 (Panel 276)	DC main buses A and B	CO_2 sensor is located between inlet and outlet manifolds of suit circuit in LHEB. CO_2 partial pressure normal metabolic operating range is 0.0 to 7.6 mm Hg, and emergency metabolic operating range is 7.6 to 15.0 mm Hg. Both ranges are for unlimited length of time. CO_2 PP HI system status light (Panel 2) illuminates at 7.6 mm Hg. Indicates CO_2 level has risen to upper end of normal operating range.
2	M17	TLCM	S BAND ANT TUNE FOR MAX	Indicates S-band xponder receiver AGC level of selected xponder.	N/A	S-band xponder	Indicates AGC only in phase locked condition using OMNI antennas. With no lock-up, the AGC meter reads zero. As soon as the uplink lock-up occurs, approximately the first 35 to 40% of the meter is jumped by the needle. Minimum signal level is -122 dbm. Meter is from 0 to 5 vdc.
2	M19	ECS	ECS RADIATOR TEMP PRIM/SEC (LM) INLET	Displays water-glycol temperature entering primary or secondary space radiators, dependent on position of ECS INDICATORS selector switch two positions (PRIM SEC).	INSTRUMENTATION POWER CONTROL OPERATIONAL CB2 (Panel 276)	DC main buses A and B	Indicator range +50° to 120°F. Transducer output signals selected by ECS INDICATORS PRIM/SEC switch on Panel 2.
			PRIM (RM) OUTLET	Displays signal output of space radiator temperature sensor, primary.			Indicator range +50° to +100°F. Sensor transducer output to indicator, PCM and caution and warning GLY TEMP LO light at -30°F.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	M20	MISC	MISSION TIMER				
			HOURS MIN SEC	Totalizes mission elapsed time after lift-off reset to zero.	TIMERS MNA (Panel 5)	DC main bus A	Timer has provisions for manual setting, count-up readout (hours, minutes, and seconds), and reset to zero by remote control. Internal timing pulse is provided in case timing signal is lost. Clock is capable of timing from external or internal timing source without losing mission time.
2	M21	ECS	SUIT CAB ΔP (LM)				
			IN H_2O	Displays difference in pressure between suit circuit and cabin.	INSTRUMEN-TATION POWER CONTROL OPERATIONAL CB1 (Panel 276)	DC main buses A & B	Indicator range +5.0 in. H_2O to -5.0 in. H_2O suit pressure relative to cabin.
			O_2 FLOW (RM)				
			LB/HR	Provides total rate of flow indication of oxygen supplied to ECS downstream of main regulator.	INSTRUMEN-TATION POWER CONTROL OPERATIONAL CB2 (Panel 276)	DC main buses A & B	Indicator range 0.2 to 1.0 lb/hr. Signal goes to indicator, PCM, and to caution and warning lamps through a 16.5-sec time delay relay (relay powered from main B only).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S1	DKG	DOCKING PROBE				
			EXTD/REL	Applies d-c power to probe, to probe extend latch release solenoid, capture latch release motor and indicators.	DOCK PROBE MNA and MNB (Panel 8)	EPS GROUP 4 MNA and MNB (Panel 229)	Capture latch sensing switches located in probe head will have to be closed to power DEC relays.
			OFF	Removes d-c power.			
			RETRACT	Applies d-c power to DOCKING PROBE-RETRACT-PRIM and SEC switches.			
2	S2	DKG	DOCKING PROBE				
			RETRACT				
			PRIM 1	Controls d-c power from bus to pyrotechnic initiator on No. 1 nitrogen bottle.	DOCK PROBE MNA and MNB (Panel 8)	EPS GROUP 4 MNA and MNB (Panel 229)	
			OFF	No function.			
			2	Controls d-c power from bus to pyrotechnic initiator on No. 2 nitrogen bottle.			
2	S3	DKG	DOCKING PROBE				
			RETRACT				
			SEC 1	Controls d-c power from bus to pyrotechnic initiator on No. 3 nitrogen bottle.	DOCK PROBE MNA and MNB (Panel 8)	EPS GROUP 4 MNA and MNB (Panel 229)	
			OFF	No function.			
			2	Controls d-c power from bus to pyrotechnic initiator on No. 4 nitrogen bottle.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S5	MISC	S5				
			FUNCTION DELETED				
2	S6	MISC	TUNNEL LIGHTS				
			(LIGHTS)	Applies power to light fixtures located in CM tunnel.	LIGHTING - COAS/TUNNEL/ RNDZ/SPOT MNA and MNB (Panel 226)	DC main buses A and B	Six fixtures with two lamps each.
			OFF	Removes power.			
2	S7	C/W	CAUTION/WARNING				
			NORMAL	For most of mission, switch is set to NORMAL position to give normal C&W light operation. Upon receipt of abnormal condition signals, all system status lights and MASTER ALARM switch-light are capable of illumination.	C/W MNA and MNB (Panel 5)	DC main buses A and B	
			BOOST	During ascent phase, switch is set to BOOST position so that although all other C&W lights operate normally, MASTER ALARM switch-light on Panel 1 will not illuminate.			Prevents possible confusion on Panel 1 between red MASTER ALARM switch-light and adjacent red ABORT light.
			ACK	Breaks normal power path to system status lights - MASTER ALARM lights initially indicate malfunction.			System status light indicating malfunction, can be illuminated by pressing MASTER ALARM switch-light on Panels 1 or 3.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S8	C/W	CAUTION/WARNING				
			CSM	Before CSM separation, systems in both CM (with the exception of CM RCS 1 and CM RCS 2 C/W lights) and SM are monitored for malfunction or out-of-tolerance conditions with this switch in CSM position.	C/W MNA and MNB (Panel 5)	DC main buses A and B	Selects SC systems to be monitored.
			CM	After CSM separation, only systems in CM are monitored by placing switch in CM position.			Repositioning switch to CM position also prevents SC status lights and event indicators associated with SM system from remaining activated after separation.
2	S9	C/W	CAUTION/WARNING				
			POWER				
			1	Enables and selects C&W power supply No. 1 in detection unit. Selects power supply 1 in memory/tone amplifier unit.	C/W MNA and MNB (Panel 5)	DC main buses A and B	DC main buses A and B to both power supplies.
			(CENTER)	OFF position.			
			2	Enables and selects C&W power supply No. 2 in detection unit. Selects power supply 2 in memory/tone amplifier unit.			
2	S12	EPS	H_2 HEATERS				
			1				
			AUTO	Enables automatic pressure switches to control d-c power to H_2 tank No. 1 heater elements.	CRYOGENIC H_2 HTR 1 MNA (Panel 226)	DC main bus A	Switch at AUTO position will apply d-c power to H_2 tank No. 1 heater elements when two pressure switches in system are in low-pressure position at 225 psia or lower, and removes d-c power when one pressure switch is in high-pressure position at 260 psia or higher.
			(OFF)	Disconnects d-c power from H_2 tank No. 1 heater elements.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S12 (Cont)	EPS	ON	Controls d-c power directly to H_2 tank No. 1 heater elements.			Switch at ON (manual) position bypasses pressure switches applying d-c power directly to same redundant heater elements employed for automatic operation.
2	S13	EPS	H_2 HEATERS 2				
			AUTO	Enables automatic pressure switches to control d-c power to H_2 tank No. 2 heater elements.	CRYOGENIC H_2 HTR 2 MNB (Panel 226)	DC main bus B	Switch at AUTO position will apply d-c power to H_2 tank No. 2 heater elements when two pressure switches in system are in low-pressure position at 225 psia or lower, and removes d-c power when one pressure switch is in high-pressure position at 260 psia or higher.
			(OFF)	Disconnects d-c power from H_2 tank No. 2 heater elements.			
			ON	Controls d-c power directly to H_2 tank No. 2 heater elements.			Switch at ON (manual) position bypasses pressure switches applying d-c power directly to same redundant heater elements employed for automatic operation.
2	S14	EPS	O_2 HEATERS 1				
			AUTO	Enables automatic pressure switches to control d-c power to O_2 tank No. 1 heater elements.	CRYOGENIC O_2 HTR 100W 1 MNA and O_2 HTR 50W 1 MNB (Panel 226)	DC main bus A to 100 w htr elements. DC main bus B to 50 w htr element	Switch at AUTO position will apply d-c voltage to O_2 tank No. 1 heater elements when two pressure switches in system are in low-pressure position at 865 psia or lower, and will remove d-c voltage when one pressure switch is in high-pressure position at 935 psia or higher.
			(OFF)	Disconnects d-c power from O_2 tank No. 1 heater elements.			
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S14 (Cont)	EPS	ON	Controls d-c power directly to O_2 tank No. 1 heater elements.			Switch at ON (manual) position bypasses pressure switch, applying d-c voltage directly to same heater elements employed for automatic operation.
2	S15	EPS	O_2 HEATERS				
			2				
			AUTO	Enables automatic pressure switches to control d-c power to O_2 tank No. 2 heater elements.	CRYOGENIC O_2 HTR 100W 2 MNB and O_2 HTR 50W 2 MNA (Panel 226)	**DC main bus B to 100 w htr elements. DC main bus A to 50 w htr element**	Switch at AUTO position will apply d-c voltage to O_2 tank No. 2 redundant heater element when two pressure switches in system are in low-pressure position at 865 psia or lower, and will remove d-c voltage when one pressure switch is in high-pressure position at 935 psia or higher.
			(OFF)	Disconnects d-c power from O_2 tank No. 2 heater elements.			
			ON	Controls d-c power directly to O_2 tank No. 2 heater elements.			Switch at ON (manual) position bypasses pressure switches applying d-c voltage directly to same heater elements employed for automatic operation.
2	S16	EPS	O_2 PRESS IND				
			TANK 1	Connects output of O_2 tank No. 1 pressure transducer to O_2 tank No. 1 TANK PRESSURE indicator (Panel 2).	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (Panel 276)	DC main buses A & B	TANK PRESSURE-1-O_2 indicator is shared by two pressure signals. Normal position of switch prior to CSM separation except for periodic surge tank readouts.
			SURGE TANK	Connects output of ECS surge tank pressure transducer to O_2 tank No. 1 TANK PRESSURE indicator.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB2 (Panel 276)	DC main buses A & B	Normal position of switch following CSM separation.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S17	EPS	H_2 FANS 1				
			AUTO	Applies a-c power to contacts of relays which control 3Ø a-c power to circulating fan motors in H_2 tank No. 1.	CRYOGENIC CIRCULATION TANK 1 AC1 ØA. ØB, ØC/ SCE (Panel 226)	AC bus 1	Switch at AUTO position applies a-c power to H_2 tank No. 1 redundnat fan motors when two pressure switches are in low-pressure position of 225 psia or lower, and removes a-c power when either pressure switch is in higher position at 260 psia or higher.
			(OFF)	Disconnects 3Ø a-c power from H_2 tank No. 1 circulating fan motors.			
			(ON)	Controls 3Ø a-c power directly to circulating fan motors in H_2 tank No. 1.			Switch at ON (manual) position bypasses pressure switches, applying a-c power directly to same redundant H_2 tank fan motors employed by automatic operation.
2	S18	EPS	H_2 FANS 2				
			AUTO	Applies a-c power to contacts of relays which control 3Ø a-c power to circulating fan motors in H_2 tank No. 2.	CRYOGENIC CIRCULATION TANK 2 AC2 ØA, ØB, ØC/ SCE (Panel 226)	AC bus 2	Switch at AUTO position applies a-c power to H_2 tank No. 2 redundnat fan motors when two pressure switches are in low-pressure position of 225 psia or lower, and removes a-c power when either pressure switch is in higher position at 260 psia or higher.
			(OFF)	Disconnects 3Ø a-c power from H_2 tank No. 2 circulating fan motors.			
			(ON)	Controls 3Ø a-c power directly to circulating fan motors in H_2 tank No. 2.			Switch at ON (manual) position bypasses pressure switches, applying a-c power directly to same redundant H_2 fan motors employed by automatic operation.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S21	TLCM	UP TLM CM ACCEPT	Enables decoded and accepted UP TLM message from MSFN to pass from up-data link equipment to CM computer.	N/A	CMC INTERNAL PWR (CMC use only)	In series with UP TELEMETRY - ACCEPT - BLOCK switch on LEB 122 (G&N display). Provides data accept enable to command module computer if both switches are in the ACCEPT position. Enable consists of +28 vdc CMC internal power routed through both switches. Also provides ground inputs to updata link validity logic to supply correct validity signal to the PCM equipment.
			BLOCK	Blocks UP TLM message from affecting CM computer.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S28	RCS	RCS INDICATORS CM				
			1	Connects CM RCS system 1 signal outputs from temperature and pressure transducers to appropriate indicating devices.	N/A	N/A	Six-position rotary switch. CM selection of switch, positions 1 and 2, permit monitoring command module temperatures and pressures of systems 1 and 2. SM selection of switch, positions A, B, C, and D permit monitoring service module temperatures and pressures of quads A, B, C, and D. PSM installation of switch, positions 1 and 2 (if installed) permits monitoring of PSM pressures of PSM 1 and 2.
			2	Connects CM RCS system 2 signal outputs from temperature and pressure transducers to appropriate indicating devices.			Selects inputs to temperature pressure gauges, CM selections 1 and 2 functions are identical within their respective systems. SM selections A, B, C, and D functions are identical within their respective systems. PSM selections 1 and 2 functions are identical within their respective systems.
			SM QUAD				
			A	Connects SM RCS quad A signal outputs from temperature and pressure transducers to appropriate indicating devices.			
			B	Connects SM RCS quad B signal outputs from temperature and pressure transducers to appropriate indicating devices.			
			...continued	...cont	...cont	...cont	...cont

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S28 (Cont)	RCS	RCS INDICATORS				
			C	Connects SM RCS quad C signal outputs from temperature and pressure transducers to appropriate indicating devices.			
			D	Connects SM RCS quad D signal outputs from temperature and pressure transducers to appropriate indicating devices.			
			PSM				
			1	Connects SM RCS PSM 1 pressure transducers to appropriate indicating devices.			
			2 (If installed)	Connects SM RCS PSM 2 pressure transducers to appropriate indicating devices.			Position 2 not shown on panel 2, if installed this function is applicable.
2	S29	ECS	CABIN FAN				
			1	Applies a-c power to motor No. 1 cabin air fan, directing airflow through cabin heat exchanger.	CABIN FAN FANS AC1 ØA, ØB, ØC (Panel 5)	AC bus 1	Cabin air fans No. 1 and No. 2 are operated as required. Output of fan is as follows: a. Prelaunch mode - 171.45 cfm. b. Normal mode - 170.67 cfm. c. Emergency mode - 0 cfm (fan off).
			OFF	Removes a-c power from motor of No. 1 cabin air fan.			In event of malfunction, fan No. 1 is turned off and fan closure cover manually positioned over outlet to prevent backflow.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S30	ECS	CABIN FAN				
			2	Applies a-c power to motor of No. 2 cabin air fan, directing airflow through cabin heat exchanger.	CABIN FANS AC1 ØA, ØB, ØC (Panel 5)	AC bus 1	Cabin air fans No. 1 and No. 2 are operated as required. Output of fan is as follows: a. Prelaunch mode - 171.45 cfm. b. Normal mode - 170.67 cfm. c. Emergency mode - 0 cfm (fan off).
			OFF	Removes a-c power from motor of No. 2 cabin air fan.			In event of malfunction, fan No. 2 is shut down and fan closure cover is manually positioned over outlet to prevent backflow.
2	S31	RCS	CM RCS PRESS				
			(UP)	Activates two each helium isolation valves in both CM RCS systems 1 and 2.	SEQ EVENTS CONT SYS - ARM A BAT A ARM B BAT B (Panel 8)	EPS BAT BUS A & B (Panel 229)	SEQ EVENT CONT SYS PYRO ARM A switch and PYRO ARM B switch (Panel 8) for actual initiation of squib valves when relays are energized by CM RCS PRESS placed to CM RCS PRESS.
			(DOWN)	De-energizes relays removing power from squib valves.			
2	S34	RCS	SM RCS				
			QUAD HELIUM A				
			OPEN	Energizes quad A helium 1 and 2 isolation valves solenoids to magnetically latch valves in open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (LV5) (Panel 8) REACTION CONTROL SYSTEM PRPLNT ISOL MNA (LV6) (Panel 8)	EPS GROUP 1 MNB (LV5) (Panel 229) EPS GROUP 1 MNA (LV6) (Panel 229)	Quad helium isolation valves are normally open.
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S34 (Cont)	RCS	SM RCS				
			(CENTER)	Removes power from quad A helium 1 and 2 isolation valves solenoids and valves remain in last commanded position (open or closed).			
			CLOSE	Energizes quad A helium 1 and 2 isolation valves solenoids to unlatch the valves and spring and helium pressure closes valves.			
2	S35	RCS	SM RCS				
			QUAD HELIUM B				
			OPEN	Energizes quad B helium 1 and 2 isolation valves solenoids to magnetically latch valves in open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (LV6) (Panel 8) REACTION CONTROL SYSTEM PRPLNT ISOL MNB (LV5) (Panel 8)	EPS GROUP 1 MNA (LV6) (Panel 229) EPS GROUP 1 MNB (LV5) (Panel 229)	Quad helium isolation valves normally open.
			(CENTER)	Removes power from quad B helium 1 and 2 isolation valves solenoids and valves remain in last commanded position (open or closed).			
			CLOSE	Energizes quad B helium 1 and 2 isolation valves solenoids to unlatch the valves and spring and helium pressure closes valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S36 (Cont)	RCS	SM RCS QUAD HELIUM C				
			OPEN	Energizes quad C helium 1 and 2 isolation valves solenoids to magnetically latch valves in open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (LV5) (Panel 8) REACTION CONTROL SYSTEM PRPLNT ISOL MNA (LV6) (Panel 8)	EPS GROUP 1 MNB (LV5) (Panel 229) EPS GROUP 1 MNA (LV6) (Panel 229)	Quad helium isolation valves normally open.
			(CENTER)	Removes power from quad C helium 1 and 2 isolation valves solenoids and valves remain in last commanded position (open or closed).			
			CLOSE	Energizes quad C helium 1 and 2 isolation valves solenoids to unlatch the valves and spring and helium pressure closes valves.			
2	S37	RCS	SM RCS QUAD HELIUM D				
			OPEN	Energizes quad D helium 1 and 2 isolation valves solenoids to magnetically latch valves in open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (LV6) (Panel 8) REACTION CONTROL SYSTEM PRPLNT ISOL MNB (LV5) (Panel 8)	EPS GROUP 1 MNA (LV6) (Panel 229) EPS GROUP 1 MNB (LV5) (Panel 229)	Quad helium isolation valves are normally open.
			(CENTER)	Removes power from quad D helium 1 and 2 isolation valves solenoids and valves remain in last commanded position (open or closed).			
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S37 (Cont)	RCS	CLOSE	Energizes quad B helium 1 and 2 isolation valves solenoids to unlatch the valves and spring and helium pressure closes valves.			
2	S42	ECS	POT H_2O HTR				
			MNA	Supplies 28 vdc to potable water tank heaters from MNA.	ENVIRON-MENTAL CONTROL SYSTEM H_2O/URINE DUMP HTR MNA (Panel 5)	DC main bus A	Supplies power control to two heaters (20w & 25w); heaters are controlled by thermoswitches.
			OFF	Remove 28 vdc power from potable water tank heaters.			
			MNB	Supplies 28 vdc to potable water tank heaters from MNB.	ENVIRON-MENTAL CONTROL SYSTEM H_2O/URINE DUMP HTR MNB (Panel 5)	DC main bus B	
2	S43	RCS	RCS				
			CMD				
			ON	Energizes latching relay arm coils applying power enable reaction jet engine on-off control assembly through AUTO RCS SELECT switches.	SEQ EVENTS CONT SYS-ARM A BAT A ARM B BAT B (Panel 8)	EPS BAT BUS A & B (Panel 229)	Three-position toggle switch, spring-loaded to center position. Switch allows manual enable-inhibit functions to reaction jet engine on-off control assembly.
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S43 (Cont)	RCS	(CENTER)	Allows SECS to automatically control latching relay.			Inhibit-enable functions provide direct control or backup capability to SECS automatic control of RCS latching relay.
			OFF	De-energizes latching relay safe coils removing power from reaction jet engine on-off control assembly and AUTO RCS SELECT switches.			If LES abort occurs after T +61 seconds, SECS automatically closes relay 1 second after abort initiation. If SPS abort occurs, SECS automatically closes relay 3.8 seconds after abort initiation. ELSC baro switch input automatically causes relay to open at approximately 24,000 feet during CM descent.
2	S44	RCS	RCS TRNFR				
			CM	Energizes motor switch causing the following: a. Transfers all inputs from SM RCS engines to CM RCS engines. b. Removes power from translation control as far as automatic translation maneuvers are concerned.	REACTION CONTROL SYSTEM RCS LOGIC MNA (Panel 8)	EPS GROUP 5 MNA (Panel 229)	Three-position switch, spring-loaded to center position. Switch provides manual backup for automatic transfer function, or allows transfer prior to automatic separation sequence.
			(CENTER)	Enables SECS automatic control of motor switch.			Main bus A for RCS transfer motor S1 and main bus B for RCS transfer motor S2.
			SM	Energizes motor switch, transferring all inputs from CM RCS engines to SM RCS engines.	REACTION CONTROL SYSTEM RCS LOGIC MNB (Panel 8)	EPS GROUP 5 MNB (Panel 229)	Must be in this position to start SM jettison controller at CM-SM separation.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S45	RCS	CM RCS PRPLNT 1				
			(OPEN)	Energizes the CM RCS 1 propellant isolation valves solenoids to magnetically latch fuel and oxidizer isolation valves to the open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			(CENTER)	Removes power from the CM RCS 1 propellant isolation valves solenoids, and valves remain in last commanded position (open or closed).			
			OFF	Energizes the CM RCS 1 propellant isolation valves solenoids to unlatch the valves. Spring pressure and propellant pressure closes valves.			
2	S46	RCS	CM RCS PRPLNT 2				
			(OPEN)	Energizes the CM RCS 2 propellant isolation valves solenoids to magnetically latch fuel and oxidizer isolation valves to the open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
			(CENTER)	Removes power from the CM RCS 2 propellant isolation valves solenoids, and valves remain in last commanded position (open or closed).			
			...continued	...continued	...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S46 (Cont)	RCS	OFF	Energizes the CM RCS 2 propellant isolation valves solenoids to unlatch the valves. Spring pressure and propellant pressure closes valves.			
2	S47	RCS	SM RCS (QUAD PROPELLANT) A OPEN	Energizes two fuel and two oxidizer propellant isolation valves to open position and are magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	Switch controls four isolation valves (two fuel and two oxidizer) within this SM RCS quad. Switch is a three-position toggle switch, spring loaded, allowing it to return to center position after placing it to OPEN or CLOSE position. Each valve contains microswitch which completes circuit for operating valve position event indicator. OPEN position in prelaunch.
			(CENTER)	Removes solenoid excitation. Valve remains in last commanded position.			
			CLOSE	Energizes two fuel and two oxidizer propellant isolation valves to closed position and spring pressure and propellant pressure closes valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S48	RCS	SM RCS (QUAD PROPELLANT) B				
			OPEN	Energizes two fuel and two oxidizers propellant isolation valves to open position and are magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	Switch controls four isolation valves (two fuel and two oxidizer) within this SM RCS quad. Switch is a three-position toggle switch, spring loaded, allowing it to return to center position after placing it to OPEN or CLOSE position. Each valve contains microswitch which completes circuit for operating valve position event indicators. OPEN position in prelaunch.
			(CENTER)	Removes solenoid excitation; valve remains in last commanded position.			
			CLOSE	Energizes two fuel and two oxidizer propellant isolation valves to closed position and spring pressure and propellant pressure closes valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S49	RCS	SM RCS (QUAD PROPELLANT) C				
			OPEN	Energizes two fuel and two oxidizer propellant isolation valves to open position and are magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	Switch controls four isolation valves (two fuel and two oxidizer) **within this SM RCS quad.** Switch is a three-position toggle switch spring loaded, allowing it to return to center position after placing it to OPEN or CLOSE position. Each valve contains microswitch which completes circuit for operating valve position event indicator. OPEN position in prelaunch.
			(CENTER)	Removes solenoid excitation; valve remains in last commanded position.			
			CLOSE	Energizes two fuel and two oxidizer propellant isolation valves to closed position and spring pressure and propellant pressure closes valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S50	RCS	SM RCS (QUAD PROPELLANT) D				
			(OPEN)	Energizes two fuel and two oxidizer propellant isolation valves to open position and are magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	Switch controls four isolation valves (two fuel and two oxidizer) within this SM RCS quad. Switch is a three-position toggle switch, spring loaded, allowing it to return to center position after placing it to OPEN or CLOSE position. Each valve contains micro-switch which completes circuit for operating valve position event indicator. OPEN position in prelaunch.
			(CENTER)	Removes solenoid excitation; valve remains in last commanded position.			
			CLOSE	Energizes two fuel and two oxidizer propellant isolation valves to closed position and spring pressure and propellant pressure closes valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S51	ECS	SUIT CIRCUIT				
			H_2O ACCUM				
			AUTO 1	a. Removes d-c power from SUIT H_2O ACCUM-ON 1/ON 2 switch (Panel 2). b. Applies d-c power to No. 1 cyclic accumulator control unit to automatically time and actuate No. 1 cyclic accumulator valve for 10 seconds every 10 minutes.	ENVIRONMENTAL CONTROL SYSTEM H_2O ACCUM MNA (Panel 5)	DC main bus A	In automatic mode, 10-second pulse signal for accumulator operation is received from CTE.
			OFF	a. Remove d-c power from No. 1 and No. 2 cyclic accumulator control units. Applies d-c power to ON 1/ON 2 switch. b. Applies d-c power to H_2O ACCUM-ON 1/ON 2 switch, permitting manual control of No. 1 or No. 2 cyclic accumulator valves.	ENVIRONMENTAL CONTROL SYSTEM H_2O ACCUM MNA & MNB (Panel 5)	DC main buses A & B	Switch position selects manual backup mode, permitting manual cyclic accumulator valve actuation in event both cyclic accumulator automatic control units should fail.
			AUTO 2	a. Removes d-c power from H_2O ACCUM-ON 1/ON 2 switch. b. Applies d-c power to No. 2 cyclic accumulator control unit to automatically time and actuate No. 2 cyclic accumulator valve for 10 seconds every 10 minutes.	ENVIRONMENTAL CONTROL SYSTEM H_2O ACCUM MNB (Panel 5)	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S52	ECS	SUIT CIRCUIT				
			H_2O ACCUM				
			1 ON	Back-up switch position to apply d-c power to solenoid valve of No. 1 cyclic accumulator, manually controlling oxygen flow to accumulator.	ENVIRON-MENTAL CONTROL SYSTEM H_2O ACCUM MNA (Panel 5)	DC main bus A	Switch position is momentary to preclude possibility of expending oxygen needlessly. Switch may be operated when convenient or when suit circuit humidity level becomes uncomfortable.
			OFF	Removes power from both solenoid valves, shutting off oxygen flow to either accumulator.			
			2 ON	Back-up switch position to apply d-c power to solenoid valve to No. 2 cyclic accumulator, manually controlling oxygen flow to accumulator.	ENVIRON-MENTAL SYSTEM H_2O ACCUM MNB (Panel 5)	DC main bus B	This switch position is momentary to preclude possibility of expending oxygen needlessly. Switch may be operated when convenient or when suit circuit humidity level becomes uncomfortable.
2	S53	ECS	SEC COOLANT LOOP				
			EVAP	Supplies 115-vac 1Ø power to secondary glycol evaporator temperature control.	ECS SECONDARY COOLANT LOOP - AC1 (Panel 5)	AC bus 1 ØA	
			OFF	Removes power from control.			
			RESET	Supplies 115-vac 1Ø power to motor of secondary glycol evaporator back-pressure control valve to drive valve closed.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S54	ECS	SEC COOLANT LOOP				
			PUMP				
			AC1	Supplies 200-vac 3Ø power to secondary coolant loop pump from a-c bus 1.	ECS SECONDARY COOLANT LOOP - AC1 (Panel 5)	AC bus 1	
			OFF	Removes power from pump.			
			AC2	Supplies 200-vac 3Ø power to secondary coolant loop pump from a-c bus 2.	ECS SECONDARY COOLANT LOOP - AC2 (Panel 5)	AC bus 2	
2	S56	ECS	H_2O QTY IND				
			POT	Selects potable water tank quantity signal for display on WATER QUANTITY indicator.	INSTRUMENTATION POWER CONTROL CB1 (Panel 276)	DC main buses A and B	WATER - QUANTITY indicator is shared by two quantity signals.
			WASTE	Select waste water tank quantity signal for display on WATER QUANTITY indicator.			
2	S57	ECS	SUIT CIRCUIT				
			HEAT EXCH				
			ON	Applies power to drive the SUIT HT EXCH PRIMARY GLYCOL VALVE to the FLOW position, allowing glycol to flow through suit heat exchanger.	ECS GLYCOL PUMPS AC1 ØA (Panel 4)	AC bus 1	Valve can be manually operated on Panel 382.
			OFF	Removes power.			
			BYPASS	Applies power to drive valve to opposite position, thereby bypassing the glycol around the heat exchanger.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S58	ECS	GLYCOL EVAP				
			H_2O FLOW				
			AUTO	a. Applies a-c power to steam press/wetness control unit. b. Closes circuit from control unit to water control valve for automatically regulating water inflow to water-glycol evaporator.	ECS-GLYCOL PUMPS-AC2, ØA (Panel 4)	AC bus 2	
			OFF	Removes one source of a-c power from control unit and interrupts d-c power to water control valve.			Water control valve is solenoid-operated.
			ON	Manual backup mode to apply d-c power to solenoid-operated water control valve, which opens valve and permits water to enter water-glycol evaporator.	ECS H_2O/ URINE DUMP HTR MNA (Panel 5)		Switch position is momentary. Close coordination between switch actuation and GLY EVAP-OUTLET TEMP indicator (Panel 2) is necessary to obtain correct water-glycol temperature and/or to prevent flooding evaporator.
2	S59	ECS	GLYCOL EVAP				
			STEAM PRESS				
			AUTO	a. Removes a-c power from GLYCOL EVAP-STEAM PRESS-INCR/DECR switch (Panel 2). b. Applies a-c power to steam pressure/wetness control unit. c. Closes circuit from control section to steam pressure control valve to automatically regulate steam pressure in evaporator.	ECS-GLYCOL PUMPS-AC2 ØA (Panel 4)	AC bus 2	Steam pressure control valve full travel required 58 seconds (max).
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S59 (Cont)	ECS	MAN	a. Removes one source of a-c power from steam pressure/wetness control unit. b. Opens circuit from control section to steam pressure control valve. c. Applies a-c power to GLYCOL EVAP-STEAM PRESS-INCR/DECR switch.			Switch position selects manual backup mode, permitting manual operation of steam pressure control valve actuator in event of steam pressure controller malfunction.
2	S60	ECS	GLYCOL EVAP				
			STEAM PRESS				
			INCR	Applies a-c power to actuator of steam pressure control valve, which moves valve in closed direction and increases steam pressure.	ECS-GLYCOL PUMPS-AC1 ØC (Panel 4)	AC bus 1	Switch position is momentary. Until motor-driven steam pressure control valve reaches its maximum limit, short periods of switch activation result in proportional increases in steam pressure. Valve full travel requires 58 seconds (max).
			OFF	Removes a-c power from valve actuator.			
			DECR	Applies a-c power to actuator of steam pressure control valve, which moves valve in open direction and decreases steam pressure.			Switch position is momentary. Until motor-driven steam pressure control valve reaches its maximum limit, short periods of switch activation result in proportional decreases in steam pressure. Valve full travel requires 58 seconds (max).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S61	ECS	GLYCOL EVAP				
			TEMP IN				
			AUTO	Applies a-c power to water-glycol temperature control unit, which automatically regulates temperature of coolant entering evaporator by mixing hot and cold water-glycol.	ECS-GLYCOL PUMPS-AC1 ØA (Panel 4)	AC bus 1	Temperature control unit sensor is located at inlet to water-glycol evaporator. Water-glycol evaporator temperature control valve full travel requires 37.5 seconds (max).
			MAN	Removes a-c power from water-glycol temperature control unit, permitting manual override operation of GLYCOL EVAP TEMP IN valve (Panel 382).			Manual control of water-glycol evaporator temperature control valve is required during docked operations, or in event of failure of automatic control unit. Close coordination between valve adjustments and GLY EVAP-OUTLET TEMP indicator (Panel 2) may be necessary to obtain correct water-glycol temperature.
2	S63	SEQ	ABORT SYSTEM				
			PRPLNT				
			DUMP AUTO	Enables SECS circuits to automate requirements of mode 1A abort.	SEQ EVENTS CONT SYS - LOGIC A BAT A LOGIC B BAT B (Panel 8)	EPS BAT bus A and B (Panel 229)	Requirements peculiar to mode 1A aborts are: (1) Ignition of pitch control motor. (2) Automatic dumping of CM RCS propellants and pressurant.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S63 (Cont)	SEQ	RCS CMD	Enables SECS circuits to automate requirements of any abort, other than mode 1A, or for a normal mission.			Time delay relay logic (T +61 seconds), together with manually switching to RCS CMD position makes configuration change in SECS circuits.
2	S64	SEQ	ABORT SYSTEM				Relays located in the SIVB IU.
			2 ENG OUT				
			AUTO	Enables EDS for a two-engine out automatic abort capability by de-energizing two-engine out auto abort deactivate relays.	N/A	LV-IU batteries	
			OFF	Disables EDS for a two-engine out automatic abort capability by energizing two-engine out auto abort deactivate relays.			The two-engine out AUTO abort capability is also inhibited by programming in the IU prior to staging.
2	S65	SEQ	ABORT SYSTEM				Relays located in the SIVB IU.
			LV RATES				
			AUTO	Enables EDS for excessive rates automatic abort capability by de-energizing excessive rates auto abort deactivate relays.	N/A	LV-IU battery buses	
			OFF	Disables EDS for excessive rates automatic abort capability by energizing excessive rates auto abort deactivate relays.			Excessive rates auto abort capability is also inhibited by programming in the IU prior to staging.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S66	SEQ	ABORT SYSTEM				
			TWR JETT 1	Energizes relays which initiate tower jettison motor ignition and actuates tower separation system.	N/A	a. MESC LOGIC buses A and B b. EDS change-over bus when EDS POWER switch is (ON) (Panel 7)	Three-position toggle switch with a maintain position to AUTO and to OFF and TWR JETT position is momentary being spring-loaded to OFF position. After LES tower has been manually jettisoned, switch will spring back to neutral OFF position.
			OFF	In off position, tower jettison and physical monitor circuits are disabled.			
			AUTO	Provides the capability for an automatic tower jettison subsequent to any LES abort.			Once tower is jettisoned SECS is automatically placed in SPS abort mode by relay logic.
2	S67	SEQ	EDS				
			AUTO	Provides a current path for lift-off signal to energize automatic abort enable relays.	EDS 1 & 3 BAT A & B (Panel 8)	EPS BAT bus A and B (Panel 229)	
			OFF	Disables automatic abort capability.			
2	S69	G&N	LV GUIDANCE				
			IU	Normal position for this switch. Allows Saturn guidance system to function normally and control flight of spacecraft.			
			CMC	Will initiate Saturn guidance takeover mode of PGNCS.	GUIDANCE/ NAVIGATION IMU MNA & MNB (Panel 5) G/N POWER IMU SWITCH	DC main buses A and B	CMC provides guidance only if IU has LV guidance failure during boost phase of mission.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S71	SEQ	MAIN RELEASE				
			(UP)	Releases main parachutes from command module.	SEQ EVENTS CONT SYS LOGIC A BAT A & LOGIC B BAT B (Panel 8)	EPS BAT bus A and B (Panel 229) For PYRO POWER see CB48 Panel 229	Switch is electrically enabled when 10,000-foot baro switches close and 14-second time delay has expired during normal descent and will release parachutes when actuated. Switch should never be moved to up (release) position until after splash-down. Switch is spring-loaded to down position.
2	S79	C/W	CAUTION/WARNING				
			LAMP TEST				
			1	Momentary position, tests illumination of left-hand group of status lights on Panel 2 and MASTER ALARM switchlight on Panel 1.	C/W MNA & MNB (Panel 5)	DC main buses A and B	NOTE: MASTER ALARM light on Panel 122 is tested by placing CONDITION LAMPS switch on Panel 122 to TEST.
			(CENTER)	Normal operating position.			Switch provides capability to test lamps of system status and MASTER ALARM lights.
			2	Momentary position, tests illumination of right-hand group of status lights on Panel 2 and MASTER ALARM switchlight on Panel 3.			
2	S84	ECS	ECS RADIATORS				
			FLOW CONT				
			AUTO	Places radiator flow proportioning control in AUTO mode.	ENVIRON-MENTAL CONTROL SYS-TEM PRIM RAD CONTROL MNA & MNB (Panel 5)	DC main bus A	ECS RADIATOR CONTROLLER AC1 and AC2 circuit breakers supply a-c power for system operation.
			1	Selects No. 1 flow proportioning control.			
			2	Selects No. 2 flow proportioning control.		DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S85	ECS	ECS RADIATORS FLOW CONT PWR (CENTER) MAN SEL MODE	 Applies power to AUTO switch. No function. Applies power to MAN SEL switch.	ENVIRON-MENTAL CONTROL SYS-TEM PRIM RAD CONTROL MNA & MNB (Panel 5)	DC main buses A and B DC main bus B	Supplies power for flow proportioning control. Supplies power for radiator panel isolation.
2	S86	ECS	ECS RADIATORS MAN SEL RAD 1 (CENTER) RAD 2	 Closes RAD 2 isolation valves. Closes RAD 1 and RAD 2 isolation valves. Closes RAD 1 isolation valves.	ENVIRON-MENTAL CONTROL SYS-TEM PRIM RAD CONTROL MNB (Panel 5)	DC main bus B	Circuit breakers ECS PRIMARY RADIATOR CONTROL AC1 and AC2 supply a-c power for valve operation. MAN-SEL switch controls four, d-c operated solid state switches for switching a-c power to valve motors.
2	S87	ECS	ECS RADIATORS HEATER PRIM 1 (OFF) PRIM 2	 Selects primary heater controller No. 1 Disables heater controllers. Selects primary heater controller No. 2.	ENVIRON-MENTAL CONTROL SYS-TEM PRIM RAD CONTROL MNA & MNB (Panel 5)	DC main bus B DC main bus A	ECS PRIMARY RADIATOR CON-TROL MNB supplies power to primary inlet temper-ature sensor through HEATER-PRIM switch in all positions.
2	S88	ECS	ECS RADIATORS HEATER SEC OFF	 Selects secondary heater controller. Disables secondary heater controller.	ECS SECONDARY COOLANT LOOP HTR CONTR MNA (Panel 5)	DC main bus A	ECS PRIMARY RADIATOR CONTROL MNB supplies power to secondary radiator inlet, and outlet, temper-ature sensors through HEATER-SEC switch in both positions.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S89	ECS	ECS INDICATORS				
			PRIM	Selects primary ECS displays: a. ECS RADIATOR TEMP INLET b. GLYCOL EVAPORATOR STEAM PRESS c. GLYCOL DISCH PRESS d. GLYCOL ACCUM QUANTITY e. GLYCOL EVAPORATOR OUTLET TEMPERATURE	N/A	N/A	Switches output of primary and secondary transducers to shared indicators.
			SEC	Selects secondary ECS displays: a. GLYCOL EVAPORATOR OUTLET TEMPERATURE b. ECS RADIATOR TEMP INLET c. GLYCOL EVAPORATOR STEAM PRESS d. GLYCOL DISCH PRESS e. GLYCOL ACCUM QUANTITY			
2	S96	SEQ	ABORT SYSTEM				
			TWR JETT 2	Energizes the relays which initiate tower jettison motor ignition and actuates tower separation system.	N/A	a. MESC LOGIC buses A and B b. EPS changeover bus when the EDS POWER switch is ON (Panel 7)	Three-position toggle switch with a maintain position to AUTO and to OFF and TWR JETT position is momentary being spring-loaded to OFF position. After LES tower has been manually jettisoned, switch will spring back to neutral OFF position. Once tower is jettisoned the SECS is automatically placed in SPS abort mode by relay logic.
			OFF	In the off position, tower jettison and physical monitor circuits are disabled.			
			AUTO	Provide capability for an automatic tower jettison subsequent to any LES abort.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S98	RCS	RCS IND				
			MANF PRESS	Allows PSM propellant fuel and oxidizer manifold pressure information to be supplied to RCS INDICATORS rotary select switch in SM QUAD positions A, B, C, D, or PSM 1, 2 (if installed) positions, thus SM RCS FUEL-MANF-OXID meters.	N/A	N/A	
			TK PRESS/QTY	a. Allows SM RCS quad A, B, C or D propellant quantity information to be supplied to RCS INDICATORS rotary select switch in SM QUAD A, B, C, D positions and thus SM RCS QTY meter. b. Allows PSM 1, 2 (if installed) propellant quantity information to be supplied to RCS INDICATORS rotary select switch in PSM 1, 2 position and thus SM RCS QTY meter. c. Allows SM RCS quad A, B, C, D secondary fuel pressure information to be supplied to RCS INDICATORS rotary switch in SM RCS QUAD A, B, C, D positions and thus SM RCS FUEL TK PRESS meter. d. Allows PSM 1, 2 (if installed) fuel tank pressure information to be supplied to RCS INDICATORS rotary switch in PSM 1, 2 position and thus SM RCS FUEL TK PRESS meter.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S100	MISC	MSN TIMER				
			START	Starts mission timer.	TIMERS MNA (Panel 5)	DC main bus A	Upon receipt of lift-off signal, timer will reset to zero and start counting up with switch in START position. Timer may be stopped at anytime by selecting STOP. To reset timer, momentarily hold switch to RESET position.
			STOP	Stops mission timer.			
			RESET	Resets mission timer.			
2	S101	MISC	MISSION TIMER				
			HOURS				
			TENS	Changes HOURS numerical readout in tens and hundreds.	TIMERS MNA (Panel 5)	DC main bus A	Mission timer can only slew up to add time.
			(CENTER)	No function.			
			UNITS	Changes HOURS numerical readout in units.			
2	S102	MISC	MISSION TIMER				
			MIN				
			TENS	Changes MIN numerical readout in tens.	TIMERS MNA (Panel 5)	DC main bus A	
			(CENTER)	No function.			
			UNITS	Changes MIN numerical readout in units.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S103	MISC	MISSION TIMER				
			SEC				
			TENS	Changes SEC numerical readout in tens.	TIMERS MNA (Panel 5)	DC main bus A	
			(CENTER)	No function.			
			UNITS	Changes SEC numerical readout in units.			
2	S109	SEQ	DOCK RING SEP				
			1	Switch initiates both systems for abandonment or jettison of the docking ring subsequent to SPS abort.	SEQ EVENTS CONT SYS ARM A BAT A ARM B BAT B (Panel 8)	Battery buses A and B	Toggle switch spring-loaded to the down position.
2	S110	SEQ	CM/SM SEP				
			1	Switch activates systems A and B to perform the following functions: a. CM-SM deadface b. CM-RCS pressurize c. CM-SM separation d. CM-SM separation pyro control cutout e. RCS control transfers (providing CM-RCS LOGIC is in CM-RCS LOGIC) f. SM jettison controller start	ELS/CM-SM SEP BAT A and BAT B (Panel 8)	Battery buses A and B	Toggle switch spring-loaded to down position.
			(DOWN)	No function.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S111	SEQ	CM/SM SEP 2	Switch activates systems A and B to perform the following functions: a. CM-SM deadface b. CM-RCS pressurize c. CM-SM separation d. CM-SM separation pyro control cutout e. RCS control transfers (providing CM-RCS LOGIC is in CM-RCS LOGIC) f. SM jettison controller start.	ELS CM-SM SEP BAT A and BAT B (Panel 8)	EPS BAT bus A and B (Panel 229)	Toggle switch spring-loaded to down position.
			(DOWN)	Off position.			
2	S112	SEQ	DOCK RING SEP 2	Switch initiates both systems for abandonment or jettison of the docking ring subsequent to SPS abort.	SEQ EVENTS CONT SYS ARM B BAT B and A-BAT A (Panel 8)	EPS BAT bus A and B (Panel 229)	Toggle switch spring-loaded to the down position.
2	S114	MISC	SPOT LIGHT OFF	Removes power.	LIGHTING COAS/TUNNEL SPOT DOOR MNB (Panel 226)	DC main bus B	3 position toggle switch; center and top are OFF. Center position preferable for use as OFF position.
			(OFF)	Removes power.			
			ON	Applies power to exterior spotlight and exterior door release actuator.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S116	RCS	SM RCS QUAD SEC FUEL PRESS A				
			OPEN	Energizes quad A secondary fuel pressure valve solenoid to open position and magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	Open in prelaunch to pressurize secondary fuel tank to system regulated pressure, then closed. Will be opened in flight when primary propellant fuel tank has expended its fuel supply allowing pressure in fuel manifold to drop, triggering SM RCS A caution/warning light, along with SEC PRPLNT FUEL pressure readout on panel 2, informing crew to open SEC PRPLNT FUEL PRESS valve allowing tank to remain pressurized for duration.
			(CENTER)	Removes solenoid excitation; valve remains in last commanded position.			
			CLOSE	Energizes secondary propellant fuel pressure valve solenoid to closed position; spring pressure and helium pressure closes valve.			
2	S117	RCS	SM RCS QUAD SEC FUEL PRESS B				
			OPEN	Energizes B quad secondary fuel pressure valve solenoid to open position and magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	Open in prelaunch to pressurize secondary fuel tank to system regulated pressure, then closed. Will be opened in flight when primary propellant fuel tank has expended its fuel supply allowing pressure in fuel manifold to drop, triggering SM RCS
			(CENTER)	Removes solenoid excitation; valve remains in last commanded position.			
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S117 (Cont)	RCS	CLOSE	Energizes secondary propellant fuel pressure valve solenoid to closed position; spring pressure and helium pressure closes valve.			B caution/warning light along with SEC PRPLNT FUEL pressure readout on Panel 2, informing crew to open SEC PRPLNT FUEL PRESS valve allowing tank to remain pressurized for duration.
2	S118	RCS	SM RCS QUAD SEC FUEL PRESS C				
			OPEN	Energizes C quad secondary fuel pressure valve solenoid to open position and magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	Open in prelaunch to pressurize secondary fuel tank to system regulated pressure, then closed. Will be opened in flight when primary propellant fuel tank has expended its fuel supply allowing pressure in fuel manifold to drop, triggering SM RCS C caution/warning light, along with SEC PRPLNT FUEL pressure readout on Panel 2, informing crew to open SEC PRPLNT FUEL PRESS valve allowing tank to remain pressurized for duration.
			(CENTER)	Removes solenoid excitation; valve in last commanded position.			
			CLOSE	Energizes secondary propellant fuel pressure valve solenoid to closed position; spring pressure and helium pressure closes valve.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S119	RCS	SM RCS QUAD SEC FUEL PRESS D				
			OPEN	Energizes D quad secondary fuel pressure valve solenoid to open position and magnetically latched open.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	Open in prelaunch to pressurize secondary fuel tank to system regulated pressure, then closed. Will be opened in flight when primary propellant fuel tank has expended its fuel supply allowing pressure in fuel manifold to drop, triggering SM RCS D caution/warning light, along with SEC PRPLNT FUEL pressure readout on Panel 2, informing crew to open SEC PRPLNT FUEL PRESS valve allowing tank to remain pressurized for duration.
			(CENTER)	Removes solenoid excitation; valve remains in last commanded position.			
			CLOSE	Energizes secondary propellant fuel pressure valve solenoid to closed position; spring pressure and helium pressure closes valve.			
2	S120	C/W	C/W MEMORY				
			RECALL	Momentary position illuminates appropriate C&W lamp (Panel 2) by signal stored in memory.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Six C/W signals are monitored by memory unit 1. FC1 2. FC3 3. CRYO PRESS 4. O_2 TK1 HTR TEMP 5. O_2 TK2 HTR TEMP 6. GLYCOL FLOW LOW
			(CENTER)	Allows memory unit to accept and store up to ten out of tolerance C/W occurrences (transient or sustained).			
			RESET	Momentary position enables memory power supply and clears all signals put into memory unit.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S121	ECS	SEC EVAP H_2O FLOW				
			AUTO	Permits signals from automatic controller to actuate the evap water control secondary valve.			EVAP WATER CONTROL, SECONDARY selector valve (Panel 382) must be in AUTO position to obtain water flow in either automatic or manual modes.
			OFF	Interrupts power to water control valve.			
			ON	Opens EVAP WATER CONTROL SECONDARY solenoid valve	ECS H_2O ACCUM MNB (Panel 5)	DC main bus B	
2	S124	RCS	SM RCS PSM PRPLNT				
			A				
			OPEN	Energizes PSM quad A fuel and oxidizer isolation valves solenoids to magnetically latch fuel and oxidizer isolation valves to the open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	PSM quad A fuel and oxidizer manifold isolation valves, when open, allow propellant from applicable PSM to quad A. These valves are normally closed.
			(CENTER)	Removes power from the PSM quad A isolation valves and valves remain in the last commanded position (open or closed).			
			CLOSED	Energizes PSM quad A isolation valves solenoids to unlatch the valves. Spring pressure and propellant pressure closes the valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S125	RCS	SM RCS PSM PRPLNT B				
			OPEN	Energizes PSM quad B fuel and oxidizer isolation valves solenoids to magnetically latch fuel and oxidizer isolation valves to the open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	PSM quad B fuel and oxidizer manifold isolation valves, when open, allow propellants from the applicable PSM to quad B. These valves are normally closed.
			(CENTER)	Removes power from the PSM quad B isolation valves and valves remain in the commanded position (open or closed).			
			CLOSED	Energizes PSM quad B isolation valves solenoids to unlatch the valves. Spring pressure and propellant pressure closes the valves.			
2	S126	RCS	SM RCS PSM PRPLNT C				
			OPEN	Energizes PSM quad C fuel and oxidizer isolation valves solenoids to magnetically latch fuel and oxidizer isolation valves to the open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	PSM quad C fuel and oxidizer manifold isolation valves, when open, allow propellant from applicable PSM to quad C. These valves are normally closed.
			(CENTER)	Removes power from the PSM quad C isolation valves and valves remain in the last commanded position (open or closed).			
			CLOSED	Energizes PSM quad C isolation valves solenoids to unlatch the valves. Spring pressure and propellant pressure closes the valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S127	RCS	SM RCS PSM PRPLNT D				
			OPEN	Energizes PSM quad D fuel and oxidizer isolation valves solenoids to magnetically latch fuel and oxidizer isolation valves to the open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	PSM quad D fuel and oxidizer manifold isolation valves, when open, allow propellants from the applicable PSM to quad D. These valves are normally closed.
			(CENTER)	Removes power from the PSM quad D isolation valves and valves remain in the commanded position (open or closed)			
			CLOSED	Energizes PSM quad D isolation valves solenoids to unlatch the valves. Spring pressure and propellant pressure closes the valves.			
2	S128	RCS	SM RCS PSM 1 He				
			OPEN	Energizes the two helium isolation valves solenoids to magnetically latch helium valves to open position.	REACTION CONTROL SYSTEM PRPLNT ISOL MNB (LV5), MNA (LV6) (Panel 8)	EPS GROUP 1 MNB (Panel 229) (PSM 1 helium LV5)	
			(CENTER)	Removes power from the two helium isolation valve solenoids and valves remain in last commanded position (open or closed).		EPS GROUP 1 MNA (Panel 229) (PSM 1 helium LV6)	
			CLOSE	Energizes the two helium isolation valves solenoids to unlatch magnetic latch. Spring pressure and helium pressure close the valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S129	RCS	SM RCS PSM 1				
			MANF ISOL				
			OPEN	Energizes the two PSM manifold isolation fuel and two PSM oxidizer isolation valves solenoids to magnetically latch valves in open position.	REACTION CONTROL SYSTEM PRPLNT ISOL (LV3, LV4) MNA (LV7, LV8) MNB (Panel 8)	EPS GROUP 1 MNA (Panel 229) (PSM 1 manifold isolation fuel LV3, oxidizer LV4)	
			(CENTER)	Removes power from the two PSM manifold isolation fuel and two manifold isolation oxidizer isolation valves, and valves remain in last commanded position (open or closed).		EPS GROUP 1 MNB (Panel 229) (PSM 1 manifold isolation fuel LV8, oxidizer LV7)	
			CLOSE	Energizes the two PSM fuel and two PSM manifold isolation oxidizer isolation valves solenoids to unlatch magnetic latch. Spring pressure and propellant pressure close valves.			
2	S130	RCS	SM RCS PSM 2				
			He				
			OPEN	Energizes the two helium isolation valves solenoids to magnetically latch helium valves to open position.	REACTION CONTROL SYSTEM PRPLNT ISOL (LV6) MNA (LV5) MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229) (PSM 2 helium LV5)	S130 is not shown on Panel 2, if installed this function is applicable.
			(CENTER)	Removes power from the two helium isolation valve solenoids and valves remain in last commanded position (open or closed).		EPS GROUP 1 MNA (Panel 229) (PSM 2 helium LV6)	
			CLOSE	Energizes the two helium isolation valve solenoids to unlatch the magnetic latch. Spring pressure and helium pressure close valves.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	S131	RCS	SM RCS PSM 2 MANF ISOL				
			OPEN	Energizes the two PSM manifold isolation fuel and two PSM oxidizer isolation valve solenoids to magnetically latch valves in open position.	REACTION CONTROL SYSTEM PRPLNT ISOL (LV3, LV4) MNA (LV7, LV8) MNB (Panel 8)	EPS GROUP 1 MNA (Panel 229) (PSM 2 manifold isolation fuel LV3, oxidizer LV4)	S131 is not shown on Panel 2; if installed this function is applicable.
			(CENTER)	Removes power from the two PSM manifold isolation fuel and two manifold isolation oxidizer isolation valves, and valves remain in last commanded position (open or closed).		EPS GROUP 1 MNB (Panel 229) (PSM 2 manifold isolation fuel LV8, oxidizer LV7)	
			CLOSE	Energizes the two PSM fuel and two PSM manifold isolation oxidizer isolation valve solenoids to unlatch magnetic latch. Spring pressure and propellant pressure close valves.			
2	S135	EPS	SM H_2O TANK				
			OPEN	Opens inlet valve to allow fuel cell water into H_2O tank located in SM.	ENVIRONMENTAL CONTROL SYSTEM H_2O URINE DUMP HTR MNA (Panel 5)	DC main bus A	
			CLOSE	Allows valve to close.			Spring actuated to close.
2	VI	ECS	POST LDG VENT VALVE UNLOCK				
			PULL	Allows inlet and outlet valves to be electrically opened.	N/A	N/A	Ball-lock device in handle deters inadvertant actuation.
				Note: All the following C/W status lamps should be limited to 10 minutes of on time (on the ground only) to prevent overheating.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS1A1	C/W	BMAG 1 TEMP	Light illuminates when temperature of any gyro in GA1 exceeds limits of 170°±2°F.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. BMAG POWER 1 switch must be in WARM UP or ON position for light to operate (Panel 7). Lamp inhibited when C/W INPUTS switch (Panel 201) 10A in INHIBIT position.
2	XDS1B1	C/W	BMAG 2 TEMP	Light illuminates when temperature of any gyro in GA2 exceeds limits of 170°±2°F.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. BMAG POWER 2 switch must be in WARM UP or ON position for light to operate (Panel 7). Lamp inhibited when C/W INPUTS switch (Panel 201) 10B in INHIBIT position.
2	XDS1C1	C/W	Not assigned.				
2	XDS1D1	C/W	CO_2 PP HI	Light illuminates when CO_2 partial pressure exceeds 7.6 mm Hg.	C/W MNA & MNB (Panel 5)	DC main buses A and B	
2	XDS2E1	C/W	Not assigned.				
2	XDS2F1	C/W	FC1	Indicates one of the following conditions exist in FC1: a. pH factor of 9 or over. b. FC skin temperature below 360°F or above 475°F. c. FC condenser exhaust temperature below 150°F or above 175°F. d. H_2 or O_2 reactant valve closed.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Event indicator (elec/mech) PH HI (Panel 3) also activated. Talkback indicator FUEL CELL REACTANTS (Panel 3) also activated.
2	XDS2G1	C/W	Not assigned.				
2	XDS2H1	C/W	FC3	Indicates one of the following conditions exist in FC3. a. pH factor of 9 or over. b. FC skin temperature below 360°F or above 475°F. c. FC condenser exhaust temperature below 150°F or above 175°F. d. H_2 or O_2 reactant valve closed.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Event indicator (elec/mech) PH HI (Panel 3) is also activated. Talkback indicator FUEL CELL REACTANTS (Panel 3) also activated.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS1A2	C/W	PITCH GMBL 1	Indicates overcurrent has occurred in primary drive motor of pitch gimbal actuator.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. Overcurrent condition dependent on time and temperature.
2	XDS1B2	C/W	YAW GMBL 1	Indicates overcurrent has occurred in primary drive motor of yaw gimbal actuator.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. Overcurrent condition dependent on time and temperature.
2	XDS1C2	C/W	O_2 TK 1 HTR TEMP	Indicates O_2 tank 1 heater temp above +350°F.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light.
2	XDS1D2	C/W	O_2 TK 2 HTR TEMP	Indicates O_2 tank 2 heater temp above +350F.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light.
2	XDS2E2	C/W	Not assigned.				
2	XDS2F2	C/W	INV 1 TEMP HI	Indicates overtemperature (190°F or more) exists in inverter 1.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light.
2	XDS2G2	C/W	Not assigned.				
2	XDS2H2	C/W	Not assigned.				
2	XDS1A3	C/W	PITCH GMBL 2	Indicates overcurrent has occurred in secondary d drive motor of pitch gimbal actuator.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. Overcurrent condition dependent on time and temperature.
2	XDS1B3	C/W	YAW GMBL 2	Indicates overcurrent has occurred in secondary drive motor of pitch gimbal actuator.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. Overcurrent condition dependent on time and temperature.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS1C3	C/W	CRYO PRESS	Indicates tank pressures as follows: a. Hydrogen tank 1 or 2 200 psia or below 270 psia or above b. Oxygen tank 1 or 2 800 psia or below 950 psia or above	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light will illuminate if either or both H_2 tanks are above or below proper pressure limits. Pressure in H_2 tanks can be monitored by meters on Panel 2. (CRYOGENIC TANKS-PRESSURE-H_2 1 and 2). Or if either or both O_2 tanks are above or below proper pressure limits. Pressure in O_2 tanks can be monitored by meters on Panel 2. (CRYOGENIC TANKS-PRESSURE-O_2 1 and 2).
2	XDS1D3	C/W	GLYCOL FLOW LOW	Indicates when primary glycol flow from the coldplate network decreases to 130 lbs/hr.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Glycol flow rate transducer range = 130 to 300 lbs/hr. Flow rate is telemetered; low flow event is not.
2	XDS2E3	C/W	SPS PRESS	Indicates oxidizer and/or fuel ullage tank pressure (regulated helium pressures) are not within proper operating range (157 to 200 psia nominal).	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. Continuous pressures are displayed by SPS PRPLNT TANKS - PRESS-FUEL and OXID meters on Panel 3.
2	XDS2F3	C/W	Not assigned.				
2	XDS2G3	C/W	AC BUS 1	Indicates either of the following conditions exists in any of the three phases of AC BUS 1: a. Undervoltage (95 vac or below) b. Overvoltage (130 vac or above) c. Will illuminate with AC BUS 1 overload light.	C/W MNA & MNB (Panel 5)	DC main buses A and B	The yellow AC BUS 1 light will not illuminate when the AC 1 RESET switch (Panel 3) is in the OFF position. Inverters will not be disconnected from buses on undervoltage condition, but will be disconnected from bus on overvoltage.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS2H3	C/W	AC BUS 2	Indicates either of the following conditions exists in any of the three phases of AC BUS 2: a. Undervoltage (95 vac or below). b. Overvoltage (130 vac or above). c. Will illuminate with AC BUS 2 overload light.	C/W MNA & MNB (Panel 5)	DC main buses A and B	The yellow AC BUS 2 light will not illuminate when AC 2 RESET switch (Panel 3) is in the OFF position. Inverters will not be disconnected from buses on undervoltage condition, but will be disconnected from bus on overvoltage.
2	XDS1A4	C/W	CM RCS 1	Indicates over- or under-pressure condition (below 260 psia or above 330 psia nominal) in regulator manifold of system 1.	C/W MNA & MNB (Panel 5)	DC main buses A and B	Yellow light. CM RCS 1 light will not illuminate when CAUTION/WARNING mode switch is in CSM position. RCS INDICATORS select switch (Panel 2) will be utilized in conjunction with the following meter to determine malfunctions within a system: CM RCS - PRESS-MANF Indicates an underpressure condition in regulator manifold prior to pressurization of respective system if C/W mode switch is positioned to CM position prior to complete pressurization.
2	XDS1B4	C/W	CM RCS 2 ...continued	Indicates over- or under-pressure condition (below 260 psia or above 330 psia nominal) in regulator manifold of system 2.	C/W MNA & MNB (Panel 5) ...cont	DC main buses A and B ...cont	Yellow light. CM RCS 2 light will not illuminate when CAUTION/WARNING mode switch is in CSM position. RCS INDICATORS select switch (Panel 2) will be utilized in conjunction with the following meter to determine malfunctions within a system: CM RCS - PRESS-MANF ...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS1B4 (Cont)	C/W					Indicates an underpressure condition in regulator manifold prior to pressurization of respective system if C/W mode switch is positioned to CM position prior to complete pressurization.
2	XDS1C4	C/W	SM RCS PSM 1	PSM 1 fuel tank pressure above 215 psia.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light.
2	XDS1D4	C/W	SM RCS PSM 2	PSM 2 fuel tank pressure above 215 psia.	C/W MNA & MNB (Panel 5)	DC main buses A & B	SM RCS PSM 2 not shown on Panel 2 if installed function description is applicable.
2	XDS2E4	C/W	Not assigned.				
2	XDS2F4	C/W	SM PWR DISCONNECT	Light illuminates when selected SM power source is automatically disconnected from d-c main bus A or B.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. Automatic disconnect due to overload or reverse current.
2	XDS2G4	C/W	AC BUS 1 OVERLOAD	Indicates an overload (3Ø, 27 amps total for 15±5 seconds or 1Ø, 11 amps for 5±1 seconds) exists on AC BUS 1.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. Inverter is automatically disconnected from bus. Will not illuminate when AC 1 RESET switch (panel 3) is in OFF position.
2	XDS2H4	C/W	AC BUS 2 OVERLOAD	Indicates an overload (3Ø, 27 amps total for 15±5 seconds or 1Ø, 11 amps for 5±1 seconds) exists on AC BUS 2.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. Inverter is automatically disconnected from bus. Will not illuminate when AC 2 RESET switch (panel 3) is in OFF position.
2	XDS1A5	C/W	SM RCS A	Indicates one of the following: a. Package temperature below 75°F or above 205°F. b. Secondary fuel pressure (SEC FUEL) below 145 psia or above 215 psia.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. RCS INDICATORS select switch on Panel 2 will be utilized in conjunction with the following meters to determine malfunctions within a RCS quad: SM RCS - TEMP PKG SM RCS - PRESS-SEC FUEL

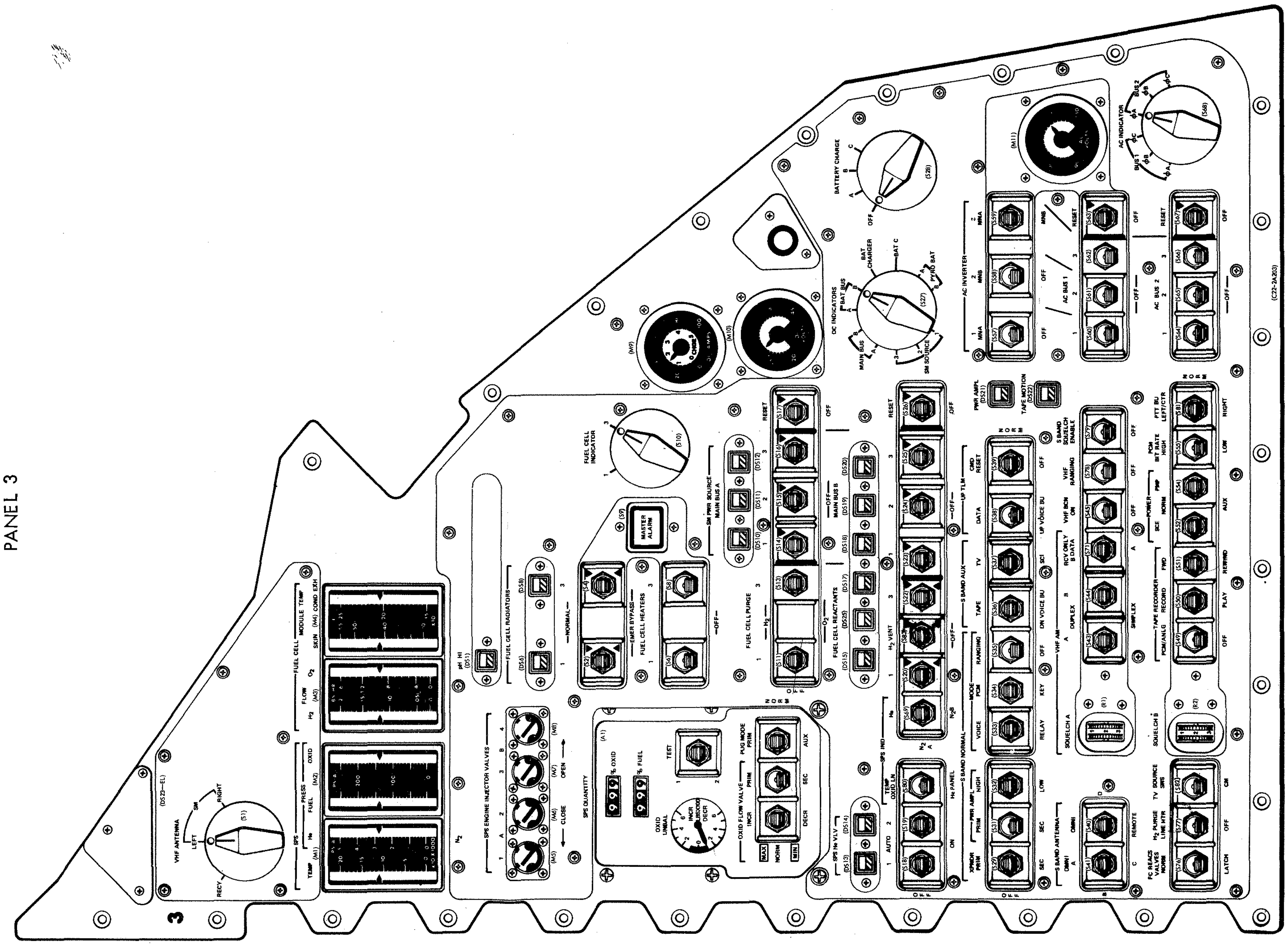
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS1B5	C/W	SM RCS B	Indicates one of the following: a. Package temperature below 75°F or above 205°F. b. Secondary fuel pressure (SEC FUEL) below 145 psia or above 215 psia.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. RCS INDICATORS select switch on Panel 2 will be utilized in conjunction with the following meters to determine malfunctions within a RCS quad: SM RCS - TEMP PKG SM RCS - PRESS-SEC FUEL
2	XDS1C5	C/W	SM RCS C	Indicates one of the following: a. Package temperature below 75°F or above 205°F. b. Secondary fuel pressure (SEC FUEL) below 145 psia or above 215 psia.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. RCS INDICATORS select switch on Panel 2 will be utilized in conjunction with the following meters to determine malfunctions within a RCS quad: SM RCS - TEMP PKG SM RCS - PRESS-SEC FUEL
2	XDS1D5	C/W	SM RCS D	Indicates one of the following: a. Package temperature below 75°F or above 205°F. b. Secondary fuel pressure (SEC FUEL) below 145 psia or above 215 psia.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. RCS INDICATORS select switch on Panel 2 will be utilized in conjunction with the following meters to determine malfunctions within a RCS quad: SM RCS - TEMP PKG SM RCS - PRESS-SEC FUEL
2	XDS2E5	C/W	CMC ...continued	The CMC status light will illuminate if the following occurs: a. Loss of prime power. b. Scaler fail - if scaler stage 17 fails to produce pulses. c. Counter fail - continuous requests or fail to happen following increment request. d. SCADBL - 100 pps scaler stage >200 pps. ...continued	C/W MNA & MNB (Panel 5) ...cont	DC main buses A & B ...cont	Red light. Items e through j will cause restart in the CMC. This will also illuminate the RESTART and PGNS lights on Panel 122. The CMC light on Panel 122 will also be activated. See NOTE XDS1A1. ...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS2E5 (Cont)	C/W		e. Parity fail - accessed word, whose address is octal 10 or greater, contains even number of ones. f. Interrupt - too long or infrequent - 140 ms to 300 ms. g. TC trap - too many TC or TCF instructions or TCF instructions too infrequent. h. Night watchman - computer fails to access address 67 within .64 sec to 1.92 sec. i. V fail - 4v supply >4.4v 4v supply <3.6v 14v supply >16.0v 14v supply <12.5v 28v supply <22.6v j. If oscillator stops. k. Alarm test.			Items c through j will cause CMC to illuminate if the failure occurs at a frequency of >6 per second. Lamp inhibited when C/W INPUTS switch (Panel 201) 10C is in the INHIBIT position.
2	XDS2F5	C/W	CREW ALERT	Activated and deactivated by real time command from MSFN through UDL or by switch 1A on Panel 201.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Red light.
2	XDS2G5	C/W	MN BUS A UNDERVOLT	Indicates transient or sustained d-c voltage drop below 25.60 vdc on DC MAIN BUS A.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. Will not illuminate when MAIN A RESET switch (Panel 3) is in OFF position.
2	XDS2H5	C/W	MN BUS B UNDERVOLT	Indicates transient or sustained d-c voltage drop below 25.60 vdc on DC MAIN BUS B.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Yellow light. Will not illuminate when MAIN B RESET switch (Panel 3) is in OFF position.
2	XDS1A6	C/W	Not assigned.				
2	XDS1B6	C/W	Not assigned.				
2	XDS1C6	C/W	Not assigned.				
2	XDS1D6	C/W	Not assigned.				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS2E6	C/W	ISS	The ISS status light will illuminate if the following occurs: a. IMU fail: 1. IG servo error >2.9 mr for 2 sec. 2. MG servo error >2.9 mr for 2 sec. 3. OG servo error >2.9 mr for 2 sec. 4. 3200 cps <50%. 5. 800 cps wheel supply <50%. b. PIPA fail: 1. No pulse during 312.5 msec period. 2. If both plus and minus pulses occur during 312.5 msec period. 3. If no plus and minus pulses occur between 1.28 to 3.84 sec. c. CDU fail: 1. CDU fine error >1.0 vrms. 2. CDU coarse error >2.5 vrms. 3. Read counter limit >160 cps. 4. Cos $(\theta - \psi)$ <2.0 v. 5. +14 dc supply <50%.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Red light. IMU fail signal inhibited by CMC when in coarse align mode. ISS light on Panel 122 also illuminated. PIPA fail signal inhibited by CMC except during CMC-controlled translation or thrusting. PGNS and PROG light on DSKY also illuminated. CDU fail signal inhibited by CMC during CDU zero mode. Lamp inhibited when C/W INPUTS switch (Panel 201) 10D is in the INHIBIT position.
2	XDS2F6	C/W	C/W	Indicates when selected caution detection unit power supply voltage (positive or negative) is outside of 11.7 to 13.9 volts normal range or if selected memory/tone amplifier unit power supply failed.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Red light.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
2	XDS2G6	C/W	O_2 FLOW HI	Indicates when total ECS oxygen flow exceeds 1 lb/hr for a period of 16.5±1.5 seconds.	C/W MNA & MNB (Panel 5)	DC main buses A & B	Red light. Illuminates at critical flow rate which, if continuous, indicates possible cabin leakage or oxygen subsystem leakage. Continuous O_2 flow is displayed by O_2 FLOW indicator (Panel 2).
2	XDS2H6	C/W	SUIT COMPRESSOR	Indicates suit compressor differential pressure of 0.22 psia or below.	C/W MNA & MNB	DC main buses A & B	Red light.

PANEL 3



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	A1	SPS	SPS QUANTITY				
			% FUEL		SERVICE PROPULSION SYSTEM GAUGING MNA & MNB (Panel 8)	EPS GROUP 4 MNA and MNB (Panel 229)	
			% OXID		AC bus 1 or 2 through SPS GAUGING switch (Panel 4)	AC bus 1 and 2	
			OXID UNBAL	Rendered inoperative because of removal of propellant utilization gauging control unit and probe simulator for flight. Reason for removal is due to weight reduction requirement.			
			OXID FLOW VALVE				
			INCR		SERVICE PROPULSION SYSTEM GAUGING MNA & MNB (Panel 8) AC bus 1 or 2 through SPS GAUGING switch (Panel 4)	EPS GROUP 4 MNA and MNB and AC buses 1 or 2 (Panel 229)	
			NORM				
			... continued		... cont	... cont	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	A1 (Cont)	SPS	DECR OXID FLOW VALVE PRIM SEC PUG MODE PRIM NORM AUX	Rendered inoperative because of removal of propellant utilization gauging control unit and probe simulator for flight. Reason for removal is due to weight reduction requirement.	SERVICE PROPULSION SYSTEM GAUGING MNA & MNB (Panel 8) AC1 or AC2 through SPS GAUGING switch (Panel 4)	EPS GROUP 4 MNA and MNB and AC buses 1 or 2 (Panel 229)	
			...continued		...cont	...cont	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	A1 (Cont)	SPS	TEST 1 (CENTER) 2	Rendered inoperative because of removal of propellant utilization gaging control unit and probe simulator for flight. Reason for removal is due to weight reduction requirement.			
3	DS1	EPS	pH HI (Striped-line) (Gray)	Indicates pH factor (alkalinity) of water from selected fuel cell is over 9. Indicates pH factor of water from selected fuel cell is below 9.	FUEL CELL 1 & FUEL CELL 3 PUMPS - AC (Panel 226)	AC bus 1 or 2 ØA	Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (Panel 3). The pH HI event indicator is part of the C&Ws. ØA power supplied through FUEL CELL PUMPS switches (Panel 5).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	DS6	EPS	FUEL CELL RADIATORS-1 (Striped-line) (Gray)	Indicates when radiator emergency bypass is used on fuel cell 1. Indicates normal (open) position of valve.	FUEL CELL 1 - RAD BAT RLY (Panel 226)	Battery relay bus	Event indicator functions in conjunction with respective switch located directly below.
3	DS8	EPS	FUEL CELL RADIATORS-3 (Striped-line) (Gray)	Indicates when radiator emergency bypass is used on fuel cell 3. Indicates normal (open) position of valve.	FUEL CELL 3 - RAD BAT RLY (Panel 226)	Battery relay bus	Event indicator functions in conjunction with respective switch located directly below.
3	DS10	EPS	SM PWR SOURCE MAIN BUS A 1 (Striped-line) (Gray)	Indicates when the selected SM power source (fuel cell 1 or descent battery 1) is disconnected from dc main bus A. Indicates when the selected SM power source (fuel cell 1 or descent battery 1) is connected.	SM BUS CONT 1 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 1 or descent battery 1 selection is performed by SM PWR SOURCE switch (Panel 5).
3	DS11	EPS	SM PWR SOURCE MAIN BUS A 2 (Striped-line) (Gray)	Indicates when descent battery 2 is disconnected from DC main bus A. Indicates when descent battery 2 is connected.	SM BUS CONT 2 BAT RLY (Panel 226)	Battery relay bus	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	DS12	EPS	SM PWR SOURCE MAIN BUS A 3 (Striped-line) (Gray)	(Striped-line) Indicates when the selected SM power source (fuel cell 3 or descent battery 3) is disconnected from DC main bus A. (Gray) Indicates when the selected SM power source (fuel cell 3 or descent battery 3) is connected.	SM BUS CONT 3 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 3 or descent battery 3 selection is performed by SM PWR SOURCE switch (Panel 5).
3	DS13	SPS	SPS He VLV 1	Striped line display indicates closed condition of valve controlled by switch located directly below indicator. Gray display indicates open condition of valve.	SERVICE PROPULSION SYSTEM He VALVE MNA (Panel 8)	EPS GROUP 4 MNA (Panel 229)	Gray display controlled by solenoid action, and striped line display controlled by permanent magnet action.
3	DS14	SPS	SPS He VLV 2	Striped line display indicates closed condition of valve controlled by switch located directly below indicator. Gray display indicates open condition of valve.	SERVICE PROPULSION SYSTEM He VALVE MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	Gray display controlled by solenoid action, and stiped line display controlled by permanent magnet action.
3	DS15	EPS	FUEL CELL REACTANTS 1	Striped line indicates when H_2 or O_2 shutoff valve is closed on fuel cell 1. Gray display indicates both valves are open.	SM BUS CONT 1 BAT RLY (Panel 226)	Battery relay bus	Event indicator functions in conjunction with respective switch located directly below. Valve closure also indicated by FC 1 C/W light.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	DS17	EPS	FUEL CELL REACTANTS 3	Striped line indicates when H_2 or O_2 shutoff valve is closed on fuel cell 3. Gray displays indicates both valves are open.	SM BUS CONT 3 BAT RLY (Panel 226)	Battery relay bus	Event indicator functions in conjunction with respective switch located directly below. Valve closure also indicated by FC 3 C/W light.
3	DS18	EPS	SM PWR SOURCE MAIN BUS B 1	Striped line indicates when the selected SM power source (fuel cell 1 or descent battery 1) is disconnected from dc main bus B. Gray indicates when the selected SM power source (fuel cell 1 or descent battery 1) is connected.	SM BUS CONT 1 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 1 or descent battery 1 selection is performed by SM PWR SOURCE switch (Panel 5).
3	DS19	EPS	SM PWR SOURCE MAIN BUS B 2	Striped line indicates descent battery 2 is disconnected from dc main bus B. Gray indicates when descent battery 2 is connected.	SM BUS CONT 2 BAT RLY (Panel 226)	Battery relay bus	
3	DS20	EPS	SM PWR SOURCE MAIN BUS B 3	Striped line indicates when the selected SM power source (fuel cell 3 or descent battery 3) is disconnected from main bus B. Gray indicates when the selected SM power source (fuel cell 3 or descent battery 3) is connected.	SM BUS CONT 3 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 3 or descent battery 3 selection is performed by SM PWR SOURCE switch (Panel 5).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	DS21	TLCM	PWR AMPL	Activated when S-band power amplifier, selected for use with xponder by PWR AMPL PRIM SEC switch, is activated in its high- or low-level power mode.	N/A	S-band power amplifier equipment	Activated after a 90-second delay due to filament warm-up time of power amplifier TWT. Power amplifier talk-back will be gray when either power amplifier is selected for PM operation. Opposite power amplifier will not have a talk-back. Only a 60 millisecond delay to switch between two power amplifiers if both are being used (warmup override). Full 90-second delay for an unused power amp.
3	DS22	TLCM	TAPE MOTION	Activated whenever data storage equipment tape is in motion.	N/A	Data storage equipment	Talk-back will indicate gray when TAPE RECORDER - FWD - REWIND switch is in the FWD or REWIND position, power is available, and the sensor electronics indicates tape motion is present.
3	DS25	EPS	FUEL CELL REACTANTS H_2 VENT	Striped line indicates when H_2 vent valve is open. Gray indicates valve is closed.	H_2 VENT BAT RLY (Panel 226)	Battery relay bus	Opened to evacuate H_2 tanks through orificed non-propulsive vent in bay IV.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	M1	SPS	SPS				
			TEMP (LM)	Indicates SPS engine feed line oxidizer temperature or helium panel temperature, dependent upon S80 position.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (oxidizer) CB3 (helium panel) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	
		C	PRESS (RM)				
			He	Indicates helium tank source pressure.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (He tank) CB3 (system A) CB4 (system B) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	The indication on this me meter is dependent upon S69.
			N_2 (SPS PRPLNT A TANKS PRESS)	Indicates GN_2 system A source pressure for bi-propellant valve bank A.			
			N_2 (SPS PRPLNT B TANKS PRESS)	Indicates GN_2 system B source pressure for bi-propellant valve bank B.			
3	M2	SPS	SPS				
			PRESS				
			FUEL (LM)	Provides constant monitoring of SPS fuel tank pressure.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (fuel) CB3 (oxidizer) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	Indicator consists of d'Arsonval-type meter with fixed dial and movable pointer. Pointer movement is vertical as observed from crew couch. Indicator is calibrated in psia with range of 0 to 250 psia.
			OXID (RM)	Provides constant monitoring of SPS oxidizer tank pressure.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	M3	EPS	FUEL CELL FLOW H_2 (LM)	Indicates flow rate of H_2 into selected fuel cell.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (Panel 276)	DC main buses A and B	Normal operating range (indicator green band) is 0.036 lb/hr to 0.163 lb/hr. Sensors for indicators are located in FUEL CELL O_2 inlet lines. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (Panel 3).
			O_2 (RM)	Indicates flow rate of O_2 into selected fuel cell.			Normal operating range (indicator green band) is 0.288 lb/hr to 1.304 lb/hr. Sensors for indicator are located in FUEL CELL O_2 inlet lines. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (Panel 3).
3	M4	EPS	FUEL CELL MODULE TEMP SKIN (LM) ...continued	Indicates skin temperature of selected fuel cell.	TELECOMMUNICATIONS SIG CONDR FLT BUS (Panel 225) ...cont	DC main buses A and B ...cont	Normal indication is 385° to 455°F. Alarm limits to caution and warning system are 360°F lower, 475°F upper. Sensors for the indicator are located in pressurized portion of fuel cells. Fuel cell to be monitored is selected by FUEL CELL INDICATOR switch (Panel 3).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	M4 (Cont)	EPS	COND EXH (RM)	Indicates temperature of selected fuel cell condensor exhaust.			Condensor exhaust operating range is 150° to 175°F. Alarm limits to caution and warning system are below 150° or above 175°F. Sensors for indicator are located in exhaust manifold of fuel cell condensor. Fuel cell to be monitored is selected by FUEL CELL INDICATOR switch (Panel 3).
3	M5	SPS	SPS ENGINE INJECTOR VALVES A1 OPEN CLOSE	 Provides visual indication SPS engine main propellant valves A1 are in the open condition. Provides visual indication SPS engine main propellant valves A1 are in the closed condition.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	Meters 5, 6, 7, and 8 are identical. Each is a needle-movement-type meter with inputs supplied by position potentiometer located in valve actuator. Left needle deflection indicates CLOSE; right needle deflection indicates OPEN.
3	M6	SPS	SPS ENGINE INJECTOR VALVES A2 OPEN CLOSE	 Provides visual indication SPS engine main propellant valves A2 are in the open condition. Provides visual indication SPS engine main propellant valves A2 are in the closed condition.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	Meters 5, 6, 7, and 8 are identical. Each is a needle-movement-type meter with inputs supplied by position potentiometer located in valve actuator. Left needle deflection indicates CLOSE; right needle deflection indicates OPEN.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	M7	SPS	SPS ENGINE INJECTOR VALVES				
			B3				
			OPEN	Provides visual indication SPS engine main propellant valves B3 are in the open condition.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3 (Panel 276)	INSTRUMENTA- MNA and MNB (Panel 5)	Meters 5, 6,7, and 8 are identical. Each is a needle-movement-type meter with inputs supplied by position potentiometer located in valve actuator.
			CLOSE	Provides visual indication SPS engine main propellant valves B3 are in the closed position.			Left needle deflection indicates CLOSE; right needle deflection indicates OPEN.
3	M8	SPS	SPS ENGINE INJECTOR VALVES				
			B4				
			OPEN	Provides visual indication SPS engine main propellant valves B4 are in the open condition.	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	Meters 5, 6, 7, and 8 are identical. Each is a needle-movement-type meter with inputs supplied by position potentiometer located in valve actuator.
			CLOSE	Provides visual indication SPS engine main propellant valves B4 are in the closed position.			Left needle deflection indicates CLOSE; right needle deflection indicates OPEN.
3	M9	EPS	DC AMPS				
			CHGR	Indicates d-c current of selected source, unit, or bus.	N/A	As selected by DC INDICATORS switch	Meter functions in conjunction with DC INDICATORS switch. DC AMPS meter range is 0 to 100 amperes, 0 to 5 amperes expanded scale is battery charger output. Selectable sources are SM SOURCE 1, 2, 3, BAT BUS A, B, BAT CHARGER, BAT C and PYRO BAT A, B.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	M10	EPS	DC VOLTS	Indicates d-c voltage of selected source, unit, or bus.	Descent Bats-Fused MNA-EPS SENSOR SIGNAL-MNA (Panel 5) MNB-EPS SENSOR SIGNAL-MNB (Panel 5) BAT BUS A-BAT CHGR-CHG-BAT A (Panel 5) BAT BUS B-BAT CHRG-CHG-BAT B (Panel 5) BAT C-BAT CHGR-CHG-BAT C (Panel 5) PYRO A-PYRO BUS A-PYRO BAT A (Panel 229) PYRO B-PYRO BUS B-PYRO BAT B (Panel 229)	As selected by DC INDICATORS switch	Meter functions in conjunction with DC INDICATORS switch. DC VOLTS meter range is 20 to 45 vdc. Selectable sources are SM SOURCE 1, 2, 3 (descent battery 1, 2, 3 voltage) MAIN BUS A and B, BAT BUS A and B, BAT CHARGER, BAT C, and PYRO BAT A and B.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	M10	EPS	DC VOLTS	Indicates d-c voltage of selected source, unit, or bus.	N/A	As selected by DC INDICATORS switch	Meter functions in conjunction with DC INDICATORS switch. DC VOLTS meter range is 20 to 45 vdc. Selectable sources are SM SOURCE 1, 2, 3 (descent battery 1, 2, 3 voltage) MAIN BUS A and B, BAT BUS A and B, BAT CHARGER, BAT C, and PYRO BAT A and B.
3	M11	EPS	AC VOLTS	Indicates a-c voltage of selected source and phase.	EPS SENSOR-SIGNAL AC1 & AC2 (Panel 5)	As selected by AC INDICATORS switch	Meter functions in conjunction with AC INDICATORS switch. AC VOLTS meter range is 90 to 130 vac.
3	R1	TLCM	VHF AM SQUELCH A	A thumbwheel controls 5k ohm potentiometer assembly to adjust minimum RF level required to override squelch action of VHF-AM 296.8-mc receiver.	N/A	N/A	Prevents unwanted noise in headset during periods of no communication. Thumbwheel settings from 1 to 9 indicate minimum to maximum squelch.
3	R2	TLCM	VHF AM SQUELCH B	A thumbwheel controls 5k ohm potentiometer assembly to adjust minimum RF level required to override squelch action of VHF-AM 259.7-mc receiver.	N/A	N/A	Prevents unwanted noise in headset during periods of no communication. Thumbwheel settings from 1 to 9 indicate minimum to maximum squelch.
3	S1	TLCM	VHF ANTENNA RECY ...continued	Connects VHF recovery antenna No. 1 with the VHF/AM transceivers.	N/A ...cont	N/A ...cont	Antenna switch interfaces with VHF triplexer and VHF/AM transceivers. VHF survival beacon can utilize VHF recovery ant No. 1 when connected to VHF antenna switch at P102/J1 VHF triplexer interface. Scimitar antennas are located 180° apart on service module. ...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S1 (Cont)	TLCM	SM LEFT	Connects left SM-VHF scimitar antenna into the VHF/AM transceivers.			VHF recovery antenna No. 1 is deployed 8 sec after main chute is deployed. VHF recovery antenna No. 2 is connected directly to the VHF recovery beacon and is deployed 8 sec after main chute is deployed.
			SM RIGHT	Connects right SM-VHF scimitar antenna into the VHF/AM transceivers.			
3	S2	EPS	FUEL CELL RADIATORS				
			1				
			NORMAL	Momentary switch position operates radiator valve allowing use of full radiator for respective fuel cell. De-energizes talkback indicator.	FUEL CELL 1 - RAD BAT RLY (Panel 226)	Battery relay bus	
			(CENTER)	Valves remain in last selected position (normal switch position).			
			EMER BYPASS	Momentary switch position operates radiator valve to bypass 3/8 of radiator. Energizes talkback indicator to striped indication.			Three radiator panels on +Z axis are bypassed when it is desired to retain heat in fuel cells.
3	S4	EPS	FUEL CELL RADIATORS				
			3				
			NORMAL	Momentary switch position operates radiator valve allowing use of full radiator for respective fuel cell. De-energizes talkback indicator.	FUEL CELL 3 - RAD BAT RLY (Panel 226)	Battery relay bus	
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S4 (Cont)	EPS	(CENTER)	Valves remain in last selected position (normal switch position).			
			EMER BYPASS	Momentary switch position operates radiator valve to bypass 3/8 of radiator. Energizes talk-back indicator to striped indication.			Three radiator panels on +Z axis are bypassed when it is desired to retain heat in fuel cells.
3	S6	EPS	FUEL CELL HEATERS				
			1				
			(UP)	Activates in-line heater circuit for automatic operation.	N/A	Fuel cell No. 1	Allows in-line heater circuit to function automatically. (Auto on - $385^\circ \pm 5^\circ F$) (Auto off - $390^\circ \pm 5^\circ F$)
			OFF	Deactivates in-line heater circuit.			Totally disables in-line heater circuit.
3	S8	EPS	FUEL CELL HEATERS				
			3				
			(UP)	Activates in-line heater circuit for automatic operation.	N/A	Fuel cell No. 3	Allows in-line heater circuit to function automatically. (Auto on - $385^\circ F \pm 5^\circ F$) (Auto off - $390^\circ \pm 5^\circ F$)
			OFF	Deactivates in-line heater circuit.			Totally disables in-line heater circuit.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S9	C/W	MASTER ALARM	Red light illuminates to alert crewman in RH couch of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status light on Panel 2.	C/W MNA & MNB (Panel 5)	DC main buses A & B	MASTER ALARM lights on Panels 1, 3, and 122 are simultaneously illuminated, and an audio alarm tone is sent to each headset. The MASTER ALARM switch-light contains an integral push-switch. Pressing the switch-light will reset the master alarm circuit, extinguishing all the MASTER ALARM lights, and shutting off the audio alarm tone.
3	S10	EPS	FUEL CELL INDICATOR				
			1	Applies selected output of fuel cell No. 1 to fuel cell display indicators.	N/A	Dependent on position	Selects desired fuel cell to be monitored by fuel cell display indicators. Indicators associated with switch are as follows: a. FLOW meters H_2 and O_2 b. MODULE TEMP meters SKIN and COND EXH c. pH HI talkback ind.
			3	Applies selected outputs of fuel cell No. 3 to fuel cell display indicators.			
3	S11	EPS	FUEL CELL PURGE				
			1				
			H_2	Opens purge valve on H_2 side of fuel cell 1 to purge impurities from H_2 electrodes.	FUEL CELL 1 - PURGE MNA (Panel 226) (Fuse protects main B circuit)	DC main buses A & B	O_2 purge time is 2 minutes and H_2 purge time is 80 seconds. O_2 and H_2 maximum flow rates during purge are 0.6 and 0.67 lb/hr above normal flow rates, respectively.
			OFF	Disconnects power from F/C 1 O_2 or H_2 purge valve, closing valve (normal switch position).			
			O_2	Opens purge valve on O_2 side of fuel cell 1 to purge impurities from O_2 electrodes.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S13	EPS	FUEL CELL PURGE				
			3				
			H_2	Opens purge valve on H_2 side of fuel cell 3 to purge impurities from H_2 electrodes.	FUEL CELL 3 - PURGE MNB (Panel 226) (Fuse protects main A circuit)	DC main buses A & B	O_2 purge time is 2 minutes and H_2 purge time is 80 seconds. O_2 and H_2 maximum flow rates during purge are 0.6 and 0.67 lb/hr above normal flow rates, respectively.
			OFF	Disconnects power from F/C O_2 or H_2 purge valve, closing valve (normal switch position).			
			O_2	Opens purge valve on O_2 side of fuel cell 3 to purge impurities from O_2 electrodes.			
3	S14	EPS	SM PWR SOURCE				
			MAIN BUS A				
			1				
			(UP)	Momentary switch position connects electrical output of fuel cell 1 or descent battery 1 to DC main bus A.	SM BUS CONT 1 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 1 or descent battery 1 selection is performed by SM PWR SOURCE switch (Panel 5).
			(CENTER)	Normal position when power source is connected. Connects SM PWR DISCONNECT C/W light into circuit.			
			OFF	Disconnects output of fuel cell 1 or descent battery 1 from DC main bus A and extinguishes SM PWR DISCONNECT C/W light if illuminated by this circuit.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S15	EPS	SM PWR SOURCE				
			MAIN BUS A				
			2				
			(UP)	Momentary switch position connects electrical output of descent battery 2 to DC main bus A.	SM BUS CONT 2 BAT RLY (Panel 226)	Battery relay bus	
			(CENTER)	Normal position when power source is connected. Connects SM PWR DISCONNECT C/W light into circuit.			
			OFF	Disconnects output of descent battery 2 from DC main bus A and extinguishes SM PWR DISCONNECT C/W light if illuminated by this circuit.			
3	S16	EPS	SM PWR SOURCE				
			MAIN BUS A				
			3				
			(UP)	Momentary switch position connects electrical output of fuel cell 3 or descent battery 3 to DC main bus A.	SM BUS CONT 3 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 3 or descent battery 3 selection is performed by SM PWR SOURCE switch (Panel 5).
			(CENTER)	Normal position when power source is connected. Connects SM PWR DISCONNECT C/W light into circuit.			
			OFF	Disconnects output of fuel cell 3 or descent battery 3 from DC main bus A and extinguishes SM PWR DISCONNECT C/W light if illuminated by this circuit.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S17	EPS	RESET				
			(RESET)	Momentary switch position resets d-c main bus A undervoltage sensing unit and extinguishes d-c under-voltage lamp after activation.	EPS SNSR PWR BAT RLY 1 (Panel 5)	Battery relay bus	DC main bus A undervoltage sensing circuit energizes MN BUS A UNDERVOLT warning light (Panel 2) when d-c voltage drops below 25.60 vdc.
			(CENTER)	Connects power to MN BUS A UNDERVOLT warning light and battery relay bus power to d-c main bus A under-voltage latching circuit.			Sensing signal and sensor power applied through EPS SENSOR SIGNAL MNA circuit breaker (Panel 5).
			OFF	Disconnects power from MN BUS A UNDERVOLT light and sensor latching.			
3	S18	SPS	SPS He VLV				
			1				
			AUTO	Provides power to SPS THRUST ON-OFF relays which automatically apply and remove power to helium isolation valve solenoid for opening and closing.	SERVICE PROPULSION SYSTEM He VALVE MNA (Panel 8)	EPS GROUP 4 MNA (Panel 229)	Switch is three-way toggle switch. With switch in AUTO position, valve open-ing and closing is con-trolled automatically by CMC or SCS or SPS THRUST DIRECT ON. Complete manual control of valve position can be maintained by utilizing ON-OFF switch positions.
			OFF	Removes power from helium isolation valve solenoid, allowing valve to spring load closed.			
			ON	Applies power to open helium isolation valve solenoid.			Valve opening allows helium source pressure to pressure regulator assemblies.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S19	SPS	SPS He VLV				
			2				
			AUTO	Provides power to SPS THRUST ON-OFF relays which automatically apply and remove power to helium isolation valve solenoid for opening and closing.	SERVICE PROPULSION SYSTEM He VALVE MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	Switch is three-way toggle switch. With switch in AUTO position, valve opening and closing is controlled automatically by CMC or SCS or SPS THRUST DIRECT ON. Complete manual control of valve position can be maintained by utilizing ON-OFF switch positions.
			OFF	Removes power from helium isolation valve solenoid, allowing valve to spring load closed.			
			ON	Applies power to open helium isolation valve solenoid.			Valve opening allows helium source pressure to pressure regulator assemblies.
3	S20	EPS	FUEL CELL REACTANTS				
			1				
			(ON)	Momentary switch position connects d-c power to fuel cell 1 O_2 and H_2 reactant valve actuators, driving valves to open position.	FUEL CELL 1 REACS BAT RLY (Panel 226)	Battery relay bus	Provides ON-OFF control of reactant flow (H_2 and O_2) for fuel cell.
			(CENTER)	Valves remain in last selected position (normal switch position).			
			OFF	Momentary switch position connects d-c power to fuel cell 1 O_2 and H_2 reactant valve actuator driving valves to closed position.			Event indicator, located directly above respective switch, displays striped lines when either the H_2 or O_2 shutoff valve is in closed position. FC 1 C/W light illuminates when either or both valves are closed.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S22	EPS	FUEL CELL REACTANTS				
			3				
			(ON)	Momentary switch position connects d-c power to fuel cell 3 O_2 and H_2 reactant valve actuators, driving valves to open position.	FUEL CELL 3 REACS BAT RLY (Panel 226)	Battery relay bus	Provides ON-OFF control of reactant flow (H_2 and O_2) for fuel cell.
			(CENTER)	Valves remain in last selected position (normal switch position).			Event indicator, located directly above respective switch, displays striped lines when either the H_2 or O_2 shutoff valve is in closed position. FC 3 C/W light illuminates when either or both valves are closed.
			OFF	Momentary switch position connects d-c power to fuel cell 3 O_2 and H_2 reactant valve actuators driving valves to closed position.			
3	S23	EPS	SM PWR SOURCE				
			MAIN BUS B				
			1				
			(UP)	Momentary switch position connects electrical output of fuel cell 1 or descent battery 1 to DC main bus B.	SM BUS CONT 1 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 1 or descent battery 1 selection is performed by SM PWR SOURCE switch (Panel 5).
			(CENTER)	Normal position when power source is connected. Connects SM PWR DISCONNECT C/W light into circuit.			
			OFF	Disconnects output of fuel cell 1 or descent battery 1 from DC main bus B and extinguishes the SM PWR DISCONNECT C/W light if illuminated by this circuit.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S24	EPS	SM PWR SOURCE MAIN BUS B 2				
			(UP)	Momentary switch position connects electrical output of descent battery 2 to DC main bus B.	SM BUS CONT 2 BAT RLY (Panel 226)	Battery relay bus	
			(CENTER)	Normal position when power source is connected. Connects SM PWR DISCONNECT C/W light into circuit.			
			OFF	Disconnects output of descent battery 2 from DC main bus B and extinguishes SM PWR DISCONNECT light if illuminated by this circuit.			
3	S25	EPS	SM PWR SOURCE MAIN BUS B 3				
			(UP)	Momentary switch position connects electrical output of fuel cell 3 or descent battery 3 to DC main bus B.	SM PWR CONT 3 BAT RLY (Panel 226)	Battery relay bus	Fuel cell 3 or descent battery 3 selection is performed by SM PWR SOURCE switch (Panel 5).
			(CENTER)	Normal position when power source is connected. Connects SM PWR DISCONNECT C/W light into circuit.			
			OFF	Disconnects output of fuel cell 3 or descent battery 3 from DC main bus B and extinguishes C/W SM PWR DISCONNECT light if illuminated by this circuit.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S26	EPS	RESET				
			(RESET)	Momentary switch position resets d-c main bus B undervoltage sensing unit and extinguishes d-c undervoltage lamp.	EPS SNSR PWR BAT RLY 2 (Panel 5)	Battery relay bus	DC main bus B undervoltage sensing circuit energizes MN BUS B UNDERVOLT warning light (Panel 2) when d-c voltage drops below 25.60 vdc.
			(CENTER)	Connects power to MN BUS B UNDERVOLT warning light and battery relay bus power to d-c bus B undervoltage latching circuit.			Sensing signal and sensor pwr applied through EPS SENSOR SIGNAL MNB circuit breaker (Panel 5).
			OFF	Disconnects power from MN BUS B UNDERVOLT warning light and sensor latching.			
3	S27	EPS	DC INDICATORS				
			SM SOURCE 1	Applies output of fuel cell 1 or descent battery 1 to DC AMPS meter and descent battery 1 to DC VOLTS meter.	N/A	Fuel cell No. 1 or descent battery 1	Fuel cell 1 or descent battery 1 selection is performed by SM PWR SOURCE switch (Panel 5).
			SM SOURCE 2	Applies output of descent battery 2 to DC AMPS meter and to DC VOLTS meter.	N/A	Descent battery No. 2	
			SM SOURCE 3	Applies output of fuel cell 3 or descent battery 3 to DC AMPS meter and descent battery 3 to DC VOLTS meter.	N/A	Fuel cell No. 3 or descent battery No. 3	Fuel cell 3 or descent battery 3 selection is performed by SM PWR SOURCE switch (Panel 5).

...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S27 (Cont)	EPS	MAIN BUS A	Applies voltage of d-c main bus A to DC VOLTS meter.	EPS SENSOR SIGNAL MNA (Panel 5)	DC main bus A	Listed circuit breaker controls d-c voltage indication and measurement for telemetry.
			MAIN BUS B	Applies voltage of d-c main bus B to DC VOLTS meter.	EPS SENSOR SIGNAL MNB (Panel 5)	DC main bus B	Listed circuit breaker controls d-c voltage indication and measurement for telemetry.
			BAT BUS A	Applies voltage of battery bus A to DC VOLTS meter and output of battery A shunt to DC AMPS meter.	BAT CHARGER CHARGE BAT A (Panel 5)	Battery bus A	Listed circuit breaker controls d-c voltage indication and measurement for telemetry.
			BAT BUS B	Applies voltage of battery bus B to DC VOLTS meter and output of battery B shunt to DC AMPS meter.	BAT CHARGER CHARGE BAT B (Panel 5)	Battery bus B	Listed circuit breaker controls d-c voltage indication and measurement for telemetry.
			BAT CHARGER	Applies voltage output of battery charger to DC VOLTS meter and current output of battery charger shunt to DC AMPS meter (inner scale 0 to 5 amps).	N/A	Battery charger	Charger current and voltage output will be according to charge required by battery (up to 2.8 amps and 39.8 vdc).
			BAT C	Applies voltage and current outputs of battery C to DC VOLTS and DC AMPS meters respectively.	BAT CHARGER CHARGE BAT C/EDS 2 (Panel 5)	Battery C	Listed circuit breaker controls d-c voltage indication and measurement for telemetry.
			PYRO BAT A	Applies output voltage of pyro bus A to DC VOLTS meter and battery output current to DC AMPS meter.	PYRO BUS A PYRO BAT A (Panel 229)	Pyro battery A	As pyro batteries are not normally connected to a load, open circuit voltage will be indicated on voltmeter.
			PYRO BAT B	Applies output voltage of pyro bus B to DC VOLTS meter and battery output current to DC AMPS meter.	PYRO BUS B PYRO BAT B (Panel 229)	Pyro battery B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S28	EPS	BATTERY CHARGE				
			OFF	Disconnects electrical power from battery charger.			Switch actuates battery charger input power control relay, routing a-c and d-c through relay contacts to battery charger. AC power for battery charger is selected from a-c bus 1 or a-c bus 2 by BAT CHRGR AC1-AC2 switch (Panel 5).
			A	Controls a-c and d-c power to battery charger and routes output of battery charger to battery bus A.	For charger input BAT CHARGER MNA & MNB and AC For charger output BAT CHARGER CHARGE BAT A (Panel 5)	DC main buses A and B and AC bus 1 or 2	Position can be used to charge pyro battery A.
			B	Controls a-c and d-c power to battery charger and routes output of battery charger to battery bus B.	For charger input BAT CHARGER MNA & MNB and AC For charger output BAT CHARGER CHARGE BAT B (Panel 5)	DC main buses A and B and AC bus 1 or 2	Position can be used to charge pyro battery B.
			C	Controls a-c and d-c power to battery charger and routes output of battery charger to entry battery C.	BAT CHARGER CHARGE BAT C/EDS 2 (Panel 5)	DC main buses A and B and AC bus 1 or 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S29	TLCM	S BAND NORMAL				
			XPNDR				
			PRIM	Actuates No. 1 transponder of unified S-band equipment (USBE).	TELECOMMUNI-CATIONS S BAND PWR AMPL/PHASE MOD XPNDR 1 FLT BUS & GROUP 1 (Panel 225)	Telecom flight bus	When switching from PRIM to SEC positions, operator should pause at off position to preclude unwanted activation of both XPNDRS. PRIM or SEC position of S-BAND NORMAL XPNDR switch supplies power to S-BAND ANTENNA switch. A transponder must be selected to allow switching of the S-band omni antennas.
			OFF	Switches both transponders off.			
			SEC	Actuates No. 2 transponder of the USBE.	TELECOMMUNI-CATIONS S BAND PWR AMPL/PHASE MOD XPNDR 2 FLT BUS & GROUP 2 (Panel 225)	AC bus 1 or 2	
3	S31	TLCM	S BAND NORMAL				
			PWR AMPL				
			PRIM	Selects No. 1 power amplifier of S-band power amplifier equipment for operation with transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.	TELECOMMUNI-CATIONS S BAND PWR AMPL/PHASE MOD XPNDR 1 FLT BUS & GROUP 1 (Panel 225)	Telecom flight bus	Power amplifier not selected will automatically be used with S-BAND FM XMTR. Power amplified selected will be used for transponder selected and activate power amplifier talk-back after a 90-second delay provided HIGH or LOW is selected on S-BAND NORMAL - PWR AMPL switch. Power amplifier not selected will be used with the FM transmitter and will not have a talk-back indicator. Full 90 sec delay required for an unused power amplifier. Warmup override of 60 millisec delay if both amplifiers are used and it is desirable to interchange.
			SEC	Selects No. 2 power amplifier of S-band power amplifier equipment of operation with transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.	TELECOMMUNI-CATIONS S BAND PWR AMPL/PHASE MOD XPNDR 2 FLT BUS & Group 2 (Panel 225)	AC bus 1 or 2	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S32	TLCM	S BAND NORMAL PWR AMPL				
			HIGH	Selects high-level mode of operation of power amplifier selected by S-BAND NORMAL PWR AMPL PRIM-SEC switch.	N/A	N/A	Power amplified not selected will automatically go to the high power mode for use with S-BAND FM transmitter. High-level mode of operation is 20 watts. Low-level mode of operation is 5 watts. This represents output power of traveling wave tubes only and not power at antenna interface which would include coax loss. Bypass mode will use the output of transponder only which is approximately 250 milliwatts. Circuit breaker utilization dependent on S-BAND PWR AMPL PRIM/SEC switch position.
			(OFF)	Selects bypass mode of operation for transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.			
			LOW	Selects low-level mode of operation of power amplifier selected by S-BAND NORMAL PWR AMPL PRIM-SEC switch.			
3	S33	TLCM	S BAND NORMAL MODE				
			VOICE	Selects voice mode subcarrier output for transmission via transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.	N/A	S-band equipment	VOICE position applies power to voice modulator module in the Premodulation Processor. Voice modulator module develops the 1.25 MHz voice subcarrier for transmission via the S-band transponder. RELAY position has no function for Skylab missions however wiring still exists. If RELAY is selected, SPT microphone will be disconnected.
			(OFF)	Selects no modes.			
			RELAY	Relay mode does not pertain to Skylab Missions. Its purpose is for LM and EVA relay to MSFN during J-Missions.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S34	TLCM	S BAND NORMAL				
			MODE				
			PCM	Selects real time PCM biphase modulator output for transmission via transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.	N/A	Premodulation processor equipment	PCM position will amplify voice subcarrier in order to simultaneously transmit voice and telemetry via the S-band transponder. Biphase modulator output contains telemetry on a 1.024 MHz subcarrier. Key position routes 512 KHz input from CTE to the S-band transponder and provides a 400 HZ sidetone to headset when pressing PTT control on Comm Cable Umbilical. Down voice back-up or S-band ranging cannot be used during this mode of operation.
			(OFF)	Selects no modes.			
			KEY	Selects output of emergency key subcarrier for transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.			
3	S35	TLCM	S BAND NORMAL				
			MODE				
			RANGING	Retransmits received ranging signal via transponder selected by S-BAND NORMAL XPNDR PRIM-OFF-SEC switch.	N/A	S-band equipment	Ranging signal is pseudo random noise ranging from MSFN to determine spacecraft distance, velocity and acceleration cannot be used with down voice backup or emergency key.
			OFF	Selects no modes.			Breaks the signal path between the USBE wide-band receiver output and the transponder transmitter modulator.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S36	TLCM	S BAND AUX				
			TAPE	Activates FM transmitter of USBE and connects output to power amplifier NOT selected by S-BAND NORMAL PWR AMPL PRIM-SEC switch. Activates power amplifier in high-level mode. Connects tape playback functions selected by the TAPE RECORDER switches to FM transmitter. Selection of this mode will override S-BAND AUX TV-OFF-SCI switch.	TELECOMMUNICATIONS S BAND FM XMTR DATA STORAGE EQUIP FLT BUS (Panel 225)	Flight bus	Can be used to turn on FM transmitter to send auxiliary real time CM/PCM due to a PMP or transponder failure. DN VOICE BU position re-routes normal voice and baseband modulates S-band transponder in event of voice modulator failure. Down voice back-up can be used with low bit rate telemetry however for maximum voice signal <u>do not</u> select PCM and <u>do</u> select high bit rate telemetry. Down voice back-up cannot be used with emergency key or S-band ranging.
			(OFF)	Selects no modes.			
			DN VOICE BU	Selects PM baseband voice mode of transponder selected by S-BAND NORMAL XPNDR PRIM OFF SEC switch.			
3	S37	TLCM	S BAND AUX				
			TV	Activates TV camera on FM transmitter for VIDEO transmission.	TELECOMMUNICATIONS S BAND FM XMTR DATA STORAGE EQUIP FLT BUS (Panel 225)	Flight bus	TV position applies 28 vdc to TV camera and activates FM transmitter. Selects high-level mode of operation of power amplifier. Cannot have tape dump during TV operations. SCI position has no function. Scientific channels have not been assigned for Skylab missions.
			(OFF)	Selects no modes.			
			SCI	Same as above TV, but in lieu of video signal experiment analog information in real time or stored on 3 tracks of DSE is fed to S-BAND FM transmitter modulator.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S38	TLCM	UP TLM				
			DATA	Selects up voice and updata demodulator for normal operation.	TELECOMMUNI-CATIONS PMP POWER PRIM FLT BUS & AUX FLT BUS (Panel 225)	PMP equipment	Utilization of PRIM FLT BUS and/or AUX FLT bus circuit breakers is dependent on POWER PMP switch (NORM/AUX) on Panel 3. MSFN normally transmits voice on the 30 KHz subcarrier and data on the 70 KHz subcarrier. During the up voice back-up mode, voice is transmitted on the 70 KHz subcarrier in event of a 30 KHz demodulator failure. MSFN must, in this mode of operation, time share up-data and voice information on 70-kc subcarrier. Data would be audible in the headset during the up voice back-up mode.
			UP VOICE BU	Switches up voice 30-kc subcarrier demodulator to output of up-data 70-kc demodulator and connects to both audio center and up-data link.			
3	S39	TLCM	UP TLM				
			CMD RESET	Actuation resets all of real time command relays bank "A". Actuation does not interrupt power to up-data link (UDL) equipment.	TELECOMMUNI-CATIONS UDL FLT BUS (Panel 225)	Flight bus	CMD RESET position will not reset abort light system A or the crew alarm. This switch is not spring loaded in the CMD RESET position therefore must be returned each time to the NORM position to allow MSFN real time command control.
			NORM	Applies power to UDL equipment.			
			OFF	Disables power to UDL equipment.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S40	TLCM	S BAND ANTENNA				
			OMNI	Provides power to S-BAND ANTENNA OMNI A-B-C switch to enable selection of omniantenna A, B or C.	TELECOM-MUNICATIONS S-BAND PWR AMPL/PHASE MOD XPNDR 1 FLT BUS (Panel 225) or TELECOM-MUNICATIONS S-BAND PWR AMPL/PHASE MOD XPNDR 2 FLT BUS (Panel 225)	Flight bus	Power is obtained through S-BAND NORMAL XPNDR-PRIM-OFF-SEC switch. Utilization of No. 1 or No. 2 FLT BUS is dependent on this switch position. S-band antennas may be selected manually by the crew or by real time commands from MSFN through the CSM up-data link system or the SWS Digital Command System. Antenna selection should be determined by best indication on S-band AGC meter (MDC-2). Fail safe capabilities to the B omniantenna if switching functions fail. Antenna selection information is transmitted to MSFN via telemetry.
			D	Selects omniantenna D which is located between spacecraft coordinates +Y and -Z.			
			REMOTE	Allows for remote switching of S-band antennas through SWS Digital Command System.			
3	S41	TLCM	S BAND ANTENNA				
			OMNI				
			A	Selects omniantenna A which is located between spacecraft coordinates +Z and +Y, when S-BAND ANTENNA OMNI-D-REMOTE switch is in OMNI position.	TELECOM-MUNICATIONS S BAND PWR AMPL/PHASE MOD XPNDR 1-FLT BUS or 2-FLT BUS (Panel 225)	Flight bus	S-band antennas may be selected manually by the crew or by real time commands from MSFN through the CSM up-data link system or the SWS Digital Command System. Antenna selection should be determined by best indication on S-band AGC meter (MDC-2). Fail safe capabilities to the B omniantenna if switching functions fail. Antenna selection information is transmitted to MSFN via telemetry.
			B	Selects omniantenna B which is located between spacecraft coordinates -Y and +Z, when S-BAND ANTENNA OMNI-D-REMOTE switch is in OMNI position.			
			C	Selects omniantenna C which is located between spacecraft coordinates -Z and -Y, when S-BAND ANTENNA OMNI-D-REMOTE switch is in OMNI position.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S43	TLCM	VHF AM A				
			DUPLEX	Selects VHF-AM 296.8-mc transmitter and 259.7-mc receiver for voice communication.	TELECOM-MUNICATIONS VHF/CREW STATION AUTIO-CTR FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	Provides for voice communications between MSFN and CSM. Utilizes selected VHF Scimitar antenna for transmit and receive. Must use PTT control for transmitting. Applies 28 vdc to required transmitter and receiver.
			(OFF)	Selects no mode.			
			SIMPLEX	Selects 296.8-mc transmitter and receiver for voice communication.			
3	S44	TLCM	VHF AM B				
			DUPLEX	Selects VHF-AM 259.7-mc transmitter and 296.8-mc receiver to receive voice.	TELECOM-MUNICATIONS VHF/CREW STATION AUDIO-CTR FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	Provides for voice communications between CSM and MSFN and CSM - SWS VHF/AM ranging. Utilizes selected VHF Scimitar antenna for transmit and receive. Must use PTT control for transmitting. Applies 28 vdc to required transmitter and receiver. Utilizes the 259.7 MHz transmitter and 296.8 MHz receiver for VHF/AM ranging between CSM and SWS. Digital range generator provides tones necessary to determine range and range rate. Transmitter will be continually keyed by placing VHF RANGING switch in the RANGING position.
			(OFF)	Selects no mode.			
			SIMPLEX	Selects VHF-AM 259.7-mc transmitter and receiver for voice communication.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S45	TLCM	VHF BCN ON OFF	 Activates VHF beacon equipment. Disables all power to VHF beacon.	TELECOM-MUNICATIONS VHF/CREW STATION AUDIO-L FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	VHF beacon will use recovery antenna No. 2 8 seconds after main chute deployment. Survival radio can be used as back-up beacon in event of VHF beacon failure. Connection will be made at J2 through triplexer access door in lower equipment bay.
3	S49	TLCM	TAPE RECORDER PCM/ANLG OFF	 (ANLG=Analog) Selects playback of recorded CSM PCM, CSM - SWS voice and three analog channels of scientific instrumentation. Selects no playback mode.	TELECOM-MUNICATIONS S-BAND FM XMTR DATA STORAGE EQUIP FLT BUS (Panel 225)	DSE equipment	PCM/ANLG position enables automatic speed select circuit for tape playback. Tape will play back at 15 ips if recorded in high bit rate and 120 ips if recorded in low bit rate. Power to switch is from the PLAY position of the TAPE RECORDER - RECORD/PLAY switch.
3	S50	TLCM	TAPE RECORDER RECORD (OFF) PLAY	 Selects record mode. Selects no mode. Selects playback mode.	TELECOM-MUNICATIONS S-BAND FM XMTR, DATA STORAGE EQUIP GROUP 1 & FLT BUS (Panel 225)	Flight bus	Record position supplies power to PCM high-low switch which determines recording speed. PLAY position supplies power to the TAPE RECORDER - RECORD/PLAY switch. Provides power to record and erase circuit in RECORD. Provides power to reproduce circuit in PLAY. If switch is off and FWD is selected, tape will run fast forward at 120 ips.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S51	TLCM	TAPE RECORDER				
			FWD	Closes power circuit to tape transport for operation in forward direction.	TELECOM-MUNICATIONS S BAND FM XMTR, DATA STORAGE EQUIP GROUP 1 & FLT BUS (Panel 225)	Flight bus	Forward speed will be 120 ips if PLAY or RECORD is not selected. Forward speed is determined by DSE RECORD-PLAY switch, PCM HIGH-LOW switch, and data rate recorded on tape. RECORD in HIGH gives 15 ips. RECORD in LOW gives 3.75 ips. PLAY with HBR on tape gives 15 ips. PLAY with LBR on tape gives 120 ips.
			(CENTER)	Closes power circuit such that tape transport shall be in stationary position. Closes power circuit such that DSE electronics are disabled.			
			REWIND	Closes power circuit to tape transport for operation in rewind mode at 120 ips.			No record or play in this position.
3	S52	TLCM	POWER				
			SCE				
			NORM	Energizes SCE primary power supply and error detection circuit which automatically switches SCE to redundant power supply if primary power supply voltages go out of tolerance.	TELECOM-MUNICATIONS SIG CONDR FLT BUS (Panel 225)	Flight bus	No indication to crew of power supply failure. Function will be automatic. MSFN will direct crew if power supply switching, by use of AUX position, is necessary.
			(OFF)	Switches the SCE off.			
			AUX	Provides manual switching of SCE power supplies by repeated selection of this position.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S54	TLCM	POWER				
			PMP				
			NORM	Energizes primary power supply of PMP (premodulation processor).	TELECOMMUNICATIONS PMP POWER PRIM FLT BUS & AUX FLT BUS (Panel 225)	Flight bus	
			(OFF)	Switches PMP off.			
			AUX	Energizes auxiliary power supply of PMP.			AUX selects not only auxiliary power supply, but also disconnects playback CM/PCM line from recorder and connects real time CM/PCM to transponder transmitter and to FM transmitter. AUX position is necessary in event of normal biphase modulator failure which would result in loss of all real time telemetry. AUX position would select the auxiliary biphase modulator for real time telemetry but also disconnect playback telemetry.
3	S55	TLCM	PCM BIT RATE				
			HIGH	Selects normal PCM data mode equipment. Selects normal (15 ips) speed for recording on DSE.	N/A	PCM equipment	High bit rate telemetry is 51.2 kbps and is used during critical phases of the mission. Low bit rate telemetry is 1.6 kbps. Switch enables the format control circuit in the PCM programmer.
			LOW	Selects reduced PCM data mode (low bit rate) in PCM equipment. Selects slow (3-3/4 ips) speed for recording on DSE.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S57	EPS	AC INVERTER				
			1				
			MNA	Applies d-c power to inverter No. 1.	INVERTER CONT-1 - BAT RLY (Panel 5)	Battery relay bus	Controls d-c power to inverter No. 1 by actuating a motor-driven switch which accomplishes actual switching function.
			OFF	Disconnects d-c power from inverter No. 1 and disconnects inverter 1 from a-c buses 1 and 2.			Circuit breaker associated with delivering power to inverter 1 from d-c main bus A is INVERTER POWER-1 - MNA (Panel 250).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S58	EPS	AC INVERTER 2				
			MNB	Applies d-c power to inverter No. 2.	INVERTER CONT-2 - BAT RLY (Panel 5)	Battery relay bus	Controls d-c power to inverter No. 2 by actuating a motor-driven switch which accomplishes actual switching function.
			OFF	Disconnects d-c power from inverter No. 2 and disconnects inverter 2 from a-c buses 1 and 2.			Circuit breaker associated with delivering power to AC inverter 2 from d-c main bus B is INVERTER POWER-2 - MNB (Panel 250).
3	S59	EPS	AC INVERTER 3				
			MNA	Applies d-c power from main bus A to inverter No. 3.	INVERTER CONT-3 - BAT RLY (Panel 5)	Battery relay bus	Controls d-c power to inverter No. 3 by actuating one of two motor-driven switches depending on bus selected.
			OFF	Disconnects d-c power from inverter No. 3 and disconnects inverter 3 from a-c buses 1 and 2.			Inverter No. 3 can receive power from either d-c main bus A or d-c main bus B. Associated circuit breakers are INVERTER POWER-3 - MNA and MNB (Panel 250).
			MNB	Applies d-c power from main bus B to inverter No. 3.			
3	S60	EPS	AC INVERTER AC BUS 1				
			1	Applies a-c output of inverter No. 1 to a-c bus 1 and disconnects inverter No. 2 from a-c bus 1 (if inverter 3 switch is off).	INVERTER-CONT-1 - BAT RLY (Panel 5)	Battery relay bus	Controls a-c output of inverters No. 1 & 2 to a-c bus 1.
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S60 (Cont)	EPS	OFF	Disconnects a-c output of inverter No. 1 from a-c bus 1 and allows inverter 2 to be connected.			Actuates a motor-driven switch which accomplishes actual switching function. Interlocking circuitry between AC INVERTER 1, 2 & 3-AC BUS 1 switches (Panel 3) prevents more than one inverter from being connected to a-c bus 1 at same time.
3	S61	EPS	AC INVERTER AC BUS 1 2	Applies a-c output of inverter No. 2 to a-c bus 1 and disconnects inverter No. 3 from a-c bus 1 (if inverter 1 switch is off).	INVERTER-CONT-2 - BAT RLY (Panel 5)	Battery relay bus	Controls a-c output of inverters No. 2 & 3 to a-c bus 1.
			OFF	Disconnects a-c output of inverter No. 2 from a-c bus 1 and allows inverter 3 to be connected.			Actuates a motor-driven switch which accomplishes actual switching function. Interlocking circuitry between AC INVERTER 1, 2 & 3-AC BUS 1 switches (Panel 3) prevents more than one inverter from being connected to a-c bus 1 at same time.
3	S62	EPS	AC INVERTER AC BUS 1 3	Applies a-c output of inverter No. 3 to a-c bus 1 and disconnects inverter No. 1 from a-c bus 1 (if inverter 2 switch is off).	INVERTER CONT-3 - BAT RLY (Panel 5)	Battery relay bus	Controls a-c output of inverters No. 3 & 1 to a-c bus 1. Actuates a motor-driven switch which accomplishes actual switching function.
			...continued		...cont	...cont	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S62 (Cont)	EPS	OFF	Disconnects a-c output of inverter No. 3 from a-c bus 1 and allows inverter 1 to be connected.			Interlocking circuitry between AC INVERTER 1, 2 & 3-AC BUS 1 switches (Panel 3) prevents more than one inverter from being connected to a-c bus 1 at same time.
3	S63	EPS	AC INVERTER AC BUS 1				
			RESET	Switch position resets a-c bus 1 over-undervoltage and overload sensing units.	EPS SNSR PWR BAT RLY-1 (Panel 5)	Battery relay bus	Provides capability of resetting a-c bus 1 over-undervoltage and overload sensing units. Also releases relay which reconnects operating inverter to a-c bus 1, if it had been tripped off due to overvoltage or overload.
			(CENTER)	Energizes a-c bus 1 over-undervoltage and overload sensing units for operation.			
			OFF	Disconnects a-c bus 1 over-undervoltage and overload sensing units from system and extinguishes C/W AC BUS 1 AND AC BUS 1 OVERLOAD lights if illuminated.			Resetting a-c bus 1 over undervoltage and overload sensing unit also turns off AC BUS 1 and AC BUS 1 OVERLOAD caution and warning lights (panel 2).
3	S64	EPS	AC INVERTER AC BUS 2				
			1	Applies output of inverter No. 1 to a-c bus 2 and disconnects inverter No. 2 from a-c bus 2 (if inverter 3 switch is off).	INVERTER CONT-2 - BAT RLY (Panel 5)	Battery relay bus	Controls output of inverters No. 1 & 2 to a-c bus 2. Actuates a motor-driven switch which accomplishes actual switching function.
			OFF	Disconnects output of inverter No. 1 from a-c bus 2 and allows inverter No. 2 to be connected.			Interlocking circuitry between AC INVERTER 1, 2,
			...continued		...cont	...cont	...continued

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S64 (Cont)	EPS					& 3 AC BUS 2 switches (Panel 3) prevents more than one inverter from being connected to a-c bus 2 at same time.
3	S65	EPS	AC INVERTER AC BUS 2				
			2	Applies output of inverter No. 2 to a-c bus 2 and disconnects inverter No. 3 from a-c bus 2 (if inverter 1 switch is off).	INVERTER CONT-3 - BAT RLY (Panel 5)	Battery relay bus	Controls output of inverters No. 2 & 3 to a-c bus 2. Actuates a motor-driven switch which accomplishes actual switching function. Interlocking circuitry between AC INVERTER 1, 2 & 3 AC BUS 2 switches (Panel 3) prevents more than one inverter from being connected to a-c bus 2 at same time.
			OFF	Disconnects output of inverter No. 2 from a-c bus 2 and allows inverter No. 3 to be connected.			
3	S66	EPS	AC INVERTER AC BUS 2				
			3	Applies output of inverter No. 3 to a-c bus 2 and disconnects inverter No. 1 from a-c bus 2 (if inverter 2 switch is off).	INVERTER CONT-1 - BAT RLY (Panel 5)	Battery relay bus	Controls output of inverters No. 3 & 1 to a-c bus 2. Actuates a motor-driven switch which accomplishes actual switching function. Interlocking circuitry between AC INVERTER 1, 2 & 3 AC BUS 2 switches (Panel 3) prevents more than one inverter from being connected to a-c bus 2 at same time.
			OFF	Disconnects output of inverter No. 3 from a-c bus 2 and allows inverter No. 1 to be connected.			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S67	EPS	AC INVERTER				
			AC BUS 2				
			RESET	Resets a-c bus 2 over-undervoltage and overload sensing units.	EPS SNSR PWR BAT RLY-1 (Panel 5)	Battery relay bus	Provides capability of resetting a-c bus 2 over-undervoltage and overload sensing units. Also releases relay which reconnects operating inverter to a-c bus No. 2 if it has been tripped off due to overvoltage or overload. Resetting a-c bus 2 over-undervoltage and overload sensing units also turns off AC BUS 2 and AC BUS 2 OVERLOAD caution and warning lights (Panel 2).
			(CENTER)	Energizes a-c bus 2 over-undervoltage and overload sensing units for operation.			
			OFF	Disconnects a-c bus 2 over-undervoltage and overload sensing units from the system and extinguishes C/W AC BUS 2 and AC BUS 2 OVERLOAD lights if illuminated.			
3	S68	EPS	AC INDICATOR				
			BUS 1				
			ØA	Applies a-c phase A voltage from a-c bus 1 to AC VOLTS meter.	EPS SENSOR SIGNAL - AC1 (Panel 5)	AC bus 1	Provides means of monitoring voltage output of inverters. Normal operating range for phases A, B, and C (a-c bus 1 and a-c bus 2) is 115 ± 5 vac.
			ØB	Applies a-c phase B voltage from a-c bus 1 to AC VOLTS meter.			
			ØC	Applies a-c phase C voltage from a-c bus 1 to AC VOLTS meter.			
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S68 (Cont)	EPS	BUS 2				
			ØA	Applies a-c phase A voltage from a-c bus 2 to AC VOLTS meter.	EPS SENSOR SIGNAL - AC2 (Panel 5)	AC bus 2	
			ØB	Applies a-c phase B voltage from a-c bus 2 to AC VOLTS meter.			
			ØC	Applies a-c phase C voltage from a-c bus 2 to AC VOLTS meter.			
3	S69	SPS	SPS IND				
			He	Connects SPS helium storage tank pressure output to He TANK PRESS indicator (Panel 3).	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4 (He tank) CB3 (system A) CB4 (system B) (Panel 276)	INSTRUMENTATION MNA and MNB (Panel 5)	Three-position toggle switch used to select SPS helium or nitrogen tank pressure input to He or N_2 SPS TANKS PRESS indicator on Panel 3.
			N_2A	Connects SPS gaseous nitrogen storage tank pressure output of engine control valve system A to N_2A PRESS indicator (Panel 3).			
			N_2B	Connects SPS gaseous nitrogen storage tank pressure output of engine control valve system B to N_2B PRESS indicator (Panel 3).			
3	S71	TLCM	VHF AM				
			RCV ONLY				
			B DATA	Selects VHF-AM 259.7-mc receiver only.	TELECOMMUNICATIONS VHF/CREW STATION AUDIO-CTR FLT/POST LDG BUS (Panel 225)	VHF AM equipment	B DATA nomenclature does not pertain to Skylab missions. Was previously used to receive low bit rate LM telemetry. Functions as a receiver for voice only.
			...continued		...cont	...cont	

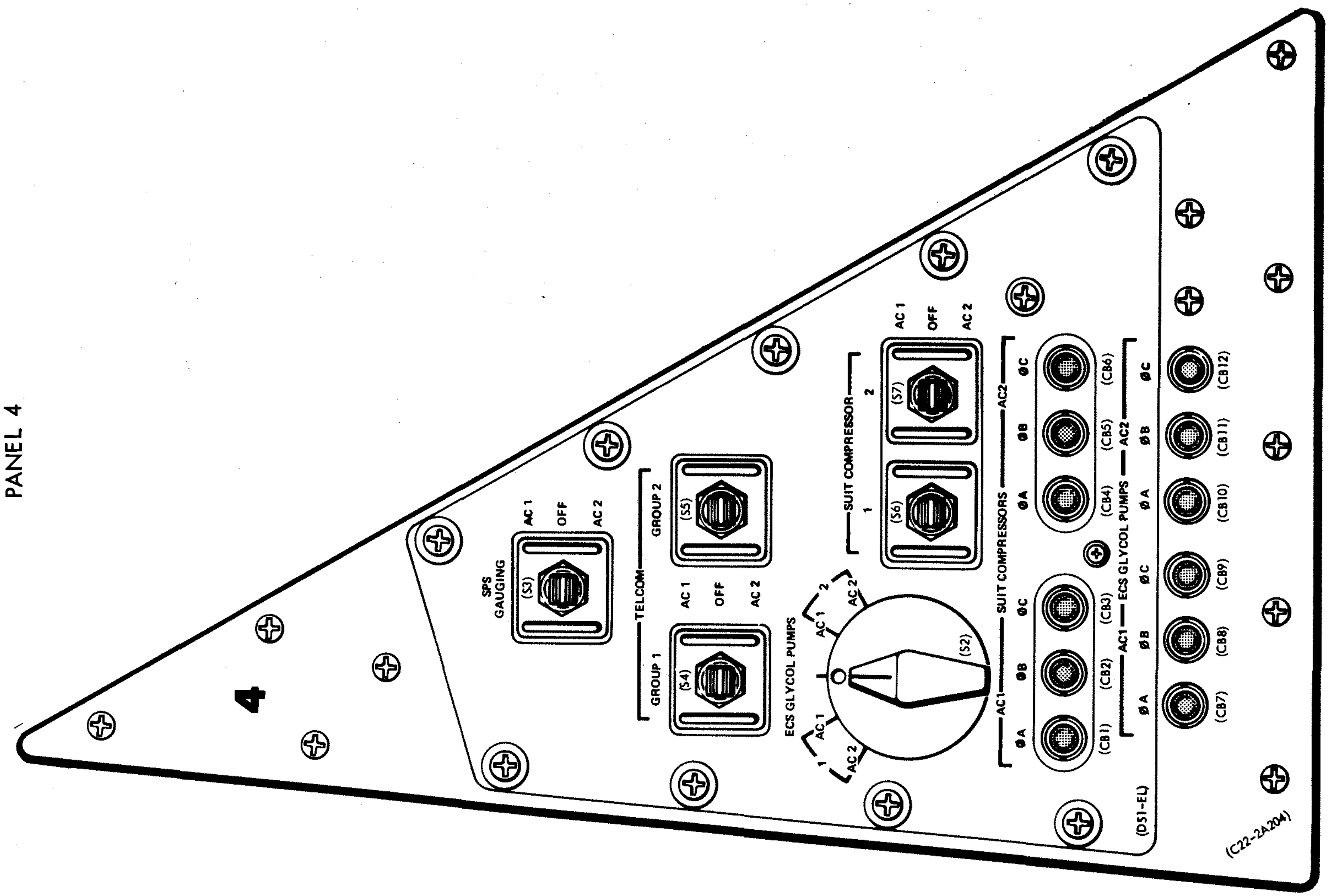
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S71 (Cont)	TLCM	(OFF)	Selects no modes.			
			A	Selects VHF-AM 296.8-mc receiver only.			Provides for monitoring during the recovery phase.
3	S76	EPS	FC REACS VALVES				
			NORM	Maintaining position disconnects holding voltage from reactant valves of all fuel cells and from H_2 vent valve.			Latch position of maintaining switch provides holding voltage to open solenoids of FC reactant valves to prevent inadvertent closing of valves and to H_2 vent valve to prevent inadvertent opening during launch, ascent and SIVB separation.
			LATCH	Maintaining position applies holding voltage to the open solenoids of all FUEL CELL H_2 and O_2 reactant valves and to closed solenoid of H_2 vent valve.	a. SM BUS CONT 1 BAT RLY (Panel 226) b. SM BUS CONT 3 BAT RLY (Panel 226)	Battery relay bus	a. SM BUS CONT-1 circuit breaker provides circuit protection and voltage for FUEL CELL 1 reactant valves and to H_2 vent valve. b. SM BUS CONT-3 circuit breaker provides circuit protection and voltage for FUEL CELL 3 reactant valves.
3	S77	EPS	H_2 PURGE LINE HTR				
			(UP)	Maintaining switch applies power to hydrogen purge line heaters.	a. FUEL CELL 1-PURGE MNA (Panel 226) b. FUEL CELL 3-PURGE MNB (Panel 226)	DC main buses A & B	Maintaining switch provides capability to apply voltage to redundant hydrogen purge line heaters to prevent freezing during hydrogen purge.
			OFF	Disables hydrogen purge line heaters.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S78	TLCM	VHF RANGING OFF	 RANGING: Activates digital ranging generator. OFF: Disables all power to digital ranging generator.	TELECOMMUNI-CATIONS VHF/CREW STATION AUDIO-R FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	RANGING position provides continuous PTT keying for VHF ranging. Duplex B must be used for VHF ranging. Ranging sequence is initiated by VHF RNG RESET switch on MDC 9. Voice transmission is restricted during first 15 seconds of ranging sequence. Tones will be audible in headset.
3	S79	TLCM	S BAND SQUELCH ENABLE OFF	 ENABLE: Provides bias to squelch noise during absence of specified voice subcarrier signal level. OFF: Removes squelch bias for normal receiver operation. Received signal level (voice subcarrier) is limited by receiver sensitivity.	N/A	N/A	Squelch is not adjustable by crew. S-band squelch OFF provides crew with indication of MSFN lock-up by absence of noise. Squelch circuit is internal to the PMP, using same power source as PMP.
3	S80	SPS	SPS IND TEMP OXID LN He PANEL	 OXID LN: Allows SPS engine oxidizer line temperature to be displayed on temperature meter. He PANEL: Allows SPS helium panel temperature to be displayed on temperature meter.	INSTRUMEN-TATION POWER CONTROL OPERATIONAL CB4 (oxidizer) CB3 (helium panel) (Panel 276)	INSTRUMEN-TATION MNA and MNB (Panel 5)	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
3	S81	TLCM	PTT BU				
			LEFT/CTR	Parallels CDR and SPT PTT functions.	N/A	Audio center	Provides for use by own Comm Cable for PTT function when in the backup mode of the audio center. Provides for critical workshop PTT function in case of audio center failure. AUDIO CONTROL switch of failed audio center must be placed in BACKUP position.
			NORM	Provides for normal PTT functions.			
			RIGHT	Parallels SPT and PLT PTT functions.			
3	S82	TLCM	TV SOURCE				
			SWS	Connects SWS TV video to FM transmitter.	TELECOMMUNI-CATIONS S BAND FM XMTR DATA STORAGE EQUIP FLT BUS (Panel 225)	DC main buses A and B	Switch selects source of TV video information for transmission of TV over the FM transmitter to MSFN.
			CM	Connects CM TV video to FM transmitter.			
3	S83	EPS	FUEL CELL REACTANTS				
			H_2 VENT	Momentary position opens H_2 vent valve.	H_2 VENT BAT RLY (Panel 226)	Battery relay bus	Talk back striped when valve is open.
			(CENTER)	Valve remains in last selected position (normal switch position).			
			OFF	Momentary position closes H_2 vent valve.			Provides capability to evacuate H_2 tanks.

CONTROLS AND DISPLAYS

PANEL 4



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
4	CB1	ECS	SUIT COMPRESSORS AC1 ØA	Protects wiring circuit to suit compressors No. 1 and No. 2.	N/A	AC bus 1	
4	CB2	ECS	SUIT COMPRESSORS AC1 ØB	Protects wiring circuit to suit compressors No. 1 and No. 2.	N/A	AC bus 1	
4	CB3	ECS	SUIT COMPRESSORS AC1 ØC	Protects wiring circuit to suit compressors No. 1 and No. 2.	N/A	AC bus 1	
4	CB4	ECS	SUIT COMPRESSORS AC2 ØA	Protects wiring circuit to suit compressors No. 2 and No. 1.	N/A	AC bus 2	
4	CB5	ECS	SUIT COMPRESSORS AC2 ØB	Protects wiring circuit to suit compressors No. 2 and No. 1.	N/A	AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
4	CB6	ECS	SUIT COMPRESSORS AC2 ØC	Protects wiring circuit to suit compressors No. 2 and No. 1.	N/A	AC bus 2	
4	CB7	ECS	ECS GLYCOL PUMPS AC1 ØA	Protects wire circuit to: a. Glycol evaporator inlet temperature control. b. Glycol pumps 1 and 2.	N/A	AC bus 1	
4	CB8	ECS	ECS GLYCOL PUMPS AC1 ØB	Protects wire circuit to glycol pumps 1 and 2.	N/A	AC bus 1	
4	CB9	ECS	ECS GLYCOL PUMPS AC1 ØC	Protects wire circuit to: a. PRIM GLYCOL EVAP STEAM PRESS INCR/DECR switch. b. Glycol pumps 1 and 2.	N/A	AC bus 1	
4	CB10	ECS	ECS GLYCOL PUMPS AC2 ØA	Protects wire circuit to: a. Automatic water-glycol H_2O flow and glycol evaporator steam pressure controllers. b. Glycol pumps 1 and 2.	N/A	AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
4	CB11	ECS	ECS GLYCOL PUMPS				
			AC2				
			ØB	Protects wiring circuit to glycol pumps 1 and 2.	N/A	AC bus 2	
4	CB12	ECS	ECS GLYCOL PUMPS				
			AC2				
			ØC	Protects wiring circuit to glycol pumps 1 and 2.	N/A	AC bus 2	
4	S2	ECS	ECS GLYCOL PUMPS				
			1 AC2	Applies a-c power to motor of No. 1 water-glycol pump from bus No. 2.	ECS-GLYCOL PUMPS-AC2 ØA ØB ØC (Panel 4)	AC bus 2	Only one water-glycol pump can be operated at a time, with second pump for standby redundance. 5 position rotary switch.
			1 AC1	Applies a-c power to motor of No. 1 water-glycol pump from bus No. 1.	ECS-GLYCOL PUMPS-AC1 ØA ØB ØC (Panel 4)	AC bus 1	
			(OFF)	Removes a-c power from motors of water-glycol pumps.			
			2 AC1	Applies a-c power to motor of No. 2 water-glycol pump from bus No. 1	ECS-GLYCOL PUMPS-AC1 ØA ØB ØC (Panel 4)	AC bus 1	
			2 AC2	Applies a-c power to motor of No. 2 water-glycol pump from bus No. 2.	ECS-GLYCOL PUMPS-AC2 ØA ØB ØC (Panel 4)	AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
4	S3	SPS	SPS GAUGING				
			AC1	Propellant utilization gauging control unit and probe simulator removed for flight rendering gauging inoperative. Reason for removal is due to a weight reduction requirement.	SERVICE PROPULSION SYSTEM GAUGING AC1 (Panel 8) NORMAL POSITION IS OUT	AC bus 1	
			OFF				
			AC2		SERVICE PROPULSION SYSTEM GAUGING AC2 (Panel 8) NORMAL POSITION IS OUT	AC bus 2	
4	S4	TLCM	TELCOM				
			Group 1				
			AC1	Connects a-c bus 1 electrical power into Group 1 circuit breakers.	N/A	AC bus 1	Supplies power to circuit breakers on MDC 225 for distribution to telecommunications equipment.
			OFF	Disconnects a-c power from Group 1 circuit breakers.			
			AC2	Connects a-c bus 2 electrical power into Group 1 circuit breakers.		AC bus 2	
4	S5	TLCM	TELCOM				
			Group 2				
			AC1	Connects a-c bus 1 electrical power into Group 2 circuit breakers.	N/A	AC bus 1	Supplies power to circuit breakers on MDC 225 for distribution to telecommunications equipment.
			...continued		...cont		

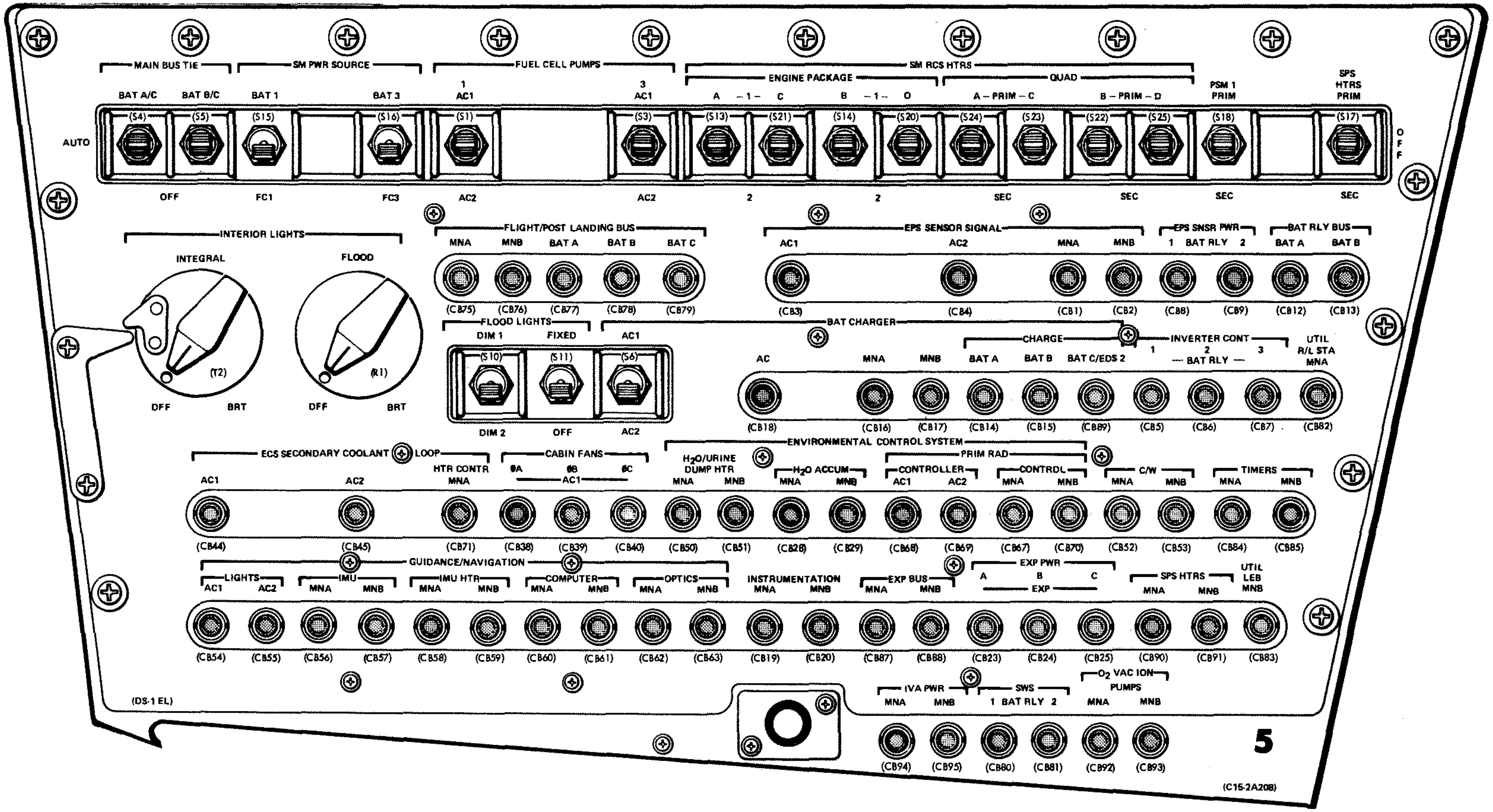
Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
4	S5 (Cont)	TLCM	OFF	Disconnects power from Group 2 circuit breakers.			
			AC2	Connects a-c bus 2 electrical power into Group 2 cricuit breakers.		AC bus 2	
4	S6	ECS	SUIT COMPRESSOR 1				
			AC1	Applies a-c power to motor of suit compressor No. 1 from bus No. 1.	SUIT COMPRESSORS AC1 ØA ØB ØC (Panel 4)	AC bus 1	Output of compressor is as follows: a. Prelaunch mode - 32.7 cfm and ΔP of 0.7 to 0.9 psi. b. Normal mode - 35 cfm and ΔP of 0.36 psi. c. Emergency mode - 33.6 cfm and ΔP of 0.26 psi. d. Suit compressor C&W light at 0.22 psid.
			OFF	Removes a-c power from motors of suit compressors.			
			AC2	Applies a-c power to motor of suit compressor No. 1 from bus No. 2.	SUIT COMPRESSORS AC2 ØA ØB ØC (Panel 4)	AC bus 2	
4	S7	ECS	SUIT COMPRESSOR 2				
			AC1	Applies a-c power to motor of suit compressor No. 2 from bus No. 1.	SUIT COMCOMPRESSORS AC1 ØA ØB ØC (Panel 4)	AC bus 1	Output of compressor as follows: a. Prelaunch mode - 32.7 cfm and ΔP of 0.7 to 0.9 psi. b. Normal mode - 35 cfm and ΔP of 0.36 psi.
			...continued				...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
4	S7 (Cont)	ECS					c. Emergency mode - 33.6 cfm and ΔP of 0.26 psi. d. Suit compressor C&W light at 0.22 psid.
			OFF	Removes a-c power from motor of suit compressor.			
			AC2	Applies a-c power to motor of suit compressor No. 2 from bus No. 2.	SUIT COM-PRESSORS AC2 ØA ØB ØC (Panel 4)	AC bus 2	

Admin Pubs 60791 Exp 10-13-69

PANEL 5


MAIN BUS TIE
SM PWR SOURCE
FUEL CELL PUMPS
SM RCS HTRS
ENGINE PACKAGE
QUAD
BAT A/C
BAT B/C
BAT 1
BAT 3
1 AC1
3 AC1
A – 1 – C
B – 1 – D
A – PRIM – C
B – PRIM – D
PSM 1 PRIM
SPS HTRS PRIM
(S4)
(S5)
(S15)
(S16)
(S1)
(S3)
(S13)
(S21)
(S14)
(S20)
(S24)
(S23)
(S22)
(S25)
(S18)
(S17)
AUTO
OFF
OFF
FC1
FC3
AC2
AC2
2
2
SEC
SEC
SEC
SEC
INTERIOR LIGHTS
INTEGRAL
FLOOD
(T2)
(R1)
OFF
BRT
OFF
BRT
FLIGHT/POST LANDING BUS
MNA
MNB
BAT A
BAT B
BAT C
(CB75)
(CB76)
(CB77)
(CB78)
(CB79)
FLOOD LIGHTS
DIM 1
FIXED
AC1
(S10)
(S11)
(S6)
DIM 2
OFF
AC2
EPS SENSOR SIGNAL
AC1
AC2
MNA
MNB
EPS SNSR PWR
1 BAT RLY 2
BAT RLY BUS
BAT A
BAT B
(CB3)
(CB4)
(CB1)
(CB2)
(CB8)
(CB9)
(CB12)
(CB13)
BAT CHARGER
CHARGE
INVERTER CONT
AC
MNA
MNB
BAT A
BAT B
BAT C/EDS 2
1
2
3
BAT RLY
UTIL R/L STA MNA
(CB18)
(CB16)
(CB17)
(CB14)
(CB15)
(CB89)
(CB5)
(CB6)
(CB7)
(CB82)
ENVIRONMENTAL CONTROL SYSTEM
ECS SECONDARY COOLANT LOOP
AC1
AC2
HTR CONTR MNA
CABIN FANS
ØA
ØB
ØC
AC1
H_2O/URINE DUMP HTR
MNA
MNB
H_2O ACCUM
MNA
MNB
PRIM RAD
CONTROLLER
AC1
AC2
CONTROL
MNA
MNB
C/W
MNA
MNB
TIMERS
MNA
MNB
(CB44)
(CB45)
(CB71)
(CB38)
(CB39)
(CB40)
(CB50)
(CB51)
(CB28)
(CB29)
(CB68)
(CB69)
(CB67)
(CB70)
(CB52)
(CB53)
(CB84)
(CB85)
GUIDANCE/NAVIGATION
LIGHTS
AC1
AC2
IMU
MNA
MNB
IMU HTR
MNA
MNB
COMPUTER
MNA
MNB
OPTICS
MNA
MNB
INSTRUMENTATION
MNA
MNB
EXP BUS
MNA
MNB
EXP PWR
A
B
C
EXP
SPS HTRS
MNA
MNB
UTIL LEB MNB
(CB54)
(CB55)
(CB56)
(CB57)
(CB58)
(CB59)
(CB60)
(CB61)
(CB62)
(CB63)
(CB19)
(CB20)
(CB87)
(CB88)
(CB23)
(CB24)
(CB25)
(CB90)
(CB91)
(CB83)
IVA PWR
MNA
MNB
SWS
1 BAT RLY 2
O_2 VAC ION PUMPS
MNA
MNB
(CB94)
(CB95)
(CB80)
(CB81)
(CB92)
(CB93)
(DS-1 EL)
5
(C15-2A208)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB1	EPS	EPS SENSOR SIGNAL MNA	Protects circuit supplying signal and operating power from d-c main bus A to d-c undervoltage sensing units, and voltage to DC INDICATORS switch and DC VOLTS meter (Panel 3), and telemetry.	N/A	DC main bus A	
5	CB2	EPS	EPS SENSOR SIGNAL MNB	Protects circuit supplying signal and operating power from d-c main bus B to d-c undervoltage sensing units, and voltage to DC INDICATORS switch and DC VOLTS meter (Panel 3), and telemetry.	N/A	DC main bus B	
5	CB3	EPS	EPS SENSOR SIGNAL AC1	Protects circuit supplying signal voltages from three phases of a-c bus 1 to a-c over-undervoltage sensing unit and to AC INDICATORS switch and AC VOLTS meter (Panel 3), and ØA to telemetry.	N/A	AC bus 1	
5	CB4	EPS	EPS SENSOR SIGNAL AC2	Protects circuit supplying signal voltages from three phases of a-c bus 2 to a-c over-undervoltage sensing unit and to AC INDICATORS switch and AC VOLTS meter (Panel 3), and ØA to telemetry.	N/A	AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB5	EPS	INVERTER CONT BAT RLY 1	Protects circuit supplying d-c power from battery relay bus to AC INVERTER 1 MNA and AC BUS 1-1, and AC INVERTER 3 AC BUS 2-3 switches (Panel 3).	N/A	Battery relay bus	
5	CB6	EPS	INVERTER CONT BAT RLY 2	Protects circuit supplying d-c power from battery relay bus to AC INVERTER-2 MNB and AC BUS 1-2, and AC INVERTER 1 AC BUS 2-1 switches (Panel 3).	N/A	Battery relay bus	
5	CB7	EPS	INVERTER CONT BAT RLY 3	Protects circuit supplying d-c power from battery relay bus to AC INVERTER 3 MNA-OFF-MNB and AC BUS 1-3, and AC INVERTER 2 AC BUS 2-2 switches (Panel 3).	N/A	Battery relay bus	
5	CB8	EPS	EPS SNSR PWR BAT RLY-1	Provides protection in circuit supplying operating power thru AC BUS 1 RESET switch (Panel 3) to AC Bus 1 over-undervoltage sensor and the overvoltage and overload disconnect relay.	N/A	Battery relay bus	Is connected to dc main bus A undervoltage sensor for latching circuit and for charging master alarm trigger.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB9	EPS	EPS SNSR PWR BAT RLY-2	Provides protection in circuit supplying operating power thru AC BUS 2 RESET switch (Panel 3) to AC Bus 2 over-undervoltage sensor and the overvoltage and overload disconnect relay; and relay bus voltage to SYSTEM TEST meter (Panel 101) and for telemetry.	N/A	Battery relay bus	Is connected to dc main bus B undervoltage sensor for latching circuit and for charging master alarm trigger.
5	CB12	EPS	BAT RLY BUS BAT A	Protects circuit supplying d-c power from battery bus A through an isolation diode to battery relay bus.	N/A	Battery bus A	Cb opened when charging EPL battery A or pyro battery A.
5	CB13	EPS	BAT RLY BUS BAT B	Protects circuit supplying d-c power from battery bus B through an isolation diode to battery relay bus.	N/A	Battery bus B	Cb opened when charging EPL battery B or pyro battery B.
5	CB14	EPS	BAT CHARGER CHARGE BAT A	Protects circuit supplying d-c power from battery bus A to MAIN BUS TIE - BAT A/C switch (Panel 3), to DC INDICATORS switch (Panel 3), and to telemetry. Protects circuit supplying output of BATTERY CHARGE switch position A to battery bus A for recharge of entry battery A or pyro battery A.	N/A	Battery bus A or battery charger	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB15	EPS	BAT CHARGER CHARGE BAT B	Protects circuit supplying d-c power from battery bus B to MAIN BUS TIE - BAT B/C switch (Panel 3), to DC INDICATORS switch (Panel 3), and to telemetry. Protects circuit supplying output of BATTERY CHARGE switch position B to battery bus B for recharge of entry battery B or pyro battery B.	N/A	Battery bus B	
5	CB16	EPS	BAT CHARGER MNA	Protects circuit supplying power from d-c main bus A, through an isolation diode, to BATTERY CHARGE selector switch (Panel 3) and d-c contacts of battery charger input-power control relay.	N/A	DC main bus A	
5	CB17	EPS	BAT CHARGER MNB	Protects circuit supplying power from d-c main bus B, through an isolation diode, to BATTERY CHARGE selector switch (Panel 3) and d-c contacts of battery charger input-power control relay.	N/A	DC main bus B	
5	CB18	EPS	BAT CHARGER AC	Protects circuit supplying three-phase power from a-c bus No. 1 or a-c bus No. 2 thru contacts of battery charger input-power control relay to battery charger.	N/A	AC bus 1 or 2	A-C bus 1 or 2 selection by BAT CHARGER - switch (Panel 5).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB19	EPS	INSTRUMENTATION MNA	Protects circuit supplying d-c power from d-c main bus A through diode to OPER INSTRUMENTATION circuit breakers on Panel 276.	N/A	DC main bus A	
5	CB20	EPS	INSTRUMENTATION MNB	Protects circuit supplying d-c power from d-c main bus B through diode to OPER INSTRUMENTATION circuit breakers on Panel 276.	N/A	DC main bus B	
5	CB23	**EXP**	EXP PWR EXP A	Protects circuit supplying experiment bus power to experiments.	EXP BUS MNA & MNB (Panel 5)	DC main buses A and B	
5	CB24	**EXP**	EXP PWR EXP B	Protects circuit supplying experiment bus power to experiments.	EXP BUS MNA & MNB (Panel 5)	DC main buses A and B	
5	CB25	**EXP**	EXP PWR EXP C	Protects circuit supplying experiment bus power to experiments.	EXP BUS MNA & MNB (Panel 5)	DC main buses A and B	
5	CB28	ECS	ENVIRONMENTAL CONTROL SYSTEM H_2O ACCUM MNA	Protects wiring to cyclic accumulator control 1.	N/A	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB29	ECS	ENVIRONMENTAL CONTROL SYSTEM H_2O ACCUM MNB	Protects wiring circuit to cyclic accumulator control 2, and manual control of secondary glycol evaporator H_2O flow.	N/A	DC main bus B	
5	CB38	ECS	CABIN FANS AC1 ØA	Protects ØA wiring to 3Ø cabin fans 1 and 2.	N/A	AC bus 1 ØA	
5	CB39	ECS	CABIN FANS AC1 ØB	Protects ØB wiring to 3Ø cabin fans 1 and 2.	N/A	AC bus 1 ØB	
5	CB40	ECS	CABIN FANS AC1 ØC	Protects ØC wiring to 3Ø cabin fans 1 and 2.	N/A	AC bus 1 ØC	
5	CB44	ECS	ECS SECONDARY COOLANT LOOP AC1	Protects circuit wiring to: a. SEC LOOP GLY PUMP. b. SEC GLYCOL EVAP switches: STEAM PRESS AUTO/ MAN INCR/DECR H_2O FLOW AUTO (ØA only)	N/A	AC bus 1	Three-phase ganged-type circuit breaker, single control reset. Overload on any phase trips all three phases.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB45	ECS	ECS SECONDARY COOLANT LOOP AC2	Protects circuit wiring to SEC LOOP GLY PUMP.	N/A	AC bus 2	Three-phase ganged-type circuit breaker, single control reset. Overload on any phase trips all three phases.
5	CB50	ECS	ENVIRONMENTAL CONTROL SYSTEM H_2O/URINE DUMP HTR MNA	Applies power to two 2-watt strip heaters on the water and urine dump nozzles (one heater each) and protects circuit wiring to waste water dump switch, urine dump switch (MDC 2), and steam duct heaters A. Also protects circuit wiring to SM H_2O tank switch (Panel 2).	N/A	DC main bus A	
5	CB51	ECS	ENVIRONMENTAL CONTROL SYSTEM H_2O/URINE DUMP HTR MNB	Applies power to two 2-watt strip heaters on the water and urine dump nozzles (one heater each) and protects circuit wiring to waste water dump switch, urine dump switch (MDC 2), and steam duct heaters B.	N/A	DC main bus B	
5	CB52	C/W	C/W MNA	Provides circuit protection and power from d-c main bus A through a diode to caution and warning system.	N/A	DC main bus A	
5	CB53	C/W	C/W MNB	Provides circuit protection and power from d-c main bus B through a diode to caution and warning system.	N/A	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB54	G&N	GUIDANCE/NAVIGATION LIGHTS AC1	AC1 supplies power and protection for G&N lighting system (Panel 122 C/W LAMPS, STAR ACQ LAMP, and OPTICS TPAC READOUT AND RETICLES) from a-c bus 1 through the G/N LIGHTS switch on Panel 100.	N/A	AC bus 1	
5	CB55	G&N	GUIDANCE/NAVIGATION LIGHTS AC2	AC2 supplies power and protection for G&N lighting system (Panel 122 C/W LAMPS, STAR ACQ LAMP and OPTICS TPAC READOUT AND RETICLES) from a-c bus 2 through the G/N LIGHTS switch on Panel 100.	N/A	AC bus 2	
5	CB56	G&N	GUIDANCE/NAVIGATION IMU MNA	Provides power and protection from d-c main bus A to inertial subsystem through G/N POWER IMU switch on Panel 100.	N/A	DC main bus A	CAUTION This breaker is not to be energized unless the corresponding IMU HTR circuit breaker is energized, as damage to the platform may result.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB57	G&N	GUIDANCE/NAVIGATION IMU MNB	Provides power and protection from d-c main bus B to inertial subsystem through G/N POWER IMU switch on Panel 100.	N/A	DC main bus B	CAUTION This breaker is not to be energized unless the corresponding IMU HTR circuit breaker is energized, as damage to the platform may result.
5	CB58	G&N	GUIDANCE/NAVIGATION IMU HTR MNA	Provides d-c power from main bus A and circuit protection to energize standby thermal control system on IMU and excitation to gyros and accelerometer magnetic output axis suspension.	N/A	DC main bus A	CAUTION This breaker must always be energized or accuracy of the platform may be impaired.
5	CB59	G&N	GUIDANCE/NAVIGATION IMU HTR MNB	Provides d-c power from main bus B and circuit protection to energize standby thermal control system on IMU and excitation to gyros and accelerometer magnetic output axis suspension.	N/A	DC main bus B	CAUTION This breaker must always be energized or accuracy of the platform may be impaired.
5	CB60	G&N	GUIDANCE/NAVIGATION COMPUTER MNA	Provides d-c power from main bus A and circuit protection to energize CMC.	N/A	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB61	G&N	GUIDANCE/NAVIGATION COMPUTER MNB	Provides d-c power from main bus B and circuit protection to energize CMC.	N/A	DC main bus B	
5	CB62	G&N	GUIDANCE/NAVIGATION OPTICS MNA	Provides d-c power from main bus A and circuit protection to energize optical subsystem through G/N POWER OPTICS switch on Panel 100.	N/A	DC main bus A	
5	CB63	G&N	GUIDANCE/NAVIGATION OPTICS MNB	Provides d-c power from main bus B and circuit protection to energize optical subsystem through G/N POWER OPTICS switch on Panel 100.	N/A	DC main bus B	
5	CB67	ECS	ENVIRONMENTAL CONTROL SYSTEM PRIM RAD CONTROL MNA	Protects wiring to PRIM 1 radiator heater controller, flow proportioning switch AUTO or 1 positions, and radiator MAN SEL switch.	N/A	DC main bus A	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB68	ECS	ENVIRONMENTAL CONTROL SYSTEM PRIM RAD CONTROLLER AC1	Protects wiring to space radiators flow proportioning control system No. 1, and radiator isolation valves between flow proportion valve No. 1 and radiator panels No. 1 and No. 2.	N/A	AC bus 1 ØC	
5	CB69	ECS	ENVIRONMENTAL CONTROL SYSTEM PRIM RAD CONTROLLER AC2	Protects wiring to space radiators flow proportioning control system and radiator isolation valves between flow proportion valve No. 2 and radiator panels No.1 and No. 2.	N/A	AC bus 2 ØC	
5	CB70	ECS	ENVIRONMENTAL CONTROL SYSTEM PRIM RAD CONTROL MNB	Protects wiring circuit to PRIM 2 radiator heater controller, primary radiator inlet temperature sensor, and flow proportioning system 2.	N/A	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB71	ECS	ECS SECONDARY COOLANT LOOP HTR CONTR MNA	Protects wiring to secondary radiator heater controller, and secondary radiator inlet and outlet temperature sensors.	N/A	DC main bus A	
5	CB75	EPS	FLIGHT/POST LANDING BUS MNA	Protects circuit supplying power from d-c main bus A through diode to flight and postlanding bus.	N/A	DC main bus A	
5	CB76	EPS	FLIGHT/POST LANDING BUS MNB	Protects circuit supplying power from d-c main bus B through diode to flight and postlanding bus.	N/A	DC main bus B	
5	CB77	EPS	FLIGHT/POST LANDING BUS BAT A	Protects circuit supplying d-c power from battery bus A through two diodes to flight and postlanding bus.	N/A	Battery A	Circuit breaker remains disengaged during flight, and is engaged (pushed in) during main chute descent.
5	CB78	EPS	FLIGHT/POST LANDING BUS BAT B	Protects circuit supplying d-c power from battery bus B through two diodes to flight and postlanding bus.	N/A	Battery B	Circuit breaker remains disengaged during flight, and is engaged (pushed in) during main chute descent.
5	CB79	EPS	FLIGHT/POST LANDING BUS BAT C	Protects circuit supplying d-c power from BAT C through two diodes to flight and postlanding bus.	N/A	Battery C	Circuit breaker remains disengaged during flight, and is engaged (pushed in) during main chute descent.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB80	EPS	SWS BAT RLY-1	Provides protection in circuit supplying power to CSM/SWS INTERFACE POWER MNA CONNECT-DISCONNECT switch (Panel 230) to control circuit for power transfer from SWS bus 1 to CM main d-c bus A, and through SIGNALS switch (Panel 230) to control circuit for one of two SWS to CSM signals transfer umbilicals.	N/A	Battery relay bus	
5	CB81	EPS	SWS BAT RLY-2	Provides protection in circuit supplying power through CSM/SWS INTERFACE POWER MNB CONNECT-DISCONNECT switch (Panel 230) to control circuit for power transfer from SWS bus 2 to CM main d-c bus B, and through SIGNALS switch (Panel 230) to control circuit for second of two SWS to CSM signals transfer umbilicals.	N/A	Battery relay bus	
5	CB82	MISC	UTILITY R/L STA MNA	Protects circuit supplying 28 vdc to UTILITY switch and connectors on Panels 15 and 16.	N/A	DC main bus A	
5	CB83	MISC	UTILITY LEB MNB	Protects circuit supplying 28 vdc to UTILITY switch and connectors on Panel 100.	N/A	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB84	MISC	TIMERS MNA	Protects circuit supplying power from d-c main bus A to event timers on Panel 1 and Panel 306, and mission timer on Panel 2.	N/A	DC main bus A	
5	CB85	MISC	TIMERS MNB	Protects circuit supplying power from d-c main bus B to event timers on Panel 1 and Panel 306, and mission timer on Panel 306.	N/A	DC main bus B	
5	CB87	EXP	EXP BUS MNA	Protects circuit supplying d-c main bus A power to EXP PWR A, B, and C cbs on Panel 5.	N/A	DC main bus A	Dioded with DC main bus B.
5	CB88	EXP	EXP BUS MNB	Protects circuit supplying d-c main bus B power to EXP PWR A, B, and C cbs on Panel 5.	N/A	DC main bus B	Dioded with DC main bus A.
5	CB89	EPS	BAT CHARGER CHARGE BAT C/EDS 2	Protects circuit supplying d-c voltage from battery C to DC INDICATORS switch (Panel 3), and to telemetry. Protects circuit supplying output of BATTERY CHARGE switch position C to battery C for recharge. Protects circuit supplying power to EDS-2-BAT C circuit breaker (Panel 8).	N/A	Battery C	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	CB90	SPS	SPS HTRS MNA	Protects circuit supplying 28 vdc to SPS HTRS switch on Panel 5.	N/A	DC main bus A	
5	CB91	SPS	SPS HTRS MNB	Protects circuit supplying 28 vdc to SPS HTRS switch on Panel 5.	N/A	DC main bus B	
5	CB92	EPS	O_2 VAC ION PUMPS MNA	Provides protection in circuit supplying power to O_2 tank 1 vac-ion pump.	N/A	DC main bus A	Opened on launch pad. Closed as required.
5	CB93	EPS	O_2 VAC ION PUMPS MNB	Provides protection in circuit supplying power to O_2 tank 2 vac-ion pump.	N/A	DC main bus B	Opened on launch pad. Closed as required.
5	CB94	MISC	IVA PWR MNA	Protects circuit supplying 28 vdc to IVA PWR switch on Panel 604.	N/A	DC main bus A	Power source for IVA **crewman ALSA via IVA umbilical.**
5	CB95	MISC	IVA PWR MNB	Protects circuit supplying 28 vdc to IVA PWR switch on Panel 604.	N/A	DC main bus B	Power source for IVA crewman ALSA via IVA umbilical.
5	R1	EPS	INTERIOR LIGHTS FLOOD OFF BRT	 Removes power from right floodlight. Indicates maximum floodlight brightness has been reached.	LIGHTING FLOOD MNB (Panel 226)	DC main bus B	Rheostat control may be adjusted for desired brightness of primary or secondary lighting dependent on position of FLOODLIGHTS DIM 1 or DIM 2 switch.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S1	EPS	FUEL CELL PUMPS				
			1				
			AC1	Applies 3Ø a-c power from a-c bus No. 1 to fuel cell No. 1 pump motors and ØA to pH sensor. Connects power factor correction box to a-c bus 1.	N/A	AC bus 1	Two parallel pump motors are associated with each fuel cell. One motor drives H_2 circulating pump and water separation centrifuge. Other motor drives glycol circulating pump. Switch is located between bus and circuit breaker.
			(CENTER)	Disconnects a-c power from pump motors and pH sensor, and power factor correction box from a-c buses 1 and 2.			
			AC2	Applies 3Ø a-c power from a-c bus No. 2 to fuel cell No. 1 pump motors and ØA to pH sensor. Connects power factor correction box to a-c bus 2.		AC bus 2	
5	S3	EPS	FUEL CELL PUMPS				
			3				
			AC1	Applies 3Ø a-c power from a-c bus No. 1 to fuel cell No. 3 pump motors and ØA to pH sensor. Connects power factor correction box to a-c bus 1.	N/A	AC bus 1	Two parallel pump motors are associated with each fuel cell. One motor drives H_2 circulating pump and water separation centrifuge. Other motor drives glycol circulating pump. Switch is located between bus and circuit breaker.
			(CENTER)	Disconnects a-c power from pump motors and pH sensor, and power factor correction box from a-c buses 1 and 2.			
			AC2	Applies 3Ø a-c power from a-c bus No. 2 to fuel cell No. 3 pump motors and ØA to pH sensor. Connects power factor correction box to a-c bus 2.		AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S4	EPS	MAIN BUS TIE				
			BAT A/C	Allows manual control of bus tie motor switch to connect battery bus A to d-c main bus A and battery C to d-c main bus B.	BAT CHARGER CHARGE BAT A (Panel 5)	Battery bus A	Actuates motor-driven switches which accomplish switching function.
			AUTO	Provides for auto connection of entry batteries A and C to d-c buses at CM-SM separation.			Automatically connects entry batteries A and C to main d-c buses at CM-SM separation. (Used only during prelaunch.)
			OFF	Allows manual control of motor switches to disconnect battery bus A from d-c main bus A and battery C from d-c main bus B.			
5	S5	EPS	MAIN BUS TIE				
			BAT B/C	Allows manual control of bus tie motor switches to connect battery bus B to d-c main bus B and battery C to d-c main bus A.	BAT CHARGER CHARGE BAT B (Panel 5)	Battery bus B	Actuates motor-driven switches which accomplish switching function.
			AUTO	Provides for auto connection of entry batteries B and C to d-c buses at CM-SM separation.			Automatically connects entry batteries B and C to main d-c buses at CM-SM separation. (Used only during prelaunch.)
			OFF	Allows manual control of motor switches to disconnect battery bus B from d-c main bus B and battery C from d-c main bus A.			
5	S6	EPS	BAT CHARGER				
			AC1	Selects a-c bus 1 3Ø power to battery charger thru BAT CHARGER AC cb (Panel 5)		AC bus 1	
			AC2	Selects a-c bus 2 3Ø power to battery charger thru BAT CHARGER AC cb (Panel 5)		AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S10	EPS	FLOODLIGHTS				
			DIM 1	Applies rheostat control to right primary floodlight lamps and on-off control to secondary lamps.	LIGHTING-FLOOD MNA or MNB (Panel 226)	DC main bus A or B	Provides crew capability of shifting primary or secondary lamps to variable FLOOD light switch.
			DIM 2	Applies rheostat control to right secondary floodlight lamps on-off control to primary lamps.			
5	S11	EPS	FLOODLIGHTS				
			FIXED	Turns ON lamps not controlled by rheostat.	LIGHTING FLOOD MNA (Panel 226)	DC main bus A	Secondary when DIM switch on 1. Primary when DIM switch on 2.
			OFF	Removes power.			
5	S13	RCS	SM RCS HTRS				
			ENGINE PACKAGE A				
			1	Supplies power to engine package primary therm-o-switch and heater elements.	REACTION CONTROL SYSTEM SM HEATERS A/C MNA (SEC) A/C MNB (PRIM) (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	
			(OFF)	Removes power from all engine package heaters for quad A.			
			2	Supplies power to engine package redundant therm-o-switch and heater elements.			
5	S14	RCS	SM RCS HTRS				
			ENGINE PACKAGE B				
			1	Supplies power to engine package primary therm-o-switch and heater elements.	REACTION CONTROL SYSTEM SM HEATERS B/D MNA (PRIM) B/D MNB (SEC) (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
			(OFF)	Removes power from all engine package heaters for quad B.			
			2	Supplies power to engine package redundant therm-o-switch and heater elements.			

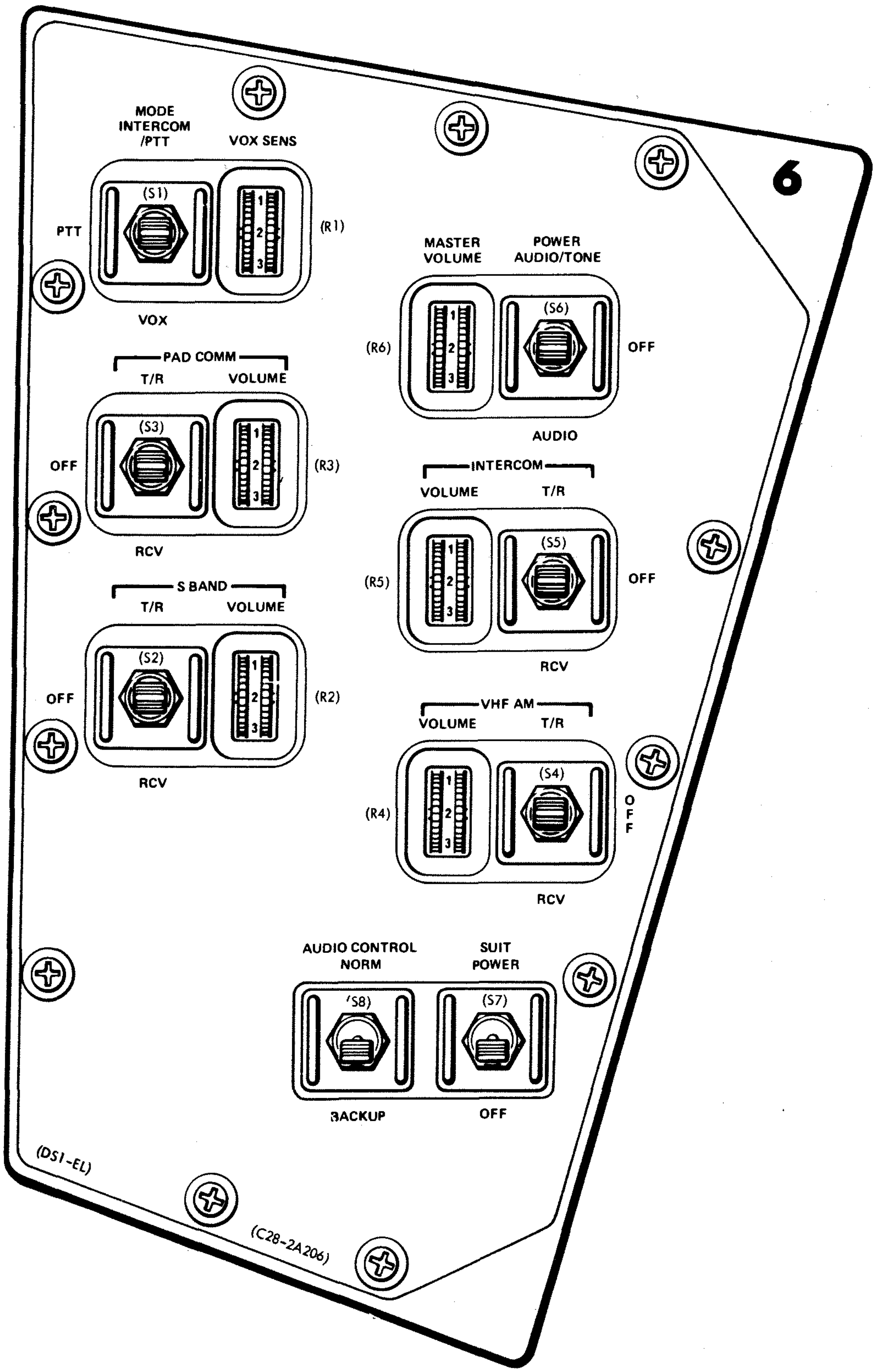
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S15	EPS	SM PWR SOURCE				
			BAT 1	Selects descent battery 1 as d-c main bus power source.	SM BUS CONT - BAT RLY - 1 (Panel 226)	Battery relay bus	
			FC1	Selects fuel cell 1 as d-c main bus power source.			
5	S16	EPS	SM PWR SOURCE				
			BAT 3	Selects descent battery 3 as d-c main bus power source.	SM BUS CONT - BAT RLY - 3 (Panel 226)	Battery relay bus	
			FC3	Selects fuel cell 3 as d-c main bus power source.			
5	S17	SPS	SPS HTRS				
			PRIM	Provides 28 vdc to primary temperature controllers and heaters elements.	SPS HTRS MNA (Panel 5)	DC main bus A	
			OFF	Removes power from all temperature controllers and heaters elements.			
			SEC	Provides 28 vdc to secondary temperature controllers and heaters elements.	SPS HTRS MNB (Panel 5)	DC main bus B	
5	S18	RCS	SM RCS HTRS				
			PSM 1				
			PRIM	Supplies 28 vdc to primary temperature controller and heater elements.	REACTION CONTROL SYSTEM SM HEATERS A/C MNA (SEC) A/C MNB (PRIM) (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	
			OFF	Removes all power from PSM 1 temperature controller and heater elements.			
			SEC	Supplies 28 vdc to secondary temperature controller and heater elements.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S19	RCS	SM RCS HTRS				
			PSM 2				
			PRIM	Supplies 28 vdc to primary temperature controller and heater elements.	REACTION CONTROL SYSTEM SM HEATERS B/D MNA (PRIM) B/D MNB (SEC) (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	If S19 is installed functional description is applicable.
			OFF	Removes all power from PSM 2 temperature controller and heater elements.			
			SEC	Supplies 28 vdc to secondary temperature controller and heater elements.			
5	S20	RCS	SM RCS HTRS				
			ENGINE PACKAGE D				
			1	Supplies power to engine package primary therm-o-switch and heater elements.	REACTION CONTROL SYSTEM SM HEATERS B/D MNA (PRIM) B/D MNB (SEC) (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
			(OFF)	Removes power from all engine package heaters for quad D.			
			2	Supplies power to engine package redundant therm-o-switch and heater elements.			
5	S21	RCS	SM RCS HTRS				
			ENGINE PACKAGE C				
			1	Supplies power to engine package primary therm-o-switch and heater elements.	REACTION CONTROL SYSTEM SM HEATERS A/C MNA (SEC) A/C MNB (PRIM) (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	
			(OFF)	Removes power from all engine package heaters for quad C.			
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S21 (Cont)	RCS	2	Supplies power to engine package redundant therm-o-switch and heater elements.			
5	S22	RCS	SM RCS HTRS QUAD PRIM - B (OFF) SEC	 Supplies 28 vdc to quad B primary temperature controller and heaters. Removes power from all SM RCS blanket B temperature controllers and heaters. Supplies 28 vdc to quad B secondary temperature controller and heaters.	REACTION CONTROL SYSTEM SM HEATERS B/D MNA (PRIM) B/D MNB (SEC) (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
5	S23	RCS	SM RCS HTRS QUAD PRIM - C OFF SEC	 Supplies 28 vdc to quad C primary temperature controller and heaters. Removes power from all SM RCS blanket C temperature controllers and heaters. Supplies 28 vdc to quad C secondary temperature controller and heaters.	REACTION CONTROL SYSTEM SM HEATERS A/C MNB (PRIM) A/C MNA (SEC) (Panel 8)	EPS GROUP 3 MNA and MNB (Panel 229)	
5	S24	RCS	SM RCS HTRS QUAD PRIM - A ...continued	 Supplies 28 vdc to quad A primary temperature controller and heaters.	REACTION CONTROL SYSTEM SM HEATERS A/C MNB (PRIM) A/C MNA (SEC) (Panel 8) ...cont	EPS GROUP 3 MNA and MNB (Panel 229) ...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
5	S24 (Cont)	RCS	(OFF)	Removes all power from SM RCS blanket A temperature controller and heaters.			
			SEC	Supplies 28 vdc to quad A secondary temperature controller and heaters.			
5	S25	RCS	SM RCS HTRS				
			QUAD				
			PRIM - D	Supplies 28 vdc to quad D primary temperature controller and heaters.	REACTION CONTROL SYSTEM SM HEATERS B/D MNA (PRIM) B/D MNB (SEC) (Panel 8)	EPS GROUP 1 MNA and MNB (Panel 229)	
			(OFF)	Removes power from all SM RCS blanket heater D temperature controller and heaters.			
			SEC	Supplies 28 vdc to quad D secondary temperature controller and heaters.			
5	T2	EPS	INTERIOR LIGHTS				
			INTEGRAL				
			OFF	Removes power from right area panels 3, 4, 5, 6, 16, and part of panel 2.	LIGHTING NUMERALS/ INTEGRAL R MDC - AC1 (Panel 226)	AC bus 1	Integral lighting system controls EL lamps behind nomenclature on applicable panels.
			BRT	Indicates maximum brightness has been reached.			

PANEL 6


6
MODE
INTERCOM
/PTT
VOX SENS
PTT
(S1)
(R1)
VOX
PAD COMM
T/R
VOLUME
OFF
(S3)
(R3)
RCV
S BAND
T/R
VOLUME
OFF
(S2)
(R2)
RCV
MASTER
VOLUME
POWER
AUDIO/TONE
(R6)
(S6)
OFF
AUDIO
INTERCOM
VOLUME
T/R
(R5)
(S5)
OFF
RCV
VHF AM
VOLUME
T/R
(R4)
(S4)
OFF
RCV
AUDIO CONTROL
NORM
SUIT
POWER
(S8)
(S7)
BACKUP
OFF
(DS1-EL)
(C28-2A206)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
6	R1	TLCM	VOX SENS	Thumbwheel-type control which operates a 25k ohm potentiometer is provided to adjust sensitivity of voice-operated relay in audio center module.	N/A	Audio center equipment	Adjustment of this control is necessary when the MODE switch is in the VOX position. Numbers 1 to 9 indicate minimum to maximum sensitivity.
6	R2	TLCM	S BAND VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust S-band receiver audio level to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
6	R3	TLCM	PAD COMM VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust audio level from hardline intercomm to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
6	R4	TLCM	VHF AM VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust audio level from VHF AM receiver to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
6	R5	TLCM	INTERCOM VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust audio level from intercom bus to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on thumbwheel are provided to adjust audio level from minimum to maximum.
6	R6	TLCM	MASTER VOLUME	Thumbwheel-type control which operates a 2.5k ohm potentiometer is provided to adjust audio level from earphone amplifier to earphone.	N/A	Audio center equipment	Master volume thumbwheel controls overall volume to headset independent of individual volume controls.

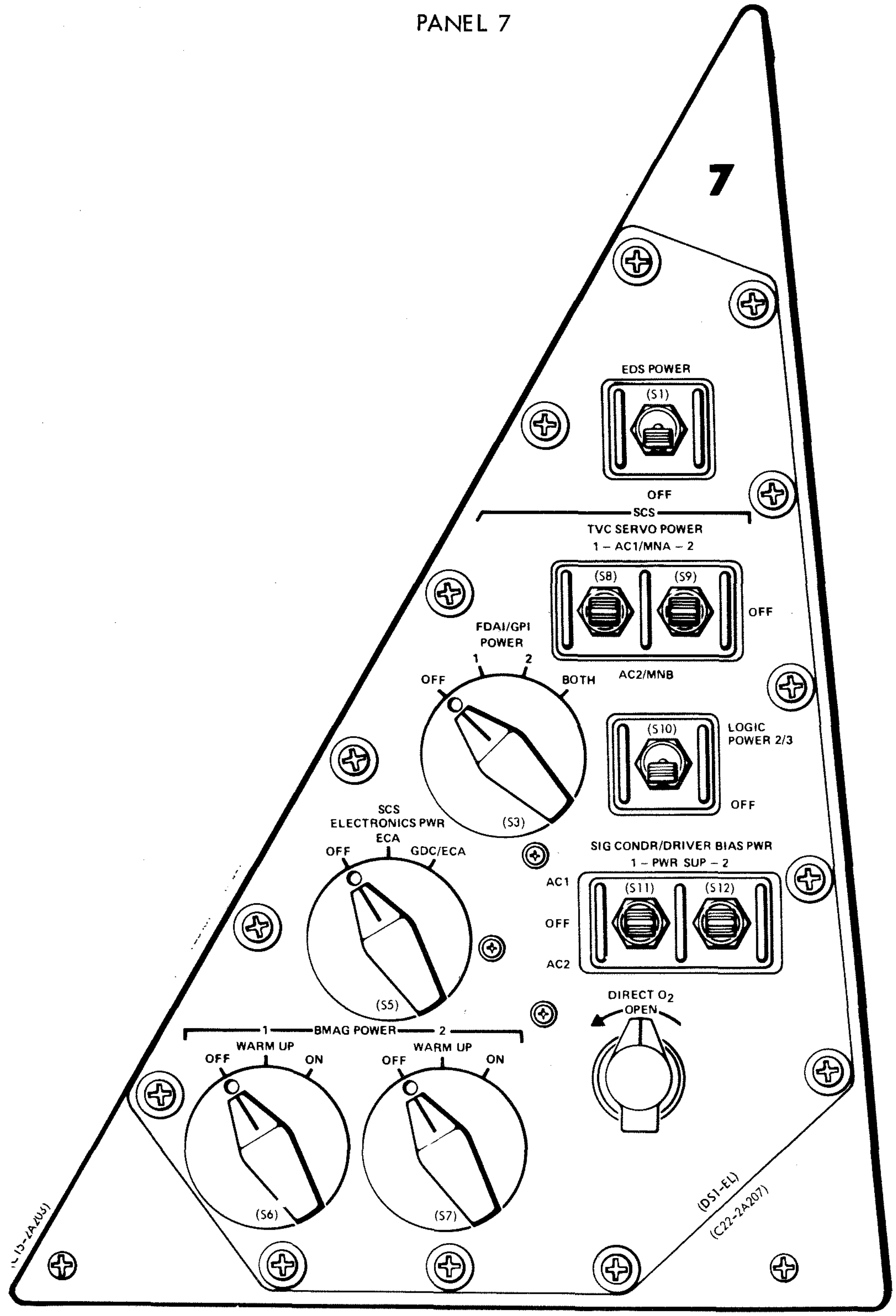
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
6	S1	TLCM	MODE				
			INTERCOM/PTT	Provides hot mike operation for intercom and PTT operation for RF transmission.	N/A	Audio center equipment	PTT function is controlled by crewmans individual comm cable umbilical; also SCS rotation control No. 1 and No. 2. Hot mike intercomm is provided by continuous operation of the microphone amplifier in the audio center however PTT must be used for RF transmit modes.
			PTT	Enables PTT operation for intercom and RF transmission.			
			VOX	Provides VOX operation for both intercom and RF transmission.			
6	S2	TLCM	S BAND				
			T/R	Enables, by circuit closure, headset to receive and transmit over S-band equipment operating in VOICE mode.	N/A	Audio center equipment	Channel A used for S-band communications between CSM and SWS to MSFN. VOICE mode includes not only VOICE or RELAY mode positions, but also VOICE BU positions of S BAND AUX and UP TLM sections, all with their attendant limitations.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, the headset to receive (only) output of S-band equipment operating in VOICE mode.			
6	S3	TLCM	PAD COMM				
			T/R	Enables, by circuit closure, headset to receive and transmit over hardline intercom to launch operations.	N/A	Audio center equipment	May be used as an intercomm backup capability in event of normal intercom failure. PAD COMM must be in the OFF position prior to liftoff due to extreme noise on hardline after liftoff occurs. Pad comm circuit will be unloaded during this period.
			...continued		...cont	...cont	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
6	S3 (Cont)	TLCM	OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of hardline intercom from launch operations.			
6	S4	TLCM	VHF AM				
			T/R	Enables, by circuit closure, headset to receive and transmit over VHF AM equipment.	N/A	Audio center equipment	Correct settings of the simplex/duplex switches are required.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of VHF AM receiver.			
6	S5	TLCM	INTERCOM				
			T/R	Enables, by circuit closure, headset to receive and transmit over the intercom system.	N/A	Audio center equipment	Used for voice communications between crewmen in CSM and SWS. Must be in OFF position on Channel B for annotation of experiments on tape recorder in SWS and prevent interference with S-band communications which is on Channel A.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of intercom system.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
6	S6	TLCM	POWER				
			AUDIO/TONE	Provides primary power to PLT audio center and enable audible crew alarm signal to be heard at this astronaut station.	TELECOMMUNI-CATIONS VHF/CREW STATION AUDIO FLT/POST LDG BUS R (Panel 225)	Flight and postlanding bus	Provides suit power for microphone amplifiers through SUIT POWER switch.
			OFF	Removes primary power and audible crew alarm signal from PLT audio center.			
			AUDIO	Provides primary power to PLT audio center and dis-connects audible crew alarm signal to PLT headset.			
6	S7	TLCM	SUIT				
			POWER	Applies power to left- and right-hand microphones and biomed preamplifiers in the suit associated with audio control Panel 6.	TELECOMMUNI-CATIONS VHF/CREW STATION AUDIO-CTR & R (Panel 225)	Flight and postlanding bus	To remove all power on the Comm Cable Umbilical it is also necessary to place the VHF/AM T/R switch in the OFF position to remove the 28 vdc keying voltage.
			OFF	Removes power from left- and right-hand microphones and biomed preamplifiers in the suit associated with audio control Panel 6.			
6	S8	TLCM	AUDIO CONTROL				
			NORM	Routes PLT audio signals through audio control Panel 6 and associated audio module.	N/A	N/A	Provided in event of audio center failure CDR shares SPT audio center, PLT shares SPT audio center, and SPT shares CDR audio center if BACKUP is selected on respectable audio control panels. PTT control on comm cable umbilical is selected by PTT BU switch on MDC 3.
			BACKUP	Routes PLT audio signals through control Panel 10 and associated audio center module.			

PANEL 7


7
EDS POWER
(S1)
OFF
SCS
TVC SERVO POWER
1 – AC1/MNA – 2
(S8)
(S9)
OFF
AC2/MNB
FDAI/GPI
POWER
1
2
OFF
BOTH
(S3)
(S10)
LOGIC
POWER 2/3
OFF
SCS
ELECTRONICS PWR
ECA
OFF
GDC/ECA
(S5)
SIG CONDR/DRIVER BIAS PWR
1 – PWR SUP – 2
AC1
(S11)
(S12)
OFF
AC2
DIRECT O_2
OPEN
1 BMAG POWER 2
WARM UP
OFF
ON
WARM UP
OFF
ON
(S6)
(S7)
(DS1-EL)
(C22-2A207)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
7	S1	SEQ	EDS POWER				
			(ON)	Supplies entry battery A, B, and C power to EDS buses 1, 3, and 2 in the SIVB IU.	EDS-1, 2 & 3 BAT A BAT C and BAT B (Panel 8)	Battery buses A, B, and entry battery C	Closing of EDS POWER switch provides power to EDS display circuitry and also supplies power for EDS auto abort initiating circuitry.
			OFF	Removes power from EDS buses 1, 2, and 3 in the SIVB IU.			
7	S3	SCS	FDAI/GPI POWER				
			OFF	Not wired.			
			1	a. Supplies 3-phase a-c power to EDA.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1	Provides power to electronics that drive indicators on FDAI No. 1. Supplies (through EDA) power to servometric potentiometers and motors (ball) on FDAI No. 1.
				b. Supplies 28 vdc to EDA.	STABILIZATION/ CONTROL SYSTEM - SYSTEM MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	Provides power to operate GPI meter movements. (PITCH 1 and YAW 1)
			2	a. Supplies 3-phase a-c power to EDA.	STAB CONT SYSTEM-AC2 (Panel 8)	AC bus 2	Provides power to electronics that drive indicators on FDAI No. 2. Supplies (through EDA) power to servometric potentiometers and motors (ball) on FDAI No. 2.
				b. Supplies 28 vdc to EDA.	STABILIZATION/ CONTROL SYSTEM - SYSTEM-MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	Provides power to operate redundant (pitch 2 and yaw 2) GPI meter movements.
			BOTH	Both functions for positions 1 and 2 are provided.			Both FDAIs are active. Total GPI displays active.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
7	S5	SCS	SCS ELECTRONICS PWR				
			OFF	Not wired.			
			ECA	a. Supplies phase A bus 1 power to ECA.	STAB CONT SYSTEM AC1 (Panel 8)	AC bus 1 (phase A)	AC power to ECA for ECA power supplies, demod ref.; routed through transformer (in ECA) to provide rotation controller (RC) transducer reference. AC1 goes to RC-1 and AC2 to RC-2.
				b. Supplies phase A bus 2 power to ECA.	STABILIZATION/ CONTROL SYSTEM-ECA/TVC-AC2 (Panel 8)	AC bus 2 (phase A)	
				c. Supplies 28 vdc to ECA.	STABILIZATION/ CONTROL SYSTEM - SYSTEM MNA and MNB (Panel 8)	EPS GROUP 2 MNA and MNB (Panel 229)	
			GDC/ECA	a. Supplies phase A bus 1 to GDC.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1 (phase A)	
				b. Supplies phase A bus 2 to GDC.	STAB CONT SYSTEM-AC2 (Panel 8)	AC bus 2 (phase A)	
				c. Supplies 28 vdc to GDC.	STABILIZATION/ CONTROL SYSTEM - SYSTEM MNA and MNB (Panel 8)	EPS GROUP 2 MNA and MNB (Panel 229)	

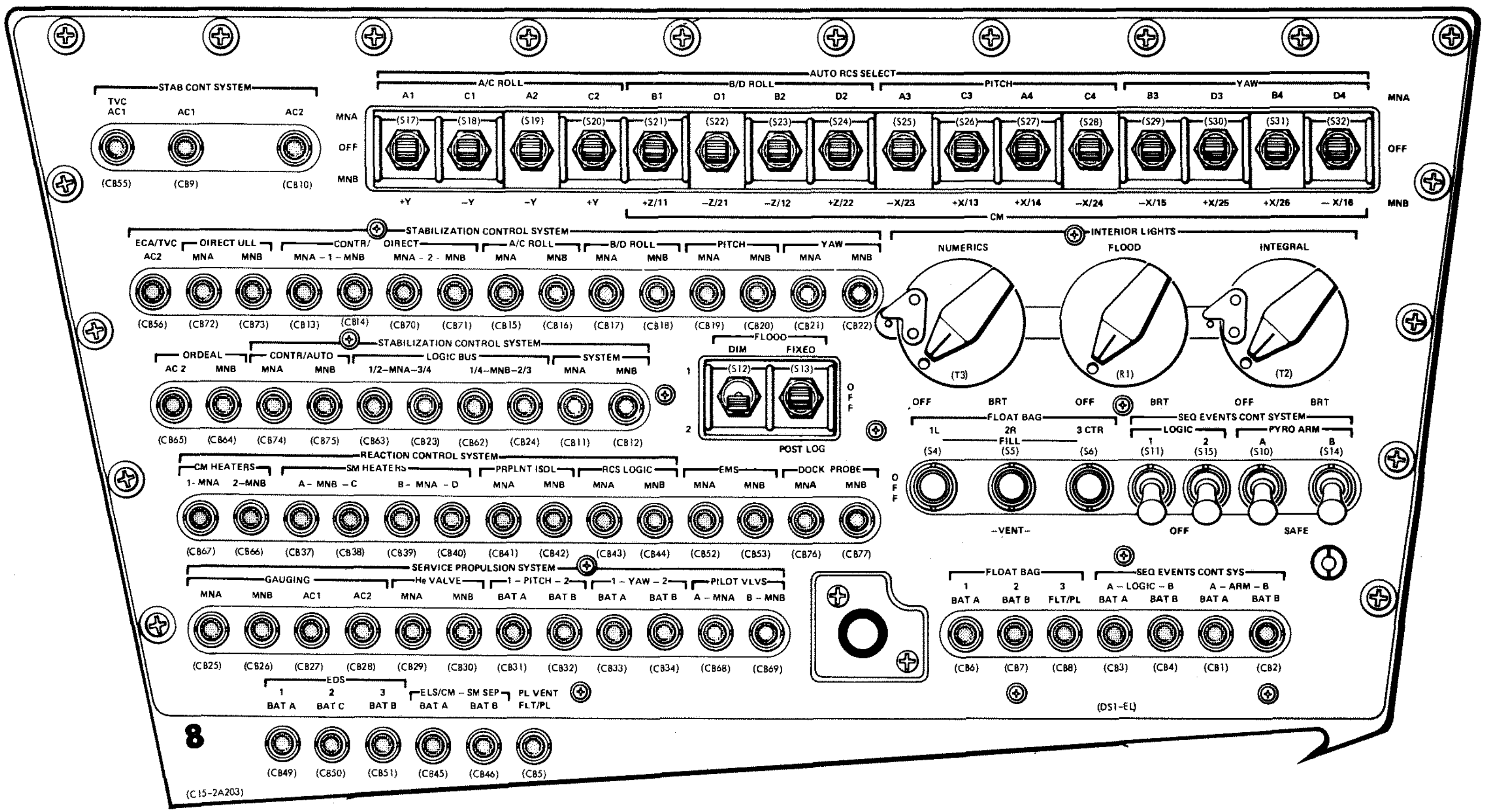
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
7	S5 (Cont)	SCS		d. Supplies phase A bus 1 power to ECA.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1 (phase A)	
				e. Supplies phase A bus 2 power to ECA.	STABILI-ZATION/ CONTROL SYSTEM-ECA/TVC-AC2 (Panel 8)	AC bus 2 (phase A)	
				f. Supplies 28 vdc to ECA.	STABILI-ZATION/ CONTROL SYSTEM - SYSTEM MNA and MNB (Panel 8)	EPS GROUP 2 MNA and MNB (Panel 229)	
7	S6	SCS	BMAG POWER-1				
			OFF	No power supplied.			
			WARMUP	Supplies 28 vdc to GA-1 for heaters and electronics.	STABILI-ZATION CONTROL SYSTEM - SYSTEM-MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	WARMUP and ON poles of BMAG POWER switch are tied together for d-c power switching.
			ON	D-C power, same as in WARMUP.			
				A-C power, supplies 3-phase power to GA-1.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1 (3-phase)	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
7	S7	SCS	BMAG POWER-2				
			OFF	No power supplied.			
			WARMUP	Supplies 28 vdc to GA-2 for heaters and electronics.	STABILIZA- TION CONTROL SYSTEM - SYSTEM MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	WARMUP and ON poles of BMAG power switch are tied together for d-c power switching.
			ON	D-C power, same as in WARMUP.	STAB CONT SYSTEM-AC2 (Panel 8)	AC bus 2 (3-phase)	
				A-C power, supplies 3-phase power to GA-2.			
7	S8	SCS	SCS				
			TVC SERVO POWER-1				
			AC1/MNA	a. Supplies a-c phase A to both (pitch and yaw) primary servo channels in TVSA.	STAB CONT SYSTEM- TVC-AC1 (Panel 8)	AC bus 1 (phase A)	
				b. Supplies 28-vdc power through TVSA to both (pitch and yaw) primary clutches (through normally closed relay contacts).	STABILIZA- TION CONTROL SYSTEM - SYSTEM MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	
			OFF	Not wired.			
			AC2/MNB	a. Supplies a-c phase A to both (pitch and yaw) primary servo channels in TVSA.	STAB CONT SYSTEM-AC2 (Panel 8)	AC bus 2 (phase A)	
				b. Supplies 28-vdc power through TVSA to both (pitch and yaw) primary clutches (through normally closed relay contacts).	STABILI- ZATION/ CONTROL SYSTEM - SYSTEM MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
7	S9	SCS	SCS				
			TVC SERVO POWER-2				
			AC1/MNA	a. Supplies a-c phase A to both (pitch and yaw) secondary servo channels in TVSA.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1 (phase A)	
				b. Supplies 28-vdc power through TVSA (normally open relay contacts) for both secondary clutches.	STABILIZATION/CONTROL SYSTEM - SYSTEM MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	
			OFF	Not wired.			
			AC2/MNB	a. Supplies a-c phase A to both (pitch and yaw) secondary servo channels in TVSA.	STABILIZATION/CONTROL SYSTEM-ECA/TVC-AC2 (Panel 8)	AC bus 2 (phase A)	
				b. Supplies 28-vdc power through TVSA (normally open relay contacts) for both secondary clutches.	STABILIZATION/CONTROL SYSTEM - SYSTEM MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	
7	S10	SCS	SCS				
			LOGIC POWER 2/3	Enables SCS logic buses 2 and 3 to Panel 1 switches and to TC-CW switch.	STABILIZATION/CONTROL SYSTEM LOGIC BUS 3/4 MNA 1/2 MNA 2/3 MNB (Panel 8)	EPS GROUP 1 MNA GROUP 3 MNA GROUP 1 MNB (Panel 229)	Refer to logic bus circuit breakers for Panel 1 switches that are enabled from this switch.
			OFF	Removes power to Panel 1 switches and TC-CW switch.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
7	S11	SCS	SIG CONDR/DRIVER BIAS PWR				
			1-PWR UP				
			AC1	Enables analog signal conditioning power supply in EDA and -4V No. 1 power supply in RJEC.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1	
			OFF	Removes power.			
			AC2	Same as AC1 position.	STAB CONT SYSTEM-AC2 (Panel 8)	AC bus 2	
7	S12	SCS	SIG CONDR/DRIVER BIAS PWR				
			2-PWR UP				
			AC1	Enables -4V No. 2 power supply and analog signal conditioning power supply in RJEC.	STAB CONT SYSTEM-AC1 (Panel 8)	AC bus 1	
			OFF	Removes power.			
			AC2	Same as AC1 position.	STAB CONT SYSTEM-AC2 (Panel 8)	AC bus 2	
7	V1	ECS	DIRECT O_2				Valve has a shaft rotation 1-3/4 turns from OPEN to close. Permanent knob installed to provide ready access.
			OPEN (ccw)	Permits controlled flow of oxygen directly into suit circuit.	N/A	N/A	Valve is opened at crew insertion to maintain suit purge (100% O_2) for launch. May be opened to purge contaminates from suit circuit during flight, or to provide ventilation during "suited" entry. In full open position flow rate is 0.67 pound/minute minimum.
			(Close) (cw)	Shuts off flow of oxygen directly into suit circuit.			Normal position of valve is closed.

PANEL 8


STAB CONT SYSTEM
TVC AC1
AC1
AC2
(CB55)
(CB9)
(CB10)
AUTO RCS SELECT
A/C ROLL
B/D ROLL
PITCH
YAW
A1 C1 A2 C2 B1 D1 B2 D2 A3 C3 A4 C4 B3 D3 B4 D4
MNA
OFF
MNB
(S17) (S18) (S19) (S20) (S21) (S22) (S23) (S24) (S25) (S26) (S27) (S28) (S29) (S30) (S31) (S32)
+Y −Y −Y +Y +Z/11 −Z/21 −Z/12 +Z/22 −X/23 +X/13 +X/14 −X/24 −X/15 +X/25 +X/26 −X/16
CM
STABILIZATION CONTROL SYSTEM
ECA/TVC AC2
DIRECT ULL MNA MNB
CONTR/ DIRECT MNA - 1 - MNB
MNA - 2 - MNB
A/C ROLL MNA MNB
B/D ROLL MNA MNB
PITCH MNA MNB
YAW MNA MNB
(CB56) (CB72) (CB73) (CB13) (CB14) (CB70) (CB71) (CB15) (CB16) (CB17) (CB18) (CB19) (CB20) (CB21) (CB22)
INTERIOR LIGHTS
NUMERICS
FLOOD
INTEGRAL
(T3)
(R1)
(T2)
OFF BRT
OFF BRT
OFF BRT
STABILIZATION CONTROL SYSTEM
ORDEAL AC 2 MNB
CONTR/AUTO MNA MNB
LOGIC BUS 1/2-MNA-3/4 1/4-MNB-2/3
SYSTEM MNA MNB
(CB65) (CB64) (CB74) (CB75) (CB63) (CB23) (CB62) (CB24) (CB11) (CB12)
FLOOD
DIM
FIXED
(S12)
(S13)
1
2
OFF
POST LOG
FLOAT BAG
1L 2R 3 CTR
FILL
(S4) (S5) (S6)
VENT
SEQ EVENTS CONT SYSTEM
LOGIC 1 2
PYRO ARM A B
(S11) (S15) (S10) (S14)
OFF
SAFE
REACTION CONTROL SYSTEM
CM HEATERS 1-MNA 2-MNB
SM HEATERS A - MNB - C B - MNA - D
PRPLNT ISOL MNA MNB
RCS LOGIC MNA MNB
EMS MNA MNB
DOCK PROBE MNA MNB
OFF
(CB67) (CB66) (CB37) (CB38) (CB39) (CB40) (CB41) (CB42) (CB43) (CB44) (CB52) (CB53) (CB76) (CB77)
SERVICE PROPULSION SYSTEM
GAUGING MNA MNB AC1 AC2
He VALVE MNA MNB
1 - PITCH - 2 BAT A BAT B
1 - YAW - 2 BAT A BAT B
PILOT VLVS A - MNA B - MNB
(CB25) (CB26) (CB27) (CB28) (CB29) (CB30) (CB31) (CB32) (CB33) (CB34) (CB68) (CB69)
FLOAT BAG 1 BAT A 2 BAT B 3 FLT/PL
SEQ EVENTS CONT SYS
A - LOGIC - B BAT A BAT B
A - ARM - B BAT A BAT B
(CB6) (CB7) (CB8) (CB3) (CB4) (CB1) (CB2)
(DS1-EL)
EDS 1 BAT A 2 BAT C 3 BAT B
ELS/CM - SM SEP BAT A BAT B
PL VENT FLT/PL
8
(CB49) (CB50) (CB51) (CB45) (CB46) (CB5)
(C15-2A203)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB1	SEQ	SEQ EVENTS CONT SYS ARM-A BAT A	Prevents current overload on following logic control circuits: a. ARM/SAFE MESC logic bus b. ARM/SAFE SECS pyro buses c. FIRE LES MOTOR d. DEPLOY CANARDS e. SEPARATE CSM/LV f. PRESSURIZE CM RCS g. Enable/disable RCS REACTION JET ENGINE ON/OFF control assembly h. SEPARATE DOCKING RING.	EPS BAT BUS A (Panel 229)	Bat bus A	Includes the following switches: a. SEQ EVENTS CONT SYSTEM LOGIC 1 & 2 (Panel 8) b. SEQ EVENTS CONT SYSTEM PYRO ARM A&B (Panel 8) c. LES MOTOR FIRE (Panel 1) d. CANARD DEPLOY (Panel 1) e. CSM/LV SEP (Panel 1) f. CM RCS PRESS (Panel 2) g. RCS CMD (Panel 2) h. DOCK RING SEP FINAL SEP (Panel 2).
8	CB2	SEQ	SEQ EVENTS CONT SYS ARM-B BAT B	Prevents current overload on following logic control circuits: a. ARM/SAFE MESC logic bus b. ARM/SAFE SECS pyro buses c. FIRE LES MOTOR d. DEPLOY CANARDS e. SEPARATE CSM/LV f. PRESSURIZE CM RCS g. Enable/disable RCS REACTION JET ENGINE ON/OFF control assembly h. SEPARATE DOCKING RING.	EPS BAT BUS B (Panel 229)	Bat bus B	Includes the following switches: a. SEQ EVENTS CONT SYSTEM LOGIC 1 & 2 (Panel 8) b. SEQ EVENTS CONT SYSTEM PYRO ARM A&B (Panel 8) c. LES MOTOR FIRE (Panel 1) d. CANARD DEPLOY (Panel 1) e. CSM/LV SEP (Panel 1) f. CM RCS PRESS (Panel 2) g. RCS CMD (Panel 2) h. DOCK RING SEP FINAL SEP (Panel 2).

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB3	SEQ	SEQ EVENTS CONT SYS LOGIC-A BAT A	Prevents current overload on the following bus arming circuits: a. LOGIC BAT BUS A b. MESC LOGIC BUS.	EPS BAT BUS A (Panel 229)	Bat bus A	Parallel relay contacts used to ARM/SAFE MESC LOGIC BUS.
8	CB4	SEQ	SEQ EVENTS CONT SYS LOGIC-B BAT B	Prevents current overload on the following bus arming circuits: a. LOGIC BAT BUS B b. MESC LOGIC BUS.	EPS BAT BUS B (Panel 229)	Bat bus B	Parallel relay contacts used to ARM/SAFE MESC LOGIC BUS.
8	CB5	ECS	PL VENT FLT/PL	Protects circuit wiring to postlanding vent valves No. 1 and 2, and PLV BLOWER.	N/A	Flight and postlanding bus	
8	CB6	SEQ	FLOAT BAG 1 BAT A	Prevents current overload on following postlanding control circuits: a. Control valve of No. 1 (-Y) flotation bag b. Control relay of compressor No. 1.	EPS BAT BUS A (Panel 229)	Bat bus A	Includes FLOAT BAG 1L FILL switch (Panel 8).
8	CB7	SEQ	FLOAT BAG 2 BAT B	Prevents current overload on following postlanding control circuits: a. Control valve of No. 2 (+Y) flotation bag b. Control relay of compressor No. 2.	EPS BAT BUS B (Panel 229)	Bat bus B	Includes FLOAT BAG 2R FILL switch (Panel 8).

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB8	SEQ	FLOAT BAG 3 FLT/PL	Prevents current overload on following postlanding control circuits: a. FLOAT BAG 3 CTR switch (Panel 8) b. POST LANDING BCN LT switch (Panel 15) c. POST LANDING DYE MARKER switch (Panel 15).	N/A	Flight and postlanding bus	Includes following switches: a. FLOAT BAG 3 CTR FILL switch (Panel 8) b. POST LANDING BCN LT switch (Panel 15) c. POST LANDING DYE MARKER switch (Panel 15)
8	CB9	SCS	STAB CONT SYSTEM AC1	Supplies a. 3-phase power to 1. BMAG POWER-1 switch (ON position) 2. FDAI/GPI POWER switch (1 and BOTH positions). b. Phase A power to 1. TVC SERVO POWER-2 switch (AC1/MNA position) 2. SCS ELECTRONICS POWER switch (ECA and GDC/ECA positions) 3. SIG CONDR/DRIVER BIAS PWR - PWR SUP1 - PWR SUP2 switches (AC1 positions).	N/A	AC bus 1 (3-phase)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB10	SCS	STAB CONT SYSTEM AC2	Supplies a. 3-phase power to 1. BMAG POWER-2 switch (ON position) 2. FDAI/GPI POWER switch (2 and BOTH positions). b. Phase A power to 1. SCS ELECTRONICS POWER switch (GDC/ECA position) 2. TVC SERVO POWER 1 switch (AC2/MNB position) 3. SIG CONDR/DRIVER BIAS PWR - PWR SUP1 - PWR SUP 2 switches (AC2 positions).	N/A	AC bus 2 (3-phase)	
8	CB11	SCS	STABILIZATION CONTROL SYSTEM SYSTEM MNA	Supplies 28 vdc to a. BMAG POWER-1 switch (WARMUP and ON positions) b. SCS ELECTRONICS POWER switch (ECA and GDC/ECA positions) c. FDAI/GPI POWER switch (1 and BOTH positions) d. TVC SERVO POWER-1 and -2 switches (AC1/MNA positions).	EPS GROUP 2 MNA (Panel 229)	DC main bus A	
8	CB12	SCS	STABILIZATION CONTROL SYSTEM SYSTEM MNB ...continued	Supplies 28 vdc to a. BMAG POWER-2 switch (WARMUP and ON positions)	EPS GROUP 2 MNB (Panel 229)	DC main bus B	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB12 (Cont)	SCS		b. SCS ELECTRONICS POWER switch (ECA and GDC/ECA positions) c. FDAI/GPI POWER switch (2 and BOTH positions) d. TVC SERVO POWER-1 and -2 switches (AC2/MNB positions).			
8	CB13	SCS	STABILIZATION CONTROL SYSTEM CONTR/DIRECT 1 MNA	Supplies 28 vdc to ROT CONTR PWR-1 switch MNA/MNB and MNA positions.	EPS GROUP 5 MNA (Panel 229)	DC main bus A	
8	CB14	SCS	STABILIZATION CONTROL SYSTEM CONTR/DIRECT 1 MNB	Supplies 28 vdc power to ROT CONTR PWR-1 switch MNA/MNB position.	EPS GROUP 5 MNB (Panel 229)	DC main bus B	
8	CB15	SCS	STABILIZATION CONTROL SYSTEM A/C ROLL MNA	Supplies 28 vdc power to AUTO RCS SELECT A/C ROLL switches, MNA positions.	EPS GROUP 2 MNA (Panel 229)	DC main bus A	With switches in position A, circuit breaker supplies enabling voltage to auto coils on A1, C2, C1, and A2 and serves no function after CM-SM separation.
8	CB16	SCS	STABILIZATION CONTROL SYSTEM A/C ROLL MNB	Supplies 28 vdc power to AUTO RCS SELECT A/C ROLL switches, MNB positions.	EPS GROUP 2 MNB (Panel 229)	DC main bus B	With switches in position B, circuit breaker supplies enabling voltage to auto coils on A1, C2, C1, and A2 and serves no function after CM-SM separation.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB17	SCS	STABILIZATION CONTROL SYSTEM B/D ROLL MNA	Supplies 28 vdc power to AUTO RCS SELECT B/D ROLL switches, MNA positions.	EPS GROUP 4 MNA (Panel 229)	DC main bus A	With switches in position A, circuit breaker supplies enabling voltage to auto coils on SM RCS B1, D2, D1, and B2 and when transferred to CM RCS, auto coils 11, 12, 21, and 22.
8	CB18	SCS	STABILIZATION CONTROL SYSTEM B/D ROLL MNB	Supplies 28 vdc power to AUTO RCS SELECT B/D ROLL switches, MNB positions.	EPS GROUP 4 MNB (Panel 229)	DC main bus B	With switches in position B, circuit breaker supplies enabling voltage to auto coils on SM RCS B1, D2, D1, and B2 and when transferred to CM RCS, auto coils 11, 12, 21, and 22.
8	CB19	SCS	STABILIZATION CONTROL SYSTEM PITCH MNA	Supplies 28 vdc power to AUTO RCS SELECT PITCH switches, MNA positions.	EPS GROUP 1 MNA (Panel 229)	DC main bus A	With switches in position A, circuit breaker supplies enabling voltage to auto coils on C3, A4, A3, and C4 and when transferred to CM RCS, auto coils 13, 23, 14, and 24.
8	CB20	SCS	STABILIZATION CONTROL SYSTEM PITCH MNB	Supplies 28 vdc power to AUTO RCS SELECT PITCH switches, MNB positions.	EPS GROUP 1 MNB (Panel 229)	DC main bus B	With switches in position B, circuit breaker supplies enabling voltage to auto coils on C3, A4, A3, and C4 and when transferred to CM RCS, auto coils 13, 23, 14, and 24.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB21	SCS	STABILIZATION CONTROL SYSTEM YAW MNA	Supplies 28 vdc power to AUTO RCS SELECT YAW switches, MNA positions.	EPS GROUP 3 MNA (Panel 229)	DC main bus A	With switches in position A, circuit breaker supplies enabling voltage to auto coils on D3, B4, B3, and D4 and when transferred to CM RCS, auto coils 15, 25, 16, and 26.
8	CB22	SCS	STABILIZATION CONTROL SYSTEM YAW MNB	Supplies 28 vdc to AUTO RCS SELECT YAW switches, MNB positions.	EPS GROUP 3 MNB (Panel 229)	DC main bus B	With switches in position B, circuit breaker supplies enabling voltage to auto coils on D3, B4, B3, and D4 and when transferred to CM RCS, auto coils 15, 25, 16, and 26.
8	CB23	SCS	STABILIZATION CONTROL SYSTEM LOGIC BUS MNA-3/4 ...continued	Supplies 28 vdc, MNA, to SCS logic bus 4 and 28 vdc, MNA, to SCS LOGIC PWR 2/3 switch.	EPS GROUP 1 MNA (Panel 229) ...cont	DC main bus A ...cont	Respective logic buses supply the following switches: SCS LOGIC BUS NO. 1 SW NO. NAME 2 CMC ATT (IMU) 7 MANUAL ATT-ROLL (MIN IMP & ACCEL CMD) 8 MANUAL ATT-PITCH (MIN IMP & ACCEL CMD) 9 MANUAL ATT-YAW (MIN IMP & ACCEL CMD) 10 LIMIT CYCLE (OFF) 11 ATT DEADBAND (MIN) ...continued

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB23 (Cont)	SCS					SW NO. NAME 12 RATE (HIGH) 20 BMAG MODE - ROLL (RATE 1) 21 BMAG MODE - PITCH (RATE 1) 22 BMAG MODE - YAW (RATE 1) 24 DIRECT ULLAGE (LOGIC FUNCTION) 25 THRUST ON 27 TVC GMBL DRIVE - PITCH (AUTO) 28 TVC GMBL DRIVE - YAW (AUTO) (PANEL 1) SCS LOGIC BUS NO. 2 SW NO. NAME 3 FDAI SCALE (5-5) 5 FDAI SOURCE (CMC) 6 ATT SET (IMU) 18 SC CONTROL (CMC) 20 BMAG MODE - ROLL (ATT 1/RATE 2 & RATE 2) 51 ENTRY .05 G (OFF) TC CLOCKWISE SWITCH (PANEL 1 & TC) SCS LOGIC BUS NO. 3 SW NO. NAME 4 FDAI SELECT (1 & 2) 5 FDAI SOURCE (ATT SET & GDC) 18 SC CONTROL (SCS) 21 BMAG MODE - YAW (ATT 1/RATE 2 & RATE 2)
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB23 (Cont)	SCS					SW NO. NAME 22 BMAG MODE - YAW (ATT 1/RATE 2 & RATE 2) 27 TVC GMBL DRIVE - PITCH (2) 28 TVC GMBL DRIVE - YAW (2) 38 SCS TVC - PITCH } (AUTO, RATE CMD & ACCEL CMD) 39 SCS TVC - YAW } (PANEL 1) SCS LOGIC BUS NO. 4 SW NO. NAME 2 CMC ATT (IMU) 3 FDAI SCALE (50/15 - 50/10) 4 FDAI SELECT (BOTH) 6 ATT SET (GDC) 37 GDC ALIGN 50 ENTRY EMS ROLL (up) 51 ENTRY .05 G (up) (PANEL 1) NOTE: See circuit breakers 24, 62, 63, 78, and 79.
8	CB24	SCS	STABILIZATION CONTROL SYSTEM LOGIC BUS MNB-2/3	Supplies 28 vdc, MNB to SCS logic buses 2 and 3 through the SCS LOGIC PWR 2/3 switch.	EPS GROUP 1 MNB (Panel 229)	DC main bus B	See Remarks circuit breaker 23. NOTE: See circuit breakers 23, 62, and 63.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB25	SPS	SERVICE PROPULSION SYSTEM GAUGING MNA	Applies d-c power to the following: a. SPS thrust ON-OFF relays b. SPS quantity gauging TEST switch.	EPS GROUP 4 MNA (Panel 229)	DC main bus A	CB25, 26, 27 and 28 are pulled out: SPS gauging is rendered inoperative due to removal of propellant utilization gauging control unit. Reason for removal is due to weight reduction requirements.
8	CB26	SPS	SERVICE PROPULSION SYSTEM GAUGING MNB	Applies d-c power to the SPS thrust ON-OFF relays.	EPS GROUP 4 MNB (Panel 229)	DC main bus B	
8	CB27	SPS	SERVICE PROPULSION SYSTEM GAUGING AC1	Applies power from a-c bus 1 to AC1 of SPS GAUGING switch (Panel 4).	N/A	AC bus 1	
8	CB28	SPS	SERVICE PROPULSION SYSTEM GAUGING AC2	Applies power from a-c bus 2 to AC2 of SPS GAUGING switch (Panel 4).	N/A	AC bus 2	
8	CB29	SPS	SERVICE PROPULSION SYSTEM He VALVE MNA	Applies d-c power to the following: a. 1 SPS HELIUM switch (Panel 3) b. ΔV THRUST-NORMAL-A switch for injector pre-valve A c. 1 SPS helium talkback indicator.	EPS GROUP 4 MNA (Panel 229)	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB30	SPS	SERVICE PROPULSION SYSTEM He VALVE MNB	Applies d-c power to the following: a. 2 SPS HELIUM switch (Panel 3) b. ΔV THRUST-NORMAL-B switch for injector pre-valve B c. 2 SPS helium talkback indicator.	EPS GROUP 4 MNB (Panel 229)	DC main bus B	
8	CB31	SPS	SERVICE PROPULSION SYSTEM 1 - PITCH BAT A	Applies power from battery bus A to SPS GIMBAL MOTORS-PITCH 1 switch (Panel 1).	EPS BAT BUS A (Panel 229)	Battery bus A	
8	CB32	SPS	SERVICE PROPULSION SYSTEM 2 - PITCH BAT B	Applies power from battery bus B to SPS GIMBAL MOTORS-PITCH 2 switch (Panel 1).	EPS BAT BUS B (Panel 229)	Battery bus B	
8	CB33	SPS	SERVICE PROPULSION SYSTEM 1 - YAW BAT A	Applies power from battery bus A to SPS GIMBAL MOTORS-YAW 1 switch (Panel 1).	EPS BAT BUS A (Panel 229)	Battery bus A	
8	CB34	SPS	SERVICE PROPULSION SYSTEM 2 - YAW BAT B	Applies power from battery bus B to SPS GIMBAL MOTORS-YAW 2 switch (Panel 1).	EPS BAT BUS B (Panel 229)	Battery bus B	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB37	RCS	SM RCS HTRS AC-PRIM MNB	Supplies 28 vdc to SM RCS HTRS ENGINE PACKAGE A and C switches PRIM position, SM RCS HEATERS QUAD A and C switches PRIM position, and SM RCS HTRS PSM 1 switch PRIM position on panel 5.	EPS GROUP 3 MNB (Panel 229)	DC main bus B	
8	CB38	RCS	SM RCS HTRS SEC-B/D MNB	Supplies 28 vdc to SM RCS HTRS ENGINE PACKAGE B and D switches SEC position, SM RCS HTRS QUAD B and D switches SEC position, SM RCS HTRS PSM 2 switch SEC position (if installed), on panel 5.	EPS GROUP 1 MNB (Panel 229)	DC main bus B	
8	CB39	RCS	SM RCS HTRS SEC-A/C MNA	Supplies 28 vdc to SM RCS HTRS ENGINE PACKAGE A and C switches SEC position, SM RCS HTRS QUAD A and C switches SEC position, and SM RCS HTRS PSM 1 switch SEC position on panel 5.	EPS GROUP 1 MNA (Panel 229)	DC main bus A	
8	CB40	RCS	SM RCS HTRS B/D-PRIM MNA	Supplies 28 vdc to SM RCS HTRS ENGINE PACKAGE B and D switches PRIM position, SM RCS HEATERS QUAD B and D switches PRIM position, SM RCS HTRS PSM 2 switch PRIM position (if installed), on panel 5.	EPS GROUP 1 MNA (Panel 229)	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB41	RCS	REACTION CONTROL SYSTEM PRPLNT ISOL MNA	Applies power from d-c main bus A to the following: a. SM RCS QUADS B and D switches for HELIUM, QUAD SEC FUEL PRESS, QUAD propellant, SM RCS PSM propellant, 1/2 of PSM helium 1 and 2 and 1/2 of PSM manifold fuel and oxidizer isolation valves b. CM RCS-1 PROPELLANT switch and indicator, and CM RCS-1 propellant valve closure on a 0 to T +61-second abort.	EPS Group 1 MNA (Panel 229)	DC main bus A	Thermal, push-pull manual reset-type circuit breakers with the amperage rating of each denoted by a white placard.
8	CB42	RCS	REACTION CONTROL SYSTEM PRPLNT ISOL MNB	Applies power from d-c main bus B to the following: a. SM RCS QUADS A and C switches for HELIUM, QUAD SEC FUEL PRESS, QUAD propellant, SM RCS PSM propellant, 1/2 of PSM helium 1 and 2 and 1/2 of PSM manifold fuel and oxidizer isolation valves b. CM RCS-2 propellant switch and indicator, and CM RCS-2 propellant valve closure on a 0 to T +61-second abort.	EPS Group 1 MNB (Panel 229)	DC main bus B	Thermal, push-pull manual reset-type circuit breakers with the amperage rating of each denoted by a white placard.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB43	RCS	REACTION CONTROL SYSTEM LOGIC MNA	Applies power from d-c main bus A to the following: a. RCS TRNFR switch (Panel 2) b. CM RCS LOGIC switch (Panel 1) c. CM RCS HTRS switch (Panel 101) d. CM RCS He DUMP push-button on Panel 1.	EPS GROUP 5 MNA (Panel 229)	DC main bus A	Thermal, push-pull manual reset-type circuit breakers with the amperage rating of each denoted by white placard.
8	CB44	RCS	REACTION CONTROL SYSTEM LOGIC MNB	Applies power from d-c main bus B to the following: a. RCS TRNFR switch (Panel 2) b. CM RCS LOGIC switch (Panel 1) c. CM RCS HTRS switch (Panel 101) d. CM RCS He DUMP push-button on Panel 1.	EPS GROUP 5 MNB (Panel 229)	DC main bus B	Thermal, push-pull manual reset-type circuit breakers with the amperage rating of each denoted by white placard.
8	CB45	SEQ	ELS/CM-SM SEP BAT A	Prevents current overload on following logic control circuits: a. Separation of the CM from the SM b. Jettison of the apex cover c. Deploy main chutes.	EPS BAT BUS A (Panel 229)	Bat bus A	Includes the following switches: a. CM/SM SEP switches (Panel 2) b. APEX COVER JETT switch (Panel 1) c. DROGUE DEPLOY switch (Panel 1) d. MAIN DEPLOY switch (Panel 1).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB46	SEQ	ELS/CM-SM SEP BAT B	Prevents current overload on following logic control circuits: a. Separation of the CM from the SM b. Jettison of the apex cover c. Deploy main chutes.	EPS BAT BUS B (Panel 229)	Bat bus B	Includes the following switches: a. CM/SM SEP switches (Panel 2) b. APEX COVER JETT switch (Panel 1) c. DROGUE DEPLOY switch (Panel 1) d. MAIN DEPLOY switch (Panel 1).
8	CB49	SEQ	EDS 1 BAT A	Prevents current overload on following EDS circuits: a. ARM/SAFE EDS BUS 1 (SIVB, IU) b. Booster cutoff and LES or SPS abort start relay coils (MESC, system A).	EPS BAT BUS A (Panel 229)	Bat bus A	Includes the following switches and relay logic: a. One pole of EDS POWER switch (Panel 7) b. Coil of EDS bus changeover relay (MESC, system A) c. Contacts of EDS bus changeover relay (MESC, system A). d. Contacts of relay voting logic (2 or 3 abort initiate, MESC, system A) e. Contacts of auto abort enable relays (MESC, system A) f. Time delays (auto abort initiate, MESC, system A) g. Coils of booster cutoff and LES or SPS abort start relays (MESC, system A).

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB50	SEQ	EDS 2 BAT C	Prevents current overload on EDS BUS 2 ARM/SAFE circuitry (SIVB, IU).	BATTERY CHARGER CHARGE BAT C/EDS 2 (Panel 5)	Entry and postlanding battery C	Includes one pole of EDS POWER switch (Panel 7) and relay contacts of EDS BUS changeover circuits. This relay logic will automatically switch battery C power to the A and/or B systems in the event of a power failure.
8	CB51	SEQ	EDS 3 BAT B	Prevents current overload on following EDS circuits: a. ARM/SAFE EDS Bus 3 (SIVB, IU) b. Booster cutoff and LES or SPS abort start relay coils (MESC, system B).	EPS BAT BUS B (Panel 229)	Bat bus B	Includes the following switches and relay logic: a. One pole of EDS POWER switch (Panel 7) b. Coil of EDS bus changeover relay (MESC, system B) c. Contacts of EDS bus changeover relay (MESC, system B) d. Contacts of relay voting logic (2 of 3 abort initiate, MESC, system B) e. Contacts of auto abort enable relays (MESC, system B) f. Time delays (auto abort initiate, MESC, system B) g. Coils of booster cutoff and LES or SPS abort start relays.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB52	SCS	EMS MNA	Provides d-c power to EMS from MNA.	EPS GROUP 4 MNA (Panel 229)	DC main bus A	Also supplies power to SPS THRUST light on EMS Panel 1.
8	CB53	SCS	EMS MNB	Provides d-c power to EMS from MNB.	EPS GROUP 4 MNB (Panel 229)	DC main bus B	Also supplies power to SPS THRUST light on EMS Panel 1.
8	CB55	SCS	STAB CONT SYSTEM TVC AC1	Supplies a-c phase A power to TVC SERVO POWER-1 switch (AC1/MNA position).	N/A	AC bus 1 (ØA)	
8	CB56	SCS	STABILIZATION CONTROL SYSTEM ECA/TVC AC2	Supplies phase A to a. SCS ELECTRONICS POWER switch (ECA and GDC/ECA positions) b. TVC SERVO POWER-2 switch (AC2/MNB position).	N/A	AC bus 2 (ØA)	
8	CB62	SCS	STABILIZATION CONTROL SYSTEM LOGIC BUS MNB-1/4	Supplies 28 vdc, MNB, to SCS logic buses 1 and 4.	EPS GROUP 3 MNB (Panel 229)	DC main bus B	See Remarks circuit breaker 23. NOTE: See circuit breakers 23, 24, and 63.
8	CB63	SCS	STABILIZATION CONTROL SYSTEM LOGIC BUS MNA-1/2	Supplies 28 vdc, MNA, to SCS logic bus 1 and to the SCS LOGIC PWR 2/3 switch.	EPS GROUP 3 MNA (Panel 229)	DC main bus A	See Remarks circuit breaker 23. NOTE: See circuit breakers 23, 24, and 62.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB64	SCS	ORDEAL MNB	Enabling voltage for ORDEAL stepper motor operation.	EPS GROUP 3 MNB (Panel 229)	DC main bus B	ORDEAL unit is Panel 13.
8	CB65	SCS	ORDEAL AC2	Enabling voltage for ORDEAL logic operation and lighting.	N/A	AC bus 2	ORDEAL unit is Panel 13.
8	CB66	RCS	CM RCS HTRS 2 MNB	Supplies 28 vdc to 12 CM RCS 2 engine direct coils for CM RCS heating.	EPS GROUP 5 MNB (Panel 229)	DC main bus B	Provides power to 12 CM RCS engines, system 2, providing CM RCS HTRS switch placed to CM RCS HTRS, on Panel 101, CM RCS LOGIC switch placed to LOGIC on Panel 1 and RCS LOGIC breaker B on Panel 8 is in.
8	CB67	RCS	CM RCS HTRS 1 MNA	Supplies 28 vdc to 12 CM RCS 1 engine direct coils for CM RCS heating.	EPS GROUP 5 MNA (Panel 229)	DC main bus A	Provides power to 12 CM RCS engines, system 1, providing CM RCS HTRS switch placed to CM RCS HTRS, on Panel 101, CM RCS LOGIC switch placed to LOGIC on Panel 1 and RCS LOGIC breaker A on Panel 8 is in.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB68	SPS	SERVICE PROPULSION SYSTEM PILOT VLVS A-MNA	Supplies 28 vdc to ΔV THRUST NORMAL switch A.	EPS GROUP 5 MNA (Panel 229)	DC main bus A	ΔV THRUST NORMAL switch placed to A, power provided to SPS A bank thrust on-off logic, SPS relays and solenoid control valves.
8	CB69	SPS	SERVICE PROPULSION SYSTEM PILOT VLVS B-MNB	Supplies 28 vdc to ΔV THRUST NORMAL switch B.	EPS GROUP 5 MNB (Panel 229)	DC main bus B	ΔV THRUST NORMAL switch placed to B, power provided to SPS B bank thrust on-off logic, SPS relays and solenoid control valves.
8	CB70	SCS	STABILIZATION CONTROL SYSTEM CONTR/DIRECT 2 MNA	Supplies 28 vdc to ROT CONTR PWR-2 switch. MNA to MNA/MNB position.	EPS GROUP 5 MNA (Panel 229)	DC main bus A	
8	CB71	SCS	STABILIZATION CONTROL SYSTEM CONTR/DIRECT 2 MNB	Supplies 28 vdc to ROT CONTR PWR-2 switch. MNB to MNA/MNB and MNB positions.	EPS GROUP 5 MNB (Panel 229)	DC main bus B	
8	CB72	SCS	STABILIZATION CONTROL SYSTEM DIRECT ULL MNA	Applies 28 vdc, MNA, to direct ullage pushbutton on Panel 1.	EPS Group 5 MNA (Panel 229)	DC main bus A	MNA to SM RCS engines B4 and D3 when DIRECT ULLAGE depressed.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB73	SCS	STABILIZATION CONTROL SYSTEM DIRECT ULL MNB	Applies 28 vdc, MNB, to direct ullage pushbutton on Panel 1.	EPS GROUP 5 MNB (Panel 229)	DC main bus B	MNB to SM RCS engines A4 and C3 when DIRECT ULLAGE depressed.
8	CB74	SCS	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA	a. Supplies 28 vdc power to ROT CONTR PWR NORMAL - 1 & 2 switches, AC/DC positions b. Supplies 28 vdc power to TRANS CONTR PWR switch c. Supplies 28 vdc power through SECS A for auto RCS drivers (16) enable power.	EPS GROUP 1 MNA (Panel 229)	DC main bus A	
8	CB75	SCS	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB	a. Supplies 28 vdc power to ROT CONTR PWR NORMAL - 1 & 2 switches, AC/DC positions b. Supplies 28 vdc power to TRANS CONTR PWR switch c. Supplies 28 vdc power through SECS B for auto RCS drivers (16) enable power.	EPS GROUP 1 MNB (Panel 229)	DC main bus B	
8	CB76	DKG	DOCK PROBE MNA	Power to operate system A capture latch motor, talk-back indicator, extension latch, and probe retract relays.	EPS GROUP 4 MNA (Panel 229)	DC main bus A	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	CB77	DKG	DOCK PROBE				
			MNB	Power to operate system B capture latch motor, talk-back indicator, extension latch, and probe retract relays.	EPS GROUP 4 MNB (Panel 229)	DC main bus B	
8	R1	EPS	INTERIOR LIGHTS				
			FLOOD				
			OFF	Removes power from commander's rheostat controlled floodlights.	LIGHTING FLOOD MNA (Panel 226)	DC main bus A	Primary when DIM switch is on 1; secondary when DIM switch is on 2.
			BRT	BRT indicates maximum brightness has been reached.			
8	S4	SEQ	FLOAT BAG				
			1L				
			FILL	Closes vent and opens fill valves of No. 1 (-Y) bag. Energizes starting relay for two compressors.	FLOAT BAG 1 BAT A (Panel 8)	Bat bus A through EPS BAT BUS A circuit breaker (Panel 229)	Switch must remain in VENT position during launch and throughout flight.
			OFF	Neutral (off) position.			
			VENT	Opens vent and closes fill valves of No. 1 (-Y) bag. De-energizes starting relay for two compressors.			UPRIGHTING SYSTEM COMPRESSOR circuit breakers (Panel 278) must be closed before compressors can be started.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S5	SEQ	FLOAT BAG				
			2R				
			FILL	Closes vent and opens fill valves of No. 2 (+Y) bags. Energizes starting relay for two compressors.	FLOAT BAG 2 BAT B (Panel 8)	Bat bus B through EPS BAT BUS B circuit breaker (Panel 229)	UPRIGHTING SYSTEM COMPRESSOR circuit breakers (Panel 278) must be closed before compressor can be started.
			OFF	Neutral (off) position.			
			VENT	Opens vent and closes fill valves of No. 2 (+Y) bag. De-energizes starting relay for two compressors.			Switch must remain in VENT position during launch and throughout flight.
8	S6	SEQ	FLOAT BAG				
			3 CTR				
			FILL	Closes vent and opens fill valves of No. 3 (+Z) bag.	FLOAT BAG 3 FLT/PL (Panel 8)	Flight and postlanding bus	Switch must remain in the VENT position during launch and throughout flight.
			OFF	Neutral (off position).			
			VENT	Opens vent and closes fill valves of No. 3 (+Z) bag.			
8	S10	SEQ	SEQ EVENTS CONT SYSTEM				
			PYRO ARM				
			A	Energizes pyro bus ARM/SAFE motor switch in the A system DEC.	SEQ EVENTS CONT SYSTEM ARM A BAT A (Panel 8)	Bat bus A through EPS BAT BUS A circuit breaker (Panel 229)	Drives contacts of motor switch to ARM following A system pyro buses. a. DEC b. RCSC c. MESC & ELSC (ELSC bus coupled to MESC bus).
			SAFE	Energizes pyro bus ARM/SAFE motor switch in the A system DEC.			
			...continued		...cont	...cont	...continued

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S10 (Cont)	SEQ					Drives contacts of motor switch to SAFE PYRO buses listed above. Logic power automatically removed from motor switch at end of travel in either direction.
8	S11	SEQ	SEQ EVENTS CONT SYSTEM LOGIC 1 OFF	 Energizes MESC logic arm relays in A and B systems. De-energizes MESC logic arm relays in A and B systems.	 SEQ EVENTS CONT SYSTEM ARM A BAT A (Panel 8)	 Bat bus A through EPS BAT BUS A circuit breaker (Panel 229)	 Two-pole switch. One pole in system A, the other pole in system B, arming circuits of MESC logic buses.
8	S12	EPS	FLOOD DIM 1 2	 Applies rheostat control to primary floodlights and on-off control to secondary floodlights. Applies rheostat control to secondary floodlights and on-off control to primary floodlights.	 LIGHTING FLOOD MNA & MNB (Panel 226)	 DC main buses A and B	 Provides crew capability of shifting primary or secondary lamps to variable FLOOD light switch.
8	S13	EPS	FLOOD FIXED ...continued	 Turns on lamps not controlled by rheostat.	 LIGHTING FLOOD MNB & FLT/PL (Panel 226) ...cont	 DC main bus B and flight and post-landing bus ...cont	 On-off control of floodlights not on rheostat control.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S13 (Cont)	EPS	OFF	Removes power.			Secondary when DIM switch is on 1; primary when DIM switch is on 2.
			POST LDG	Connects postlanding bus to commander's lights.			Illuminates lamps located on LH couch arm and LH inner mold line.
8	S14	SEQ	SEQ EVENTS CONT SYSTEM PYRO ARM				
			B	Energizes pyro bus ARM/ SAFE motor switch in the B system DEC.	SEQ EVENTS CONT SYSTEM ARM B BAT B (Panel 8)	Bat bus B through EPS BAT BUS B circuit breaker (Panel 229)	Drives contacts of motor switch to ARM following B system pyro buses: a. DEC b. RCSC c. MESC & ELSC (ELSC bus coupled to MESC bus).
			SAFE	Energizes pyro bus ARM/ SAFE motor switch in the B system DEC.			Drives contacts of motor switch to SAFE PYRO buses listed above. Logic power automatically removed from motor switch at end of travel in either direction.
8	S15	SEQ	SEQ EVENTS CONT SYSTEM LOGIC				
			2	Energizes MECS logic arm relays in A and B systems.	SEQ EVENTS CONT SYSTEM ARM B BAT B (Panel 8)	Bat bus B through EPS BAT BUS B circuit breaker (Panel 8)	Two-pole switch. One pole in system A, the other pole in system B, arming circuits of MESC logic buses.
			OFF	De-energizes MESC logic arm relays in A and B systems.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S17	SCS	AUTO RCS SELECT A/C ROLL A1/+Y MNA	Applies 28 vdc, MNA, to RCS auto coils.	STABILIZATION CONTROL SYSTEM A/C ROLL MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	Alphanumerics at the top of switch is SM engine number. Alphanumerics below switch represent translational capability that may be obtained from the SM engine.
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	A/C ROLL switches serve no function after CM/SM separation.
			OFF	Removes 28 vdc from auto coils and solenoid drivers.			
			MNB	Applies 28 vdc, MNB, to RCS auto coils.	STABILIZATION CONTROL SYSTEM A/C ROLL MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid drivers.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S18	SCS	AUTO RCS SELECT A/C ROLL C1/-Y MNA	Applies 28 vdc, MNA, to RCS auto coils.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	See Remarks for switch 17.
			...continued	...continued			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S18	SCS		Applies 28 vdc, MNA to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coils and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coils.	STABILIZATION CONTROL SYSTEM A/C ROLL MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	
				Applies 28 vdc MNB to enable solenoid drivers.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S19	SCS	AUTO RCS SELECT				See Remarks for switch 17.
			A/C ROLL				
			A2/-Y				
			MNA	Applies 28 vdc, MNA, to RCS auto coils.	STABILIZATION CONTROL SYSTEM A/C ROLL MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S19 (Cont)	SCS	OFF	Removes 28 vdc from auto coils and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coils.	STABILIZA-TION CONTROL SYSTEM A/C ROLL MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid drivers.	STABILIZA-TION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S20	SCS	AUTO RCS SELECT				See Remarks for switch 17.
			A/C ROLL				
			C2/+Y				
			MNA	Applies 28 vdc, MNA, to RCS auto coils.	STABILIZA-TION CONTROL SYSTEM A/C ROLL MNA (Panel 8)	EPS GROUP 2 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZA-TION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			...continued	...continued			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S20 (Cont)	SCS	OFF	Removes 28 vdc from auto coils and solenoid drivers.			
			MNB	Applies 28 vdc, MNB, to RCS auto coils.	STABILIZA- TION CONTROL SYSTEM A/C ROLL MNB (Panel 8)	EPS GROUP 2 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid drivers.	STABILIZA- TION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S21	SCS	AUTO RCS SELECT B/D ROLL B1/CM+Z/11 MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZA- TION CONTROL SYSTEM B/D ROLL MNA (Panel 8)	EPS GROUP 4 MNA (Panel 229)	Alphanumerics at the top of switch is SM engine number. Alphanumerics below the switch represents both the translational capability from the SM (1st No.) and the number for the CM engine (2nd No.).
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZA- TION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coils and solenoid driver.			
			...continued	...continued			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S21 (Cont)	SCS	MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S22	SCS	AUTO RCS SELECT B/D ROLL D1/CM-Z/21				See Remarks for switch 21.
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNA (Panel 8)	EPS GROUP 4 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coils and solenoid driver.			
			...continued	...continued			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S22 (Cont)	SCS	MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S23	SCS	AUTO RCS SELECT B/D ROLL B2/CM-Z/12				See Remarks for switch 21.
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNA (Panel 8)	EPS GROUP 4 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coils and solenoid driver.			
			...continued	...continued			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S23 (Cont)	SCS	MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S24	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			B/D ROLL				
			D2/CM+Z/22				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNA (Panel 8)	EPS GROUP 4 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
				Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM B/D ROLL MNB (Panel 8)	EPS GROUP 4 MNB (Panel 229)	
			...continued				

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S24 (Cont)	SCS	MNB	Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
8	S25	SCS	AUTO RCS SELECT PITCH A3/CM-X/23				See Remarks for switch 21.
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM PITCH MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM PITCH MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S26	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			PITCH				
			C3/CM+X/13				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM PITCH MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM PITCH MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S27	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			PITCH				
			A4/CM+X/14				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZA-TION CONTROL SYSTEM PITCH MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZA-TION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZA-TION CONTROL SYSTEM PITCH MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZA-TION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S28	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			PITCH				
			C4/CM-X/24				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM PITCH MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM PITCH MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S29	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			YAW				
			B3/CM-X/15				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZA-TION CONTROL SYSTEM YAW MNA (Panel 8)	EPS GROUP 3 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZA-TION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZA-TION CONTROL SYSTEM YAW MNB (Panel 8)	EPS GROUP 3 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZA-TION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S30	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			YAW				
			D3/CM+X/25				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM YAW MNA (Panel 8)	EPS GROUP 3 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM YAW MNB (Panel 8)	EPS GROUP 3 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S31	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			YAW				
			B4/CM+X/26				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM YAW MNA (Panel 8)	EPS GROUP 3 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM YAW MNB (Panel 8)	EPS GROUP 3 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 3 MNB (Panel 229)	

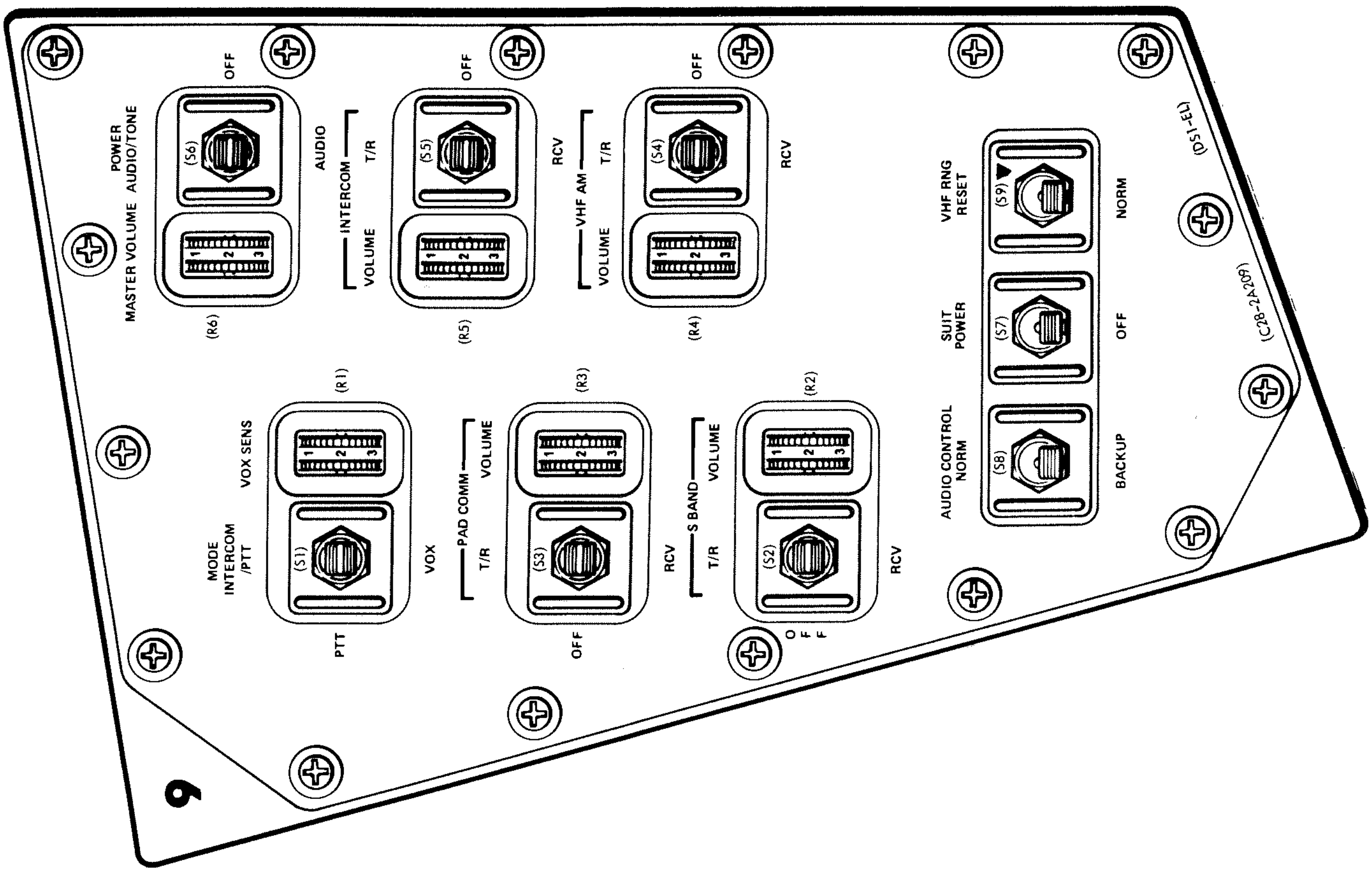
Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
8	S32	SCS	AUTO RCS SELECT				See Remarks for switch 21.
			YAW				
			D4/CM-X/16				
			MNA	Applies 28 vdc, MNA, to RCS auto coil.	STABILIZATION CONTROL SYSTEM YAW MNA (Panel 8)	EPS GROUP 3 MNA (Panel 229)	
				Applies 28 vdc, MNA, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNA (Panel 8)	EPS GROUP 1 MNA (Panel 229)	
			OFF	Removes 28 vdc from auto coil and solenoid driver.			
			MNB	Applies 28 vdc, MNB, to RCS auto coil.	STABILIZATION CONTROL SYSTEM YAW MNB (Panel 8)	EPS GROUP 3 MNB (Panel 229)	
				Applies 28 vdc, MNB, to enable solenoid driver.	STABILIZATION CONTROL SYSTEM CONTR/AUTO MNB (Panel 8)	EPS GROUP 1 MNB (Panel 229)	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Posjtion	Function	Circuit Breaker	Power Source	Remarks
8	T2	EPS	INTERIOR LIGHTS INTEGRAL				
			OFF	Removes power from CM 1 panels 1, 7, 8, 9, 15 and FDAIs (No. 1 and No. 2), DSKY (Panel 2), ASCP, EMS and GPI.	LIGHTING NUMERICS/ INTEGRAL L MDC-AC1 (Panel 226)	AC bus 1 ØA	Integral lighting system controls EL lamps behind nomenclature of applicable panels.
			BRT	BRT indicates maximum brightness has been obtained.			Mechanical stop prevents positioning to OFF. Control exercised by use of circuit breakers.
8	T3	EPS	INTERIOR LIGHTS NUMERICS				
			OFF	Removes power from caution and status indicators on DSKY (Panel 2); EMS range and delta V, and panel mission timer. Also potentiometer on rear of control controls DSKY (Panel 2) electro-luminescent power supply.	LIGHTING NUMERICS/ INTEGRAL L MDC-AC1 (Panel 226)	AC bus 1 ØA	Numerics lighting system controls numerics or flashing numbers on DSKYs, EMS, and timers.
			BRT	BRT indicates maximum brightness has been reached.			Mechanical stop prevents positioning switch to OFF. Control exercised by use of circuit breakers.

PANEL 9


POWER AUDIO/TONE
OFF
MASTER VOLUME
(S6)
(R6)
AUDIO
INTERCOM
T/R
VOLUME
(S5)
(R5)
RCV
VHF AM
T/R
VOLUME
(S4)
(R4)
RCV
VHF RNG RESET
(S9)
NORM
SUIT POWER
(S7)
OFF
AUDIO CONTROL NORM
(S8)
BACKUP
(DS1-EL)
(C28-2A209)
MODE INTERCOM /PTT
VOX SENS
(R1)
(S1)
VOX
PTT
PAD COMM
VOLUME
T/R
(R3)
(S3)
RCV
OFF
S BAND
VOLUME
T/R
(R2)
(S2)
RCV
OFF
9

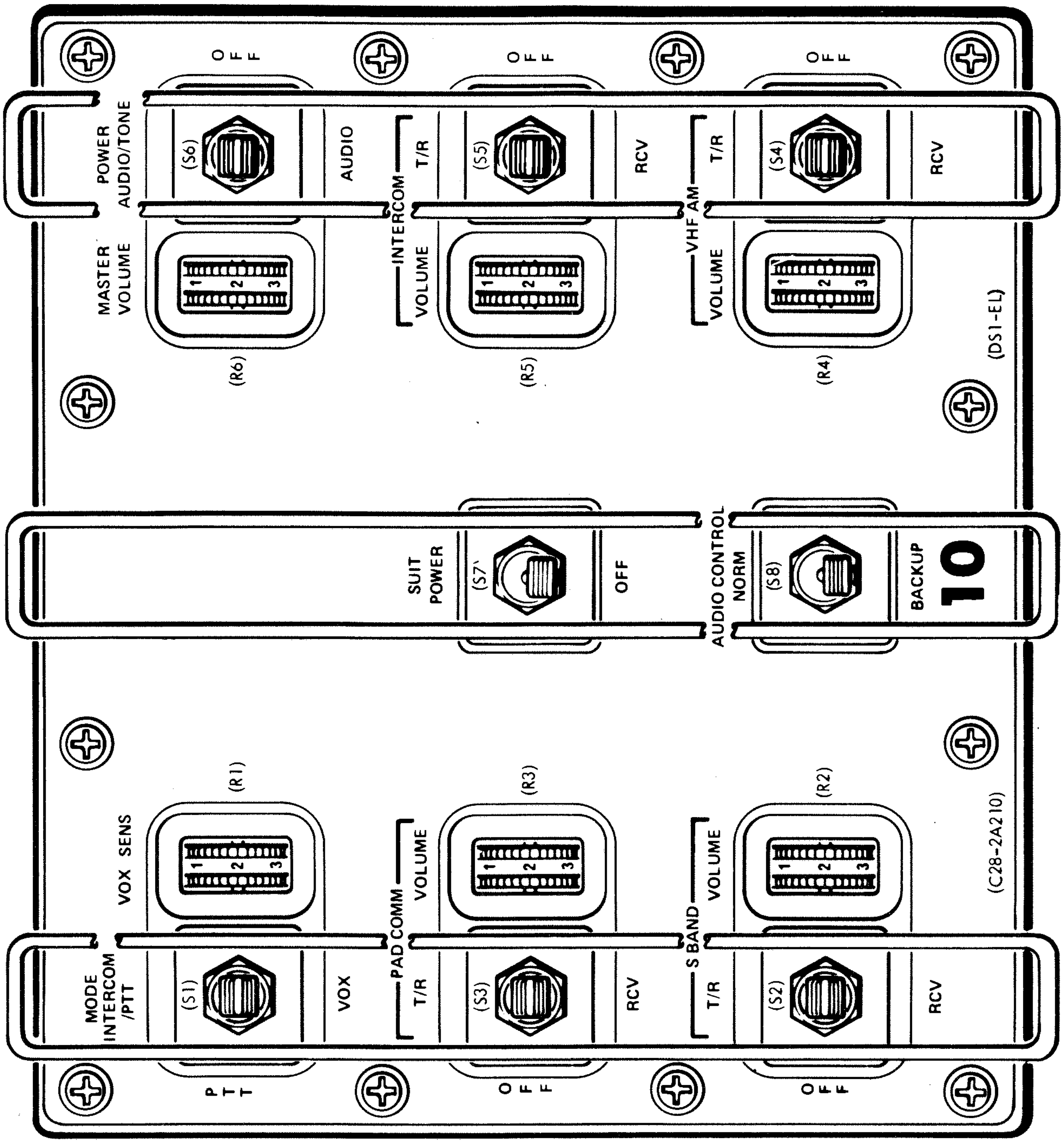
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
9	R1	TLCM	VOX SENS	Thumbwheel-type control, which operates a 25k ohm potentiometer, is provided to adjust the sensitivity of the voice operated relay in audio center module.	N/A	Audio center equipment	Adjustment of this control is necessary when the MODE switch is in the VOX position. Numbers 1 to 9 indicate minimum to maximum sensitivity.
9	R2	TLCM	S BAND VOLUME	Thumbwheel-type control, which operates a 500k ohm potentiometer, is provided to adjust S-band receiver audio level to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
9	R3	TLCM	PAD COMM VOLUME	Thumbwheel-type control, which operates a 500k ohm potentiometer, is provided to adjust audio level from hardline intercom to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
9	R4	TLCM	VHF AM VOLUME	Thumbwheel-type control, which operates a 500k ohm potentiometer, is provided to adjust audio level from VHF-AM receiver to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
9	R5	TLCM	INTERCOM				
			VOLUME	Thumbwheel-type control, which operates a 500k ohm potentiometer, is provided to adjust audio level from intercom bus to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
9	R6	TLCM	MASTER VOLUME	Thumbwheel-type control, which operates a 2.5k ohm potentiometer, is provided to adjust audio level from earphone amplifier to earphone.	N/A	Audio center equipment	Master volume thumbwheel controls overall volume to headset independent of individual volume controls.
9	S1	TLCM	MODE				
			INTERCOM/PTT	Provides hot mike operation for intercom and PTT operation for RF transmission.	N/A	Audio center equipment	PTT function is controlled by crewmans individual comm cable umbilical; also SCS rotation control No. 1 and No. 2. Hot mike intercomm is provided by continuous operation of the microphone amplifier in the audio center however PTT must be used for RF transmit modes.
			PTT	Enables PTT operation for intercom and RF transmission.			
			VOX	Provides VOX operation for both intercom and transmission.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
9	S2	TLCM	S BAND				
			T/R	Enables, by circuit closure, the headset to receive and transmit over the S-band equipment operating in VOICE mode.	N/A	Audio center equipment	Channel A used for S-band communications between CSM and SWS to MSFN. VOICE mode includes not only VOICE or RELAY mode positions, but also VOICE BU positions of S BAND AUX and up TLM sections, all with their attendant limitations.
			OFF	Selects no mode.			
			RCV	Enables, by circuit closure, headset to receive (only) output of S-band equipment operating in VOICE mode.			
9	S3	TLCM	PAD COMM				
			T/R	Enables, by circuit closure, headset to receive and transmit over a hardline intercom to launch operations.	N/A	Audio center equipment	May be used as an intercomm backup capability in event of normal intercom failure. PAD COMM must be in the OFF position <u>prior</u> to liftoff due to extreme noise on hardline <u>after</u> liftoff occurs. Pad comm circuit will be unloaded during this period.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of hardline intercom from launch operations.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
9	S4	TLCM	VHF AM				
			T/R	Enables, by circuit closures, headset to receive and transmit over VHF-AM equipment.	N/A	Audio center equipment	Correct settings of the simplex/duplex switches are required.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of VHF-AM receiver.			
9	S5	TLCM	INTERCOM				
			T/R	Enables, by circuit closure, headset to receive and transmit over intercom system.	N/A	Audio center equipment	Used for voice communications between crewmen in CSM and SWS. Must be in OFF position on Channel B for annotation of experiments on tape recorder in SWS and prevent interfere with S-band communications which is on Channel A.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of intercom system.			
9	S6	TLCM	POWER				
			AUDIO/TONE	Provides primary power to CDR audio center and enables audible crew alarm signal to be heard at this astronaut station.	TELECOMMUNICATION VHF/CREW STATION AUDIO-R FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	Provides suit power for microphone amplifiers through SUIT POWER switch.
			OFF	Removes primary power and audible crew alarm signal from CDR audio center.			
			AUDIO	Provides primary power to CDR audio center and disconnects audible crew alarm signal to CDR headset.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
9	S7	TLCM	SUIT				
			POWER	Applies power to left and right microphone preamplifier in headset and biomed preamplifier in the suit associated with audio control Panel No. 9.	TELECOMMUNI-CATION VHF/CREW STATION AUDIO R & L FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	To remove all power on the Comm Cable Umbilical it is also necessary to place the VHF/AM T/R switch in the OFF position to remove the 28 vdc keying voltage.
			OFF	Removes power from left and right microphone preamplifier in headset and biomed preamplifier in the suit associated with audio control Panel No. 9.			
9	S8	TLCM	AUDIO CONTROL				
			NORM	**Routes CDR audio signals through audio control Panel No. 9 and associated audio module.**	N/A	N/A	Provided in event of audio **center failure CDR shares SPT audio center, PLT shares SPT audio center, and SPT shares CDR audio center if BACKUP** is selected on respectable audio control panels. PTT control on comm cable umbilical is selected by PTT BU switch on MDC 3.
			BACKUP	**Routes CDR audio signals through control Panel No. 10 and associated audio center module.**			
9	S9	TLCM	VHF RNG				
			RESET	Initiates an automatic tracking phase.	TELECOMMUNI-CATION VHF/CREW STATION AUDIO-R FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	RESET position is spring-loaded and must be held for at least one second for SWS RTTA lockup. Initiates ranging tones which are audible in headset voice communications on VHF/AM is restricted for the first 15 seconds. EMS will display range approx 15 seconds after a reset. Resets digital ranging generator.
			NORM	Allows DRG to develop ranging after a RESET.			


OFF
POWER AUDIO/TONE
(S6)
AUDIO
INTERCOM
T/R
(S5)
RCV
VHF AM
T/R
(S4)
RCV
MASTER VOLUME
(R6)
VOLUME
(R5)
VOLUME
(R4)
(DS1-EL)
SUIT POWER
(S7)
OFF
AUDIO CONTROL
NORM
(S8)
BACKUP
10
VOX SENS
(R1)
PAD COMM
VOLUME
(R3)
S BAND
VOLUME
(R2)
(C28-2A210)
MODE INTERCOM /PTT
(S1)
VOX
T/R
(S3)
RCV
T/R
(S2)
RCV
PTT
OFF
OFF

PANEL 10

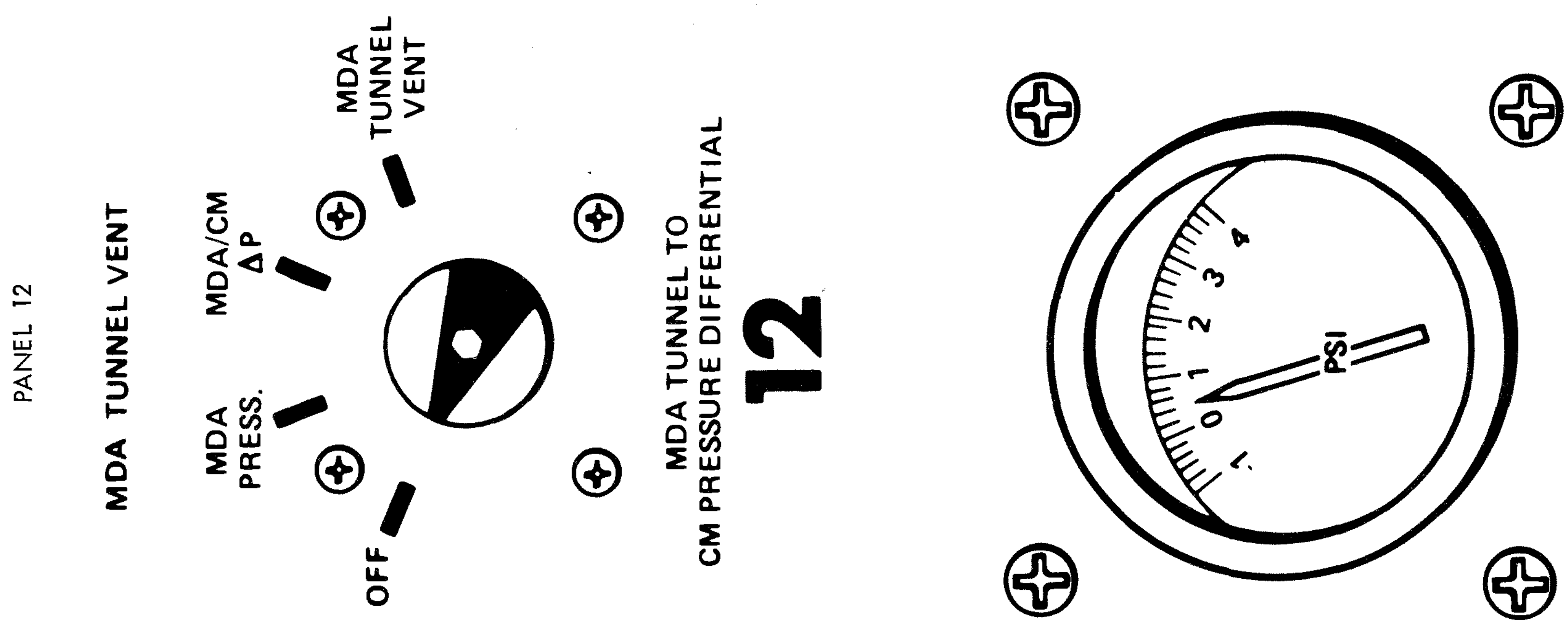
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
10	R1	TLCM	VOX SENS	Thumbwheel-type control which operates a 25k ohm potentiometer is provided to adjust sensitivity of voice-operated relay in audio center module.	N/A	Audio center equipment	Adjustment of this control is necessary when the MODE switch is in the VOX position. Numbers 1 to 9 indicate minimum to maximum sensitivity.
10	R2	TLCM	S BAND VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust S-band receiver audio level to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
10	R3	TLCM	PAD COMM VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust audio level from hardline intercom to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
10	R4	TLCM	VHF AM VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust audio level from VHF-AM receiver to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.
10	R5	TLCM	INTERCOM VOLUME	Thumbwheel-type control which operates a 500k ohm potentiometer is provided to adjust audio level from intercom bus to earphone amplifier.	N/A	Audio center equipment	Numbers 1 to 9 on the thumbwheel are provided to adjust audio level from minimum to maximum.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
10	R6	TLCM	MASTER VOLUME	Thumbwheel-type control which operates a 2.5k ohm potentiometer is provided to adjust audio level from earphone amplifier to earphone.	N/A	Audio center equipment	Master volume thumbwheel controls overall volume to headset independent of individual volume controls.
10	S1	TLCM	MODE				
			INTERCOM/PTT	Provides hot mike operation for intercom and PTT operation for RF transmission.	N/A	Audio center equipment	PTT function is controlled by crewmans individual comm cable umbilical; also SCS rotation control No. 1 and No. 2. Hot mike intercomm is provided by continuous operation of the microphone amplifier in the audio center however PTT must be used for RF transmit modes.
			PTT	Enables PTT operation for intercom and RF transmission.			
			VOX	Provides VOX operation for both intercom and RF transmission.			
10	S2	TLCM	S BAND				
			T/R	Enables, by a circuit closure, the headset to receive and transmit over S-band equipment operating in VOICE mode.	N/A	Audio center equipment	Channel A used for S-band communications between CSM and SWS to MSFN. VOICE mode includes not only VOICE or RELAY mode positions, but also VOICE BU positions of S BAND AUX and UP TLM sections, all with their attendant limitations.
			OFF	Selects no modes.			
			RCV	Enables, by a circuit closure, the headset to receive (only) output of the S-band equipment operating in VOICE mode.			

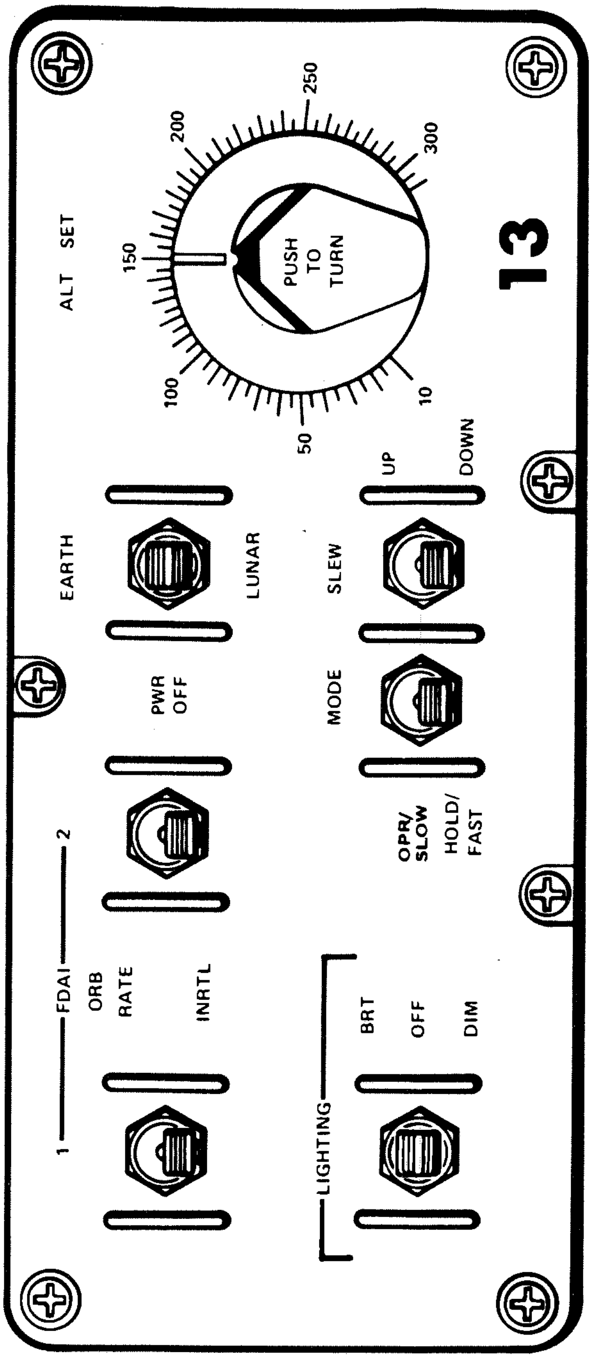
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
10	S3	TLCM	PAD COMM				
			T/R	Enables, by circuit closure, headset to receive and transmit over hardline intercomm to launch operations.	N/A	Audio center equipment	May be used as an intercomm backup capability in event of normal intercom failure. PAD COMM must be in the OFF position prior to liftoff due to extreme noise on hardline after liftoff occurs. Pad comm circuit will be unloaded during this period.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output of hardline intercom from launch operations.			
10	S4	TLCM	VHF AM				
			T/R	Enables, by circuit closures, headset to receive and transmit over VHF-AM equipment.	N/A	Audio center equipment	Correct settings of the simplex/duplex switches are required.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, the headset to receive (only) output of VHF-AM receiver.			
10	S5	TLCM	INTERCOM				
			T/R	Enables, by circuit closure, headset to receive and transmit over intercom system.	N/A	Audio center equipment	Used for voice communications between crewmen in CSM and SWS. Must be in OFF position on Channel B for annotation of experiments on tape recorder in SWS and prevent interfere with S-band communications which is on Channel A.
			OFF	Selects no modes.			
			RCV	Enables, by circuit closure, headset to receive (only) output to intercom system.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
10	S6	TLCM	POWER				
			AUDIO/TONE	Provides primary power to SPT audio center and enables audible crew alarm signal to be heard at this astronaut station.	TELECOMMUNI-CATION VHF/CREW STATION AUDIO CTR FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	Provides suit power for microphone amplifiers through SUIT POWER switch.
			OFF	Removes primary power and audible crew alarm signal from SPT audio center.			
			AUDIO	Provides primary power to SPT audio center and disconnects audible crew alarm signal to SPT headset.			
10	S7	TLCM	SUIT				
			POWER	Applies power to the left- and right-hand microphone preamplifiers and suit biomed preamplifiers associated with audio control Panel No. 10.	TELECOMMUNI-CATION VHF/CREW STATION AUDIO CTR & L FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	To remove all power on the Comm Cable Umbilical it is also necessary to place the VHF/AM T/R switch in the OFF position to remove the 28 vdc keying voltage.
			OFF	Removes power from the left- and right-hand microphone preamplifiers and suit biomed preamplifiers associated with audio control Panel No. 10.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
10	S8	TLCM	AUDIO CONTROL				
			NORM	Routes SPT audio signals through audio control Panel No. 10 and associated audio module.	N/A	N/A	Provided in event of audio center failure. SPT shares CDR audio center, PLT shares SPT audio center, and CDR shares SPT audio center if BACKUP is selected on respectable audio control panels. PTT control on comm cable umbilical is selected by PTT BU switch on MDC 3.
			BACKUP	Routes SPT audio signals through control Panel No. 9 and associated audio center module.			


PANEL 12
MDA TUNNEL VENT
MDA PRESS.
MDA/CM ΔP
MDA TUNNEL VENT
OFF
MDA TUNNEL TO CM PRESSURE DIFFERENTIAL
12
PSI
-1
0
1
2
3
4

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
12	V1	ECS	MDA TUNNEL VENT				
			OFF	All ports closed.	N/A	N/A	Manually controlled valve.
			MDA PRESS	Connects CM cabin to MDA tunnel.			Backup for pressurizing MDA tunnel.
			MDA ΔP	Connects MDA tunnel to ΔP gauge.			Used to determine difference in pressure between CM cabin and MDA tunnel.
			MDA TUNNEL VENT	Connects MDA tunnel to ambient.			Used for depressurizing MDA tunnel to check quality of CM forward hatch pressure seal.
12	M1	ECS	MDA TUNNEL TO CM PRESSURE DIFFERENTIAL	Indicates pressure differential between MDA tunnel and CM cabin.	N/A	N/A	Range -1.0 to +4.0 psid.


ALT SET
150
200
250
300
100
50
10
PUSH TO TURN
13
EARTH
LUNAR
PWR OFF
UP
DOWN
SLEW
MODE
OPR/SLOW
HOLD/FAST
FDAI
1
2
ORB RATE
INRTL
LIGHTING
BRT
OFF
DIM

PANEL 13

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
13	R1	SCS	ALT SET	Enables ORDEAL output to be varied with altitude. ORDEAL output will be function of both EARTH/ LUNAR switch and ALT SET CONTROL.	N/A	N/A	
13	S1	SCS	(EARTH/LUNAR)				
			EARTH	Establishes basic orbital rate for earth orbit.	ORDEAL AC2 & MNB (Panel 8)	AC bus 2 and DC main bus B	PWR OFF position removes power from ORDEAL but does not isolate FDAIs from ORDEALs angular bias. FDAI 1 and 2 switches control interface between ORDEAL and FDAIs.
			(PWR OFF)	Disables power to ORDEAL.			
			LUNAR	Establishes basic orbital rate for lunar orbit.			
13	S2	SCS	MODE				
			OPR/SLOW	Normal position when operating ORDEAL. Permits slewing of ORDEAL at slow rate (0.55°/sec).	N/A	N/A	
			HOLD/FAST	Holds ORDEAL output constant except when setting up ORDEAL initially via fast slew (10°/sec).			
13	S3	SCS	SLEW				
			UP	Provides increasing ORDEAL output to FDAI (ball drives down) at either 0.55°/sec or 10°/sec.	N/A	N/A	
			DOWN	Provides decreasing ORDEAL output to FDAI (ball drives up) at either 0.55°/sec or 10°/sec.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
13	S4	SCS	FDAI				
			1				
			ORB RATE	Enables FDAI (Panel 1) to display total attitude with respect to local horizontal in pitch axis. Interfaces ORDEAL with total attitude source on FDAI 1.	N/A	N/A	During launch and entry phases ORDEAL panel is stowed in UEB (U3). FDAI 1 and 2 switches must be in INRTL when ORDEAL is stowed.
			INRTL	Enables FDAI 1 (Panel 1) to display inertial attitude in all axes. ORDEAL is bypassed.			
13	S5	SCS	FDAI				
			2				
			ORB RATE	Enables FDAI 2 (Panel 2) to display total attitude with respect to local horizontal in the pitch axis. Interfaces ORDEAL with total attitude source on FDAI 2.	N/A	N/A	During launch and entry phases ORDEAL panel is stowed in UEB (U3). FDAI 1 and 2 switches must be in INRTL when ORDEAL is stowed.
			INRTL	Enables FDAI 2 (Panel 2) to display inertial attitude in all axes. ORDEAL is bypassed.			
13	S6	SCS	LIGHTING				
			BRT	Provides bright lighting for E-L panels.	ORDEAL AC2 (Panel 8)	AC bus 2	
			OFF	Removes power.			
			DIM	Provides dim lighting for E-L panels.			

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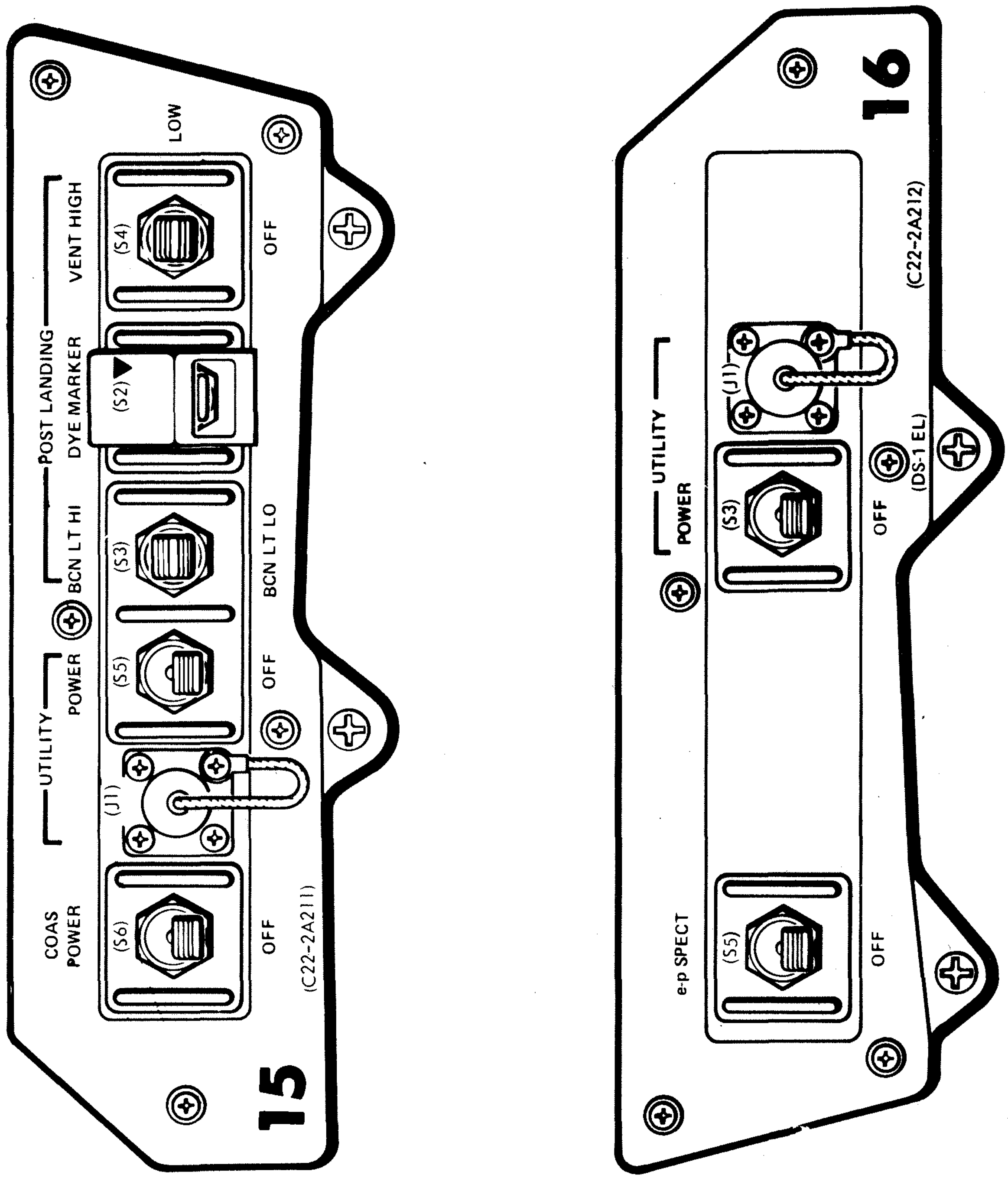

15
COAS
POWER
(S6)
OFF
(C22-2A211)
UTILITY
POWER
(J1)
(S5)
OFF
BCN LT HI
(S3)
BCN LT LO
POST LANDING
DYE MARKER
(S2)
VENT HIGH
(S4)
OFF
LOW
16
e-p SPECT
(S5)
OFF
UTILITY
POWER
(S3)
OFF
(J1)
(DS-1 EL)
(C22-2A212)

PANELS 15, 16

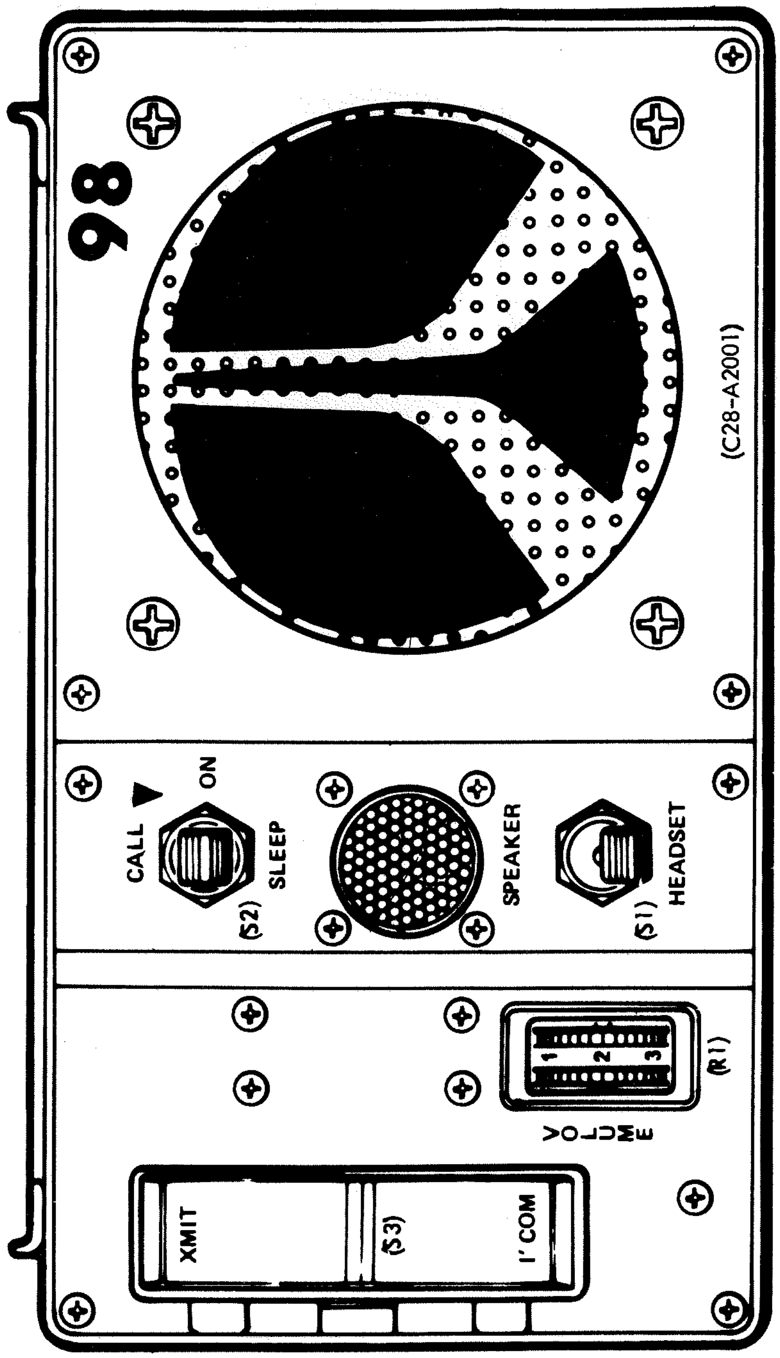
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
15	J1	MISC	UTILITY (RECEPTACLE)	Utility power receptacle for 16mm sequence camera and auxiliary urine dump nozzle cable.	UTILITY R/L STA-MNA (Panel 5)	DC main bus A	D-C power for miscellaneous equipment.
15	S2	SEQ	POST LANDING				
			DYE MARKER	Applies d-c power to melting wire of actuator that causes pin to retract and jettisons dye marker overboard from forward compartment of CM after splashdown.	FLOAT BAG 3 FLT/PL (Panel 8)	Flight and postlanding bus	Guarded - momentary position switch.
			(DOWN)	Removes power from dye marker circuitry.			
15	S3	MISC	POST LANDING				
			BCN LT HI	Applies d-c power to flashing beacon light for a fast flash rate (120 fpm).	FLOAT BAG 3 FLT/PL (Panel 8)	Flight and postlanding bus	For positive identification of CM after location during darkness.
			(CENTER)	Removes power to flashing beacon light.			
			BCN LT LO	Applies d-c power to flashing beacon light for a slow flash rate (15 fpm).			For locating CM during darkness.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
15	S4	ECS	POST LANDING				
			VENT HIGH	Applies d-c power to open both PL vent valves and drive fan at high rate (150 cfm).	PL VENT FLT/PL (Panel 8)	Flight and postlanding bus	VALVE UNLOCK POST LDG VENT handle (Panel 2) must be pulled before applying power.
			LOW	Applies d-c power to open both PL vent valves and drive fan at low rate (100 cfm).			
			OFF	Applies d-c power to close both PL vent valves and removes power from fan motors.			
15	S5	MISC	UTILITY				
			POWER	Applies 28 vdc to utility receptacle (Panel 15).	UTILITY R/L STA-MNA (Panel 5)	DC main bus A	
			OFF	Removes power from utility receptacle.			
15	S6	DKG	COAS POWER				
			(POWER)	Applies 28 vdc to receptacle located on COAS mount on left rendezvous window frame.	LIGHTING COAS/TUNNEL/ RNDZ/SPOT MNA (Panel 226)	DC main bus A	
			OFF	Removes power from left COAS receptacle.			

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
16	J1	MISC	UTILITY				
			(RECEPTACLE)	Utility power connector for 16mm sequence camera and utility.	UTILITY R/L STA-MNA (Panel 5)	DC main bus A	D-C power for miscellaneous equipment.
16	S3	MISC	UTILITY				
			POWER	Applies 28 vdc to utility receptacle (Panel 16).	UTILITY R/L STA-MNA (Panel 5)	DC main bus A	
			OFF	Removes power from utility receptacle.			
16	S5	EXP	ep SPECT				
			(ON)	Applies 28 vdc to the electron proton spectrometer heater circuit and the UDL switching logic.	EXP PWR B EXP (Panel 5)	Noness bus	UDL provides control of power to ep SPECT power supply and detectors.
			OFF	Removes power from ep spectrometer.			

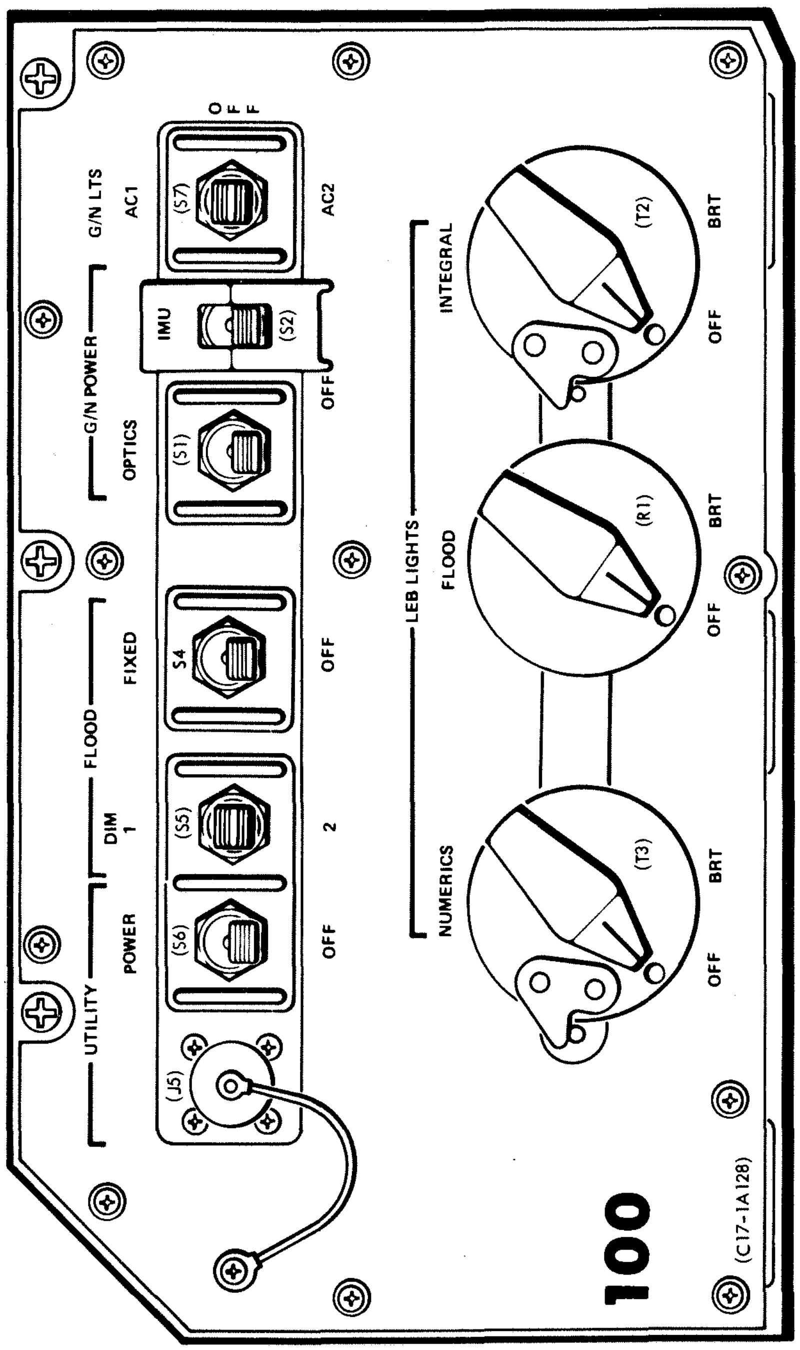
PANEL 98


98
(C28-A2001)
CALL
ON
SLEEP
(S2)
SPEAKER
HEADSET
(S1)
VOLUME
1 2 3
(R1)
XMIT
(S3)
I'COM

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
98	R1	TLCM	(SPEAKER INTERCOM BOX) VOLUME	Thumbwheel-type control which operates a potentiometer, is provided to adjust audio level from speaker.	TELECOMMUNICATIONS VHF/CREW STATION AUDIO CTR FLT/POST LDG BUS (Panel 225)	Audio center equipment	Numbers 1 to 9 on thumbwheel adjust audio level from minimum to maximum.
98	S1	TLCM	(SPEAKER INTERCOM BOX) SPEAKER HEADSET	Connects SPT to speaker box panel. Connects SPT to communications cable.	TELECOMMUNICATIONS VHF/CREW STATION AUDIO CTR FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	SPEAKER position only interfaces with SPT audio system which in turn connects to Channels A and B through the intercom bus. SPEAKER position is the normal sleep mode of operation. HEADSET position removes power from SPEAKER box.
98	S2	TLCM	(SPEAKER INTERCOM BOX) CALL ON SLEEP	Connects SPT to A and B audio hardline channels to SWS. Applies power to speaker intercom box. Removes power from the speaker intercom box.	TELECOMMUNICATIONS VHF/CREW STATION AUDIO CTR FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	CALL position is spring-loaded to the ON position for channels A and B CSM CALL to SWS configuration. Must be returned to the ON position to listen. SLEEP position can be overridden by a workshop originated crew call to the CSM.
98	S3	TLCM	(SPEAKER INTERCOM BOX) XMIT I'COM	Enables SPT to transmit to MSFN. Enables SPT utilization of intercom line.	TELECOMMUNICATIONS VHF/CREW STATION AUDIO CTR FLT/POST LDG BUS (Panel 225)	Flight and postlanding bus	XMIT AND I'COMM positions have the same functions as the comm cable umbilicals. Switch is spring-loaded to both positions and must be held unless CALL position is used. Switch cannot be used when SPEAKER/HEADSET switch is in the HEADSET position.

CONTROLS AND DISPLAYS

PANEL 100

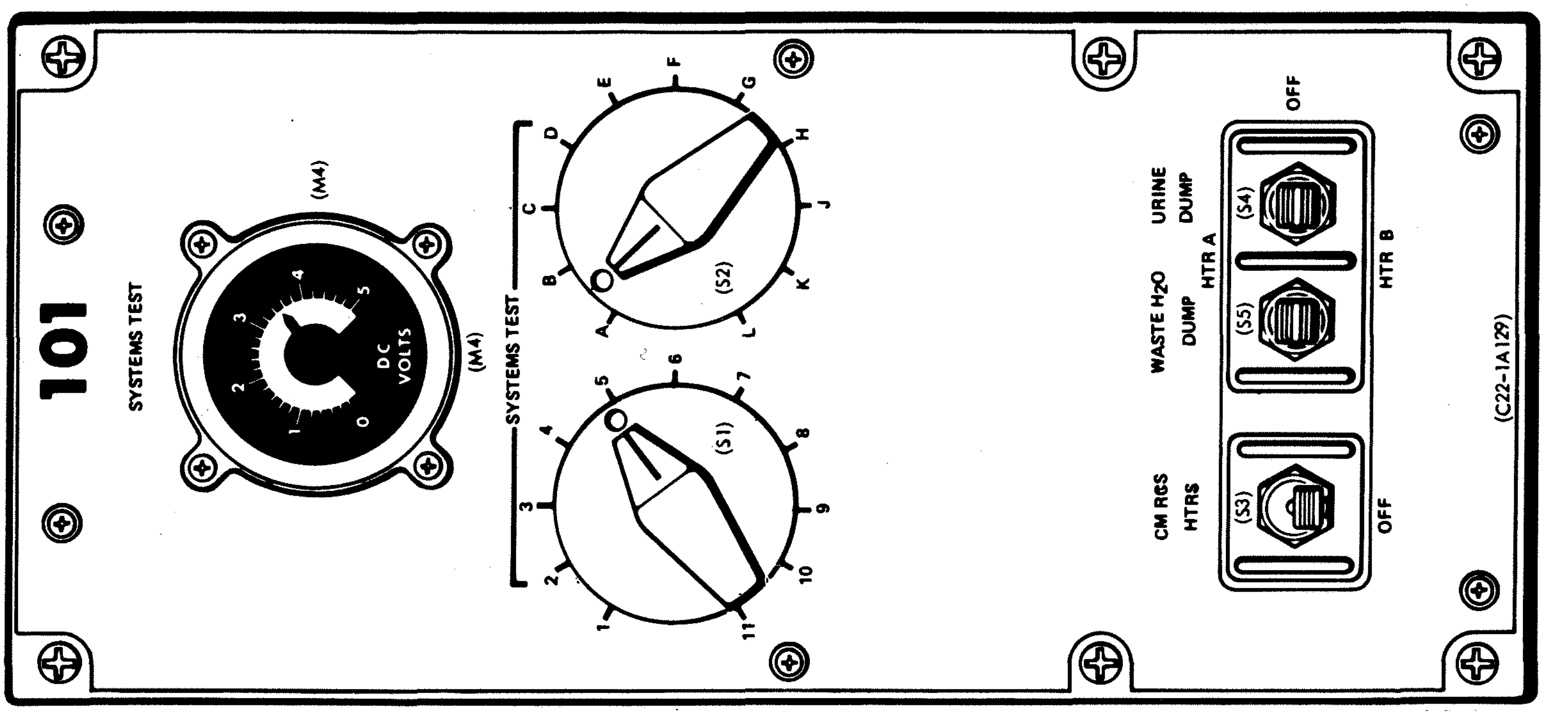


Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
100	J5	MISC	UTILITY	Receptacle for 16mm sequence camera and utility.	UTILITY LEB MNB (Panel 5)	DC main bus B	Receptacle has seven jacks.
100	R1	EPS	LEB LIGHTS FLOOD OFF BRT	Removes power from CM LEB rheostat controlled floodlight. (OFF) Indicates maximum floodlight brightness has been reached. (BRT)	LIGHTING FLOOD MNA (Panel 226)	DC main bus A	Primary when DIM switch is on 1; secondary when DIM switch is on 2.
100	S1	G&N	G/N POWER OPTICS OFF	Provides operating power to optics subsystem. (OPTICS) Removes operating power from optics subsystem. (OFF)	GUIDANCE/ NAVIGATION OPTICS MNA & MNB (Panel 5)	DC main buses A and B	
100	S2	G&N	G/N POWER IMU OFF	Provides operating power to inertial subsystem. (IMU) Removes operating power from inertial subsystem. (OFF)	GUIDANCE/ NAVIGATION IMU MNA & MNB (Panel 5)	DC main buses A and B	Switch can be guarded in either IMU or OFF position.
100	S4	EPS	FLOOD FIXED OFF	Turns on lamps not controlled by rheostat. (FIXED) Removes power. (OFF)	LIGHTING FLOOD MNB (Panel 226)	DC main bus B	On-off control of floodlights not on rheostat control. Secondary when DIM switch is on 1; primary when DIM switch is on 2.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
100	S5	EPS	FLOOD				
			DIM				
			1	Applies rheostat control to LEB primary floodlights and on-off control to secondary floodlights.	LIGHTING FLOOD MNA & MNB (Panel 226)	DC main buses A and B	
			2	Applies rheostat control to LEB secondary floodlights and on-off control to primary floodlights.			Provides crew capability of shifting primary or secondary lamps to variable FLOODLIGHT switch for LEB area illumination.
100	S6	MISC	UTILITY				
			POWER	Provides power to adjacent receptacle (J5).	UTILITY LEB MNB (Panel 5)	DC main bus B	D-C power for miscellaneous equipment.
			OFF	Removes power from adjacent utility receptacle (J5).			
100	S7	G&N	G/N LIGHTS				
			AC1	AC1 selects a-c bus 1 to supply power for G&N lighting.	GUIDANCE/ NAVIGATION LIGHTS AC1 (Panel 5)	AC bus 1	Supplies power for G&N reticle dimmer power supply. Power supply supplies power to Panel 122 C/W lamps and STAR ACQ lamp and optics reticle and TPACS.
			OFF	Removes power from G&N lighting system.			
			AC2	AC2 selects a-c bus 2 to supply power for G&N lighting system.	GUIDANCE/ NAVIGATION LIGHTS AC2 (Panel 5)	AC bus 2	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
100	T2	EPS	LEB LIGHTS INTEGRAL OFF BRT	 Removes power to nomenclature on Panels 10, 100, 101, 122, 140, 225, 226, 229, 230, 275, and event timer on 306. Indicates maximum brightness has been reached.	 LIGHTING NUMERICS/ INTEGRAL LEB AC2 (Panel 226)	 AC bus 2 ØA	 Integral lighting system controls EL lamps behind nomenclature of respective panels. Mechanical stop prevents positioning switch to OFF. Control exercised by use of circuit breakers.
100	T3	EPS	LEB LIGHTS NUMERICS OFF BRT	 Removes power from Panel 140 (G&N DSKY) caution & warning annunciators and Panel 306 mission timer numerics. Also potentiometer on rear of control controls DSKY (Panel 140) electro-luminescent power supply. Indicates maximum brightness has been reached.	 LIGHTING NUMERICS/ INTEGRAL LEB AC2 (Panel 226)	 AC bus 2 ØA	 Numerics lighting system controls numerics or flashing numbers on LEB DSKY, caution & warning annunciators, and on Panel 306 mission timer. Mechanical stop prevents positioning switch to OFF. Control exercised by use of circuit breakers.

PANEL 101


101
SYSTEMS TEST
(M4)
DC VOLTS
SYSTEMS TEST
(S2)
(S1)
URINE DUMP
(S4)
HTR A
WASTE H2O DUMP
(S5)
HTR B
OFF
CM RCS HTRS
(S3)
OFF
(C22-1A129)

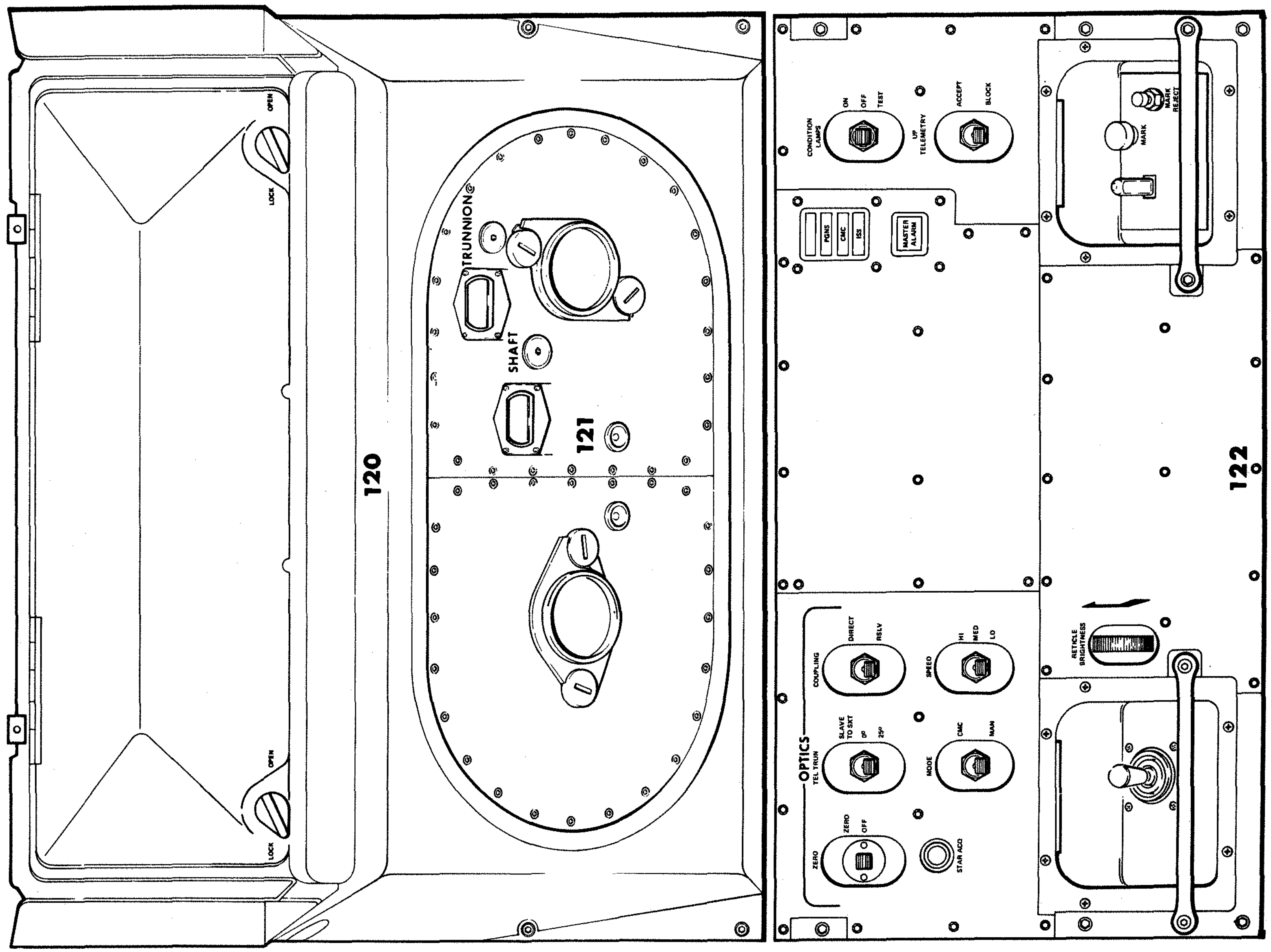
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
101	M4	EPS RCS SPS	SYSTEMS TEST DC VOLTS	Indicates d-c voltage of selected measurement points.	N/A	Instrumentation signal conditioners	Meter functions in conjunction with two SYSTEMS TEST switches (S1) and (S2) located directly below meter. Meter range is 0 to 5 volts.
101	S1	EPS RCS SPS	SYSTEMS TEST	Provides for readouts of specific EPS, RCS and SPS measurements.	N/A	N/A	Switch is numerical 11 position selector switch. Refer to following chart for selections and meter readouts.
101	S2	EPS RCS SPS	SYSTEMS TEST	Provides for readouts of specific EPS, RCS and SPS measurements.	N/A	N/A	Switch is an alphabetical 11 position selector switch. Refer to following chart for selections and meter readouts.
			SWITCH POSITIONS	METER INDICATIONS			Meter ranges are called out in sections 2.4, 2.5, and 2.6.

S1	S2	M4
1	A	FC 1 N_2 PRESS
2	A	FC 1 O_2 PRESS
3	A	FC 1 H_2 PRESS
4	A	FC 1 RAD OUT TEMP
5	A	FC 3 N_2 PRESS
6	A	FC 3 O_2 PRESS
7	A	FC 3 H_2 PRESS
8	A	FC 3 RAD OUT TEMP
9	A	Not assigned
10	A	Not assigned
11	A	Not assigned
1	B	Not assigned
2	B	BAT COMPT PRESS
3	B	BAT RELAY BUS VOLTAGE
4	B	CM RCS ENG 12 VLV TEMP
5	B	CM RCS ENG 14 VLV TEMP
6	B	CM RCS ENG 16 VLV TEMP
7	B	CM RCS ENG 21 VLV TEMP
8	B	CM RCS ENG 23 VLV TEMP
9	B	CM RCS ENG 25 VLV TEMP
10	B	SM RCS PSM 1 FUEL TK TEMP
11	B	SM RCS PSM 2 FUEL TK TEMP (if installed)

...continued ...continued ...cont ...cont

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
101	S2 (Cont)	EPS RCS SPS	SWITCH POSITIONS	METER INDICATIONS			
			S1 / S2	M4			
			1 / C	SM RCS A PRIM FUEL TK TEMP			
			2 / C	SM RCS B PRIM FUEL TK TEMP			
			3 / C	SM RCS C PRIM FUEL TK TEMP			
			4 / C	SM RCS D PRIM FUEL TK TEMP			
			5 / C	SPS ENG FUEL VLV BODY TEMP			
			6 / C	SPS OXID FEED TANK LINE TEMP			
			7 / C	SPS SEC FUEL CHECK VALVE BRACKET TEMP			
			8 / C	SPS OXID SUMP TANK OUTBOARD TEMP			
			9 / C				
			10 / C	O_2 TK 1 HTR TEMP			
			11 / C	O_2 TK 2 HTR TEMP			
			D thru L	Not assigned			
101	S3	RCS	CM RCS				
			HTRS	Activates relays which apply +28 vdc to direct coils of all CM RCS engine solenoid injector valves.	REACTION CONTROL SYSTEM CM HEATERS 1 MNA and 2 MNB (Panel 8)	EPS GROUP 5 MNA and MNB (Panel 229)	Two-position toggle switch, used to preheat all CM RCS engine valves if required in order to preclude propellant freezing when system is pressurized prior to entry. Switch is enabled by CM RCS LOGIC switch (Panel 1) in the CM RCS LOGIC position.
			OFF	Deactivates relays which remove +28 vdc from the direct coils of all CM RCS engine solenoid injector valves.			
101	S4	ECS	URINE DUMP				
			HTR A	Applies d-c power to urine dump nozzle heater A (5.7w).	H_2O/URINE DUMP HTR MNA (Panel 5)	DC main bus A	Heaters keep urine dump nozzle (aluminum) warm to prevent urine or water from freezing and clogging nozzle when dumped overboard.
			OFF	De-energizes power to urine dump nozzle heaters.			
			HTR B	Applies d-c power to urine dump nozzle heater B (5.7w).	H_2O/URINE DUMP HTR MNB (Panel 5)	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
101	S5	ECS	WASTE H_2O				
			DUMP				
			HTR A	Applies d-c power to waste water dump nozzle heater A (5.7w).	H_2O/URINE DUMP HTR MNA (Panel 5)	DC main bus A	Heaters keep waste water dump nozzle (aluminum) warm to prevent waste water or urine from freezing and clogging the nozzle when dumped overboard.
			OFF	De-energizes power to waste water dump nozzle heaters.			
			HTR B	Applies d-c power to waste water dump nozzle heater B (5.7w).	H_2O/URINE DUMP HTR MNB (Panel 5)	DC main bus B	



PANELS 120, 121, 122

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
120	NONE	G&N	(LOCKS)	Secures panel closure for sextant and scanning telescope eyepiece storage.	N/A	N/A	

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
121	A1	G&N	(Scanning Telescope)	Optical instrument used primarily for acquiring targets initially.	GUIDANCE/ NAVIGATION OPTICS MNA & MNB (Panel 5)	DC main buses A & B	Power for telescope is routed from the buses through G/N-OPTICS ON and OFF switch, located on Panel 100. Scanning telescope has a 60-degree field of view and magnification of one. In event of power failure scanning telescope may be manually positioned, using universal tool.
			(Sextant)	Optical instrument utilized for making fine angular measurements.			Power for sextant is routed from the buses through G/N-OPTICS ON and OFF switch, located on Panel 100. Sextant has a 1.8-degree field of view with a magnification of 28.
			SHAFT (ANGLE display)	Provides mechanical readout of scanning telescope shaft angle.	N/A	N/A	
			(Shaft Angle Manual Drive Access)	Facilitates use of universal tool to manually position telescope shaft.	N/A	N/A	While manually positioning scanning telescope shaft, angle may be read out on shaft angle display.
			TRUNNION (ANGLE display)	Provides mechanical readout of scanning telescope trunnion angle.	N/A	N/A	
			(Trunnion Angle Manual Drive Access)	Facilitates use of universal tool to manually position telescope trunnion.	N/A	N/A	While manually positioning scanning telescope trunnion, angle may be read out on trunnion angle display.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
122	A1	G&N	(G/N INDICATOR/CONTROL PANEL)				
			ATTITUDE IMPULSE CONTROLLER SWITCH	This 3-axis controller provides navigator with the capability of spacecraft minimum impulse control through CMC when CSM RCS or docked digital autopilot is in free mode of operation.	N/A	CMC	Controller is used to apply one or any combination of pitch, roll, or yaw minimum thrust impulse to the spacecraft. One pulse is produced each time control is moved from center position.
			CONDITION LAMPS (SW)	Provides a means for enabling condition lamp circuitry.	GUIDANCE/ NAVIGATION LIGHTS AC1 & AC2 (Panel 5)	AC buses 1 and 2	
			ON	Supplies power to lower equipment bay annunciator lamps.			
			OFF	Removes power from annunciator lamp circuit.			
			TEST	Lights navigation station master warning, and star acquired lamps.	N/A	N/A	TEST position applies ground to Panel 122 MASTER ALARM light and STAR ACQ lamp.
			CMC	CMC status light will illuminate if the following occurs: a. Loss of prime power. b. Scaler fail - if scaler stage 17 fails to produce pulses. c. Counter fail - continuous requests or fail to happen following increment request. d. SCADBL - 100 pps scaler stage 200 pps.	GUIDANCE/ NAVIGATION LIGHTS AC1 & AC2 (Panel 5)	AC buses 1 and 2	
			...continued	...continued	...cont	...cont	

Admin Pubs 60791 Exp 10-13-69

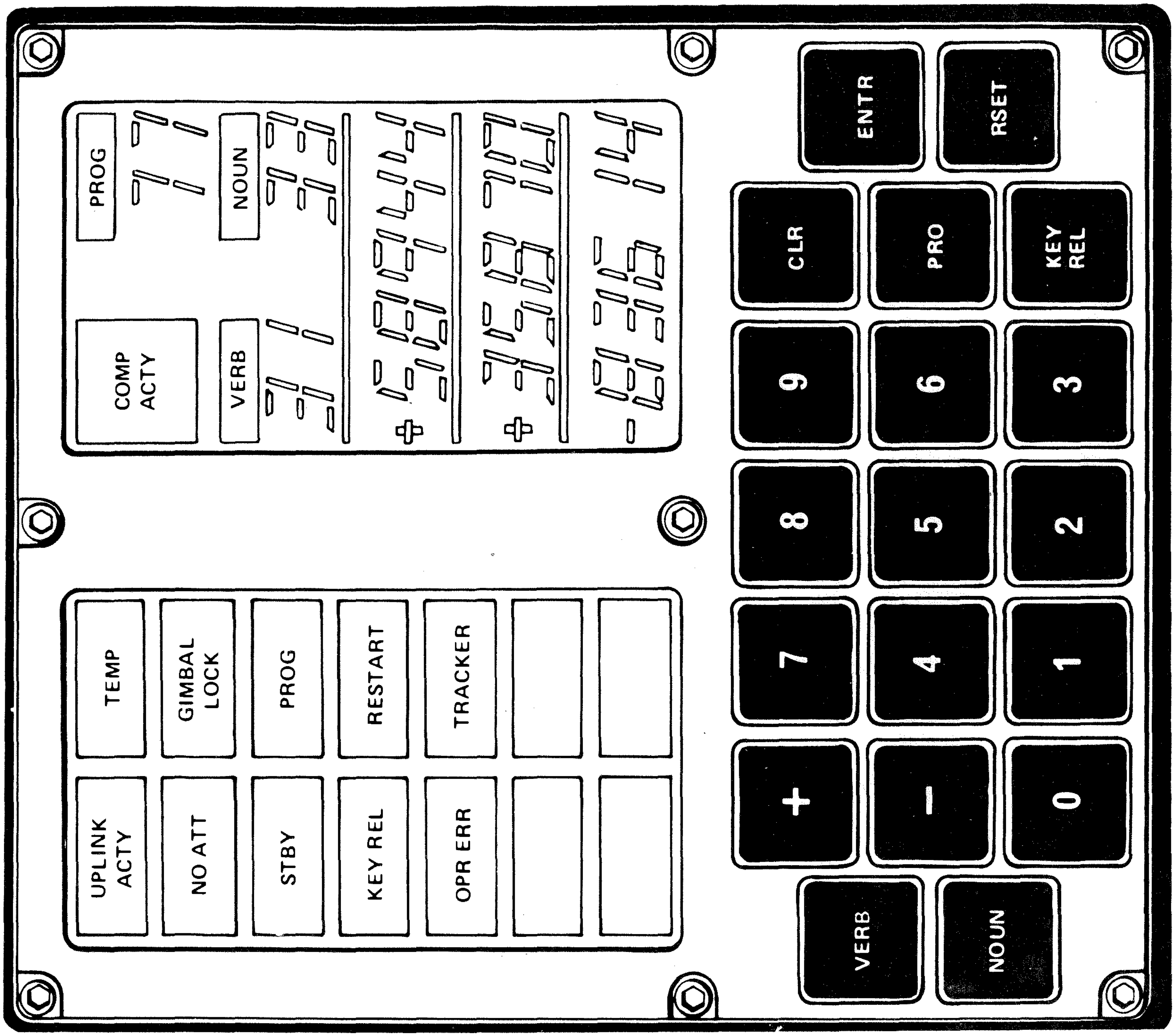
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
122	A1 (Cont)	G&N		e. Parity fail - accessed word, whose address is octal 10 or greater, contains even number of ones. f. Interrupt too long or infrequent - 140 ms to 300 ms. g. TC trap - too many TC or TCF instructions or TCF instructions too infrequent. h. Night watchman - computer fails to access address 67 within 64 seconds to 1.92 seconds. i. V fail - 4v supply 4.4v 4v supply 3.6v 14v supply 16.0v 14v supply 12.5v 28v supply 22.6v j. If oscillator stops. k. Alarm test.			Items e through k will cause restart in CMC. Items c through j will cause CMC to illuminate if fault occurs at a frequency >6 per second.
			ISS	ISS status light will illuminate if the following occurs: a. IMU fail: 1. IG servo error 2.9 mr for 2 sec. 2. MG servo error 2.9 mr for 2 sec. 3. OG servo error 2.9 mr for 2 sec. 4. 3200 cps 50%. 5. 800 wheel supply 50%.			IMU fail signal inhibited by CMC when in coarse align mode.
			...continued	...continued	...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
122	A1 (Cont)	G&N		b. PIPA fail: 1. No pulse during 312.5 m sec period. 2. If both + and - pulses occur during 312.5 m sec period. 3. If no + or - pulses occur between 1.28 to 3.84 sec. c. CDU fail: 1. CDU fine error 1.0 vrms. 2. CDU coarse error 2.5 vrms. 3. Read counter limit 160 cps. 4. Cos (0 - Ø) 2.0v. 5. +14 dc supply 50%.			PIPA fail signal inhibited by CMC except during CMC-controlled translation or thrusting. CDU fail signal by CMC during CDU zero mode.
			MASTER ALARM	Red light illuminates to alert crewman of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on Panel 2.	C/W MNA and MNB (Panel 5)	DC main buses A and B	MASTER ALARM lights on Panels 1, 3, and 122 are simultaneously illuminated, and audio alarm tone is sent to each headset. MASTER ALARM switch-light contains an integral push-switch. Pressing switch-light will reset master alarm circuit, extinguishing and shutting off audio alarm.
			PGNS ...continued	PGNS status light will illuminate if the following occurs: a. CMC restart during operation. b. IMU temp 126.3°F. c. IMU temp 134.3°F. d. Middle gimbal angle greater than 70°. e. Program alarm. Caused by a variety of situations in each program.	GUIDANCE/ NAVIGATION LIGHTS AC1 & AC2 (Panel 5)	AC buses 1 and 2	Under program control, CMC inhibits PROG alarm for 10 sec after system turn-on.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
122	A1 (Cont)	G&N	MARK (pushbutton)	Signals CMC to record optics SHAFT and TRUNNION angles, IMU gimbal angles X, Y, & Z and ground elapsed time (GET).	N/A	CMC	Used in conjunction with optical sightings.
			MARK REJECT (pushbutton)	Signals CMC to reject last mark.			
			(OPTICS HAND CONTROLLER)	Provides electrical commands to the optics shaft and trunnion drive motor.	N/A	PSA	A 5-position controller spring-loaded to center off position.
			OPTICS (switches)				
			COUPLING				Functions if MODE switch in MAN and ZERO switch in OFF only.
			DIRECT	Optics controller signals X and Y drive shaft and trunnion control directly.	N/A	N/A	
			RSLV	Optics controller signals X and Y are resolved into X and Y motions in field of view.			
			SPEED	Selects gain of optics controller to line-of-sight motion.			Functions if MODE switch MAN only.
			HI	Provides maximum drive rate of line of sight in respect to optics controller displacement.			Maximum drive rates: shaft 19.5 deg/sec, trunnion 10 deg/sec.
			MED	Provides medium drive rate of line of sight in respect to optics controller displacement.			Maximum drive rates: shaft 2.0 deg/sec, trunnion 1.0 deg/sec.
			LO	Provides minimum drive rate of line of sight in respect to optics controller displacement.			Maximum drive rates: shaft 0.2 deg/sec, trunnion 1.0 deg/sec.
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
122	A1 (Cont)	G&N	MODE	Selects optics mode of operation.			Functions if ZERO switch in OFF position.
			CMC	Optics under computer program control.			
			MAN	Optics under astronaut's manual control using optics controller.			
			ZERO	Optics driven to zero shaft and trunnion.			
			OFF	Applies ground to MODE switch, removes 28 vdc discrete from CMC, and removes ground from PSA, disabling optics zeroing.			
			STAR ACQ	This light is not active.			On when CONDITION LAMPS switch in TEST position.
			TEL TRUN				
			SLAVE TO SXT	Slave SCT trunnion axis to SXT trunnion.			
			0°	Drives SCT trunnion to zero independent of sextant.			Zero position is parallel to SXT shaft axis.
			25°	Drives SCT trunnion to 25 degrees offset from shaft axis.			This is a fixed 25-degree independent of sextant trunnion position.
			RETICLE BRIGHTNESS	Adjusts brightness of sextant and scanning telescope reticles, and telescope angle counters.	GUIDANCE NAVIGATION LIGHTS AC1 & AC2 (Panel 5)	AC buses 1 and 2	
			UP TELEMETRY (switch)				There are two up-telemetry switches, one on Panel 122 and the other on Panel 2. These switches are wired in series and either switch in BLOCK position will block up-telemetry information into CMC.
			ACCEPT	Computer accepts telemetry data.	N/A	CMC	
			BLOCK	Computer does not accept up-telemetry data.			

CONTROLS AND DISPLAYS



PANEL 140

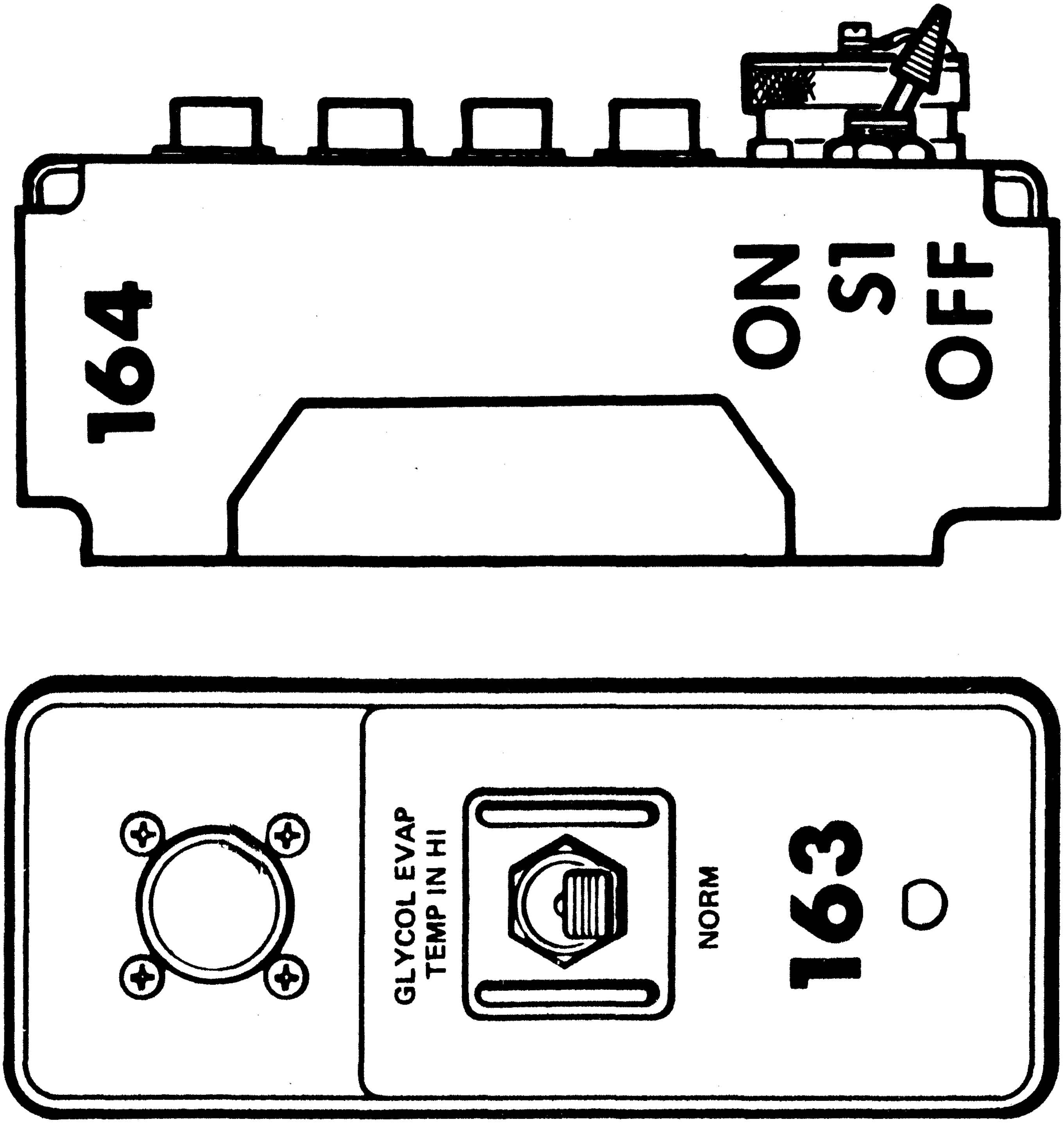
140

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
140	A1	G&N	(G/N DSKY)				
			(Keyboard)				
			CLR	Depression of clear button will blank the register being loaded.	N/A	N/A	
			ENTR	Informs CMC that assembled data is complete and/or to execute desired function.			
			KEY REL	Releases DSKY displays initiated by keyboard action so that information supplied by CMC program may be displayed.			
			NOUN	Sets computer to accept next two digits as noun code.			Pressing noun button will initially blank noun window.
			RSET	Extinguishes status lamps that are controlled by CMC.			In those areas where an error or malfunction exists, pressing reset switch will not extinguish status lamps.
			PRO	Informs routine requesting operator's response that operator wishes requesting routine to proceed without further inputs from operator; or places CMC in standby mode when pressed, upon request from CMC.			
			VERB	Sets computer to accept next two digits as verb code.			Pressing verb button will initially blank verb window.
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
140	A1 (Cont)	G&N	+	Denotes data to follow has positive decimal value.			
			-	Denotes data to follow has a negative decimal value.			
			0 through 9	Switches 0 to 9 are used to enter data, address code, and action request codes into the CMC.			
			(Registers)				
			COMP ACTY (light)	CMC is energized in computation.			
			NOUN (light & display)	Two-digit display indicating noun code selected.			On-board data provides definition of PROGRAM and NOUN digits.
			PROG (light & display)	Two-digit display indicating number of program (major mode) presently in progress.			
			(REGISTER 1) (display)	Displays contents of selected register or memory location. First component of extended data word, if applicable.			Displays may be commanded manually or by CMC.
			(REGISTER 2) (display)	Displays contents of selected register or memory location. Second component of extended data word, if applicable.			
			...continued		...cont	...cont	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
140	A1 (Cont)	G&N	(REGISTER 3) (display)	Displays contents of selected register or memory location. Third component of extended data word, if applicable.			
			VERB (light & display)	Two-digit display indicating verb code selected.			On-board data provided definition of VERB digits.
			(Status lights)				
			GIMBAL LOCK	Gimbal lock-light will illuminate under computer control whenever middle gimbal angle of platform exceeds 70 degrees.	LIGHTING NUMERICS/ INTEGRAL AC2 LEB (Panel 226)	AC bus 2 ØA	Illumination of lights warns of pending gimbal lock position
			KEY REL	Internal CMC program needs DSKY circuits to continue program.			Request for operator to press KEY REL pushbutton.
				A crew keystroke is made when internal flashing display is currently on DSKY (exceptions: PRO, ENTER, RESET).			
				Crew makes keystroke on top of his selected monitor verb.			
			NO ATT	This light will illuminate whenever inertial subsystem is not in a mode to provide attitude reference.			
			ORP ERR	This light will illuminate when illegal keyboard entry is made into CMC.			
			...continued		...cont	...cont	

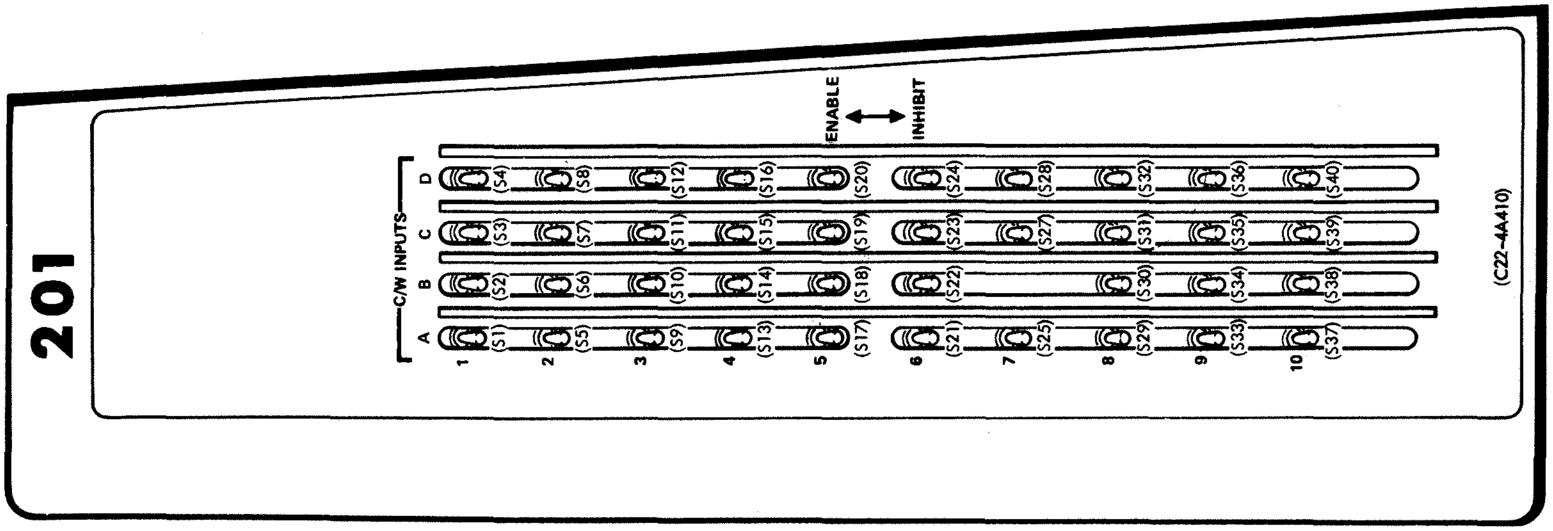
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
140	A1 (Cont)	G&N	PROG	Light illuminates when additional functions, operations, or information is requested by the computer to complete specific operation or function.			
			RESTART	This light will be illuminated whenever computer goes into restart program.			
			STBY	This light will be illuminated whenever computer subsystem is in standby mode of operation.			
			TEMP	This light will illuminate whenever temperature of stable platform deviates more than $\pm 5^{\circ}F$ from nominal.			Indicates an out of tolerance temperature, plus or minus, on stable platform.
			TRACKER	This light will illuminate whenever there is a failure of one of the optical CDU.			
				Data good discrete not present after reading range from VHF DATA LINK.			
			UPLINK ACTY	CMC is receiving data link information by up-telemetry.			



PANELS 163, 164

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
163	S1	ECS	ECS GLYCOL EVAP				
			TEMP IN HI	Temperature of glycol entering evaporator controlled at 60°F.	N/A	N/A	When in HI position, switch adds 590 ohm resistor to control circuit to shift operating point from 45° to 60°F.
			NORM	Temperature controlled at 45°F.			
164	J1	EXP	Receptacle	28-vdc power outlet receptacle for experiment connectors.	N/A	DC main buses A and B	LEB Panel 164 is in back (outboard) of stowage compartment B6 and is not accessible during a mission
164	S1	EXP	S1				
			ON	Supplies electrical power to Panel 164 receptacle.	EXP PWR EXP B (Panel 5)	DC main buses A and B	Used for S015, Human Cell zero "g" experiment on SC 116 (SL 2). Auxiliary cable from Panel 164 to auxiliary panel in B6 furnishes power for S015.
			OFF	Removes power.			

PANEL 201


201
ENABLE
INHIBIT
C/W INPUTS
A
B
C
D
1
2
3
4
5
6
7
8
9
10
(S1)
(S2)
(S3)
(S4)
(S5)
(S6)
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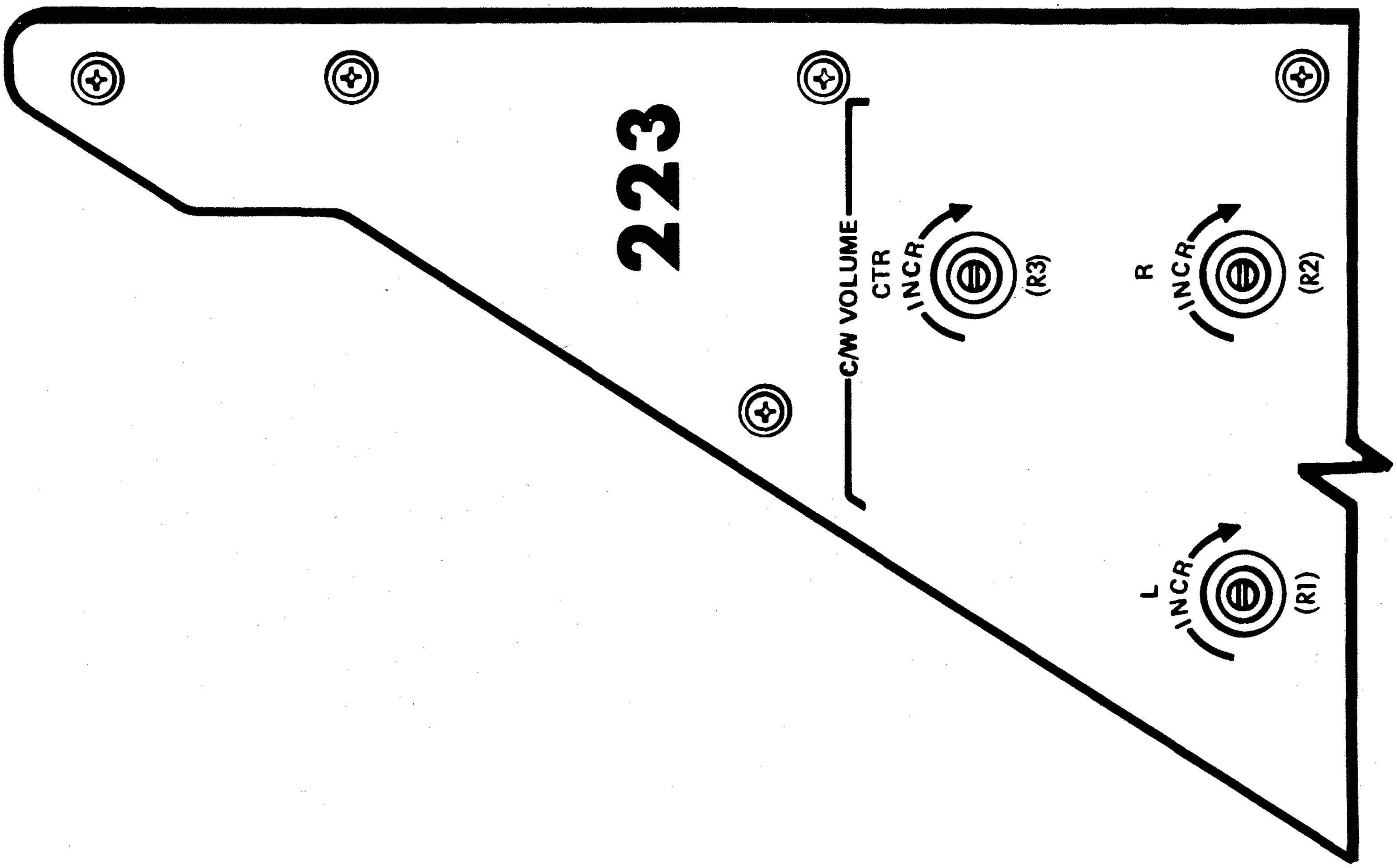
(S34)
(S35)
(S36)
(S37)
(S38)
(S39)
(S40)
(C22-4A410)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
201		C/W	C/W INPUTS ENABLE INHIBIT		C/W MNA & MNB (Panel 5)	DC main buses A and B	All caution and warning status lights are located on panel 2.
			1				
	S1		A	Inhibits input signal to CREW ALERT status light.			
	S2		B	Inhibits input signal to INV 1 TEMP HI status light.			
	S3		C	Inhibits signal inputs to O_2 TK 1 and O_2 TK 2 HTR TEMP lights respectively.			O_2 TK 1 HTR TEMP.
	S4		D				O_2 TK 2 HTR TEMP.
			2				
	S5		A	Inhibit individual signal inputs to CRYO PRESS status light.			O_2 tank 1 pressure.
	S6		B				O_2 tank 2 pressure.
	S7		C				H_2 tank 1 pressure.
	S8		D				H_2 tank 2 pressure.
			3				
	S9		A	Inhibit individual signal inputs to FC 1 status light.			FC 1 COND EXH TEMP
	S10		B				FC 1 SKIN TEMP
	S11		C				FC 1 pH
	S12		D				FC 1 REAC VALVE CLOSE
			4				
	S13		A	Inhibit individual signal inputs to FC 3 status light.			FC 3 COND EXH TEMP
	S14		B				FC 3 SKIN TEMP
	S15		C				FC 3 pH
	S16		D				FC 3 REAC VALVE CLOSE

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
201	(Cont)	C/W	C/W INPUTS		C/W MNA & MNB (Panel 5)	DC main buses A and B	
			5				
	S17		A	Inhibit individual signal inputs to SM RCS A status light.			SM RCS A fuel tank pressure.
	S18		B				SM RCS A package temperature.
	S19		C	Inhibit individual signal inputs to SM RCS B status light.			SM RCS B fuel tank pressure.
	S20		D				SM RCS B package temperature.
			6				
	S21		A	Inhibits individual signal inputs to SM RCS C status light.			SM RCS C fuel tank pressure.
	S22		B				SM RCS C package temperature.
	S23		C	Inhibits individual signal inputs to SM RCS D status light.			SM RCS D fuel tank pressure.
	S24		D				SM RCS D package temperature.
			7				
	S25		A	Inhibits signal input to SM RCS PSM 1 status light.			SM RCS PSM 1 fuel tank pressure.
	S26		B	Not assigned.			
	S27		C	Inhibits individual signal inputs to SPS PRESS status light.			SPS OXID pressure.
	S28		D				SPS FUEL pressure.
			8				
	S29		A	Inhibits signal input to PITCH GMBL 1 status light.			
	S30		B	Inhibits signal input to PITCH GMBL 2 status light.			

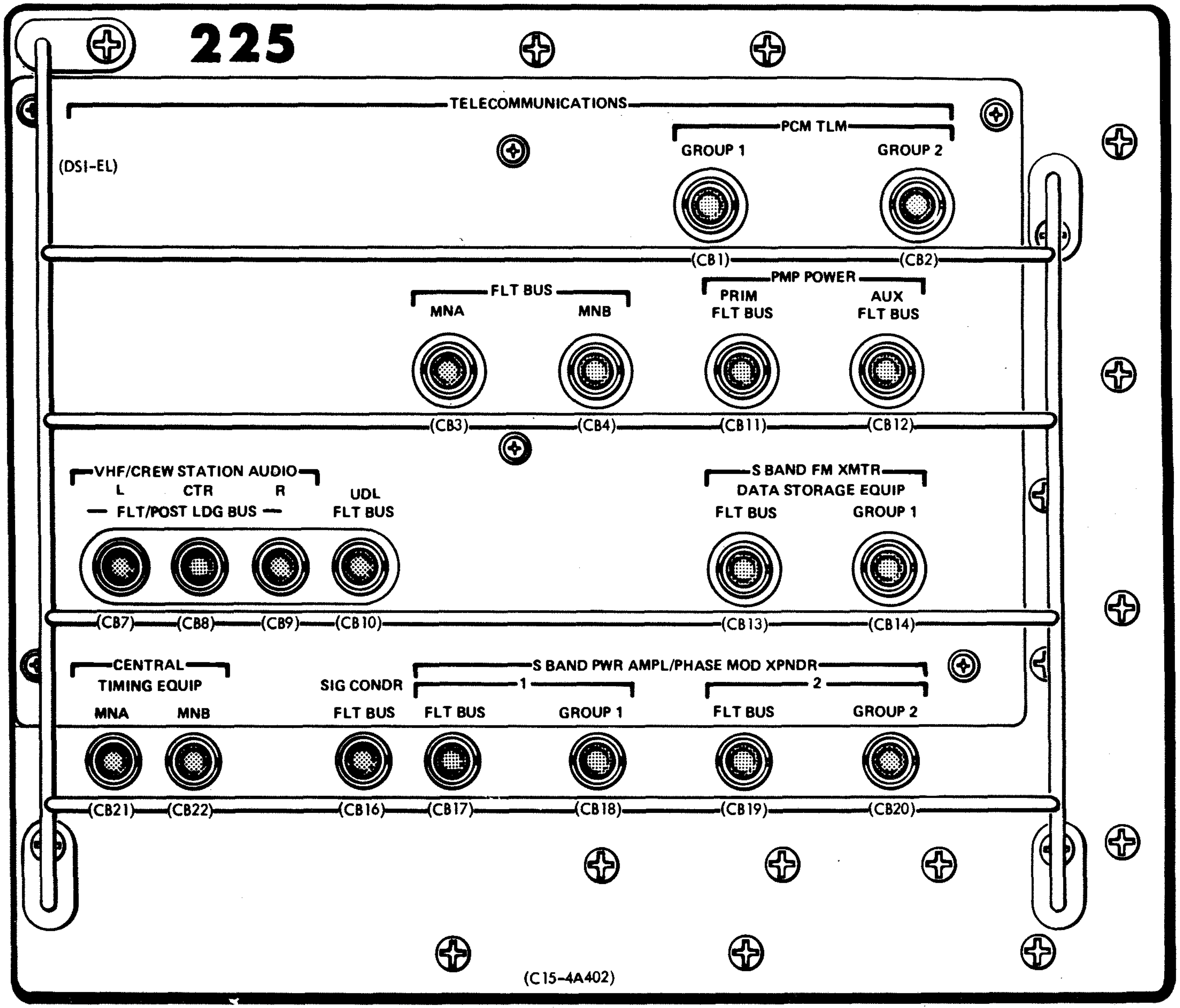
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
201	(Cont)	C/W	C/W INPUTS		C/W MNA & MNB (Panel 5)	DC main buses A and B	
			8				
	S31		C	Inhibits signal input to YAW GMBL 1 status light.			
	S32		D	Inhibits signal input to YAW GMBL 2 status light.			
			9				
	S33		A	Inhibits signal input to CO_2 PP HI status light.			
	S34		B	Inhibits signal input to GLYCOL FLOW LOW status light.			
	S35		C	Inhibits signal input to O_2 FLOW HI status light.			
	S36		D	Inhibits signal input to SUIT COMPRESSOR status light.			Suit compressor ΔP.
			10				
	S37		A	Inhibits signal input to BMAG 1 TEMP status light.			
	S38		B	Inhibits signal input to BMAG 2 TEMP status light.			
	S39		C	Inhibits signal input to CMC status light.			
	S40		D	Inhibits signal input to ISS status light.			



PANEL 223

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
223	R1	C/W	C/W VOLUME L	Adjusts volume of tone supplied to AUDIO/TONE position of POWER switch on panel 9.	N/A	C/W tone generator	
223	R2	C/W	C/W VOLUME CTR	Adjusts volume of tone supplied to AUDIO/TONE position of POWER switch on panel 10.	N/A	C/W tone generator	
223	R3	C/W	C/W VOLUME R	Adjusts volume of tone supplied to AUDIO/TONE position of POWER switch on panel 6.	N/A	C/W tone generator	

PANEL 225


225
TELECOMMUNICATIONS
(DSI-EL)
PCM TLM
GROUP 1
GROUP 2
(CB1)
(CB2)
FLT BUS
MNA
MNB
PMP POWER
PRIM FLT BUS
AUX FLT BUS
(CB3)
(CB4)
(CB11)
(CB12)
VHF/CREW STATION AUDIO
L
CTR
R
FLT/POST LDG BUS
UDL FLT BUS
S BAND FM XMTR
DATA STORAGE EQUIP
FLT BUS
GROUP 1
(CB7)
(CB8)
(CB9)
(CB10)
(CB13)
(CB14)
CENTRAL TIMING EQUIP
MNA
MNB
SIG CONDR FLT BUS
S BAND PWR AMPL/PHASE MOD XPNDR
1
FLT BUS
GROUP 1
2
FLT BUS
GROUP 2
(CB21)
(CB22)
(CB16)
(CB17)
(CB18)
(CB19)
(CB20)
(C15-4A402)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
225	CB1	TLCM	TELECOMMUNICATIONS PCM TLM GROUP 1	Provides power from the group I telecom a-c bus to the PCM.	N/A	Group I telecom bus, 115v 400 cps 3Ø ac	Supplies power to power supply A in the PCM equipment. Power supply A and B are paralleled and diode isolated.
225	CB2	TLCM	TELECOMMUNICATIONS PCM TLM GROUP 2	Provides power from the group II telecom a-c bus to the PCM.	N/A	Group II telecom bus, 115v 400 cps 3Ø ac	Supplies power to power supply B in the PCM equipment. Power supply A and B are paralleled and diode isolated.
225	CB3	TLCM	TELECOMMUNICATIONS FLT BUS MNA	Provides power from main d-c bus A to the telecom flight bus.	N/A	DC main bus A	Supplies all necessary dc power to the telecommunications equipment except for flight and postlanding dc bus requirements.
225	CB4	TLCM	TELECOMMUNICATIONS FLT BUS MNB	Provides power from main d-c bus B to the telecom flight bus.	N/A	DC main bus B	Supplies all necessary dc power to telecommunications equipment except for flight and postlanding dc bus requirements.
225	CB7	TLCM	TELECOMMUNICATIONS VHF/CREW STATION AUDIO L FLT/POST LDG BUS	Provides d-c power from flight and postlanding bus to CDR audio center and left microphone, VHF recovery BCN, and emergency power to SPT right microphone.	N/A	Flight and postlanding bus	Flight and postlanding dc bus receives power through FLIGHT/POSTLANDING - MAIN A and MAIN B circuit breakers on RHEB MDC 5 which in turn receives power from main dc bus A and B. Supplies power to the SUIT POWER switches on the audio control panels.

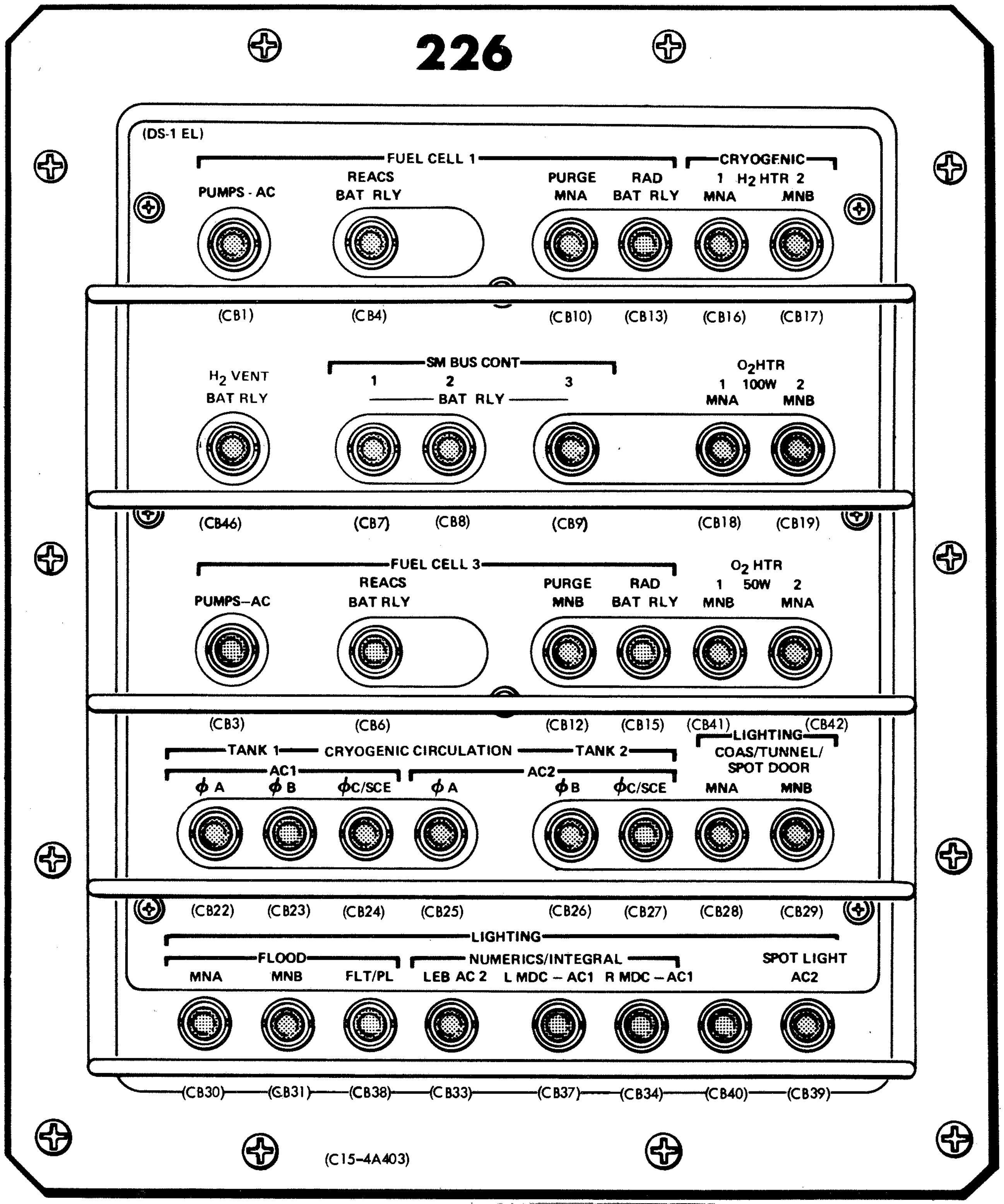
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
225	CB8	TLCM	TELECOMMUNICATIONS VHF/CREW STATION AUDIO CTR FLT/POST LDG BUS	Provides d-c power from flight and postlanding bus to SPT audio center and left microphone, VHF/AM SPEAKER box, and emergency power to PLT right microphone.	N/A	Flight and postlanding bus	Flight and postlanding dc bus receives power through FLIGHT/POSTLANDING - MAIN A and MAIN B circuit breakers on RHEB MDC 5 which in turn receives power from main dc bus A and B. Supplies power to the SUIT POWER switches on the audio control panels.
225	CB9	TLCM	TELECOMMUNICATIONS VHF/CREW STATION AUDIO R FLT/POST LDG BUS	Provides d-c power from flight and postlanding bus to PLT audio center and left microphone, digital ranging generator and emergency power to CDR right microphone.	N/A	Flight and postlanding bus	Flight and postlanding dc bus receives power through FLIGHT/POSTLANDING - MAIN A and MAIN B circuit breakers on RHEB MDC 5 which in turn receives power from main dc bus A and B. Supplies power to the SUIT POWER switches on the audio control panels.
225	CB10	TLCM	TELECOMMUNICATIONS UDL FLT BUS	Provides d-c power from flight bus to UDL equipment.	N/A	Telecom flight bus, 28 vdc	Provides dc power to UDC power supply when UP TLM switch is in CMD RESET or NORM position.
225	CB11	TLCM	TELECOMMUNICATIONS PMP POWER PRIM FLT BUS	Provides d-c power to PMP primary power supply.	N/A	Telecom flight bus, 28 vdc	Power is supplied to the POWER-PMP-NORM/AUX switch on MDC 3 which selects not only power supplies but biphase modulators.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
225	CB12	TLCM	TELECOMMUNICATIONS PMP POWER AUX FLT BUS	Provides d-c power to PMP auxiliary power supply.	N/A	Telecom flight bus, 28 vdc	Power is supplied to the POWER-PMP-NORM/AUX switch on MDC 3 which selects not only power supplies but biphase modulators.
225	CB13	TLCM	TELECOMMUNICATIONS S BAND FM XMTR DATA STORAGE EQUIP FLT BUS	Provides d-c power from telecom flight bus to S BAND FM XMTR, the DSE, and the TV camera.	N/A	Telecom flight bus 28 vdc	Power interface is through the TAPE RECORDER switches and S-BAND AUX switches.
225	CB14	TLCM	TELECOMMUNICATIONS S BAND FM XMTR DATA STORAGE EQUIP GROUP 1	Provides a-c power from Group I telecom a-c bus to DSE and S BAND FM XMTR.	N/A	Group I telecom a-c bus, 115v 400 cps 3Ø dc	No power interface through switches.
225	CB16	TLCM	TELECOMMUNICATIONS SIG CONDR FLT BUS	Provides d-c power from telecom flight bus to SCE.	N/A	Telecom flight bus, 28 vdc	Power is supplied to the POWER-SCE-NORM/AUX switch on MDC 3 which selects one of two redundant power supplies.
225	CB17	TLCM	TELECOMMUNICATIONS S BAND PWR AMPL/PHASE MOD XPNDR 1 FLT BUS	Provides d-c power from telecom flight bus to S-band primary XPNDR and PA.	N/A	Telecom flight bus, 28 vdc	Supplies power to S-band omniantenna switches on MDC 3 to select A, B, C or D omniantenna provided S-BAND NORMAL XPNDR switch is in PRIM or SEC position.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
225	CB18	TLCM	TELECOMMUNICATIONS S BAND PWR AMPL/PHASE MOD XPNDR 1 GROUP 1	Provides a-c power from Group I telecom bus to S-band primary transponder and PA.	N/A	Group I telecom bus, 115v 400 cps 3Ø ac	No power interface through switches.
225	CB19	TLCM	TELECOMMUNICATIONS S BAND PWR AMPL/PHASE MOD XPNDR 2 FLT BUS	Provides d-c power from telecom flight bus to S-band secondary transponder and PA.	N/A	Telecom flight bus, 28 vdc	Supplies power to S-band omniantenna switches on MDC 3 to select A, B, C or D omniantenna provided S-BAND NORMAL XPNDR switch is in PRIM or SEC position.
225	CB20	TLCM	TELECOMMUNICATIONS S BAND PWR AMPL/PHASE MOD XPNDR 2 GROUP 2	Provides a-c power from telecom Group II bus to S-band secondary transponder and PA.	N/A	Group II telecom bus, 115v 400 cps 3Ø ac	No power interface through switches.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
225	CB21	MISC	TELECOMMUNICATIONS CENTRAL TIMING EQUIP MNA	Provides d-c power from main bus A to CTE.	N/A	DC main bus A	Supplies power to CTE No. 1 power supply. Power supplies 1 and 2 are paralleled and isolated. No power interface through switches.
225	CB22	MISC	TELECOMMUNICATIONS CENTRAL TIMING EQUIP MNB	Provides d-c power from main bus B to CTE.	N/A	DC main bus B	Supplies power to CTE No. 2 power supply. Power supplies 1 and 2 are paralleled and isolated. No power interface through switches.

PANEL 226


226
(DS-1 EL)
FUEL CELL 1
PUMPS - AC
REACS BAT RLY
PURGE MNA
RAD BAT RLY
CRYOGENIC
1 H2 HTR 2
MNA
MNB
(CB1)
(CB4)
(CB10)
(CB13)
(CB16)
(CB17)
H2 VENT BAT RLY
SM BUS CONT
1
2
3
BAT RLY
O2 HTR
1 100W 2
MNA
MNB
(CB46)
(CB7)
(CB8)
(CB9)
(CB18)
(CB19)
FUEL CELL 3
PUMPS–AC
REACS BAT RLY
PURGE MNB
RAD BAT RLY
O2 HTR
1 50W 2
MNB
MNA
(CB3)
(CB6)
(CB12)
(CB15)
(CB41)
(CB42)
TANK 1
CRYOGENIC CIRCULATION
TANK 2
AC1
AC2
ϕ A
ϕ B
ϕC/SCE
ϕ A
ϕ B
ϕC/SCE
LIGHTING
COAS/TUNNEL/ SPOT DOOR
MNA
MNB
(CB22)
(CB23)
(CB24)
(CB25)
(CB26)
(CB27)
(CB28)
(CB29)
LIGHTING
FLOOD
MNA
MNB
FLT/PL
NUMERICS/INTEGRAL
LEB AC 2
L MDC – AC1
R MDC – AC1
SPOT LIGHT AC2
(CB30)
(CB31)
(CB38)
(CB33)
(CB37)
(CB34)
(CB40)
(CB39)
(C15-4A403)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB1	EPS	FUEL CELL 1 PUMPS-AC	Protects 3Ø circuits supplying a. Power from a-c bus No. 1 or 2 (selected by FC PUMPS-1 switch - panel 5) to H_2/water separator and glycol pump motors in fuel cell 1. b. ØA power to FC 1 pH sensor probe. c. Provides connection of FC 1 power factor correction circuit to either a-c bus.	N/A	AC bus 1 or 2	
226	CB3	EPS	FUEL CELL 3 PUMPS-AC	Protects 3Ø circuits supplying a. Power from a-c bus No. 1 or 2 (selected by FC PUMP-3 switch - panel 5) to H_2/water sep and glycol pump motors in fuel cell 3. b. ØA power to FC 3 pH sensor probe. c. Provides connection of FC 3 power factor correction circuit to either a-c bus.	N/A	AC bus 1 or 2	
226	CB4	EPS	FUEL CELL 1 REACS BAT RELAY	Protects circuit supplying d-c power from battery relay bus to FUEL CELL REACTANTS 1 switch (Panel 3).	N/A	Battery relay bus	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB6	EPS	FUEL CELL 3 REACS BAT RLY	Protects circuit supplying d-c power from battery relay bus to FUEL CELL 3 - REACTANTS switch (Panel 3).	N/A	Battery relay bus	
226	CB7	EPS	SM BUS CONT 1 BAT RLY	Protects circuit supplying a. D-C power for SM PWR SOURCE-1 bus control through SM PWR SOURCE - MAIN BUS A-1 and MAIN BUS B-1 switches (Panel 3). b. D-C power for SM PWR SOURCE - BAT 1 - FC 1 selector switch (Panel 5). c. Logic power for SM PWR SOURCE 3 overload/ reverse current sensor. d. Power to FC 1 reactants event indicator (Panel 3). e. Power for latching FC 1 reactant valves open solenoids and the H_2 vent valve closed solenoid.	N/A	Battery relay bus	
226	CB8	EPS	SM BUS CONT 2 BAT RLY	Protects circuit supplying a. D-C power for SM PWR SOURCE-2 bus control through SM PWR SOURCE - MAIN BUS A-2 and MAIN BUS B-2 switches (Panel 3). b. Logic power for SM PWR SOURCE 1 overload/ reverse current sensor.	N/A	Battery relay bus	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB9	EPS	SM BUS CONT 3 BAT RLY	Protects circuit supplying a. D-C power for SM PWR SOURCE-3 bus control through SM PWR SOURCE - MAIN BUS A-3 and MAIN BUS B-3 and switches (Panel 3). b. D-C power for SM PWR SOURCE - BAT 3 - FC 3 selector switch (Panel 5). c. Logic power for SM PWR SOURCE 1 overload/reverse current sensor. d. Power to FC 3 reactants event indicator (Panel 3). e. Power for latching FC 3 reactant valves open solenoids.	N/A	Battery relay bus	
226	CB10	EPS	FUEL CELL 1 PURGE MNA	Protects circuit supplying a. Power from d-c main bus A to FC 1 purge valves through FUEL CELL PURGE 1 switch (Panel 3). b. Power to H_2 PURGE LINE HTR switch (Panel 3).	N/A	DC main bus A	NOTE: A fuse (5 amp) protects MAIN BUS B power to FC 1 PURGE VALVE control switch.
226	CB12	EPS	FUEL CELL 3 PURGE MNB	Protects circuit supplying a. Power from d-c main bus B to FC 3 purge valves through FUEL CELL PURGE-3 switch (Panel 3). b. Power to H_2 PURGE LINE HTR switch (Panel 3).	N/A	DC main bus B	NOTE: A fuse (5 amp) protects MAIN BUS A power to FC 3 PURGE VALVE control switch.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB13	EPS	FUEL CELL 1 RAD BAT RLY	Protects circuit supplying power to FUEL CELL RADIATORS-1 switch (Panel 3).	N/A	Battery relay bus	
226	CB15	EPS	FUEL CELL 3 RAD BAT RLY	Protects circuit supplying power to FUEL CELL RADIATORS-3 switch (Panel 3).	N/A	Battery relay bus	
226	CB16	EPS	CRYOGENIC H_2 HTR 1 MNA	Protects circuit supplying power from d-c main bus A to H_2 HEATERS 1 switch (Panel 2).	N/A	DC main bus A	
226	CB17	EPS	CRYOGENIC H_2 HTR 2 MNB	Protects circuit supplying power from d-c main bus B to H_2 HEATERS 2 switch (Panel 2).	N/A	DC main bus B	
226	CB18	EPS	CRYOGENIC O_2 HTR 1 100W MNA	Protects circuit supplying power from d-c main bus A to O_2 HEATERS 1 switch (Panel 2).	N/A	DC main bus A	10-amp cb. Power to O_2 tank 1 100-watt heater elements (5-amp fuses between cb and each of two heater elements).

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB19	EPS	CRYOGENIC O_2 HTR 2 100W MNB	Protects circuit supplying power from d-c main bus B to O_2 HEATERS 2 switch (Panel 2).	N/A	DC main bus B	10-amp cb. Power to O_2 tank 2 100-watt heater elements (5-amp fuses between cb and each of two heater elements).
226	CB22	EPS	CRYOGENIC CIRCULATION TANK 1 AC1 ØA	Protects circuit supplying ØA power from a-c bus No. 1 to a. H_2 FANS - 1 switch (Panel 2).	N/A	AC bus 1 ØA	
226	CB23	EPS	CRYOGENIC CIRCULATION TANK 1 AC1 ØB	Protects circuit supplying ØB power from a-c bus No. 1 to a. H_2 FANS - 1 switch (Panel 2).	N/A	AC bus 1 ØB	
226	CB24	EPS	CRYOGENIC CIRCULATION TANK 1 AC1 ØC/SCE	Protects circuit supplying ØC power from a-c bus No. 1 to a. H_2 FANS - 1 switch (Panel 2). b. H_2 and O_2 tank 1 quantity and fluid temp signal conditioning equipment.	N/A	AC bus 1 ØC	

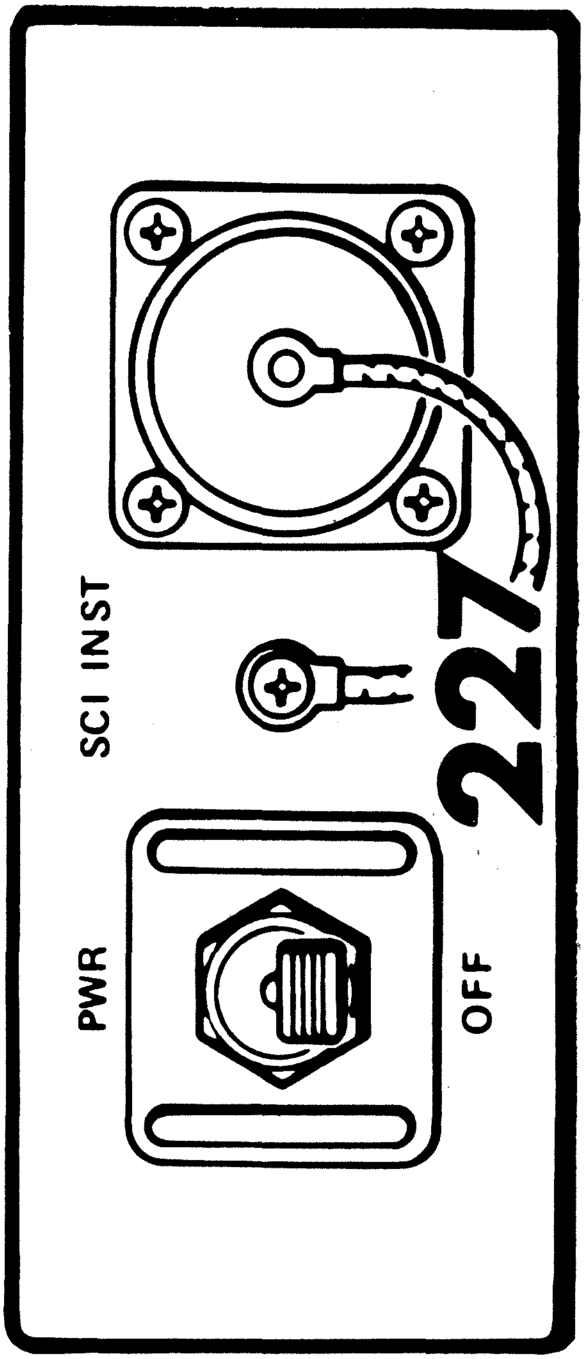
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB25	EPS	CRYOGENIC CIRCULATION TANK 2 AC2 ØA	Protects circuit supplying ØA power from a-c bus No. 2 to H_2 FANS - 2 switch (Panel 2).	N/A	AC bus 2 ØA	
226	CB26	EPS	CRYOGENIC CIRCULATION TANK 2 AC2 ØB	Protects circuit supplying ØB power from a-c bus No. 2 to H_2 FANS - 2 switch (Panel 2).	N/A	AC bus 2 ØB	
226	CB27	EPS	CRYOGENIC CIRCULATION TANK 2 AC2 ØC/SCE	Protects circuit supplying ØC power from a-c bus No. 2 to a. H_2 FANS - 2 switch (Panel 2). b. H_2 and O_2 tank 2 quantity and fluid temp signal conditioning equipment.	N/A	AC bus 2 ØC	
226	CB28	MISC	LIGHTING COAS/TUNNEL/ SPOT DOOR MNA	Provides circuit protection for COAS switch on Panel 15 and TUNNEL LIGHTS switches on Panel 2.	N/A	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB29	MISC	LIGHTING COAS/TUNNEL/ SPOT DOOR MNB	Provides circuit protection for COAS switch on Panel 15 and TUNNEL LIGHTS and SPOT DOOR switches on Panel 2.	N/A	DC main bus B	
226	CB30	EPS	LIGHTING FLOOD MNA	Provides circuit protection from DC MAIN BUS A to FLOOD rheostat switches (Panel 8), FLOOD FIXED switch (Panel 5), and FLOOD rheostat switch (Panel 100).	N/A	DC main bus A	
226	CB31	EPS	LIGHTING FLOOD MNB	Provides circuit protection from DC MAIN BUS B to FLOOD - FIXED/OFF/POST LDG switch (Panel 8), FLOOD rheostat switch (Panel 5), and FLOOD - FIXED/OFF switch (Panel 100).	N/A	DC main bus B	
226	CB33	EPS	LIGHTING NUMERICS/INTEGRAL LEB AC2	Provides circuit protection from AC BUS 2 ØA to INTEGRAL and NUMERICS rheostat switches (Panel 100).	N/A	AC bus 2 ØA	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB34	EPS	LIGHTING NUMERICS/INTEGRAL R MDC-AC1	Provides circuit protection from AC BUS 1 ØB to INTEGRAL rheostat switch (Panel 5).	N/A	AC bus 1 ØB	
226	CB37	EPS	LIGHTING NUMERICS/INTEGRAL L MDC-AC1	Provides circuit protection from AC BUS 1 ØA to INTEGRAL and NUMERICS rheostat switches (Panel 8).	N/A	AC bus 1 ØA	
226	CB38	EPS	LIGHTING FLOOD FLT/PL	Provides circuit protection from flight/postlanding bus to FLOOD - FIXED/OFF/ POST LDG switch (Panel 8).	N/A	Postlanding batteries	
226	CB39	MISC	LIGHTING SPOTLIGHT AC2	Provides circuit protection from AC BUS 2 ØB to SPOT DOOR switch on Panel 2.	N/A	AC bus 2 ØB	
226	CB40	MISC	CB40 Function Deleted				

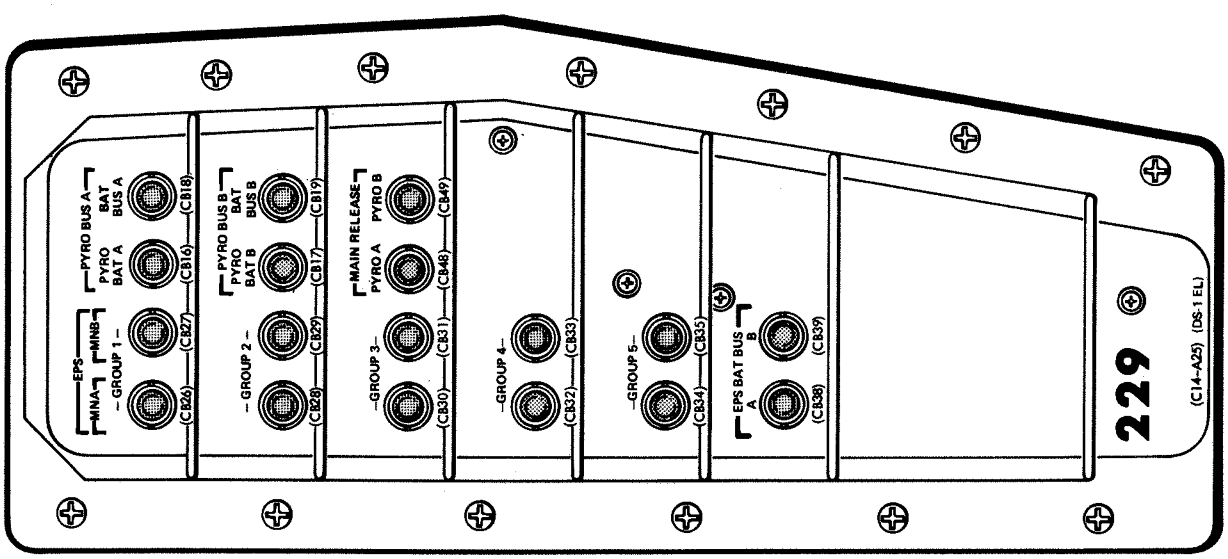
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
226	CB41	EPS	CRYOGENIC O_2 HTR 1 50W MNB	Protects circuit providing power to O_2 HEATERS 1 switch (Panel 2).	N/A	DC main bus B	5-amp cb. Power to O_2 tank 1 50W heater element (5-amp fuse between cb and heater element).
226	CB42	EPS	CRYOGENIC O_2 HTR 2 50W MNA	Protects circuit providing power to O_2 HEATERS 2 switch (Panel 2).	N/A	DC main bus A	5-amp cb. Power to O_2 tank 2 50W heater element (5-amp fuse between cb and heater element).
226	CB46	EPS	H_2 VENT BAT RLY	Protects circuit providing power to H_2 VENT switch (Panel 3).	N/A	Battery relay bus	5 amp cb.

PANEL 227



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
227	J85	MISC	SCI INST				
			(RECEPTACLE)	Receptacle is utilized for experiment power and PCM return signals.	N/A	N/A	
227	S1	MISC	SCI INST				
			PWR	Applies 28 vdc power to receptacle.	INSTRUMEN-TATION MNA & MNB (Panel 5)	DC main buses A and B	
			OFF	Removes power.			

PANEL 229


PYRO BUS A
PYRO BAT A
BAT BUS A
EPS
MNA
MNB
GROUP 1
(CB18)
(CB16)
(CB27)
(CB26)
PYRO BUS B
PYRO BAT B
BAT BUS B
GROUP 2
(CB19)
(CB17)
(CB29)
(CB28)
MAIN RELEASE
PYRO A
PYRO B
GROUP 3
(CB49)
(CB48)
(CB31)
(CB30)
GROUP 4
(CB33)
(CB32)
GROUP 5
(CB35)
(CB34)
EPS BAT BUS
A
B
(CB39)
(CB38)
229
(C14-A25) (DS-1 EL)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
229	CB16	SEQ	PYRO BUS A PYRO BAT A	Prevents current overload on interface wiring to SECS PYRO buses and DEC switch contacts.	CB53 (Battery mounted)	Pyro battery A	Must be opened if PYRO BUS A BAT BUS A circuit breaker (CB18) is closed. Reference Volume 1, section 2.9. CB16 is normally closed.
229	CB17	SEQ	PYRO BUS B PYRO BAT B	Prevents current overload on interface wiring to SECS PYRO buses and DEC switch contacts.	CB52 (Battery mounted)	Pyro battery B	Must be opened if PYRO BUS B BAT BUS B circuit breaker (CB19) is closed. Reference Volume 1, section 2.9. CB17 is normally closed.
229	CB18	SEQ	PYRO BUS A BAT BUS A	Prevents current overload on interface wiring to SECS PYRO buses and DEC motor switch contacts.	BAT BUS A BAT A (Panel 275)	Entry and postlanding battery A	Colored yellow to denote contingency situation. Closed only if there is a power failure of pyro battery A. Reference Volume 1, section 2.9. CB18 is normally open.
229	CB19	SEQ	PYRO BUS B BAT BUS B	Prevents current overload on interface wiring to SECS PYRO buses and DEC motor switch contacts.	BAT BUS B BAT B (Panel 275)	Entry and postlanding battery B	Colored yellow to denote contingency situation. Closed only if there is a power failure of pyro battery B. Reference Volume 1, section 2.9. CB19 is normally open.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
229	CB26	EPS	EPS GROUP 1 MNA	Applies power to panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM-PITCH-MNA. b. SM RCS HTRS PRIM - B/D MNA package. (Also applies power to QUAD B/D PRIM and PSM 2 PRIM heaters if installed.) c. REACTION CONTROL SYSTEM - PRPLNT ISOL - MNA. d. SCS - LOGIC BUS 3/4 MNA. e. SCS - CONTR/AUTO MNA.	N/A	DC main bus A	
229	CB27	EPS	EPS GROUP 1 MNB	Applies power to Panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM-PITCH-MNB. b. SM RCS HTRS SEC - B/D MNB package. (Also applies power to QUAD B/D SEC and PSM 2 SEC heaters.) c. REACTION CONTROL SYSTEM - PRPLNT ISOL - MNB. d. SCS LOGIC BUS 2/3 MNB. e. SCS CONTR/AUTO MNB.	N/A	DC main bus B	
229	CB28	EPS	EPS GROUP 2 MNA	Applies power to Panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM - SYSTEM MNA. b. STABILIZATION CONTROL SYSTEM - AC ROLL MNA.	N/A	DC main bus A	

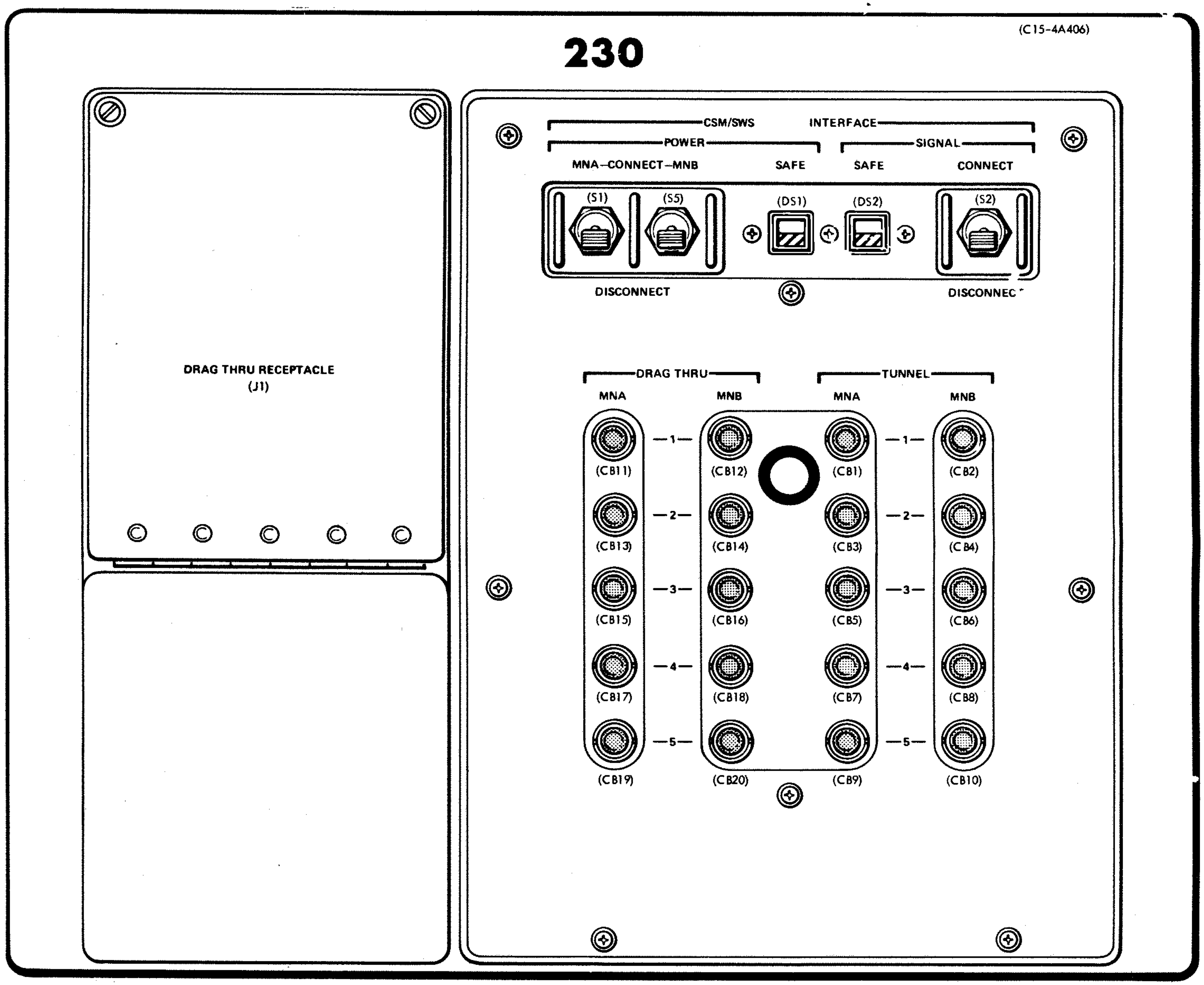
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
229	CB29	EPS	EPS GROUP 2 MNB	Applies power to Panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM - SYSTEM MNB. b. STABILIZATION CONTROL SYSTEM-A/C ROLL-MNB.	N/A	DC main bus B	
229	CB30	EPS	EPS GROUP 3 MNA	Applies power to Panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM-YAW - MNA. b. SM RCS HTRS A/C - SEC MNA package. (Also applies power to QUAD A/C SEC and PSM 1 SEC heaters.) c. SCS LOGIC BUS 1/2 MNA.	N/A	DC main bus A	
229	CB31	EPS	EPS GROUP 3 MNB	Applies power to Panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM-YAW - MNB. b. SM RCS HTRS A/C - PRIM MNB package. (Also applies power to QUAD A/C PRIM and PSM 1 PRIM heaters.) c. SCS-LOGIC PWR-1/4 - MNB. d. ORDEAL-MNB.	N/A	DC main bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
229	CB32	EPS	EPS GROUP 4 MNA	Applies power to Panel 8 circuit breakers: a. STABILIZATION CONTROL SYSTEM-B/D ROLL-MNA. b. SERVICE PROPULSION SYSTEM-GAUGING-MNA. c. SERVICE PROPULSION SYSTEM-He VALVE-MNA. d. EMS MNA. e. DOCK PROBE MNA.	N/A	DC main bus A	
229	CB33	EPS	EPS GROUP 4 MNB	Applies power to Panel 8 circuit breakers: a. SERVICE PROPULSION SYSTEM-GAUGING - MNB. b. STABILIZATION CONTROL SYSTEM-B/D ROLL-MNB. c. EMS MNB. d. SERVICE PROPULSION SYSTEM-He VALVE-MNB. e. DOCK PROBE - MNB.	N/A	DC main bus B	
229	CB34	EPS	EPS GROUP 5 MNA	Applies power to Panel 8 circuit breakers: a. REACTION CONTROL SYSTEM-RCS LOGIC-MNA. b. REACTION CONTROL SYSTEM-CM HEATERS-1 - MNA. c. SPS-PILOT VALVES-MNA. d. SCS-CONTR/DIRECT-1 MNA. e. SCS-CONTR/DIRECT-2 MNA. f. SCS-DIRECT ULL-MNA.	N/A	DC main bus A	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
229	CB35	EPS	EPS GROUP 5 MNB	Applies power to Panel 8 circuit breakers: a. REACTION CONTROL SYSTEM-RCS LOGIC-MNB. b. REACTION CONTROL SYSTEM-CM HEATERS-2-MNB. c. SPS-PILOT VLVS-MNB. d. SCS-CONTR/DIRECT 1 MNB. e. SCS-CONTR/DIRECT 2 MNB. f. SCS-DIRECT ULL MNB.	N/A	DC main bus B	
229	CB38	EPS	EPS BAT BUS A	Applies d-c power from battery bus A to following circuit breakers on Panel 8: a. SERVICE PROPULSION SYSTEM-PITCH 1 - BAT A. b. SERVICE PROPULSION SYSTEM-YAW 1 - BAT A. c. SEQ EVENTS CONT SYSTEM ARM A - BAT A. d. SEQ EVENTS CONT SYSTEM LOGIC A - BAT A. e. ELS/CM-SM SEP. f. EDS 1 - BAT A. g. FLOAT BAG 1 - BAT A.	N/A	Battery bus A	
229	CB39	EPS	EPS BAT BUS B	Applies d-c power from battery bus B to following circuit breakers on Panel 8: a. SERVICE PROPULSION SYSTEM-PITCH 2 - BAT B. b. SERVICE PROPULSION SYSTEM-YAW 2 - BAT B.	N/A	Battery bus B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
229	CB39 (Cont)	EPS		c. SEQ EVENTS CONT SYSTEM-ARM B - BAT B. d. SEQ EVENTS CONT SYSTEM LOGIC B - BAT B. e. ELS/CM-SM SEP. f. EDS 3 - BAT B. g. FLOAT BAG 2 - BAT B.			
229	CB48	SEQ	MAIN RELEASE PYRO A	Safety feature. Maintains open circuit in pyro power to main chute release initiators. Prevents premature release of main parachutes in the event of a malfunction in logic control circuits.	N/A	MESC pyro bus A	Closed after splashdown. Normally open.
229	CB49	SEQ	MAIN RELEASE PYRO B	Safety feature. Maintains open circuit in pyro power to main chute release initiators. Prevents premature release of main parachutes in the event of a malfunction in logic control circuits.	N/A	MESC pyro bus B	Closed after splashdown. Normally open.

PANEL 230

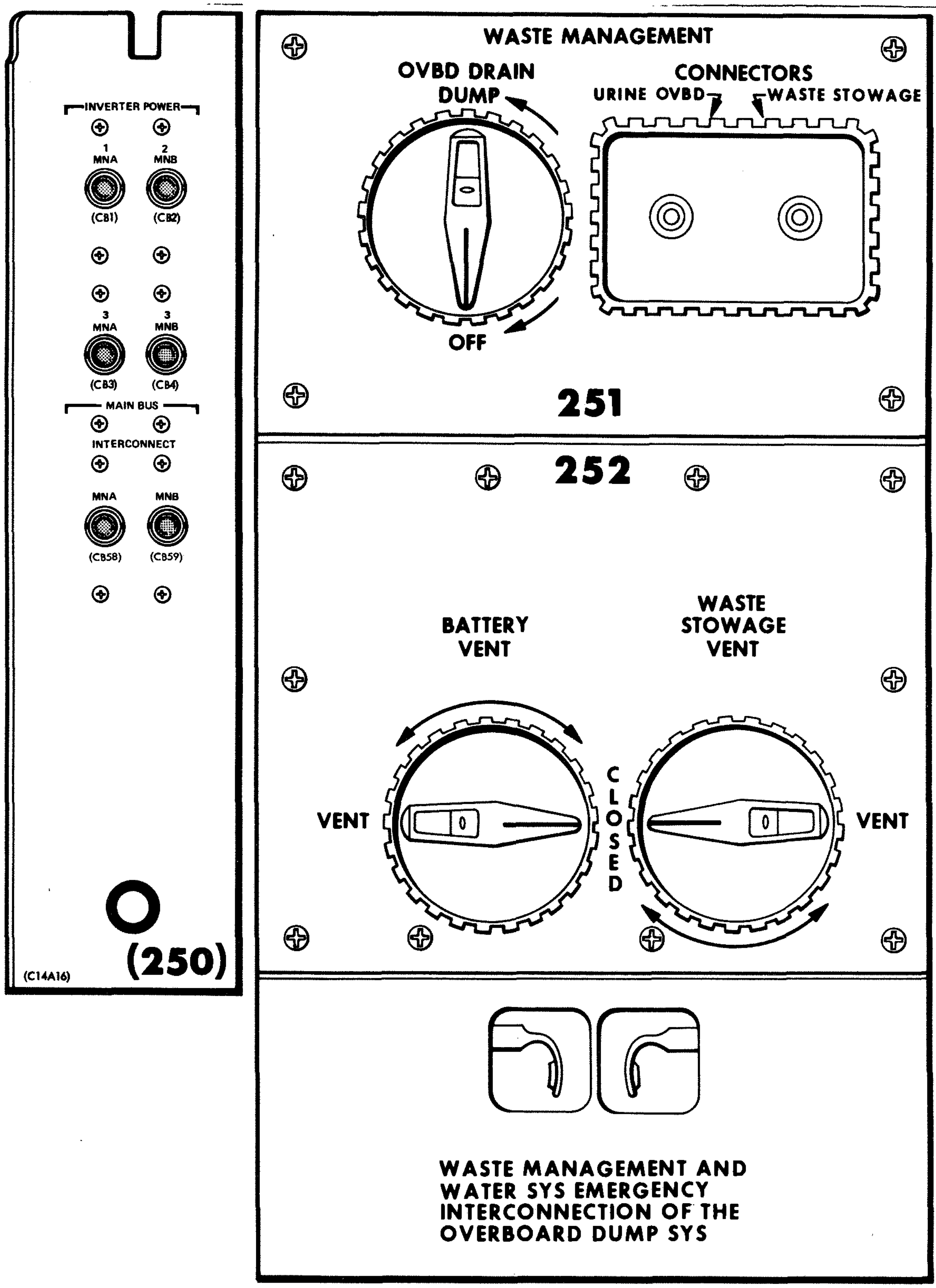

230
(C15-4A406)
DRAG THRU RECEPTACLE
(J1)
CSM/SWS
INTERFACE
POWER
SIGNAL
MNA–CONNECT–MNB
SAFE
SAFE
CONNECT
(S1)
(S5)
(DS1)
(DS2)
(S2)
DISCONNECT
DISCONNECT
DRAG THRU
TUNNEL
MNA
MNB
MNA
MNB
1
2
3
4
5
(CB11)
(CB12)
(CB1)
(CB2)
(CB13)
(CB14)
(CB3)
(CB4)
(CB15)
(CB16)
(CB5)
(CB6)
(CB17)
(CB18)
(CB7)
(CB8)
(CB19)
(CB20)
(CB9)
(CB10)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
230	CB1 3 5 7 9	EPS	CSM/SWS INTERFACE TUNNEL MNA	Provide protection in each of five lines in tunnel umbilical used for power transfer from SWS bus 1 to CM main d-c bus A.	N/A	SWS bus 1 or CM main d-c bus A	
230	CB11 13 15 17 19	EPS	CSM/SWS INTERFACE DRAG THRU MNA	Provide protection in each of the five lines in drag-thru umbilical used for contingency power transfer from SWS bus 1 to CM main d-c bus A.	N/A	SWS bus 1 or CM main d-c bus A	Used only in event of failure of tunnel umbilical or one SWS bus.
230	CB2 4 6 8 10	EPS	CSM/SWS INTERFACE TUNNEL MNB	Provide protection in each of five lines in tunnel umbilical used for power transfer from SWS bus 2 to CM main d-c bus B.	N/A	SWS bus 2 or CM main d-c bus B	
230	CB12 14 16 18 20	EPS	CSM/SWS INTERFACE DRAG THRU MNB	Provide protection in each of the five lines in drag-thru umbilical used for contingency power transfer from SWS bus 2 to CM d-c bus B.	N/A	SWS bus 2 or CM main d-c bus B	Used only in event of failure of tunnel umbilical or one SWS bus.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
230	DS1	EPS	CSM/SWS INTERFACE POWER SAFE	Indicates whether motor switch power transfer is or is not made to connect SWS bus 1 to CM main d-c bus A and SWS bus 2 to CM main d-c bus B.	SWS INTER-FACE CONT PWR BAT RLY-1. (Panel 5)	Battery relay bus	Striped indicates motor switch connections are made in either umbilical to CM d-c main bus A or B.
230	DS2	TLCM	CSM/SWS INTERFACE SIGNAL SAFE	Indicates whether the signals umbilicals deadface is closed or open.	SWS INTER-FACE CONT PWR BAT RLY-2 (Panel 5)	Battery relay bus	Striped indicates motor switch connections in both umbilicals are made.
230	J1	EPS	DRAG THRU RECEPTACLE	Receptacle for connecting drag-thru umbilical.	N/A	N/A	
230	S1	EPS	CSM/SWS INTERFACE POWER CONNECT MNA DISCONNECT	Powers motor switch to connect SWS bus 1 to CM main d-c bus A thru tunnel and drag-thru umbilicals. Powers motor switches to disconnect SWS bus 1 from CM main d-c bus A.	SWS INTER-FACE CONT PWR BAT RLY-1 (Panel 5)	Battery relay bus	
230	S2	TLCM	CSM/SWS INTERFACE SIGNAL CONNECT DISCONNECT	Powers motor switches to connect signal output from SWS to CM communication system. Disconnects SWS signal output from CM communication system.	SWS INTER-FACE CONT PWR BAT RLY-1 & 2 (Panel 5)	Battery relay bus	CB BAT RLY-1 (Panel 5) powers first umbilical transfer and CB BAT RLY-2 (Panel 5) powers second umbilical transfer.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
230	S5	EPS	CSM/SWS INTERFACE				
			POWER				
			CONNECT MNB	Powers motor switch to connect SWS bus 2 to CM main d-c bus B thru tunnel and drag-thru umbilicals.	SWS INTER-FACE CONT PWR BAT RLY-2 (Panel 5)	Battery relay bus	
			DISCONNECT	Powers motor switches to disconnect SWS bus 2 from CM main d-c bus B.			

PANELS 250, 251, 252



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
250	CB1	EPS	INVERTER POWER 1 MNA	Protects d-c input circuit to No. 1 inverter.	N/A	DC main bus A	
250	CB2	EPS	INVERTER POWER 2 MNB	Protects d-c input circuit to No. 2 inverter.	N/A	DC main bus B	
250	CB3	EPS	INVERTER POWER 3 MNA	Protects d-c input circuit to No. 3 inverter.	N/A	DC main bus A	
250	CB4	EPS	INVERTER POWER 3 MNB	Protects d-c input circuit to No. 3 inverter.	N/A	DC main bus B	
250	CB58	EPS	MAIN BUS INTERCONNECT MNA	Provides contingency connection and protects circuit between CM main d-c bus A and B (in series with MNB cb).	N/A	N/A	Normally open. Used only in event of failure of one SWS bus.
250	CB59	EPS	MAIN BUS INTERCONNECT MNB	Provides contingency connection and protects circuit between CM main d-c bus A and B (in series with MNA cb).			Normally open. Used only in event of failure of one SWS bus.

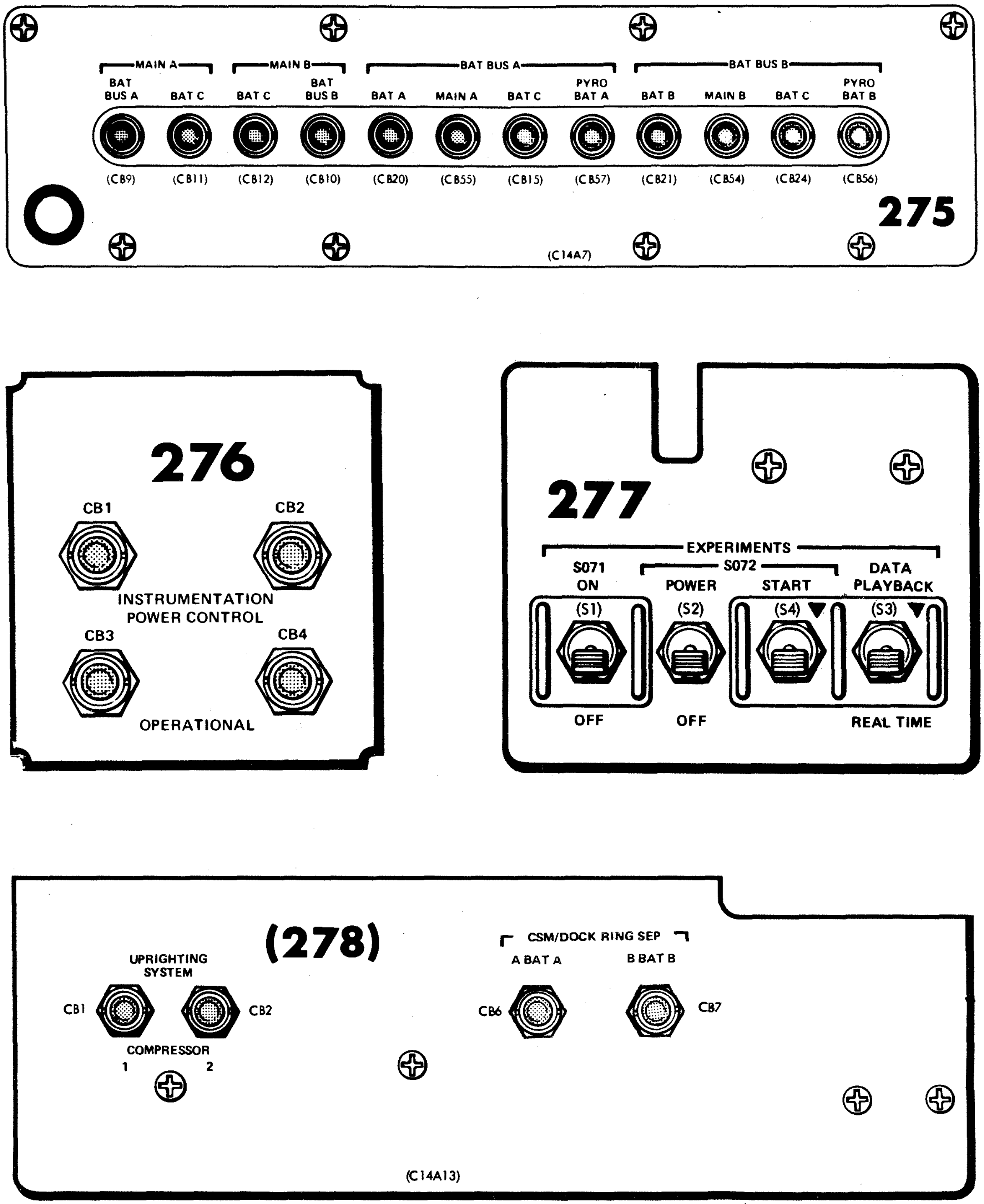
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
251	V1	ECS	WASTE MANAGEMENT OVBD DRAIN DUMP	Connects WMS urine overboard dump line from URINE OVBD QD (adjacent to valve) through selector valve to outside atmosphere, permitting dumping of urine overboard.	N/A	N/A	Valve is set to DUMP position for dumping. OVBD DRAIN valve is manually controlled by bar knob.
			OFF	Close WMS overboard dump line to outside atmosphere.			Upon completion of dumping operation, OVBD DRAIN valve is set to OFF position.
252	V1	ECS	BATTERY VENT VENT	Permits gases generated by CM batteries to be vented to waste/water dump line.	N/A	N/A	Valve is manually controlled by a bar knob.
			CLOSED	Shuts off the venting of CM batteries.			Normal position of valve is vent. Valve should be closed during waste water or contingency urine dump.
252	V2	ECS	WASTE STOWAGE VENT VENT	Connects WASTE STOWAGE QD to urine overboard dump line, permitting fecal odor from the portable fecal stowage bladder to be vented overboard.	N/A	N/A	Valve is manually controlled by a bar knob.
			CLOSED	Stops overboard odor dump capability.			Normal position of valve is closed.

PANEL 274

To be supplied at a later date.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
274	CB1	EPS	SWS POWER MNA	Protects SWS bus 1 power circuit supply between MNA power filter and CSM main d-c bus A.	N/A	SWS bus 1	
274	CB2	EPS	SWS POWER MNB	Protects SWS bus 2 power circuit supply between MNB power filter and CSM main d-c bus B.	N/A	SWS bus 2	

PANELS 275, 276, 277, 278

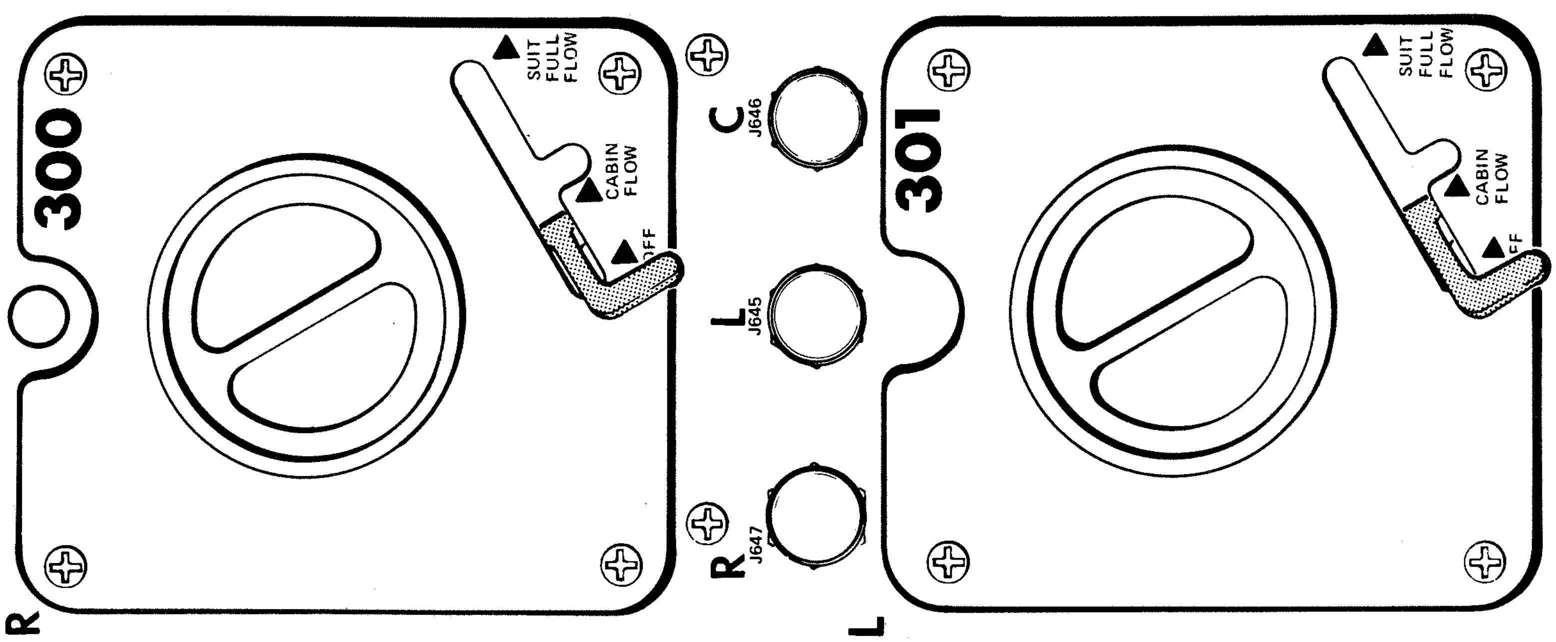


Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
275	CB9	EPS	MAIN A BAT BUS A	Protects circuit supplying d-c power from battery bus A to d-c main bus A through contacts of BAT A&C BUS TIE motor switch and isolation diode.	BAT BUS A BAT A or BAT BUS A PYRO BAT A (Panel 275)	Battery bus A	
275	CB10	EPS	MAIN B BAT BUS B	Protects circuit supplying d-c power from battery bus B to d-c main bus B through contacts of BAT B/C BUS TIE motor switch and isolation diode.	BAT BUS B BAT B or BAT BUS B PYRO BAT B (Panel 275)	Battery bus B	
275	CB11	EPS	MAIN A BAT C	Protects circuit supplying d-c power from entry battery C to d-c main bus A through contacts of BAT B/C BUS TIE motor switch and isolation diode.	CB43 (on battery case)	Battery C	Normally open circuit breaker. Closed when battery C required.
275	CB12	EPS	MAIN B BAT C	Protects circuit supplying d-c power from entry battery C to d-c main bus B through contacts of BAT A/C BUS TIE motor switch and isolation diode.	CB43 (on battery case)	Battery C	Normally open circuit breaker. Closed when battery C required.
275	CB15	EPS	BAT BUS A BAT C	Protects backup circuit to power bat bus A in case of entry battery A failure.	CB43 (on battery case)	Battery C	Normally open circuit breaker.
275	CB20	EPS	BAT BUS A BAT A	Protects circuit which connects entry battery A to battery bus A.	CB41 (on battery case)	Entry battery A	Opened during docked operation.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
275	CB21	EPS	BAT BUS B BAT B	Protects circuit which connects entry battery B to battery bus B.	CB42 (on battery case)	Entry battery B	Opened during docked operation.
275	CB24	EPS	BAT BUS B BAT C	Protects backup circuit to power bat bus B in case of entry battery B failure.	CB43 (on battery case)	Battery C	Normally open circuit breaker.
275	CB54	EPS	BAT BUS B MAIN B	Protects circuit and used to connect main d-c bus B power to battery bus B.	N/A	DC main bus B	Closed only during docked operation.
275	CB55	EPS	BAT BUS A MAIN A	Protects circuit and used to connect main d-c bus A power to battery bus A.	N/A	DC main bus A	Closed only during docked operation.
275	CB56	EPS	BAT BUS B PYRO BAT B	Protects circuit and used to connect pyro battery B power as backup to battery bus B.	CB52 (on battery case)	Pyro battery B	Normally open circuit breaker.
275	CB57	EPS	BAT BUS A PYRO BAT A	Protects circuit and used to connect pyro battery A power as backup to battery bus A.	CB53 (on battery case)	Pyro battery A	Normally open circuit breaker.
276	CB1	EPS	INSTRUMENTATION POWER CONTROL OPERATIONAL CB1	Provides d-c power to essential instrumentation.	INSTRUMENTATION MNA & MNB (Panel 5)	DC main buses A and B	

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
276	CB2	EPS	INSTRUMENTATION POWER CONTROL OPERATIONAL CB2	Provides d-c power to essential instrumentation.	INSTRUMENTATION MNA & MNB (Panel 5)	DC main buses A and B	
276	CB3	EPS	INSTRUMENTATION POWER CONTROL OPERATIONAL CB3	Provides d-c power to essential instrumentation.	INSTRUMENTATION MNA & MNB (Panel 5)	DC main buses A and B	
276	CB4	EPS	INSTRUMENTATION POWER CONTROL OPERATIONAL CB4	Provides d-c power to essential instrumentation.	INSTRUMENTATION MNA & MNB (Panel 5)	DC main buses A and B	
277	S1	EXP	EXPERIMENTS S071 ON OFF	Supplies 28-vdc power to the S071 experiment package. Removes 28-vdc power from the S071 experiment package.	EXP PWR B EXP (Panel 5)	EXP BUS (Panel 5)	7.5 amp. SC 117 only. S071 experiment package is located in the SM.
277	S2	EXP	EXPERIMENTS S072 POWER OFF	Supplies 28-vdc power to the S072 experiment package. Removes 28-vdc power from the S072 experiment package.	EXP PWR B EXP (Panel 5)	EXP BUS (Panel 5)	7.5 amps. SC 117 only. S072 experiment package is located in the SM.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
277	S3	MISC	EXPERIMENTS				
			DATA PLAYBACK	Supplies 28 vdc power to the DATA DUMP COMD function of the S072 experiment package.	EXP PWR B EXP (Panel 5)	EXP BUS (Panel 5)	7.5 amp. SC 117 only. DATA DUMP COMD power can also be supplied by UDL functions.
			REAL TIME				
277	S4	MISC	EXPERIMENTS				
			S072				
			START	Supplies 28-vdc power to the INITIATE COMMAND function of the S072 experiment package.	EXP PWR B EXP (Panel 5)	EXP BUS (Panel 5)	SC 117 only.
			OFF	Removes 28-vdc power from the INITIATE COMMAND function.			
278	CB1	MISC	UPRIGHTING SYSTEM				
			COMPRESSOR 1	Connects power from battery bus A to motor through control relays.	N/A	Battery bus A	
278	CB2	MISC	UPRIGHTING SYSTEM				
			COMPRESSOR 2	Connects power from battery bus B to motor through control relays.	N/A	Battery bus B	
278	CB6	SEQ	CSM/DOCK RING SEP				
			A BAT A	Connects circuit from DOCK RING SEP switch S109 to DEC A.	N/A	Secs ARM BAT A CB1 (Panel 8)	
278	CB7	SEQ	CSM/DOCK RING SEP				
			B BAT B	Connects circuit from DOCK RING SEP switch S112 to DEC B.	N/A	Secs ARM BAT B CB2 (Panel 8)	

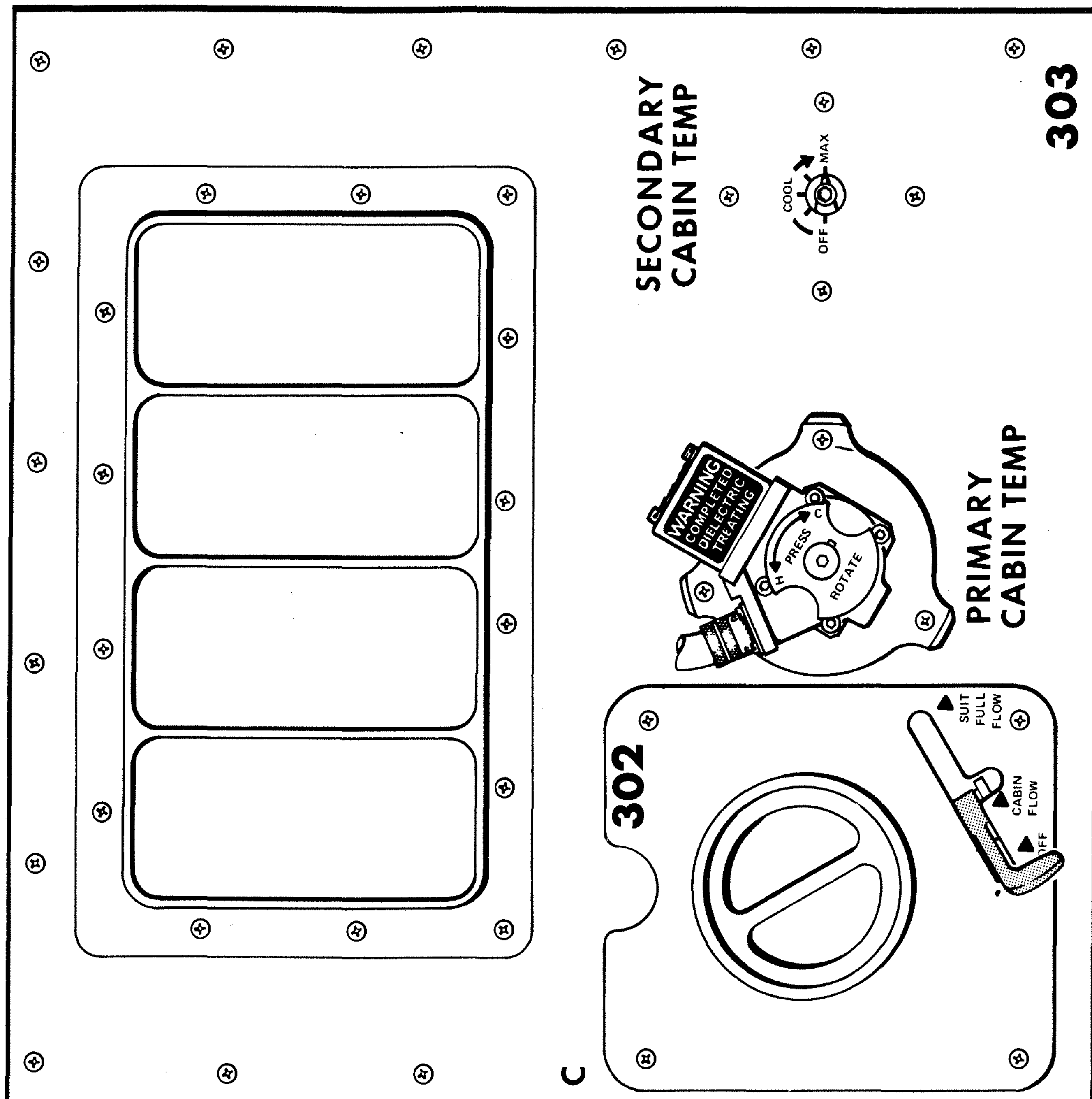


PANELS 300, 301

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
300	V1	ECS	(CABIN FLOW/SUIT FULL FLOW)				
			OFF	Closes valve shutting off flow of oxygen to and from suit connector.	N/A	N/A	Suit may be connected or disconnected only with valve in OFF position.
			CABIN FLOW	Partially opens valve, permitting oxygen flow into cabin (or suit) at a rate compatible to the requirements of one crewman.			Valve position may be used for reduced flow to PGA (suit connected), or for normal flow to cabin for shirtsleeve mode (suit not connected). Suit hose is not disconnected from suit connector panel when going to shirtsleeve mode.
			SUIT FULL FLOW	Fully opens valve, permitting oxygen flow to suit at a rate compatible to the requirements of one crewman.			With valve in SUIT FULL FLOW position (suit connected), flow is at the rate of 17 lb/hr minimum. However, flow rate will vary along suit flow adjustment range from SUIT FULL FLOW to CABIN FLOW positions. NOTE: Crewman electrical umbilical connector(s) R-L-C CTR interface with crewman electrical umbilicals. Connectors provide access to audio center, audio warning system, and provides a bath for crewman biomedical information to go to telemetering unit.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
301	V1	ECS	(CABIN FLOW/SUIT FULL FLOW)				
			OFF	Closes valve shutting off flow of oxygen to and from suit connector.	N/A	N/A	Suit may be connected or disconnected only with valve in OFF position.
			CABIN FLOW	Partially opens valve, permitting oxygen flow into cabin (or suit) at a rate compatible to the requirements of one crewman.			Valve position may be used for reduced flow to PGA (suit connected), or for normal flow to cabin for shirtsleeve mode (suit not connected). Suit hose is not connected from suit connector panel when going to shirtsleeve mode.
			SUIT FULL FLOW	Fully opens valve, permitting oxygen flow to suit at a rate compatible to the requirements of one crewman.			With valve in SUIT FULL FLOW position (suit connected), flow is at the rate of 17 lb/hr minimum. However, flow rate will vary along suit flow adjustment range from SUIT FULL FLOW to CABIN FLOW positions. NOTE: Crewman electrical umbilical connector(s) R-L-C CTR interface with crewman electrical umbilicals. Connectors provide access to audio center, audio warning system, and provides a path for crewman biomedical information to go to telemetering unit.

Admin Pubs 60791 Exp 10-13-69



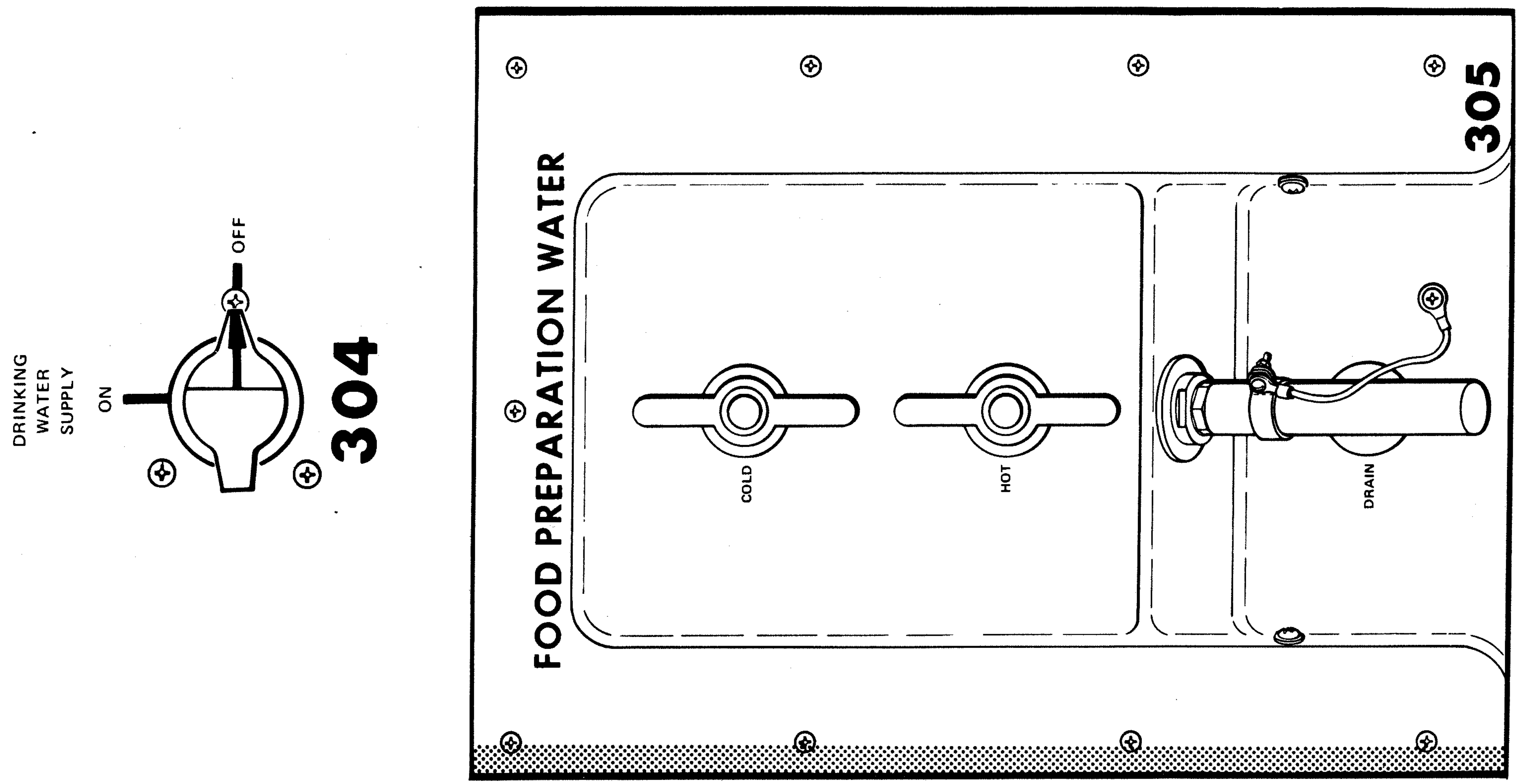
PANELS 302, 303

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
302	V1	ECS	(CABIN FLOW/SUIT FULL FLOW)				
			OFF	Closes valve shutting off flow of oxygen to and from suit connector.	N/A	N/A	Suit may be connected or disconnected only with valve in OFF position.
			CABIN FLOW	Partially opens valve permitting oxygen flow into cabin (or suit) at a rate compatible to the requirements of one crewman.			Valve position may be used for reduced flow to PGA (suit connected), or for normal flow to cabin for shirtsleeve mode (suit not connected. Suit hose is not connected from suit connector panel when going to shirtsleeve mode.
			SUIT FULL FLOW	Fully opens valve, permitting oxygen flow to suit at a rate compatible to the requirements of one crewman.			With valve in SUIT FULL FLOW position (suit connected), flow is at the rate of 17 lb/hr minimum. However, flow rate will vary along suit flow adjustment range from SUIT FULL FLOW to CABIN FLOW positions. NOTE: Crewman electrical umbilical connector(s) R-L-C CTR interface with crewman electrical umbilicals. Connectors provide access to audio center, audio warning system, and provides a path for crewman biomedical information to go to telemetering unit.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
303	V1	ECS	PRIMARY CABIN TEMP				
			H	Manual mode of cabin temperature control valve to increase cabin temperature.	N/A	N/A	Motor-operated valve is manually controlled by integral knob. Rotational movement from H to C is approximately 1/2 turn. Manual mode control knob is used because cabin temperature control components have been deleted on SKYLAB. This is a dual valve on a single shaft permitting water-glycol flow to heat exchanger to be regulated. Rotation toward H (heat) position results in proportional increase in cabin temperature by directing warm water-glycol to cabin heat exchanger. There is a definite time lag in cabin temperature response following manual adjustment; therefore, close coordination between manual adjustments and TEMP-CABIN indicator (Panel 2) is not necessary.
			C	Manual mode of cabin temperature control valve to decrease cabin temperature.			Rotation towards C (cool) position results in proportional decrease in cabin temperature by directing cool water-glycol to cabin heat exchanger. There is a definite time lag in cabin temperature response following manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (Panel 2) is not necessary.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
303	V2	ECS	SECONDARY CABIN TEMP				
			OFF	Prevents flow of water glycol to cabin heat exchanger.	N/A	N/A	Manually controlled valve.
			COOL	Meters water-glycol flow through cabin heat exchanger from OFF to MAX.			
			MAX	Full flow of secondary water-glycol system through cabin heat exchanger.			

PANELS 304, 305



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
304	V1	ECS	DRINKING WATER SUPPLY				
			ON	Permits flow of potable water to water (gun) delivery unit.	N/A	N/A	Shutoff valve manually controlled by permanently installed knob. Normal position of valve is ON.
			OFF	Turns off flow of potable water to water (gun) delivery unit.			Valve is closed in event of leak in water delivery unit.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
305	V1	ECS	FOOD PREPARATION WATER COLD	Upon actuation, permits metered amount of cold water (nominal 50°F) to food reconstitution nozzle.	N/A	N/A	To actuate, pull on syringe-type finger grips. Cold water is metered at a rate of 1.00 ± 0.05 ounce per valve actuation. Water is delivered upon release of valve.
305	V2	ECS	FOOD PREPARATION WATER HOT	Upon actuation, permits metered amount of hot water (nominal 154°F) to food reconstitution nozzle.	N/A	N/A	To actuate pull on syringe-type finger grips. Hot water is metered at a rate of 1.00 ± 0.05 ounce per valve actuation. Water is delivered upon release of valve.

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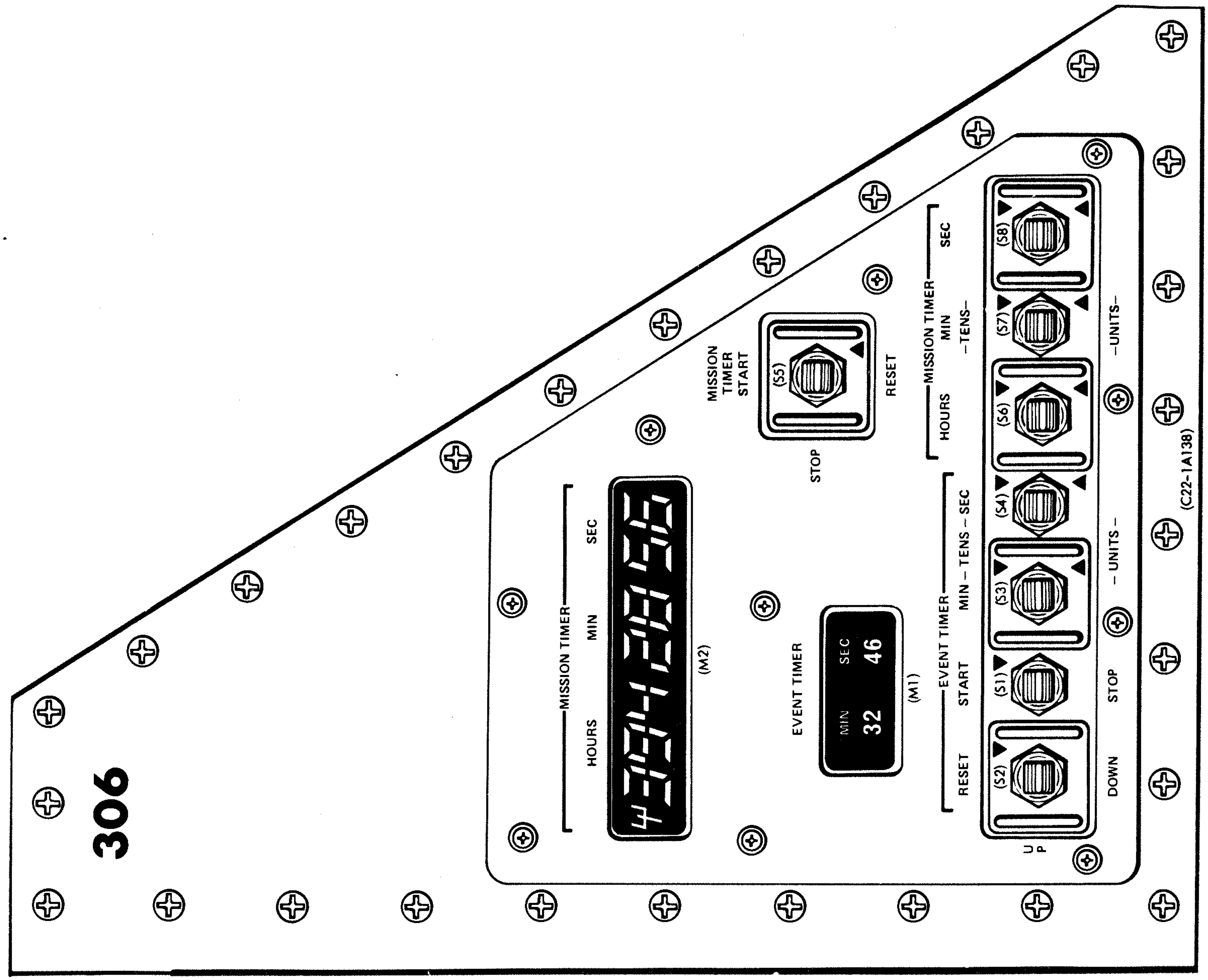
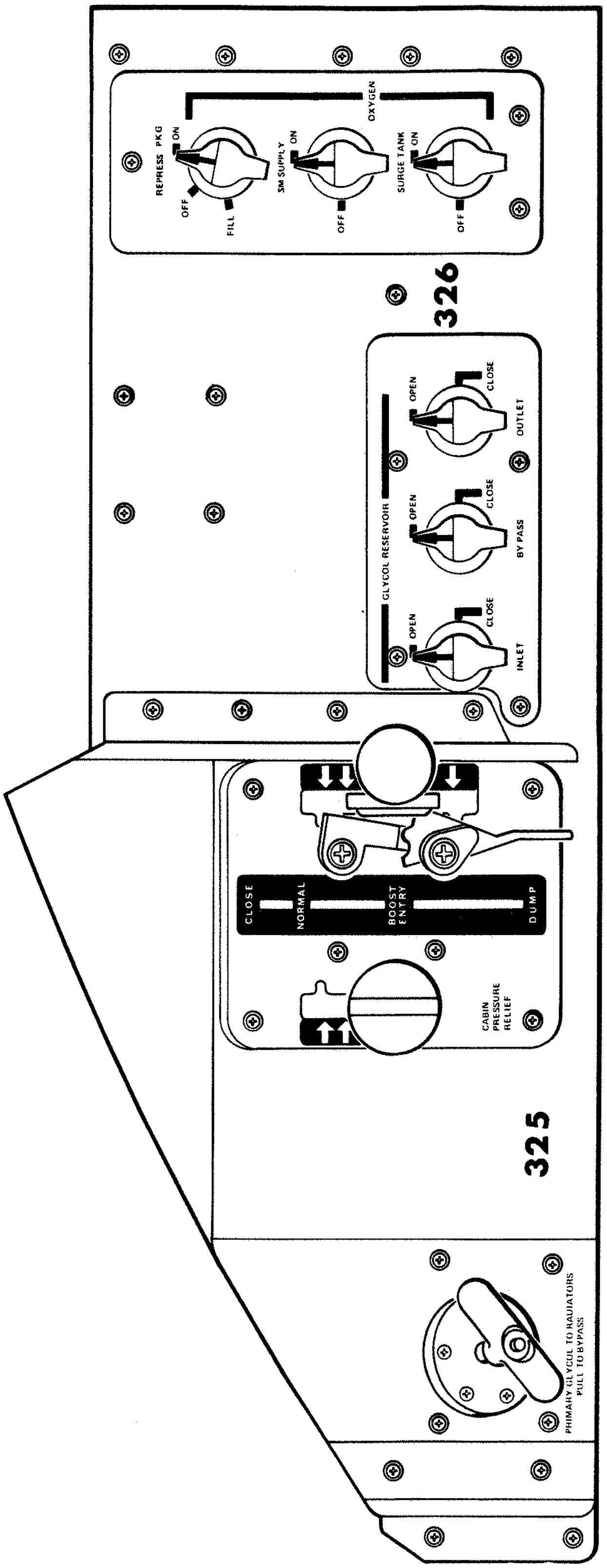
PANEL 306


306
MISSION TIMER
HOURS
MIN
SEC
(M2)
EVENT TIMER
MIN
SEC
32
46
(M1)
MISSION TIMER START
(S5)
RESET
STOP
MISSION TIMER
HOURS
MIN
SEC
-TENS-
-UNITS-
(S6)
(S7)
(S8)
EVENT TIMER
MIN - TENS - SEC
- UNITS -
RESET
START
STOP
DOWN
UP
(S1)
(S2)
(S3)
(S4)
(C22-1A138)

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
306	M1	SEQ	EVENT TIMER	Enables crew to monitor event time lines.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	Digital display controlled by four toggle switches, reference Volume 1, section 2.9.
306	M2	SEQ	MISSION TIMER	Enables crew to monitor mission elapsed time.	TIMERS MNB (Panel 5)	DC main bus B	Digital display controlled by four toggle switches, reference Volume 1, section 2.9.
306	S1	SEQ	EVENT TIMER				
			START	Manual control for start.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	Momentary position.
			(CENTER)	Enables timer to run.			Maintain position (normal at lift-off).
			STOP	Manual control for stop.			Maintain position.
306	S2	SEQ	EVENT TIMER				
			RESET	Manual control for resetting timer to zero.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	Momentary position. In addition to resetting the timer, this position will stop the unit if running.
			UP	Manual control for selecting count up mode of operation.			Maintain position. Timer will count up when running or slewing. (Normal position at lift-off.)
			DOWN	Manual control for selecting count down mode of operation.			Maintain position. Timer will count down when running or slewing.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
306	S3	SEQ	EVENT TIMER				
			MIN				
			TENS	Manual control for slewing tens of minutes.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	Momentary position.
			(CENTER)	No function.			Maintain position (normal at lift-off).
			UNITS	Manual control for slewing units of minutes.			Momentary position.
306	S4	SEQ	EVENT TIMER				
			SEC				
			TENS	Manual control for slewing tens of seconds.	TIMERS MNA & MNB (Panel 5)	DC main buses A and B	Momentary position.
			(CENTER)	No function.			Maintain position (normal at lift-off).
			UNITS	Manual control for slewing units of seconds.			Momentary position.
306	S5	SEQ	MISSION TIMER				
			START	Manual control for starting timer.	TIMERS MNB (Panel 5)	DC main bus B	Maintain position (normal at lift-off).
			STOP	Manual control for stopping timer.			Maintain position.
			RESET	Manual control for resetting timer to zero.			Momentary position. If timer is running when this control is triggered, the unit will reset and continue running.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
306	S6	SEQ	MISSION TIMER				
			HOURS				
			TENS	Manual control for slewing tens and hundreds of hours.	TIMERS MNB (Panel 5)	DC main bus B	Momentary position. Transition from hundreds to tens is automatic.
			(CENTER)	No function.			Maintain position. (Normal at lift off.)
			UNITS	Manual control for slewing units of hours.			Momentary position.
306	S7	SEQ	MISSION TIMER				
			MIN				
			TENS	Manual control for slewing tens of minutes.	TIMERS MNB (Panel 5)	DC main bus B	Momentary position.
			(CENTER)	No function.			Maintain position. (Normal at lift off.)
			UNITS	Manual control for slewing units of minutes.			Momentary position.
306	S8	SEQ	MISSION TIMER				
			SEC				
			TENS	Manual control for slewing tens of seconds.	TIMERS MNB (Panel 5)	DC main bus B	Momentary position.
			(CENTER)	No function.			Maintain position. (Normal at lift off.)
			UNITS	Manual control for slewing units of seconds.			Momentary position.



PANELS 325, 326

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
325	V1	ECS	CABIN PRESS RELIEF		N/A	N/A	There are two cabin pressure-relief valves on Panel 325 that normally operate automatically to provide positive and negative cabin pressure relief. Upper manual control (three-valve position) and lower manual control (four-valve position) can override their corresponding relief valves to CLOSE and NORMAL positions, while only lower manual control can override its corresponding relief valve to DUMP position. Horizontal pressure must be applied to move controls out of detent.
			CLOSE	Manual override position to close either cabin pressure-relief valve.			Both relief valves are closed for prelaunch checkout and during CM RCS propellant dump, while either one or both relief valves are closed in flight in event of valve malfunction.
			NORMAL	Manual override position to limit travel of cabin pressure-relief valve in automatic mode.			Normal position of controls for flight period between ascent and entry. Valves are limited to partially open position to prevent rapid cabin decompression in event valves fail open.
			BOOST ENTRY	Neutral position of override mechanism to permit cabin pressure-relief valve full travel in automatic mode.			Except for time required to dump RCS propellants during descent, both controls are normally set to the BOOST ENTRY position for ascent and entry phases.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
325	V2	ECS	CABIN PRESS RELIEF		N/A	N/A	There are two cabin pressure-relief valves on Panel 325 that normally operate automatically to provide positive and negative cabin pressure relief. Upper manual control (three-valve position) and lower manual control (four-valve position) can override their corresponding relief valves to CLOSE and NORMAL positions, while only lower manual control can override its corresponding relief valve to DUMP position. Horizontal pressure must be applied to move controls out of detent.
			CLOSE	Manual override position to close either cabin pressure-relief valve.			Both relief valves are closed for prelaunch checkout and during CM RCS propellant dump, while either one or both relief valves are closed in flight in event of valve malfunction.
			NORMAL	Manual override position to limit travel of cabin pressure-relief valve in automatic mode.			Normal position of controls for flight period between ascent and entry. Valves are limited to partially open position to prevent rapid cabin decompression in event valves fail open.
			BOOST ENTRY	Neutral position of override mechanism to permit cabin pressure-relief valve full travel in automatic mode.			Except for time required to dump RCS propellants during descent, both controls are normally set to BOOST ENTRY position for ascent and entry phases.
			DUMP	Manual override position of lower control to open corresponding cabin pressure-relief valve.			Valve is opened to intentionally vent cabin. Mechanical safety latch must be off to set lever in dump position.

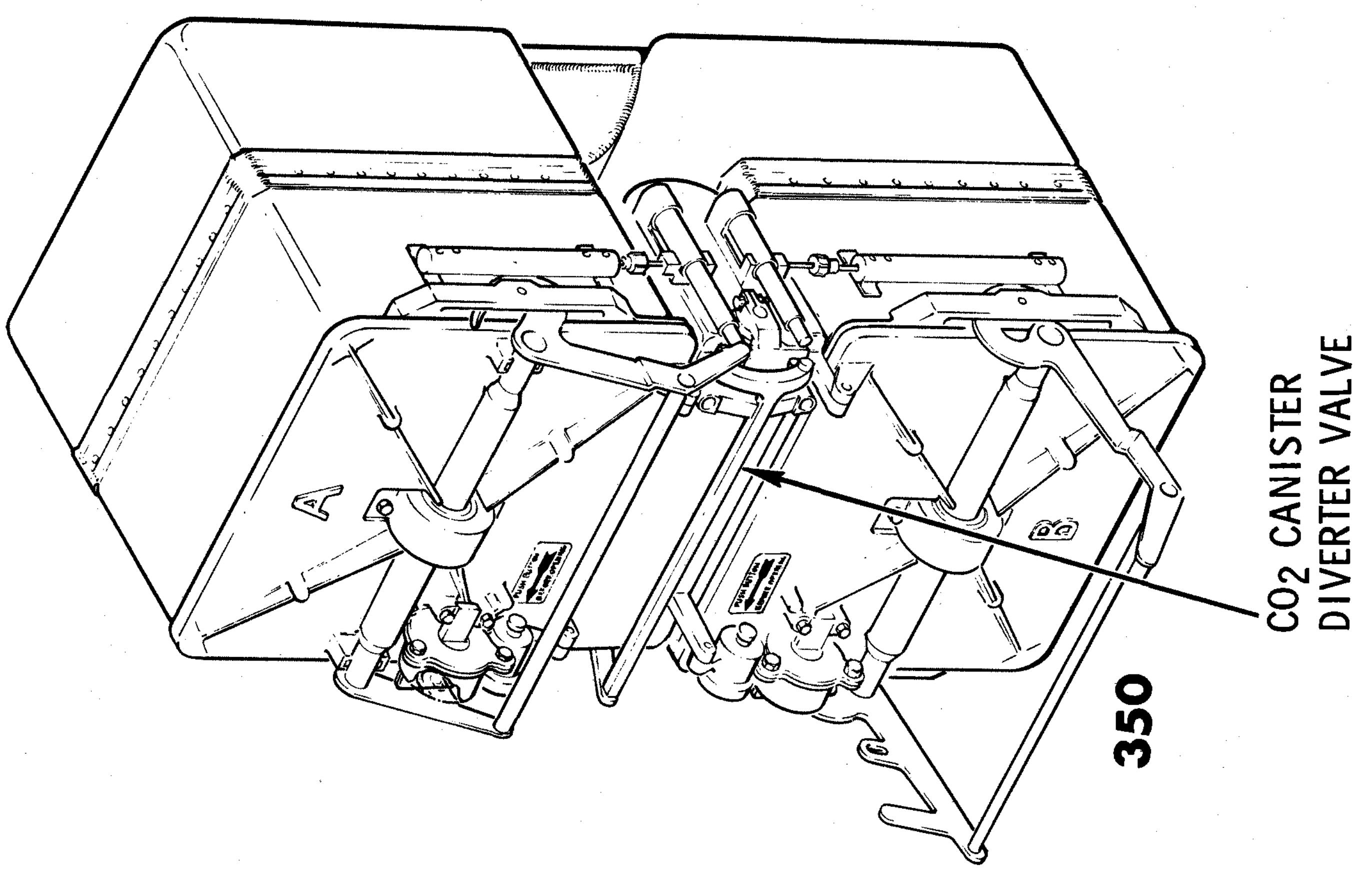
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
325	V3	ECS	PRIMARY GLYCOL TO RADIATORS				
			PULL TO BYPASS	Directs flow of primary glycol to bypass radiators.	N/A	N/A	Valve remotely controlled through "Teleflex" cable.
			(PUSH)	Directs flow of primary glycol through radiators.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
326	V1	ECS	GLYCOL RESERVOIR				
			INLET				
			OPEN	Permits flow of water-glycol from system into reservoir.	N/A	N/A	Valve is opened to direct water-glycol flow through reservoir during prelaunch and ascent phases and is operated in conjunction with GLYCOL RESERVOIR OUTLET and GLYCOL RESERVOIR BYPASS valves. Valve manually controlled by knob.
			CLOSE	Shuts off flow of water-glycol from system into reservoir.			Valve is closed upon completion of ascent phase to isolate reservoir from system.
326	V2	ECS	GLYCOL RESERVOIR				
			BYPASS				
			OPEN	Opens bypass line permitting flow around water-glycol reservoir.	N/A	N/A	Valve is opened upon completion of ascent phase to bypass and isolate reservoir from system, and is operated in conjunction with GLYCOL RESERVOIR OUTLET and GLYCOL RESERVOIR INLET valves. Valve is manually controlled by knob.
			CLOSE	Close bypass line that permits flow around water-glycol reservoir.			Valve is closed to direct water-glycol flow through reservoir during prelaunch and ascent phases.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
326	V3	ECS	GLYCOL RESERVOIR				
			OUTLET				
			OPEN	Permits flow of water-glycol from outlet of reservoir into system.	N/A	N/A	Valve is opened to direct water-glycol flow through reservoir during prelaunch and ascent phases, and is operated in conjunction with GLYCOL RESERVOIR INLET and GLYCOL RESERVOIR BYPASS valves. Valve is manually controlled by knob.
			CLOSE	Shuts off flow of water-glycol from outlet of reservoir into system.			Valve is closed upon completion of ascent phase to isolate reservoir from system.
326	V4	ECS	OXYGEN				
			SURGE TANK				
			ON	Permits flow of oxygen to and from surge tank.	N/A	N/A	Normal position of valve is ON, permitting surge tank to carry out functions of supplying additional oxygen beyond normal maximum flow capability from SM, and for entry.
			OFF	Shuts off flow of oxygen to and from surge tank.			Valve is closed when necessary to isolate surge tank from system.
326	V5	ECS	OXYGEN				
			SUPPLY CM				
			ON	Permits flow of oxygen to CM from supply in SM.	N/A	N/A	Normal position of valve is ON. Valve is manually controlled by knob.
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
326	V5 (Cont)	ECS	OFF	Shuts off flow of oxygen to CM from supply in SM.			Valve is closed prior to CSM separation to prevent CM entry oxygen supply from flowing overboard in event of check valve failure.
326	V6	ECS	OXYGEN REPRESS PKG FILL	Permits flow from CM oxygen supply subsystem to bypass check valve and thus fill three 1-pound tanks. It also allows flow from surge tank to bypass check valve during cabin repressurization.	N/A	N/A	
			OFF	Shuts off flow between three 1-pound tanks and CM oxygen supply subsystem.			
			ON	Permits flow from three 1-pound oxygen tanks into CM oxygen supply subsystem through check valve.			

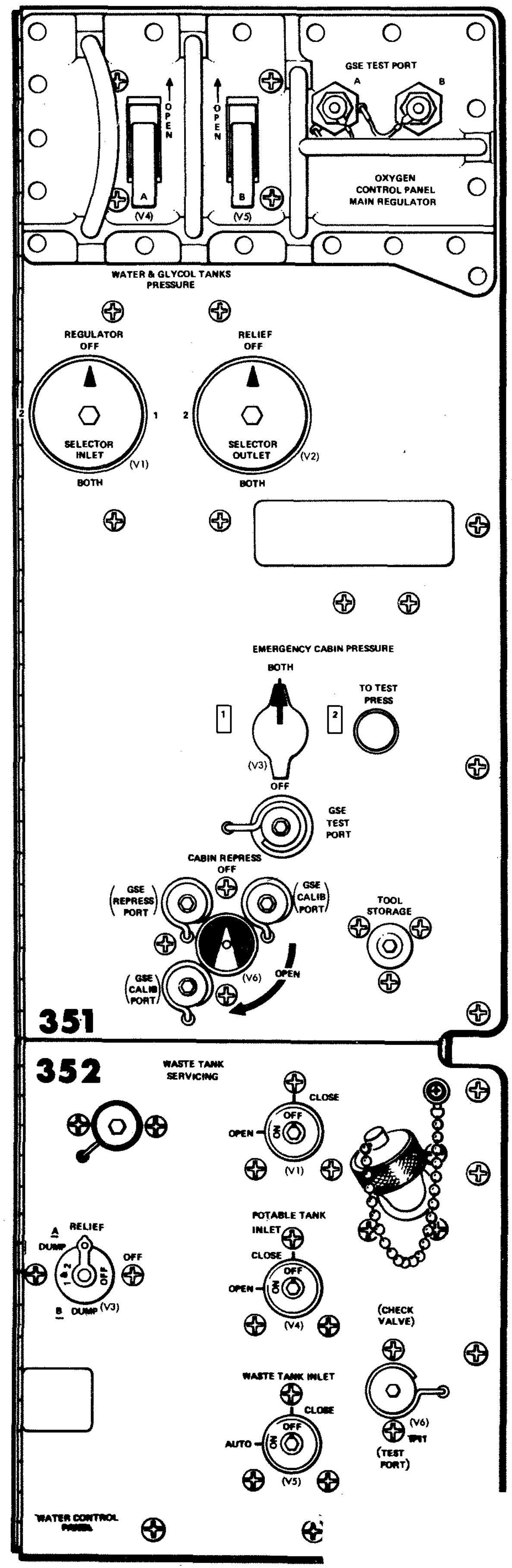
PANEL 350



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
350	V1	ECS	(CO_2 CANISTERS)				
			A	Shuts off suit circuit flow to canister B and diverts full flow to canister A.	N/A	N/A	Diverter valve linkage includes mechanical interlock that assures cover removal of only canister that has been isolated from suit flow.
			(CTR)	Neutral position of valve permitting equal suit circuit flow to each canister.			
			B	Shuts off suit circuit flow to canister A and diverts full flow to canister B.			

Admin Pubs 60791 Exp 10-13-69

PANELS 351, 352



Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
351	V1	ECS	WATER & GLYCOL TANKS PRESSURE				
			REGULATOR				
			OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators.	N/A	N/A	With valve in OFF position, tank pressurization system is isolated from regulated oxygen supply. Selector valve is manually controlled.
			1	Directs regulated oxygen (100±10 psig) to No. 1 tank pressure regulator for reduction to 20±2-psig tank pressure.			Valve is set to position 1 in event of malfunction of No. 2 tank pressure regulator. NOTE: If SELECTOR INLET valve is placed to position 1 or 2, SELECTOR OUTLET valve should be placed to corresponding position for proper operation.
			BOTH	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators for reduction to 20±2 psig tank pressure.			Both tank pressure regulators are selected for simultaneous use under normal conditions for redundancy in event of one regulator malfunctioning.
			2	Directs regulated oxygen (100±10 psig) to No. 2 tank pressure regulator for reduction to 20±2-psig tank pressure.			Valve is set to position 2 in event of malfunction of No. 1 tank pressure regulator.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
351	V2	ECS	WATER & GLYCOL TANKS PRESSURE				
			RELIEF				
			OFF	Shuts off oxygen pressure from tanks to No. 1 and No. 2 tank pressure relief valves.	N/A	N/A	With valve in OFF position, any increase in tank(s) pressure is trapped and cannot be relieved. Selector valve is manually controlled.
			1	Directs oxygen pressure from tanks to No. 1 tank pressure relief valve.			Valves set to position 1 in event of malfunction of No. 2 tank pressure relief valve. NOTE: If SELECTOR OUTLET valve is placed to position 1 or 2, SELECTOR INLET valve should be placed to corresponding position for proper operation.
			BOTH	Directs oxygen pressure from tanks to No. 1 and No. 2 tank pressure relief valves.			Both tank pressure-relief valves are selected for simultaneous use under normal conditions for redundancy in event of one relief valve malfunctioning. Pressurization of potable and waste water tanks and glycol reservoir is telemetered.
			2	Directs oxygen pressure from tanks to No. 2 tank pressure regulator relief valve.			Valve set to position 2 in event of malfunction of No. 1 tank pressure relief valve.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
351	V3	ECS	EMERGENCY CABIN PRESSURE				
			1	Directs regulated oxygen (100±10 psig) to No. 1 emergency cabin pressure regulator.	N/A	N/A	Valve set to position 1 in event of malfunction of No. 2 emergency regulator.
			BOTH	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency cabin pressure regulators.			Both emergency regulators are selected for simultaneous use under normal conditions, for redundancy in event of emergency decompression.
			2	Directs regulated oxygen (100±10 psig) to No. 2 emergency cabin pressure regulator.			Valve set to position 2 in event of malfunction of No. 1 emergency regulator.
			OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency cabin pressure regulators.			Valve is set to OFF position whenever all crewman are suited. With valve in OFF position, both emergency regulators are isolated from regulated oxygen supply.
			TO TEST PRESS (pushbutton)	Permits No. 1 and No. 2 emergency cabin pressure regulators to be tested for operational verification.			With pushbutton pressed, vents for reference chambers of both regulators are closed off. This allows artificial reference pressure to build up which results in regulator operation. This test may be accomplished at ground checkout or during flight.

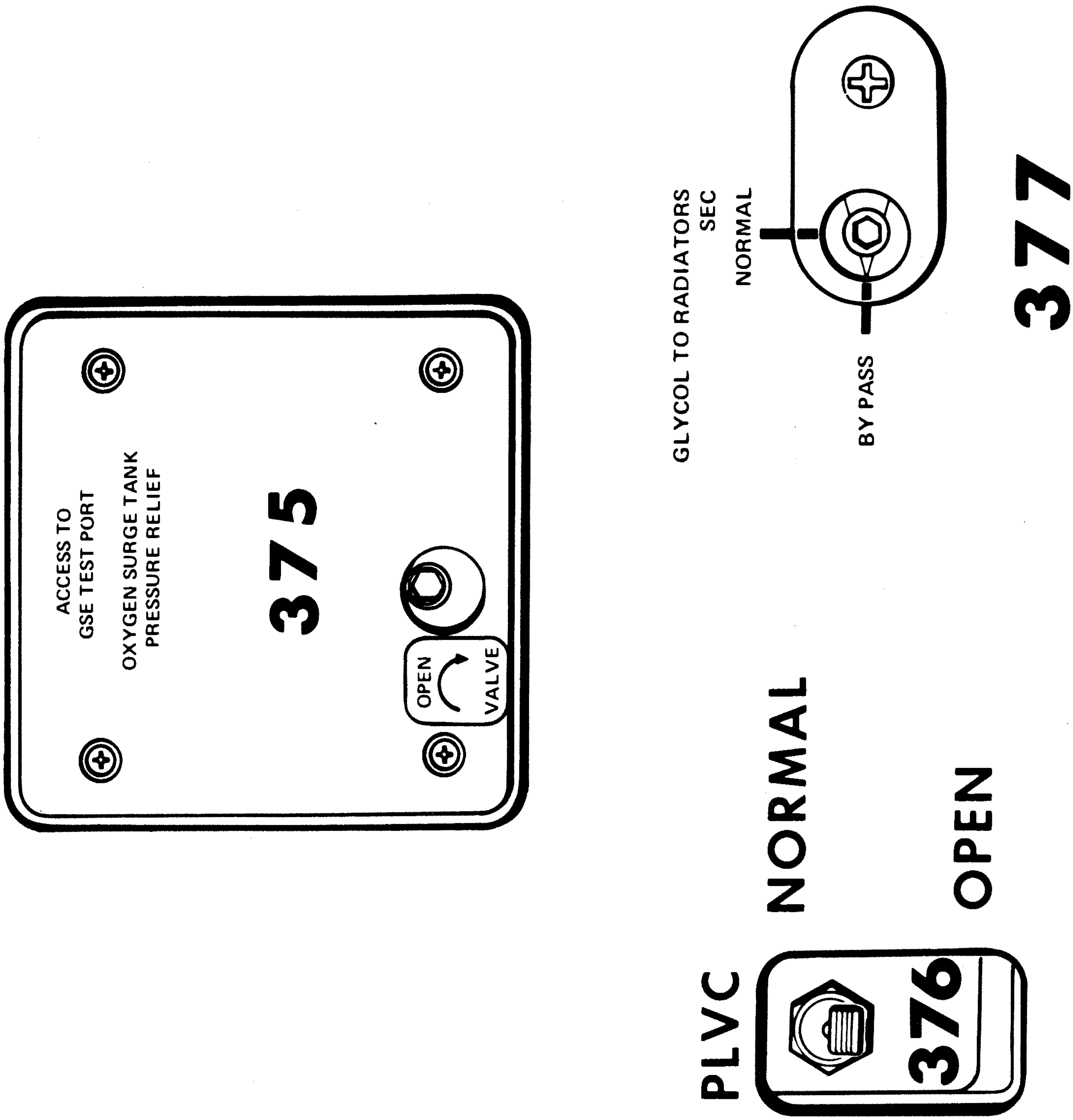
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
351	V4	ECS	OXYGEN CONTROL PANEL MAIN REGULATOR A OPEN	Directs supply of oxygen to No. 1 main pressure regulator and relief valve.	N/A	N/A	Valve is closed in event of malfunction of A main pressure regulator, or relief valve. Valve is manually controlled by integral toggle. Both valves are selected for simultaneous use under normal conditions.
351	V5	ECS	OXYGEN CONTROL PANEL MAIN REGULATOR B OPEN	Directs supply of oxygen to No. 2 main pressure regulator and relief valve.	N/A	N/A	Valve is closed in event of malfunction of B main pressure regulator, or relief valve. Valve is manually controlled by integral toggle. Both valves are selected for simultaneous use under normal conditions.

Admin Pubs 60791 Exp 10-13-69

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
351	V6	ECS	CABIN REPRESS				
			OFF	Shuts off oxygen flow into cabin.	N/A	N/A	
			OPEN	Directs oxygen into cabin at flow rate of 6.0 lb per hr minimum with 85 psi inlet pressure. Poppet-type valve is an independent unit of cabin pressure regulator assembly.			Will pressurize CM cabin from zero to 5 psia in 75 to 90 minutes. Shutoff valve is manually controlled by integral knob. Rotational movement from OPEN to close is approximately 3/4 turn.
351			TOOL STORAGE	Flush-mounted receptacle for storing handle adapter (E-tool) used in positioning numerous manually operated valves.	N/A	N/A	

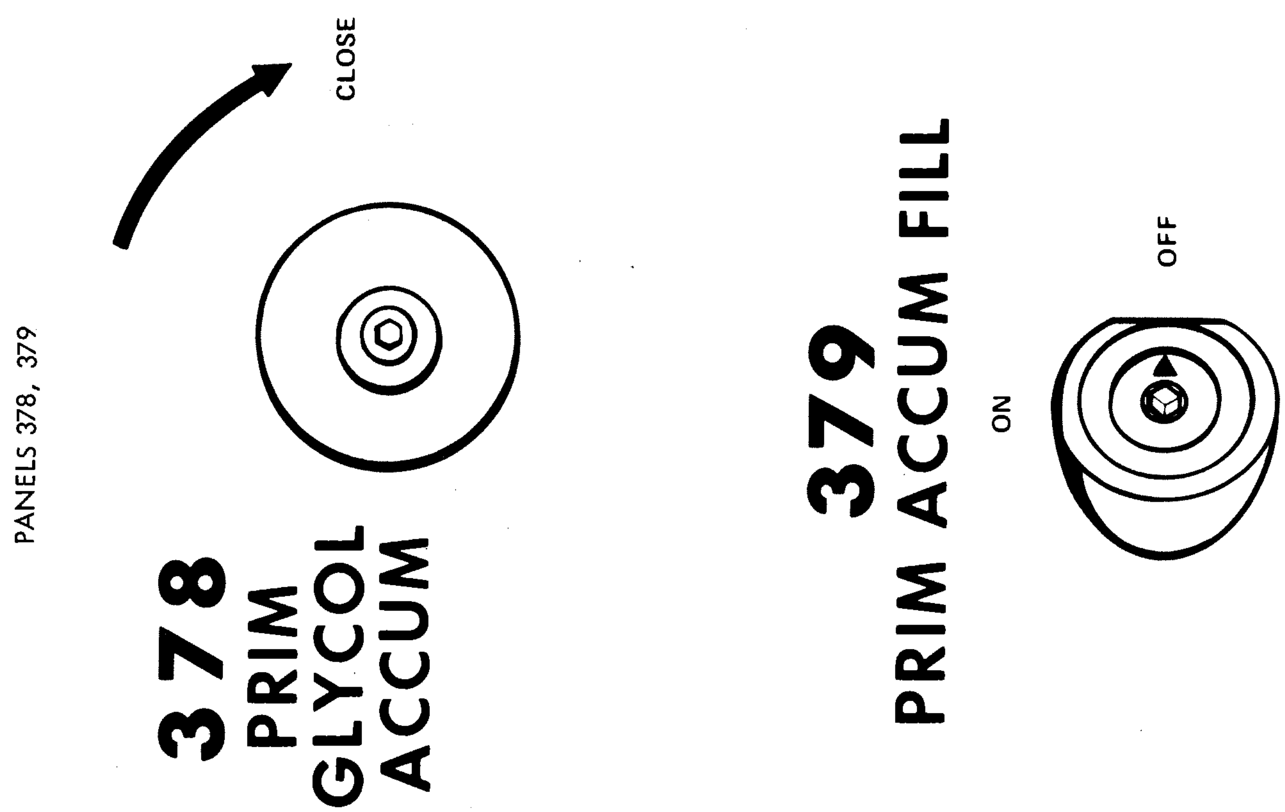
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
352	V1	ECS	WASTE TANK SERVICING				
			OPEN	Permits flow of water into waste water tank from ground servicing connection.	N/A	N/A	Valve is opened when used in conjunction with adjacent WASTE TANK SERVICING connector.
			CLOSE	Shuts off flow of water.			Valve is manually controlled by E-tool.
352	V3	ECS	PRESSURE RELIEF				
			B DUMP	Dumps waste water and/or potable water overboard.	N/A	N/A	The number 1 relief valve mechanism has been removed to provide a means for dumping excess water manually.
			A DUMP	Dumps waste water and/or potable water overboard.			
			RELIEF	Directs flow of excess potable and waste water to No. 2 pressure relief valve.			Number 2 position provides normal relief function.
			OFF	Prevents relief valve operation.			OFF position used in case number 2 relief valve fails to open in flight.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
352	V4	ECS	POTABLE TANK INLET				
			OPEN	Permits flow of water from fuel cells into potable water tank.	N/A	N/A	Shutoff valve is manually controlled by E-tool. Normal position of valve is open.
			CLOSE	Shuts off flow of water from fuel cells into potable water tank.			Valve set to CLOSE position to isolate potable water tank in event water from fuel cells becomes contaminated.
352	V5	ECS	WASTE TANK INLET				
			AUTO	Permits flow of water from fuel cells into waste water tank when relief valve differential pressure reaches 6.0 ± 0.5 psi.	N/A	N/A	Normal position of valve is AUTO. If potable water tank is full, or POTABLE TANK INLET valve is closed, water from fuel cells will flow into waste water tank. Shutoff function of this relief-shutoff valve is manually controlled by T-handle tool.
			CLOSE	Prevents flow of water from fuel cells to waste water tank.			Valve set to CLOSE position in event relief valve fails open.



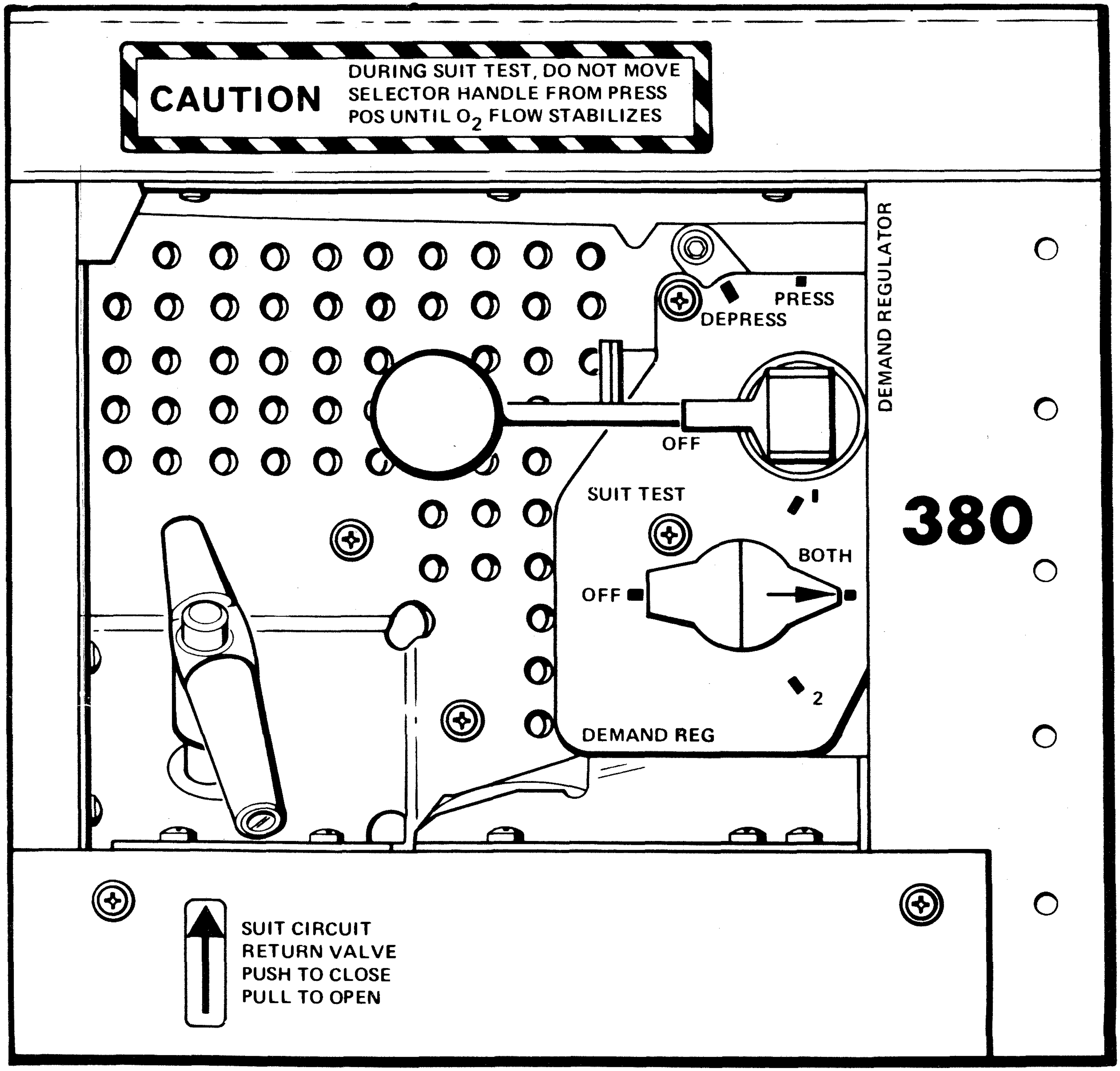
PANELS 375, 376, 377

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
375	V1	ECS	ACCESS TO GSE VENT PORT OXYGEN SURGE TANK PRESSURE RELIEF				
			OXYGEN				
			OPEN	Opens line from surge tank to relief valve permitting relief function.	N/A	N/A	OPEN position enables relief valve to function when surge tank pressure increases to 1045±25 psig.
			(CLOSE)	Closes line from surge tank to relief valve eliminating relief function.			Valve is closed only if surge tank relief valve fails open. Shutoff valve is manually controlled by E-tool. Rotational movement from OPEN to close is 1/4 turn.
376	S2	ECS	PLVC				
			NORMAL	Routes d-c power to pendulum-type attitude sensing switch of PLV system during normal post-landing operations.	PL VENT FLT/PL (Panel 8)	Flight & postlanding bus	POST LANDING VENT switch (Panel 15) must be in HIGH or LOW position to supply power to PLVC switch. Switch set to NORMAL position to permit normal operation of attitude sensing switch (to close PLV valves) when CM becomes inverted or tilts beyond a specified limit.
			OPEN	Routes d-c power directly to PLV valves, placing valves in open position in event of abnormal post-landing operations.			Switch set to OPEN position in event of attitude sensing switch failure, or to aid crew to escape from inverted CM.
377	V1	ECS	GLYCOL TO RADIATORS				
			SEC				
			NORMAL	Directs water-glycol flow to secondary space radiator.	N/A	N/A	NORMAL position CW rotation.
			BY PASS	Directs water-glycol flow to bypass secondary space radiators.			


PANELS 378, 379
CLOSE
378
PRIM
GLYCOL
ACCUM
379
PRIM ACCUM FILL
ON
OFF

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
378	V1	ECS	PRIM GLYCOL ACCUM				
			CLOSE	Isolates accumulator from primary glycol system.	N/A	N/A	When valve is closed reservoir must be placed on-stream in order to maintain positive pump inlet pressure. Valve is closed to isolate leaking accumulator from water-glycol system. Shutoff valve is manually controlled by torque wrench and 10-inch driver.
			(OPEN)	Places accumulator on-stream.			Normal position of valve is open, permitting accumulator to carry out function of damping surges and oscillations, and maintaining pump inlet pressure.
379	V1	ECS	PRIM ACCUM FILL				
			ON	Directs water-glycol flow from reservoir to fill primary accumulator.	N/A	N/A	Manual control valve, 1/4 turn. ON position CCW; OFF position CW.
			OFF	Block, flow from reservoir to accumulator.			

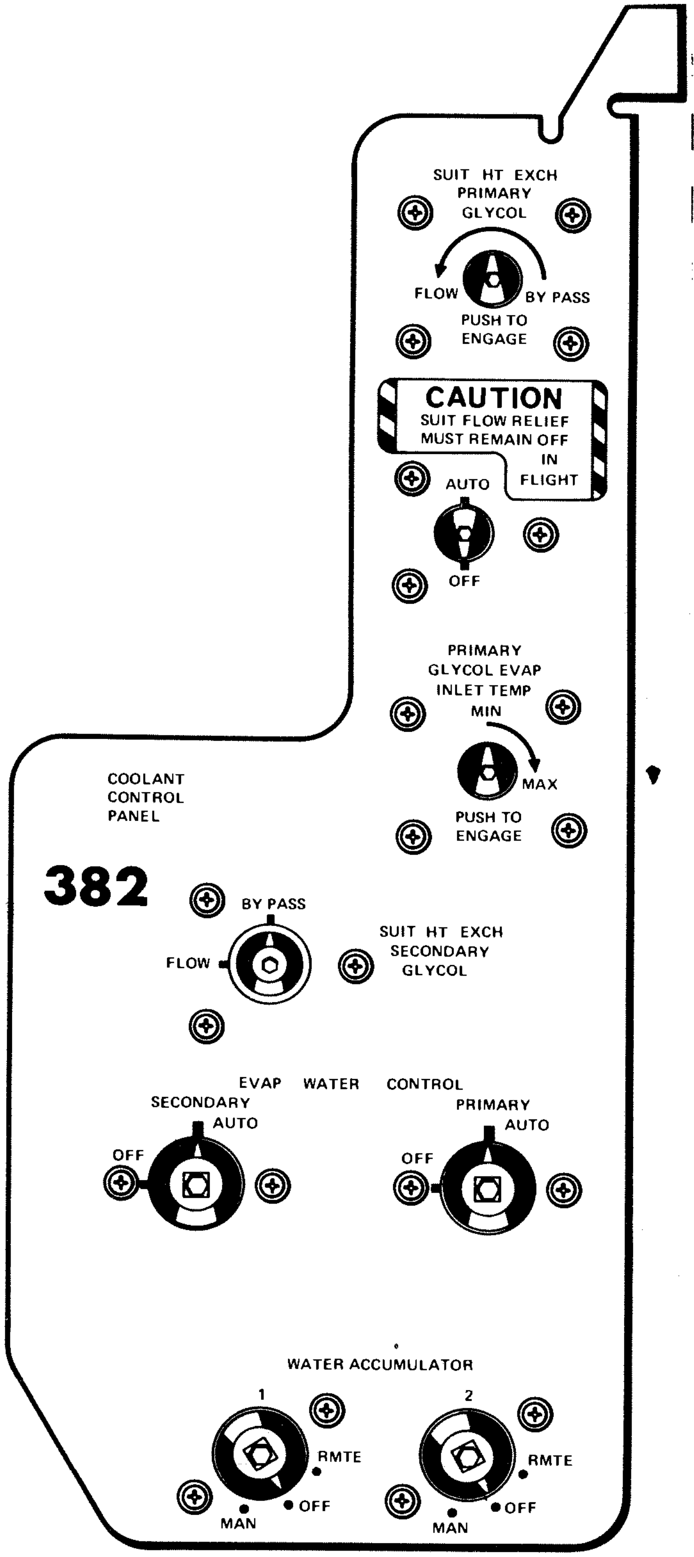
PANEL 380

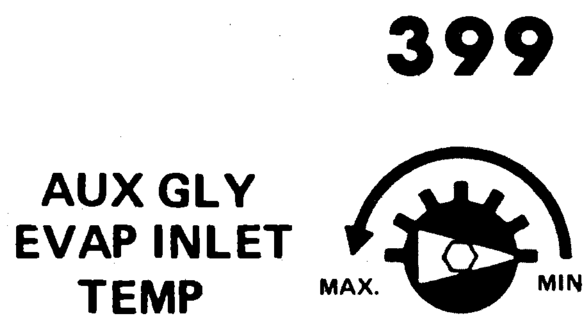

CAUTION
DURING SUIT TEST, DO NOT MOVE
SELECTOR HANDLE FROM PRESS
POS UNTIL O_2 FLOW STABILIZES
DEMAND REGULATOR
PRESS
DEPRESS
OFF
SUIT TEST
BOTH
OFF
1
2
DEMAND REG
380
SUIT CIRCUIT
RETURN VALVE
PUSH TO CLOSE
PULL TO OPEN

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
380	V1	ECS	(O_2) DEMAND REGULATOR				
			SUIT TEST				
			OFF	Permits normal O_2 flow to suit demand pressure regulator.	N/A	N/A	Normal position of valve when not conducting PGA/suit circuit test. Valve must not be set to off position before suit circuit has returned to nominal pressure. Valve is operated by an integral lever.
			DEPRESS	Shuts off O_2 flow to suit circuit upon completion of test, permitting reduction of pressure at an average bleedoff rate of 4 psig per minute.			Approximately 75 seconds must be allowed for increased suit circuit pressure to bleed back to cabin pressure.
			PRESS	Routes regulated oxygen flow (100 ± 10 psig) directly into suit circuit through a pressurization orifice at a maximum buildup rate of 4 psig per minute for PGA/suit circuit tests.			With valve in PRESS position, suit circuit will increase 4.1 to 4.5 psi above cabin pressure. Approximately 75 seconds must be allowed for suit circuit pressure to reach maximum. This test may be performed at ground checkout or during flight.
380	V2	ECS	(O_2) DEMAND REGULATOR				
			DEMAND REG				
			OFF	Shuts off regulated oxygen (100 ± 10 psig) to No. 1 and No. 2 suit demand pressure regulators.	N/A	N/A	Valve set to OFF position only if both suit demand pressure regulators malfunction. Valve is manually controlled by permanent knob.
			...continued	...continued			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
380	V2 (Cont)	ECS	1	Directs regulated oxygen (100±10 psig) to No. 1 suit demand pressure regulator.	N/A	N/A	Valve set to position 1 in event of malfunction of No. 2 demand pressure regulator.
			BOTH	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 suit demand pressure regulators.			Both demand pressure regulators are selected for simultaneous use under normal conditions for redundancy in event of one regulator malfunctioning.
			2	Directs regulated oxygen (100±10 psig) to No. 2 suit demand pressure regulator.			Valve set to position 2 in event of malfunction of No. 1 demand pressure regulator.
380	V3	ECS	SUIT CIRCUIT RETURN VALVE				
			PULL TO OPEN	Permits flow of cabin gases to enter suit circuit for processing.	N/A	N/A	Shutoff valve is manually controlled.
			PUSH TO CLOSE	Shuts off flow of cabin gases entering suit circuit.			The valve is closed when all three astronauts are suited.

PANELS 382, 399



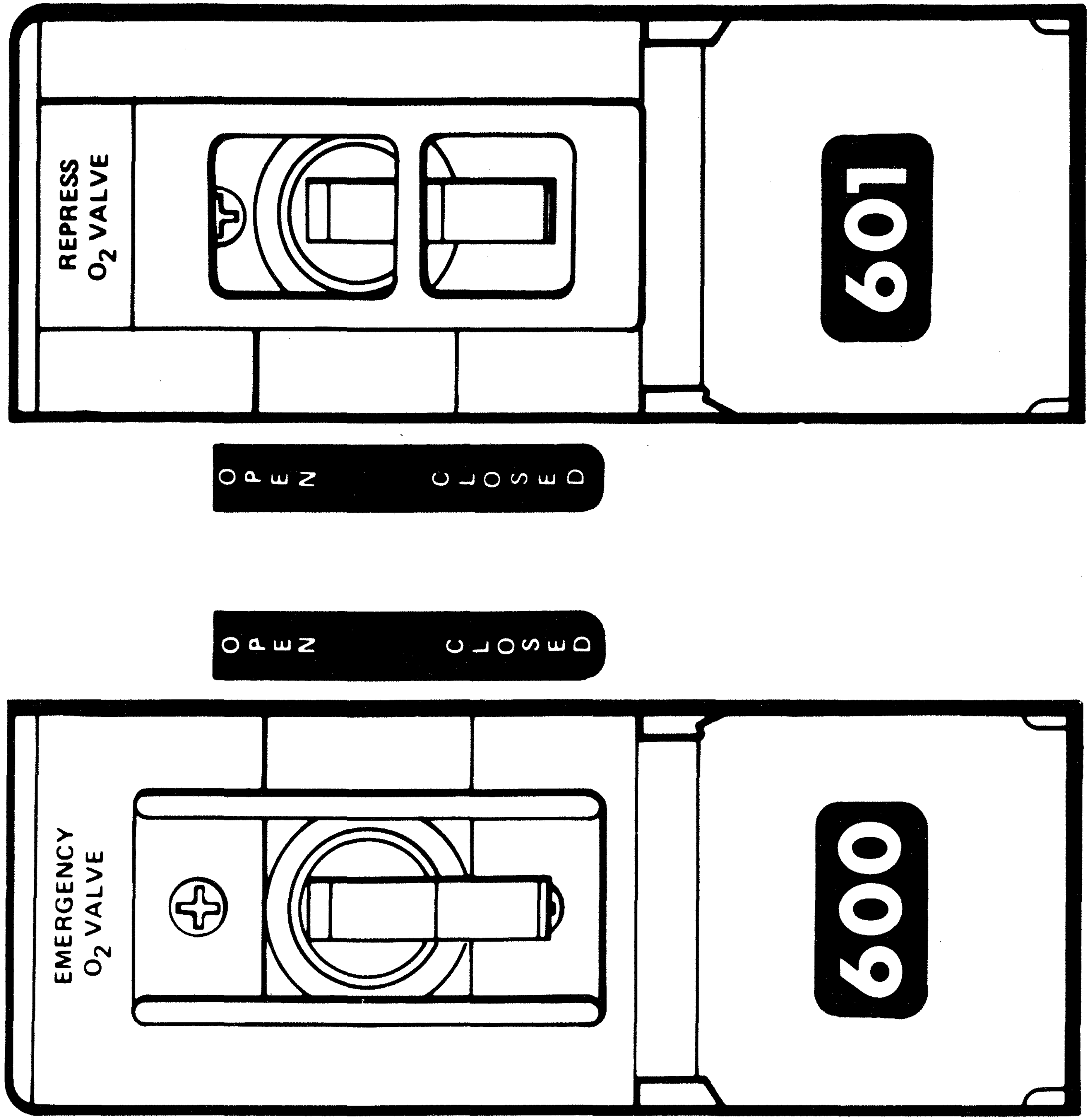


Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
382	V1	ECS	SUIT HT EXCH PRIMARY GLYCOL				
			FLOW	Permits water-glycol system flow through suit heat exchanger.	N/A	N/A	Motor driven valve controlled by SUIT CIRCUIT HEAT EXCH switch on panel 2. Manual override when switch is OFF.
			BYPASS	Permits water-glycol system to bypass heat exchanger.			
			PUSH TO ENGAGE	Provides for manual override.			
382	V2	ECS	CAUTION SUIT FLOW RELIEF MUST REMAIN OFF IN FLIGHT.				
			AUTO	Removes override from poppet valve, permitting automatic pressure-relief action.	N/A	N/A	Valve is closed for duration of mission.
			OFF	Applies override lever to poppet valve, holding valve in closed position.			
382	V3	ECS	PRIMARY GLYCOL EVAP INLET TEMP				
			MIN	Closed position.	N/A	N/A	Rotation toward MAX position results in a proportional temperature increase by changing mixture ratio of cold-to-hot water-glycol. Close coordination between valve adjustments and GLY EVAP - OUTLET TEMP indicator is necessary to obtain correct water-glycol temperature. Motor-operated valve is manually controlled by E-tool. Rotational movement from MIN to MAX is 90°.
			...continued				

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
382	V3 (Cont)	ECS	MAX (CW)	Full OPEN position.	N/A	N/A	Backup mode is used in event of malfunction of water-glycol temperature control components. Rotation toward MIN position results in a proportional temperature decrease by changing mixture ratio of hot-to-cold water-glycol. Close coordination between valve adjustments and GLY EVAP - OUTLET TEMP indicator is necessary to obtain correct water-glycol temperature.
382	V4	ECS	SUIT HT EXCH SECONDARY GLYCOL FLOW BYPASS	 Permits secondary water-glycol system flow through suit heat exchanger. Direct secondary water-glycol system flow to bypass suit heat exchanger.	N/A	N/A	Valve is manually controlled, CW position BYPASS, CCW position is FLOW.
382	V5	ECS	EVAP WATER CONTROL PRIMARY AUTO OFF	 Permits H_2O flow to remotely controlled solenoid valve, which controls water flow to primary glycol evaporator. Manual selection to OFF position prevents water from entering evaporators.	N/A	N/A	Manually operated shutoff valve is placed in OFF position in case solenoid valve leaks. (Prevents flooding evaporator.)

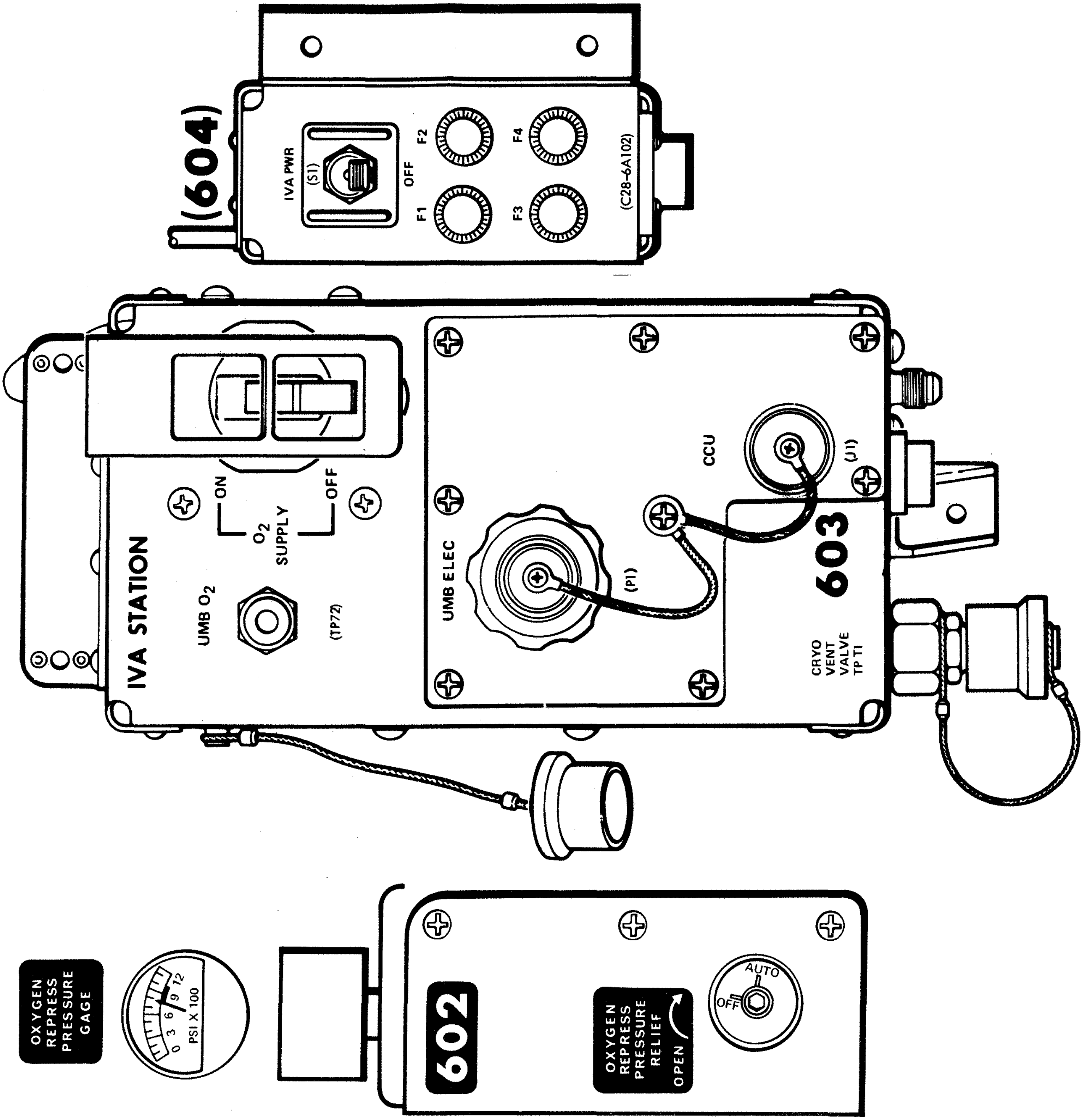
Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
382	V6	ECS	EVAP WATER CONTROL				
			SECONDARY				
			AUTO	Permits H_2O flow to remotely controlled solenoid valve, which controls flow of water to secondary glycol evaporator.	N/A	N/A	Manually operated shutoff valve is placed only in OFF position in case solenoid valve leaks. (Prevents flooding the evaporator.)
			OFF	Manual selection to OFF position prevents water from entering the evaporators.			
382	V7	ECS	WATER ACCUMULATOR				
			1				
			MAN	Routes regulated oxygen (100$\pm$10 psig) to No. 1 cyclic accumulator, bypassing solenoid shutoff valve.	N/A	N/A	Valve position is selected only when No. 2 accumulator has failed; and No. 1 solenoid shutoff valve cannot be operated automatically or by manually selected electrical impulse. Valve will then be positioned to MAN for approximately 10 seconds every 10 minutes. Valve manually controlled by E-tool.
			OFF	Shuts off regulated oxygen (100$\pm$10 psig) to solenoid shutoff valve and bypass line to No. 1 cyclic accumulator.			
			RMTE	Routes regulated oxygen (100$\pm$10 psig) to solenoid shutoff valve of No. 1 cyclic accumulator.			Normal position of valve is RMTE, permitting automatic (CTE) or manually selected electrical impulse to operate solenoid shutoff valve. Manually selected electrical operation is used in event of automatic control unit malfunction.

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
382	V8	ECS	WATER ACCUMULATOR 2				
			MAN	Routes regulated oxygen (100±10 psig) to No. 2 cyclic accumulator, bypassing solenoid shutoff valve.	N/A	N/A	Valve position is selected only when No. 1 accumulator has failed and No. 2 solenoid shutoff valve cannot be operated automatically or by manually selected electrical impulse. Valve will be positioned to MAN for approximately 10 seconds every 10 minutes. Valve manually controlled by E-tool.
			OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line to No. 2 cyclic accumulator.			
			RMTE	Routes regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 2 cyclic accumulator.			Normal position of valve is RMTE permitting automatic CTE or manually selected electrical impulse to operate solenoid shutoff valve. Manually selected electrical operation is used in event of automatic control unit malfunction.
399	V1	ECS	CM GLYCOL TEMP				
			OFF	Shuts off auxiliary glycol bypass.	N/A	N/A	
			INCR	Permits auxiliary glycol bypass flow.			Valve is used during docked operations for controlling glycol evap inlet temperature.



PANELS 600, 601

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
600	V1	ECS	EMERGENCY O_2 VALVE				
			OPEN	Permits oxygen to flow to emergency breathing oxygen regulator.	N/A		Supplies oxygen to crew through oxygen masks when cabin gases become contaminated.
			CLOSED	Shuts off flow of oxygen to emergency breathing oxygen regulator.			
601	V1	ECS	REPRESS O_2 VALVE				
			OPEN	Dumps oxygen into cabin at very high flow rate (approx 5.4 lbs in 1.0 min).	N/A	N/A	Can be used for repressurizing the CM rapidly.
			CLOSED	Shut off.			

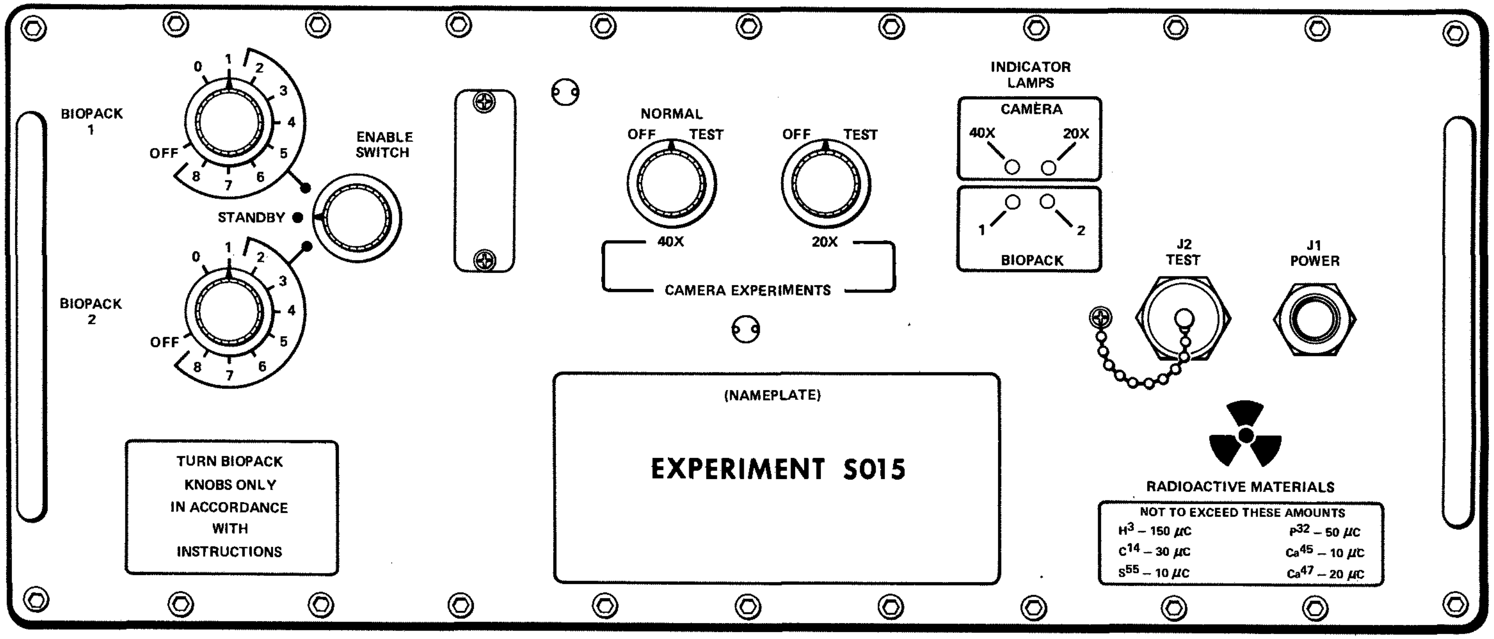


PANELS 602, 603, 604

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
602	M1	ECS	OXYGEN REPRESS PRESSURE GAGE	Indicates pressure in oxygen repressurization tanks.	N/A	N/A	Range 0-1200 psig; full at 900±35 psig.
602	V1	ECS	OXYGEN REPRESS PRESSURE RELIEF				
			OPEN	Permits oxygen to flow to relief valve inlet. Valve will crack open and reseat between pressures 1020 to 1070 psig.	N/A	N/A	If valve fails open E-tool is used for manual closing. Maximum flow is 3.4 lb/hr at 70°F.
603	J1	ECS	IVA STATION				
			CCU	Crewman comm umbilical (comm cable) receptacle.	N/A	N/A	Serves as a jumper cable function.
603	P1	ECS	IVA STATION				
			UMB ELEC	EVA umbilical comm receptacle.	N/A	N/A	Serves as a jumper cable function.
603	TP 72	ECS	IVA STATION				
			UMB O_2	EVA umbilical O_2 connection.	N/A	N/A	EVA umbilical O_2 QD is locked on by a clip.
603	TP 71	ECS	CRYO VENT VALVE (QD)	QD is attach point for cryo vent valve and IVA pressure gauge.	N/A	N/A	
603	V1	ECS	IVA STATION				
			O_2 SUPPLY				
			ON	Permits flow to pressure regulator.	N/A	N/A	Regulates pressure 100 psi to IVA umbilical or to manually installed flow orifices.
			OFF	Shuts off O_2 flow.			

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
604	S1	ECS	IVA PWR	Supplies 28 vdc to Astronaut Life Support Assembly (ALSA) via the IVA umbilical.	IVA PWR MNA & MNB (Panel 5)	DC main buses A and B	
			OFF	Removes power.	N/A	N/A	

PANEL S015


BIOPACK 1
0 1 2 3 4 5 6 7 8 OFF
ENABLE SWITCH
STANDBY
BIOPACK 2
0 1 2 3 4 5 6 7 8 OFF
NORMAL
OFF TEST
40X
OFF TEST
20X
CAMERA EXPERIMENTS
INDICATOR LAMPS
CAMERA
40X 20X
1 2
BIOPACK
J2 TEST
J1 POWER
TURN BIOPACK KNOBS ONLY IN ACCORDANCE WITH INSTRUCTIONS
(NAMEPLATE)
EXPERIMENT S015
RADIOACTIVE MATERIALS
NOT TO EXCEED THESE AMOUNTS
H3 – 150 μC
P32 – 50 μC
C14 – 30 μC
Ca45 – 10 μC
S55 – 10 μC
Ca47 – 20 μC

Panel	Reference Designator	Sys	Nomenclature and Position	Function	Circuit Breaker	Power Source	Remarks
				Panel S015 is GFE and stowed in B-6 and receives power from Panel 164.			

APPENDIX A

ABBREVIATIONS AND SYMBOLS

AB	Aft bulkhead
AC	Alternating current
A/C	Audio center
A/C	A and C quads (RCS)
ACCEL	Accelerometer/acceleration
ACCUM	Accumulator
ACE	Acceptance checkout equipment
ACK	Acknowledge
ACPT	Accept
ACPTD	Accepted
ACQ	Acquire/acquisition
ACS	Attitude control subsystem
ACTY	Activity
A/D	Analog to digital
ADA	Angular differentiating accelerometer
ADAP	Adapter
ADJ	Adjust
AESB	Aft equipment stowage bay
AF	Audio frequency/atmospheric flight
AGC	Automatic gain control
AH	Ampere-hours
ALIGN	Alignment
ALT	Altitude
ALTM	Altimeter
AM	Airlock module
AM	Amplitude modulation
AMB	Ambient
AMP	Ampere
AMPL	Amplifier
AMPS	Amperes
ANAL	Analyzer
ANLG	Analog
ANT	Antenna
AOA	Angle of Attack
APS	Auxiliary propulsion system
ARS	Attitude reference subsystem
ASA	Abort sensor assembly
ASCP	Attitude set control panel
ASD	Apollo standard detonator
AS/GPI	Attitude set/gimbal position indicator
ASSY	Assembly
ATM	Apollo telescope mount
ATT	Attenuator/attitude/ Attenuation
ATT SET	Attitude set
AUTO	Automatic
AUX	Auxiliary
AVAIL	Available
AVC	Automatic volume control
AVE	Average
B ANGLE	Beta angle
BARO	Barometric
BAT	Battery
BCD	Binary-coded decimal
BCN	Beacon
BD	Band
B/D	B and D quads (RCS)
BECO	Booster engine cutoff
BIOINST	Bioinstrumentation
BIOMED	Biomedical
BLWR	Blower
BMAG	Body-mounted attitude gyro
B.O.	Breakout switches
BP	Barberpole
BPC	Boost protective cover
bps	Bits per second
BRT	Bright
Btu	British thermal unit
BU	Backup
BUR	Backup rate
BURR	Backup rate roll
BURP	Backup rate pitch
BURY	Backup rate yaw
BYP	Bypass
CAB	Cabin
CA(OH)2	Calcium hydroxide
CALIB	Calibrate
CAMR	Camera
CB	Circuit breaker
cc	Cubic centimeter
CCW	Counterclockwise
C&D	Controls and displays
CDF	Confined detonating fuse
CDH	Constant delta altitude

CDU	Coupling data unit
CF	Coasting flight
CFE	Contractor-furnished equipment
CFP	Concentric flight plan
cfm	Cubic feet per minute
CG	Center of gravity
CHAN	Channel
CHG(R)	Charge(r)
CHLOR	Chlorine
CKT	Circuit
CLR	Clear
CM	Command module
CMC	Command module computer
CMD	Command
CMPNT(S)	Component(s)
COAS	Crewman optical alignment sight
COI	Contingency orbit insertion
COMM	Communications
COMP	Computation
COMP	Compute/computing
COMPR	Compressor
COND	Condenser/conditioner
CONDR	Conditioner
CONN	Connect(or)
CONT	Control
CONTAM	Contamination
CONTIN	Continuous
CONTR	Controller
COOL	Coolant
COORD	Coordinate
CO2	Carbon dioxide
CPC	Cold plate clamp
cps	Cycles per second
CRSRNG	Crossrange
CRYO	Cryogenic
CSC	Cosecant computing amplifier
CSI	Coelliptic sequence initiation
CSM	Command and service module
CSS	Computer subsystem
CTE	Central timing equipment
CTS	Computer test set
$\overline{CCW}$	Not clockwise
CW	Clockwise/continuous wave
C/W	Caution and warning
CWG	Constant wear garment
C&WS	Caution and warning system
DA	Detector assembly
D/A	Digital-to-analog
DAC	Digital to analog converter
DAP	Digital auto pilot
db	Decibel
DB	Deadband
DC	Direct current
D&C	Displays and controls
D&CT	Docking and crew transfer
DDP	Data distribution panel
DEA	Display electronic assembly
DEC	Decrease/decimal
DECR	Decrease
DEG	Degree
DEMOD	Demodulate
DET	Digital event timer/detector/ determination
DIFF	Difference
DIR	Direct
DISCH	Discharge
DISP	Display
DKG	Docking
DLH	Docking lock handle
DN	Down
DNRNG	Downrange
DPST	Double-pole single-throw
DRG	Digital ranging generator
DS	Docking subsystem
DSE	Data storage equipment
DSIF	Deep Space Instrumentation Facility
DSKY	Display and keyboard
DU	Direct ullage
DUP	Duplex
E	Elevation angle
ECA	Electronic control assembly
EC&L	Error counter and logic
ECG	Electrocardiograph
ECO	Engine cutoff
ECS	Environmental control system
ECU	Environmental control unit
EDA	Electronic display assembly
EDS	Emergency detection system
Eig	Voltage-inner gimbal
EL	Electroluminescent
ELEC	Electronics
ELS	Earth landing subsystem
ELSC	Earth landing sequence controller
EMER	Emergency
Emg	Voltage-middle gimbal
EMS	Entry monitor system
EMU	Extravehicular mobility unit

ENBL	Enable
ENC	Encode
ENG	Engine
ENTR	Enter
E.O.	Earth Orbit
Eog	Voltage-outer gimbal
EOS	Emergency oxygen system
EPS	Electrical power subsystem
EQUIP	Equipment
ERR	Error
ESS	Essential
EV	Extravehicular
EVA	Extravehicular activities
EVAP	Evaporator
EVCT	Extravehicular crew transfer
E Visor	Extravehicular visor assembly
EVNT TMR	Event Timer
EVT	Extravehicular transfer
EXCH	Exchanger
EXEC	Executive
EXH	Exhaust
EXT	Extension
EXTD	Extended
FC (F/C)	Fuel cell
FCD	Flight control division
FCS	Fecal containment system
FCSD	Flight Crew Support Division (MSC)
FDAI	Flight director attitude indicator
FE	Fecal emesis
FL	Flash
FLSC	Flexible linear-shaped charge
FLT	Flight
FM	Frequency modulation
FNL	Final
FOV	Field of view
FPS	Feet per second/frame per second
FS	Fail sense
FST	Free space transfer
FUNC	Function
FUNCT	Functional
FWD	Forward
GA	Gyro assembly
G&C	Guidance and control
g	Gravity
g/v	Gravity vs velocity
GDC	Gyro display coupler
GET	Ground elapse time
GFE	Government furnished equipment
GFP	Government-furnished property
GLY	Glycol
GMBL	Gimbal
GMT	Greenwich Mean Time
G/N (G&N)	Guidance and navigation
GN2	Gaseous nitrogen
GPI	Gimbal position indicator
GRD	Ground
GRP	Group
GSE	Ground support equipment
GSOP	Guidance system operations plan
GTA	Ground test access
GUID	Guidance
GYRO	Gyroscope
ha	Apogee altitude
HBR	High-bit rate
HDS	Heads
He	Helium
HEX	Hexagonal
HF	High frequency
HI	High
HORIZ	Horizon
hp	Perigee altitude
HR	Hour
HT EXCH	Heat exchanger
HTRS	Heaters
H2	Hydrogen
H20	Water
HS	Heat shield
HS	Helmet shield
Hz	Hertz (cps)
IC	Intravehicular cover
ICDU	Inertial coupling data unit
ICS	Intercommunication system
ID	Identification
IECO	Inboard engine cut-off
IF	Intermediate frequency
IGA	Inner gimbal angle
IGN	Ignition
IMP	Impulse
IMU	Inertial measurement unit
INBD	Inboard
INCR (INC)	Increase
IND	Indicator
INIT	Initiate/initiated/initialization
INJ	Inject
INST (INSTR)	Instrument
INV	Inverter
IPB	Illuminated pushbutton
ips	Inches per second

IRIG	Inertial rate integrating gyro
ISOL	Isolation
ISS	Inertial subsystem
ITMG	Integrated thermal meteoroid garment
IU	Instrument units
IV	Intravehicular
IVA	Intravehicular activity
IVT	Intravehicular transfer
JETT	Jettison
KBS (KBPS)	Kilo bits per second
kc	Kilocycle
kHz	Kilo Hertz (kilocycles)
kmc	Kilomegacycle
KmHz	Kilomega Hertz
KOH	Potassium hydroxide
LAT	Latitude/lateral
lb/hr	Pounds per hour
lb min	Pounds per minute
LBR	Low-bit rate
LCC	Launch control center
LCG	Liquid cooled garment
LCL	Local
LDEC	Lunar decking events controller
LDG	Landing
LEA	Launch escape assembly
LEB	Lower equipment bay
LEM	Launch escape motor
LET	Launch escape tower
LEV	Launch escape vehicle
LH	Left hand
LHEB	Left-hand forward equipment bay
LIQ	Liquid
LLOS	Landmark line of sight
LMK	Landmark
LO	Low/lunar orbit
LONG	Longitude
LOS	Line of sight
LPH	Legrest pin handle
LSB	Least significant bit
LSC	Linear shaped charge
LT	Light
LTG	Lighting
LV	Launch vehicle
MAG	Magnitude
MAN	Manual
MANF	Manifold
MAX	Maximum
mc	Megacycles
MCC	Midcourse correction
MCC	Mission Control Center
MCT	Memory cycle time
MDA	Motor drive amplifier
MDA	Multiple docking adapter
MDC	Main display console
MDF	Mild detonating fuse
MERU	Milli earth rate unit
MESC	Master event sequence controller
MGA	Middle gimbal angle
MGMT	Management
MHz	Mega Hertz
MIN	Minimum/minute
MMH	Monomethylhydrazine
mm Hg	Millimeters of mercury
MN	Main
MN A	Main bus A
MN B	Main bus B
MNVRS	Manuevers
MOM	Momentary
MON	Monitor/monitoring
MOT(S)	Motor(s)
MRK	Mark
MSC	Manned Spacecraft Center
MSD	Monitor selection decoder
MSFC	Marshall Space Flight Center
MSFN	Manned space flight network
MSN	Mission
MT	Mission timer
MTVC	Manual thrust vector control
MULTI	Multiplexer
NAV	Navigation
NB	Navigation base
NEUT	Neutral
NM	Nautical miles
NO.	Number
NOM	Nominal
NON	None
NORM	Normal
NPDS	Nuclear particle detection system
NR	North American Rockwell Corporation
NRZ	Non-return to zero
NUM	Numerics
NX-POP	OA X-Axis perpendicular to the orbital plane with the MDA in a northerly direction

N2	Nitrogen
N2H4	Hydrazine (fuel)
N2O4	Nitrogen tetroxide (oxidizer)
OA	Orbital assembly
OCDU	Optical coupling data unit
OCT	Octal
OECO	Outboard engine cutoff
OGA	Outer gimbal angle
OI	Orbit insertion
OMNI	Omnidirectional
OPR	Operator
OPS	Oxygen purge system
OPT	Optics
ORB	Orbit/orbital
ORDEAL	Orbit rate drive electronics Apollo LM
ORIENT	Orientation
OSC	Oscillator
OSS	Optics subsystem
OUTBD	Outboard
OVBD	Overboard
OVHD	Overhead
OVLD	Overload
OWS	Orbital workshop
OXID	Oxidizer
O2	Oxygen
p	Roll control axis
PA	Power amplifier
PAM	Pulse amplitude modulation
PARAM	Parameter
PB	Pushbutton
P/B	Playback
PCM	Pulse code modulation/pitch control motor
PCS	Pointing control system
PCVB	Pyro continuity verification box
PE	Payload enclosure
PF	Powered flight
PGA	Pressure garment assembly
PGNCS	Primary guidance, navigation and control system
PH	Phase
pH	Alkalinity to acidity content (hydrogen ion concentration)
PIPA	Pulsed integrating pendulous accelerometer
PKG	Package
PL	Postlanding
PLSS	Portable life support system
PLV	Postlanding ventilation control
PM	Phase modulation
PMP	Premodulation processor
PNL	Panel
POS	Position
POSS	Possible
POT	Potable
PP	Partial pressure
PPK	Pilot's preference kit
pps	Pulses-per-second
PRD	Personnel radiation dosimeter
PRED	Predicted
PREF	Preferred
PREP	Preparation
PRESS	Pressure/pressurize/pressurization
PRF	Pulse repetition frequency
PRIM (PRI)	Primary
PRN	Pseudo-random noise
PRO	Proceed
PROCED	Procedure
PROG	Program
PROP	Propellant/propulsion
PRPLNT	Propellant
PRR	Pulse repetition rate
PS	Payload shroud
PSA	Power servo assembly
PSC	Pressure suit circuit
PSI	Pounds per square inch
PSIA	Pounds per square inch absolute
PSID	Pounds per square inch differential
PSIG	Pounds per square inch gauge
PSO	Pad safety officer
PTT	Push to talk
PU	Propellant utilization
PUGS	Propellant utilization and gauging system
PWR	Power
PYRO	Pyrotechnic
q	Pitch control axis
QTY	Quantity
QUAD	Quadrant
QUAL	Qualification
r	Yaw control axis
RAD	Radiator
RAI	Roll attitude indicator
RC	Rotation control
RCD	Record

RCDR	Recorder
RCS	Reaction control system
RCSC	Reaction control system controller
RCV (RCVR)	Receive/Receiver
REACQ	Reacquire
REACS	Reactants
REC	Receive
RECT	Rectifier
RECY	Recovery
REF	Reference
REFSMMAT	Ref-to-stable member matrix
REG	Regulator
REJ	Reject
REL	Release
RELF	Relief
REQT	Requirements
RESTRT	Restart
RESVR	Reservoir
RET	Return
RETRO	Retrofire
REV	Reverse
RF	Radio frequency
RH	Right hand
RHC	Rotational hand control
RHEB	Right-hand equipment bay
RHFEB	Right-hand forward equipment bay
RJD	Reaction jet driver
RJEC	Reaction jet engine ON-OFF control
RL	Radioluminescent
R/L	Right/Left
RLSE	Release
RLVDT	Rotary linear variable differential transformer
RLY	Relay
R-M	Reference and measurement
RNDZ	Rendezvous
RNG	Ranging
ROT	Rotation
R/R	Remove/replace
RRT	Rendezvous radar transponder
RSET	Reset
RSI	Roll stability indicator
RSM	Radiation survey meter
RSO	Range safety officer
R/T	Real time
RTC	Real-time commands
RUPT	Interrupt
RZ	Return to zero
SA	Signal analyzer assembly
SAB	Solar array batteries
SAS	Solar array system
SBASI	Single bridgewire Apollo standard initiator
SC	Spacecraft
SCE	Signal conditioning equipment
SCI	Scientific
SCIN	Scimitar-notch
SCT	Scanning telescope
SCO	Sub-carrier oscillator
SCS	Stabilization and control system
SEC	Secondary/Second
SECO	SIVB engine cutoff
SECS	Sequential events control system
SEL	Select
SENS	Sensitivity
SEP	Separation
SEQ	Sequencer/sequential
SHFT	Shaft
SIG	Signal
SIM	Simplex
SLA	Spacecraft lunar module adapter
SLOS	Star line of sight
SM	Service module
SMJC	Service module jettison controller
SMRD	Spin motor rotation detector
SNSR	Sensor
SOH	Skylab Operations Handbook
SOL	Solenoid
SOV	Shutoff valve
SPEC	Specification
SPLH	Seat pin lock handle
SPS	Service propulsion system/sample per second
SQ	Square
SSA	Space suit assembly
SSB	Single side-band
S/S	Samples per second
STA	Station
STAB	Stabilization
STAT	Status
STBY	Standby
STD	Standard
STM	Steam
STRT	Start
SU	Separation ullage
SUP	Supply
SV	Space Vehicle
S.V.	State Vector
SVWS	Saturn V workshop
SW	Switch

SX-POP	OA X-Axis perpendicular to the orbital plane with the MDA in a northerly direction
SXT	Sextant
SYNC	Synchronize
SYS	System
TB	Talkback
TBD	To be determined
TC	Translation control
TELCOM (T/C)	Telecommunications
TEC	Transearth coast
TEI	Transearth injection
TEMP	Temperature
TERM	Terminate
TFF	Time of freefall
TFL	Time-from-launch
THC	Translation hand control
THRU	Through
TIG	Time of ignition
TJM	Tower jettison motor
TK	Tank
TLM	Telemetry or telemetered
TMG	Thermal meteoroid garment
TMR(S)	Timer(s)
TOL	Tolerance
TOT	Total
TPAC	Telescope Precision Angle Counter
TPF	Transfer phase final
TPI	Terminal phase initiation
T/R	Transmit/receive
TRGT	Target
TRNFR	Transfer
TRUN	Trunnion
TTE	Time-to-event
TTINT	Time to intercept
TV	Television
TVC	Thrust vector control
TVSA	Thrust vector position servo amplifier
TWR	Tower
TWT	Traveling wave tube
UCD	Urine collection device
UCTA	Urine collection and transfer assembly
UDL	Up-data link
UDMH	Unsymmetrical dimethyl hydrazine (fuel)
UHF	Ultra-high frequency
ULL	Ullage
UMB	Umbilical
UNBAL	Unbalance
UPTL	Up-link telemetry
USBE	Unified S-band equipment
USBS	Unified S-band system
UTIL	Utility
V	Velocity
VABD	Van Allen belt dosimeter
VAC	Vacuum/volts alternating current/vacant
VAR	Variable
Vc	Circular velocity
VCTR	Vector
VCO	Voltage control oscillator
VDC	Volts direct current
VEH	Vehicle
VENT	Ventilation
VENT	Ventilator
VERIF	Verification
VERT	Vertical
VHF	Very-high frequency
VIS	Visual
VLV	Valve
VM	Velocity measured
Vo	Initial velocity
VOL	Volume
VOLT	Voltage
VOX	Voice-operated relay/ voice-operated transmission
WACS	Workshop attitude control system
WARN	Warning
W/G	Water-glycol
WMS	Waste management system
XCVR	Transceiver
XDUCER	Transducer
XFMR	Transformer
XLATION	Translation
X-LVgg	OA X-Axis local vertical (gravity gradient)
XMIT	Transmit
XMTR	Transmitter
XPNDR (XPONDER)	Transponder
X-POP	OA-Axis perpendicular to the orbital plane with the MDA direction unspecified
X-POP/z-LV	OA-Axis perpendicular to the orbital plane, z-axis along local vertical

ZN	Zinc
ZP	Impedance pneumograph
Δ	Delta
ΔP	Differential pressure
ΔV	Differential velocity
Ø	Roll axis designation/phase
θ	Pitch axis designation
ψ	Yaw axis designation
α	Entry pitch attitude
γ	Angle between local horizontal and velocity vector
&	And
≈	Approximately
°	Degree
%	Percent

ALPHABETICAL INDEX

The following index consists of all paragraphs. They are arranged in alphabetical order and location paragraph numbers are given. This index includes material from sections 1 through 3 only.