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SPACE OPERATIONS CENTER — SHUTTLE INTERACTION STUDY (NAS9-16153)

SSD 81-0076

FINAL REPORT

VOLUME II, APPENDICES, BOOK I OF II

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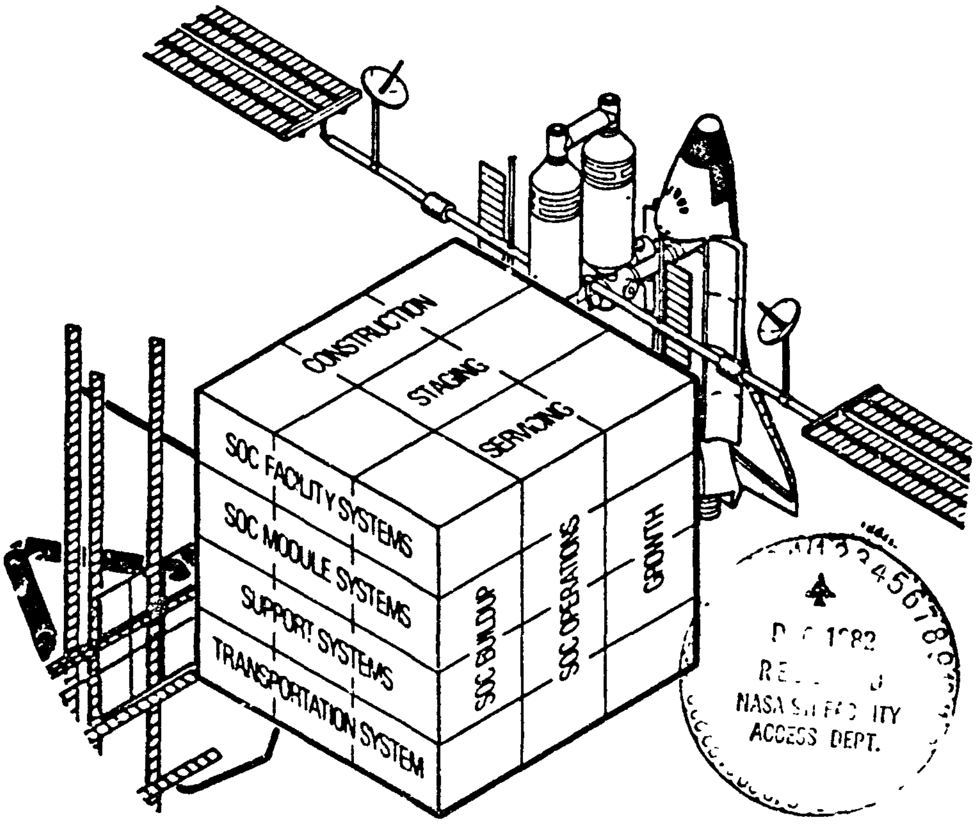

DRL T-1626

LINE ITEM 3

April 17, 1981

Space Operations and Satellite Systems Division
Rockwell International

N83-13140 #

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SPACE OPERATIONS CENTER/SHUTTLE INTERACTION STUDY

FINAL REPORT, VOLUME II
APPENDIXES (BOOK 1 OF 2)

Contract No. NAS9-16153
DRL T-1626
Line Item 3

April 17, 1981

Rockwell International

Space Operations and
Satellite Systems Division
Space Systems Group

APPENDIXES

A. Concept Drawings and Layouts Summary

B. Terminal Closure Trajectory Analysis Package

C. JSC Reference Data Package for STS Payload Delivery Performance Standard STS and Thrust Augmented STS

D. Servicing Activity Data Sheets

E. SPAR RMS Berthing Analysis Package

APPENDIX A

CONCEPT DRAWINGS AND LAYOUTS SUMMARY

DRAWING No.	TITLE
42690-002	Docking Tunnel Concept, External Extendable
42690-004	Docking Tunnel Concept, External Extendable
42690-005	Docking Tunnel with Utility Routing
42690-006	Orbiter Tunnel Adaptor to Docking Adapter
42690-007	Layout Service Module Port Arrangement
42690-008	Docking Module MMU and Cherrypicker Storage Arrangement
42690-009	HM-1 to SOC Assembly Sequence Using R/CM and Alignment Aids
42690-010	Minimum Clearance Between Orbiter and Module During Docking Operation
42690-011	Mid Deck Seating Arrangement for SOC Crew Delivery and Exchange
42690-012	Flight Support Facility Concept Arrangements
42690-013	Flight Support Facility OTV Configuration Arrangements
42690-014	Fuel Transfer Line Routing Concepts
42690-015	Flight Support Facility OTV Redocking Concepts
42690-016	Replacement Concepts, Avionics LRU's Configuration Arrangements
42690-017	Unscheduled Maintenance/Repair on Avionics/Propulsion Modules
42690-019	Baseline and Growth Configuration Flight Support Facility

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APPENDIX B

Terminal Closure Trajectory Analysis Package

APPENDIX B
TERMINAL CLOSURE TRAJECTORY ANALYSIS PACKAGE

SUBJECT: Preliminary Orbiter to Space Operations Center (SOC) Terminal Closure Trajectory Analysis

ABSTRACT

This data package presents a description of the groundrules and procedures that evolved in simulating Shuttle Orbiter to Space Operations Center (SOC) docking. Also presented and discussed are the High Fidelity Relative Motion Program (HFRMP) results derived from the simulations. The current simulation technique evolved as the study progressed through experience gained in using HFRMP and by a better knowledge of astronaut activities and hardware limitations of the Orbiter. It is probably far from complete and changes and rule exceptions will invariably take place as higher fidelity studies are made. The drawback of this study and HFRMP is that it is not a real time simulation; that is, it does not have a "man-in-the-loop" capability. The method used here is to start the Orbiter at some stand-off distance from the SOC, make translational burns, and let the Orbiter coast in "ballistically." It is felt that, in most cases, if the Orbiter can dock this way, it can do at least as good with a "man-in-the-loop." This is not intended to be an all encompassing study; there is a near infinite number of docking scenarios and parameters to vary. This study touches upon a number of the major variables, and serves to produce, with some degree of logic and order, a workable guide for some preliminary conclusions and future studies. The important conclusions are that out-of-plane docking is difficult, and that $\overline{V}$ and $\overline{R}$ dockings are marginal. This is true even at minimum distance and with a reduced number of thrusters firing to reduce the granularity of the impulse imparted. Appended to the end of this report are the results and the graphical output of the HFRMP computer runs.

I. STUDY OBJECTIVES

The purpose of this study was to explore, in a preliminary fashion, the feasibility of Shuttle Orbiter docking to the Space Operations Center (SOC) (A NASA concept design space station for the late 1980s.) SOC is depicted in Figure 1. Specifically the task was to simulate the in-orbit relative motion of the free-flying Orbiter and SOC, accounting for the Orbiter RCS and Digital Autopilot (DAP) systems, orbital mechanics, center of gravity (c.g.) offset of the Orbiter docking port, aero and gravity gradient effects, and other pertinent natural and man-made phenomena.

Within this task, many basic assumptions can be made as to initial conditions. Since there is no specified flight path and procedure for docking, terminal closure sensitivities have been investigated. First order effects investigated are: Orbiter approach direction (±R-bar, ±V-bar, ±V-bar out of plane; see Figure 2 at the end of the report); Orbiter approach attitude (nose up or down (+V-bar), payload bay up or down (±R-bar), both in plane; Orbiter sideways (+$\overline{V}$-bar), out of plane; DAP thruster compensation mode; final ballistic docking distance and time to dock; rate and excursion attitude deadbands; and selection of various thruster combinations (differing from nominal) for translational pulses.

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II. STUDY APPROACH

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A. Docking Scenario

The main tool used to simulate Orbiter docking was the High Fidelity Relative Motion Program (HFRMP). This program models the relative motion of the Orbiter and a payload (or SOC) and outputs orbital and relative motion parameters. The location and force components of each of the 44 RCS thrusters are contained in program. They are used to model the Orbiter translational and rotational maneuvers currently possible, along with propellant consumption. A thorough description of HFRMP and references to its mechanization are contained in Reference 1.

The docking scenario used is as follows: the Orbiter begins at the same inclination (and the same altitude if it is a $\bar{V}$ approach) as SOC, approximately 3,000 to 5,000 ft. away. In a series of three or four impulsive burns the Orbiter "hops" (see Figure 1) along its velocity vector until it reaches its terminal closure distance, approximately 50 ft. along either $\bar{V}$ or $\bar{R}$. From there, a combination of thruster burns is made so that the Orbiter "ballistically" coasts until docking. There are no pre-dock "man-in-the-loop" correction burns, with the exception of an optional mid-course rotational correction. Due to the time allocated to finishing this task, and because the propagation of initial ΔV errors during terminal closure determines a successful docking, only the terminal closure portion of the scenario was simulated. Reference 2 provides information on the "hopping" portion of the approach.

B. Initial Conditions

The HFRMP simulations performed were started with the face of the Orbiter docking port at distances of 50 and 30 feet from the face of the SOC docking port. The face of the Orbiter port was taken to be at X_o = 620", Y_o = 0", Z_o = 515" in structural body coordinates, with a diameter of 76 inches. HFRMP state variable inputs are appended to the end of the report in Table 1, along with all other figures, tables and HFRMP graphical output. Most of the inputs are self-explanatory; those that are not are explained below. Payload mass properties selected (Shuttle Data File items 1-7) were from Mission 1 (due east, 28.5 inclination) in Reference 3. The Orbiter time event is pre-payload deployment, payload doors-open. The SOC c.g. is in a 200 nautical mile orbit at 28.5 inclination. The symmetry of SOC is assumed to be such that the centerline of the docking part passes thru the c.g. and that the center of the docking port is only displaced from the c.g. along its X-axis. The c.g. of the SOC is assumed then to be on the face of the SOC port; for HFRMP purposes the docking results are unaffected. Figure 3 shows the c.g. offset of the docking face, the body axis coordinate system (X_b, Y_b, Z_b), and the docking coordinate system (X_d, Y_d, Z_d). The centerlines of the Orbiter port and SOC port are on the same V for +V docking with X_b parallel to the radius vector, $\bar{R}$ (nose up or down) and Y_b perpendicular to the orbit plane. The c.g. is therefore offset above or below the orbit path of the SOC.

For $\bar{R}$ docking, the centerlines of the Orbiter port and SOC port are on the same $\bar{R}$ separated by the initial docking distance. The Orbiter Y_b axis is perpendicular to the orbit plane and X_b parallel to the velocity vector, $\bar{V}$ of the orbiter (payload bay or down). The c.g. is then displaced forward or aft of R. For sideways docking the centerlines of the two ports are both initially along the velocity vector of the SOC c.g. This means the shuttle c.g. is displaced out of the orbital plane of the SOC; it has a slightly different orbit inclination. The X_b axis is perpendicular to the orbit plane and the Y_b axis is parallel to $\bar{R}$.

The c.g. offsets are needed because of the astronaut requirement to see the SOC docking port directly above out the upper cabin windows. The Shuttle and Payload I-states are the only HFRMP program files that must be updated for different approach paths. Items 9-11 of both files control initial attitudes of the Shuttle and payload respectively. Items 2-7 of the Payload I-state control initial displacement and velocity of the payload with respect to the Orbiter. The inputs shown are for a 50 foot $-\bar{R}$ terminal closure approach. Not shown are the flight profile segments. They are input segments of time for the flight during which RCS (vernier or primary) firings can be commanded, attitude holds specified, and RCS thruster compensation modes specified. A segment commanding a $-Z_b$ primary thruster burn was follwed by a segment commanding a $-X_b$ thrust. Both burns were for less than a second and gave the desired ΔV's. They were followed in some cases by a segment commanding a primary pitch correction burn, followed by a drift segment until docking. Another pitch correction segment during draft is optional. If docking sideways was being attempted, a $-Y_b$ thruster firing in the beginning would be added along with segments for yaw and roll corrections. The ΔVs required for the docking and the relative velocities of the payload with respect to the Orbiter were obtained by running the relative motion program in Reference 4 before running HFRMP.

C. Simulation Model

HFRMP is not a real-time program capable of making "man-in-the-loop" calculations. For example, during docking, if the astronaut sees he will miss the dock by a few inches, he would command corrective pulses to control the error. However, this cannot be known ahead of time using HFRMP and thus cannot be corrected in this way. These kind of errors must be accepted as "dispersions" and weighed against whether a real time "man-in-the-loop" capability could correct them. That is why all the HFRMP docking terminal closure runs are "ballistic" or unguided after the initial burns. It was felt that if a fair number of docking runs met the docking conditions, then a man at the thruster controls could certainly make any corrections necessary.

Additionally, there was the problem of simulating the digital autopilot (DAP). The computer sampling rate is 80 milliseconds. Any commanded burn is then a multiple of 80 milliseconds. The worst error occurs when the required firing time is slightly more or less than some multiple of 80 milliseconds. Then, the computer will fire approximately 80 milliseconds too long or too short.

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Therefore, the thruster firing times used for dispersions are the "ideal" times necessary to achieve the exact ΔV's plus or minus 80 milliseconds. The ideal firing times come from solving simultaneously the coupled thrust equations for all the translational and rotational commands. The coupling coefficients are obtained by exercising a HFRMP auxiliary program that outputs the "response matrices." As explained in the paragraph after next, the primary thrusters are not symmetrical about the c.g. and do not thrust through the c.g., causing unwanted translations and rotations which may or may not be compensated. Firing time errors in multiples greater than 80 milliseconds must be investigated in later studies.

The RCS thrusters can be used in either the vernier mode (6 thrusters), or the primary mode (38 thrusters). When one set of jets is used, the other is disabled. The vernier jets have a very low level of thrust and can only be used to control attitude. The primaries also have this ability but with lesser accuracy and larger deadbands. The verniers cannot be commanded to impart translations. Therefore, the primaries must be used at the beginning of the terminal closure for translational burns. This means that to use the verniers for rotational corrections, the control mode must be changed by computer entry, which could be done in a short time by a second man. Additionally, with a "man-in-the-loop", the astronaut would tend to make iterative minimum impulse (.08 second) translational burns until docking. Because of this and because of a possible emergency which could require large translational burns immediately to prevent collision, the astronauts would be very reluctant to switch thruster modes, especially since it takes more than a few seconds to key in the computer entries. For these reasons, the primary thrusters are used for all RCS thruster burns in this docking simulation. To date, NASA has used this approach for Orbiter Remote Manipulator System (RMS) arm rendezvous and grappling simulations.

A compensation mode for the primary thrusters exists (Reference 5) that nulls out extraneous translations and rotations for a given translational or rotational command. The firing time of the compensating jets is generally one-tenth the firing time of the command and maneuver itself. Since the rotational or translational commanded firing time is only a few multiples of 80 milliseconds, it follows the corrective pulses probably are not possible. The simulations performed in this report are therefore all completely uncompensated. The coupling effect of translation and rotational commands becomes a major effect in the simulation.

III. SUMMARY AND CONCLUSIONS

A. Summary of Results

The results discussed here are appended on the end of this report. The graphical HFRMP output for each simulation is also included. The results are summarized in terms of the shuttle docking coordinate system, centered on the face of the Orbiter docking port. This is shown in Figure 3. Table 2 shows the docking design impact conditions specified for SOC operations. These are the conditions that must be met for a "successful" docking. Tables 3, 4, and 5 summarizes the docking results. There are no $-\bar{V}$ cases because they are mathematically the same as $+\bar{V}$. The cases are labeled in the following fashion: 1.2.5.6., etc. Table 6 summarizes the numbering code. Additionally, the ideal time from start of closure to docking is 1.8 minutes for 30 ft. approaches and 3 minutes for 50 ft. approaches. These times were selected to get a contact velocity of about 0.33 ft./sec.

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Most of the headings in Tables 2, 3 and 4 are self-explanatory. The firing times shown are the ideal times to achieve a perfect docking for the X or Z thrusters ±80 milliseconds. The post burn ΔV's are the ΔV's achieved immediately after the initial terminal closure firings (translational and rotational) but before the midcourse corrections (if any).

Observing Tables 3, 4, and 5 and comparing to Table 2, the critical docking condition is lateral misalignment. Successful cases are indicated. All the other docking conditions can be met easily, if a pitch deadband is maintained (HFRMP lacks the automatic capability to simulate limit-cycling deadband behavior). For Tables 3 and 4, nine cases are successful; 19% of the 30 ft. +$\bar{V}$ cases. For Table 4, 25% of the 50 ft. $\bar{R}$ cases and 50% of the 30 ft. $\bar{R}$ cases are successful. Note the success rate is doubled by approximately halving the closure distance. This is to be expected as it gives the initial errors only half as long to propagate. The success rates at 30 ft. for $\bar{V}$ and $\bar{R}$ approaches cannot be compared directly. Since the $\bar{V}$ cases had higher initial pitch rates, they needed more pitch corrections. Also, all the $\bar{R}$ cases used a single nose thruster to provide X_b thrust; 44% of the single nose thruster, pitch rotationally corrected 30 ft. 1.8 min. $\bar{V}$ cases were successful; 50% of the 1.8 min. 30 ft. $\bar{R}$ cases were successful. Interesting to note is the effect of one primary nose thruster (F3F) vs. two (F1F, F2F); only 8% of the 2 thruster $\bar{V}$ cases were successful as compared to 29% of the 1 thruster $\bar{V}$ cases. One thruster firing and missing its ideal time by .08 seconds gives a ΔV increment closer to the required value than two thrusters each missing their ideal time by .08 seconds.

All except one of the successful docking cases in Tables 2, 3, and 4 occur when both the Z_b and X_b thrusters burn either 80 milliseconds too long or too short. These cases are virtually split between long or short. This makes sense because when one set of thrusters fires too long and the other too short, the error is effectively twice that of when they both fire short or long. Approach attitude appears to have little effect in terms of aero drag, or gravity gradient, as long as the orbiter is in a stable or semistable attitude (one principle axis along $\bar{R}$ or $\bar{V}$ and one perpendicular to the orbit plane) because of the short docking times involved. This was proven early in the study by making identical HFRMP docking runs from 50 ft. with and without full aero and gravity gradient effects. The only discernable effect was a difference in lateral misalignment of 0.1 inches.

However, the offset of the c.g. from the Orbiter docking port causes orbital mechanics effects, particularly in the sideways approach case (to be discussed later). The c.g. is displaced approximately 39 ft. from the port along the X_b axis. When the astronaut targets the SOC port he lines it up with the Orbiter port so he can see it out the windows on the top of the cabin. Therefore, depending on the approach attitude, the ΔV requirements will be different because of the way the c.g. is oriented with respect to the port. The astronaut has to be aware of this. An even bigger problem is Orbiter rotations. The astronaut in the cabin cannot perceive a difference between Orbiter translations and rotations because he is so far from the c.g. The solution for this would be to keep a very tight angle deadband. This approach was not desired during the simulation because the translations imparted during .08 second pitch corrections can make the leteral misalignment worse. Also, the allowed 6 degree pitch misalignment docking condition in Table 1 permits large deadbands. Simulating tight deadbands to make the analysis more complete could be done in a follow-up study using HFRMP.

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Some deadband information can be gleaned from this study, however. Tables 7 and 8 show the maximum Orbiter attitude errors and equivalent deadbands, respectively. Table 7 shows the largest rate and angle excursions per case from the initial terminal approach attitude. Yaw rates and angles are not shown because they are essentially zero. Notice how roll errors are very small also and probably do not require correction. The deadbands shown in Table 8 are derived by equating pitch corrections to deadbanding behavior. For applicable cases, a rounded-off value from Table 7 is listed in Table 8 as a rate deadband if it occurs at the beginning of the run and as an excursion deadband if it occurs halfway thru the run. The roll values were so low that as before, they were excluded. The runs listed in Table 8 have rate deadbands of approximately .05°/sec., and excursion deadbands of roughly 3 degrees. If HFRMP had full attitude hold capabilities (it can only simulate the amount of propellant used in attitude holds), the runs probably would not be significantly different if these deadbands were used. The rate deadband wouldn't be realistic however, because according to Reference 5, the minimum rate deadband with primary jets, is 0.2 degree/second. Then probably all attitude control during terminal approach would have to be accomplished using small (1.0 or less) pitch excursion deadbands. Vernier jets are capable of rate deadbands as low as 0.01°/sec, but cannot be used because they are disabled when the primary mode is initiated.

An interesting effect occurred on all runs because of the ΔV component imparted in the $+X_b$ direction when firing the $-Z_b$ direction primaries. On runs with initial attitudes set up so that the tail ($+X_b$) primary thrusters would provide the impulse velocity needed along the X axis ($+\bar{V}$, nose down for example), the $-Z_b$ primary thruster firing yielded more impulse along +X than necessary. Therefore, the nose primaries had to fire, instead of the tail primaries, to decrease the impulse along the X axis to the correct level. The same happened in all other cases, because the initial attitude was selected so that the open payload bay and Orbiter port faced the SOC port. Most of the ΔV increase is required in the $-Z_b$ direction; therefore, the $+X_b$ component of thrust due to a -Z command builds up due to the relatively long firing time of the primaries in the $-Z_b$ direction. Figure 4 illustrates this for $\bar{V}$ docking scenarios, for one and two nose thrusters, versus terminal docking distance. The time to dock has been normalized out of the plotted data by requiring an axial docking speed of about 0.33 ft./sec. At approximately 53 ft. for the nose down Orbiter, the X_b thrusters do not have to be turned on because the $-Z_b$ primaries contributes enough $+X_b$ thrust. For a greater distance they do not provide enough thrust so for nose down cases the aft thrusters have to be used. For a nose up Orbiter, the $-Z_b$ thrusting provides $+X_b$ impulse in the wrong direction, so that the nose thrusters always have to null out this ΔV besides providing the ΔV of opposite sign for docking. This is why the nose up case curve never crosses the horizontal. The curves for other approach cases are about the same.

The sideways $\bar{V}$ docking cases are presented in Table 9. They are presented here separately because they were not analyzed as thoroughly as $\bar{V}$ and $\bar{R}$ cases and because the procedure involved in sideways $\bar{V}$ docking requires an extra out-of-plane translational burn and extra rotational burns. The Orbiter is initially sideways with its port lined up in the SOC's orbital plane, and with its velocity in the X_b direction initially zero. This requires an orbiter orbit with a slightly different inclination because the c.g. is not in the same plane as SOC. Whether this initial position can be established accurately before the terminal closure begins remains

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to be established. The Orbiter c.g. cannot be in-plane initially, because then the c.g. has to move out-of-plane during terminal closure. The Orbiter port would be lined up with the SOC port at impact, but the lateral velocity for ballistic closures would be nearly twice the maximum allowed value.

Two in-plane burns are required ($-Z_b$, $+Y_b$) identical to those required for a $\bar{V}$ approach. However, a third out-of-plane burn ($-X_b$) is necessary to line up the docking ports at contact. Because of a lack of thruster compensation, the third burn is not independent of the first two. Three axis translational thrust coupling causes especially high rotational rates. A human operator would have difficulty in predicting the coupled reactions to a selected translational command. Unlike $\bar{V}$ and $\bar{R}$ in-plane maneuvers which require only pitch corrections, sideways docking requires corrections about all axes, inducing additional errors. Table 9 shows that at 30 ft., sideways docking is worse than $+\bar{V}$ docking at 50 ft. in Table 5.

Finally, there was one problem that was identified but not investigated in this study. The astronaut has to know his distance from the SOC with a fair degree of accuracy. This distance is too short for radar. The only device currently on the Orbiter that can be used is the Crewman Optical Alignment Sight (COAS). It would have a transparent overlay that gave distance as a function of the size of the image in the viewpiece. The astronaut would then presumably look at a chart to determine how many thruster pulses to use for docking vs. distance. The accuracy of this system is in doubt, however. How would the COAS measure relative velocities, for instance? These questions must be studied by a simulation with man-in-the-loop capability.

8. Conclusions

The results show that a terminal docking approach should be started from as close to its target as possible. They also show that because the granularity of the thruster impulse is less when one nose thruster is used instead of two, the docking success rate is much bett... However, even at 30 ft., roughly minimum terminal approach distance, and with one nose thruster, $\bar{V}$ and $\bar{R}$ docking succeeds less than 50% of the time with optimistic initial conditions (thruster firing errors of only 80 milliseconds, for example). Ballistic, out of plane, sideways $\bar{V}$ docking appears to be nearly impossible from the small number of cases studied here. Translating in three dimensions with coupling between the impulses is too complex.

From these results, it appears there is little accuracy difference between $\bar{V}$ and $\bar{R}$ docking. The use of one or another would depend upon the respective orbital paths of the two vehicles and the location of the SOC docking port.

All the docking contact conditions are easy to achieve except the lateral displacement limit of ± 9 inches. The primary jets do not have very fine control in translation.

From the results with and without aero drag and gravity gradient, it was proven they have almost no discernable effect on docking at the 200 n.mi. altitude range considered. It was also concluded that because of the large c.g. offset of the Orbiter docking port, small deadbands of a degree or less should be used.

There is also the combined effect of thrust cross-coupling and initial attitude. The result is that for all the docking cases studied, the Orbiter X_b axis direction thrust is provided by the nose $-X_b$ primary jets and the $+X_b$ component of the $-Z_b$ jets, but never with the aft OMS pod $+X_b$ jets. This could lead to premature propellant depletion of the forward RCS tanks.

This study has been preliminary in scope. This fact and the nature of the results lead to the final conclusion that more comprehensive simulations will have to be performed on Orbiter docking.

References

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4. Barbarika, H., "HP9825A Program for Relative Motion and Rendezvous Maneuvering", AS-SPT-80-043, August 14, 1980.

5. Shuttle Operational Data Book, Vol. I, Shuttle Performance and Constraints Data, Revision B, Admendment 91, JSC-08934.

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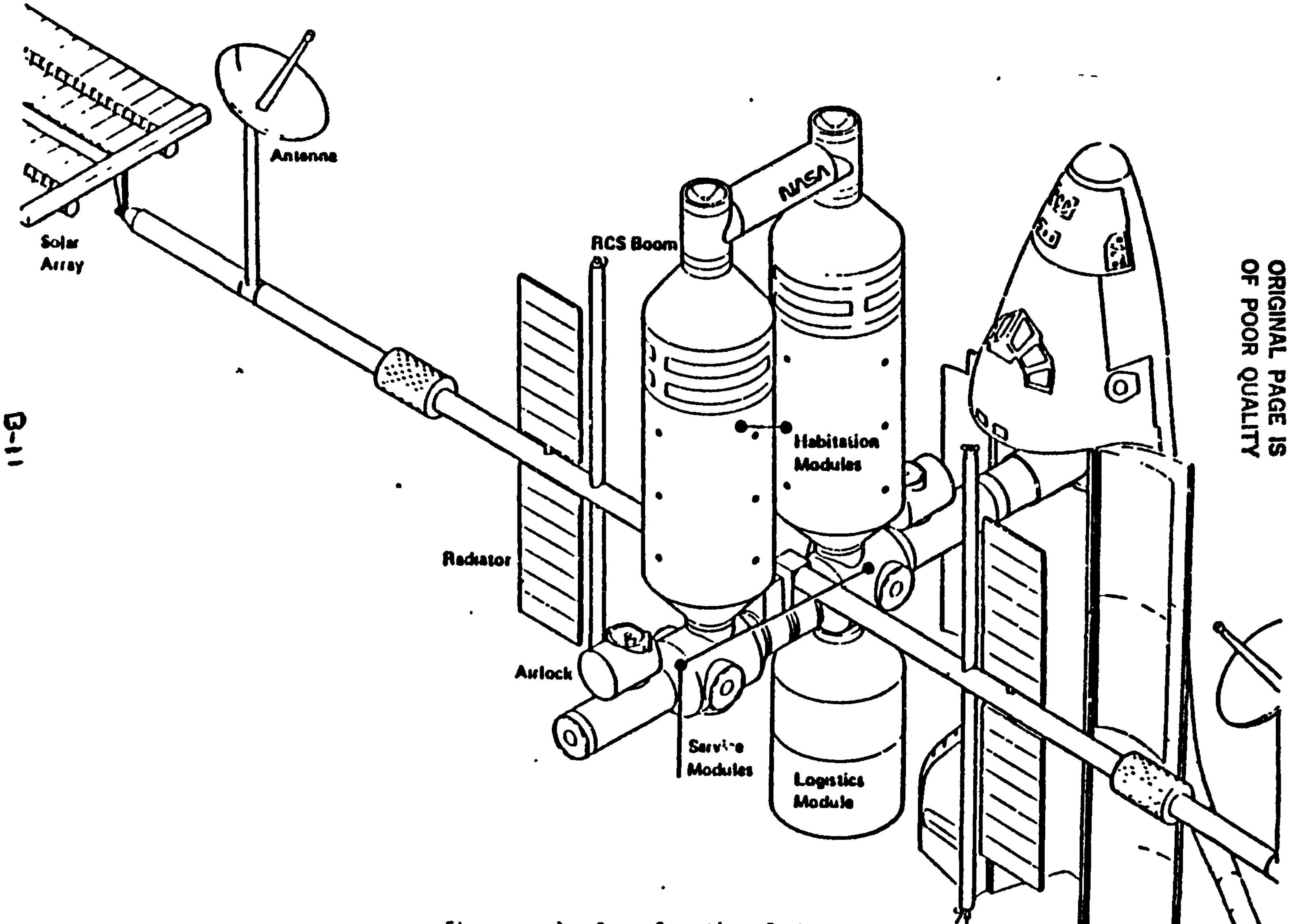
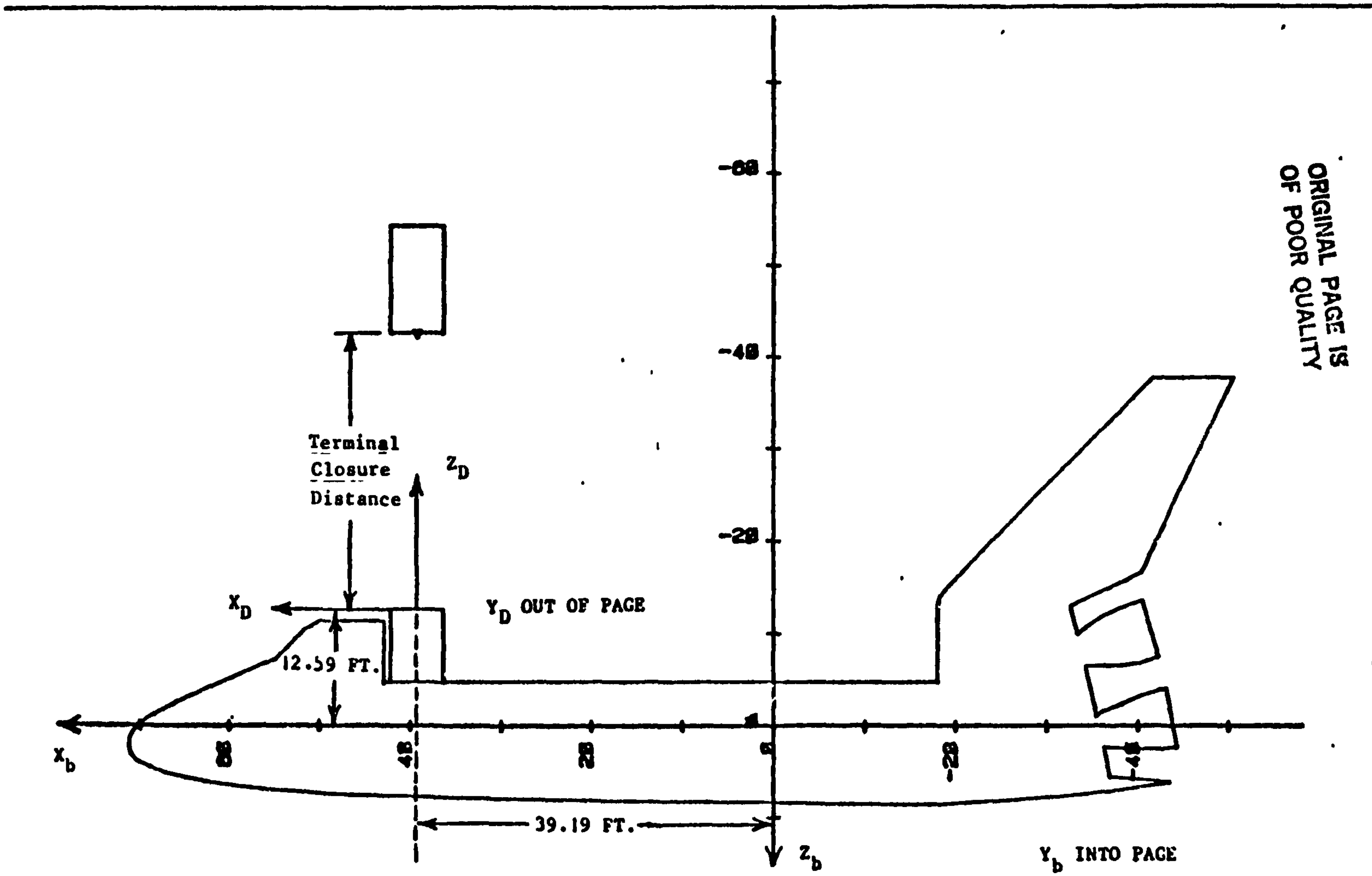


Figure 1. Space Operations Center

Enclosure I

Figure 3

ORBITER CONFIGURATION FOR DOCKING SIMULATION ANALYSIS



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Enclosure 1

Figure 2: Orbiter Docking Terminal Approach Paths

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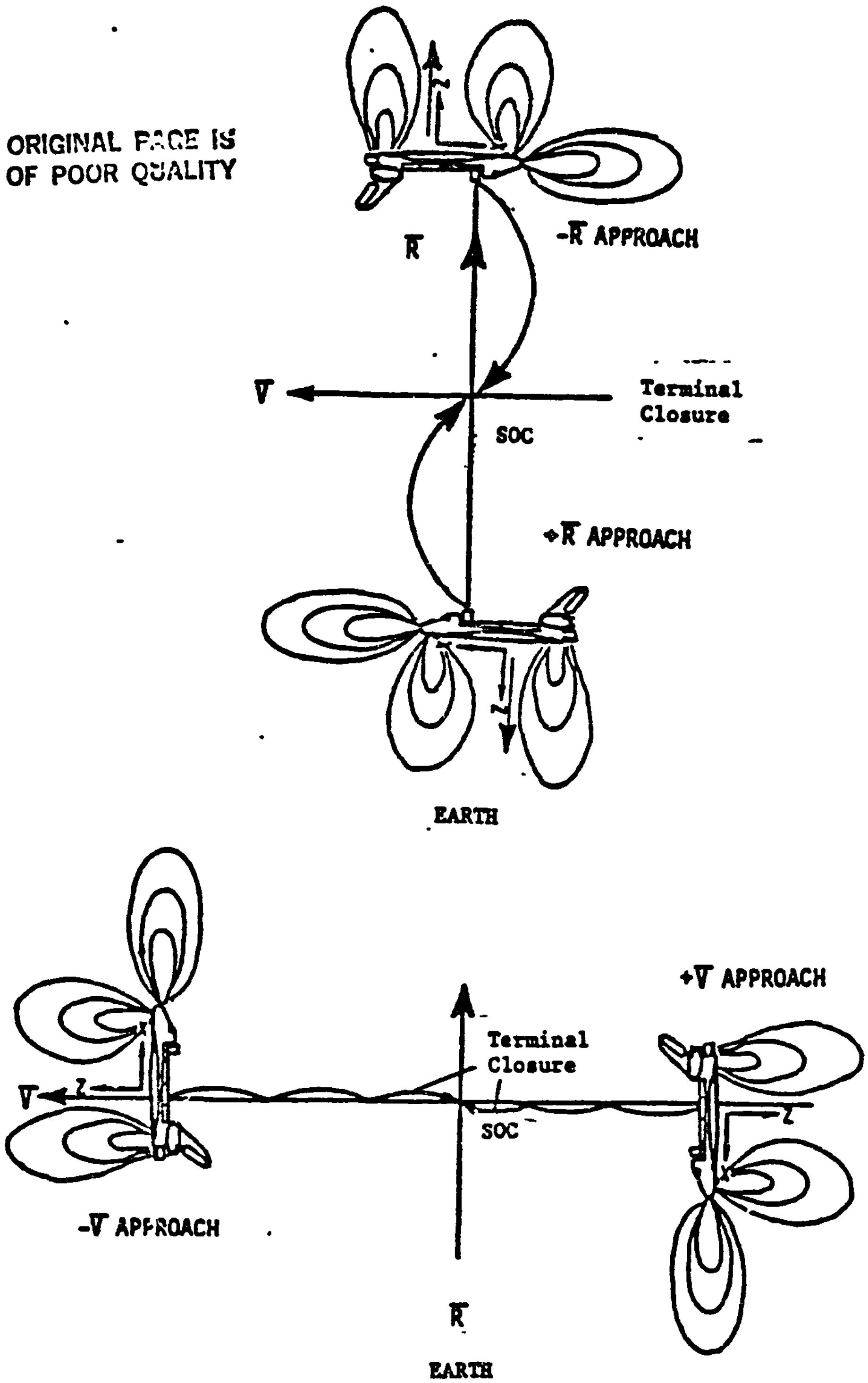
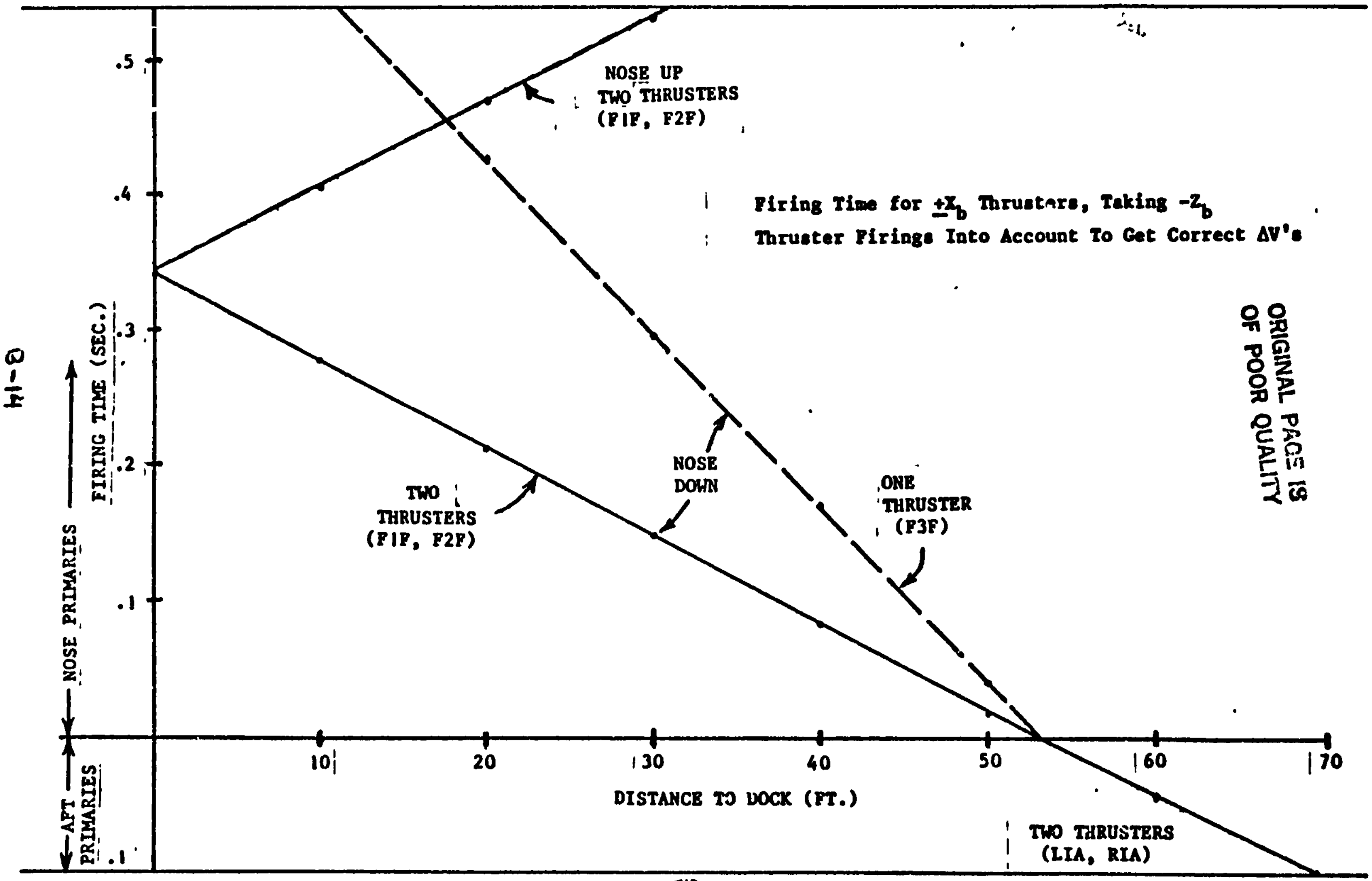


Figure 4
Uncompensated X_b Primary Thruster Burn for $\bar{V}$ Docking



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Enclosure 1

Enclosure 1

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Table 1
HFRMP Input Files

SHUTTLE DATA FILE

ITEM	DESCRIPTION	VALUE
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3	IYY	7254606.0000 SLUG-FT^2
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5	IYZ	-1945.6000 SLUG-FT^2
6	IZX	295259.5000 SLUG-FT^2
~~7~~	~~IXY~~	~~-4441.1000 SLUG-FT^2~~
8	CG STA	1090.3000 IN
9	CG BL	0.3000 IN
~~10~~	~~CG WL~~	~~363.9000 IN~~
11	SENSOR STA	620.0000 IN
12	SENSOR BL	0.0000 IN
~~13~~	~~SENSOR WL~~	~~515.0000 IN~~
14	SENSOR AXES PITCH	0.0000 DEG
15	SENSOR AXES YAW	0.0000 DEG
~~16~~	~~SENSOR AXES ROLL~~	~~0.0000 DEG~~
17	DAP CYCLE	80.0000 MILLISEC

PAYLOAD DATA FILE

ITEM	DESCRIPTION	VALUE
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4	IZZ	1.0000 SLUG-FT^2
5	IYZ	0.0000 SLUG-FT^2
~~6~~	~~IZX~~	~~0.0000 SLUG-FT^2~~
7	IXY	0.0000 SLUG-FT^2
8	CG STA	140.0000 IN
~~9~~	~~CG BL~~	~~0.0000 IN~~
10	CG WL	0.0000 IN
11	TARGET POINT STA	140.0000 IN
~~12~~	~~TARGET POINT BL~~	~~0.0000 IN~~
13	TARGET POINT WL	0.0000 IN
14	DIAMETER	70.0000 IN
~~15~~	~~LENGTH~~	~~140.0000 IN~~

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Enclosure 1

Table 1
HFRMP Input Files (Cont'd.)

~~GRAPHICS DATA FILE~~

ITEM	DESCRIPTION	VALUE
~~1~~	~~PLOT TYPE (NONE,RSBY,CPLV)~~	~~RSBY~~
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3	PLOT SCALE	15 PU/IN
~~4~~	~~X PANEL WIDTH~~	~~9.0000 IN~~
5	Y PANEL WIDTH	0.0000 IN
6	PANEL HEIGHT	6.0000 IN
~~7~~	~~X MAX~~	~~30.0000 PU~~
8	Y MAX	40.0000 PU
9	Z MAX	15.0000 PU
~~10~~	~~TIC INTERVAL~~	~~10 PU~~
11	LABEL INTERVAL	2 TICS
12	PLOT PAPER SIZE (LRG,REG)	REG

TIME/ATM/GRAV FILE

ITEM	DESCRIPTION	VALUE
1	LAUNCH YEAR	1986
~~2~~	~~LAUNCH MONTH (JAN,FEB,MAR,.....,NOV,DEC)~~	~~FEB~~
3	LAUNCH DAY	11
4	LAUNCH GMT	1100.0000 HHMM.SS
~~5~~	~~INITIAL GET~~	~~600.0000 HHMM.SS~~
6	ATMOSPHERIC DENSITY FACTOR	1.0000
7	GRAV MODEL (NORM,NOJ2)	NORM
~~8~~	~~GRAV GRADIENT (NONE,FULL)~~	~~FULL~~

SHUTTLE ISTATE

ITEM	DESCRIPTION	VALUE
1	STATE TYPE (OM50,IMLD)	OM50
~~2~~	~~SMA~~	~~3643.6231 NMI~~
3	ECC	0.0000
4	INC	23.5000 DEG
~~5~~	~~RAN~~	~~0.0000 DEG~~
6	ARG	0.0000 DEG
7	TRA	0.0000 DEG
~~8~~	~~ATT REF (SLV)~~	~~SLV~~
9	PITCH	0.0000 DEG
10	YAW	0.0000 DEG
~~11~~	~~ROLL~~	~~180.0000 DEG~~
12	RATE REF (M50,SLV)	SLV
13	XB RATE	0.0000 DEG/SEC
~~14~~	~~YB RATE~~	~~0.0000 DEG/SEC~~
15	ZB RATE	0.0000 DEG/SEC

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Table 1
HFRMP Input Files (Cont'd.)

~~PAYLOAD ISTATE~~

~~ITEM~~	~~DESCRIPTION~~	~~VALUE~~
~~1~~	~~STATE TYPE (RSLV,RSBY)....................~~	~~RSLV~~
2	X..	39.1920 FT
3	Y..	-0.0250 FT
~~4~~	~~Z..~~	~~62.5917 FT~~
5	XDOT.....................................	0.1069 FT/SEC
6	YDOT.....................................	0.0000 FT/SEC
~~7~~	~~ZDOT.....................................~~	~~0.0000 FT/SEC~~
8	ATT REF (PLV,SBY)........................	PLV
9	PITCH....................................	-90.0000 DEG
~~10~~	~~YAW......................................~~	~~0.0000 DEG~~
11	ROLL.....................................	0.0000 DEG
12	RATE REF (MSO,PLV,SBY)...................	PLV
~~13~~	~~XB RATE..................................~~	~~0.0000 DEG/SEC~~
14	YB RATE..................................	0.0000 DEG/SEC
15	ZB RATE..................................	0.0000 DEG/SEC

TABLE 2
DOCKING-DESIGN IMPACT CONDITIONS (IN THE DOCKING COORDINATE SYSTEM)

AXIAL CLOSING VELOCITY (V_Z)	0.16-0.50 ft./sec.
LATERAL VELOCITY $\left(V_x^2 + V_y^2\right)^{1/2}$	$\leq$0.2 ft./sec.
ANGULAR VELOCITY $\left(\dot{\theta}_x^2 + \dot{\theta}_y^2 + \dot{\theta}_z^2\right)^{1/2}$	$\leq$.6 deg./sec.
LATERAL MISALIGNMENT $\left(X^2 + Y^2\right)^{1/2}$	0.75 ft.
ANGULAR MISALIGNMENT	$\leq$5.0 deg. roll (θ_x)
	$\leq$6.0 deg. pitch/yaw (θ_y, θ_z)

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Table 3

30 ft., +$\bar{V}$ Nose Down 1.8 Minute Terminal Approach Case

Exact ΔV's Required: $\Delta V_{\bar{V}}$ = .3430 ft./sec.; $\Delta V_{\bar{R}}$ = -.0422

Nose Primary Thrusters Used for $-X_b$ Translation

CASE	firing time (sec.)		Fuel Used (lbs.)	Post Burn ΔV's (ft./sec.)		Docking Parameters WRT SS Body Axes Centered on SS Dock							
	$-X_b$	$-Z_b$		ΔV_{xb}	ΔV_{zb}	T_{dock} (sec.)	V_z (ft/sec)	$\sqrt{V_x^2+V_y^2}$ (ft./sec.)	$\sqrt{\dot{\theta}_x^2+\dot{\theta}_y^2+\dot{\theta}_z^2}$ (deg./sec.)	$\sqrt{X^2+Y^2}$ (inches)	$\lvert\theta x\rvert$ (deg.)	$\lvert\theta y\rvert$ (deg.)	$\lvert\theta z\rvert$ (deg.)
1.1.1	T_i+.08	T_i+.08	18.1	.006	.329	91.0	.330	.036	.035	16.7	.49	3.08	.02
1.1.2	T_i+.08	T_i+.08	18.8	.006	.329	96.0	.289	.033	.027	11.8	.53	1.91	.01
1.1.3	T_i+.08	T_i+.08	17.7	.073	.2721	111.0	.260	.082	.054	7.8	.67	6.06	.02
1.2.1	T_i-.08	T_i+.08	17.1	.031	.344	88.7	.348	.005	.049	19.3	.48	4.27	.02
1.2.2	T_i-.08	T_i+.08	17.8	.031	.344	97.1	.312	.004	.013	26.0	.54	2.43	.01
1.2.3	T_i-.08	T_i+.08	16.08	.099	.287	102.8	.293	.035	.040	38.9	.62	4.14	.02
► 1.3.1	T_i-.08	T_i-.08	14.1	.010	.275	108.2	.279	.011	.055	1.4	.45	5.94	.02
1.3.2	T_i-.08	T_i-.08	14.8	.010	.275	117.0	.241	.011	.007	9.9	.52	2.98	.01
1.3.3	T_i-.08	T_i-.08	13.1	.078	.218	135.5	.217	.055	.033	18.0	.67	4.54	.03
1.4.1	T_i+.08	T_i-.08	15.1	.015	.260	115.6	.261	.053	.041	46.8	.49	4.79	.02
1.4.2	T_i+.08	T_i-.08	15.8	.015	.260	126.4	.214	.057	.020	41.6	.57	1.20	.00
1.4.3	T_i+.08	T_i-.08	14.1	.052	.203	153.7	.175	.107	.046	4.4	.75	7.30	.02
► 1.5.1	T_i+.08	T_i+.08	17.8	.018	.327	90.8	.330	.025	.030	4.2	.39	2.66	.02
► 1.5.2	T_i+.08	T_i+.08	18.6	.018	.327	96.4	.289	.025	.031	1.8	.43	.73	.01
1.5.3	T_i+.08	T_i+.08	16.8	.090	.270	112.0	.264	.079	.058	6.9	.56	6.62	.02
1.6.1	T_i+.08	T_i-.08	14.8	.040	.260	116.9	.260	.048	.038	31.8	.39	4.40	.02
1.6.2	T_i+.08	T_i-.08	15.6	.040	.260	126.5	.216	.049	.022	27.3	.45	.81	.01
1.6.3	T_i+.08	T_i-.08	13.9	.060	.200	152.2	.180	.102	.049	36.4	.61	7.68	.02
► 1.7.1	T_i-.08	T_i-.08	14.3	.016	.270	112.4	.270	.026	.045	7.3	.33	5.04	.02
► 1.7.2	T_i-.08	T_i-.08	15.1	.010	.270	120.9	.230	.026	.016	1.5	.43	.91	.02
1.7.3	T_i-.08	T_i-.08	13.4	.080	.210	142.0	.200	.072	.042	8.5	.57	6.16	.02
1.8.1	T_i-.08	T_i+.08	17.3	.030	.330	82.2	.340	.001	.037	9.6	.35	3.00	.02
1.8.2	T_i-.08	T_i+.08	18.1	.030	.330	99.4	.300	.029	.024	19.8	.45	1.32	.01
1.8.3	T_i-.08	T_i+.08	16.3	.083	.291	106.7	.279	.051	.051	27.1	.53	5.49	.02

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30 ft., + $\overline{V}$ Nose Up, 1.8 Minute Terminal Approach Case
Exact ΔV's Required: $\Delta V_{\overline{V}}$ = .2098 ft./sec.; $\Delta V_{\overline{R}}$ = -.0258

Nose Primary Thrusters Used for $-X_b$ Translation

CASE	firing time (sec.) $-X_b$	firing time (sec.) $-Y_b$	Fuel Used (lbs.)	Post Burn ΔV's (ft./sec.) ΔV_{xb}	Post Burn ΔV's (ft./sec.) ΔV_{zb}	Docking Parameters WRT SS Body Axes Centered on SS Dock: T_{dock} (sec.)	V_z (ft/sec)	$\sqrt{V_x^2+V_y^2}$ (ft/sec)	$\sqrt{\dot{\theta}_x^2+\dot{\theta}_y^2+\dot{\theta}_z^2}$ (deg/sec)	$\sqrt{X^2+Y^2}$ (inches)	$\lvert\theta x\rvert$ (deg.)	$\lvert\theta y\rvert$ (deg.)	$\lvert\theta z\rvert$ (deg.)
2.1.1	T_i+.08	T_i+.08	14.0	.058	.327	90.5	.329	.020	.030	20.6	.31	2.66	.01
2.1.2	T_i+.08	T_i+.08	14.7	.058	.327	95.7	.289	.030	.030	12.7	.34	.72	.00
2.1.3	T_i+.08	T_i+.08	13.0	.009	.770	111.0	.274	.003	.058	7.0	.46	7.07	.01
2.2.1	T_i-.08	T_i+.08	13.0	.033	.342	88.6	.331	.059	.045	14.3	.30	3.88	.01
2.2.2	T_i-.08	T_i+.08	13.7	.033	.342	92.4	.300	.070	.017	23.1	.33	2.20	.01
2.2.3	T_i-.08	T_i+.08	12.0	.034	.285	105.5	.285	.044	.044	48.4	.43	4.73	.02
2.3.1	T_i-.08	T_i-.08	10.0	.013	.216	109.7	.268	.037	.051	10.7	.24	5.55	.02
2.3.2	T_i-.08	T_i-.08	10.7	.054	.273	119.0	.230	.046	.010	4.8	.20	2.51	.01
2.3.3	T_i-.08	T_i-.08	9.0	.054	.273	138.4	.217	.004	.036	31.0	.41	5.75	.02
2.4.1	T_i+.08	T_i-.08	11.0	.080	.258	113.6	.268	.004	.037	54.6	.27	4.38	.01
2.4.2	T_i+.08	T_i-.08	11.7	.012	.201	119.0	.228	.056	.010	19.4	.23	2.50	.01
2.4.3	T_i+.08	T_i-.08	16.0	.012	.201	147.1	.207	.016	.050	25.7	.44	7.66	.01
2.5.1	T_i+.08	T_i+.08	13.7	.048	.327	91.6	.326	.029	.028	10.2	.24	2.49	.01
2.5.2	T_i+.08	T_i+.08	14.5	.019	.270	96.5	.287	.039	.039	1.8	.28	.50	.01
2.5.3	T_i+.08	T_i+.08	12.7	.019	.270	111.4	.273	.011	.060	19.3	.38	6.78	.01
2.6.1	T_i-.08	T_i+.08	13.2	.035	.334	91.0	.327	.049	.035	7.7	.24	3.19	.01
2.6.2	T_i-.08	T_i+.08	14.0	.035	.334	94.8	.291	.039	.025	16.5	.26	1.24	.01
2.6.3	T_i-.08	T_i+.08	7.0	.032	.277	108.3	.290	.032	.053	40.4	.32	5.82	.01
2.7.1	T_i-.08	T_i-.08	10.3	.058	.266	112.5	.266	.028	.043	19.8	.19	4.79	.01
2.7.2	T_i-.08	T_i-.08	11.0	.058	.266	121.5	.226	.036	.017	4.9	.23	1.55	.00
2.7.3	T_i-.08	T_i-.08	9.3	.098	.209	142.3	.213	.014	.044	19.2	.35	6.46	.01
2.8.1	T_i+.08	T_i-.08	10.8	.070	.259	114.3	.266	.008	.036	42.1	.19	3.98	.01
2.8.2	T_i+.08	T_i-.08	11.5	.070	.259	124.2	.223	.016	.024	28.6	.25	.61	.00
2.8.3	T_i+.08	T_i-.08	10.8	.003	.202	147.0	.207	.007	.051	9.6	.35	7.72	.01

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Table 5

$\pm\bar{R}$ 30 ft. (1.8 min.) and 50 ft. (3 min.) Terminal Approach Cases

Nose Primary Thruster Used for $-X_b$ Translation

CASE	firing time (sec.)		Fuel Used (lbs.)	Post Burn ΔV's (ft./sec.)		Docking Parameters WRT Docking Coordinate System							
	$-X_b$	$-Z_b$		ΔV_{xb}	ΔV_{zb}	T_{dock} (sec.)	V_z (ft/sec)	$\sqrt{V_x^2+V_y^2}$ (ft/sec)	$\sqrt{\dot\theta_x^2+\dot\theta_y^2+\dot\theta_z^2}$ (deg./sec.)	$\sqrt{X^2+Y^2}$ (inches)	$\lvert\theta x\rvert$ (deg.)	$\lvert\theta y\rvert$ (deg.)	$\lvert\theta z\rvert$ (deg.)
► 3.5.4.1	T_i+.08	T_i+.08	15.1	.002	.285	100.0	.331	.018	.039	3.4	.42	1.49	.04
3.6.4.1	T_i-.08	T_i+.08	14.6	.014	.292	98.2	.333	.036	.046	22.6	.38	.85	.04
3.7.4.1	T_i+.08	T_i-.08	12.1	.021	.217	120.0	.266	.005	.047	28.7	.35	.40	.04
► 3.8.4.1	T_i-.08	T_i-.08	11.6	.008	.224	120.0	.267	.025	.055	4.1	.34	1.26	.04
3.5.4.2	T_i+.08	T_i+.08	15.0	.008	.294	163.3	.327	.040	.041	12.3	.69	1.25	.08
3.6.4.2	T_i-.08	T_i+.08	14.5	.002	.301	161.0	.325	.061	.049	42.0	.62	.14	.09
3.7.4.2	T_i+.08	T_i-.08	12.0	.033	.226	182.5	.262	.031	.049	43.6	.58	2.04	.09
► 3.8.4.2	T_i-.08	T_i-.08	11.5	.023	.233	180.0	.258	.052	.058	5.2	.57	3.44	.10
► 4.5.4.1	T_i+.08	T_i+.08	16.8	.006	.315	92.0	.363	.010	.031	5.3	.39	2.63	.03
4.6.4.1	T_i-.08	T_i+.08	16.3	.014	.322	90.2	.366	.031	.039	22.9	.40	1.97	.03
4.7.4.1	T_i+.08	T_i-.08	13.8	.016	.247	112.3	.297	.101	.041	21.7	.36	1.01	.03
► 4.8.4.1	T_i-.08	T_i-.08	13.3	.003	.255	110.1	.299	.021	.047	1.3	.37	.50	.04
► 4.5.4.2	T_i+.08	T_i+.08	15.0	.007	.294	163.2	.326	.043	.042	5.8	.63	1.11	.08
4.6.4.2	T_i-.08	T_i+.08	14.5	.003	.302	161.0	.324	.064	.050	36.1	.62	.07	.09
4.7.4.2	T_i+.08	T_i-.08	12.0	.032	.226	202.5	.262	.034	.050	48.3	.58	2.30	.09
4.8.4.2	T_i-.08	T_i-.08	11.5	.022	.234	200.0	.257	.054	.058	9.6	.57	3.62	.10

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Enclosure 1

TABLE 6
Explanation of Case Numbering System

1st Number: approach path and attitude

1. $+\overline{V}$, nose down
2. $+\overline{V}$, nose up
3. $-\overline{R}$, nose (X_b) in $+\overline{V}$ direction
4. $+\overline{R}$, nose (X_b) in $-\overline{V}$ direction

2nd Number: firing time errors

For a given case, numbers 1 through 4 designate the four possible ways to fire the $-X_b$ and $-Z_b$ body thrusters, either -.08 seconds of the ideal firing time.

Additionally, using 5 through 8 for the 2nd number designates the same thing except one nose thruster only is used.

3rd Number: angular correction options

1. X_b and Z_b translational burns immediately followed by a .08 second pitch rotational correction
2. Same as 1 with another .08 second pitch rotational correction approximately halfway to the SOC dock.
3. Same as 1 except no rotational corrections.
4. Same as 1 except the pitch correction occurs midcourse.

4th Number:

1 is a 30 ft. terminal closure, 2 or no number is a 50 ft. closure.

Table 7
Maximum Orbiter Attitude Errors
(W/Rst to the Ideal Local Vertical Orientation)

CASE NUMBER	MAXIMUM ERROR RATE (°/sec)		MAXIMUM ERROR EXCURSION (degrees)	
	pitch	roll	pitch	roll
1.1.1	056	006	3.08	.49
1.1.2	.056	.006	2.03	.53
1.1.3	.056	.006	6.06	.67
1.2.1	049	.006	4.27	.48
1.2.2	.049	.006	2.86	.54
1.2.3	.041	.006	4.14	.62
1.3.1	055	.005	5 94	.45
1.3.2	055	.005	3.25	.52
1.3.3	.035	.005	4.54	.67
1.4.1	.049	.005	4.79	.49
1.4.2	.049	.005	2.44	.57
1.4.3	.049	.005	7.30	.75
1 5.1	.060	.005	2.66	.39.
1.5.2	.060	.005	1.77	.43
1 5.3	.060	005	6.62	.56
1.6.1	.052	.004	4.40	.39
1.6.2	.052	.004	2.27	.45
1.6.3	.052	.004	7.68	.61
1.7.1	.045	004	2.08	.53
1.7.2	.045	.004	2.71	.43
1.7.3	045	.004	6.16	.57
1.8.1	.053	.005	3.00	.35
1.8.2	.053	.005	2.21	.45
1.8.3	.053	.005	5.49	.53

CASE NUMBER	MAXIMUM ERROR RATE (°/sec)		MAXIMUM ERROR EXCURSION (degrees)	
	pitch	roll	pitch	roll
2.1.1	.060	.004	2.66	.31
2.1.2	.060	.004	1.77	.34
2.1.3	.060	.004	7.07	.46
2.2.1	.046	.004	3.88	.30
2.2.2	.046	.004	2.65	.33
2.2.3	.046	.004	4.73	.43
2.3.1	051	003	5.55	.24
2.3.2	051	003	3.05	.20
2.3.3	.039	.003	5.25	.41
2.4.1	.054	.003	4.38	.27
2.4.2	.054	.003	2.50	.23
2.4.3	.054	.003	7.66	.44
2.5.1	.062	.003	2.49	.24
2.5.2	.062	.003	1.64	.28
2.5.3	.062	.003	6.78	.38
2.6.1	.055	.003	3.19	.24
2.6.2	.055	.003	2.09	.26
2.6.3	.055	.003	5.87	.32
2.7.1	047	.002	4.79	.19
2.7.2	.047	.002	2.58	.23
2.7.3	.047	.002	6.46	.35
2.8.1	.054	.002	3.98	.19
2.8.2	.054	.002	2.14	.25
2.8.3	.054	.002	7.72	.35

CASE NUMBER	MAXIMUM ERROR RATE (°/sec)		MAXIMUM ERROR EXCURSION (degrees)	
	pitch	roll	pitch	roll
3.1.4.1	.050	.004	3.02	.42
3.2.4.1	.042	.004	2.57	.38
3.3.4.1	.042	.003	2.52	.35
3.4.4.1	.035	.003	2.08	.34
3.1.4.2	.047	.004	4.24	.69
3.2.4.2	.050	.004	3.57	.62
3.3.4.2	.051	.003	3.50	.58
3.4.4.2	.058	.003	2.83	.57
4.1.4.1	.058	.005	3.59	.39
4.2.4.1	.051	.005	3.05	.40
4.3.4.1	.050	.004	2.99	.36
4.4.4.1	.047	.004	2.55	.37
4.1.4.2	.045	.004	4.16	.63
4.2.4.2	.051	.004	2.49	.62
4.3.4.2	051	003	3 41	.58
4.4.4.2	.059	.003	2.75	.57

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Table 8
Equivalent Orbiter Deadbands
(W/Rst to the Ideal Local Vertical Orientation)

CASE NUMBER	DEADBANDS RATE (°/sec) pitch	DEADBANDS RATE (°/sec) roll	DEADBANDS EXCURSION (degrees) pitch	DEADBANDS EXCURSION (degrees) roll
1.1.1	.06	—	—	—
1.1.2	.06	—	2.0	—
1.1.3	—	—	—	—
1.2.1	.05	—	—	—
1.2.2	.05	—	3.0	—
1.2.3	—	—	—	—
1.3.1	.06	—	—	—
1.3.2	.06	—	3.0	—
1.3.3	—	—	—	—
1.4.1	.05	—	—	—
1.4.2	.05	—	2.0	—
1.4.3	—	—	—	—
1.5.1	.06	—	—	—
1.5.2	.06	—	2.0	—
1.5.3	—	—	—	—
1.6.1	.05	—	—	—
1.6.2	.05	—	2.0	—
1.6.3	—	—	—	—
1.7.1	.05	—	—	—
1.7.2	.05	—	3.0	—
1.7.3	—	—	—	—
1.8.1	05	—	—	—
1.8.2	.05	—	2.0	—
1.8.3	—	—	—	—

CASE NUMBER	DEADBANDS RATE (°/sec) pitch	DEADBANDS RATE (°/sec) roll	DEADBANDS EXCURSION (degrees) pitch	DEADBANDS EXCURSION (degrees) roll
2.1.1	.06	—	—	—
2.1.2	06	—	2.0	—
2.1.3	—	—	—	—
2.2.1	05	—	—	—
2.2.2	.05	—	3.0	—
2.2.3	—	—	—	—
2.3.1	.05	—	—	—
2.3.2	.05	—	3.0	—
2.3.3	—	—	—	—
2.4.1	.05	—	—	—
2.4.2	.05	—	3.0	—
2.4.3	—	—	—	—
2.5.1	.06	—	—	—
2.5.2	.06	—	2.0	—
2.5.3	—	—	—	—
2.6.1	.06	—	—	—
2.6.2	.06	—	2.0	—
2.6.3	—	—	—	—
2.7.1	.05	—	—	—
2.7.2	.05	—	3.0	—
2.7.3	—	—	—	—
2.8.1	.05	—	—	—
2.8.2	.05	—	2.0	—
2.8.3	—	—	—	—

CASE NUMBER	DEADBANDS RATE (°/sec) pitch	DEADBANDS RATE (°/sec) roll	DEADBANDS EXCURSION (degrees) pitch	DEADBANDS EXCURSION (degrees) roll
3.1.4.1	.05	—	3.0	—
3.2.4.1	.04	—	3.0	—
3.3.4.1	.04	—	3.0	—
3.4.4.1	.04	—	2.0	—
3.1.4.2	.05	—	4.0	—
3.2.4.2	.05	—	4.0	—
3.3.4.2	.05	—	4.0	—
3.4.4.2	.06	—	3.0	—
4.1.4.1	.06	—	4.0	—
4.2.4.1	.05	—	3.0	—
4.3.4.1	.05	—	3.0	—
4.4.4.1	.05	—	3.0	—
4.1.4.2	.05	—	4.0	—
4.2.4.2	.05	—	3.0	—
4.3.4.2	.05	—	3.0	—
4.4.4.2	.06	—	3.0	—

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Enclosure 1

Table 9
Sideways $+\bar{V}$ 1.8 min., 30 ft. Approach Cases
2 Nose Primary Thrusters Used for $-X_b$ Translations

CASE	Firing time (sec.) $-X_b$	Firing time (sec.) $-Y_b$	Firing time (sec.) $-Z_b$	Fuel Used (lbs.)	Post Burn ΔV's (ft./sec.) ΔV_{xb}	Post Burn ΔV's (ft./sec.) ΔV_{yb}	Post Burn ΔV's (ft./sec.) ΔV_{zb}	Docking Parameters WRT SS Body Axes Centered on SS Dock: T_{dock} (sec.)	V_z (ft/sec)	$\sqrt{V_x^2+V_y^2}$ (ft/sec.)	$\sqrt{\dot\theta_x^2+\dot\theta_y^2+\dot\theta_z^2}$ (deg/sec.)	$\sqrt{X^2+y^2}$ (inches)	$\lvert\theta x\rvert$ (deg.)	$\lvert\theta y\rvert$ (deg.)	$\lvert\theta z\rvert$ (deg.)
1. Sideways w/ .08 sec initial roll, pitch and yaw rotational corrections	t_i+.08	t_i+.08	t_i+.08	19.3	.033	.035	.302	91	.330	.045	.064	33.5	5.01	1.60	2.76
2. Sideways w/ one mid course pitch correction	t_i+.08	t_i+.08	t_i-.08	16.1	.031	.093	.275	115	.228	.044	.060	37.9	7.30	2.70	2.45
3. Same as 1	t_i-.08	t_i-.08	t_i-.08	14.3	.031	.021	.276	110	.268	.073	.064	57.5	2.50	6.05	7.45
4. Same as 2	t_i-.08	t_i-.08	t_i-.08	15.1	031	.021	.276	118	.230	.075	.046	14.1	1.42	.97	1.25

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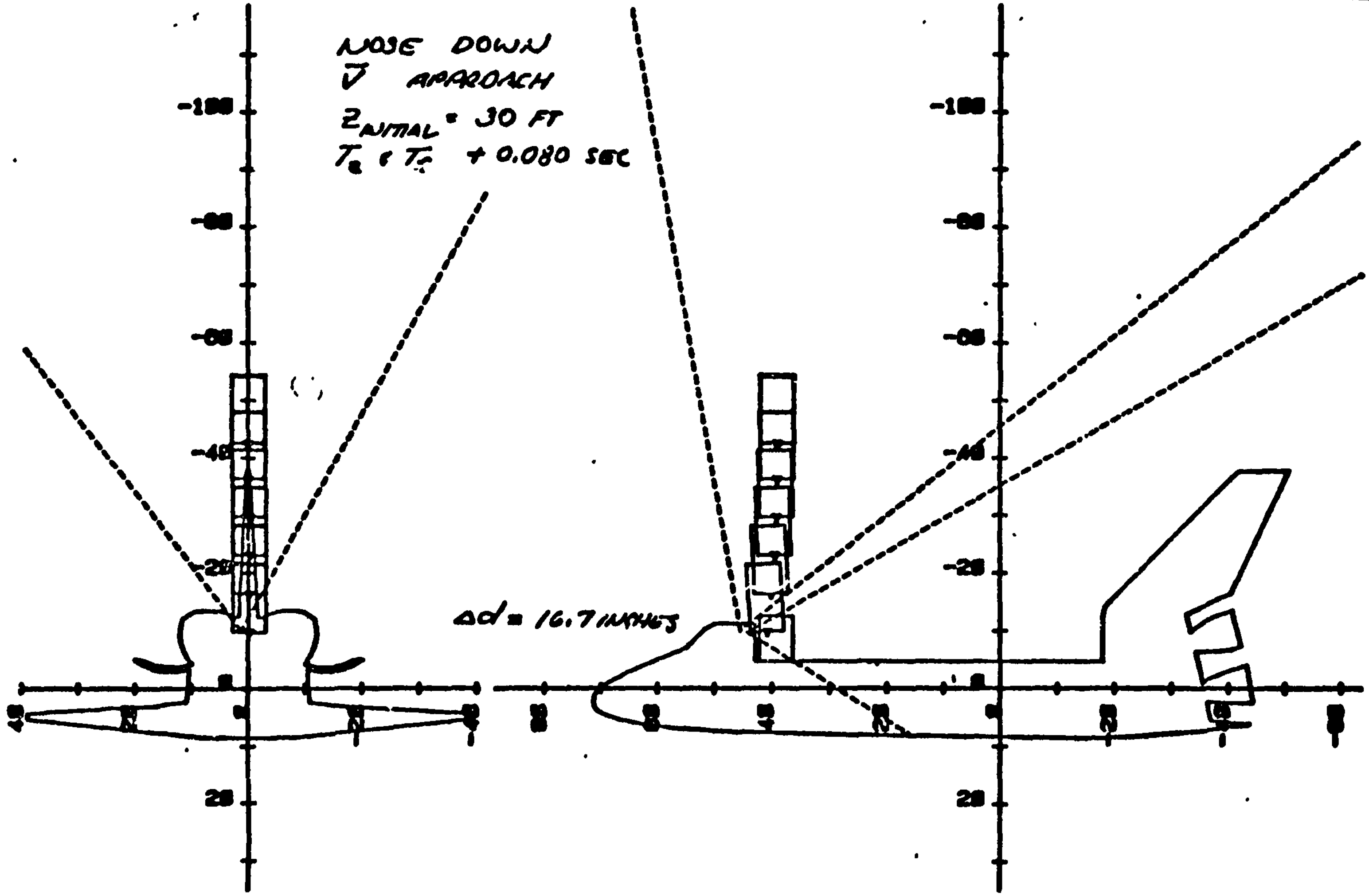
Enclosure 1

DOCKING CASE 1.1.1



30 Fs 1.0 min DOCK, +.08 SEC -Z, -X, ALL NO COMP P V/ROT COR, SEE OUTPUT FOR V'=, T'=

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Enclosure 2

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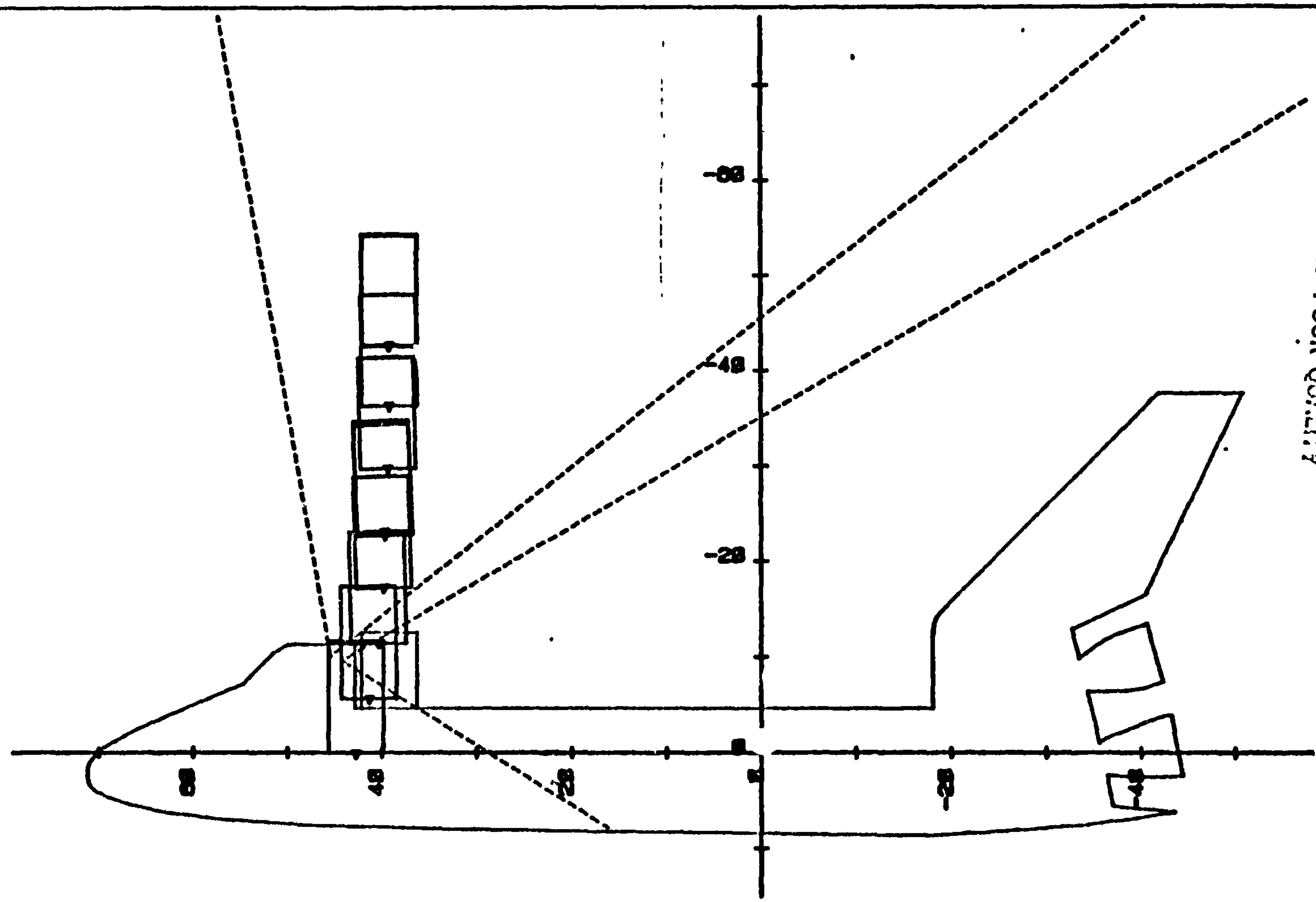

REPLACEMENT 1.1.2 (7/28/80)

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Enclosure 2

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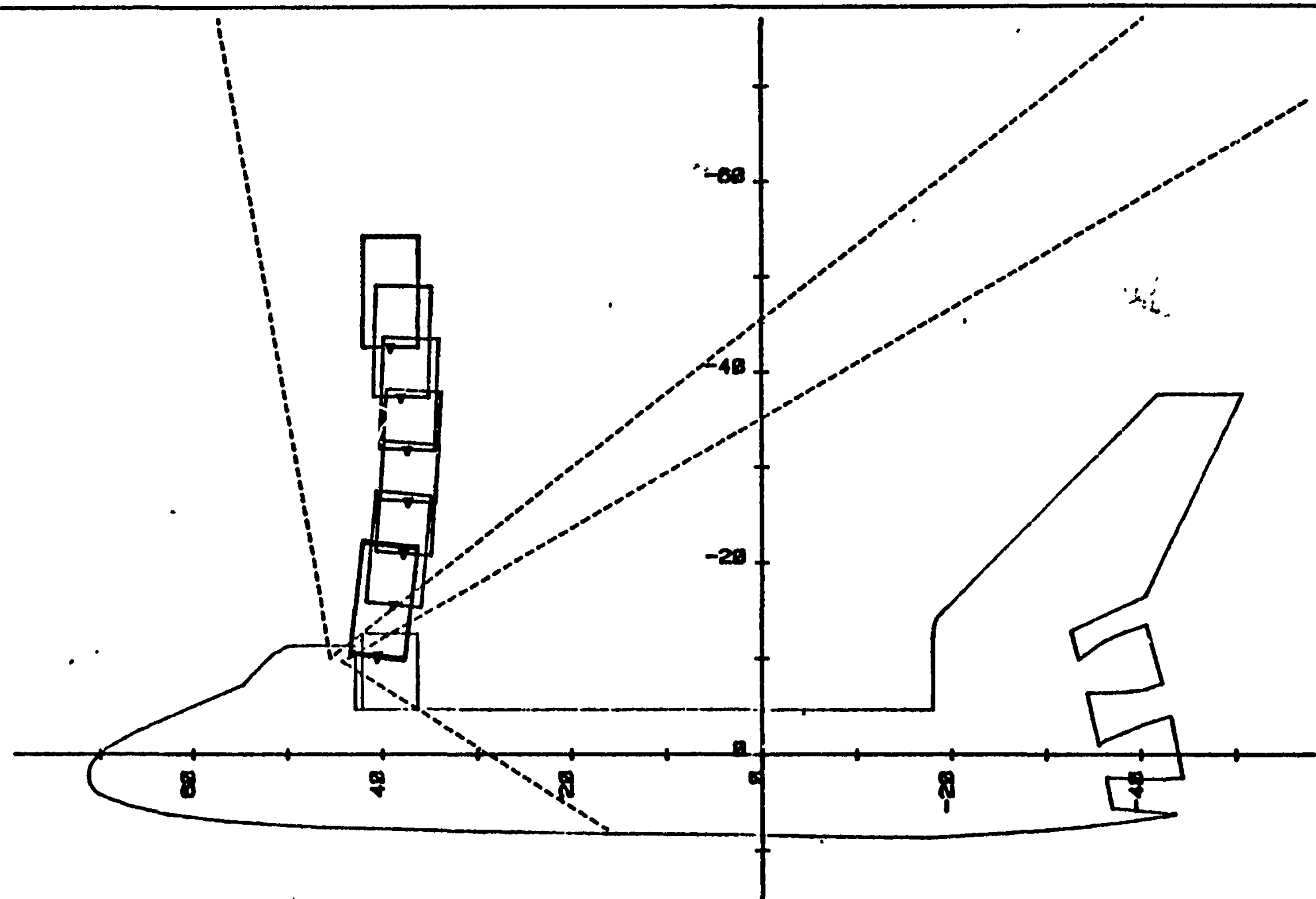
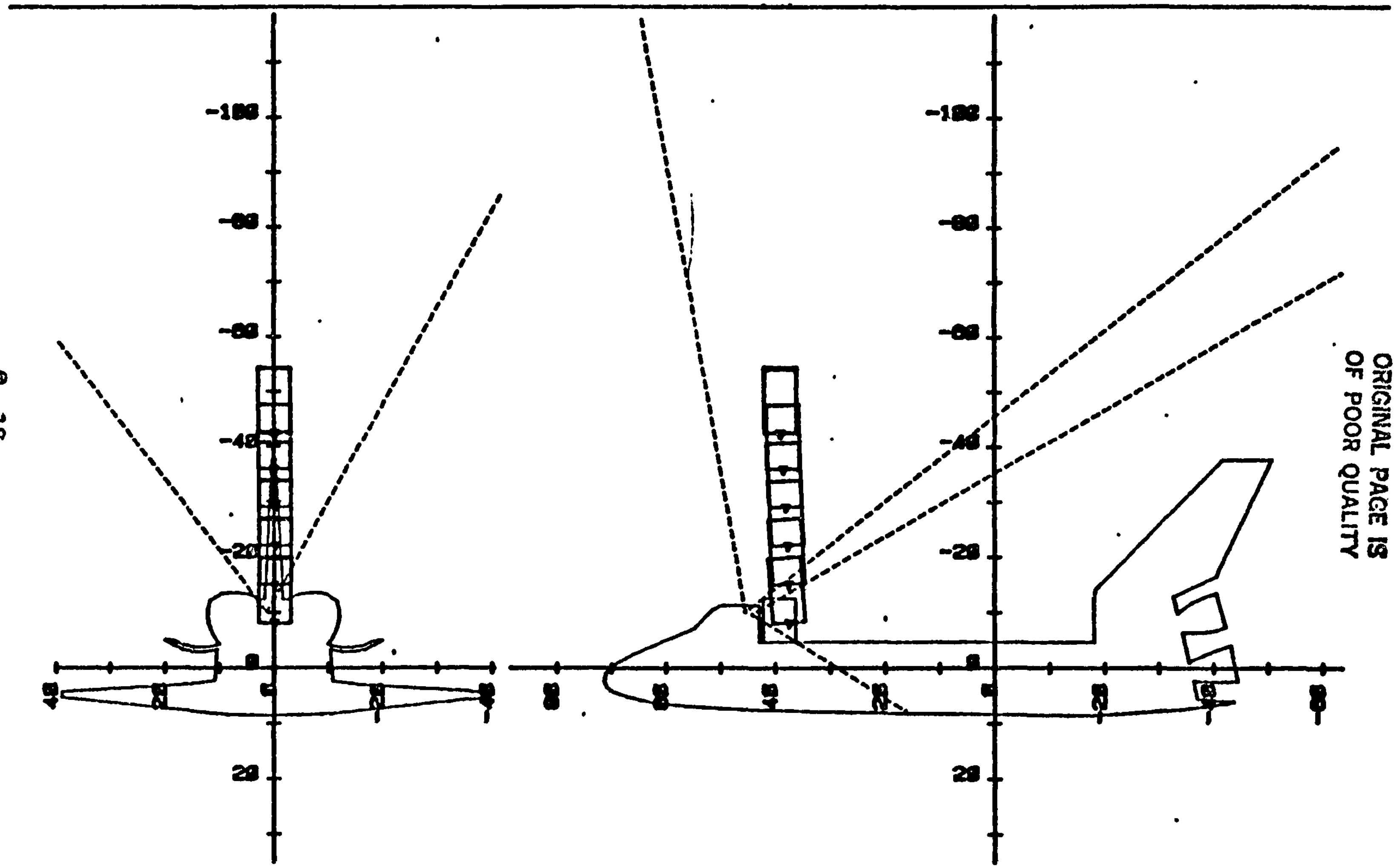
Enclosure 2



CASE 1.1.3 (OVER IN -Z, -X, NO P ROT CORRECTION AT ALL) (07/10/80)

CASE 1.2.1



30 ft 1.0 min DOCK, +.00eee-Z, -.00eee-X, NO COMP P ROT COR, (7/9/80)

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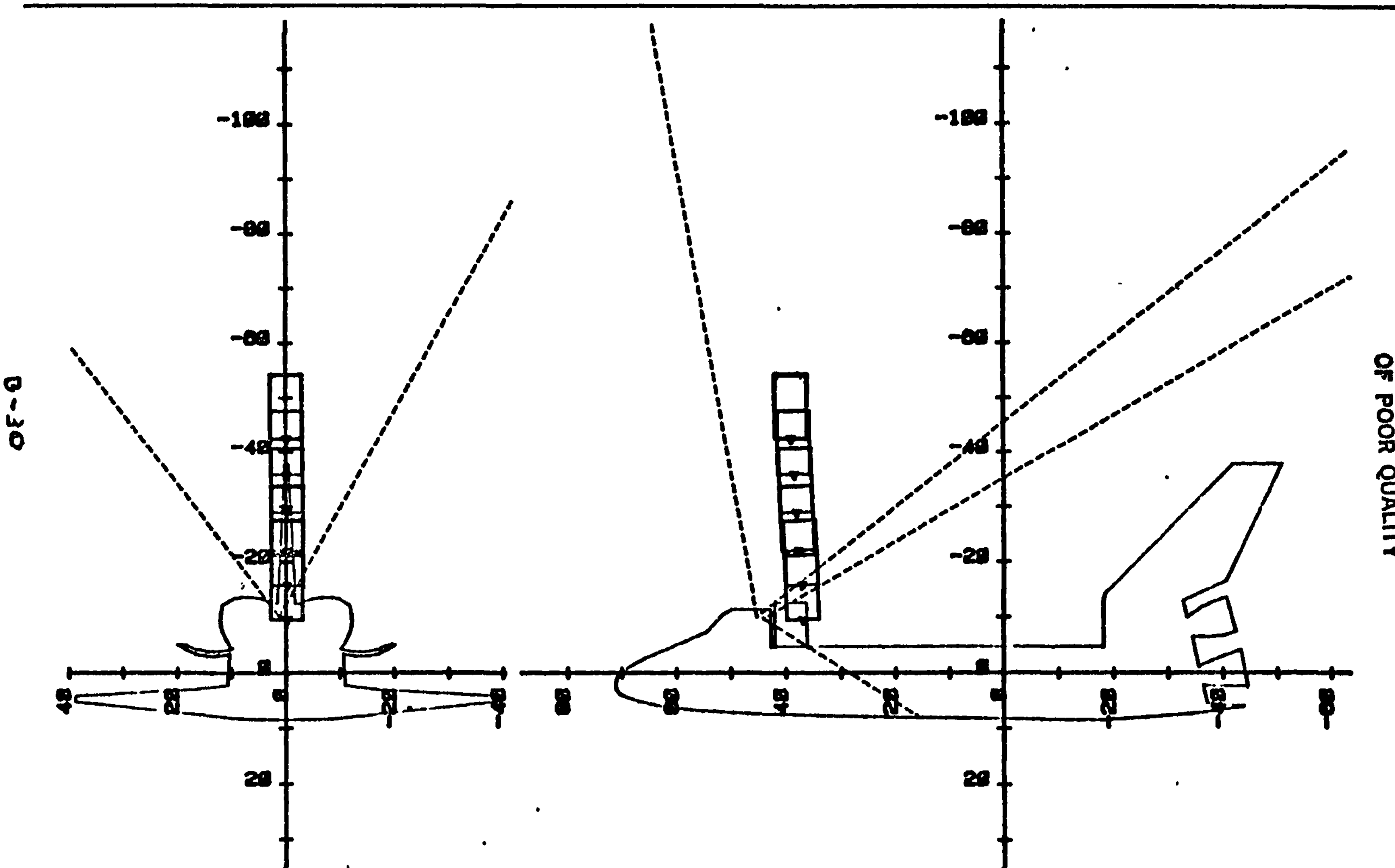
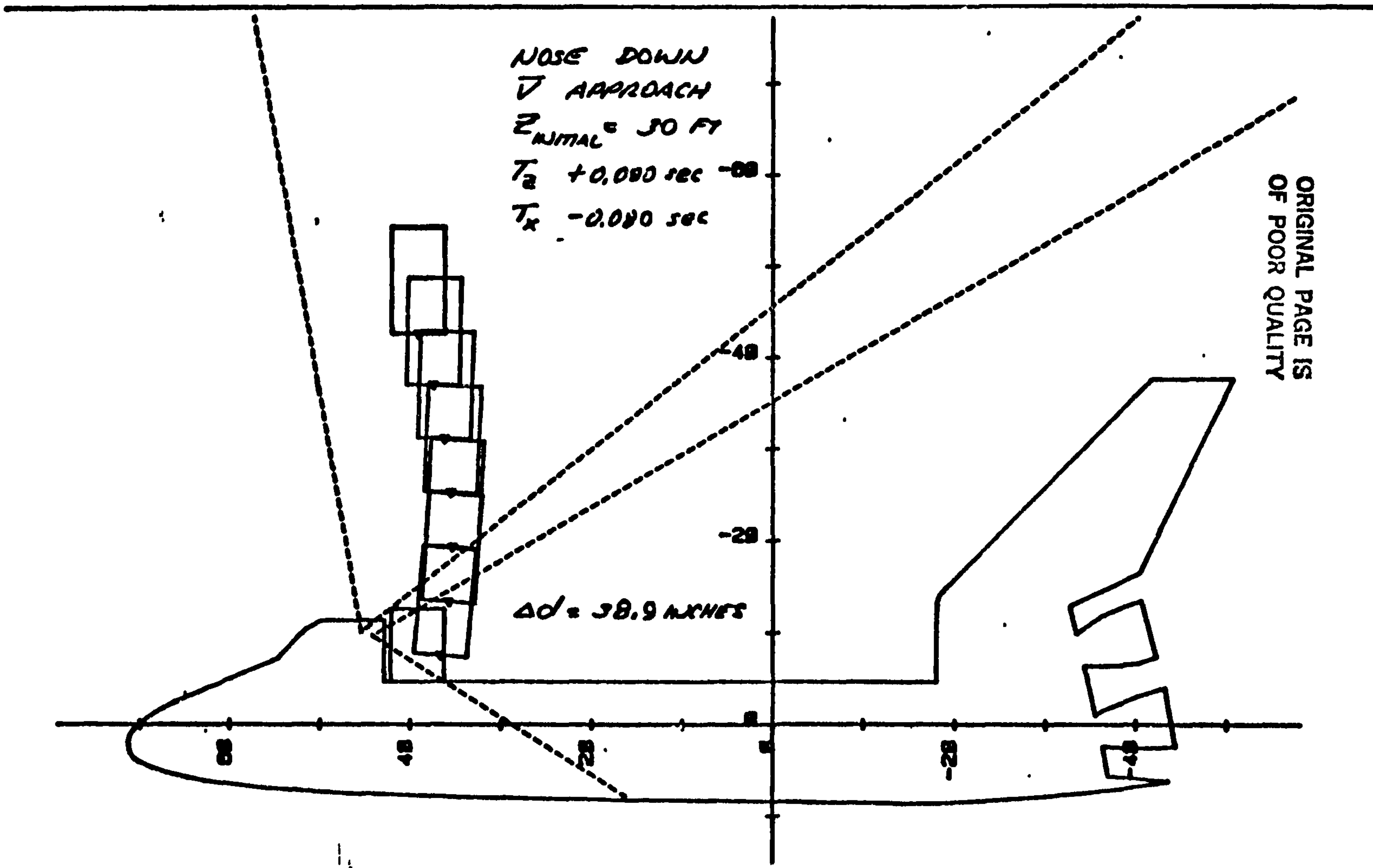


CASE 1.2.2 (MID-COURSE ROT CORRECTION)

Enclosure 2

DOCKING CASE 1.2.3



CASE 1.2.3 (UNDER-X, OVER-Z, NO ROT CORRECTION) (07/10/80)

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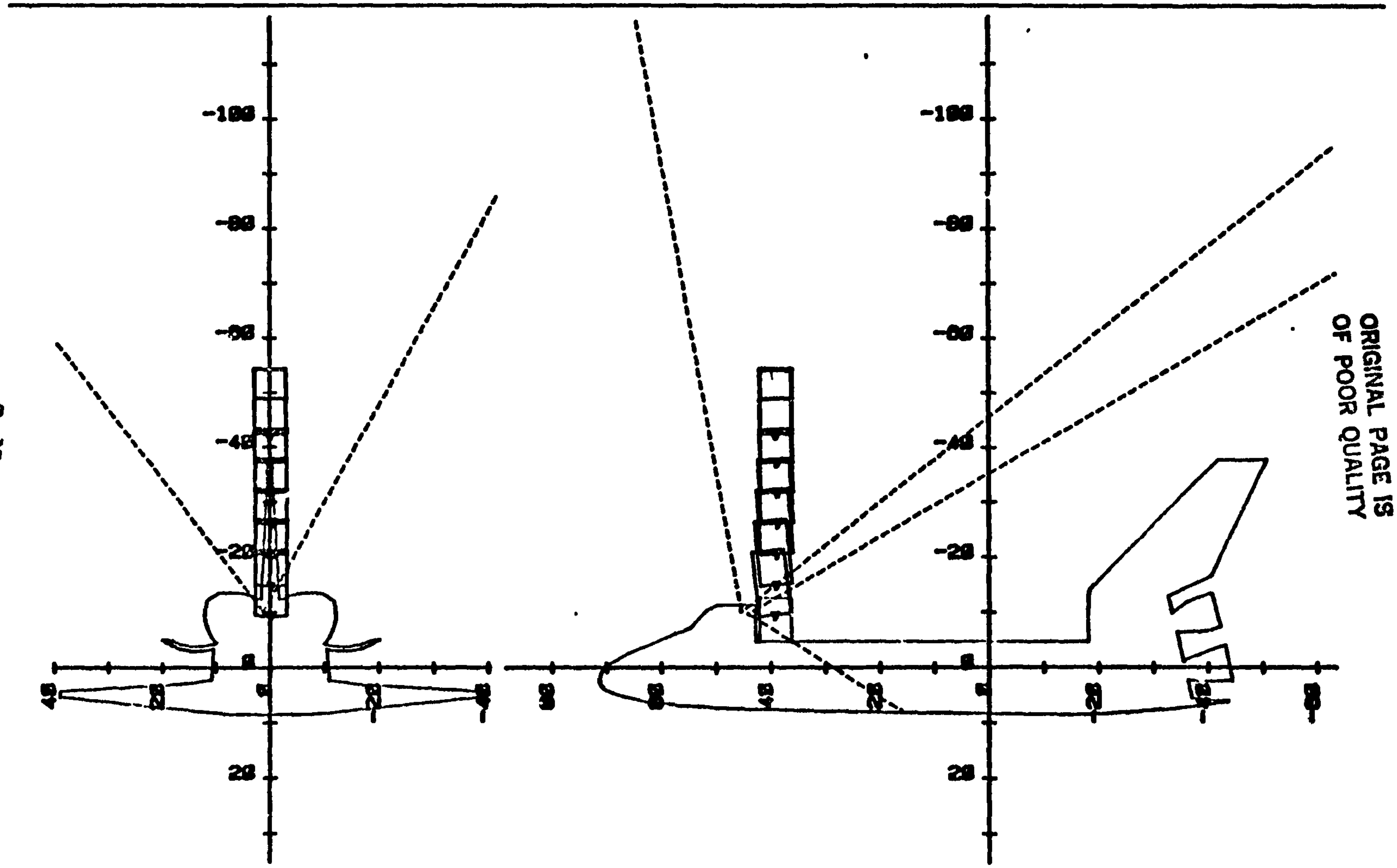

**** 30 ft 1.0 min DOCK,-.00ooo-Z,-X,NO COMP ROT COR., 07/03/80 CASE 1.3.1 *****

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Enclosure 2

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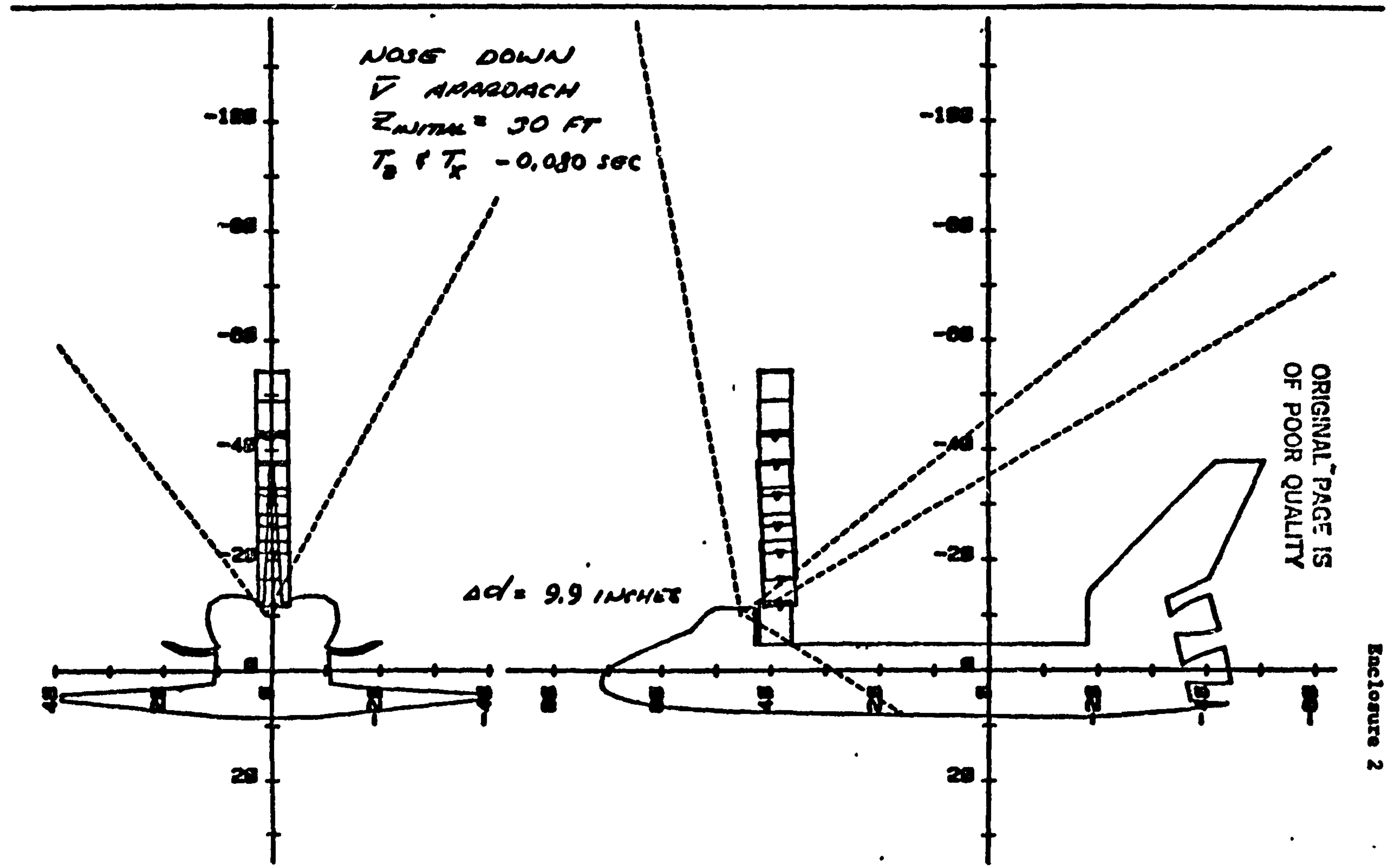
DOCKING CASE 1, 3, 2



30 ft 1.0 min DOCK, -.08sec-Z, -X, NO COMP ROT W/MID COURSE COR., (7/8/80)

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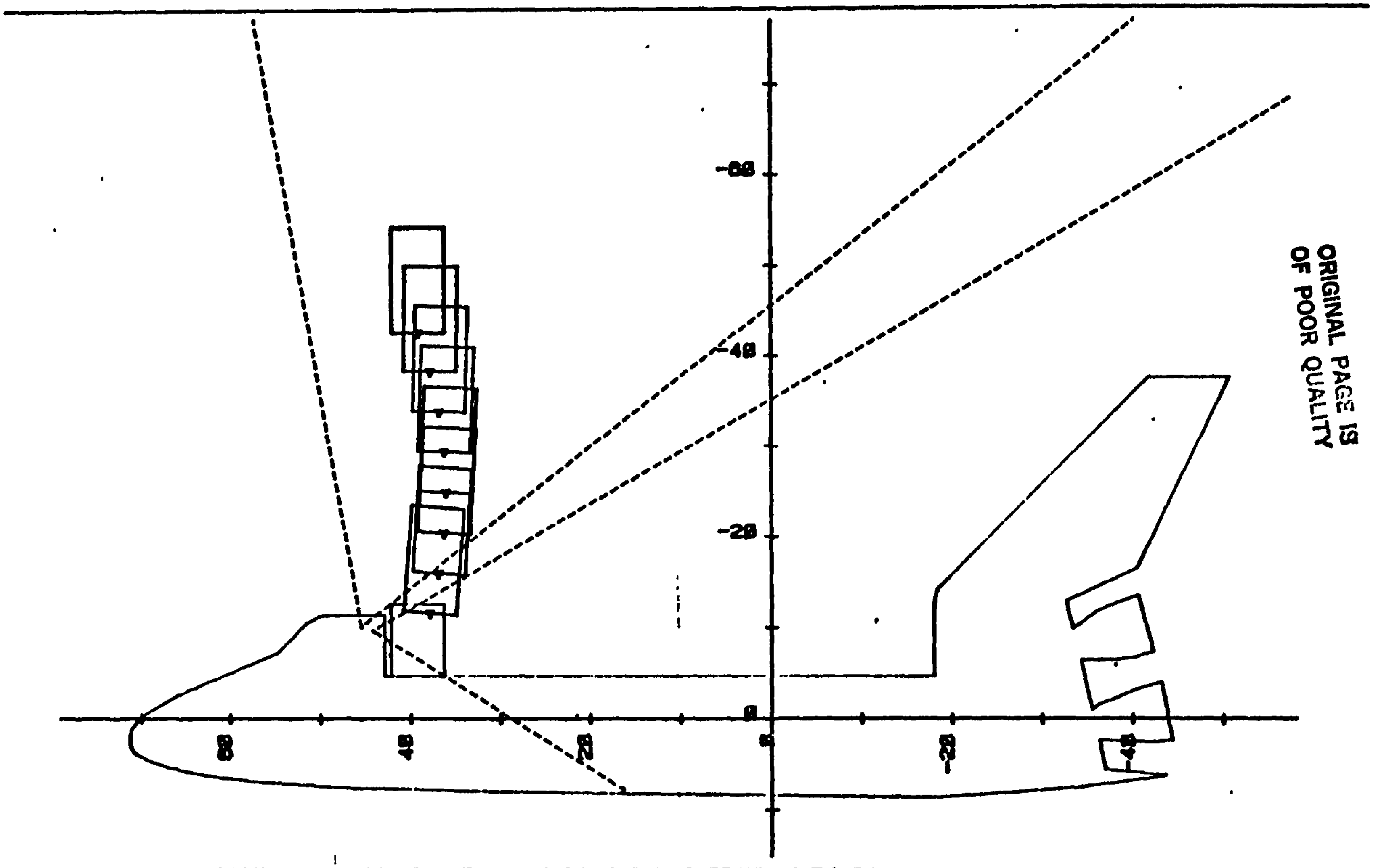

CASE 1.3.3 (UNDER -Z, -X, NO PROT CORRECTION) (07/10/80)

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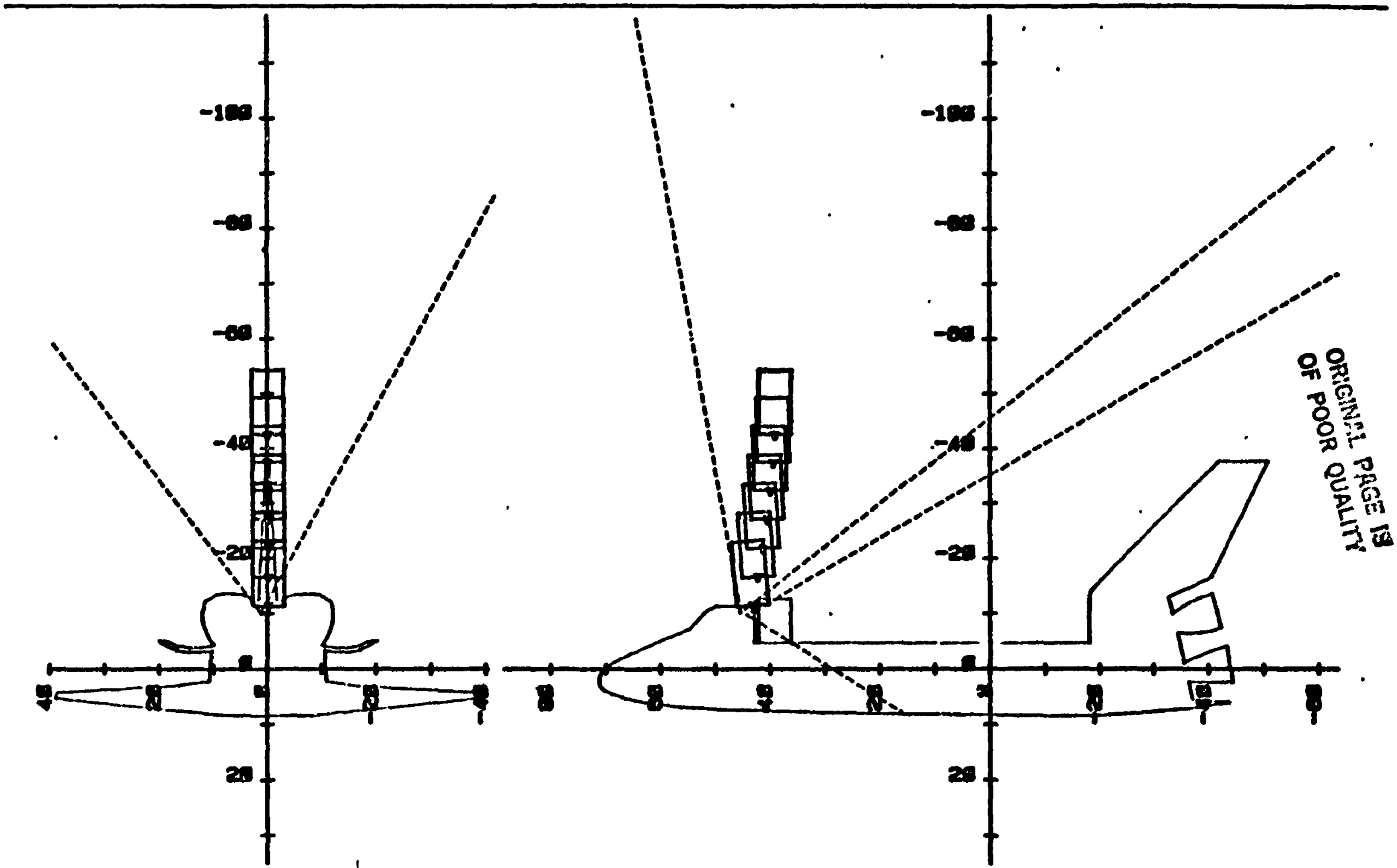
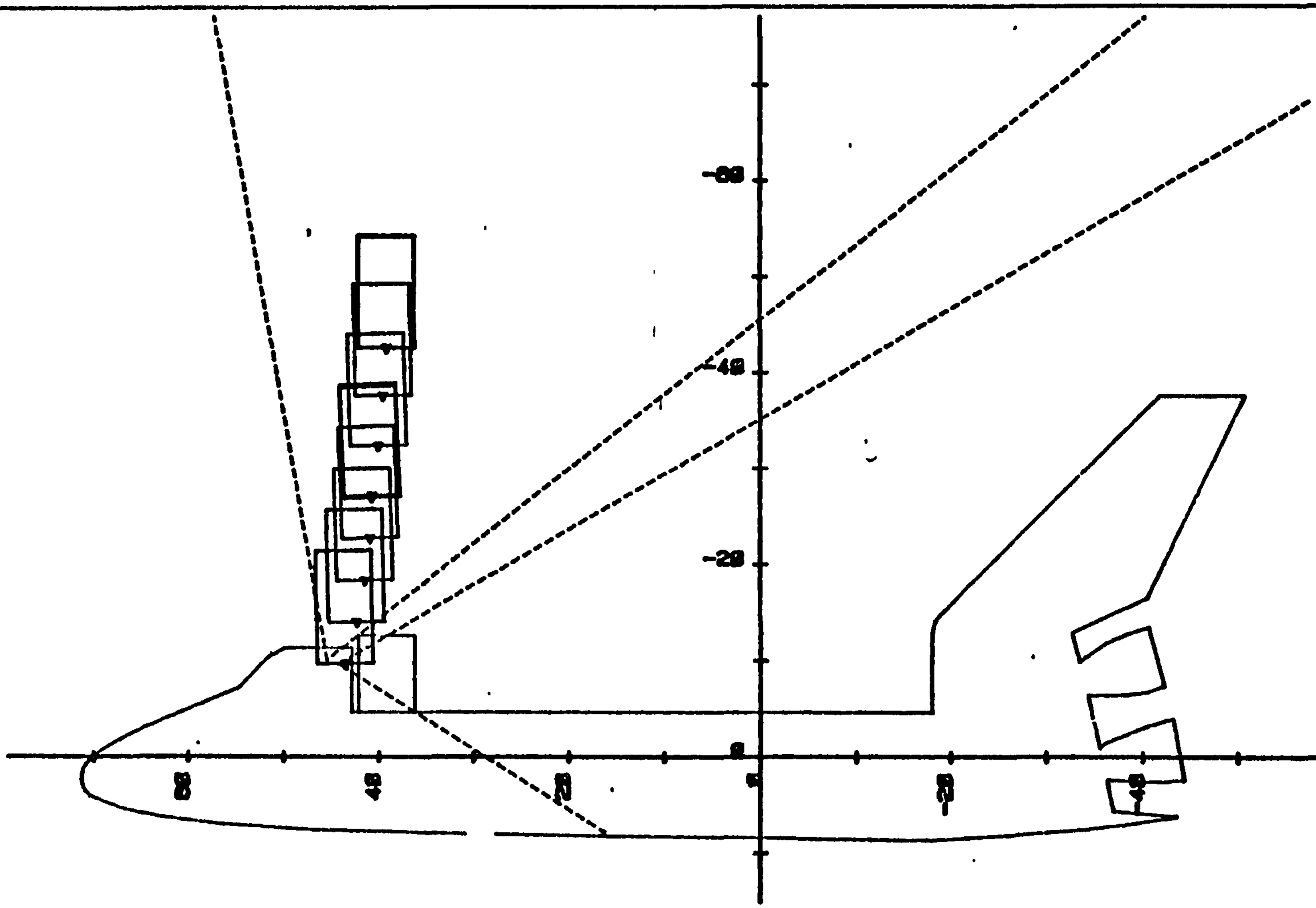


CASE 1.4.1

Enclosure 2



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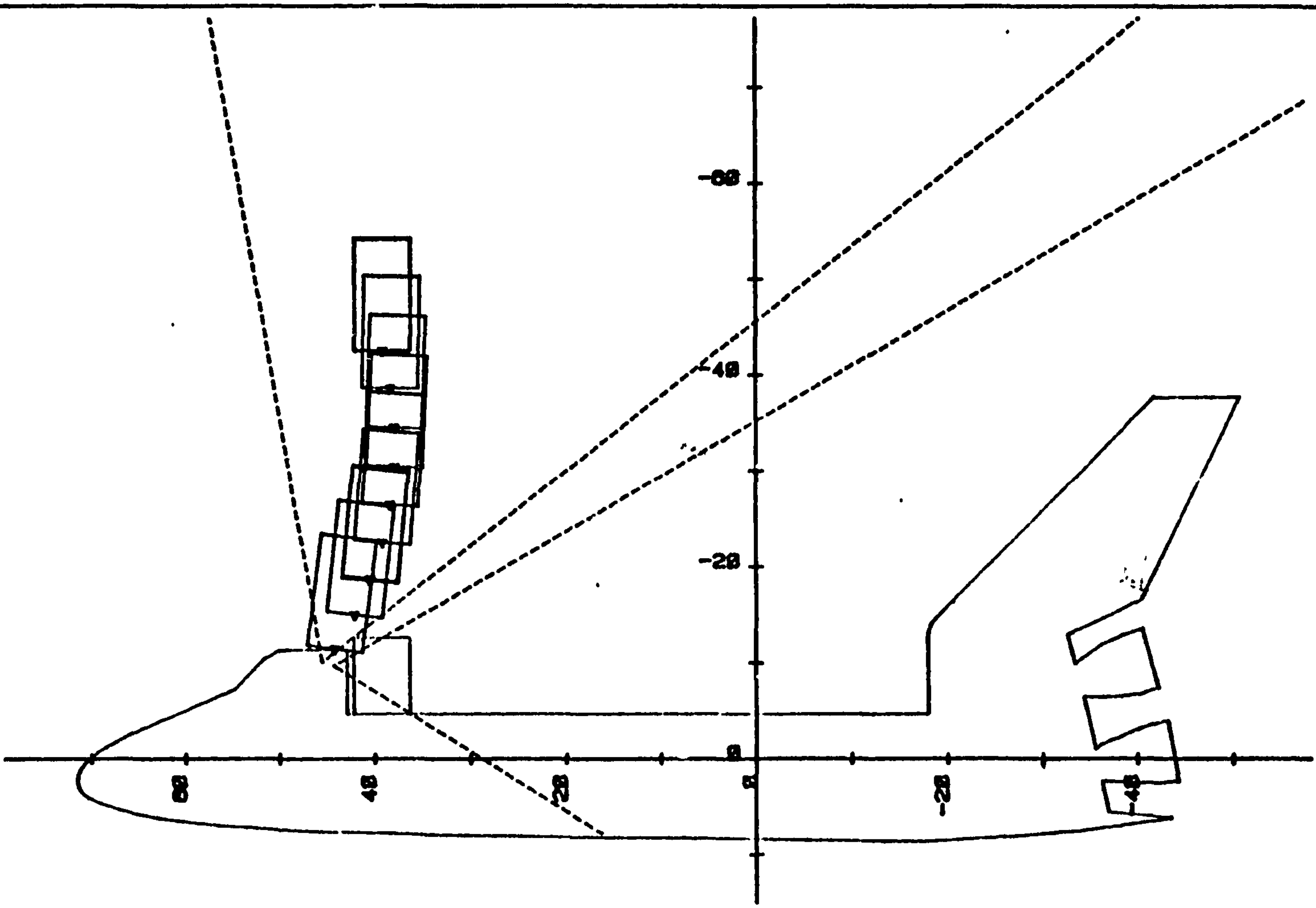
REPLACEMENT 1.4.2 (07/28/80)



CASE 1.4.3 (NO ROT CORRECTION AT ALL, OVER -X, UNDER -Z) (07/10/80)

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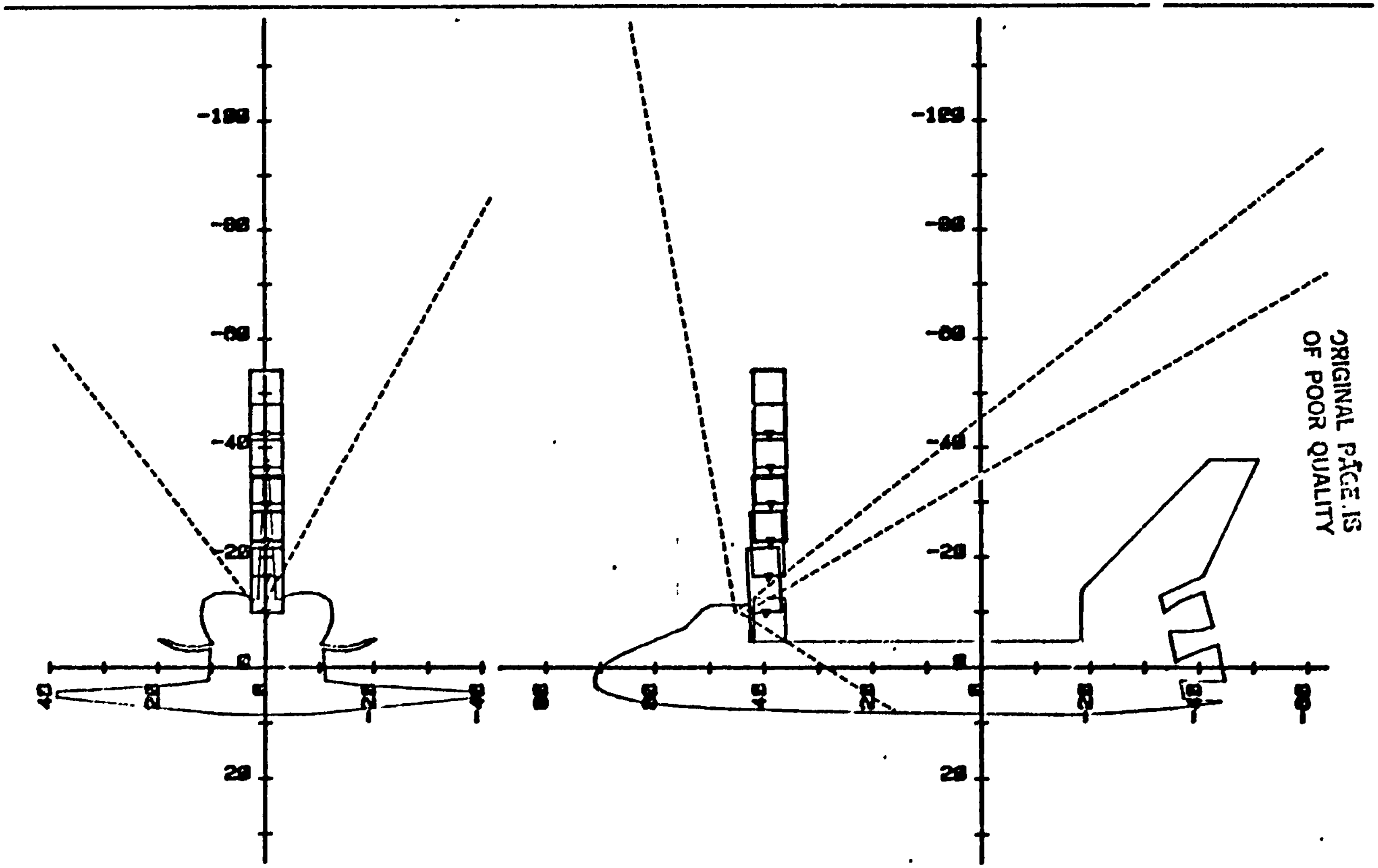
Enclosure 2



CASE 1.5.1 (P ROT CORRECTION ONLY) (07/09/80)

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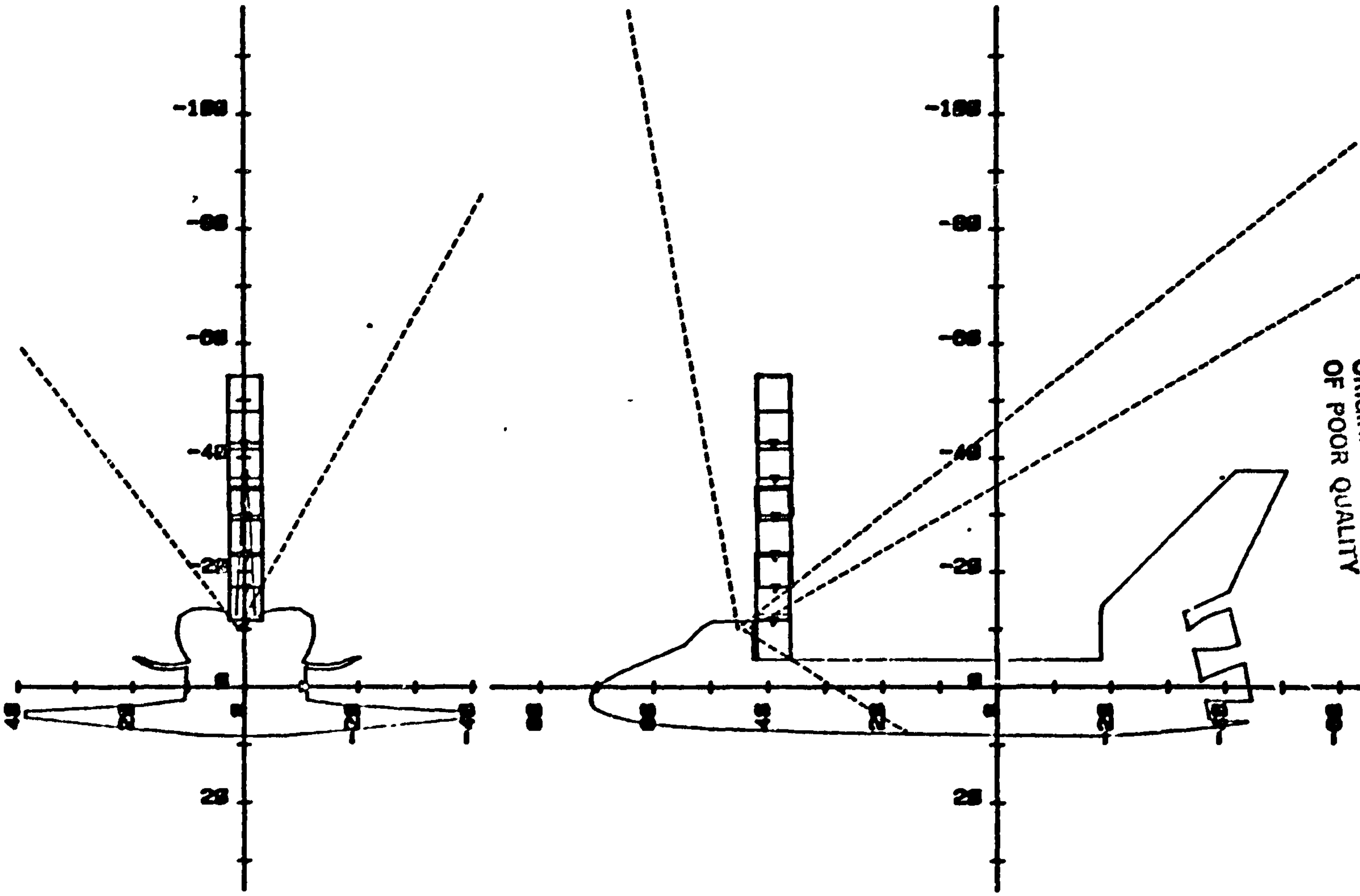

CASE 1.5.2 (MID COURSE CORRECTION) (07/00/00)

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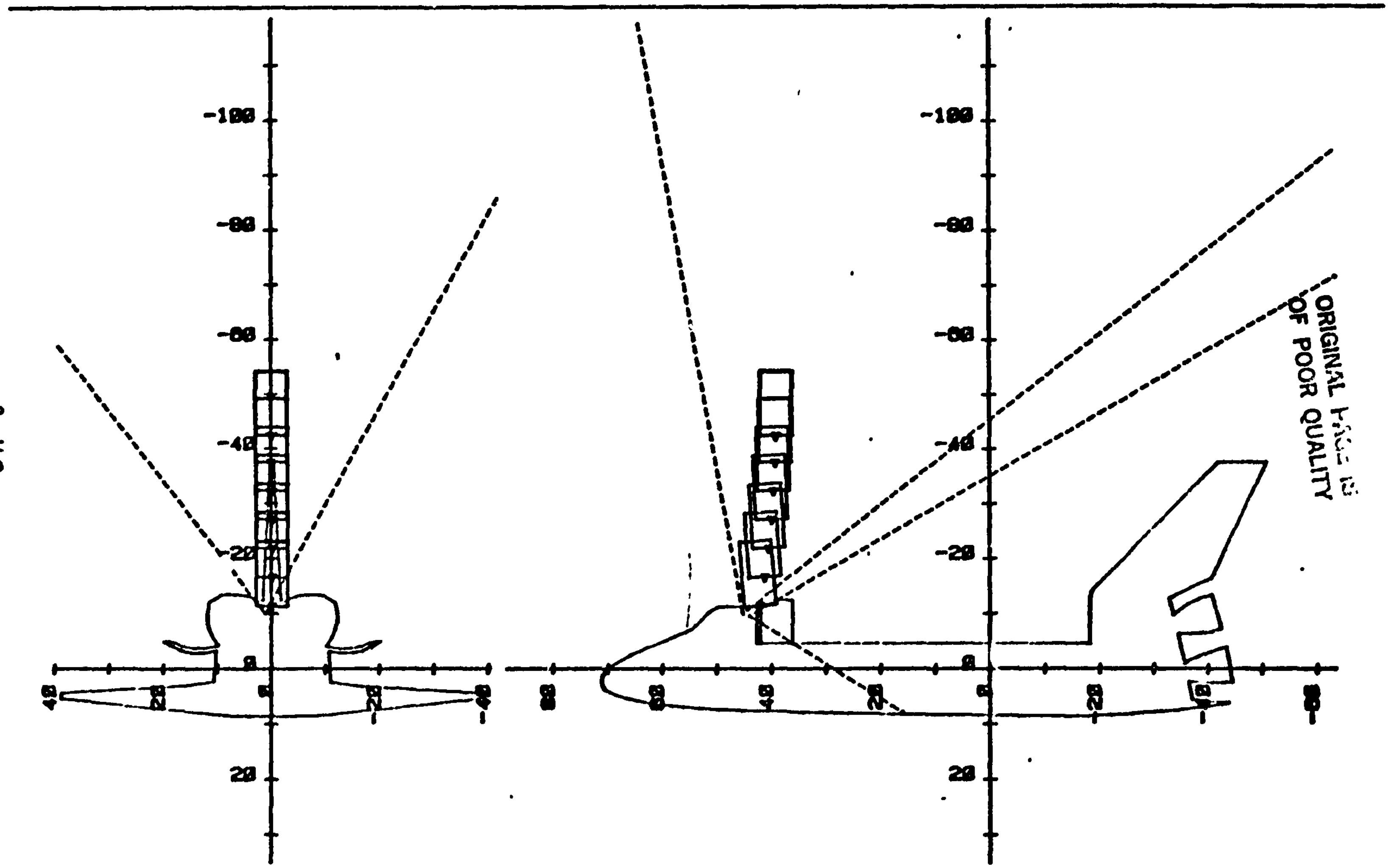

CASE 1.6.1 (P ROT CORRECTION, -Z UNDER, -X OVER) (07/09/80)

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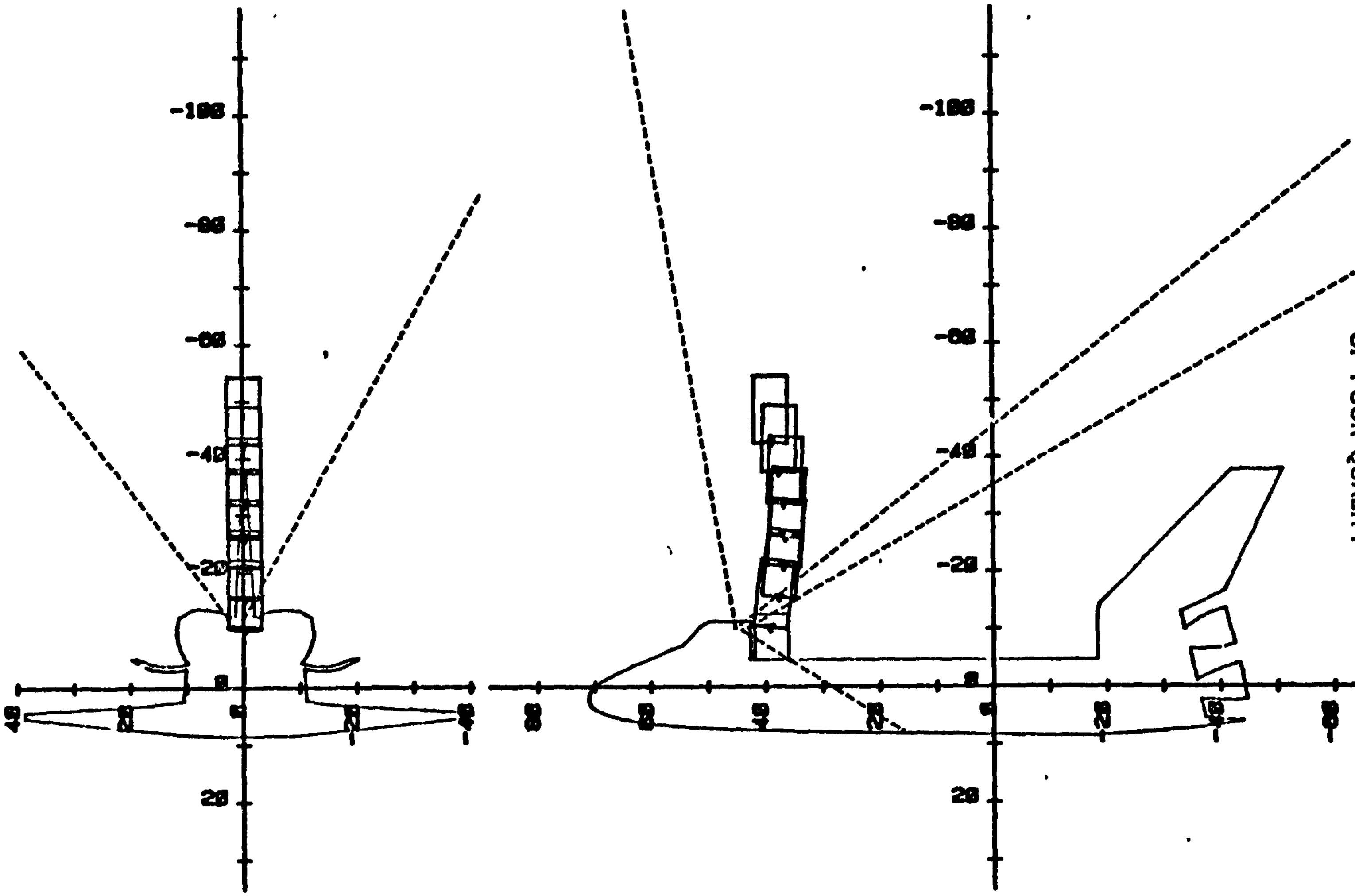

CASE 1.5.3 (NO P ROT CORRECTION AT ALL) (07/09/80)

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Enclosure 2

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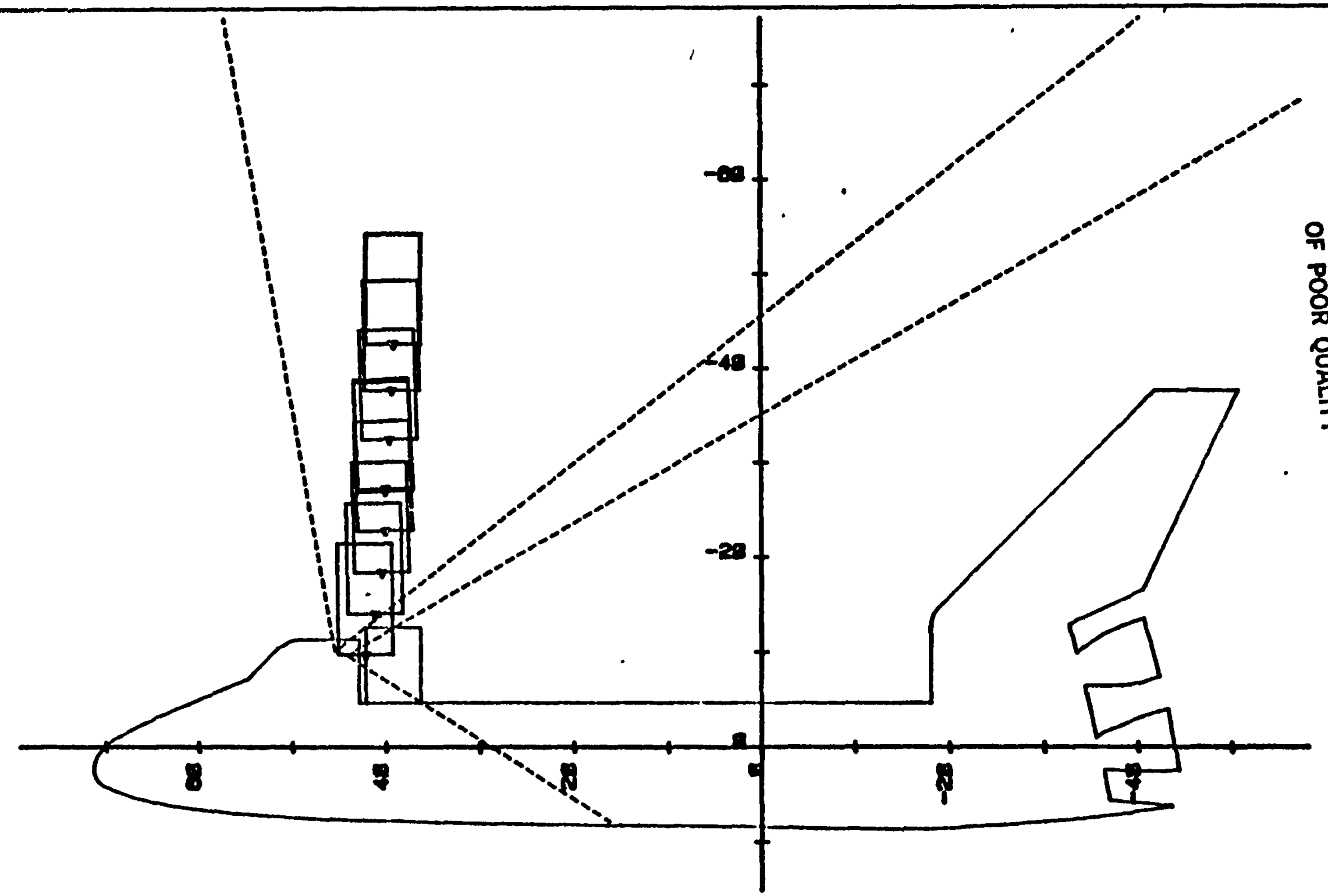
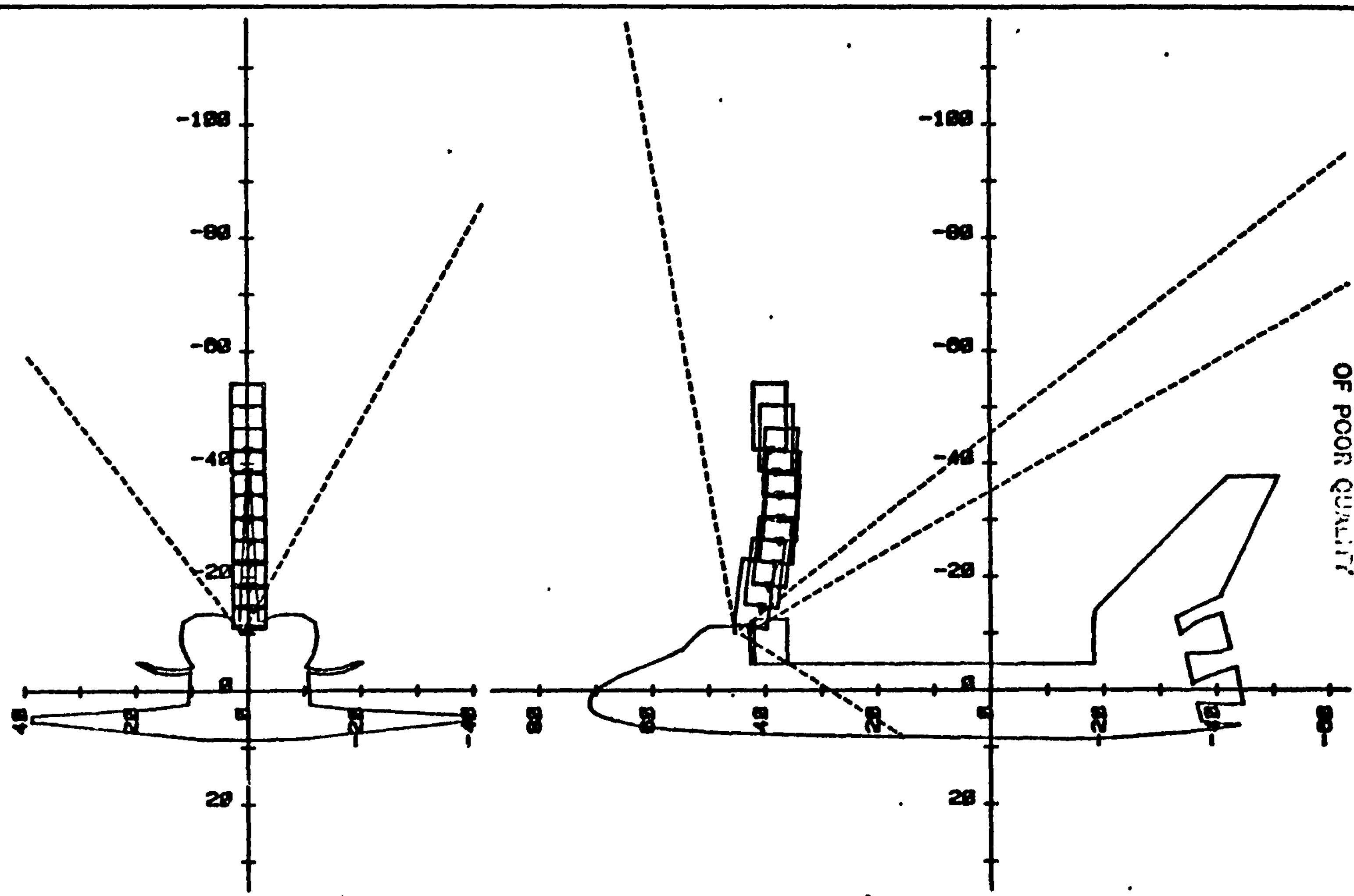
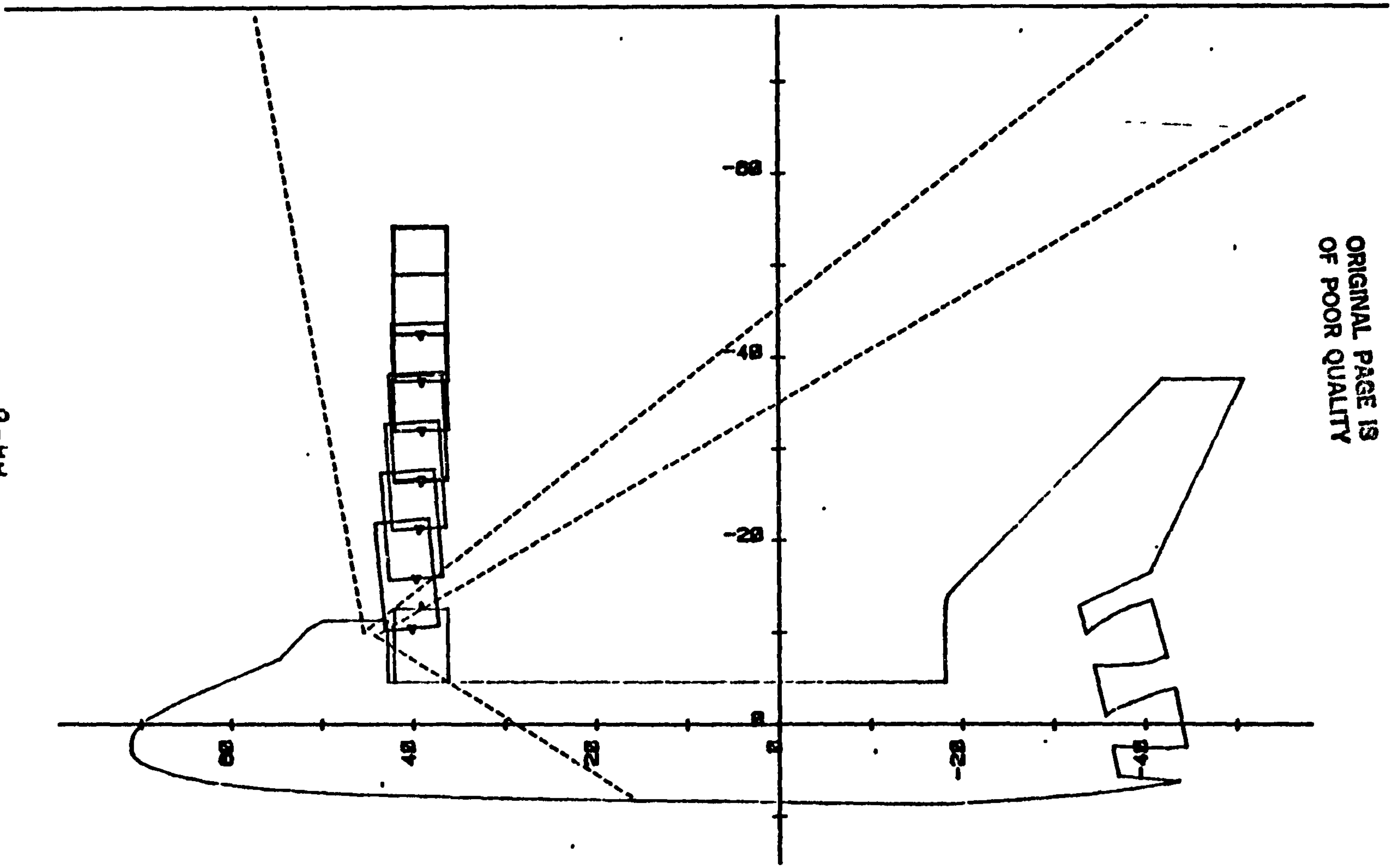


REPLACEMENT 1.8.2 (07/29/80)



CASE 1.6.3 (NO P ROT CORRECTION--Z UNDER, -X OVER) (07/09/82)

Enclosure 2



CASE 1.7.1 (-Z, -X UNDER, BEGINNINNG ROT CORRECTION) (07/09/80)

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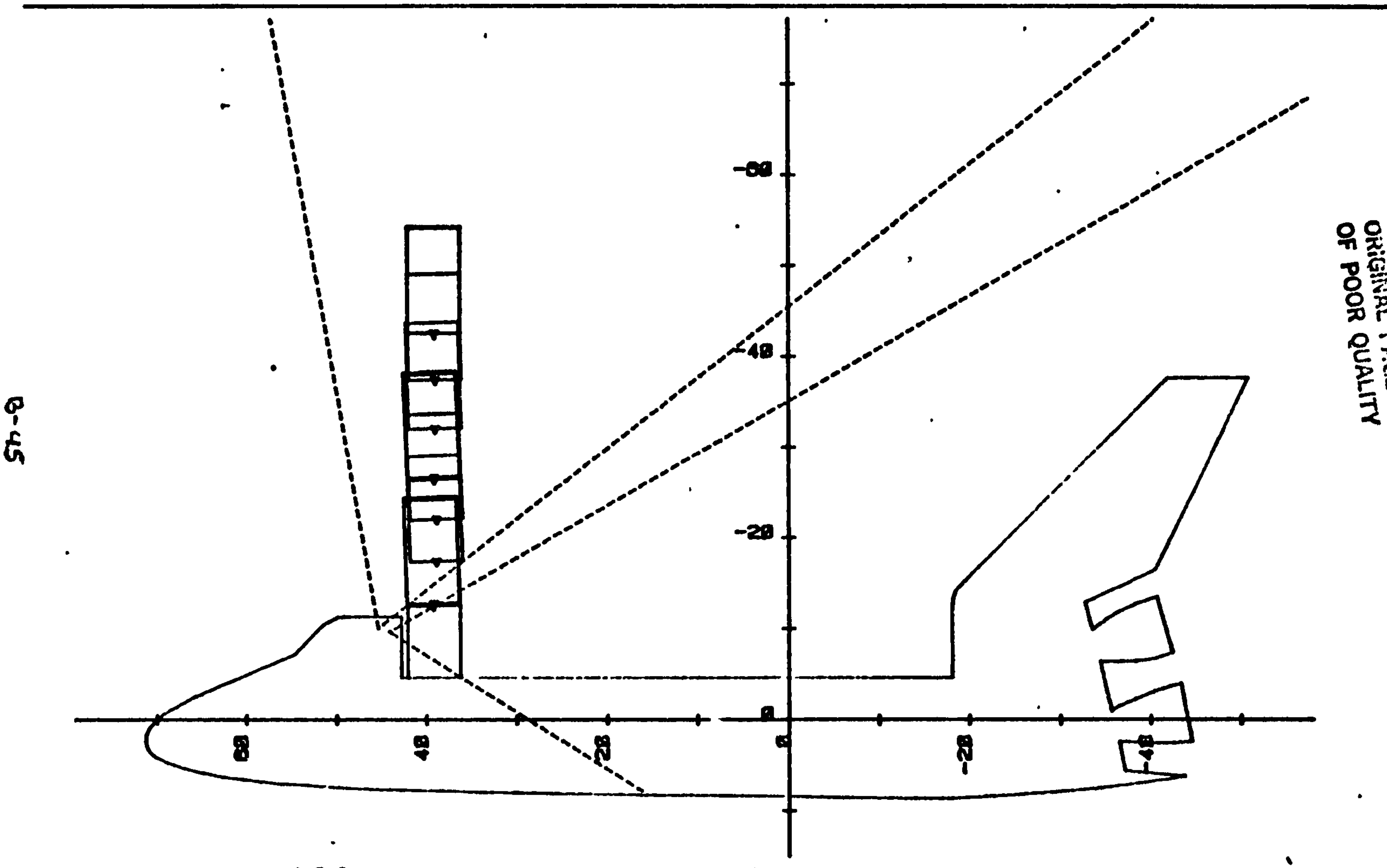

CASE 1.7.2 (-Z,-X UNDER, BEGINNING & MID CORSE ROT CORRECTION)

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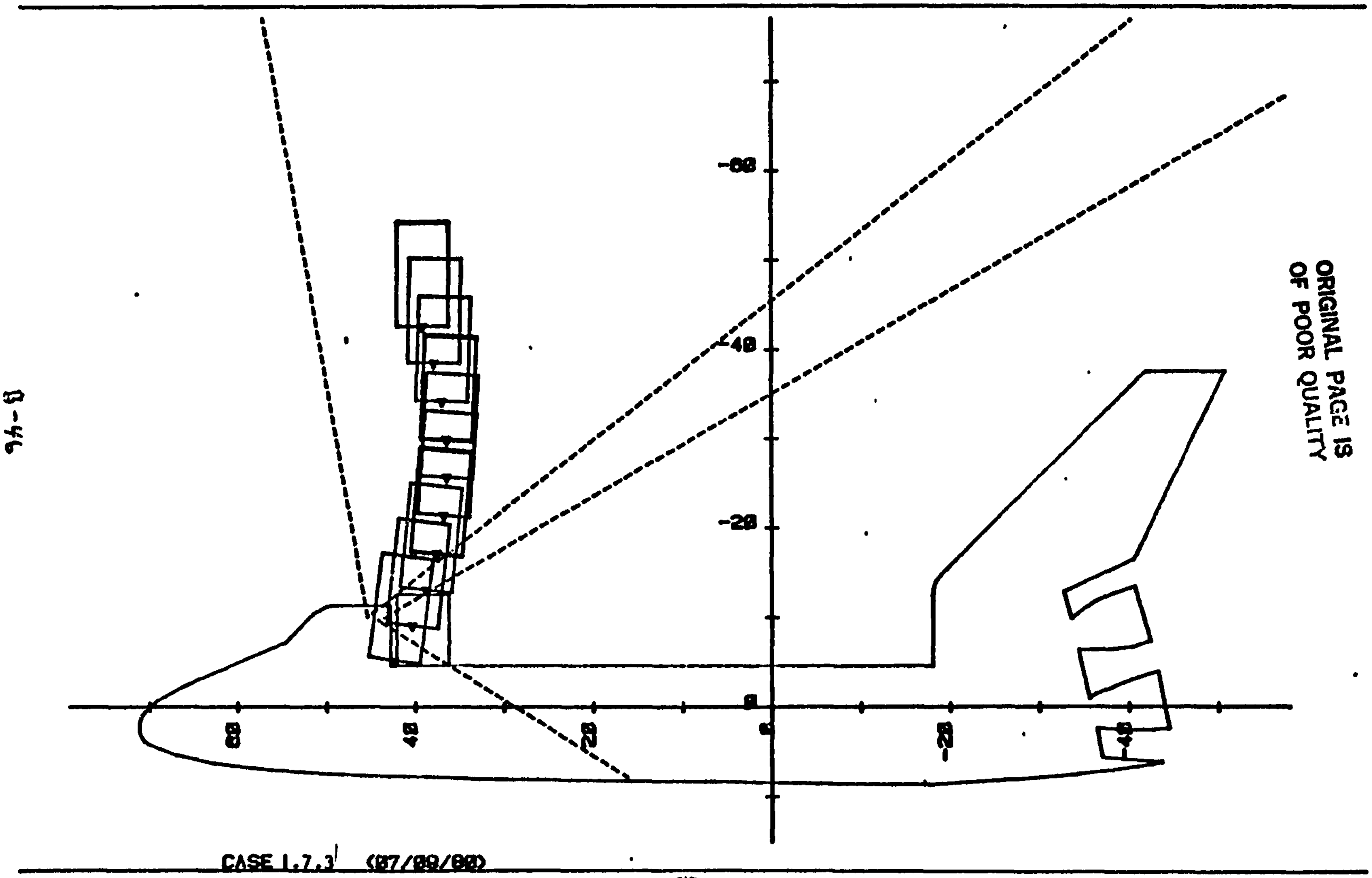

CASE 1.7.3 (07/09/80)

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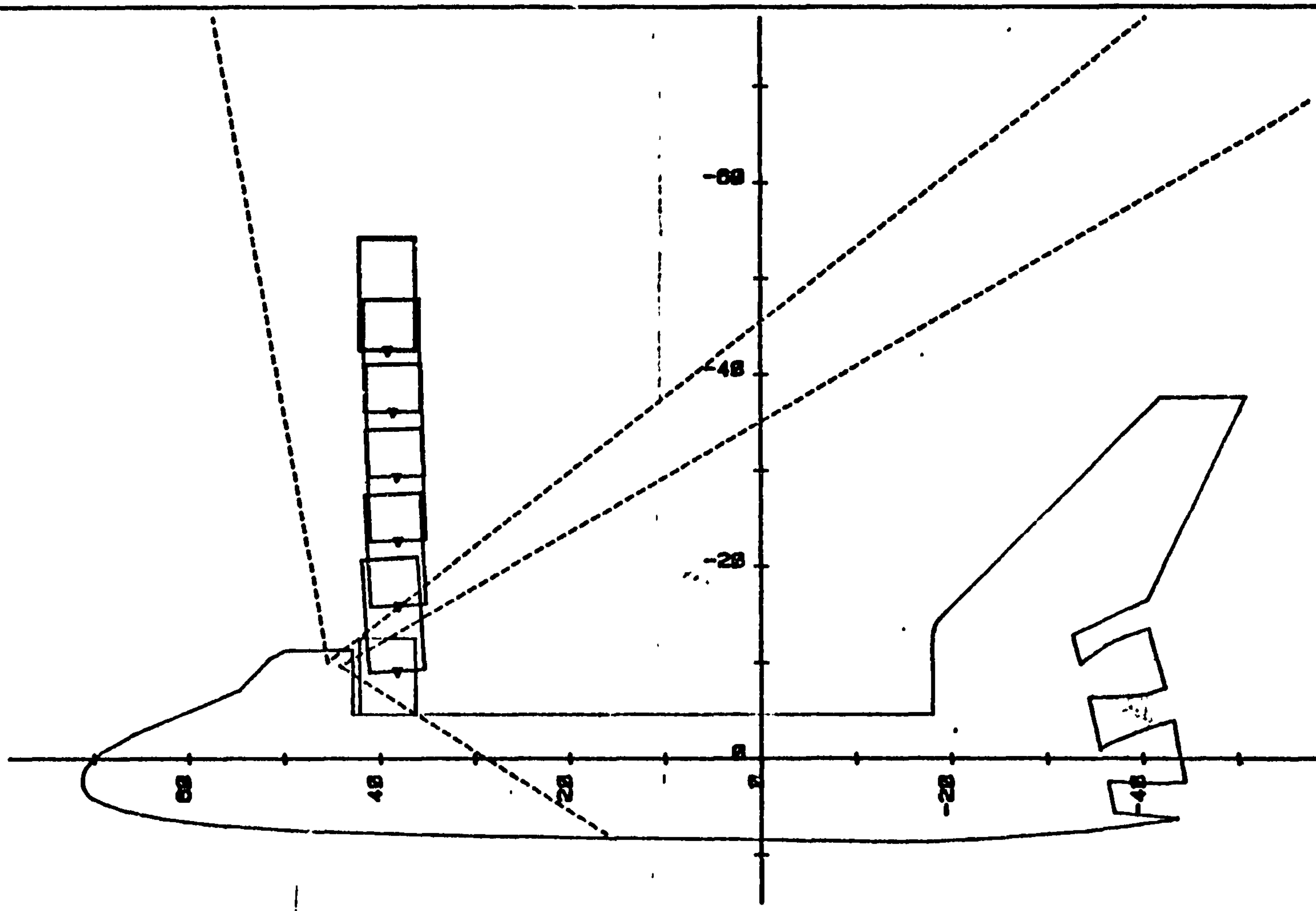
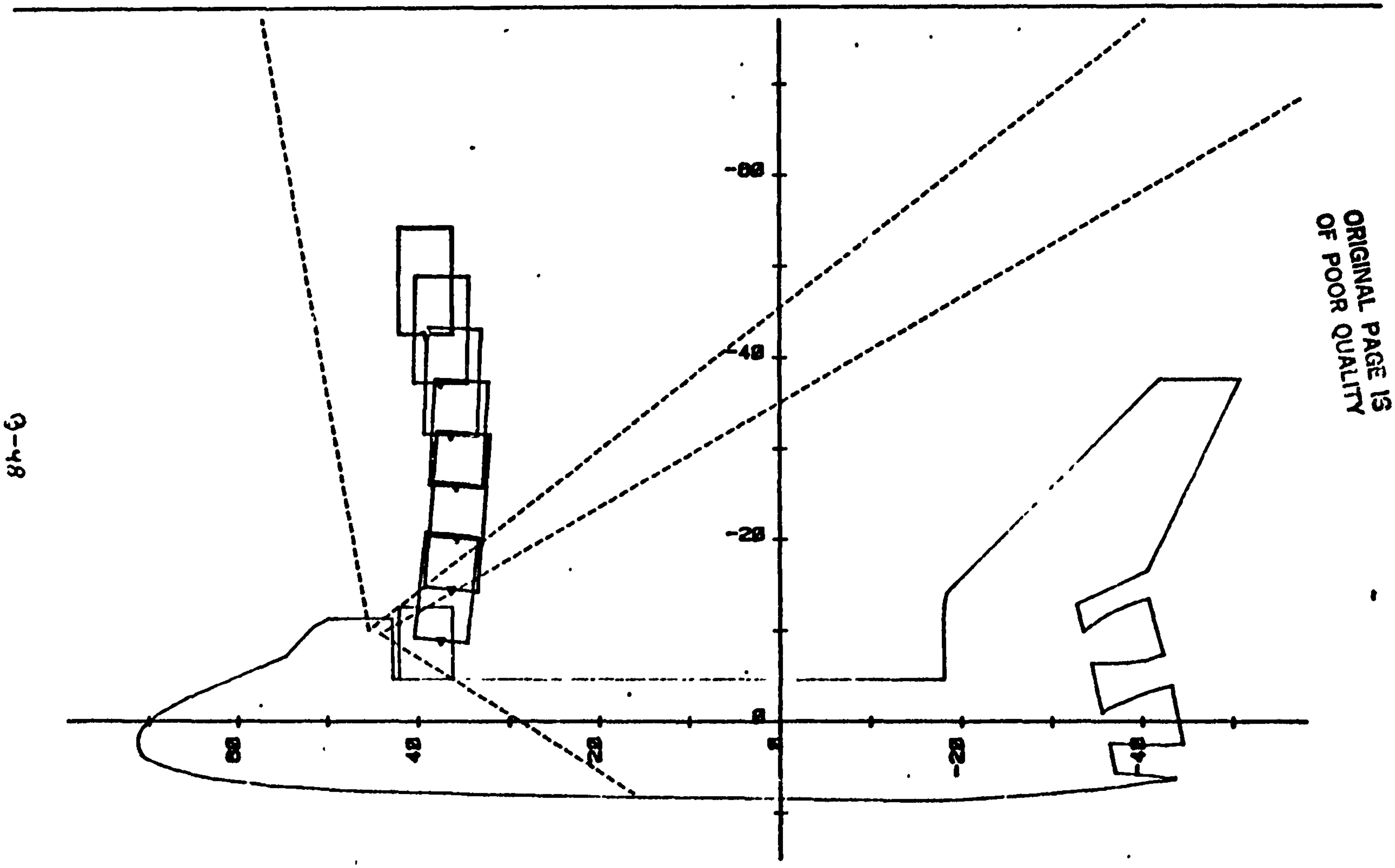


CASE 1.8.1 (P ROT CORRECTION) (07/09/80)



CASE 1.8.3 (NO ROT CORRECTION) (07/09/80)

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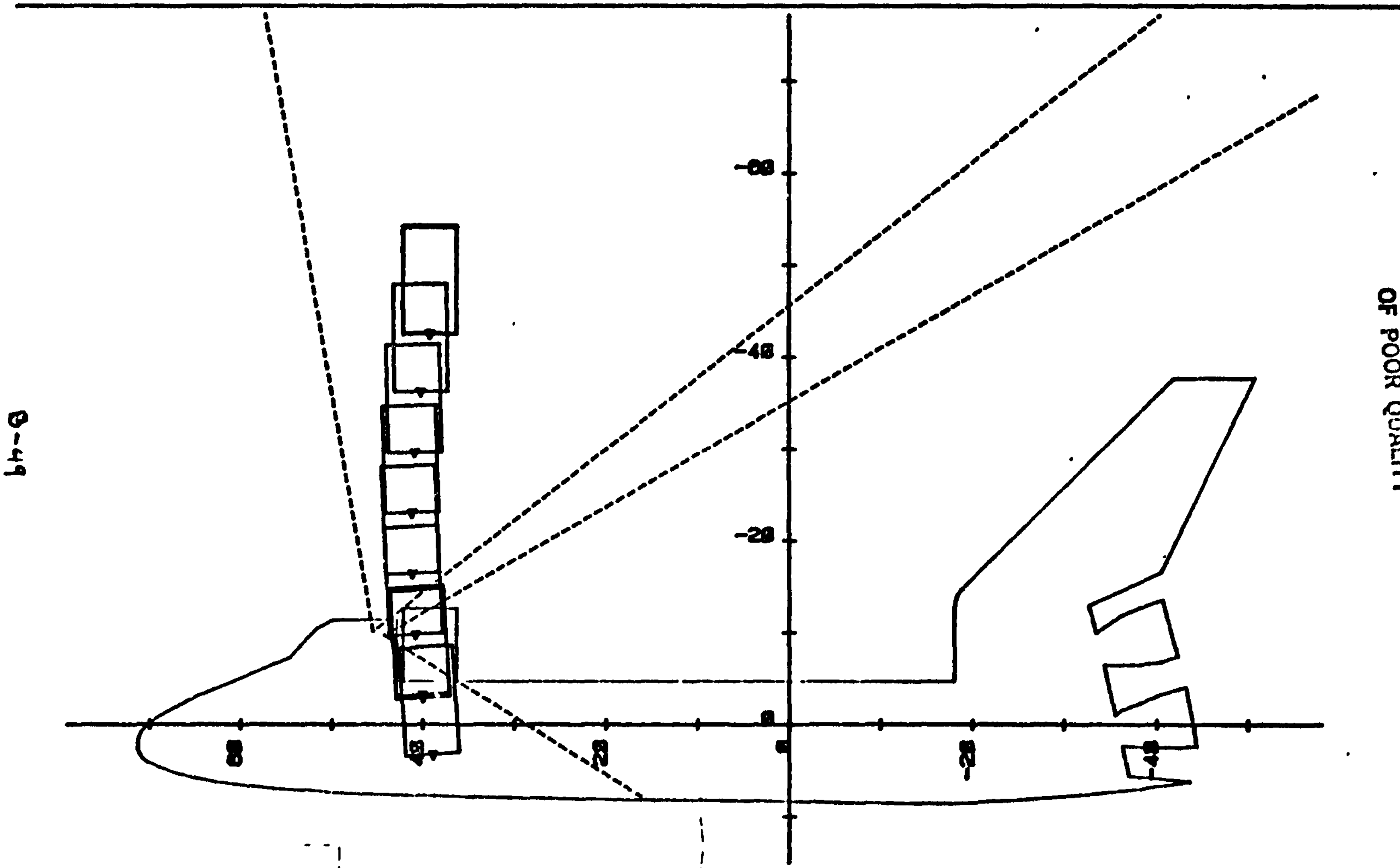

CASE 2.1.1 (INITIAL ROT P CORRECTION, OVER -Z,-X) (07/10/80)

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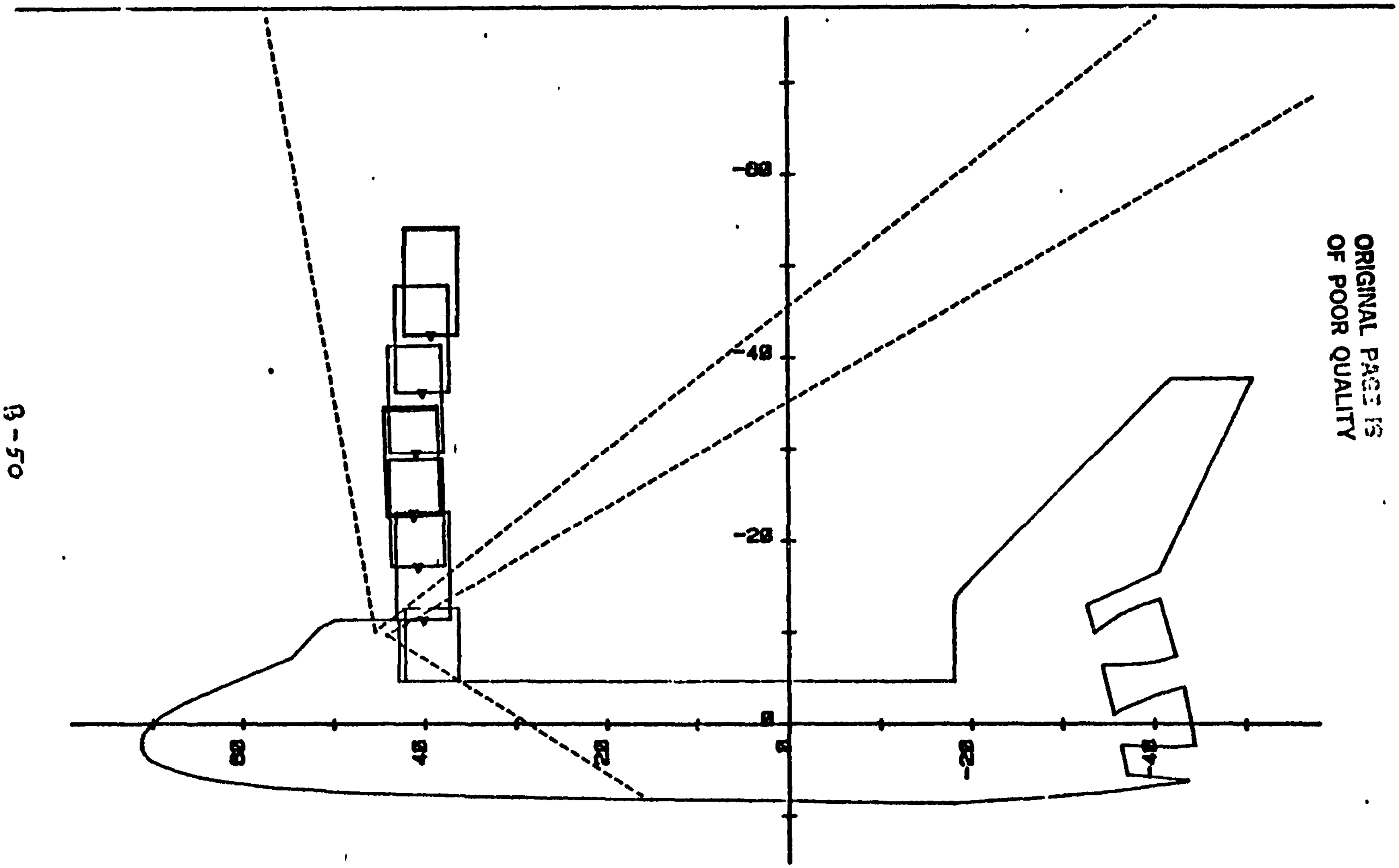

CASE 2.1.2 (P ROT CORRECTION W/MID COURSE CORRECTION, -Z, -X OVER) (07/10/80)

Enclosure 2

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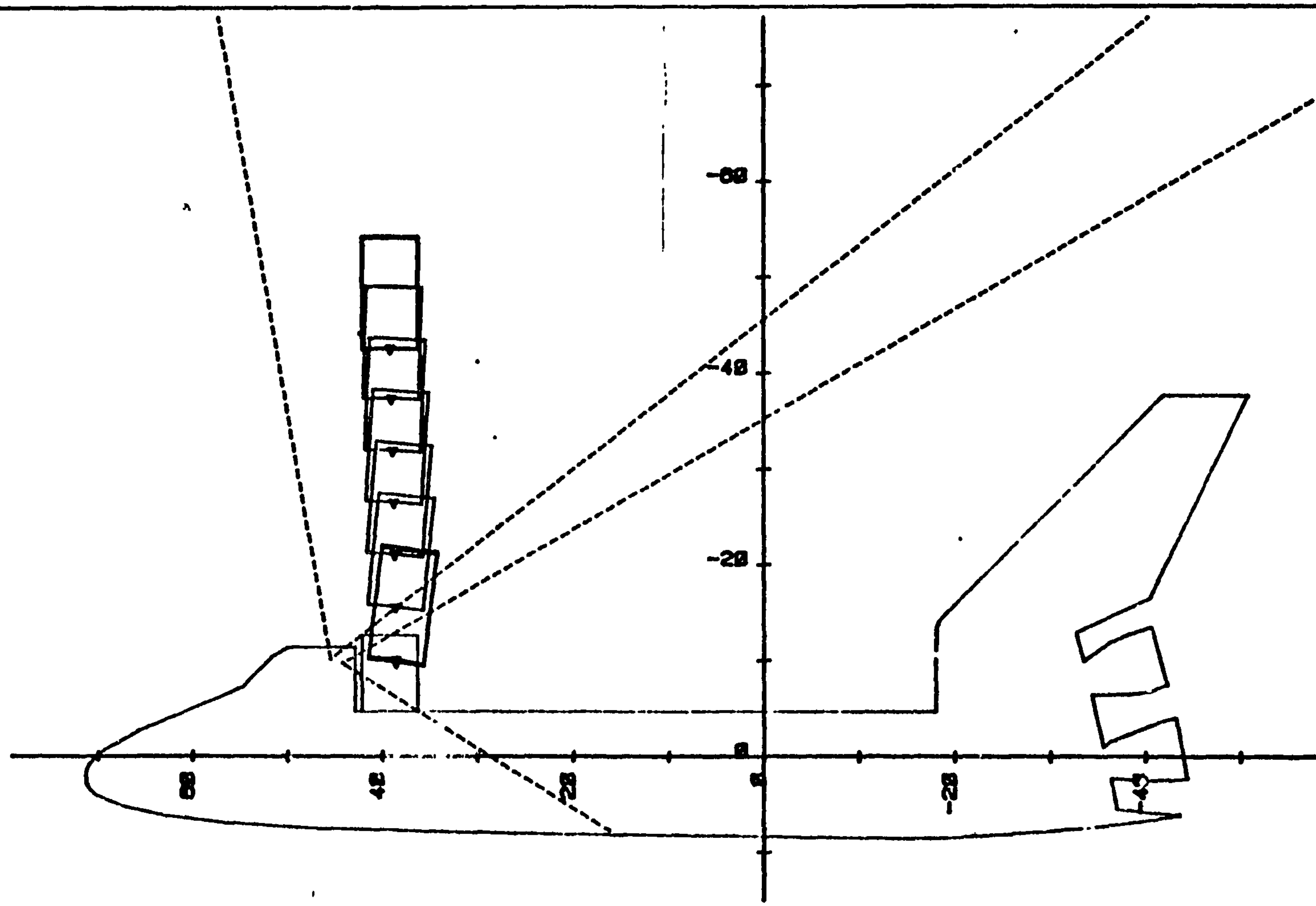
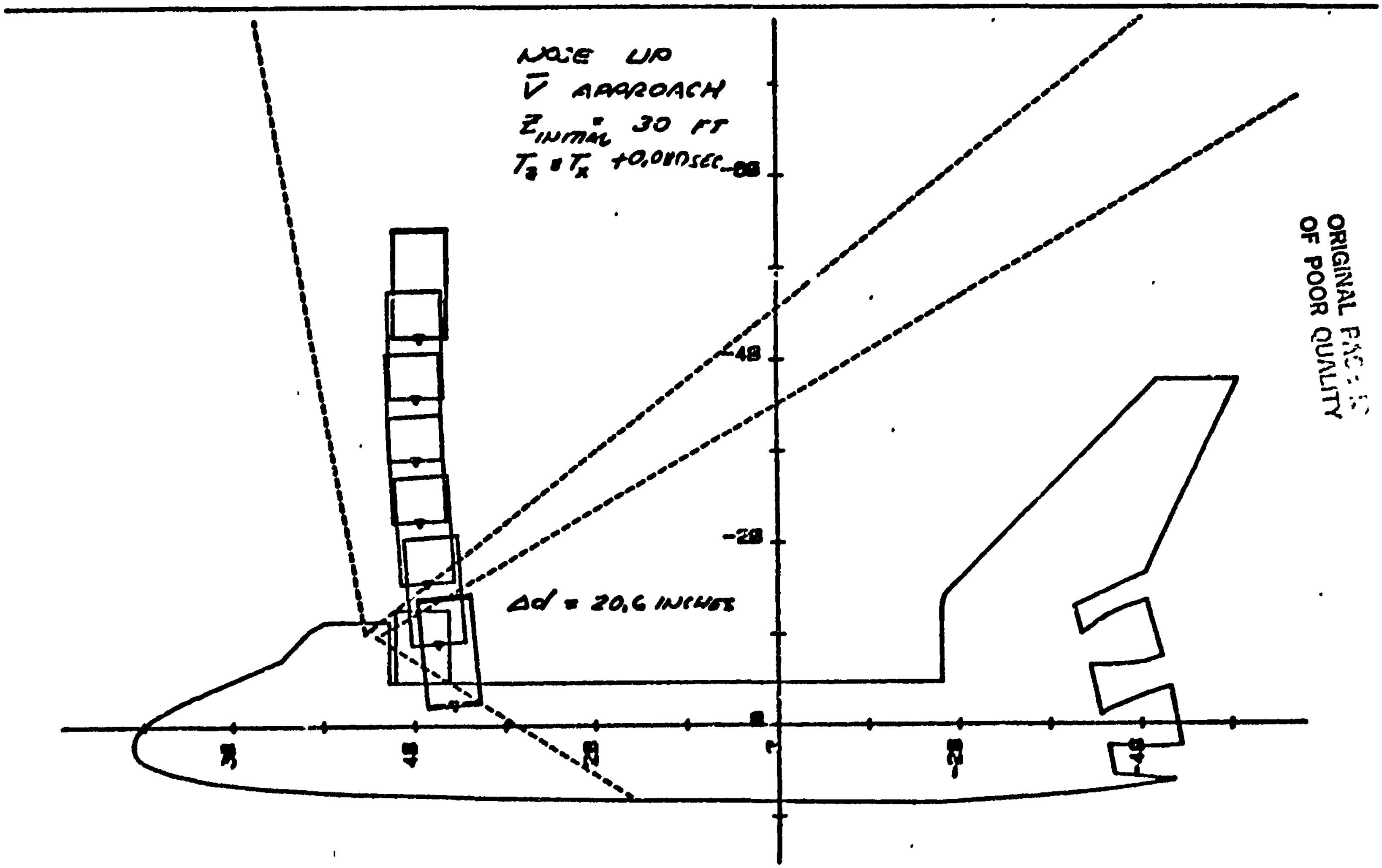


CASE 2.1.3 (COVER -Z,-X, NO P ROT CORRECTION) (07/10/89) (CASE IS NOSE-UP)

DOCKING CASE 2.2.1



CASE 2.2.1 (OVER -Z UNDER -X, ORBITER NOSE UP) (07/18/80)

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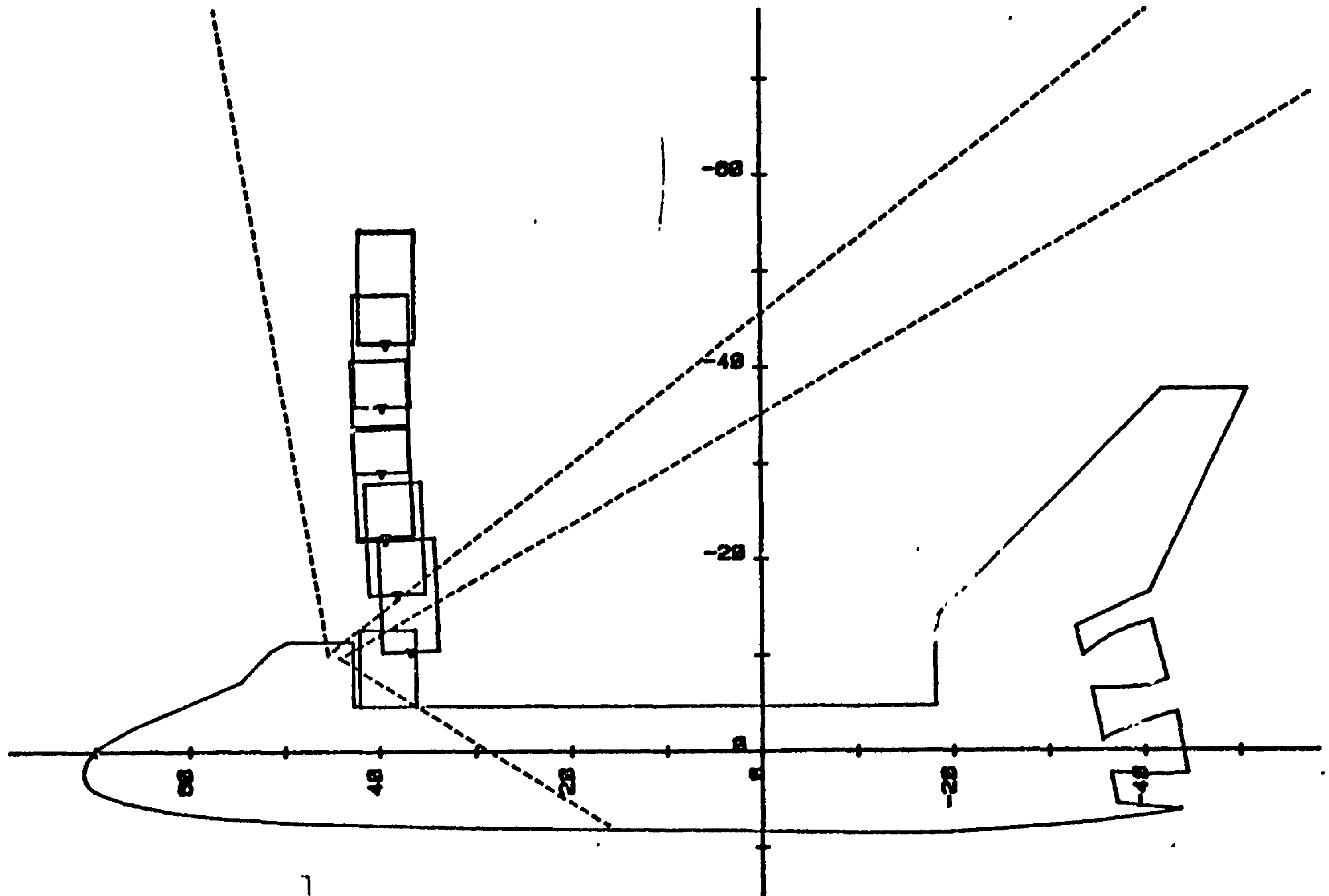
Enclosure 2



CASE 2.2.2 (OVER -Z, UNDER -X, MID COURSE ROT CORRECT, ORBITER NOSE UP) (07/10/80)

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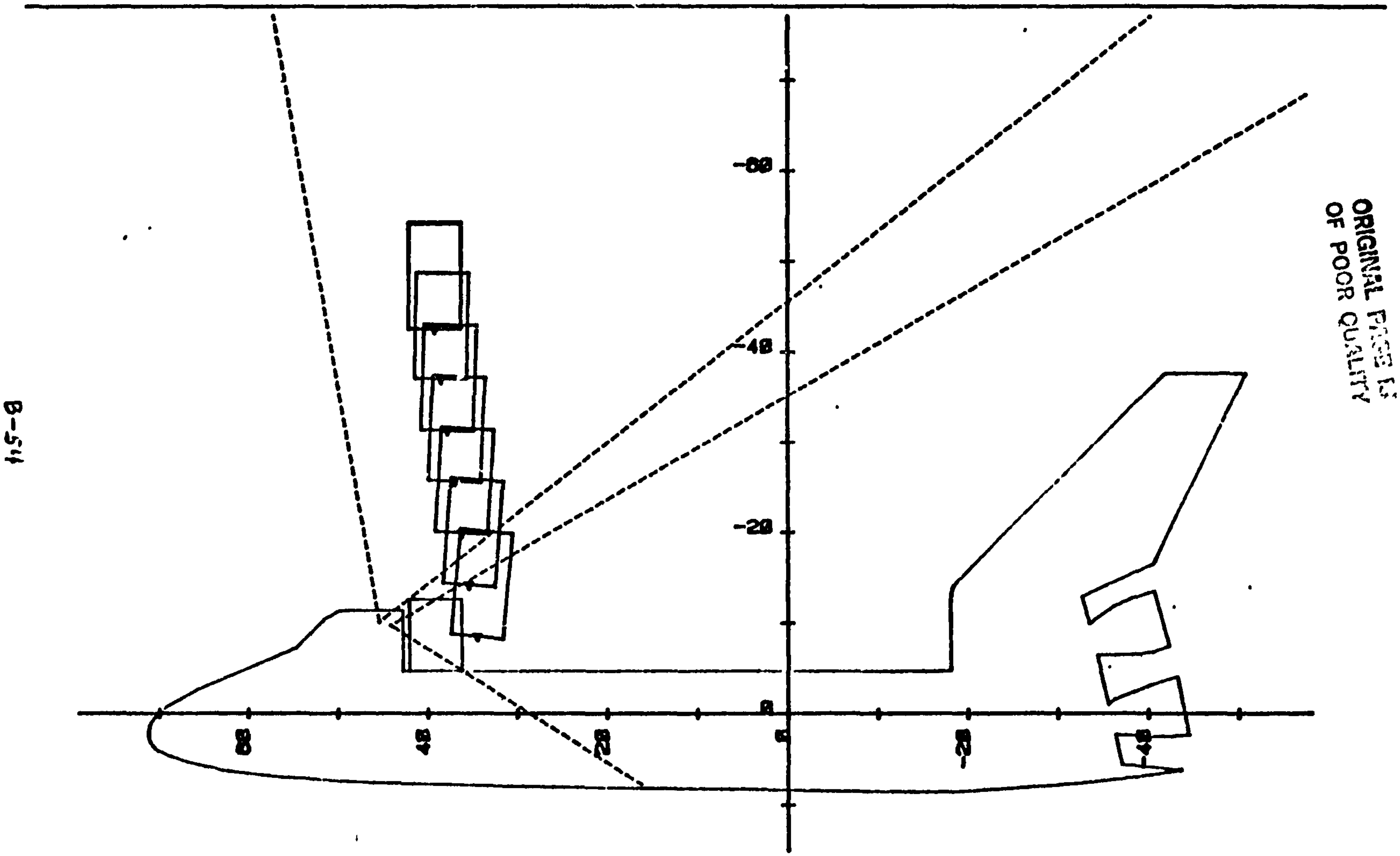
Enclosure 2



CASE 2.2.3' (NO ROT CORRECTIONS, -Z OVER, -X UNDER) (07/10/80)

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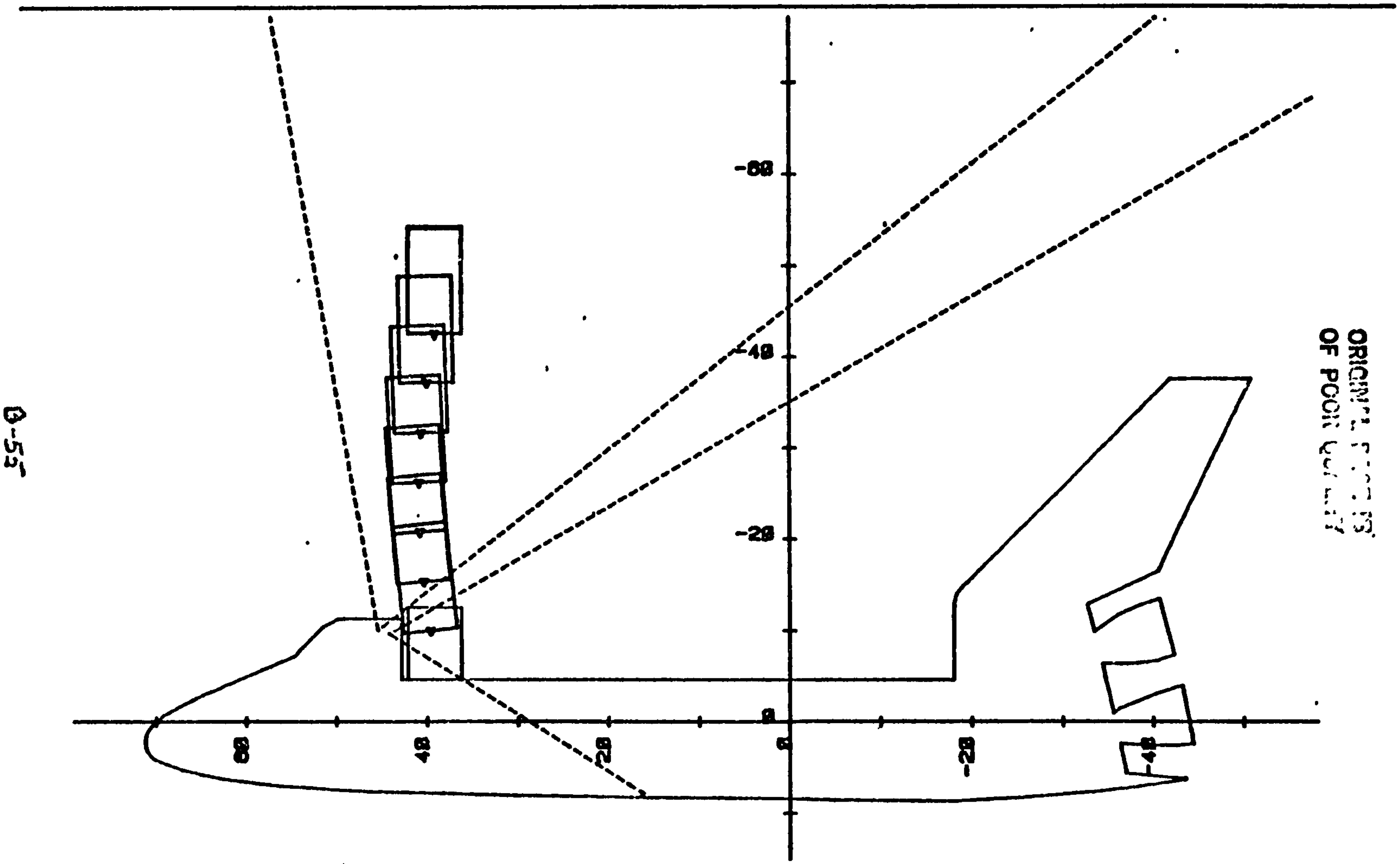
Enclosure 2



CASE 2.3.1 (UNDER -Z, -X, ROT COMP) (07/13/80)

Enclosure 2

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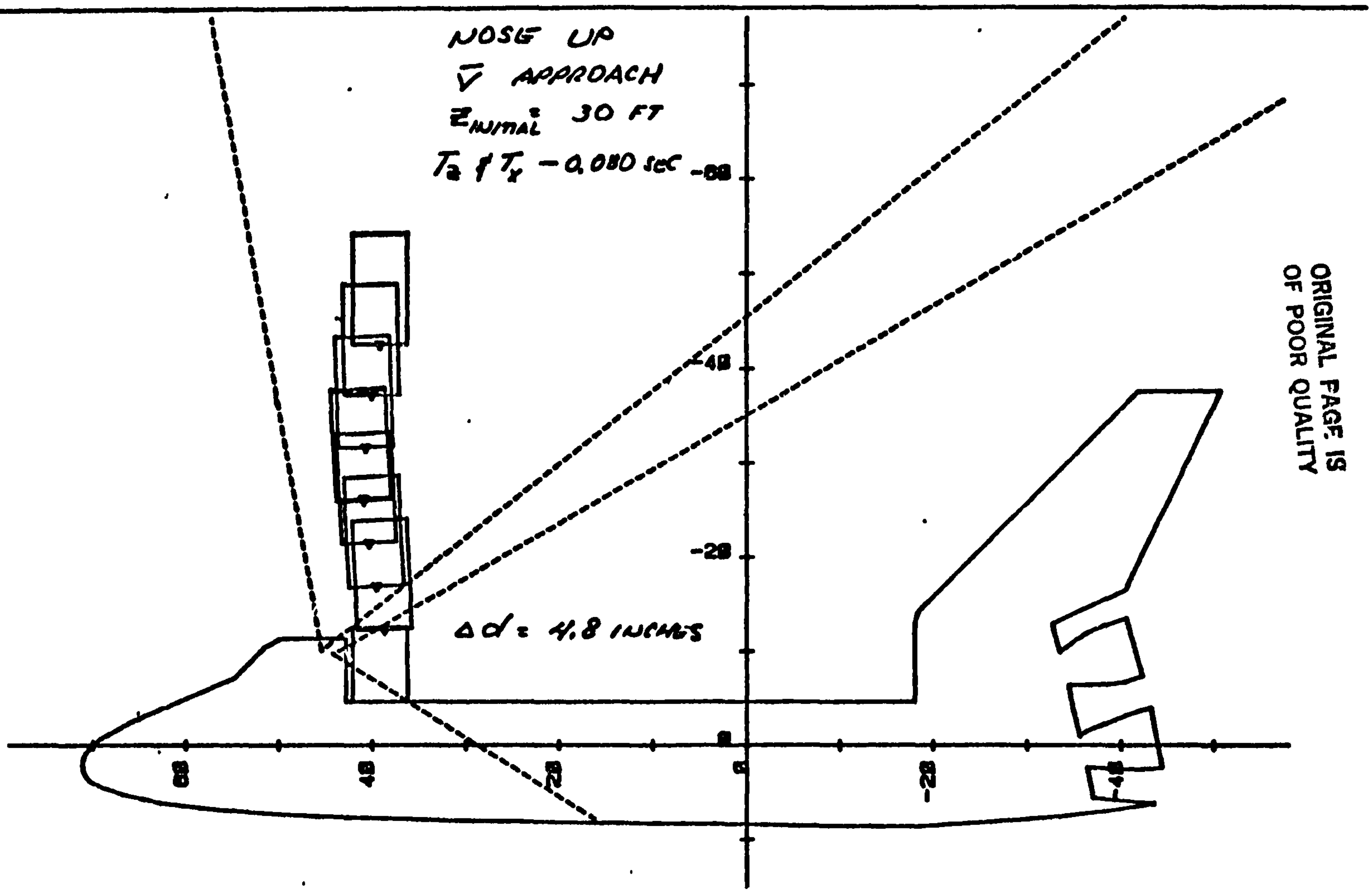
DOCKING CASE 2.3.2



CASE 2.3.2 (P ROT WITH MID-COURSE CORRECTION) (ORBITER NOSE-UP) (07/19/89)

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Enclosure 2

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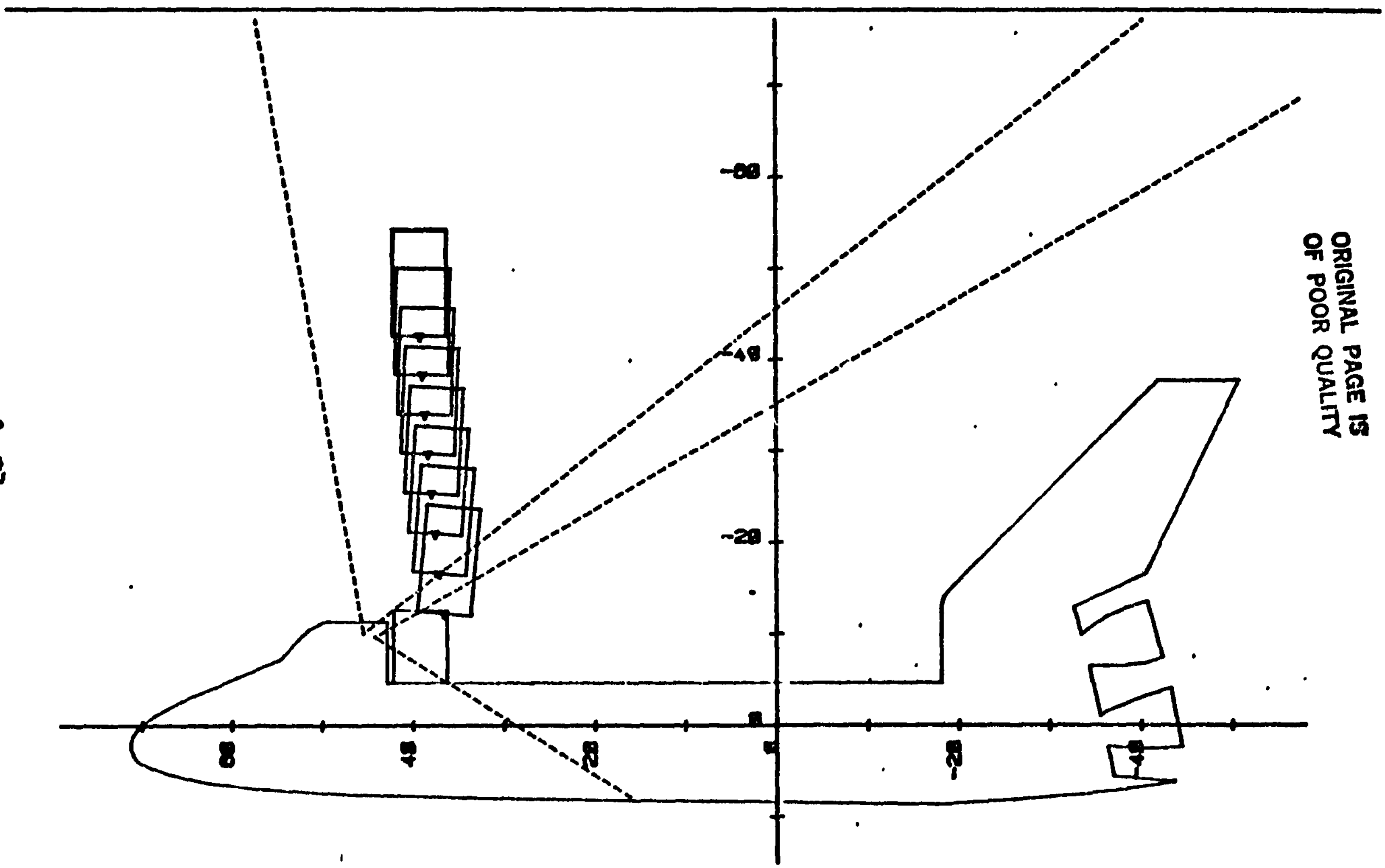
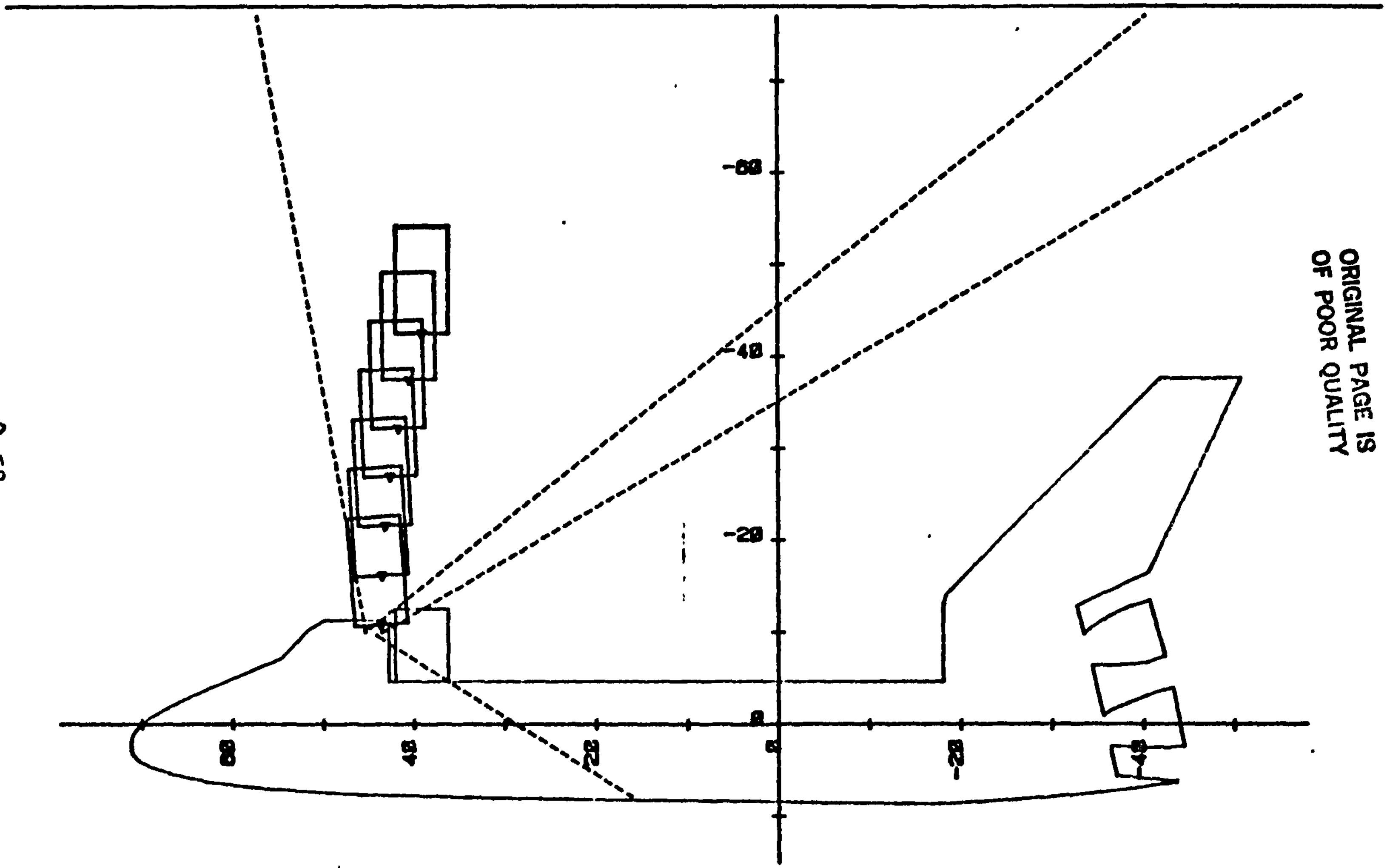


CASE 2.3.3 (NO ROT CORRECTIONS, -Z,-X UNDER, NOSE UP) (07/10/80)

Enclosure 2



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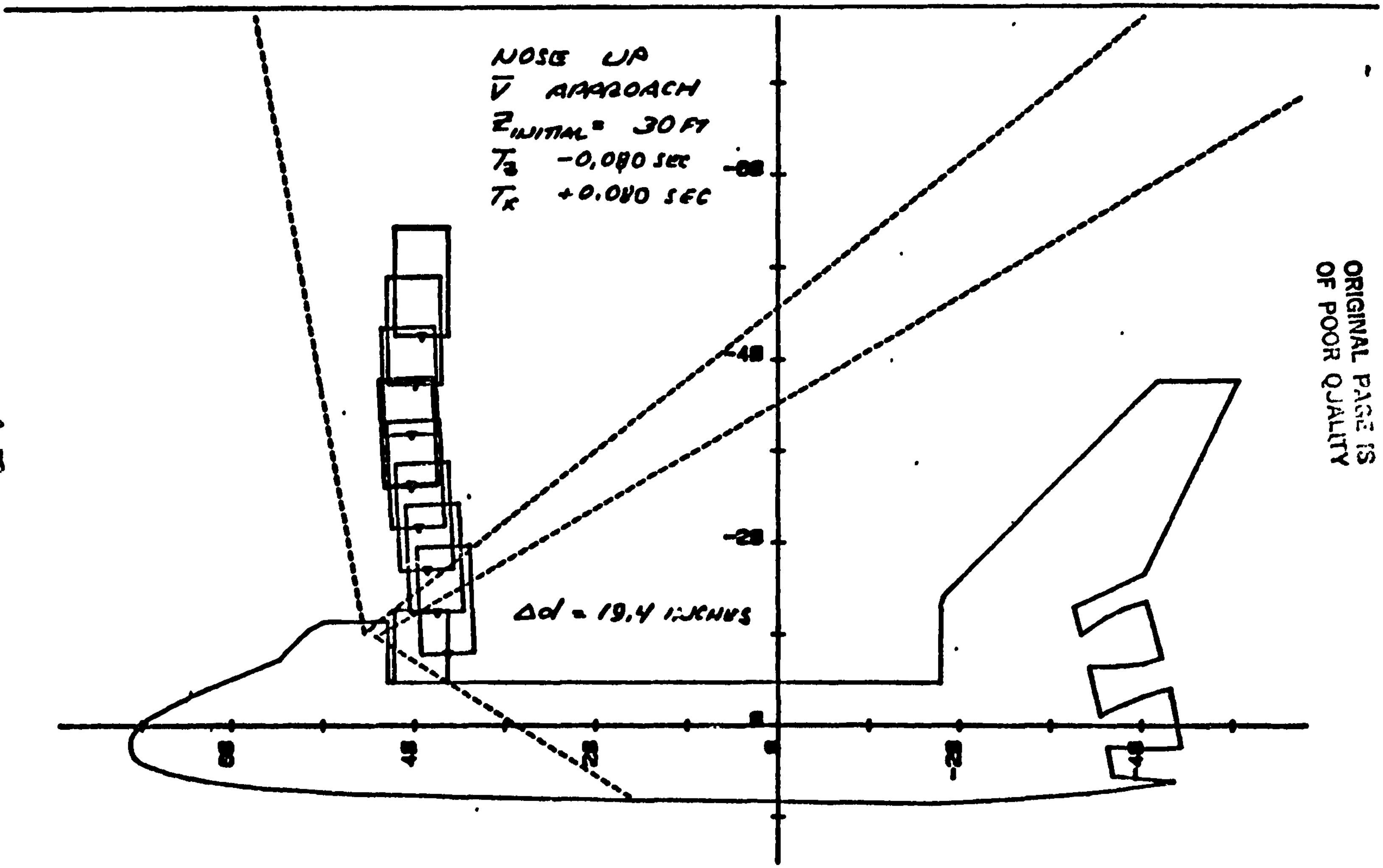
CASE 2.4.1 (INITIAL P ROT CORRECTION) (ORBITER NOSE UP) (07/18/80)

Enclosure 2

DOCKING CASE 2.4.2



REPLACEMENT FOR 2.4.2 (07/24/80)

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Enclosure 2

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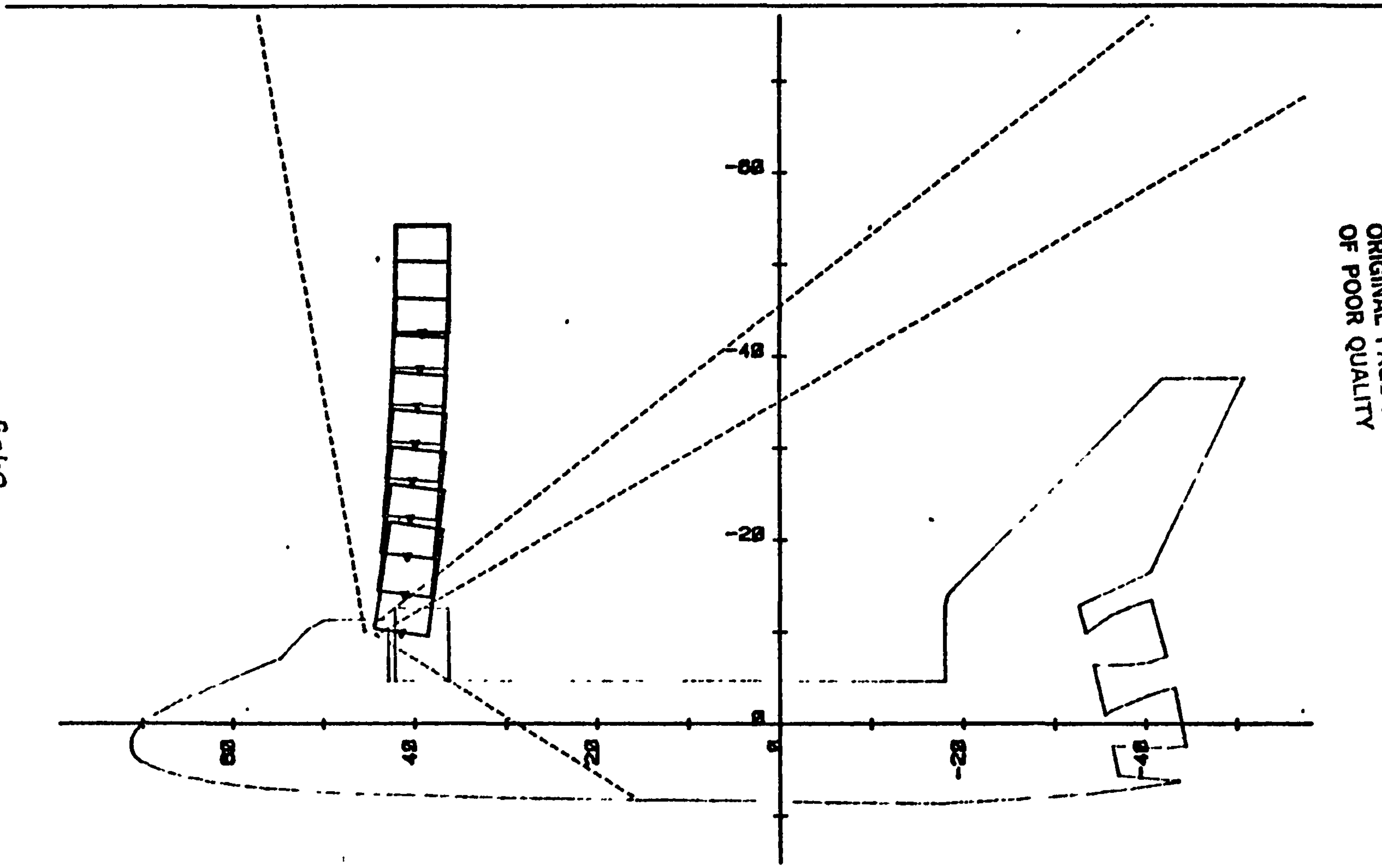
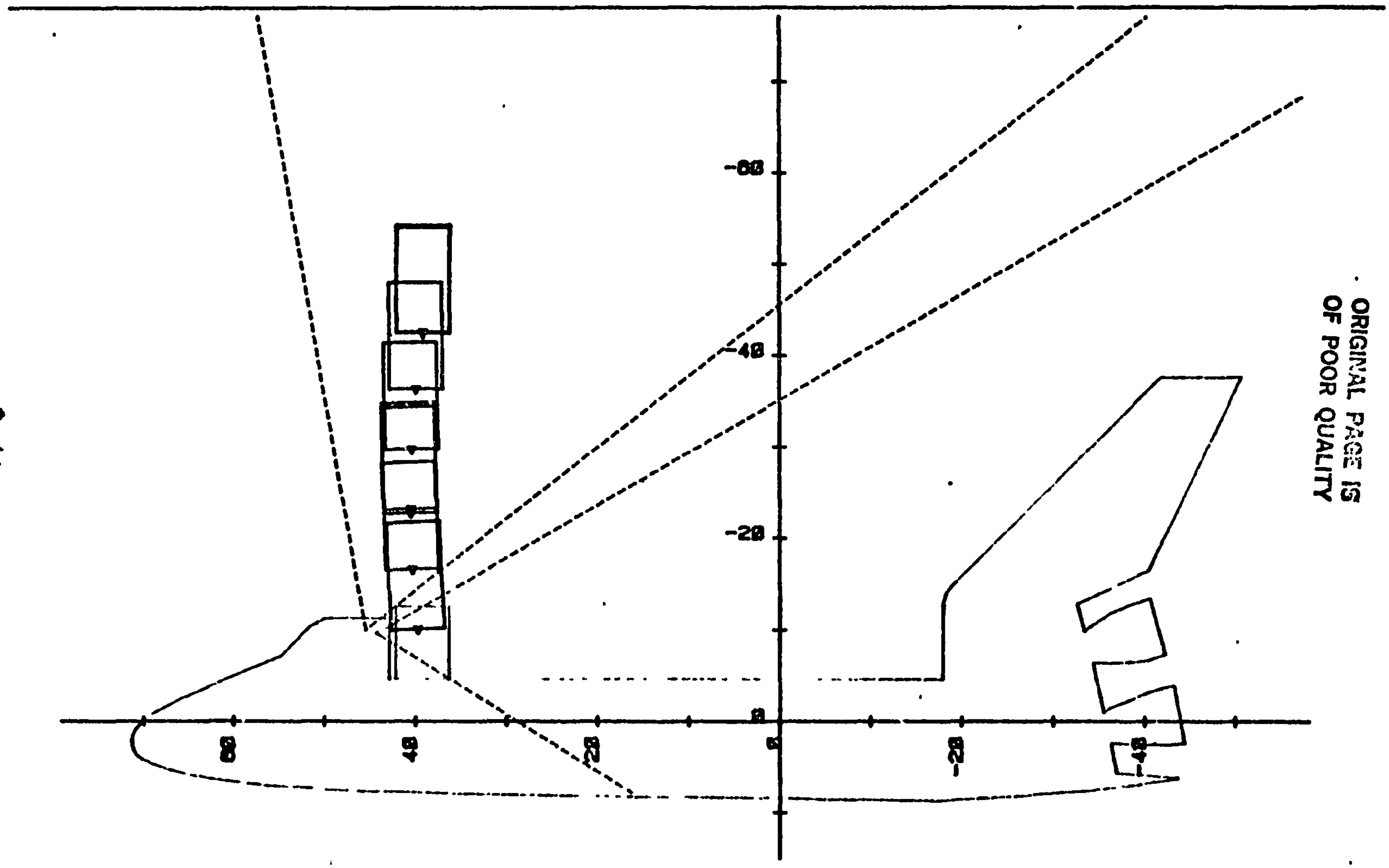


CASE 2.4.3 (NO ROT COMP CORRECTIONS) (ORBITER NOSE UP) (07/18/80)

Enclosure 2



CASE 2 . , (ROT P CORRECTION, ORBITER NOSE UP) (07/14/80)

Enclosure 2

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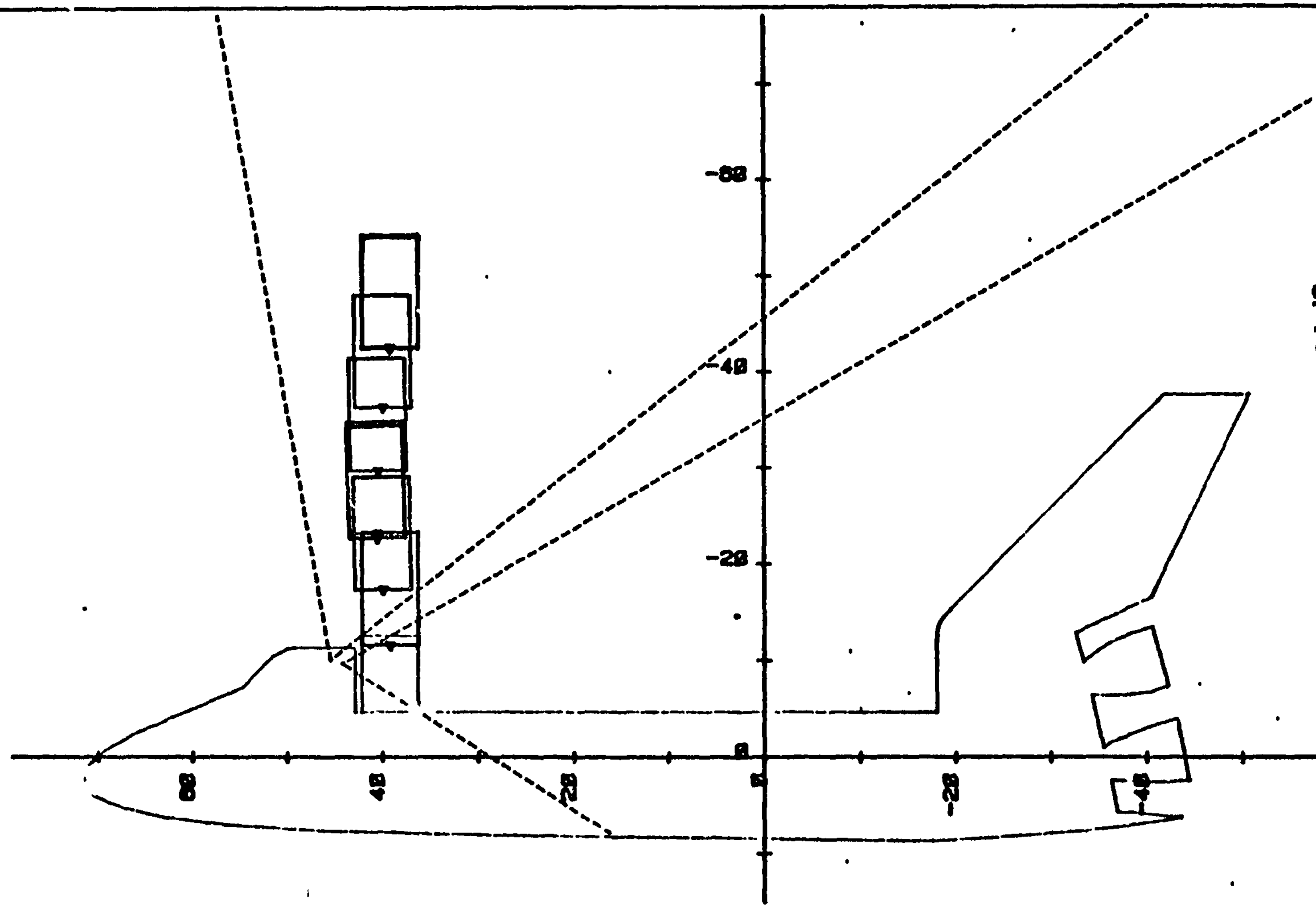
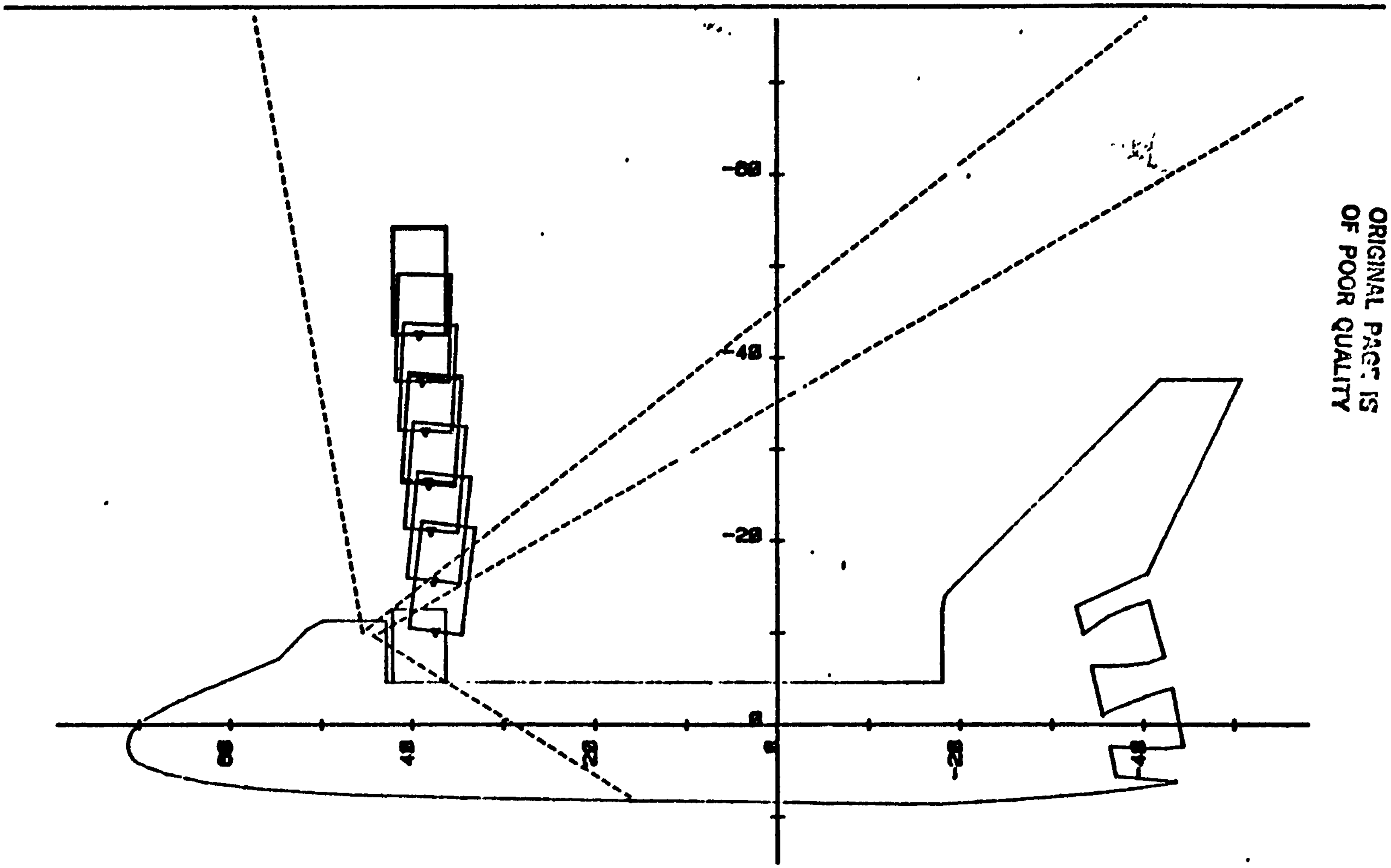


CASE 2.5.2 (ROT P CORRECTION W/MID-COURSE CORRECTION, ORBITER NOSE-UP) (07/14/80)



CASE 2.5.3 (NO P ROT CORRELTIONS, ORBITER NOSE UP) (07/14/80)

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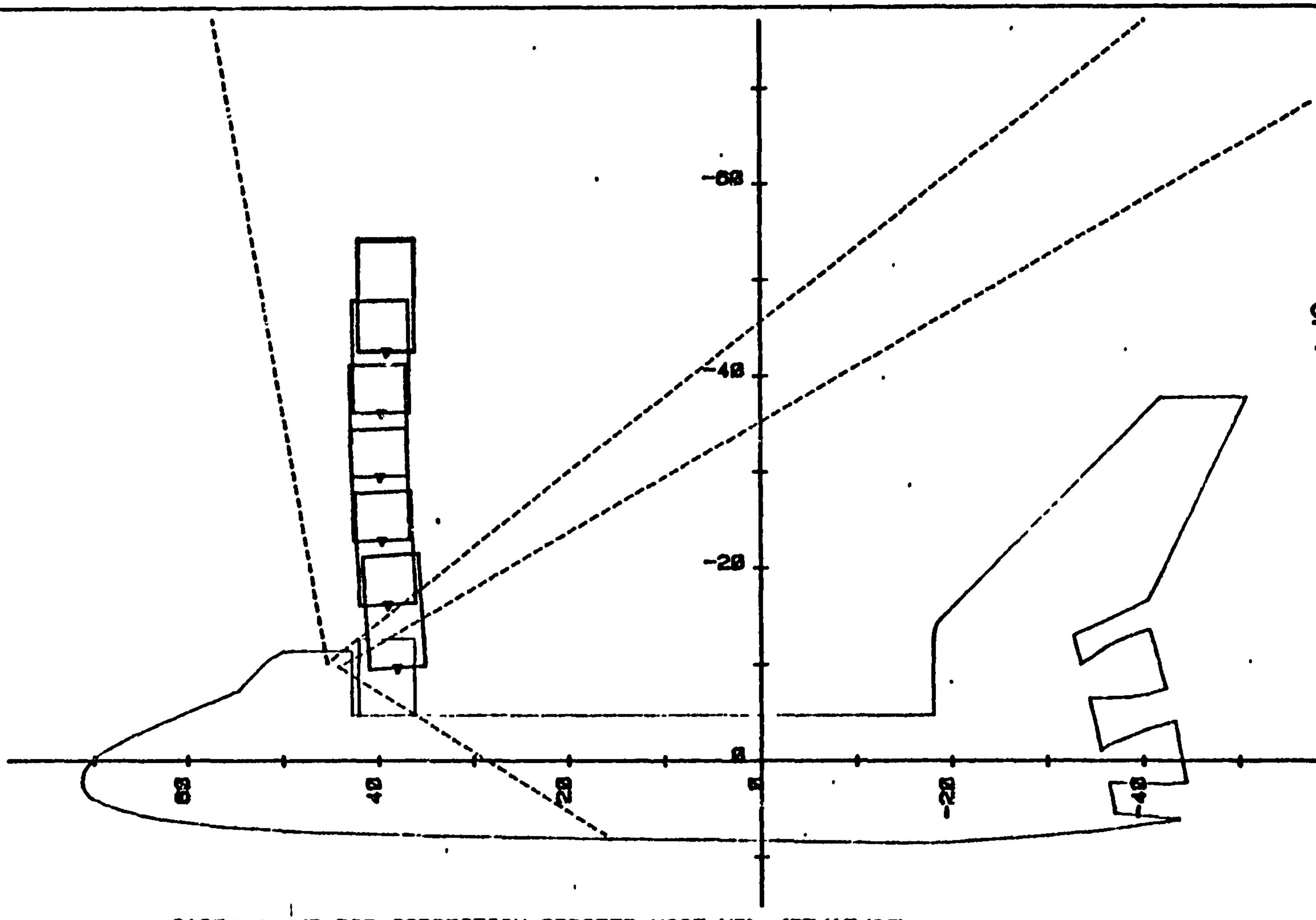

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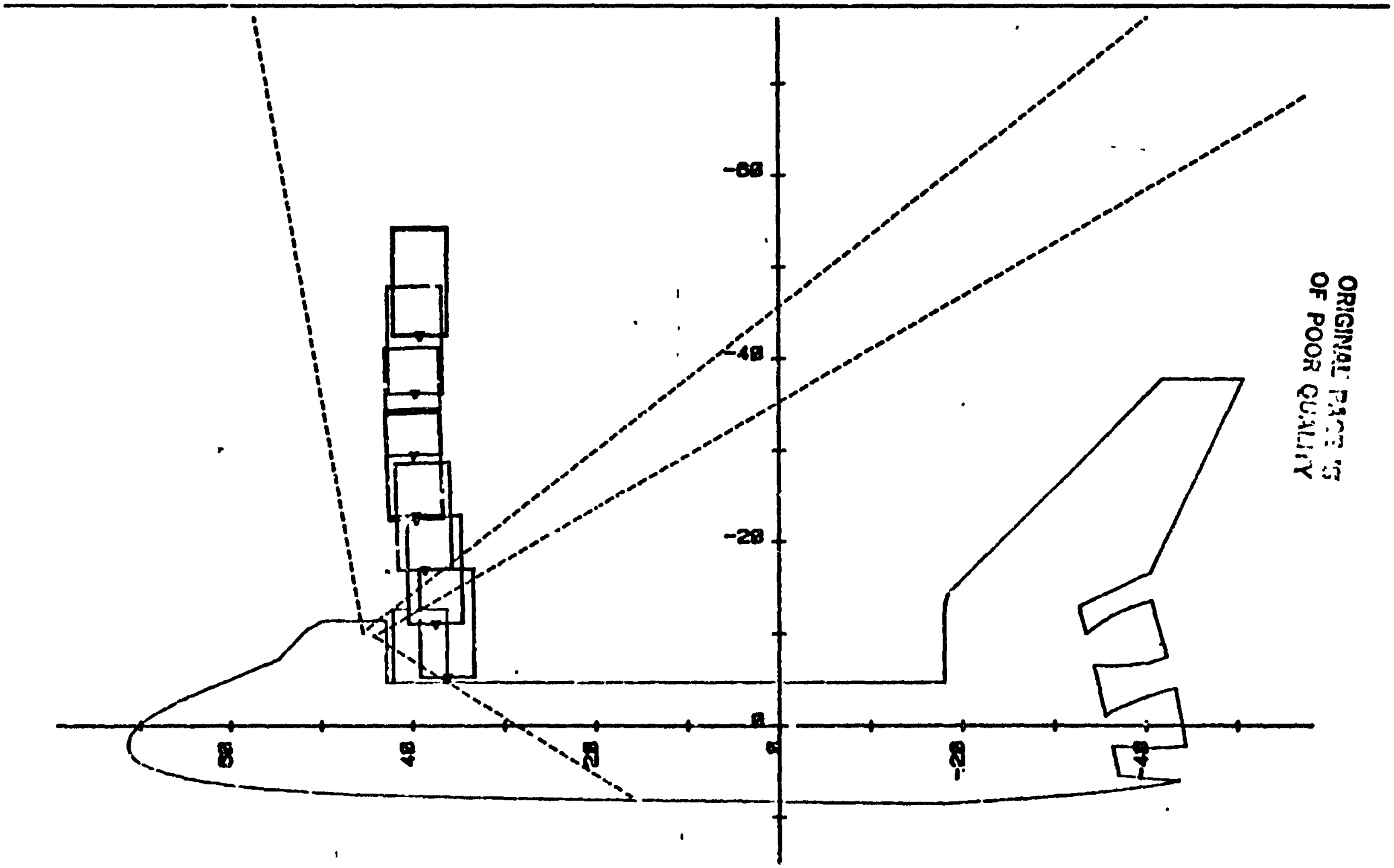
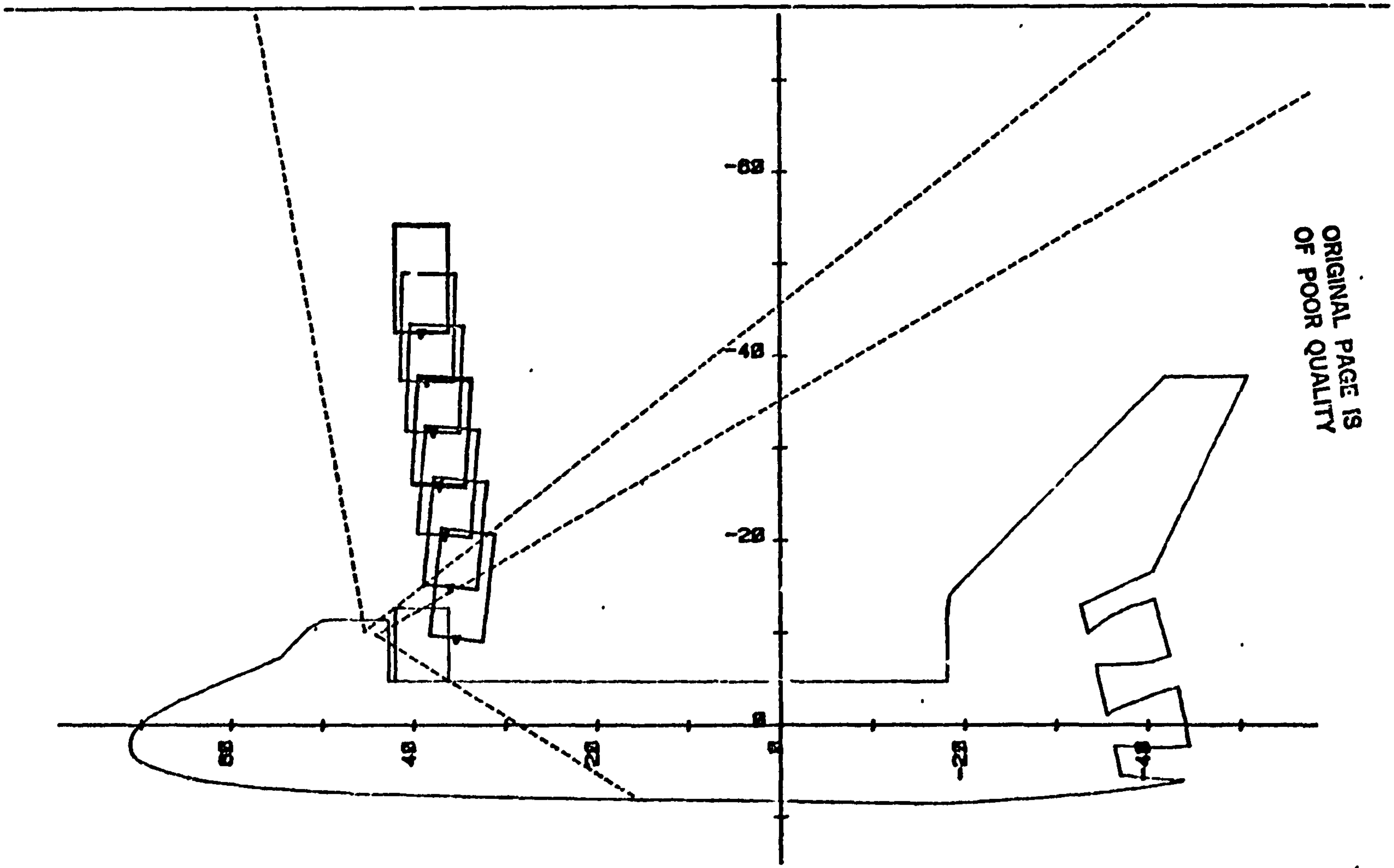
CASE 2.6.1 (P ROT CORRECTION, ORBITER NOSE-UP) (07/15/80)



CASE 2.6.2 (P ROT CORRECTION W/MID-COURSE CORRECTION, ORBITER NOSE UP) (07/15/80)

Enclosure 2



CASE 2.6.3 (NO ROT CORRECTIONS, ORBITER NOSE-UP) (07/15/80)

Enclosure 2

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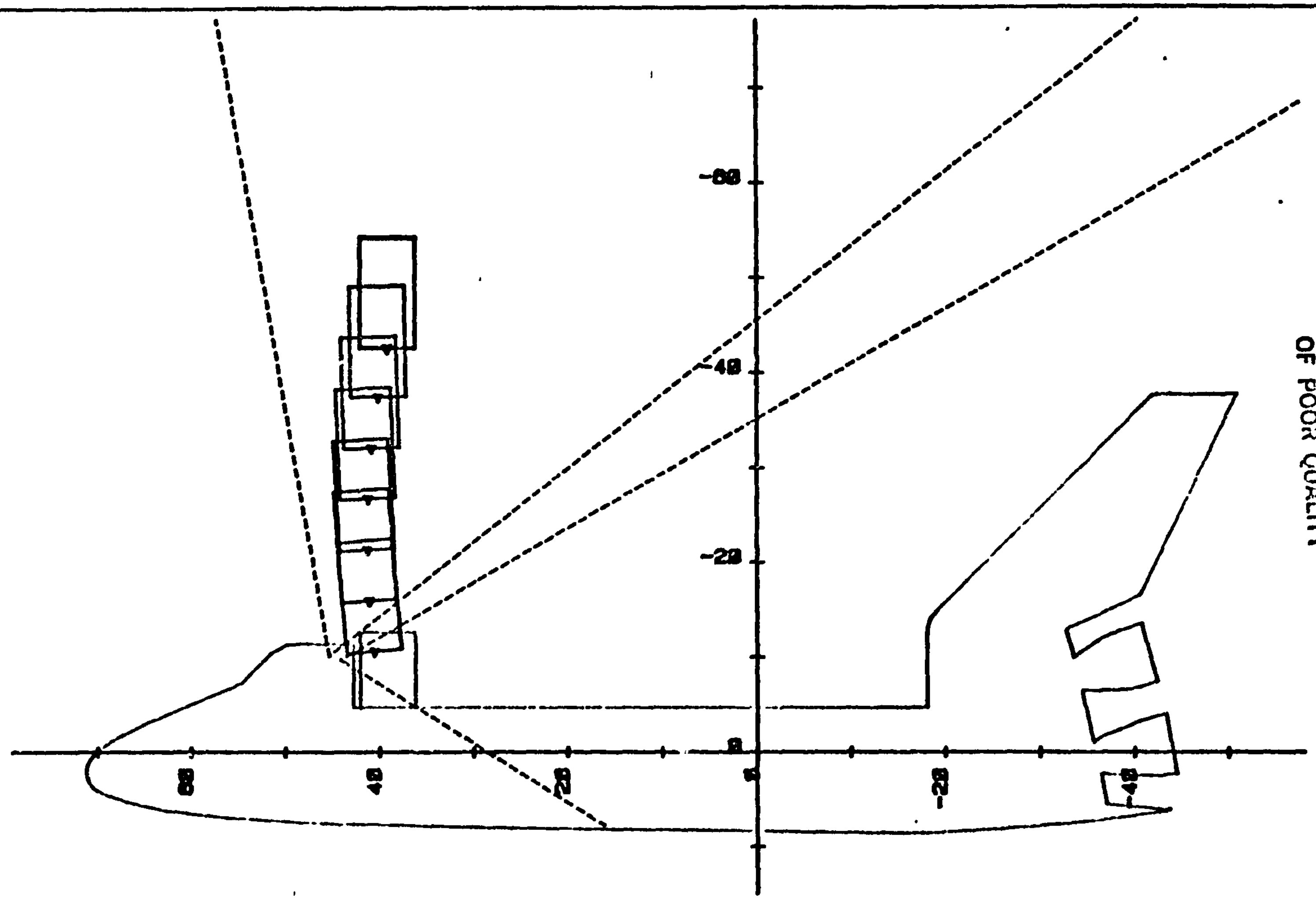

CASE 2.7.1 (P ROT CORRECTIION, NO COMP, ORBITER NOSE-UP, -Z, -X UNDER, 1 NOSE THRUSTER)

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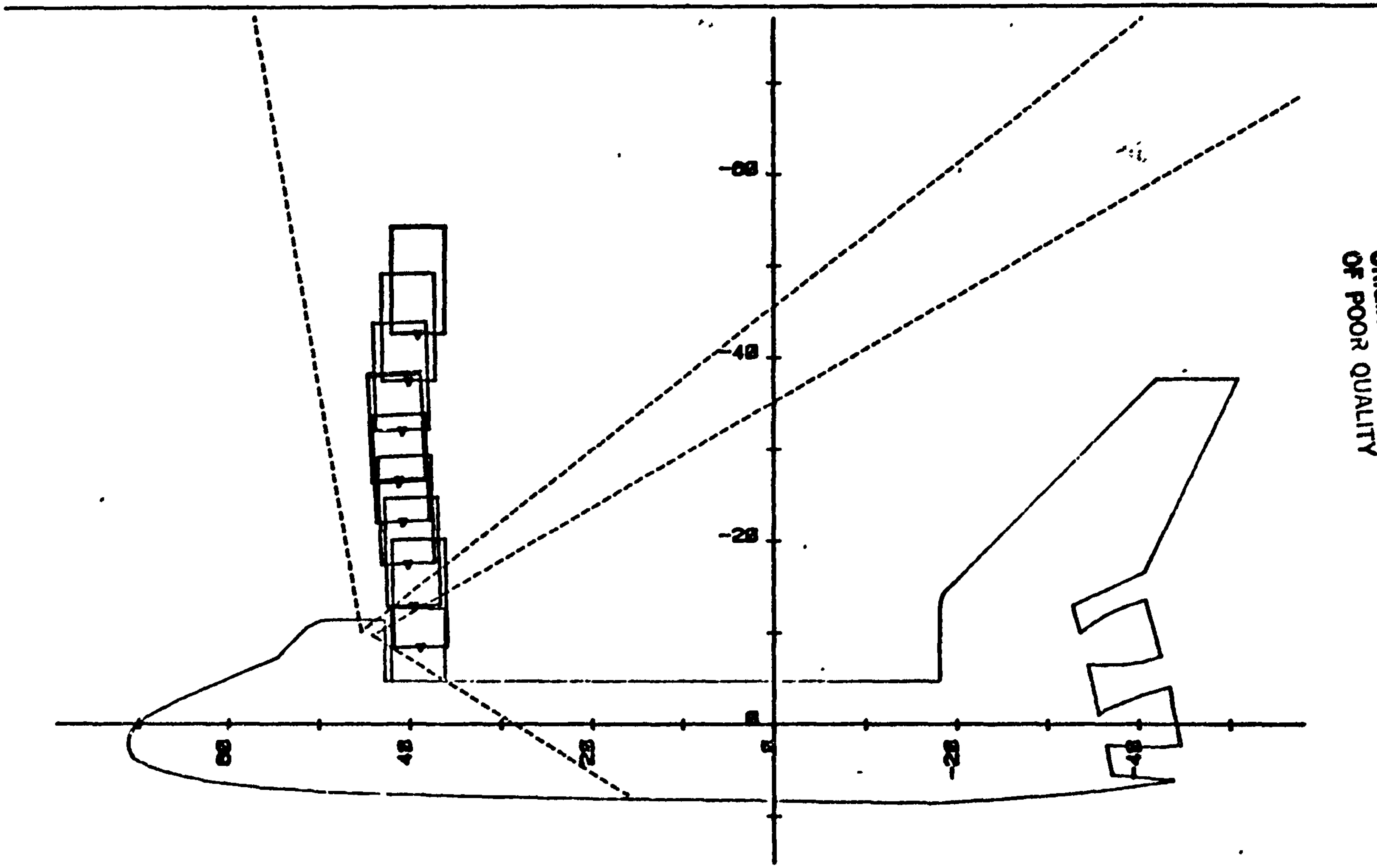
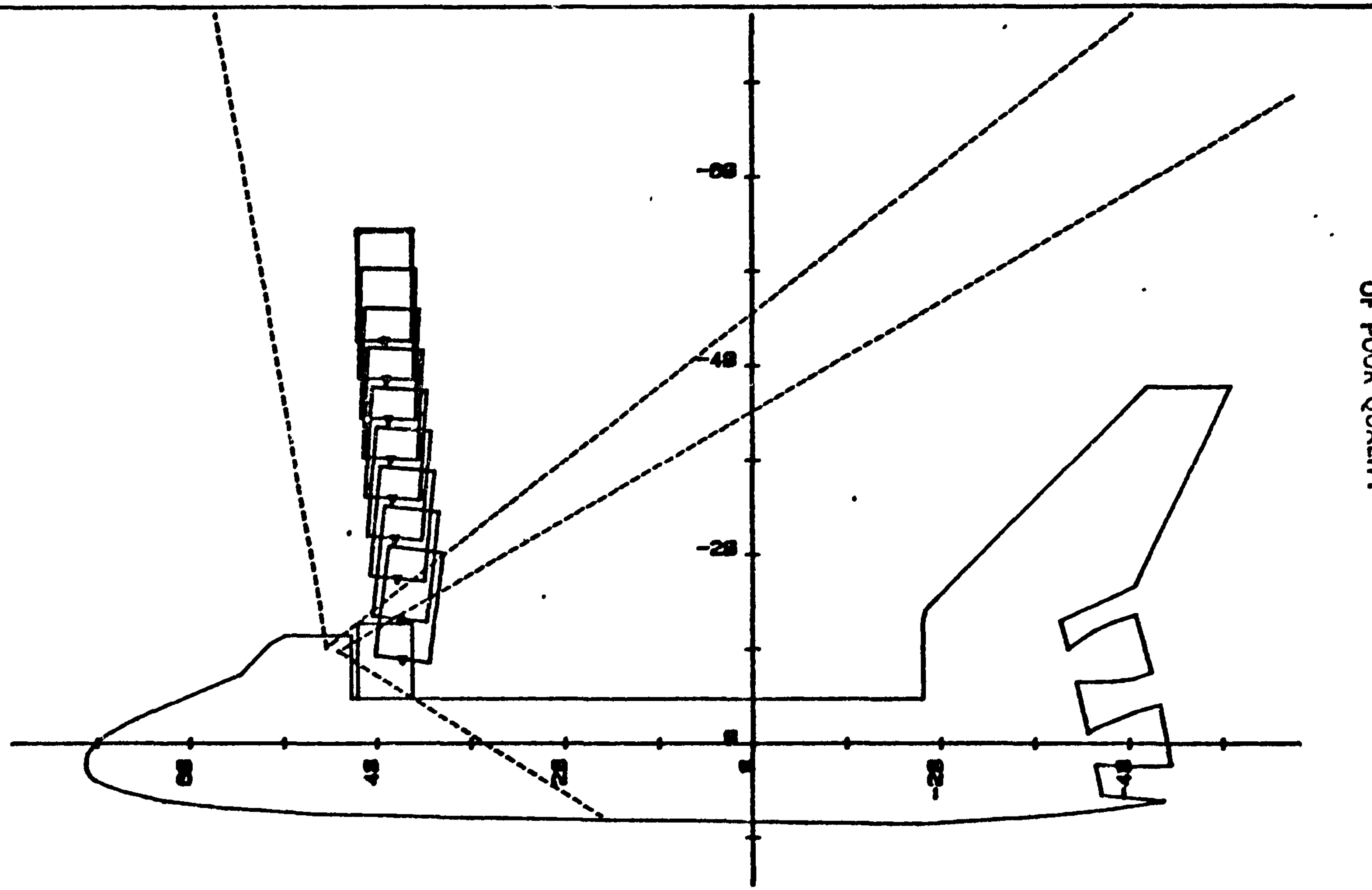


CASE 2.7.2 (MID COURSE P ROT CORRECTION, -Z, -X UNDER, ORBITER NOSE-UP) (7/15/80)

Space Systems Group Rockwell International

Enclosure 2



CASE 2.7.3 (NO ROT CORRECTIONS, UNDER -Z, -X, ORBITER NOSE-UP) (07/15/80)

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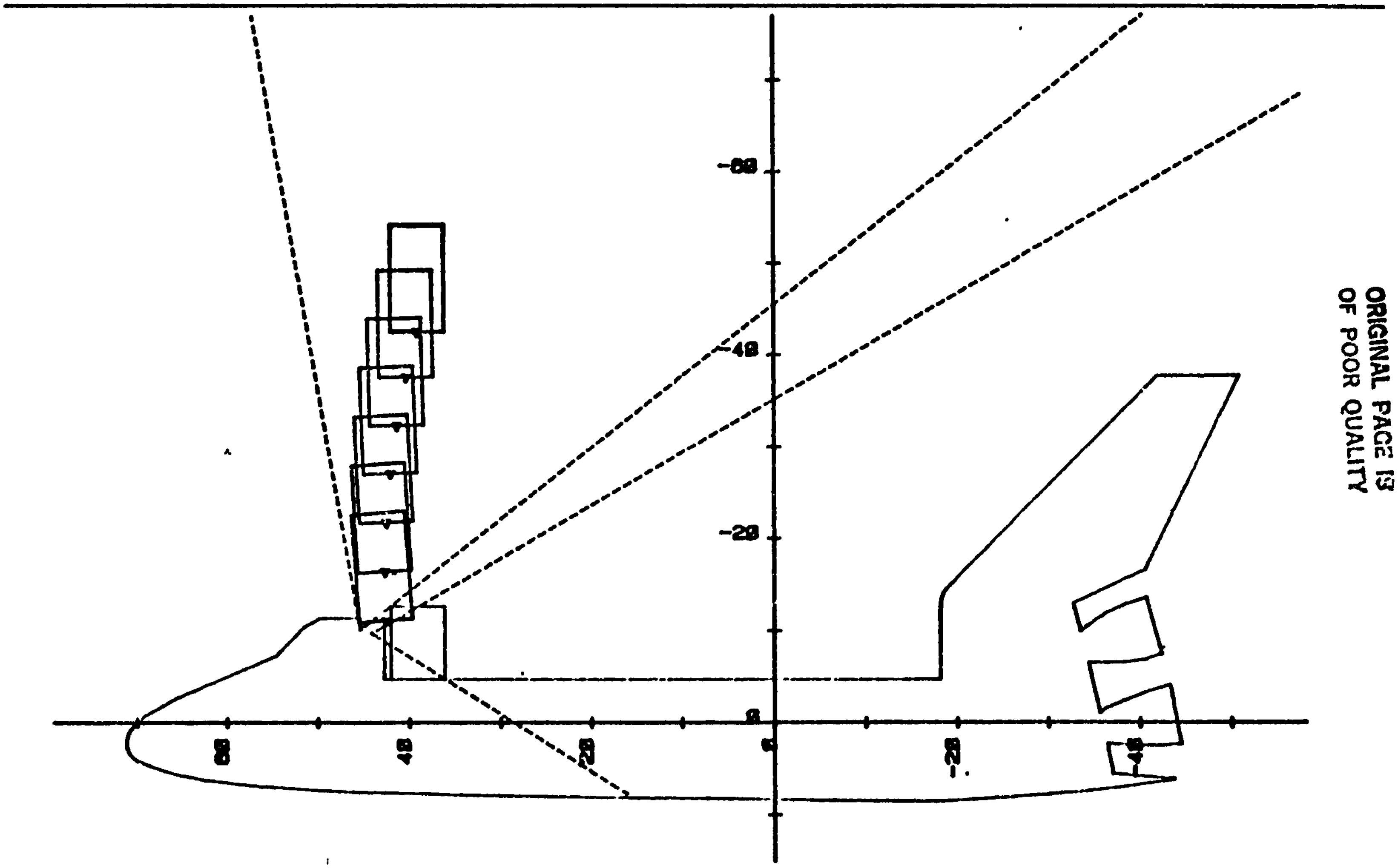
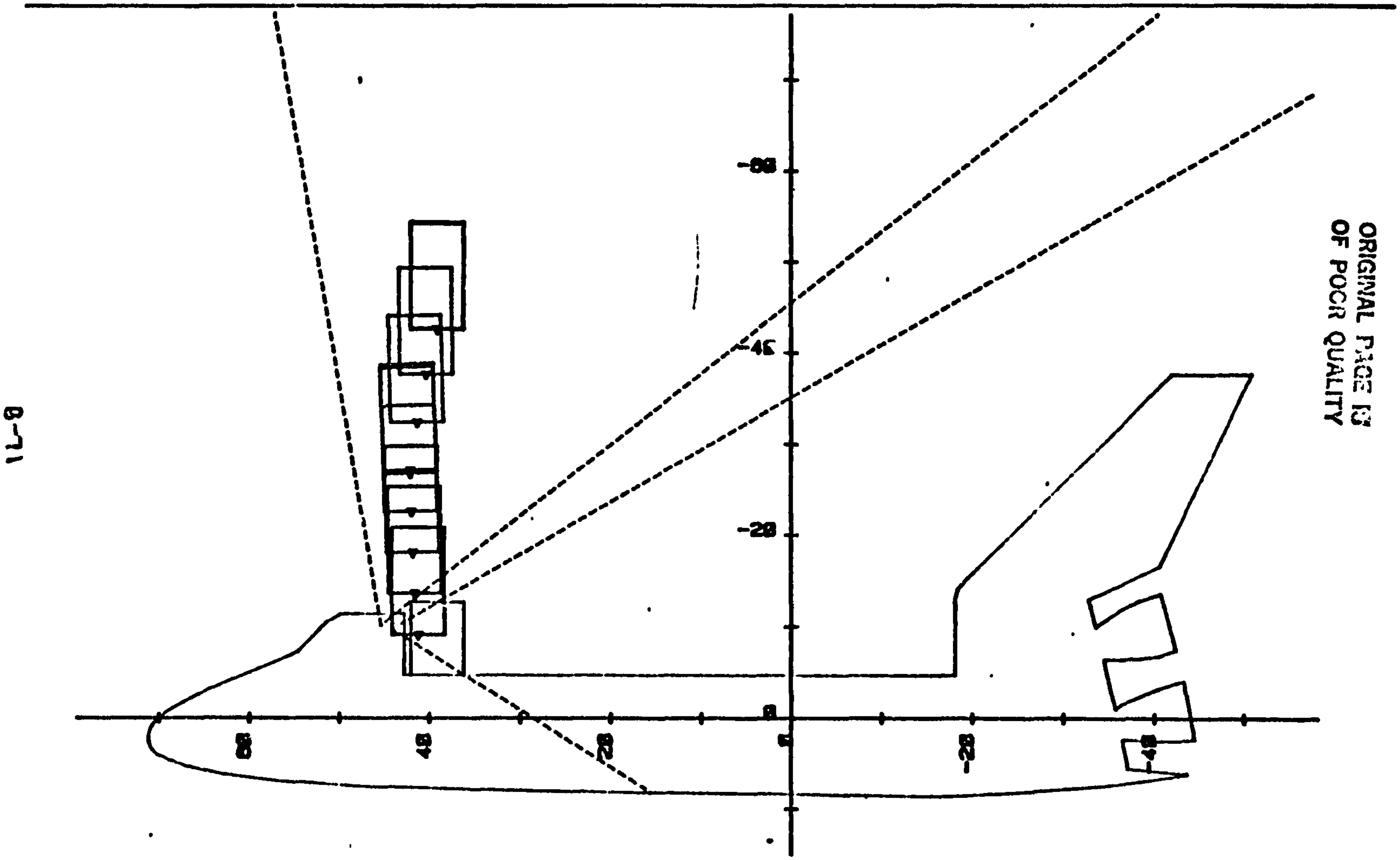
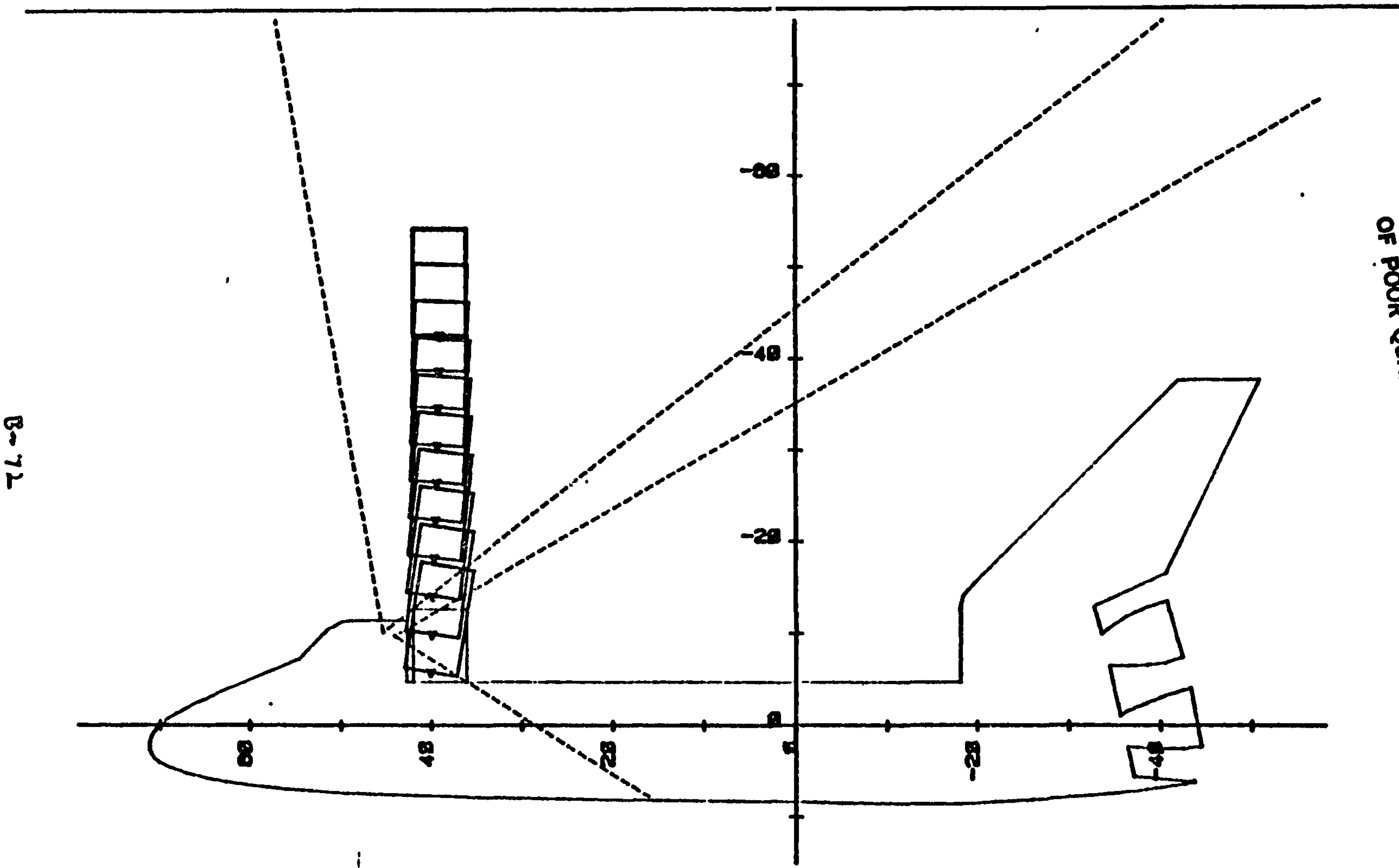


CASE 2.8.1 (P ROT CORRECTION, -Z UNDER, -X OVER, NOSE UP) (07/15/80)



CASE 2.8.2 GMID COURSE P ROT CORRECTION, -Z UNDER, -X OVER, NOSE UP, 7/15/80

Space Systems Group Rockwell International



CASE 2.8.3 (NO PHOT CORRECTIONS, -Z UNDER, -X OVER, NOSE UP, 1 NOSE THRUSTER, 7/15/80)

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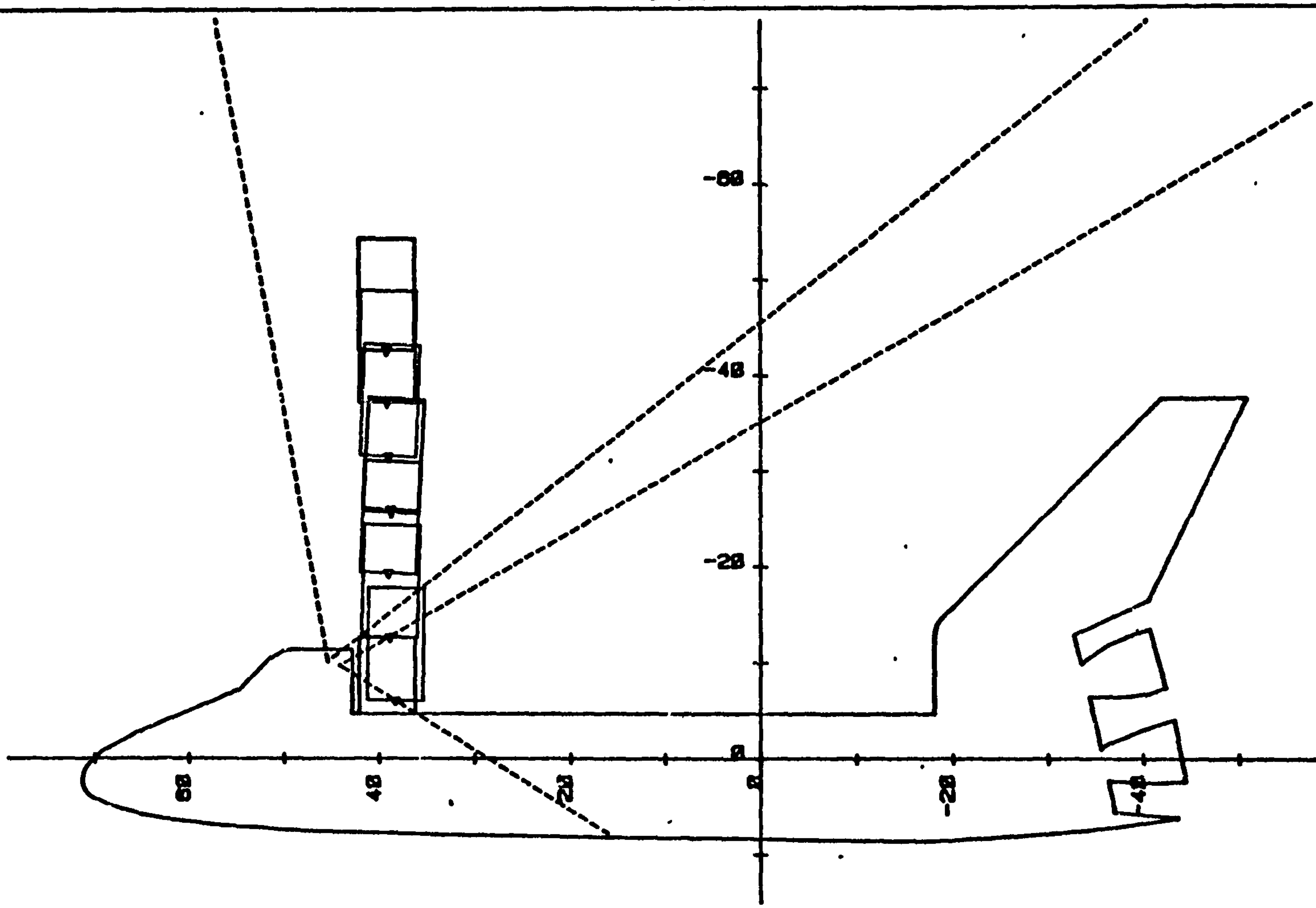
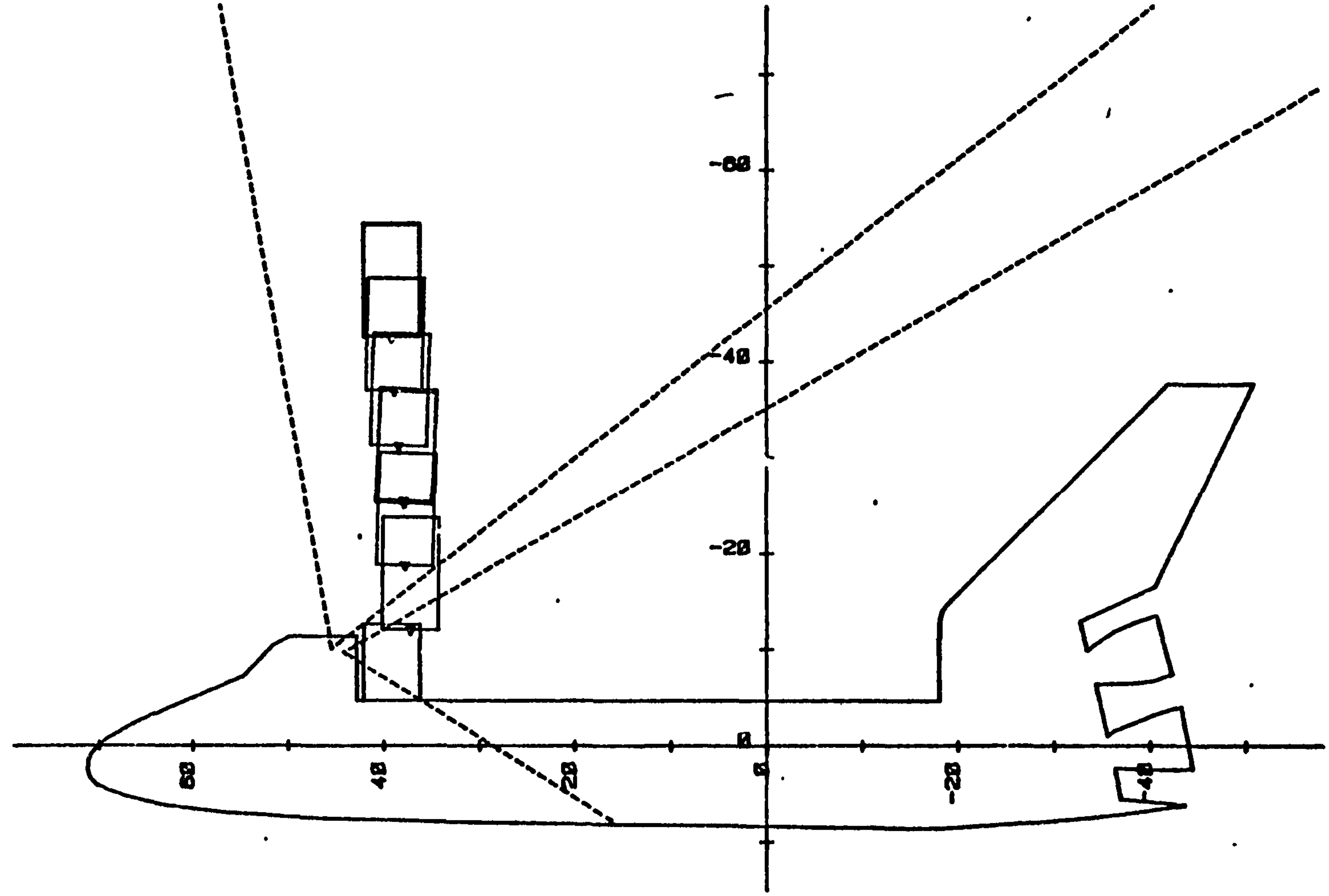
Enclosure 2



30 ft 1.0 min. -R-bar CASE W/NO COMP P & MID-COURSE CORRECTION, +. 00 sec -X, -Z

Enclosure 2

3.6.4.1



30 ft 1.0 min. -R-bar CASE W/MID COURSE P ROT, NO COMP P, OVER-Z, UNDER-X, 7/20/80

Enclosure 2

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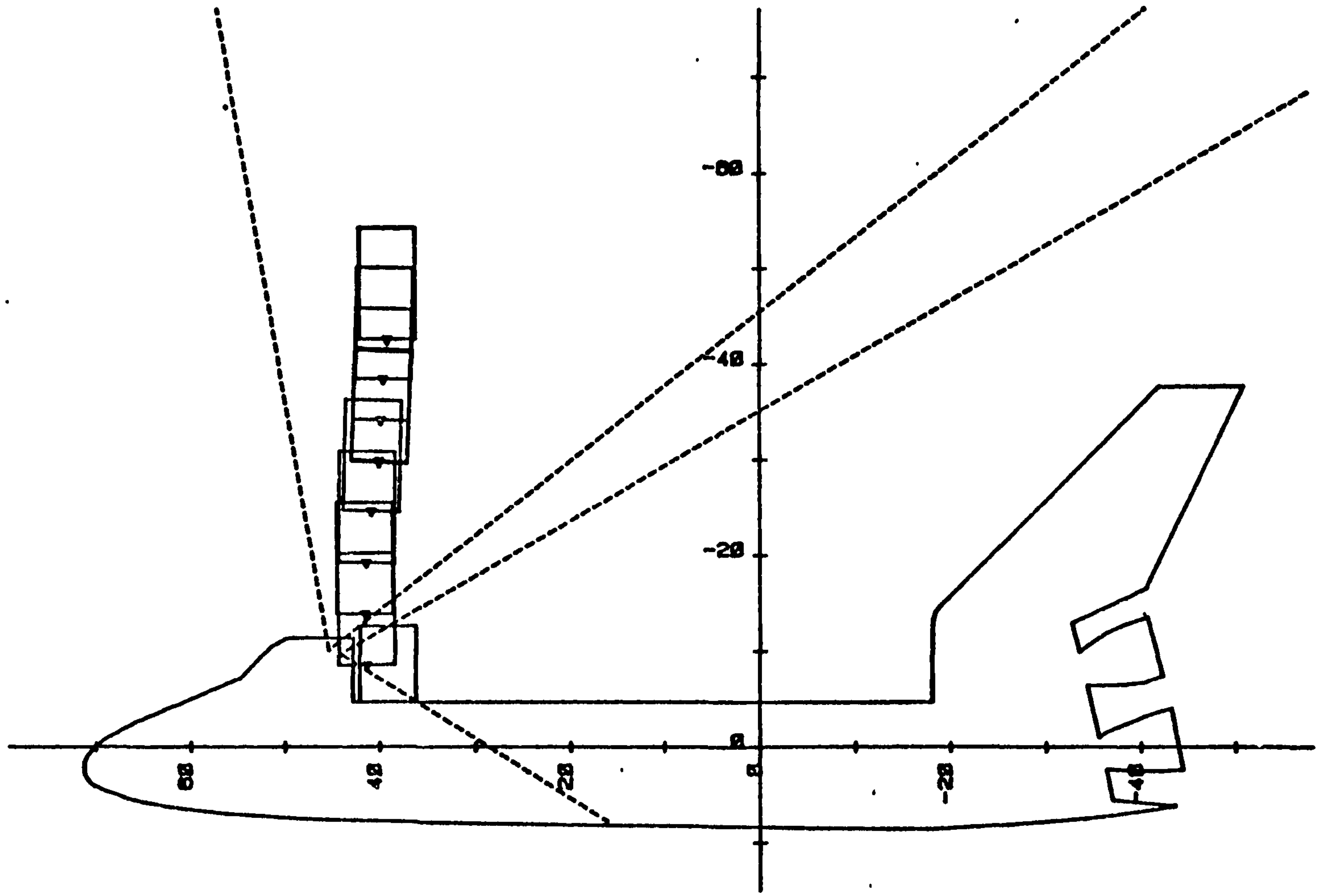
3.7.4.1



30 ft 1.8 min -R-bar DOCK W/MID-COURSE P ROT.NO COMP P.OVER-X,UNDER-Z,7/29/80

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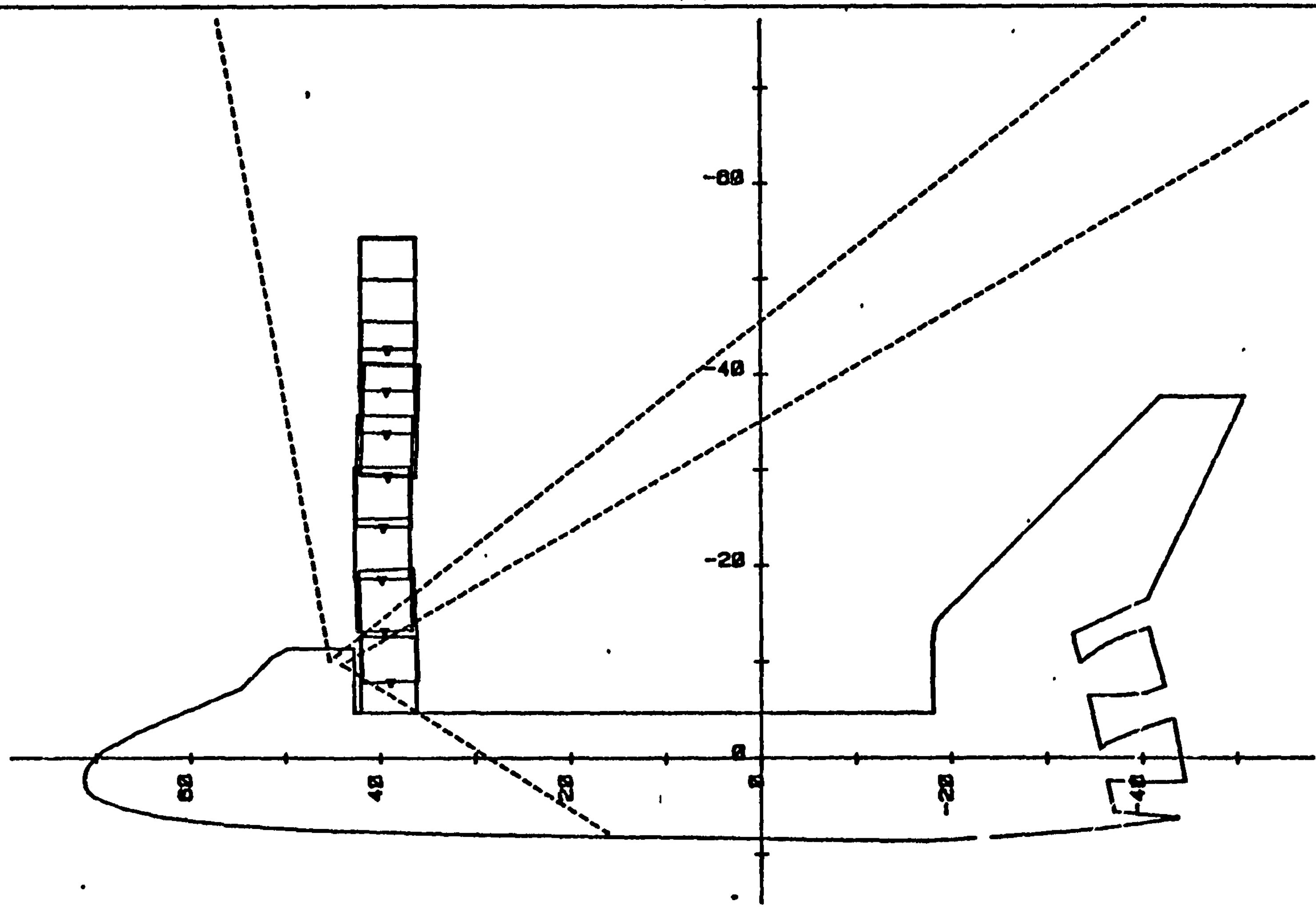

30 ft 1.0 min. -R-bar DOCK W/MID COURSE P ROT, NO COMP P, UNDER -Z, -X. (07/20/80)

Space Systems Group Rockwell International

Enclosure 2

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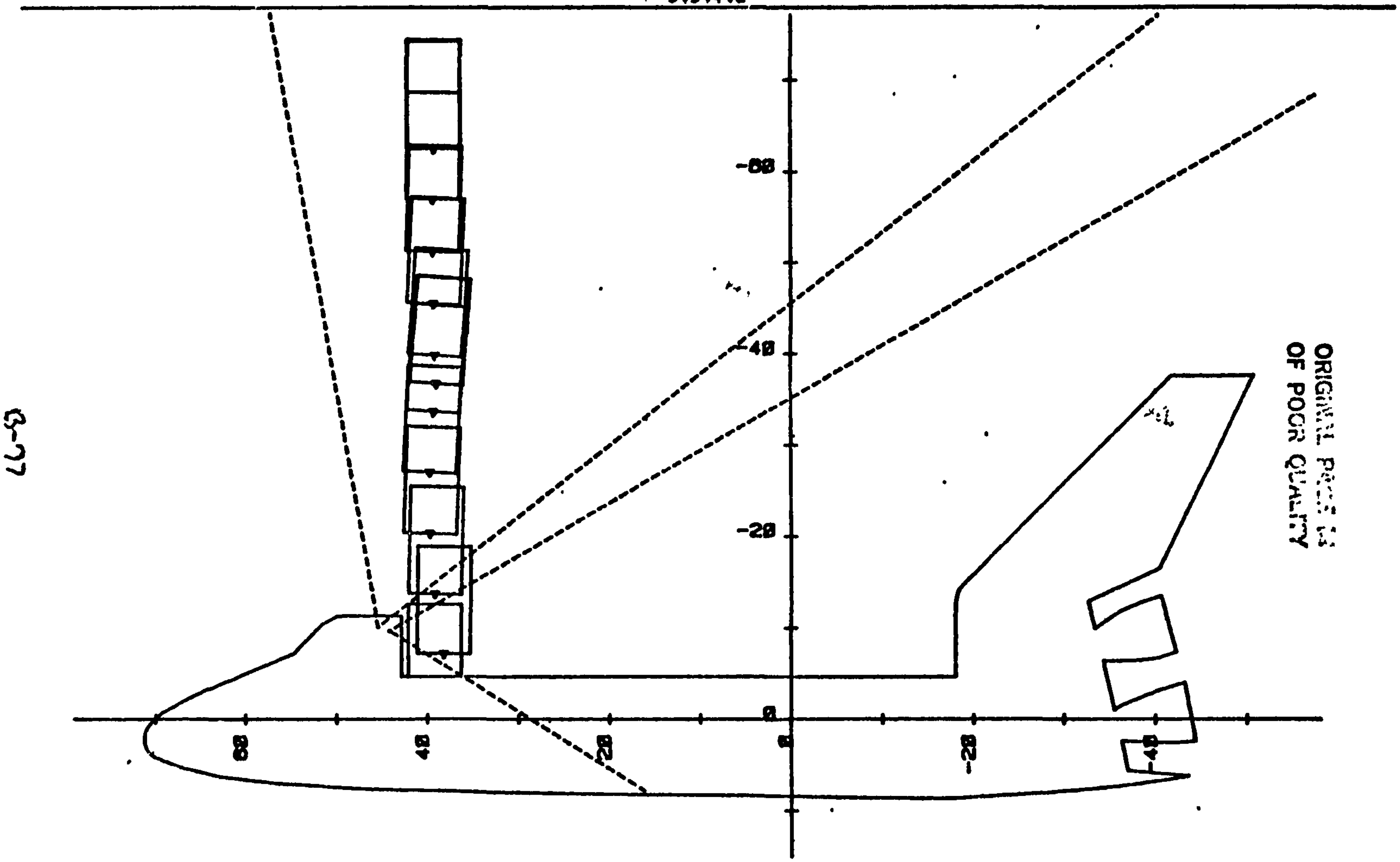

50 ft DOCK FROM ABOVE, 180 secs., NO COMP P W/ROT CORR. MID COURSE ONLY -Z, -X OVER

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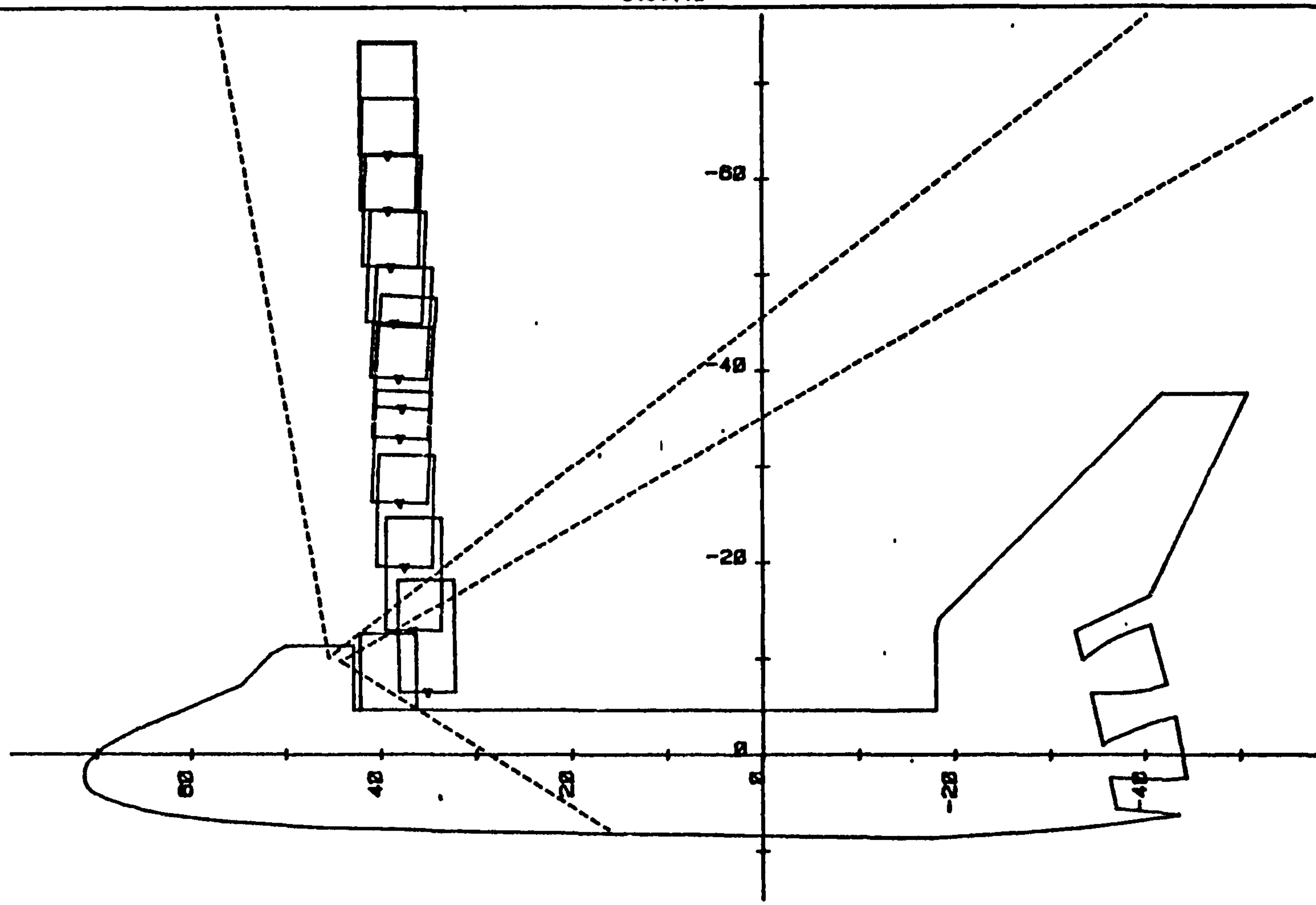
Enclosure 2



50 ft DOCK FROM ABOVE, 3 min, -Z OVER, -X UNDER (07/28/80)

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Enclosure 2

B-78

Enclosure 2

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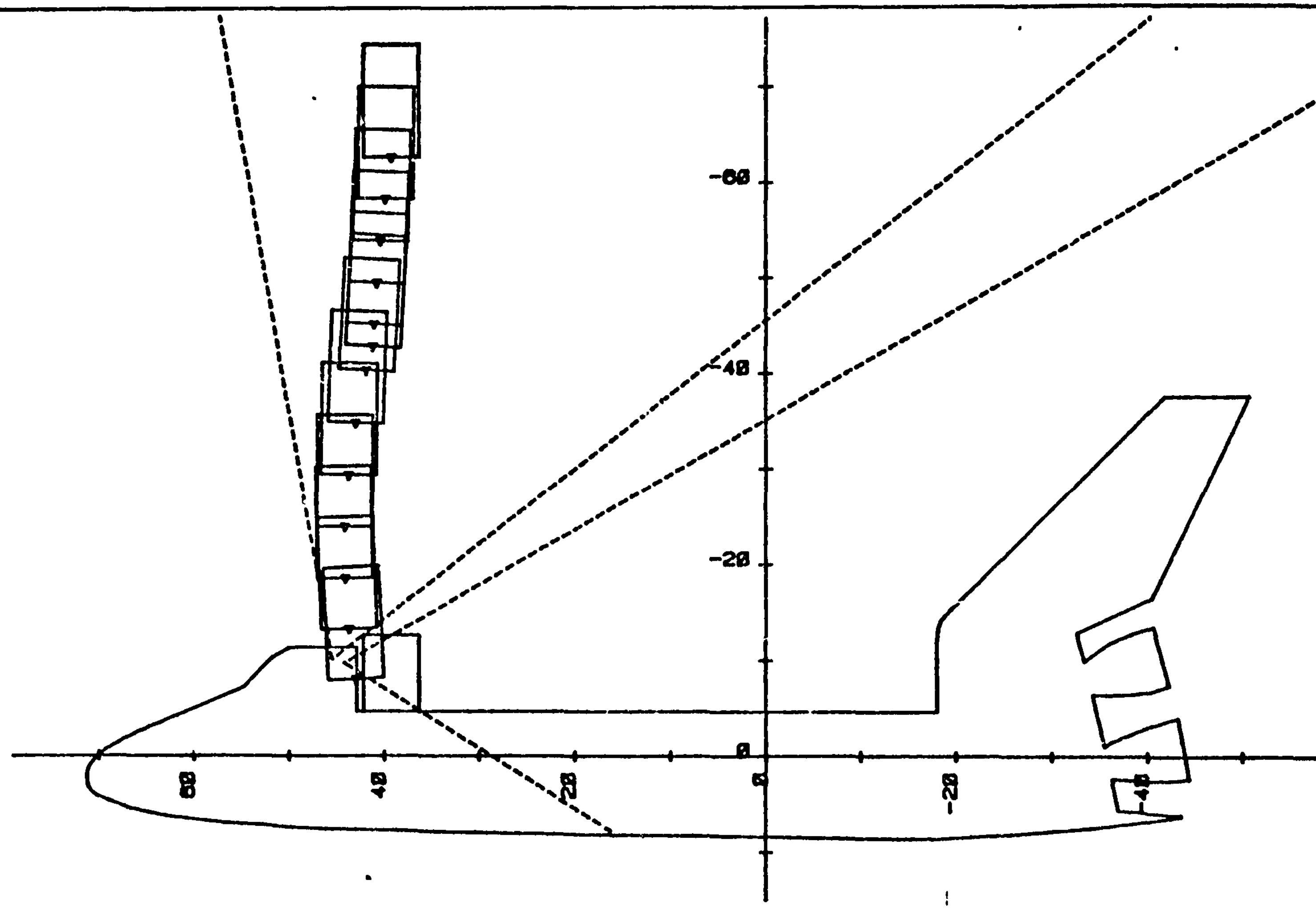

50 ft DOCK FROM ABOVE, 3 min. -Z UNDER, -X OVER (07/28/80) 3.7.4.2

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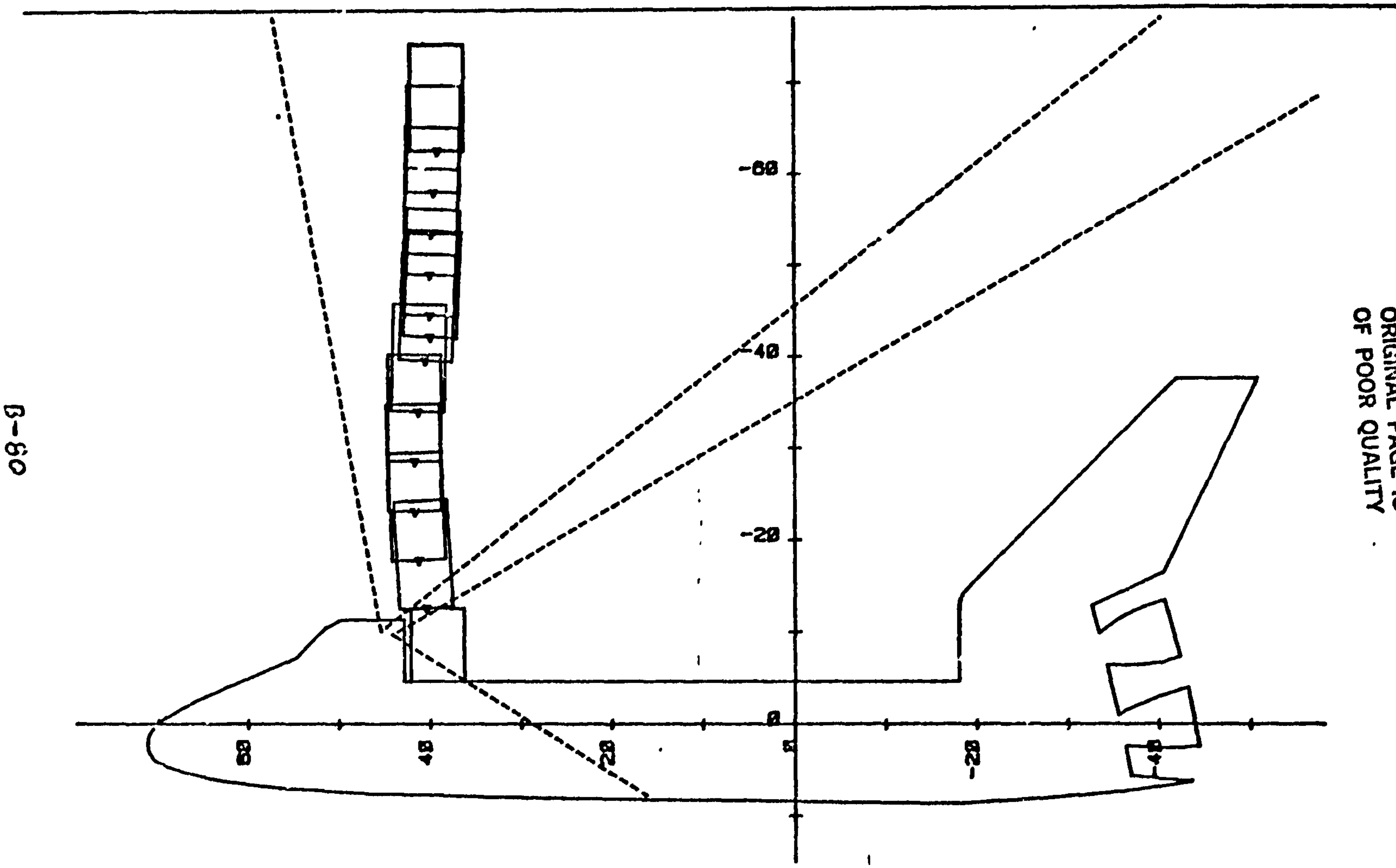
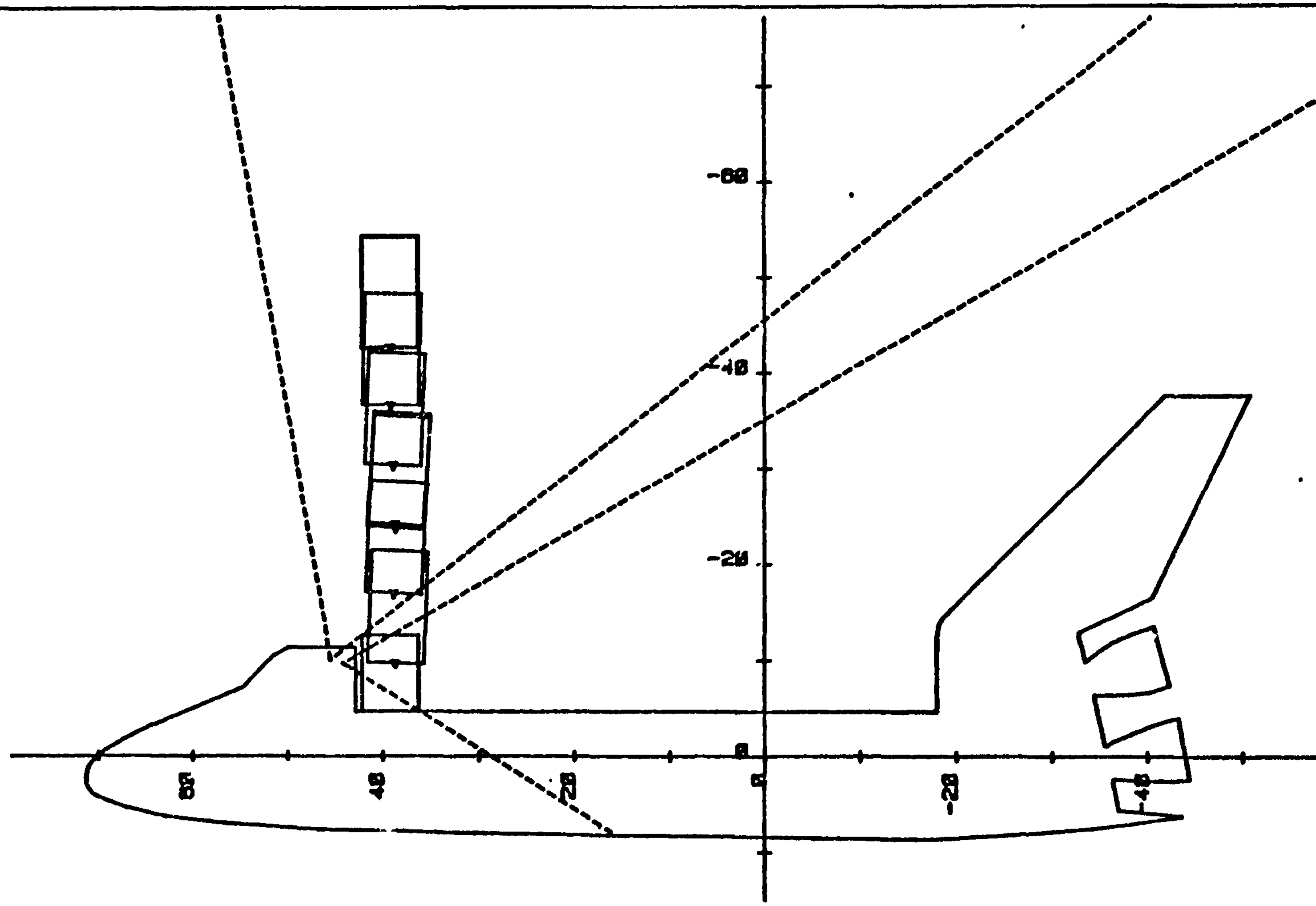


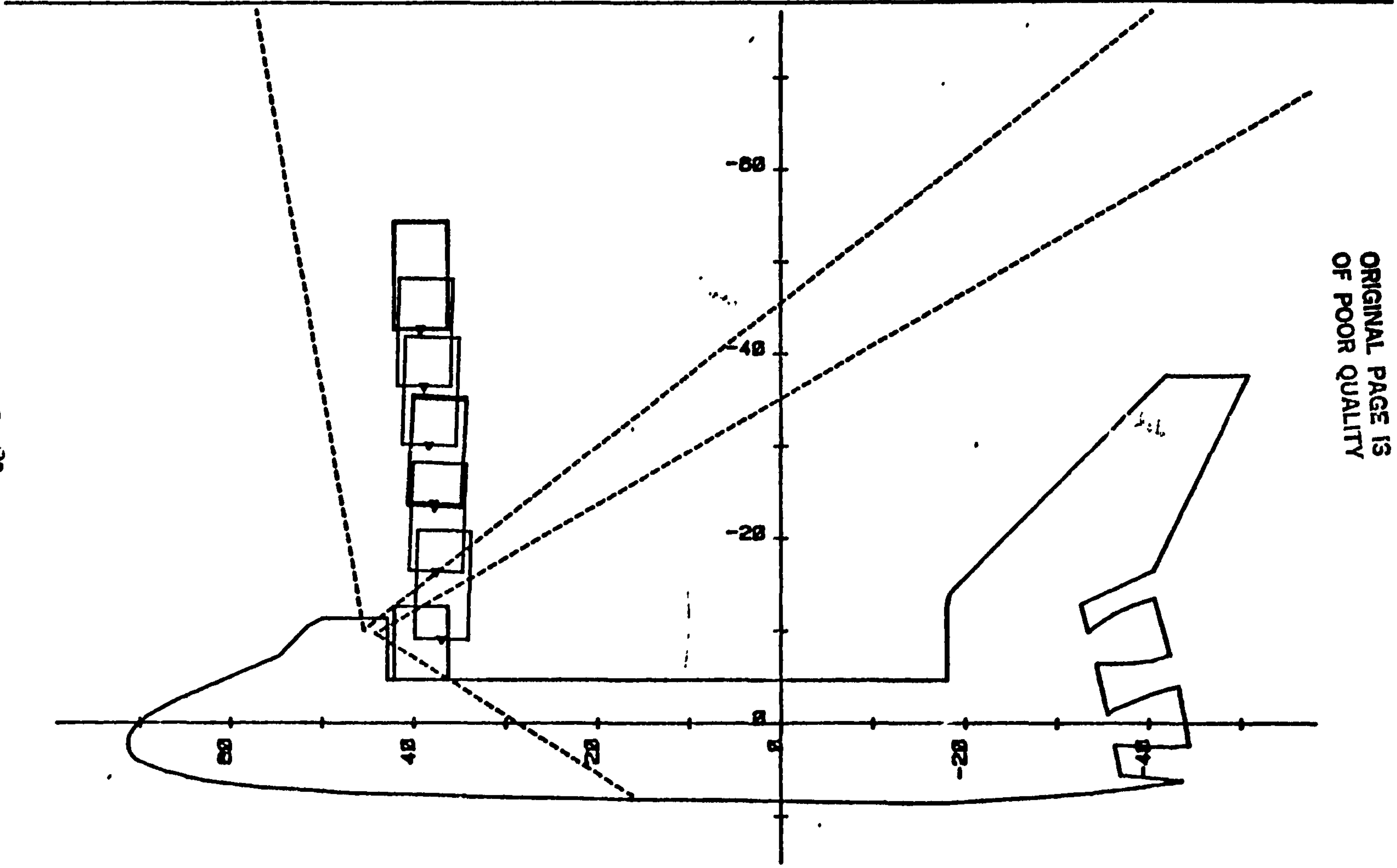
50 ft DOCK ABOVE, 3 min. -Z, -X UNDER (07/28/80)   3.8.4.2



30 ft 1.0 min +R-bar W/NO COMP P&UNCOR. P MID-COURSE ROT COR. -Z,-X OVER 7/31/80

Space Systems Group
Rockwell International

Enclosure 2



30 ft1.8min+R-bar W/NO COMP P&UNCOR. P MID-COURSE ROT COR,-Z OVER,-X UNDER 7/30

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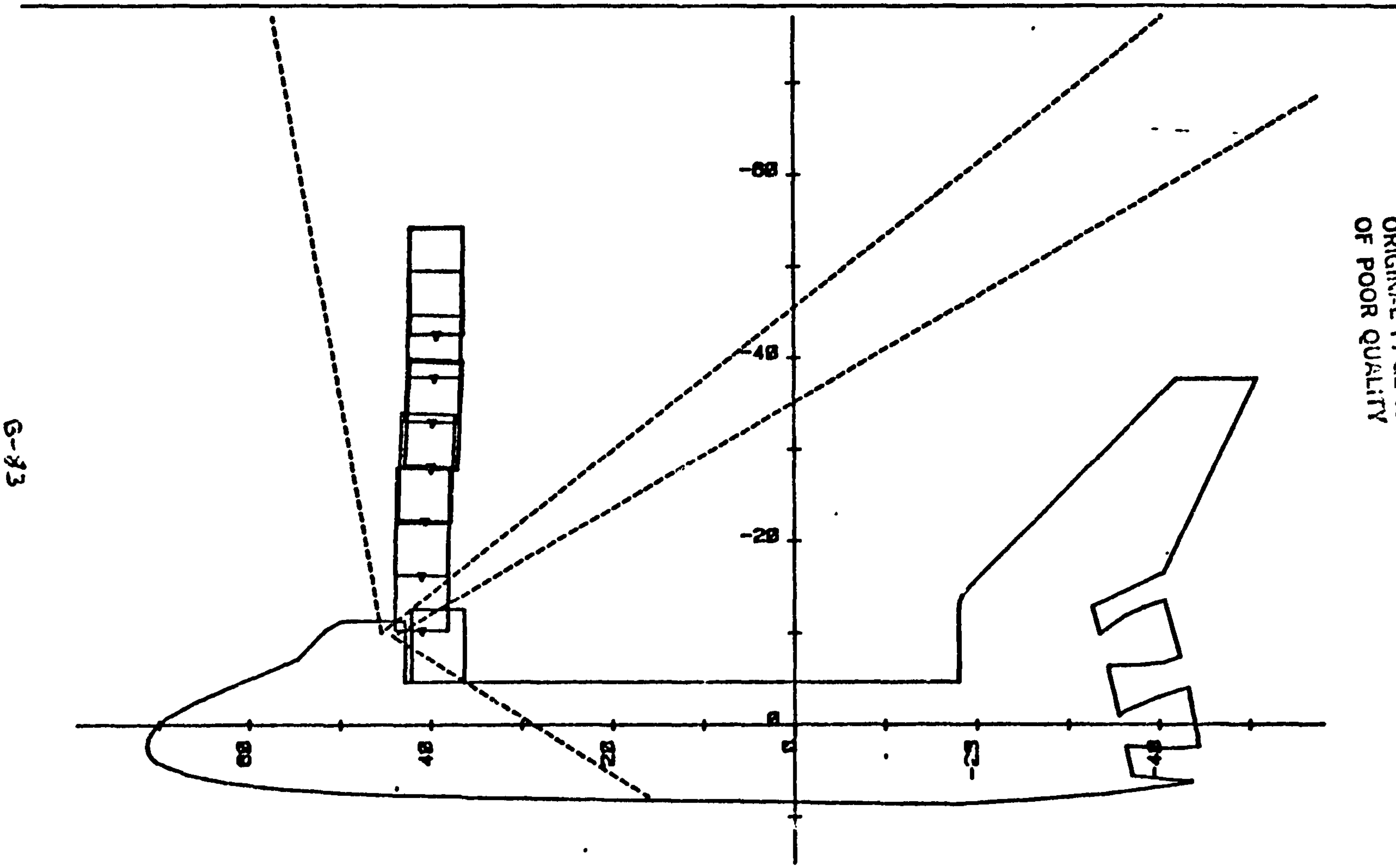

30ft1.0min+R-bar W/NO COMP P&UNCOR.P MID-COURSE ROT COR,-ZUNDER,-XOVER 7/31/80

Space Systems Group Rockwell International

Enclosure 2

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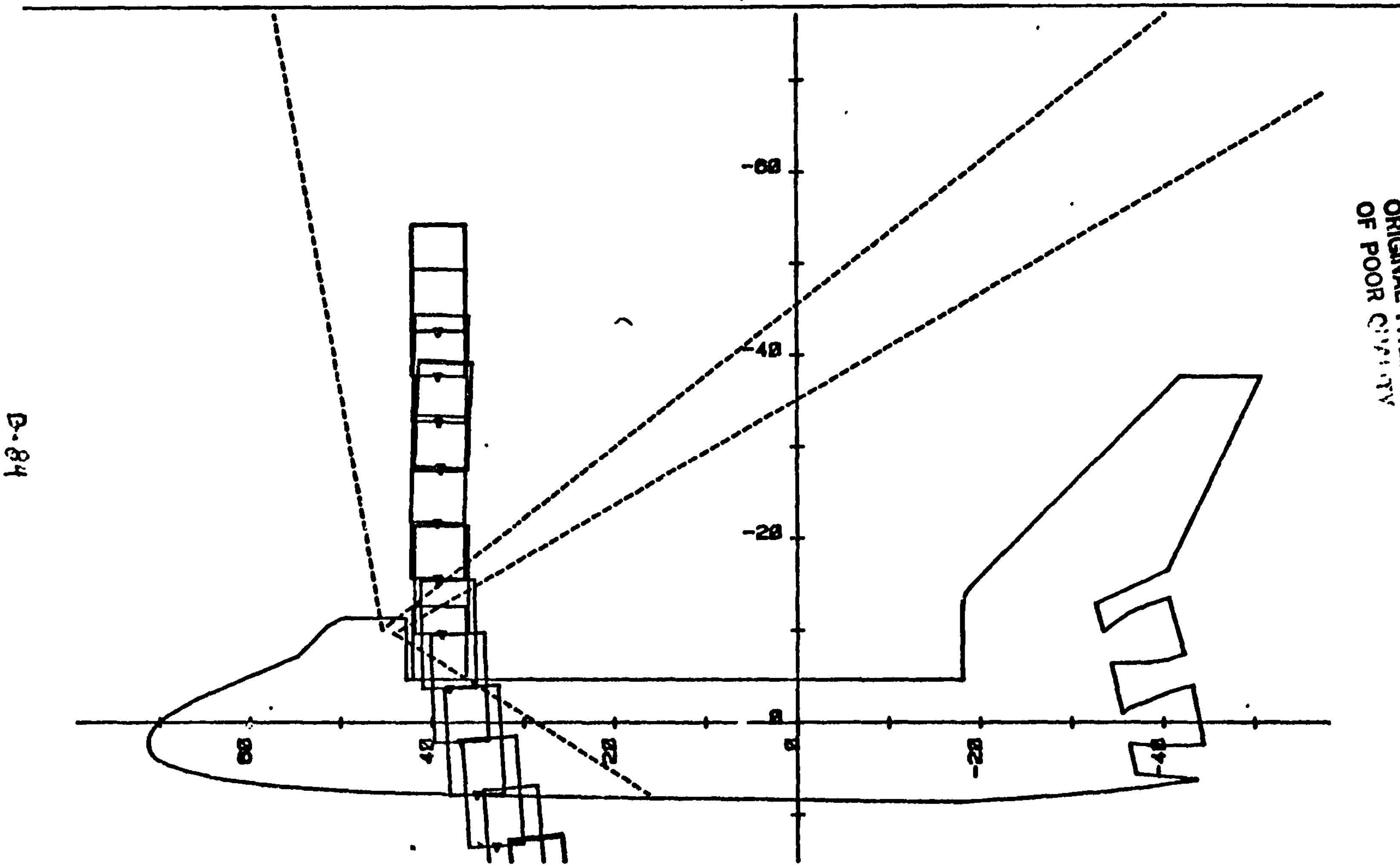

30ft1.8min+R-bar W/NO COMP P&UNCOR. P MID-COURSE ROT COR,-Z,-X UNDER 7/31/80

Enclosure 2

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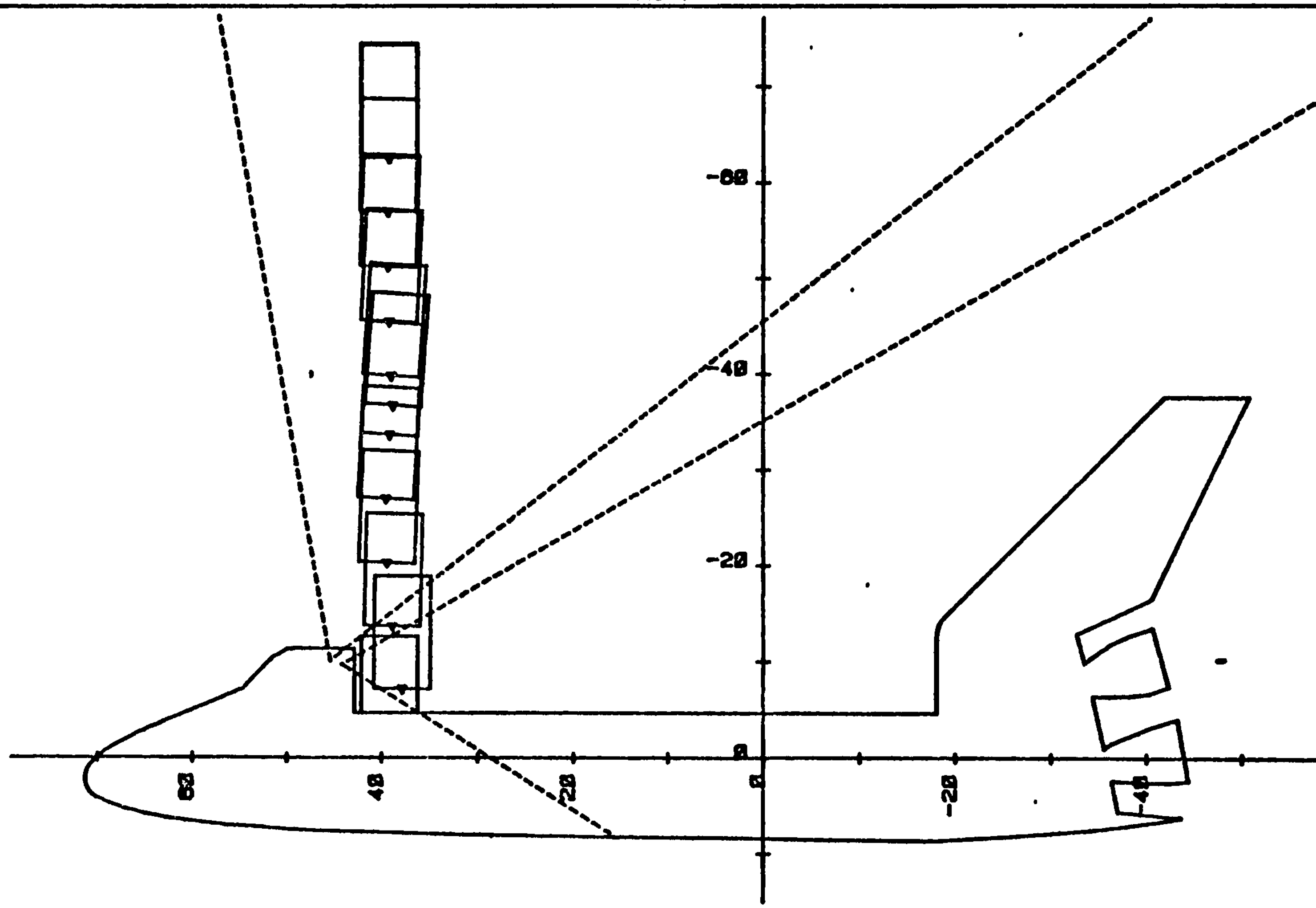

50 ft 3 min NO COMPED P DOCK W/MID-COURSE P ROT CORRECTION, -Z, -X OVER 7/30/80

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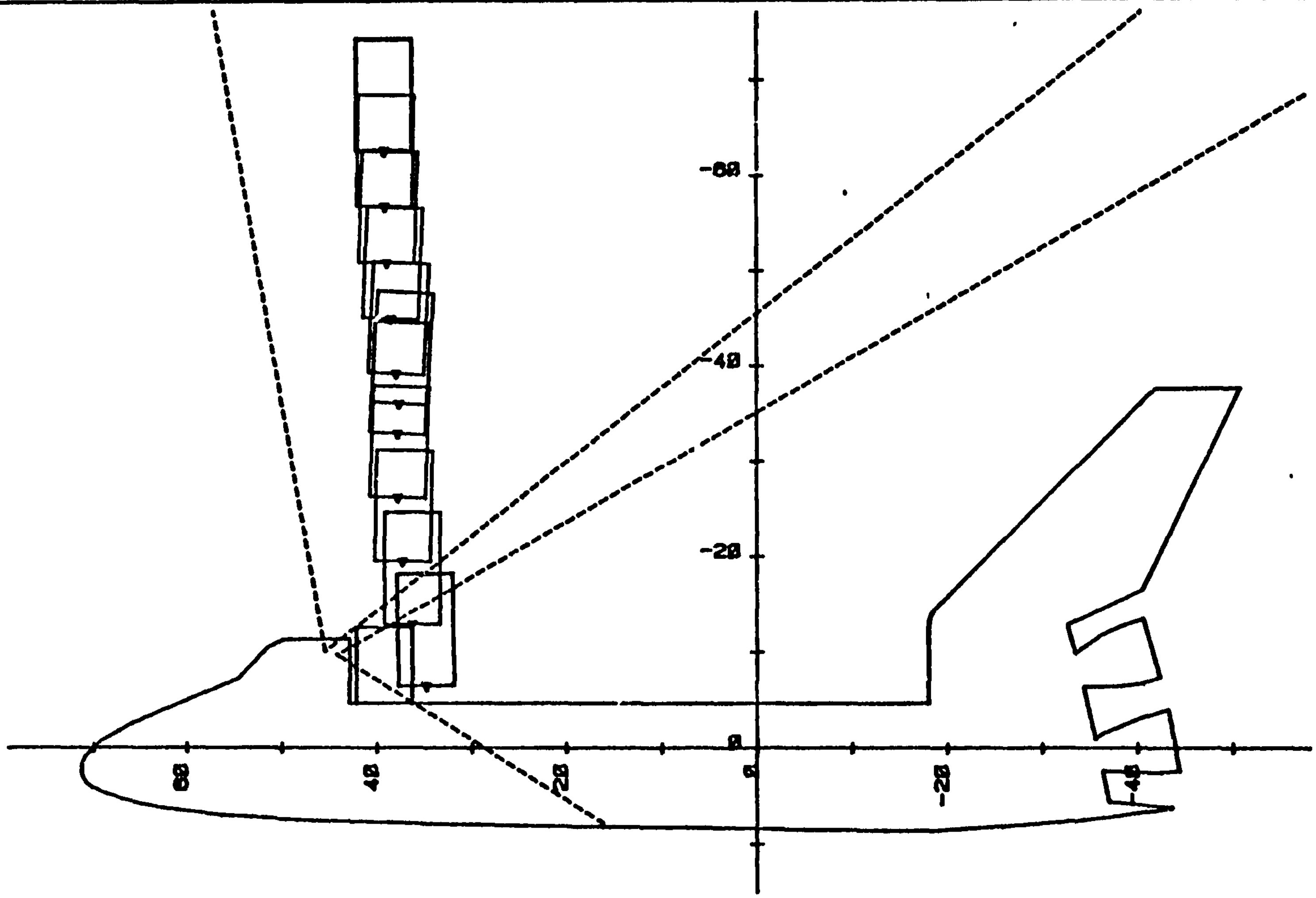

50 ft 3 min +R-bar DOCK, -Z OVER, -X UNDER, W/MID-COURSE P ROT CORRECTION (7/30/80)

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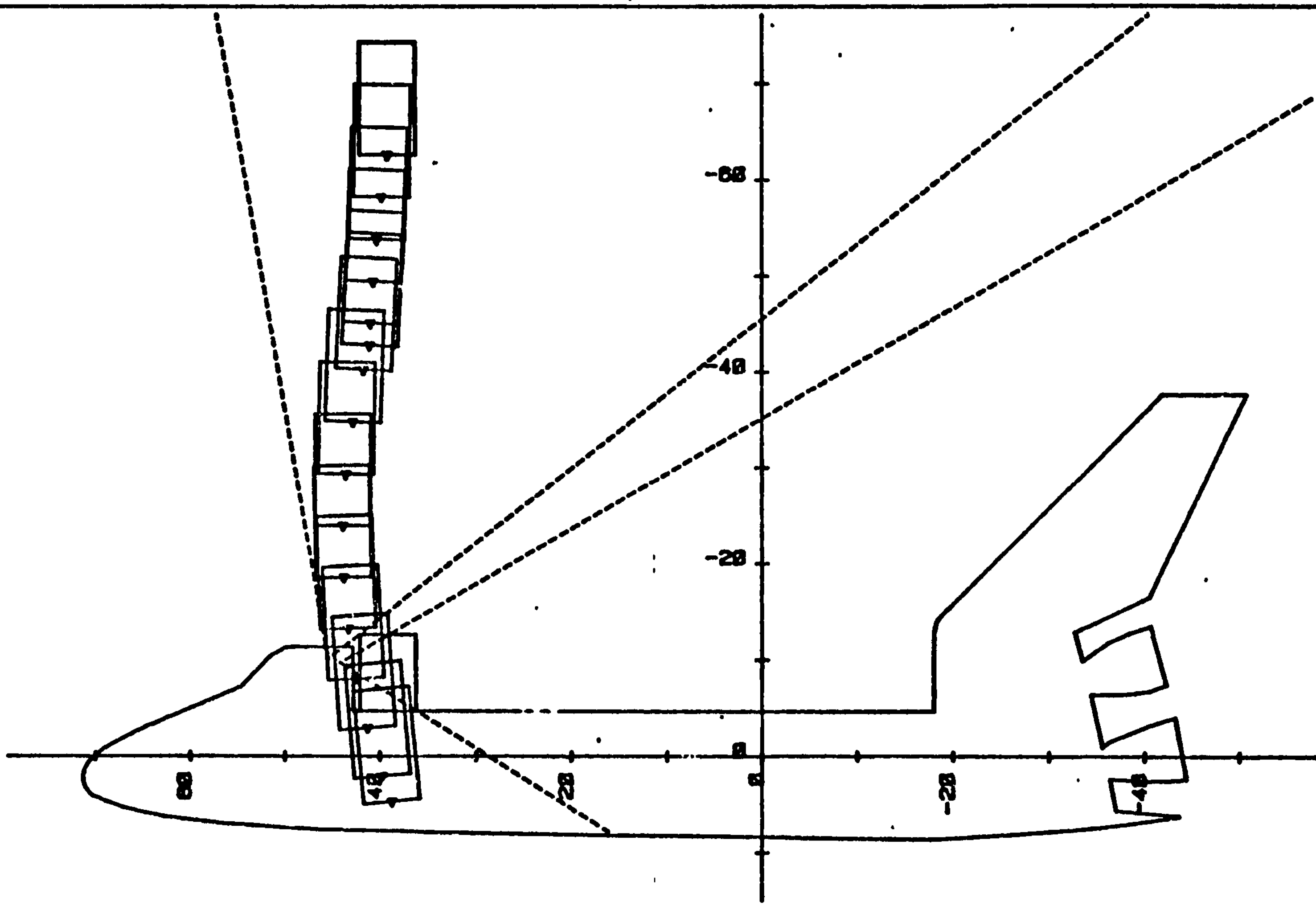
Enclosure 2



50 ft +R-bar 3 min DOCK, -Z UNDER, -X OVER; W/MID-COURSE P ROT CORRECTION (7/30/80)

Space Systems Group Rockwell International

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Enclosure 2

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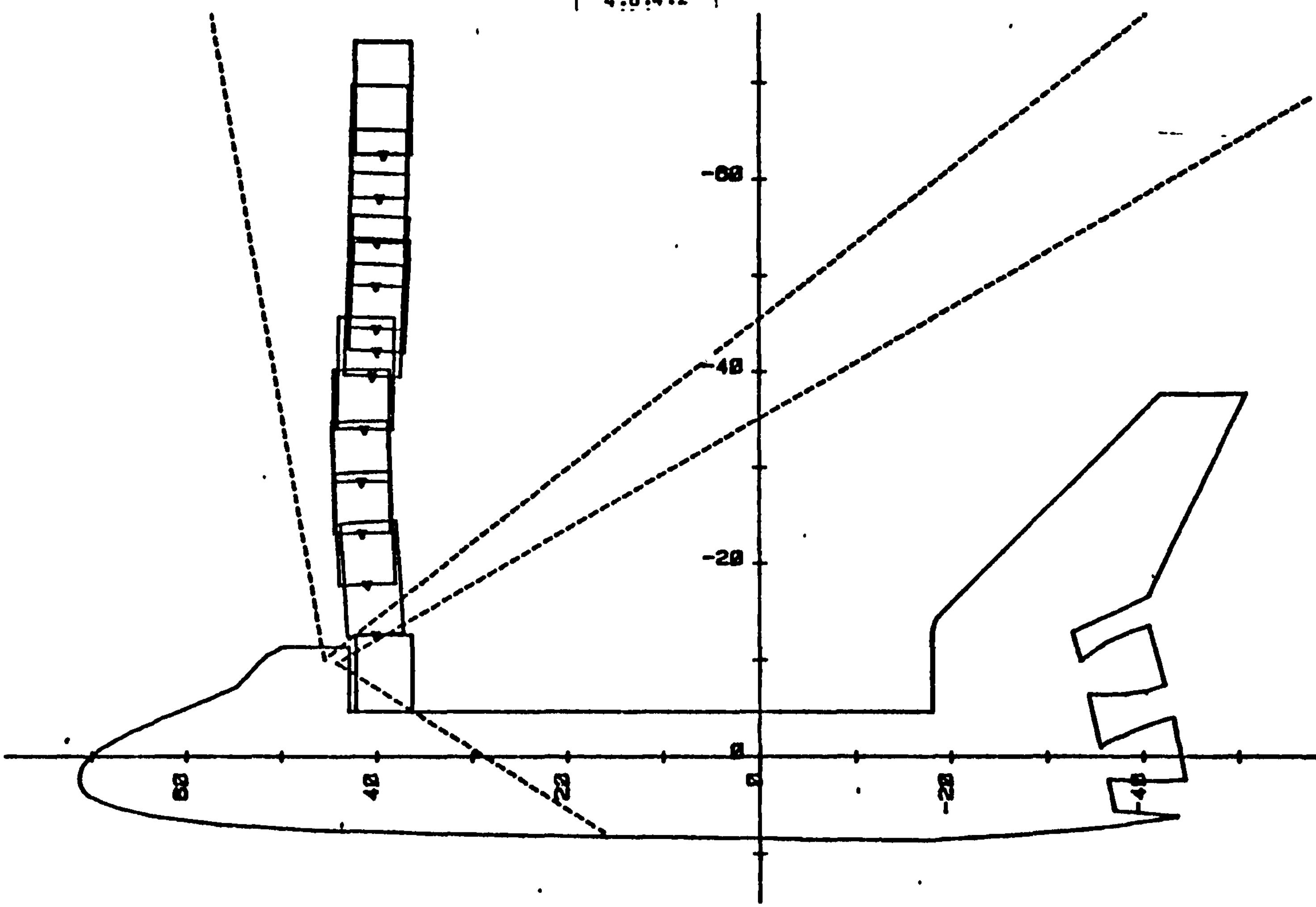
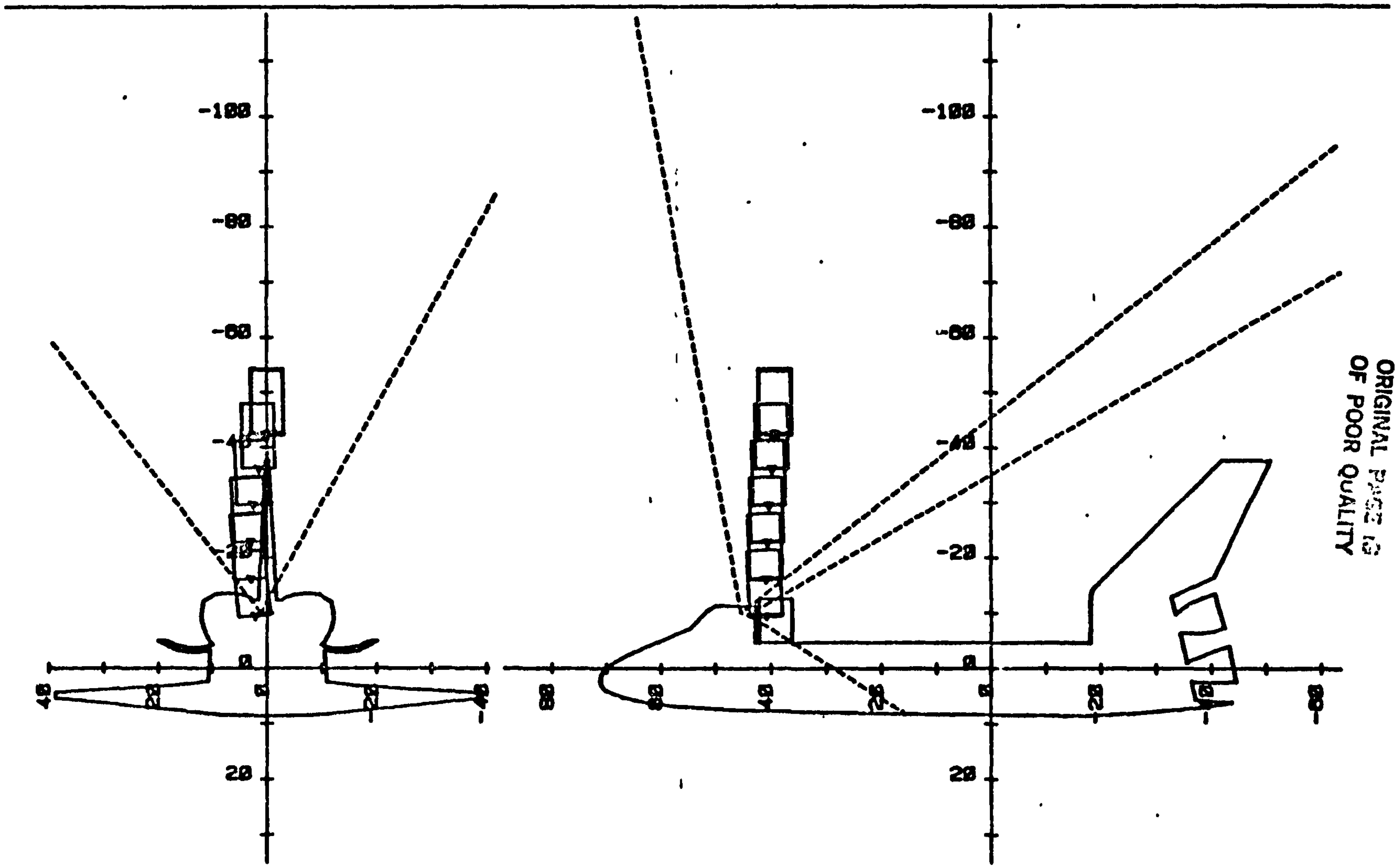
Enclosure 2



50 ft 3 min +R-bar DOCK, -Z, -X UNDER, W/MID-COURSE P ROT CORRECTION (07/30/80)

Enclosure 2



SIDEWAYS 6x6 W/+.08 sec -X,-Y,-Z & .08 sec ROT CORS. (08/07/80)

Space Systems Group   Rockwell International

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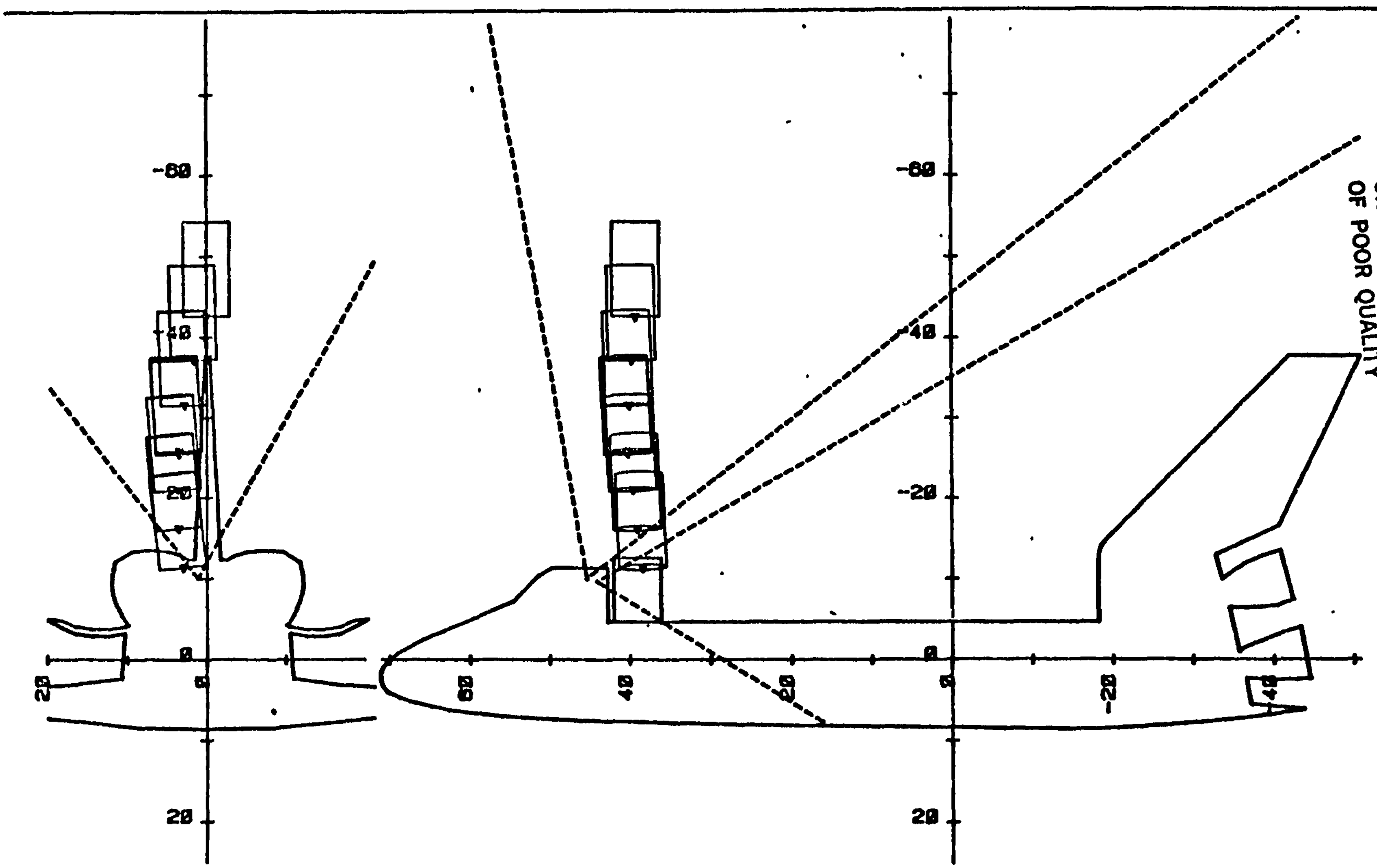
B-99



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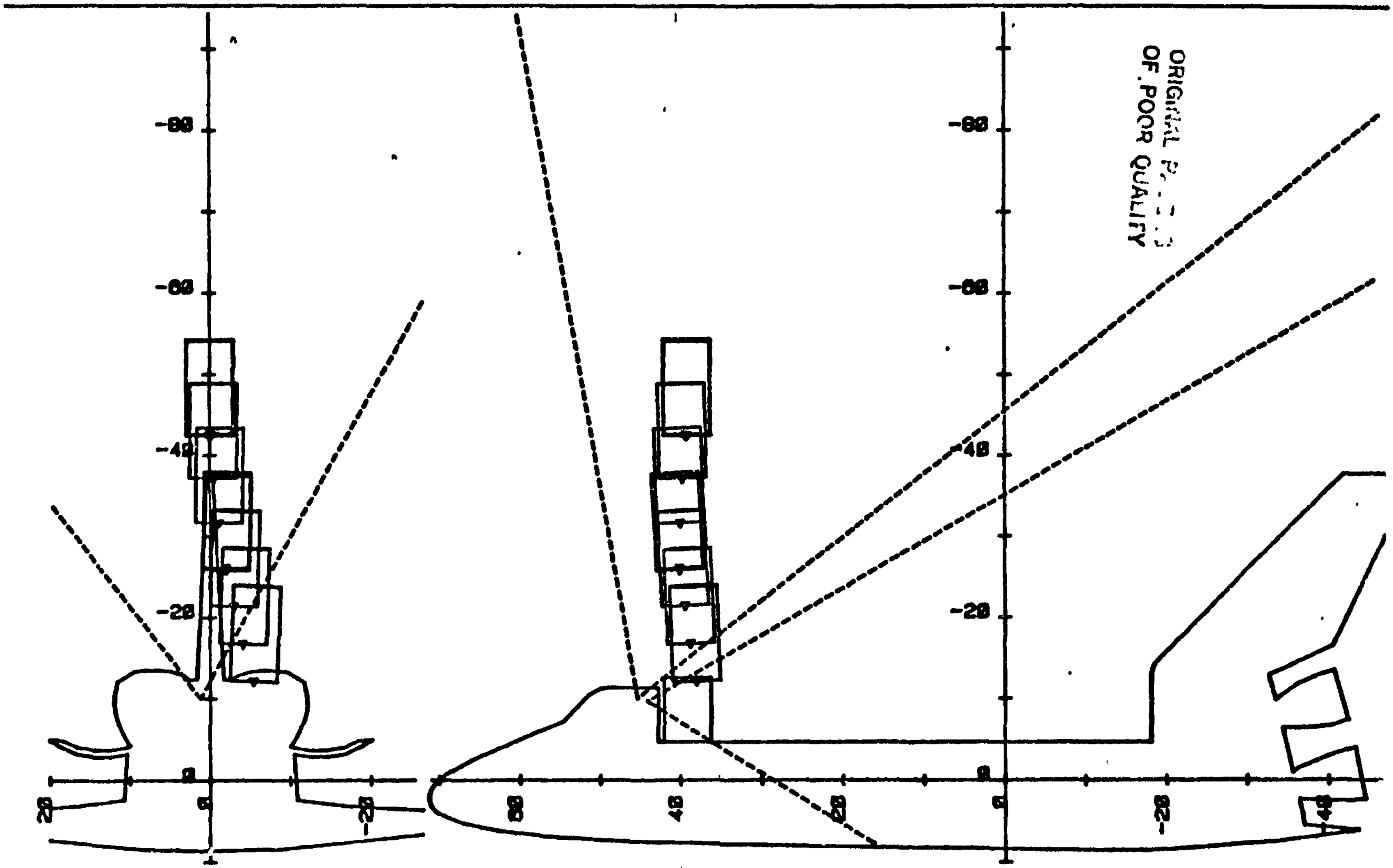
SIDEWAYS 8x8 W/-.08 sec -Z, -Xs +.08 sec -Y & .08 ROT COR. W/1 MIDCOURSE PCH COR.

Enclosure 2

Enclosure 2



SIDEWAYS 6x6 W/-.08 sec -X,-Y,-Z & .08 sec ROT COR. W/1 MIDCOURSE PCH COR 8/7/80

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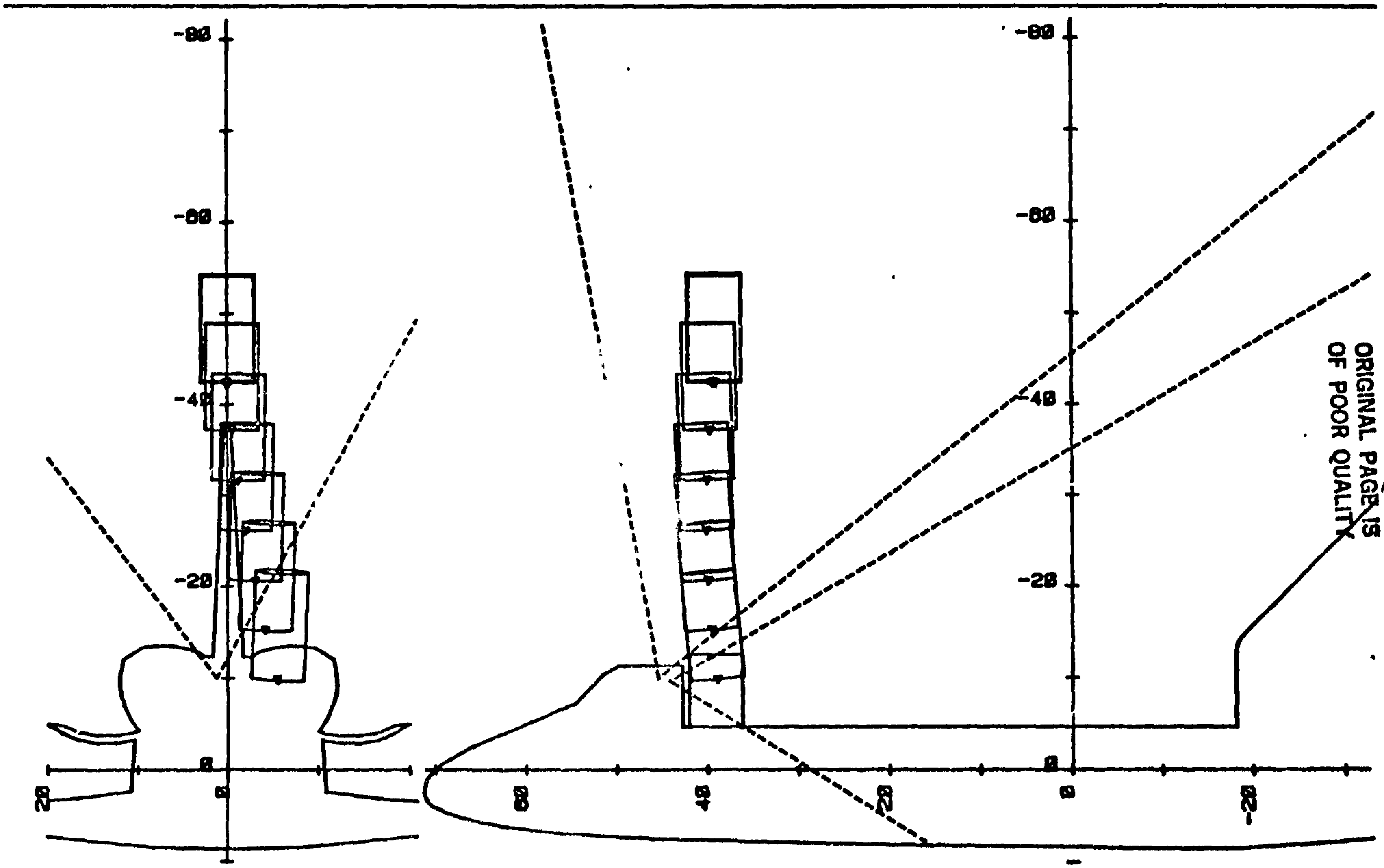
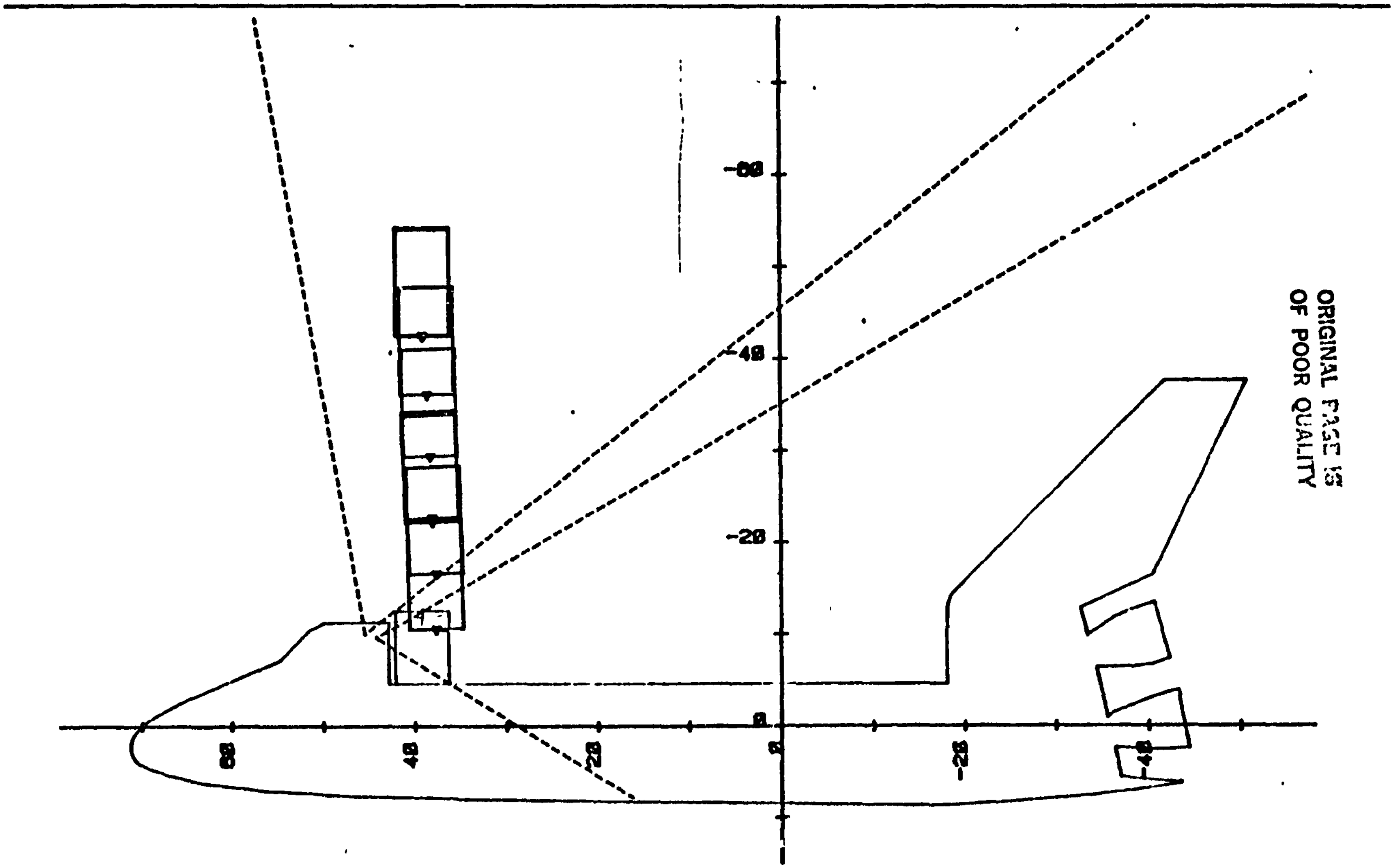


SIDEWAYS 6x6 W/-.08 sec -X,-Z,-Y & .08sec ROT CORRECTIONS. AUGUST 7,1980



CASE 1.8.2 (P ROT & MID-FLIGHT CORRECTION, -Z OVER, -X UNDER) (07/09/80)

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Enclosure 2

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APPENDIX C

JSC Reference Data Package for STS Payload

Delivery Performance

Standard STS

and

Thrust Augmented STS

C-2

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U.S. Government
MEMORANDUM

Lyndon B. Johnson Space Center **NASA**

REFER TO: EX42/8003-32	DATE: APR 8 1980	INITIATOR: EX42/GHLauney:md:3-20-80:2040	ENCL: 16

TO: EX/Chief, Engineering Analysis Division

CC:
EA4/R. Piland
EA4/A. Louviere
EW4/H. Benson
EW4/L. Livingston
EW4/W. Beckman
EX/F. Garcia
FM15/D. Nelson
FM2/G. Babb
FM4/A. Bordano
EW4/S. Nassiff (3)

FROM: EX4/Chief, Integrated Ascent Analysis Branch

SIGNATURE: Paul G. Thomas

SUBJ: Space Operations Center Ascent Performance Analysis

An analysis was conducted to establish the payload capability for the Space Operations Center (SOC) missions using the Shuttle Transportation System. Payload capability and OMS loading requirements were established as a function of SOC operational orbit altitude for both the current Shuttle and for the Shuttle with Titan liquid boost module (LBM) thrust augmentation.

The trajectories were simulated using a three-dimensional, three degree-of-freedom static moment balance trajectory program. All trajectories were biased for the August mean wind. August was used as the reference launch month. Previous analyses (reference 8) have shown this to be the minimum ascent performance month for a maximum dynamic pressure constraint of 680 psf. The aerodynamic data base from reference 1 was used for this analysis. The aerodynamic data base was corrected for all trajectories simulated with the Titan LBM using data obtained from Mr. Dave Hengeveld of Rockwell. The $Q\alpha$ profile obtained from reference 2 was flown during the Mach number region from 0.6 to 2.0. The angle-of-attack (α) was then varied linearly from 0 degrees at a Mach number of 2.0 to a value of +2.0 degrees at a Mach number of 2.9. The angle-of-attack was then held constant at +2.0 degrees from Mach 2.9 to SRB staging due to aerodynamic heating constraints. The angle-of-sideslip (β) was held constant at 0.0 degrees and the body roll or bank angle (ϕ_b) was held constant at 180.0 degrees from a Mach number of 0.6 to SRB staging. The body attitude was held constant after SRB staging for 4.0 seconds. A linear-tangent steering active guidance routine was then used to steer the vehicle from the end of the body attitude freeze phase to main engine cutoff (MECO). Upon initiating active guidance the vehicle was targeted to a pseudo MECO altitude until the mode boundary (first AOA/last RTLS) state vector was attained. Targeting to the pseudo MECO altitude during this flight phase lofts the trajectory to account for the possibility of a loss of engine (LOE) during the flight phase between the mode boundary and nominal MECO. If no LOE occurred at the mode boundary the vehicle was re-targeted to the nominal MECO state vector. If a LOE occurred at or after the mode boundary the vehicle was re-targeted to the abort-once-around (AOA) MECO stage vector holding the orbit inclination (i) and descending node (Ω_d) constant during this flight phase at values equal to the LOE values. The pseudo MECO target altitude was determined in order to balance the excess MPS propellant on both the nominal and AOA trajectory legs. For cases where the pseudo altitude had to be lower than the nominal MECO altitude, the trajectories were shaped for the nominal mission. The maximum payload weight was determined by having no excess MPS propellant remaining at either nominal or AOA MECO.

After MECO occurred a 40.0 second coast period was allowed for external tank (ET) separation. During this coast period the Orbiter flight performance reserve (FPR) propellant and the Orbiter and SSME trapped MPS propellant were jettisoned. After the coast period (on the nominal trajectory leg) the OMS engines were ignited and burned to attain an apogee of 150 nautical miles. The Orbiter then coasted to near apogee of this orbit where the OMS engines were re-ignited to circularize the orbit at 150 n.m. The OMS engines were then used to transfer the vehicle (Orbiter and delivered payload) to the SOC operational orbit. On the AOA trajectory leg the OMS engines and +X RCS jets were used to place the vehicle on a trajectory such that the Orbiter had an entry range of 5,500 n.m. from the landing site (launch site for this analysis) at an entry altitude of 400,000 feet. The vehicle then coasted to apogee of the AOA trajectory where the -X RCS jets (using propellant from the forward RCS tanks) were used for a retro burn to adjust the inertial entry flight path angle to -0.90 degrees.

The Shuttle vehicle used for this analysis is defined in enclosure 1. Enclosure 2 contains a summary of the vehicle weights used in this analysis. The mission and trajectory groundrules are given in enclosure 3. The post MECO velocity increment (ΔV) requirements for both the nominal and AOA trajectory legs are given in enclosure 4. The ΔV requirements for the nominal mission were obtained from reference 5 and from reference 7 for the AOA trajectory leg.

On the AOA leg of the trajectory all OMS and RCS propellant not needed post-MECO and during entry was burned and dumped during a pre-MECO burn. Data from references 3, 6, and 11 was used to construct the thrust and flow rate profiles for the AOA pre-MECO OMS and RCS burn/dump.

The SRB thrust and flow rate profiles and weight data was taken from reference 4. The thrust and flow rate profiles obtained from this reference were referenced to a propellant mean bulk temperature (PMBT) of 60°F. For this analysis these profiles were adjusted for the ETR PMBT for August 15 (80.12°F). The OMS and RCS propellant capacities used in this analysis are given in enclosure 5.

The Shuttle Orbiter and ET weight data and the Titan LBM weight and engine performance data were obtained from Mr. Dave Hengeveld of Rockwell. The Titan LBM data is summarized in enclosure 6.

The SOC component weight estimates are given in enclosure 7.

The on-orbit and de-orbit ΔV requirements calculated for this analysis are given in enclosure 4 for the current-baseline SOC operational orbit of 265 n.m. The ascent trajectory target MECO state vectors for the pseudo, nominal and AOA trajectory legs and the OMS and RCS propellant capacities and loadings are given in enclosure 8 for the vehicle with no thrust augmentation. This data is for a SOC mission with an operational orbit altitude of 256 n.m. This trajectory was shaped for the nominal leg of the mission and required the addition of one OMS payload bay kit (PBK). The complete summary weight breakdown for this vehicle is given in enclosure 9. The vehicle has a delivered payload capability of 50,000 pounds for this mission. The AOA leg pre-MECO OMS and RCS burn/dump thrust and flow rate profile is given in enclosure 10 for this mission. Similar data is given for the vehicle with Titan LBM thrust augmentation in enclosures 11 through 13 for the SOC operational orbit altitude of 265 n.m. This vehicle required a pseudo MECO altitude of 57.5 n.m. This vehicle with Titan LBM thrust augmentation has a delivered payload capability of 68,000 pounds for the SOC operational orbit altitude of 265 n.m. and also requires one OMS PBK.

Plots of pseudo-MECO altitude versus SOC operational orbit altitude are given in enclosure 14 for both vehicles with and without thrust augmentation. For the vehicle with no thrust augmentation the trajectory is shaped for the nominal mission for SOC operational altitudes greater than 230 n.m. The trajectory for the vehicle with Titan LBM thrust augmentation is shaped for the nominal mission with SOC operational orbit altitudes greater than 268 n.m. The total required OMS propellant loading is given in enclosure 15 for both vehicles as a function of SOC operational orbit altitude. Enclosure 16 gives plots of maximum delivered payload as a function of SOC operational orbit altitude for both vehicles with and without Titan LBM thrust augmentation. The vehicle with Titan LBM thrust augmentation can deliver 18,000 pounds more payload than the vehicle without thrust augmentation. The vehicle with Titan LBM thrust augmentation can deliver an additional 1,000 pounds if no payload is returned. An additional 1,400 pounds can be delivered by the vehicle with no thrust augmentation for no return payload.

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REFERENCES

1. EX33/7904-63, "STS-1 Cycle 3 Integrated Aerodynamic Design Data Base", May 14, 1979.
2. LE-M-216, "Minutes of August 14-15, 1979, AFSIG Meeting", September 25, 1979.
3. P&AS-DLJ-78-137, "OMS/RCS Characteristics for RTLS Abort", September 21, 1978.
4. JSC-07700-Volume 10, Appendix 10, 12, "Space Shuttle System Requirements".
5. JSC Internal Note No. 75-FM-1, "The Orbiter Configuration Control OMS and RCS Propellant Budget, Revision 2", April 4, 1977.
6. SAS/MR&I-77-168, "Aft-RCS Propellant Usable for AOA", July 6, 1977.
7. SAS/MR&I-77-208, "CDR Post-MECO AOA Ascent Performance for Reference Missions 1 and 3A", October 4, 1977.
8. EX42/7907-55, "Performance Comparison of ETR and WTR SRM Launched from ETR", July 20, 1979.
9. MSFC Memorandum SA51 (79-331), "Preliminary Performance Characteristics for Engines 2005, 2006, 2007", July 24, 1979.
10. MSFC Memorandum EL24 (79-126), "MPS Ascent Performance Propulsion Parameters", November 26, 1979.
11. SAS/MR&I-77-128, "Nominal Mission 4 Ascent Trajectory for the CDR Baseline Configuration-Winter Launch", July 12, 1977.

Lyndon B Johnson Space Center

Engineering and Development Directorate

STS LAUNCH VEHICLE DEFINITION	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

- ORBITER VEHICLE 103 WITH 4,000 LB WEIGHT SAVINGS
- ET 26 AND SUBSEQUENT WITH 6,000 LB WEIGHT SAVINGS
- TC 121-78 SRB (VOLUME 10)
- FULL RCS LOAD
- OMS LOAD AS REQUIRED FOR MISSION
- ADD UP TO 3 OMS PBK'S (AS REQUIRED)
- TITAN LBM (OPTIONAL)

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Enclosure 1


SOC MODULE INTERFACE
SCALE 1/10
SEALS
HATCH
CAPTURE LATCH
SCALE 1/3
2° INSULATION
TUNNEL SEAL
TUNNEL EXTENDED
TUNNEL RETRACTED
GUIDE RING RETRACTED
8" TOTAL GUIDE RING EXTENSION (5" ATTENUATION PLUS 3")
HATCH CLOSED
HATCH OPEN
GUIDE RING EXTENDED
GUIDE PETALS
ATTENUATOR
CABLE RETRACT SYSTEM FOR GUIDE RING
ATTENUATORS RETRACTED
ATTENUATORS EXTENDED
61" TUNNEL MOVEMENT
2 SEALS
4 SCREWJACKS WITH CHAIN DRIVE
4 PAIRS OF ATTENUATORS
CHAIN DRIVE & CHAIN TENSION
CHAIN
SCREWJACK
NUT
IDLER
ORBITER DOCKING MODULE
SCALE 1/10
DOCKING TUNNEL CONCEPT, EXTERNAL EXTENDABLE
03953

DR BY R. HART		Rockwell International Corporation Space Division
CHK BY		DOCKING TUNNEL CONCEPT, INTERNAL, EXTENDABLE.
APPROVED BY		
SIZE L	CODE IDENT NO 03953	DRAWING NO. 42630-004
SCALE		SHEET

NASA Lyndon B. Johnson Space Center

Engineering and Development Directorate

VEHICLE SUMMARY WEIGHTS	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

● OV-103 (LESS 4,000 LBS)	140,820
● ORBITER LBM WEIGHT PENALTY	220
● 3 X SSME (EMPTY)	20,484
● ET-26 AND SUBSEQUENT (LESS 6,000 LBS)	70,990
● ET LBM WEIGHT PENALTY	2,505
● RCS PROPELLANT CAPACITY	7,374
● ORBITER OMS PROPELLANT CAPACITY	25,156
● 2 X TC 121-78 SRB	2,589,760
● SRB LBM WEIGHT PENALTY	280
● TITAN LBM	382,650

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Enclosure 3

NASA Lyndon B. Johnson Space Center — Engineering and Development Directorate

MISSION AND TRAJECTORY GROUNDRULES	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

- DUE EAST LAUNCH FROM ETR (INCLINATION = 28.5 DEG)
- BASELINE LAUNCH MONTH WAS AUGUST (MINIMUM PAYLOAD)
- MAXIMUM DYNAMIC PRESSURE (MAX Q) WAS 680 PSF
- 2.75 SECOND SRB IGNITION DELAY FROM SSME POWER LEVEL OF 90 PERCENT
- IGNITE LBM 5.0 SECONDS AFTER SRB IGNITION COMMAND
- JETTISON LBM STAGE AT LBM BURNOUT (205.4 SECONDS)
- POST MECO INSERTION ORBIT WAS 150 NAUTICAL MILE CIRCULAR ORBIT
- ORBITAL TRANSFER (ORBITER AND PAYLOAD) FROM INSERTION ORBIT TO SOC OPERATIONAL ORBIT
- SOC OPERATIONAL ORBIT ALTITUDES FROM 150 TO 450 NAUTICAL MILES WERE CONSIDERED
- CURRENT BASELINE SOC OPERATIONAL ORBIT ALTITUDE IS 265 NAUTICAL MILES
- INERTIAL ENTRY FLIGHT PATH ANGLE WAS -1.35 DEGREES
- MAXIMUM PAYLOAD DELIVERED TO SOC OPERATIONAL ORBIT
- OMS RETRO PROPELLANT WAS CALCULATED BASED ON RETURNING 42,000 POUND PAYLOAD
- OPERATE SSME'S AT FPL (109 PERCENT OF RPL)
- SSME THROTTLE RATE WAS 10.0 PERCENT/SEC
- THROTTLE SSME'S FOR MAX Q CONTROL
- THROTTLE SSME'S TO LIMIT MAXIMUM ACCELERATION TO 3.0 g's
- THROTTLE SSME'S TO MPL (65 PERCENT OF RPL) SIX SECONDS BEFORE MECO
- THRUST VECTOR CONTROL (TVC) USING SRB GIMBAL FROM LIFTOFF UNTIL SRB CHAMBER PRESSURE DECAYED TO 50 PSIA (Pc = 50)
- SSME GIMBAL FOR TVC FROM Pc = 50 TO MECO
- NO LBM GIMBAL FOR TVC
- PRE-MECO OMS AND RCS BURN/DUMP DURATION LIMITED TO 300 SECONDS ON AOA TRAJECTORY LEG
- VEHICLE ORIENTED WITH TAIL POINTED SOUTH ON LAUNCH PAD
- MAXIMUM RETURN PAYLOAD IS HEAVIEST SINGLE SOC COMPONENT

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F1 FREON SUPPLY
F2 FREON RETURN
MODULE TO MODULE ONLY
W1 WATER COOLANT SUPPLY
W2 WATER COOLANT RETURN
W3 DRINKING WATER
W4 WASTE WATER
ESD ELECTRIC SIGNAL/DATA
O2 OXYGEN SUPPLY
N2 NITROGEN SUPPLY
AP AIR PRESSURE
EP ELECTRIC POWER
L LATCH
LS LATCH STRIKER
SECTION X-X
SECTION Y-Y
SCALE 1/10
DETAIL A
SCALE: 1/4
PLB 180" DIA
78" DIA
57.50 DIA
36" DIA
TUNNEL EXTENDED
TUNNEL RETRACTED
SCREWJACK LUGS
AIR DUCT
ELECTRIC SIGNAL/DATA
ELECTRIC POWER ROUTING
SEE DETAIL A FOR CONFIGURATION OF THIS INTERFACE
SEE SHEET 2 FOR CONFIGURATION OF THIS BULKHEAD
WIRING FOR CLOSE RING MECHANISMS & SWITCHES
42690-005 SHEET 2
80220-005
DOCKING TUNNEL WITH UTILITY ROUTING
03953
42690 -005
SHEET 1 OF 2

SECTION A-A
DETAIL B
ORBITER - BASIC TUNNEL ADAPTER
DOCKING ADAPTER
TUNNEL ADAPTER
AIRLOCK
ORBITER CABIN
SEAL ASSEMBLY
42690-006
42690-006
ORBITER TUNNEL ADAPTER
TO DOCKING ADAPTER
CONCEPT CONFIGURATIONS
SIZE L
CODE IDENT NO 03953
42690 - C06

Lyndon B. Johnson Space Center — Engineering and Development Directorate

POST MECO VELOCITY INCREMENT REQUIREMENTS	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

- NOMINAL MISSION POST MECO ΔV REQUIREMENTS (150 N. MI. CIRCULAR INSERTION ORBIT)
  - INSERTION BURN — 207.2 fps
  - CIRCULARIZATION BURN — 177.4 fps
  - LEVEL 1 RESERVES — 17.8 fps
- AOA POST MECO ΔV REQUIREMENTS (ENTRY RANGE = 5,500 N.MI., ENTRY FPA = -.90 DEG)
  - INSERTION BURN — 219.0 fps
  - APOGEE RETRO BURN — 40.0 fps
  - LEVEL 1 RESERVES — 17.8 fps
- ON-ORBIT ΔV REQUIREMENTS
  - TRANSFER FROM 150 N.MI. CIRCULAR ORBIT TO 150 X 265 N.MI. ELIPTICAL ORBIT — 199.12 fps
  - CIRCULARIZE AT 265 N.MI. — 197.56 fps
- DEORBIT ΔV REQUIREMENT (ENTRY = 1.35 deg) — 412.41 fps

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C-9

Enclosure 4

NASA Lyndon B Johnson Space Center

Engineering and Development Directorate

OMS AND RCS LOADING CAPACITIES	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

• ORBITER RCS CAPACITY	7,374
• ORBITER OMS CAPACITY	25,156
• OMS PAYLOAD BAY KIT (PBK) WEIGHTS	
• PBK NO. 1 USABLE PROPELLANT CAPACITY	12,176
• PBK NO. 1 INERT	4,126
• PBK NO. 2 USABLE PROPELLANT CAPACITY	12,281
• PBK NO. 2 INERT	885
• PBK NO. 3 USABLE PROPELLANT CAPACITY	12,278
• PBK NO. 3 INERT	1,287

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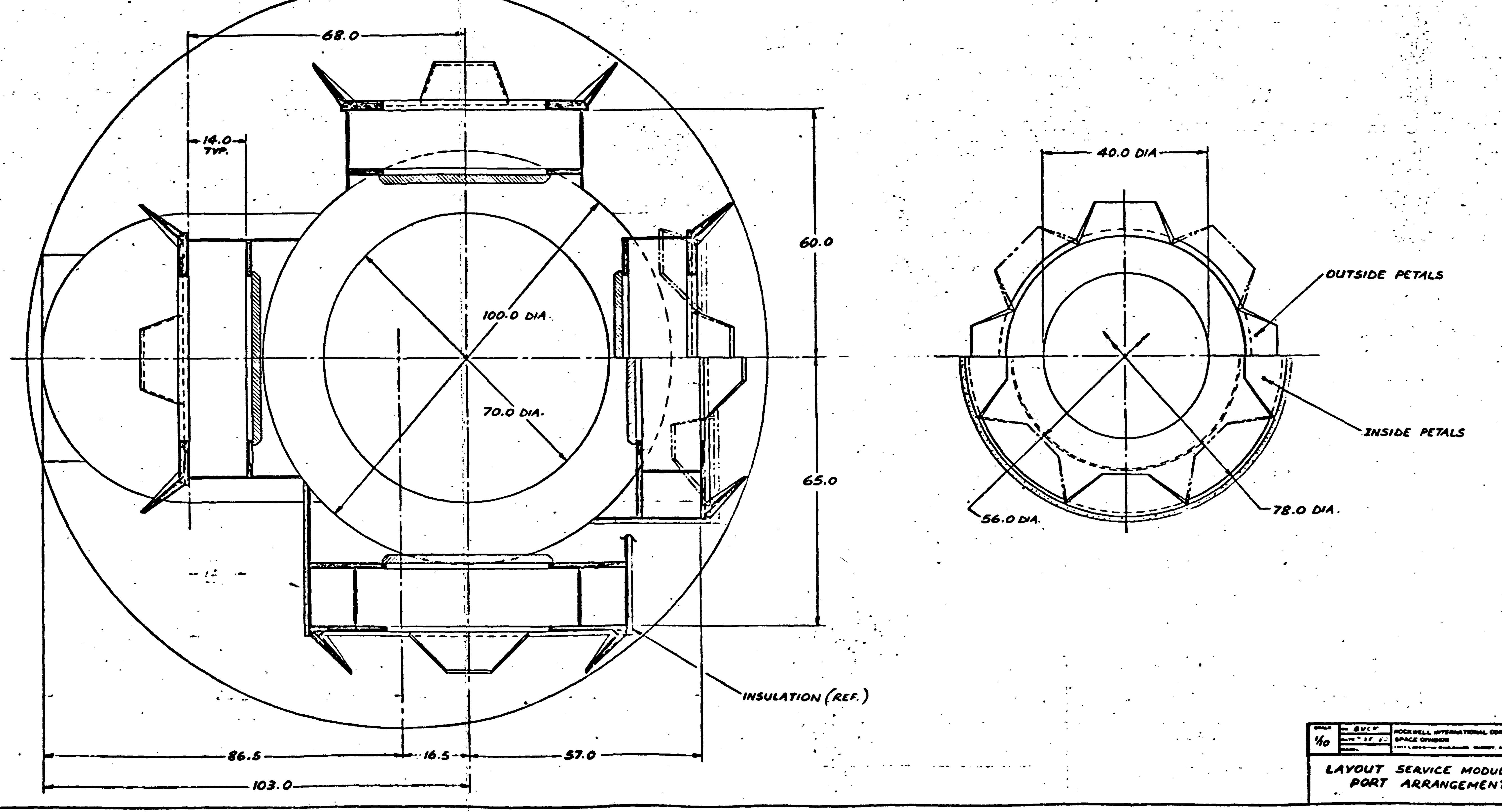

1/10	BUCK	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION	
LAYOUT SERVICE MODULE PORT ARRANGEMENT			42690-007

Rockwell International Corporation
Space Division

DOCKING MODULE, MANNED MANEUVERING UNIT, & CHERRY PICKER STORAGE ARRANGEMENT

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42690 - 008

SCALE 1/20 SHEET

TITAN LBM SUMMARY WEIGHT AND PERFORMANCE DATA	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

• TOTAL MODULE WEIGHT, LBS	382,650
• USABLE PROPELLANT, LBS	(348,900)
• INERT, LBS	(33,750)
• AVERAGE VACUUM THRUST, LBS	530,000
• AVERAGE VACUUM Isp, SEC	301.7
• IGNITION TIME, SEC	5.0
• STAGING TIME, SEC	205.4

SOC COMPONENT WEIGHT ESTIMATES*	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

• SERVICE MODULE	42,174
• HABITATION MODULE	38,264
• LOGISTICS MODULE	19,298
• TUNNEL	6,630
• STAGE ASSEMBLY	17,616
• RMS/CONTROL	19,315
• CONSTRUCTION FACILITY	21,406

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*SUPERCEDES NASA DOCUMENT JSC-16277 IN CASE OF CONFLICT
*INCLUDES 50 PERCENT GROWTH OVER ESTIMATED VALUES
*1/18/80

Enclosure 7


REVISIONS
OPEN CHERRY PICKER ENVELOPE
DOCKING ADAPTER
TUNNEL ADAPTER
DOCKING MODULE SUPPORT STRUCTURE
MMU/FSS ENVELOPE
ORBITER CABIN
AIRLOCK
DOCKING ADAPTER
TUNNEL ADAPTER
BASIC TUNNEL ADAPTER
CHERRY PICKER ENVELOPE
DOCKING ADAPTER
Rockwell International Corporation
Space Division
DOCKING MODULE, MANNED MANEUVERING UNIT, & CHERRY PICKER STORAGE ARRANGEMENT
L
03953
42690 - 008
42690-008

SOC MISSION ASCENT TRAJECTORY MECO PARAMETERS AND OMS AND RCS LOADINGS
(NO THRUST AUGMENTATION)

(SOC OPERATIONAL ORBIT ALTITUDE=265n.m.)

	PSEUDO	NOMINAL	ABORT
ALTITUDE	57.00	57.00	57.00
VELOCITY	25680.00	25680.00	25676.00
GAMMA	0.6500	0.6500	0.6500
INCLINATION	28.447	28.447	28.546
DESC NODE	89.995	89.995	89.729

TOTAL OMS CAPACITY		37332.
NO. OF OMS KITS	1.	
ORBITER OMS CAPACITY	25156.	
OMS PBK NO. 1 CAPACITY	12176.	
TOTAL LOADED OMS		30960.
TOTAL RCS CAPACITY		7574.
TOTAL LOADED RCS		7574.

SOC MISSION VEHICLE SUMMARY WEIGHT BREAKDOWN
(NO THRUST AUGMENTATION)

(SOC OPERATIONAL ORBIT ALTITUDE=265n.m.)

	NOMINAL	ABORT
PAYLOAD	50085.	50085.
OMS PAYLOAD BAY KITS	4126.	4126.
MISSION SUPPORT EQUIP	1608.	1608.
PERSONELL	2644.	2644.
ORBITER - EMPTY	140821.	140821.
- NON PROP CONSUMABLES	3748.	3748.
- USABLE RCS	5652.	2687.
- RCS RESERVES	903.	[illegible]
- RCS RESIDUALS	567.	567.
- OMS PROP (ON ORBIT)	14620.	0.
- OMS PROP (DE-ORBIT)	9367.	0.
- RCS PROP (DE-ORBIT)	0.	1470.
- OMS RESERVES	769.	388.
- OMS RESIDUALS	891.	891.
SSME (EMPTY)	20484.	20484.
ORBITER AT INSERTION	256285.	229913.
POST-MECO MANEUVER-(OMS PROP)	5314.	3917.
POST-MECO MANEUVER-(RCS PROP)	0.	1271.
ORBITER AT OMS IGNITION	261599.	235100.
TRAPPED MPS PROP - ORBITER	887.	1818.
TRAPPED MPS PROP - SSME	1524.	1524.
FLIGHT PERF RESERVE - ORBITER	2771.	1840.
FLIGHT PERF RESERVE - SSME	0.	0.
ORBITER AFTER ET SEPARATION	266781.	240282.
RCS PROPELLANT	252.	252.
ORBITER AT ET JETTISON	267053.	240534.

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REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

Rockwell International Corporation
Space Division

DR BY: BUCK

CHK BY

APPROVED BY

HM1 TO SOC ASSEMBLY SEQUENCE USING R/CM & ALIGNMENTS AIDS.

SIZE: L | CODE IDENT NO: 03953 | DRAWING NO.: 42690-009

SCALE 1/100 | SHEET

SOC MISSION VEHICLE SUMMARY WEIGHT BREAKDOWN (CONT'D)
(NO THRUST AUGMENTATION

	NOMINAL	ABORT
EXTERNAL TANK - EMPTY	70990.	70990.
- RESIDUALS	4011.	4198.
- NON PROP CONS	423.	423.
FLIGHT PERFORMANCE RESERVE-ET	2860.	1789.
FUEL BIAS	1047.	1100.
EXCESS MPS PROPELLANT	-7.	1452.
EXPELLED MPS PROPELLANT	228.	152.
ET WEIGHT AT MECO	79552.	80104.
INJECTED WEIGHT AT MECO	346585.	320638.
MPS PROP (MODE BOUNDARY/MECO)	757047.	756418.
PRE - MECO OMS BURN	0.	10435.
PRE - MECO RCS BURN	0.	735.
PRE - MECO OMS DUMP	0.	15329.
WEIGHT AFTER MODE BDY	1103632.	1103556.
EXPELLED MPS	0.	76.
WEIGHT PRIOR TO MODE BDY	1103632.	1103632.
MPS PROP (STAGING/MODE BOUNDARY)	422364.	
WEIGHT AFTER STAGING		1525996.
SRB CASE JETTISON WEIGHT	357069.	
WEIGHT PRIOR TO STAGING		1883065.
SECONDARY PROP SYSTEM JETTISON WT	0.	
SECONDARY PROP (L/O - STAGING	0.	
SRB PROPELLANT	2231319.	
MPS PROP (LIFTOFF/STAGING)	382176.	
LIFTOFF WEIGHT		4496560.
MPS PROPELLSNT	724.	
SRB PROPELLANT	1373.	
SRB IGNITION COMMAND (T = 0)		4498656.
MPS BURNED PRIOR TO SRB IGN COMMANL	7701.	
WEIGHT AT MPS THRUST COMMITMENT		4506357.

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NASA Lyndon B Johnson Space Center

Engineering and Development Directorate

PRE-MECO OMS AND RCS BURN/DUMP THRUST AND FLOW RATE PROFILE (NO THRUST AUGMENTATION)	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

(SOC OPERATIONAL ORBIT ALTITUDE=265n.m.)

TIME (SEC)	THRUST (LBS)	FLOW RATE (LB/SEC)	JETS
0.0	12,140	38.760	2 X OMS
4.5	12,140	38.760	2 X OMS
4 5	13,566	98.971	2 X OMS + 24 X RCS
239.28	13,566	98.971	2 X OMS + 24 X RCS
239.28	12,140	38.760	2 X OMS
243.78	12,140	38.760	2 X OMS
243.78	15,801	51.836	2 [illegible] + 4 X RCS
300.00	15,801	51.836	2 [illegible] 4 X RCS

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C-16

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
DOCKING RING
13°
7°
14.0 CLR.
ATTENUATORS
6° OUT OF LINE CONTACT BETWEEN PORTS WITH DOCKING RING BEING FORCED TO PITCH AN ADDITIONAL 7°
Xo 621
SERVICE MODULE
DOCKING PORT
6°
34.0 CLR.
Zo 515
8.0 ATTENUATION
DOCKING MODULE
1ST CONTACT BETWEEN PORTS (NO ATTENUATION)
MODULE 6° OUT OF LONGITUDINAL ALIGNMENT
SCALE: 1/20
BERTHING PORT
12.0 MIN.
5.0 CLR.
13°
TPS
MODULE 6° OUT OF LINE & BOTTOMED OUT ON DOCKING RING, WHICH IN TURN IS PITCHED AT ITS MAX. ATTENUATION
ORBITER DOCKED TO (SOC) SERVICE MODULE
SCALE: 1/100
BERTHING PORT
11°15'
11°15'
45°
11°15
11°15'
B
A
A
B
8.50 AVAILABLE FOR UTILITIES
76.0 DIA.
45°
DOCKING RING
UTILITIES & LATCH MATING SURFACE
Zo 515 INTERFACE
SECTION B-B
45°
9.0
.50
3.0
40.0 DIA.
57.50 DIA.
58.0 DIA.
64.0 DIA.
SECTION A-A
DOCKING PORT
SCALE: 1/10
DR BY BUCK
CHK BY
APPROVED BY
Rockwell International Corporation
Space Division
MIN. CLEARANCES BETWEEN ORBITER & MODULE DURING DOCKING OPERATION.
SIZE L
CODE IDENT NO 03953
42690-010
SCALE
SHEET
42690-010

Rockwell International Corporation
Space Division

MID DECK SEATING ARRANGEMENT FOR SOC CREW DELIVERY AND EXCHANGE

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42690-011

SCALE 1/40

SOC MISSION ASCENT TRAJECTORY MECO PARAMETERS AND OMS AND RCS LOADINGS
(TITAN LBM THRUST AUGMENTATION)
(SOC OPERATIONAL ORBIT ALTITUDE=265 n.m.)

	PSEUDO	NOMINAL	ABORT
ALTITUDE	57.50	57.00	57.00
VELOCITY	25680.00	25660.00	25676.00
GAMMA	0.6500	0.6500	0.6500
INCLINATION	28.147	28.447	28.517
DESC NODE	89.996	89.997	89.969
TOTAL OMS CAPACITY			37332.
NO. OF OMS KITS		1.	
ORBITER OMS CAPACITY		25156.	
OMS PBK NO. 1 CAPACITY		12176.	
TOTAL LOADED OMS			32474.
TOTAL RCS CAPACITY			7374.
TOTAL LOADED RCS			7374.

SOC MISSION VEHICLE SUMMARY WEIGHT BREAKDOWN
(TITAN LBM THRUST AUGMENTATION)

(SOC OPERATIONAL ORBIT ALTITUDE = 265 n.m.)

	NOMINAL	ABORT
PAYLOAD	68091.	68091.
OMS PAYLOAD BAY KITS	4126.	4126.
MISSION SUPPORT EQUIP	1608.	1608.
PERSONNELL	2644.	2644.
ORBITER - EMPTY	140821.	140821.
- SCAR WEIGHT	220.	220.
- NON PROP CONSUMABLES	3748.	3748.
- USABLE RCS	5652.	2128.
- RCS RESERVES	903.	392.
- RCS RESIDUALS	567.	567.
- OMS PROP (ON ORBIT)	15723.	0.
- OMS PROP (DE-ORBIT)	9376.	0.
- RCS PROP (DE-ORBIT)	0.	1548.
- OMS RESERVES	769.	388.
- OMS RESIDUALS	891.	691.
SSME (EMPTY)	20484.	20494.
ORBITER AT INSERTION	275623.	248247.
POST-MECO MANEUVER-(OMS PROP)	5715.	4230.
POST-MECO MANEUVER-(RCS PROP)	0.	1372.
ORBITER AT OMS IGNITION	281338.	253900.
TRAPPED MPS PROP - ORBITER	887.	1818.
TRAPPED MPS PROP - SSME	1524.	1524.
FLIGHT PERF RESERVE - ORBITER	2771.	1640.
FLIGHT PERF RESERVE - SSME	0.	0.
ORBITER AFTER ET SEPARATION	286520.	259082.
RCS PROPELLANT	252.	252.
ORBITER AT ET JETTISON	286772.	259334.

PLAN VIEW
SIDE VIEW
END VIEW
PLAN VIEW
SIDE VIEW
END VIEW
PLAN VIEW
(BASIC SOC CONFIG.)
SIDE VIEW
(BASIC SOC CONFIG.)
END VIEW
(BASIC SOC CONFIG.)
42690-012
42690-012
FLIGHT SUPPORT FACILITY
CONCEPT ARRANGEMENTS
SPACE OPERATIONS CENTER
L
03953
42690-012

SOC MISSION VEHICLE SUMMARY WEIGHT BREAKDOWN (CONT'D)
(TITAN L3'. THRUST AGUMENTATION)

	NOMINAL	ABORT
EXTERNAL TANK - EMPTY	70990.	70990.
- SCAR WEIGHT	2505.	2505.
- RESIDUALS	4011.	4198.
- NON PROP CONS	423.	423.
FLIGHT PERFORMANCE RESERVE-ET	2860.	1789.
FUEL BIAS	1047.	1100.
EXCESS MPS PROPELLANT	1.	-25.
EXPELLED MPS PROPELLANT	228.	152.
ET WEIGHT AT MECO	82065.	81132.
INJECTED WEIGHT AT MECO	368837.	340465.
MPS PROP (MODE BOUNDARY/MECO)	804525.	805381.
PRE - MECO OMS BURN	0.	10334.
PRE - MECO RCS BURN	0.	474.
PRE - MECO OMS DUMP	0.	16631.
WEIGHT AFTER MODE BDY	1173362.	1173286.
EXPELLED MPS	0.	76.
WEIGHT PRIOR TO MODE BDY	1173362.	1173362.
MPS PROP (STAGING/MODE BOUNDARY)	372981.	
SECONDARY PROP SYSTEM JETTISON WT	33759.	
SECONDARY PROP (STG/MODE BDY)	143479.	
WEIGHT AFTER STAGING		1723582.
SRB CASE JETTISON WEIGHT	357397.	
WEIGHT PRIOR TO STAGING		2080979.
SECONDARY PROP (L/O - STAGING	205415.	
SRB PROPELLANT	2230974.	
MPS PROP (LIFTOFF/STAGING)	384013.	
LIFTOFF WEIGHT		4901380.
MPS PROPELLSNT	784.	
SRB PROPELLANT	1669.	
SRB IGNITION COMMAND (T - 0)		4903833.
MPS BURNED PRIOR TO SRB IGN COMMAND	7701.	
WEIGHT AT MPS THRUST COMMITMENT		4911554.

NASA Lyndon B Johnson Space Center

Engineering and Development Directorate

PRE MECO OMS AND RCS BURN/DUMP THRUST AND FLOW RATE PROFILE (TITAN LOW THRUST AUGMENTATION)	Engineering Analysis Division	
	G. Launey - EX42	3-12-80

(SOC OPERATIONAL ORBIT ALTITUDE=265 n.m.)

TIME SEC	THRUST (LBS)	FLOW RATE (LB/SEC)	JETS
0.0	12,140	38.760	2 X OMS
4.5	12,140	38.760	2 X OMS
4.5	13,566	98.971	2 X OMS + 24 X RCS
259.22	13,566	98.971	2 X OMS + 24 X RCS
259.22	12,140	38.760	2 X OMS
263.72	12,140	38.760	2 X OMS
263.72	15,801	51.836	2 X OMS + 4 X RCS
300.00	15,801	51.836	2 X OMS + 4 X RCS

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Enclosure 13

Rockwell International Corporation
Space Division

FLIGHT SUPPORT FACILITY
OTV CONFIG. ARRANGEMENTS
SPACE OPERATIONS CENTER

SIZE	CODE IDENT NO	DRAWING NO.
L	03953	42690-013

OPTION 1
- 2 TRANSFER BOOMS STOWED IN ORBITER.
- FLEX. LINES EACH SIDE OF SAM PLATFORM.
- WEIGHT OF BOOMS INCLUDED IN TOTAL ORBITER CAPACITY.

OPTION 2
- DUAL TRANSFER BOOMS FROM THE SAM PLATFORM.
- DUAL OF SEGREGATED FLEX. LINES ON SAM.
- ORBITER TANKAGE AT FULL CAPACITY.

OPTION 3
- HARD LINE ROUTING WITH CONNECTIONS ACROSS INTERFACE.
- COMPLEX LINE ACTUATION IN ORBITER BAY
- HEAVIEST IMPACT ON FUEL CAPACITY.

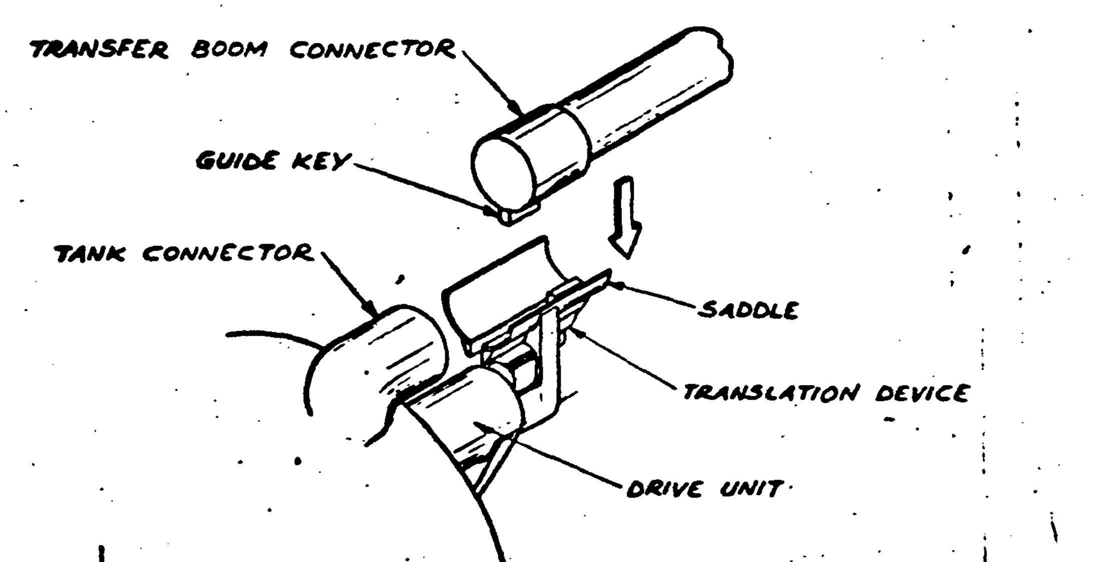
OPTION 4
- HARD LINE ROUTING WITHOUT DOCKING INTERFACE CONNECTION.
- SEGREGATED SHORT BOOMS & FLEX. LINES.
- ORBITER TANKAGE AT FULL CAPACITY.

A rev. Sheet 2 Added.

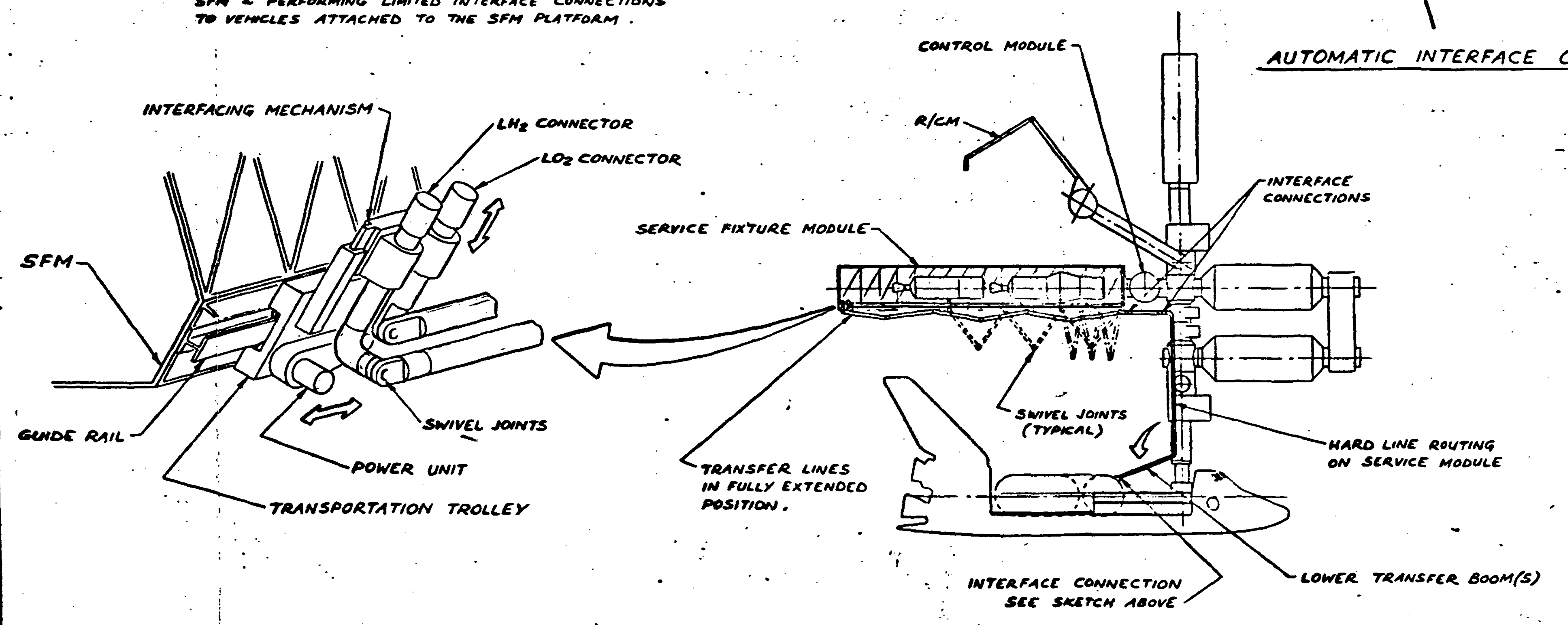
1/200 1/20	Buck 11/4/80 SOC	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION	
FUEL TRANSFER LINE ROUTING CONCEPTS - SOC BASELINE			42690-14A Sheet 1 of 2

OPTION 6

- THIS CONCEPT REQUIRES TWO INTERFACE CONNECTIONS TO BE MADE DURING THE INITIAL ASSEMBLY STAGE.
- THE LOWER BOOM IS IDENTICAL OR SIMILAR TO OPTION 5 DEPENDING ON THE LH_2 & LH_2 LINES BEING ROUTED SEPERATELY OR TOGETHER.
- THIS SYSTEM WOULD BE FULLY AUTOMATED REQUIRING NO ASSIST FROM THE R/CM.
- THE FUEL LINES WOULD RUN ADJACENT TO THE SFM ALONG ITS ENTIRE LENGTH. THE CONNECTOR ENDS OF THESE LINES, WHICH ARE EXTENDIBLE BY MEANS OF FLEX JOINTS, ARE ATTACHED TO A TROLLEY RUNNING THE LENGTH OF THE PLATFORM.
- THE TROLLEY IS CAPABLE OF POSITIONING THE END CONNECTORS ANYWHERE ALONG THE LENGTH OF THE SFM & PERFORMING LIMITED INTERFACE CONNECTIONS TO VEHICLES ATTACHED TO THE SFM PLATFORM.



AUTOMATIC INTERFACE CONNECTION UNIT

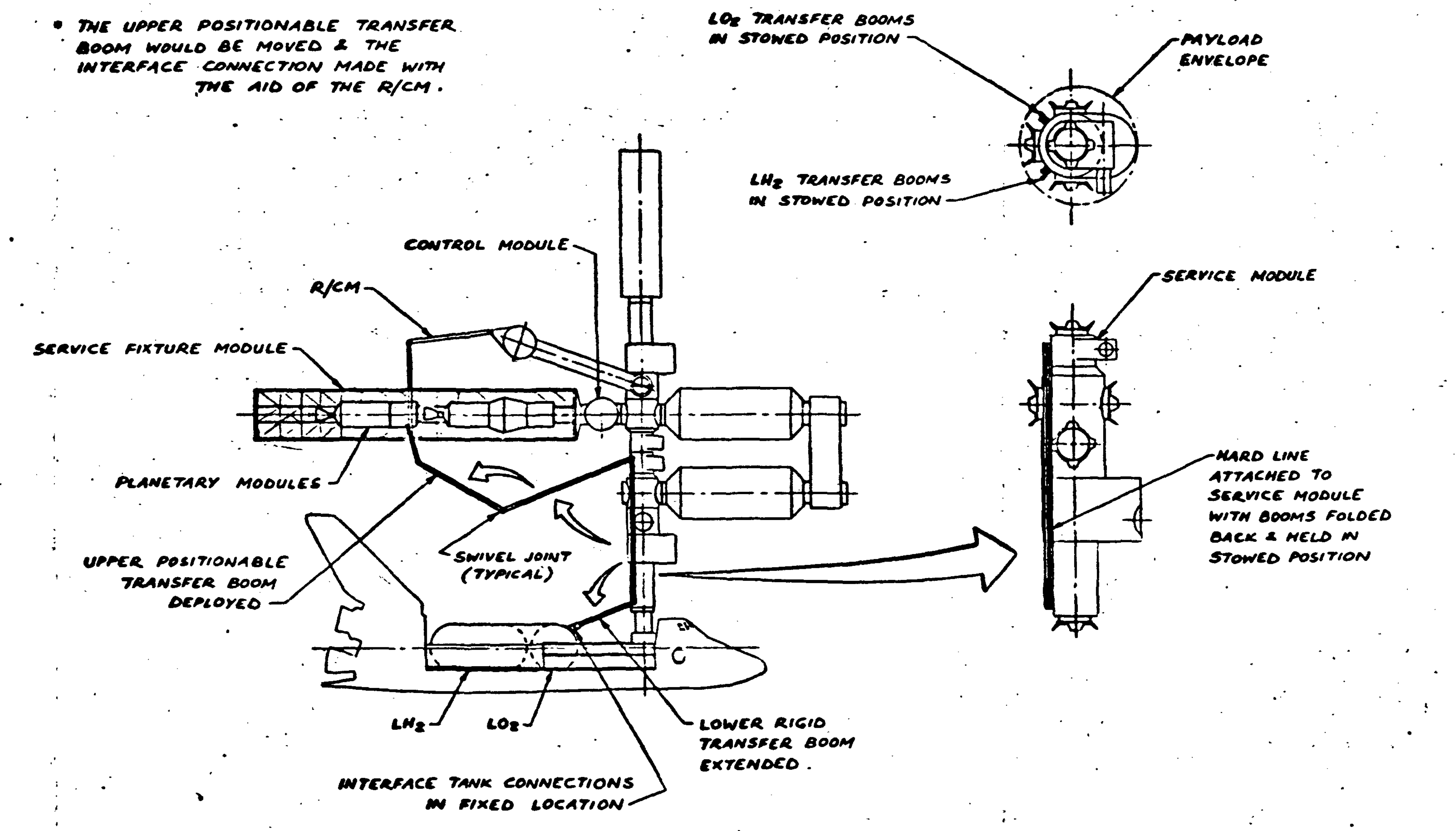


FUEL TRANSFER FROM ORBITER TO SFM

VIA., TROLLEY SUPPORTED EXTENDIBLE LINES.

OPTION 5

- THIS CONCEPT HAS NO INTERFACES TO TRAVERSE, THEREFORE THE ONLY CONNECTIONS REQUIRED ARE TANK TO TANK.
- THE TRANSFER BOOM END CONNECTORS ARE DROPPED INTO A SADDLE ON THE TANKAGE WHICH ACTIVATES A TRANSLATION MECHANISM CLOSING THE INTERFACE - SEE SKETCH.
- THE LOWER RIGID TRANSFER BOOM CAN BE AUTOMATICALLY DEPLOYED & RETRACTED.
- THE UPPER POSITIONABLE TRANSFER BOOM WOULD BE MOVED & THE INTERFACE CONNECTION MADE WITH THE AID OF THE R/CM.



FUEL TRANSFER FROM ORBITER TO VEHICLE(S) ATTACHED TO SFM.

VIA., TRANSFER BOOMS

1/300	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION	
FUEL TRANSFER LINE ROUTING CONCEPTS - WITH 'SFM' - SOC.		42690-14 SHEET 2 of 2

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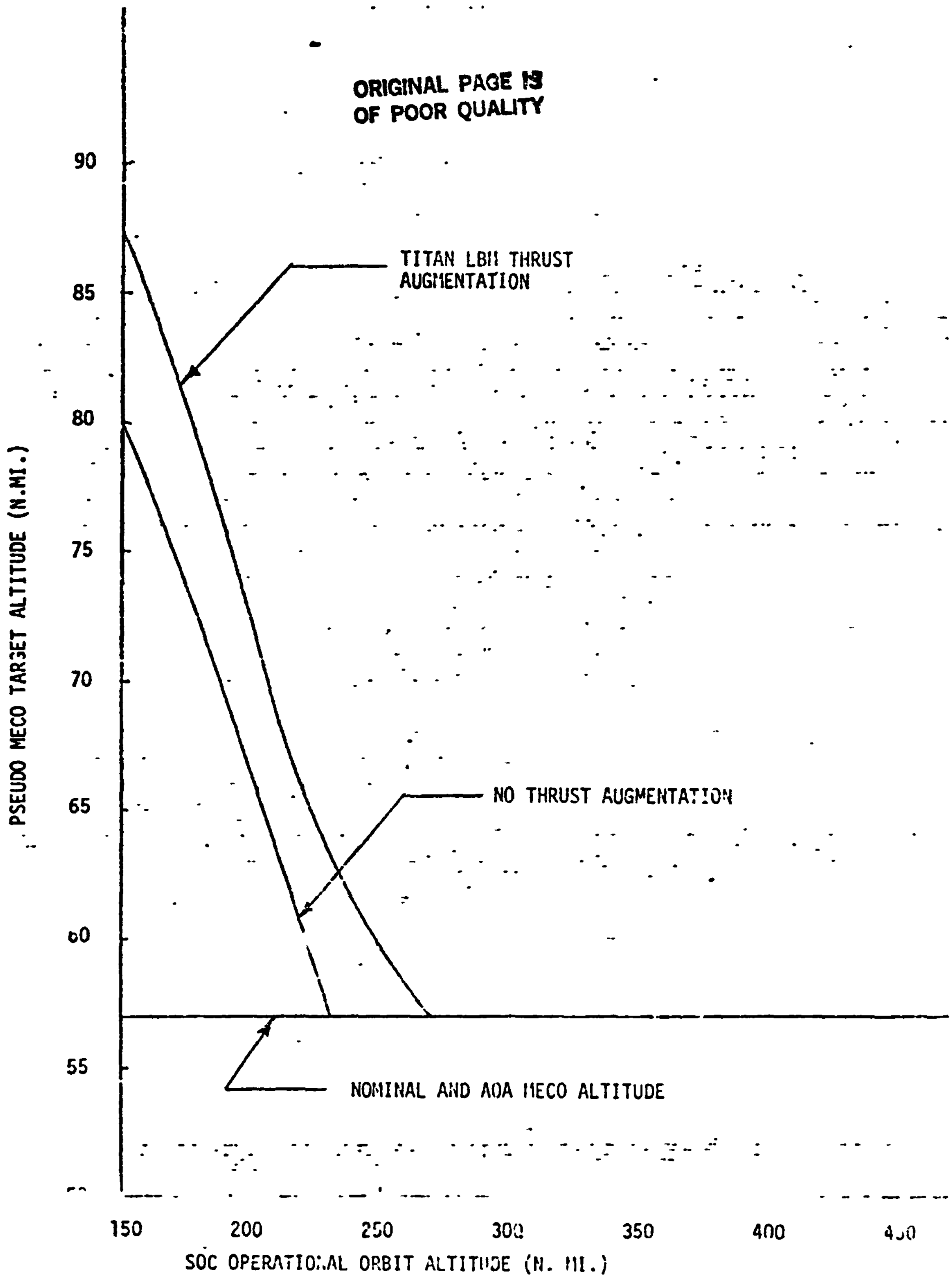

Enclosure

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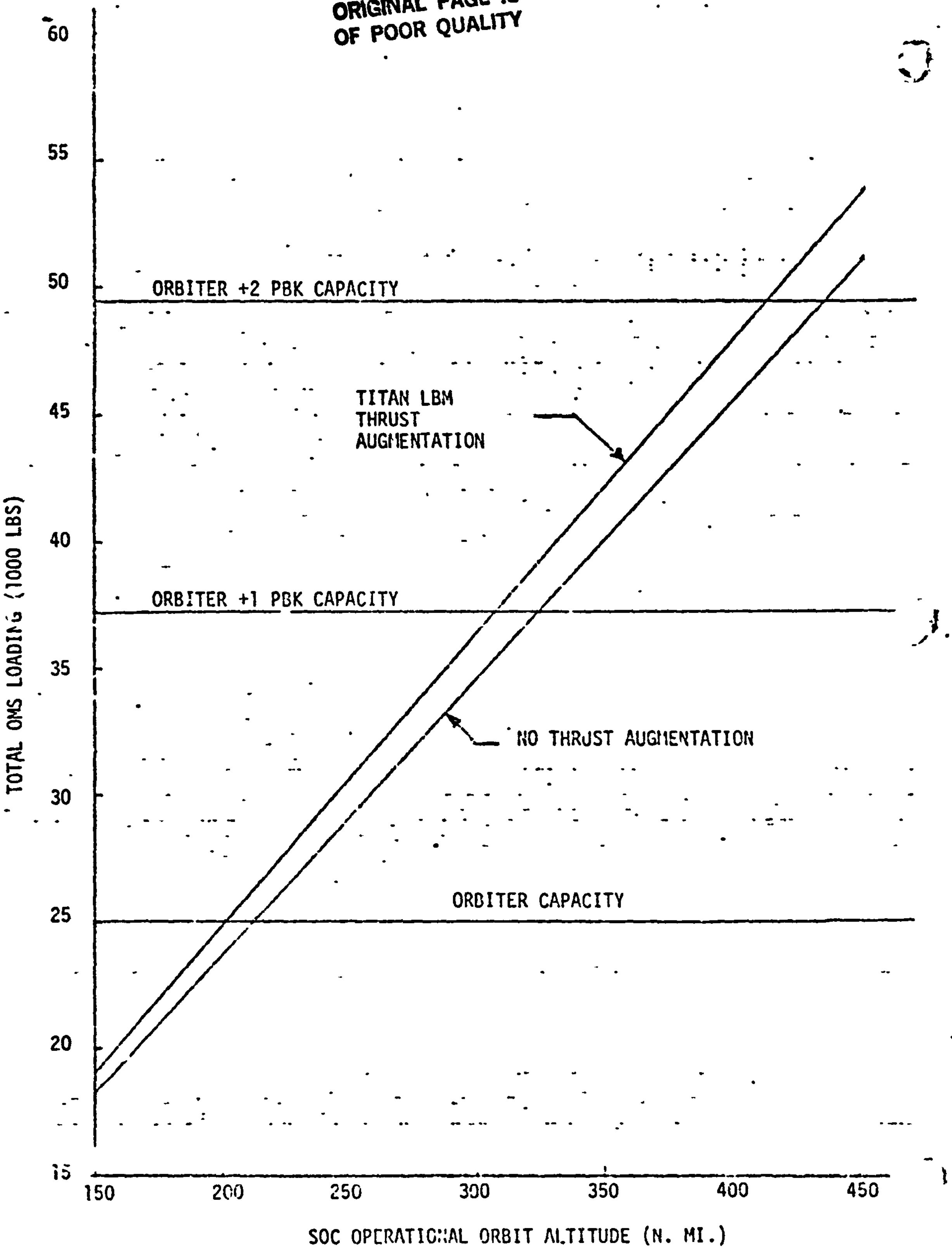



DOCKING APPROACH CONFIG
DOCKED CONFIG
VIEW B
VIEW C-C
REMOTE CONTROL MODULE UTILIZATION
42690-015
VIEW A-A
42690-015
SPACE OPERATIONS CENTER (SOC) CONFIG
FLIGHT SUPPORT FACILITY
OTV RE-DOCKING CONCEPTS
SPACE CPERATIONS CENTER
L
03953
42690-015

METHODS – SUBSYSTEM EXCHANGE

1. REMOVE & REPLACE TOTAL SUBSYSTEM ASSEMBLY
2. REMOVE & REPLACE SUBSYSTEM MODULES
3. REMOVE COVER PANEL & EXCHANGE INDIVIDUAL SUBSYSTEM COMPONENTS

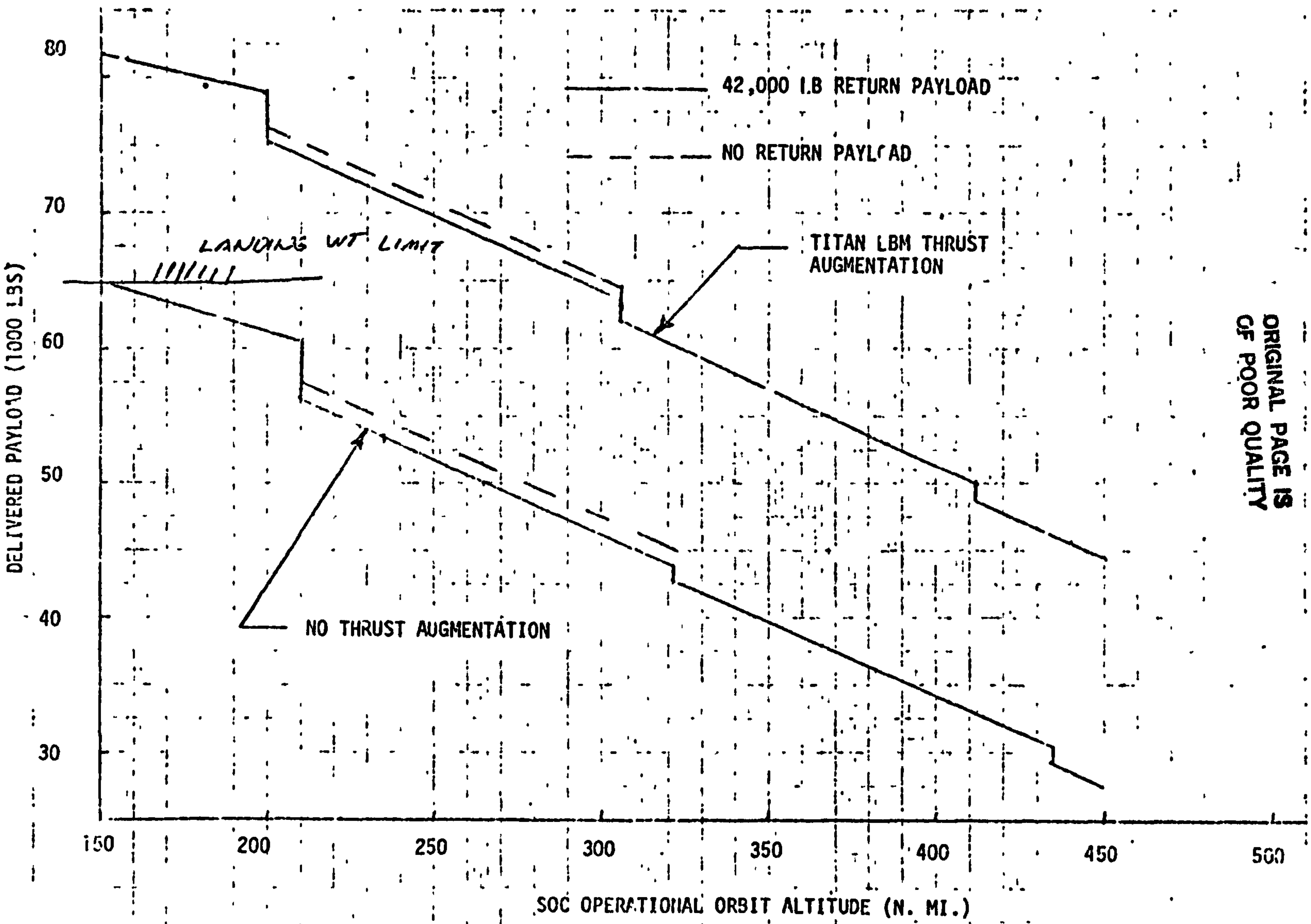
STORAGE – SUBSYSTEM MODULES/COMPONENTS

- SOC TO PROVIDE STORAGE FOR COMPLETE REPLACEMENT OF OTV MODULES AND/OR SPACE FOR TOTAL EXCHANGE OF INDIVIDUAL SYSTEM COMPONENT PACKAGES

OPERATIONS – HANDLING OPTIONS

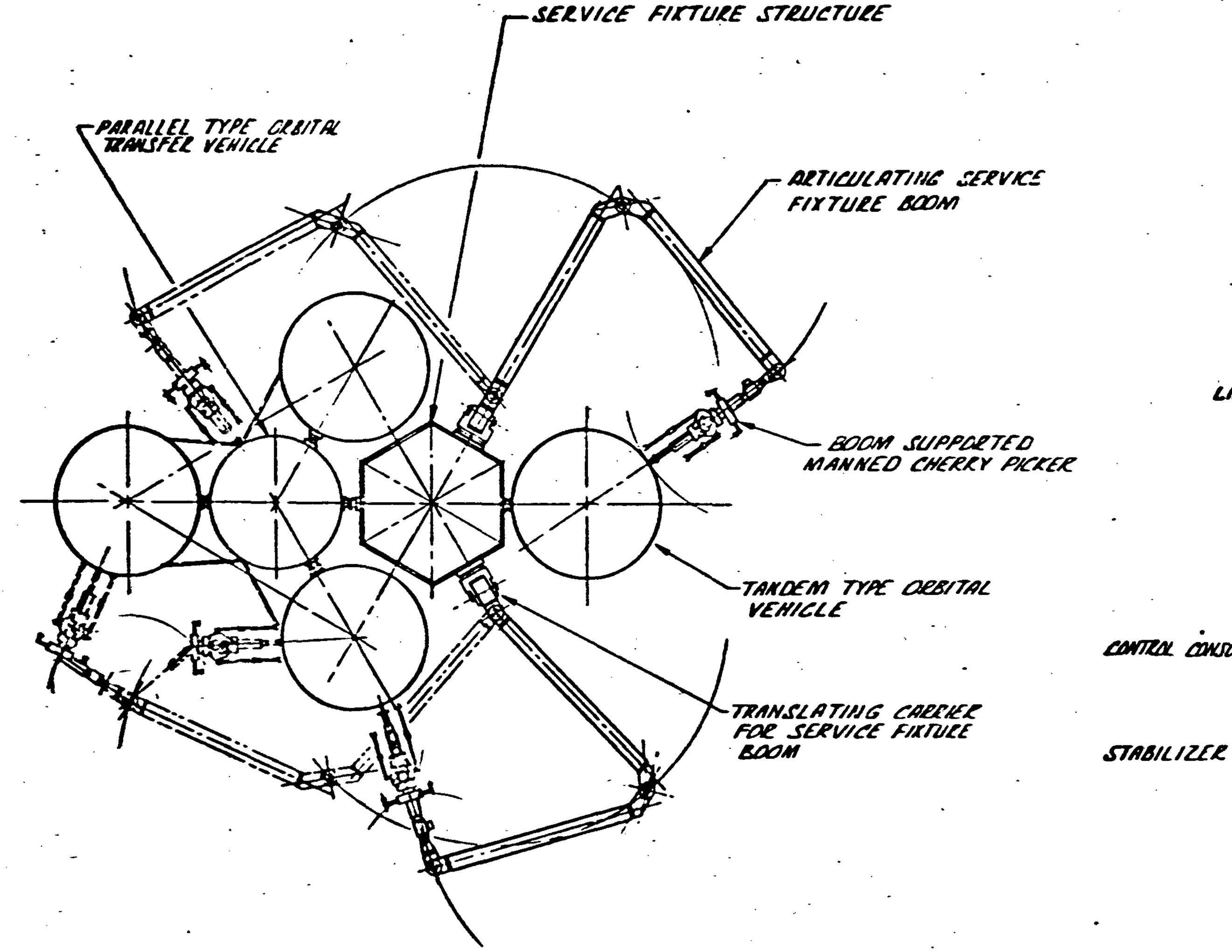
- UTILIZE RCM OR SFM TRANSLATING BOOM ASSY
- MANNED CHERRY PICKER SUPPORTED BY RCM OR SFM BOOM
- MANNED MMU


SERVICE FIXTURE MODULE STRUCTURE ASSY
OTV REPLACEMENT MODULES (ATTACHED TO EXTERNAL SURFACE OF SERVICE FIXTURE)
VIEW D - D
SCALE 1/20
SERVICE FIXTURE MODULE (SFM)
OTV REPLACEMENT MODULES
250 MM BLK'HD
3.05 M (120.0)
ACCESS DOOR IN SFM FOR OTV MODULE INGRESS/EGRESS
OTV MODULE HANDLING & SUPPORT SWING ARM
NOTE: GUIDE RAILS & TRANSPORT CARRIERS OMITTED FOR CLARITY
OTV REPLACEMENT MODULES OR SUPPORT EQUIPMENT
VIEW C - C
SCALE 1/20
SERVICE FIXTURE PAYLOAD HANDLING BOOM
3.87 M (152.42)
GUIDE RAILS & TRANSLATING SUPPORT CARRIER
PIDA HEAD DOCKING PORT & SUPPORT CARRIER ASSY
OTV MODULE IN DELIVERY/EXCHANGE POSITION
ACCESS DOOR TO MODULE STORAGE COMPARTMENT
1.52 M (60.0)
2.23 M (88.0)
CONTROLLED SWING ARM WITH MODULE HANDLING & EXCHANGE CAPABILITY
OTV REPLACEMENT MODULES (1.0M × 1.0M × .5M)
OTV REPLACEMENT MODULES (ALTERNATE STORAGE POS.)
ACCESS DOOR TO STORAGE COMPARTMENT
GUIDE RAILS & TRANSLATING SUPPORT CARRIER
SECTION VIEW B - B
SCALE 1/20
LOCATION FOR PARALLEL TYPE OTV/MOTV CONFIG
4.06 M DIA (160.0) EXPENDABLE DROP TANK (3)
"PIDA HEAD" TYPE SUPPORT ASSY (TRANSLATION CAPABILITY ALONG SFM)
LOCATION FOR TANDEM TYPE OTV
4.45 M (175.0)
4.06 M DIA (NOM) (160.0)
MOTV PROPULSION CORE TANK 3.65 M. DIA (144.0)
ACCESS DOOR TO OTV MODULE & EQUIPMENT STORAGE
1.52 M (60.0)
SOC SERVICE FIXTURE MODULE (ALTERNATE CONFIG) (SEE DETAIL - ZONE 38)
OTV / SERVICE FIXTURE CONFIG
SCALE 1/40
MODULE SUPPORT TO ORBITER SUPPORT STRUCTURE
OTV MODULES 1.0 M × 1.0 M × .50 M (39.4 × 39.4 × 18)
Y_o 0.0
ORBITER DYNAMIC ENVELOPE 4.57 M. DIA (180.0)
Y_o 94.0
Y_o 105
GUIDE CONES & GRAPPLE HEAD (TYP ALL MODULES)
Z_o 414
Z_o 400
Z_o 410
OTV REPLACEMENT MODULES
ORBITER BAY INSTAL
SCALE 1/20
AVIONICS/PROPULSION MODULE WITH REPLACEABLE LRU'S
HI PRESSURE EXPENDABLES
3.81 M. DIA (150.0)
SERVICE FIXTURE MODULE
OTV PROPULSION CORE TANK
OTV SUPPORT FITTING
SERVICE FIXTURE STRUCTURE
42690-016 2
L 03953 42690-016

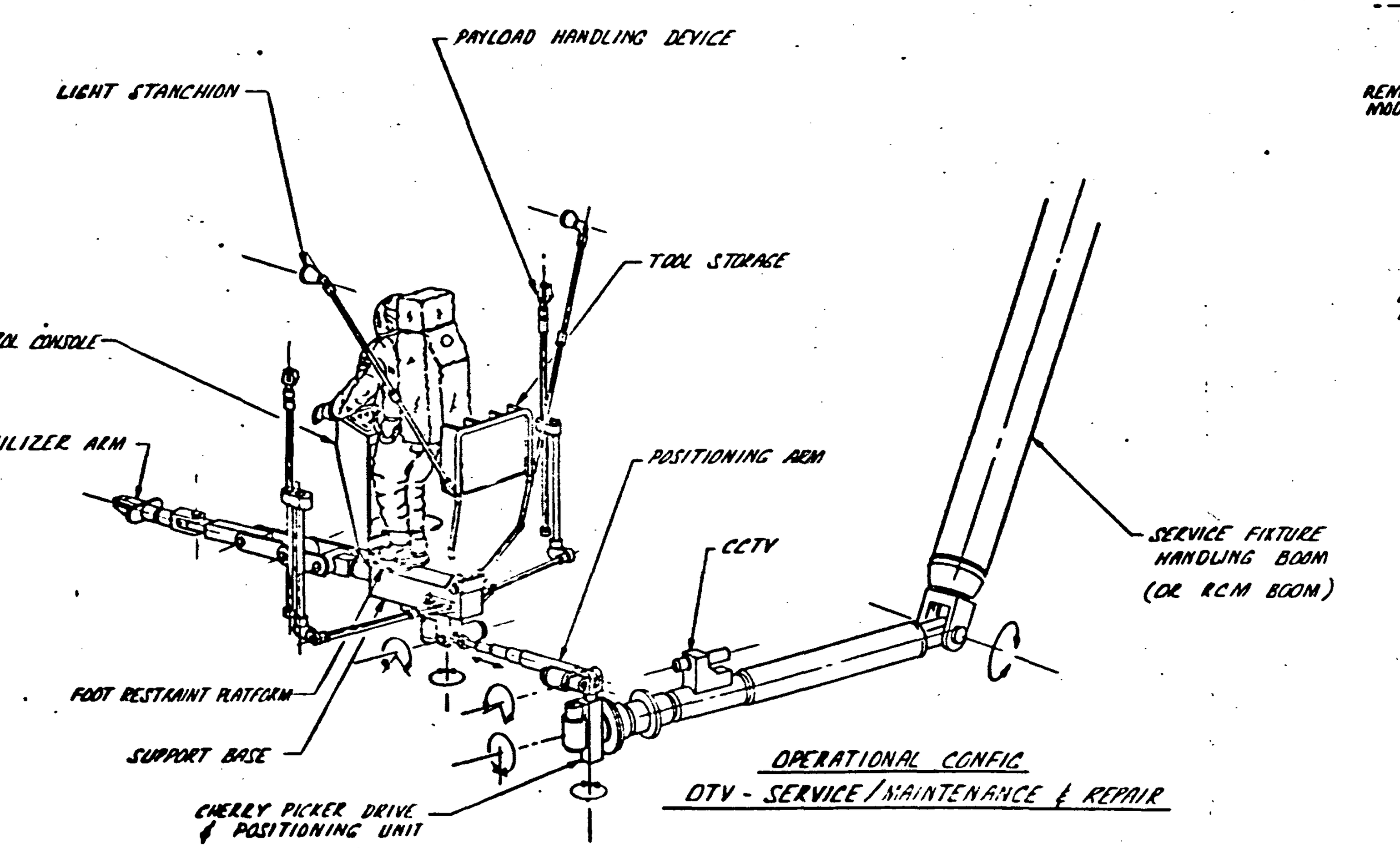


C-23

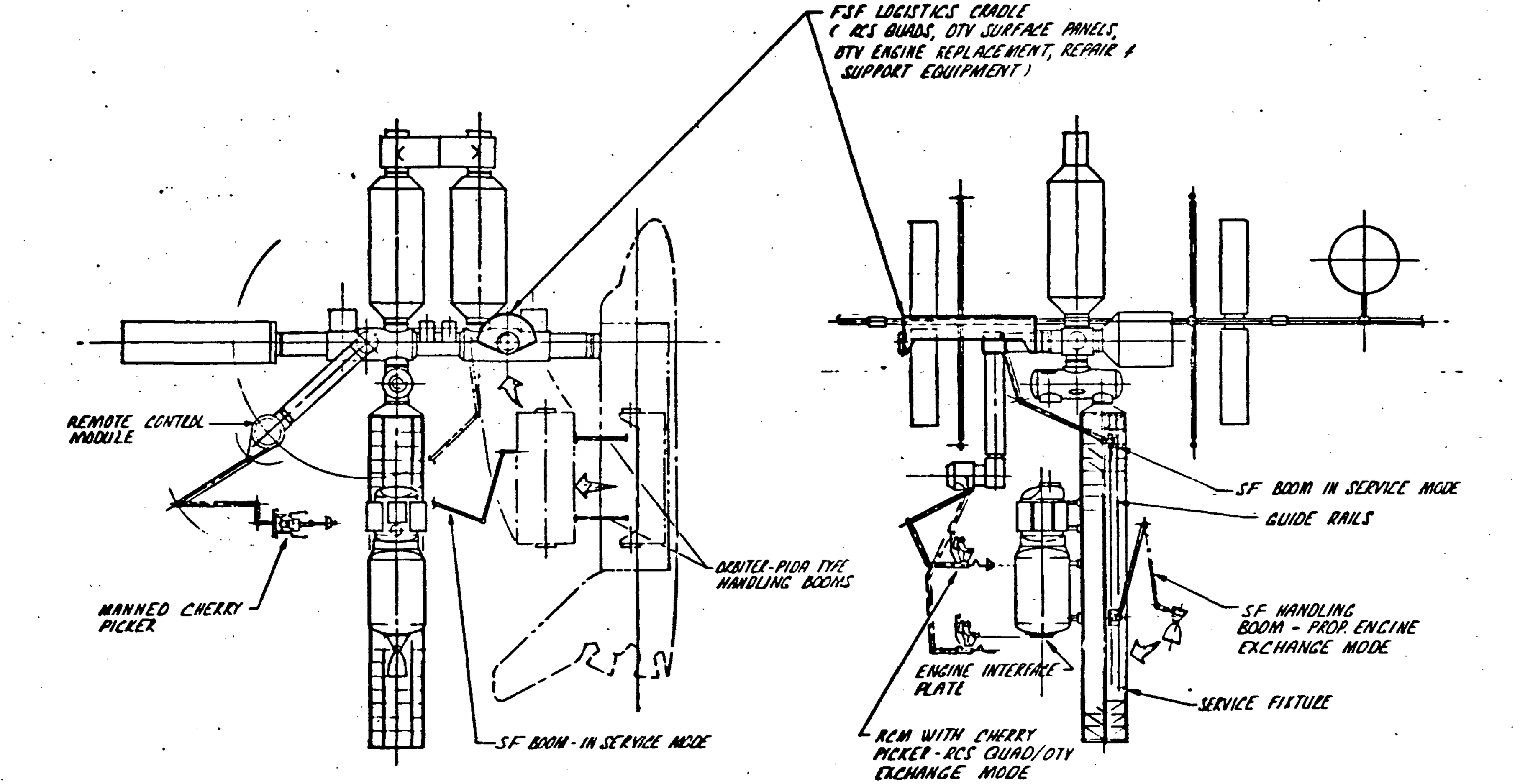
Enclosure 16

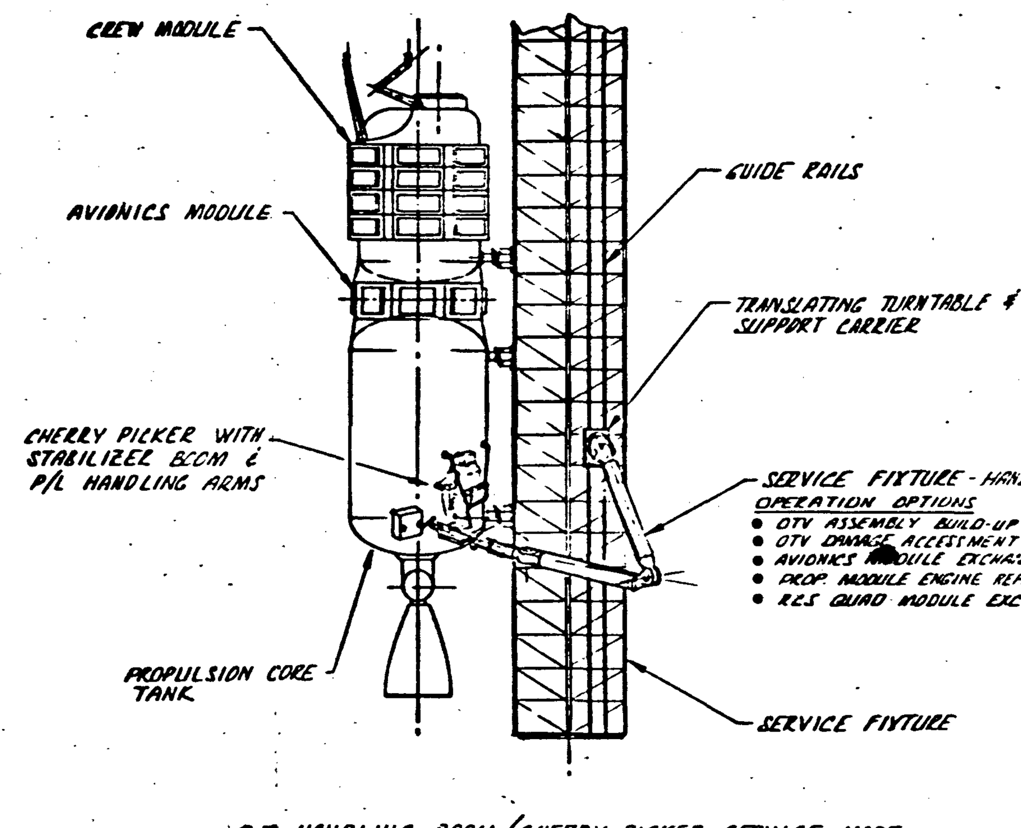


SERVICE FIXTURE BOOM - REACH CAPABILITY

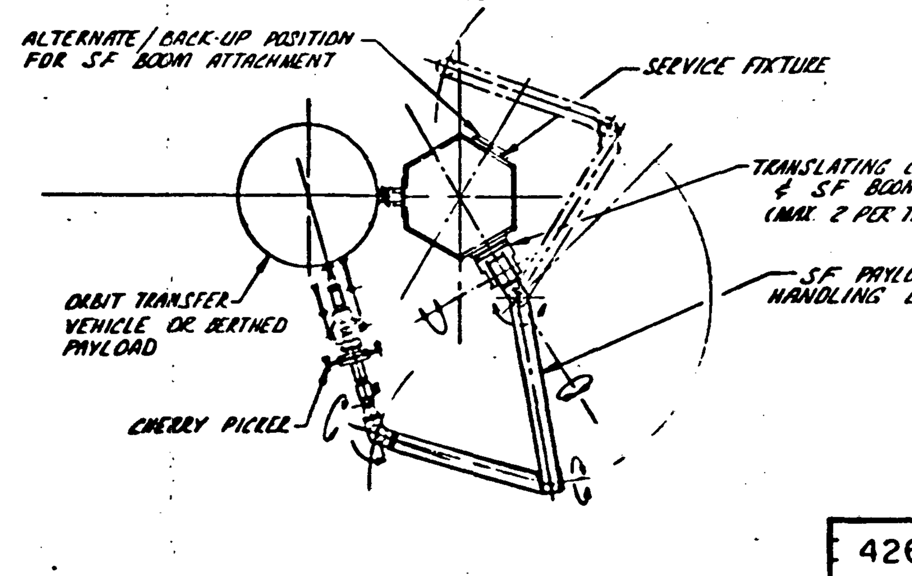


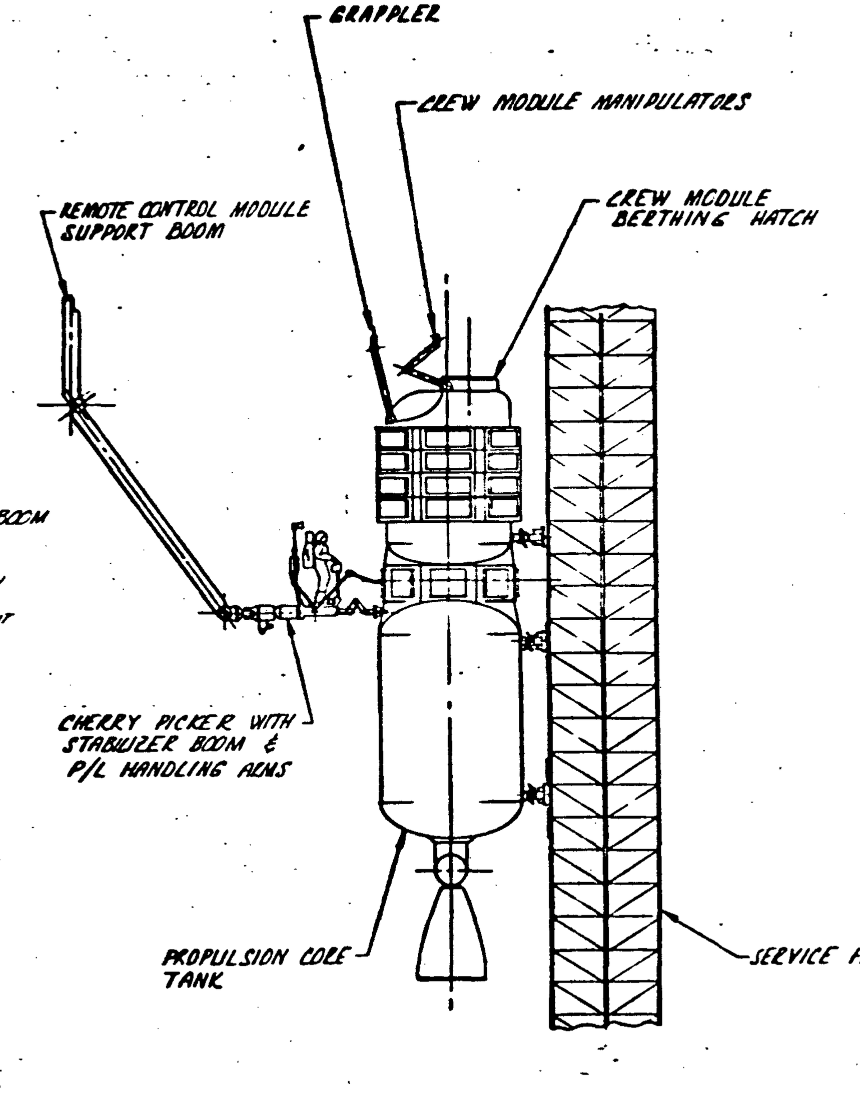
OPERATIONAL CONFIG
OTV - SERVICE / MAINTENANCE & REPAIR



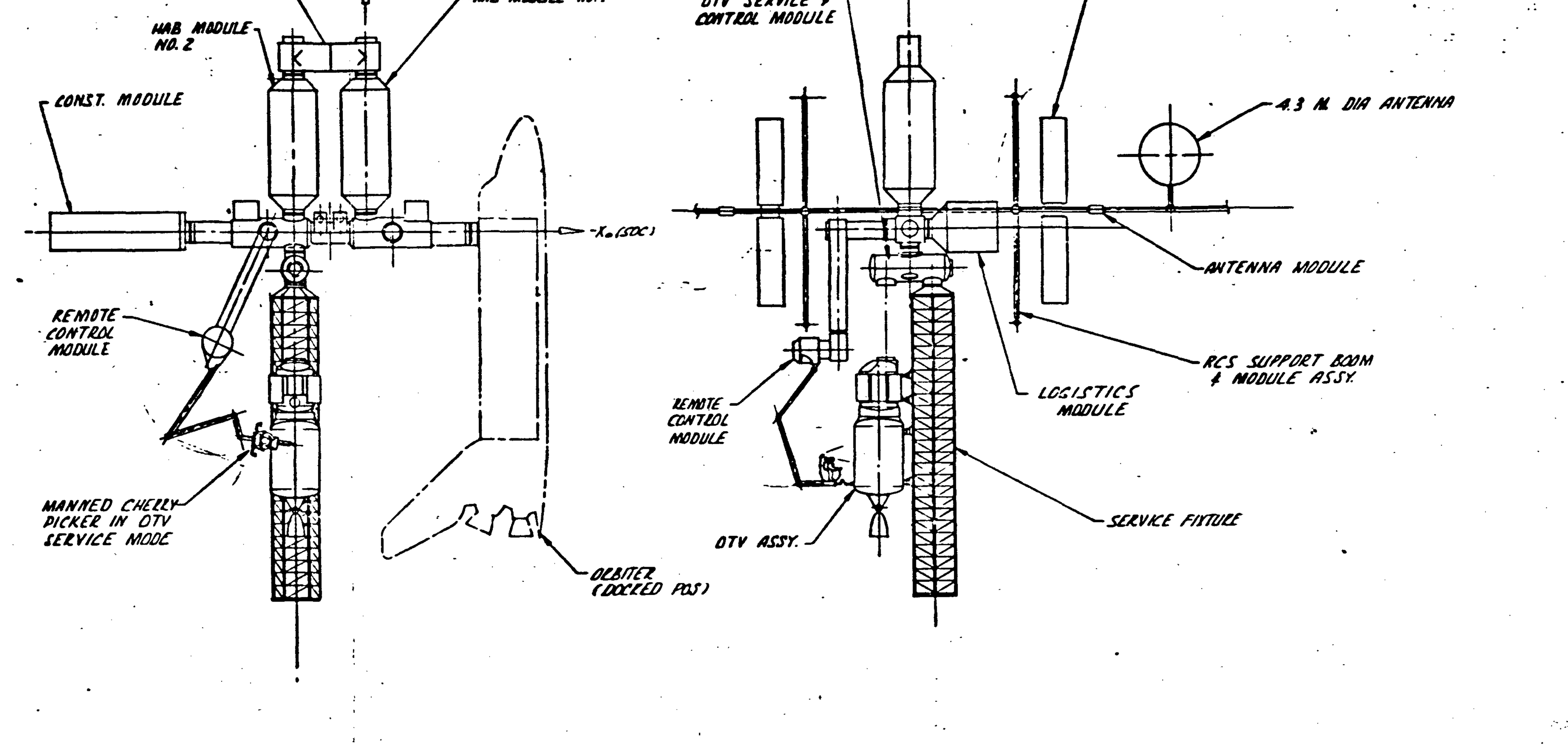


SF HANDLING BOOM / CHERRY PICKER SERVICE MODE
SCALE 1/80





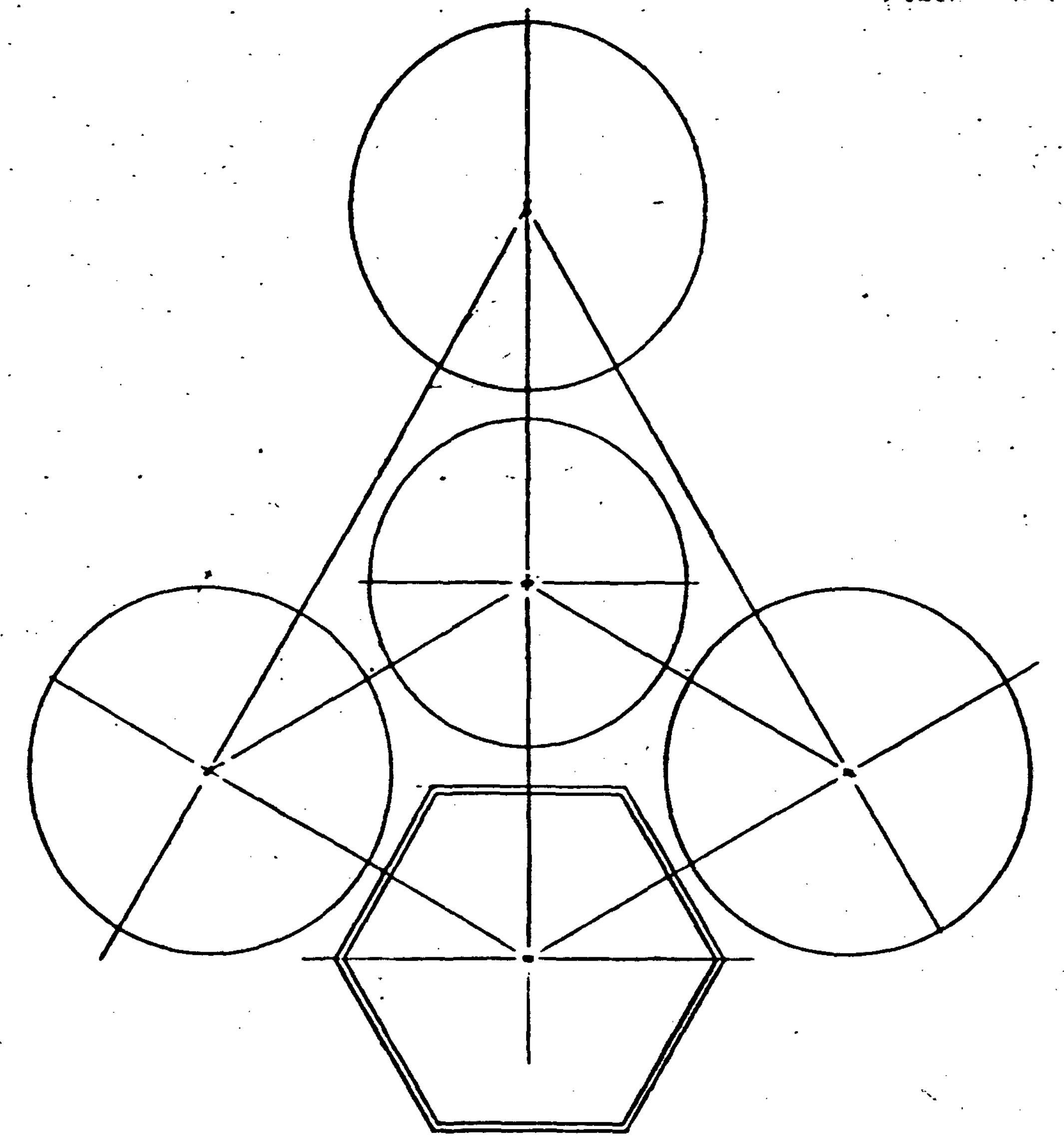
REMOTE CONTROL MODULE SYSTEM / CHERRY PICKER SERVICE MODE
SCALE 1/80

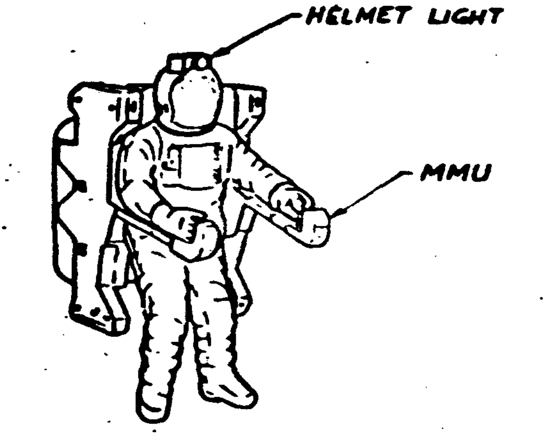


OTV / SOC ASSY CONFIG
SCALE 1/200

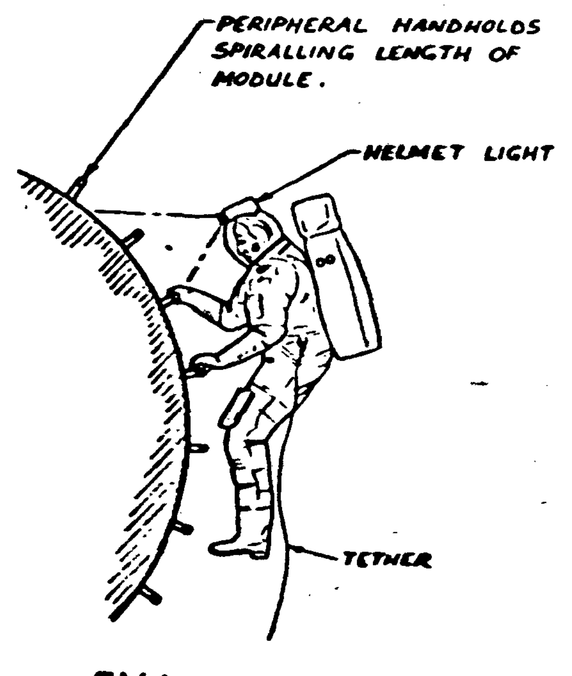
42690-017

DR BY [signature] 1-81	Rockwell International Corporation Space Division
CHK BY	UNSCHEDULED MAINT / REPAIR ON AVIONICS/PROPULSION MODULES - SPACE OPER CENTER
APPROVED BY	SIZE L · CODE IDENT NO 03953 · DRAWING NO. 42690-017
	SCALE · SHEET

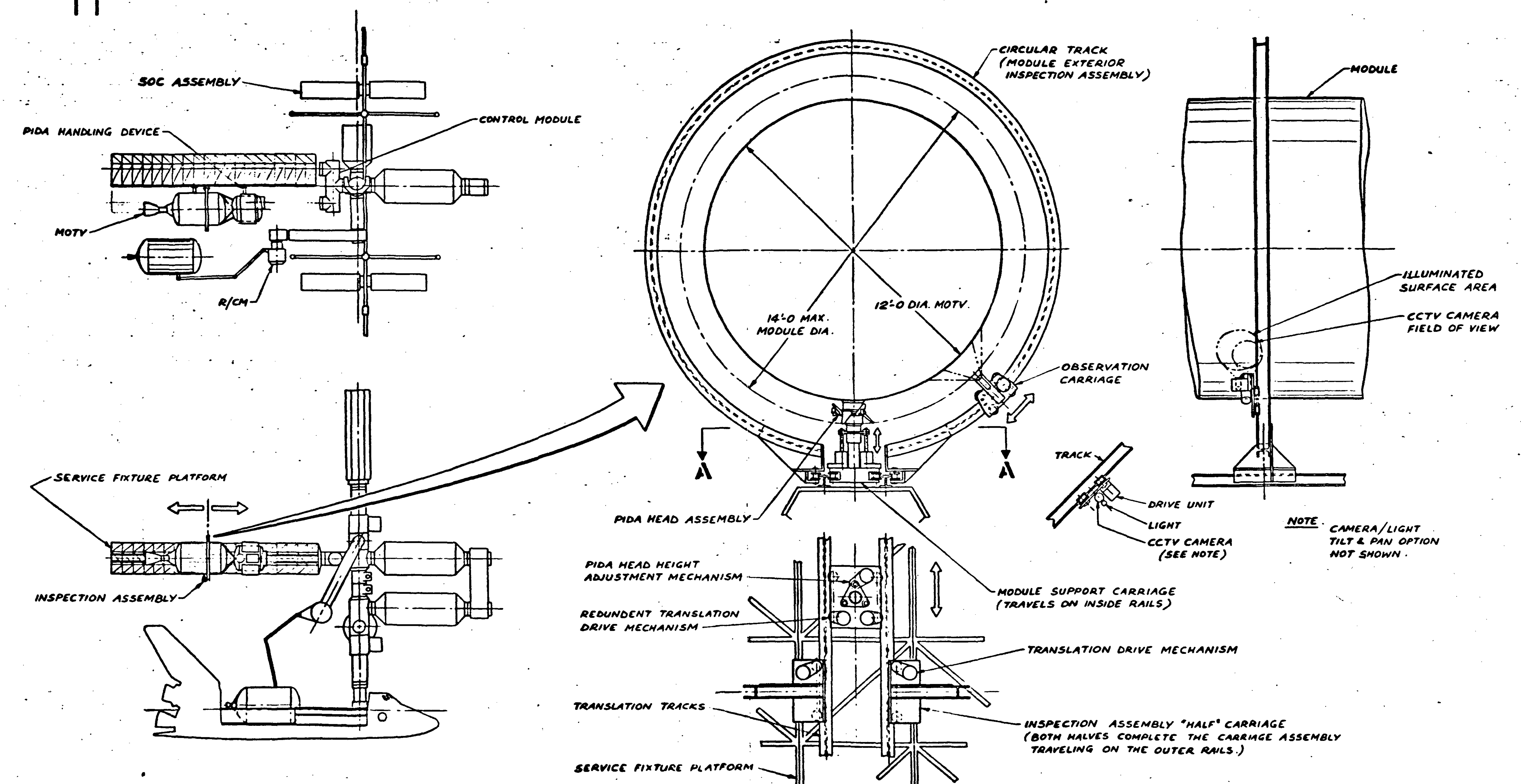




FREE FLYER



EVA



MODULE HANDLING & INSPECTION DEVICES.

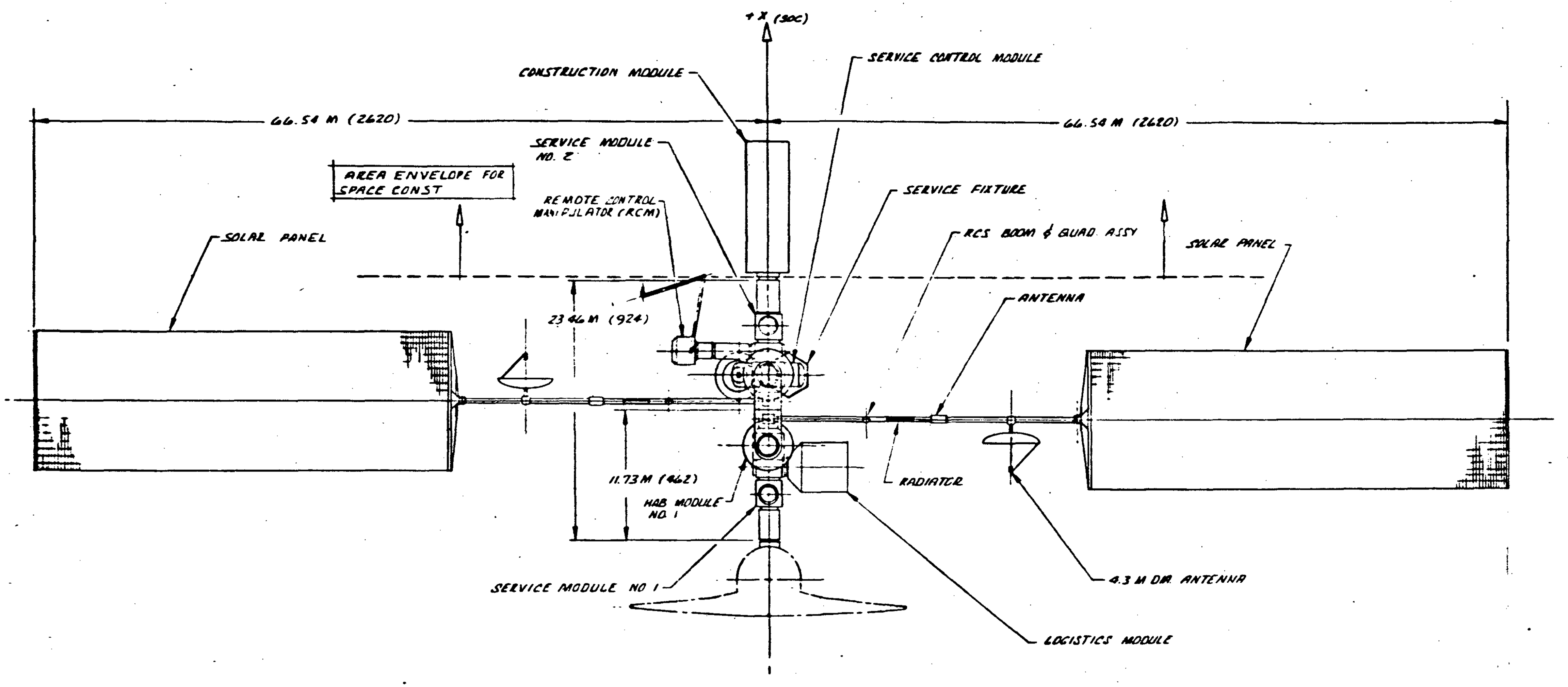
SECTION A - A

Rockwell International Corporation
Space Division

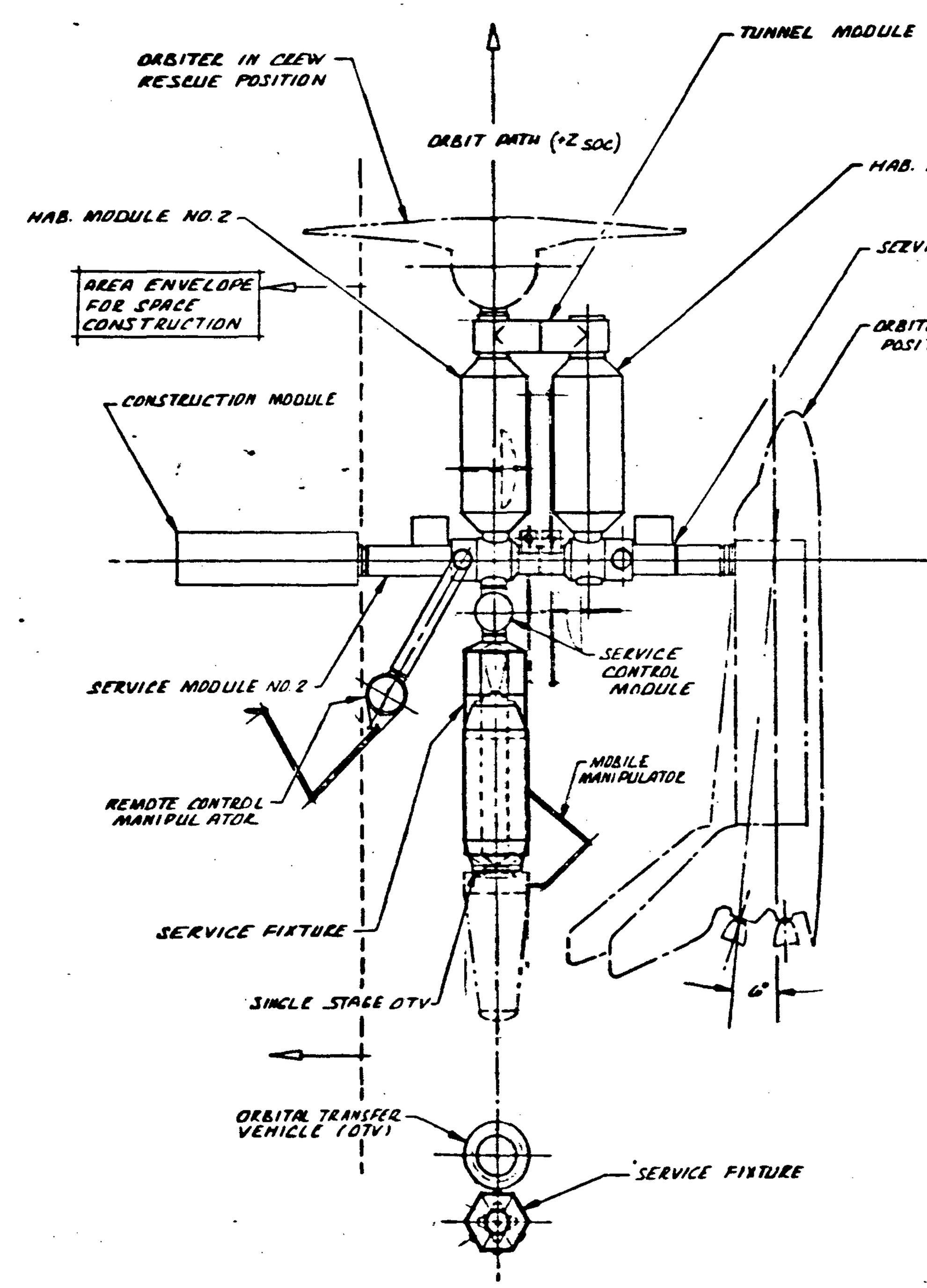
DR BY D BUCK 1-23-81

INSPECTION CONCEPTS
IN-SPACE OTV
SPACE OPERATIONS CENTER.

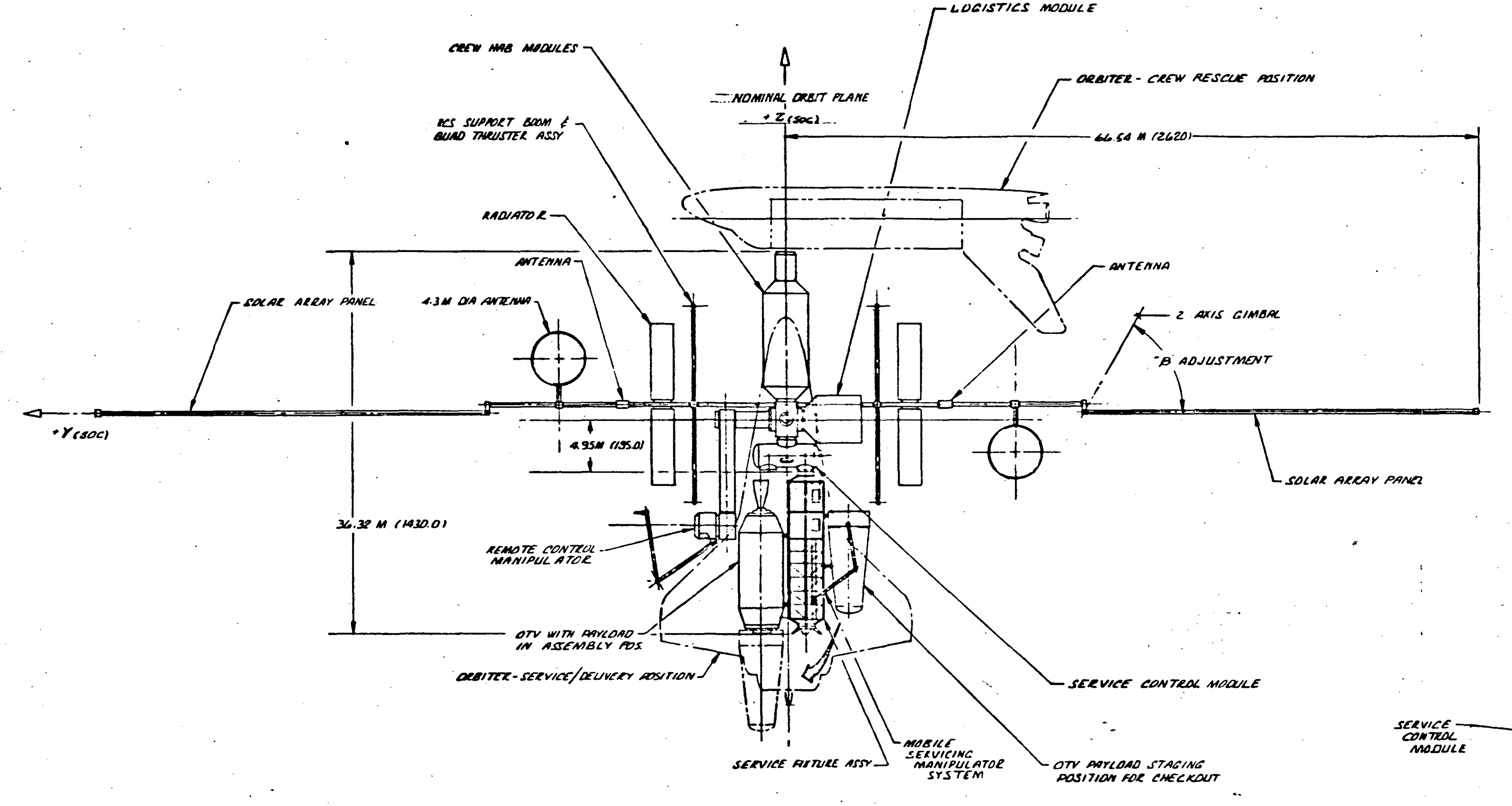
SIZE L | CODE IDENT NO 03953 | DRAWING NO. 42690-018



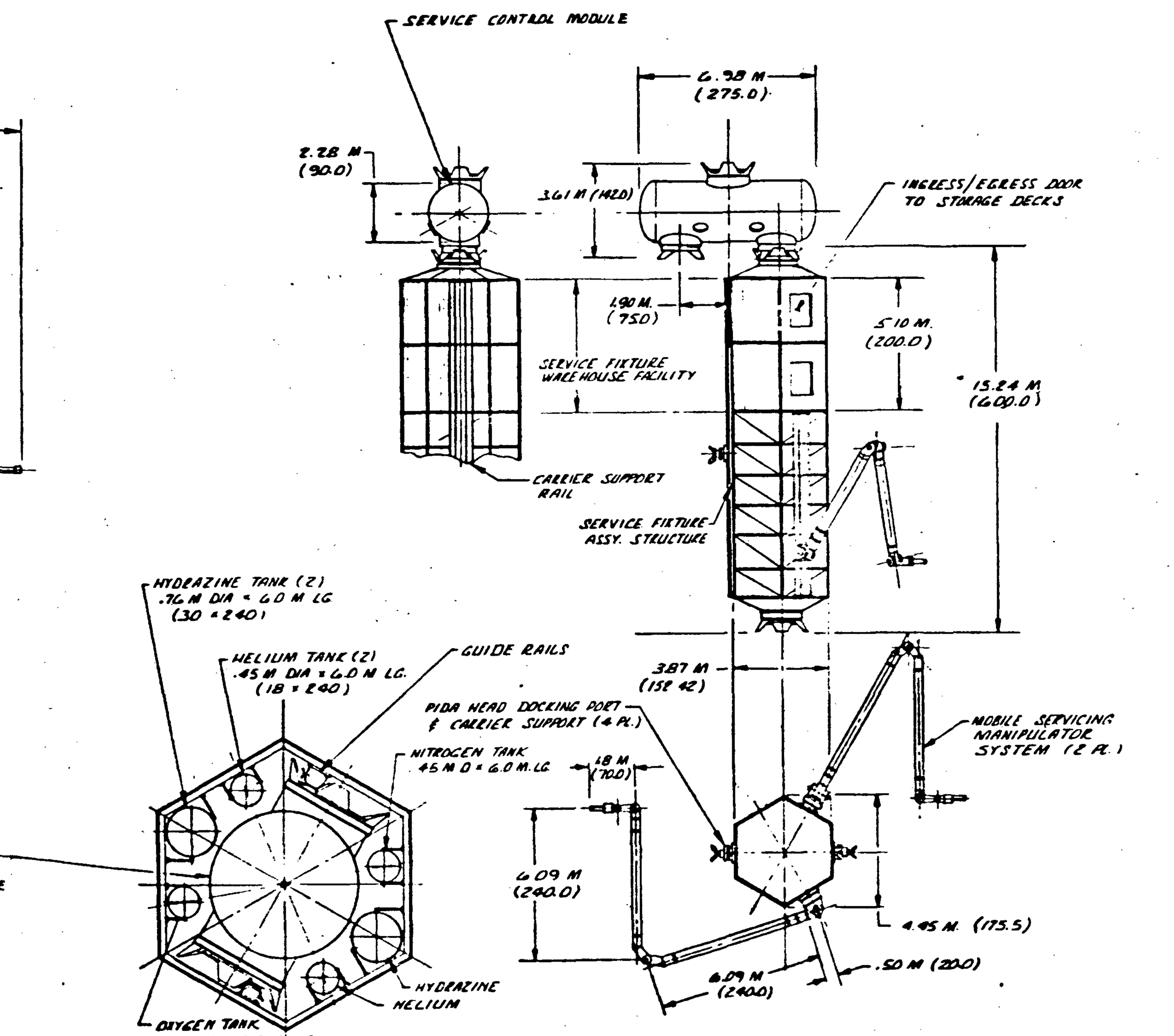
PLAN VIEW – INITIAL CONFIG



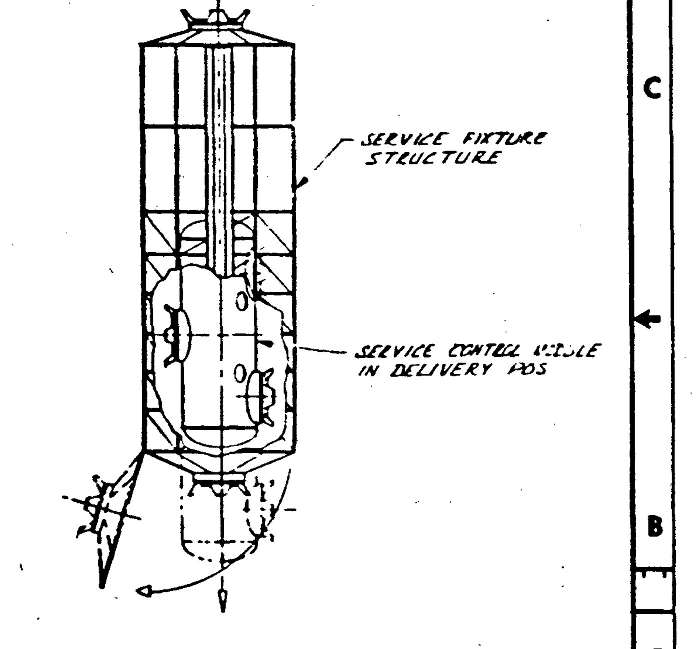
SIDE VIEW – INITIAL CONFIG



END VIEW – INITIAL CONFIG



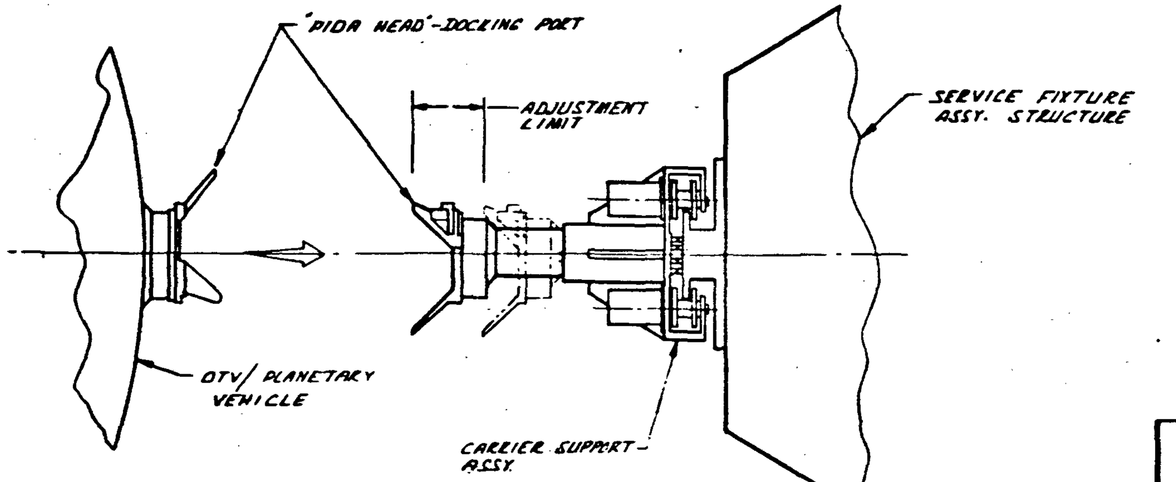
OTV SERVICING SYSTEM ASSY – INITIAL CONFIG



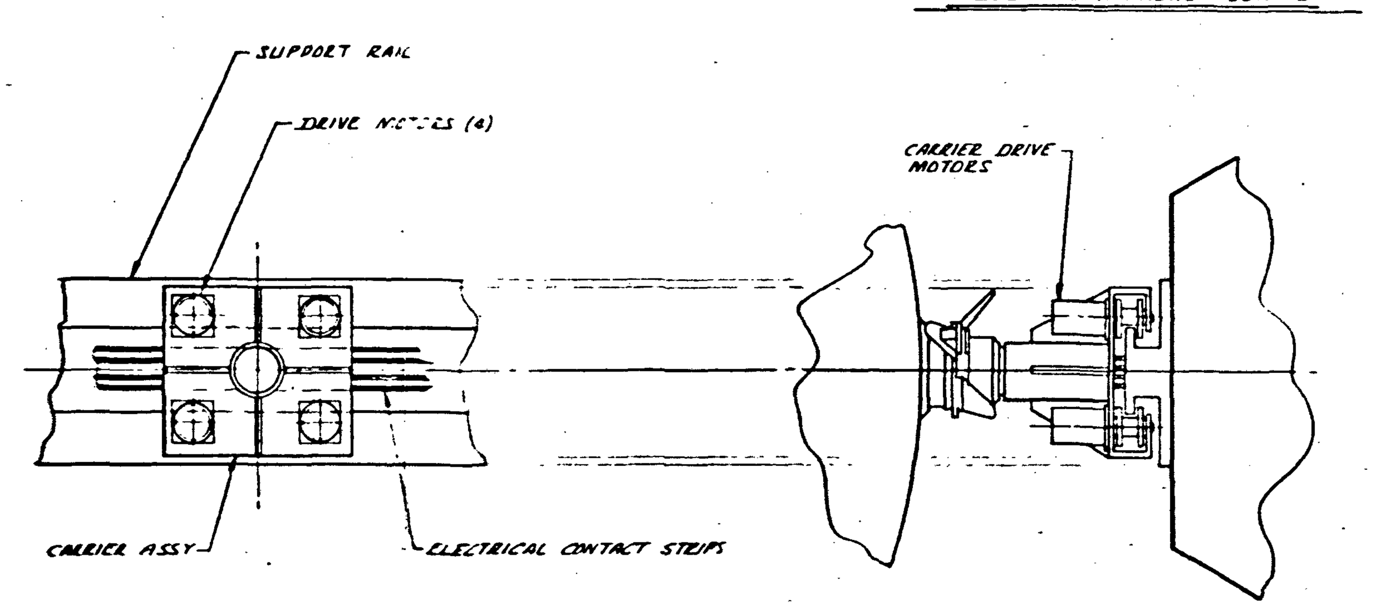
PAYLOAD PACKAGE CONFIG

DR BY	2-81	Rockwell International Corporation Space Division
CHK BY		BASELINE & GROWTH CONFIG FLIGHT SUPPORT FACILITY SPACE OPERATIONS CENTER
APPROVED BY		SIZE L · CODE IDENT NO 03953 · DRAWING NO. 42690-019
SCALE		SHEET 1 OF 2

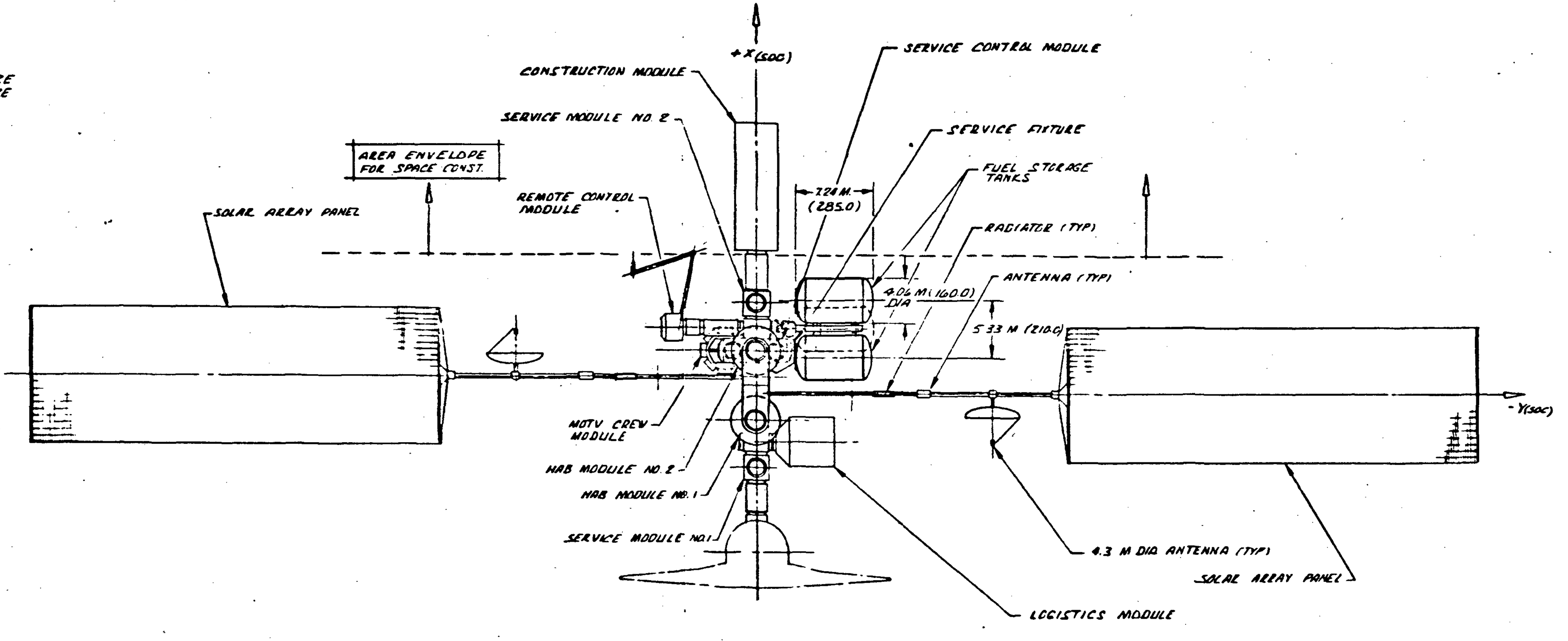
42690-019



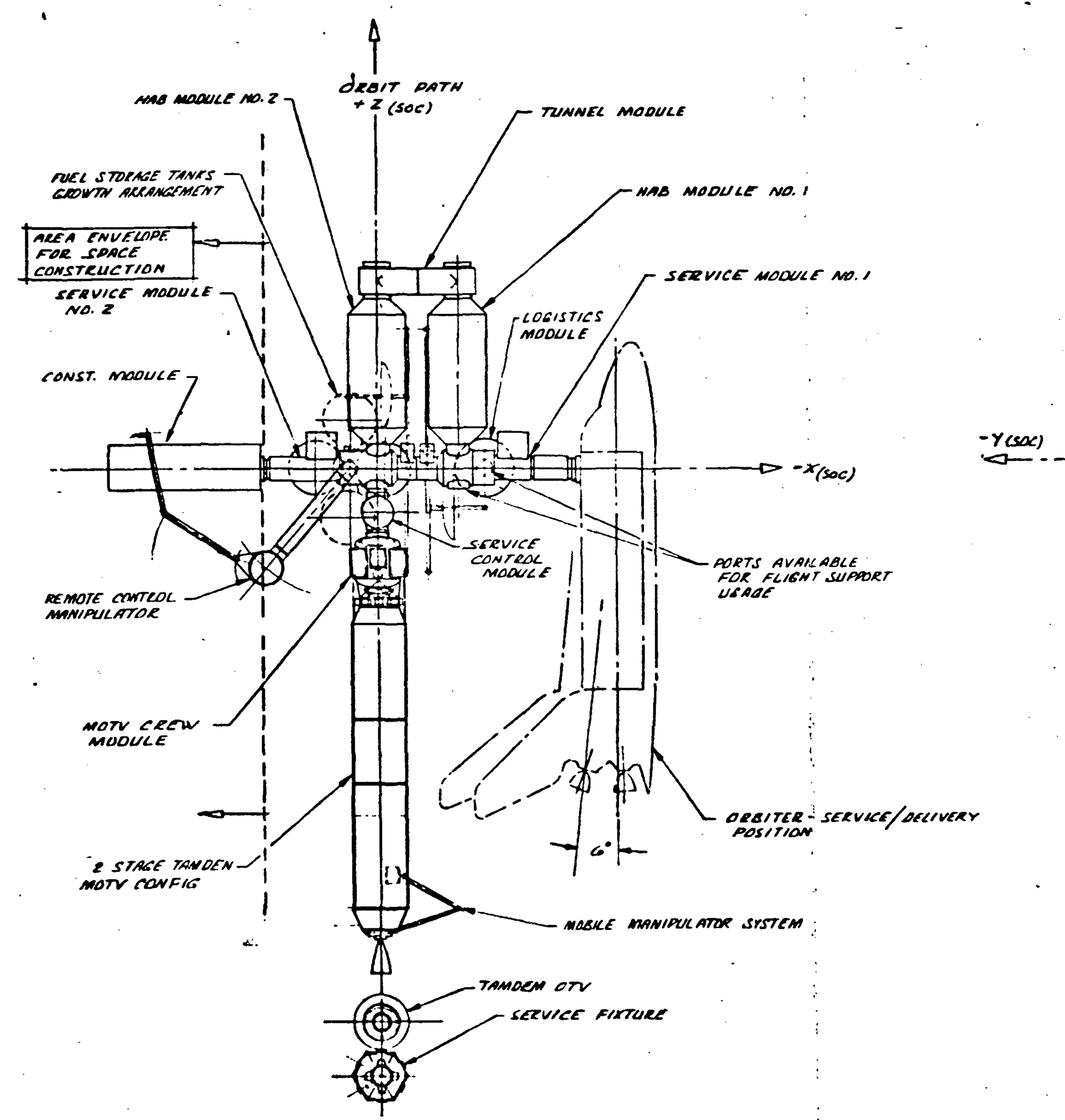
DOCKING APPROACH CONFIG



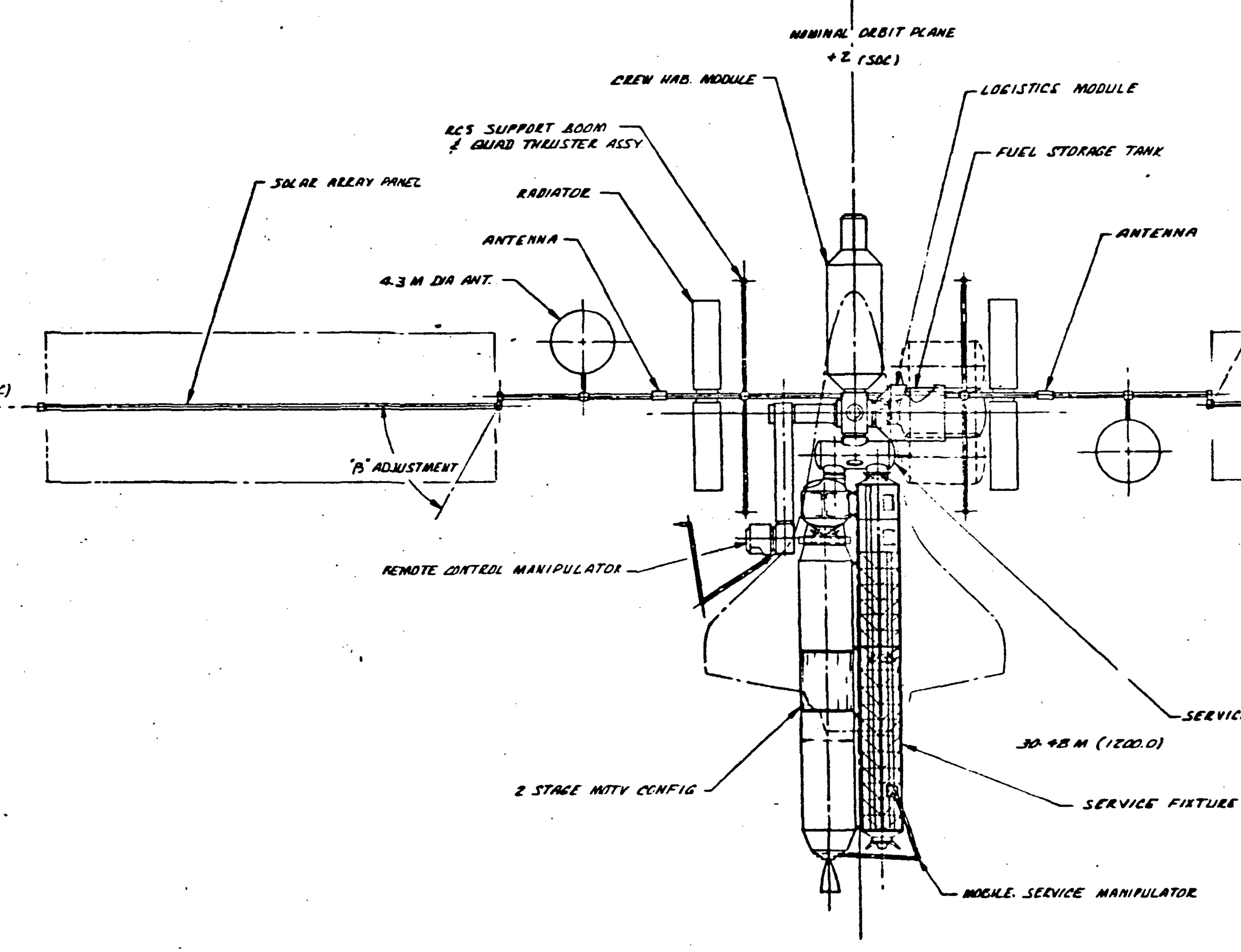
DOCKED CONFIG.



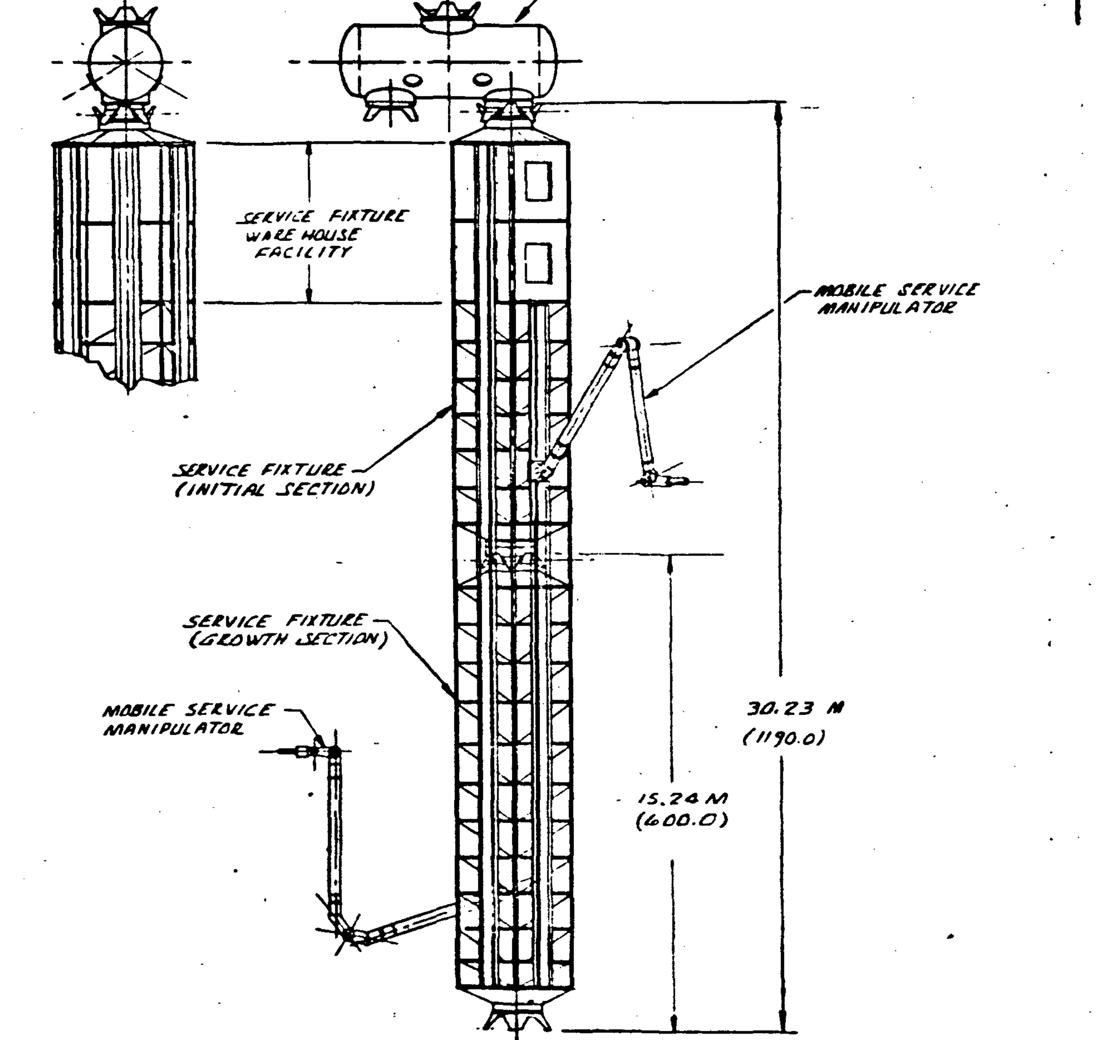
PLAN VIEW - GROWTH CONFIG



SIDE VIEW - GROWTH CONFIG



END VIEW - GROWTH CONFIG



OTV SERVICING SYSTEM - GROWTH CONFIG

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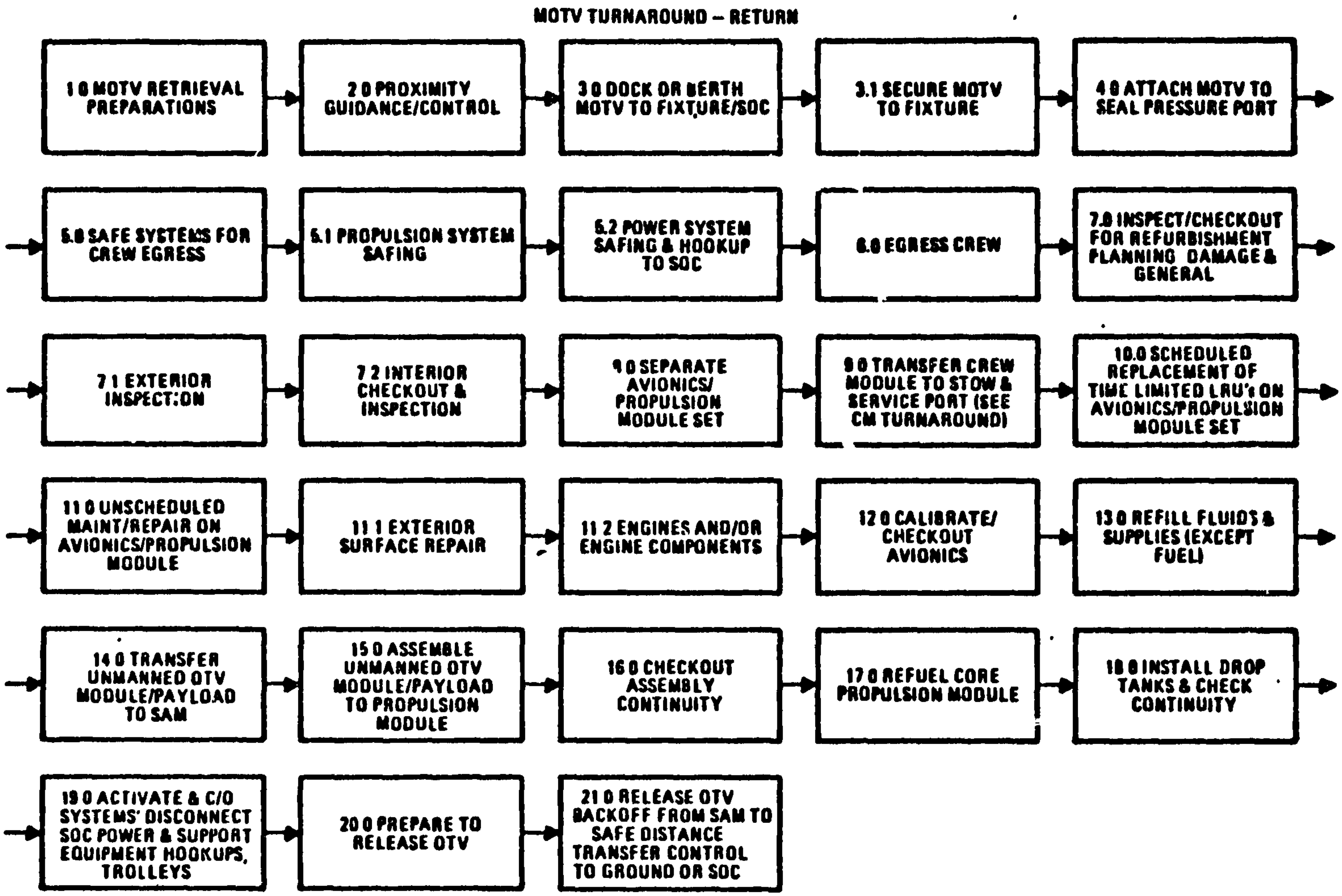
APPENDIX D

SERVICING ACTIVITY DATA SHEETS

The Service Fixture (SF) arrangement described in Section 5 was based on the activities depicted in Figure D-1 as representative of the type of function the SF is expected to provide. Those significant activities of Figure D-1 which will drive the design of the SF were analyzed in detail and Servicing Activity Data Sheets were generated for each. This appendix includes a Servicing Activity Data Sheet for Activities Nos. 5, 7, 8, 9, 10, 11, 14, 17 and 18.

D-1

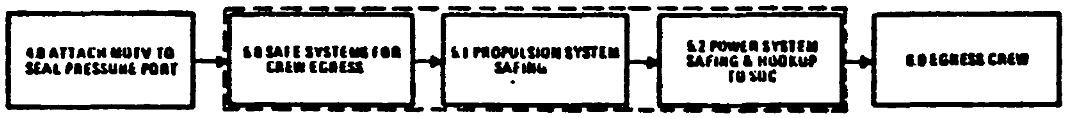
FIGURE D-1
MOTV TURNAROUND FLOW CHART



SERVICING ACTIVITY DATA SHEET

Project: Servicing OTV at SOC

Activity No 5.0



Reference Data

1. Grumman, Manned Orbital Transfer Vehicle (MOTV) Volume 5, Turnaround Analysis, Contract NAS9-25779, 7 November 1979.

Description of Activity

Although this activity was designated No. 5 in the turn-around flow chart, safing operations must be carried out continuously over several activities starting with activity No. 1 when the MOTV is prepared for retrieval operations. A complete MOTV safing can be described as a three-phased operation. In the first phase, active on-board systems, such as propulsion and power, are safed prior to crew egrees. In the second phase, subsequent to crew egress, passive systems are safed to an extent dependent upon the finding of inspection and servicing operations.

In the third phase, as an emergency or contingency operation, hazardous fluids and/or gasses may have to be eliminated as soon as practical and before egress because of system damage or failures recoenized early in the return scenario.

A first phase safing would consist of five activities.

1. Main Engine Shut-off.

2. Safe the Propulsion System:

    Shut-off M.E. isolation valves & verify

    Shut-off Cyro isolation valves & verify

3. Retract Solar Arrays

4. Safe Attitude Control System:

Shutoff RCS propellant isolation valves & verify

Shutoff RCS helium isolation valves & verify

5. Safe Electric Power System:

Shutoff reactant control valves & verify

Shutoff water control valves & verify

The second and third phase safing consists of ridding the MOTV of stowed and expendible gasses and fluids which would have some effect on the servicing/maintenance activities or safety of the re-berthed vehicle.

Support Equipment

Vent and purge line connections to the service fixture

Crew Involvement

MOTV IVA

Control Module IVA

SOC Provision

Service fixture feedlines/pumps/storage tanks

Service fixture expendibles dump system

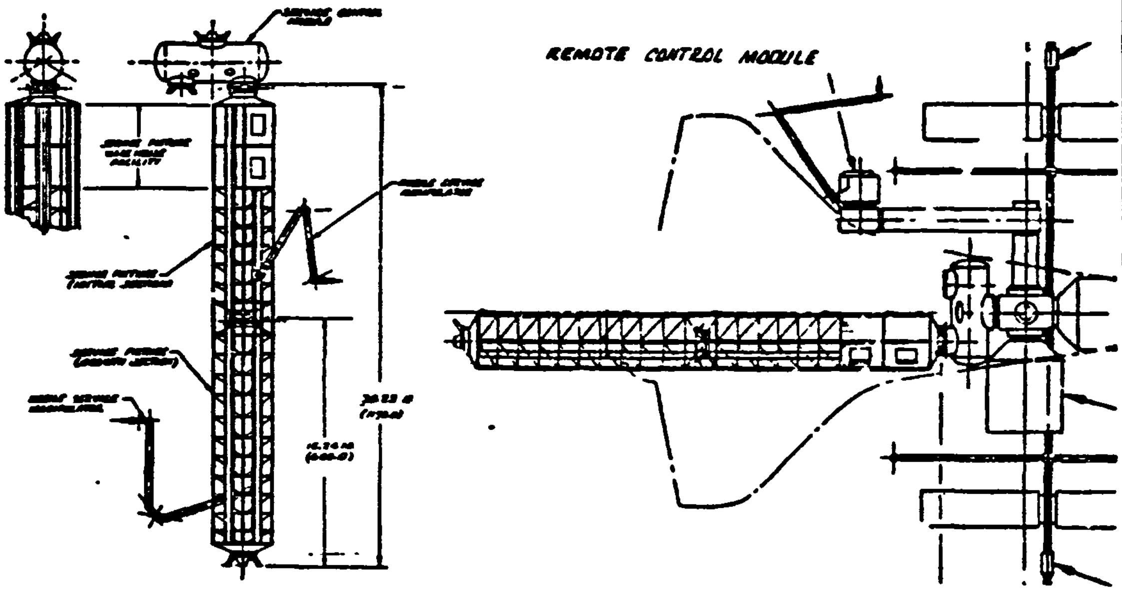
Spacecraft Design Impact

Vent and purge line connections.

Orbiter Design Impact

N/A

FUNCTION 5.0 Safe Systems for Crew Egress ITEM N/A		ATTACHMENT	1
METHOD N/A		PAGE	1 OF 1
SUBJECT SOC Configureation			



The SF of the SOC baseline configuration has an MOTV docking port at the outer end, a handling boom, and longitude translation rails. It may also include tankage and routing lines for expendibles.

SERVICING ACTIVITY DATA

FUNCTION ITEM	5.0 Safe Systems for Crew Egress Phase 1	ATTACHMENT	2
METHOD	Safing Sequent	PAGE	1 OF 1
SUBJECT	Description of Selected Method		

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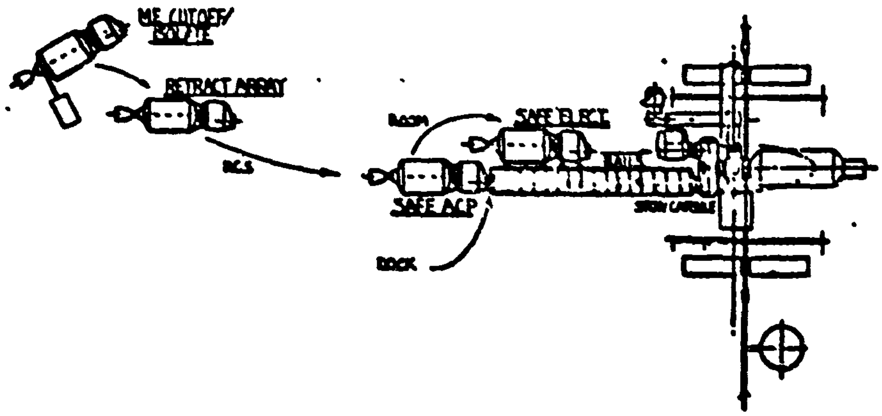


Description of Selected Method

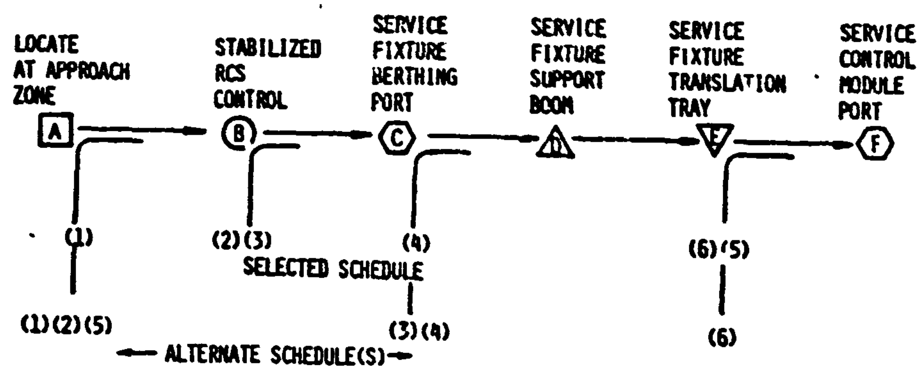
The main propulsion system is safed by closing and verifying the M.E. and cyro isolation valves subsequent to M.E. cutoff and the attainment of control stability. The solar array is retracted next during approach to the SOC.

From that time until docked to the SF, power can be supplied by on-board batteries and/or fuel cells. Once docked to the SF, the ACS is safed by closing and verifying propellant and helium isolation valves.

Power supply duties can be transferred to the SOC once the MOTV is berthed on the transluation rails.

SERVICING ACTIVITY DATA

FUNCTION ITEM	5.0 Safe Systems for Crew Egress Phase 1	ATTACHMENT	3
METHOD	N/A	PAGE	1 OF 2
SUBJECT	Rationale and Trades Data		



(1) MAIN ENGINE SHUTOFF
(2) SAFE PROPULSION SYSTEM—SHUT OFF/VERIFY M.E., CRYO, ISO, VALVES
(3) RETRACT SOLAR ARRAY
(4) SAFE RCS—SHUT OFF/VERIFY HE, PROPELLANT, ISO VALVES
(5) SAFE ELECTRIC SYSTEM—SHUT OFF/VERIFY REACTANT WATER ISO. VALVES
(6) HOOK UP TO SOC POWER

Safing Sequence-First Phase

The selected sequence of safing is indicated above with other options of scheduling the activities.

(1) Main engine shut-off is mandatory upon reaching an appropriate zone to begin the redocking entry.

(2) Safing the main propulsion system could be performed at this initial time but would have some adverse effect on the immediate stabilization of RCS control. The minor time delay from A to B should not imperil the operation.

(5) Safing the electrical system could be performed at any point as early as A, running the remaining sequence on battery power. However no appreciable savings result except minimizing water storage.

FUNCTION ITEM	5.0 Safe Systems for Crew Egress Phase 1	ATTACHMENT	3
METHOD	N/A	PAGE	2 OF 2
SUBJECT	Rationale and Trades Data		

(3) Solar array retraction could be delayed until the MOTV is docked to the end of the service fixture port (C), however this delay could detain the activity of the support boom in transferring the MOTV to the translation tray, or postpone the recognition of any difficulties inherent in the retraction activity.

(4) Safing the RCS is logical only at the point of SOC control, after (C).

(6) Hookup to SOC power is possible only at the point of berthing to the translation tray where power is provided normally during maintenance operations.

SERVICING ACTIVITY DATA

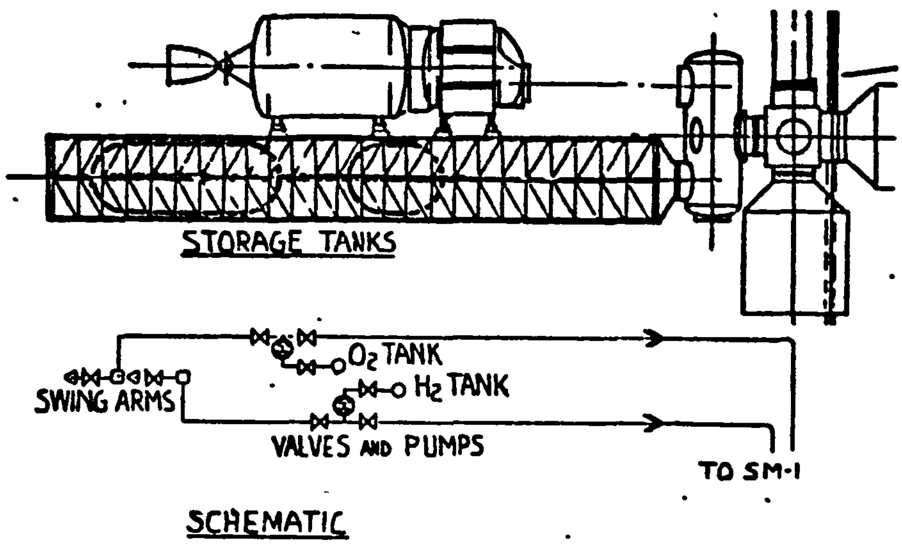
FUNCTION ITEM	5.0 Safe Systems for Crew Egress Phase 2	ATTACHMENT	4
METHOD	Transfer	PAGE	1 OF 2
SUBJECT	Requirements		

Second phase safing activities are dependent on duration of crew module storeage and extent of maintenance operations. Mainly, transferring expendibles to SOC storage, their purging and venting are required of the following systems:

- o Main Propulsion
  - o Purge Main Engine using He
  - o Purge LH_2 Tank and Lines using He
  - o Purge LO_2 Tank and Lines using He or N_2
  - o Vent He Tank and Lines
- o Attitude Control System
  - o Purge N_2H_4 and MMH Fuel Tanks using He
  - o Purge Lines and Thrusters using He
- o Electric Power System
  - o Vent H_2 and O_2 Tanks
  - o Vent H_2O Tanks

SERVICING ACTIVITY DATA

FUNCTION ITEM	5.0 Safe Systems for Crew Egress Phase 2	ATTACHMENT	4
METHOD	Transfer	PAGE	2 OF 2
SUBJECT	Description of Selected Method		



MOTV core module is located at maintenance station on translation rails. Connections are made to the service fixture manifold lines and expendibles are transferred to storage tanks located either inside the service fixtuer structure or at some other SOC location.

MOTV tanks and lines are purged and then vented overboard to safe the vehicle for storage or future servicing.

SERVICING ACTIVITY DATA

FUNCTION ITEM	5.0 Contingency System Safing Phase 3	ATTACHMENT	5
METHOD	Dump	PAGE	1 OF 3
SUBJECT	Requirements		

Contingency removal of gasses and fluids because of hazard consists of the following activities.

- o Main Propulsion
  - o Dump/Purge LH_2 Tank and Lines using He
  - o Dump/Purge LO_2 Tank and Lines using He or N_2
  - o Vent He Tank and Lines
- o Attitude Control System
  - o Dump/Purge N_2H_4 and MMH Fuel Tanks using He
- o Electric Power System
  - o Vent H_2 and O_2 Tanks

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SERVICING ACTIVITY DATA

FUNCTION ITEM	5.0 Contingency System Safing Phase 3	ATTACHMENT	5
METHOD	MOTV Dump	PAGE	3 OF 3
SUBJECT	Description of Alternate Method		

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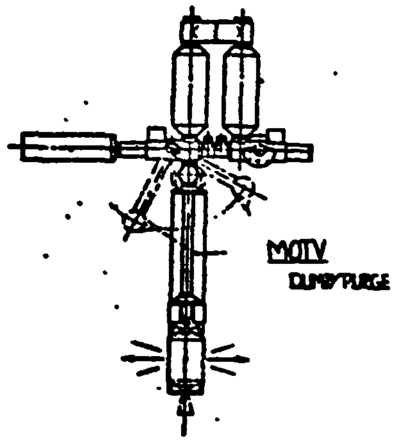
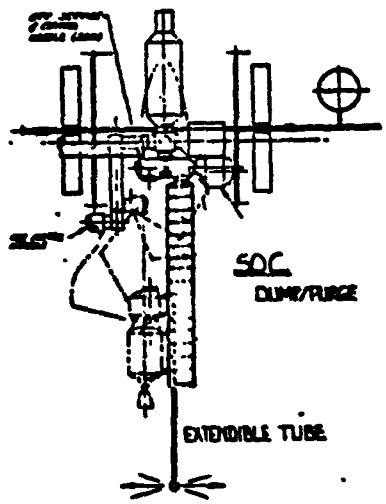


MOTV docks to the end of the service fixture where all subsequent operations can be controlled by the SOC.

MOTV opens dump valves permiting expendibles to be released from counter balanced orifices on opposite sides of the vehicle.

SERVICING ACTIVITY DATA

FUNCTION ITEM	5.0 Contingency System Safing Phase 3	ATTACHMENT	5
METHOD	SOC Dump Manifold	PAGE	2 OF 3
SUBJECT	Description of Selected Method		



MOTV docks to the service fixture and is repositioned with the handling boom to the translation rails on the service fixture where the standard fuel interface connections are made to the service fixture manifold lines. An extendible tube is released from the SF positioned 140/150 feet from the main SOC structure, to where hazardous fluids and gasses can be dumped safely. Purge gasses could be available from SOC storage to supplement the MOTV tankage. The extendible tube can also be utilized for dumping SOC tankage.

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SERVICING ACTIVITY DATA SHEET

Project: Servicing MOTV/OTV at SOC

Activity No. 7.0

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Reference Data

1. Drawing 42690-017, Unscheduled Maintenance/Repair on Avionics/Propulsion Modules, Space Operations Center

2. Drawing 42690-018, Inspection Concepts, In-Space OTV, Space Operations Center

Description of Activity

As the MOTV returns from its mission, it is secured to the servicing fixture (SF) and subsequently mated to the seal pressure port. When the crew egresses the MOTV crew module, a set of inspection operations will commence to determine the general conditions of the crew module and the avionics/ propulsion module. Both internal and external inspection operations will be performed. The crew compartment will be examined internally by SOC crew members by observation and performing preplanned checkout operations. For the external inspection, several concepts involving EVA were considered. The selected concept is based on the use of the Manned Remote Work Station (MRWS) or Open Cherry Picker (OCP) on which an EVA astronaut is stationed. The OCP can be transported to any particular area that requires inspection by the handling boom. The procedure requires the handling boom to secure the OCP while it is in its storage compartment and translate it to the vicinity of an airlock. The astronaut can then egress from the airlock while secured by a tether. Once secured within the foot restraints of OCP, the astrunaut will release the tether and the handling boom will then transport him to any particular exterior surface of the OTV. Reversing the procedure upon completion of the inspection operations will return the astronaut to the airlock and the OCP to its storage compartment.

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Support Equipment

- SF Payload Handling Boom
- Open Cherry Picker (OCP)

Crew Involvement

- One EVA crewman to man the OCP and perform external inspections.

SOC Provisions/Configuration Impact

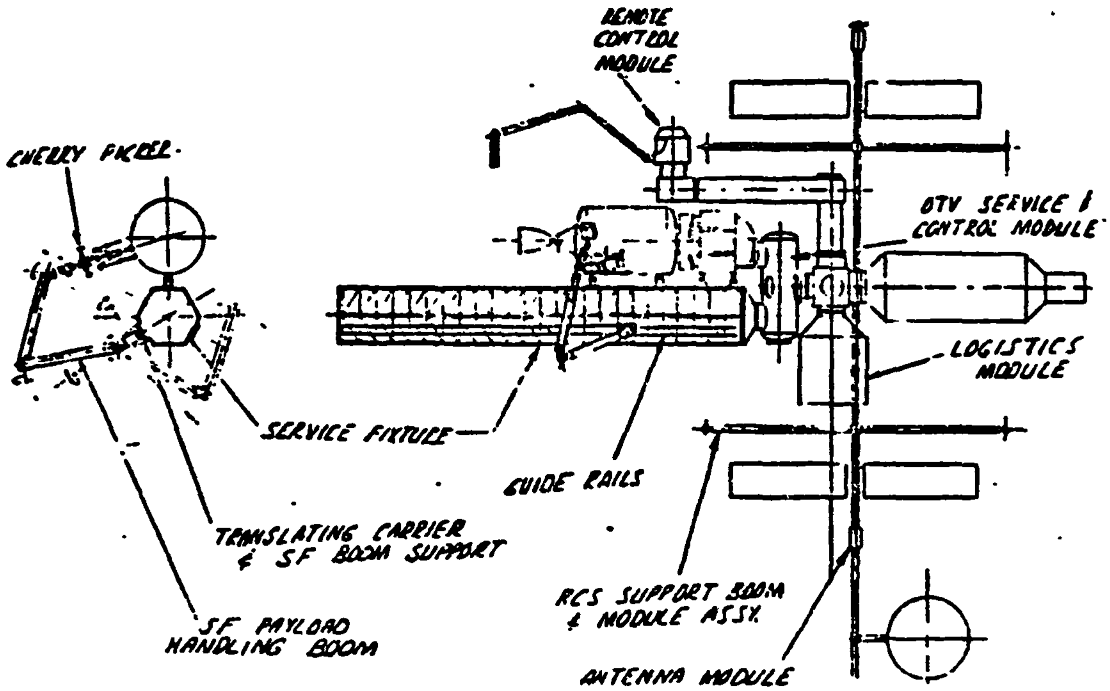
Provisions for storing the open cherry picker on the SF are required. A handling boom that interfaces with the OCP is also required. The handling boom must be designed so that it can be controlled from the OCP as well as from the control module.

Spacecraft Design Impact: N/A

Orbiter Design Impact: N/A

SERVICING ACTIVITY DATA

FUNCTION ITEM	(7.0) MOTV Inspection/Checkout MOTV/OTV & SF	ATTACHMENT	1
METHOD	N/A	PAGE	1 OF 1
SUBJECT	Description of Selected Method		



While the MOTV is berthed to the seal pressure port, the task of inspecting the exterior surfaces of the crew and propulsion core modules is accomplished by an EVA operation involving the OCP in conjunction with the handling boom. Inspection operations may be visual only and/or involving the handling of components. Besides the exterior surfaces, the astronauts will be able to remove panels to inspect critical components located beneath the exterior surfaces. The entire surfaces of both modules are within the reach of the handling boom as presently baselined.

FUNCTION ITEM	(7.0) MOTV Inspection/Checkout MOTV/OTV & SF	ATTACHMENT	2
METHOD	N/A	PAGE	1 OF 1
SUBJECT	Rationale for Selected Method		

The use of the OCP for inspecting the exterior surfaces of the MOTV is the most feasible method of those considered, but not the only one. The use of the Manned Maneuvering Unit (MMU) was also considered feasible and should be utilized as a backup mode in the event its use is found necessary for other SOC operations such as space construction. There are two major reasons for selecting the OCP over the MMU:

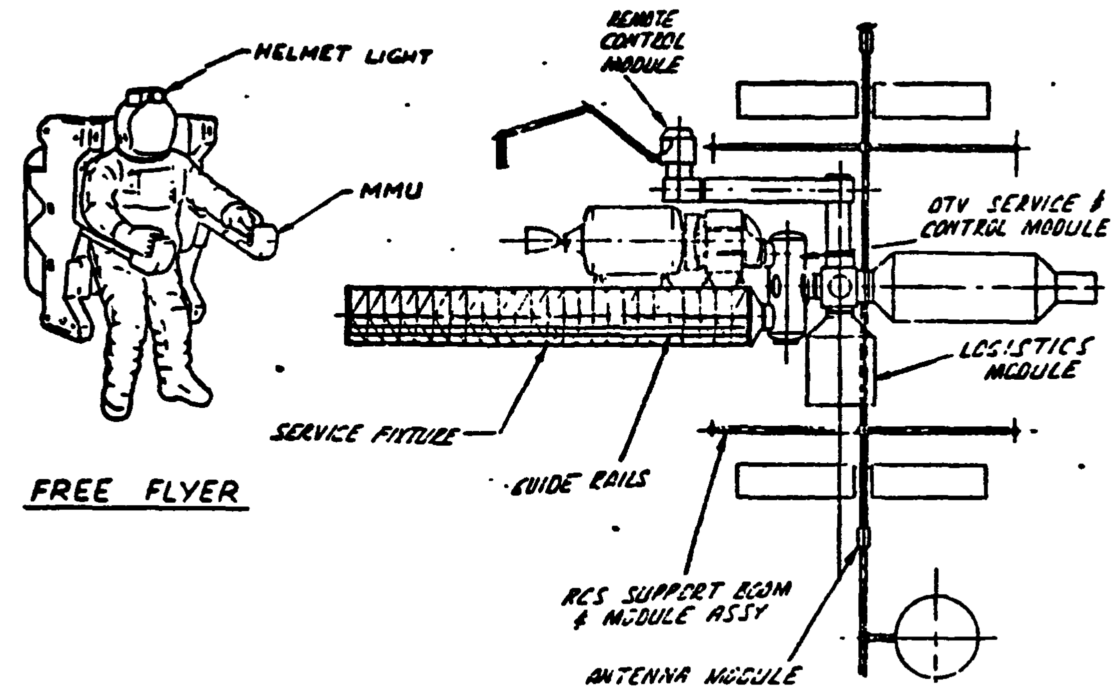
1. The MMU was not designated to perform any other OTV turnaround operation. Hence, it was not necessary to dictate its use when other pieces of equipment are available to perform the inspection task. The OCP, in conjunction with the handling boom, is required to perform repair operations and can just as well perform inspection operations.

2. Inspecting the exterior surfaces of the MOTV is not only a visual task. It may well involve handling components and removing panels. To perform these physical tasks, a work station such as the OCP is more appropriate for reacting forces than a free-flyer such as the MMU.

The other alternate methods that were considered were not as convenient or flexible in their use as the selected method. In addition, they add complexity to the SF and MOTV designs without providing operating advantages.

SERVICING ACTIVITY DATA

FUNCTION (7.0) MOTV Inspection/Checkout ITEM MOTV/OTV & SF		ATTACHMENT	3
METHOD N/A		PAGE	1 OF 1
SUBJECT Description of Alternate Method No. 1			



The procedural steps of inspecting the exterior surfaces of the MOTV can only be pre-planned to a certain degree. Depending on the findings of the inspection operation, unplanned activities are certain to appear. A free-flyer such as the MMU provides maximum adaptability to these unplanned activities by transporting the astronauts to areas that may not be reachable by other means. It is versatile and does not require the use of any additional equipment. However, the minimal stability that it can provide by its reaction jets is not comparable to the OCP when utilized as a work platform.

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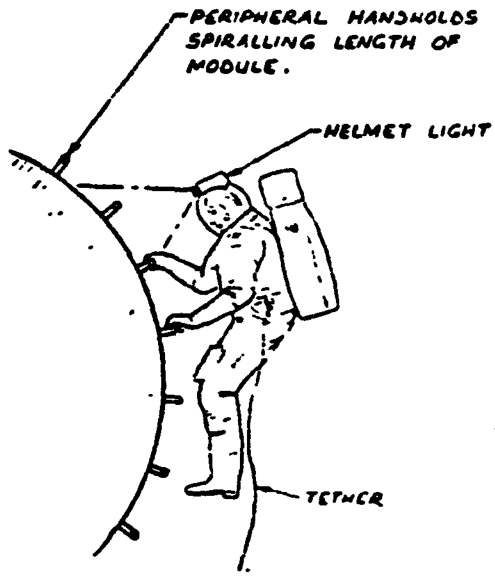
SERVICING ACTIVITY DATA

FUNCTION ITEM	(7.0) MOTV Inspection/Checkout MOTV/OTV & SF	ATTACHMENT	4
METHOD	N/A	PAGE	1 OF 1
SUBJECT	Description of Alternate Method No. 2		



EVA

This method proposes to incorporate handholds at strategic locations on the periphery of the core module for use by a tethered astronaut to perform the inspection operations. Considering the limited reach of a pressure-suited astronaut and the size of the core module, a considerable number of handholds will have to be added. Although the handholds are less complex than the OCP or the MMU, the flexibility of their use is limited.

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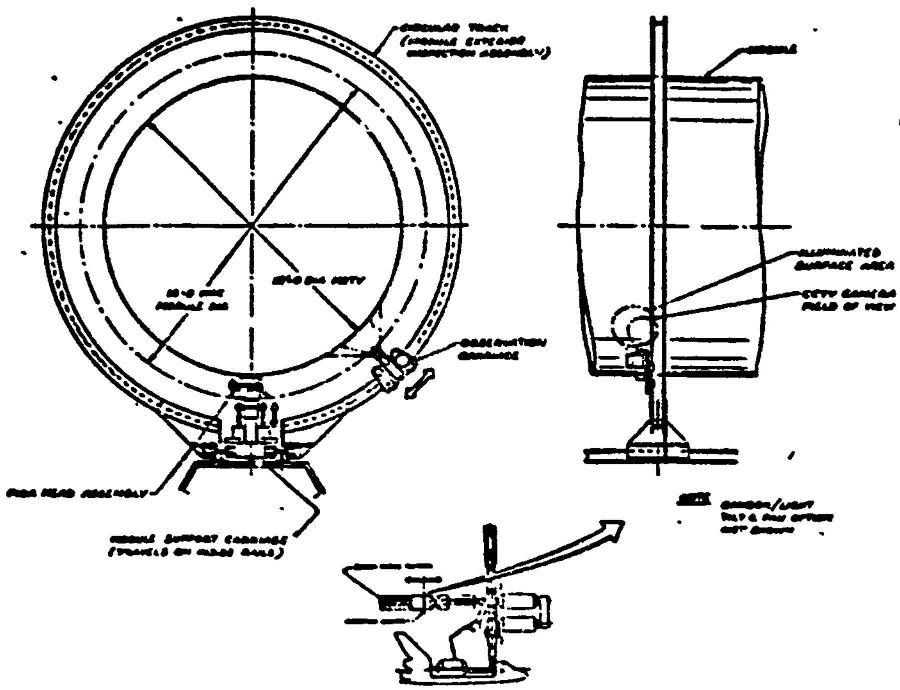
SERVICING ACTIVITY DATA

FUNCTION ITEM	(7.0) MOTV Inspection/Checkout MOTV/OTV & SF	ATTACHMENT	5
METHOD	N/A	PAGE	1 OF 1
SUBJECT	Description of Alternate Method No. 3		



The distinguishing feature of this method is the absence of EVA. It consists of a circular track for an observation carriage on which a CCTV camera is mounted. The circular track rides on the translation rail of the SF and encompasses the entire MOTV. By the strategic positioning of the circulation track and the observation carriage, the CCTV camera will be able to observe the entire exterior surfaces of the core module and the crew module. As an automated technique it avoids EVA operations completely. However, the mechanization inherent in this method is quite complex and it does not allow the added advantage of the astronaut's feel or the ability to remove panel for inspecting beneath the exterior surfaces.

SERVICING ACTIVITY DATA SHEET

Project: Servicing MOTV/OTV at SOC

Activity No: 8.0

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Reference Data

1. Grumman, Manned Orbital Transfer Vehicle (MOTV), Vol 5, Turnaround Analysis, Contract NAS9-15779, 7 November 1979

2. Drawing 42690-013, Flight Support Facility, OTV Configuration Arrangements, Space Operations Center

Description of Activity

It is assumed that the OTV/SOC configuration prior to the initiation of this activity is as illustrated in Attachment 1. As such, the OTV is supported on SF rails and its power is supplied by SOC through its docking port. With the availability of power, all separation mechanisms are envisioned to be remotely controlled. However, manual override provisions along with accessibility and compatibility with EVA operations must characterize all separation mechanisms for contingency conditions. The activity encompasses the separation of fluid, electrical and structural systems and the translation of the avionics/propulsion core module away from the berthed crew module by utilizing the SF translation rail system.

Support Equipment

A translation rail system on the SF is required for this activity with separately controlled support provisions for the crew module and the avionics/propulsion core module. No manipulators are required for this activity.

Crew Involvement

One IVA crewman is needed to operate the SF rail system. One EVA crewman is required in the event of contigencies only.

SOC Provisions/Configuration Impact

As a part of the SF, a translation rail system is required as discussed under Support Equipment. In addition, a control panel from which to operate the rail systm as well as all the separation mechanism would be required within the control module.

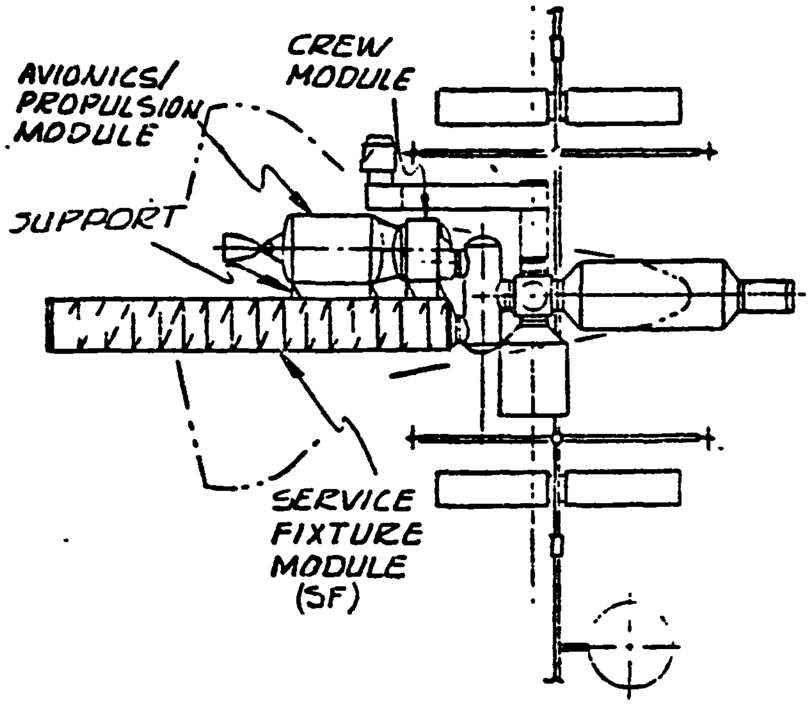
Spacecraft Design Impact

Both the OTV crew module and the avionics/propulsion core module will require provisions to interface with the SF translation rail system. These interfaces are in the form of two PIDA heads for each module. Three mechanisms are required to separate the OTV structural, fluid and electrical subsystems. Since remote actuation is envisioned, control provisions leading to a control panel aboard the control module would be required.

Orbiter Design Impact: N/A

SERVICING ACTIVITY DATA

FUNCTION	(8.0) Separation of Crew Module from OTV Core	ATTACHMENT	1
ITEM	MOTV/OTV & SFM		
METHOD	N/A	PAGE	1 OF 4
SUBJECT	Pre-Separation SOC Configuration		



The significant feature of the SOC during this activity is the support rail system of the servicing fixture (SF). Two individually activated sets of supports are required, one for the crew module and the other for the avionics/propulsion core module. In this way, the core module can be translated away from the core module once the separation mechanisms were activated.

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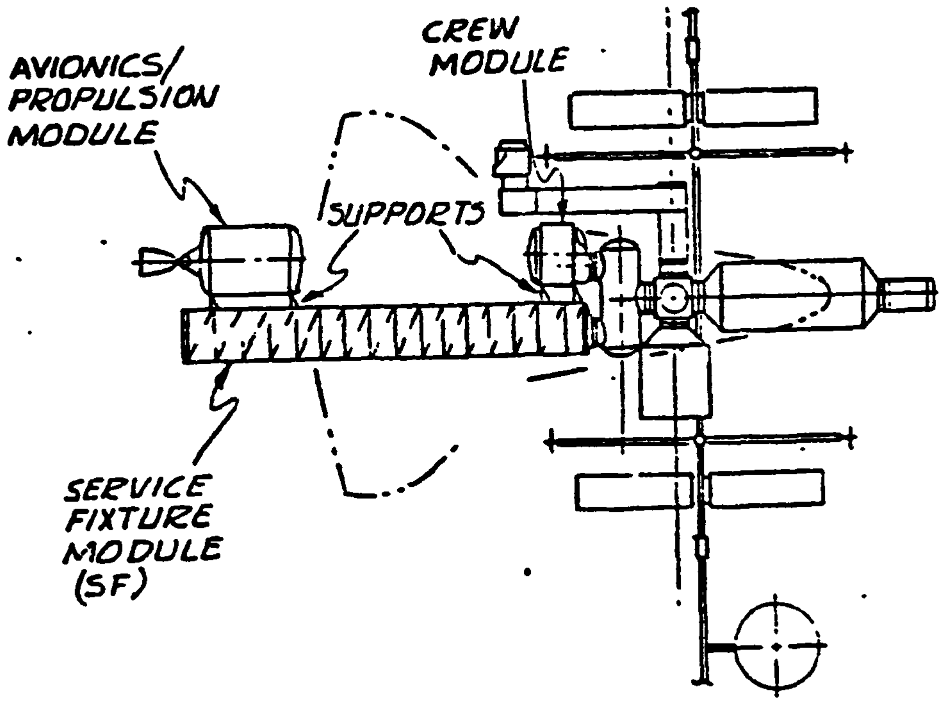
SERVICING ACTIVITY DATA

FUNCTION ITEM	(8.0) Separation of Crew Module from OTV Core MOTV/OTV & SFM	ATTACHMENT	1
METHOD	N/A	PAGE	2 OF 4

SUBJECT Post Separation SOC Configuration

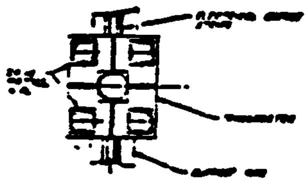


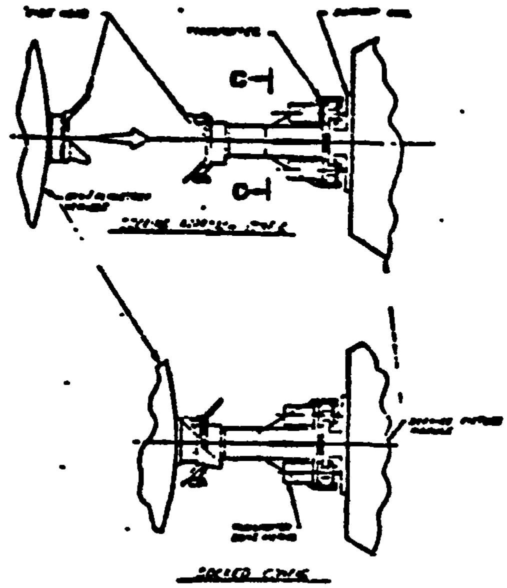
Three major subsystem mechanisms are required to fully separate the crew module from the avionics/propulsion core module. The main procedural steps that lead to the activation of each subsystem separation mechanism are listed below:

- o Fluid Systems
  - o Close shutoff valves on both sides of separation interface
  - o Verify valve closure
  - o Vent/purge interface cavities
  - o Activate separation mechanism
  - o Verify demating
- o Electrical Systems
  - o Shutoff power across separation interface
  - o Verify power off
  - o Activate separation mechanism
  - o Verify demating
- o Structural Systems
  - o Activate separation mechanism
  - o Verify demating
  - o Translate avionics/propulsion module away from crew module

SERVICING ACTIVITY DATA

FUNCTION	(8.0) Separation of Crew Module from OTV Core	ATTACHMENT	1
ITEM	MOTV/OTV & SFM		
METHOD	N/A	PAGE	3 OF 4
SUBJECT	OTV/SFM Interface		





Both the crew module and the avionics/propulsion core module are attached to SF rail by a two-point support system. Each support is a PIDA head interface as shown above. The crew module interfaces are structural supports only while the avionics/propulsion core interface may incorporate utilities and monitoring provisions in addition to their structural support functions.

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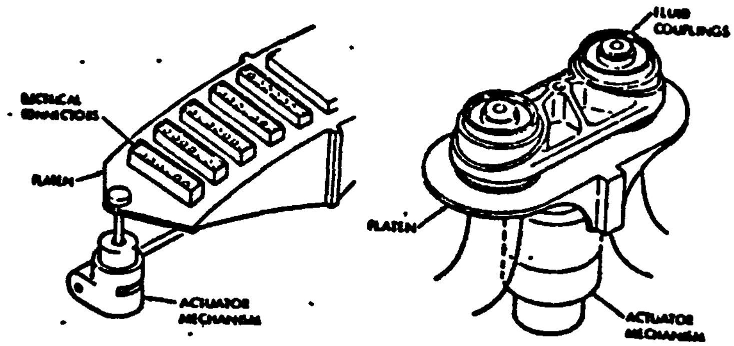
FUNCTION ITEM	(8.0) Separation of Crew Module from OTV Core MOTV/OTV	ATTACHMENT	1
METHOD	N/A	PAGE	4 OF 4
SUBJECT	Typical Separation Mechanism concepts		



· REMOTE ACTUATED INTERFACE CONNECTORS CONCEPTS

Three types of mechanisms are required to separate the crew module from the avionics/propulsion module. The first type is a set of solenoid operated latches similar to those utilized in docking mechanisms. Their main function is to maintain a structural connection between the crew module and the core. The other two types are functionally similar in that each consists of a motorized actuator driving acme screws to which attached is a platten that supports the electrical or fluid connections as illustrated above. These active halves of the interfaces will be located on the crew module side. The other halves, on the avionics/propulsion core module will be passive devices that accepts the illustrated plattens. Appropriate guides and alignment pins will be incorporated into the plattens.

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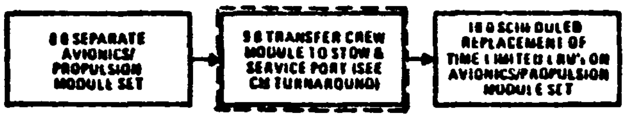
SERVICING ACTIVITY DATA SHEET

Project: Servicing MOTV/OTV at SOC

Activity No: 9.0



Reference Data

1. Drawing 42690-013, Flight Support Facility, OTV Configuration Arrangements, Space Operations Center

Description of Activity

The OTV servicing activity flow chart specified that whenever a subsequent OTV mission is unmanned, the crew module is separated from the OTV and stored on board the SOC until the next manned OTV mission. A special store and service port was designed where the crew module can be stored as illustrated in the reference drawing. At the end of Activity 8, the crew module was attached to the seal pressure port of the SF. Various options were considered to transfer the crew module from the seal pressure port to the store and service port. However, the activity analysis has shown that the seal pressure port can also be utilized as a stow and service port and, if so utilized, will eliminate the need for a transfer operation as well as the need for a special store and service port. One disadvantage of this procedure is a restriction on the mobility of the RCM. Whenever the RCM is required to swing across the SF, the RCM cab must be oriented away from the SF to avoid collision with the stored crew module. This condition is clearly implied in the attachment describing a crew module transfer operation in the event this approach was found unacceptable by a future analysis. In the meantime, the concept of using the seal pressure port as a stow and service port will be adopted as the baseline.

Support Equipment: N/A

Crew Involvement: N/A

SOC Provisions/Configuration Impact

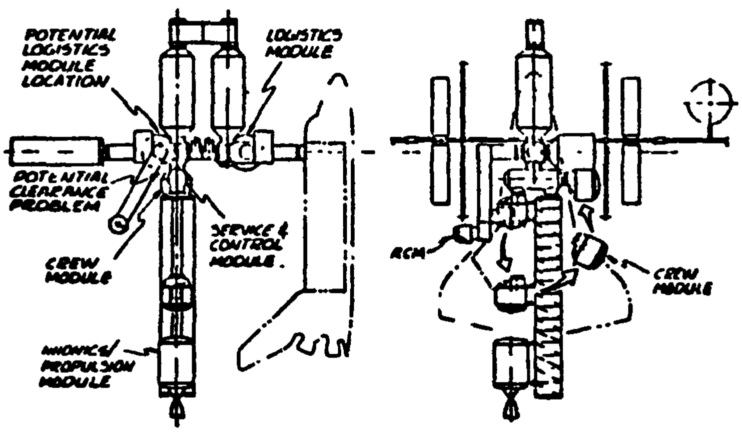
Provisions to maintain the crew module in a state of readiness and its use as an additional habitation compartment must be incorporated into the seal pressure port.

Spacecraft Design Impact: N/A

Orbiter Design Impact: N/A

SERVICING ACTIVITY DATA

FUNCTION	(9.0) Crew Module Transfer to Stow & Service Port	ATTACHMENT	1
ITEM	MOT'/OTV & SF	PAGE	1 OF 1
METHOD	N/A		
SUBJECT	Description of Alternate Method		



To transfer the crew module to the store and service prot, the following major procedural steps are required:

- o Close seal pressure port
- o Demate crew module from seal pressure port
- o Translate crew module (on SF rails) away from seal pressure port
- o Grasp crew module by RCM arm
- o Release latches (PIDA heads) holding crew module to SF supports
- o Transfer crew module toward store and service port and orient.
- o Berth crew module to store and service port.

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SERVICING ACTIVITY DATA SHEET

Project: Servicing OTV at SOC

Activity No 10.0

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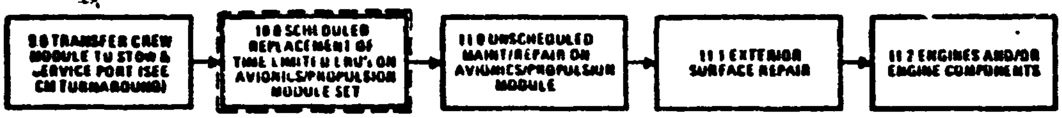


Reference Data

1. Drawing 42690-016, Replacement Concepts, Avionics LRU's - Configuration Arrangement, Space Operations Center

Description of Activity

To remove and replace a LRU module, the activity begins by removing the deflective module from the OTV using the handling boom. The handling boom transports the defective LRU to the LRU storage compartment and hands off to the storage compartment swing arm. The swing arm disposes of the defective module by installing it in an empty module slot. Then the swing arm reaches over to a new module, removes it from its slot and hands it off to the handling boom. The handling boom transports the new LRU module to the OTV and installs it in place of the previously removed defective module. This activity will be repeated until all defective LRU modules are replaced with new ones.

Support Equipment

- o Handling Boom
- o Storage Compartment Swing Arm

Crew Involvement

One IVA crewman within the SF control module to operate the handling boom and the swing arm.

SOC Provision/Configuration Impact

SF provisions that are required for this activity include the handling boom, storage compartments for the LRU's and a swing arm for each storage compartment. As an initial configuration two storage compartments are sufficient for servicing the OTV.

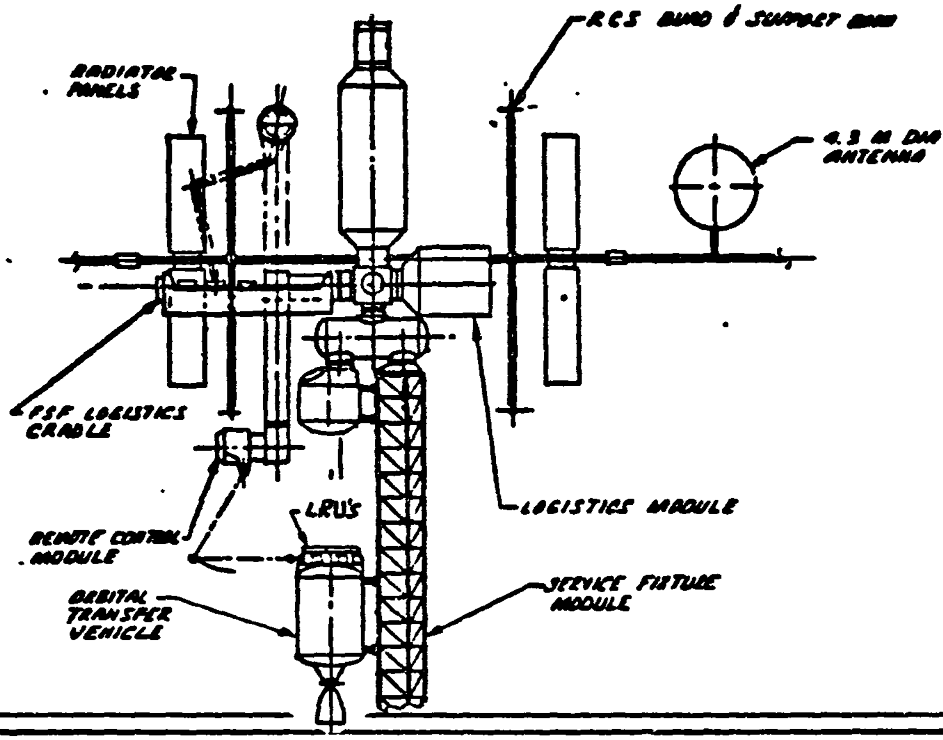
Spacecraft Design Impact

The replaceable LRU's must be accessible to and operationally compatible with the handling boom and its end effector. The LRU's must be similarly compatible with swing arm operations.

Orbiter Design Impact N/A

SERVICING ACTIVITY DATA

FUNCTION ITEM	10.0 Replacing LRU's MOTV/OTV	ATTACHMENT	1
METHOD	N/A	PAGE	1 OF 4
SUBJECT	SOC Basic Configuration Description		



At the initiation of this activity, the MOTV crew module is berthed to the control module seal pressure port and separated from the core avionics/propulsion module which is now located at the OTV servicing station. The LRU's are housed at the forward end of the core module where all avionics components for operating and controlling the OTV are housed.

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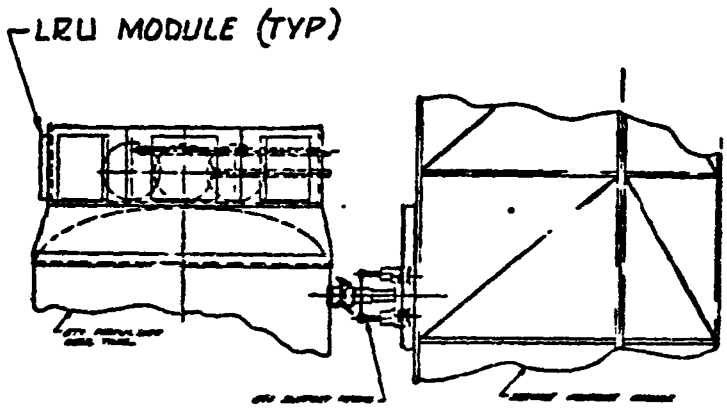
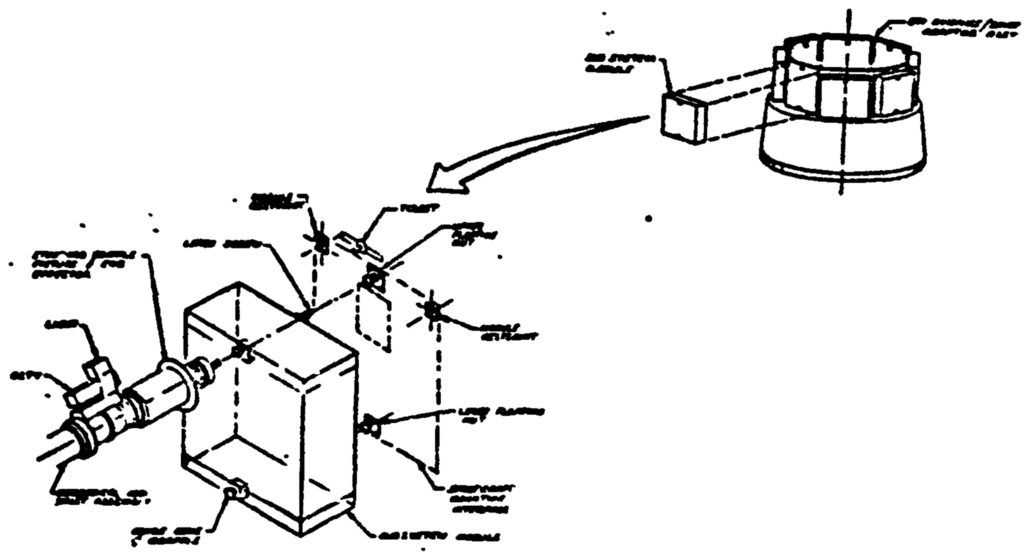
FUNCTION ITEM	(10.0) Replacing LRU's MOTV/OTV	ATTACHMENT	1
METHOD	N/A	PAGE	2 OF 4
SUBJECT	SOC Basic Configuration Description		



The LRU's are externally mounted on a skirt that connects the propulsion module to the crew module. The skirt houses other elements and components of the OTV internally. Since the forward end of the skirt is totally accessible, LRU's could conceivably be located internal to the skirt. However, this condition is dependent on the servicing sequence.

SERVICING ACTIVITY DATA

FUNCTION (10.0) Replacing LRU's ITEM MOTV/OTV		ATTACHMENT	1
METHOD Module Exchange		PAGE	3 OF 4
SUBJECT Description of Selected Method			

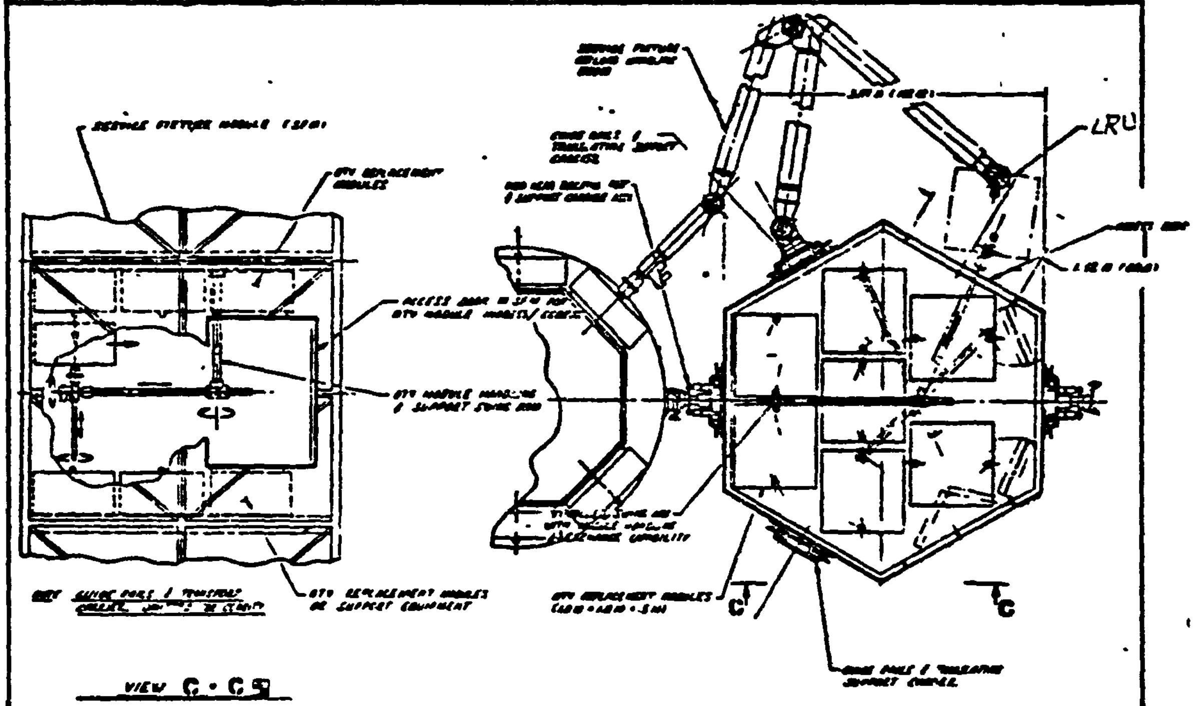


MODULE EXCHANGE SYSTEM

Attachments of the LRU on the OTV and within the storage compartment are similar in concept as illustrated above. The mounting surfce features two module restraint pins, a target for the end effector TV camera and two floating nuts which accept the captive latch crew of the module. The latch screws penetrate the entire module to the opposite side where they interface with an adapter fitting as part of the standard grapple end effector. Turning the adapter one way will unthread the latch screw and the other way to mount the module on the surface.

SERVICING ACTIVITY DATA

FUNCTION	(10.0) Replacing LRU's	ATTACHMENT	1
ITEM	MOTV/OTV		
METHOD	LRU Storage	PAGE	4 OF 4
SUBJECT	Description of Selected Method		



The storage compartment of the LRU s and the associted swing arm is illustrated above. A total of 14 units can be stored in one compartment and serviced by a single swing arm. Two access doors are provided on the SF to facilitate LRU handouts to or from either of two handling booms. The swing arm features five degrees of freedom and a CCTV camera to allow the swing arm operator to observe mounting or dismounting operations.

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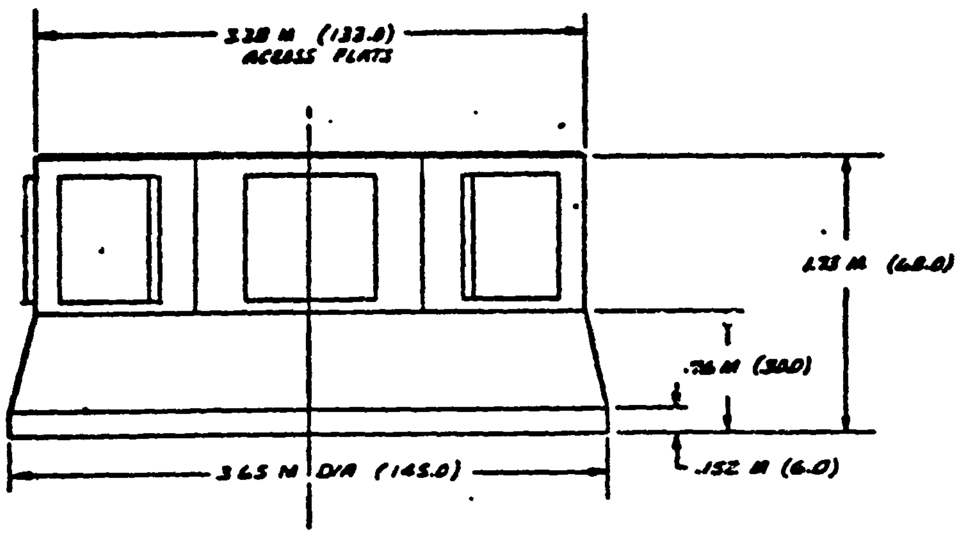
SERVICING ACTIVITY DATA

FUNCTION (10.0) Replacing LRU's ITEM MOTV/OTV		ATTACHMENT	2
METHOD N/A		PAGE	1 OF 1
SUBJECT Rationale for selected Method			

Logistics considerations, such as ease of handling, storage and exchange operations were the primary drivers in the selected concept. The typical LRU module is approximately 1.0m x 1.0m x 0.5m in size which can be handled quite easily by the handling boom and the swing arm. The LRU size is comparable to modules utilized similarly in the Multi Mission Modular Spacecraft (MMS) program and it is compatible with passage through docking ports in the event future SOC growth provisions included a repair facility for LRU's. In Alternate Method "A", where the entire avionics skirt/adapter must be exchanged, the efficiency of LRU usage is considerably less than the selected method. The number of spare units that can be stored is also less than the selected method. Futhermore, the avionics skirt/adapter may house other subsystem components with a different replacement rate requirement than the LRU's. On the other hand, alternate Method "B", where component replacements are suggested, consumes more time operationally than the selected method, requires more spare units to be in storage, and introudces the difficulty of handling smaller units with a grappling end effector.

SERVICING ACTIVITY DATA

FUNCTION (10.0) Replacing LRU's ITEM MOTV/OTV	ATTACHMENT 3
METHOD Avionics Skirt/Adapter Exchange	PAGE 1 OF 1
SUBJECT Description of Alternate Method "A"	



OTV AVIONICS ADAPTOR SKIRT ASSY

This method is operationally similar to the selected method except the entire avionics adapter skirt is replaced rather than individual modules. With its size shown, the adapter is considerably larger than a module and introduces more logistical problems than the selected method.

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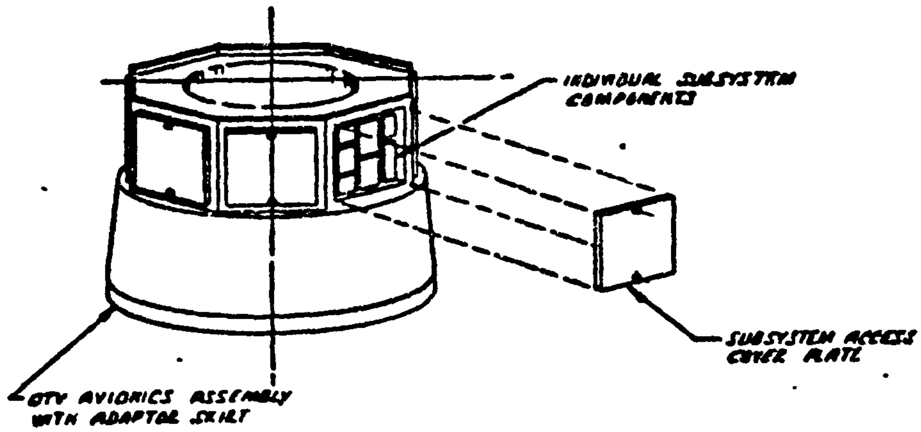
SERVICING ACTIVITY DATA

FUNCTION ITEM	(10.0) Replacing LRU's MOTV/OTV	ATTACHMENT	4
METHOD	Component Exchange	PAGE	1 OF 1
SUBJECT	Component of Alternate Method "B"		



INDIVIDUAL COMPONENT PACKAGE CONCEPT

Similar operational procedures are required for this method as those in the selected method except that individual components are exchanged, as suggusted by the above sketch, rather than modules as in the selected method. Again, this method introduced logistical problems that were not introudced in the selected method such as the number of the required spare parts.

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SERVICING ACTIVITY DATA SHEET

Project: Unscheduled Maintenance/Repair to an OTV at the Service Fixture

Activity No.: 11.0

Reference Data

1. Grumman, Manned Orbital Transfer Vehicle (MOTV), Vol. 5, Turnaround Analysis, Contract NAS9-25779, 7 November 1979

2. Drawing 42690-015, Flight Support Facility, OTV Redocking Concepts, Space Operations Center, November 1980

3. Drawing 42690-016, Replacement Concepts, LRU's Configuration Arrangements, Space Operations Center, December 1980

Description of Activity

The activity of unscheduled maintenance/repair for an orbital transfer vehicle would involve vehicle components such as avionics module, RCS quad engine, vehicle propulsion engine, and damage to surface panels. There are three methods to assess or repair operational failure or damage. The primary method utilizes the handling boom as a transfer agent in conjunction with the OCP as a manned working platform. The two secondary methods are the Remote Control Module (RCM) arm in conjunction with the OCP, or the Manned Maneuvering Unit (MMU). Both secondary methods would be backup modes which will provide a measure of redundancy to this activity.

Support Equipment

- o Translation rails on Service Fixture
- o Handling Boom & Support Carrier
- o Cherry Picker

- RCM Arm
- MMU
- Lighting & CCTV

Crew Involvement

IVA: One man operating service fixture handling boom from service control module

EVA: One man to operate cherry picker

SOC Provisions/Configuration Impact

The translation system, with its capability to handle equipment during buildup or service to an OTV operation, is a required provision of the service fixture assembly. The translation system and its handling boom are discussed in Activity No. 3.0. This activity also requires storage provisions for the cherry picker when not in use, and for spare items on a logistics cradle. Lighting and CCTV must be incorporated into the service fixture operational system.

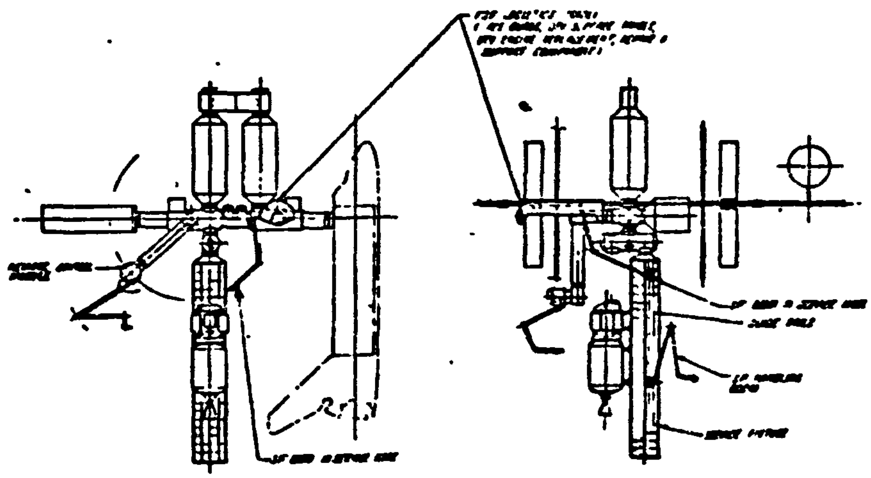
Spacecraft Design Impact

Unscheduled OTV maintenance operations in space are almost a certainty. To accommodate these activities as many OTV components as possible, such as engines, skin panels and onboard propellant tanks, must be designed to be easily removed and replaced in space while the OTV is berthed to the service fixture. On the other hand, the provision of such an operational flexibiltiy may be too costly to implement, when compared to a system that would require replacement, repair or modification made at an earth based facility. A comprehensive trade study would be required to determine a feasible OTV configuration along these guidelines.

Orbiter Design Impact: None

SERVICING ACTIVITY DATA

FUNCTION ITEM	11.0 OTV Unscheduled Maintenance/Repair OTV/SF	ATTACHMENT	1
METHOD	N/A	PAGE	1 OF 4
SUBJECT	SOC Configuration		



The SOC configuration at the initiation of this activity is shown above. The crew or payload module and the core propulsion module are berthed on the service fixture and sufficient spare parts to perform the activity are stored either within specially designed compartments within the service fixture or at a logistics cradle berthed to one of the SOC ports as shown.

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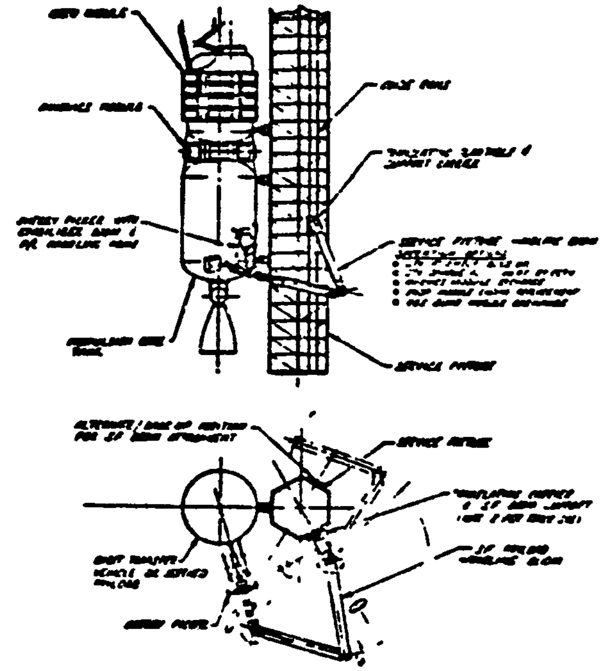
SERVICING ACTIVITY DATA

FUNCTION ITEM	11.0 OTV Unscheduled Maintenance/Repair OTV/SF	ATTACHMENT	1
METHOD	Translating Handling Boom	PAGE	2 OF 4
SUBJECT	Description of Selected Method		



<u>Operation Procedure</u>

- o With SF handling boom and manned cherry picker, remove damage component (RCS quad, propellant engine, skin panel, etc.)
- o Transport part to logistic cradle and secure
- o Pickup replacement and transport to OTV for attachment
- o Activate latches, mechanisms or systems to mate replacement part to orbital vehicle
- o Verify mating interface
- o Checkout complete functional system

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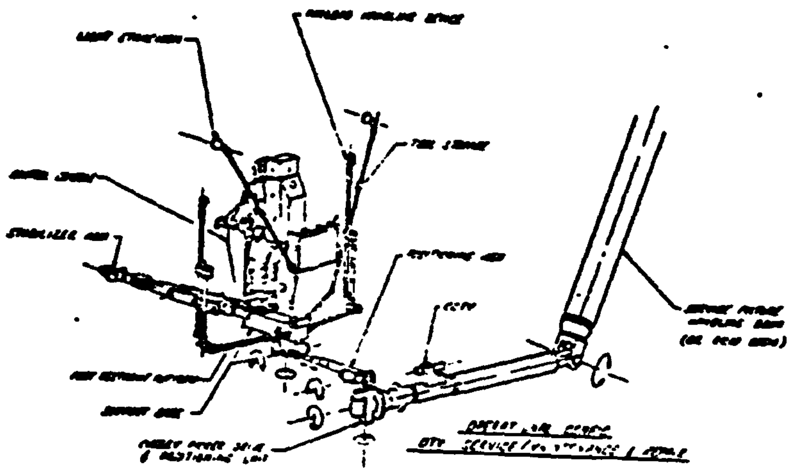
SERVICING ACTIVITY DATA

FUNCTION	11.0 OTV Unscheduled Maintenance/Repair	ATTACHMENT	1
ITEM	OTV/SF		
METHOD	SF Handling Boom With Cherry Picker	PAGE	3 OF 4
SUBJECT	Description of Selected Method		



Operation Procedure

The service fixture handling boom translates along rails supported by the SF structure. A boom moving along these rails can perform work functions at or around vehicles berthed along the system. To aid in these tasks, a cherry picker can be supported from the end effector of the boom. An astronaut in the cherry picker has the capability to control the complete system to facilitate all work assignments within the reach limits of the booms.

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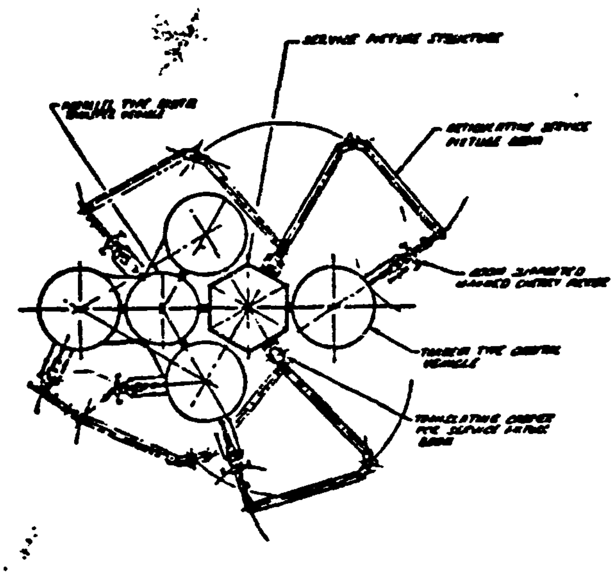
SERVICING ACTIVITY DATA

FUNCTION ITEM	11.0 OTV Unscheduled Maintenance/Repair OTV/SF	ATTACHMENT	1
METHOD	SF Handling Boom Reach Limits	PAGE	4 OF 4
SUBJECT	Description of Selected Method		



Operation Procedure

The service fixture as configured can accommodate more than one handling boom. This arrangement would allow more than one operation to be performed simultaneously. As shown above, a two track system may be utilized to aid in the overall service/repair operations associated with an OTV. A system configured in this manner has the capability of servicing parallel or tandem type OTVs.

SERVICING ACTIVITY DATA

FUNCTION ITEM	11.0 OTV Unscheduled Maintenance/Repair OTV/SF	ATTACHMENT	2
METHOD	N/A	PAGE	1 OF 1
SUBJECT	Rationale for Selected Method		

The selected method to perform unscheduled maintenance/repair of an OTV, was base-lined primarily because the handling boom/cherry picker combination is available, and it can utilize the most direct transfer path. The boom also provides the most accurate operation, since it is anchored to the service fixture and all assembly operations. Using this combination as the primary method allows the secondary systems; the remote control module (RCM) and the MMU to perform other operations simultaneously within the SOC and service fixture circle of activity.

The alternative method using the RCM can also perform this activity adequately. However, its assignment as a backup method would allow it to perform other functions associated with large space construction. The MMU has good maneuverability but could be limited in service/handling of other than small components during exchange/repair operations.

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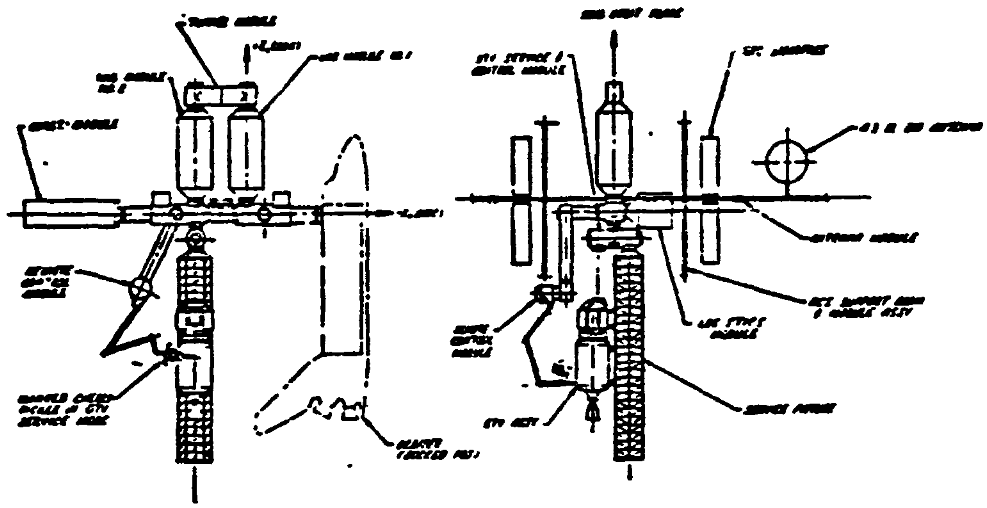
FUNCTION ITEM	11.0 OTV Unscheduled Maintenance/Repair OTV/SF	ATTACHMENT	3
METHOD	RCM With Manned Cherry Picker	PAGE	1 OF 1
SUBJECT	Description of Alternate Method "A"		

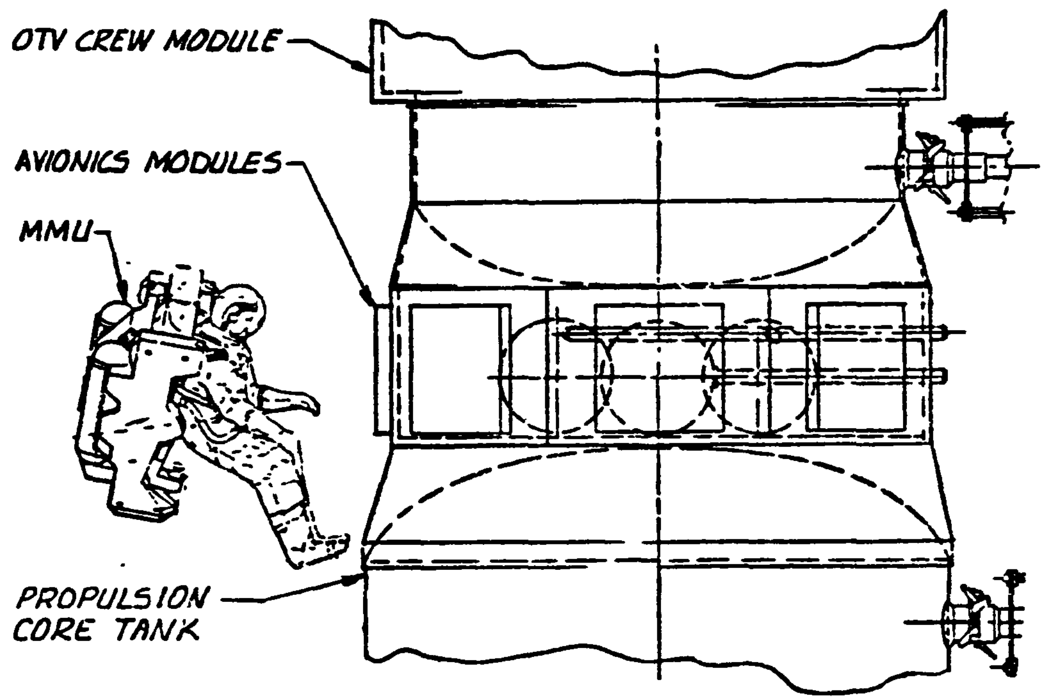


Operation Procedure

- o RCM with manned cherry picker removes OTV component engine or panels
- o Transport part to logistics cradle and secure part
- o Pick up replacement and transport to respective area on OTV and attach.
- o Checkout to verify mating attachment and operation.

SERVICING ACTIVITY DATA

FUNCTION ITEM	11.0 OTV Unscheduled Maintenance/Repair OTV/SF	ATTACHMENT	4
METHOD	Manned Maneuvering Unit	PAGE	1 OF 1
SUBJECT	Description of Alternate Method "B"		



Operation Procedure

The utilization of an MMU in a service/repair mode would primarily consist of visual inspection and damage assessment. The performance of actual component exchanges from an MMU requires the astronaut to have all necessary tools, equipment, and MMU retention tie-downs on hand to execute basic exchange operations.

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SERVICING ACTIVITY DATA

Servicing OTV at SOC

14.0

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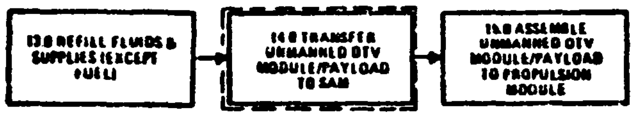


Reference Data

Rockwell Drawing 42690-015, 016

Description of Activity

- SOC is docked to the orbiter on service module-1
- Payload is located in orbiter payload bay with the OTV interface forward
- Payload is deployed from the payload bay using a single PIDA deployment aid. Dual PIDA deployment may be used where the payload length would dictate
- Payload is grasped by the OTV handling boom end effector at a grapple fixture normal to the PIDA interface
- Payload is released from the PIDA, rotated 180° about the end effector roll axis and relocated next to the inboard side of the SF
- Payload is berthed onto the SF support carrier PIDA head interface and released from the OTV handling boom

NOTE: If the payload is located in the payload bay with the OTV interface aft, the PIDA head would be required to rotate the payload 180° in roll prior to Activity 15.0.

Support Equipment: PIDA, OTV handling boom, support carrier interface

Crew Involvement: IVA - Orbiter and SOC operations

SOC Provisions/Configuration Impact

The OTV support carrier with PIDA-head pickup is utilized to secure the payload to the SF. The OTV handling boom with end effector provides the transport from the orbiter to the SF. Control for these operations is accomplished from the flight support servicing control center located in the SF support adaptor.

Payload Design Impact

PIDA interfaces are required for deployment from the orbiter payload bay. The same interface will be utilized to secure the payload to the SF support carrier fittings.

A grapple fixture is required to interface with the SF OTV handling boom.

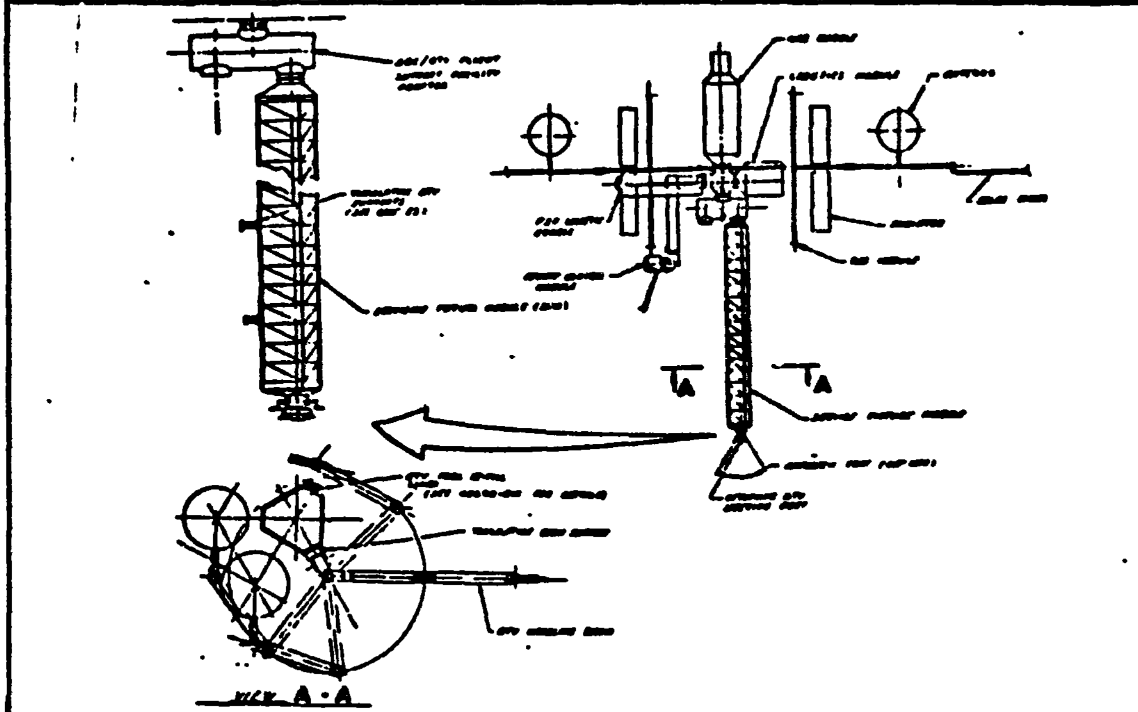
Orbiter Impact

PIDA devices are required for the payload deployment operation.

SERVICING ACTIVITY DATA

FUNCTION ITEM	14.0 Transfer OTV P/L to SF SOC	ATTACHMENT	1
METHOD		PAGE	1 OF 2

SUBJECT SOC Configuration



Significant Servicing Features

- o Service fixture (SF) module provides operating structure and support carriers for OTV payload handling and assembly
- o OTV handling boom on translation rails provides on-site manipulation of OTV components including payload module. Boom incorporates RMS type end effector. Boom is located on SF as shown in View A-A above.

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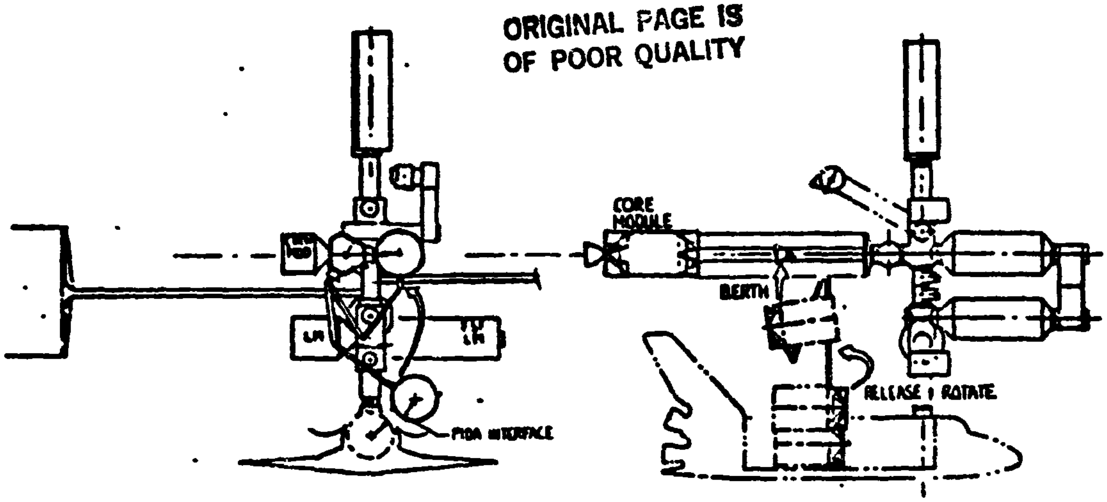
SERVICING ACTIVITY DATA

FUNCTION 14.0 Transfer OTV Payload to SF ITEM N/A		ATTACHMENT	1
METHOD OTV Handling Boom		PAGE	2 OF 2
SUBJECT Description of Selected Method			



Description of Selected Method

The selected method for transferring the payload from the orbiter to the SF utilizes the OTV handling boom located on the SF. The boom is located on the SF as indicated on the above sketch. This location permits the handling boom to reach the payload. The payload is deployed from the orbiter utilizing a PIDA device(s). The PIDA interface is utilized both for the payload deployment from the orbiter and to secure the payload to the SF via the support carrier. The payload is rotated as shown in order to utilize the common PIDA attachment interface.

The payload is berthed to the support carrier on the SF by a handling boom utlizing appropriate lighting, TV, and alignment aids.

SERVICING ACTIVITY DATA

FUNCTION	14.0 Transfer OTV Payload to SF	ATTACHMENT	2
ITEM	N/A		
METHOD	N/A	PAGE	1 OF 2
SUBJECT	Rational and Trade Data		

The function inherently requires three separate activities -deployment from the payload bay, transportation to the SF, station, and berthing to the SF.

Deployment

The payload envelope is assumed to be in the range of the maximum payload bay diameter, thus, requiring a payload deployment device such as the PIDA. The PIDA interface on the payload to accommodate deployment will also be utilized to interface with the SF support carrier, thus, minimizing the hardware and interfaces required on the payload.

Transportation

The Orbiter RMS has insufficient reach capability to transport the payload to the SF. The SOC RMS has the reach capability for transport, however, the OTV payload transfer could impact other parallel SOC activities that require the RCM.

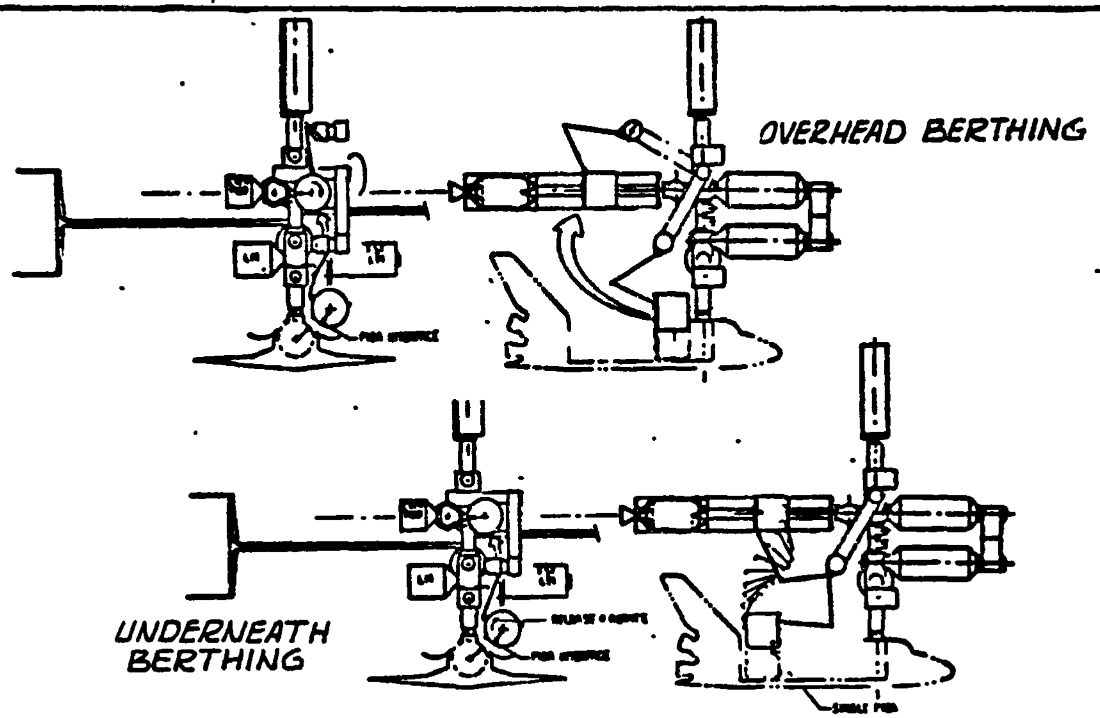
The OTV handling boom, dedicated to handling and assembly of components on the SF, has the reach capability to the PIDA deployment station. Consequently, the handling boom was selected for this activity because it has sufficient reach capability and will not interfer with other SOC operations.

Berthing

The SOC RCM has the capability to berth the OTV payload to the SF support carrier. The SF handling boom is also capable of performing this function. However, the boom being attached to the SF will provide a more positive berthing control operation, and was, therefore, selected to perform this function. In addition, use of the boom for this operation will free the RCM to perform other functions simultaneously.

SERVICING ACTIVITY DATA

FUNCTION ITEM	14.0 Transfer OTV Payload to SF	ATTACHMENT	3
METHOD	SOC RCM	PAGE	1 OF 1
SUBJECT	Description of Alternate Method		



SOC RCM removes payload from PIDA deployment, transfers payload to SF, and berths payload onto the SF support carrier interface.

RCM has reach capability to make installation from overhead (upper sketch), where the payload is carried in the orbiter payload bay with the interface aft; or to make installation from underneath (lower sketch), where the payload is carried with the interface forward. The latter method requires rotation of the payload 180° during transport in order to align the common PIDA interface.

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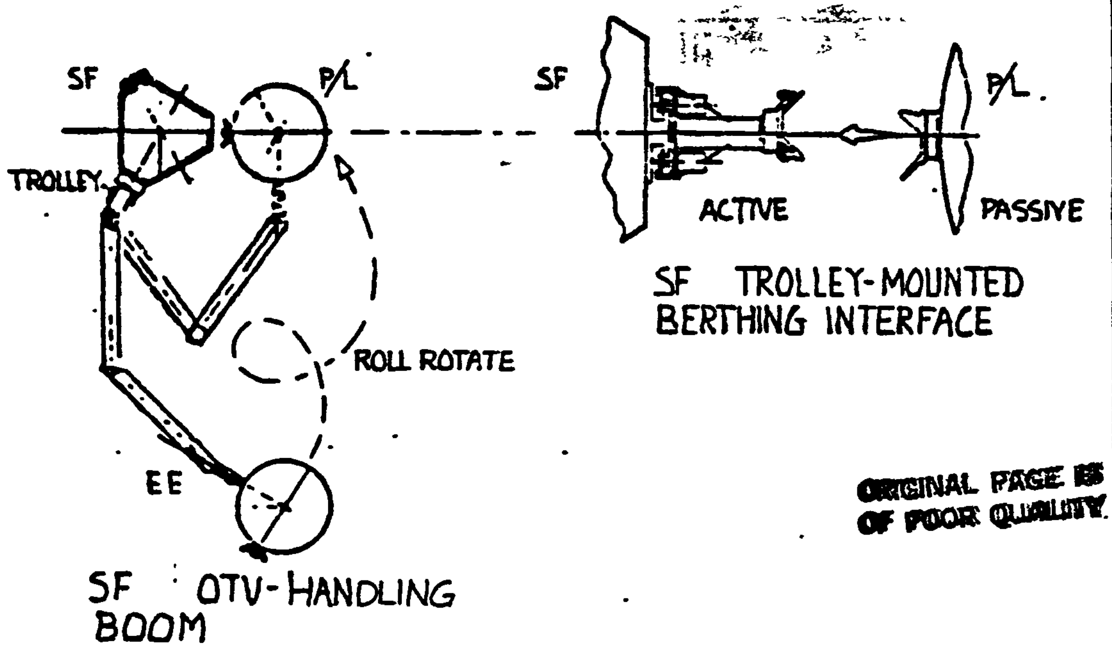
SERVICING ACTIVITY DATA

FUNCTION 14.0 Transfer OTV Payload to SF ITEM N/A		ATTACHMENT	4
METHOD N/A		PAGE	1 OF 1
SUBJECT Support Equipment			



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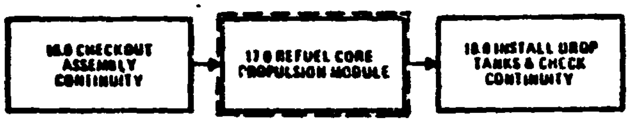
	METHODS	
	Selected Boom	Alternate RCM
(1) Support Rails on SF	X	X
a) Trolley Mounted Berthing	X	X
b) PIDA Interface	X	X
c) TV-Lights-Reticles	X	X
(2) OTV Handling Boom	X	-
a) End Effector	X	-
b) TV-Lights	X	-
(3) RCM	-	X
a) End Effector	-	X
b) TV-Lights	-	X
(4) Payload Equipment		
a) PIDA Interface	1	1
b) Grapple Fixture	1	1
(5) IVA		
a) Service Fixture Module	X	-
b) RCM Control Module	-	X

SERVICING ACTIVITY DATA SHEET

Project: Servicing OTV at SOC

Activity No: 17.0



Reference Data

Task 4 Dwg No. 42690-14, 42696-17

Description of Activity

. The activity assumes the SOC configuration to be as shown in Attachment 1 where the transfer is routed from the payload bay to a location on the service fixture designated as the fueling station. At that point, the interface connection to the propulsion core module LO_2 and LH_2 are mated and the tanks refilled with the aid of payload bay back pressure and/or service fixture pumps.

Support Equipment

- o Lines and swing-arm fule connectors on service fixture
- o Service fixture station-indexing controls
- o SF lighting and TV

Crew Involvement

EVA: None

IVA: SOC service fixture operator

SOC Provisions

- o Longitudinal distribution lines/valves/pumps internal to the service facility structure
- o Single degree of freedom swing-arms to interconnect with the spacecraft tanks external to the service facility
- o Lighting and TV for viewing the actual interface as connections are made and monitored during the fill cycle

Spacecraft Design Impact

Specific standard coordinate locations for fueling/refueling interconnections on core module tanks and any other tanks requiring fuel transfer - to match fueling station coordinates.

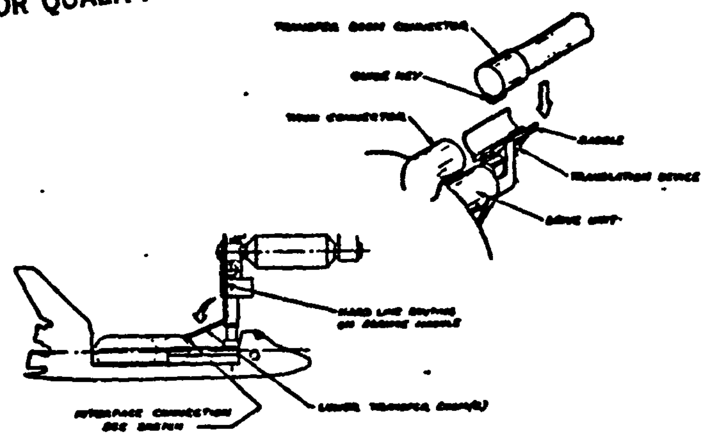
Orbiter Design Impact: None

Attachments

1. SOC Configuration
2. Selected Method
3. Rationale and Trades
4. Alternate Method

SERVICING ACTIVITY DATA

FUNCTION 17.0 Refuel Core Propulsion Module		ATTACHMENT	1
ITEM N/A			
METHOD N/A		PAGE	1 OF 2
SUBJECT SOC Configuration			



The SOC baseline configuration for fuel transfer is taken from Drawing 42690-014.

Fuel is transferred from the payload bay through a short swivel boom to hardline routing on the SOC; starting at service module 1, up and across to the OTV service fixture. LO_2 and LH_2 are in separate line routings on opposite sides of the service module.

FUNCTION 17.0 Refuel Core Propulsion Module ITEM N/A		ATTACHMENT	1
METHOD N/A		PAGE	2 OF 2
SUBJECT SOC Configuration			

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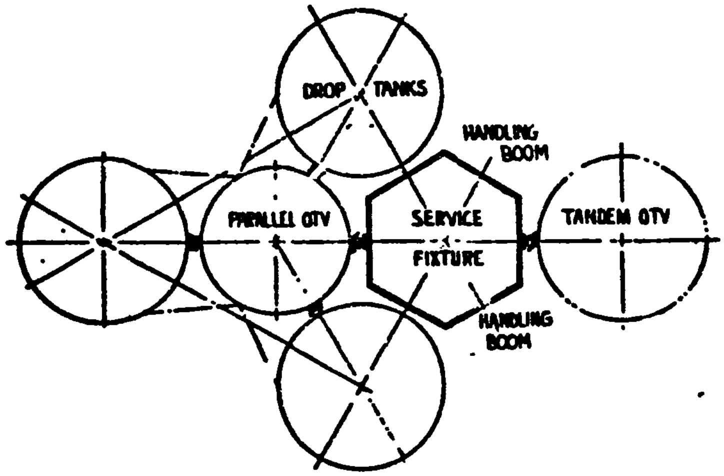

The SOC service fixture as described in Drawing 42690-017, is essentially utilized on all six external surfaces by spacecraft storage or servicing and by OTV handling booms. Routing and interconnect fixtures external to the SF structure would impact or provide hazard to other external activities. All refueling activity elements are located inside the structure as described in Attachment 2.

SERVICING ACTIVITY DATA

FUNCTION ITEM	17.0 Refuel Core Propulsion Module Distribution	ATTACHMENT	2
METHOD	Internal to SF	PAGE	1 OF 3
SUBJECT	Description of Selected Method		

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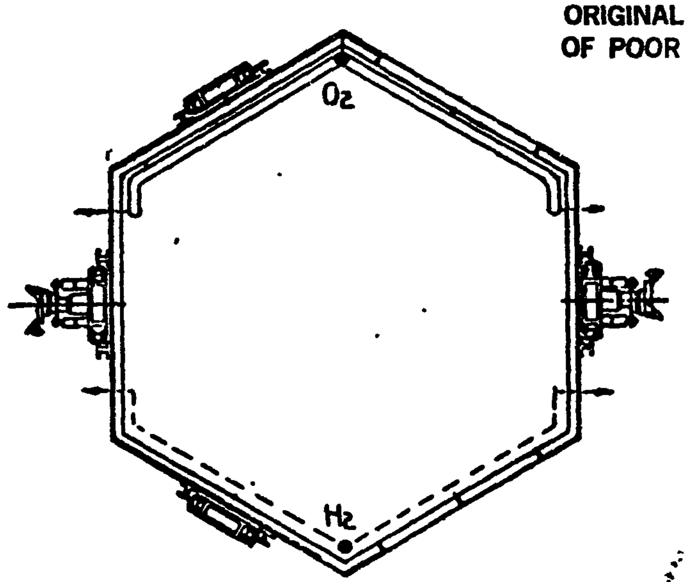
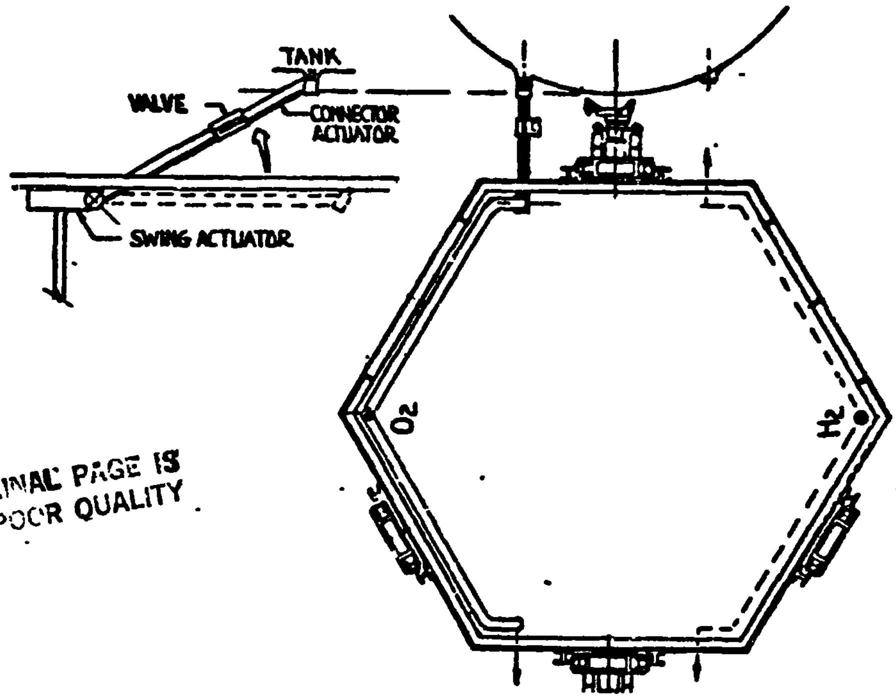


The fuel distribution along the service fixture consists of H_2 and O_2 lines routed longitudinally inside the two opposite corners of the SF. Interface branches at one or more refueling stations are routed inside the SF for access to either side where the support rails can translate spacecraft for servicing. Interface branches could be made as desired to the drop tank support rails in the same manner while maintaining separation.

FUNCTION 17.0 Refuel Core Propulsion Module ITEM Branching Interfaces		ATTACHMENT	2
METHOD Single Axis Swing Arm		PAGE	2 OF 3
SUBJECT Description of Selected Method			



SOC operator translates core module to the selected refueling station, where the tank interfaces are indexed to match the swing arm (approximately 32 inches). A connector actuator actively engages the fluid connector and pulls in to make a solid connection. The swing arm has a single axis of rotation. When the distribution valve and the tank valve are opened, fuel may be transferred. After refueling the swing arm is rotated back completely inside the SF structure. Both connector halves are self-sealing poppet connectors.

SERVICING ACTIVITY DATA

FUNCTION 17.0 Refuel Core Propulsion Module ITEM Versatility		ATTACHMENT	2
METHOD N/A		PAGE	3 OF 3
SUBJECT Description of Selected Method			

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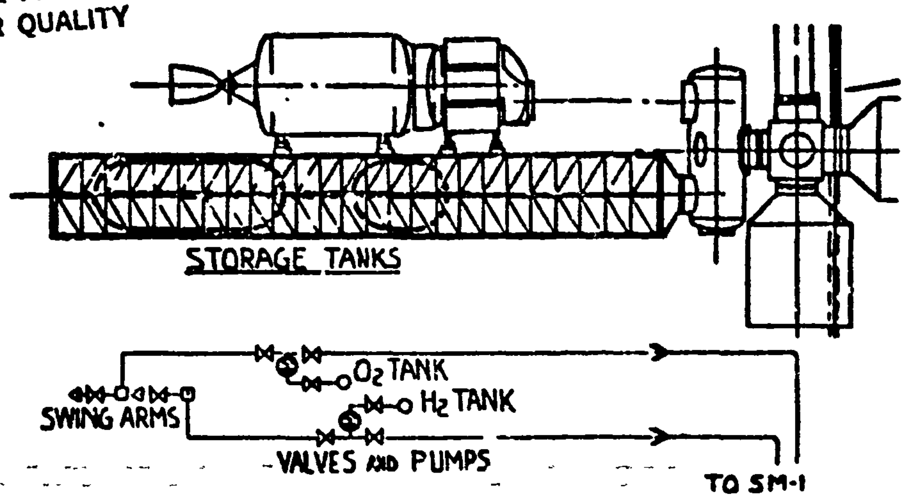


SCHEMATIC

Reference Data

The distribution system as shown has the versatility to support functions other than core module refueling.

If propellant storage tanks were to be incorporated in the service fixture: fuel transfer to and from the storage tanks could be made; payload bay excess following refueling could be stored in the tanks for future use; orbiter refueling schedules need not be tied to the core module scenario; and excess vehicle fuel at the time of docking could be stored for reuse.

Tow refueling stations would permit fuel transfer and direct topping-off of drop tank propellants for contingency.

SERVICING ACTIVITY DATA

FUNCTION ITEM	17.0 Refuel Core Propulsion Module N/A	ATTACHMENT	3
METHOD	N/A	PAGE	1 OF 1
SUBJECT	Rationale and Trades		

Distribution System

The distribution system described in Attachment 2 is necessary for safe refueling operations. It features maximum separation of O_2 and H_2 lines to minimize hazardous conditions in the event leakage occurs.

Interface Connections

Connections through the support assembly, Attachment 4, have an advantage of mating accuracy. They also have some distinct disadvantages:

1. It requires close proximity connections where leakage could be a serious hazard
2. Routing fuel lines through an interface already requiring data and control connections is complex
3. It requires flexible or telescoping lines that pose difficult sealing requirements

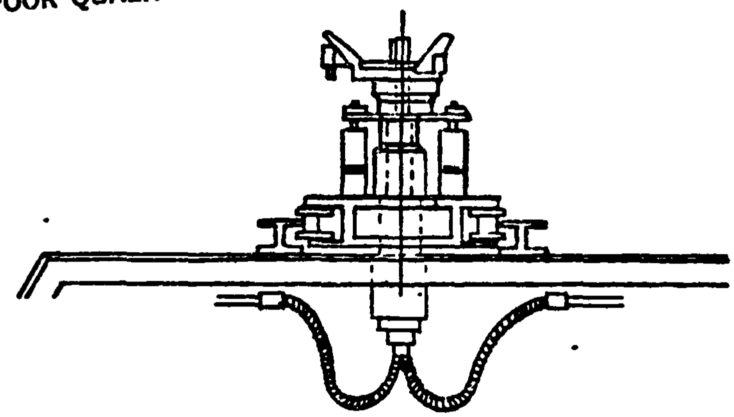
Connections through separate swing arms, Attachment 2, have the advantage of maximum separation and of a simplified sealing requirement at only one joint. Disadvantages are:

1. Slightly less built-in accuracy although the support assembly travel requirement is the same as above and the support assembly can be extended or retracted to the desired height.
2. The off-center connection location may not be most convenient for all tanks that might be considered.

These disadvantages are not critical drivers and the method described in Attachment 2 was selected as the baseline.

SERVICING ACTIVITY DATA

FUNCTION ITEM	17.0 Refuel Core Propulsion Module N/A	ATTACHMENT	4
METHOD	Through PIDA Support Assembly	PAGE	1 OF 1
SUBJECT	Description of Alternate Method		



The refueling interface to the core module is routed directly through the PIDA support assembly.

Internal service fixture lines are fed up through the support assembly to interface with the tank connectors at the berthing interface. The connections have excellent mating accuracy. Prior to and after refueling, the connection device is retracted to the SF surface, so that the support assembly can be moved along the translation rails.

SERVICING ACTIVITY DATA SHEET

Project: Servicing MOTV/OTV at SOC

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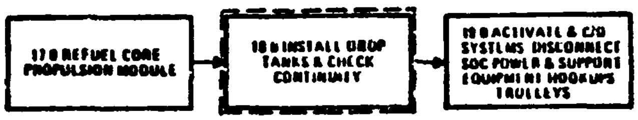
Activity No 18.0



Reference Data

1. Grumman, Manned Orbital Transfer Vehicle (MOTV) Volume 5, Turnaround Analysis, Contract NAS9-25779, 7 November 1979

2. Drawing 42690-013, Flight Support Facility, OTV Config. Arrangements, Space Operations Center, October 1980

3. Drawing 42690-015, Flight Support Facility, OTV Redocking Concepts, Space Operations Center, November 1980

Description of Activity

Three major tasks comprise the installation of each OTV drop tank, its deployment from the cargo bay, its transfer to the service fixture module and its berthing to the OTV propulsion core. The selected tank installation method includes one primary method and two secondary ones which can be utilized as backup. All three utilize the same tank deployment and berthing techniques. They oiffer only in the use of a tank transfer agent. In the primary method the handling boom is utilized as the transfer agent. In the secondary methods, one utilizes the RCM arm as the transfer agent and the other a combination of the RMS and the handling boom. An alternate method is persented which employs a different berthing technique and it also has the option of using anyone of the transfer agents utilized for the selected method. In either case, the activity assumes that the OTV propulsion core is located on a protion of the SF designated as the OTV assembly station with the necessary provisions to perform OTV tank installation. It begins by a PIDA assisted deployment of the tank fom the cargo bay, tranferring it to the SF by any of the agents discussed and berthing it directly to the OTV propulsion core.

Construction Support Equipment

- o Translation Rails on SF
- o Handling Boom
- o RMS
- o RCM Arm
- o Manned Remote Working Station - MRWS (Open Cherry Picker - OCP)
- o PIDA
- o Lighting and TV

Crew Involvement

IVA: One man for operating the PIDA, and the RMS. One man for operating the RCM arm and the handling boom

EVA: One man to perform structural attachments

SOC Provisions/Configuration Impact

A translation system by which to move and place the OTV propulsion core on the OTV assembly station is a required provision of the service fixture module (SF). In addition, the handling boom along with its own translation system, as discussed in Activity 3 would be a required piece of equipment on the SF to provide the primary capability for transferring the tanks from the orbiter cargo bay to the SF.

To provide an OTV assembly station, lighting and CCTV provisions must be incorporated into the SF in addition to the aforementioned equipment.

Spacecraft Design Impact

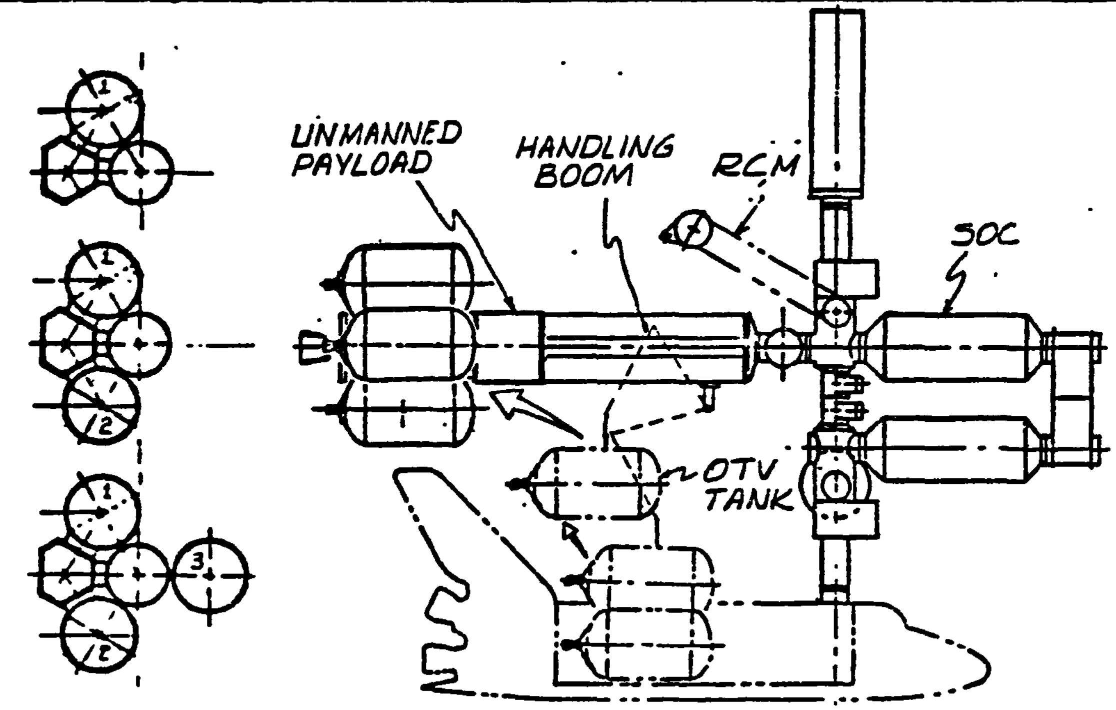
Structural and utility interface provisions are required to attach each tank to the propulsion core and integrate their systems. These interfaces, two between each tank and the core, are envisions to be relatively simple docking/berthing devices similar to the PIDA. To minimize the number of attachment provisions, the PIDA interfaces which aided in deploying each tank can also be used as interface to the propulsion core. If so utilized, they must also incorporate the necessary utility provisions. Typical PIDA interfaces are illustrated in Attachment 1, Page 4.

Orbiter Design Impact

A set of two PIDAs are required on the orbiter to assist in the deployment of the tanks from the orbiter cargo bay.

SERVICING ACTIVITY DATA

FUNCTION 18.0 OTV Tank Installation ITEM MOTV/OTV & SF		ATTACHMENT	1
METHOD Tank Transfer to SF		PAGE	1 OF 5
SUBJECT Description of Selected Primary Method			



Installation Procedure

- o Deploy tank 1 from P/L bay using PIDA
    - o Grasp tank 1 by handling boom and release PIDA
    - o Transfer tank to SF and orient
    - o Berth tank 1 to OTV core using PIDA head interface
    - o Activate mechanism to mate interface connections
    - o Verify mating
- o Deploy tank 2
- o Deploy tank 3
- o Attach structural members between tanks and OTV using EVA (Assumptions: Required structural members are stowed on each tank in conjunction with the MRWS and the handling boom)

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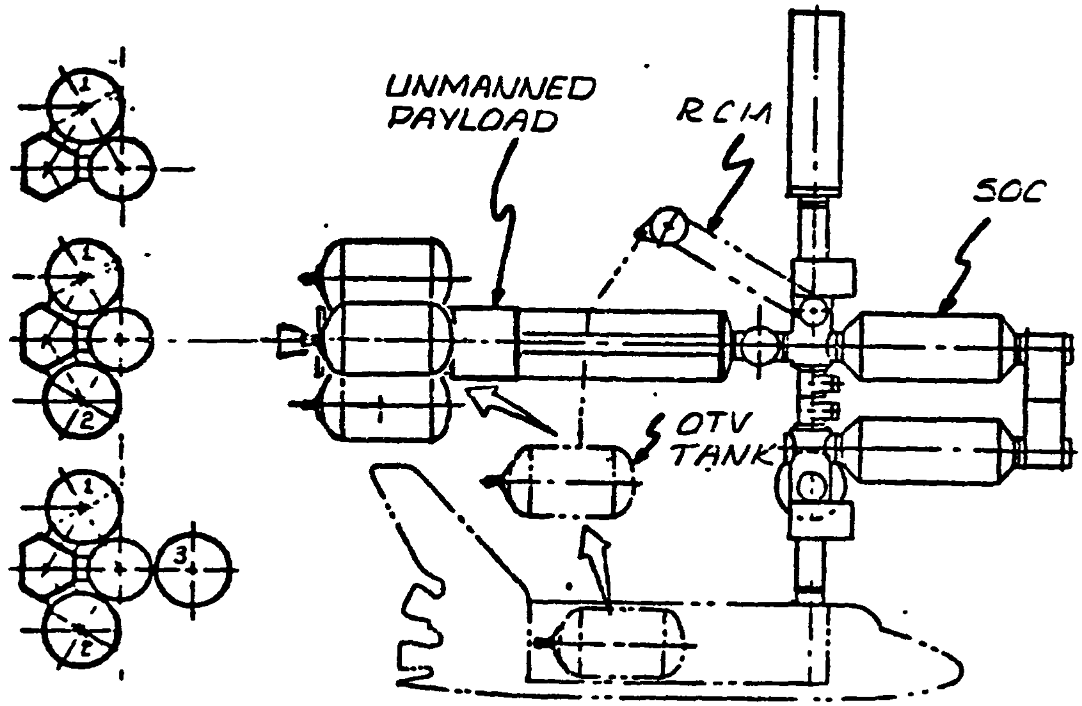
SERVICING ACTIVITY DATA

FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SF	ATTACHMENT	1
METHOD	Tank Transfer to SF	PAGE	2 OF 5
SUBJECT	Description of Selected Secondary Method 1		



Installation Procedure

- o Deploy tank 1 from P/L bay using PIDA
  - o Grasp tank 1 by RCM arm and release PIDA
  - o Transfer tank to SF and orient
  - o Berth tank 1 to OTV core using PIDA head interface
  - o Activate mechanism to mate interface connections
  - o Verify mating
- o Deploy tank 1
- o Deploy tank 3
- o Attach structural members between tanks and OTV using EVA (Assumptions: Required Structural members are stowed on each tank in conjunction with the MRWS amd the handling boom)

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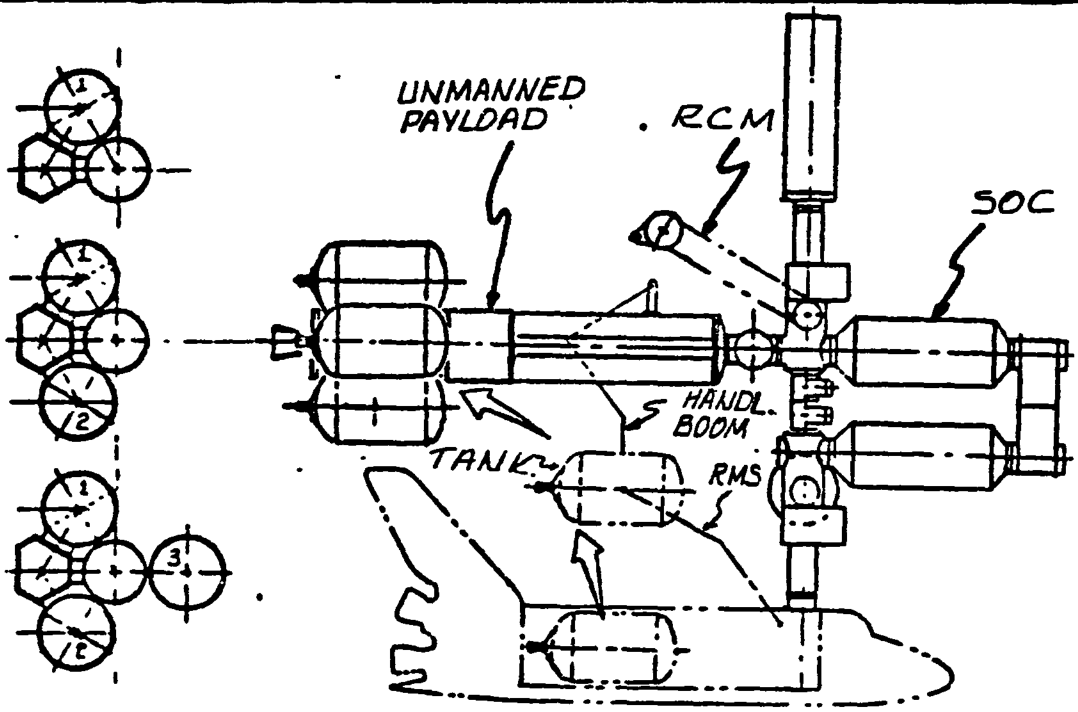
SERVICING ACTIVITY DATA

FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SF	ATTACHMENT	1
METHOD	Tank Transfer to SF	PAGE	3 OF 5
SUBJECT	Description of Selected Secondary Method 2		



Installation Procedure

- o Deploy tank 1 from P/L bay using PIDA
  - o Grasp tank 1 by RMS and release PIDA
  - o Transfer tank 1 to within reach of handling boom
  - o Grasp tank 1 by OTV handling boom and release RMS
  - o Transfer tank to SF and orient
  - o Berth tank 1 to OTV core using PIDA head interface
  - o Activate mechanism to mater interface connections
  - o Verify mating
- o Deploy tank 2
- o Deploy tank 3
- o Attach structural members between tanks and OTV using EVA (Assumptions: Required Structural members are stowed on each tank in conjunction with the MRWS amd the handling boom)

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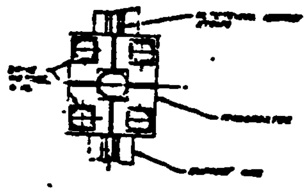
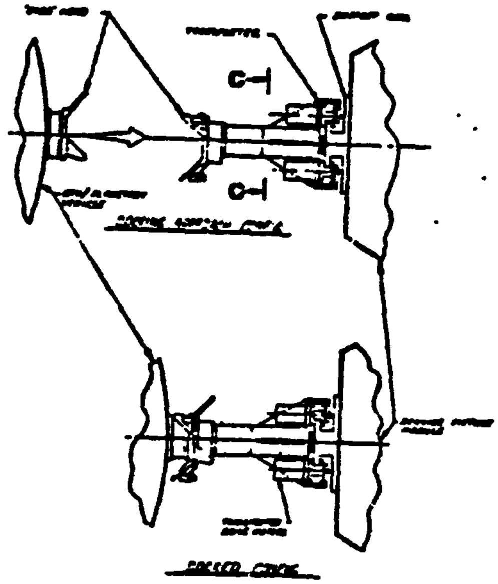
SERVICING ACTIVITY DATA

FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SF	ATTACHMENT	1
METHOD	Tank Transfer to SF	PAGE	4 OF 5
SUBJECT	OTV CORE/SF Interface on Rails		

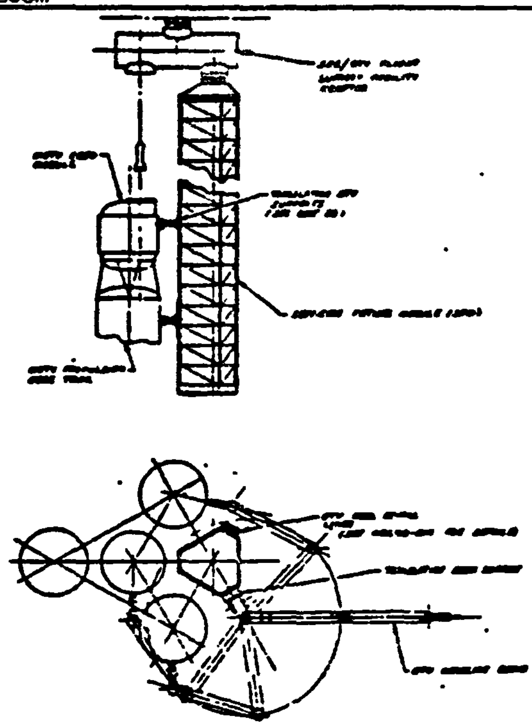




The interface between the OTV propulsion core and the SF is a two-point attachment system consisting of a set of PIDA heads on a translation rail as illustrated above. The passive halves of the PIDA heads are incorporated in the propulsion core and the active halves in the SF. Similar two-point attachments are required to interface each tank to the propulsion core. However, the passive halves are part of the tank and the active halves part of the propulsion core.

SERVICING ACTIVITY DATA

FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SF	ATTACHMENT	1
METHOD	Tank Transfer to SF	PAGE	5 OF 5.
SUBJECT	Handling Boom		



The handling boom was utilized in Activity 3 for transferring the OTV propulsion core/crew module from its berthing adapter at the end of the SF to the translation rail discussed in the previous page. For this activity, however, it will be the primary means by which to transfer the OTV tanks from the orbiter cargo bay to the SF. It also doubles as a secondary method for the same purpose in conjunction with the RMS. If used in the secondary mode, an additional grapple fixture on each OTV tank will be required.

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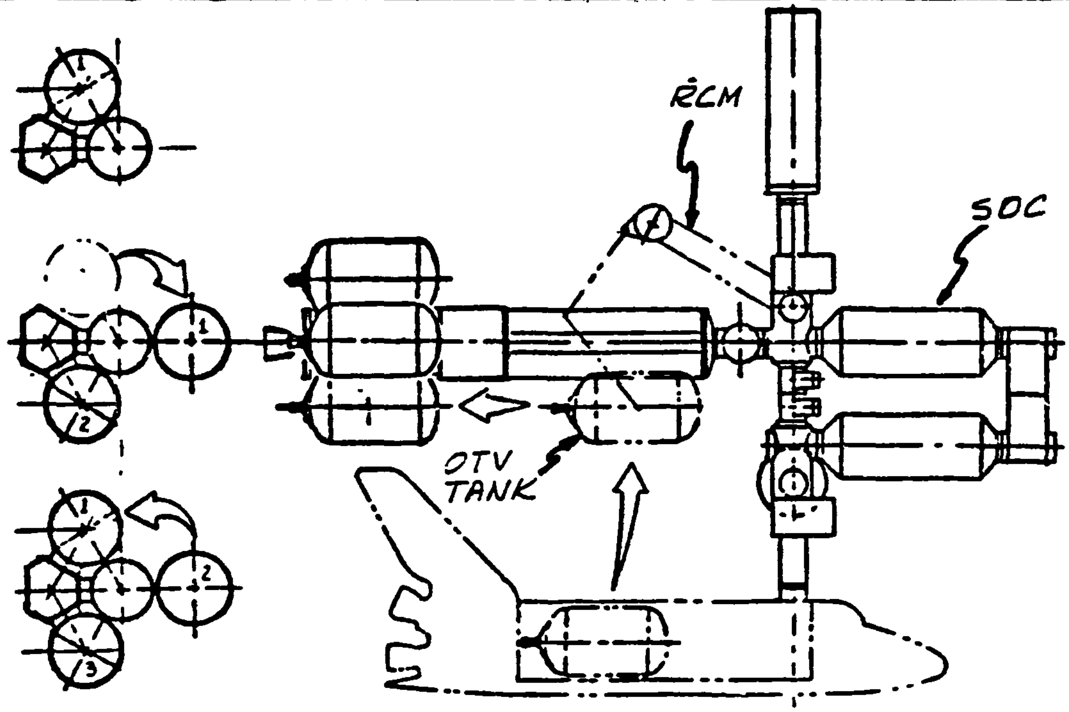
FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SF	ATTACHMENT	2
METHOD	Tank Transfer to SF	PAGE	1 OF 1
SUBJECT	Rationale for Selected Method		

In the selected methods, primary and secondary, the tank transfer operation from the cargo bay to the SF relies heavily on available equipment that was required for other activities and operations. As such it does not require additional equipment specifically dedicated to this activity. Of the three transfer agents available for this operation, the handling boom was designated as the primary agent because its use provides the most direct transfer path. In addition, because the boom is anchored on the SF where assembly operations are being performed, berthing accuracy limits can best be controlled by the boom. Designating the boom as the transfer agent also allows the RCM arm (and the RMS) to perform other functons simultaneously with OTV tank installation operations.

The alternate method, as illustrated in Attachment (3), utilizes a different berthing approach than the selected methods. In this case, the tank is berthed to the translation rail rather than directly to the propulsion core. By this approach, the rail system could double as an alignment fixture for mating each tank to the core and automate the attachment operation. However, berthing each tank on the rail system is similar to berthing it on the core. Consequently, no advantage is realized by using the alternate approach. In addition, the selected method of mating two bodies in a two-point attachment was discussed with NASA MDF personnel where a similar test was conducted in which a large payload was berthed to two PIDAs. The conclusion of the test was that the operation is quite feasible.

FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SF	ATTACHMENT	3
METHOD	Tank Transfer to SF	PAGE	1 OF 2
SUBJECT	Alternate Method		



The same tank transfer methods utilized by the selected method of installing OTV tanks also apply to this alternate. Only the use of the RCM arm as a transfer agent as presented for brevity.

Installation Procedure

- o Deploy tank 1 from P/L bay using PIDA
  - o Grasp tank 1 by RCM arm and release PIDA
  - o Transfer tank 1 to far side of SF and orient
  - o Berth tank 1 to SF rail system
  - o Translate tank 1 to OTV assembly station
  - o Activate mechanism to mate structural and utility interfaces
  - o Verify mating
  - o Rotate OTV core 120° until tank 1 is in the tank 2 position

FUNCTION ITEM	18.0 OTV Tank Installation MOTV/OTV & SFM	ATTACHMENT	3
METHOD	Tank Transfer to SFM	PAGE	2 OF 2
SUBJECT	Alternate Method		

- o Deploy tank 2 from P/L bay using PIDA
  - o Grasp tank 2 by RCM arm and release PIDA
  - o Transfer tank 2 to near side of SFM and orient
  - o Berth tank 2 to near side of SFM rail system
  - o Translate tank 2 to OTV assembly station
  - o Activate mechanism to mate structural and utility interfaces
  - o Verify mating
  - o Rotate OTV core 120° back to its starting position
- o Deploy tank 3 from P/L bay using PIDA
  - o Grasp tank 3 by RCM arm and release PIDA
  - o Translate tank 3 to near side of SFM and orient
  - o Berth tank 3 to near side of SFM rail system
  - o Translate tank 3 to OTV assembly station
  - o Activate mechanism to mate structural and utility interfaces
  - o Verify mating
- o Attach structural members between tanks and OTV using EVA (Assumptions: Required structural members are stowed on each tank)

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