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# STS-57
# SPACE SHUTTLE
# MISSION REPORT

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STS-57

SPACE SHUTTLE

MISSION REPORT

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# INTRODUCTION

The STS-57 Space Shuttle Program Mission Report provides a summary of the Payloads, as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the fifty-sixth flight of the Space Shuttle Program and fourth flight of the Orbiter vehicle Endeavour (OV-105). In addition to the Orbiter, the flight vehicle consisted of an ET (ET-58); three SSME's which were designated as serial numbers 2019, 2034, and 2017 in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-059. The lightweight RSRM's that were installed in each SRB were designated as 360L032A for the left SRB and 360W032B for the right SRB.

The STS-57 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement, as documented in NSTS 07700, Volume VIII, Appendix E. That document states that each major organizational element supporting the Program will report the results of their hardware evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of this flight were to perform the operations necessary to fulfill the requirements of the NASA-leased Spacehab-1 payload and to retrieve the European Retrievable Carrier (EURECA) payload. The secondary objectives of this flight were to perform the operations necessary to fulfill the requirements of the Superfluid Helium On-orbit Transfer (SHOOT) payload, the Shuttle Amateur Radio Experiment-II (SAREX-II) activities, the Fluid Acquisition and Resupply Experiment (FARE), the Air Force Maui Optical Site Calibration Test (AMOS), the Consortium for Materials Development in Space Complex Autonomous Payload-IV (CONCAP-IV), and the Get-Away Special (GAS) payloads carried on the GAS Bridge Assembly (GBA). In addition to the primary and secondary objectives assigned to STS-57, 16 Development Test Objectives (DTO's) and 11 Detailed Supplementary Objectives (DSO's) were assigned to the flight.

The sequence of events for the STS-57 mission is shown in Table I, the official Orbiter and GFE Projects Problem Tracking List is shown in Table II, and the official MSFC In-flight Anomaly List is shown in Table III. In addition, the Integration and Payload in-flight anomalies are referenced in the applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document. All times given in this report are in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The STS-57 mission was planned as a 7-day mission with an additional day being highly desirable. This additional day capability was to be determined in real-time based on consumables, with mission planning accommodating the longer duration wherever appropriate. Also, two additional contingency days existed in the planning.

In addition to presenting a summary of subsystem performance, this report also discusses the payload operations and results, as well as each in-flight anomaly that was assigned to each major element (Orbiter, SSME, ET, SRB, and RSRM).

Listed in the discussion of each anomaly in the applicable subsection of the report is the officially assigned tracking number as published by each respective Project Office in their respective Problem Tracking List.

The crew for this fifty-sixth flight of the Space Shuttle was Ronald J. Grabe, Col., USAF, Commander; Brian Duffy, Col., USAF, Pilot; G. David Low, Civilian, Payload Commander and Mission Specialist 1; Nancy Jane Sherlock, Civilian, Mission Specialist 2; Peter J. K. Wisoff, Ph.D., Civilian, Mission Specialist 3; and Janice Voss, Ph.D., Civilian, Mission Specialist 4. STS-57 was the fourth space flight for the Commander, the third space flight for Mission Specialist 1, the second space flight for the Pilot, and the first space flight for Mission Specialists 2, 3, and 4.

## MISSION SUMMARY

The countdown for the planned launch on June 20, 1993, progressed satisfactorily up to the T-9 minute hold. The hold at T-9 minutes was continued until no launch window remained because of unacceptable weather at the three trans-Atlantic abort landing sites as well as at the return-to-launch-site (RTLS) abort landing site at the Shuttle Landing Facility (SLF). The countdown was continued to T-5 minutes in anticipation that the weather would become acceptable; however, the weather remained unsatisfactory at all four sites throughout the 71-minute launch window. As a result, the launch was scrubbed for June 20, 1993, and rescheduled for June 21, 1993.

During crew ingress for the second launch attempt, a scratch was noted on the outer hatch seal. Evaluation of the condition revealed that the seal required replacement prior to flight. The replacement was completed satisfactorily with no impact to the countdown.

The countdown for the June 21, 1993, launch of the Space Shuttle vehicle proceeded satisfactorily until an unplanned hold of 22 seconds was called at T-5 minutes until an unidentified aircraft departed the range. Shortly after auxiliary power unit (APU) 2 start, the gearbox was repressurized when the pressure reached 5.9 psia. The gearbox pressure trend was increasing after the repressurization which was acceptable per the Launch Commit Criteria (LCC).

The Space Shuttle was successfully launched at 172:13:07:21.989 G.m.t. (8:07:22 a.m. c.d.t.) on June 21, 1993, from launch pad 39B. The Solid Rocket Boosters (SRB's) separated and main engine cutoff (MECO) occurred at the planned times.

The orbital maneuvering subsystem (OMS) 1 maneuver was not required. The OMS-2 maneuver was performed at 172:13:49:35.8 G.m.t. [00:00:42:13.8 mission elapsed time (MET)]. The maneuver was approximately 197 seconds in duration and the differential velocity ($\Delta V$) was 316 ft/sec. The resulting orbit was 212 by 252 nmi.

The remote manipulator system (RMS) on-orbit initialization was performed at 172:15:26 G.m.t. (00:02:19 MET). All elements of the RMS operated satisfactorily until RMS power-down when an unexpected ABE COMM annunciation occurred. The crew cycled the power to the RMS and then again powered down the

RMS; however, the condition did not repeat as no ABE COMM annunciation was observed. The crew was advised to expect warnings during deselect as a part of the RMS checkout.

The RMS checkout was successfully performed between 173:13:28 G.m.t. (01:00:20 MET) and 173:14:54 G.m.t. (01:01:47 MET). No problems were noted and no ABE COMM fault detection annunciations (FDA's) were observed during power-down following the checkout.

Consumables remained well above the requirements for the planned mission, thus the one-day extension was authorized by the Mission Management Team (MMT) on June 23.

The crew reported that the cabin was warm, and the cabin temperature was 85.6°F at that time. The crew commented that the cabin temperature control valve was not pinned to either the A or B actuator nor was it pinned in a fixed position. The unpinned valve tended to slide over to the "full hot" position. The crew connected the valve to the primary actuator and the actuator moved the valve to the "full cold" position, and the cabin temperature recovered to the desired level. The actuator movement caused a slug of water to pass through the humidity separator (causing a humidity separator alarm) and into the lower equipment bay. The crew later cleaned up the water using the free-fluid nozzle. During the water cleanup, the crew was unable to remove the torque tip screws holding the lithium hydroxide (LiOH) box in the middeck. As a result, access to the lower equipment bay was through the MD44F panel. The cabin temperature controller performed nominally throughout the remainder of the mission.

During EMU checkout, the crew reported that the small tether hook on the waist tether would not lock closed. The lock/lock buttons did pop out, but the tether hook did not lock. An IFM procedure was performed to restore positive crew-capture capability for the extravehicular activity (EVA) using a "D" ring on the crewman's EMU and a shackle from the servicing and cooling umbilical (SCU).

Rendezvous with the EURECA was completed satisfactorily and EURECA grapple was completed at 175:13:53 G.m.t. (03:00:46 MET). The Ku-band radar tracked the EURECA from 149,000 feet to approximately 90 feet with no loss of tracking.

Prior to the EURECA grapple, neither of the EURECA antennae could be stowed completely or latched. However, the EURECA was berthed and the antennae were secured during the EVA.

After the EURECA was captured and rigidized on the RMS arm, a standard switch panel command was given to activate the RMS special purpose end effector (SPEE) connector power relay to provide power to the EURECA, but it was not successful. Since the EURECA was successfully berthed, power transfer through the RMS was not required. A review of the on-orbit video and postflight inspection results revealed that the SPEE was incorrectly rotated 180 degrees when installed.

At the West-to-East Tracking and Data Relay Satellite (TDRS) hand-over at 176:03:57 G.m.t. (03:14:50 MET), the S-band did not establish a forward link. A good return link was established. During each of the several momentary acquisitions of the forward link, the receive signal strength was low. The transponder, antenna electronics, and power amplifier were switched one at a time from string 2 to string 1 without success. The forward link remained bad for all of orbit 56 East except the last six minutes of the pass. The forward link was regained but intermittent dropouts were experienced thereafter on the lower left antenna. The lower left antenna consistently exhibited noisy automatic gain control (AGC) in both high- and low-frequency operation.

A very successful 5-hour 50-minute EVA was completed during which both EURECA antennae were latched and most of the DTO 1210 objectives were met. Data show that both EMU's performed nominally.

During the RMS stow process, the crewperson operating the RMS reported that the motor control assembly (MCA) POWER AC3 3-phase circuit breaker (CB13) did not remain closed on the first attempt to close. This breaker provides three-phase power to some vent door motors, payload bay door motors, RMS manipulator positioning mechanism (MPM) motors, and several other motors on the Orbiter. The closure attempt had occurred during a period of numerous data dropouts, and the circuit breaker was left open as the dump data were being reviewed. The data review revealed no short existed and the crew was given permission for another closure attempt. The Commander attempted to close the circuit breaker using very little force, and again the circuit breaker did not remain closed. The ground controllers suggested another closure attempt be made using stronger force, and the circuit breaker remained closed after this attempt. A drive test of the right vent door 5 was performed to verify electrical continuity. During this drive test, both the open and close commands were inadvertently uplinked without a reset command between the two commands, causing a phase-to-phase short. This resulted in the temporary loss of some Spacehab power; however, all systems were recovered and reconfigured properly with no further problems.

The fuel cell 3 shutdown/restart DTO 412 was aborted when the fuel cell 3 hydrogen reactant valve failed to close upon command. Fuel cell 3 was initially shut down at 177:11:49:52 G.m.t. (04:22:42:30 MET). With the fuel cell shutdown, the cell performance monitor (CPM) that detected hydrogen/oxygen crossover was powered off. To limit the amount of reactants that could feed an undetected crossover when the fuel cell is powered off, the reactant valves are normally closed. Both valves are controlled by the same onboard switch. The oxygen reactant valve was closed at 177:11:50:52 G.m.t. (04:22:43:00 MET), but the hydrogen reactant valve indicated that it was still open. The valves were commanded open at 177:11:51:40 G.m.t. (04:22:43:48 MET), followed by the second attempt to close the valves 6 seconds later. Again the hydrogen valve did not indicate closed. With the hydrogen valve possibly open and the oxygen valve closed, a potential existed for hydrogen over-pressurization which could damage the fuel cell. The valves were reopened and the fuel cell was restarted at 177:11:55:42 G.m.t. (04:22:48:20 MET).

Flight control system (FCS) checkout was performed at 179:07:15 G.m.t. (06:18:08 MET). APU 1 operated for approximately 4 minutes 50 seconds and consumed approximately 14 lb of fuel. Hydraulics/WSB system 1 operation was nominal; no spraying by WSB 1 was required. Aerosurface and controller performance was nominal. The speedbrake command meter on the surface position indicator (SPI) was biased low during FCS checkout. The speedbrake position meter functioned properly. This bias presented no impact to the mission, since other methods (CRT display) were available for the crew to determine the position command to the speedbrake.

The reaction control system (RCS) hot-fire test was completed satisfactorily with all thrusters operating properly. Thermal traces have shown that RCS vernier thruster R5D has a failed-on heater. This condition did not affect thruster operations for the remainder of the mission.

Both payload bay doors were closed nominally by 180:09:01:45 G.m.t. (07:19:54:23 MET). Because of unsatisfactory weather at the Shuttle Landing Facility, the landing initially was delayed one orbit; however, the weather did not improve and the landing was delayed for 24 hours. The payload bay doors were reopened at 180:13:59 G.m.t. (08:00:52 MET).

Following the initial 24-hour delay in the planned landing and while operating in the backup flight system (BFS) for systems management (SM), the centerline latch gang 5-8 release A, starboard door forward bulkhead latch release A, and port door forward bulkhead latch release B indications failed to actuate. Door opening was completed successfully in the manual mode. All indications appeared within approximately 30 minutes, and were in the correct configuration.

A second attempt was made to land at KSC on June 30, 1993. The payload bay doors were closed at 181:08:09 G.m.t. (08:19:02 MET). The weather was again unacceptable for landing and the decision was made to delay the landing an additional 24 hours. As a result, the payload bay doors were again opened at 181:12:26 G.m.t. (08:23:19 MET). During the second opening of the doors, there was no repeat of the latch release problem noted during the door opening on the previous day.

The final attempt to land was made on July 1, 1993, with payload bay door closure occurring at 182:09:15 G.m.t. (09:20:08 MET). The deorbit maneuver was performed at 182:11:41:41.9 G.m.t. (09:22:34:19.1 MET). The maneuver was approximately 254.9 seconds in duration and the $\Delta V$ was 408 ft/sec. Entry interface occurred at 182:12:21:21 G.m.t. (09:23:13:59 MET).

Main landing gear touchdown occurred at the Shuttle Landing Facility on concrete runway 33 at 182:12:52:16 G.m.t. (09:23:44:54 MET) on July 1, 1993. Nose landing gear touchdown occurred 18 seconds after main gear touchdown with the Orbiter drag chute being deployed satisfactorily at 182:12:52:25.3 G.m.t. The drag chute was jettisoned at 182:12:52:57.1 G.m.t., with wheels stop occurring at 182:12:53:21 G.m.t. The rollout was normal in all respects. The flight duration was 9 days 23 hours 44 minutes 54 seconds. All three APU's were powered down by 182:13:14:28.62 G.m.t. The crew completed the required postflight reconfigurations and departed the Orbiter at 182:13:39 G.m.t.

Postlanding, the ammonia boiler B secondary controller was activated. After 7 minutes of good cooling, the outlet temperature and tank pressure indicated that ammonia cooling had ceased. The crew switched to system A secondary controller and it operated for about 7 minutes before cooling was lost. Both system primary controllers were activated in an unsuccessful attempt to restore ammonia cooling. Ground cooling was initiated in time to prevent an emergency power down of the vehicle.

## PAYLOADS

All payloads met or exceeded their minimum objectives. The EURECA was successfully retrieved, and the performance of the Spacehab module on its maiden voyage was exemplary.

The payloads carried by Endeavour included the NASA-leased privately built middeck augmentation module known as SPACEHAB, which carried a large number of experiments that the crew performed during the course of the mission. Other experiments not included in Spacehab were the Superfluid Helium On-Orbit Transfer (SHOOT); the Fluid Acquisition and Resupply Experiment; the Consortium For Materials Development in Space Complex Autonomous Payload-IV (CONCAP-IV), and the Get-Away Special (GAS) Bridge Assembly (GBA); the Shuttle Amateur Radio Experiment (SAREX); and the Air Force Maui Optical Site Calibration Test (AMOS); and the EURECA after it was retrieved.

### SPACEHAB

The Spacehab module and its subsystems performed almost flawlessly on its first mission. Module structure showed no damage from the launch environment, and there was no loss of cabin pressure during the EVA when the module was isolated from the Orbiter. The electrical power distribution subsystem performed properly throughout the mission as did Spacehab avionics (fire detection and suppression, command and data, crew communications, and displays and controls). An unscheduled IFM procedure was performed on flight day 6 to replace three blown power distribution unit (PDU) ac circuit fuses that were required because of an Orbiter ac bus short.

The Spacehab module environmental control subsystem worked well, but it tended to keep the module too cool. Two unscheduled IFM procedures were performed to manually adjust the cold water bypass valve, and this succeeded in raising the cabin temperature to 76°F from the 69°F temperature noted early in the mission. The cooler-than-expected module temperatures are attributed to lower Spacehab electrical power requirements than were predicted during premission planning. The atmospheric revitalization system fan differential pressures rose slowly throughout the mission from approximately 2.1 inches of water at launch to 4.0 inches of water at fan deactivation for entry. This condition is symptomatic of fan filter screens becoming obstructed with debris as the flight progressed; however, this condition did not impact Spacehab operations.

At 178:16:00 G.m.t. (06:02:53 MET), the crew reported a pungent non-electrical chemical type odor in the module that lasted approximately one minute. Plots of Spacehab electrical and environmental parameters showed no anomalies, and no visible leakage was observed. A sniffer test with the Combustible Products Analyzer (CPA) did not provide data to determine the source of the odor.

Spacehab experiment operations were very successful. Total experiment complement results, as measured by the number of samples processed, run time, and activities performed, exceed 90 percent of the premission planned objectives. Six of the 21 experiments carried as part of Spacehab experienced some difficulties in obtaining data. The following paragraphs discuss the pertinent activities of each experiment.

## Bioserve Pilot Laboratory

Seventy-seven of the 80 samples were successfully processed from the 40 bioprocessing modules (BPM's). Science data were lost on three samples whose BPM's experienced breaches in the first of three levels of containment during activation. Six other BPM's experienced first-level breaches of containment on deactivation; however, no science data were lost on these samples. All leaking BPM's were bagged and stowed in accordance with the existing procedures.

## Liquid Encapsulated Melt Zone

The experiment operations were nominal, but some difficulty was experienced in the initial power-up of the experiment. This condition was resolved by repositioning the heater element translation mechanism. The operation of the sample heating apparatus was nominal, but several data communications failures occurred between the experiment and the payload and general support computer (PGSC), which was being used to record data. Reinitializing the PGSC software resolved the problem. The most significant data communications failure occurred during unattended overnight sample processing. Some science data (temperatures and translation versus time) were lost, but the samples themselves were unaffected.

## Environmental Control and Life Support System Flight Experiment

The bellows and phase separator portions of the Environmental Control and Life Support System Flight Experiment (EFE) performed nominally. The unibed portion of the experiment, approximately 50 percent of the science content of the EFE, was unsuccessful. The unibed was not activated successfully because of a failure of the potassium iodide (KI) feed system. The KI was a simulated contaminant which was to have been filtered out of the experiment water circulation loop by the unibeds. Attempts to back flush the KI feed system to clear any obstruction in the 0.021-inch diameter KI metering line were unsuccessful. A real-time IFM procedure to remove the unibed front panel and flush out the KI feed line was developed and approved. The IFM was attempted on flight day 8, but the procedure was unsuccessful when leakage of the KI feed line fittings within the experiment could not be controlled following completion of the line flushing operation.

## Human Factors Assessment

All Human Factors Assessment (HFA) sound measurement data were acquired. Abbreviated crew questionnaires were uplinked on the second wave-off day with the request that the crew take the sound measurements if time allowed.

## Physiological Systems Experiment

On flight day 9, it was noted during the daily status check that the day/night cycle timer for the animal enclosure module (AEM) lighting was not functioning. The crew was requested to manually cycle AEM lights per the timer schedule. During the flight day 10 status check, the water level indications for 3 of 4 AEM water bladders were at their refill levels. Based on the remaining flight time and the threat of another mission extension, a decision was made to perform a water refill. The crew re-entered the Spacehab module using an abbreviated ingress procedure, retrieved the water refill services and refilled the AEM's.

## Space Acceleration Measurement System

Some Space Acceleration Measurement System (SAMS) data were lost as a result of the failure of one optical disc drive.

## Superfluid Helium On-Orbit Transfer

The Superfluid Helium On-Orbit Transfer (SHOOT) experiment pump-down to operating temperatures was completed about 14 hours 30 minutes into the mission. After Orbiter rotational and translational firings were performed in preparation for the cryogenic fluid transfer operation, the starboard dewar was discovered to have lost Helium pressure. This is believed to have been caused by a malfunction in the high-flow phase separator on the starboard dewar. This limited the premission planned activities. Transfers of fluid between the port and starboard dewars in a quasi-static environment and during Orbiter accelerations were accomplished on flight days 2 and 3. Despite curtailing some activities, SHOOT successfully completed all of the primary mission objectives and many of the secondary mission science goals. Appendix C contains a more detailed discussion of the SHOOT experiment.

## Consortium For Materials Development In Space Complex Autonomous Payload-IV and Get-Away Special Bridge Assembly

The CONCAP-IV and the Get-Away Special (GAS) payloads (G-022, G-399, G-450, G-452, G-453, G-454, G-535, G-601, and G-647) were all activated and deactivated in accordance with the timeline. G-324 completed all of its activities for earth photography. The crew reported that G-454 and G-647 both had indications of low batteries toward the end of the mission. The impact, if any, of the battery condition on these two GAS payloads has not been determined. All of the GAS payloads require postflight analysis to determine their success or lack thereof.

# MIDDECK EXPERIMENTS

## Fluid Acquisition and Resupply Experiment

The Fluid Acquisition and Resupply Experiment (FARE) was operated on flight days 6 and 7. All major science objectives were met, and the hardware operated normally without any failures or anomalies. Tests 6 and 7 could not be performed because of time constraints; since these were repeats of tests 1 and 2, the science impact was minimal. The zero gravity fluid mechanics aspects of the vane device in the FARE receiver tank was much more challenging than predicted, but the crew reacted well to the required changes in the test sequence. The FARE tests demonstrated that a tank can be filled on orbit to levels of greater than 95 percent without venting liquid overboard. Also, the test showed that a partially filled tank can be vented in zero gravity to reduce its pressure without losing liquid overboard.

## Shuttle Amateur Radio Experiment

The SAREX equipment operated satisfactorily with almost all contacts being made. Only one school, Dapto High School, New South Wales, Australia, was not contacted because of school accessibility and timeline constraints encountered during real-time replanning.

## Air Force Maui Optical Site Calibration Test

None of the Air Force Maui Optical Site Calibration Test activities were completed because of the lack of opportunities and support capability.

# VEHICLE PERFORMANCE

## SOLID ROCKET BOOSTER/REDESIGNED SOLID ROCKET MOTOR

All SRB systems performed nominally. The SRB prelaunch countdown was normal, and no SRB or RSRM in-flight anomalies were identified. No SRB or RSRM LCC or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred.

Power-up and operation of all case, igniter, and field joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. For this flight, the low-pressure heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint and flexible bearing temperatures within the required LCC ranges. At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt.

Preliminary data indicate that the flight performance of both RSRM's was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 76°F at lift-off. The table on the following page provides a summary of RSRM performance.

Both SRB's were separated from the External Tank (ET) at lift-off plus 124.7 seconds. Both of the SRB's experienced lagging parachutes. The left SRB main parachute 1 inflated normally. However, the left SRB parachutes 2 and 3 inflated initially, but both collapsed and remained severely under-inflated until completion of the first disreef. Both parachutes began inflating normally shortly after the first disreef and were fully inflated to a normal second stage drag area prior to the second disreef. Because main parachutes 2 and 3 were under-inflated at the first disreef, it is suspected that main parachute 1 experienced a load higher than its design load of 175,000 lb. The right SRB main parachute 3 inflated normally. Right SRB main parachute 1 inflated initially, but collapsed and remained under-inflated through the first disreef when it inflated to a normal second stage drag area prior to the second disreef. Right SRB main parachute 2 lagged initially but it inflated to a normal first stage drag area prior to the first disreef. Because the lagging of main parachutes 1 and 2 was sequential rather than simultaneous, main parachute 3 did

RSRM PROPULSION PERFORMANCE

| Parameter | Left motor, 76°F | | Right motor, 76°F | |
|---|---|---|---|---|
| | Predicted | Actual | Predicted | Actual |
| Impulse gates | | | | |
| I-20, $10^6$ lbf-sec | 65.86 | 65.02 | 65.85 | 64.95 |
| I-60, $10^6$ lbf-sec | 175.50 | 174.43 | 175.48 | 174.15 |
| I-AT, $10^6$ lbf-sec | 297.38 | 296.55 | 297.21 | 295.99 |
| Vacuum Isp, lbf-sec/lbm | 268.60 | 267.80 | 268.60 | 267.50 |
| Burn rate, in/sec @ 60°F at 625 psia | 0.3673 | 0.3668 | 0.3675 | 0.3668 |
| Burn rate, in/sec @ 66°F at 625 psia | 0.3715 | 0.3708 | 0.3717 | 0.3708 |
| Event times, seconds | | | | |
| Ignition interval | 0.232 | N/A | 0.232 | N/A |
| Web time[a] | 109.50 | 110.10 | 109.50 | 110.40 |
| Separation cue, 50 psia | 119.20 | 119.80 | 119.20 | 119.80 |
| Action time | 121.40 | 122.00 | 121.30 | 121.90 |
| Separation command | 124.10 | 124.80 | 124.10 | 124.80 |
| PMBT, °F | 76.00 | 76.00 | 76.00 | 76.00 |
| Maximum ignition rise rate, psia/10 ms | 90.4 | N/A | 90.4 | N/A |
| Decay time, seconds (59.4 psia to 85 K), klbf-sec | 2.80 | 3.10 | 2.80 | 2.80 |
| Tailoff imbalance | Predicted | | Actual | |
| Impulse differential, | N/A | | 268.2[b] | |

Note:
[a] All times are referenced to ignition command time except where noted by the letter a. These items are referenced to lift-off time (Ignition interval).

not experience an overload condition. All three main parachutes on each SRB were fully inflated prior to water impact, which was at the nominal impact velocity.

The postlaunch inspection of the SRB holddown posts (HDP) revealed that only seven of the eight HDP's operated nominally. The plunger was found to be only lightly seated at HDP 2 and only 11 percent of the potential debris was retained at this post. Evidence indicates that one or both of the frangible nut halves may have rebounded off of the lead shock absorber and obstructed the plunger from seating on the spherical washer. This would allow the debris to escape the debris containment device (DCD). Upon water impact, the nut halves may have been forced out of the way, thus allowing the plunger to seat under the force of the spring (causing the light seating impressions). Also, additional debris may have been washed out of the DCD at that time.

The postflight inspection of nozzle joint 2 of the left RSRM revealed two gas paths at 132.5 and 318 degrees with soot to the primary O-ring. No O-ring damage or heat-affected metal were noted. The glass cloth phenolic experienced slight erosion at both locations (0.0006 inch maximum depth at 132.5 degrees and 0.0003 inch at 318 degrees).

## EXTERNAL TANK

The ET flight performance was excellent. All flight objectives were satisfied. All electrical and instrumentation equipment performed satisfactorily. All ET heaters operated successfully, and there were no unacceptable ice/frost formations.

All objectives and requirements associated with the ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation operated satisfactorily. ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were noted.

Typical ice/frost formations for the June atmospheric environment were observed on the ET during the countdown. Normal quantities of ice or frost were present on the $LO_2$ and $LH_2$ feedlines and on the pressurization line brackets, and some frost or ice was present along the $LH_2$ protuberance air load (PAL) ramps. These observations were acceptable per NSTS-08303. There was no observed ice or frost on the acreage of the $LO_2/LH_2$ tank barrels.

The ET pressurization system functioned properly throughout engine start and flight. The minimum $LO_2$ ullage pressure experienced during the period of the ullage pressure slump was 13.6 psid.

ET separation was confirmed, and main engine cutoff (MECO) occurred within expected tolerances. ET entry and breakup occurred approximately 16 nmi. downrange of the preflight prediction and within the expected footprint.

The crew video-taped and photographed the ET after separation and recorded some excellent close-up photography of the ET. The photography revealed approximately nine divots between 6 and 8 inches in diameter that were located along a line on the -Y thrust panel; over 50 "popcorn" divots on the intertank stringer heads forward of the bipods; three divots in the $LH_2$ tank-to-intertank flange closeout; a 6- to 8-inch diameter divot in the -Y longeron closeout; and foam missing from the +Y thrust strut flange. All of these observations were typical of conditions noted on previous flights.

## SPACE SHUTTLE MAIN ENGINE

All SSME parameters appeared to be normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. The engine-ready indication was achieved at the proper time; all LCC were met; and engine start and thrust buildup were normal.

Flight data indicate that SSME performance during mainstage, throttling, shutdown, and propellant dump operations were normal. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specification throughout engine operation. The cutoff times for SSME 1, 2, and 3 were 518.52, 518.64, and 518.76 seconds, respectively, referenced to the engine start command. MECO occurred at lift-off plus 512.16 seconds. The specific impulse was rated as 452.50 seconds based on trajectory data. The controller and software performance was good with no anomalies.

As a note of interest, no data spikes were observed on the SSME pressure measurements. This is the first block II controller flight at the 28.45-degree inclination which had no spiking in the pressure measurements. The range radar power was attenuated during the critical time frame as a test on this flight, and results are consistent with the theory that the radar signal is the source of noise causing the spikes. This test will also be conducted on STS-51.

## SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected throughout the countdown and flight.

As planned, the SRB S&A devices were safed, and SRB system power was turned off prior to SRB separation. The ET system remained active until ET separation from the Orbiter.

## ORBITER SUBSYSTEMS

### Main Propulsion System

The overall performance of the main propulsion system (MPS) was as expected. During the first launch attempt, the SSME 2 750-psi Helium regulator B outlet pressure was expected to reach a low of 732 psia during the purge sequence 3 SSME fuel system purges. The history of the transducer which measures the regulator outlet pressure shows a bias of 11-psi low. A concern existed that during purge sequence 4 (L-4 minutes to SSME start) when the helium flow rate would be three times greater than the purge sequence 3 flow rate, the regulator would violate the LCC lower limit of 730 psia. As a result, the lower limit was changed to 724 psia to allow for the bias; however, the countdown was scrubbed at L-5 minutes and purge sequence 4 was never initiated. This concern did not arise during the final countdown before the flight.

During the detanking operations following the scrub, a ground support equipment (GSE) gaseous nitrogen ($GN_2$) regulator panel failed. This panel supplied nitrogen to various systems including the $LO_2$ disconnect umbilical cavity purge and $LO_2$ T-0 umbilical. As a result of the failure, the purge pressure to the disconnect and the T-0 umbilical reached 1000 psig and 1400 psig, respectively. The maximum allowable pressures are 550 and 750 psig, respectively. Analyses showed that the hardware had suffered no significant damage, and waivers were issued for flight. However, during the scrub turnaround, the $GN_2$ purge regulator and several other components in the $GN_2$ purge system were replaced.

Propellant loading for the final launch attempt, which was delayed over one hour, was satisfactory in all respects. The loading delay was needed to verify the $GN_2$ purge regulator set points in the primary and backup systems. $LO_2$ and $LH_2$ loading was then performed as planned with no stop flows or reverts. No other OMRSD or LCC violations occurred.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (which occurred immediately after the start of the $LH_2$ recirculation pumps) was approximately 178 ppm, which compares favorably with previous data from this vehicle.

The $LH_2$ loading operations were normal throughout chilldown, fast fill, topping and replenish. Based on the analysis of the loading system data, the $LH_2$ load at the end of replenish was 231,849 lbm. A comparison with the planned load of 231,853 lbm, shows a difference of -0.002 percent, which is well within the required MPS loading accuracy of $\pm$ 0.37 percent.

The $LO_2$ loading operations were normal through chilldown, slow fill, topping and replenish. Based on the analysis of the loading system data, the $LO_2$ load at the end of replenish was 1,387,087 lbm. A comparison with the planned load of 1,387,628 lbm revealed a difference of -0.05 percent, which is well within the MPS required loading accuracy of $\pm$ 0.43 percent.

Ascent MPS performance appeared to be completely normal. Data indicate that the $LO_2$ and $LH_2$ pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight.

The MPS Helium system performed as expected and met all requirements during powered flight, propellant dump, and vacuum inerting operations. During entry, Helium consumption was a nominal 56.9 lb.

The ascent performance of the $GO_2$ fixed orifice pressurization system was as predicted. The $GH_2$ pressurization system performed nominally. Evaluation of the flow control valve data revealed no problems.

During the postflight walk-around inspection of the $LH_2$ umbilical, a 15-inch piece of foam was discovered near the $LH_2$ 4-inch disconnect (Flight Problem STS-57-V-17A). The foam was removed from the vehicle and was found to also contain a piece of the red purge barrier seal which is located around the circumference of the umbilical. Both the foam and seal should have remained with the ET following separation. Further investigation has shown that some of the foam which is used to close out the 4-inch disconnect leak-check port may have leaked past the room temperature vulcanizing (RTV) flow barrier and adhered to the purge barrier seal and the Orbiter disconnect plate. The ET umbilical cameras also showed loose foam on the 4-inch disconnect side of the umbilical. The piece of foam and seal were removed for analysis, and alternate methods are being investigated for closing the leak-check port to prevent a recurrence of this problem.

A 2-inch by 2-inch piece of foam was also found on the inboard side of the $LO_2$ ET door (Flight Problem STS-57-V-17B). This foam apparently came loose during ET separation and became trapped in the door hinge area during door closure. The foam did not impede door travel as evidenced by the nominal ET door closing time. Additionally, there was no indication of hot gas intrusion in the $LO_2$ umbilical cavity. The foam was removed and sent to a laboratory for analysis to determine type and origin.

A 2.5-inch crack was discovered on the $LH_2$ purge curtain attach plate near the forward pyrotechnic bolt hole (Flight Problem STS-57-V-17C). The crack extends through the 0.126-inch fiberglass plate. While cracks in the plate have been noted previously, this is the first one to penetrate the entire plate. The plate has been removed and sent to a laboratory for analysis and determination of the cause of the overstress condition in this area.

## Reaction Control Subsystem

The reaction control subsystem (RCS) operated satisfactorily throughout the mission. A total of 5,016.2 lbm of RCS propellants was consumed during the mission. In addition, 2310 lbm of orbital maneuvering subsystem (OMS) propellants (20.92 percent of OMS load) were consumed by the RCS in crossfeed operations. Three anomalies occurred in the RCS and are discussed in the following paragraphs. None of these anomalies impacted the mission.

The reaction jet driver power and logic switch problem is discussed in the Electrical Power and Distribution section of this report.

During low vernier thruster activity periods, thermal traces have shown that RCS thruster R5D cooldown response was indicative of a failed-on heater (Flight Problem STS-57-V-13). The temperature behavior of this thruster was not the same as the other vernier thrusters because the temperature did not drop below 180°F. In addition, the vernier temperatures converged once the heaters were turned off for entry. This condition did not affect mission operations.

The RCS hot-fire test was completed satisfactorily with all thrusters operating properly.

The RCS was used to perform a significant number of firings on-orbit to support the mission objectives. These firings are shown in the table on the following page.

| RCS Firing | Firing time/axis |
|---|---|
| NC | 5.9 ft/sec/+X axis |
| SH1 | 3.5 ft/sec/+X axis |
| NC2 | -X axis |
| SH2 | 3.5 ft/sec/-X axis |
| SH3 | 3.5 ft/sec/-X axis |
| NSR | 2.5 ft/sec/multiaxis |
| NH | 6.1 ft/sec/+X axis |
| Null | 1.0 ft/sec/-X axis |
| NCC | 2.4 ft/sec/multiaxis |
| TI | 4.5 ft/sec/multiaxis |
| Correction firing | Multiaxis |
| Correction firing | Multiaxis |

Following the landing wave-off, the left aft RCS manifold 3/4/5 crossfeed valve indicated barberpole when the switch was moved to Close from GPC. The crew cycled the switch and the problem did not clear. Data review verified that no valves were moved during these switch changes and that the valve was in the proper position. Approximately two hours later, the crew reported the talkback correctly indicated closed.

## Orbital Maneuvering Subsystem

The OMS performance was excellent throughout the mission with four straight-feed firings performed, of which three were dual engine and one was single engine. The total firing time for the left-hand engine was 570.8 seconds and 503.1 seconds for the right-hand engine. The gauging system worked very satisfactorily with all postfiring quantities within one percent of calculated values. A total of 23,308 lbm of propellants was used during the mission, of which the RCS used 2310 lbm during crossfeed operations.

The following table presents the pertinent parameters for each firing.

| OMS firing | Engine used | Time, G.m.t./MET | Firing duration, sec | ΔV, ft/sec |
|---|---|---|---|---|
| 2 | Both | 172:13:49:34.7 G.m.t.<br>00:00:42:12.7 MET | 198.5 | 315.6 |
| 3 | Left-hand | 174:17:07:58.2 G.m.t.<br>02:04:00:36.2 MET | 67.7 | 55.4 |
| 4 | Both | 176:08:08:56.4 G.m.t.<br>03:19:01:34.4 MET | 51.2 | 81.5 |
| Deorbit | Both | 182:11:41:42.2 G.m.t.<br>09:22:34:20.2 MET | 253.4 | 423.4 |

## Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem operated nominally and met all requirements of the mission. A total of 2538 lb of oxygen was consumed during the mission, of which 116 lb was used by the environmental control and life support system (ECLSS) for crew life support. A total of 305 lb of hydrogen was also used during the mission. Cryogenics remaining at touchdown would have provided for a mission extension of 24 hours at a power level of 14.7 kW.

At 172:19:26:24 G.m.t. (00:06:19:02 MET), the crew attempted to close the PRSD oxygen manifold 1 isolation valve while configuring for sleep, but the valve failed to close (Flight Problem STS-57-V-03). A second attempt was made about 1 minute later and it was also unsuccessful. The redundant oxygen and hydrogen manifold 2 isolation valves were successfully closed about 17 and 10 minutes later, respectively. The same manifold 1 isolation valve failed to close during STS-49 and STS-54. There is no flight history of PRSD leaks requiring closure of manifold valves. Troubleshooting with the valve on the vehicle has not determined the cause of the failure. Another valve that failed similarly on OV-104 was tested at the NASA Shuttle Logistics Depot (NSLD). A successful attempt to close the oxygen manifold 1 isolation valve was made at 180:04:04 G.m.t. (07:14:57 MET).

## Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem performance was nominal. The total energy produced by the fuel cells was 3518 kWh at an average power level of 14.7 kW, and average load of 479 amperes. The fuel cells consumed 305 lb of hydrogen, 2422 lb of oxygen, and produced 2727 lb of water. Six fuel cell purges were performed during the mission.

The fuel cell 3 voltage measurement was erratic for the first portion of the mission, toggling between data bits. However, as soon as the crew turned off the emergency lighting, the voltage stabilized.

The fuel cell 3 shutdown/restart (DTO 412) was aborted when the fuel cell 3 hydrogen reactant valve failed to close upon command (Flight Problem STS-57-V-06). Fuel cell 3 was initially shut down at 177:11:49:52 G.m.t. (04:22:42:30 MET). With the fuel cell shutdown, the CPM that detected hydrogen/oxygen crossover was powered off. To limit the amount of reactants that could feed an undetected crossover, the reactant valves are normally closed when the fuel cell is shut down. Both valves are controlled by the same onboard switch.

The hydrogen and oxygen reactant valves were commanded closed at 177:11:50:52 G.m.t. (04:22:43:00 MET), but the hydrogen reactant valve indicated that it was still open. The valves were commanded open at 177:11:51:40 G.m.t. (04:22:43:48 MET), followed by the second attempt to close the valves 6 seconds later. Again the hydrogen valve did not close. With the hydrogen valve open and the oxygen valve closed, a potential existed for hydrogen over-pressurization which could damage the fuel cell. The valves were reopened and the fuel cell was restarted at 177:11:55:42 G.m.t. (04:22:48:20 MET). Postlanding, the hydrogen reactant valve for fuel cell 3 was tested because of the problem earlier in the mission when the valve would not close. Fuel cell 3 was shut down while still on the runway and the reactant valve closed satisfactorily on the first attempt.

The fuel cell 3 stack inlet temperature dropped to 177°F at the time the fuel cell was reconnected to the bus, but the stack inlet temperature never fully recovered to its pre-shutdown temperature range of 182°F to 183°F. For the remainder of the mission, the stack inlet temperature held steady at 178°F to 179°F, occasionally toggling to 180°F, even when the load on the fuel cell was greater than 200 amperes for over three hours. A comparison of the percentage of the total electrical load each fuel cell carried before and after the shutdown did not change, thus indicating that there was no ill effect on the performance of the fuel cell as a result of the shutdown. It is expected that this temperature will return to the 182°F range when the fuel cell is activated for the next flight.

The leakage signatures on the fuel cell 2 and 3 alternate water lines that were observed on STS-54 repeated on this flight. The alternate water line check valves were tested for the proper cracking and reseat pressures, and all of the valves were within specification. This condition continues to be evaluated in an effort to determine the cause.

## Auxiliary Power Unit Subsystem

The improved auxiliary power unit (IAPU) subsystem performed normally throughout the mission with no anomalies noted. STS-57 was the first flight of the improved controller, which was flown with APU 2 and performed nominally. The following table shows the run times and fuel consumption for each APU.

Shortly after APU 2 start prior to ascent, the gearbox was repressurized when the pressure reached 5.9 psia. The gearbox pressure trend was increasing after the repressurization; this is acceptable per the LCC and there was no impact to the flight.

| Flight Phase | IAPU 1 (S/N 303) | | IAPU 2 (S/N 401) | | IAPU 3 (S/N 207) | |
|---|---|---|---|---|---|---|
| | Time, min:sec | Fuel consumption, lb | Time, min:sec | Fuel consumption, lb | Time, min:sec | Fuel consumption, lb |
| Ascent | 21:32 | 54 | 21:41 | 55 | 21:13 | 51 |
| FCS checkout | 4:50 | 14 | | | | |
| Entry[a] | 66:05 | 150 | 97:41 | 193 | 66:06 | 134 |
| Total[a] | 92:27 | 218 | 119:22 | 248 | 87:19 | 185 |

Notes:
[a] The IAPU's ran for 22 minutes 13 seconds after landing (touchdown).

The APU 1 seal cavity drain system pressure decayed from 18 to 2 psia over a 10-hour period and remained there until after the FCS checkout when it further decayed to 0.4 psia. During entry and landing, the pressure increased to 14.7 psia. Also, the APU 2 seal cavity drain system pressure slowly decayed from approximately 15 psia to 8 psia during the course of the mission. The APU 3 seal cavity drain system pressure decayed from approximately 19 psia to 0.2 psia over a 16-hour period and remained there until entry and postlanding when it increased to 12.5 psia. Leakage through the drain relief valve is suspected as this is a common occurrence that has been seen on previous flights. The system 1 and 2 valves did not show any leakage during the previous flight (STS-54); however, the system 3 valve leaked during that flight. APU 3 had the only gearbox repressurization that occurred during entry 16 minutes prior to landing. Repressurizations of this APU gearbox are typical because of the $GN_2$ leakage past the turbine carbon seal. All three valves passed the preflight OMRSD requirements for cracking, reseating, and leaking.

In support of DTO 414 - APU Shutdown Test (Sequence A), the APU's were shut down in serial order (3, 1, 2) with at least 5 seconds between individual APU shut-downs after ascent. No hydraulic motor backdrive symptoms were detected during the shut down sequence nor were any anomalous pressure hang-ups noted. The sponsor has the data from the shut down, and the data are being evaluated. The results of that evaluation will be reported in separate documentation.

## Hydraulic/Water Spray Boiler Subsystem

The hydraulic/water spray boiler (WSB) performance during the flight was satisfactory.

During the prelaunch activities, the WSB 1 regulator outlet pressure reached 44.7 psia and should have been no greater than 44.0 psia. A waiver was approved to fly with this condition. The cause was a combination of the thermal effects and minor internal leakage.

System 3 WSB ascent performance was significantly improved from the previous flight of this Orbiter (STS-54), although a minor freeze-up (lubrication oil temperature - 275°F maximum, 278.6°F observed) was observed prior to start of spray cooling. WSB 3 had been preloaded with 5.0 lb of water (normal load is 3.75 $\pm$ 0.25 lb) in a successful attempt to lessen the severity of the ascent freeze-up. The core temperature indicated a small spray rate 41 seconds prior to the lubrication oil temperature peaking, and this appears indicative of a partial freeze-up of the spray bar. This WSB will continue to be preloaded with 5.0 lb of water on future flights to lessen the severity of the ascent freeze-up.

The system 2 WSB also experienced a minor "in-specification" freeze-up prior to the start of spray cooling when the maximum lubrication oil temperature reached 267°F. This system will be monitored closely on the next flight for possible freeze-ups, should they occur.

The hydraulic system 1 priority valve required 11 seconds to open and equalize the bootstrap pressure with the main pump pressure (Flight Problem STS-57-V-21). The OMRSD requirement allows not more than a 1-second lag in the priority valve opening. The valve has been removed and replaced, and the valve has been sent to the vendor for failure analysis.

## Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. Data were collected for DTO 663 - Acoustical Noise Dosimeter Data, and the results are presented in the Development Test Objective section of this report.

During pre-sleep activities at 175:18:21 G.m.t. (03:05:14 MET), the reaction jet driver (RJD) power and logic switches were switched off per the group B power-down procedures. This is done to prevent a failed-on primary thruster during the crew sleep period. The RJDA-1B switch indicated off momentarily and then one switch contact indicated on again (Flight Problem STS-57-V-09). Seven minutes later, the switch was toggled, after which the correct switch indication was restored. The data review showed all four poles of the switch initially opened when the switch was placed to off; however, one pole subsequently remade contact while the other three remained open. The switch will be replaced during the turnaround activities.

As a part of the RMS power-down procedures At 176:21:24 G.m.t. (04:08:17 MET), more than normal force was required to close the motor control assembly (MCA) Power AC3 3-phase circuit breaker (CB13) (Flight Problem STS-57-V-08). A review of the data did not show a short in the circuit. A drive test of the right vent door 5 was performed to verify electrical continuity of the breaker. While commanding the right vent door 5 to open, an AC3 phase B to phase C short occurred. This short resulted from the procedure not containing a reset command between the open and close commands for the door. Once the door started to travel, the limit switch removed the inhibit to the close relay, thereby causing both the close and open relays to be powered simultaneously. This action caused the MCA power AC3 circuit breaker to open due to the high current. The dual commands were removed from the vent door motor, the AC3 mid 4 circuit breaker was reset, and right vent door 5 motor 2 was successfully used to reopen the door. No problems were experienced in opening the door and the motor operated satisfactorily for the remainder of the mission.

During payload bay floodlight operations for EURECA retrieval, the mid main bus C current indicated an increase of 15 amperes for approximately three seconds. This type of current signature is indicative of a 10-amp-rated remote power controller (RPC) going into current-limiting mode and subsequently tripping out. At that point, it could not be determined which floodlight (aft port or mid starboard) had failed. During the EVA, an RPC trip signature was again observed on the mid main bus C current data, and the EVA crewman verified that the mid starboard floodlight was off.

## Environmental Control and Life Support System

All atmospheric revitalization system (ARS) systems performed flawlessly throughout the mission with atmosphere mixing with the Spacehab being as predicted.

The atmospheric revitalization pressure control system (ARPCS) operated nominally with the exception of the partial pressure oxygen ($PPO_2$) sensor. During prelaunch operations, the oxygen partial pressure sensor B reading was 0.14 psi below the other two PPO2 sensors. At 178:00:37 G.m.t. (05:11:30 MET), this differential increased to 0.22 psia; however, for the cabin temperatures experienced on this flight, the maximum differential should have been less than 0.15 psia (Flight Problem STS-57-V-02). Sensor B was inhibited from the onboard oxygen concentration calculation, and sensor A was used to control both pressure control systems (PCS) 1 and 2. Troubleshooting at KSC revealed a small sliver of material, which appeared to be metal, on the face of the sensor membrane face. Since this configuration sensor is being phased out of the Program on an attrition basis, no further troubleshooting was performed.

The active thermal control system (ATCS) performance was nominal throughout the mission. The cooling provided to the Spacehab was more than adequate with one Freon loop flow proportioning valve changed from the "payload" to the "interchanger" position. This was done to reduce cooling provided to the Spacehab and increase cabin temperature to 70°F.

The ammonia boiler system (ABS) was activated approximately 8 minutes after landing when the radiator coldsoak was depleted. The secondary controller for tank B was selected first according to the standard rotation of controllers. The secondary B controller operated nominally for 7 minutes 37 seconds at 37°F when the evaporator outlet temperature rose suddenly indicating the loss of cooling by the ammonia boiler (Flight Problem STS-57-V-15). The secondary controller for tank A was then selected and it operated normally at 34°F for 8 minutes 22 seconds when it stopped cooling. The primary/GPC controller for tank A was then selected, and this was followed by the the primary/GPC controller for tank B, after which the secondary controller for tank B was again selected. Although a slight temporary decrease in the evaporator outlet temperature was noted each time the controllers were activated, there was no corresponding decrease in ammonia tank pressure to indicate ammonia flow from the tank to the heat exchanger. The secondary A controller was then selected again at about the same time that KSC established ground cooling and further attempts at ABS operation were terminated.

The supply water and waste management systems performed nominally throughout the mission with no anomalies noted, and by the end of the mission all of the associated in-flight checkout requirements that were performed were satisfied.

Supply water was managed through the use of the flash evaporator system (FES). The supply water dump line temperature was maintained between 71°F and 102°F throughout the mission with the operation of the line heater. One overboard supply water dump of 113 lb was performed concurrently with the third waste water dump, and at an average rate of 1.49 percent/minute (2.45 lb/min).

Waste water was gathered at the predicted rate. Four waste water dumps were performed at an average dump rate of 1.93 percent/minute (3.2 lb/min). The waste water dump line temperature was maintained between 54°F and 85°F throughout the mission, while the vacuum vent line temperature was maintained between 57°F and 81.7°F.

The waste collection system operated successfully throughout the mission.

The crew reported that the cabin was warm, and the cabin temperature was indicating 85.6°F at that time. The crew commented that the cabin temperature control valve was not pinned to either the A or B actuator nor was it pinned in a fixed position. The unpinned valve tended to slide over to the "full hot" position. The crew connected the valve to the primary actuator and the actuator moved the valve to the "full cold" position, and the cabin temperature recovered to the desired level. The actuator movement caused a slug of water to pass through the humidity separator (causing a humidity separator alarm) and into the lower equipment bay. The crew later cleaned up the water using the free fluid nozzle. During the water cleanup, the crew was unable to remove the torque tip screws holding the lithium hydroxide (LiOH) box in the middeck. As a result, access to the lower equipment bay was through the MD44F panel. The cabin temperature controller performed nominally throughout the remainder of the mission.

## Smoke Detection and Fire Suppression Subsystems

The smoke detection system parameters remained within normal ranges and showed no indications of smoke generation throughout the mission. The use of the fire suppression system was not required.

## Airlock Support System

All airlock support and tunnel adapter systems performed satisfactorily throughout the mission.

The EVA was performed while maintaining a 14.7-psia cabin pressure which required the EVA crewmembers to perform a 4-hour in-suit prebreathe period. The tunnel adapter C hatch was used to perform the scheduled EVA. This was the first time that the tunnel adapter hatch was used for an EVA, and no problems were noted with the hatch during the EVA.

## Avionics and Software Subsystems

The integrated guidance, navigation, and control performance during the mission was nominal with no problems noted.

The Orbiter performed a successful rendezvous with the EURECA satellite on flight day 4. All elements of the avionics and software subsystems performed in an excellent manner during the rendezvous operations. No control problems encountered during the retrieval activity when in the attitude-hold mode or during maneuvers. All digital autopilot (DAP) control was accomplished using the vernier thrusters with the control acceleration selections required at each specific position. The DAP mode was changed to free as required while the EURECA was being repositioned and berthed.

FCS checkout was performed at 179:07:15 G.m.t. (06:18:08 MET). Aerosurface and controller performance was nominal. The flight control system operated nominally throughout entry and landing with no discrepancies noted.

The inertial measurement unit (IMU) performed satisfactorily as did the star tracker.

The data processing system (DPS) operated satisfactorily throughout the mission with one minor discrepancy occurring after landing. At 182:13:04:49 G.m.t. (approximately 11 minutes after landing), the BFS commanded the S-band phase modulation (PM) system to the lower left aft quad antenna. The BFS was still in the OPS 3 mode while the primary avionics software system (PASS) had already been transitioned to OPS 9 (not controlling). Since BFS state vector calculations are not as accurate as PASS calculations, the SM selected an inappropriate antenna. This switchover was not expected since no ground stations were in view of the antenna and the multiplexer/demultiplexer (MDM) lines had been zero (i.e., no active selection) since shortly before landing. Radiating from the lower antenna is a safety concern, and therefore, the ground controllers commanded the system back to the upper left aft quad antenna. In the future, the ground controllers will inhibit antenna selection either immediately prior to or immediately after landing.

The displays and controls performed nominally. Following the EURECA retrieval, the mid starboard floodlight tripped the RPC on two separate power-on attempts (Flight Problem STS-57-V-07A). The aft starboard floodlight tripped the RPC and failed during the deorbit preparations on the third landing attempt (Flight Problem STS-57-V-7B). The mid port floodlight may also have failed during the deorbit preparations; however, an investigation is still underway to positively ascertain the condition of the floodlight (Flight Problem STS-57-V-7C).

The left aft RCS manifold 3/4/5 crossfeed valve indicated barberpole when the switch was moved to Close from GPC (Flight Problem STS-57-V-12). The crew cycled the switch and the problem cleared. No valves were moved during these switch changes.

During the FCS checkout, the speedbrake command meter (0 to 100 percent) on the SPI had a -7-percent bias, which represented an error of 5/32 inch over a 2-inch scale (Flight Problem STS-57-V-10). Review of the STS-57 turnaround flow data showed the speedbrake command scale had a bias of -5 percent with a turnaround test limit of ± 5 percent. The speedbrake position meter functioned properly. This bias presented no impact to the mission, since other methods (CRT display) were available for the crew to determine the position command to the speedbrake.

## Communications and Tracking Subsystems

During prelaunch preparations for the initial launch attempt, automatic gain control (AGC) excursions were noted on TACAN 1, but these stabilized when a valid channel (59Y) was selected prelaunch. Performance was nominal during on-orbit checks as well as during landing.

The crew reported during ascent that the intercommunications (ICOM) were not operating with Mission Specialists (MS) 1 and 2 (Flight Problem STS-57-V-01). Audio terminal units were switched during ascent in an unsuccessful attempt to regain the ICOM capability. After MECO, the crew reported that ICOM operation was restored with no additional action taken. During entry, the audio ICOM system was configured with MS 2 connected to the Payload Specialist (PS) audio terminal unit (ATU) using the spare headset interface unit (HIU) and MS1 connected to the MS ATU. This configuration was based on laboratory test results that indicated the most likely cause of the ascent ICOM failure was the HIU or the cable between the HIU and the multiple headset adapter.

At 173:13:26:00 G.m.t. (01:00:19:38 MET), the crew reported that no closed circuit television (CCTV) camera B image was appearing on the onboard monitor. Camera power was cycled and the camera was reselected, but again no image was obtained. Later in the mission in preparation for the EVA, camera B was repowered and a usable video picture was obtained. Camera B operation was erratic throughout the remainder of the mission.

The Ku-band radar tracked the EURECA from 149,000 feet to approximately 90 feet with no loss of tracking.

At the West-to-East TDRS hand-over at 176:03:57 G.m.t. (03:14:50 MET), the S-band did not establish a forward link (Flight Problem STS-57-V-05). A good return link was established. During each of the several momentary acquisitions of the forward link, the receive signal strength was low. The transponder, antenna electronics, and power amplifier were switched one-at-a-time from string 2 to string 1 without success. The forward link remained bad for all of orbit 56 East except the last six minutes of the pass. The forward link was regained but experienced intermittent dropouts thereafter, on only the lower left antenna. The lower left antenna consistently exhibited noisy AGC in both high- and low-frequency operation.

Intermittent communications were noted during entry while operating with the TDRS.

The text and graphics system (TAGS) experienced a single-event-upset when operating early in the mission. The TAGS continued to operate properly for the remainder of the mission.

During the crew debriefings, the crew reported that dropouts had been experienced on the wireless communications when operating through the audio interface unit (AIU) -C wall unit (Flight Problem STS-57-V-19).

The operational instrumentation operated satisfactorily throughout the mission; however, prior to the deorbit maneuver, the modular auxiliary data system (MADS) recorder was commanded on but the tape did not move (Flight Problem STS-57-V-16). After the deorbit maneuver, the MADS recorder was again commanded on and tape movement was noted. It is suspected that a "sticky" tape problem existed. As a result, the deorbit maneuver data were lost, but all other MADS data were recorded.

## Structures and Mechanical Systems

All structures and mechanical systems operated nominally. During the postflight inspection, a 15-inch piece of foam material was found adhered to the $LH_2$ umbilical plate near the 4-inch disconnect (Flight Problem STS-57-V-17A). In addition, a piece of foam material was found lodged between the edge member and the thermal barrier on the right-hand ET door hinge line (Flight Problem STS-57-V-17B). Neither of these pieces of material impacted the entry operations.

Following the initial 24-hour delay in the planned landing and while operating in the BFS, the starboard forward bulkhead latch release A microswitch, the centerline latch gang 5-8 release A microswitch, and the port forward bulkhead latch release B microswitch failed to indicate open after reopening the door (Flight Problem STS-57-V-14A, B, and C). These mechanisms were confirmed released by their redundant microswitches and by observing slip currents on the motors associated with the failed indications. All indications recovered to the correct configuration within 30 minutes after the opening procedure was completed. The microswitches performed nominally during the deorbit preparations backout after the second landing delay 24 hours later.

This flight marked the eighth use of the drag chute. The drag chute was used in the 90-percent disreef configuration during this landing with good results. The drag chute was deployed as planned as 182:12:52:25.3 G.m.t. (prior to nose gear touchdown) and the drag chute was jettisoned 31.8 seconds later.

The landing and braking data are presented in the table on the following page.

## Aerodynamics, Heating, and Thermal Interfaces

The ascent and entry aerodynamics were nominal. Aerodynamic and plume heating was nominal with no anomalous conditions noted. The thermal interface temperatures were nominal and all within limits.

LANDING AND BRAKING PARAMETERS

| Parameter | From threshold, ft | Speed, keas | Sink rate, ft/sec | Pitch rate, deg/sec |
|---|---|---|---|---|
| Main gear touchdown | 2305 | 206.1 | ~1.9 | n/a |
| Nose gear touchdown | 7499 | 135.8 | n/a | 2.92 |

| | |
|---|---|
| Braking initiation speed | 101.1 knots (keas) |
| Brake-on time | 37.4 seconds (sustained) |
| Rollout distance | 9,946 feet |
| Rollout time | 65.0 seconds |
| Runway | 33 (concrete) at KSC |
| Orbiter weight at landing | 224,459 lb (landing estimate) |

| Brake sensor location | Peak pressure, psia | Brake assembly | Energy, million ft-lb |
|---|---|---|---|
| Left-hand inboard 1 | 1128 | Left-hand outboard | 19.90 |
| Left-hand inboard 3 | 1176 | Left-hand inboard | 19.09 |
| Left-hand outboard 2 | 1188 | Right-hand inboard | 11.42 |
| Left-hand outboard 4 | 1176 | Right-hand outboard | 8.84 |
| Right-hand inboard 1 | 1092 | | |
| Right-hand inboard 3 | 1008 | | |
| Right-hand outboard 2 | 972 | | |
| Right-hand outboard 4 | 936 | | |

## Thermal Control Subsystem

The performance of the thermal control subsystem (TCS) was nominal throughout the mission with only one heater failure. The RCS aft vernier thruster R5D heater failed on. This problem is discussed in the Reaction Control Subsystem Section of this Report.

The tunnel adapter C hatch thermal cover came loose and opened during launch. Similar occurrences of this condition have been observed on STS-40 and STS-55. The loose thermal cover did not affect the mission and the cover was closed at the end of the EVA. A design change that will add two more retention straps (total of seven) of Velcro as well as replace the current Velcro with a type having a higher peel strength is being implemented to rectify this condition for the next tunnel adapter flight (STS-58).

## Aerothermodynamics

Local and acreage heating was nominal with all recorded temperatures within the experience base. Several gap fillers were found protruding from the surface of the Orbiter near the forward centerline.

## Thermal Protection Subsystem

The thermal protection subsystem (TPS) performed satisfactorily throughout the mission based on structural temperature response data. The overall boundary layer transition from laminar to turbulent flow was symmetric. Transition occurred 1260 seconds after entry interface on the forward portion of the vehicle and also 1260 seconds after entry interface on the aft portion of the vehicle.

Debris impact damage was lower than average, with 75 impacts on the lower surface of the vehicle and a total of 106 hits on all surfaces of the vehicle of which 12 had a major dimension of one inch or greater. The number of impacts on the lower surface with a major dimension of one inch or greater was 10, which is much lower than the average. Three tiles were removed and replaced due to impact damage. This includes the aft stinger drain tile which was damaged during drag chute deployment.

The chin-panel to nose-cap gap was again excessively large after landing. The gap filler was breached for two inches. This gap filler was custom designed to fill the excessive chin-panel-to-nose-cap gap. The chin panel will be shimmed during the next flow to reduce this gap.

Two aft-edge nose landing gear door (NLGD) tiles were damaged and will be repaired. The primary NLGD thermal barrier was in good condition; however, the secondary barrier had a small breach at the right-hand forward edge. There was no evidence of flow, indicating that the damage probably occurred when the NLGD opened. Approximately 10 NLGD thermal barriers were breached and/or worn enough to warrant replacement. Two protruding Ames gap fillers were noted on the lower surface, one aft of the reusable carbon carbon (RCC) arrowhead and one on the right-hand chine area.

The main landing gear door (MLGD) thermal barriers were in good condition except for one protruding barrier on the left-hand door. The ET door thermal barriers were also in good condition. Minor edge slumping was noted on two tiles at the left-hand elevon-elevon gap. These tiles will be replaced due to a forward facing step, which may have contributed to the slumping.

The SSME 1 dome-mounted heat-shield blanket was frayed at the 6 and 8 o'clock positions. Base heat shield peppering was moderate. The elevon cove, payload bay doors, upper wing, and OMS pod TPS performance was nominal.

The Shuttle thermal imager was used to measure the surface temperatures of several areas on the vehicle in accordance with OMRSD requirements. Twenty-one minutes after landing, the Orbiter nosecap RCC temperature was 179°F. The right-hand wing leading edge RCC panel 9 temperature was 140°F when measured three minutes after the previous measurement, and the temperature of panel 17 was 127°F.

The Orbiter windows 2, 3, 4, and 5 exhibited moderate hazing. Only a light haze was present on the other Orbiter windows. Some streaks were visible on windows 2, 3, and 4. Surface vipes were taken from all windows for laboratory analysis.

## REMOTE MANIPULATOR SYSTEM

Overall RMS performance was very satisfactory throughout the mission. Retrieval of the EURECA was the primary RMS objective for this mission. The RMS was also used during EVA in support of DTO 1210, which was an evaluation of the RMS/EVA interaction for the Hubble Space Telescope repair mission (STS-61). During the mission, no RMS or end effector anomalies were noted, although one in-flight anomaly was logged on the RMS special purpose end effector (SPEE) connector.

The RMS checkout was successfully performed between 173:13:28 G.m.t. (01:00:20 MET) and 173:14:54 G.m.t. (01:01:47 MET). During the checkout, the RMS was initialized with the shoulder brace released and with GPC temperature monitoring. At the end of the procedure when using the RMS Select switch to deselect the port arm, an ABE COMM fault message occurred. Data sent by the manipulator controller interface unit (MCIU) to the arm is echoed back to the MCIU on a one-directional, serial data bus looping from the MCIU to the arm-based electronics (ABE) and then back to the MCIU. In the MCIU's ABE communication algorithm, the returned data are checked against the original data. A mismatch between the signals annunciates the ABE COMM message. This algorithm runs whenever the MCIU senses that the +28V arm power flag running from the RMS Select switch through the port arm and back to the MCIU is above a threshold level of +7V. An investigation indicates that the ABE began to power down at about 17 volts, sending zeroed or garbled data back to the MCIU. The time constant of the power-on-flag line voltage drop from 17 to 7 volts can vary depending on the capacitance in the ABE and can be longer than a 126-millisecond MCIU inhibit of the ABE COMM annunciation flag to the GPC. Review of previous flight data showed several instances on six flights of the ABE COMM being set for one general purpose computer (GPC) cycle after the RMS was powered down. Since the flag was set for only one GPC cycle, no alarm occurred as the command must be present for two GPC cycles to cause an alarm. In addition, a review of KSC checkout data revealed instances of ABE COMM also being set for one cycle on the last three processing flows. It was established that the message occurrence posed no threat to the flight and may be received randomly on future arm selections.

Approximately 24 hours into the flight, a successful RMS checkout was performed per standard procedures. This was followed by a payload bay survey with the wrist CCTV camera to familiarize the RMS operators with the flight system.

Three days into the mission, the RMS was powered up for EURECA retrieval operations. EURECA was deployed with the RMS about 11 months earlier during the STS-46 mission, and the EURECA was successfully grappled by the RMS at 175:13:53 G.m.t. (03:00:6 MET). As planned, EURECA's solar arrays were retracted prior to berthing, but two antennae failed to achieve ready-to-latch indications. The decision was made to berth the payload and secure the antennae during the next day's planned EVA. The antennae were sufficiently retracted to cause no clearance concern and the berthing operation was completed successfully.

During the retrieval and berthing process, an unsuccessful attempt was made to apply +28V Orbiter power to EURECA through the SPEE connector on the end effector (EE). This capability was used during the deployment mission and the STS-57 attempt was performed to verify the capability for the contingency of an inability to supply +28V Orbiter power to EURECA through the remotely operated electrical umbilical (ROEU) once the payload was berthed and latched. When SPEE power transfer was activated via the Orbiter's standard switch panel, EURECA provided no response that power was received (Flight Problem STS-57-V-11). A review of on-orbit video of the EE during the RMS checkout provided a positive indication that the SPEE connector was mounted upside down on the EE and was unable to mate with the complementary connector on EURECA's electrical flight-releasable grapple fixture (EFGF). This was the third flight of this EE (S/N 401), but the first flight on which there was SPEE utilization. The condition did not impact the accomplishment of the STS-57 flight objectives as the ROEU mated correctly.

The RMS supported the EVA on the following flight day. The EVA was originally planned in support of DTO 1210; however, the primary goal of the EVA became the latching of the EURECA antennae and the DTO became secondary. Both objectives required maneuvering crewmen on the end of the arm in the manipulator foot restraint (MFR). The antennae were successfully latched and many of the DTO 1210 planned activities were accomplished. After the EVA, the arm was cradled, latched, and stowed as no more RMS activities were planned for the mission.

## EXTRAVEHICULAR ACTIVITY

The preflight planned EMU battery change-out IFM procedure was performed at 174:12:37 G.m.t. (01:12:37 MET). Battery serial no. 1190 was installed in place of serial no. 1202 in EMU 2 as planned preflight. The crew member making the change reported what appeared to be two small patches of white crystals on the top of the removed battery. Based on the report, these patches were assumed to be a slight electrolyte leak and per existing procedures, the battery was bagged and stowed for examination on the ground. The possibility of an EMU battery leak caused by an epoxy crack was identified preflight, and a spare battery was stowed onboard for this EMU.

EMU equipment preparation and checkout for the STS-57 EVA were completed on flight day 3. During the checkout operations, one EMU waist tether hook was found to be locked in the open position and would not close (Flight Problem STS-57-V-04). This tether hook was replaced by a shackle taken from one of the service and cooling umbilical (SCU) tethers. This replacement created a permanent mount for the tether on the EMU. At the completion of the checkout operations, the EMU's were considered ready to support the planned EVA.

On flight day 5, the two extravehicular (EV) crew members donned the EMU's and performed the four-hour prebreathe prior to depressing the tunnel adapter and beginning the EVA. During the prebreathe period, each suited crew member disconnected from their SCU and performed a short familiarization operation that was designed to help each crewman evaluate EMU operations in a microgravity environment. While performing these operations, the EV 1 crewman was disconnected from the SCU for approximately 18.5 minutes and the EV 2 crewman was disconnected from the SCU for approximately 23.8 minutes.

At the completion of the four-hour prebreathe period, the tunnel adapter was depressurized to 5.0 psia. Following the programmed suit leak check at 5.0 psia, both crewmen placed their oxygen actuators in the EVA position. While performing this operation, the EV 2 crewman encountered some difficulty that delayed his achieving the EVA position for approximately 3 minutes. At the same time, the tunnel adapter pressure rose approximately 0.60 psi. This caused the caution and warning system on EMU 1 to transition to an X-state of 8 (believing that an airlock repressurization was in progress) and issue the "set $O_2$ to Press" message on the display and control module display. this is an appropriate action for the caution and warning system to take under these circumstances and is not considered to be a problem. EV 2 did not receive this message due to the delay in going to the EVA position.

Following depressurization of the tunnel adapter to vacuum, EV 1 and 2 ingressed the payload bay and proceeded with the stowage of the antenna on the EURECA payload. Following antenna stowage, the crewmen continued with selected operations from the EVA plan.

Over the course of the 5-hour 50-minute EVA, the EMU's performed nominally and no anomalies were noted. At the completion of the EVA, the crewmen ingressed the tunnel adapter and repressurized the adapter to 14.7 psia. At cabin pressure, the EMU's were doffed and maintenance/recharge operations were performed.

## FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

All flight crew equipment operated satisfactorily, and the tools supported the tools and diagnostics system experiments in the Spacehab in a very satisfactory manner.

## CARGO INTEGRATION

The inability of the RMS SPEE to connect electrically with the EURECA payload occurred during the retrieval grapple maneuver on flight day 4. This failure prevented the application of power to the payload thermal unit, resulting in a potential hydrazine freezing hazard. Orbiter positioning for optimum solar influence resolved this concern. The upside down mounting of the SPEE was confirmed. This condition did not impact payload operations as the ROEU electrical umbilical operated properly. This was the first ROEU use with a payload launched on a previous Shuttle mission.

## DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

### DEVELOPMENT TEST OBJECTIVES

Sixteen DTO's were assigned to this mission. Data were collected on 14 of these DTO's.

DTO 301D - Ascent Structural Capability Evaluation - Data were collected for this DTO on the MADS recorder, and the data have been given to the sponsor for evaluation. The results of the data evaluation will be reported in separate documentation.

DTO 305D - Ascent Compartment Venting Evaluation - Data were collected for this DTO on the MADS recorder, and the data have been given to the sponsor for evaluation. The results of the data evaluation will be reported in separate documentation.

DTO 306D - Descent Compartment Venting Evaluation - Data were collected for this DTO on the MADS recorder, and the data have been given to the sponsor for evaluation. The results of the data evaluation will be reported in separate documentation.

DTO 307D - Entry Structural Capability - Data were collected for this DTO on the MADS recorder, and the data have been given to the sponsor for evaluation. The results of the data evaluation will be reported in separate documentation.

DTO 312 - ET TPS Performance (Method 1 without +X translation, and 3 with 2X converter) - In addition to the still photography normally obtained for this DTO, the crew was able to obtain about 3 minutes of camcorder imagery of the ET. This imagery ranged over a 5-minute period with about a 2-minute time lapse. This was the first camcorder imagery of an ET during the Space Shuttle Program. The ET appeared to be in good condition with possible divots noted on the $LH_2$ tank/intertank closeout flange. The ET nose, portions of the ET aft dome, and a majority of the left hemisphere of the ET (from the Orbiter perspective) were visible in the camcorder views. Using three of the camcorder views, it was verified that the video was being taken at 30 frames per second. Based on this information, the rotational velocity was calculated to be 0.58 deg/sec.

One roll of excellent quality 35-mm film of the ET was taken with the designated camera, a 300-mm lens, and a 2X extender. Thirty-seven views of the ET were acquired. The views were of the ET aft dome, +Z axis (side of ET near the Orbiter), the -Y axis (left SRB side of ET), the nose, and -Z axis (side of ET away from Orbiter). The pictures have excellent exposure and, for the most part, have very sharp focus. The first picture was taken about 15 minutes after lift-off and the last picture was taken about 6 1/2 minutes later. Observations made from these photographs are as follows:

a. Nine or ten divots are visible on the ET intertank TPS acreage to the right of the forward left SRB attachment point (-Y axis).

b. A divot is visible on the ET intertank/$LH_2$ tank interface flange closeout (below and to the left of the ET access door) on the -Y/+Z axis. A second divot is visible on the interface flange closeout below the left SRB attachment point. Three more divots can be seen above this interface divot on the intertank TPS.

c. A divot is visible on an aft vertical support brace near the $LH_2$ umbilical.

d. Numerous scar marks or possible small divots are visible on the intertank TPS just above the forward ET/Orbiter attachment bipod (+Z axis).

e. Pieces of white debris (probably ice) are visible in the background on many of the views.

The 16 mm motion picture film taken from the Orbiter $LH_2$ umbilical well was reviewed. The view from the camera was of the left SRB and ET separation and it also showed the normal venting and debris associated with those events. The left SRB separation sequence frames showed multiple pieces of light-colored TPS debris of various shapes and sizes before, during, and after the separation.

The ET frames show multiple pieces of white debris (ice/frost) and white vapors. After the ET separation from the Orbiter, a piece of loose insulation or foam is visible on the view of the inboard side of the ET $LH_2$ umbilical. This piece of foam is over 20 inches long and 4 inches wide. Also, a slender piece of white debris that appeared to be flexing is visible on the left side of the film view of the ET $LH_2$ umbilical after ET separation. Very small pieces of debris were noted inside the umbilical well camera housing. Pieces of white debris continued to move across the field of view until the end of the film.

A total of 64 well-focused 35 mm frames of the ET separation were obtained. The only significant finding was the appearance of possible TPS damage or a piece of loose insulation near the upper left corner of the $LO_2$ umbilical. This possible loose insulation may be related to a three-inch piece of ET foam that was found during the postlanding inspection of the $LO_2$ umbilical.

DTO 412 - Fuel Cell On-Orbit Shutdown/Restart (Fuel Cell 3) - DTO 412 was aborted when the fuel cell 3 hydrogen reactant valve failed to close upon command. Fuel cell 3 was initially shut down at 177:11:49:52 G.m.t. (04:22:42:30 MET). With the fuel cell shutdown, the CPM that detected hydrogen/oxygen crossover was powered off. To limit the amount of reactants that could feed an undetected crossover, the reactant valves are normally closed. Both valves are controlled by the same onboard switch. The hydrogen and oxygen reactant valves were commanded closed at 177:11:50:52 G.m.t. (04:22:43:00 MET), but the hydrogen reactant valve indicated that it was still open. The valves were commanded open at 177:11:51:40 G.m.t. (04:22:43:48 MET), followed by the second attempt to close the valves 6 seconds later. Again the hydrogen valve did not close. With the hydrogen valve open and the oxygen valve closed, a potential existed for hydrogen over-pressurization which could damage the fuel cell. The valves were reopened and the fuel cell was restarted at 177:11:55:42 G.m.t. (04:22:48:20 MET).

DTO 414 - APU Shutdown Test (Sequence A) - The APU's were shut down in serial order (3, 1, 2) with at least 5 seconds between individual APU shutdowns after ascent. No hydraulic motor backdrive symptoms were detected during the shut-down sequence nor were any anomalous pressure hang-ups noted. The sponsor has the data from the shut-down, and the data are being evaluated. The results of that evaluation will be reported in separate documentation.

DTO 521 - Orbiter Drag Chute System - The 90-percent disreefed drag chute was deployed as planned after the beginning of derotation but prior to nose gear touchdown. The drag chute operated properly and the data have been given to the sponsor for evaluation. The results of this evaluation will be reported in separate documentation.

DTO 623 - Cabin Air Monitoring - Air sampling was performed for this DTO and the data have been given to the sponsor for evaluation. The results of the data evaluation will be reported in separate documentation.

DTO 662 - EDO WCS Evaluation - Data were gathered for this DTO from the crew by the sponsor, and the data are being evaluated. The results of the data evaluation will be reported in separate documentation.

DTO 663 - Acoustical Noise Dosimeter Data - One hour of acoustical noise data were collected during the last hour of EMU battery charger operation. These data have been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

DTO 665 - Acoustical Noise Sound Level Data (Using Sound Level Meter) - These measurements were made during the EMU battery charger operation. The data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DTO 671 - EVA Hardware for Future Scheduled EVA Missions (14.7-psia Prebreathe Protocol) - Data were gathered for this DTO during the 5-hour 50-minute EVA that was conducted on flight day 5. These data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DTO 700-2 - Laser Range and Range Rate Device - No data were collected for this DTO because of crew time constraints during the rendezvous operations.

DTO 805 - Crosswind Landing Performance - No data were collected for this DTO as crosswinds were not of the required magnitude for the DTO.

DTO 1210 - EVA Operations Protocol/Training (14.7-psia Prebreathe Protocol) - This DTO was accomplished by the 5-hour 50-minute EVA on flight day 5. The crew provided data to the sponsor for evaluation. The results of this DTO will be reported in separate documentation.

## DETAILED SUPPLEMENTARY OBJECTIVES

DSO 485 - Inter Mars Tissue Equivalent Proportional Counter (ITEPC) - This equipment was activated in accordance with the timeline and deactivated 6 hours prior to the deorbit maneuver. The sponsor has the data for evaluation. The results of that evaluation will be reported in separate documentation.

DSO 603 - Orthostatic Function During Entry, Landing, and Egress (0603B Schedule) - This DSO was completed and the sponsor is evaluating the data. The results of that evaluation will be reported in separate documentation.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation (Investigations OI-1 and OI-3) - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DSO 614 - The Effect of Prolonged Space Flight on Head and Gaze Stability During Locomotion - Data were collected during preflight and postflight operations and the data are being evaluated by the sponsor. The results of that evaluation will be reported in separate documentation.

DSO 618 - Effects of Intense Exercise During Space Flight on Aerobic Capacity and Orthostatic Function - Data were collected on flight day 3, 8, and 10. The data are being evaluated by the sponsor, and the results will be reported in separate documentation.

DSO 624 - Pre and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise - Some data were collected for this DTO; however, the planned data collection period on flight day 3 was not completed.

DSO 625 - Measurement of Blood Volumes Before and After Space Flight - The required preflight data could not be completely collected. Consequently, the landing day and other postflight data were not collected for this DSO.

DSO 626 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight - The required preflight data could not be completely collected for this DSO. Consequently, the landing day and other postflight data were not collected for this DSO.

DSO 901 - Documentary Television - Video was taken throughout the mission for general documentary usage. This video is being evaluated by the sponsor.

DSO 902 - Documentary Motion Picture Photography - Motion picture photography was taken throughout the mission for general documentary usage. This photography is being evaluated by the sponsor.

DSO 903 - Documentary Still Photography - Still photography was taken throughout the mission using a variety of cameras. This photography is being evaluated by the sponsor.

## PHOTOGRAPHY AND TELEVISION ANALYSIS

### LAUNCH PHOTOGRAPHIC AND VIDEO DATA ANALYSIS

A total of 24 videos were screened from the launch. In addition, 53 of the planned 56 films were reviewed. Three cameras, E54, E57, and E213, did not run. The screening of the long-range tracking film and videos was hampered by clouds. No anomalies were noted during the screening of the video and films.

### ON-ORBIT PHOTOGRAPHIC AND VIDEO DATA ANALYSIS

The on-orbit photographic films of the ET for DTO 312 are discussed in the Development Test Objectives section of this report. No other on-orbit film or video analysis was required.

### LANDING PHOTOGRAPHIC AND VIDEO DATA ANALYSIS

Ten videos in addition to NASA Select video of the Orbiter approach and landing were analyzed. No significant anomalies were noted from the screening.

TABLE I.- STS-57 SEQUENCE OF EVENTS

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| APU activation | APU-1 GG chamber pressure | 172:13:02:33.93 |
| | APU-2 GG chamber pressure | 172:13:02:34.75 |
| | APU-3 GG chamber pressure | 172:13:02:35.56 |
| SRB HPU activation[a] | LH HPU system A start command | 172:13:06:54.169 |
| | LH HPU system B start command | 172:13:06:54.329 |
| | RH HPU system A start command | 172:13:06:54.489 |
| | RH HPU system B start command | 172:13:06:54.609 |
| Main propulsion System start[a] | Engine 1 start command accepted | 172:13:07:15.429 |
| | Engine 2 start command accepted | 172:13:07:15.556 |
| | Engine 3 start command accepted | 172:13:07:15.672 |
| SRB ignition command (lift-off) | SRB ignition command to SRB | 172:13:07:21.989 |
| Throttle up to 100 percent thrust[a] | Engine 3 command accepted | 172:13:07:25.910 |
| | Engine 1 command accepted | 172:13:07:25.912 |
| | Engine 2 command accepted | 172:13:07:25.916 |
| Throttle down to 72 percent thrust[a] | Engine 3 command accepted | 172:13:07:51.030 |
| | Engine 1 command accepted | 172:13:07:51.032 |
| | Engine 2 command accepted | 172:13:07:51.037 |
| Maximum dynamic pressure (q) | Derived ascent dynamic pressure | 172:13:08:14 |
| Throttle up to 104 percent thrust[a] | Engine 3 command accepted | 172:13:08:21.591 |
| | Engine 1 command accepted | 172:13:08:21.593 |
| | Engine 2 command accepted | 172:13:08:21.597 |
| Both SRM's chamber pressure at 50 psi[a] | LH SRM chamber pressure mid-range select | 172:13:09:21.629 |
| | RH SRM chamber pressure mid-range select | 172:13:09:21.749 |
| End SRM action[a] | RH SRM chamber pressure mid-range select | 172:13:09:24.079 |
| | LH SRM chamber pressure mid-range select | 172:13:09:24.219 |
| SRB separation command | SRB separation command flag | 172:13:09:27 |
| SRB physical separation[a] | LH rate APU A turbine speed LOS | 172:13:09:26.749 |
| | RH rate APU A turbine speed LOS | 172:13:09:26.749 |
| Throttle down for 3g acceleration[a] | Engine 1 command accepted | 172:13:14:53.438 |
| | Engine 3 command accepted | 172:13:14:53.440 |
| | Engine 2 command accepted | 172:13:14:53.444 |
| 3g acceleration | Total load factor | 172:13:14:53.4 |
| Throttle down to 67 percent thrust[a] | Engine 1 command accepted | 172:13:15:47.839 |
| | Engine 3 command accepted | 172:13:15:47.841 |
| | Engine 2 command accepted | 172:13:15:47.845 |
| Engine Shutdown[a] | Engine 1 command accept | 172:13:15:54.199 |
| | Engine 3 command accept | 172:13:15:54.201 |
| | Engine 2 command accept | 172:13:15:54.206 |
| MECO | Command flag | 172:13:15:55 |
| | Confirm flag | 172:13:15:56 |
| ET separation | ET separation command flag | 172:13:16:14 |

[a]MSFC supplied data

TABLE I.- STS-57 SEQUENCE OF EVENTS (Continued)

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| OMS-1 ignition | Left engine bi-prop valve position | Not performed - direct insertion trajectory flown |
| | Right engine bi-prop valve position | |
| OMS-1 cutoff | Left engine bi-prop valve position | |
| | Right engine bi-prop valve position | |
| APU deactivation | APU-3 GG chamber pressure | 172:13:23:47.73 |
| | APU-1 GG chamber pressure | 172:13:24:05.56 |
| | APU-2 GG chamber pressure | 172:13:24:15.81 |
| OMS-2 ignition | Right engine bi-prop valve position | 172:13:49:34.7 |
| | Left engine bi-prop valve position | 172:13:49:34.7 |
| OMS-2 cutoff | Right engine bi-prop valve position | 172:13:52:53.3 |
| | Left engine bi-prop valve position | 172:13:52:53.3 |
| Payload bay door open | PLBD right open 1 | 172:14:38:38 |
| | PLBD left open 1 | 172:14:39:57 |
| OMS-3 ignition | Right engine bi-prop valve position | |
| | Left engine bi-prop valve position | 174:17:07:58.2 |
| OMS-3 cutoff | Right engine bi-prop valve position | |
| | Left engine bi-prop valve position | 174:17:09:06.2 |
| EURECA grapple | Payload capture flag | 175:13:53:25 |
| EURECA berthing | Payload latch 1A latched indication | 175:16:44:32 |
| OMS-4 ignition | Left engine bi-prop valve position | 176:08:08:56.4 |
| | Right engine bi-prop valve position | 176:08:08:56.5 |
| OMS-4 cutoff | Left engine bi-prop valve position | 176:08:09:48.0 |
| | Right engine bi-prop valve position | 176:08:09:48.1 |
| Airlock depressurization | Airlock differential pressure 1 | 176:13:02:38 |
| Airlock repressurization | Airlock differential pressure 1 | 176:18:56:42 |
| Fuel cell 3 shutdown | Fuel cell no. 3 ready | 177:11:49:52 |
| Fuel cell 3 power-up | Fuel cell powerplant 3 $O_2$ reactant valve open | 177:11:52:23 |

TABLE I.- STS-57 SEQUENCE OF EVENTS (Concluded)

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| Flight control system checkout | | |
| APU start | APU-1 GG chamber pressure | 179:07:15:45.57 |
| APU stop | APU-1 GG chamber pressure | 179:07:20:34.46 |
| Payload bay door 1 close | PLBD left close 1 | 180:08:58:04 |
| | PLBD right close 1 | 180:09:00:21 |
| Payload bay door 2 close | PLBD left close 1 | 181:08:06:19 |
| | PLBD right close 1 | 181:08:08:02 |
| Payload bay door 3 close | PLBD left close 1 | 182:09:11:53 |
| | PLBD right close 1 | 182:09:13:33 |
| APU activation for entry | APU-2 GG chamber pressure | 182:11:36:47.32 |
| | APU-1 GG chamber pressure | 182:12:08:21.91 |
| | APU-3 GG chamber pressure | 182:12:08:23.24 |
| Deorbit maneuver ignition | Right engine bi-prop valve position | 182:11:41:42.2 |
| | Left engine bi-prop valve position | 182:11:41:42.2 |
| Deorbit maneuver cutoff | Right engine bi-prop valve position | 182:11:45:55.9 |
| | Left engine bi-prop valve position | 182:11:45:55.9 |
| Entry interface (400K) | Current orbital altitude above reference ellipsoid | 182:12:21:12 |
| Blackout ends | Data locked at high sample rate | No blackout |
| Terminal area energy management | Major mode change (305) | 182:12:45:53 |
| Main landing gear contact | LH MLG tire pressure | 182:12:52:16 |
| | RH MLG tire pressure | 182:12:52:16 |
| Main landing gear weight on wheels | LH MLG weight on wheels | 182:12:52:16 |
| | RH MLG weight on wheels | 182:12:52:16 |
| Drag chute deploy | Drag chute deploy 1 CP Volts | 182:12:52:25.5 |
| Nose landing gear contact | NLG tire pressure | 182:12:52:34 |
| Nose landing gear weight on wheels | NLG WT on Wheels -1 | 182:12:52:34 |
| Drag chute jettison | Drag chute jettison 1 CP Volts | 182:12:52:57.1 |
| Wheels stop | Velocity with respect to runway | 182:12:53:21 |
| APU deactivation | APU-1 GG chamber pressure | 182:13:14:26.63 |
| | APU-2 GG chamber pressure | 182:13:14:27.61 |
| | APU-3 GG chamber pressure | 182:13:14:28.62 |

TABLE II.- STS-57 PROBLEM TRACKING LIST

| Number | Title | Reference | Comments |
|---|---|---|---|
| STS-57-V-01 | Mission Specialists 1 and 2 Intercommunications Transmit Levels Low With Intermittent Dropouts During Ascent.<br><br>Level III closure. | 172:13:10 G.m.t.<br>IM 57RF01<br>IPR 61V-0003 | Mission Specialists 1 and 2 experienced intermittent dropouts on intercommunications during ascent at approximately the 2 g level. Crew switched to backup ATU and to ACCU 2 without success, then returned to normal configuration. Intercommunications capability returned after MECO. Suspect intermittent problem with MHA, HIU, or cable between the MHA and HIU. Crew has tagged suspect hardware. Entry configuration will have MS2 plug into the PS ATU and MS1 plug into MS ATU. |
| STS-57-V-02 | $PPO_2$ Sensor B Biased Low | 172:17:58 G.m.t.<br>PR ECL-5-05-0320 | Sensor B indicates approximately 0.14 to 0.18 psi lower than A and C sensors. Prelaunch bias was 0.06 to 0.08 psi (LCC and Flight Rules < 0.15 psi). Sensor has been inhibited from onboard computation. Old sensor design.<br>KSC: Normal replacement procedures during postflight turnaround activities. |
| STS-57-V-03 | PRSD Oxygen Manifold 1 Isolation Valve Failed to Close | 172:19:17 G.m.t.<br>IM 57RF05 | Valve failed to close when configuring for sleep. Isolation valve operated successfully during $O_2$ PRSD manifold valve cycle test. (180:04:04 G.m.t.). This condition has occurred previously on OV-105 (STS-49 and STS-54), and has also occurred on OV-104 (STS-34 and STS-37). The condition could not be reproduced on the ground. Deferred UA-5-A0002 still open. The O2 manifold 2 isolation valve from OV-104 is presently at NSLD being tested. Anomaly repeated. Potential vehicle modification for STS-61 to add instrumentation to valve coils. Reference open CAR 37RF-03-010. |
| STS-57-V-04 | EVA Waist Tether Hook Failure (GFE) | 174:21:17 G.m.t.<br>DR BE 130089 | During EMU checkout, the crew discovered that the waist tether small tether hook (S/N 181) would not lock closed. The lock/lock buttons do pop out, but the tether hook does not lock. Workaround IFM was performed. |
| STS-57-V-05 | S-Band Intermittent Losses of Forward and Return Link Using The Lower Left Quad Antenna | 176:03:57 G.m.t.<br>IM 57RF-02<br>IPR 61V-0005 | At West to East TDRS handover on orbit 56E, the S-band did not establish a forward link. The forward link remained bad for the orbit 56E pass except for the last 6 minutes of the pass. Forward and return link dropouts occurred at other times using the lower left quad antenna. Link dropouts occurred in both high and low frequency modes.<br>KSC: Troubleshoot to define anomaly. |
| STS-57-V-06 | Fuel Cell 3 $H_2$ Reactant Valve Failed to Close<br><br>STS-51 FRR Topic | 177:11:49:51 G.m.t.<br>IM 57RF-03<br>IPR 61V-0004 | During the fuel cell 3 shutdown/restart (DTO 412), fuel cell 3 $H_2$ reactant valve failed to close. A second attempt to close the valve yielded the same result. The DTO was not performed on fuel cell 3. Valve is similar design to $O_2$ manifold valve (reference STS-57-V-03). Valve was successfully closed and opened during postlanding test. |

TABLE II.- STS-57 PROBLEM TRACKING LIST

| Number | Title | Reference | Comments |
|---|---|---|---|
| STS-57-V-07 | Payload Bay Floodlight Failures:<br>A. Mid Starboard<br>B. Aft Starboard<br>C) Mid Port | 175:15:09:20 G.m.t.<br>A) IPR 61V-0006<br>IM 57RF-04<br>B) IPR 61V-0014<br>IM 57RF-10<br>C) IPR 61V-0015<br>IM 57RF-11 | During payload bay floodlight operations, a RPC overcurrent trip signature was noted on main C MPC3. At this point, it was uncertain which MID MNC floodlight (aft port or mid starboard) had failed. During EVA, a RPC trip signature was again observed on MID MNC, and the mid starboard floodlight was the only light powered by MID MPC (port aft switched off). EVA crew verified mid starboard light not illuminated. During final payload bay door closing, the crew reported the aft starboard and mid port lights inoperative. The forward bulkhead is the only floodlight verified to have worked. |
| STS-57-V-08 | MCA Power AC3 MID 4 Circuit Breaker Anomaly | 176:19:14 G.m.t.<br>PR DDC-0046<br>IM 57RF-13 | The crew reported circuit breaker 13 on panel MA73 would not remain closed when pushed in. Data indicated no circuit anomalies. Subsequent attempt to close circuit breaker with greater force successful. Suspect mechanical malfunction of the breaker.<br>KSC: Test closing force of circuit breaker. |
| STS-57-V-09 | RJDA 1 L1/R1 Manifold Driver Switch Failure | 175:18:21 G.m.t.<br>PR DDC-0047<br>IM 57RF-06 | Review of data concerning the RJDA 1 L1/R1 manifold driver (switch S4, panel 015) indicates all four poles opened when the switch was placed off for the Group B power-down. One pole subsequently remade contact while the other three remained open.<br>KSC: Remove and replace switch. Spare available. |
| STS-57-V-10 | Surface Position Indicator Speedbrake Command Bias | 179:08:07 G.m.t.<br>PR DIG-0044<br>IM 57RF-12 | During FCS checkout, the surface position indicator command indicator was 7 percent low (should be no greater than 5 percent). Indication was near limit on previous turnaround test.<br>KSC: Surface position indicator removed and replaced. |
| STS-57-V-11 | RMS to Payload Power Transfer Failure | 175:14:58 G.m.t. | Crew reported no data received at standard switch panel after EURECA was captured and rigidized. This condition is indicative of failure to transfer power from the Orbiter to payload through the special purpose end effector (SPEE) connector. Analysis of downlink video revealed SPEE connectors installed incorrectly, therefore, impossible to mate. No mission impact. Power transfer later completed via ROEU.<br>KSC: Inspection confirms incorrect mounting. No apparent damage. |
| STS-57-V-12 | LRCS Crossfeed 3/4/5 Switch Talkback Failure | 180:13:22 G.m.t.<br>IPR 61V-0012 | During the RCS reconfiguration, the crew moved the LRCS 3/4/5 crossfeed switch 33 on panel 07 from GPC to close. Indicator showed barberpole. Telemetry indicated a nominal close switch and valve configuration. Suspect intermittent indicator failure.<br>KSC: Troubleshooting will be performed. |
| STS-57-V-13 | Thruster R5D Heater Failed On. | 180:09:44 G.m.t.<br>PR RP04-0361<br>IM 57RF-09 | Injector temperature decay rate during periods of no thruster firings are indicative of failed-on heater.<br>KSC: Thruster removal planned for controller replacement. |

TABLE II.- STS-57 PROBLEM TRACKING LIST

| Number | Title | Reference | Comments |
|---|---|---|---|
| STS-57-V-14 | PLBD Latch Microswitch Anomalies<br>A) Starboard Forward A Release Intermittent<br>B) Centerline 5-8A Release Intermittent<br>C) Port Forward B Release Intermittent. | 180:13:33 G.m.t.<br>IPR 61V-0009 | When PLB doors were reopened following the first landing wave-off, these latch microswitches failed to indicate release. Release was confirmed via redundant microswitches, drive times, and currents. Indicators recovered after approximately 10 minutes. Anomaly did not repeat following second wave-off.<br>KSC: Condition did not repeat during postflight testing. |
| STS-57-V-15 | Ammonia Boiler Systems A and B Failure to Cool | 182:13:10 G.m.t.<br>IPR 61V-0007 | Postlanding, the NH3 systems A and B failed to control with either the primary or secondary controller.<br>KSC: Boiler functional test inconclusive. Borescope inspection revealed no anomaly. Will perform gas flow checkout. |
| STS-57-V-16 | MADS Recorder Anomaly<br>Level III Closure | PR INS-0140 | MADS commanded on prior to deorbit, no motion. Successfully commanded on after burn. Suspect sticky tape.<br>KSC: Removal and replacement with S/N 1006 |
| STS-57-V-17 | Postlanding Inspection Anomalies:<br>A) Foam adhered to 17" $LH_2$ Umbilical Plate<br>B) Foam Lodged in 17" $LO_2$ Door<br>C) Crack in 17-inch $LH_2$ | Postlanding<br>A)PR V070-5-05-0063<br>IM 57RF-08<br>B)PR-V070-5-05-0061<br>C)PR-MPS-0296 | A) A 15-inch piece of material was found adhered to the umbilical plate near the 4-inch disconnect.<br>B) Material was found lodged between edge member and thermal barrier on the right-hand ET door hinge line.<br>C) Postflight inspection revealed a crack approximately 3 inches long in fiberglass plate. |
| STS-57-V-18 | Deleted. | | |
| STS-57-V-19 | Wireless Communciations Anomaly (GFE)<br>Level III Closure | | Crew reported wireless communications dropout when using AIU-C wall unit. |
| STS-57-V-20 | Commander, Pilot, and Mission Specialist 2 Seat Backs Hard to Adjust<br>Level III Closure | | During crew debriefing, the crew mentioned that the Commanders' seat back was very difficult to move from launch to orbit position. Pilot and Mission Specialist 2 seat backs were also difficult to move. |
| STS-57-V-21 | Hydraulic System 1 Priority Valve Sluggish | 182:12:08 G.m.t.<br>PR HYD-0125 | Equalization of hydraulic supply pressure and bootstrap accumulator pressure took more than 11 seconds after system 1 hydraulic main pump pressure was switched to normal position during entry. Requirement is no greater than 1 second.<br>KSC: Remove and replace priority valve. |

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

| Problem | Element | Description | Comments/Status |
|---|---|---|---|
| MSFC had no in-flight anomalies during the STS-51 mission | | | |

## DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this mission report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room Daily Reports
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Quick Look Report
7. MER Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash Report
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. Shuttle Operational Data Book

## ACRONYMS AND ABBREVIATIONS

The following is a list of the acronyms and abbreviations and their definitions as these items are used in this document.

| | |
|---|---|
| ABE | arm-based electronics |
| ABS | ammonia boiler system |
| AEM | animal enclosure module |
| AGC | automatic gain control |
| AIU | audio interface unit |
| AMOS | Air Force Maui Optical Site Calibration Test |
| APU | auxiliary power unit |
| ARPCS | atmospheric revitalization pressure control system |
| ARS | atmospheric revitalization system |
| ATCS | Active thermal control system |
| ATU | audio terminal unit |
| BFS | backup flight system |
| BPM | bioprocessing module |
| CCTV | closed circuit television |
| CONCAP-IV | Consortium for Materials Development in Space Complex Autonomous Payload-IV |
| CPA | combustion products analyzer |
| CPM | cell performance monitor |
| CRT | cathode ray tube |
| DAP | digital autopilot |
| DCD | debris containment device |
| DPS | data processing system |
| DSO | Detailed Supplementary Objective |
| DTO | Development Test Objective |
| $\Delta V$ | differential velocity |
| ECLSS | Environmental Control and Life Support System |
| EFE | Environmental Control and Life Support System Flight Experiment |
| EFGF | electrical flight-releasable grapple fixture |
| EMU | extravehicular mobility unit |
| EPDC | electrical power distribution and control subsystem |
| ET | External Tank |
| EURECA | European Retrievable Carrier |
| EV | extravehicular |
| EVA | extravehicular activity |
| FARE | Fluid Acquisition and Resupply Experiment |
| FCS | flight control system |
| FDA | fault detection and annunciation |
| FES | flash evaporator system |
| GAS | getaway special |
| GBA | Gas Bridge Assembly |
| GFE | Government Furnished Equipment |
| $GH_2$ | gaseous hydrogen |
| G.m.t. | Greenwich mean time |
| GPC | general purpose computer |
| GSE | ground support equipment |
| HDP | holddown post |
| HFA | Human Factors Assessment |
| HIU | headset interface unit |

| | |
|---|---|
| HPFTP | high pressure fuel turbopump |
| HPOTP | high pressure oxidizer turbopump |
| HPU | hydraulic power unit |
| IAPU | improved auxiliary power unit |
| ICOM | intercommunications |
| IFM | in-flight maintenance |
| IMU | inertial measurement unit |
| Isp | specific impulse |
| ITEPC | Inter Mars Tissue Equivalent Proportional Counter |
| keas | knots estimated air speed |
| KI | potassium iodide |
| KSC | Kennedy Space Center |
| kWh | kilowatt hours |
| LCC | Launch Commit Criteria |
| LESC | Lockheed Engineering and Sciences Company |
| $LH_2$ | liquid hydrogen |
| LiOH | Lithium hydroxide |
| $LO_2$ | liquid oxygen |
| MADS | modular auxiliary data system |
| MCA | motor control assembly |
| MCIU | manipulator controller interface unit |
| MDM | multiplexer/demultiplexer |
| MECO | main engine cutoff |
| MET | mission elapsed time |
| MLGD | main landing gear door |
| MMT | Mission Management Team |
| MPC | mid power controller |
| MPM | manipulator positioning mechanism |
| MPS | main propulsion system |
| MS | Mission Specialist |
| MSFC | George C. Marshall Space Flight Center |
| NASA | National Aeronautics and Space Administration |
| NLGD | nose landing gear door |
| NPSP | net positive suction pressure |
| NSLD | NASA Shuttle Logistics Depot |
| OMRSD | Operations and Maintenance Requirements and Specifications Document |
| OMS | orbital maneuvering subsystem |
| PAL | protuberance air load |
| PASS | primary avionics software system |
| PCS | pressure control system |
| PDU | power distribution unit |
| PGSC | payload general support computer |
| PM | phase modulation |
| PMBT | propellant mean bulk temperature |
| $PPO_2$ | partial pressure oxygen |
| PRSD | power reactant storage and distribution |
| PS | Payload Specialist |
| RCC | reusable carbon carbon |
| RCS | reaction control subsystem |
| RJD | reaction jet driver |
| RJDA | reaction jet driver aft |
| RMS | remote manipulator system |
| ROEU | remotely operated electrical umbilical |
| RPC | remote power controller |

| | |
|---|---|
| RSRM | Redesigned Solid Rocket Motor |
| RTLS | return to launch site |
| RTV | room temperature vulcanizing |
| S&A | safe and arm |
| SAMS | Space Acceleration Measurement System |
| SAREX-II | Shuttle Amateur Radio Experiment-II |
| SCU | service and cooling unit |
| SHOOT | Superfluid Helium On-Orbit Transfer |
| SLF | Shuttle Landing Facility |
| SM | systems management |
| SPEE | Special Purpose End Effector |
| SPI | Surface Position Indicator |
| SRB | Solid Rocket Booster |
| SRM | Solid Rocket Motor |
| SRSS | Shuttle Range Safety System |
| SSME | Space Shuttle main engine |
| STS | Space Transportation System |
| TAGS | text and graphics system |
| TCS | thermal control system |
| TDRS | Tracking and Data Relay Satellite |
| TPS | thermal protection subsystem |
| USAF | U. S. Air Force |
| WCS | Waste Collection System |
| WSB | water spray boiler |

Appendix C

# SUPERFLUID HELIUM ON-ORBIT TRANSFER FLIGHT DEMONSTRATION

## SUMMARY REPORT

## SUPERFLUID HELIUM ON-ORBIT TRANSFER FLIGHT DEMONSTRATION SUMMARY

The Superfluid Helium On-Orbit Transfer (SHOOT) Flight Demonstration was designed to develop and prove the technology required to resupply superfluid helium dewars on orbit. In addition, a number of the components developed for SHOOT could be used on other liquid helium payloads as well as with other cryogenic systems. SHOOT is an attached Shuttle payload on a Hitchhiker-M cross bay carrier. The experiment consists of two 210-liter superfluid helium dewars connected by a transfer line and the electronics needed to control the experiment. The two dewars, port and starboard, are nearly identical except for liquid acquisition devices within the tanks.

The SHOOT experiment was launched on the STS-57 Endeavour mission at 9:07:22 a.m., on June 21, 1993. Over the next three days, the SHOOT Science and Engineering teams worked around the clock in the Goddard Payload Operations Command Center (POCC) and the Johnson Space Center Customer Support Room (CSR) to coordinate and complete the dewar transfer activities.

All of the assigned prelaunch mission goads and milestones were accomplished. The six highest priority transfers were completed, and a number of important and unexpected differences between the various experimental components used for fluid management were discovered. These were accomplished despite some serious hardware problems noted during the initial dewar pump-down on flight day 1. These six high priority transfers were:

a. Pump-down of normal liquid helium to superfluid on orbit;
b. Demonstration of high-rate transfers;
c. Demonstration of an autonomous crew-controlled transfer;
d. Demonstration of a warm dewar cool-down and fill;
e. Measurement of the performance of both types of fluid acquisition system;
f. Precision mass gauging and flow metering; and
g. Liquid/vapor discriminations.

Important differences between expected and actual on-orbit performance were identified and overcome. In addition, secondary objectives including observations of liquid helium sloshing and low-gravity stratification were also met. More discoveries are expected after a more complete evaluation of the data are completed.

### LAUNCH, ACTIVATION AND PUMP DOWN

The SHOOT electronics were activated successfully by baroswitches approximately 3 minutes after launch, and the crew activated the experiment at 00:01:42:28 mission elapsed time (MET). The post-ascent health check indicated that the electronics had powered up correctly; the initial telemetry showed all sensors to be working, reading reasonable values and indicating that the Low Flow Phase Separators (LFPS's) were working to pump the dewars down to superfluid temperature.

At 00:11:18 MET, valve B in each dewar was opened to use the thermochemical (TM) pump as an extra phase separator. This accelerated the pump down to prepare the dewars for the upcoming beneficial-g-procedure on flight day 2.

The B valves were closed and the D valve were opened (port at 00:04:11 MET; starboard at 00:16:25 MET) to complete the pump down to superfluid temperatures through the high-flow phase separators (HFPS's). The port dewar reached 1.145 K, and the starboard dewar 1.099 K, both of which were lower than any previous temperature reached in space. At this point, the D valves were closed and the dewars mass gauged for the first time. The results were 110 liters in the port and 42 liters in the starboard. The low level in the starboard indicated an unexpected loss of helium. Subsequent diagnostics showed that the HFPS in the starboard dewar allowed liquid to leak through. This problem precluded the use of the starboard HFPS for the rest of the mission. This also resulted in long pump down times before starboard-to-port transfers, requiring adjustments to the mission timeline and preventing high-rate starboard-to-port transfers.

## SHOOT FLIGHT DAY 2 AND FLIGHT DAY 3 ACTIVITIES

The beneficial-g-procedure was performed as scheduled. During the rotation at 3 deg/sec, the liquid settled to the forward ends and the liquid vapor discriminators (LVD) in both dewars were successfully calibrated. The LVD's allow a determination of whether liquid or gaseous helium is present at a particular location in the cryogen tank. During the translational acceleration, the liquid also settled as expected and a liquid-level detector (LLD) measurement was successfully completed on the starboard dewar. Throughout this operation, excellent coordination existed between the Goddard Space Flight Center POCC, the Mission Control Center (MCC), and the crew onboard the Shuttle, attesting to the value of the joint integrated simulations.

The first transfer (starboard to port) was attempted as scheduled and was expected to be of very short duration because of the low starboard liquid level. Although the pump appeared to be properly primed, the transfer line did not cool down over a period of 30 minutes, instead of the expected 15 minutes. Later transfers required a longer duration priming and a gradual ramping of the heater power to achieve the desired flow rates. Data analysis showed later in the flight that the starboard FAS, the screen control device, does not feed the pump as well as the port FAS, the mylar vane system. Determining this FAS behavior was one of the primary experimental goals of the SHOOT.

A second transfer (port to starboard) was then attempted with the procedure modified to also allow a longer pump priming period. the transfer proceeded smoothly, achieving a transfer rate of 400 liters/hr as expected from the pump heater power used. All but 17 liters of liquid (of the initial 100 liters) were transferred from the port dewar.

Because of the starboard HFPS problem, the third transfer (starboard to port) was delayed until 01:17:30 MET. After several unsuccessful attempts, the transfer line prickle was accomplished. Subsequently, an attempt to transfer liquid at the nominal rate of 600 liters/hr ended immediately because of cavitation of the starboard FAS. The transfer was restarted and maintained at a low rate of 90-100 liters/hr. The transfer ended normally due to pump cavitation. All but 30 liters were transferred of the initial 80 liters.

The port dewar was then conditioned for the first adverse-g-transfer (port to starboard) scheduled around a Shuttle EURECA rendezvous burn (01:21:07 MET). In the adverse-g transfer, the Shuttle applied a thrust to force the liquid away from the helium pump. A transfer was initiated at a rate of 500 liters/hr and the liquid level was brought to 30 liters (15-percent fill level) at the time of the Shuttle thruster firing. The burn consisted of one forward thruster for 10 seconds followed by two thrusters for 10 seconds. The crew monitored the transfer rate during the burns and did not see cavitation of the port FAS until two seconds after the burn was terminated. The flow subsequently recovered to about 100 liters/hr, but never to full flow. The transfer was then terminated.

An additional low-rate starboard to port transfer was then performed to move as much liquid helium to the port as possible for the first astronaut controlled transfer. The transfer proceeded until only 4 liters remained in the starboard and the port contained 54 liters.

The crewman-controlled transfer (port to starboard) was performed at 02:03:20 MET. The transfer was very successful, achieving a rate of 720 liters/hr and was terminated normally with 18 liters remaining in the port dewar, as expected based on previous transfers. The expert system software in the portable computer located in the Shuttle aft flight deck controlled the complete transfer process without any anomalies. Crew involvement was crucial to modify the transfer procedure allowing a longer pump priming period, which was an unexpected difference between ground-based and on-orbit transfers.

An additional transfer from port to starboard was performed to empty the port dewar as much as possible in preparation for the warm dewar transfer to be performed at 02:17:30 MET. The intent of this transfer was to demonstrate that a warm dewar could be cooled at a controlled rate and filled with liquid helium. The port dewar was heated to boil away all remaining liquid and raise the tank temperature. The starboard to port dewar transfer was performed, cooling the port dewar from 28 K to 2 K at a controlled rate of about 5 K/minute. The transition from dewar cooldown to fill was very smooth and occurred without loss of liquid. The transfer then proceeded at successively higher rates until cavitation occurred at 600 liters/hr and a residual helium level of 8 liters in the starboard (supply) dewar.

Following these transfers, the dewars were place in a standby mode for the upcoming EURECA and crew EVA activities.