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JULY 1968

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION

MCDONNELL DOUGLAS



CORPORATION

SATURN S-IVB-502 STAGE FLIGHT EVALUATION REPORT

DOUGLAS REPORT SM-47005
JULY 1968

PREPARED BY:
SATURN S-IVB TEST PLANNING AND
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PROJECT OFFICE - FLIGHT TEST
SATURN DEVELOPMENT ENGINEERING

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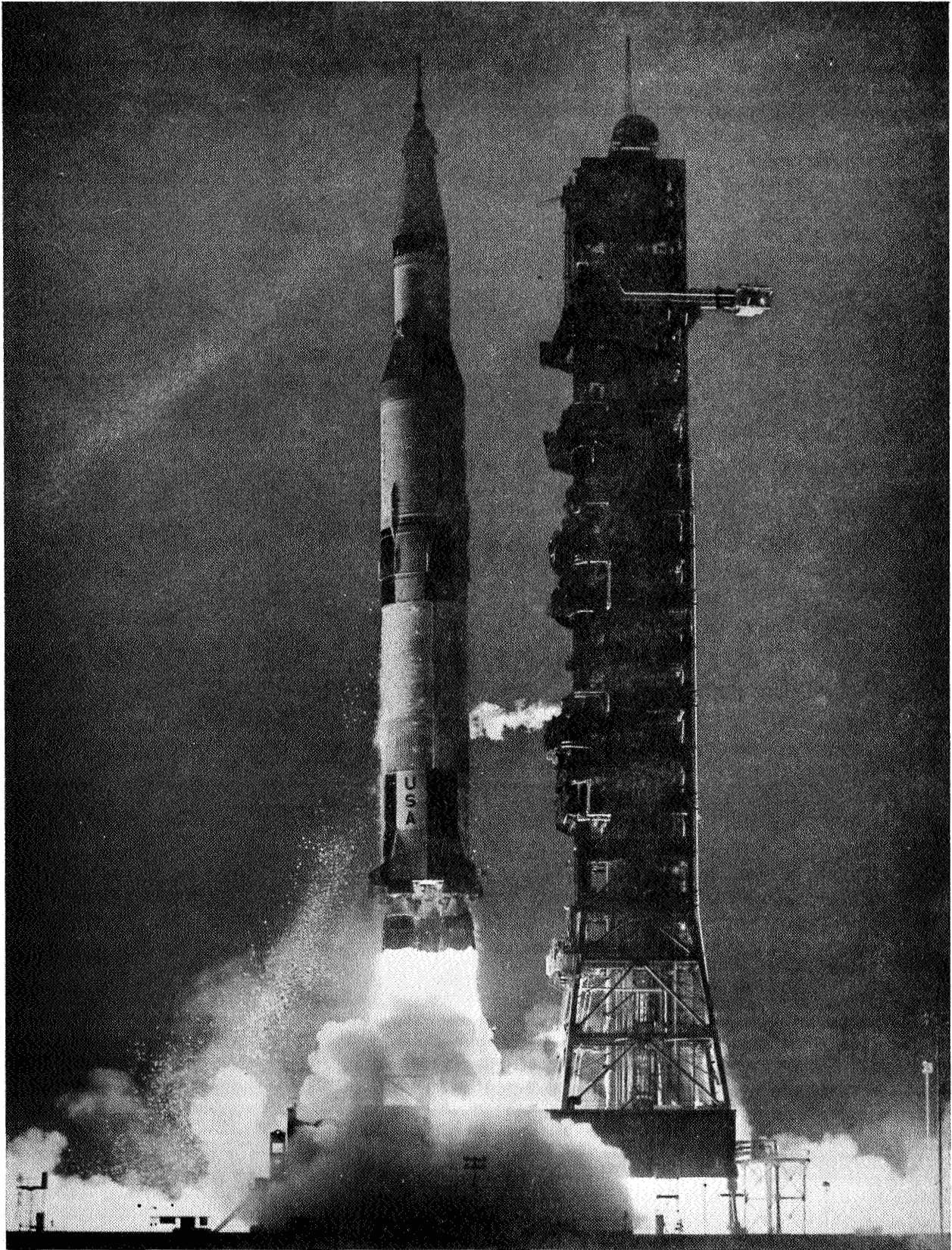


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SATURN AS-502 VEHICLE LIFTOFF

ABSTRACT

This report presents the evaluation results of the prelaunch countdown, powered flight, and orbital phase of the S-IVB-502 stage which was launched on 4 April 1968 as the third stage of the Saturn AS-502 vehicle.

The report is a contractual document as outlined in NASA Report MSFC-DRL-021, Contract Data Requirements, Saturn S-IVB Stage and GSE, dated 1 February 1968, Revision A. It was prepared by the Saturn S-IVB Test Planning and Evaluation Committee and coordinated by the Saturn S-IVB Project Office of the McDonnell Douglas Astronautics Company, Western Division.

DESCRIPTORS

| | |
|-----------------|-----------------------|
| data evaluation | S-IVB-502 |
| flight test | Saturn AS-502 vehicle |
| Saturn V | countdown |



PREFACE

The purpose of this report is to present the evaluation results of the prelaunch countdown, powered flight, and orbital phase of the S-IVB-502 stage which was launched on 4 April 1968 as the third stage of the Saturn AS-502 vehicle.

This report was prepared in compliance with the National Aeronautics and Space Administration Contract NAS7-101. It is published in accordance with NASA Report MSFC-DRL-021, Contract Data Requirements, Saturn S-IVB Stage and GSE, dated 1 February 1968, Revision A, which delineates the data required from the McDonnell Douglas Astronautics Company.

This document was prepared by the Saturn S-IVB Test Planning and Evaluation Committee and coordinated by the Saturn S-IVB Project Office of the McDonnell Douglas Astronautics Company, Western Division.

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SECTION 1

INTRODUCTION

1. INTRODUCTION

1.1 General

This report presents the results of analyses that were performed by Douglas personnel on the countdown, launch, and flight of the Saturn S-IVB-502 stage.

This evaluation report also describes tests conducted at Kennedy Space Center (KSC), and pertinent modifications made to the S-IVB and related ground support equipment.

This report is authorized by NASA Contract NAS7-101, and is the final report on the S-IVB-502 by the Douglas S-IVB Test Planning and Evaluation Committee of the Missile and Space Systems Division (MSSD), Huntington Beach, California.

1.2 History

The S-IVB-502 was assembled at the Huntington Beach Space Systems Center. A checkout was performed on 10 May 1966, in the Vehicle Checkout Laboratory prior to shipping the stage to the Sacramento Test Center (STC) on 31 May 1966. The stage was installed in Beta Test Stand I on 6 June 1966, and was acceptance fired on 28 July 1966.

The auxiliary propulsion system (APS) modules were shipped to the manufacturing and assembly (M&A) building at STC for leak and functional checks. The APS modules were then transferred to the Gamma Complex and confidence fired on 19 July and 27 July 1966. After firing, the modules were returned to the M&A building for cleaning and purging prior to shipment to KSC with the S-IVB-502.

All objectives of the acceptance firing tests were successfully completed on 28 July 1966, and are outlined in Douglas Report No. DAC-56357, Saturn S-IVB-502 Stage Acceptance Firing Report, dated 28 September 1966 and in Douglas Report No. SM-37539, S-IVB-502 Stage Acceptance Firing 15 Day Report, dated August 1966.

After completion of acceptance firing tests, the stage was shipped to KSC and installed in the low bay of the Vehicle Assembly Building on 27 February 1967. After installation of the aft interstage and completion of low bay prelaunch checkout, the stage was transferred to the high bay and mated to the AS-502 launch vehicle. The AS-502 launch vehicle was transferred to Launch Complex 39A on 6 February 1968 and was launched at 12:00:01 Greenwich Mean Time (GMT) on 4 April 1968. Figure 1-1 presents significant checkout and test history dates.

The S-IVB ignited successfully and boosted the payload into an elliptical orbit. The S-IVB experienced four significant anomalies during flight.

- a. Cold helium leakage
- b. Propellant utilization LOX probe malfunction
- c. Failure of the hydraulic system to achieve system pressure for restart
- d. Failure of the J-2 engine to restart.

These anomalies and related investigations are summarized in section 2 of this report. Detail analyses of system performance and anomalies are evaluated in respective sections of this report.

Section 1
Introduction

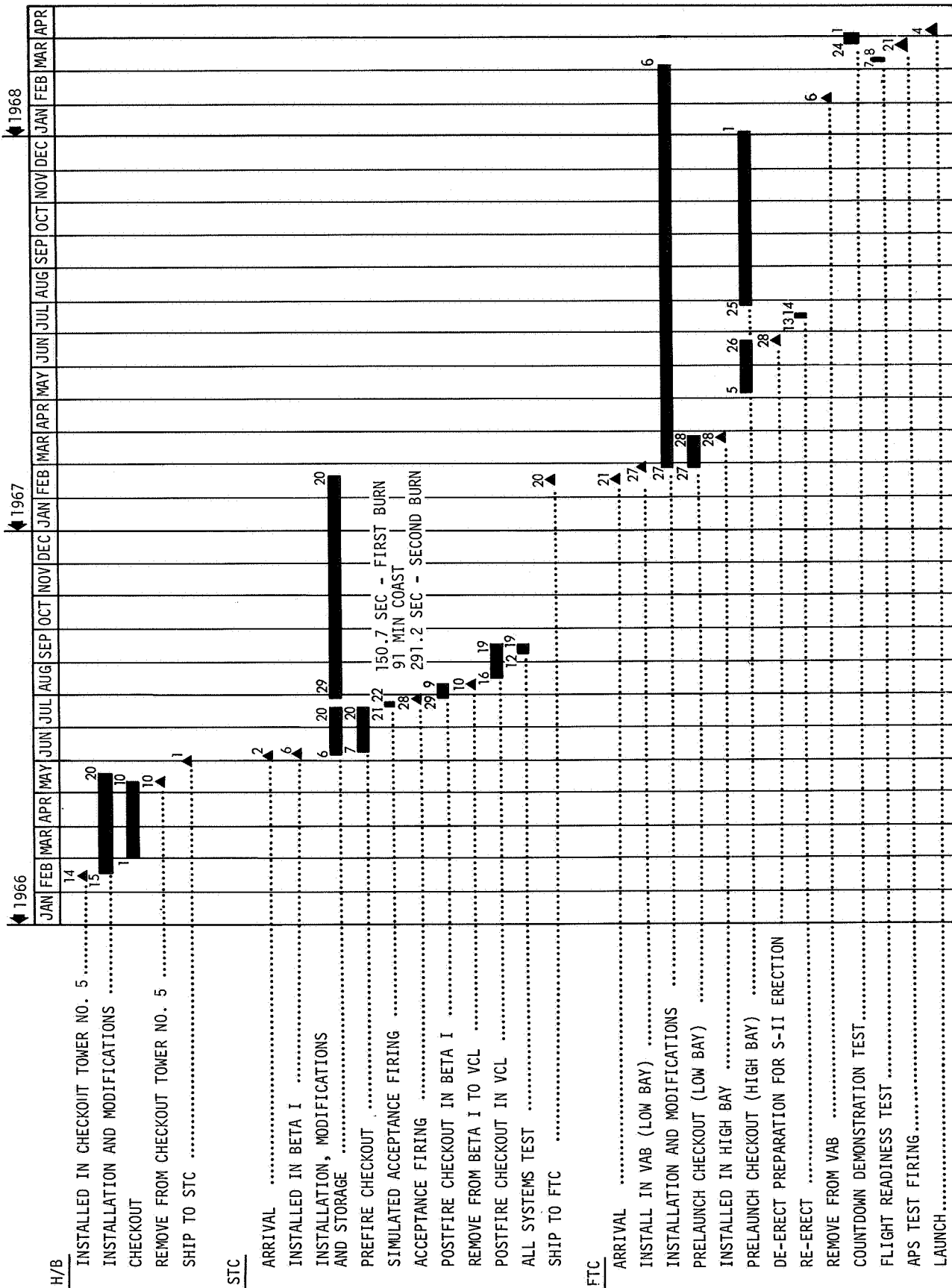


Figure 1-1. S-IVB-502 Stage Checkout and Test History

SECTION 2

FLIGHT DESCRIPTION

2. FLIGHT DESCRIPTION

2.1 Mission

The S-IVB-502 stage was the third stage of the Apollo-Saturn AS-502 Launch Vehicle which served as booster for the Apollo 6 Mission. AS-502 was the second research and development flight of the Saturn V launch vehicle. The payload consisted of a Lunar Test Article (LTA) and an unmanned Command and Service Module (CSM). It was planned that the launch vehicle would place the S-IVB/IU/LTA/CSM combination into approximately a 100 nmi circular parking orbit. During the second orbital pass over Kennedy Space Center (KSC), the S-IVB was to be reignited to inject the combination into a simulated translunar trajectory. After second burn engine cutoff, the CSM was to separate from the S-IVB/IU/LTA, perform a retrograde burn, and the command module was to re-enter and impact in the Pacific.

2.2 Countdown and Launch

After successful completion of the countdown demonstration test (CDDT) and recycle operations, the AS-502 launch countdown was initiated at 05:30:00 GMT on 3 April 1968. At initiation of the final countdown, all stage items with limited lifetimes had more than adequate life cycles remaining for the anticipated mission. The countdown was successfully completed with no major problems when the vehicle lifted from KSC Launch Complex 39A on 4 April 1968 at 12:00:01.69 GMT.

2.3 S-IC Powered Flight

2.3.1 Sequence of Significant Occurrences

| | |
|--|-----------------|
| GRR | RO -16.845 sec |
| RO (Nearest even second prior to first motion) | 12:00:01 GMT |
| IU umbilical disconnect (TB1) | RO +0.69 sec |
| Mach 1 | RO +60.5 sec |
| Max q | RO +75.2 sec |
| Peak Oscillations | RO +133 sec |
| IECO (TB2) | RO +144.949 sec |
| OECO (TB3) | RO +148.405 sec |

2.3.2 Vehicle Observations and Effects

The AS-502 vehicle lifted off with a launch azimuth of 90 deg, and following tower clearance, the vehicle executed a tilt and roll maneuver to achieve the desired 72 deg flight azimuth. The vehicle passed through mach 1 and maximum dynamic pressure without any apparent problem. Longitudinal oscillations (POGO) during S-IC boost after maximum q were approximately three times more severe than those experienced on the AS-501 flight. The severity of POGO oscillations resulted from all five engine thrust variations being inphase. At approximately RO +133 sec, significant perturbations occurred in a number of vehicle measurements. There

is photographic evidence of material separating from the spacecraft lunar module adapter (SLA) panels at this time (figure 2-1). The affected SLA section is located just above the lunar module attach plane. Additional information on this incident is presented in a NASA/MSC report entitled, Anomaly Report No. 6 - Unexpected Structural Indications During Launch Phase, unpublished as of this writing.

S-IC inboard and outboard engine sequence shutdowns were normal.

2.3.3 S-IVB Observations and Effects

2.3.3.1 POGO

During S-IC boost, the effects of POGO oscillations appeared in the S-IVB LH2 and LOX chilldown systems which exhibited flowrate and pressure oscillations. The effects were also noticed on the S-IVB aft bus No. 2 current, which reflects load changes due to the operation of the chilldown inverters and the auxiliary hydraulic pump. A 5.2 to 5.6 cps oscillation was detected by all of the S-IVB dynamic strain measurements on the forward skirt (S0086 through S0101), by two vibration measurements (E0091, Forward Field Splice, and E0092, Aft Separation Plane), by the forward skirt pitch and yaw body bending accelerometers (E0099 and E0100) and by the aft skirt pitch and yaw accelerometers (E0101 and E0102). The dynamic strain responses were generally inphase indicating that the vibration mode was primarily in the thrust axis. The longitudinal oscillations also appeared to be coupled with the body bending modes.

2.3.3.2 Unusual Indications at Approximately RO +133 Sec

Starting at approximately RO +123 sec, the aft bus No. 2 current (M0022), which supplies the chilldown inverters and auxiliary pump, started to increase from a nominal 76 amps to 80 amps at RO +128 sec. It remained at 80 amps until RO +133 sec and then rose to 84 amps. By RO +135 sec, it decreased to a nominal 76 amps.

S-IVB dynamic strain measurements, static strain measurements, pressure transducers, accelerometer measurements, and microphones responded to a sharp transient encountered at approximately RO +133 sec. Two forward skirt vibration measurements registered a +17 g response and the forward skirt static and dynamic strains made step changes in magnitude. These occurrences were accompanied by a decrease in indicated S-IVB/IU/SLA static pressure from 0.2 psi to zero psi. Also, the S-IVB pitch actuator pressure measurements registered a differential pressure spike of approximately 400 psid at RO +133 sec.

Available S-IVB data was analyzed to determine, if possible, the probable source of disturbances experienced by the launch vehicle at RO +133 sec. The analysis has eliminated the following possible sources of disturbance and verified that the observed perturbations did not originate on the S-IVB:

- a. The strain changes were not thermally induced since:
 - (1) The changes were too rapid to be from thermal effects.
 - (2) Ten temperature transducers in the forward skirt did not reveal any sudden or drastic changes in skirt temperatures.

- b. The strain changes were not inertially induced since vehicle accelerometer recordings were normal at RO +133 sec.
- c. The strain changes were not induced by sudden changes in gross mass or by sudden changes in engine thrust as indicated by the continuity and constant slope of the plotted curve from accelerometer readings.
- d. The strain changes were not induced by sudden changes in body bending moments since:
 - (1) The airloads were negligible at RO +133 sec.
 - (2) There was negligible engine gimbaling recorded at RO +133 sec.
 - (3) Body bending would be transient from engine gimbaling whereas the strain disturbances were substantially steady-state from RO +133 sec to center engine cutoff.
- e. The strain changes were not induced by faulty strain gage system electronics since:
 - (1) The data were carefully reviewed by electronic specialists with respect to steady voltages, shorts, gage debonding, wiring identifications, data transmission, data reduction, etc., and the data were evaluated as being valid.
 - (2) The pattern of strain changes at RO +133 sec was not the type expected of faulty electronics which would produce off-scale or zero readings or would result in all similarly wired gages shifting in the same direction by the same amount.
- f. The S-IVB forward skirt did not fail and cause the strain changes observed at RO +133 sec since:
 - (1) The strain gages continued to respond in a normal manner throughout the remainder of powered flight.
 - (2) The applied flight loads and temperatures did not exceed design loads and design temperatures.
 - (3) A detailed stress analysis using measured total strains in the forward skirt stringers indicated a minimum margin of safety of 97 percent.

For more detail information concerning S-IVB measurement responses and associated analyses during the S-IC boost phase, refer to sections 18, 19, 23, 25, and 26 of this report.

2.4 S-II Powered Flight

2.4.1 Sequence of Significant Occurrences

| | |
|---------------------------|-----------------|
| S-II Engine Start Command | RO +149.77 sec |
| S-II No. 2 ENG OUT | RO +412.9 sec |
| S-II No. 3 ENG OUT | RO +414.2 sec |
| S-II ECO (TB4) | RO +576.327 sec |

2.4.2 Vehicle Observations and Effects

During S-II boost, the No. 2 engine indicated abnormal operation which resulted in a launch vehicle digital computer commanded shutdown at RO +412.9 sec. Shutdown sequence for the No. 2 engine inadvertently shutdown the No. 3 engine as well since the engine circuits had been inadvertently crosswired during stage assembly. Flight control elected not to invoke flight mission rule No. 16 which requires direct staging following the shutdown of more than one S-II engine.

Engines No. 2 and No. 3 are adjacent engines located above the vehicle X-Y plane. The disturbing moment resulting from the shutdown of these engines caused the launch vehicle to assume a nose-up pitch attitude resulting in large deviations from the planned trajectory. Also, since iterative guidance mode (IGM) was programmed to operate with no more than one S-II engine out, a freeze of vehicle attitude commands was initiated, causing a nonoptimum flight path for the remainder of S-II flight. At S-II Engine Cutoff Command (ECC) the vehicle was deviating from the planned trajectory by being higher and slower than predicted.

2.5 S-II/S-IVB Separation

The separation transient in the pitch plane was considerably larger than that experienced on previous flights but was within the capabilities of the control system. This large separation transient was attributed to a large pitch attitude error existing at S-II/S-IVB separation as a result of having two engines out on the S-II. For more detailed separation information, refer to section 17 of this report.

During S-II/S-IVB separation, a 0.25 sec pulse was fired by the pitch engine on module 1. Since the APS was in a coast mode prior to initiation of burn mode, the APS pitch-yaw control was active and was attempting to correct for vehicle attitude error. This pulse had no adverse effect on lateral clearance during S-II/S-IVB separation.

At S-IVB Engine Start Command (ESC), the J-2 engine gimbaled from neutral to 6.3 deg in the pitch plane. During J-2 thrust buildup, this pitch angle increased to 6.7 deg. By the time J-2 engine thrust reached 90 percent, the engine was in the process of returning to a neutral position. This thrust vector control system (TVCS) maneuvering, like the auxiliary propulsion system (APS) response which preceded it, was a normal control system response to attitude errors accumulated during S-II boost. Although the S-IVB engine is gimbaled during all static firings, no engine start had been attempted with the engine in an extreme control position. An examination of engine start data did not reveal any start transient problems with the engine gimbaled to a hardover position.

Retrorocket performance during separation was nominal with good phasing of the thrust-time profiles. Retrorocket heating of the S-IVB structure was similar to that observed on AS-501, indicating only small differences in plume impingement. Calorimeters (C2000 and C2004) indicate that the heat flux to the J-2 engine was somewhat higher on AS-502 than on AS-501, but lower than that experienced on uprated Saturn I flights. The heat fluxes were within the maximum expected envelope. Detail aero/thermo information is provided in section 26.

2.6 S-IVB First Burn

2.6.1 Sequence of Significant Events

| | |
|-----------------------|-----------------|
| S-II/S-IVB separation | RO +577.079 sec |
| S-IVB ESC | RO +577.28 sec |
| S-IVB ECO (TB5) | RO +747.298 sec |

2.6.2 Trajectory

After separation, guidance commanded the S-IVB to assume a pitch-down attitude to correct for trajectory errors accumulated during S-II boost. The nose-down attitude was maintained until RO +645 sec, when the attitude was commanded nose-up. Trajectory simulations indicate that IGM performed as would be expected throughout first burn considering the greatly perturbed conditions at S-II/S-IVB separation.

2.6.3 Abnormal Measurement Occurrences

Between RO +599 and RO +694 sec, the LH2 turbopump vibration measurement (E0210) increased and reached an apparent value greater than the measurement range. By RO +706 sec, the vibration level returned to normal and continued at this level until S-IVB ECO. The RMS composite time history is shown in figure 25-2. Measurement E0210 has been classified as a failure since it is postulated that it was driven over band edge by a frequency outside of its intended response range. The magnitude of the actual vibration remains unknown, but since LH2 turbopump operation was completely normal, the response of this measurement cannot be considered as valid data (see paragraph 2.11.5 and table 18-4).

The corresponding vibration measurement on the LOX turbopump (E0211) was normal throughout first burn. Between RO +685 and RO +694 sec the vibration measurement on the combustion chamber dome (E0209) became erratic and failed. Continuous data was not available for any of the aforementioned vibration measurements because the information was telemetered on time shared channels.

The earliest significant indications of abnormal temperature were detected at approximately RO +635 sec, when the engine area temperature measurement C0010 began to indicate cooling trends. Ten seconds later, temperature pickup C2005 located on the engine main LOX pneumatic line began to cool abnormally.

After RO +645 sec, a number of other measurements also showed unexpected temperature and vibration response patterns. Attempts to correlate measurement patterns with one or more specific system failures have not been entirely successful. It is possible, however, to distinguish general trends which can be explained for the most part by assuming that there was a failure of the augmented spark ignitor (ASI) fuel feedline, which will be discussed in more detail later. General measurement trends are as follows:

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| <u>Time Period</u> | <u>Characteristics</u> |
|---------------------------|--|
| a. RO +645 to RO +695 sec | Temperature - Net Cooling Trend Vibration EO210 - Increases EO209 - Fails |
| b. RO +695 to RO +705 sec | Temperature - Net Heating Trend Vibration EO210 - Decreases |
| c. RO +705 to RO +715 sec | Temperature - Net Cooling Trend Vibration EO210 - Normal |

Table 2-1 summarizes the time sequence and temperature rates for the above measurement trends.

2.6.4 J-2 Engine Performance

The J-2 engine made a normal first burn engine start at RO +577.28 sec. Engine operation was normal and satisfactory until RO +682 sec, when performance began to decline. Engine performance stabilized by RO +702 sec after the following estimated performance degradation:

| | |
|------------------|-----------|
| Thrust | 6,200 lbf |
| Specific impulse | 9.5 sec |

From RO +702 sec to ECC performance remained essentially unchanged at the reduced level.

2.6.5 Source of Anomalous Conditions

Extensive investigation into the unusual occurrences encountered during S-IVB first burn has indicated that these effects resulted from a failure of the ASI fuel feedline (figure 2-2). This conclusion is supported by special testing covered in paragraph 2.11.2. It is not possible to identify, with complete confidence, the failure mechanism or the chronology of the failure, but the following hypothesis is in good agreement with recorded flight data and test results:

The failure began as a leak in the 1,200 psia ASI fuel feedline, possibly occurring as early as RO +617 sec. The leakage probably occurred at the upper bellows near the engine injector and resulted from fatigue cracks in the convolutions of the innercore produced by flow induced vibrations. LH2 efflux from the line produced a general cooling trend throughout the thrust structure area which was most pronounced between RO +645 and RO +695 sec. The effect of this leakage was a LOX-rich condition in the ASI chamber, which caused ASI chamber temperatures to increase. These increased temperatures could have resulted in damage to the ASI chamber and J-2 injector

head if the temperature increase was great enough and of sufficient duration. The amount of damage actually incurred, if any, could not be determined from the available data. The ASI fuel feedline leakage continued to increase until the line pressure was sufficiently reduced to cause a flow reversal at the ASI fuel inlet. This reversed flow exposed the ASI fuel feedline to hot combustion gases, resulting in a burn-through of the flex portion of the line. The hot combustion gases released by this burn-through produced the heating trend observed between RO +695 and RO +705 sec. After burn-through, the gases escaping from the ASI chamber were a combination of oxygen from the ASI LOX inlet and combustion products from the main chamber. Hydrogen and oxygen from the J-2 injector head may also have been present, depending on the amount of injector damage incurred prior to burn-through of the ASI fuel feedline. LH2 was also escaping from the lower portion of the burned-through ASI fuel feedline. The combination of all of these escaping gases produced a second general cooling trend in evidence after RO +705 sec. Because of the ruptured ASI fuel feedline, main chamber and gas generator (GG) pressures decreased, resulting in the J-2 engine performance shift previously mentioned. It is probable that RO +690 sec represents the approximate time of ASI fuel feedline burn-through. A detailed description of these occurrences including performance calculations, is provided in section 10 of this report.

Investigative analysis has eliminated the LOX ASI supply line as the possible source of anomalies. A summation of the analysis is presented in section 10 of this report. The investigative effort related to the LOX ASI supply line did reveal one case (S-IVB-508) at the Space Systems Center in which the LOX ASI supply line number identification had been etched beyond specification requirements. Corrective action was taken to eliminate the discrepancy and to guard against repetition on future stages.

2.7 S-IVB First and Second Orbits

Two anomalies were observed during orbit prior to the restart attempt.

2.7.1 Cold Helium Leakage

Between S-IVB first burn engine cutoff and the cold helium dump at RO +22,023 sec, a total of 129 lbm of helium usage could not be accounted for. This would calculate to be an average orbital leakage rate of approximately 0.4 lbm/min. As of this writing, the exact probable source of this leakage had not been determined. During the CDDT, a leak was detected at the cold helium vent port. The cold helium vent valve was cycled, and the leakage stopped. The cold helium vent valve on the dump module was not changed. A small leak (approximately 7 scim) was also detected at a conoseal flange in the cold helium

manifold during post-loading leak checks at KSC. This leak was stopped by retorquing the conoseal flange. Extensive mass decay checks, which were conducted after the CDDT with ambient helium at 950 psia, showed no mass decay. A mass decay check was also performed after fuel loading during the launch countdown; no leakage was noted.

Special tests (paragraphs 2.11.6 and 2.11.7) were conducted to determine if conoseal leakage could be induced by subjecting various flange sizes to temperature and vibration environments. While leakage did result in some instances, the evidence could not be considered conclusive.

The testing did reveal a large amount of torque relaxation on bolts and unions exposed to cold helium. Therefore, it will be proposed that on future stages, the torque be checked after every cold cycle of the system.

Teflon coated aluminum 7075 conoseal gaskets used in conjunction with titanium flanges were proved to be less susceptible to leakage than uncoated 6061 gaskets. An engineering change proposal (ECP) has been written to change all gaskets to teflon coated 7075.

In order to preclude transducer variations induced by severe thermal environments, an ECP has been written to relocate the transducer to a less severe environment for future flights.

2.7.2 PU Probe Problems

The LOX mass bridge operated normally during S-IVB-502 first burn. At approximately RO +10,800 sec (800 sec prior to restart), the LOX mass bridge indicated that the probe was completely filled with propellant. The PU electronics assembly (EA) calibration for S-IVB-502 would allow the coarse mass indication to read approximately 4.5 vdc and the fine mass indication to indicate approximately 2.2 vdc.

At RO +10,610 and RO +10,635 sec into flight, the LOX bridge in the PU EA began to slew at the maximum rate toward the full stop. The bridge recovered each time within 1 sec and operation returned to normal. At RO +10,660 sec, the LOX bridge again slewed at maximum rate to the full stop indicating an over-full indication. The LOX bridge remained in this position until data dropout which occurred at RO +10,880 sec. The next available data beginning at RO +10,960 sec shows the bridge had recovered at some period during data dropout. At RO +10,967 sec into flight, the LOX bridge again slewed at the maximum rate indicating an over-full condition. The bridge recovered within 3 sec and operation returned to normal. At RO +11,066, RO +11,072, RO +11,087, and RO +11,090 sec, the fine mass again indicated an anomaly by starting to slew towards the full stop at the maximum rate. Each of these malfunctions were of less than 1 sec duration. At RO +11,091 sec, the bridge again slewed at the maximum rate and this time reached the full mechanical stop of the output potentiometer. The bridge did not recover from this position for the remainder of the S-IVB flight.

There appear to be two possible causes for the PU system anomaly noted during the S-IVB-502 flight. These causes are:

- a. An intermittent open cable shield between the mass probe and the PU electronics assembly.
- b. Metallic particle(s) of some type in the LOX tank which caused a short between the inner and outer elements of the PU probe.

PU system operation was normal during first burn and the first appearance of the bridge anomaly occurred during orbiting conditions. Particle(s) in the tank during orbital conditions could be distributed anywhere in the tank and possibly lodge between the probe elements. As the PU system operation was normal during powered flight while the LOX mass probe and its associated cable and PU electronics assembly were under the highest vibration levels experienced during flight, the possibility of an intermittent open cable shield appears to be remote. Therefore, the most probable cause of the PU system anomaly was metallic particle(s) in the LOX tank shorting the inner and outer element of the LOX probe. A complete description of the PU probe malfunction is included in section 16 of this report.

2.8 S-IVB Attempted Restart

2.8.1 Sequence of Significant Events

| | |
|-------------------------------------|--------------------|
| Initiate restart preparations (TB6) | RO +11,287.733 sec |
| S-IVB ESC | RO +11,614.686 sec |
| S-IVB ECO (TB7) | RO +11,630.328 sec |
| Initiate spacecraft separation | RO +11,666.1 sec |

2.8.2 Restart Attempt

With satisfactory restart conditions a start command signal was given at RO +11,614 sec. The GG reached 250 psia and the main chamber pressure 40 psia. Spark plug operation was normal, but because of the ASI fuel feedline failure during first burn, the ASI chamber was unable to provide main chamber ignition. Absence of ignition in the main chamber was verified by lack of heat indications in the jacket and increased fuel injector temperature (CO200). Without ignition, there was no back pressure on the flow systems and the GG was unable to stabilize resulting in a GG overtemperature condition. At RO +11,630 sec the IU was unable to sense mainstage pressures and initiated spacecraft separation.

2.8.3 Hydraulic System

When the auxiliary hydraulic pump was activated at approximately RO +10,960 sec, it failed to build up system pressure. Aft bus No. 2 current drain for the pump was approximately 12.5 amps indicating that the pump was cavitating. At ESC2, the LOX turbine began to spin up and the engine driven (ED) pump reached approximately 45 percent of operating rpm. There was insufficient fluid pumped to increase system pressure or cause significant actuator movement, indicating that the ED pump was also cavitating. From an analysis of the data, it was determined that a blockage existed in the hydraulic fluid line between the accumulator reservoir assembly on the thrust cone structure and the ED pump inlet. The connecting line runs across the gimbal plane on position III. The blockage apparently resulted from frozen hydraulic fluid in the system. Based on an analysis of flight data and special test results (special testing is summarized in paragraph 2.11.9), it is considered very probable that LH2 which escaped from the ruptured ASI fuel feedline during first burn, caused the hydraulic system to freeze shortly after the auxiliary hydraulic pump was turned off. The system was still frozen when the S-IVB restart was attempted.

Details of the hydraulic system performance are presented in section 22 of this report.

2.8.4 Vibration Occurrence

The vibration measurement on the LH2 turbopump (E0210) indicated a vibration response starting at RO +11,623 sec. At RO +11,624 sec the signal level increased and exceeded band edge. After RO +11,625 sec, the measurement remained offscale high. For a more detailed description of the measurement failure see section 18.

2.9 Launch Vehicle/Spacecraft Separation

The launch vehicle spacecraft (LV/SC) separation was programmed to occur at TB7 +180 sec; however, due to failure of the S-IVB to restart, a ground command was issued to initiate LV/SC separation at TB7 +35.8 sec (RO +11,666.1 sec). The first detectable disturbances resulting from the LV/SC separation occurred at RO +11,667.85 sec, the time at which the separation ordnance was ignited. Telemetry data from both the CSM and S-IVB IU indicated unexpected disturbances were applied to both vehicles during the separation interval. From evaluation of the observed data, it was concluded that SLA panel 1 on position I failed to deploy properly during LV/SC separation possibly due to damage incurred during boost flight (incident occurring at RO +133 sec). Due to the failure of the SLA panel to deploy properly, a momentary interference or hang up with the spacecraft occurred which temporarily affected the motion of the launch vehicle as well as the spacecraft. However, the spacecraft separated successfully and the launch vehicle recovered from the momentary attitude deviation. See paragraph 21.2.5.5 for detailed separation information.

2.10 Post Separation

Following LV/SC separation, the auxiliary hydraulic pump was commanded ON two more times by ground command. Each time the hydraulic system failed to build up pressure and the current drain was 12.5 amps indicating that the pump was still cavitating.

S-IVB attitude control was maintained until approximately RO +22,053 sec when APS module 1 was depleted of propellant. Propellant depletion in module II occurred at approximately RO +22,630 sec. These depletions occurred earlier than normal because of the greater system demands resulting from high angular rates existing at S-IVB first and second engine cutoffs, and large propellant masses remaining after second engine cutoff. Nevertheless, attitude control was maintained beyond the required time period as is discussed in paragraph 7.1.

Details of APS performance and flight control are presented in sections 14 and 21, respectively.

Five days after the launch, photographs were obtained of the S-IVB/IU/SLA in orbit. Although photographic resolution was poor, the adapter panels appeared to be properly deployed, and the assembly appeared to be intact. Tracking data have shown that the S-IVB/IU/SLA remained intact until 9 days after the launch when the vehicle separated into about 15 pieces. At that time, the estimated loads, resulting from S-IVB angular rotation, exceeded the minimum strength of the attach strap fittings and the LTA support struts. Most of the pieces, including the adapter panels, entered the atmosphere within 4 days after the 13 April breakup. The S-IVB entered on 26 April 1968. The LTA is expected to remain in orbit until approximately August 1968.

2.11 Special Testing

A number of special tests were conducted to investigate the anomalies encountered in flight. The results of this testing are summarized below:

2.11.1 Low Pressure Transducer Vibration Test - Douglas/Santa Monica

Pressure transducer D0051, located in the S-IVB forward skirt (internal), registered a static pressure decrease from approximately 0.2 to 0 psi at approximately R0 +133 sec. Because of the small pressure values involved, it was suspected that the transducer might have responded to vibration rather than pressure. To investigate this possibility, a similar transducer was subjected to various vibration and pressure environments. Test results were as follows:

- a. The maximum response time required to release the transducer mechanical static friction pressure buildup was 70 ms. The maximum response time for a sudden pressure drop from 0.2 to 0 psia was 180 ms. The flight data were recorded every 250 ms. Therefore, it was possible for either a pressure drop or a static friction drop to occur during the flight since both drops occurred in less than 250 ms during the tests.
- b. Preflight and pretest calibrations on the flight and test transducers compared to test calibrations of the test transducers showed that age can increase the static friction buildup percentage. Based on test data and the latter fact, it was possible for the flight transducer to build up an indicated static friction pressure of 0.2 psi or greater.

It must be concluded that the tests were inconclusive since a response to either a static friction release or an actual pressure drop of 0.2 psi could have occurred in less than 250 ms.

2.11.2 Testing to Investigate J-2 Engine ASI Fuel Feedline Failures - Rocketdyne/Santa Susanna

A number of tests were conducted by Rocketdyne to investigate possible failure methods for the ASI fuel feedline. In one test, a leak in the ASI line was simulated by permitting fuel to flow from a tee junction, near the bellows back to the facility. After 10 sec of simulated leakage, fuel flow to the ASI line was terminated, which resulted in a burn-through of the ASI line and an engine performance shift. The amount of performance shift was less than occurred during the S-IVB-502 flight. In another test, fuel flow to the ASI chamber was restricted for approximately 20 sec after which the ASI LH2 flow was terminated completely and a burn-through of the ASI fuel feed line was simulated by opening a tee junction near the ASI chamber. Fire was observed to seep from the vicinity of the ASI chamber from the time the flow was reversed until termination of the engine test. Post-test inspection revealed considerable erosion of the ASI chamber, J-2 injector head, and gimbal block. Both the LOX and LH2 portions of the J-2 injector were eroded. The associated degradation in J-2 engine performance was somewhat comparable to that observed during the S-IVB-502 flight; however, ASI LH2 was not permitted to dump overboard as must have occurred during actual flight.

It was not possible in any of this testing to exactly simulate flight conditions; however, the testing did demonstrate that flow reversed at the ASI fuel inlet, and subsequent burn-through of the ASI fuel feedline could be produced by leakage in the ASI fuel feedline.

It was also demonstrated that leakage in the ASI fuel feedline could result in damage to the ASI chamber and J-2 injector head.

2.11.3 Testing to Investigate Possible ASI LOX Feedline Failure - Rocketdyne/Santa Susanna

A special test was also conducted to simulate failure of the LOX ASI feedline. The ASI oxidizer supply valve was closed and a line failure was simulated by opening a tee between the orifice and the ASI. Simultaneously, a tee valve was opened between the main oxidizer valve and the ASI to simulate leakage. When line failure was simulated, hydrogen backflowed through the ASI and an explosion occurred. Cause of the explosion has not been determined, and the test results are considered inconclusive.

2.11.4 Investigation of Flexible Metal Hose and Bellows Critical Resonant Conditions - Douglas/Santa Monica

Various worse case J-2 component metal flex hose and bellows are to be subjected to various flowrates to determine critical resonant conditions and to establish additional confidence in present system application. Testing was begun on 14 May 1968 and is in progress as of this writing.

2.11.5 Vibration Test of LH2 Turbopump Accelerometer, and Cable Assembly - Douglas/Santa Monica and Huntington Beach

The instrumentation cable for the LH2 turbopump lateral accelerometer measurement (E0210) passed through a clip on the ASI fuel feedline and then entered a bundle of wires also containing the instrumentation cable for the J-2 dome accelerometer measurements (E0209) on the S-IVB. This arrangement can be seen in figure 2-2. The nature of this physical arrangement and the anomalous behavior reported in paragraph 2.6.3 led to speculation that E0210 and E0209 may have responded to vibrations of the ASI fuel feedline or to sudden changes in the temperature environment rather than to actual vibrations in the LH2 turbopump and J-2 engine. To investigate this possibility, an accelerometer and cable system identical to that used for E0210 was vibrated at levels simulating the S-IVB-502 flight environment while being subjected to the following environmental conditions:

- a. Ambient temperature.
- b. Non-turbulent LN2 spray on accelerometer and cable.
- c. Turbulent LN2 on accelerometer and cable.
- d. Pouring LN2 on accelerometer and cable.
- e. Heated cable to 2,400 deg F.
- f. Heated cable to 600 deg F.

The output of the flight type transducer system was monitored during this testing. The testing was unable to simulate or reproduce the anomalous conditions experienced in flight on E0210. The failure of E0209 was simulated by shorting out the cable.

Additional testing of the transducer system was conducted including the 245 multiplexer, single sideband (SSB) and ground support demultiplexer equipment. The system response was recorded on magnetic tape which was used to generate power spectral density (PSD) plots. These plots were compared to those constructed from flight data. Overdriving by high frequency random signal (4,000 Hz to 12,000 Hz) did not duplicate characteristics observed on the flight data. Severe overdriving of the amplifier using low frequency random signal (20 to 2,000 Hz) resulted in distortion of the SSB wave shape. PSD plots of this response exhibited very similar characteristics to those obtained from the flight data. Summarizing, severe overdriving of the amplifier by high levels of low frequency random signal simulated the flight data recovered from S-IVB-502.

2.11.6 S-IVB-505N Special Cold Helium Leak Test - Douglas/Sacramento

Special cold helium leak tests were conducted at Sacramento Test Center (STC), Beta Test Stand I, utilizing S-IVB-505N. The test objectives were to obtain confidence in the cold helium system in support of S-IVB-503N launch activities, and to investigate possible leak sources with respect to cold helium leakage experienced during the S-IVB-502 flight. Examination of overall test results revealed that cold helium leakage was quite small and no information was obtained that would explain the abnormal loss of cold helium during the S-IVB-502 flight. The testing did reveal that bolts and unions exposed to cold helium are subject to a significant amount of torque relaxation.

2.11.7 Conoseal Flange and Gasket Vibration and Low Temperature Testing - Douglas/Santa Monica

Conoseal flanges and gaskets were subjected to vibration and low temperature environments to gain data related to S-IVB-502 cold helium leakage. Similar to the testing at STC, a significant amount of torque relaxation was experienced with cold helium components.

Teflon coated aluminum 7075 gaskets used in conjunction with titanium flanges were found to be less susceptible to leakage than uncoated 6061 gaskets.

2.11.8 PU Connector Assembly Temperature and Pull Test - Douglas/Santa Monica

There were three different types of electrical connectors used on the S-IVB-502 between the PU probe and the PU computer. To investigate the PU system anomaly, the three types of connectors were subjected to constant pull forces of 1, 2, 4 and 8 lbf under the following environmental conditions:

Deutsch Connectors

- a. High temperature soak at 160 deg F for 2 hr.
- b. Low temperature soak at -310 deg F for 3 hr.

Bendix Connectors

- a. High temperature soak at 160 deg F for 2 hr.
- b. Low temperature soak at 30 deg F for 1 hr.

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The tests were conducted on 32 samples at a time, and continuity was monitored continuously on two 16 channel oscillographs. Upon completion of the low temperature soak, the connectors were subjected to a pull test to destruction. Half of the connectors were pulled at low temperature and half were pulled at room temperature. Results of the test showed that several samples indicated intermittencies and discontinuities during various phases of the test. The cause of the intermittencies and discontinuities is unknown. However, it was observed that all the properly assembled connectors exhibited no discontinuities at any time.

Additional tests were also conducted on 36 samples of Deutsch connectors similar to the aforementioned tests, but with the addition of a flame test. For the flame test, the connectors were heated with an acetylene torch to an estimated 2,500 deg F temperature. No anomalies were revealed during this additional testing at any time, and the samples did not indicate any loss of continuity during the flame test.

2.11.9 Special Hydraulic Testing - Douglas/Santa Monica

A special test was conducted at Santa Monica to determine susceptibility of the hydraulic system to freezing when exposed to cryogenics. Test results indicated that the system will not freeze under conditions of fluid flow, but will become frozen approximately 85 sec after termination of flow when subjected to liquid nitrogen. With the return line frozen, the auxiliary pump current measured 12.5 amps similar to the current level experienced in flight.

2.12 Conclusions

Perturbations experienced by the launch vehicle during S-IC boost at about R0 +133 sec did not originate on the S-IVB. Although POGO oscillations during S-IC boost were more severe than expected, there is no known connection between these occurrences and S-IVB anomalies experienced later in flight.

S-II/S-IVB separation was successfully completed without collision. Control system response was normal for conditions which existed at the time of separation.

Four S-IVB anomalies were experienced in flight:

- a. J-2 engine performance degradation during first burn and failure of the engine to restart.
- b. Cold helium leakage.
- c. PU LOX probe malfunction.
- d. Failure of the hydraulic system to develop pressure during the attempted restart.

Failure of the S-IVB to restart during the second revolution as well as the J-2 engine performance shift and the unusual measurement occurrences during first burn are attributed to a failure of the ASI fuel feedline. It should be emphasized that if a failure of the

ASI fuel feedline should reoccur on some future mission, there is no assurance that the first burn would be successfully completed. Premature shutdown of the S-II No. 2 engine was attributed by North American Rockwell Corporation to a failure of the No. 2 engine ASI fuel feedline, but there is no known connection between the S-II and S-IVB engine failures. Every effort must be made to preclude a repetition of ASI fuel feedline failures. There was no evidence during the S-IVB flight of malfunction in the LOX ASI feedline, but in view of the nature of the ASI fuel feedline problems, additional investigation and testing of both ASI feedlines is necessary to insure a high degree of confidence in this system for future missions. This effort is in progress at Rocketdyne.

Source of the reported cold helium leakage remains unknown, but the investigation did reveal the necessity of torque checks after every cold cycle of the system. Relocation of the pressure transducers to a less severe environment should eliminate any instrumentation problems which might have resulted from severe temperature environment. Additionally, all conoseal gaskets in the system will be changed to teflon coated 7075 aluminum.

The most probable cause of the PU system anomaly was metallic particles in the LOX tank shorting the inner and outer element of the LOX probe. A method is being investigated to guard against this type of electrical short and to minimize the possibility of metallic particles in the system for future stages.

The S-IVB hydraulic anomaly resulted from cryogenic leakage associated with the ASI fuel feedline failure during first burn. The following hardware changes were considered with the realization that cryogenic leaks can occur during future flights:

- a. Insulate lines to protect them from hot or cold fluid impingement.
- b. Multiple thermal switches to initiate flow and protect from cold condition.
- c. Redundant path fluid lines.

The contractor's position is that redesign of the hydraulic system, in an attempt to preclude freezing from leaking cryogenic fluids is impractical because there is no definition of the extent of the leak or how long it would persist.

The solution is to redesign the ASI fuel feedline (which has been done) to guard against the possibility of any future leaks.

2.13 Mission Objectives

Douglas considers the SA-502 Launch Vehicle Mission Directive prepared by the Saturn V Test Office, Marshall Space Flight Center, Huntsville, Alabama, dated April 26, 1966, as the official document for providing identification and control of launch vehicle mission requirements. Eleven of the 16 primary objectives and both of the secondary objectives, as defined in the mission directive, directly involve the S-IVB. The SA-502 mission objectives are summarized and discussed in table 2-2.

Section 2
Flight Description

TABLE 2-1 (Sheet 1 of 2)
MEASUREMENT RESPONSE TRENDS

| MEASUREMENT GROUP | | MEASUREMENT | TREND AS-502 | RATE DEG F/SEC | |
|--|--|----------------------------------|------------------------------|----------------|--------|
| | | | | AS-502 | AS-501 |
| A 645 to 695 sec net cooling | C0010 | Eng area temp | Cooling | -0.80 | 0 |
| | C0050 | ED hyd pump oil inlet | Heating | +0.05 | +0.13 |
| | C0087 | Thrust struct - position I | Cooling | -0.35 | +0.05 |
| | C0088 | Thrust struct - position I-IV | Cooling | -0.20 | -0.10 |
| | C0152 | LOX main supply line flange wall | Cooling | -0.65 | -0.07 |
| | C0153 | LOX main support line | - | 0 | +0.05 |
| | C0154 | LOX prevalue bypass wall | - | 0 | +0.03 |
| | C0203 | Pitch act oil temp | Cooling | -0.05 | 0 |
| | C0204 | Yaw act oil temp | Cooling | -0.05 | 0 |
| | C0275 | Gas, interstage area | Cooling | -2.36 | -0.08 |
| | C2005 | Eng main pneumatic line | Cooling | -6.40 | +0.20 |
| | C2013 | LH2 turbine manifold ext wall | Less heating | +1.75 | +2.50 |
| | C2014 | LH2 turbine collector ext wall | Heating | +5.50 | 0 |
| | C2037 | GG LOX boot strap | Cooling | -0.46 | 0 |
| | E0209 | J-2 dome vibration | Fails | | |
| | E0210 | LH2 turbopump vibration | Increase and becomes clipped | | |
| | B 695 to 705 sec net heating | C0010 | Eng area temp | Heating | +30.7 |
| C0050 | | ED hyd pump oil inlet | - | 0 | +0.30 |
| C0087 | | Thrust struct - position I | Heating | +2.50 | +0.05 |
| C0088 | | Thrust struct - position I-IV | Heating | +0.50 | 0 |
| C0152 | | LOX main supply line flange wall | Off-scale high | Failed | -0.005 |
| C0153 | | LOX main support line | Heating | +0.78 | +0.05 |
| C0154 | | LOX prevalue bypass wall | Heating | +0.22 | +0.03 |
| C0203 | | Pitch act oil temp | Cooling | -0.05 | 0 |
| C0204 | | Yaw act oil temp | Cooling | -0.10 | 0 |
| C0275 | | Gas, interstage area | Heating | +25.6 | -0.08 |
| C2005 | | Eng main pneumatic line | Cooling | -7.10 | 0 |
| C2013 | | LH2 turbine manifold ext wall | Less heating | +1.00 | +3.50 |
| C2014 | | LH2 turbine collector ext wall | Heating | +4.00 | 0 |
| C2037 | | GG LOX boot strap | Heating | +16.70 | 0 |
| E0210 | | LH2 turbopump vibration | Decreases to normal | | |

TABLE 2-1 (Sheet 2 of 2)
MEASUREMENT RESPONSE TRENDS

| MEASUREMENT GROUP | | MEASUREMENT | TREND AS-502 | RATE DEG F/SEC | |
|--|-------|----------------------------------|----------------|----------------|--------|
| | | | | AS-502 | AS-501 |
| C 705 to 715 sec net cooling | C0010 | Eng area temp | Off-scale low | Failed | 0 |
| | C0050 | ED hyd pump oil inlet | Heating | +2.90 | +0.30 |
| | C0087 | Thrust struct - position I | Cooling | -1.80 | +0.05 |
| | C0088 | Thrust struct - position I-IV | Cooling | -0.25 | 0 |
| | C0152 | LOX main supply line flange wall | Off-scale high | Failed | -0.005 |
| | C0153 | LOX main support line | Heating | +0.41 | +0.05 |
| | C0154 | LOX prevalve bypass wall | Cooling | -0.10 | +0.03 |
| | C0203 | Pitch act oil temp | Cooling | -0.10 | 0 |
| | C0204 | Yaw act oil temp | Cooling | -0.40 | 0 |
| | C0275 | Gas, interstage area | Cooling | -5.00 | -0.08 |
| | C2005 | Eng main pneumatic line | Cooling | -5.00 | 0 |
| | C2013 | LH2 turbine manifold ext wall | Less heating | +1.00 | +2.00 |
| | C2014 | LH2 turbine collector ext wall | Heating | +3.00 | 0 |
| | C2037 | GG LOX boot strap | Cooling | -0.21 | 0 |
| | E0210 | LH2 turbopump vibration | Normal | | |

TABLE 2-2
MISSION OBJECTIVES SUMMARY

| PRIMARY OBJECTIVES | S-IVB MISSION ACCOMPLISHMENT |
|---|---|
| 1. Demonstrate the S-IVB restart capability. | Objective not achieved. The J-2 engine failed to restart (sections 2 and 10). |
| 2. Demonstrate the adequacy of the S-IVB CVS while in earth orbit. | Objective achieved. |
| 3. Demonstrate the capability of the S-IVB auxiliary propulsion system during S-IVB powered flight and orbital coast periods to maintain attitude control and perform required maneuvers. | Objective achieved. |
| 4. Demonstrate the S-IVB propulsion system including the propellant management systems, and determine inflight system performance parameters. | Objective partially achieved. The propulsion system suffered performance degradation during first burn and failed to restart. The LOX PU probe malfunctioned in the second orbit prior to restart (sections 2, 10, & 16). Inflight system performance parameters were evaluated. |
| 5. Demonstrate S-II/S-IVB separation. | Objective achieved. |
| 6. Demonstrate structural and thermal integrity of launch vehicle throughout powered and coasting flight, and determine inflight structural loads and dynamic characteristics. | Objective achieved. |
| 7. Determine inflight launch vehicle internal environment. | Objective achieved. |
| 8. Demonstrate the launch vehicle guidance and control system during S-IVB powered flight, achieve guidance cutoff and evaluate system accuracy. | Objective partially achieved. The main and auxiliary hydraulic pumps cavitated during the attempted restart. If restart had occurred, the thrust vector control system may have been inoperative. |
| 9. Demonstrate launch vehicle sequencing | Objective achieved. |
| 10. Evaluate performance of the emergency detection system in a closed-loop configuration. | Objective achieved. |
| 11. Demonstrate compatibility of the launch vehicle and spacecraft. | Objective achieved. |
| SECONDARY OBJECTIVES | MISSION ACCOMPLISHMENT |
| 1. Determine launch vehicle powered flight external environment. | Objective achieved. |
| 2. Determine attenuation effects of exhaust flames on RF radiating and receiving systems during main engine, retrorocket and ullage rocket firings. | Objective achieved. |

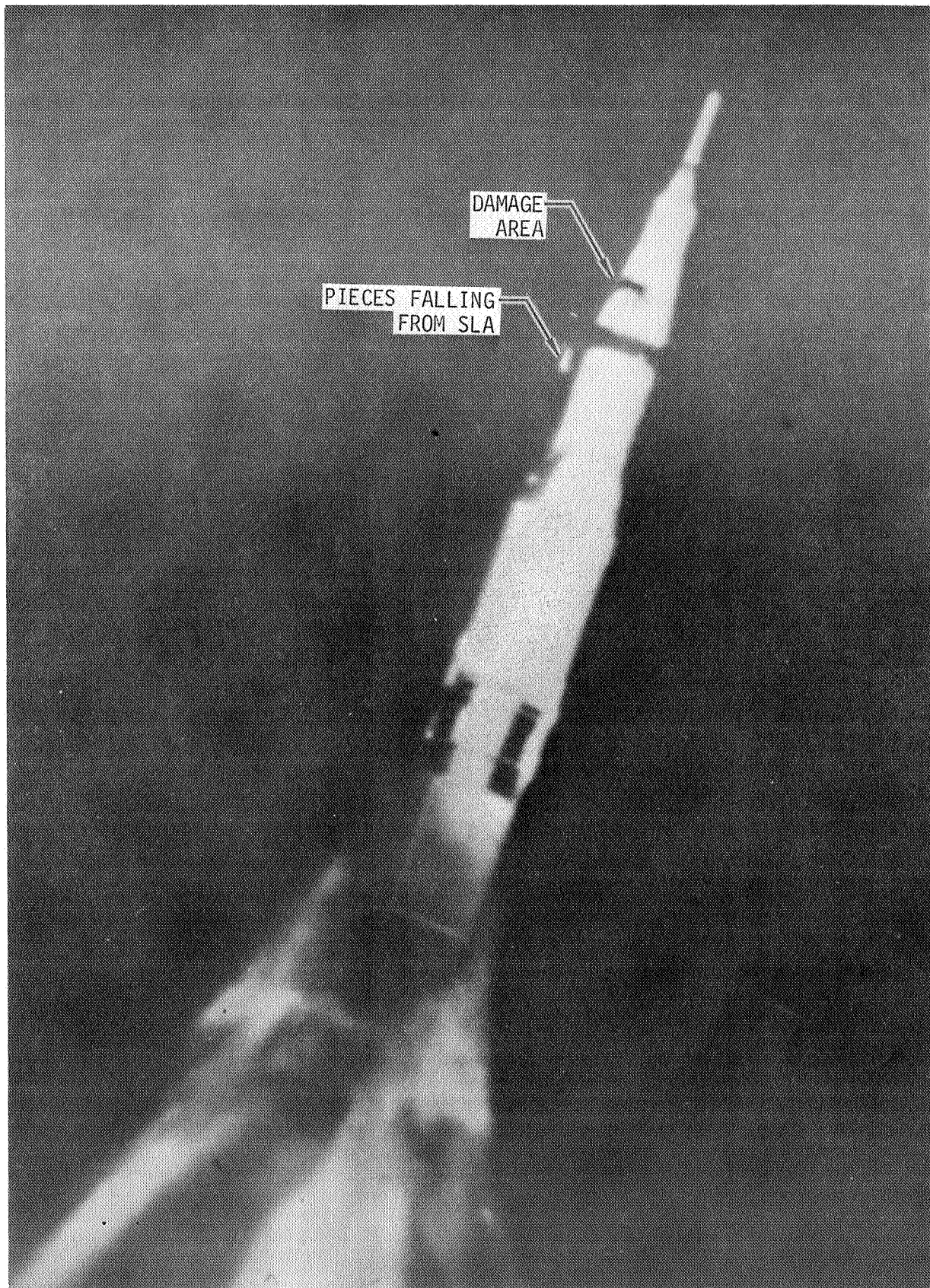


Figure 2-1. AS-502 Launch Vehicle at R0 +133.54 Sec

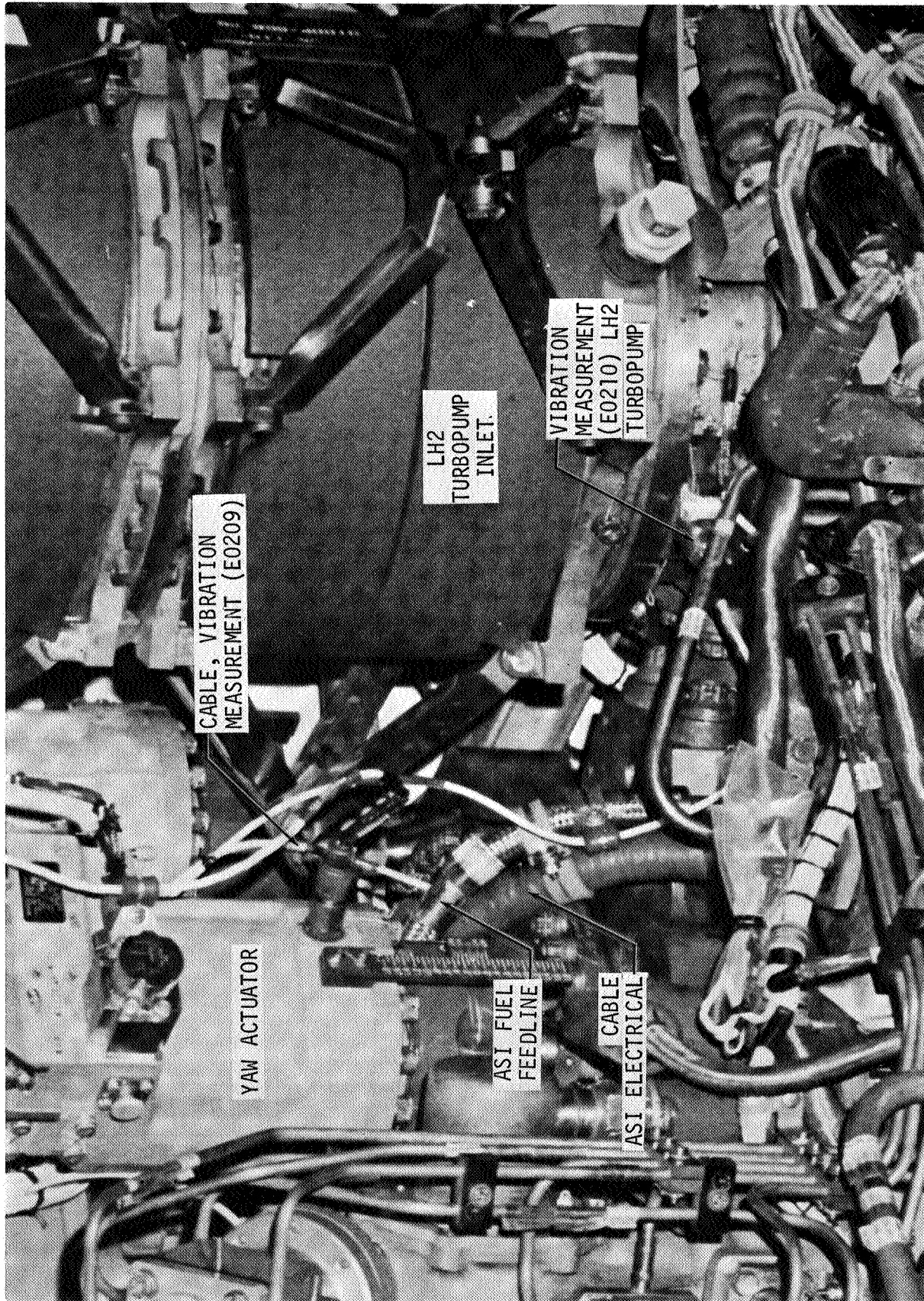


Figure 2-2. S-IVB-502 ASI Fuel Feedline

SECTION 3

SUMMARY

3. SUMMARY

The AS-502 was launched from Kennedy Space Center (KSC), Complex 39A, at 12:00:01.69 GMT on 4 April 1968. Performance of the Douglas built S-IVB stage was satisfactory during count-down and boost, although a slight degradation in J-2 engine performance occurred during first burn. Subsequent analysis disclosed that the performance degradation was caused by a failure of the J-2 engine augmented spark ignitor (ASI) fuel feedline. The S-IVB first burn time was extended because of two premature engine shutdowns on the Saturn V second stage booster. The orbit achieved deviated from that predicted by approximately +94 nmi at apogee and -6 nmi at perigee because of trajectory deviations accumulated during second stage boost. During orbital coast there was evidence of cold helium leakage, and the LOX propellant utilization (PU) probe malfunctioned, indicating off-scale high. Although conditions for restart were completely satisfactory, the earlier ASI fuel feedline failure precluded main chamber ignition. During the attempted restart, the hydraulic system failed to build system pressure or to accomplish significant actuator movement because of frozen hydraulic fluid blocking the system. Freezing of the hydraulic fluid has been attributed to the ASI fuel feedline failure during first burn.

3.1 Countdown Operations

No significant S-IVB or equipment problems occurred during the launch countdown activity, and Douglas ground support equipment (GSE) sustained no significant damage during liftoff.

3.2 Cost Plus Incentive Fee

The incentive evaluation of the AS-502 flight performance includes flight mission accomplishment and telemetry performance. Performance of the S-IC and S-II stages provided preconditions of flight (PCF) at S-II/S-IVB Separation Command that were outside of allowable tolerances. Due to failure to achieve restart of the S-IVB stage, end conditions of flight (ECF) at translunar orbit injection were not attained. Pitch attitude error and rate exceeded allowable tolerance early in S-IVB first burn. It was concluded for incentive purposes: PCF were outside of allowable tolerances; S-IVB flight was prematurely terminated because of J-2 engine failure (not the fault of Douglas); acceptable ECF would have been achieved if proper PCF had existed and the J-2 engine had functioned properly. The telemetry system operated at 98.3 percent efficiency during the telemetry performance evaluation period (TPEP) phase I and 97.6 percent efficiency during TPEP phase II.

3.3 Trajectory

The AS-502 trajectory deviated greatly from predicted, due to anomalies experienced during the boost to parking orbit. As a result of a rupture of the fuel ASI line at approximately R0 +690 sec, the S-IVB engine failed to reignite, and second burn was not achieved.

Until approximately R0 +413 sec the trajectory of the AS-502 was close to predicted. At this time the shutdown of two S-II engines began. Since the iterative guidance mode (IGM) was programmed to operate with no more than one S-II engine out, a non-optimum trajectory

resulted for the remainder of S-II flight, causing trajectory conditions at S-II/S-IVB separation to deviate greatly from predicted. These off-nominal conditions at separation were responsible for an overspeed at S-IVB engine cutoff, where the velocity was 160.2 ft/sec greater than the target velocity. S-IVB burntime was 30.8 sec longer than predicted because of the non-optimum S-II burn.

The AS-502 parking orbit was elliptical, with an apogee altitude of 194.4 nmi and a perigee altitude of 93.5 nmi. The longer period of the elliptical orbit caused restart preparations to occur 214 sec later than predicted. Second burn was not achieved.

3.4 Mass Characteristics

The S-IVB-502 stage flight mass characteristics that appear in section 9 and appendix 1 of this document are best estimate mass characteristics for the first burn and computed from available data for restart attempt. The total vehicle mass at first burn Engine Start Command was 354,232 \pm 476 lbm and 265,234 \pm 400 lbm at first burn Engine Cutoff Command.

3.5 Engine System

The J-2 engine did not meet all objectives during the AS-502 mission. The augmented spark ignitor fuel feedline failed during first burn and resulted in engine performance degradation and subjected the thrust structure to environmental changes. Because of the failure, fuel was prevented from reaching the ignitor for restart and the environmental changes prevented the hydraulic system from functioning properly.

3.6 Solid Rockets

The solid rocket motors on the S-II and S-IVB stages performed satisfactorily and accomplished their intended purpose. The S-II was separated from the S-IVB by the retrorockets, and the S-IVB propellants were settled prior to engine ignition by the ullage rockets.

3.7 Oxidizer System

The oxidizer system performed adequately, supplying LOX to the engine pump inlet within the specified operating limits throughout J-2 engine operation. The available NPSP at the LOX pump inlet exceeded the engine manufacturer's minimum requirement at all times. Ambient helium repressurization of the LOX tank was satisfactorily accomplished. Because of leakage, the cold helium sphere pressure decreased 518 psi between first burn engine cutoff and second burn Engine Start Command, but the supply would have been adequate for normal second burn operations.

3.8 Fuel System

The fuel system supplied LH2 to the engine as designed, and the NPSP exceeded the engine manufacturer's minimum requirement at all times. The LH2 tank was satisfactorily repressurized by a normal ambient helium repressurization cycle. Because of ullage pressure collapse, a second cycle was required shortly before second burn Engine Start Command.

3.9 Auxiliary Propulsion System

The auxiliary propulsion system (APS) fulfilled the attitude control, maneuvering, and ullaging requirements of the mission until APS propellant depletion. The APS propellant usage was greater than predicted as a result of booster problems encountered during the mission. All flight objectives were accomplished, and both modules performed satisfactorily except that the pitch engine chamber pressure of both modules was low at various times during the mission.

3.10 Pneumatic Control and Purge System

The pneumatic control and purge system performed satisfactorily throughout the flight. The helium supply was adequate to meet all mission requirements and to accomplish all purges; the orbital leakage rate was near zero. The only deviation was late initiation of the engine pump purge, but this was not a fault of the pneumatic system components and did not detrimentally affect the mission.

3.11 Propellant Utilization

The propellant utilization system successfully accomplished the requirements associated with propellant loading and first burn propellant management. Prior to the restart attempt a malfunction was experienced by the LOX mass measurement system and would probably have resulted in improper PU system operation had second burn operation been achieved.

The loading system performed loading of the S-IVB to 100.07 and 99.88 percent of desired load for LOX and LH2 respectively. The required stage loading inaccuracy is ± 1.39 percent. First burn PU system operation was entirely nominal with the PU valve at the LOX rich (full closed) stop. Proper operation of the PU electronics slosh filter was exhibited by a non-response of the PU system valve to first burn propellant slosh.

3.12 S-II/S-IVB Separation Dynamics

The S-II/S-IVB separation was accomplished satisfactorily within the desired time period. Separation was initiated at R0 +577.079 sec; it was completed 0.99 sec later.

The S-II and S-IVB angular velocities and lateral accelerations utilized 6.7 in. of the available 83 in. of lateral clearance. The engine gimbal position at the time of separation utilized an additional 12 in. The S-II rates were all approximately 0 deg/sec at first motion. A combination of engines two and three being out on the S-II stage and a possible retrorocket misalignment caused the pitch and yaw rates to increase to 2 deg/sec and 0.95 deg/sec by separation complete. The S-II roll rate remained approximately zero throughout separation. The S-IVB rates were all small with pitch and yaw rates remaining below 0.2 deg/sec and the roll rate remaining below 0.5 deg/sec.

3.13 Data Acquisition System

Data acquisition system performance during the mission was excellent, and is summarized as follows:

| | |
|---|-------|
| Measurements assigned | 616 |
| Measurements monitored by S-II | 4 |
| Measurements inoperative due to stage configuration | 1 |
| Checkout measurements | 11 |
| Measurements deleted prior to flight | 9 |
| Measurements prevented from being transmitted | |
| Phase I | 0 |
| Phase II | 3 |
| Measurements active for flight | |
| Phase I | 591 |
| Phase II | 588 |
| Phase I measurement failures | 10 |
| Phase I measurement efficiency | 98.3% |
| Phase II measurement failures | 14 |
| Phase II measurement efficiency | 97.6% |

The RF system blackout period during S-IC/S-II separation was not evaluated because the airborne tape recorder playback data were not recovered. Data loss was observed at R0 +149.23 for 0.83 sec. Flame attenuation was not observed during S-II/S-IVB separation.

Tape recorder performance was satisfactory. It recorded all analog data on fast record, PCM data on slow record, and played it back on command.

3.14 Electrical System

The electrical control system, with the exception of the PU system and the electrical power system, performed satisfactorily. All responses to switch selector commands were satisfactory with 17 nonprogrammed commands initiated to command the S-IVB from the Carnarvon, Hawaii, and Guaymas ground stations. All event measurements verified that the engine control system had responded properly to the Engine Start Command and Engine Cutoff Commands given for first burn and for the restart attempt. All telemetry event measurements of engine performance occurred in the proper sequential order. The APS electrical control system performed within prescribed limitations. All batteries performed within expected limits. The chill-down inverters performed satisfactorily for first burn and for the restart attempt. Both 5 v excitation modules performed satisfactorily. The static inverter/converter operated within design limits with the exception of the 5 vdc output. The out-of-tolerance performance did not affect operation of the PU control system.

3.15 Range Safety System

The range safety system was not required for propellant dispersion during the flight. All indications were that the system was operating properly and would have properly executed its function had it been called upon to do so.

3.16 Flight Control

The thrust vector control system (TVCS) responded satisfactorily to instrument unit command signals providing pitch and yaw control during S-IVB first burn. The separation transient in the pitch plane was considerably larger than that experienced on previous flights but was within the capabilities of the control system. This large separation transient was attributed to a larger pitch attitude error existing at S-II/S-IVB separation. The TVCS responded normally during this interval and provided adequate control following S-II/S-IVB separation.

The auxiliary attitude control system (AACS) provided satisfactory roll stabilization during powered flight and satisfactory pitch, yaw, and roll control during orbit. During S-II/S-IVB separation, a 0.3 sec pitch AACS firing (engine I_p) occurred commencing with the S-II/S-IVB Separation Command and terminating with the S-IVB Burn Mode ON Command. The design characteristics of the flight control computer resulted in a temporary transfer to the S-IVB coast mode between the S-II/S-IVB Separation Command and the S-IVB Burn Mode ON Command. The noted temporary S-IVB coast mode and subsequent pitch AACS firing although undesirable was not detrimental. This occurrence is normal for a Saturn V vehicle and may happen on any or all missions.

All orbital maneuvers were accomplished as planned, and vehicle attitude control was verified until approximately R0 +22,040 sec (Hawaii - fourth revolution) at which time the yaw angular rate began diverging to approximately -7.5 deg/sec followed by an oscillatory vehicle motion. AACS propellant depletion and a LOX vent occurring near this time accounted for the diverging angular rate. Depletion of AACS propellants and subsequent loss of attitude control at this time is much earlier than expected for a nominal mission, however, this is reasonable when considering the relatively large and unexpected demands on the attitude control system, particularly following first burn engine cutoff and following the attempted restart and launch vehicle/spacecraft (LV/SC) separation.

3.17 Hydraulic System

The S-IVB hydraulic system performance was satisfactory from liftoff to the end of first burn, although some system temperature data were abnormal during first burn. The temperature abnormalities resulted from a failure of the augmented spark igniter (ASI) fuel feedline as discussed in sections 2, 10, and 26. The pitch actuator experienced a large excursion during S-II/S-IVB separation, which was a normal system response to guidance commands.

When the auxiliary hydraulic pump was activated in preparation for second burn, it failed to build system pressure and current drain was approximately 12.5 amps indicating that the pump was cavitating. The engine driven pump also cavitated and failed to build system pressure or cause significant actuator movement. Data analysis has indicated that the system failure resulted from frozen hydraulic fluid in the system. Apparently the ASI fuel feedline rupture during first burn released cryogenics which caused the hydraulic system to become frozen shortly after the auxiliary pump was turned off. The system was

still frozen when the restart was attempted. Following launch vehicle/spacecraft separation, the auxiliary pump was commanded on two more times and each time the system failed to build pressure and current drain was 12.5 amps indicating that the pump was still cavitating.

3.18 Stage Structure and Environment

Strain, acceleration, pressure, and temperature data indicated that adequate structural strength existed in the stage for the conditions encountered. During S-IC stage boost at R0 +133 sec, the S-IVB experienced an unusual load redistribution in the forward skirt as indicated by strain gage measurements at skirt stringers. This load redistribution was evident throughout the remainder of the high axial loads of first stage boost to CECO (Center Engine Cutoff) at R0 +144 sec. The combined loads from the load redistribution and from unusually severe 5 1/2 cps longitudinal (POGO) vibrations were within the structural capability of the forward skirt. The load distribution to the aft skirt was normal but included the 5 1/2 cps longitudinal (POGO) vibrations. The anomaly experienced by the forward skirt at R0 +133 sec is attributed to sudden changes in structure located above the forward skirt, and the character and causes of these structural changes are being reported in a special report by NASA, referenced in paragraph 23.1.

S-IVB body bending moments and skin differential pressures were less than the maximum predicted values due to moderate winds. Vehicle axial accelerations were close to predicted values except for the structurally noncritical anomaly of two S-II engines cutting out prematurely at about R0 +414 sec. Axial loads were in agreement with computed loads from liftoff to approximately R0 +60 sec. Beyond this time, the axial load values computed from stringer strain gage data appear to be low apparently because of aerodynamic heating and because of a partial integration resulting from the limited number of instrumented stringers. Flight temperatures did not exceed maximum predicted temperatures. Propellant tank pressures did not exceed design pressures, and differential pressures on the common bulkhead were as expected. Common bulkhead internal pressure remained substantially constant at less than 1 psia as predicted.

3.19 Environmental Stage Systems

The stage environmental control systems functioned satisfactorily throughout the preflight and flight periods.

3.20 Acoustic and Vibration Environment

The acoustic and vibration amplitudes were generally similar to those measured on the AS-501 flight. The dynamic strain levels were higher than those measured on the AS-204 flight; however, there were no indications of panel flutter.

The POGO amplitudes were higher than those measured on the AS-501 flight. There were no adverse effects on the S-IVB due to POGO.

3.21 Aero/Thermodynamic Environment

The aero/thermodynamic evaluation of the S-IVB-502 stage indicated that the aerodynamic heating environment was as expected, propellant heating was nominal, and the APS and the

forward and aft skirt mounted electrical components were within their thermal limits. The boost phase pressure environment was nominal except for an apparent pressure drop in the forward compartment which occurred 133 sec after liftoff. A test was performed on pressure transducers identical to that flown to determine if the noted pressure drop was real or a mechanical friction release in the instrument. The test was inconclusive due to flight data limitations. In support of the J-2 engine restart problem, the thermal environment was defined in the thrust structure engine area covering the time period from the J-2 first burn engine start through the restart attempt.

SECTION 4

TEST CONFIGURATION

4. TEST CONFIGURATION

The general configuration and those stage and ground support equipment (GSE) modifications and deviations that were necessitated by parts shortages or other exigencies are briefly described in this section. The details of specific system modifications are discussed in the appropriate sections of this report.

Figure 4-1 is a schematic of the S-IVB-502 propulsion system and shows the locations of the telemetry instrumentation from which the test data were obtained. Figure 4-1 also lists the functional components except those in the APS system, which are shown on the APS schematic. Figure 4-2 shows the locations of the major propulsion components. Tables 4-1 and 4-2 present the propulsion system orifice characteristics and pressure switch settings. The propulsion GSE is shown in figure 4-3.

4.1 General Configuration

The general configuration of the S-IVB-502 is described in Douglas Report No. SM-46999, S-IVB-502 Stage Flight Test Plan, dated 23 October 1967. This stage was equipped with a Rocketdyne 200,000 lb-thrust engine, serial number (S/N) J-2042; additional stage information is presented in the following documents:

- a. Douglas Report SM-47378B, Saturn S-IVB-502 Stage Acceptance Firing Test Plan, dated April 1966, revised 5 August 1966
- b. Douglas drawing 1B63789B, S-IVB-502 Stage End Item Test Plan, dated 22 July 1966
- c. Douglas Report DAC-56353, Narrative End Item Report on Saturn S-IVB-502 (DAC S/N 1006), dated September 1966
- d. Douglas Report No. SM-47184, Saturn S-IVB/IB Range Safety Report, dated 19 November 1965, revised 28 February 1966.

4.2 Stage and Hardware Modifications

The significant modifications that were accomplished on the S-IVB-502 at the Florida Test Center are briefly described in table 4-3. The GSE modifications are described in table 4-4.

Section 4
Test Configuration

TABLE 4-1 (Sheet 1 of 2)
S-IVB-502 AND GSE FLIGHT ORIFICES

| FIND NO. * | DESCRIPTION | ORIFICE SIZE OR NOMINAL FLOWRATE | COEFFICIENT OF DISCHARGE | EFFECTIVE AREA (in. ²) | FIND NO. * | DESCRIPTION | ORIFICE SIZE OR NOMINAL FLOWRATE | COEFFICIENT OF DISCHARGE | EFFECTIVE AREA (in. ²) |
|------------|---|----------------------------------|--------------------------|------------------------------------|------------|---|----------------------------------|--------------------------|------------------------------------|
| | S-IVB-502 Stage | | | | | | | | |
| 12 | LH2 chilldown valve purge | 14 scfm with 3,200 psid | -- | Sintered | 47 | LH2 tank repressurization module outlet | 0.3124 in. dia | 0.86 | 0.0665 |
| 16 | Continuous vent bypass valve bellows purge | 300 scfm with 3,200 psid | -- | Sintered | 48 | LH2 tank nonpropulsive vent purge | 1 scfm with 3,200 psid | -- | Sintered |
| 17 | Continuous vent bypass valve switch cavity purge | 15 scfm with 3,200 psid | -- | Sintered | 49 | LH2 tank nonpropulsive vent No. 1 | 2.180 in. dia | -- | -- |
| 19 | Continuous vent No. 1 | 1.090 in. dia | -- | 0.92 | 50 | LH2 tank nonpropulsive vent No. 2 | 2.180 in. dia | -- | -- |
| 20 | Continuous vent No. 2 | 1.090 in. dia | -- | 0.92 | 61 | LOX chilldown pump purge | 37 scfm with 490 psid | -- | -- |
| 21 | Continuous vent purge | 1 scfm with 3,200 psid | -- | Sintered | 61A | LOX chilldown pump purge bypass | 10 scfm with 475 psid | -- | Sintered |
| 23 | LH2 fill and drain valve purge | 15 scfm with 3,200 psid | -- | Sintered | 73A | LOX sensing line purge | 1,728 scfm with 3,200 psid | -- | Sintered |
| 29 | LOX fill and drain valve purge | 15 scfm with 3,200 psid | -- | Sintered | 91 | LOX tank vent and relief valve | 65 scfm with 3,200 psid | -- | Sintered |
| 39 | LOX tank pressurization module, heat exchanger primary | 0.196 | 0.89 | 0.0268 | 119 | LOX tank ambient repressurization | 0.036 | -- | 0.00864 |
| 40 | LOX tank pressurization module, heat exchanger bypass | 0.166 | 0.89 | 0.0192 | 120A | Engine purge control module | 0.0180 in. dia | -- | -- |
| 44 | LH2 tank pressurization module (Overcontrol - second burn) | 0.2055 in. dia** | 0.85 | 0.1008*** | Al12119 | Stage 1 regulator dome vent | 0.018 in. dia | -- | -- |
| 45 | LH2 tank pressurization module (Undercontrol) | 0.330 in. dia | 0.85 | 0.0726*** | Al12120 | Stage 1 regulator 3,100 psig dome loading | 0.018 in. dia | -- | -- |
| 46 | LH2 tank pressurization module control (Overcontrol - first burn) | 0.2054 in. dia** | 0.85 | 0.1008*** | Al1852 | APS helium supply and purge | 0.027 in. dia | -- | -- |
| | | | | | Al1841 | Console 432A GN2 inerting supply | 0.031 in. dia | -- | -- |
| | | | | | Al1779 | Mainstage OK pressure switch checkout, coarse (used with Al12054) | 0.025 in. dia | -- | -- |

*Indicates location in figures 4-1 and 4-3.

**Indicates diameter of overcontrol orifice or step orifice only.

***Discharge coefficient and effective area are calculated for overcontrol or step orifices in combination with the undercontrol orifice.

TABLE 4-1 (Sheet 2 of 2)
S-IVB-502 AND GSE FLIGHT ORIFICES

| FIND NO. * | DESCRIPTION | ORIFICE SIZE OR NOMINAL FLOWRATE | COEFFICIENT OF DISCHARGE | EFFECTIVE AREA (in. ²) | FIND NO. * | DESCRIPTION | ORIFICE SIZE OR NOMINAL FLOWRATE | COEFFICIENT OF DISCHARGE | EFFECTIVE AREA (in. ²) |
|------------|--|----------------------------------|--------------------------|------------------------------------|------------|--|----------------------------------|--------------------------|------------------------------------|
| Al12054 | Mainstage OK pressure switch checkout, fine | 0.025 in. dia | -- | -- | Al1954 | Cold helium sphere pressurization supply (same orifice as above) | 0.0114 in. dia | -- | -- |
| Al1824 | LH2 system checkout supply, fine | 0.016 in. dia | -- | -- | Al1912 | LOX umbilical purge supply | 0.305 in. dia | -- | -- |
| Al1820 | LH2 system checkout supply, coarse (used with Al1824) | 0.016 in. dia | -- | -- | Al1908 | Umbilical purge supply vent | -- | -- | Variable |
| Al1837 | LOX system checkout supply, fine | 0.016 in. dia | -- | -- | Al2143 | Stage 3 regulator inlet | 0.018 in. dia | -- | -- |
| Al1836 | LOX system checkout supply, coarse (used with Al1837) | 0.016 in. dia | -- | -- | Al2152 | Stage 3 regulator outlet bleed | 0.0022 lbm/min | -- | Sintered |
| Al1748 | Console 432A stage 1 bleed | -- | -- | Variable | | Heat Exchanger 438A | | | |
| Al2113 | Stage 4 regulator vent | -- | -- | Variable | Al2106 | Circuit No. 1 upstream vent (primary) | 0.081 in. dia | -- | -- |
| Al1793 | Pressure switch checkout, low pressure, fine | 0.025 in. dia | -- | -- | Al2117 | Circuit No. 1 downstream vent (secondary) | 0.055 in. dia | -- | -- |
| Al1792 | Pressure switch checkout, low pressure, coarse (used with Al1793) | 0.025 in. dia | -- | -- | Al1971 | LH2 tank prepressurization supply | 0.113 in. dia | -- | 0.00853 |
| Al2078 | Stage 2 regulator vent | -- | -- | Variable | Al2234 | GH2 regulator dome bleed | 0.0003 lbm/min | -- | Sintered |
| | Pneumatic Console 433A | | | | | | | | |
| Al1886 | 2,000 psig cold purge purge valve supply | -- | -- | Variable | | | | | |
| Al1897 | 750 psig cold purge valve supply | -- | -- | Variable | | | | | |
| Al1937 | Thrust chamber jacket purge and chilldown supply | 0.072 in. dia | -- | 0.00347 | | | | | |
| Al1946 | Engine control helium sphere supply | 0.125 in. dia | -- | -- | | | | | |
| Al1954 | LOX tank prepressurization supply (located in model 315 aft umbilical kit) | 0.0114 in. dia | -- | -- | | | | | |

*Indicates location in figures 4-1 and 4-3.

TABLE 4-2
S-1VB-502 PRESSURE SWITCH CHECKOUT DATA

| NOMENCLATURE | SPECIFICATION | PICKUP (psia)* CALIPS | DROPOUT (psia)* CALIPS | DEADBAND (psia) CALIPS |
|--|--|--------------------------|---------------------------|---------------------------|
| LOX tank ullage P/N 1B52624-503 Serial No. 023 | Pickup: 41 psia max Dropout: 38 psia min Deadband: 0.5 psi min | 40.6 | 39.3 | 1.3 |
| LOX chilldown pump purge P/N 1B52624-503 Serial No. 020 | Pickup: 41 psia max Dropout: 38 psia min Deadband: 0.5 psi min | 40.1 | 39.2 | 0.9 |
| LOX tank regulator backup P/N 1B52624-509 Serial No. 021 | Pickup: 450-485 psia Dropout: 335-370 psia Deadband: None | 460 | 373 | 83 |
| Engine pump purge P/N 1B52623-515 Serial No. 012 | Pickup: 130 psia max Dropout: 105 psia min Deadband: 5 psi min | 122 | 114 | 8 |
| Control helium reg backup P/N 1B52624-517 Serial No. 023 | Pickup: 585-615 psia Dropout: 465-515 psia Deadband: None | 605 | 499 | 106 |
| LH2 tank ullage-2nd burn P/N 1B52624-501 Serial No. 008 | Pickup: 34 psia max Dropout: 31 psia min Deadband: 0.5 psi min | 33.8 | 32.2 | 1.8 |
| LH2 tank ullage-1st burn P/N 1B52624-511 Serial No. 010 | Pickup: 31 psia max Dropout: 28 psia min Deadband: 0.5 psi min | 31.2 | 29.6 | 1.6 |
| Mainstage OK No. 1 P/N 308390 Serial No. 25324 | Pickup: 50 +5 psig Dropout = Pickup minus 75 +25 psig | 496 | 431 | 65 |
| Mainstage OK No. 2 P/N 308390 Serial No. 25254 | Pickup: 500 +15 psig Dropout = Pickup minus 75 +25 psig | 514 | 450 | 64 |

*These values are the average of three runs.

TABLE 4-3 (Sheet 1 of 2)
S-IVB-502 CONFIGURATION AND HARDWARE MODIFICATIONS

| ECP | WRO | DESCRIPTION | ECP | WRO | DESCRIPTION |
|-----------|------|---|---------|------|--|
| J2-470 R1 | 0223 | Redesigned pressure actuated purge control valve and fast shutdown valve, and added filter to inlet ports of both. | 0972 | 4011 | Substituted a P/N 1B52623-515 engine pump purge pressure switch for a 1B52623-513 switch. |
| J2-542 | 0538 | Replaced main oxidizer valve compensator to ensure operation at low temperature. | 0973 | 4018 | Corrected mating reference designations of exploding bridge wire (EBW) connectors. |
| J2-567 | 0223 | Replaced start sphere discharge valve. | 0975 | 4029 | Eliminated cable clamp to provide slack in wire harness to allow proper installation of forward battery 1, unit 2. |
| J2-568 | 0223 | Replaced start sphere and relief valve. | 0978 | 4091 | Replaced existing fiberglass thermal spacers under panel-mounted actuation control modules in the aft skirt with larger outside diameter spacers. |
| J2-592 | 0223 | Replaced helium high pressure relief valve with one that has more resistance to vibration and additional moisture protection. | 0979 | 4093 | Installed cover plates over all uncovered connector cutouts located on forward skirt electrical feedthrough in area of main tunnel. |
| J2-594 R3 | 0223 | Redundant instrumentation, critical pressure measurements. | 0983 | 4129 | Replaced the LOX chilldown shutoff valve, P/N 1A49965-525, with P/N 1A49965-529-013. |
| J2-599 R1 | 0223 | Replaced MOV thermal compensator orifice plate. | 0985 | 3940 | Replaced the first burn flight control pressure switch, P/N 1B52624-1, with P/N 1B52624-511. |
| J2-606 R1 | 4058 | Replaced timer in electrical control assembly (ECA) package. | 0986 | 3941 | Added offset bracket for pressure switch line clamping. |
| J2-607 | 0223 | Replaced vent port check valve. | 2073 R1 | 3240 | Applied protective coating to the aluminum parts of the hydraulic actuators. |
| J2-620 R1 | 0223 | Modified oxidizer pump primary seal drain line. | 2078 R1 | 3327 | Added a low thermal emissivity shroud between the forward skirt cold plates and the stage structure. |
| 0592 R3 | 3031 | Deleted APS helium fill module. | 2103 | 3387 | Redesigned LOX tank pressurization lines and installed supports to eliminate unnecessary line connections and thus lighten hardware. |
| 0622 R3 | 2901 | Replaced 10-amp relay modules with redesigned 1A74218-509 modules. | 2130 R1 | 3291 | Conducted eddy current test of cold helium bottles that were fabricated with titanium alloys using filler wire to verify filler material was of same composition as vessel parent metal. |
| 677 R1 | 3241 | Added a redundant relay for 70-pound ullage engine start. | 2143 R1 | 3356 | Changed printed circuit board connectors in Model 270 multiplexer to correct a connector mismatch. |
| 0951 R3 | 4100 | Elimination of cable clamps on wire harness to the retrorocket pressure transducers. | 2170 | 3368 | Modified retrorocket nose fairing bulb seal to prevent water from entering the interstage cavity. |
| 0953 R1 | 3132 | Added clamps to the ullage rocket jettison system confined detonating fuse (CDF) to take up slack in the CDF. | 2175 | 3372 | Added a continuous bypass bleed to the LOX chilldown pump container purge line to assure positive pressure in the motor container in event of solenoid failure. |
| 0958 R1 | 3918 | Added orifice caps to APS module ullage vent ports to prevent excessive decay of APS propellant tank ullage pressure during system venting. | | | |
| 0963 R1 | 3971 | Relocated cable clamp on Rocketdyne augmented spark ignitor (ASI) line support bracket. | | | |
| 0964 | 3144 | Replaced pneumatic control system helium sphere, P/N 1A49990-503, with a P/N 1A49990-505. | | | |

TABLE 4-3 (Sheet 2 of 2)
S-IVB-502 CONFIGURATION AND HARDWARE MODIFICATIONS

| ECP | WRO | DESCRIPTION | ECP | WRO | DESCRIPTION |
|---------|------|--|---------|------|--|
| 2180 R2 | 3519 | Replaced LOX relief valve with a redesigned valve with greater poppet shaft strength. | 2597 | 3901 | Reinforced the main and auxiliary tunnel clips with bonded fiberglass doublers. |
| 2189 R3 | 3408 | Reworked the LH2 PU probe to supplement the spotwelds holding the outer sleeve and mounting ring together. | 2605 R1 | 3991 | Added three temperature sensors to the J-2 engine LOX bootstrap line. |
| 2218 R1 | 3746 | Changed the interface bolt holes at S-IVB/V station 2519 to accommodate 3/8-in. bolts. | 2614 R1 | 3935 | Relocated pressure transducers for D0181-409 and D0182-409 to provide thermal isolation. |
| 2224 R3 | 3711 | Added panel flutter instrumentation to the forward skirt. | 2621 | 3956 | Replaced the LOX tank pressurization control module, P/N 1B42290-505, with a module in which the Belleville spring had been installed after August 1967. |
| 2235 R1 | 3510 | Replaced, in the 2-amp relay modules used in flight critical applications, the 1B50992 relays that had had thermal cycle tests with high reliability relays P/N 1B66899. | 2628 | 3951 | Replaced the PU bridge potentiometer with one that had received a shock test. |
| 2259 | 3692 | Relocated the engine-driven hydraulic pump discharge temperature measurement and changed number from C0218-401 to C2029-401. | 2630 | 3954 | Removed the orifice from the inlet of the actuation control module. |
| 2278 R1 | 3583 | Replaced ambient helium bottles, P/N 1A49990-503, with P/N 1A49990-507 bottles. | 2633 R1 | 3962 | Replaced orifice, P/N 1B63437-501, in the LH2 tank pressurization system with one of larger size to permit the ambient helium supply pressure to drop below 300 psi in 265 sec. |
| 2405 R1 | 3795 | Installed temperature transducers externally on the LH2 and LOX chilldown inverter cases. | 2634 | 3961 | Replaced the LH2 tank pressurization control module assembly, P/N 1B64443-505, with a calibrated module assembly, P/N 1B66230-505, containing the new sized undercontrol orifice. |
| 2425 R1 | 3756 | Installed a teflon overboard line for the J-2 engine LOX pump primary seal cavity drain to accommodate Rocketdyne ECP NA-J2-620 R2. | 2645 R1 | 3960 | Removed the line from the pneumatic power control module regulator backup calip pressure switch calip port and installed a cap on the port. |
| 2454 | 3776 | Replaced the range safety safing plug with one that was rewired to isolate and prevent talkback. | 2646 | 3969 | Replaced the eight fiberglass LH2 tank external temperature sensors with sensors of ceramic construction. |
| 2480 R1 | 3805 | Replaced the APS control relay packages, P/N 1B57731-1, by ones that were redesigned by the vendor to P/N 50M35076-2. | 2652 | 3980 | Changed the PU component oven to one that had been fabricated in conformance with MSFC-PROC-158A. |
| 2487 | 3718 | Installed S-II retrorocket motors of a new type to reduce the possibility of burnout. | 2696 | 4015 | Replaced the LOX tank pressurization system orifice, P/N 1B63437, with a P/N 1B64052-503 orifice. |
| 2572 | 3873 | Added a moisture seal to the tunnel disconnect connector for the LOX PU system. | 2706 | 4008 | Replaced the LH2 tank pressurization diffuser tube 1B55512-1 and nylon diffuser 1B65814-1 with a configuration that incorporates the internally baffled, slotted tube design and a 1B65813-1 cylindrical nylon diffuser. |
| 2583 R2 | 3893 | Modified and added to the existing Korotherm ablative insulation. | 2708 | 4038 | Reduced the forward skirt vent area from 200 sq in. to 150 sq in. by adding doublers to each of the eight vents. |
| 2589 | 3907 | Replaced pressure switch, P/N 1B52624-507, with P/N 1B52624-517 after the 507 switch failed with excessive leakage. | | | |

TABLE 4-4
GSE MODIFICATIONS

| WRO | ECP | DESCRIPTION |
|---------|---------|--|
| | | <u>Model DSV-4B-315, Launch Aft Umbilical Kit</u> |
| 3932 | 0960 RI | Applied potting compound to plunger switch to prevent moisture from entering the switch housing. |
| 4099 | 0981 | Relocated clamping block to eliminate sideloads on the grounding plug and provide an improved ejection system. |
| 3937 | 2626 | Incorporated an improved balanced umbilical purge system. |
| 3039 | 0637 | Added hazardous gas monitor port bosses to the LH2 and LOX tank fill and drain disconnect assemblies to allow vehicle tank sampling and checkout. |
| 3047 | 0597 | Redesigned the ground half of the propellant fill and drain disconnects to reduce leakage. |
| 3172 | 2050 | Added a check valve in the purge vent port of the anti-debris valve to prevent moisture from entering the valve actuator cavity and thereby causing a failure. |
| | | <u>Model DSV-4B-316, Launcher Forward Umbilical Kit</u> |
| A41-256 | 0443 | Accomplished modification to accommodate the stage hazardous gas detection system. |
| 3440 | 2088 | Modified the umbilical carrier support legs to prevent inadvertent separation from the vehicle support bracket. |
| 3574 | 2253 | Installed spacers to prevent excessive leakage. |
| 3937 | 2626 | Incorporated an improved balanced umbilical purge system. |
| | | <u>Model DSV-4-303, Common Bulkhead Vacuum Monitor</u> |
| 3919 | 0966 | Modified cabinet by taping and caulking seams to maintain a static pressure of 2 in. of water. |
| | | <u>Model DSV-4B-432A, Pneumatic Console</u> |
| A41-245 | 0922 | Replaced the 0.68 in. orifice in the ambient helium pressurization line with a union. |
| 3023 | 0606 | Removed the pneumatic plumbing comprising the nitrogen and helium manifold vent system. |
| 3786 | 2459 | Modified cabinet by taping and caulking seams to maintain a static pressure of 2 in. of water. |
| | | <u>Model DSV-4B-433, Pneumatic Console</u> |
| 3967 | 0970 | Added seals to the connection of temperature transducers and the associated pneumatic lines. |
| | | <u>Model DSV-4B-438A, Gas Heat Exchanger</u> |
| A41-245 | 0909 | Installed a vent line from circuit No. 1 bleed hand valve to the vent line in GH2 control panel assembly. |
| 3107 | 0933 | Modified the LH2 pneumatic shutoff valve to provide for a GN2 purge of the microswitch. |
| 3237 | 2082 | Installed a check valve in the outlet of the LH2 tank pressurization supply vent valve. |
| 3500 | 2021 | Installed a protective cover over the vacuum probe on the heat exchanger inlet shroud. |
| 3786 | 2459 | Modified cabinet by taping and caulking seams as necessary to maintain a static pressure of 2 in. of water. |
| | | <u>Model DSV-4B-472, APS Fuel Installation Kit and Model DSV-4B-473, APS Oxidizer Installation Kit</u> |
| 3920 | 2611 | Replumbed the APS liquid level manometer system to eliminate trapped air, which causes flow restriction in the liquid level indicator. |

Section 4
Test Configuration

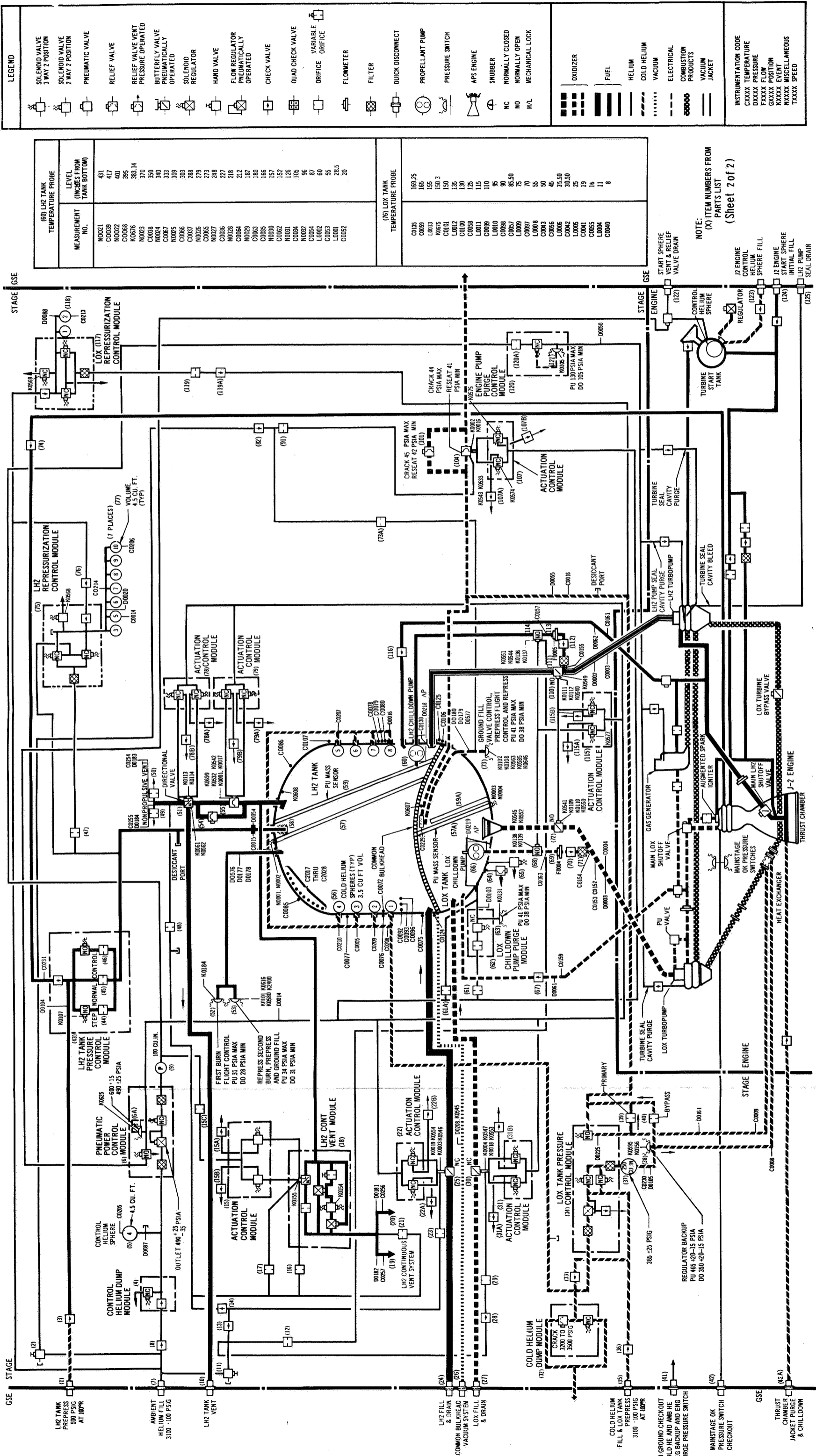


Figure 4-1. Propulsion System and Instrumentation (Sheet 1 of 2)

FOLDOUT FRAME 2

FOLDOUT FRAME

FOLDOUT FRAME 1

Section 4
Test Configuration

| FIND NO.* | PART NO. | NAME | FIND NO.* | PART NO. | NAME | FIND NO.* | PART NO. | NAME |
|-----------|-------------|---|-----------|----------------|---|-----------|-------------|---|
| 1 | 7851861-1 | Disconnect, LH2 tank pressurization | 34A | 1B67481-1 | Valve, check LOX tank pressurization regulator vent | 72 | 1A49968-507 | Prevalve, LOX |
| 2 | 1B53817-505 | Valve hand, LOX vent and relief valve purge | 35 | 7851844-501 | Disconnect, cold helium fill and LOX tank pressurization | 73 | 1B52624-503 | Switch, pressure, LOX tank pressurization, ground fill, repressurization and flight control, PU 41 psia max, DO 38 psia min |
| 3 | 1B65673-1 | Valve, check, LH2 tank pressurization line | 36 | 1B40824-503 | Valve, check, cold helium fill | 74 | 1B53920-501 | Orifice, LOX sensing line purge |
| 4 | 1A57350-507 | Module, control helium dump | 37 | 1A49991-1 | Plenum, LOX tank pressurization | 75 | 1B56653-513 | Module, LH2 repressurization control |
| 5 | 1A49990-503 | Sphere, control helium, 4.5 cu ft | 38 | 1B52624-509 | Switch, pressure, cold helium regulator backup, PU 465 +20, -15 psia, DO 350 +20, -15 psia | 76 | 1B51361-1 | Valve, check, LH2 repressurization control |
| 6 | 1A58345-519 | Module, pneumatic power control | 39 | 1B63046-525 | Orifice, LOX tank pressurization module, heat exchanger primary | 77 | 1B49990-503 | Valve, check, LH2 repressurization control module inlet |
| 6A | 1B52624-517 | Switch, control, helium regulator backup, PU 600 ±15 psia, DO 490 +25 psia | 40 | 1B63047-525 | Orifice, LOX tank pressurization module, heat exchanger bypass | 78 | 1B66692-501 | Sphere, LH2 repressurization, 4.5 cu ft |
| 7 | 7851823-503 | Disconnect, ambient helium fill | 41 | 1A49958-517 | Disconnect, ground checkout, cold helium, ambient helium, and engine purge pressure switches | 78A | 1B67481-1 | Module, actuation control, directional valve |
| 8 | 1B51361-1 | Valve, check, control helium fill | 42 | 1A49958-517 | Disconnect, mainstage OK pressure switch checkout | 78B | 1B67481-1 | Valve, check, directional valve actuation control module vent |
| 9 | 1A48857-1 | Plenum, control helium, 100 cu in. | 42A | 1A49958-519 | Disconnect, thrust chamber jacket purge and chilldown | 79 | 1B66692-501 | Module, actuation control, LH2 tank vent and relief valve |
| 10 | 1A48848-505 | Disconnect, LH2 ground vent | 43 | 1B64443-505 | Module, control, LH2 tank pressurization | 79A | 1B67481-1 | Valve, check, LH2 tank vent and relief valve actuation control module vent |
| 11 | 1B53817-505 | Valve, hand, LH2 chilldown valve, vent and relief valve, continuous vent, nonpropulsive vent, and fill valves purge | 44 | 1B64443-505** | Orifice, LH2 tank pressurization control (overcontrol - second burn) | 79B | 1B67481-1 | Valve, check, LH2 tank vent and relief valve actuation control module vent |
| 12 | 1B40622-507 | Orifice, LH2 chilldown valve purge | 45 | 1B64443-505** | Orifice, LH2 tank pressurization normal (undercontrol) | 82 | 1B51361-1 | Valve, check, LOX vent and relief valve and LOX tank sensing line purge |
| 13 | 1B51361-1 | Valve, check, LH2 fill and drain valve, continuous vent system and nonpropulsive vent purge | 46 | 1B64443-505** | Orifice, LH2 tank pressurization control (overcontrol - first burn) | 91 | 1B63206-1 | Orifice, LOX tank vent and relief valve purge |
| 14 | 1B51361-1 | Valve, check, continuous vent system, and nonpropulsive vent purge | 47 | 1B63437-507 | Orifice, LH2 tank pressurization module outlet | 101 | 1A49590-515 | Valve, relief, LOX tank, crack at 45 psia max, reset 41 psia min |
| 15 | 1B66692-501 | Module, actuation control, continuous vent bypass valve | 48 | 1B40622-501 | Orifice, LH2 tank nonpropulsive vent purge | 104 | 1A48312-505 | Valve, vent and relief, LOX tank, crack 44 psia max, reset 41 psia min |
| 15A | 1B67481-1 | Valve, check, continuous vent bypass valve actuation control module vent | 49 | 1A89881-501 | Orifice, LH2 nonpropulsive vent No. 1 | 107 | 1B66692-501 | Module, actuation control, LOX tank vent and relief valve |
| 15B | 1B67481-1 | Valve, check, continuous vent bypass valve actuation control module vent | 50 | 1A89881-501 | Orifice, LH2 nonpropulsive vent No. 2 | 107A | 1B67481-1 | Valve, check, LOX tank vent and relief valve actuation control module vent |
| 16 | 1B40622-509 | Orifice, continuous vent bypass valve bellows purge | 51 | 1A49988-1 | Valve, directional, LH2 tank vent | 107B | 1B67481-1 | Valve, check, LOX tank vent and relief valve actuation control module vent |
| 17 | 1B40622-505 | Orifice, continuous vent bypass valve switch cavity purge | 52 | 1B52624-1 | Switch, pressure, LH2 tank first burn flight control | 110 | 1A49968-509 | Prevalve, LH2 |
| 18 | 1B67193-507 | Module, continuous vent | 53 | 1B52624-513 | Switch, pressure, LH2 tank pressurization, ground fill and repressurization, PU 34 psia max, DO 31 psia min | 111 | 1B52985-501 | Filter, LH2 chilldown pump discharge |
| 19 | 1B44557-1 | Orifice, continuous vent No. 1 | 54 | 1A49991-523 | Valve, relief, LH2 tank, crack 38 psia max, reset 35 psia min | 112 | 1B53920-503 | Valve, check, LH2 chilldown pump discharge |
| 20 | 1B44557-1 | Orifice, continuous vent No. 2 | 55 | 1A48257-511 | Valve, LH2 tank vent and relief, crack 37 psia max, reset 34 psia min | 113 | 1A89104-509 | Flowmeter, LH2 chilldown pump discharge |
| 21 | 1B40622-501 | Orifice, continuous vent purge | 56 | 1A48858-1 | Sphere, cold helium, 3.5 cu ft | 114 | 1A49965-523 | Valve, shutdown, LH2 chilldown line |
| 22 | 1B66692-501 | Module, actuation control, LH2 fill and drain valve | 57 | 1A77907-503 | Probe, LH2 tank instrumentation | 115 | 1B66692-501 | Module, actuation control, chilldown valves and prevalves |
| 22A | 1B67481-1 | Valve, check, actuation control module vent, LH2 fill and drain valve | 57A | 1A48430-507 | Probe, LOX mass sensor | 115A | 1B67481-1 | Valve, check, chilldown and prevalves actuation control module vent |
| 22B | 1B67481-1 | Valve, check, actuation control module vent, LH2 fill and drain valve | 58 | 1B65812-1 | Diffuser, LH2 tank pressurization | 115B | 1B67481-1 | Valve, check, chilldown and prevalves actuation control module vent |
| 23 | 1B40622-505 | Orifice, LH2 fill and drain valve purge | 59 | 1A48431-501 | Probe, LH2 instrumentation | 116 | 1A49964-501 | Valve, check, LH2 chilldown return |
| 24 | 1B66932-501 | Disconnect, LH2 fill and drain | 59A | 1A69275-503 | Probe, LOX mass sensor | 117 | 1B56653-513 | Module, control, LOX tank repressurization |
| 25 | 1A48240-505 | Valve, LH2 fill and drain | 60 | 1A49421-503 | Pump, LH2 chilldown | 118 | 1A49990-505 | Sphere, LOX tank ambient repressurization, 4.5 cu ft |
| 26 | 1B41065-1 | Disconnect, common bulkhead vacuum system | 61 | 1A48854-1 | Orifice, LOX chilldown pump purge | 119 | 1B64052-503 | Orifice, LOX tank ambient repressurization module outlet |
| 27 | 1B66932-501 | Disconnect, LOX fill and drain | 61A | 1B40622-511 | Orifice, LOX chilldown pump purge bypass | 119A | 1B40824-505 | Valve, check, LOX repressurization module outlet |
| 28 | 1B51361-1 | Valve, check, LOX fill and drain valve purge | 62 | 1A58347-505 | Module, LOX chilldown pump purge | 120 | 1A58347-507 | Module, engine purge control |
| 29 | 1B40622-505 | Orifice, LOX fill and drain valve purge | 63 | 1B52624-503 | Switch, pressure, LOX chilldown pump purge backup, PU 41 psia max, DO 38 psia min | 120A | 1B64598-503 | Orifice, engine purge module |
| 30 | 1A48240-505 | Valve, LOX fill and drain | 64 | 1A49423-507*** | Valve, relief, LOX chilldown pump purge, crack and reset 65 to 85 psia (part of dump assembly) | 121 | 1B52623-515 | Switch, pressure, engine purge module backup, PU 130 psia max, DO 105 psia min |
| 31 | 1B66692-501 | Module, actuation control, LOX fill and drain valve | 65 | 1A67913-1 | Valve, dump, LOX chilldown pump purge | 122 | 1A49958-521 | Disconnect, engine start sphere vent and relief valve drain |
| 31A | 1B67481-1 | Valve, check, actuation control module vent, LOX fill and drain valve | 66 | 1A49423-507 | Pump, LOX chilldown | 123 | 1A49958-515 | Disconnect, engine control helium sphere fill |
| 31B | 1B67481-1 | Valve, check, actuation control module vent, LOX fill and drain valve | 67 | 1A49423-507 | Valve, LOX chilldown | 124 | 1A49958-523 | Disconnect, engine start sphere fill |
| 32 | 1B57781-503 | Module, cold helium dump | 68 | 1A49964-501 | Valve, check, LOX chilldown return line | 125 | 1A49958-517 | Disconnect, LH2 pump seal drain |
| 32A | 1B67481-1 | Valve, check, cold helium dump module relief valve vent | 68 | 1A49965-529 | Valve, LOX chilldown shutoff | | | |
| 33 | 1B49824-503 | Valve, check, cold helium fill | 69 | 1A89104-507 | Flowmeter, LOX chilldown | | | |
| 34 | 1B42290-505 | Module, LOX tank pressurization control | 70 | 1B53920-503 | Valve, check, LOX chilldown pump discharge | | | |
| | | | 71 | 1B52985-501 | Filter, LOX chilldown pump discharge | | | |

*Indicates location in figures 4-1 and 4-2

**Module No.

***Pump Part No.

Figure 4-1. Propulsion System and Instrumentation (Sheet 2 of 2)

FOLDOUT FRAME /

FOLDOUT FRAME 2

Section 4
Test Configuration

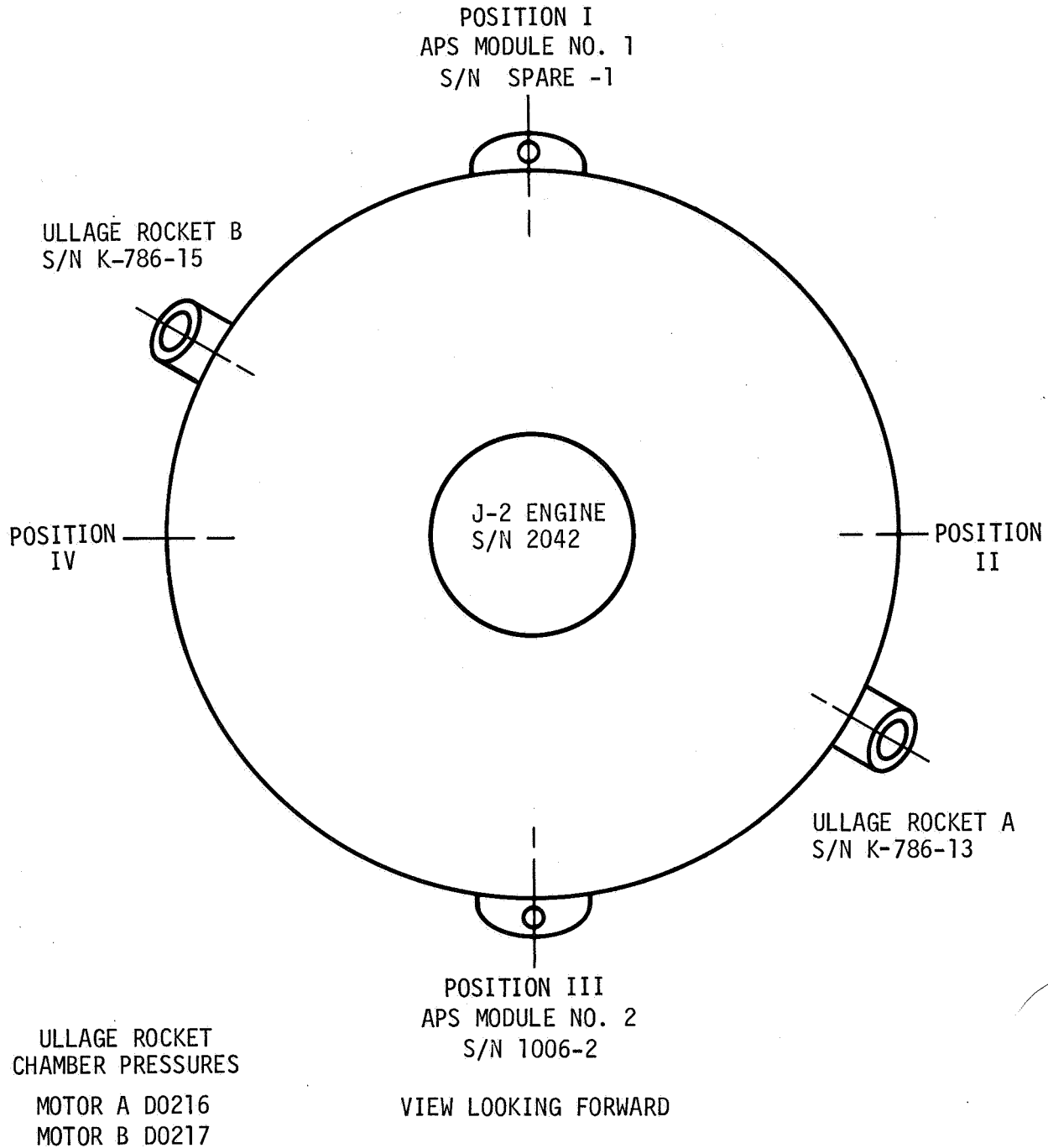


Figure 4-2. Propulsion Major Components Locations

Section 4
Test Configuration

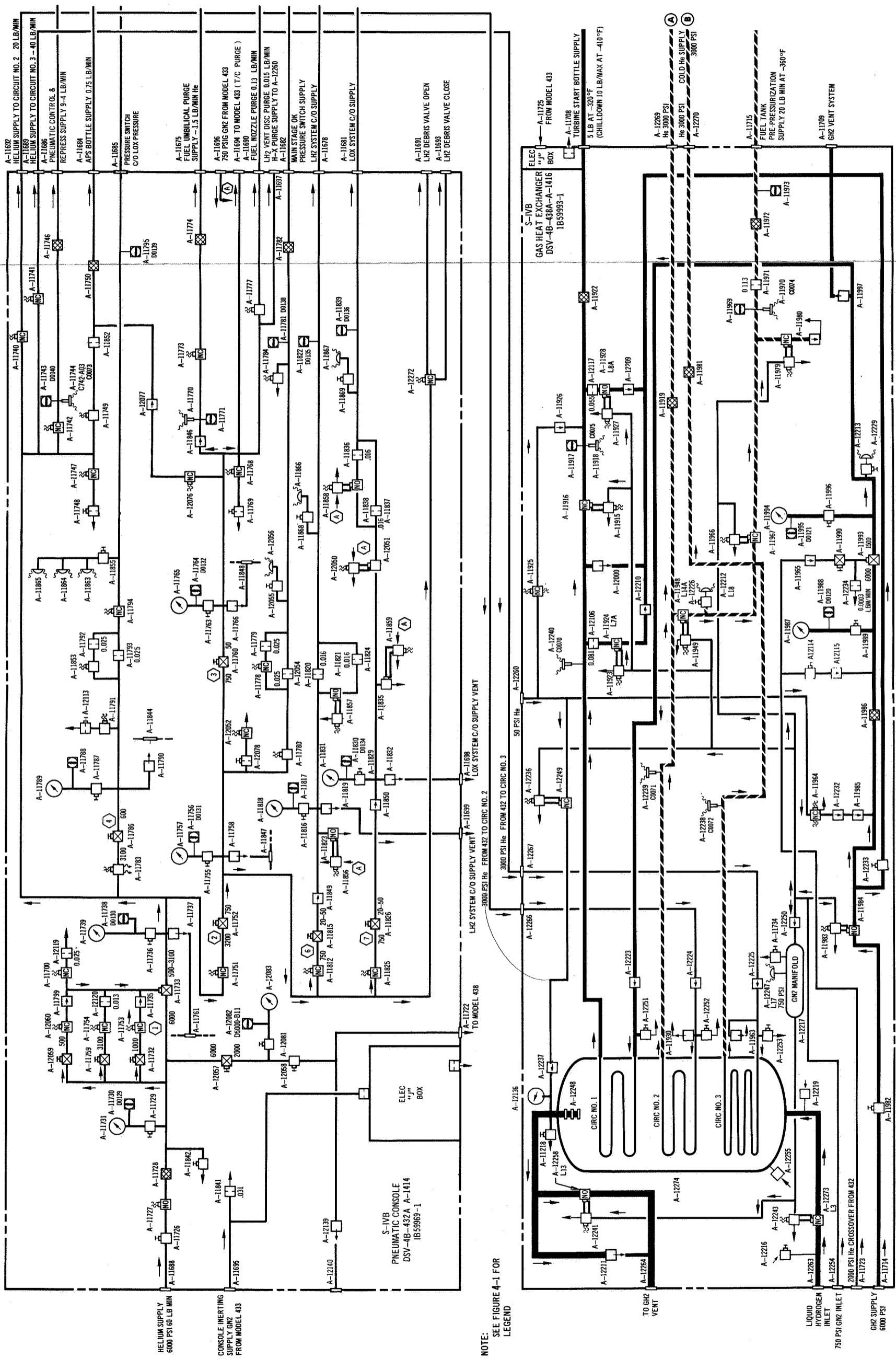
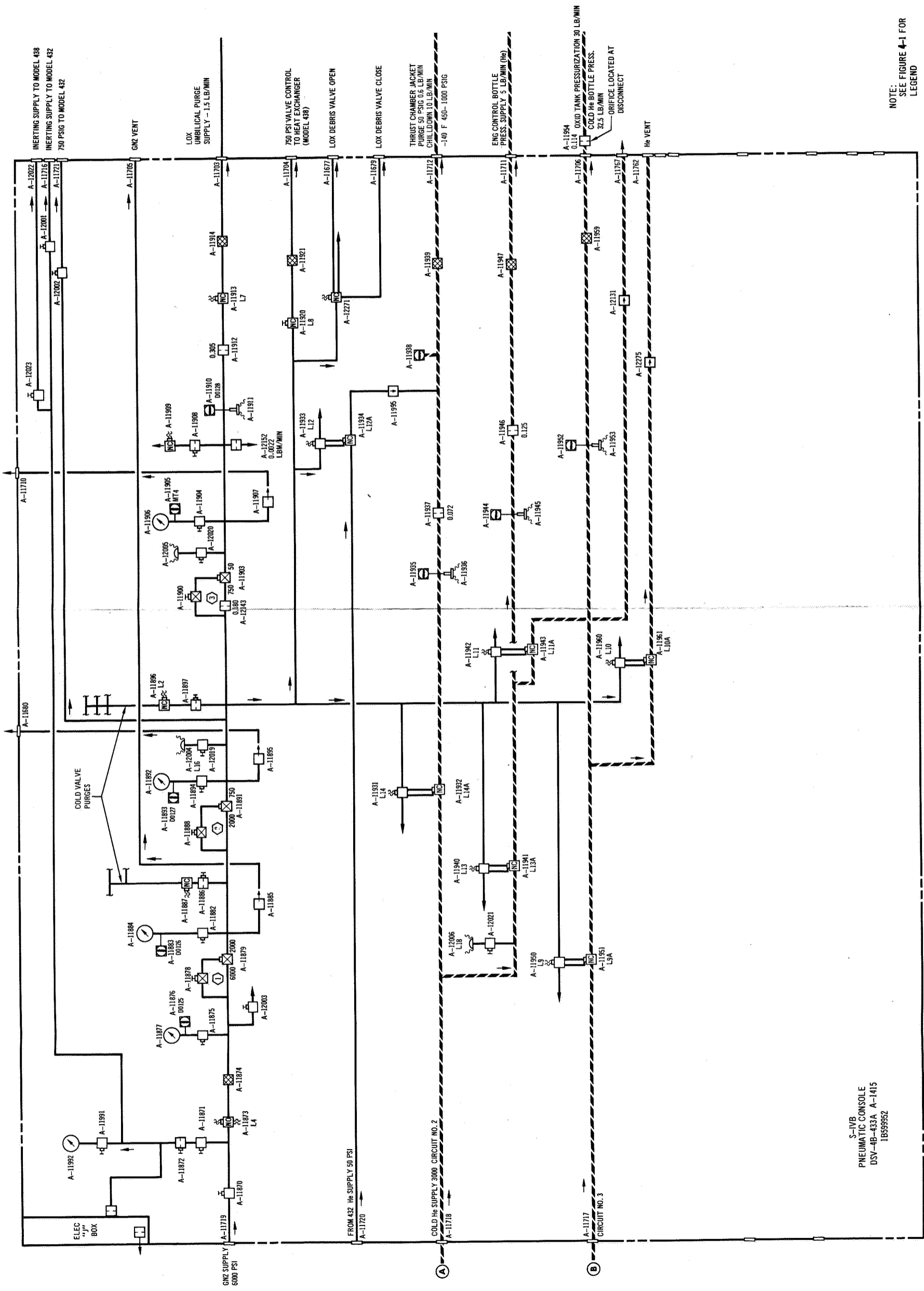


Figure 4-3. Facility Propellant and Pneumatic Loading Systems (Sheet 1 of 2)

FOLDOUT FRAME 2

FOLDOUT FRAME 1



NOTE:
SEE FIGURE 4-1 FOR
LEGEND

S-IVB
PNEUMATIC CONSOLE
DSV-4B-433A A-1415
1B599962

Figure 4-3. Facility Propellant and Pneumatic Loading Systems (Sheet 2 of 2)

FOLDOUT FRAME 2

FOLDOUT FRAME 1

SECTION 5

SEQUENCE OF EVENTS

5. SEQUENCE OF EVENTS

Table 5-1 presents the AS-502 flight sequence of events. Four types of items are included in the sequence.

a. LVDC Commands

These items originate from the Launch Vehicle Digital Computer (LVDC) in the Instrument Unit (IU), and direct vehicle system actions.

b. Events

These items are monitored occurrences resulting from vehicle performance, e.g., the time of maximum dynamic pressure.

c. Responses

These items are responses to commands that are issued from the IU and are monitored in the S-IVB.

d. Ground Commands

These items are manual commands issued from ground stations, which transmit signals to the LVDC in order to direct vehicle system actions.

In the sequence, all commands and events are preceded by an item number. Sequential series of related commands and responses are listed under the same event number with lower case letters distinguishing separate items.

5.1 Predicted and Monitored Times

The predicted times in the sequence were obtained from the Douglas memorandum A3-860-KKBH-68-M-177, published April 26, 1968, entitled S-IVB-502 Stage Predictions. Commands issued from the LVDC to the S-IC, S-II, S-IVB, and IU, were monitored at the LVDC. Times for these items were obtained from Marshall Space Flight Center (MSFC). Commands issued from the LVDC to the S-IVB were also monitored at the S-IVB switch selector. These items were obtained from Douglas data. Ground commands were monitored at the Mission Control Center and at the LVDC if received. Monitored times for events were obtained from Douglas postflight analysis of parameters associated with each event.

The time from range zero is provided for all items. Range zero, which is by definition the even second prior to liftoff, occurred at 12:00:01.0 GMT.

A time-from-base is given for all LVDC commands which were preprogrammed. A time-from-base is not applicable (N/A) for items such as events, command responses, and LVDC commands which were not preprogrammed.

The accuracies listed in table 5-1 are related to the telemetry-channel sampling rates; therefore, the items occurred at the times indicated or earlier by the amount listed in the accuracy column. The accuracy of IU signals is not shown since this information is not available.

Section 5
Sequence of Events

5.2 Time Bases

Seven sequential series of preprogrammed commands (time bases) were issued from the LVDC. Each sequential series was initiated by the establishment of its time base in the LVDC. Listed below are the seven time bases with their respective originating events.

- a. Time Base One, TB1 - IU Umbilical Disconnect
- b. Time Base Two, TB2 - S-IC Inboard Engine Cutoff
- c. Time Base Three, TB3 - S-IC Outboard Engines Cutoff
- d. Time Base Four, TB4 - S-II J-2 Engines Cutoff
- e. Time Base Five, TB5 - First S-IVB Engine Cutoff
- f. Time Base Six, TB6 - Begin Restart Preparations (LVDC solves an equation)
- g. Time Base Seven, TB7 - Second S-IVB Engine Cutoff

5.3 Ground Commands

Largely due to anomalies occurring during the flight, a number of commands to the LVDC were initiated from the ground by flight controller action. The majority of these commands would not have been transmitted had the flight anomalies not occurred.

The following is a list of the ground commands issued, including comments regarding their purpose and effectiveness. These commands are also included in table 5-1. It should be noted that there are discrepancies of up to 5 sec in table 5-1 between the issuance of certain ground commands and the receipt of the same commands by the S-IVB switch selector. Time delays of this magnitude are possible when considering (a) that in some cases a series of individual commands are stacked together and transmitted by a single ground command, and (b) the amount of time that can be spent in the process of command transmittal, verification, and execution.

| <u>Site</u> | <u>Command Time from Range Zero (hr:min:sec)</u> | <u>Command</u> | <u>Results/Comments</u> |
|-------------|--|---|--|
| CRO | 04:09:21 | Aux Hydraulic Pump Coast Mode OFF | Verified - Command disables thermal switch. Command was sent to simulate the normal pre-ignition sequence. |
| CRO | 04:09:21 | Aux Hydraulic Pump Flight Mode ON | Verified - Command turns on the aux pump. Command was sent in an attempt to turn pump on after failure had occurred during the pre-ignition sequence. A load of 12 amps was observed on Aft Battery No. 2. |
| CRO | 04:10:04 | Telemetry Calibrator Inflight Calibrate ON | Verified - Command initiates on-board calibration commands sent to verify proper functioning of onboard switch selector system and ground processing. Also provided an additional calibration for postflight analysis. |

| <u>Site</u> | <u>Command Time from Range Zero (hr:min:sec)</u> | <u>Command</u> | <u>Results/Comments</u> |
|-------------|--|--|---|
| CRO | 04:10:04 | Regular Calibrate Relays ON | Verified - Command initiates on-board calibration commands sent to verify proper functioning of onboard switch selector system and ground processing. Also provided an additional calibration for postflight analysis. |
| CRO | 04:10:37 | Aux Hydraulic Pump Coast Mode OFF | Same as above (second attempt) |
| CRO | 04:10:37 | Aux Hydraulic Pump Flight Mode ON | Same as above (second attempt) |
| CRO | 04:11:00 | Aux Hydraulic Pump Flight Mode OFF | Verified - Command turns off the aux pump. Command sent to remove load from Aft Battery No. 2. A load of 0 amps was observed on Aft Battery No. 2. |
| CRO | 04:11:38 | Telemetry Calibrator Inflight Calibrate OFF | SLV Reject - Due to telemetry dropout. |
| CRO | 04:11:38 | Regular Calibrate Relays OFF | Same as above. |
| CRO | 04:11:53 | Terminate | Ground Reject - Unified S-Band (USB) dropped modulation due to signal dropouts. |
| CRO | 04:12:06 | Terminate | Verified - Command sent to reset on-board system because a SLV Reject was received on a previous command. |
| COR | 04:12:15 | Telemetry Calibrator Inflight Calibrate OFF | Ground Reject - USB dropped modulation due to signal dropouts. |
| CRO | 04:12:15 | Regular Calibrate Relays OFF | Same as above. |
| CRO | 04:12:29 | Telemetry Calibrator Inflight Calibrate OFF | Ground Reject - USB dropped modulation due to signal dropouts. |
| CRO | 04:12:29 | Regular Calibrate Relays OFF | Same as above. |
| HAW | 04:29:33 | Telemetry Calibrator Inflight Calibrate OFF | Verified - Command sent to reset calibration mode for subsequent calibration. |
| HAW | 04:29:33 | Regular Calibrate Relays OFF | Same as above. |
| HAW | 04:30:01 | Maneuver to Align S-IVB + X Axis with Local Horizontal (Maneuver A - Alternate Sequence 6) | Verified - Command sent to terminate inertial hold and to initiate orbital pitch rate at local horizontal. This would enhance command and telemetry communications. Vehicle was observed to pitch about 160° to achieve local horizontal. |

Section 5
Sequence of Events

| <u>Site</u> | <u>Command Time from Range Zero (hr:min:sec)</u> | <u>Command</u> | <u>Results/Comments</u> |
|-------------|--|------------------------------------|--|
| GYM | 04:42:07 | Slow Record ON | Verified - Command sent to mark end of valid recorded data. |
| GYM | 04:42:07 | Slow Record OFF | Verified - Command sent to turn recorder off. |
| GYM | 04:42:07 | Tape Playback ON | Verified - Command sent to dump recorded data for postflight analysis. |
| HAW | 06:06:25 | Tape Playback OFF | Verified - Command sent to terminate playback to recorded data and provide realtime PCM data. |
| HAW | 06:06:59 | LOX Tank Flight Pressure System ON | Verified - Command sent to remove the LOX tank pressure switch from controlling the cold helium shutoff valves. |
| HAW | 06:06:59 | Coast Period OFF | Verified - Command sent to power cold helium shutoff valves open. The cold helium sphere pressure was observed to decay from approximately 571 psia to 0 at approximately R0 +6 hr 10 min. |
| HAW | 06:06:59 | LOX Tank Vent Valve Open | Verified - Command sent to open actuation control module solenoid which allows stage pneumatics to open LOX vent valve. |
| HAW | 06:06:59 | LH2 Tank Vent Valve Open | Verified - Command sent to open actuation control module solenoid which allows stage pneumatics to open LH2 vent valve. |

NOTE: The above sequence of commands sent at 06:06:59 provided a cold helium dump.

DATA OMISSIONS

A dash (--) was inserted in the flight sequence table for item times which are not available. Some items, such as command responses, had no predicted times. Due to early cutoff, commands 320 through 325 were not issued.

Actual times for items 420a and b, and 421a and b are not included inasmuch as these commands occurred prior to acquisition of signal at Hawaii, revolution 4.

COMMENTS

There are in some instances apparent conflicts in the time of command issuance from the LVDC and command receipt in the S-IVB. This conflict has been recognized by both MSFC and Douglas, but has not been resolved to date.

There are several events for which actual monitored times are not available. For these events the sequence times have been estimated from the last known time. All such derived times are indicated in table 5-1 with an asterisk.

5.4 Ground Sequence of Events

Table 5-2 presents the ground sequence of events from approximately R0 -10 min to liftoff. These events are related to the S-IVB-502 and associated ground support equipment and are derived from the digital events evaluation.

Section 5
Sequence of Events

TABLE 5-1 (Sheet 1 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|-------------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 1 | Guidance Reference Release | -00:00:16.7 (-16.7) | N/A | IU | -00:00:16.845 (-16.845) | N/A | MSFC | -- |
| 2 | S-IC Engine Start Sequence Command | -00:00:08.79 (-8.79) | N/A | IU | -00:00:08.77 (-8.77) | N/A | MSFC | -- |
| 3 | Range Zero | 00:00:00.0 (0.0) | N/A | IU | 00:00:00.0 (0.0) | N/A | MSFC | -- |
| 4 | Holddown Arms Release | 00:00:00.0 (0.0) | | IU | 00:00:00.36 (0.36) | N/A | MSFC | -- |
| 5 | First Motion | 00:00:00.0 (0.0) | N/A | GSE | 00:00:00.38 (0.38) | N/A | MSFC | -- |
| TIME BASE 1 | | | | | | | | |
| 6 | AS-502 Liftoff; IU Umbilical Disconnect | 00:00:00.3 (0.0) | TB1 +0.0 | IU | 00:00:00.69 (0.69) | TB1 +0.0 | MSFC | -- |
| 7 | Yaw Maneuver Start | 00:00:01.3 (1.3) | N/A | IU | 00:00:01.9 (1.9) | N/A | MSFC | -- |
| 8 | Signal from LVDC for: Auto - Abort Enable Relays Reset | 00:00:05.3 (5.3) | TB1 +5.0 | IU | 00:00:05.643 (5.643) | TB1 +4.953 | MSFC | -- |
| 9 | Sensor Bias ON | 00:00:05.5 (5.5) | TB1 +5.2 | IU | 00:00:05.855 (5.855) | TB1 +5.165 | | |
| 10 | Yaw Maneuver Stop | 00:00:09.3 (9.3) | N/A | IU | 00:00:09.834 (9.834) | N/A | MSFC | -- |
| 11 | Pitch Maneuver Start | 00:00:11.0 (11.0) | N/A | IU | 00:00:11.10 (11.10) | N/A | MSFC | -- |
| 12 | Roll Maneuver Start | 00:00:11.0 (11.0) | N/A | IU | 00:00:11.10 (11.10) | N/A | MSFC | -- |
| 13 | Signal from LVDC for: Multiple Engine Cutoff Enable | 00:00:14.3 (14.30) | TB1 +14.0 | IU | 00:00:14.646 (14.646) | TB1 +13.956 | MSFC | -- |
| 14 | Signal from LVDC for: S-IC Telemetry Calibrate ON | 00:00:25.1 (25.1) | TB1 +24.8 | | 00:00:25.442 (25.442) | TB1 +24.752 | MSFC | -- |
| 15 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 00:00:27.3 (27.3) | TB1 +27.0 | IU | 00:00:27.657 (27.657) | TB1 +26.967 | MSFC | -- |
| 16 | Roll Maneuver Stop | 00:00:29.0 (29.0) | N/A | IU | 00:00:31.3 (31.3) | N/A | MSFC | -- |
| 17 | Signal from LVDC for: S-IC Telemetry Calibrate OFF | 00:00:30.1 (30.1) | TB1 +29.8 | IU | 00:00:30.460 (30.460) | TB1 +29.770 | MSFC | -- |
| 18 | Signal from LVDC for: Launch Vehicle Engines EDS Cutoff Enable | 00:00:30.3 (30.3) | TB1 +30.0 | IU | 00:00:30.663 (30.663) | TB1 +29.973 | MSFC | -- |
| 19 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:00:32.3 (32.3) | TB1 +32.0 | IU | 00:00:32.644 (32.644) | TB1 +31.954 | MSFC | -- |

TABLE 5-1 (Sheet 2 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 20 | Signal from LVDC for: Fuel Pressurizing Valve No. 2 Open and Tape Recorder Record | 00:00:49.8 (49.8) | TB1 +49.5 | IU | 00:00:50.143 (50.143) | TB1 +49.453 | MSFC | -- |
| 21 | Mach 1 Achieved | 00:01:01.0 (61.0) | TB1 +60.7 | | 00:01:00.5 (60.5) | N/A | MSFC | -- |
| 22 | Signal from LVDC for: Start Data Recorders | 00:01:14.4 (74.4) | TB1 +74.1 | IU | 00:01:14.742 (74.742) | TB1 +74.052 | MSFC | -- |
| 23 | Signal from LVDC for: Cooling System Electronic Assembly Power OFF | 00:01:15.3 (75.3) | TB1 +75.0 | IU | 00:01:15.657 (75.657) | TB1 +74.967 | MSFC | -- |
| 24 | Maximum Dynamic Pressure | 00:01:19.0 (79.0) | N/A | N/A | 00:01:15.2 (75.2) | N/A | MSFC | -- |
| 25 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 00:01:30.3 (90.3) | TB1 +90.0 | IU | 00:01:30.664 (90.664) | TB1 +89.974 | MSFC | -- |
| 26 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:01:35.3 (95.3) | TB1 +95.0 | IU | 00:01:35.650 (95.650) | TB1 +94.960 | MSFC | -- |
| 27 | Signal from LVDC for: Fuel Pressurizing Valve No. 3 OPEN | 00:01:35.6 (95.6) | TB1 +95.3 | IU | 00:01:35.949 (95.949) | TB1 +95.259 | MSFC | -- |
| 28 | Signal from LVDC to Flight Control Computer for: Switch Point No. 1 | 00:01:45.3 (105.3) | TB1 +105.0 | IU | 00:01:45.658 (105.658) | TB1 +104.968 | MSFC | -- |
| 29 | Signal from LVDC for: S-IC Telemeter Calibrate ON | 00:01:55.3 (115.3) | TB1 +115.0 | IU | 00:01:55.656 (115.656) | TB1 +114.966 | MSFC | -- |
| 30a | Signal from LVDC for: Regular Calibrate Relays ON | 00:01:59.5 (119.5) | TB1 +119.2 | IU | 00:01:59.845 (119.845) | TB1 +119.155 | MSFC | -- |
| 30b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 00:01:59.846 (119.846) | TB1 +119.156 | DAC (FM) | 13 |
| 31 | Signal from LVDC for: S-IC Telemeter Calibrate OFF | 00:02:00.3 (120.3) | TB1 +120.0 | IU | 00:02:00.658 (120.658) | TB1 +119.968 | MSFC | -- |
| 32 | Signal from LVDC to: Flight Control Computer for: Switch Point No. 2 | 00:02:00.5 (120.5) | TB1 +120.2 | IU | 00:02:00.842 (120.842) | TB1 +120.152 | MSFC | -- |
| 33a | Signal from LVDC for: Regular Calibrate Relays OFF | 00:02:04.5 (124.5) | TB1 +124.2 | IU | 00:02:04.844 (124.844) | TB1 +124.154 | MSFC | -- |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 3 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 33b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 00:02:04.846 (124.846) | TB1 +124.156 | DAC (FM) | 13 |
| 34 | Signal from LVDC for: Start First PAM-FM/FM Calibration | 00:02:10.53 (130.53) | TB1 +129.84 | S-II | 00:02:10.359 (130.359) | TB1 +129.669 | MSFC | -- |
| 35 | Signal from LVDC for: Fuel Pressurizing Valve No. 4 Open | 00:02:13.8 (133.8) | TB1 +133.5 | IU | 00:02:14.159 (134.159) | TB1 +133.469 | MSFC | -- |
| 36a | Signal from LVDC for: Fast Record ON | 00:02:14.8 (134.8) | TB1 +134.5 | IU | 00:02:15.158 (135.158) | TB1 +134.468 | MSFC | -- |
| 36b | Signal Received in S-IVB for: Fast Record ON | -- | -- | S-IVB | 00:02:15.158 (135.158) | TB1 +134.468 | DAC (FM) | 13 |
| 37 | Signal from LVDC for: PAM/FM/FM Calibration Stop | 00:02:14.9 (134.9) | TB1 +134.7 | IU | 00:02:15.343 (135.343) | TB1 +134.653 | MSFC | -- |
| 38 | Signal from LVDC for: IU Tape Recorder ON | 00:02:15.2 (135.2) | TB1 +134.9 | IU | 00:02:15.553 (135.553) | TB1 +134.863 | MSFC | -- |
| 39 | Signal from LVDC for: LOX Tank Strobe Lights OFF | 00:02:15.4 (135.4) | TB1 +135.1 | S-IC | 00:02:15.743 (135.743) | TB1 +135.053 | MSFC | -- |
| 40 | Signal from LVDC for: S-IC Two-Engine Out Auto-Abort Inhibit Enable | 00:02:15.6 (135.6) | TB1 +135.3 | IU | 00:02:15.948 (135.948) | TB1 +135.258 | MSFC | -- |
| 41 | Signal from LVDC for: S-IC Two-Engine Out Auto-Abort Inhibit | 00:02:15.8 (135.8) | TB1 +135.5 | IU | 00:02:15.166 (136.166) | TB1 +135.476 | MSFC | -- |
| 42 | Signal from LVDC for: Excessive Rate (P, Y & R) Auto-Abort Inhibit Enable | 00:02:16.0 (136.0) | TB1 +135.7 | IU | 00:02:16.344 (136.344) | TB1 +135.654 | MSFC | -- |
| 43 | Signal from LVDC for: Excessive Rate (P, Y & R) Auto-Abort Inhibit | 00:02:16.2 (136.2) | TB1 +135.9 | IU | 00:02:16.544 (136.544) | TB1 +135.854 | MSFC | -- |
| 44 | Signal from LVDC for: Two Adjacent Outboard Engines Out Enable | 00:02:16.4 (136.4) | TB1 +136.1 | IU | 00:02:16.756 (136.756) | TB1 +136.066 | MSFC | -- |
| 45 | Signal from LVDC for: Inboard Engine Cutoff Enable | 00:02:16.6 (136.6) | TB1 +136.3 | -- | 00:02:16.962 (136.962) | TB1 +136.272 | MSFC | -- |

TABLE 5-1 (Sheet 4 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 46 | Signal from LVDC for: Inboard Engine Cutoff Backup Enable | 00:02:16.8 (136.8) | TB1 +136.5 | -- | 00:02:17.143 (137.143) | TB1 +136.453 | MSFC | -- |
| 47 | Stop Pitch Maneuver | 00:02:21.7 (141.7) | N/A | IU | 00:02:20.9 (140.9) | TB1 +140.21 | MSFC | -- |
| 48 | Inboard Engine Cutoff Interrupt 1520 | 00:02:23.4 (143.4) | N/A | IU | 00:02:24.95 (144.95) | N/A | MSFC | -- |
| | TIME BASE 2 | | | | | | | |
| 49 | S-IC Inboard Engine Cutoff | 00:02:23.4 (143.4) | TB2 +0.0 | S-IC | 00:02:24.949 (144.949) | TB2 +0.0 | MSFC | -- |
| 50 | Signal from LVDC for: S-II Ordnance Arm | 00:02:23.5 (143.5) | TB2 +0.1 | IU | 00:02:25.028 (145.028) | TB2 +.079 | MSFC | -- |
| 51 | Signal from LVDC for: Separation and Retro EBW Firing Units Arm | 00:02:23.7 (143.7) | TB2 +0.3 | IU | 00:02:25.202 (145.202) | TB2 +0.253 | MSFC | -- |
| 52 | Signal from LVDC for: Separation Camera ON | 00:02:23.9 (143.9) | TB2 +0.5 | IU | 00:02:25.415 (145.415) | TB2 +0.466 | MSFC | -- |
| 53 | Signal from LVDC for: Camera Lights ON | 00:02:24.0 (144.0) | TB2 +0.6 | IU | 00:02:25.513 (145.513) | TB2 +0.564 | MSFC | -- |
| 54 | Signal from LVDC for: S-IC Telemetry Measurement Switch Over | 00:02:24.2 (144.2) | TB2 +0.8 | IU | 00:02:25.702 (145.702) | TB2 +0.753 | MSFC | -- |
| 55 | Signal from LVDC for: Enable Outboard Engines Cutoff | 00:02:24.4 (144.4) | TB2 +1.0 | IU | 00:02:25.912 (145.912) | TB2 +.963 | MSFC | -- |
| 56 | Outboard Engines Cutoff Interrupt 1520 | 00:02:28.4 (148.4) | N/A | IU | 00:02:28.41 (148.41) | N/A | MSFC | -- |
| | TIME BASE 3 | | | | | | | |
| 57 | S-IC Outboard Engines Cutoff | 00:02:28.4 (148.4) | TB3 +0.0 | IU | 00:02:28.405 (148.405) | TB3 +0.0 | MSFC | -- |
| 58 | Signal from LVDC for: Camera Motor ON | 00:02:28.5 (148.5) | TB3 +0.1 | IU | 00:02:28.486 (148.486) | TB3 +0.81 | MSFC | -- |
| 59 | Signal from LVDC for: S-II LH2 Recirculation Pumps OFF | 00:02:28.7 (148.7) | TB3 +0.3 | IU | 00:02:28.659 (148.659) | TB3 +.254 | MSFC | -- |
| 60 | Signal from LVDC for: S-II Ullage Trigger | 00:02:28.9 (148.9) | TB3 +0.5 | IU | 00:02:28.874 (148.874) | TB3 +.469 | MSFC | -- |
| 61 | Signal from LVDC for: S-IC/S-II Separation | 00:02:29.1 (149.1) | TB3 +0.7 | IU | 00:02:29.078 (149.078) | TB3 +.673 | MSFC | -- |
| 62 | Signal from LVDC for: Camera Event Mark | 00:02:29.2 (149.2) | TB3 +0.8 | IU | 00:02:29.173 (149.173) | TB3 +.768 | MSFC | -- |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 5 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 63 | Signal from LVDC for: Switch Control to S-II Enable S-II Engine Out and S-II Second Separation Indication "A" Enable | 00:02:29.3 (149.3) | TB3 +0.9 | IU | 00:02:29.258 (149.258)* | TB3 + .853 | MSFC | -- |
| 64 | Signal from LVDC for: S-II Engines Cutoff Reset | 00:02:29.4 (149.4) | TB3 +1.0 | IU | 00:02:29.358 (149.358)* | TB3 + .953 | MSFC | -- |
| 65 | Signal from LVDC for: Engines Ready Bypass | 00:02:29.5 (149.5) | TB3 +1.1 | IU | 00:02:29.458 (149.458)* | TB3 +1.053 | MSFC | -- |
| 66 | Signal from LVDC for: Prevalves Lockout Reset | 00:02:29.6 (149.6) | TB3 +1.2 | IU | 00:02:29.558 (149.558)* | TB3 +1.153 | MSFC | -- |
| 67 | Signal from LVDC for: S-II Engine Start | 00:02:29.8 (149.8) | TB3 +1.4 | IU | 00:02:29.758 (149.758)* | TB3 +1.353 | MSFC | -- |
| 68 | Signal from LVDC for: Camera Event Mark | 00:02:29.9 (149.9) | TB3 +1.5 | IU | 00:02:29.858 (149.858)* | TB3 +1.453 | MSFC | -- |
| 69 | Signal from LVDC for: Enable S-II Engine Out and S-II Second Separation Indication "B" | 00:02:30.1 (150.1) | TB3 +1.7 | IU | 00:02:30.058 (150.058)* | TB3 +1.653 | MSFC | -- |
| 70 | Signal from LVDC for: Engine Ready Bypass Reset | 00:02:30.3 (150.3) | TB3 +1.9 | IU | 00:02:30.258 (150.258)* | TB3 +1.853 | MSFC | -- |
| 71 | Signal from LVDC for: Q-Ball Power OFF | 00:02:30.8 (150.8) | TB3 +2.4 | IU | 00:02:30.757 (150.757) | TB3 +2.352 | MSFC | -- |
| 72 | Signal from LVDC for: S-II Hydraulic Accumulators Unlock | 00:02:31.4 (151.4) | TB3 +3.0 | IU | 00:02:31.379 (151.379) | TB3 +2.974 | MSFC | -- |
| 73 | Signal from LVDC for: Chilldown Valves Close | 00:02:34.8 (154.8) | TB3 +6.4 | IU | 00:02:34.759 (154.759) | TB3 +6.354 | MSFC | -- |
| 74 | Signal from LVDC for: S-II start Phase Limiter Cutoff Arm | 00:02:35.1 (155.1) | TB3 +6.7 | IU | 00:02:35.078 (155.078) | TB3 +6.673 | MSFC | -- |
| 75 | Signal from LVDC for: Activate PU System | 00:02:35.2 (155.2) | TB3 +6.9 | IU | 00:02:35.258 (155.258) | TB3 +6.853 | MSFC | -- |
| 76 | Signal from LVDC for: S-II Start Phase Limiter Cutoff Arm Reset | 00:02:36.1 (156.0) | TB3 +7.7 | IU | 00:02:36.074 (156.074) | TB3 +7.669 | MSFC | -- |
| 77 | Signal from LVDC for: Stop Data Recorders | 00:02:39.8 (159.8) | TB3 +11.4 | IU | 00:02:39.780 (159.780) | TB3 +11.375 | MSFC | -- |

TABLE 5-1 (Sheet 6 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 78a | Signal from LVDC for: Fast Record OFF | 00:02:40.0 (160.0) | TB3 +11.6 | IU | 00:02:39.960 (159.960) | TB3 +11.555 | MSFC | -- |
| 78b | Signal Received on S-IVB for: Fast Record OFF | -- | -- | S-IVB | 00:02:39.961 (159.961) | TB3 +11.556 | DAC (FM) | 13 |
| 79 | Signal from LVDC for: Tape Recorder Record OFF | 00:02:40.2 (160.2) | TB3 +11.8 | | 00:02:40.174 (160.174) | TB3 +11.769 | MSFC | -- |
| 80 | Signal from LVDC for: S-II Second Plane Separation | 00:02:59.1 (179.1) | TB3 +30.7 | IU | 00:02:54.058 (179.058) | TB3 +30.653 | MSFC | -- |
| 81 | Signal from LVDC for: Camera Event Mark | 00:02:59.2 (179.2) | TB3 +30.8 | IU | 00:02:59.158 (179.158) | TB3 +30.753 | MSFC | -- |
| 82 | Signal from LVDC for: Camera Event Mark | 00:03:00.2 (180.2) | TB3 +31.8 | IU | 00:03:00.157 (180.157) | TB3 +31.752 | MSFC | -- |
| 83 | Signal from LVDC for: Water Coolant Valve Open | -- | Variable | IU | 00:03:02.294 (182.294) | TB3 +33.889 | MSFC | -- |
| 84 | Signal from LVDC for: LET Jettison "A" | 00:03:04.8 (184.8) | TB3 +36.4 | IU | 00:03:04.766 (184.766) | TB3 +36.361 | MSFC | -- |
| 85 | Signal from LVDC for: LET Jettison "B" | 00:03:05.0 (185.0) | TB3 +36.6 | IU | 00:03:04.979 (184.979) | TB3 +36.574 | MSFC | -- |
| 86 | Signal from LVDC for: Camera Eject No. 1 | 00:03:06.4 (186.4) | TB3 +38.0 | IU | 00:03:06.374 (186.374) | TB3 +37.969 | MSFC | -- |
| 87 | Signal from LVDC for: Camera Eject No. 2 | 00:03:07.0 (187.0) | TB3 +38.6 | IU | 00:03:06.960 (186.960) | TB3 +38.555 | MSFC | -- |
| 88 | Signal from LVDC for: Camera Eject No. 3 | 00:03:07.5 (187.5) | TB3 +39.1 | IU | 00:03:07.464 (187.464) | TB3 +39.059 | MSFC | -- |
| 89 | Initiate Iterative Guidance Mode | 00:03:10.4 (190.4) | N/A | IU | 00:03:10.95 (190.95) | N/A | MSFC | -- |
| 90 | Signal from LVDC to Flight Control Computer for: Switch Point No. 3 | 00:03:29.8 (209.8) | TB3 +61.4 | IU | 00:03:29.764 (209.764) | TB3 +61.359 | MSFC | -- |
| 91 | Initiate Steering Misalignment Correction | 00:03:30.01 (210.01) | N/A | | 00:03:31.99 (211.99) | N/A | MSFC | -- |
| 92 | Signal from LVDC for: Start Second PAM-FM/FM Calibration | 00:05:30.3 (330.3) | TB3 +181.9 | IU | 00:05:30.258 (330.258) | TB3 +181.853 | MSFC | -- |
| 93 | Signal from LVDC for: Stop Second PAM-FM/FM Calibration | 00:05:35.3 (335.3) | TB3 +186.9 | IU | 00:05:30.269 (335.269) | TB3 +186.864 | MSFC | -- |

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TABLE 5-1 (Sheet 7 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 94 | Signal from LVDC to Flight Control Computer for: Switch Point No. 4 | 00:05:43.9 (339.8) | TB3 +191.4 | IU | 00:05:39.759 (339.759) | TB3 +191.354 | MSFC | -- |
| 95 | Signal from LVDC for: Telemetry Calibration Inflight Calibrate ON | 00:05:50.3 (350.3) | TB3 +201.9 | IU | 00:05:50.259 (350.259) | TB3 +201.854 | MSFC | -- |
| 96 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:05:55.3 (355.3) | TB3 +206.9 | IU | 00:05:55.271 (355.271) | TB3 +206.866 | MSFC | -- |
| 97 | Signal from LVDC for: Measurement Control Switch No. 2 Activate | 00:06:01.1 (361.1) | TB3 +212.7 | IU | 00:06:01.061 (361.061) | TB3 +212.656 | MSFC | -- |
| 98 | S-II Mixture Ratio Shift (Guidance Sensed) | 00:06:52.1 (412.1) | N/A | IU | 00:08:10.75 (490.75) | N/A | MSFC | -- |
| 99 | S-II No. 2 Engine Out | -- | -- | -- | 00:06:52.9 (412.9) | N/A | MSFC | -- |
| 100 | S-II No. 3 Engine Out | -- | -- | -- | 00:06:54.2 (414.2) | N/A | MSFC | -- |
| 101 | Signal from LVDC for: Start Third PAM-FM/FM Calibration | 00:07:01.0 (421.0) | TB3 +272.6 | IU | 00:07:00.981 (420.981) | TB3 +272.576 | MSFC | -- |
| 102 | Signal from LVDC for: Stop Third PAM-FM/FM Calibration | 00:07:06.0 (426.0) | TB3 +277.6 | IU | 00:07:05.965 (425.965) | TB3 +277.560 | MSFC | -- |
| 103 | Signal from LVDC for: S-II LH2 Step Pressurization | 00:07:47.4 (467.34) | TB3 +320.0 | IU | 00:07:48.358 (468.358) | TB3 +319.953 | MSFC | -- |
| 104a | Signal from LVDC for: Regular Calibrate Relays ON | 00:07:57.3 (477.3) | TB3 +328.9 | IU | 00:07:57.259 (477.259) | TB3 +328.854 | MSFC | -- |
| 104b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 00:07:57.244 (477.244) | TB3 +328.839 | DAC (FM) | 13 |
| 105 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 00:07:57.5 (477.5) | TB3 +329.1 | IU | 00:07:57.471 (477.471) | TB3 +329.066 | MSFC | -- |
| 106a | Signal from LVDC for: Regular Calibrate Relays OFF | 00:08:02.3 (482.3) | TB3 +333.9 | IU | 00:08:02.279 (482.279) | TB3 +333.874 | MSFC | -- |
| 106b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 00:08:02.268 (482.268) | TB3 +333.863 | DAC (FM) | 13 |
| 107 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:08:02.5 (482.5) | TB3 +334.1 | IU | 00:08:02.457 (482.457) | TB3 +334.052 | MSFC | -- |

TABLE 5-1 (Sheet 8 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 108a | Signal from LVDC for: Charge Ullage Ignition ON | 00:08:02.9 (482.9) | TB3 +334.5 | IU | 00:08:02.881 (482.881) | TB3 +334.476 | MSFC | -- |
| 108b | Signal Received on S-IVB for: Charge Ullage Ignition ON | -- | -- | S-IVB | 00:08:02.868 (482.868) | TB3 +334.463 | DAC (FM) | 13 |
| 109 | Signal from LVDC for: S-II/S-IVB Ordnance Arm | 00:08:03.1 (483.1) | TB3 +334.7 | IU | 00:08:03.058 (483.058) | TB3 +334.653 | MSFC | -- |
| 110 | Signal from LVDC for: IU Tape Recorder Record ON | 00:08:03.3 (483.3) | TB3 +334.9 | IU | 00:08:03.273 (483.273) | TB3 +334.868 | MSFC | -- |
| 111a | Signal from LVDC for: Fast Record ON | 00:08:03.5 (483.5) | TB3 +335.1 | IU | 00:08:03.458 (483.458) | TB3 +335.053 | MSFC | -- |
| 111b | Signal Received in S-IVB for: Fast Record ON | -- | -- | S-IVB | 00:08:03.446 (483.446) | TB3 +335.041 | DAC (FM) | 13 |
| 112 | Signal from LVDC for: Start Recorders | 00:08:03.7 (483.7) | TB3 +335.3 | IU | 00:08:03.665 (483.665) | TB3 +335.260 | MSFC | -- |
| 113 | Signal from LVDC for: S-II LOX Depletion Sensor Cutoff Arm | 00:08:03.9 (483.9) | TB3 +335.5 | IU | 00:08:03.879 (483.879) | TB3 +335.474 | MSFC | -- |
| 114 | Signal from LVDC for: S-II LH2 Depletion Sensor Cutoff Arm | 00:08:04.1 (484.1) | TB3 +335.7 | IU | 00:08:04.058 (484.058) | TB3 +335.653 | MSFC | -- |
| 115 | Cutoff S-II J-2 Engines Interrupt 1520 | 00:08:37.16 (517.16) | N/A | IU | 00:09:36.33 (576.33) | N/A | MSFC | -- |
| | TIME BASE 4 | | | | | | | |
| 116 | S-II J-2 Engines Cutoff | 00:08:37.16 (517.16) | TB4 +0.0 | IU | 00:09:36.327 (576.327) | TB4 +0.0 | MSFC | -- |
| 117 | Signal from LVDC for: Redundant S-II Cutoff SS | 00:08:37.16 (517.16) | N/A | IU | 00:09:36.410 (576.410) | TB4 +.083 | MSFC | -- |
| 118 | Signal from LVDC for: Start Recorder Timers | 00:08:37.26 (517.26) | TB4 +0.1 | IU | 00:09:36.504 (576.504) | TB4 +.177 | MSFC | -- |
| 119a | Signal from LVDC for: Prevalves Closed OFF | 00:08:37.36 (517.36) | TB4 +0.2 | IU | 00:09:36.605 (576.605) | TB4 +.278 | MSFC | -- |
| 119b | Signal Received in S-IVB for: Prevalves Closed OFF | -- | -- | S-IVB | 00:09:36.596 (576.596) | TB4 +.269 | DAC (FM) | 13 |
| 120a | Signal from LVDC for: S-IVB Engine Cutoff OFF | 00:08:37.46 (517.46) | TB4 +0.3 | IU | 00:09:36.697 (576.697) | TB4 +.370 | MSFC | -- |
| 120b | Signal Received in S-IVB for: S-IVB Engine Cutoff OFF | -- | -- | S-IVB | 00:09:36.687 (576.687) | TB4 +.360 | DAC (FM) | 13 |

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TABLE 5-1 (Sheet 9 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 121a | Signal from LVDC for: Engine Ready Bypass | 00:08:37.66 (517.66) | TB4 +.05 | IU | 00:09:36.789 (576.789) | TB4 +.462 | MSFC | -- |
| 121b | Signal Received in S-IVB for: Engine Ready Bypass | -- | -- | S-IVB | 00:09:36.779 (576.779) | TB4 +.452 | DAC (FM) | 13 |
| 122a | Signal from LVDC for: LOX Chilldown Pump OFF | 00:08:37.76 (517.76) | TB4 +0.6 | IU | 00:09:36.882 (576.882) | TB4 +.555 | MSFC | -- |
| 122b | Signal Received in S-IVB for: LOX Chilldown Pump OFF | -- | -- | S-IVB | 00:09:36.872 (576.872) | TB4 +.545 | DAC (FM) | 13 |
| 123a | Signal from LVDC for: Fire Ullage Ignition ON | 00:08:37.96 (517.86) | TB4 +0.7 | IU | 00:09:36.981 (576.981) | TB4 +.654 | MSFC | -- |
| 123b | Signal Received in S-IVB for: Fire Ullage Ignition ON | -- | -- | S-IVB | 00:09:36.971 (576.971) | TB4 +.644 | DAC (FM) | 13 |
| 124 | Signal from LVDC for: S-II/S-IVB Separation | 00:08:37.96 (517.96) | TB4 +0.8 | IU | 00:09:37.079 (577.079) | TB5 +.752 | MSFC | -- |
| 125 | Ullage Thrust Buildup to 75% (Average) | -- | -- | -- | 00:09:37.07 (577.07) | N/A | DAC | -- |
| 126 | S-II Retrorocket Thrust Buildup to 10% (Average) | -- | -- | -- | 00:09:37.11 (577.11) | N/A | MSFC | -- |
| 127 | First Axial Separation Motion | -- | -- | -- | 00:09:38.125 (577.125) | N/A | MSFC | -- |
| 128 | S-II Retrorocket Thrust Buildup to 90% (Average) | -- | -- | -- | 00:09:37.13 (577.13) | N/A | MSFC | -- |
| 129a | Signal from LVDC for: S-IVB Engine Start Interlock Bypass ON | 00:08:38.06 (518.06) | TB4 +0.9 | IU | 00:09:37.180 (577.180) | TB4 +.853 | MSFC | -- |
| 129b | Signal Received in S-IVB for: S-IVB Engine Start Interlock Bypass ON | -- | -- | S-IVB | 00:09:37.168 (577.168) | TB4 +.841 | DAC (FM) | 13 |
| 130a | Signal from LVDC for: S-IVB Engine Start ON | 00:08:38.16 (518.16) | TB4 +1.0 | IU | 00:09:37.280 (577.280) | TB4 +.953 | MSFC | -- |
| 130b | Signal Received in S-IVB for: S-IVB Engine Start ON | -- | -- | S-IVB | 00:09:37.268 (577.268) | TB4 +.938 | DAC (FM) | 13 |
| 130c | J-2 Engine Start Sequence | | | | | | | |
| | 1. Helium Control Solenoid Energized | -- | -- | S-IVB | 00:09:37.268 (577.268) | -- | DAC (FM) | 25 |
| | 2. Main Fuel Valve Closed (Dropout) | -- | -- | S-IVB | 00:09:37.340 (577.340) | -- | DAC (FM) | 25 |

TABLE 5-1 (Sheet 10 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|--------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 3. | Main Fuel Valve Open (Pickup) | -- | -- | S-IVB | 00:09:37.363 (577.363) | -- | DAC (PCM) | 25 |
| 4. | Gas Generator Valve Closed (Dropout) | -- | -- | S-IVB | 00:09:40.839 (580.839) | -- | DAC (PCM) | 25 |
| 5. | Gas Generator Valve Open (Pickup) | -- | -- | S-IVB | 00:09:40.966 (580.966) | -- | DAC (PCM) | 25 |
| 6. | Main Oxidizer Valves Leaves Closed Position (Dropout) | -- | -- | S-IVB | 00:09:40.847 (580.847) | -- | DAC (PCM) | 25 |
| 7. | Start Tank Discharge Valve Open (Dropout) | -- | -- | S-IVB | 00:09:40.880 (580.880) | -- | DAC (PCM) | 25 |
| 8. | Oxidizer Turbine Bypass Valve Open (Dropout) | -- | -- | S-IVB | 00:09:40.988 (580.988) | -- | DAC (PCM) | 25 |
| 9. | Oxidizer Turbine Bypass Valve Closed (Pickup) | -- | -- | S-IVB | 00:09:41.212 (581.212) | -- | DAC (PCM) | 25 |
| 10. | Mainstage OK Pressure Switch No. 1 (Dropout) | -- | -- | S-IVB | 00:09:42.118 (582.118) | -- | DAC (PCM) | 25 |
| 11. | Mainstage OK Pressure Switch No. 2 (Pickup) | -- | -- | S-IVB | 00:09:42.187 (582.187) | -- | DAC (PCM) | 25 |
| 12. | Main Oxidizer Valve Reaches Open Position (Pickup) | -- | -- | S-IVB | 00:09:42.928 (582.928) | -- | DAC (PCM) | 25 |
| 13. | Gas Generator Spark System ON (Dropout) | -- | -- | S-IVB | 00:09:44.013 (584.013) | -- | DAC (PCM) | 25 |
| 14. | Thrust Chamber Spark System ON (Dropout) | -- | -- | S-IVB | 00:09:44.013 (584.013) | -- | DAC (PCM) | 25 |
| 131 | Signal from LVDC for: Flight Control Computer S-IVB Burn Mode ON "A" | 00:08:38.26 (518.26) | TB4 +1.1 | | 00:09:37.398 (577.398) | TB4 +1.071 | MSFC | -- |
| 132 | Signal from LVDC for: Flight Control Computer S-IVB Burn Mode ON "B" | 00:08:38.36 (518.36) | TB4 +1.2 | IU | 00:09:37.491 (577.491) | TB4 +1.164 | MSFC | -- |
| 133 | Signal from LVDC for: S-IVB Engine Out Indication Enable "A" ON | 00:08:38.76 (518.76) | TB4 +1.6 | IU | 00:09:37.880 (577.880) | TB4 +1.553 | MSFC | -- |

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TABLE 5-1 (Sheet 11 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 134 | Signal from LVDC for: S-IVB Engine Out Indication Enable "B" ON | 00:08:38.96 (518.96) | TB4 +1.8 | IU | 00:09:38.092 (578.092) | TB4 +1.765 | MSFC | -- |
| 135 | Separation Complete (217 in. Axial Clearance) | 00:08:34.02 (519.02) | N/A | N/A | 00:09:38.106 (578.106) | N/A | DAC | -- |
| 136a | Signal from LVDC for: Fuel Chilldown Pump OFF | 00:08:39.36 (519.36) | TB4 +2.2 | IU | 00:09:38.480 (578.480) | TB4 +2.153 | MSFC | -- |
| 136b | Signal Received in S-IVB for: Fuel Chilldown Pump OFF | -- | -- | S-IVB | 00:09:38.470 (578.470) | TB4 +2.143 | DAC (FM) | 13 |
| 137a | Signal from LVDC for: LOX Tank Flight Pressure System ON | 00:08:40.96 (520.96) | TB4 +3.8 | IU | 00:09:40.081 (580.081) | TB4 +3.754 | MSFC | -- |
| 137b | Signal Received in S-IVB for: LOX Tank Flight Pressure System ON | -- | -- | S-IVB | 00:09:40.012 (580.072) | TB4 +3.745 | DAC (FM) | 13 |
| 138a | Signal from LVDC for: Fuel Injection Temperature OK Bypass | 00:08:41.16 (521.16) | TB4 +4.0 | IU | 00:09:40.295 (580.295) | TB4 +3.968 | MSFC | -- |
| 138b | Signal Received in S-IVB for: Fuel Injection Temperature OK Bypass | -- | -- | S-IVB | 00:09:40.281 (580.281) | TB4 +3.954 | DAC (FM) | 13 |
| 139a | Signal from LVDC for: Engine Start OFF | 00:08:41.26 (521.26) | TB4 +4.2 | IU | 00:09:40.480 (580.480) | TB4 +4.153 | MSFC | -- |
| 139b | Signal Received in S-IVB for: Engine Start OFF | -- | -- | S-IVB | 00:09:40.468 (580.468) | TB4 +4.138 | DAC (FM) | 13 |
| 140a | Signal from LVDC for: First Burn Relay ON | 00:08:42.96 (522.96) | TB4 +5.8 | IU | 00:09:42.081 (582.081) | TB4 +5.754 | MSFC | -- |
| 140b | Signal Received in S-IVB for: First Burn Relay ON | -- | -- | S-IVB | 00:09:42.070 (582.070) | TB4 +5.743 | DAC (FM) | 13 |
| 141 | J-2 Thrust Buildup - 10% | -- | -- | N/A | 00:09:41.308 (581.308) | N/A | DAC | 10 |
| 142 | J-2 Thrust Buildup - 90% | 00:08:43.56 (523.56) | N/A | N/A | 00:09:42.788 (582.788) | N/A | MSFC | -- |
| 143 | Guidance Initiation | 00:08:43.56 (523.56) | N/A | IU | 00:09:44.8 (584.8) | N/A | MSFC | -- |
| 144 | Start Artificial Tau Mode | 00:08:43.56 (523.56) | N/A | IU | 00:09:44.8 (584.8) | N/A | MSFC | -- |
| 145a | Signal from LVDC for: Emergency Playback Enable ON | 00:08:44.96 (524.96) | TB4 +7.8 | IU | 00:09:44.094 (584.094) | TB4 +7.767 | MSFC | -- |

TABLE 5-1 (Sheet 12 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 145b | Signal Received in S-IVB for: Emergency Playback Enable ON | -- | -- | S-IVB | 00:09:44.082 (584.082) | TB4 +7.759 | DAC (FM) | 13 |
| 146a | Signal from LVDC for: Fast Record OFF | 00:08:45.6 (525.6) | TB4 +8.0 | IU | 00:09:44.280 (584.280) | TB4 +7.953 | MSFC | -- |
| 146b | Signal Received in S-IVB for: Fast Record OFF | -- | -- | S-IVB | 00:09:44.268 (584.269) | TB4 +7.942 | DAC (FM) | 13 |
| 147a | Signal from LVDC for: PU Activate ON | 00:08:46.16 (526.16) | TB4 +9.0 | IU | 00:09:45.300 (585.300) | TB4 +8.973 | MSFC | -- |
| 147b | Signal Received in S-IVB for: PU Activate ON | -- | -- | S-IVB | 00:09:45.288 (585.288) | TB4 +8.961 | DAC (FM) | 13 |
| 148a | Signal from LVDC for: Charge Ullage Jettison ON | 00:08:46.96 (526.96) | TB4 +9.9 | IU | 00:09:46.094 (586.094) | TB4 +9.767 | MSFC | -- |
| 148b | Signal Received in S-IVB for: Charge Ullage Jettison ON | -- | -- | S-IVB | 00:09:46.081 (586.081) | TB4 +9.754 | DAC (FM) | 13 |
| 149 | S-IVB PU Valve Reaches Hardover Position | 00:08:48.16 (528.16) | TB4 +11.0 | N/A | 00:09:49.0 (589.0) | TB4 +12.673 | DAC | 100 |
| 150 | S-IC Impact | 00:08:48.762 (528.762) | N/A | N/A | 00:08:48.93 (528.93) | N/A | MSFC | -- |
| 151a | Signal from LVDC for: Fire Ullage Jettison ON | 00:08:49.96 (529.96) | TB4 +12.8 | IU | 00:09:49.081 (589.081) | TB4 +12.754 | MSFC | -- |
| 151b | Signal Received in S-IVB for: Fire Ullage Jettison ON | -- | -- | S-IVB | 00:09:49.066 (589.066) | TB4 +12.739 | DAC (FM) | 13 |
| 152a | Signal from LVDC for: Fuel Injection Temperature OK Bypass Reset | | TB4 +14.0 | IU | 00:09:50.280 (590.280) | TB4 +13.953 | MSFC | -- |
| 152b | Signal Received in S-IVB for: Fuel Injection Temperature OK Bypass Reset | | | S-IVB | 00:09:50.268 (590.268) | TB4 +13.941 | DAC (FM) | 13 |
| 153a | Signal from LVDC for: Ullage Charging Reset | 00:08:52.76 (532.76) | TB4 +15.6 | IU | 00:09:51.880 (591.880) | TB4 +15.55 | MSFC | -- |
| 153b | Signal Received in S-IVB for: Ullage Charging Reset | -- | -- | S-IVB | 00:09:51.869 (591.869) | TB4 +15.542 | DAC (FM) | 13 |
| 154a | Signal from LVDC for: Ullage Firing Reset | 00:08:52.96 (532.96) | TB4 +15.8 | IU | 00:09:52.088 (592.088) | TB4 +15.761 | MSFC | -- |
| 154b | Signal Received in S-IVB for: Ullage Firing Reset | -- | -- | S-IVB | 00:09:52.075 (592.075) | TB4 +15.748 | DAC (FM) | 13 |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 13 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 155 | Signal from LVDC for: IU Tape Recorder Record OFF | 00:08:53.06 (533.06) | TB4 +18.9 | IU | 00:09:55.181 (595.181) | TB4 +18.854 | MSFC | -- |
| 156a | Signal from LVDC for: Emergency Playback Enable OFF | 00:08:58.46 (538.46) | TB4 +21.3 | IU | 00:09:57.580 (597.580) | TB4 +21.253 | MSFC | -- |
| 156b | Signal Received in S-IVB for: Emergency Playback Enable OFF | -- | -- | S-IVB | 00:09:57.567 (597.567) | TB4 +21.240 | DAC (FM) | 13 |
| 157 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 00:08:59.56 (539.56) | TB4 +22.4 | IU | 00:09:58.680 (598.680) | TB4 +22.353 | MSFC | -- |
| 158 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:09:04.56 (544.56) | TB4 +27.4 | IU | 00:10:03.702 (603.702) | TB4 +27.375 | MSFC | -- |
| 159a | Signal from LVDC for: Regular Calibrate Relays ON | 00:09:08.96 (548.96) | TB4 +31.8 | IU | 00:10:08.095 (608.095) | TB4 +31.768 | MSFC | -- |
| 159b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 00:10:08.082 (608.082) | TB4 +31.755 | DAC (FM) | 13 |
| 160a | Signal from LVDC for: Regular Calibrate Relays OFF | 00:09:13.96 (553.96) | TB4 +36.8 | IU | 00:10:13.080 (613.080) | TB4 +36.753 | MSFC | -- |
| 160b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 00:10:13.070 (613.070) | TB4 +36.743 | DAC (FM) | 13 |
| 161 | Introduction of Chi Tilde Guidance Mode | 00:10:22.5 (622.5) | N/A | IU | 00:11:52.3 (712.3) | N/A | MSFC | -- |
| 162a | Signal from LVDC for: Engine Pump Purge Control Valve Enable ON | 00:10:43.76 (643.76) | TB5 -7.0 | IU | 00:12:26.913 (746.913) | TB5 -.395 | MSFC | -- |
| 162b | Signal Received in S-IVB for: Engine Pump Purge Control Valve Enable ON | -- | -- | S-IVB | 00:12:26.903 (746.903) | TB5 -.394 | DAC (FM) | 13 |
| 163 | Freeze Body Attitude (Chi Freeze) | 00:10:49.5 (649.5) | N/A | IU | 00:12:26.4 (746.4) | N/A | MSFC | -- |
| 164a | Signal from LVDC for: S-IVB Engine Cutoff (Guidance Cutoff) | 00:10:57.1 (657.1) | N/A | IU | 00:12:27.041 (747.041) | N/A | MSFC | 13 |
| 164b | Signal Received in S-IVB for: S-IVB Engine Cutoff (Guidance Cutoff) | -- | -- | S-IVB | 00:12:27.032 (747.032) | N/A | DAC (FM) | 13 |
| 165 | Cutoff S-IVB Engine Interrupt 1520 | 00:10:57.1 (657.1) | N/A | IU | 00:12:27.30 (747.30) | N/A | MSFC | -- |

TABLE 5-1 (Sheet 14 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|-------------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| TIME BASE 5 | | | | | | | | |
| 166 | LVDC Initiates TB5 Maintain Cutoff Inertial Attitude | 00:10:57.1 (657.1) | TB5 +0.0 | IU | 00:12:27.29 (747.298) | TB5 +0.0 | MSFC | -- |
| 167a | LVDC Sends Redundant Signal for: S-IVB Engine Cutoff | -- | -- | IU | 00:12:27.380 (747.380) | TB5 +.082 | MSFC | -- |
| 167b | Signal Received in S-IVB for: S-IVB Engine Cutoff (Redundant Signal) | -- | -- | S-IVB | 00:12:27.37 (747.371) | TB5 +.073 | DAC (FM) | 13 |
| 168a | Signal from LVDC for: Point Level Sensor Disarming | 00:10:57.2 (657.2) | TB5 +0.1 | IU | 00:12:27.473 (747.473) | TB5 +.175 | MSFC | -- |
| 168b | Signal Received in S-IVB for: Point Level Sensor Disarming | -- | -- | S-IVB | 00:12:27.463 (747.463) | TB5 +.165 | DAC (FM) | 13 |
| 169 | S-IVB J-2 Thrust Decay to 5% (Average) | -- | -- | N/A | 00:12:27.496 (747.496) | N/A | DAC | -- |
| 170a | Signal from LVDC for: S-IVB Ullage Engine No. 1 ON | 00:10:57.4 (657.4) | TB5 +0.3 | IU | 00:12:27.565 (747.565) | TB5 +.267 | MSFC | -- |
| 170b | Signal Received in S-IVB for: S-IVB Ullage Engine No. 1 ON | -- | -- | S-IVB | 00:12:27.556 (747.556) | TB5 +.258 | DAC (FM) | -- |
| 171a | Signal from LVDC for: S-IVB Ullage Engine No. 2 ON | 00:10:57.5 (657.5) | TB5 +0.4 | IU | 00:12:27.659 (747.659) | TB5 +.361 | MSFC | -- |
| 171b | Signal Received in S-IVB for: S-IVB Ullage Engine No. 2 ON | -- | -- | S-IVB | 00:12:27.652 (747.652) | TB5 +.354 | DAC (FM) | 13 |
| 172 | Signal from LVDC for: Ullage Thrust Present ON | 00:10:57.7 (657.7) | TB5 +0.6 | IU | 00:12:27.869 (747.869) | TB5 +.571 | MSFC | -- |
| 173a | Signal from LVDC for: First Burn Relay OFF | 00:10:57.8 (657.8) | TB5 +0.7 | IU | 00:12:27.966 (747.966) | TB5 +.668 | MSFC | -- |
| 173b | Signal Received in S-IVB for: First Burn Relay OFF | -- | -- | S-IVB | 00:12:27.958 (747.958) | TB5 +.660 | DAC (FM) | 13 |
| 174a | Signal from LVDC for: PU Activate OFF | 00:10:57.0 (658.0) | TB5 +0.9 | IU | 00:12:28.153 (748.153) | TB5 +.855 | MSFC | -- |
| 174b | Signal Received in S-IVB for: PU Activate OFF | -- | -- | S-IVB | 00:12:28.143 (748.143) | TB5 +.845 | DAC (FM) | 13 |
| 175a | Signal from LVDC for: LOX Tank Flight Pressure System OFF | 00:10:58.2 (658.2) | TB5 +1.1 | IU | 00:12:28.359 (748.359) | TB5 +1.061 | MSFC | -- |

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Sequence of Events

TABLE 5-1 (Sheet 15 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 175b | Signal Received in S-IVB for: LOX Tank Flight Pressure System OFF | -- | -- | S-IVB | 00:12:28.352 (748.352) | TB5 +1.054 | DAC (FM) | 13 |
| 176a | Signal from LVDC for: Coast Period ON | 00:10:58.4 (658.4) | TB5 +1.3 | IU | 00:12:28.551 (748.551) | TB5 +1.253 | MSFC | -- |
| 176b | Signal Received in S-IVB for: Coast Period ON | -- | -- | S-IVB | 00:12:28.543 (748.543) | TB5 +1.245 | DAC (FM) | 13 |
| 177a | Signal from LVDC for: Engine Pump Purge Control Valve Enable ON | 00:10:58.6 (658.6) | TB5 +1.5 | IU | 00:12:28.752 (748.752) | TB5 +1.454 | MSFC | -- |
| 177b | Signal Received in S-IVB for: Engine Pump Purge Control Valve Enable ON | -- | -- | S-IVB | 00:12:28.742 (748.742) | TB5 +1.444 | DAC (FM) | 13 |
| 178a | Signal from LVDC for: PU Fuel Boiloff Bias Cutoff ON | 00:10:58.8 (658.8) | TB5 +1.7 | IU | 00:12:28.967 (748.967) | TB5 +1.669 | MSFC | -- |
| 178b | Signal Received in S-IVB for: PU Fuel Boiloff Bias Cutoff ON | -- | -- | S-IVB | 00:12:28.962 (748.962) | TB5 +1.664 | DAC (FM) | 13 |
| 179 | Signal from LVDC for: Flight Control Computer S-IVB Burn Mode OFF "A" | 00:11:00.6 (660.6) | TB5 +3.5 | IU | 00:12:30.755 (750.755) | TB5 +3.457 | MSFC | -- |
| 180 | Signal from LVDC for: Flight Control Computer S-IVB Burn Mode OFF "B" | 00:11:00.8 (660.8) | TB5 +3.7 | IU | 00:12:30.971 (750.971) | TB5 +3.673 | MSFC | -- |
| 181a | Signal from LVDC for: Aux. Hydraulic Pump Coast Mode ON | 00:11:01.0 (661.0) | TB5 +3.9 | IU | 00:12:31.151 (751.151) | TB5 +3.853 | MSFC | -- |
| 181b | Signal Received in S-IVB for: Aux. Hydraulic Pump Coast Mode ON | -- | -- | S-IVB | 00:12:31.110 (751.110) | TB +3.812 | DAC (FM) | 13 |
| 182a | Signal from LVDC for: Aux. Hydraulic Pump Flight Mode OFF | 00:11:02.2 (662.2) | TB5 +4.1 | IU | 00:12:31.367 (751.367) | TB5 +4.069 | MSFC | -- |
| 182b | Signal Received in S-IVB for: Aux. Hydraulic Pump Flight Mode OFF | -- | -- | S-IVB | 00:12:31.330 (751.330) | TB5 +4.032 | DAC (FM) | 13 |
| 183 | Signal from LVDC for: S-IVB Engine Out Indication "A" Enable Reset | 00:11:07.1 (667.1) | TB5 +10.0 | IU | 00:12:37.266 (757.266) | TB5 +9.968 | MSFC | -- |

TABLE 5-1 (Sheet 16 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 184 | Signal from LVDC for: S-IVB Engine Out Indication "B" | 00:11:07.3 (667.3) | TB5 +10.2 | IU | 00:13:37.452 (757.452) | TB5 +10.154 | MSFC | -- |
| 185 | Enable Reset Parking Orbit Insertion | 00:11:08.7 (668.7) | N/A | | 00:12:28.2 (748.2) | N/A | DAC | -- |
| 186 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 00:11:09.3 (669.3) | TB5 +12.2 | | 00:12:39.451 (759.451) | TB5 +12.153 | MSFC | -- |
| 187a | Signal from LVDC for: Regular Calibrate Relays ON | 00:11:09.5 (669.5) | TB5 +12.4 | | 00:12:39.660 (759.660) | TB5 +12.362 | MSFC | -- |
| 187b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 00:12:34.620 (759.620) | TB5 +12.322 | DAC (FM) | -- |
| 188 | Align Axis with Local Horizontal | 00:11:12.1 | N/A | | 00:12:44 (764) | N/A | DAC | -- |
| 189 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:11:14.3 (674.3) | TB5 +17.2 | IU | 00:12:44.470 (764.470) | TB5 +17.172 | MSFC | -- |
| 190a | Signal from LVDC for: Regular Calibrate Relays OFF | 00:11:14.5 (674.5) | TB5 +17.4 | | 00:12:44.652 (764.652) | TB5 +17.354 | MSFC | -- |
| 190b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 00:12:44.645 (764.645) | TB5 +17.302 | DAC | -- |
| 191a | Signal from LVDC for: SSB Transmitter OFF | 00:11:19.1 (679.1) | TB5 +22.0 | IU | 00:12:49.255 (769.255) | TB5 +21.957 | MSFC | -- |
| 191b | Signal Received in S-IVB for: SSB Transmitter Group OFF | -- | -- | S-IVB | 00:12:49.248 (769.248) | TB5 +21.950 | DAC (FM) | 13 |
| 192a | Signal from LVDC for: SSB Group OFF | 00:11:19.3 (679.3) | TB5 +22.2 | IU | 00:12:49.459 (769.459) | TB5 +22.161 | MSFC | -- |
| 192b | Signal Received in S-IVB for: SSB Group OFF | -- | -- | S-IVB | 00:12:49.452 (769.452) | TB5 +22.154 | DAC (FM) | 13 |
| 193a | Signal from LVDC for: LH2 Tank Continuous Vent Valve Open ON | 00:11:56.1 (716.1) | TB5 +59.0 | IU | 00:13:26.251 (806.251) | TB5 +58.953 | MSFC | -- |
| 193b | Signal Received in S-IVB for: LH2 Tank Continuous Vent Valve Open ON | -- | -- | S-IVB | 00:13:26.22 (806.22) | TB5 +58.922 | DAC (FM) | 13 |
| 194a | Signal from LVDC for: LH2 Tank Continuous Vent Valve Open OFF | 00:11:58.1 (718.1) | TB5 +61.0 | IU | 00:13:28.257 (808.257) | TB5 +60.959 | MSFC | -- |
| 194b | Signal Received in S-IVB for: LH2 Tank Continuous Vent Valve Open OFF | -- | -- | S-IVB | 00:13:28.22 (808.22) | TB5 +60.922 | DAC (FM) | 13 |

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TABLE 5-1 (Sheet 17 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 195a | Signal from LVDC for: S-IVB Ullage Engine No. 1 OFF | 00:12:25.1 (745.1) | TB5 +88.0 | IU | 00:13:55.251 (835.251) | TB5 +87.953 | MSFC | -- |
| 195b | Signal Received in S-IVB for: Ullage Engine No. 1 OFF | -- | -- | S-IVB | 00:13:55.21 (835.21) | TB5 +87.912 | DAC (FM) | 13 |
| 196a | Signal from LVDC for: S-IVB Ullage Engine No. 2 OFF | 00:12:25.2 (745.2) | TB5 +88.1 | IU | 00:13:55.350 (835.350) | TB5 +88.052 | MSFC | -- |
| 196b | Signal Received in S-IVB for: S-IVB Ullage Engine No. 2 OFF | -- | -- | S-IVB | 00:13:55.31 (835.31) | TB5 +88.012 | DAC (FM) | 13 |
| 197 | Signal from LVDC for: S-IVB Ullage Thrust Present OFF | 00:12:25.4 (745.4) | TB5 +88.3 | IU | 00:13:55.560 (835.560) | TB5 +88.262 | MSFC | -- |
| 198a | Signal from LVDC for: Emergency Playback Enable ON | 00:12:25.6 (745.6) | TB5 +88.5 | IU | 00:13:55.75 (835.75)* | TB5 +88.452 | MSFC | -- |
| 198b | Signal Received in S-IVB for: Emergency Playback Enable ON | -- | -- | S-IVB | 00:13:55.71 (835.71) | TB5 +88.412 | DAC (FM) | 13 |
| 199 | Signal from LVDC for: Tape Recorder Playback Reverse ON | 00:12:26.3 (746.3) | TB5 +89.2 | IU | 00:13:56.452 (836.452) | TB5 +89.154 | MSFC | -- |
| 200 | Roll 180° to Position III Down | 00:12:37.1 | N/A | N/A | 00:13:57 (837) | N/A | DAC | -- |
| 201a | Signal from LVDC for: Emergency Playback Enable OFF | 00:13:38.6 (818.6) | TB5 +161.5 | IU | 00:15:08.75 (908.75)* | TB5 +161.452 | MSFC | -- |
| 201b | Signal Received in S-IVB for: Emergency Playback Enable OFF | -- | -- | S-IVB | 00:15:08.72 (908.72) | TB5 +161.422 | DAC (FM) | 13 |
| 202a | Signal from LVDC for: Slow Record ON | 00:13:39.3 (819.3) | TB5 +162.2 | IU | 00:15:09.45 (909.45)* | TB5 +162.152 | MSFC | -- |
| 202b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 00:15:09.42 (909.42) | TB5 +162.122 | DAC (FM) | 13 |
| 203a | Signal from LVDC for: Slow Record ON | 00:13:49.3 (829.3) | TB5 +172.2 | IU | 00:15:19.45 (919.45)* | TB5 +172.152 | MSFC | -- |
| 203b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 00:15:19.42 (919.42) | TB5 +172.122 | DAC (FM) | 13 |
| 204 | Signal from LVDC for: Tape Recorder Playback Reverse OFF | 00:13:50.3 (830.3) | TB5 +173.2 | IU | 00:15:20.45 (920.45)* | TB5 +173.152 | MSFC | -- |
| 205 | Signal from LVDC for: Water Coolant Valve Closed | | Variable | IU | 00:18:04.077 (1084.077) | TB5 +336.779 | MSFC | -- |
| 206 | S-II Impact | 00:19:41.158 (1,181.158) | N/A | N/A | 00:20:51.24 (1,251.24) | N/A | MSFC | -- |

TABLE 5-1 (Sheet 18 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 207a | Signal from LVDC for: Engine Pump Purge Control Valve Enable OFF | 00:20:59.7 (1,259.7) | TB5 +602.6 | IU | 00:22:29.85 (1,349.85)* | TB5 +602.552 | MSFC | -- |
| 207b | Signal Received in S-IVB for: Engine Pump Purge Control Valve Enable OFF | -- | -- | S-IVB | 00:22:29.852 (1,349.852) | TB5 +602.554 | DAC (FM) | 13 |
| 208a | Signal from LVDC for: Slow Record ON | 00:37:50.6 (2,270.6) | TB5 +1,613.5 | IU | 00:39:20.75 (2,360.75)* | TB5 +1,613.452 | MSFC | -- |
| 208b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 00:39:20.70 (2,360.70) | TB5 +1,613.402 | DAC (FM) | 13 |
| 209a | Signal from LVDC for: Slow Record OFF | 00:38:22.6 (2,302.6) | TB5 +1,645.4 | IU | 00:39:52.75 (2,392.75)* | TB5 +1,645.452 | MSFC | -- |
| 209b | Signal Received in S-IVB for: Slow Record OFF | -- | -- | S-IVB | 00:39:52.70 (2,392.70) | TB5 +1,645.402 | DAC (FM) | 13 |
| 210a | Signal from LVDC for: Recorder Playback ON | 00:38:22.8 (2,302.8) | TB5 +1,645.7 | IU | 00:39:52.95 (2,392.95)* | TB5 +1,645.652 | MSFC | -- |
| 210b | Signal Received in S-IVB for: Recorder Playback ON | -- | -- | S-IVB | 00:39:52.90 (2,392.90) | TB5 +1,645.602 | DAC (FM) | 13 |
| 211a | Signal from LVDC for Recorder Playback OFF | 00:41:10.6 (2,470.6) | TB5 +1,813.5 | IU | 00:42:40.75 (2,560.75)* | TB5 +1,813.452 | MSFC | -- |
| 211b | Signal Received in S-IVB for: Recorder Playback OFF | -- | -- | S-IVB | 00:42:40.72 (2,560.72) | TB5 +1,813.422 | DAC (FM) | 13 |
| 212a | Signal from LVDC for: Slow Record ON | 00:41:10.8 (2,470.8) | TB5 +1,813.7 | IU | 00:42:40.95 (2,560.95)* | TB5 +1,813.652 | MSFC | -- |
| 212b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 00:42:40.92 (2,560.92) | TB5 +1,813.622 | DAC (FM) | 13 |
| 213a | Signal from LVDC for: Slow Record ON | 00:41:20.8 (2,480.8) | TB5 +1,823.7 | IU | 00:42:50.95 (2,570.95)* | TB5 +1,823.652 | MSFC | -- |
| 213b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 00:42:50.92 (2,570.92) | TB5 +1,823.622 | DAC (FM) | 13 |
| 214 | Initiate 20° Pitch Down | 00:51:57.1 (3,117.1) | N/A | N/A | 00:53:27 (3,207) | N/A | DAC | -- |
| 215 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 00:54:10.6 (3,250.6) | TB5 +2,593.5 | IU | 00:55:40.251 (3,340.751) | TB5 +2,593.453 | MSFC | -- |
| 216a | Signal from LVDC for: Regular Calibrate Relays ON | 00:54:10.8 (3,240.8) | TB5 +2,593.7 | IU | 00:55:40.951 (3,340.951) | TB5 +2,593.653 | MSFC | -- |
| 216b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 00:55:40.96 (3,340.96) | TB5 +2,593.655 | DAC (FM) | 13 |

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TABLE 5-1 (Sheet 19 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 217 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 00:54:15.6 (3,245.6) | TB5 +2,598.5 | IU | 00:55:45.772 (3,345.772) | TB5 +2,598.474 | MSFC | -- |
| 218a | Signal from LVDC for: Regular Calibrate Relays OFF | 00:54:15.8 (3,245.8) | TB5 +2,598.7 | IU | 00:55:45.963 (3,345.963) | TB5 +2,598.665 | MSFC | -- |
| 218b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 00:55:46.02 (3,346.02) | TB5 +2,598.722 | DAC (FM) | 13 |
| 219 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 00:59:40.803 (3,580.803) | TB5 +2,833.505 | MSFC | -- |
| 220 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 00:59:40.872 (3,580.872) | TB5 +2,833,574 | MSFC | -- |
| 221 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 01:28:15.6 (5,295.6) | TB5 +4,638.5 | IU | 01:29:45.75 (5,385.75)* | TB5 +4,638.452 | MSFC | -- |
| 222a | Signal from LVDC for: Slow Record ON | 01:28:15.8 (5,295.8) | TB5 +4,638.7 | IU | 01:29:45.95 (5,385.95)* | TB5 +4,638.652 | MSFC | 13 |
| 222b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 01:29:45.95 (5,385.93) | TB5 +4,638.632 | DAC (FM) | 13 |
| 223a | Signal from LVDC for: Regular Calibrate Relays ON | 01:28:16.0 (5,296.0) | TB5 +4,638.9 | IU | 01:29:46.15 (5,386.15)* | TB5 +4,638.822 | MSFC | -- |
| 223b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 01:29:46.12 (5,386.12) | TB5 +4,638.822 | DAC (FM) | 13 |
| 224 | Signal from LVDC for: Telemetry Calibrate OFF | 01:28:20.6 (5,300.6) | TB5 +4,643.5 | IU | 01:29:50.749 (5,390.749) | TB5 +4,643.451 | MSFC | -- |
| 225a | Signal from LVDC for: Regular Calibrate Relays OFF | 01:28:21.0 (5,301.0) | TB5 +4,643.9 | IU | 01:29:51.150 (5,391.150) | TB5 +4,643.852 | MSFC | -- |
| 225b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 01:29:51.11 (5,391.11) | TB5 +4,643.812 | DAC (FM) | 13 |
| 226a | Signal from LVDC for: Slow Record OFF | 01:28:47.8 (5,327.8) | TB5 +4,670.7 | IU | 01:30:17.951 (5,417.951) | TB5 +4,670.653 | MSFC | -- |
| 226b | Signal Received in S-IVB for: Slow Record OFF | -- | -- | S-IVB | 01:30:17.95 (5,417.95) | TB5 +4,670.652 | DAC (FM) | 13 |
| 227a | Signal from LVDC for: Recorder Playback ON | 01:28:48.2 (5,328.2) | TB5 +4,671.1 | IU | 01:30:18.351 (5,418.351) | TB5 +4,671.053 | MSFC | -- |
| 227b | Signal Received in S-IVB for: Recorder Playback ON | -- | -- | S-IVB | 01:30:18.33 (5,418.33) | TB5 +4,671.032 | DAC (FM) | 13 |
| 228 | Initiate 90° Pitch Up Maneuver | 01:28:57.1 (5,337.1) | N/A | | 01:30:27 (5,427) | N/A | DAC | -- |
| 229a | Signal from LVDC for: Recorder Playback OFF | 01:34:44.6 (5,684.6) | TB5 +5,027.5 | IU | 01:36:14.751 (5,774.751) | TB5 +5,027.453 | MSFC | -- |

TABLE 5-1 (Sheet 20 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 229b | Signal Received in S-IVB for: Recorder Playback OFF | -- | -- | S-IVB | 01:36:14.71 (5,774.71) | TB5 +5,027.412 | DAC (FM) | 13 |
| 230a | Signal from LVDC for: Slow Record ON | 01:34:45.0 (5,685.0) | TB5 +5,027.9 | IU | 01:36:15.151 (5,775.151) | TB5 +5,027.853 | MSFC | -- |
| 230b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 01:36:15.09 (5,775.09) | TB5 +5,027.792 | DAC (FM) | 13 |
| 231 | Roll 180° (Position I Down) | 01:34:45.73 (5,685.73) | N/A | -- | 01:36:27 (5,787) | N/A | DAC | -- |
| 232a | Signal from LVDC for: Slow Record ON | 01:34:55.0 (5,695.0) | TB5 +5,037.9 | IU | 01:36:15.152 (5,785.152) | TB5 +5,037.854 | MSFC | -- |
| 232b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 01:36:25.12 (5,785.12) | TB5 +5,037.822 | DAC (FM) | 13 |
| 233 | Roll 180° to Position I Down | 01:34:57.1 (5,697.1) | TB5 +5,040.0 | N/A | 01:36:27 (5,787) | TB5 +5,040 | DAC | -- |
| 234 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 01:37:01.509 (5,821.509) | TB5 +5,074.211 | MSFC | -- |
| 235 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 01:37:01.580 (5,821.580) | TB5 +5,074.282 | MSFC | -- |
| 236 | Signal from LVDC for: Water Coolant Valve Open | | Variable | IU | 01:38:11.178 (5,891.178) | TB5 +5,143.880 | MSFC | -- |
| 237 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 01:38:45.512 (5,925.512) | TB5 +5,178.214 | MSFC | -- |
| 238 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 01:38:45.582 (5,925.582) | TB5 +5,178.284 | MSFC | -- |
| 239 | Signal from LVDC for: Water Coolant Valve Closed | | Variable | IU | 01:43:11.646 (6,191.646) | TB5 +5,444.348 | MSFC | -- |
| 240 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 01:44:10.6 (6,250.6) | TB5 +5,593.5 | IU | 01:45:751 (6,340.751) | TB5 +5,593.453 | MSFC | -- |
| 241a | Signal from LVDC for: Regular Calibrate Relays ON | 01:44:10.8 (6,250.8) | TB5 +5,593.7 | IU | 01:45:40.951 (6,340.951) | TB5 +5,593.653 | MSFC | -- |
| 241b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 01:45:40.92 (6,340.92) | TB5 +5,593.622 | DAC (FM) | 13 |
| 242 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 01:44:15.6 (6,255.6) | TB5 +5,598.5 | IU | 01:45:45.757 (6,345.757) | TB5 +5,598.459 | MSFC | -- |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 21 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 243a | Signal from LVDC for: Regular Calibrate Relays OFF | 01:44:15.8 (6,255.8) | TB5 +5,598.7 | IU | 01:45:45.957 (6,345.957) | TB5 +5,598.659 | MSFC | -- |
| 243b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 01:45:45.92 (6,345.92) | TB5 +5,598.622 | DAC (FM) | 13 |
| 244 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 01:50:37.210 (6,637.210) | TB5 +5,889.912 | MSFC | -- |
| 245 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 01:50:37.281 (6,637.281) | TB5 +5,889.983 | MSFC | -- |
| 246a | Signal from LVDC for: Slow Record ON | 02:10:17.6 (7,817.6) | TB5 +7,160.5 | IU | 02:11:47.75 (7,907.75)* | TB5 +7,160.452 | MSFC | -- |
| 246b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 02:11:47.73 (7,907.73) | TB5 +7,160.432 | DAC (FM) | 13 |
| 247a | Signal from LVDC for: Slow Record OFF | 02:10:49.6 (7,849.6) | TB5 +7,192.5 | IU | 02:12:19.765 (7,939.765)* | TB5 +7,192.476 | MSFC | -- |
| 247b | Signal received in S-IVB for: Slow Record OFF | -- | -- | S-IVB | 02:12:19.72 (7,939.72) | TB5 +7,192.422 | DAC (FM) | 13 |
| 248a | Signal from LVDC for: Recorder Playback ON | 02:10:49.8 (7,849.8) | TB5 +7,192.7 | IU | 02:12:19.965 (7,939.965)* | TB5 +7,192.667 | MSFC | -- |
| 248b | Signal Received in S-IVB for: Recorder Playback ON | -- | -- | S-IVB | 02:12:19.92 (7,939.92) | TB5 +7,192.622 | DAC (FM) | 13 |
| 249 | Signal from LVDC for: Water Coolant Valve Closed | | Variable | IU | 02:13:15.446 (7,995.446) | TB5 +7,248.148 | MSFC | -- |
| 250a | Signal from LVDC for: Recorder Playback OFF | 02:15:20.4 (8,120.4) | TB5 +7,463.3 | IU | 02:16:50.55 (8,210.55)* | TB5 +7,463.252 | MSFC | -- |
| 250b | Signal Received in S-IVB for: Recorder Playback OFF | -- | -- | S-IVB | 02:16:50.50 (8,210.50) | TB5 +7,463.202 | DAC (FM) | 13 |
| 251a | Signal from LVDC for: Slow Record ON | 02:15:20.6 (8,120.6) | TB5 +7,463.5 | IU | 02:16:50.75 (8,210.75)* | TB5 +7,463.452 | MSFC | -- |
| 251b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 02:16:50.70 (8,210.70) | TB5 +7,463.402 | DAC (FM) | 13 |
| 252a | Signal from LVDC for: Slow Record ON | 02:15:30.6 (8,130.6) | TB5 +7,473.5 | IU | 02:17:00.752 (8,220.752)* | TB5 +7,473.454 | MSFC | -- |
| 252b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 02:17:00.70 (8,220.70) | TB5 +7,473.402 | DAC (FM) | 13 |
| 253a | Signal from LVDC for: Regular Calibrate Relays ON | 02:28:10.6 (8,890.6) | TB5 +8,233.5 | IU | 02:29:40.752 (8,980.752) | TB5 +8,233.454 | MSFC | -- |
| 253b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 02:29:40.74 (8,980.74) | TB5 +8,233.442 | DAC (FM) | 13 |

TABLE 5-1 (Sheet 22 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 254 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 02:28:10.8 (8,890.8) | TB5 +8,233.7 | IU | 02:29:40.952 (8,980.952) | TB5 +8,233.654 | MSFC | -- |
| 255a | Signal from LVDC for: Regular Calibrate Relays OFF | 02:28:15.6 (8,895.6) | TB5 +8,238.5 | IU | 02:29:45.751 (8,985.751) | TB5 +8,238.453 | MSFC | -- |
| 255b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 02:29:45.70 (8,985.70) | TB5 +8,238.402 | DAC (FM) | 13 |
| 256 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 02:28:15.8 (8,895.8) | TB5 +8,238.7 | IU | 02:29:45.951 (8,985.951) | TB5 +8,238.653 | MSFC | -- |
| 257a | Signal from LVDC for: Slow Record ON | 02:52:00.6 (10,320.6) | TB5 +9,663.5 | IU | 02:53:30.75 (10,410.75)* | TB5 +9,663.452 | MSFC | -- |
| 257b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 02:53:30:739 (10,410.739) | TB5 +9,663.441 | DAC (FM) | 13 |
| 258a | Signal from LVDC for: Slow Record OFF | 02:52:32.6 (10,352.6) | TB5 +9,695.5 | IU | 02:54:02.75 (10,442.75)* | TB5 +9,695.452 | MSFC | -- |
| 258b | Signal Received in S-IVB for: Slow Record OFF | -- | -- | S-IVB | 02:54:02.755 (10,442.755) | TB5 +9,695.457 | DAC (FM) | 13 |
| 259a | Signal from LVDC for: Recorder Playback ON | 02:52:32.8 (10,352.8) | TB5 +9,695.7 | IU | 02:54:02.95 (10,442.95)* | TB5 +9,695.652 | MSFC | -- |
| 259b | Signal Received in S-IVB for: Recorder Playback ON | -- | -- | S-IVB | 02:54:02.949 (10,442.949) | TB5 +9,695.651 | DAC (FM) | 13 |
| 260a | Signal from LVDC for: Recorder Playback OFF | 02:56:57.6 (10,377.6) | TB5 +9,960.5 | IU | 02:58:27.75 (10,707.75)* | TB5 +9,960.452 | MSFC | -- |
| 260b | Signal Received in S-IVB for: Recorder Playback OFF | -- | -- | S-IVB | 02:58:27.731 (10,707.731) | TB5 +9,960.433 | DAC (FM) | 13 |
| 261a | Signal from LVDC for: Slow Record ON | 02:56:57.8 (10,377.8) | TB5 +9,960.7 | IU | 02:58:27.95 (10,707.95)* | TB5 +9,960.652 | MSFC | -- |
| 261b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 02:58:27.931 (10,707.931) | TB5 +9,960.633 | DAC (FM) | 13 |
| 262a | Signal from LVDC for: Slow Record ON | 02:57:07.8 (10,627.8) | TB5 +9,970.7 | IU | 02:58:37.95 (10,717.95)* | TB5 +9,970.652 | MSFC | -- |
| 262b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 02:58:37.935 (10,717.935) | TB5 +9,970.637 | DAC (FM) | 13 |
| 263a | Signal from LVDC for: Aux. Hydraulic Pump Flight Mode ON | 02:58:52.1 (10,732.1) | TB5 +10,075.0 | IU | 03:00:22.25 (10,822.25)* | TB5 +10,074.952 | MSFC | -- |
| 263b | Signal Received in S-IVB for: Aux. Hydraulic Pump Flight Mode ON | -- | -- | S-IVB | 03:00:22.231 (10,822.231) | TB5 +10,074.933 | DAC (FM) | 13 |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 23 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 264a | Signal from LVDC for: Aux. Hydraulic Pump Coast Mode OFF | 02:58:52.3 (10,732.3) | TB5 +10,075.2 | IU | 03:00:22.45 (10,822.45)* | TB5 +10,075.152 | MSFC | -- |
| 264b | Signal Received in S-IVB for: Aux. Hydraulic Pump Coast Mode OFF | -- | -- | S-IVB | 03:00:22.435 (10,822.435) | TB5 +10,075.147 | DAC (FM) | 13 |
| 265a | Signal from LVDC for: LOX Chilldown Pump ON | 02:59:42.1 (10,782.1) | TB5 +10,125.0 | IU | 03:01:12.25 (10,872.25)* | TB5 +10,124.952 | MSFC | -- |
| 265b | Signal Received in S-IVB for: LOX Chilldown Pump ON | -- | -- | S-IVB | 03:01:12.205 (10,872.205) | TB5 +10,124.907 | DAC (PCM) | 25 |
| 266a | Signal from LVDC for: Fuel Chilldown Pump ON | 02:59:47.1 (10,787.1) | TB5 +10,130.0 | IU | 03:01:17.225 (10,877.25)* | TB5 +129.952 | MSFC | -- |
| 266b | Signal Received in S-IVB for: Fuel Chilldown Pump ON | -- | -- | S-IVB | 03:01:17.225 (10,877.225) | TB5 +10,129.927 | DAC (PCM) | 25 |
| 267a | Signal from LVDC for: Prevalves Close ON | 02:54:57.1 (10,747.1) | TB5 +10,140.0 | IU | 03:01:27.25 (10,887.25)* | TB5 +10,139.952 | MSFC | -- |
| 267b | Signal Received in S-IVB for: Prevalves Close ON | -- | -- | S-IVB | 03:01:27.225 (10,887.225) | TB5 +10,139.927 | DAC (PCM) | 25 |
| 268 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 03:04:29.038 (11,069.038) | N/A | MSFC | -- |
| 269 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 03:04:29.038 (11,069.109) | N/A | MSFC | -- |
| 270 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 03:06:10.6 (11,170.6) | TB5 +10,513.5 | IU | 03:07:40.751 (11,260.751) | TB5 +10,513.453 | MSFC | -- |
| 271a | Signal from LVDC for: Regular Calibrate Relays ON | 03:06:10.8 (11,170.8) | TB5 +10,513.7 | IU | 03:07:40.950 (11,260.950) | TB5 +10,513.652 | MSFC | -- |
| 271b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 03:07:40.93 (11,260.93) | TB5 +10,513.632 | DAC (FM) | 13 |
| 272 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 03:06:15.6 (11,175.6) | TB5 +10,518.5 | IU | 03:07:45.757 (11,265.757) | TB5 +10,518.459 | MSFC | -- |
| 273a | Signal from LVDC for: Regular Calibrate Relays OFF | 03:06:15.8 (11,175.8) | TB5 +10,518.7 | IU | 03:07:45.956 (11,265.956) | TB5 +10,518.658 | MSFC | -- |
| 273b | Signal Received in LVDC for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 03:07:45.93 (11,265.93) | TB5 +10,518.632 | DAC (FM) | 13 |

TABLE 5-1 (Sheet 24 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|-------------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| TIME BASE 6 | | | | | | | | |
| 274 | Begin Restart Preparations | 03:04:34.0 (11,074) | TB6 +0.0 | IU | 03:08:07.733 (11,287.733) | TB6 +0.0 | MSFC | -- |
| 275a | Signal from LVDC for: S-IVB Ullage Engine No. 1 ON | 03:04:34.2 (11,074.2) | TB6 +0.2 | IU | 03:08:07.904 (11,287.904) | TB6 +0.171 | MSFC | -- |
| 275b | Signal Received in S-IVB for: S-IVB Ullage Engine No. 1 ON | -- | -- | S-IVB | 03:08:07.888 (11,287.888) | TB6 +.155 | DAC (FM) | 13 |
| 276a | Signal from LVDC for: S-IVB Ullage Engine No. 2 ON | 03:04:34.3 (11,074.3) | TB6 +0.3 | IU | 03:08:08.005 (11,288.005) | TB6 +.272 | MSFC | -- |
| 276b | Signal Received in S-IVB for: Ullage Engine No. 2 ON | -- | -- | S-IVB | 03:08:07.989 (11,287.989) | TB6 +.259 | DAC (FM) | 13 |
| 277 | Signal from LVDC for: S-IVB Ullage Thrust Present ON | 03:04:34.5 (11,074.5) | TB6 +0.5 | IU | 03:08:08.188 (11,288.188) | TB6 +.455 | MSFC | -- |
| 278a | Signal from LVDC for: LH2 Tank Vent Valve Boost Close ON | 03:04:34.8 (11,074.8) | TB6 +0.8 | IU | 03:08:08.485 (11,288.485) | TB6 +.752 | MSFC | -- |
| 278b | Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close ON | -- | -- | S-IVB | 03:08:08.464 (11,288.464) | TB6 +.731 | DAC (FM) | 13 |
| 279a | Signal from LVDC for: LOX Tank Vent Valve Boost Close ON | 03:04:35.0 (11,075.0) | TB6 +1.0 | IU | 03:08:08.691 (11,288.691) | TB6 +.958 | MSFC | -- |
| 279b | Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close ON | -- | -- | S-IVB | 03:08:08.672 (11,288.672) | TB6 +.939 | DAC (FM) | 13 |
| 280a | Signal from LVDC for: Continuous Vent Valve Close ON | 03:04:35.2 (11,075.2) | TB6 +1.2 | IU | 03:08:08.886 (11,288.886) | TB6 +1.153 | MSFC | -- |
| 280b | Signal Received in S-IVB for: Continuous Vent Valve Close ON | -- | -- | S-IVB | 03:08:08.867 (11,288.867) | TB6 +1.134 | DAC (FM) | 13 |
| 281 | Signal from LVDC for: C-Band Transponders No. 1 & No. 2 ON | 03:04:35.0 (11,075.0) | TB6 +1.4 | IU | 02:08:09.086 (11,289.086) | TB6 +1.353 | MSFC | -- |
| 282a | Signal from LVDC for: LH2 Tank Vent Valve Boost Close OFF | 03:04:36.8 (11,076.8) | TB6 +2.8 | IU | 03:08:10.486 (11,290.486) | TB6 +2.753 | MSFC | -- |
| 282b | Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close OFF | -- | -- | S-IVB | 03:08:10.47 (11,290.470) | TB6 +2.857 | DAC (FM) | 13 |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 25 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 283a | Signal from LVDC for: LOX Tank Vent Valve Boost Close OFF | 03:04:37.0 (11,077) | TB6 +3.0 | IU | 03:08:10.690 (11,290.690) | TB6 +2.957 | MSFC | -- |
| 283b | Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close OFF | -- | -- | S-IVB | 03:08:10.674 (11,290.674) | TB6 +2.941 | DAC (FM) | 13 |
| 284a | Signal from LVDC for: Continuous Vent Valve Close OFF | 03:04:37.2 (11,077.2) | TB6 +3.2 | IU | 03:08:10.910 (11,290.910) | TB6 +3.177 | MSFC | -- |
| 284b | Signal Received in S-IVB for: Continuous Vent Valve Close OFF | -- | -- | S-IVB | 03:08:10.895 (11,290.895) | TB6 +3.162 | DAC (FM) | 13 |
| 285a | Signal from LVDC for: Fuel Chilldown Pump ON | 03:04:40.0 (11,080.0) | TB6 +6.0 | IU | 03:08:13.687 (11,293.687) | TB6 +5.954 | MSFC | -- |
| 285b | Signal Received in S-IVB for: Fuel Chilldown Pump ON | -- | -- | S-IVB | 03:08:13.667 (11,293.667) | TB6 +5.934 | DAC (FM) | 13 |
| 286a | Signal from LVDC for: LOX Chilldown Pump ON | 03:04:45.0 (11,085.0) | TB6 +11.0 | IU | 03:08:18.686 (11,298.686) | TB6 +10.953 | MSFC | -- |
| 286b | Signal Received in S-IVB for: LOX Chilldown Pump ON | -- | -- | S-IVB | 03:08:18.671 (11,298.671) | TB6 +10.938 | DAC (FM) | 13 |
| 287a | Signal from LVDC for: Prevalves Close ON | 03:04:55.0 (11,095.0) | TB6 +21.0 | IU | 03:08:28.686 (11,308.686)* | TB6 +20.953 | MSFC | -- |
| 287b | Signal Received in S-IVB for: Prevalves Close ON | -- | -- | S-IVB | 03:08:28.671 (11,308.671) | TB6 +20.938 | DAC (FM) | 13 |
| 288a | Signal from LVDC for: LOX Repress Valve Open ON | 03:06:14.0 (11,174.0) | TB6 +100.0 | IU | 03:09:37.687 (11,387.687) | TB6 +99.954 | MSFC | -- |
| 288b | Signal Received in S-IVB for: LOX Repress Valve Open ON | -- | -- | S-IVB | 03:09:37.670 (11,387.670) | TB6 +99.937 | DAC (FM) | 13 |
| 289 | Signal from LVDC for: Telemetry Calibration Inflight Calibrate ON | 03:07:62.3 | TB6 +148.3 | IU | 03:10:36.004 (11,436.004) | TB6 +148.271 | MSFC | -- |
| 290a | Signal from LVDC for: Telemetry Calibrate Inflight Calibrate OFF | 03:07:07.3 (11,227.3) | TB6 +153.3 | IU | 03:10:40.985 (11,440.985) | TB6 +153.25 | MSFC | -- |
| 290b | Initiate Pitch and Yaw Maneuver for Restart Attitude Orientation | 03:07:54.0 (11,274.0) | N/A | IU | 03:11:27.4 (11,487.4) | N/A | DAC | 100 |
| 291a | Signal from LVDC for: LH2 Repress Control Valve Open ON | 03:07:54.0 (11,274.0) | TB6 +200.0 | IU | 03:11:27.695 (11,487.695) | TB6 +199.962 | MSFC | -- |

TABLE 5-1 (Sheet 26 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 291b | Signal Received in S-IVB for: LH2 Re-press Control Valve Open ON | -- | -- | S-IVB | 03:11:27.695 (11,487.695) | TB6 +199.962 | DAC (FM) | 13 |
| 292a | Signal from LVDC for: SSB/FM Group ON | 03:08:02.3 (11,282.3) | TB6 +208.3 | IU | 03:11:35.995 (11,495.995) | TB6 +208.262 | MSFC | -- |
| 292b | Signal Received in S-IVB for: SSB/FM Group ON | -- | -- | S-IVB | 03:11:35.975 (11,495.975) | TB6 +208.242 | DAC (FM) | 13 |
| 293a | Signal from LVDC for: SSB/FM Transmitter ON | 03:08:02.5 (11,282.5) | TB6 +208.5 | IU | 03:11:36.208 (11,496.208) | TB6 +208.475 | MSFC | -- |
| 293b | Signal Received in S-IVB for: SSB/FM Transmitter ON | -- | -- | S-IVB | 03:11:36.189 (11,496.189) | TB6 +208.456 | DAC (FM) | 13 |
| 294a | Signal from LVDC for: Regular Calibrate Relays ON | 03:09:02.5 (11,342.5) | TB6 +268.5 | IU | 03:12:36.186 (11,556.186) | TB6 +268.453 | MSFC | -- |
| 294b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 03:12:36.168 (11,556.168) | TB6 +268.435 | DAC (FM) | 13 |
| 295a | Signal from LVDC for: Regular Calibrate Relays OFF | 03:09:07.5 (11,352.5) | TB6 +273.5 | IU | 03:12:41.197 (11,561.197) | TB6 +273.464 | MSFC | -- |
| 295b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 03:12:41.179 (11,561.179) | TB6 +273.446 | DAC (FM) | 13 |
| 296a | Signal from LVDC for: PU Valve Hardover Position ON | 03:09:21.0 (11,366.0) | TB6 +287.0 | IU | 03:12:54.689 (11,574.689) | TB6 +286.956 | MSFC | -- |
| 296b | Signal Received in S-IVB for: PU Valve Hardover Position ON | -- | -- | S-IVB | 03:12:54.669 (11,574.669) | TB6 +286.936 | DAC (FM) | 13 |
| 297a | Signal from LVDC for: Prevalve Closed OFF | 03:09:50.2 (11,390.2) | TB6 +316.2 | IU | 03:13:23.896 (11,603.896) | TB6 +316.163 | MSFC | -- |
| 297b | Signal Received in S-IVB for: Prevalve Close OFF | -- | -- | S-IVB | 03:13:23.881 (11,603.881) | TB6 +316.189 | DAC (FM) | 13 |
| 298 | Signal from LVDC for: S-IVB Restart Alert | 03:09:51.0 (11,391.0) | TB6 +317.0 | IU | 03:13:24.691 (11,604.691) | TB6 +316.958 | MSFC | -- |
| 299a | Signal from LVDC for: Engine Cutoff OFF | 03:09:59.6 (11,399.6) | TB6 +325.6 | IU | 03:13:33.290 (11,613.290) | TB6 +325.557 | MSFC | -- |
| 299b | Signal Received in S-IVB for: Engine Cutoff OFF | -- | -- | S-IVB | 03:13:33.271 (11,613.271) | TB6 +325.579 | DAC (FM) | 13 |
| 300a | Signal from LVDC for: Engine Ready Bypass | 03:09:59.8 (11,399.8) | TB6 +325.8 | IU | 03:13:33.505 (11,613.505) | TB6 +325.772 | MSFC | -- |
| 300b | Signal Received in S-IVB for: Engine Ready Bypass | -- | -- | S-IVB | 03:13:33.485 (11,613.485) | TB6 +325.793 | DAC (FM) | 13 |

Section 5
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TABLE 5-1 (Sheet 27 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|--------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 301a | Signal from LVDC for: LH2 Repress Control Valve Open OFF | 03:10:00.0 (11,400) | TB6 +326.0 | | 03:13:33.686 (11,613.686) | TB6 +325.953 | MSFC | -- |
| 301b | Signal Received in S-IVB for: LH2 Repress Control Valve Oper OFF | -- | -- | S-IVB | 03:13:33.668 (11,613.668) | TB6 +325.935 | DAC | 13 |
| 302a | Signal from LVDC for: Fuel Chilldown Pump OFF | 03:10:00.2 (11,400.2) | TB6 +326.2 | IU | 03:13:33.899 (11,613.899) | TB6 +326.166 | MSFC | -- |
| 302b | Signal Received in S-IVB for: Fuel Chilldown Pump OFF | -- | -- | S-IVB | 03:13:33.880 (11,613.880) | TB6 +326.147 | DAC (FM) | 13 |
| 303a | Signal from LVDC for: LOX Chilldown Pump OFF | 03:10:00.4 (11,400.4) | TB6 +326.4 | IU | 03:13:34.087 (11,614.087) | TB6 +326.354 | MSFC | -- |
| 303b | Signal Received in S-IVB for: LOX Chilldown Pump OFF | -- | -- | S-IVB | 03:13:34.069 (11,614.069) | TB6 +326.336 | DAC (FM) | 13 |
| 304a | Signal from LVDC for: LOX Repress Control Valve Open OFF | 03:10:00.8 (11,400.8) | TB6 +326.8 | IU | 03:13:34.505 (11,614.505) | TB6 +326.772 | MSFC | -- |
| 304b | Signal Received in S-IVB for: LOX Repress Control Valve Open OFF | -- | -- | S-IVB | 03:13:34.486 (11,614.486) | TB6 +326.767 | DAC (FM) | 13 |
| 305a | Signal from LVDC for: Engine Start ON | 03:10:01.0 (11,401.0) | TB6 +327.0 | IU | 03:13:34.686 (11,614.686) | TB6 +326.953 | MSFC | -- |
| 305b | Signal Received in S-IVB for: Engine Start ON | -- | -- | S-IVB | 03:13:34.677 (11,614.667) | TB6 +326.936 | DAC (FM) | 13 |
| 305c | J-2 Engine Start Sequence | | | | | | | |
| | 1. Helium Control Solenoid Energized | -- | -- | S-IVB | 03:13:34.667 (11,614.667) | -- | DAC (PCM) | 25 |
| | 2. Main Fuel Valve Close (Dropout) | -- | -- | S-IVB | 03:13:34.729 (11,614.729) | -- | DAC (PCM) | 25 |
| | 3. Main Fuel Valve Open (Pickup) | -- | -- | S-IVB | 03:13:34.752 (11,614.752) | -- | DAC (PCM) | 25 |
| | 4. Gas Generator Valve Closed (Dropout) | -- | -- | S-IVB | 03:13:43.251 (11,623.251) | -- | DAC (PCM) | 25 |
| | 5. Gas Generator Valve Open (Pickup) | -- | -- | S-IVB | 03:13:43.367 (11,623.367) | -- | DAC (PCM) | 25 |
| | 6. Main Oxidizer Valve Leaves Close Position (Dropout) | -- | -- | S-IVB | 03:13:43.239 (11,623.239) | -- | DAC (PCM) | 25 |

TABLE 5-1 (Sheet 28 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|---|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 305d J-2 Engine Start Sequence (Cont'd) | | | | | | | | |
| 7. | Start Tank Discharge Valve Open (Dropout) | -- | -- | S-IVB | 03:13:43.262 (11,623.262) | -- | DAC (PCM) | 25 |
| 8. | Oxidizer Turbine Bypass Valve Open (Dropout) | -- | -- | S-IVB | 03:13:43.342 (11,623.342) | -- | DAC (PCM) | 25 |
| 9. | Oxidizer Turbine Bypass Valve Close (Pickup) | -- | -- | S-IVB | 03:13:43.567 (11,623.567) | -- | DAC (PCM) | 25 |
| 10. | Mainstage OK Pressure Switch 1 (Dropout) | -- | -- | S-IVB | Not Activated | | DAC (PCM) | 25 |
| 11. | Mainstage OK Pressure Switch 2 (Pickup) | -- | -- | S-IVB | Not Activated | | DAC (PCM) | 25 |
| 12. | Main Oxidizer Valve Reaches Open Position (Pickup) | -- | -- | S-IVB | 03:13:45.192 (11,625.192) | -- | DAC (PCM) | 25 |
| 13. | Gas Generator Spark System ON (Dropout) | -- | -- | S-IVB | 03:13:46.392 (11,626.392) | -- | DAC (PCM) | 25 |
| 14. | Thrust Chamber Spark System ON (Dropout) | -- | -- | S-IVB | 03:13:46.392 (11,626.392) | -- | DAC (PCM) | 25 |
| 306 | Signal from LVDC for: S-IVB Engine Out Indication "A" Enable ON | 03:10:01.8 (11,401.8) | TB6 +327.8 | IU | 03:13:35.486 (11,615.486) | TB6 +327.753 | MSFC | -- |
| 307 | Signal from LVDC for: S-IVB Engine Out Indication "B" Enable ON | 03:10:02.0 (11,402.0) | TB6 +328.0 | IU | 03:13:35.696 (11,615.696) | TB6 +327.963 | MSFC | -- |
| 308a | Signal from LVDC for: Ullage Engine No. 1 OFF | 03:10:04.0 (11,404.0) | TB6 +330.0 | IU | 03:13:37.686 (11,617.686) | TB6 +329.953 | MSFC | -- |
| 308b | Signal Received in S-IVB for: Ullage Engine No. 1 OFF | -- | -- | S-IVB | 03:13:37.669 (11,617.669) | TB6 +329.936 | DAC (FM) | 13 |
| 309a | Signal from LVDC for: Ullage Engine No. 2 OFF | 03:10:04.1 (11,404.1) | TB6 +330.1 | IU | 03:13:37.785 (11,617.785) | TB6 +330.052 | MSFC | -- |
| 309b | Signal Received in S-IVB for: Ullage Engine No. 2 OFF | -- | -- | S-IVB | 03:13:37.767 (11,617.767) | TB6 +330.034 | DAC (FM) | 13 |
| 310 | Signal from LVDC for: Ullage Thrust Present OFF | 03:10:04.3 (11,404.3) | TB6 +330.3 | IU | 03:13:37.992 (11,617.992) | TB6 +330.259 | MSFC | -- |
| 311 | Signal from LVDC for: Control Computer S-IVB Burn Mode ON "A" | 03:10:08.6 (11,408.6) | TB6 +334.6 | IU | 03:13:42.286 (11,622.286) | TB6 +334.553 | MSFC | -- |

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TABLE 5-1 (Sheet 29 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 312 | Signal from LVDC for: Computer S-IVB Burn Mode ON "B" | 03:10:08.8 (11,408.8) | TB6 +334.8 | IU | 03:13:42.494 (11,622.494) | TB6 +334.761 | MSFC | -- |
| 313a | Signal from LVDC for: Injection Temperature OK Bypass | 03:10:09.0 (11,409.0) | TB6 +335.0 | IU | 03:13:42.685 (11,622.685) | TB6 +334.952 | MSFC | -- |
| 313b | Signal Received in S-IVB for: Injection Temperature OK Bypass | -- | -- | S-IVB | 03:13:42.666 (11,622.666) | TB6 +334.933 | DAC (FM) | 13 |
| 314a | Signal from LVDC for: LOX Tank Flight Press System ON | 03:10:09.2 (11,409.2) | TB6 +335.2 | IU | 03:13:42.899 (11,622.899) | TB6 +335.166 | MSFC | -- |
| 314b | Signal Received in S-IVB for: Tank Flight Press System ON | -- | -- | S-IVB | 03:13:42.881 (11,622.881) | TB6 +335.148 | DAC (FM) | 13 |
| 315a | Signal from LVDC for: Coast Period OFF | 03:10:09.4 (11,409.4) | TB6 +335.4 | IU | 03:13:43.088 (11,623.088) | TB6 +335.355 | MSFC | -- |
| 315b | Signal Received in S-IVB for: Coast Period OFF | -- | -- | S-IVB | 03:13:43.069 (11,623.069) | TB6 +335.336 | DAC (FM) | 13 |
| 316a | Signal from LVDC for: Engine Start OFF | 03:10:09.6 (11,409.6) | TB6 +335.6 | IU | 03:13:43.296 (11,623.296) | TB6 +335.563 | MSFC | -- |
| 316b | Signal Received in S-IVB for: Engine Start OFF | -- | -- | S-IVB | 03:13:43.277 (11,623.277) | TB6 +335.544 | DAC (FM) | 13 |
| 317 | J-2 Thrust Buildup (10%) | -- | N/A | -- | Not Achieved | | DAC | 10 |
| 318 | J-2 Thrust Buildup (90%) | 03:10:11.4 | TB6 +337.4 | -- | Not Achieved | | MSFC | -- |
| 319a | Signal from LVDC for: Second Burn Relay ON | 03:10:11.6 (11,411.6) | TB6 +337.6 | IU | 03:12:45.285 (11,625.285) | TB6 +337.552 | MSFC | -- |
| 319b | Signal Received in S-IVB for: Second Burn Relay ON | -- | -- | S-IVB | 03:12:45.268 (11,625.268) | TB6 +337.535 | DAC (FM) | 13 |
| 320a | Signal from LVDC for: PU Activate ON | 03:10:13.8 (11,413.8) | TB6 +339.8 | IU | 03:12:47.499 (11,627.499) | TB6 +339.766 | MSFC | -- |
| 320b | Signal Received in S-IVB for: PU Activate ON | -- | -- | S-IVB | 03:12:47.470 (11,627.470) | TB6 +339.737 | DAC (FM) | 13 |
| 321a | Signal from LVDC for: PU Valve Hardover Position OFF | 03:10:14.0 (11,414.0) | TB6 +340.0 | IU | 03:12:47.686 (11,627.686) | TB6 +339.953 | MSFC | -- |
| 321b | Signal Received in S-IVB for: PU Valve Hardover Position OFF | -- | -- | S-IVB | 03:12:47.669 (11,627.669) | TB6 +339.936 | DAC (FM) | 13 |
| 322 | Guidance Initiation | 03:10:14.0 (11,414.0) | N/A | IU | 03:12:47.73 (11,627.73) | N/A | MSFC | -- |

TABLE 5-1 (Sheet 30 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 323 | Start Artificial Tau Mode | 03:10:14.0 (11,414.0) | N/A | IU | 03:12:47.73 (11,627.73) | N/A | MSFC | -- |
| 324 | Signal from LVDC for: Fuel Injection Temp OK Bypass Reset | 03:10:15.0 (11,415.0) | TB6 +345.0 | IU | Not Issued | | MSFC | -- |
| 325 | Signal from LVDC for: Flight Control Computer Switch Point No. 5 | 03:14:31.0 (11,671.0) | TB6 +597.0 | IU | Not Issued | | MSFC | -- |
| 326 | Introduction of Chi Tilde Guidance Mode | 03:14:53.0 | N/A | IU | Not Achieved | | MSFC | -- |
| 327 | Signal from LVDC for: Freeze Body Attitude (Chi Freeze) | 03:15:18.0 (11,718.0) | N/A | IU | Not Achieved | | DAC | |
| 328 | Signal from LVDC for: Point Level Sensor Arming | 03:15:59.2 (11,759.2) | TB6 +663.2 | IU | Not Issued | | MSFC | -- |
| 329a | LVDC Sends Signal for: Cutoff S-IVB Engine (Guidance Cutoff) | 03:15:25.6 (11,725.6) | N/A | IU | Not Issued | | MSFC | -- |
| 329b | S-IVB Receives Signal for: Cutoff S-IVB Engine (Guidance Cutoff) | -- | -- | S-IVB | Not Issued | | DAC (FM) | -- |
| 329c | S-IVB Engine Interrupt 1520 TIME BASE 7 | -- | -- | | 03:13:50.32 (11,630.32) | N/A | MSFC | -- |
| 330 | LVDC Initiates Time Base 7 | 03:15:25.6 (11,725.6) | TB7 +0.0 | IU | 03:13:50.328 (11,630.328) | TB7 +0.0 | MSFC | -- |
| 331a | LVDC Sends Redundant Signal for: Cutoff S-IVB Engine | -- | -- | IU | 03:13:50.410 (11,630.410) | TB7 +0.082 | MSFC | -- |
| 331b | Signal Received in S-IVB for: Cutoff S-IVB Engine (Redundant Signal) | -- | -- | S-IVB | 03:13:50.394 (11,630.394) | TB7 +0.066 | DAC (FM) | 13 |
| 332 | S-IVB J-2 Thrust Decay to 5% (Average) | -- | -- | N/A | Not Achieved | | DAC | -- |
| 333a | Signal from LVDC for: LOX Tank Vent Valve Open ON | 03:15:25.8 (11,725.8) | TB7 +0.2 | IU | 03:13:50.506 (11,630.506) | TB7 +.178 | MSFC | -- |
| 333b | Signal Received in S-IVB for: LOX Tank Vent Valve Open | -- | -- | S-IVB | 03:13:50.490 (11,630.490) | TB7 +0.164 | DAC (FM) | 13 |
| 334a | Signal from LVDC for: Point Level Sensors Disarming | 03:15:25.9 (11,725.9) | TB7 +0.3 | IU | 03:13:50.599 (11,630.599) | TB7 +0.271 | MSFC | -- |

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TABLE 5-1 (Sheet 31 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 334b | Signal Received in S-IVB for: Point Level Sensors Disarming | -- | -- | S-IVB | 03:13:50.584 (11,630.584) | TB7 +.256 | DAC (FM) | 13 |
| 335a | Signal from LVDC for: LH2 Tank Vent Valve Open ON | 03:15:26.0 (11,726.0) | TB7 +0.4 | IU | 03:13:50.697 (11,630.697) | TB7 +.369 | MSFC | -- |
| 335b | Signal Received in S-IVB for: LH2 Tank Vent Valve Open ON | -- | -- | S-IVB | 03:13:50.681 (11,630.681) | TB7 +.353 | DAC (FM) | 13 |
| 336a | Signal from LVDC for: Second Burn Relay OFF | 03:15:26.4 (11,726.4) | TB7 +0.8 | IU | 03:13:51.081 (11,631.081) | TB7 +.753 | MSFC | -- |
| 336b | Signal Received in S-IVB for: Second Burn Relay OFF | -- | -- | S-IVB | 03:13:51.066 (11,631.066) | TB7 +.738 | DAC (FM) | 13 |
| 337a | Signal from LVDC for: LOX Tank Flight Press System OFF | 03:15:26.6 (11,726.6) | TB7 +1.0 | IU | 03:13:51.290 (11,631.290) | TB7 +.962 | MSFC | -- |
| 337b | Signal Received in S-IVB for: LOX Tank Flight Press System OFF | -- | -- | S-IVB | 03:13:51.274 (11,631.274) | TB7 +.946 | DAC (FM) | 13 |
| 338a | Signal from LVDC for: Coast Period ON | 03:15:26.8 (11,726.8) | TB7 +1.2 | IU | 03:13:51.498 (11,631.498) | TB7 +1.170 | MSFC | -- |
| 338b | Signal Received in S-IVB for: Coast Period ON | -- | -- | S-IVB | 03:13:51.479 (11,631.479) | TB7 +1.151 | DAC (FM) | 13 |
| 339a | Signal from LVDC for: PU Activate OFF | 03:15:27.0 (11,727.0) | TB7 +1.4 | IU | 03:13:51.705 (11,631.703) | TB7 +1.375 | MSFC | -- |
| 339b | Signal Received in S-IVB for: PU Activate OFF | -- | -- | S-IVB | 03:13:51.684 (11,631.684) | TB7 +1.356 | DAC (FM) | 13 |
| 340a | Signal from LVDC for: PU Inverter and DC Power OFF | 03:15:27.1 (11,727.1) | TB7 +1.5 | IU | 03:13:51.799 (11,631.799) | TB7 +1.471 | MSFC | -- |
| 340b | Signal Received in S-IVB for: PU Inverter and DC Power OFF | -- | -- | S-IVB | 03:13:51.781 (11,631.781) | TB7 +1.453 | DAC (FM) | 13 |
| 341a | Signal from LVDC for: LOX Chilldown Pump Purge Control Valve Open OFF | 03:15:27.2 | TB7 +1.6 | IU | 03:13:51.892 (11,631.892) | TB7 +1.564 | MSFC | -- |
| 341b | Signal Received in S-IVB for: LOX Chilldown Pump Purge Control Valve Open OFF | -- | -- | S-IVB | 03:13:51.873 (11,631.873) | TB7 +1.545 | DAC (FM) | 13 |
| 342 | Signal from LVDC for: Flight Control Computer S-IVB Burn Mode OFF "A" | 03:15:29.1 (11,729.1) | TB7 +3.5 | IU | 03:13:53.784 (11,633.784) | TB7 +3.456 | MSFC | -- |

TABLE 5-1 (Sheet 32 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 343 | Signal from LVDC for: Flight Control Computer S-IVB Burn Mode OFF "B" | 03:15:29.3 (11,729.3) | TB7 +3.7 | IU | 03:13:53.999 (11,633.999) | TB7 +3.671 | MSFC | -- |
| 344a | Signal from LVDC for: Auxiliary Hydraulic Pump Flight Mode OFF | 03:15:29.5 (11,729.5) | TB7 +3.9 | IU | 03:13:54.182 (11,634.182) | TB7 +3.854 | MSFC | -- |
| 344b | Signal Received in S-IVB for: Auxiliary Hydraulic Pump Flight | -- | -- | S-IVB | 03:13:54.166 (11,634.166) | TB7 +3.838 | DAC (FM) | 13 |
| 345 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 03:15:24.7 (11,724.7) | TB7 +4.1 | IU | 03:13:54.393 (11,634.393) | TB7 +4.065 | MSFC | -- |
| 346a | Signal from LVDC for: Regular Calibrate Relays ON | 03:15:29.9 (11,729.4) | TB7 +4.3 | IU | 03:13:54.581 (11,634.581) | TB7 +4.253 | MSFC | -- |
| 346b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 03:13:54.565 (11,634.565) | TB7 +4.237 | DAC (FM) | 13 |
| 347 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate OFF | 03:15:34.7 (11,734.7) | TB7 +9.1 | IU | 03:13:59.384 (11,639.384) | TB7 +9.056 | MSFC | -- |
| 348a | Signal from LVDC for: Regular Calibrate Relays OFF | 03:15:34.9 (11,734.9) | TB7 +9.3 | IU | 03:13:59.587 (11,639.587) | TB7 +9.259 | MSFC | -- |
| 348b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 03:13:59.572 (11,639.572) | TB7 +9.254 | DAC (FM) | 13 |
| 349a | Signal from LVDC FOR: SSB/FM Transmitter OFF | 03:15:35.1 (11,735.1) | TB7 +9.5 | IU | 03:13:59.804 (11,639.804) | TB7 +9.476 | MSFC | -- |
| 349b | Signal Received in S-IVB for: SSB/FM Transmitter OFF | -- | -- | S-IVB | 03:13:59.787 (11,639.787) | TB7 +9.459 | DAC (FM) | 13 |
| 350a | Signal from LVDC for: SSB/FM Group OFF | 03:15:35.3 (11,735.3) | TB7 +9.7 | IU | 03:13:59.982 (11,639.982) | TB7 +9.654 | MSFC | -- |
| 350b | Signal Received in S-IVB for: SSB/FM Group OFF | -- | -- | S-IVB | 03:13:59.964 (11,639.964) | TB7 +9.636 | DAC (FM) | 13 |
| 351a | Signal from LVDC for: LOX Tank Vent Valve Close | 03:15:35.6 (11,735.6) | TB7 +10.0 | IU | 03:14:00.281 (11,640.281) | TB7 +9.953 | MSFC | -- |
| 351b | Signal Received in S-IVB for: LOX Tank Vent Valve Close | -- | -- | S-IVB | 03:14:00.276 (11,640.276) | TB7 +9.948 | DAC (FM) | 13 |
| 352a | Signal from LVDC for: LOX Tank Vent Valve Boost Close ON | 03:15:38.6 (11,738.6) | TB7 +13.0 | IU | 03:14:03.294 (11,643.294) | TB7 +12.966 | MSFC | -- |
| 352b | Signal Received in S-IVB for: LOX Tank Vent Boost Close ON | -- | -- | S-IVB | 03:14:03.288 (11,643.288) | TB7 +12.960 | DAC (FM) | 13 |

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Sequence of Events

TABLE 5-1 (Sheet 33 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (MS) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 353a | Signal from LVDC for: LOX Tank Vent Valve Boost Close OFF | 03:15:40.6 (11,740.6) | TB7 +15.0 | IU | 03:14:05.283 (11,645.283) | TB7 +14.955 | MSFC | -- |
| 353b | Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close OFF | -- | -- | S-IVB | 03:14:05.23 (11,645.23) | TB7 +14.83 | DAC (FM) | 13 |
| 354 | Initiate Maneuver to Attain Separation Inertial Attitude (End of Chi Freeze) | 03:15:45.6 (11,745.6) | N/A | IU | 03:14:10.1 (11,650.1) | N/A | DAC | 1,000 |
| 355 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 03:14:10.443 (11,650.443) | TB7 +20.115 | MSFC | -- |
| 356 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 03:14:10.540 (11,650.540) | TB7 +20.212 | MSFC | -- |
| 357 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 03:14:18.677 (11,658.677) | TB7 +28.349 | MSFC | -- |
| 358 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 03:14:18.749 (11,658.749) | TB7 +28.421 | MSFC | -- |
| 359 | Ground Command Issued for: Initiate Spacecraft Separation 0-1.7 sec: Coast 1.7-10.0 sec: RCS Thruster Burn 10-50 sec: Spacecraft Reorientation 50-100 sec: Spacecraft Coast 100 sec: SPS Ignition | -- | -- | IU | 03:14:26.1 (11,666.1)* | N/A | MSFC | -- |
| 360 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 03:14:59.128 (11,699.128) | TB7 +68.800 | MSFC | -- |
| 361 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 03:14:59.198 (11,699.198) | TB7 +68.870 | MSFC | -- |
| 362 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 03:15:08.330 (11,707.330) | TB7 +77.002 | MSFC | -- |
| 363 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 03:15:07.403 (11,707.403) | TB7 +77.075 | MSFC | -- |
| 364 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 03:15:22.603 (11,722.603) | TB7 +92.275 | MSFC | -- |

TABLE 5-1 (Sheet 34 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|---|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 365 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 03:15:22.689 (11,722.689) | TB7 +92.361 | MSFC | -- |
| 366a | Signal from LVDC for: LH2 Tank Vent Valve Close | 03:17:25.6 (11,845.6) | TB7 +120.0 | IU | 03:15:50.281 (11,750.281) | TB7 +119.953 | MSFC | -- |
| 366b | Signal Received in S-IVB for: LH2 Tank Vent Valve Close | -- | -- | S-IVB | 03:15:50.263 (11,750.263) | TB7 +119.935 | DAC (FM) | 13 |
| 367a | Signal from LVDC for: LH2 Tank Vent Valve Boost Close ON | 03:17:28.6 (11,848.6) | TB7 +123.0 | IU | 03:15:53.291 (11,753.291) | TB7 +122.963 | MSFC | -- |
| 367b | Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close ON | -- | -- | S-IVB | 03:15:53.273 (11,753.273) | TB7 +119.945 | DAC (FM) | 13 |
| 368a | Signal from LVDC for: LH2 Tank Vent Valve Boost Close OFF | 03:17:30.6 (11,850.6) | TB7 +125.0 | IU | 03:15:55.281 (11,755.281) | TB7 +124.953 | MSFC | -- |
| 368b | Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close OFF | -- | -- | S-IVB | 03:15:55.261 (11,755.261) | TB7 +124.933 | DAC (FM) | 13 |
| 369 | Stop Roll Maneuver for CSM Separation Attitude | -- | -- | -- | 03:16:14.5 (11,774.5) | N/A | DAC | 1,000 |
| 370 | LV/SC Separation Sequence Start | 03:18:25.6 (11,905.6) | TB7 +180.0 | IU | 03:16:50.280 (11,810.280) (Previously Spacecraft Separated) | TB7 +179.952 | MSFC | -- |
| 371 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 03:17:30.657 (11,850.657) | TB7 +220.329 | MSFC | -- |
| 372 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 03:17:30.728 (11,850.728) | TB7 +200.400 | MSFC | -- |
| 373 | Signal from LVDC for: Water Coolant Valve Open | | Variable | IU | 03:23:23.467 (12,203.467) | TB7 +573.139 | MSFC | -- |
| 374 | Signal from LVDC for: Maneuver to Post-Separation Inertial Attitude | 03:25:25.6 (12,325.6) | TB7 +600 | | 03:23:50.1 (12,230.1) | TB7 +599.772 | MSFC | -- |
| 375 | Signal from LVDC for: Switch PCM to Low Gain Antenna (Fail Safe) | 03:35:25.6 (12,925.6) | TB7 +1,200.0 | | 03:33:50.28 (12,830.28)* | TB7 +1,199.952 | MSFC | -- |
| 376 | Signal from LVDC for: Switch CCS to Low Gain Antenna | 03:35:25.8 (12,925.8) | TB7 +1,200.2 | | 03:33:50.48 (12,830.48)* | TB7 +1,200.152 | MSFC | -- |

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TABLE 5-1 (Sheet 35 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|--------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 377a | Signal from LVDC for: LH2 Tank Continuous Vent Valve Open ON | 03:35:26.0 (12,926.0) | TB7 +1,200.4 | | 03:33:50.68 (12,830.68)* | TB7 +1,200.352 | MSFC | -- |
| 377b | Signal Received in S-IVB for: LH2 Tank Continuous Vent Valve Open ON | -- | -- | | 03:33:50.747 (12,830.747)* | TB7 +1,200.419 | DAC (PCM) | -- |
| 378a | Signal from LVDC for: LH2 Tank Continuous Vent Valve Open OFF | 03:35:28.0 (12,928.0) | TB7 +1,202.4 | | 03:33:52.68 (12,832.68)* | TB7 +1,202.352 | MSFC | -- |
| 378b | Signal Received in S-IVB for: LH2 Tank Continuous Vent Valve Open OFF | -- | -- | | 03:33:52.747 (12,832.747)* | TB7 +1,202.419 | DAC (PCM) | -- |
| 379 | Signal from LVDC for: Telemetry Calibrator Inflight Calibrate ON | 03:37:15.9 (13,035.9) | TB7 +1,310.3 | IU | 03:35:40.58 (12,940.58)* | TB7 +1,310.252 | MSFC | -- |
| 380a | Signal from LVDC for: Regular Calibrate Relays ON | 03:37:16.1 (13,036.1) | TB7 +1,310.5 | | 03:35:40.78 (12,940.78)* | TB7 +1,310.452 | MSFC | -- |
| 380b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | | 03:35:40.847 (12,940.847)* | TB7 +1,310.519 | DAC (PCM) | -- |
| 381 | Signal from LVDC for: Telemeter Calibrate Inflight Calibrate OFF | 03:37:20.9 (13,040.9) | TB7 +1,315.3 | | 03:35:45.58 (12,945.58)* | TB7 +1,315.252 | MSFC | -- |
| 382a | Signal from LVDC for: Regular Calibrate Relays OFF | 03:38:21.1 (13,041.1) | TB7 +1,315.5 | | 03:35:45.78 (12,945.78)* | TB7 +1,315.452 | MSFC | -- |
| 382b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | | 03:35:45.847 (12,945.847)* | TB7 +1,315.519 | DAC (PCM) | -- |
| 383a | Ground Command Issued for: Aux Hydraulic Pump Coast Mode OFF | -- | -- | Ground | 04:09:21.0 (14,961.0) | N/A | MSFC | -- |
| 383b | Signal Received in S-IVB for: Aux. Hyd. Pump Coast Mode OFF | -- | -- | S-IVB | 04:09:21.0 (14,961.0)* | N/A | DAC (FM) | -- |
| 384a | Ground Command Issued for: Aux. Hyd. Pump Flight Mode ON | -- | -- | Ground | 04:09:21.0 (14,961.0) | N/A | MSFC | -- |
| 384b | Signal Received in S-IVB for: Aux. Hyd. Pump Flight Mode ON | -- | -- | S-IVB | 04:09:21.89 (14,961.89)* | N/A | DAC (FM) | -- |
| 385 | Ground Command Issued for: Telemetry Calibrator Inflight Calibrate ON | -- | -- | Ground | 04:10:04.0 (15,004.0) | N/A | MSFC | -- |
| 386a | Ground Command Issued for: Regular Calibrate Relays ON | -- | -- | Ground | 04:10:04.0 (15,004.0) | N/A | MSFC | -- |

TABLE 5-1 (Sheet 36 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) | |
|----------|--|---|----------------------|--------------------------|--|----------------------|-------------|---------------|--|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | | |
| 386b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | S-IVB | 04:10:05.29 (15,005.29)* | N/A | DAC (FM) | -- | |
| 387a | Ground Command Issued for: Aux. Hyd. Pump Coast Mode OFF | -- | -- | Ground | 04:10:37.0 (15,037.0) | N/A | MSFC | -- | |
| 387b | Signal Received in S-IVB for: Aux. Hyd. Pump Coast Mode OFF | -- | -- | S-IVB | 04:10:37.67 (15,037.67)* | N/A | DAC (FM) | -- | |
| 388a | Ground Command Issued for: Aux. Hyd. Pump Flight Mode ON | -- | -- | Ground | 04:10:37.0 (15,037.0) | N/A | MSFC | -- | |
| 388b | Signal Received in S-IVB for: Aux. Hyd. Pump Flight Mode ON | -- | -- | S-IVB | 04:10:38.58 (15,038.58)* | N/A | DAC (FM) | -- | |
| 389a | Ground Command Issued for: Aux. Hyd. Pump Flight Mode OFF | -- | -- | Ground | 04:11:00.0 (15,060.0) | N/A | MSFC | -- | |
| 389b | Signal Received in S-IVB for: Aux. Hyd. Pump Flight Mode OFF | -- | -- | S-IVB | 04:10:59.83 (15,059.83)* | N/A | DAC (FM) | -- | |
| 390 | Ground Command Issued for: Telemetry Calibrator Inflight Calibrate OFF | -- | -- | Ground | 04:11:38.0 (15,098.0) | N/A | MSFC | -- | |
| 391a | Ground Command Issued for: Regular Calibrate Relays OFF | -- | -- | Ground | 04:11:38.0 (15,098.0) | N/A | MSFC | -- | |
| 391b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | ----- Not Received ----- | | | | | |
| 392 | Ground Command Issued for: Terminate | -- | -- | Ground | 04:11:53.0 (15,113.0) | N/A | MSFC | -- | |
| 393 | Ground Command Issued for: Terminate | -- | -- | Ground | 04:12:06.0 (15,126.0) | N/A | MSFC | -- | |
| 394 | Ground Command Issued for: Telemetry Calibrator Inflight Calibrate OFF | -- | -- | Ground | 04:12:15.0 (15,135.0) | N/A | MSFC | -- | |
| 395a | Ground Command Issued for: Regular Calibrate Relays OFF | -- | -- | Ground | 04:12:15.0 (15,135.0) | N/A | MSFC | -- | |
| 395b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | ----- Not Received ----- | | | | | |
| 396 | Ground Command Issued for: Telemetry Calibrator Inflight Calibrate OFF | -- | -- | Ground | 04:12:29.0 (15,149.0) | N/A | MSFC | -- | |

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TABLE 5-1 (Sheet 37 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 397a | Ground Command Issued for: Regular Calibrate Relays OFF | -- | -- | Ground | 04:12:29.0 (15,149.0) | N/A | MSFC | -- |
| 397b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | ----- Not Received ----- | | | | | | |
| 398 | Ground Command Issued for: Telemetry Calibrator Inflight Calibrate OFF | -- | -- | Ground | 04:29:33.0 (16,173.0) | N/A | MSFC | -- |
| 399a | Ground Command Issued for: Regular Calibrate Relays OFF | -- | -- | Ground | 04:29:33.0 (16,173.0) | N/A | MSFC | -- |
| 399b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 04:29:32.0 (16,172.0)* | N/A | DAC (PCM) | -- |
| 400 | Ground Command Issued for: Maneuver to Align S-IVB + X Axis with Local Horizontal | -- | -- | Ground | 04:30:01.0 (16,201.0) | N/A | MSFC | -- |
| 401 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 04:39:46.450 (16,786.450) | TB7 +5,156.122 | MSFC | -- |
| 402 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 04:39:46.521 (16,786.521) | TB7 +5,156.193 | MSFC | -- |
| 403a | Ground Command Issued for: Slow Record ON | -- | -- | Ground | 04:42:08.816 (16,928.816) | N/A | MSFC | -- |
| 403b | Signal Received in S-IVB for: Slow Record ON | -- | -- | S-IVB | 04:42:08.85 (16,928.85) | N/A | DAC (FM) | 13 |
| 404a | Ground Command Issued for: Slow Record OFF | -- | -- | Ground | 04:42:09.717 (16,929.717) | N/A | MSFC | -- |
| 404b | Signal Received in S-IVB for: Slow Record OFF | -- | -- | S-IVB | 04:42:09.74 (16,929.74) | N/A | DAC (FM) | 13 |
| 405a | Ground Command Issued for: Recorder Playback ON | -- | -- | Ground | 04:42:10.621 (16,930.621) | N/A | MSFC | -- |
| 405b | Signal Received in S-IVB for: Recorder Playback ON | -- | -- | S-IVB | 04:42:10.64 (16,930.64) | N/A | DAC (FM) | 13 |
| 406 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | | 04:42:51.006 (16,971.006) | TB7 +5,340.678 | MSFC | -- |
| 407 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | | 04:42:51.077 (16,971.077) | TB7 +5,340.749 | MSFC | -- |
| 408 | Signal from LVDC for: Switch PCM to High Gain Antenna | 04:45:25.6 (17,125.6) | TB7 +5,400.0 | IU | 04:43:50.281 (17,030.281) | TB7 +5,399.953 | MSFC | -- |

TABLE 5-1 (Sheet 38 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 409 | Signal from LVDC for: Switch CCS to High Gain Antenna (Fail Safe) | 04:45:25.8 (17,125.8) | TB7 +5,400.2 | IU | 04:43:50.494 (17,030.494) | TB7 +5,400.166 | MSFC | -- |
| 410 | Signal from LVDC Telemetry Calibrator Inflight Calibrate ON | 04:47:15.9 (17,235.9) | TB7 +5,510.3 | IU | 04:45:40.586 (17,140.586) | TB7 +5,510.258 | MSFC | -- |
| 411a | Signal from LVDC for: Regular Calibrate Relays ON | 04:47:16.1 (17,236.1) | TB7 +5,510.5 | IU | 04:45:40.787 (17,140.787) | TB7 +5,510.459 | MSFC | -- |
| 411b | Signal Received in S-IVB for: Regular Calibrate Relays ON | -- | -- | IU | 04:45:40.73 (17,140.73) | TB7 +5,510.405 | DAC (FM) | 13 |
| 412 | Signal from LVDC for: Telemetry Calibrate Inflight Calibrate OFF | 04:47:20.9 (17,240.9) | TB7 +5,515.3 | IU | 04:45:45.580 (17,145.580) | TB7 +5,515.252 | MSFC | 13 |
| 413a | Signal from LVDC for: Regular Calibrate Relays OFF | 04:47:30.1 (17,250.1) | TB7 +5,515.5 | IU | 04:45:45.781 (17,145.781) | TB7 +5,515.453 | MSFC | -- |
| 413b | Signal Received in S-IVB for: Regular Calibrate Relays OFF | -- | -- | S-IVB | 04:45:45.71 (17,145.71) | TB7 +5,515.382 | DAC (FM) | 13 |
| 414 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 04:47:14.535 (17,234.535) | TB7 +5,604.207 | MSFC | -- |
| 415 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 04:47:14.606 (17,234.606) | TB7 +5,604.278 | MSFC | -- |
| 416 | Signal from LVDC for: Water Coolant Valve Close | | Variable | IU | 04:47:14.288 (17,314.288) | TB7 +5,683.960 | MSFC | -- |
| 417 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 OFF | | Variable | IU | 04:52:35.174 (17,555.174) | TB7 +5,924.846 | MSFC | -- |
| 418 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 04:52:35.245 (17,555.245) | TB7 +5,924.917 | MSFC | -- |
| 419 | Signal from LVDC for: Maneuver to Align S-IVB/CSM + X Axis with Local Horizontal | 05:15:25.6 (18,925.6) | N/A | ----- Not Applicable ----- | | | | |
| 420a | Signal from LVDC for: LH2 Tank Continuous Vent Valve Close ON | 06:05:25.6 (21,925.6) | TB7 +10,200.0 | } These Commands occurred prior to acquisition of signal at Hawaii, Revolution 4. | | | | |
| 420b | Signal Received in S-IVB for: LH2 Tank Continuous Vent Valve Close ON | -- | -- | | | | | |
| 421a | Signal from LVDC for: LH2 Tank Continuous Vent Valve Close OFF | 06:05:27.6 (21,927.6) | TB7 +10,202.0 | | | | | |
| 421b | Signal Received in S-IVB for: LH2 Tank Continuous Vent Valve Close OFF | -- | -- | | | | | |

Section 5
Sequence of Events

TABLE 5-1 (Sheet 39 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|--|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 422a | Ground Command Issued for: Recorder Playback OFF | -- | -- | Ground | 06:06:27.418 (21,987.418) | N/A | MSFC | -- |
| 422b | Signal Received in S-IVB for: Recorder Playback OFF | -- | -- | S-IVB | 06:06:27.39 (21,987.39) | N/A | DAC (FM) | 13 |
| 423a | Ground Command Issued for: LOX Tank Flight Pressure System ON | -- | -- | Ground | 06:07:01.485 (22,021.485) | N/A | MSFC | -- |
| 423b | Signal Received in S-IVB for: LOX Tank Flight Pressure System ON | -- | -- | S-IVB | 06:07:01.45 (22,021.45) | N/A | DAC (FM) | 13 |
| 424a | Ground Command Issued for: Coast Period OFF | -- | -- | Ground | 06:07:02.389 (22,022.389) | N/A | MSFC | -- |
| 424b | Signal Received in S-IVB for: Coast Period OFF | -- | -- | S-IVB | 06:07:02.35 (22,022.35) | N/A | DAC (FM) | 13 |
| 425a | Ground Command Issued for: LOX Tank Vent Valve Open ON | -- | -- | Ground | 06:07:03.301 (22,023.301) | N/A | MSFC | -- |
| 425b | Signal Received in S-IVB for: LOX Tank Vent Valve Open ON | -- | -- | S-IVB | 06:07:03.25 (22,023.25) | N/A | DAC (FM) | 13 |
| 426a | Ground Command Issued for: LH2 Tank Vent Valve Open ON | -- | -- | Ground | 06:07:04.207 (22,024.207) | N/A | MSFC | -- |
| 426b | Signal Received in S-IVB for: LH2 Tank Vent Valve Open ON | -- | -- | S-IVB | 06:07:04.17 (22,024.17) | N/A | DAC (FM) | 13 |
| 427 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 06:09:30.389 (22,170.389) | TB7 +10,540.061 | MSFC | -- |
| 428 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 06:09:30.460 (22,170.460) | TB7 +10,540.132 | MSFC | -- |
| 429 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 06:16:34.883 (22,594.883) | TB7 +10,964.555 | MSFC | -- |
| 430 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 06:16:34.954 (22,594.954) | TB7 +10,964.626 | MSFC | -- |
| 431 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 06:16:51.165 (22,611.165) | TB7 +10,980.837 | MSFC | -- |
| 432 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 06:16:51.253 (22,611.253) | TB7 +10,980.937 | MSFC | -- |

TABLE 5-1 (Sheet 40 of 40)
AS-502 SEQUENCE OF EVENTS

| ITEM NO. | EVENT | PREDICTED TIME | | SIGNAL MONITORED AT | MONITORED TIME | | DATA SOURCE | ACCURACY (ms) |
|----------|---|---|----------------------|---------------------|--|----------------------|-------------|---------------|
| | | TIME FROM RANGE ZERO (hr:min:sec) (sec) | TIME FROM BASE (sec) | | TIME FROM RANGE ZERO* (hr:min:sec) (sec) | TIME FROM BASE (sec) | | |
| 433 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 06:17:54.803 (22,674.803) | TB7 +11,044.476 | MSFC | -- |
| 434 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 06:17:54.873 (22,674.873) | TB7 +11,044.546 | MSFC | -- |
| 435 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 06:19:14.560 (22,754.560) | TB7 +11,124.232 | MSFC | -- |
| 436 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 06:19:14.631 (22,754.631) | TB7 +11,124.303 | MSFC | -- |
| 437 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 06:22:43.268 (22,963.268) | TB7 +11,332.940 | MSFC | -- |
| 438 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 06:22:43.339 (22,963.339) | TB7 +11,333.011 | MSFC | -- |
| 439 | Signal from LVDC for: C-Band Transponder No. 1 and No. 2 ON | | Variable | IU | 06:23:46.894 (22,026.894) | TB7 +11,396.566 | MSFC | -- |
| 440 | Signal from LVDC for: C-Band Transponder No. 2 OFF | | Variable | IU | 06:23:46.965 (23,026.965) | TB7 +11,396.637 | MSFC | -- |
| 441 | Signal from LVDC for: C-Band Transponder No. 1 & No. 2 ON | | Variable | IU | 06:25:22.760 (23,122.760) | TB7 +11,492.432 | MSFC | -- |
| 442 | Signal from LVDC for: C-Band Transponder No. 1 OFF | | Variable | IU | 06:25:22.831 (23,122.831) | TB7 +11,492.503 | MSFC | -- |

TABLE 5-2 (Sheet 1 of 2)
GROUND SEQUENCE OF EVENTS

| MIN | TIME | | EVENT | EVENT |
|-----|---------|-----|--|---------------------------------------|
| | MIN | SEC | | |
| -9 | -25.290 | | Engine Control Power ON | Start Tank Supply Valve Closed |
| | -22.114 | | Engine Cutoff Command ON | Start Tank Supply Vent Open |
| | -7.674 | | Engine Ignition Power ON | Start Tank Supply Vent Closed |
| | -7.666 | | Engine Ready ON | Control Bottle Supply Valve Closed |
| | -54.868 | | Auxiliary Hydraulic Pump Fit Relay Reset OFF | Control Bottle Supply Vent Open |
| | -54.782 | | Auxiliary Hydraulic Pump Power ON | Start Tank Supply Vent Open |
| | -54.780 | | Ready for 4D411 Power OFF | LOX Chilldown Pump ON |
| | -50.784 | | Auxiliary Hydraulic Pump Coast Reset ON | LOX Chilldown Relay Reset OFF |
| | -59.894 | | LOX Vent Closed | LOX Chilldown Pump Inverter Power ON |
| | -58.166 | | LOX Vent Open | Prevalves Close Command ON |
| -8 | -55.920 | | LH2 Vent Closed | LH2 Prevalves Closed |
| | -53.926 | | LH2 Directional Vent Valve - Flight Position | LOX Prevalves Closed |
| | -52.172 | | LH2 Directional Vent Valve - Ground Position | Switch Selector Inhibit ON |
| | -49.882 | | LH2 Vent Open | Cold Helium Crossover Valve Closed |
| | -45.348 | | S&A Device Armed | Terminal Countdown Sequence Ready ON |
| | -45.324 | | Ordnance OK Indication ON | APS No. 2 Engine Power ON |
| | -34.314 | | S-IVB DC Power Supply Commit | APS No. 1 Engine Power ON |
| | -28.968 | | Heat Exchanger Circuit No. 1 Vent Closed | S-IVB Preps Complete ON |
| | -23.850 | -3 | All Stages Ready for Power Transfer ON | Terminal Countdown Sequence Ready OFF |
| | -59.016 | -2 | Fuel Chilldown Pump ON | Terminal Countdown Sequence Output ON |
| -4 | -59.008 | | LH2 Chilldown Pump Inverter Power ON | START OF TERMINAL SEQUENCE |
| | -59.008 | | LH2 Chilldown Relay Reset OFF | LOX Vent Closed |

TABLE 5-2 (Sheet 2 of 2)
GROUND SEQUENCE OF EVENTS

| MIN | TIME | | EVENT | EVENT | TIME | | EVENT |
|-----|---------|-----|--|--|---------|-----|---|
| | MIN | SEC | | | MIN | SEC | |
| | -46.602 | | LOX Tank Pressurization Command ON | S-IVB Stage on Internal Power | -49.912 | | |
| | -31.604 | | LOX 100 Pct Flight Mass ON | LOX 100 Pct Flight Mass ON | -49.562 | | S-IVB Power Transfer Complete |
| | -31.046 | | LOX Fill and Drain Valve Closed | LOX Fill and Drain Valve Closed | -39.696 | | Directional Vent In-Flight Position |
| | -30.324 | | S-IVB LOX Tank Pressurized | S-IVB LOX Tank Pressurized | -39.694 | | S-IVB Ready for Launch |
| | -30.324 | | LOX Minimum Liftoff Press OK | LOX Minimum Liftoff Press OK | -16.986 | | RSCR's 1 & 2 PD Blocked OFF |
| | -29.360 | | GN2 LOX Umbilical Purge Supply Open | GN2 LOX Umbilical Purge Supply Open | -8.894 | | Ignition Enabled |
| -1 | -36.700 | | LH2 Tank Vent Valve Closed | LH2 Tank Vent Valve Closed | -8.892 | | Ignition Sequence Start ON |
| | -36.506 | | LH2 Tank Pressurization Command ON | LH2 Tank Pressurization Command ON | -8.836 | | LH2 Tank Prepress Supply Vent |
| | -36.428 | | LH2 Tank Ground Prepress Supply Valve Open | LH2 Tank Ground Prepress Supply Valve Open | -8.814 | | Engine TC Chilldown Supply Valve Closed |
| | -15.072 | | LH2 Minimum Liftoff Pressure OK | LH2 Minimum Liftoff Pressure OK | -8.796 | | Cold Helium Bottle Supply Closed |
| | -15.072 | | LH2 Tank Pressurized | LH2 Tank Pressurized | -8.704 | | Cold Helium Bottle Supply Vent Open |
| | -15.002 | | LH2 Tank Ground Prepress Supply Valve Closed | LH2 Tank Ground Prepress Supply Valve Closed | -8.574 | | LH2 Ground Control and Prepress Supply Closed |
| | -11.720 | | LOX Vent Open | LOX Vent Open | -8.476 | | 3000 Helium Supply Closed |
| | -11.394 | | LOX Vent Closed | LOX Vent Closed | -1.414 | | All Engines Running |
| | -4.676 | | LH2 100 Pct Mass ON | LH2 100 Pct Mass ON | -0.008 | | Time for Commit |
| | -3.928 | | LH2 Fill and Drain Valve Closed | LH2 Fill and Drain Valve Closed | -0.008 | | S-IC Commit |
| -0 | -59.770 | | LH2 Umbilical Purge Supply Open | LH2 Umbilical Purge Supply Open | | | RO = 12:00:01.000 GMT |
| | -51.162 | | GH2 Supply Pressure Switch Mode | GH2 Supply Pressure Switch Mode | +0.068 | | LH2 Nozzle Purge Supply Closed |
| | -49.918 | | S-IVB Aft Bus No. 1 on Internal Power | S-IVB Aft Bus No. 1 on Internal Power | +0.268 | | GN LOX Umbilical Purge Supply Closed |
| | -49.916 | | S-IVB Aft Bus No. 2 on Internal Power | S-IVB Aft Bus No. 2 on Internal Power | +0.556 | | IU Liftoff |
| | -49.916 | | S-IVB Fwd Power on Internal | S-IVB Fwd Power on Internal | +0.608 | | S-IC Liftoff |
| | -49.916 | | S-IVB On External Power OFF | S-IVB On External Power OFF | +0.310 | | LH2 Debris Valve Closed |
| | | | | | +0.626 | | LOX Debris Valve Closed |

SECTION 6

COUNTDOWN OPERATIONS

6. COUNTDOWN OPERATIONS

No significant S-IVB or equipment problems occurred during the launch countdown activity, and Douglas ground support equipment sustained no significant damage during liftoff. The precountdown and countdown activities are reviewed and evaluated in the following paragraphs which include discussions of the prelaunch checkouts, purges, propellant and pneumatic loading, and the terminal countdown. Significant events occurred at the following times:

| <u>Event</u> | <u>Time</u> |
|-------------------------------|--------------|
| LOX loading initiated | 05:32:00 GMT |
| LH2 loading initiated | 09:46:00 GMT |
| Cold helium loading initiated | 10:18:42 GMT |
| Terminal countdown initiated | 11:30:01 GMT |
| Liftoff | 12:00:01 GMT |

6.1 Propulsion System Checkouts

Preflight checkouts of the S-IVB-502 were conducted in accordance with handling and checkout requirements drawings listed in Douglas report No. DAC-56353, Narrative End Item Report on Saturn S-IVB-502 (Douglas S/N 1006), dated September 1966.

6.2 Launch Vehicle Tests

The S-IVB-502 was subjected to the launch vehicle tests listed in table 6-1 to determine that switch selector, interfaces, etc., were functional for launch. These tests were performed in the vehicle assembly building (VAB) or on Pad 39A.

6.2.1 Countdown Demonstration Test

The AS-502 vehicle countdown demonstration test (CDDT) was initiated at 23:00:00 GMT on 24 March 1968 with the count at T -103 hr. The planned CDDT cutoff at T -8.9 sec occurred at approximately 19:25:46 GMT on 31 March. The test was performed in accordance with NASA procedure V-20044; the Douglas preparations and securing steps were conducted in accordance with procedure V-20043. Three runs were necessary to complete Part III (T -7 hr to T -0) of the CDDT.

Run 1 (29 March 1967) was scrubbed at 23:00:00 GMT while in a hold at T -6 hr because of a leak at the LOX fill quick disconnect/debris valve flange.

Run 2 (30 October 1967) was scrubbed at 14:03:00 GMT with the count at T -4 hr because of S-IC electrical power problems. The LOX aboard the S-IVB was drained without problems.

Section 6
Countdown Operations

Run 3 (31 March 1968) was initiated at 11:00:00 GMT with the count at T -7 hr and was completed at 19:25:46 GMT. The first terminal count sequence was terminated at T -32 sec because of a high LOX pump discharge temperature on the S-II.

Several unexpected problems occurred during the CDDT. Leakages were found in the cold helium system, at the LOX debris valve, and in two calips switches at the diaphragm. These were corrected, and mass decay checks that were subsequently performed showed no mass decay. In addition, two redlines were changed for the launch countdown because of the following problems:

- a. The LH2 recirculation flowrate was at or near 130 gpm, and the minimum redline limit was changed from 130 to 120 gpm.
- b. The LH2 pump inlet temperature was within 0.5 deg of the redline limit, and the maximum redline limit for this parameter was increased by 1 deg.

Inspection of the LH2 recirculation system after the CDDT revealed that a piece of insulation had not been installed. The insulation was installed for the launch countdown, and the LH2 recirculation flowrate and pump inlet temperature were well within limits.

6.2.2 Flight Readiness Test

The AS-502 flight readiness test was conducted on 7 and 8 March 1968 in order to assure the proper functioning of the space vehicle in the launch configuration (except for the overall test [OAT] equipment). This test was conducted at LC 39A in accordance with Kennedy Space Center procedure V-20017, revision 005, dated 8 February 1968. S-IVB preparations, functional testing, and securing operations were conducted in accordance with procedure S-V-31028, dated 23 February 1968.

The APS dry fire was conducted at T -1 hr 30 min without difficulty, and all data stations reported good results. This test verified that the APS firing program and all data stations were ready for the APS hot firing.

6.3 APS Preparations

6.3.1 APS Loading

APS module propellant loading preparations were started on 4 March and satisfactorily completed on 20 March 1968 in accordance with KSC procedure S-V-24-109. The loading data are presented in table 6-2. During module 2 fuel loading, the differential pressure across the bladder in the module 1 fuel tank slowly increased to 38 psid (allowable is 20 psid) because of a temperature differential between the environmental control system air and the propellant. The ullage pressure remained at a constant 29 psia, indicating that the bladder was not damaged, and a waiver was written to accept the excessive differential pressure for AS-502.

6.3.2 APS Gas Removal

Gas removal from APS modules 1 and 2 oxidizer tanks was satisfactorily accomplished before the APS test firing. Propellant loss data are presented in table 6-2.

6.3.3 APS Test Firing

The APS test firing was accomplished on 21 March 1968 in accordance with NASA procedure V-25303, revision 002. The engines were fired in a sequence that consisted of one 250-ms clearing burst and two 65-ms pulses with a 750-ms delay between each pulse, the ullage engines were each fired for one pulse.

The firing sequence was as follows:

- a. Minus pitch - engine 2-2
- b. Minus roll - engines 1-1 and 2-1
- c. Ullage engine (one 400-ms pulse) - engine 1-4
- d. Plus pitch - engine 1-2
- e. Plus roll - engines 1-3 and 2-3
- f. Ullage engine (one 400-ms pulse) - engine 2-4

Evaluation of the data from these firings indicated that the systems were acceptable for flight.

6.4 AS-502 Launch Countdown

- * The launch countdown activities began at 05:30:00 GMT on 3 April (immediately after the CDDT recycle was completed) and was terminated at 12:00:01.69 GMT on 4 April 1968 with space vehicle launch. The final portion of the countdown progressed without incident or delay to firing command initiation.

6.4.1 Prelaunch Preparations and Purges

The prelaunch preparations and purges were accomplished in accordance with procedures V-20043, S-IVB Support Preparations for Countdown Demonstration and Countdown; and Douglas procedure 1B61615, Pneumatic Console and Heat Exchanger Operating Instructions.

During the preparations the systems were leak checked, purges and valve actuations were verified, and the helium supply was analyzed for purity and moisture content.

The engine purges required by Rocketdyne were accomplished just prior to LOX loading during LOX transfer line chilldown. The LOX and LH2 tank purges included the fill and drain valves, the LOX umbilical vent valve, and the S-IVB umbilical line drain valve.

An APS gas bubble removal test was simulated during CDDT. It was found to be adequate and was not altered for prelaunch preparations.

6.4.2 Loading Operations

LOX and LH2 loading, propellant tank prepressurization, thrust chamber chilldown, and helium and GH2 sphere loading were all satisfactorily accomplished.

6.4.2.1 Propellant Loading

S-IVB LOX and LH2 loadings were conducted in accordance with procedure V-35007-AS-502. Both loadings were uninterrupted and accomplished smoothly. Pressures, temperatures, and flowrates at significant times are presented in table 6-3.

6.4.2.2 Helium and GH2 Loading

Final pressurization of all S-IVB helium spheres, both cold and ambient, was accomplished without difficulty; pressurization of the APS helium tanks from blanket to full pressure was accomplished in one step at T -55 min. Pressurization of the engine control sphere from ambient to full pressure was accomplished in two steps approximately 5 min apart to limit the temperature rise. Sphere pressurization data are presented in table 6-4.

6.4.3 Terminal Count

The launch terminal count was initiated at T -30 min and was completed without any significant problems. During this period, final engine and stage conditioning were accomplished. Table 6-5 presents the sequence of terminal countdown events.

6.4.3.1 Engine Conditioning

The J-2 engine conditioning was initiated with a 50-psig ambient helium purge through the start sphere. After the purge was terminated, the start sphere was chilled with cold GH2 circulated through heat exchanger circuit No. 1; it was maintained at the proper temperature by opening the heat exchanger circuit No. 1 vent valve (primary bleed) at the proper time. Start sphere chilldown was terminated with the initiation of start sphere pressurization by closing the start sphere vent valve. No problems occurred during start sphere conditioning for launch.

The J-2 engine thrust chamber jacket conditioning was initiated with a 50-psig ambient helium purge. The purge was terminated at T -10 min, and thrust chamber chilldown was initiated with cold helium flowing through heat exchanger circuits 2 and 3 for approximately 5 min; chilldown was then continued with cold helium supplied through heat exchanger circuit No. 2 only. Thrust chamber jacket temperature was well within redline limits at both the initiation of automatic sequence and at T -19 sec.

The engine control sphere was pressurized at T -40 min and conditioned during start sphere chilldown. The supply was closed at T -5 min. The differential temperature between the GH2 start sphere and the engine control sphere was +13.7 deg R at T -19 sec, which is within the ± 30 deg R required at this time.

6.4.3.2 Stage Conditioning

LOX turbopump chilldown was performed with a LOX flowrate of 40 gpm unpressurized and 43 gpm pressurized. The chilldown was normal in every respect.

LH2 turbopump chilldown was performed at an LH2 flowrate of 92 gpm unpressurized and 133 gpm pressurized. The chilldown was normal and provided satisfactory LH2 pump inlet conditions for launch. The low LH2 chilldown pump flowrate and high LH2 pump inlet temperature encountered during the CDDT did not occur during the launch countdown because the proper insulation had been installed on the recirculation pump and shutoff valve. Chilldown is further discussed in sections 11 and 12.

LOX and LH2 tank prepressurization were completed in the expected times, and the tank ullage pressures were satisfactory at T -19 sec. Two LOX tank ullage pressure makeup cycles were accomplished satisfactorily.

The stage pneumatic system functioned normally during the terminal count. The control regulator discharge pressure during periods of low demand was 540 to 560 psia, as expected.

6.5 Redline Limits

The redline limits for launch vehicle parameters are presented in the Apollo 6 (AS-502) Launch Mission Rules, Rev A, dated 8 March 1968; and in Douglas report SM-46999, Saturn S-IVB-502 Stage Flight Test Plan, dated 23 October 1967; and in the A41 Redline Monitoring Brief. All redlines were satisfied before the launch; however, two were changed after the CDDT because of the poor LH2 chilldown system performance during CDDT. The LH2 pump flowrate redline was decreased from 130 to 120 gpm, and the LH2 pump inlet temperature redline was increased 1 deg R. However, these measurements were well within the original redline limit for launch.

6.6 Countdown Operations

6.6.1 Environmental Control Systems

The aft interstage thermoconditioning and purge system functioned properly during the countdown, maintaining the APS oxidizer temperatures within the launch redline limits of 535 to 560 deg R. At liftoff, the oxidizer temperature in APS module 1 was 556 deg R and in APS module 2 was 545 deg R.

6.6.2 Common Bulkhead Evaluation

The vacuum monitor console setups were started at 15:30:00 GMT on 3 April. A gas sample was taken at 15:51:00 GMT and the vacuum supply valves opened at 16:09:00 GMT with an internal bulkhead pressure of 0.9 psia. Results of the gas sample indicated a satisfactory inert atmosphere inside the bulkhead at liftoff, as shown in the following table.

Results of Gas Sample

| <u>Gas</u> | <u>Concentration</u> |
|-----------------|----------------------|
| H ₂ | 0.16% |
| He | 0.28% |
| N ₂ | 37.6% |
| O ₂ | 5.9% |
| A | 53.7% |
| CO ₂ | 1.9% |

Section 6
Countdown Operations

The vacuum supply valves were closed on 4 April at 05:08:00 GMT, 24 min prior to LOX loading. A satisfactory internal pressure was maintained throughout the count with a pressure of 0.17 psia at liftoff. During flight and orbital coast, the internal pressure remained steadily at 0.2 psia until loss of signal from KSC, 6-1/2 hr after liftoff.

The bulkhead internal pressure remained well below the relief valve setting of 1.0 psia, and the entire flight pressure history was indicative of a sound bulkhead.

6.6.3 Countdown Problems

The following problems were encountered during the launch countdown:

- a. At 21:59:00 GMT on 2 April, after the CDDT and during recycle operations, the pneumatic console Model DSV-4B-432A, 3,200 psia helium dome regulator, A11733, P/N 1A66985-503, S/N 168 was found to be chattering during periods of high flowrate. The regulator was removed and replaced.
- b. At 12:19:00 GMT on 3 April 1968, during propulsion preparations for launch, the pneumatic console Model DSV-4B-432A, 500 psi helium dome loader regulator, A12059, P/N 1B37340-519, S/N 10248, was found to be leaking internally. The regulator was removed and replaced.
- c. Temperature measurement C0205-403 was recommended for deletion prior to launch. This recommendation was based on a misinterpretation of the data. The transducer appeared to be hung up at 80 percent of full scale, but the temperature was actually being maintained at this level by air from the environmental control system.

6.7 Atmospheric Conditions

The atmospheric conditions for the AS-502 launch on 4 April 1968 were as follows:

| <u>Time (GMT)</u> | <u>Ambient Temp. (deg F)</u> | <u>Dew Point Temp. (deg F)</u> | <u>Relative Humidity (percent)</u> | <u>Ambient Press* (in. of HG)</u> | <u>Wind Direction** (deg from N)</u> | <u>Wind Velocity** (knots)</u> |
|-----------------------|--------------------------------------|--|--|---|--|--|
| 06:00:00 | 69 | 62 | 79 | 30.16 | 130 | 9 |
| 07:00:00 | 69 | 62 | 79 | 30.15 | 120 | 6 |
| 08:00:00 | 68 | 63 | 84 | 30.13 | 140 | 7 |
| 09:00:00 | 68 | 64 | 87 | 30.12 | 140 | 7 |
| 10:00:00 | 69 | 64 | 84 | 30.13 | 140 | 9 |
| 11:00:00 | 69 | 64 | 84 | 30.14 | 140 | 8 |
| 12:00:00 (liftoff) | 71 | 65 | 81 | 30.14 | 140 | 10 |

*Ambient pressure at sea level.

**Wind direction and velocity from location 60 ft above ground level and 3 miles West of LC Pad 39A.

TABLE 6-1
LAUNCH VEHICLE TESTS

| TEST | NASA PROCEDURE | COMPLETION |
|---|------------------|------------------------|
| AS-502 Launch Vehicle OAT No. 1 (Plugs In) | V-20011 | 21 Dec 67 |
| AS-502 Launch Vehicle OAT No. 1 (Plugs Out) | V-20035 | 28 & 29 Dec 67 |
| AS-502 Space Vehicle OAT No. 1 (Plugs In) | V-20010, rev 001 | 16 Jan 68 |
| AS-502 Launch Vehicle Propellant Simulated Loading Test | V-25166 | 15 Feb 68 |
| AS-502 Launch Vehicle LH2 Simulated Loading Test | V-25126 | 12 Feb 68 |
| AS-502 Launch Vehicle LOX Simulated Loading Test | V-25116 | 13 Feb 68 |
| AS-502 Space Vehicle Cutoff and Malfunction Test | V-20021, rev 004 | 16 Feb 68 |
| AS-502 Launch Vehicle LOX System Cold Flow Test | V-25333 | 19 Feb 68 |
| AS-502 LH2 System Cold Flow Test | V-20034, rev 004 | 24 Feb 68 |
| AS-502 Launch Vehicle MCC-H Interface Command Test (Pad) | V-20027 | 27 Feb 68 |
| AS-502 Launch Vehicle MCC-H Interface Command Test (VAB) | V-20023 | 4 & 5 Jan 68 |
| AS-502 Space Vehicle OAT No. 2 (Plugs Out) | V-20012 | 24 & 25 Jan 68 |
| AS-502 Launch Vehicle OAT No. 2 (Plugs In) | V-20029 | 29 & 30 Aug 67 |
| AS-502 Launch Vehicle Flight Sequence and EBW Functional | V-20007 | 10 Aug 67 |
| AS-502 Launch Vehicle OAT No. 1 (Plugs In) S-II Spacer | V-20011S, rev A | 13 June 67 |
| AS-502 Launch Vehicle Sequence Malfunction Test with S-II Spacer | V-20019S | 5, 6, 7, and 8 June 68 |
| AS-502 Launch Vehicle Sequence and EBW Functional Test with S-II Spacer | V-20007S, rev B | 1 June 67 |

TABLE 6-2
APS LOADING DATA

| ITEM | VOLUME (IN. ³) | TEMPERATURE (DEG R) |
|--|----------------------------|---------------------|
| Module 1 | | |
| Oxidizer System | | |
| Loaded | 4,102 | 80 |
| Offloaded | 372 | 75 |
| Removed with bubble bleed during burp firing | 28 | 88.5 |
| Removed with bubble bleed during countdown | 38 | 85 |
| Fuel System | | |
| Loaded | 4,102 | 81.5 |
| Offloaded | 88 | 83 |
| Removed during countdown | 38 | 84 |
| Module 2 | | |
| Oxidizer System | | |
| Loaded | 4,102 | 82 |
| Offloaded | 372 | 82 |
| Removed with bubble bleed during burp firing | 21 | 91 |
| Removed with bubble bleed during countdown | 30 | 84 |
| Fuel System | | |
| Loaded | 4,102 | 79 |
| Offloaded | 88 | 80.5 |
| Removed with bubble bleed during countdown | 28 | 82 |

Section 6
Countdown Operations

TABLE 6-3
S-IVB-502 STAGE PROPELLANT LOADING DATA

| PARAMETER | UNITS | LOX | LH2 |
|----------------------------|---------|--------------|----------------|
| Chilldown initiated | GMT | 04:57:00 | 09:46:00 |
| Slow Fill | | | |
| Levels | percent | 0 to 5 | 0 to 5 |
| Initiation time | GMT | 05:32:00 | 09:46:00 |
| Flowrate | gpm | 720 | 400 |
| Maximum swing arm pressure | psia | 47 | 20.7 |
| Maximum ullage pressure | psia | 23.5 | 18.5 |
| Fast fill | | | |
| Levels | percent | 5 to 96 | 5 to 98 |
| Initiation time | GMT | 05:34:00 | 09:59:00 |
| Flowrate | gpm | 950 to 1,050 | 2,700 to 3,000 |
| Swing arm pressure | | | |
| Maximum | psia | 44 | 20.7 |
| Stabilized | psia | 42.5 to 44 | 20.7 |
| Maximum ullage pressure | psia | 23.5 | 17.5 |
| Final slow fill | | | |
| Level at initiation | percent | 96 | 98 |
| Initiation time | GMT | 05:53:00 | 10:23:00 |
| Flowrate | gpm | 450 | 500 |
| Swing arm pressure | psia | 21 | 20.7 |
| Maximum ullage pressure | psia | 16.5 | 17.5 |
| Total time required | min | 22 | 40 |

TABLE 6-4
SPHERE PRESSURIZATION DATA

| SPHERE | VOLUME (ft ³) | FINAL PRESSURIZATION | | INITIAL PRESSURE (psia) | FINAL PRESSURE (psia) | PRESSURE AT LIFTOFF (psia) | TEMPERATURE AT LIFTOFF (deg R) | MASS AT LIFTOFF (lbm) |
|------------------|---------------------------|----------------------|------------------|-------------------------|-----------------------|----------------------------|--------------------------------|-----------------------|
| | | INITIATION TIME | REQUIRED TIME | | | | | |
| Repressurization | | | | | | | | |
| LOX | 9.0 | 80% LH2 | 8 min | 2,625 | 3,120 | 3,080 | 495 | 18.58 |
| LH2 | 31.5 | 80% LH2 | 8 min | 2,580 | 3,100 | 3,053 | 486 | 66.2 |
| Control helium | 4.5 | 80% LH2 | 7 min | 2,850 | 3,110 | 3,100 | 545 | 8.54 |
| Cold helium | 28.0 | 80% LH2 | 16.5 min | 1,080 | 3,100 | 2,966 | 38.9 | 332.0 |
| APS helium | | | | | | | | |
| Module 1 | 0.540 | T -55 min | 3 min | 3,120 | 3,120 | 3,120 | 558 | 1.02 |
| Module 2 | 0.540 | T -55 min | 3 min | 3,100 | 3,100 | 3,100 | 545 | 1.03 |
| Engine control | 0.578 | T -32 min | 1 min 30 sec* | 3,080 | 2,972 | 2,968 | 290 | 1.87 |
| Engine GH2 start | 4.224 | T -5 min 30 sec | approx 15 sec | 1,100 | 1,280 | 1,304 | 278 | 3.47 |

*Pressurized in two steps.

TABLE 6-5
 TERMINAL COUNTDOWN SEQUENCE

| FUNCTION | TIME FROM LIFTOFF (sec) |
|---|----------------------------|
| Start sphere purge initiated | -1,200 |
| Thrust chamber purge initiated | -870 |
| Start sphere purge terminated | -870 |
| Start sphere chilldown initiated | -870 |
| Thrust chamber purge terminated | -600 |
| Thrust chamber chilldown initiated | -600 |
| Start sphere chilldown terminated | -293.8 |
| Engine control sphere supply closed | -289.1 |
| LOX turbopump chilldown initiated | -284.2 |
| LH2 turbopump chilldown initiated | -299.0 |
| Cold helium crossover valve closed | -258.3 |
| Fuel pre valve closed | -275.6 |
| Oxidizer pre valve closed | -275.6 |
| LOX tank vent valve closed | -166.7 |
| LOX tank prepressurization terminated | -150.3 |
| LH2 tank vent valve closed | -96.7 |
| LH2 tank prepressurization terminated | -75.1 |
| LH2 directional vent to flight position | -39.7 |
| Commit and liftoff (12:00:01.69 GMT) | 0 |

SECTION 7

COST PLUS INCENTIVE FEE

7. COST PLUS INCENTIVE FEE

7.1 S-IVB-502 Flight Mission Accomplishment Results

S-IVB preconditions of flight (PCF) were outside of allowable tolerances as a result of non-nominal lower stage performance caused by the premature shutdown of two S-II stage engines. S-IVB end conditions of flight (ECF) also were not achieved due to premature termination of flight caused by a malfunction of the J-2 engine which is not considered Douglas' fault as defined in paragraphs 3.3.7 and 3.3.9 of Exhibit J to Supplemental Agreement 1100 to Contract NAS7-101. S-IVB performance was satisfactory throughout the S-IVB first burn and parking orbit phases of the mission, and the required ECF would have been achieved if proper PCF had existed and the J-2 engine had not malfunctioned. Substantiation of this position is presented in the following paragraphs.

Table 7-1 presents a comparison of the actual PCF determined from flight data and allowable PCF defined in MSFC Letter I-CO-S-IVB-8-303, dated 27 March 1968. It can be seen that all of the trajectory parameters and the pitch attitude parameter of the PCF differed from nominal by substantially more than the allowable tolerances.

Flight evaluation results have established that the failure of the S-IVB to restart was caused by a failure of the J-2 engine augmented spark igniter (ASI) assembly which occurred during S-IVB first burn. The evaluation results also show that all S-IVB systems were functioning properly until after this failure occurred. The subsequent failure of the S-IVB hydraulic system can be attributed directly to the J-2 engine failure.

S-IVB anomalies that cannot be definitely attributed to the ASI failure are:

- a. Excessive S-IVB cold helium leakage in orbit
- b. Abnormal operation of the S-IVB propellant utilization system in orbit.

Neither of these problems would have precluded successful attainment of required ECF, if proper PCF had existed and the J-2 engine had not failed. Sufficient cold helium remained for a full duration second S-IVB burn. The propellant utilization system anomaly could have resulted in high engine mixture ratio (5.5:1) operation during the second S-IVB burn phase. If proper PCF had existed, sufficient reserve propellants would have been available to accommodate this mode of operation. As shown in table 7-2, the ECF that would have resulted are within the allowable tolerances stated in MSFC Letter I-CO-S-IVB-8-329, dated 29 March 1968. These ECF were obtained from a trajectory simulation that was based on the following conditions:

- a. Nominal PCF
- b. Actual S-IVB first burn performance (excluding effects of ASI failure)
- c. Propellant utilization valve at the extreme high mixture ratio limit during second S-IVB burn.

S-IVB attitude control ECF were evaluated throughout the portion of the planned mission that was successfully accomplished. This includes first S-IVB burn and parking orbit (until

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issuance of the command to restart the S-IVB J-2 engine). Table 7-3 presents the actual and allowable attitude control ECF during this period. The allowable envelopes are those defined in MSFC Letter I-CO-S-IVB-8-303 dated 27 March 1968. Pitch attitude error and pitch rate temporarily exceeded allowable tolerances early in S-IVB first burn. This was caused by the out of tolerance pitch attitude PCF parameter. S-IVB control system performance was normal and all other parameters were within tolerance throughout this period.

7.2 Telemetry Performance

Evaluation of the telemetry performance indicated that the telemetry system operated at 98.3 percent efficiency during the telemetry performance evaluation period (TPEP) phase I (liftoff to first S-IVB engine cutoff +10 sec) and performed at 97.6 percent efficiency during the TPEP phase II (liftoff to planned LV/SC separation as defined in NASA drawing 40M33622, Interface Control Document Definition of Saturn SA-502 Flight Sequence Program).

The results of the telemetry performance analysis are shown in table 7-4.

TABLE 7-1
S-IVB-502 PRECONDITIONS OF FLIGHT

| PARAMETER | UNITS | NOMINAL | ACTUAL | ALLOWABLE DEVIATION* | ACTUAL DEVIATION |
|---------------------------|---------|---------|---------|----------------------|------------------|
| Range | km | 1,505.4 | 1,815.5 | +55.4 -71.1 | 310.1** |
| Crossrange | km | 40.8 | 30.7 | +3.5 -3.8 | -10.1** |
| Altitude | km | 188.8 | 195.2 | +3.4 -3.4 | 6.4** |
| Velocity vector magnitude | m/sec | 6,834.4 | 6,728.7 | +52.4 -66.1 | -105.7** |
| Velocity vector direction | deg | 0.78 | 1.60 | +0.38 -0.34 | 0.82** |
| Pitch attitude | deg | -96.3 | -82.2 | +5.0 -5.0 | 14.2** |
| Pitch rate | deg/sec | 0.0 | -0.1 | +1.5 -1.5 | -0.1 |
| Yaw attitude | deg | 0.3 | -1.0 | +3.8 -3.7 | -1.3 |
| Yaw rate | deg/sec | 0.0 | -0.2 | +1.5 -1.5 | -0.2 |
| Roll attitude | deg | 0.0 | -0.5 | +4.0 -4.0 | -0.5 |
| Roll rate | deg/sec | 0.0 | -0.1 | +1.5 -1.5 | -0.1 |

NOTE: PCF are evaluated at the instant of Separation Command

*Deviations consist of allowable error plus evaluation uncertainty

**Exceeds allowable tolerance

TABLE 7-2
SIMULATED TRAJECTORY END CONDITIONS OF FLIGHT FOR PU MALFUNCTION
RESULTING IN HIGH EMR OPERATION

| PARAMETER | UNITS | NOMINAL | SIMULATED | ALLOWABLE DEVIATION | SIMULATED DEVIATION |
|--------------------------|----------------------------------|------------|------------|----------------------|---------------------|
| Inclination | deg | 32.485 | 32.486 | +0.049 -0.052 | +0.001 |
| Node | deg | 122.490 | 122.499 | +0.220 -0.225 | +0.009 |
| Energy (C ₃) | m ² /sec ² | -1,491,156 | -1,494,147 | +125,675 -193,679 | -2,991 |
| Eccentricity | -- | 0.97532 | 0.97528 | +0.00206 -0.00332 | -0.00004 |

NOTE: The Simulated ECF are based on:

- a. Nominal PCF
- b. Actual S-IVB first burn performance (excluding effect of ASI failure)
- c. Propellant utilization valve at the extreme high mixture ratio limit during second S-IVB burn.

TABLE 7-3
 ATTITUDE CONTROL END CONDITIONS OF FLIGHT
 (TO RESTART ATTEMPT)

| PARAMETER | ALLOWABLE ENVELOPE | MAXIMUM FLIGHT VALUE |
|-----------------------------|--------------------|----------------------|
| S-IVB First Burn | | |
| Pitch Attitude Error (deg) | <u>+6</u> | +7.6** |
| Yaw Attitude Error (deg) | <u>+6</u> | +2.4 |
| Roll Attitude Error (deg) | <u>+13.5</u> | -1.0 |
| Pitch Rate (deg/sec) | <u>+3</u> | -3.5** |
| Yaw Rate (deg/sec) | <u>+3</u> | +1.0 |
| Roll Rate (deg/sec) | <u>+1.5</u> | -0.6 |
| Parking Orbit | | |
| *Pitch Attitude Error (deg) | <u>+4</u> | +1.3 |
| *Yaw Attitude Error (deg) | <u>+4</u> | -1.1 |
| *Roll Attitude Error (deg) | <u>+13.5</u> | -0.6 |
| Pitch Rate (deg/sec) | <u>+1.2</u> | -0.3 |
| Yaw Rate (deg/sec) | <u>+1.2</u> | -0.5 |
| Roll Rate (deg/sec) | <u>+1.5</u> | -0.6 |

*Excluding normal transients and maneuvers

**Temporary out of tolerance condition resulting from out of tolerance preconditions of flight.

TABLE 7-4 (Sheet 1 of 3)
 FLIGHT TELEMETRY PERFORMANCE SUMMARY

| ITEM | DESCRIPTION | TOTAL |
|------|---|-------|
| 1. | Total number of measurements listed in the <u>S-IVB-502 Instrumentation Program and Components List (IP&CL)</u> , Douglas Drawing IB43567, AL Change. | 616 |
| 2. | Measurements listed in the IP&CL which are not wholly on the S-IVB-502 stage: Measurements transmitted by the S-II telemetry system: D0153-423 Press - Chamber Retrorocket Posit IV-I D0154-421 Press - Chamber Retrorocket Posit II-III D0155-420 Press - Chamber Retrorocket Posit I-II D0156-422 Press - Chamber Retrorocket Posit III-IV Measurements wholly transmitted landline to the Launch Control Center: D0545-407 Press - Common Bulkhead Internal - H/W D0576-408 Press - Fuel Tank Ullage Umbilical - H/W D0577-406 Press - Oxid Tank Ullage Umbilical - H/W | 7 |
| 3. | Measurements known to be inoperative at start of automatic launch sequence, or became inoperative prior to start of automatic launch sequence: | 18 |

TABLE 7-4 (Sheet 2 of 3)
 FLIGHT TELEMETRY PERFORMANCE SUMMARY

| ITEM | DESCRIPTION | TOTAL |
|------|--|-----------------------|
| | <p>The function of the following measurements is to monitor the output voltage of exploding bridgewires (EBW) by means of pulse sensors during checkout. The pulse sensors are removed prior to launch, thus making the measurements inoperative during flight.</p> <p>K0141-411 Event - R/S 1 Pulse Sensor</p> <p>K0142-411 Event - R/S 2 Pulse Sensor</p> <p>K0149-404 Event - Ullage Jettison 1 P/S</p> <p>K0150-404 Event - Ullage Jettison 2 P/S</p> <p>K0169-404 Event - EBW Pulse Sensor Off Indication</p> <p>K0176-404 Event - Ullage Rocket Ignition P/S 1 Ind</p> <p>K0177-404 Event - Ullage Rocket Ignition P/S 2 Ind</p> <p>The following measurement was listed in the IP&CL, and the capability to make the measurements existed on the stage. MSFC did not require the associated rate gyro installation; therefore, the measurement is inoperative.</p> <p>K0152-404 Event - Rate Gyro Wheel Speed OK Ind</p> <p>The following measurement is used for checkout only. The IU flight sequencing tape is not programmed to activate this measurement in flight. Therefore, it is inoperative.</p> <p>K0168-404 Event - Switch Selector Register Test</p> <p>The following measurements malfunctioned and became inoperative prior to the start of automatic sequence</p> <p>C0041-406 Temp - LOX Tank, Posit 2</p> <p>C0056-406 Temp - LOX Tank Ullage Gas, 20 percent</p> <p>C0150-401 Temp - Eng LH2 Pump Surface</p> <p>C0155-404 Temp - LH2 Prevalve Bypass Line</p> <p>C0205-403 Temp - He Prepress Sphere, No. 4 Gas</p> <p>C0301-415 Temp - APS Oxid, Tank 2</p> <p>D0018-401 Press - Eng Reg Outlet</p> <p>D0058-401 Press - PU Valve Inlet</p> <p>S0087-426 Strain - Dyn, Fwd Skirt, Pnl 17</p> | |
| 4. | <p>Measurements from which Douglas could not obtain data due to noise from unknown sources, and measurements which were degraded or prevented from being transmitted.</p> <p>Phase I</p> <p>Phase II</p> <p>C0010-403 Temp - Engine Area Ambient</p> <p>C0152-403 Temp - LOX Main Line Flg Wall</p> <p>E0209-401 Vib - Combustion Chamb Dome, Long</p> | <p>0</p> <p>3</p> |
| 5. | <p>The total number of measurements to be evaluated for incentive performance for both TPEP phase I and phase II is item 1 minus the sum of items 2, 3, and 4.</p> <p>Phase I</p> <p>Phase II</p> | <p>591</p> <p>588</p> |

TABLE 7-4 (Sheet 3 of 3)
 FLIGHT TELEMETRY PERFORMANCE SUMMARY

| ITEM | DESCRIPTION | TOTAL |
|------|--|-------|
| 6. | <p>Measurements which were failures during TPEP phase I (Liftoff to first S-IVB engine cutoff +10 sec). Details regarding these measurement failures may be obtained in section 18 of this report.</p> <p>B0023-404 Acoustic - Aft (2400 - 4800), Int C0008-403 Temp - Heat Exch He Inlet C0049-405 Temp - Electrical Tunnel, Loc 1 C0058-406 Temp - LOX Tank Ullage, 80 percent C0111-426 Temp - Fwd Skirt, Loc 8 C0151-401 Temp - LOX Pump Surface C0286-415 Temp - APS Fairing 2-4 D0105-404 Press - LOX Tank Press Mod, He Gas E0114-411 Vib - Fwd Skirt, EBW R/S Pnl, Radial E0210-401 Vib - LH2 Turbopump - Lateral</p> | 10 |
| 7. | <p>Measurements which were failures during TPEP phase II (Liftoff to planned LV/SC separation as defined in NASA drawing 40M33622, <u>Interface Control Document Definition of Saturn SA-502 Flight Sequence Program</u>). Details regarding these measurement failures may be obtained in section 18 of this report.</p> <p>All measurements which were failures during TPEP phase I are included as phase II failures because phase II encompasses phase I. These ten measurements are shown in item 6 above.</p> <p>In addition to those measurements which were failures during TPEP phase I, the following four measurements were failures during phase II.</p> <p>C0189-414 Temp - APS Inj Wall, Eng 1-2 C2015-401 Temp - Crossover Duct Ext Wall 1 D0003-403 Press - LOX Pump Inlet D0224-401 Press - LH2 Pump Intrstg Outlet</p> <p>Calculation of phase I performance: Item 5 minus item 6, divided by item 5, multiplied by 100, and rounded off to the nearest one-tenth of one percent.</p> $\frac{591-10}{591} \times 100 = 98.3 \text{ percent}$ <p>Calculation of phase II performance: Item 5 minus item 7, divided by item 5, multiplied by 100, and rounded off to the nearest one-tenth of one percent.</p> $\frac{588-14}{588} \times 100 = 97.6 \text{ percent}$ | 14 |

SECTION 8

TRAJECTORY

8. TRAJECTORY

8.1 Scope

This section presents a discussion of the AS-502 vehicle trajectory. Comparisons are made between the actual observed trajectory and the preflight and postflight predicted trajectories; also results of a simulation of the actual trajectory are presented. Actual observed trajectory deviations from predicted are explained in terms of S-IVB and lower stage system performance deviations.

Also presented is the parking orbit continuous vent system (CVS) thrust determined from trajectory analysis. A comparison of this thrust with predicted is presented.

As areas of interest, discussions are included of the vehicle overspeed problem which occurred at the end of the S-IVB first burn, and the stage motion and breakup after the unsuccessful restart attempt.

8.2 Comparison Between Actual and Preflight Predicted Trajectories

A comparison is made between the actual trajectory (based on tracking and telemetry data) and the preflight predicted trajectory. The predicted trajectory, during S-IC and S-II stage burns, is that presented in the Boeing final operational trajectory. The S-IVB portion of the predicted trajectory is the Douglas final predicted trajectory.

The flight trajectory of the AS-502 was characterized by several anomalies (section 2) resulting in large deviations from the predicted trajectory beginning at approximately RO +413 sec and continuing throughout the remainder of the boost to parking orbit phase and the parking orbit coast phase. Most significant of the anomalies was a failure of the S-IVB J-2 engine to reignite for boost into translunar orbit. Powered flight comparisons of actual and predicted trajectory conditions as presented in this section will, therefore, be restricted to the boost to parking orbit phase.

Figures are presented comparing the actual and predicted values of altitude, ground range, crossrange position, crossrange velocity, inertial velocity, axial acceleration, inertial flight path elevation angle, and inertial flight path azimuth angle for the powered and orbital coast phases of the flight.

Figures 8-1 through 8-25 compare the actual and predicted histories for each trajectory parameter. Figures 8-26 through 8-31 present a history of the differences between the preflight and postflight predicted and actual trajectory parameters during the S-IVB and orbital phases of flight. Table 8-1 shows conditions at certain significant event times.

The S-IC stage trajectory was close to predicted. As shown in table 8-1, the maximum dynamic pressure was 31.5 lbf/ft^2 higher than predicted and it occurred 4.14 sec earlier than predicted. Approximately 100 sec into the S-IC flight, a longitudinal pogo oscillation of approximately 5 cps was observed. This oscillation lasted through the remaining portion of S-IC flight producing no significant effect on the trajectory. S-IC/S-II separation

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occurred 1.35 sec later than predicted. As shown in table 8-1, the altitude at S-IC/S-II separation was 3,379 ft higher than predicted and the inertial velocity was 33.2 ft/sec higher than predicted.

The S-II stage trajectory was close to predicted until R0 +412.9 sec. At this time the No. 2 engine prematurely shut down. Reportedly because of prevalve cross wiring, the No. 3 engine was shut down at R0 +414.2 sec following the detection of a thrust loss on engine No. 2. As a result of the shutdown of these engines, S-II propellant depletion was not reached until R0 +576.3 sec, at which time the three remaining engines cut off normally. The iterative guidance mode (IGM) was not implemented to fly optimally with two engines out. The IGM detected a loss of a single engine and adjusted S-II burn time-to-go by 20 percent. When the second engine shut down, no further adjustment of time-to-go could be made. As a result, the guidance commands were frozen approximately 58 sec prior to S-II cutoff, causing a far-from-optimum trajectory during the latter part of S-II boost. S-II/S-IVB separation occurred at R0 +577.08 sec, 59.12 sec later than predicted. At this time the trajectory could be characterized as slow, high, long, and to the right of the predicted path. This is shown in table 8-1. The inertial velocity was 354.9 ft/sec lower than predicted while the altitude was 21,323 ft higher than predicted. The inertial flight path elevation angle was 0.822 deg higher than predicted. Figures 8-1 through 8-14 present the S-IC/S-II trajectory parameter histories.

Because of the nonoptimum trajectory conditions at S-II/S-IVB separation which resulted from the large period of frozen attitude commands, guidance commanded the S-IVB to pitch nose down at the maximum rate of 1 deg/sec for 60 sec. At this time, altitude reached its peak value (figure 8-26) and began to decrease toward the target value. Figure 8-29 shows that at this time inertial flight path angle was decreasing rapidly from the target value of 0 deg which is necessary to obtain the desired orbit. In order to attain target flight path angle, the vehicle was commanded to pitch nose up. This nose up maneuver became rate limited near the end of S-IVB burn. Figure 8-23 presents pitch attitude commands during these maneuvers. When target velocity of 25,561.1 ft/sec was attained at approximately R0 +739 sec, the guidance was still attempting to rotate the velocity vector to a 0 deg flight path orientation. At R0 +747.04 sec, after guidance had entered the high-speed loop, the velocity magnitude was found to be greater than its target value and engine cutoff was commanded. This overspeed problem is discussed in detail in paragraph 8.5.

Another significant problem occurred during the S-IVB first burn. At approximately R0 +690 sec, the LH2 augmented spark igniter (ASI) feedline ruptured. This caused an approximate 5,000 lbf (paragraph 8.4) loss in thrust to occur. The lower acceleration caused by this loss in thrust is shown in figure 8-20. Table 8-1 presents the trajectory conditions at S-IVB first burn Engine Cutoff Command. These conditions can be characterized as low, fast, and long. The altitude was 1,987 ft lower than predicted while the inertial velocity was 160.2 ft/sec higher than predicted. The inertial flight path elevation angle was 0.4 deg lower than predicted. Figures 8-15 through 8-29 present the S-IVB trajectory.

A parking orbit was achieved which had an apogee altitude of 194.4 nmi, a perigee altitude of 93.5 nmi, and a period of 89.8 min, instead of the target 100 nmi circular parking orbit. The elliptical orbit was caused by the vehicle overspeed. Had the vehicle overspeed not occurred and S-IVB cutoff been commanded when target velocity magnitude was reached, the resulting parking orbit would have had a perigee radius of 67 nmi and an apogee radius of 157 nmi since flight path angle would still have been approximately 0.7 deg below the target value. Trajectory conditions and parking orbit elements at insertion are presented in table 8-1. The CVS thrust appeared to be close to nominal throughout the parking orbit (paragraph 8.6). Preparations to restart the S-IVB were begun 11,287.73 sec into the flight. This was 213.7 sec later than predicted because of the higher-than-predicted elliptical parking orbit period. Trajectory conditions at this time are presented in table 8-1. Figure 8-30 and 8-31 present the parking orbit trajectory.

Restart of the S-IVB J-2 engine was attempted at R0 +11,614.7 sec. Table 8-1 presents the trajectory conditions at this time. Following fuel lead, LOX and LH2 were dumped through the engine in the normal manner, and the combination of pumped propellants and gas generator exhaust produced approximately 10,000 lbf of J-2 engine thrust. However, due to the rupture of the LH2 ASI line during first burn, reignition did not occur. The instrument unit automatically initiated TB7 at R0 +11,630.32 sec, when the mainstage pressure switch did not detect sufficient chamber pressure to indicate that ignition was accomplished. Launch vehicle/spacecraft (LV/SC) separation was initiated by ground command at R0 +11,666.1 sec. Trajectory conditions at TB7 and LV/SC separation are presented in table 8-1.

8.3 Postflight Predicted Trajectory Evaluation

To assist in the isolation of S-IVB performance deviations which contributed to trajectory deviations, a postflight S-IVB predicted trajectory was generated. This trajectory was generated using predicted S-IVB performance characteristics and actual S-II/S-IVB separation trajectory conditions. Trajectory deviations between the actual and the postflight predicted are due to S-IVB performance deviations, observed trajectory evaluation errors, and instrument unit navigation or guidance errors.

To support this evaluation, the following set of parameters were selected to define the S-IVB trajectory: Altitude, ground range, crossrange position, crossrange velocity, inertial velocity, axial acceleration, inertial flight path elevation angle, and inertial flight path azimuth angle. Figures 8-26 through 8-31 show that deviations from predicted for each of these parameters are due primarily to lower stage performance deviations. S-IVB performance, with the exception of the ASI fuel feedline rupture at approximately R0 +690 sec, was nearly nominal as indicated by figure 8-32 through 8-35. These figures compare the postflight predicted trajectory with observed data.

Over most of the S-IVB powered flight, the postflight predicted trajectory is long, low, fast, and to the right of actual. Figure 8-34 shows that actual vehicle acceleration was lower than predicted, which accounts for the slower-than-predicted inertial velocity (figure 8-34) and the shorter-than-predicted ground range (figure 8-32). Postflight simulated trajectory analysis (paragraph 8.4) shows that a thrust vector misalignment in both the pitch and yaw planes accounts for the deviations between postflight predicted and actual altitude (figure 8-32), crossrange position and velocity (figure 8-33), and inertial

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flight path elevation and azimuth angles (figure 8-35). The impact of the overspeed phenomenon on S-IVB cutoff conditions is evident from figures 8-34 and 8-35. The target cutoff velocity was exceeded by approximately 160 ft/sec, but the overspeed caused both elevation and azimuth flight path angles to more closely approach target values. Guidance responses causing the overspeed are discussed in detail in paragraph 8.5.

The S-IVB burntime was 30.8 sec longer than predicted. The table below shows that the primary contributors to this deviation were deviations in preconditions of flight.

The magnitude of these contributions were obtained from postflight trajectory analysis using the actual preconditions of flight and predicted S-IVB performance. Another large contributor was the overspeed. The magnitude of this contribution was obtained by subtracting from the actual cutoff time the time at which the launch vehicle digital computer (LVDC) output indicated the magnitude of the target velocity was reached. The remainder of the contributions bring the total burntime deviation to 32.6 sec. This is 1.8 sec more than the actual burntime deviation. The additional 1.8 sec of burntime could be accounted for by uncertainties in preconditions of flight and uncertainties in the thrust average obtained from trajectory reconstruction.

| <u>CONTRIBUTOR</u> | <u>DEVIATION (ACTUAL MINUS PREDICTED)</u> | <u>CONTRIBUTION TO BURNTIME DEVIATION</u> |
|--------------------------------------|---|---|
| Preconditions of flight (simulation) | | +23.1 sec |
| Velocity magnitude | -354.9 deg | |
| Elevation flight path angle | +0.822 deg | |
| Altitude | +21,300 ft | |
| Overspeed (LVDC) | +160.2 ft/sec | +8.1 sec |
| S-IVB thrust | -1,985 lb | +1.0 sec |
| S-IVB mass flow | +0.48 lb | <u>+0.4 sec</u> |
| Total | | +32.6 sec |

Figures 8-30 and 8-31 compare the postflight predicted and actual parking orbit trajectories. Because of the overspeed at S-IVB cutoff, the AS-502 flight vehicle was inserted into a perturbed parking orbit with an apogee altitude of 194.4 nmi and a perigee altitude of 93.5 nmi. Since the CVS thrust was near predicted (paragraph 8.6), the deviation in postflight predicted and actual parking orbit is due primarily to the guidance overspeed phenomenon.

8.4 Powered Flight Simulated Trajectory Evaluation

Using a five-degrees-of-freedom trajectory simulation program, a trajectory was generated which closely matched the observed trajectory (appendix 3). The simulation program employed a differential correction technique which determined the necessary adjustments to the levels of thrust and weight flow from the engine analysis and adjustments to pitch and yaw engine thrust misalignment angles from the control system analysis to match the observed trajectory.

These adjustments were determined by minimizing, in a least-squares sense, the weighted differences in altitude, earth-fixed velocity, earth fixed velocity azimuth angle, and inertial acceleration between the observed and simulated trajectories.

Differences between the observed and simulated trajectories are presented in figure 8-36. The standard deviation of the differences and the maximum of the differences are:

| <u>PARAMETER</u> | <u>UNITS</u> | <u>STANDARD DEVIATION</u> | <u>MAXIMUM DEVIATION</u> |
|------------------------------------|---------------------|---------------------------|--------------------------|
| Altitude | ft | 97.15 | 190.1 |
| Earth-fixed velocity | ft/sec | 2.618 | 4.77 |
| Earth-fixed velocity azimuth angle | deg | 0.0020 | 0.0041 |
| Inertial acceleration | ft/sec ² | 0.0714 | 0.179 |

Figure 8-37 shows the thrust history determined by engine analysis. To obtain a match of the observed trajectory initial results indicated that the thrust level after the performance shift should have been higher than that determined by engine analysis. Consequently, a study was conducted to parameterize the size of the performance shift.

A series of simulations was made in which the thrust level after the performance shift was varied by applying a multiplier from a range time of 700 sec to Engine Cutoff Command before the differential correction procedure was applied. Figure 8-38 shows the resultant behavior of two parameters as a function of this multiplier. The first parameter, L, is the non-dimensional weighted sum of the squares of the differences between the observed and simulated trajectories and is a measure of the trajectory fit. This is the quantity that is minimized by the trajectory hunting procedure. The other parameter, Δw , represents the difference between the weights as determined from the trajectory simulation and that determined by the best estimate of mass technique (section 9). It is interesting to note that where the trajectory weight determination coincides with that determined by the other methods, the trajectory fit parameter, L, is also minimized. These results indicate that the multiplier adjusting the thrust level should be equal to 0.6 percent, which indicates a smaller performance shift than determined by engine analysis.

The following table compares the average performance from 90 percent thrust as calculated by trajectory reconstruction and engine analysis with the predicted performance. The table also compares performance before and after the performance shift as calculated by trajectory reconstruction with that calculated by engine analysis.

Section 8
Trajectory

| <u>PARAMETER</u> | <u>UNITS</u> | <u>PREDICTED</u> | <u>ENGINE ANALYSIS</u> | <u>TRAJECTORY RECONSTRUCTION</u> |
|---------------------------------|--------------|------------------|------------------------|----------------------------------|
| Total average thrust | lb | 228,310 | 226,565 | 227,838 |
| Total average weight flow | lb/sec | 538.21 | 537.91 | 537.34 |
| Total average specific impulse | sec | 424.01 | 421.19 | 424.03 |
| <u>Before Performance Shift</u> | | | | |
| Average thrust | lb | -- | 229,200 | 229,897 |
| Average weight flow | lb/sec | -- | 540.6 | 539.56 |
| Average specific impulse | sec | -- | 424 | 426.09 |
| <u>After Performance Shift</u> | | | | |
| Average thrust | lb | -- | 223,000 | 226,154 |
| Average weight flow | lb/sec | -- | 536.9 | 538.77 |
| Average specific impulse | sec | -- | 414.5 | 419.77 |

The S-IVB weights as determined by trajectory reconstruction are:

| | <u>PREDICTED</u> | <u>SIMULATED</u> |
|-----------------------------|------------------|------------------|
| Engine Start Command (lbm) | 353,300 | 354,175 |
| Engine Cutoff Command (lbm) | 280,524 | 265,300 |

These weights were derived from the composite best estimate ignition and cutoff weight (section 9). The weights were determined by finding the point on the trajectory reconstruction line (figure 9-5), that has the highest probability of being equal to the best estimate value for ignition and cutoff weight. Using the nonpropellant weights of 117,649 lbm at Engine Start Command and 117,574 lbm at Engine Cutoff Command presented in section 16 and the best estimate of the liquid oxygen to liquid hydrogen ratios presented there, flight simulation results indicate the following propellant consumptions:

| | <u>LOX</u> | <u>LH2</u> | <u>TOTAL PROPELLANTS</u> |
|------------|-----------------------------|------------|--------------------------|
| | <u>ENGINE START COMMAND</u> | | |
| Actual | 194,088 | 42,438 | 236,526 |
| Predicted | 193,273 | 42,493 | 235,766 |
| Deviation* | 815 | -55 | 760 |

*Deviation equals actual minus predicted.

| | <u>LOX</u> | <u>LH2</u> | <u>TOTAL PROPELLANTS</u> |
|------------|------------------------------|------------|--------------------------|
| | <u>ENGINE CUTOFF COMMAND</u> | | |
| Actual | 119,219 | 28,507 | 147,726 |
| Predicted | 132,047 | 31,185 | 163,232 |
| Deviation* | -12,828 | -2,678 | -15,506 |
| | <u>TOTAL CONSUMED</u> | | |
| Actual | 74,869 | 13,931 | 88,800 |
| Predicted | 61,226 | 11,308 | 72,534 |
| Deviation* | 13,643 | 2,623 | 16,266 |

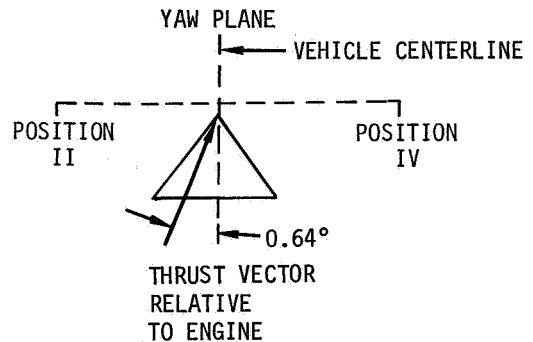
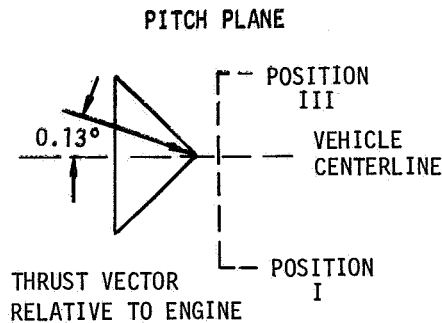
*Deviation equals actual minus predicted

The pitch and yaw thrust misalignment angles as established by control system and trajectory analysis, compare favorably. The values obtained are given below.

| <u>PARAMETER</u> | <u>UNITS</u> | <u>CONTROL ANALYSIS VALUE</u> | <u>SIMULATED VALUE</u> |
|---------------------------|--------------|-------------------------------|------------------------|
| Pitch thrust misalignment | deg | 0.25 | 0.13 |
| Yaw thrust misalignment | deg | 0.42 | 0.64 |

A positive pitch misalignment produces a nose-above commanded attitude, and a positive yaw misalignment produces a nose-left of commanded attitude (looking downrange).

The steady-state thrust vector as determined by flight simulation was located relative to the vehicle as shown below:



8.5 S-IVB First Burn Guidance Response Analysis

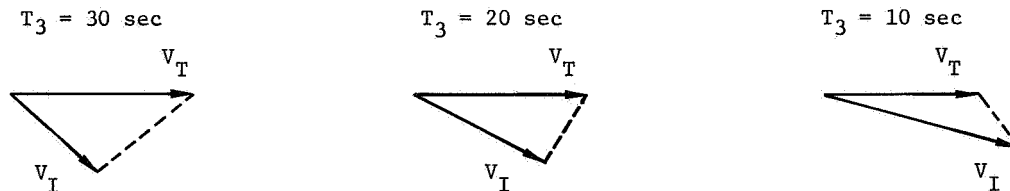
This section presents results of an analysis of the operation of the IGM during AS-502 boost to parking orbit. The IGM response to the S-II double engine-out trajectory, leading to the overspeed phenomenon at S-IVB cutoff, is explained in detail. Results of a trajectory simulation, assuming that direct staging was implemented as per flight mission rule No. 16, are also presented.

On AS-502, the IGM was capable of continuing to provide optimum commanded attitude angles in the event of no more than one S-II engine out. The IGM was not programmed to cope with two S-II engines out, hence guidance was nonoptimum during S-II two engine out operation.

At S-II/S-IVB separation, altitude (h) and inertial velocity flight path angle (γ_{1I}') were higher and inertial velocity (V_I) lower than predicted. Given those initial conditions and the nonoptimum value of commanded pitch attitude angle (χ_p) at S-IVB IGM initiation, guidance commanded the vehicle to pitch nose down at the maximum rate of 1 deg/sec for 60 sec until optimum χ_p was reached. The optimum χ_p command rate at that time was nose up, becoming rate limited toward the end of S-IVB burn (figure 8-40).

A key IGM parameter pertinent to the overspeed problem is time-to-go to stage cutoff (T_3). T_3 is determined directly from the root sum square (RSS) of the three velocity-to-go components (difference between present velocity and target velocity). It is important to note that velocity-to-go and hence T_3 are dependent not only on velocity magnitude (V_I) but also velocity direction (γ_{1I}').

After T_3 becomes less than 35 sec, guidance is based on the assumption that the altitude targeting constraint has been satisfied. Thereafter, guidance strives only to achieve the three components of target velocity. On the AS-502 flight, an unusually large inertial velocity flight path angle change requirement still existed toward the end of S-IVB first burn, causing the RSS of velocity-to-go components to be unusually large, even after target velocity magnitude (V_T) had been exceeded. This is shown in the sequence of diagrams below where the dashed line indicates velocity-to-go.



The large velocity-to-go as V_I approached V_T caused T_3 to be large also. The cutoff logic is not entered until after T_3 becomes less than 8 sec. After T_3 becomes less than 8 sec, the commanded attitude angles are frozen and guidance is based on the assumption that the cutoff velocity direction has been achieved and only the cutoff velocity magnitude constraint remains unsatisfied. Thus, all the IGM does once $T_3 < 8 \text{ sec}$ is to order engine cutoff when $V_I \geq V_T$.

Two trajectory simulations were made which resulted in overspeed at S-IVB first burn engine cutoff and allowed the isolation of guidance mechanism which caused the overspeed. In both cases, the actual PCF at S-II/S-IVB separation were perturbed as follows: γ_{1I} , 10 percent more non-nominal, h, 10 percent less non-nominal. (This was necessary because the post-flight predicted trajectory, starting from observed PCF at S-II/S-IVB separation, did not exhibit overspeed. The postflight predicted trajectory achieved cutoff at the specified velocity 2.5 sec after $T_3 < 8$ sec.)

Case 1: The trajectory simulation assumed predicted J-2 engine performance and observed trajectory conditions perturbed by the above amounts at S-II/S-IVB separation. IGM and particularly the cutoff logic operation in this case were very similar to actual AS-502 operation. As previously noted, due to the large flight path angle error existing near end of burn, T_3 did not become less than 8 sec until after target velocity magnitude had been exceeded (figure 8-39). On the first guidance compute point after $T_3 < 8$ sec, IGM entered the velocity cutoff searching logic and cutoff occurred almost immediately.

Case 2 assumed subnominal engine performance as indicated by engine performance data and the perturbed trajectory conditions at separation. This case missed cutoff entirely. As previously noted, cutoff logic is not entered until T_3 becomes less than 8 sec. In this case, T_3 never became less than 8 sec and thus cutoff was not initiated (figure 8-39). It appears from actual 502 data that this situation very nearly occurred.

The results obtained indicate that given the actual initial conditions at S-IVB IGM start and the 1 deg/sec rate limit on X's, it was not possible to achieve the target first burn end conditions.

8.5.1 AS-502 Direct Staging Simulation Summary

A simulation was made of the trajectory that would have resulted if direct staging (TB4A) had been initiated after S-II second engine shutdown as per flight mission rule No. 16. The sequence of events and trajectory conditions achieved at S-IVB first burn engine cutoff are shown below.

To achieve S-IVB second burn ECF, a velocity gain of $\Delta V \sim 10,000$ fps is required after the parking orbit conditions are achieved. The direct staging simulation indicates that the desired parking orbit would have been achieved with only $W_{LOX} = 57,790$ lbm $W_{LH2} = 13,275$ lbm available for second burn. These propellants are sufficient to provide an available velocity gain of $\Delta V \sim 6,520$ fps. Therefore, translunar injection (TLI) conditions could not have been achieved. This agrees with the alternate mission prediction that TLI will not be achieved for direct staging prior to R0 +505 sec, assuming nominal performance until then.

Direct Staging Sequence of Events

| <u>Event</u> | <u>Time from Range Zero (sec)</u> |
|----------------------------|-----------------------------------|
| No. 2 out | 412.9 |
| No. 3 out | 414.2 |
| S-II Engine Cutoff Command | 449.5 |
| Time Base 4A | 452.5 |

| <u>Event</u> | <u>Time from Range Zero</u> |
|-----------------------------|-----------------------------|
| S-IVB Engine Start Command | 458.2 |
| S-IVB Engine Cutoff Command | 764.2 |

Conditions achieved at S-IVB first burn engine cutoff after direct staging

| | |
|----------------|------------|
| t | 764.2 sec |
| h | 627,275 ft |
| V _I | 25,561 fps |
| γ_{1I} | -0.003 deg |
| γ_{2I} | 90.23 deg |

8.6 Orbital Trajectory Simulation Analysis

This paragraph presents a determination of the thrust provided during S-IVB parking orbit by the CVS. The level of CVS thrust is an important factor on normal Saturn V missions from two aspects: first, the accuracy of second burn engine cutoff conditions and, secondly, the S-IVB second burn performance capability.

Three-degrees-of-freedom trajectory simulations were conducted to determine the CVS thrust history required to closely match the observed orbital trajectory. The observed trajectory was generated from guidance accelerometer and tracking data. Figure 8-42 presents a comparison of predicted CVS thrust with the best estimate of actual thrust as determined from trajectory analysis. Figure 8-43 compares the difference between observed altitude during parking orbit and simulated altitude using both predicted and actual CVS thrusts. The actual CVS thrust provides a close fit of the observed altitude. To obtain this close fit, it was necessary to decrease the observed velocity at parking orbit insertion by 0.5 ft/sec, which is well within the 9.84 ft/sec accuracy band quoted for the observed velocity data.

As shown in figure 8-42, the S-IVB parking orbit CVS thrust was close to predicted, with the average thrust only 1.5 percent lower than predicted. This deviation would have had no significant effect on S-IVB performance during second burn, and no significant influence on S-IVB injection accuracy.

8.7 Orbital Motion following LV/SC Separation

Paragraph 21.2.6 discusses the loss of vehicle attitude control following depletion of APS propellant during the fourth parking orbit revolution. This section discusses the motion of the vehicle and orbit characteristic after control loss.

At RO +22,023 sec LOX propulsive venting was initiated by ground command in order to assure APS depletion prior to loss of stage electrical power.

Shortly after this ground action was taken, module 1 depleted at RO +22,053 sec, and yaw control was lost. Following module 2 depletion at RO +22,630 sec, complete stage attitude control was lost and the vehicle assumed conical rotational motion. By the time of

module 2 depletion the LOX venting thrust had decayed from an initial value of 700 lbf to 250 lbf thrust and continued to decrease to 25 lbf at approximately 6,000 sec after the vent was opened and may have sustained this level until loss of electrical power to the LOX vent solenoid valve.

Following loss of electrical power, the valve would close and remain closed until the vent pressure relief setting was reached. The time of electrical power loss to the vent valve and the time of relief venting is not known since these events were preceded by loss of power to the telemetry system.

Figure 8-44 presents the stage angular velocities following loss of attitude control. The motion in pitch and yaw was sinusoidal with one rate being an extremum when the other was zero; these rates induced a nearly flat spin with a half cone angle of 82 deg. To verify that the observed motion during this interval was consistent with known occurrences, such as APS depletion and LOX venting, Euler's equations of rotational motion were solved using estimated mass and LOX vent characteristics. The resultant solution yielded a sufficiently close match of the actual rate data to indicate that the observed motion was caused by LOX vent thrust. The simulation is included in figure 8-44.

Figure 8-45 presents the orbit semi-major axis and rotational rate to 31 days after launch. Under the influence of LOX tank venting the body rate of the total vehicle continued to increase to approximately 180 deg/sec on the ninth day after launch. The centrifugal acceleration loads resulting from this high rate caused the vehicle to break up into six major parts. Orbital decay and eccentricity of these parts is shown in figure 8-45. One major component to break loose was the LTA. Reportedly, the loads induced by the observed high rotational rate at structural breakup were sufficient to expect LTA attachment failure.

TABLE 8-1 (Sheet 1 of 4)
TRAJECTORY CONDITIONS AT SIGNIFICANT EVENT TIMES

| PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION | PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION |
|--|-------------------|---------------------|-----------|---------|-----------|--|-------------------|---------------------|-----------|-----------|-----------|
| CONDITIONS AT MAXIMUM DYNAMIC PRESSURE | | | | | | | | | | | |
| Range time | (t) | sec | 79.38 | 75.24 | -4.14 | Range | (S) | ft | 274,162 | 277,721 | 3,559 |
| Dynamic pressure | (q) | lbf/ft ² | 753.0 | 784.5 | 31.5 | Dynamic pressure | (q) | lbf/ft ² | 21.6 | 19.6 | -2.0 |
| Altitude | (h) | ft | 44,760 | 39,429 | -5,331 | Pitch angle of attack | (α) | deg | 1.45 | -3.72 | -5.17 |
| Mach number | (M) | -- | 1.79 | 1.61 | -0.18 | Yaw angle of attack | (β) | deg | 0.50 | -2.14 | -2.64 |
| Ambient pressure | (Pa) | lbf/ft ² | 336.4 | 434.4 | 98.0 | CONDITIONS AT S-II/S-IVB SEPARATION | | | | | |
| Pitch angle of attack | (α) | deg | 0.28 | 1.56 | 1.28 | Range time | (t) | sec | 517.96 | 577.08 | 59.12 |
| Yaw angle of attack | (β) | deg | 0.09 | 0.62 | 0.53 | Downrange distance | (Z _P) | ft | 5,040,251 | 6,055,052 | 1,014,801 |
| CONDITIONS AT S-IC/S-II SEPARATION | | | | | | | | | | | |
| Range time | (t) | sec | 147.73 | 149.08 | 1.35 | Vertical distance | (X _P) | ft | 21,545 | -226,677 | -248,222 |
| Downrange distance | (Z _P) | ft | 276,470 | 280,158 | 3,688 | Crossrange distance | (Y _P) | ft | 77,797 | 100,850 | 23,053 |
| Vertical distance | (X _P) | ft | 191,768 | 195,260 | 3,492 | Downrange velocity | (Z _P) | ft/sec | 20,587.8 | 20,076.7 | -511.1 |
| Crossrange distance | (Y _P) | ft | 2,167 | -442 | -2,609 | Vertical velocity | (X _P) | ft/sec | -4,630.8 | -5,223.2 | -592.4 |
| Downrange velocity | (Z _P) | ft/sec | 7,245.9 | 7,291.3 | 45.4 | Crossrange velocity | (Y _P) | ft/sec | 516.5 | 567.0 | 50.5 |
| Vertical velocity | (X _P) | ft/sec | 2,962.1 | 2,942.6 | -19.5 | Relative velocity | (V _P) | ft/sec | 21,108.5 | 20,752.7 | -354.8 |
| Crossrange velocity | (Y _P) | ft/sec | 59.9 | -12.5 | -72.4 | Inertial velocity | (V _I) | ft/sec | 22,430.5 | 22,075.6 | -354.9 |
| Relative velocity | (V _P) | ft/sec | 7,828.2 | 7,862.7 | 34.5 | Inertial flight path elevation angle | (V _I) | deg | 0.775 | 1.597 | 0.822 |
| Inertial velocity | (V _I) | ft/sec | 9,038.8 | 9,072.0 | 33.2 | Inertial flight path azimuth angle | (V _I) | deg | 81.641 | 83.416 | 1.775 |
| Inertial flight path elevation angle | (V _I) | deg | 19.725 | 19.530 | -0.195 | Altitude | (h) | ft | 619,247 | 640,570 | 21,323 |
| Inertial flight path azimuth angle | (V _I) | deg | 75.491 | 74.996 | -0.495 | Range | (S) | ft | 4,942,133 | 5,956,445 | 1,014,312 |
| Altitude | (h) | ft | 193,738 | 197,117 | 3,379 | CONDITIONS AT S-IVB FIRST BURN ENGINE CUTOFF COMMAND | | | | | |
| Deviation = Actual minus predicted | | | | | | | | | | | |

TABLE 8-1 (Sheet 2 of 4)
TRAJECTORY CONDITIONS AT SIGNIFICANT EVENT TIMES

| PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION | PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION |
|---------------------------------------|-------------------|--------|------------|------------|-----------|--------------------------------------|-------------------|----------------------------------|-------------|-------------|-----------|
| Vertical distance | (\dot{X}_E) | ft | -922,905 | -1,626,565 | -703,660 | Inertial flight path elevation angle | (γ_{I1}) | deg | 0.001 | -0.377 | -0.376 |
| Crossrange distance | (\dot{Y}_E) | ft | 170,971 | 232,687 | 61,716 | Inertial flight path azimuth angle | (γ_{I2}) | deg | 87.567 | 90.675 | 3.108 |
| Downrange velocity | (\dot{X}_E) | ft/sec | 22,481.5 | 21,749.0 | -732.5 | Altitude | (h) | ft | 627,721 | 623,979 | -3,742 |
| Vertical velocity | (\dot{Y}_E) | ft/sec | -9,019.1 | -11,013.7 | -1,994.6 | Range | (S) | ft | 8,223,999 | 9,892,549 | 1,668,550 |
| Crossrange velocity | (\dot{X}_E) | ft/sec | 840.5 | 973.8 | 133.3 | PARKING ORBIT ELEMENTS AT INSERTION | | | | | |
| Relative velocity | (\dot{V}_E) | ft/sec | 24,237.8 | 24,398.1 | 160.3 | Range time | (t) | sec | 667.12 | 757.04 | 89.92 |
| Inertial velocity | (\dot{V}_I) | ft/sec | 25,561.1 | 25,721.3 | 160.2 | Semi-major axis | (a) | nmi | 3,543.9 | 3,587.9 | 44.0 |
| Inertial flight path elevation angle | (γ_{I1}) | deg | 0.000 | -0.400 | -0.400 | Apogee altitude* | (h_A) | nmi | 100.0 | 194.4 | 94.4 |
| Inertial flight path azimuth angle | (γ_{I2}) | deg | 87.133 | 90.237 | 3.104 | Perigee altitude* | (h_P) | nmi | 100.0 | 93.5 | -6.5 |
| Altitude | (h) | ft | 627,681 | 625,694 | -1,987 | Apogee velocity | (V_A) | ft/sec | 25,567.7 | 25,055.7 | -512.0 |
| Range | (S) | ft | 7,988,636 | 9,655,615 | 1,666,979 | Perigee velocity | (V_P) | ft/sec | 25,567.9 | 25,770.6 | 202.7 |
| CONDITIONS AT PARKING ORBIT INSERTION | | | | | | | | | | | |
| Range time | (t) | sec | 667.12 | 757.04 | 89.92 | Eccentricity | (e) | -- | 0.0000 | 0.0141 | 0.0141 |
| Downrange distance | (Z_E) | ft | 8,252,204 | 9,809,284 | 1,557,080 | Inclination | (i) | deg | 32.561 | 32.567 | 0.006 |
| Vertical distance | (X_E) | ft | -1,014,379 | -1,737,882 | -723,503 | Period | (P) | min | 88.19 | 89.84 | 1.65 |
| Crossrange distance | (Y_E) | ft | 179,463 | 242,504 | 63,041 | Inertial velocity | (V_I) | ft/sec | 25,567.8 | 25,728.6 | 160.8 |
| Downrange velocity | (\dot{X}_E) | ft/sec | 22,384.3 | 21,633.5 | -750.8 | Inertial flight path elevation angle | (γ_{I1}) | deg | 0.001 | -0.377 | -0.376 |
| Vertical velocity | (\dot{Y}_E) | ft/sec | -9,273.7 | -11,253.6 | -1,979.9 | Descending node | (θ_N) | deg | 123.176 | 123.196 | 0.020 |
| Crossrange velocity | (\dot{X}_E) | ft/sec | 857.7 | 990.3 | 132.6 | Conic energy | (C_3) | m ² /sec ² | -60,732,254 | -59,872,268 | 859,986 |
| Relative velocity | (\dot{V}_E) | ft/sec | 24,244.4 | 24,405.6 | 161.2 | CONDITIONS AT TIME BASE 6 | | | | | |
| Inertial velocity | (\dot{V}_I) | ft/sec | 25,567.8 | 25,728.6 | 160.8 | Range time | (t) | sec | 11,074.00 | 11,287.73 | 213.73 |

Deviation = Actual minus predicted
*Measured with respect to a mean earth radius of 3,443.94 nmi.

TABLE 8-1 (Sheet 3 of 4)
TRAJECTORY CONDITIONS AT SIGNIFICANT EVENT TIMES

| PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION | PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION |
|--|--------------------|--------|------------|------------|-----------|---|--------------------|--------|-----------|------------|------------|
| Downrange distance | (Z _E) | ft | -8,628,597 | -8,922,271 | -293,674 | Inertial velocity | (V _I) | ft/sec | 25,556.7 | 25,724.0 | 167.3 |
| Vertical distance | (X _E) | ft | -1,871,562 | -1,995,040 | -123,478 | Inertial flight path elevation angle | (γ _I) | deg | -0.009 | -0.334 | -0.325 |
| Crossrange distance | (Y _E) | ft | -5,343,617 | -5,530,985 | -187,368 | Inertial flight path azimuth angle | (γ _{2I}) | deg | 94.270 | 94.166 | -0.104 |
| Downrange velocity | (Ż) | ft/sec | 19,692.2 | 19,626.3 | -65.9 | Altitude | (h) | ft | 660,588 | 651,462 | -9,126 |
| Vertical velocity | (Ẋ) | ft/sec | 11,288.6 | 11,470.8 | 182.2 | Range | (S) | ft | 2,757,853 | 3,043,955 | 286,102 |
| Crossrange velocity | (Ẏ) | ft/sec | 8,465.4 | 8,621.2 | 155.8 | CONDITIONS AT S-IVB SECOND BURN ENGINE CUTOFF COMMAND | | | | | |
| Relative velocity | (V _E) | ft/sec | 24,225.6 | 24,312.4 | 86.8 | Range time | (t) | sec | 11,725.56 | 11,630.32 | -95.24 |
| Inertial velocity | (V _I) | ft/sec | 25,550.0 | 25,640.2 | 90.2 | Downrange distance | (Z _E) | ft | 6,359,520 | -1,760,955 | -8,120,475 |
| Inertial flight path elevation angle | (γ _I) | deg | -0.013 | -0.589 | -0.576 | Vertical distance | (X _E) | ft | -11,688 | 469,487 | 481,175 |
| Inertial flight path azimuth angle | (γ _{2I}) | deg | 80.296 | 80.141 | -0.155 | Crossrange distance | (Y _E) | ft | 2,023,130 | -2,147,518 | -4,170,648 |
| Altitude | (h) | ft | 661,121 | 718,846 | 57,725 | Downrange velocity | (Ż _E) | ft/sec | 29,698.8 | 21,666.1 | -8,032.7 |
| Range | (S) | ft | 10,242,365 | 10,595,769 | 353,404 | Vertical velocity | (Ẋ _E) | ft/sec | -6,429.7 | 2,723.9 | 9,153.6 |
| CONDITIONS AT S-IVB SECOND BURN ENGINE START COMMAND | | | | | | | | | | | |
| Range time | (t) | sec | 11,401.00 | 11,614.69 | 213.69 | Crossrange velocity | (Ẏ _E) | ft/sec | 15,861.7 | 10,892.6 | -4,969.1 |
| Downrange distance | (Z _E) | ft | -1,800,704 | -2,099,419 | -298,715 | Relative velocity | (V _E) | ft/sec | 34,244.3 | 24,402.6 | -9,841.7 |
| Vertical distance | (X _E) | ft | 473,415 | 423,629 | -49,786 | Inertial velocity | (V _I) | ft/sec | 35,581.2 | 25,727.0 | -9,854.2 |
| Crossrange distance | (Y _E) | ft | -2,190,662 | -2,317,223 | -126,561 | Inertial flight path elevation angle | (γ _I) | deg | 6.673 | -0.320 | -6.993 |
| Downrange velocity | (Ż _E) | ft/sec | 21,595.4 | 21,641.2 | 45.8 | Inertial flight path azimuth angle | (γ _{2I}) | deg | 108.652 | 94.840 | -13.812 |
| Vertical velocity | (Ẋ _E) | ft/sec | 2,891.5 | 3,143.8 | 252.3 | Altitude | (h) | ft | 1,026,528 | 649,075 | -377,453 |
| Crossrange velocity | (Ẏ _E) | ft/sec | 10,603.8 | 10,821.6 | 217.8 | Range | (S) | ft | 6,463,519 | 2,702,029 | -3,761,490 |
| Relative velocity | (V _E) | ft/sec | 24,231.4 | 24,399.4 | 168.0 | | | | | | |

Deviation = Actual minus predicted

TABLE 8-1 (Sheet 4 of 4)
TRAJECTORY CONDITIONS AT SIGNIFICANT EVENT TIMES

| PARAMETER | SYMBOL | UNITS | PREDICTED | ACTUAL | DEVIATION |
|--------------------------------------|-------------------|-----------------------------------|-----------|-------------|-----------|
| ORBIT ELEMENTS AT LV/SC SEPARATION | | | | | |
| Range time | (t) | sec | | 11,666.1 | |
| Semi-major axis | (a) | nmi | | 3,596.1 | |
| Apogee altitude* | (h _A) | nmi | | 204.8 | |
| Perigee altitude* | (h _P) | nmi | | 99.5 | |
| Apogee velocity | (V _A) | ft/sec | | 25,012.7 | |
| Perigee velocity | (V _P) | ft/sec | | 25,755.9 | |
| Eccentricity | (e) | -- | | 0.0146 | |
| Inclination | (i) | deg | | 32.568 | |
| Period | (P) | min | | 90.15 | |
| Inertial velocity | (V _I) | ft/sec | | 25,733.3 | |
| Inertial flight path elevation angle | (γ _I) | deg | | -0.286 | |
| Descending node | (θ _N) | deg | | 122.268 | |
| Conic Energy | (C ₃) | ft ² /sec ² | | -59,738,957 | |

Deviation = Actual minus predicted
*Measured with respect to a mean earth radius of 3,443.94 nmi.

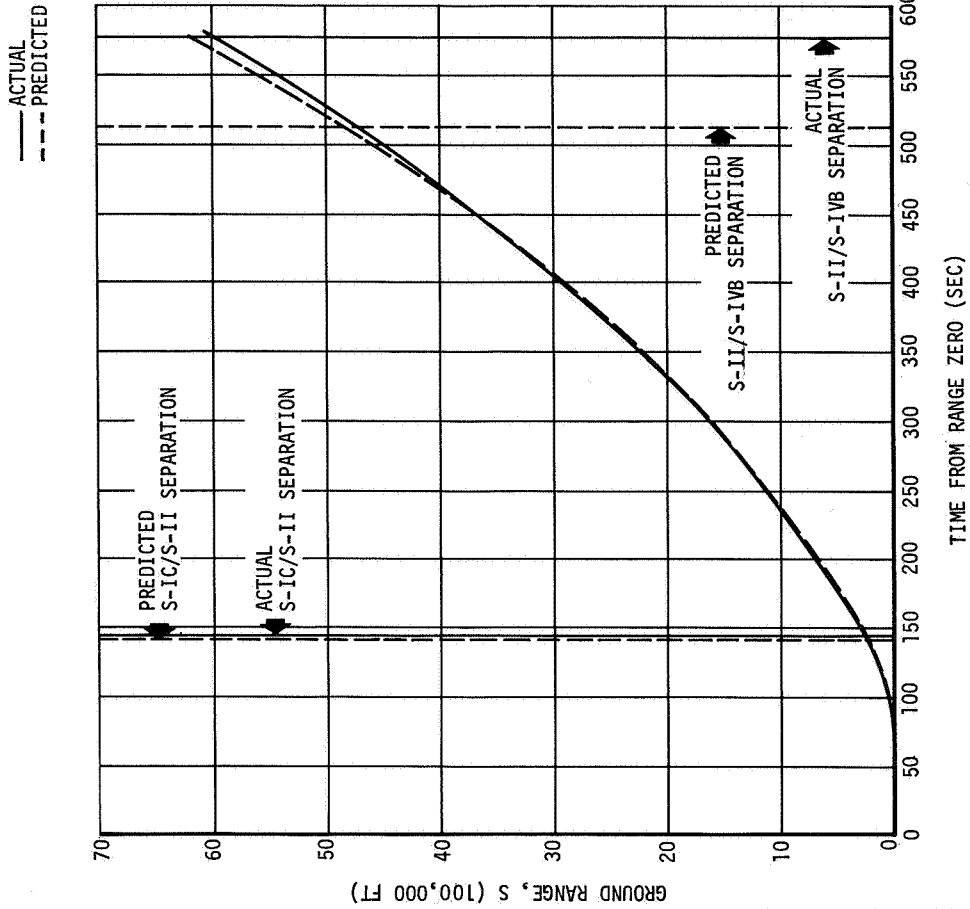


Figure 8-1. S-IC/S-II Altitude History

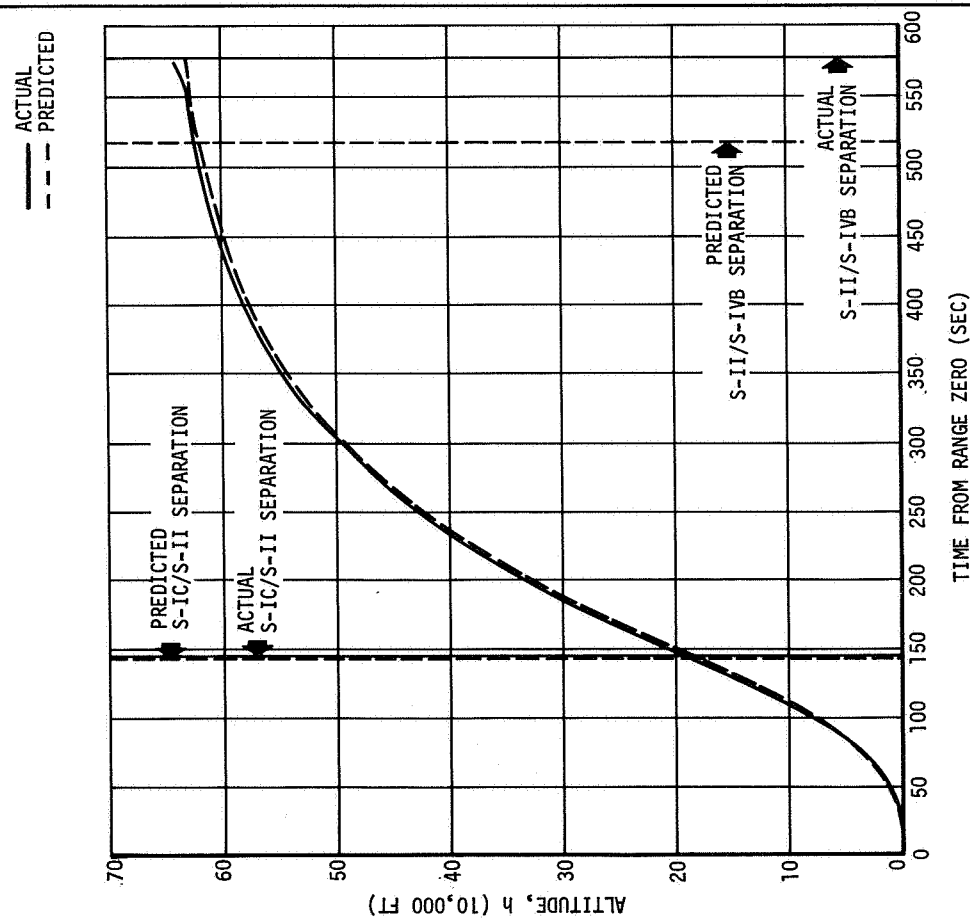


Figure 8-2. S-IC/S-II Ground Range History

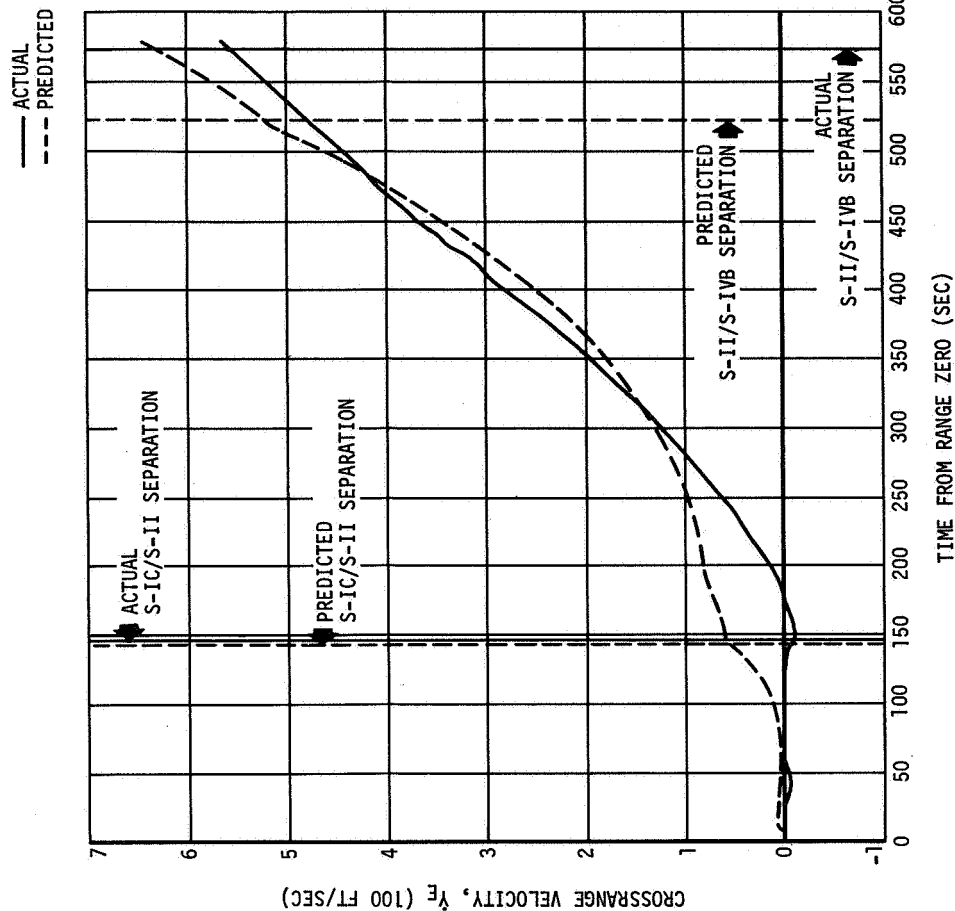


Figure 8-4. S-IC/S-II Crossrange Velocity History

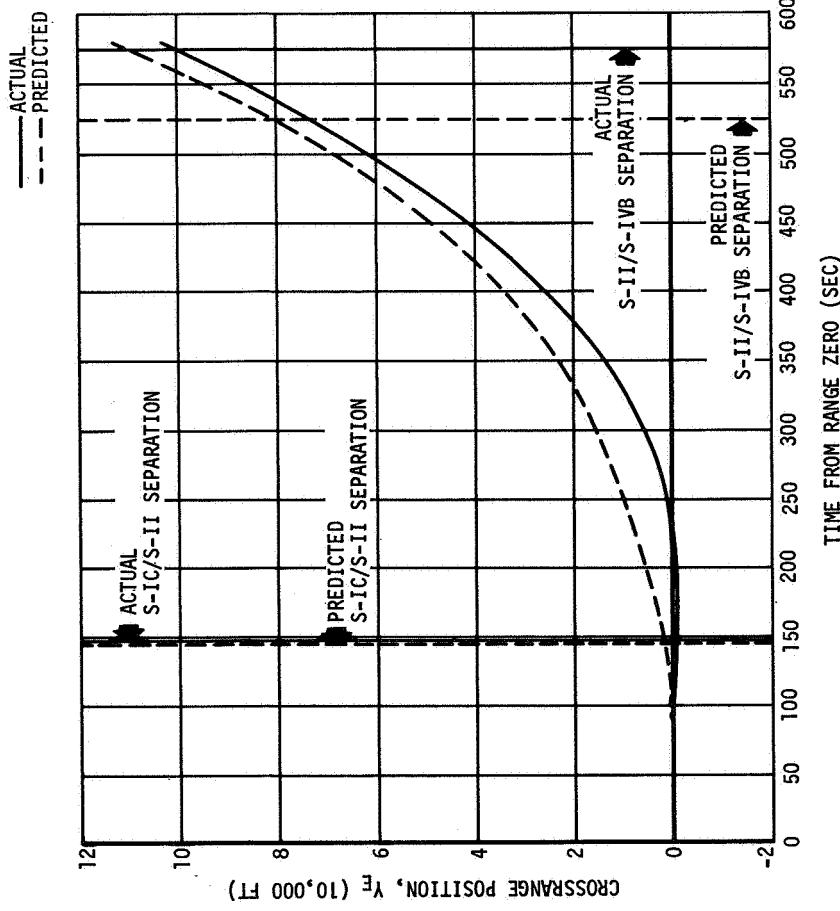


Figure 8-3. S-IC/S-II Crossrange Position History

— ACTUAL
- - - PREDICTED

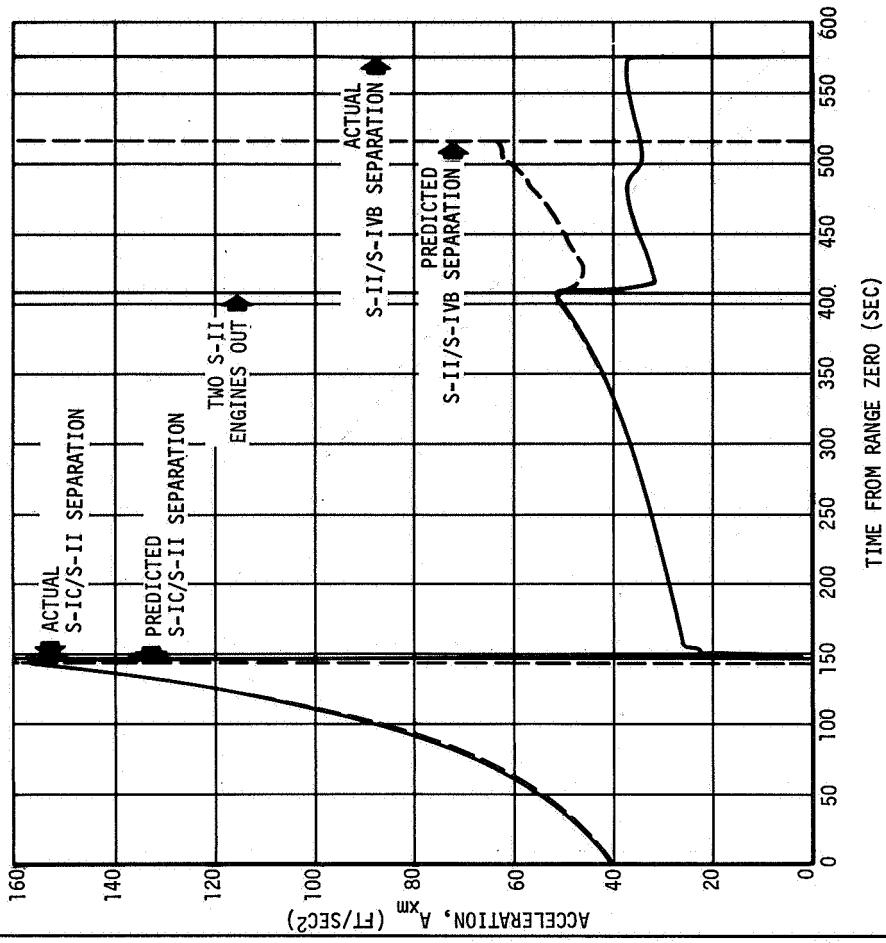


Figure 8-5. S-IC/S-II Inertial Velocity History

— ACTUAL
- - - PREDICTED

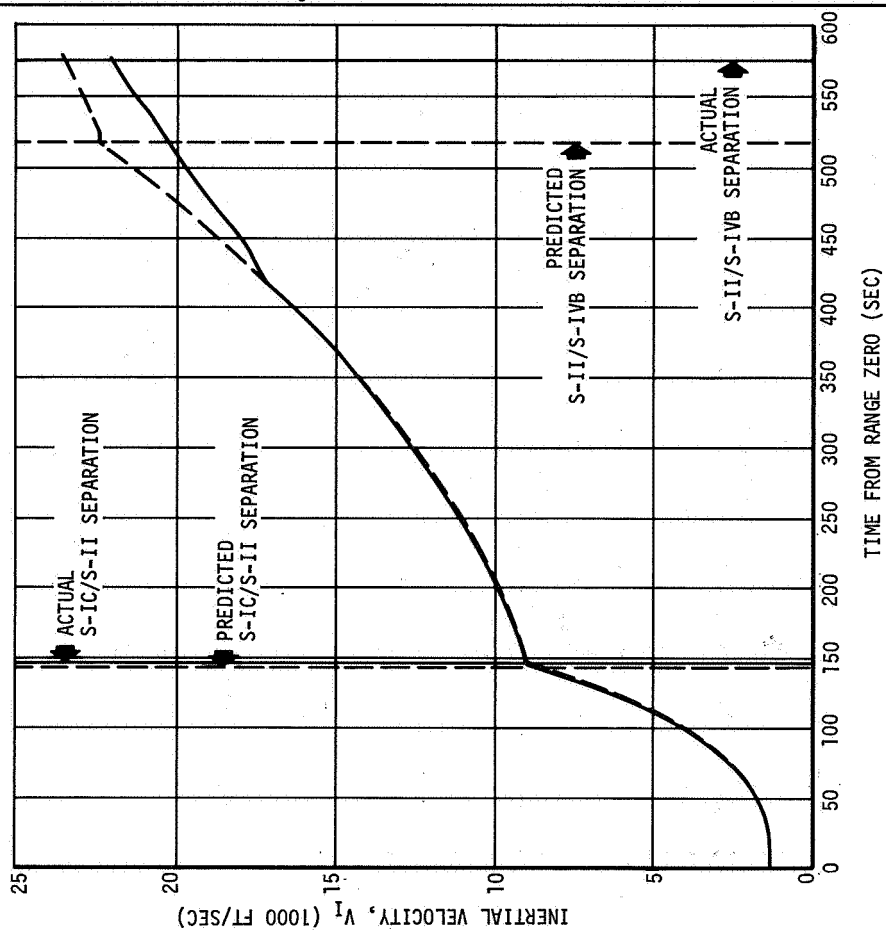


Figure 8-6. S-IC/S-II Axial Acceleration History

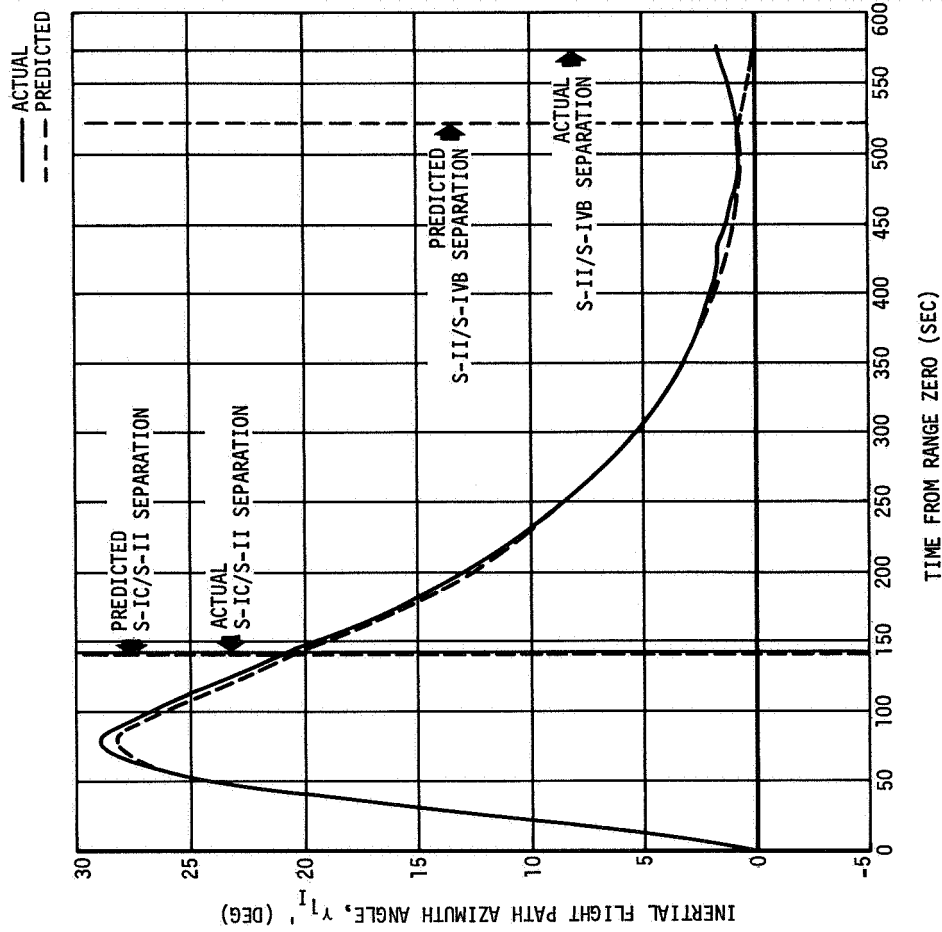


Figure 8-7. S-IC/S-II Inertial Flight Path Elevation Angle History

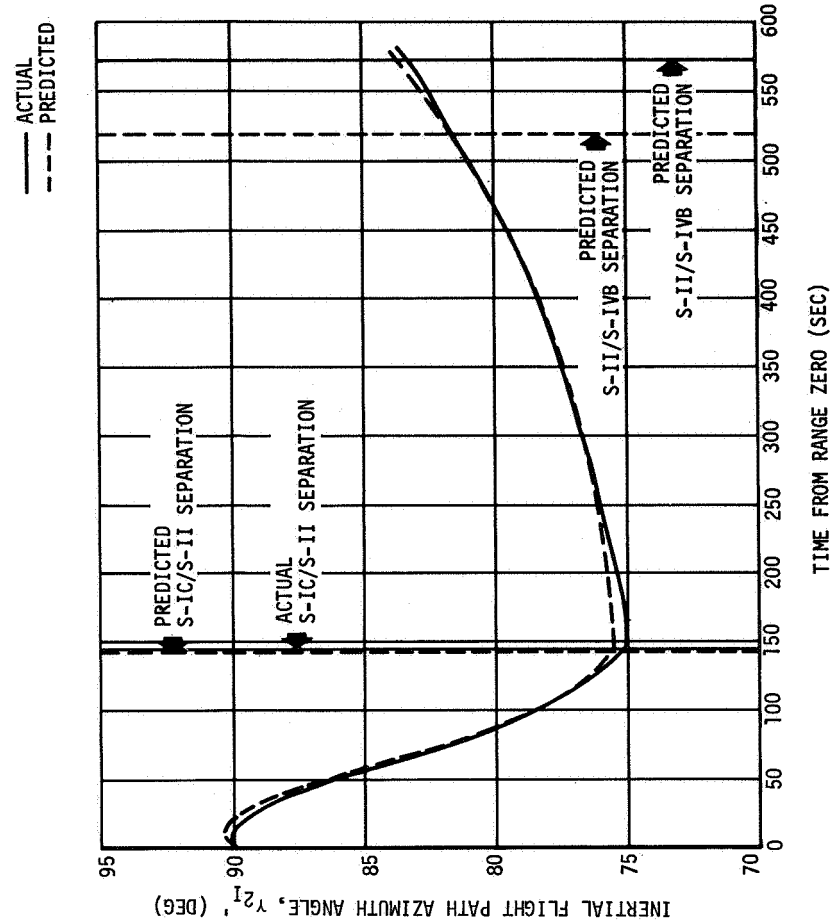


Figure 8-8. S-IC/S-II Inertial Flight Path Azimuth Angle History

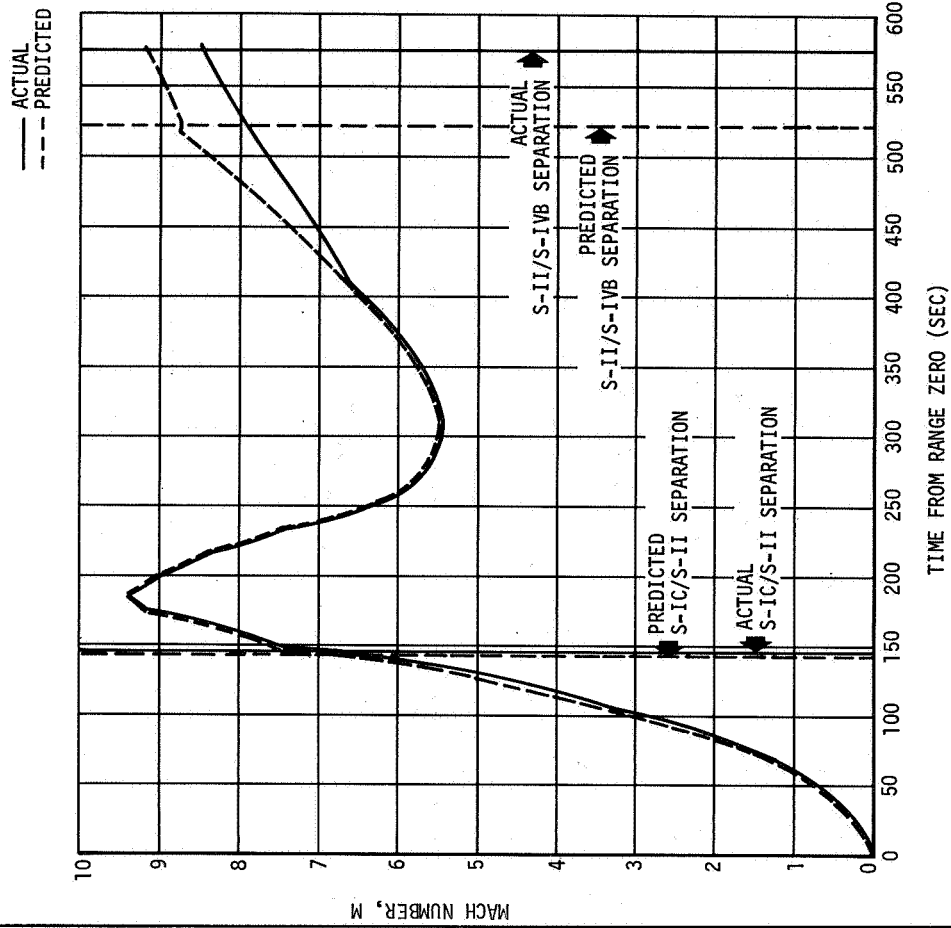


Figure 8-9. S-IC Dynamic Pressure History

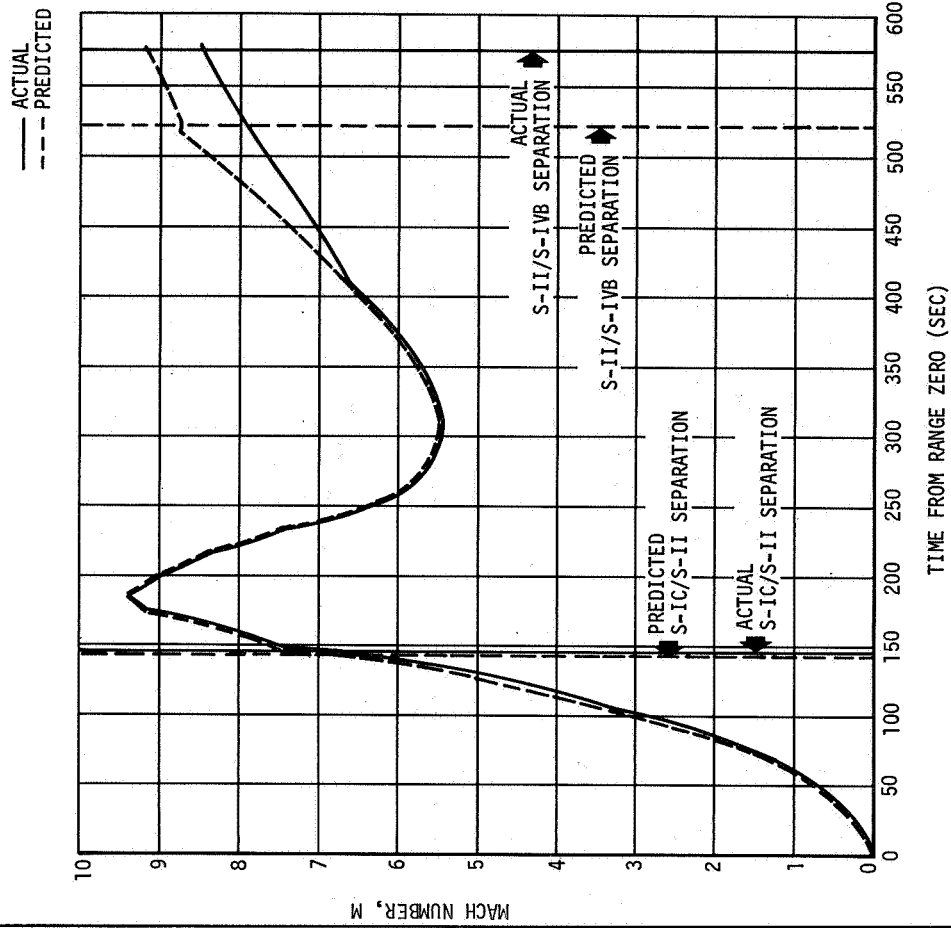


Figure 8-10. S-IC/S-II Mach Number History

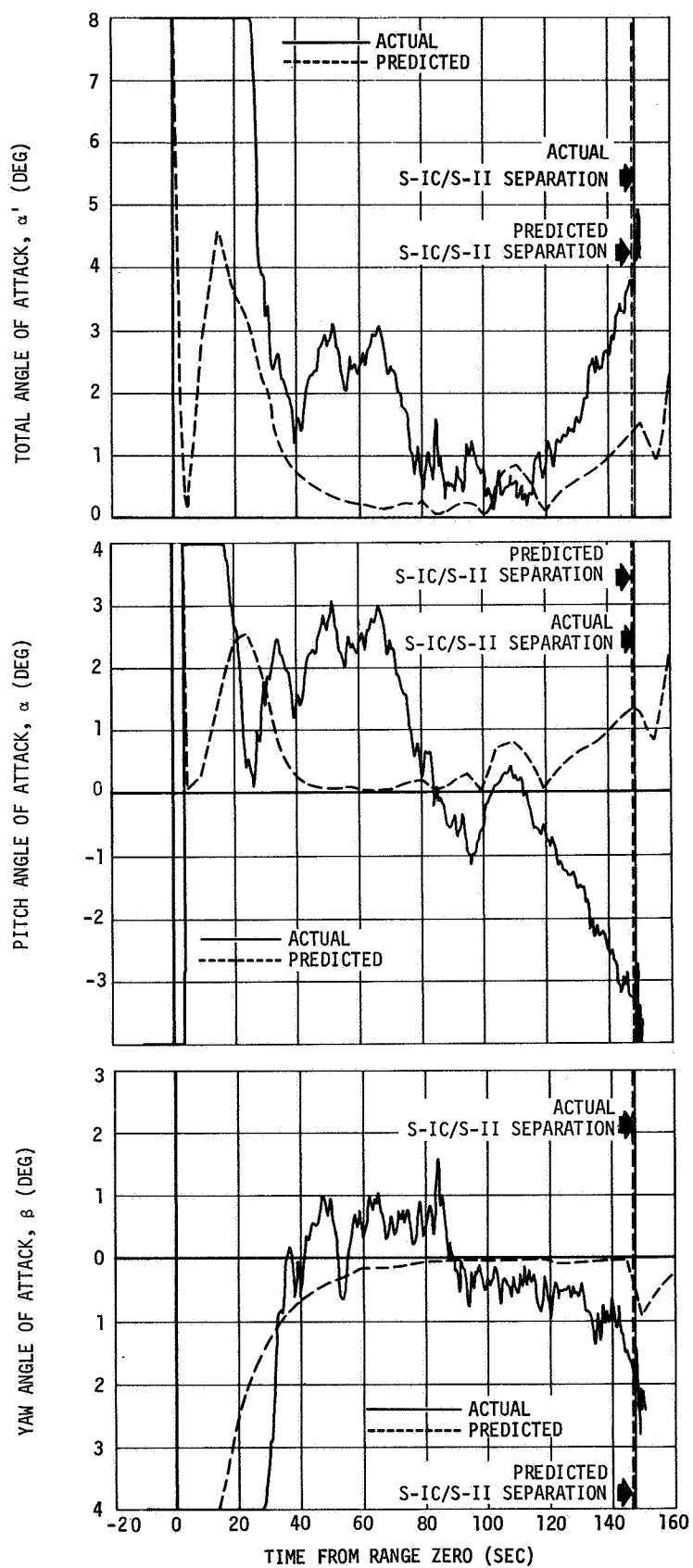


Figure 8-11. S-IC Angle of Attack History

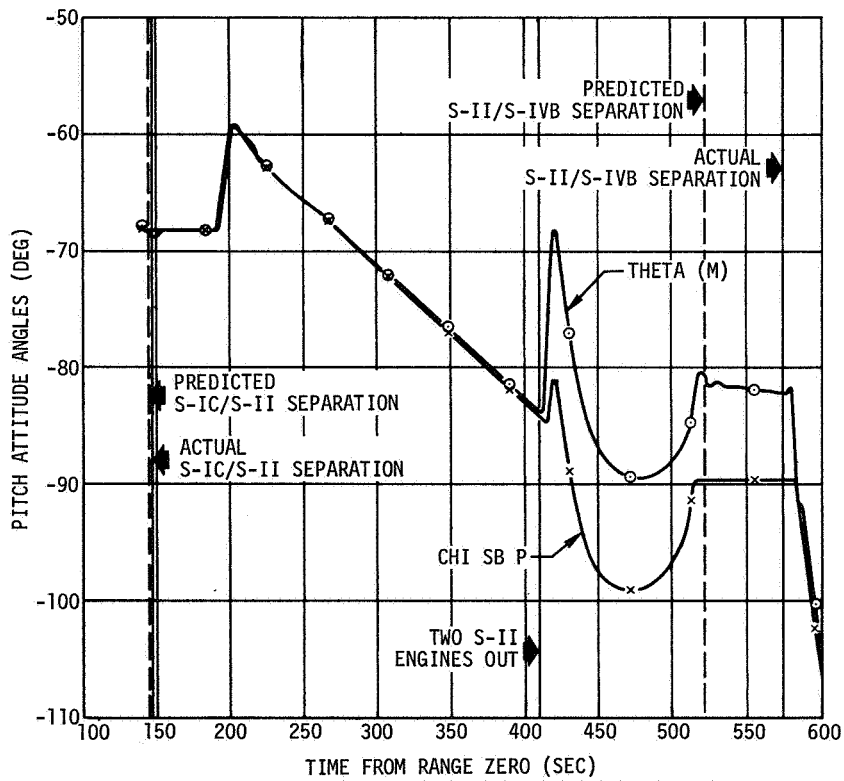
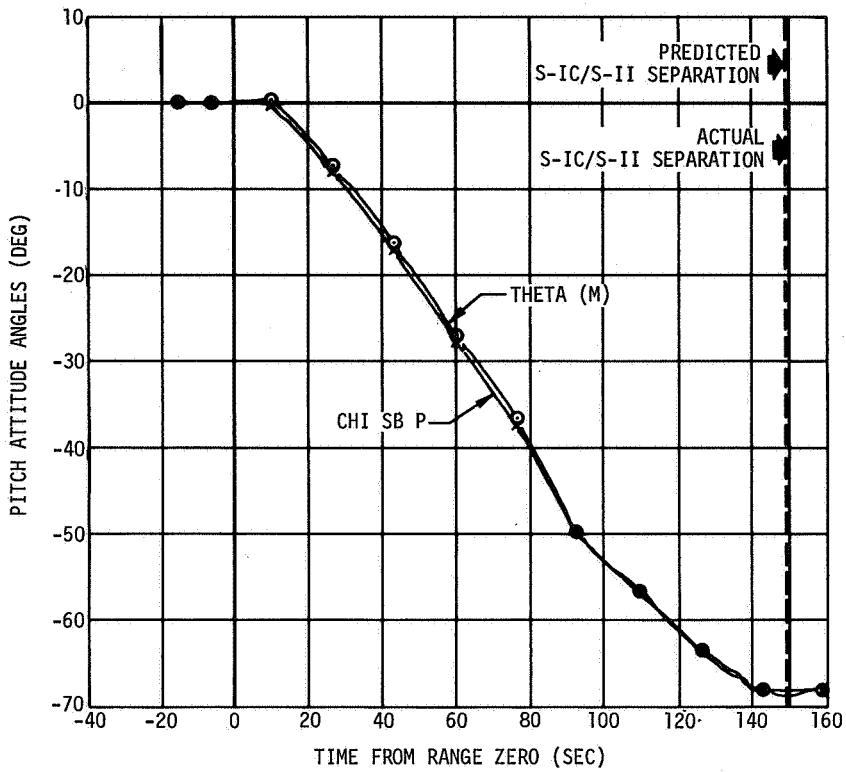


Figure 8-12. S-IC/S-II Pitch Attitude Angle History

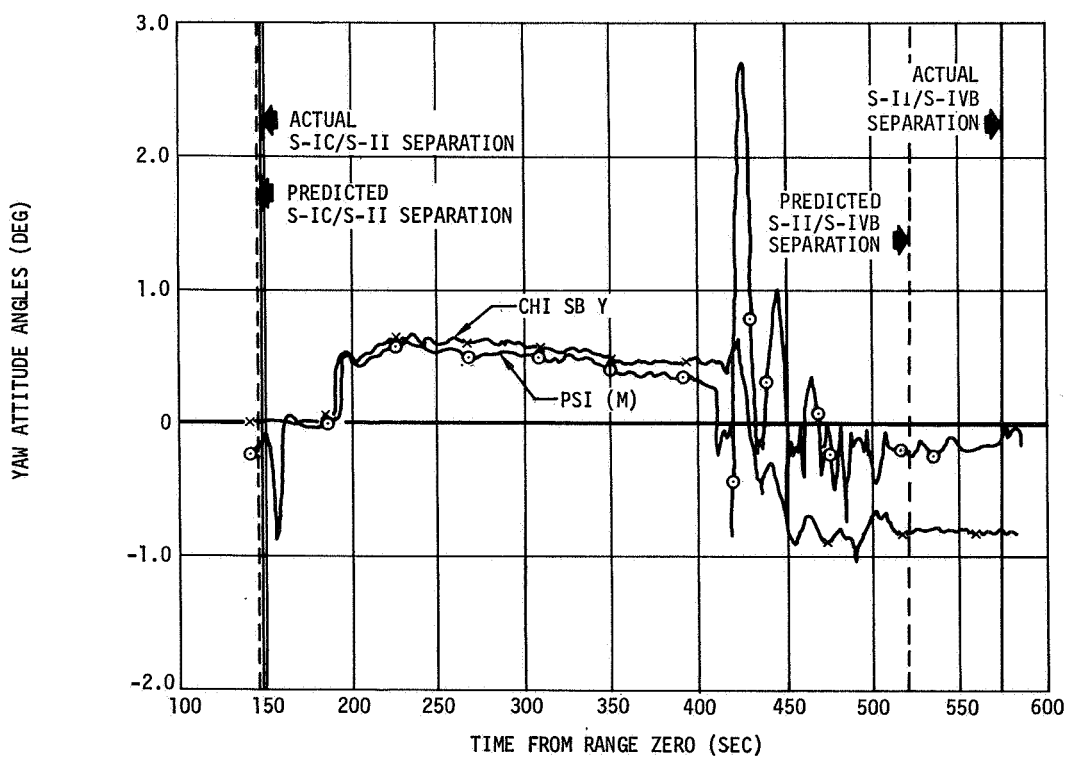
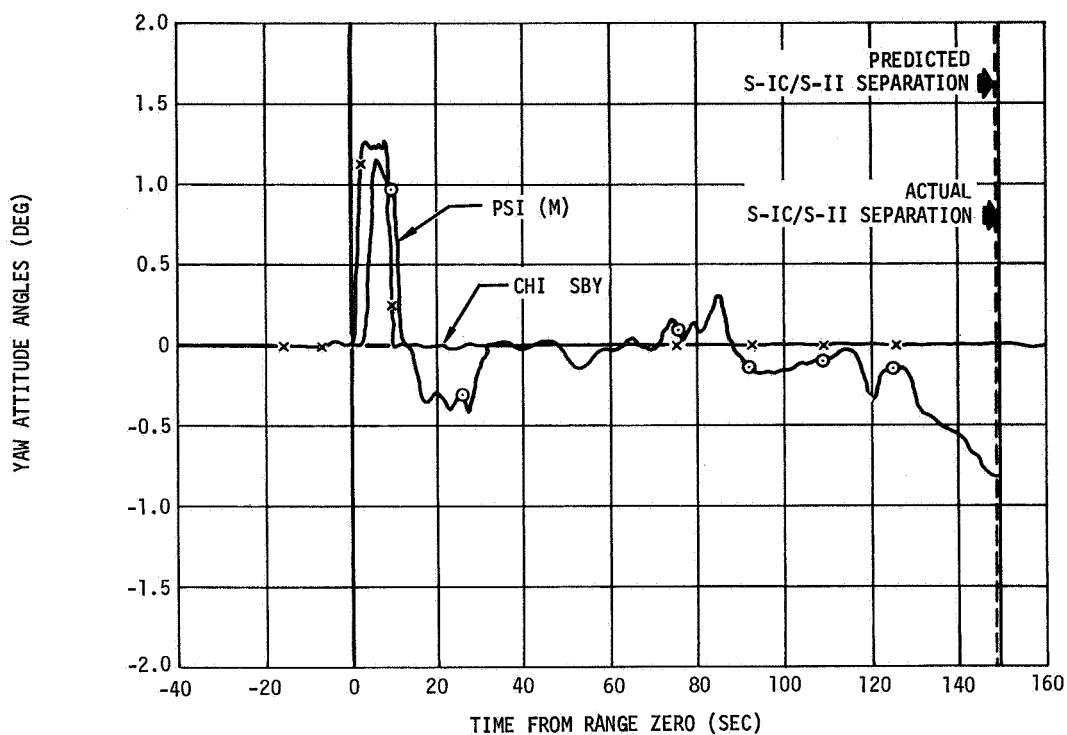


Figure 8-13. S-IC/S-II Yaw Attitude Angle History

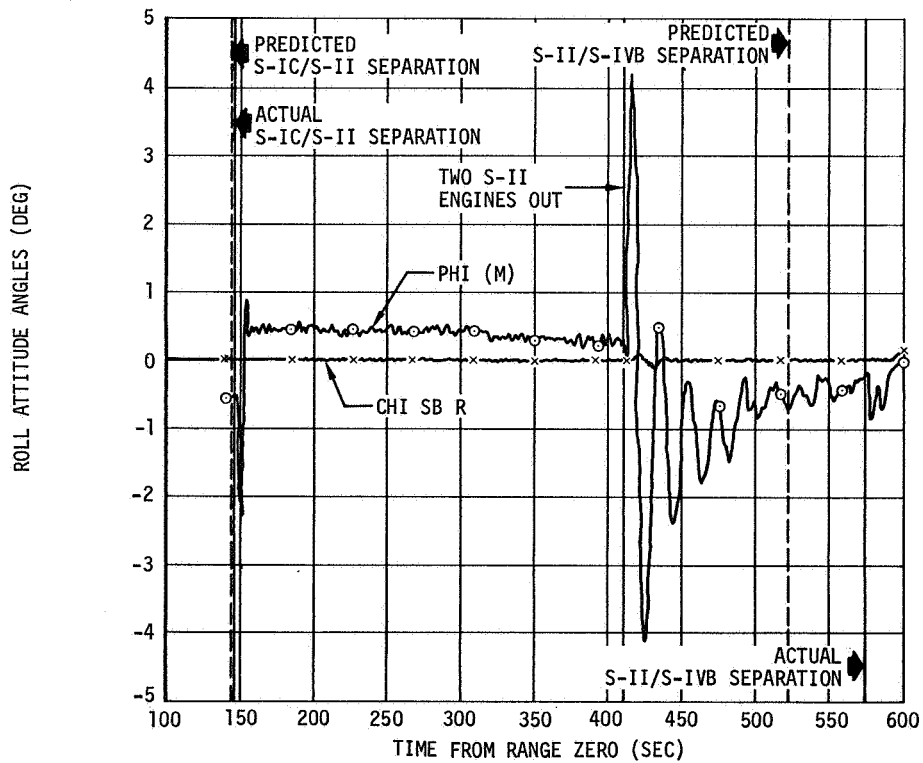
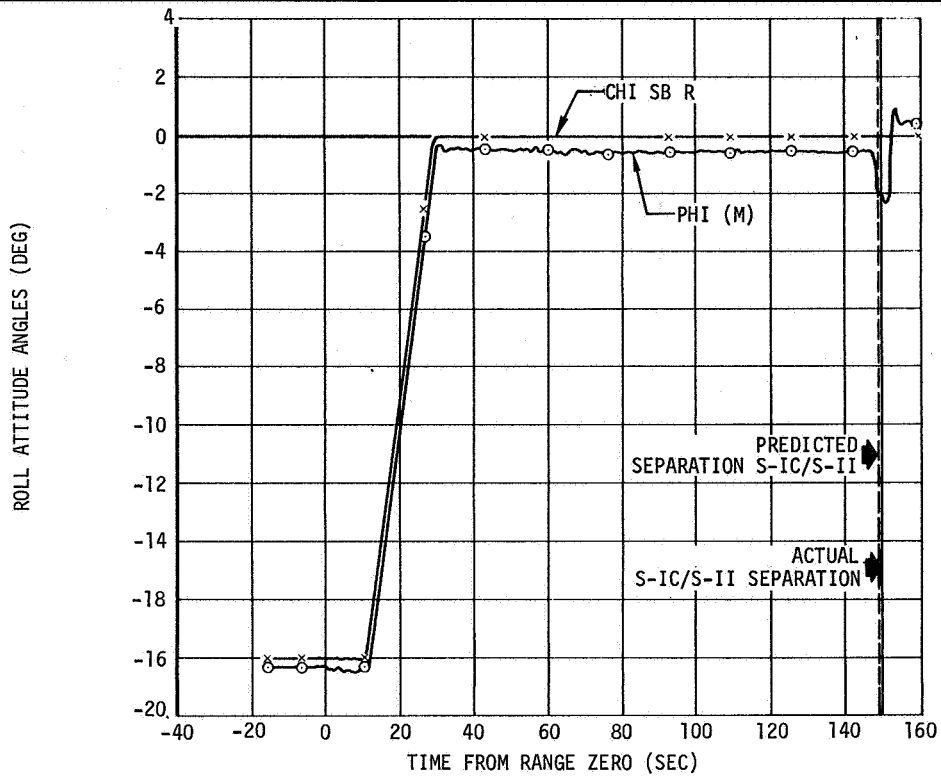


Figure 8-14. S-IC/S-II Roll Attitude Angle History

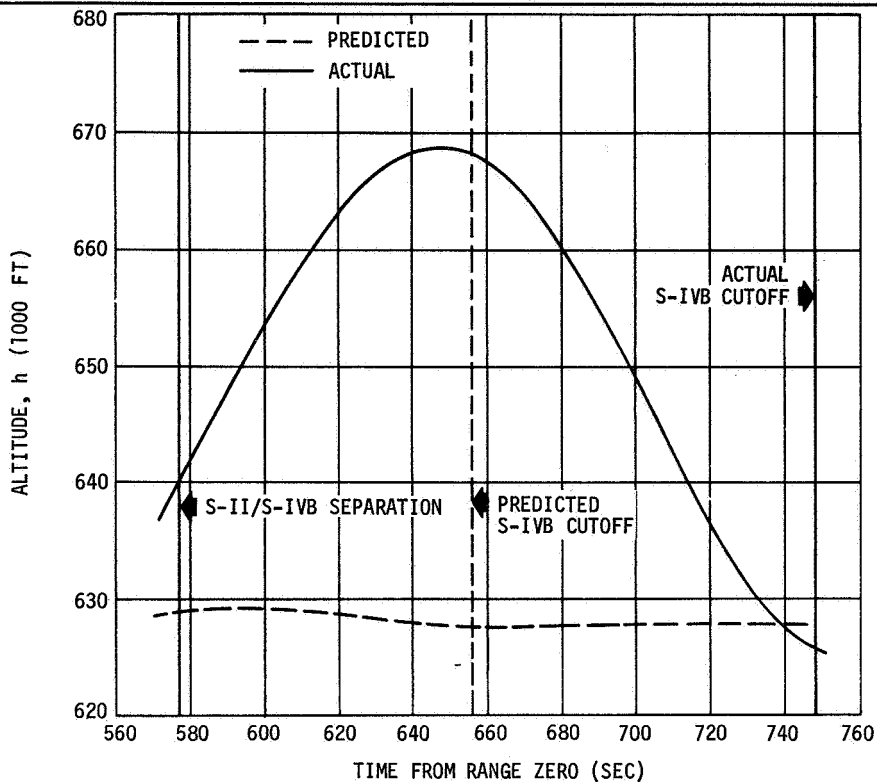


Figure 8-15. Altitude History

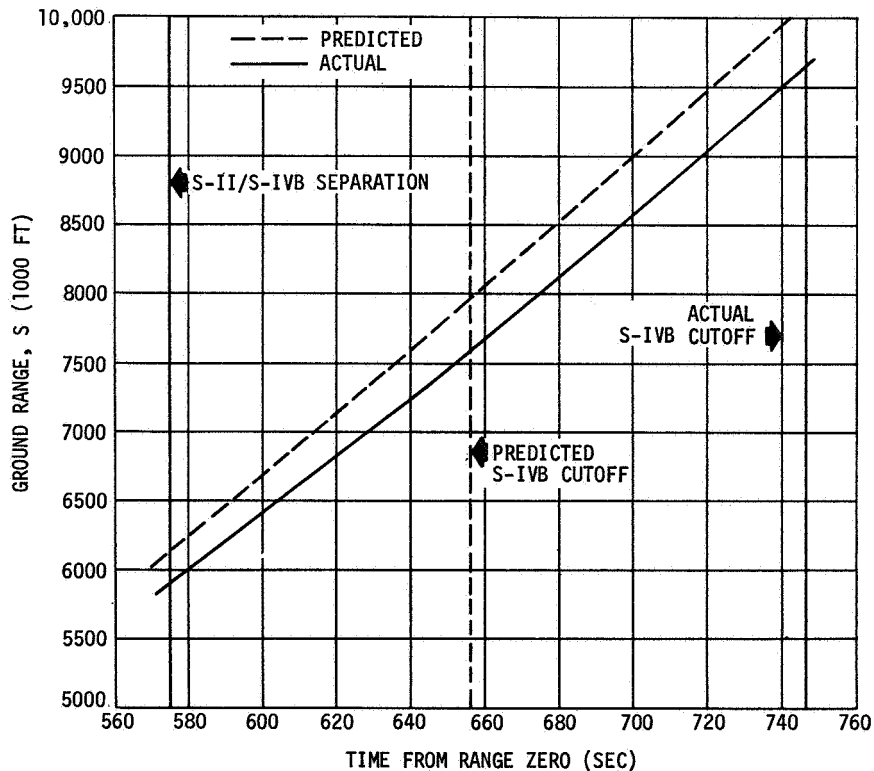


Figure 8-16. Ground Range History

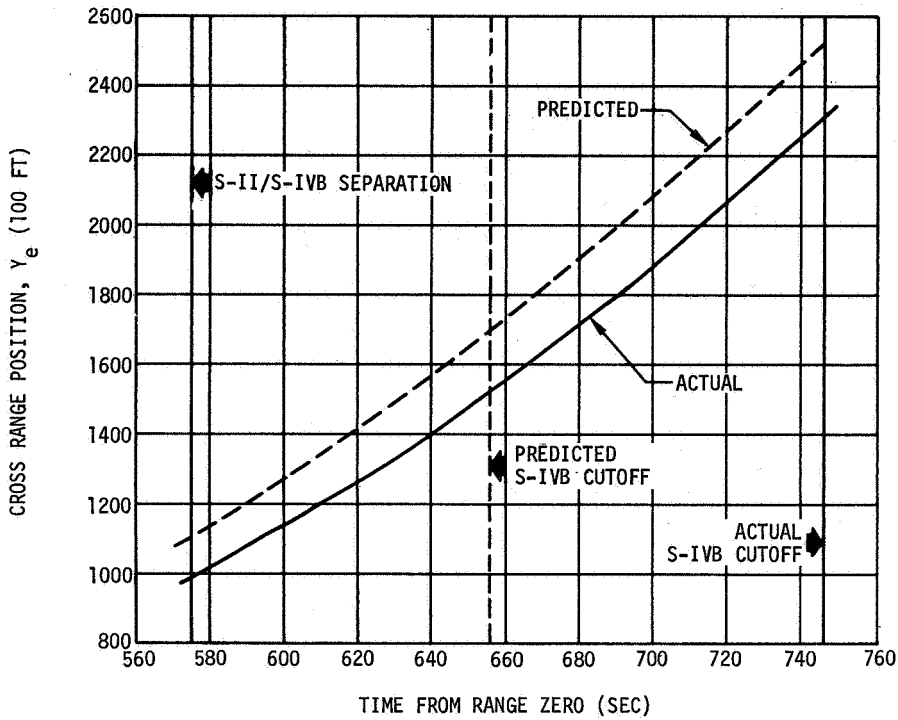


Figure 8-17. Crossrange Position History

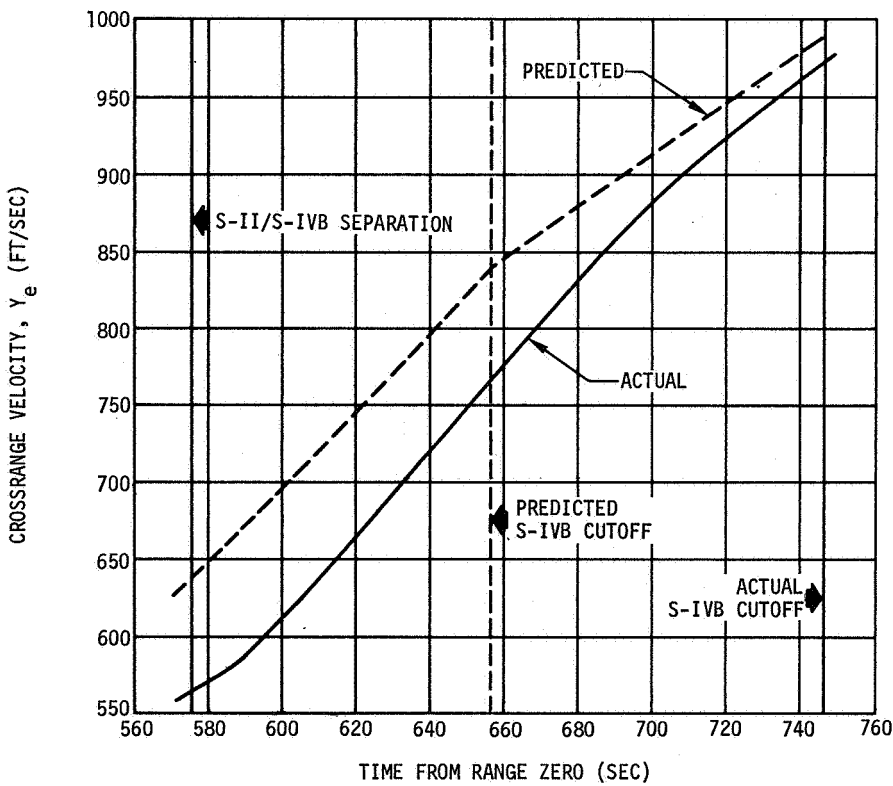


Figure 8-18. Crossrange Velocity History

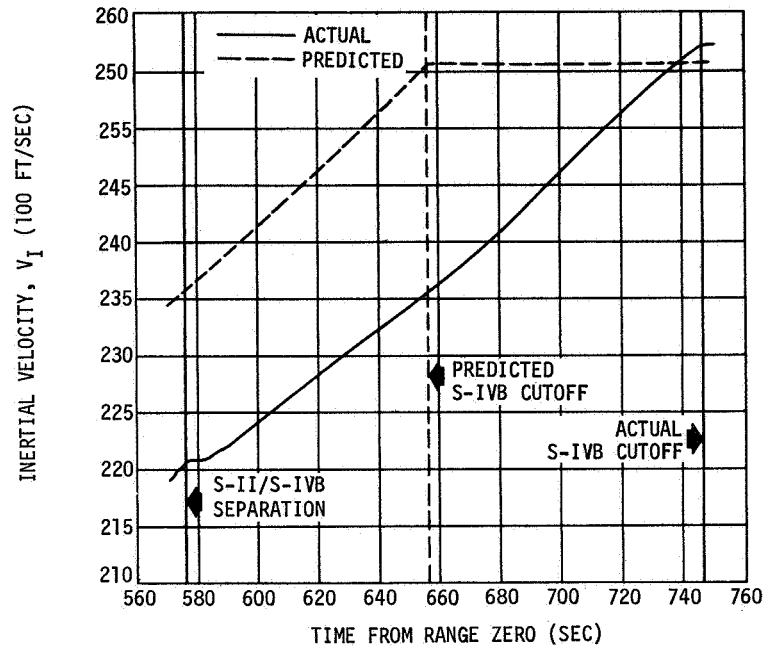


Figure 8-19. Inertial Velocity History

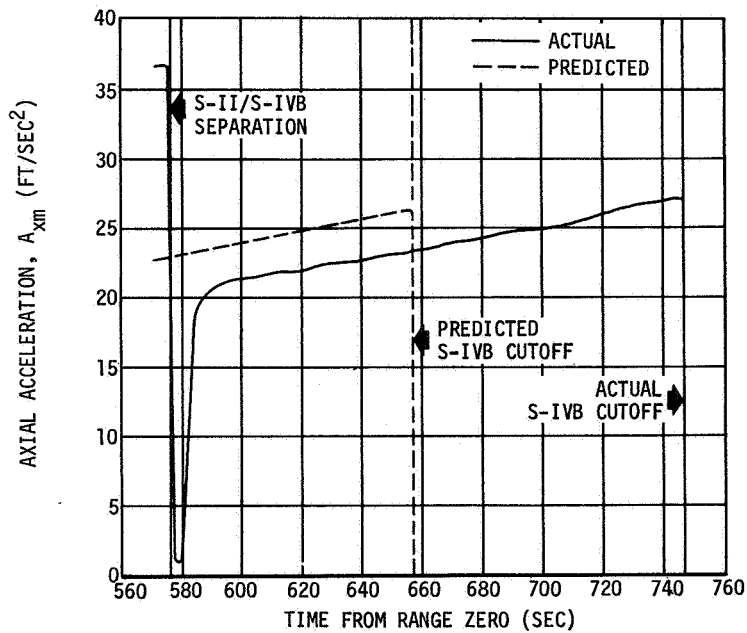


Figure 8-20. Axial Acceleration History

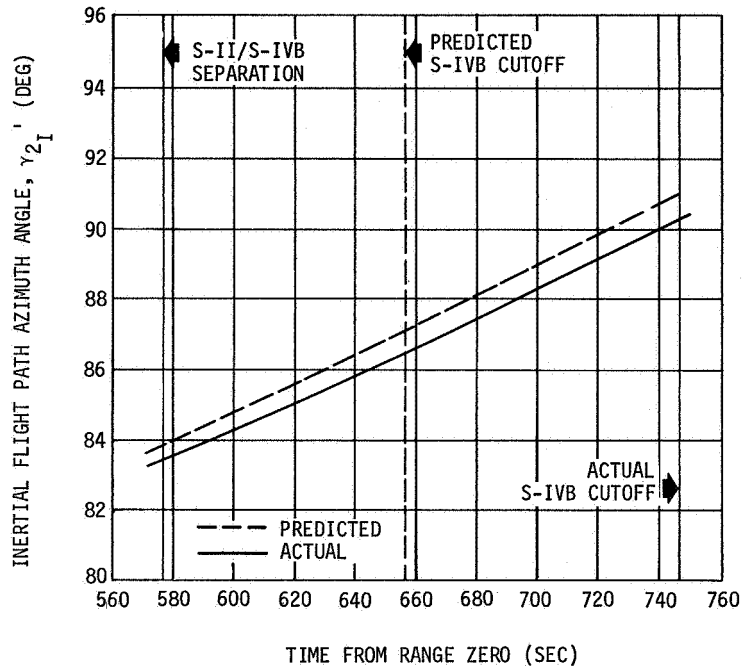


Figure 8-21. Inertial Flight Path Azimuth Angle History

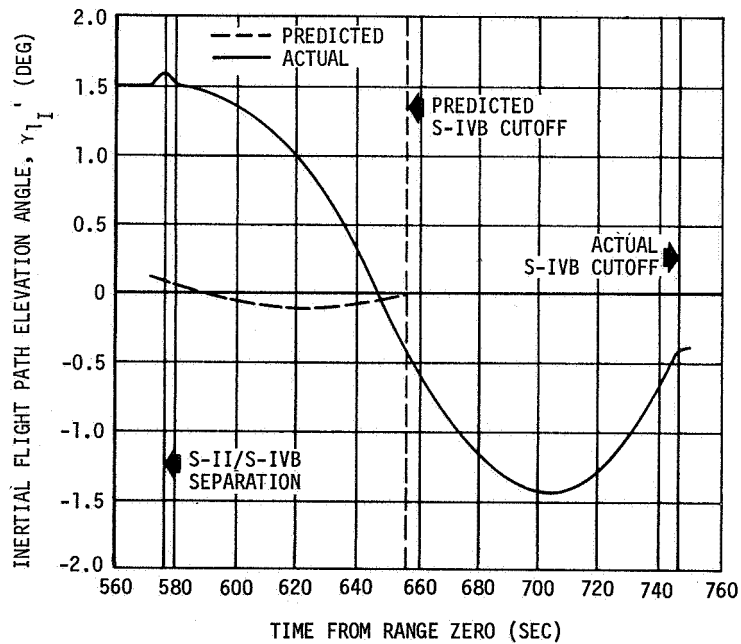


Figure 8-22. Inertial Flight Path Elevation Angle History

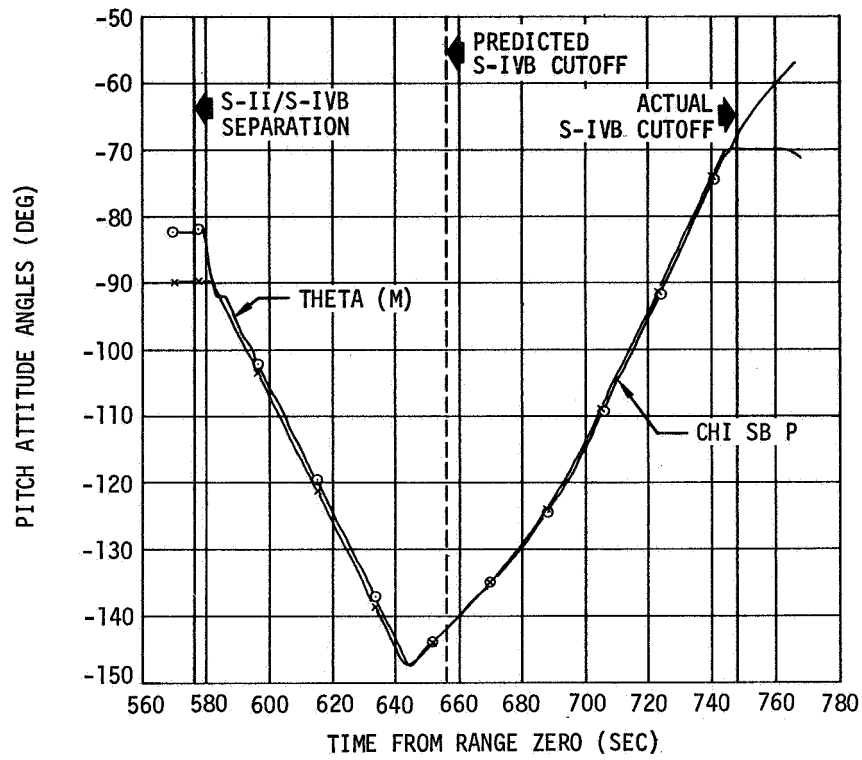


Figure 8-23. Pitch Attitude Angle History

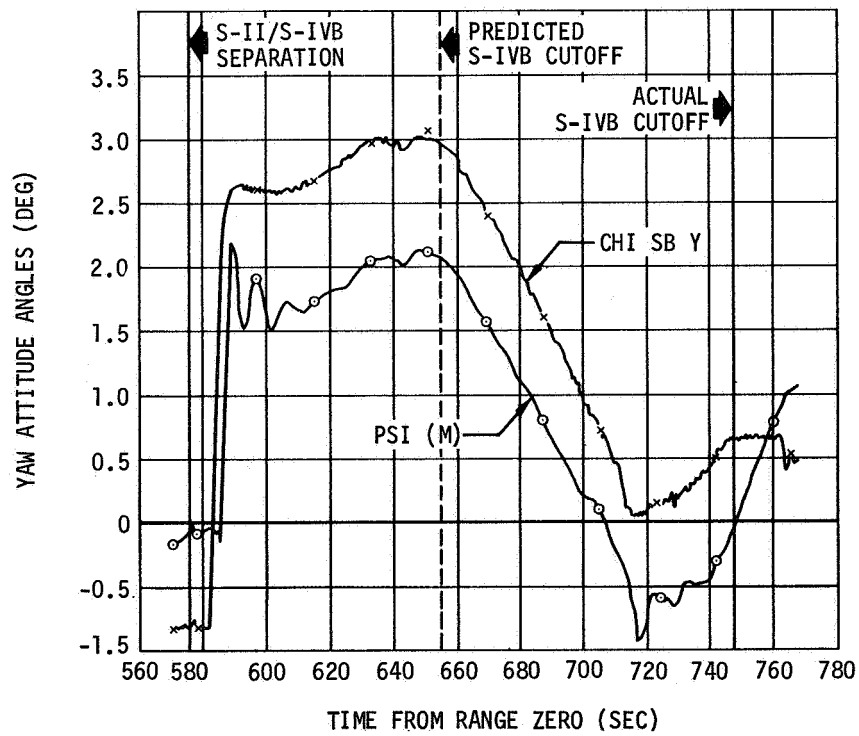


Figure 8-24. Yaw Attitude Angle History

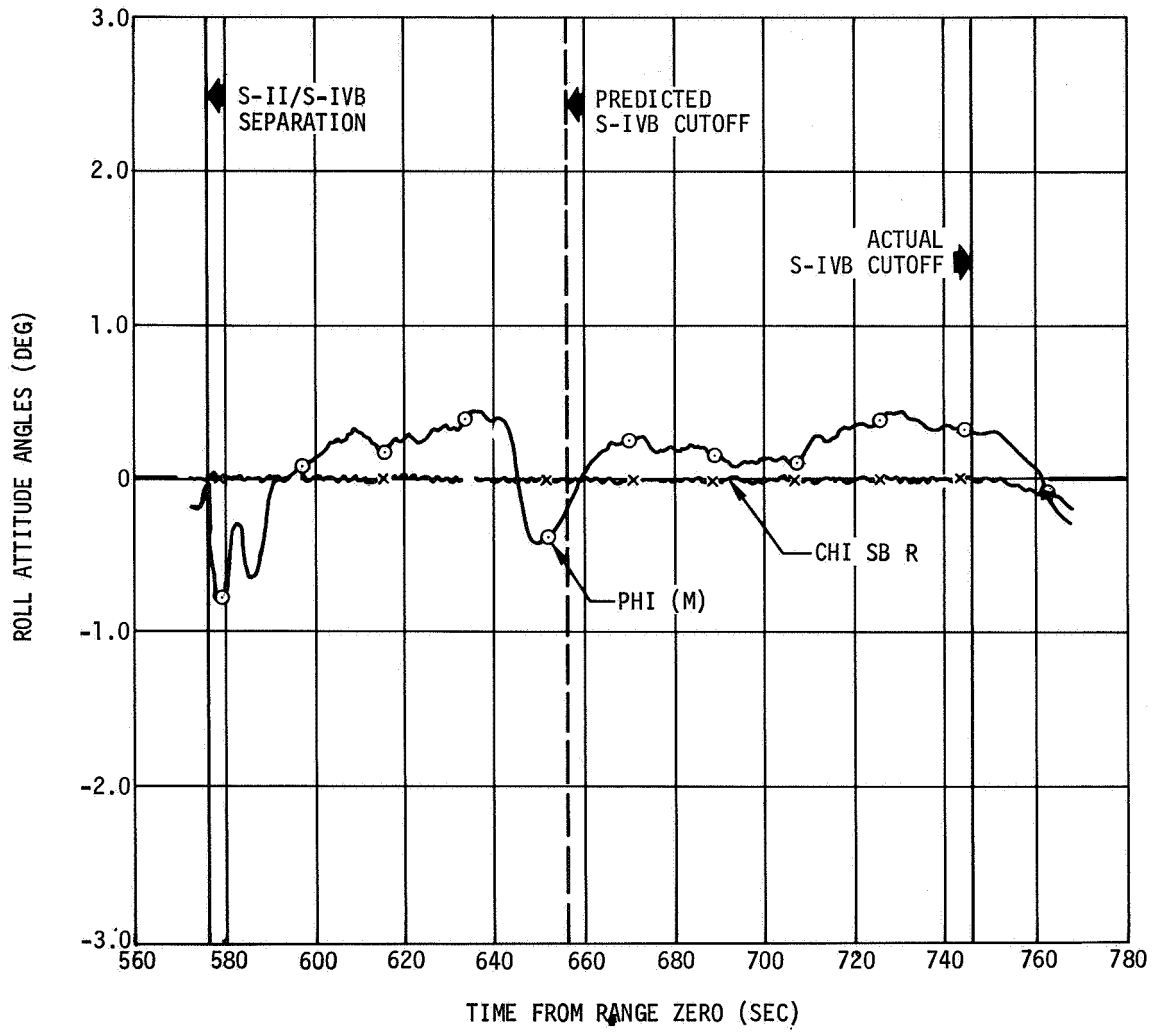


Figure 8-25. Roll Attitude Angle History

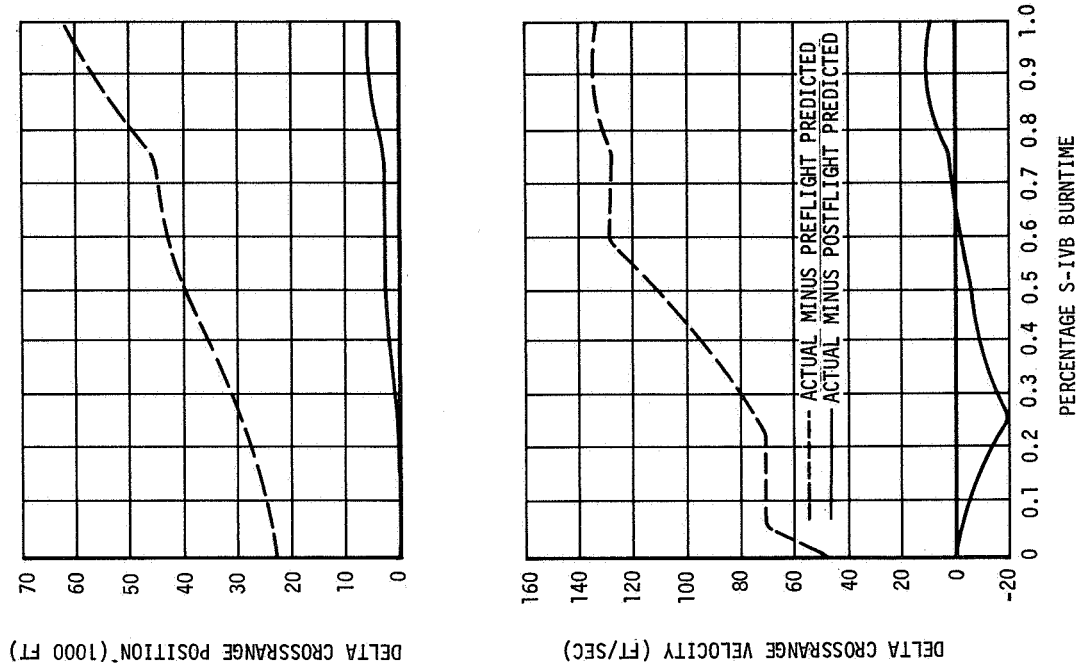


Figure 8-27. Crossrange Position and Crossrange Velocity Difference Histories

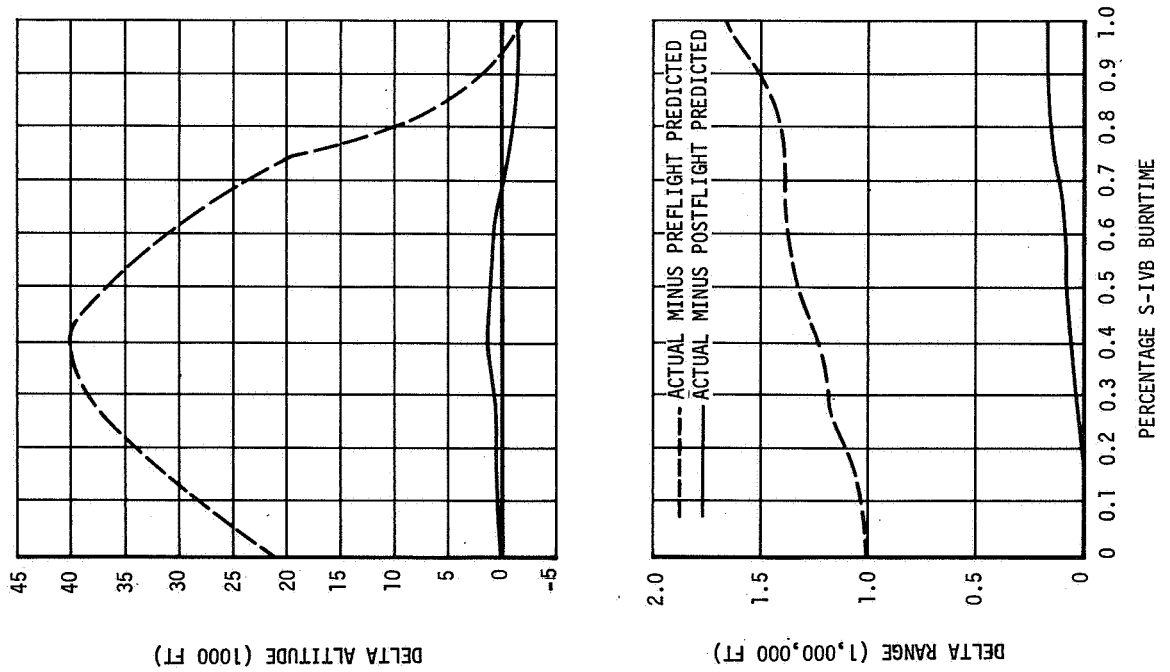


Figure 8-26. Altitude and Range Difference Histories

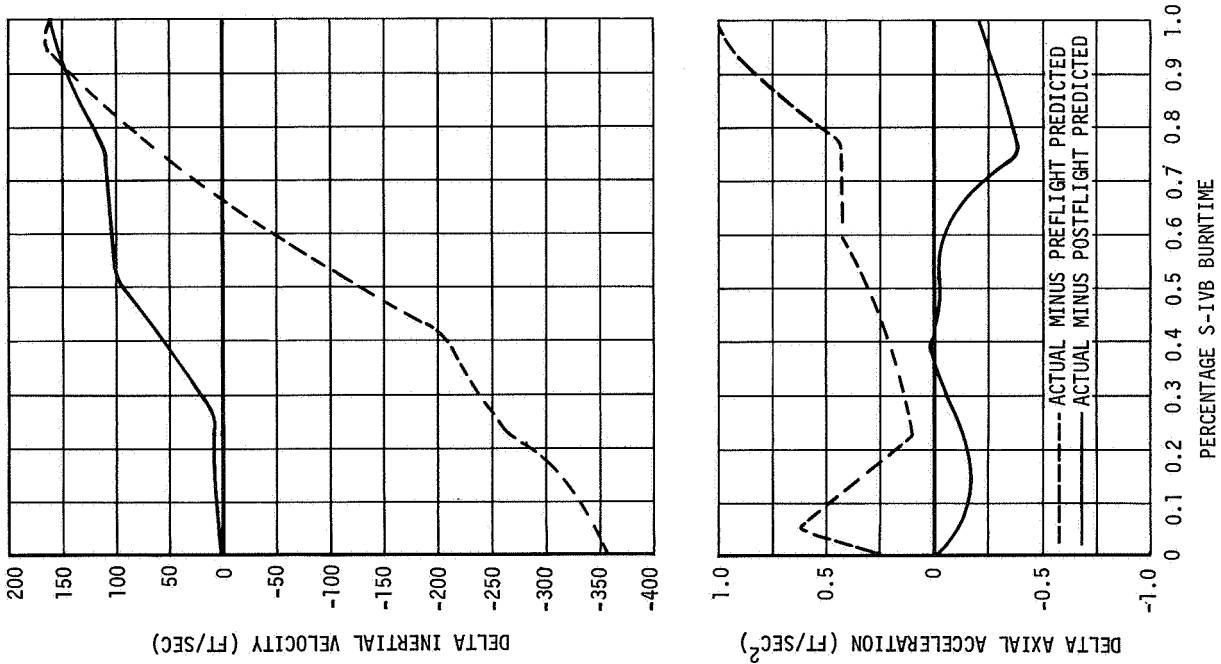


Figure 8-28. Inertial Velocity and Axial Acceleration Difference Histories

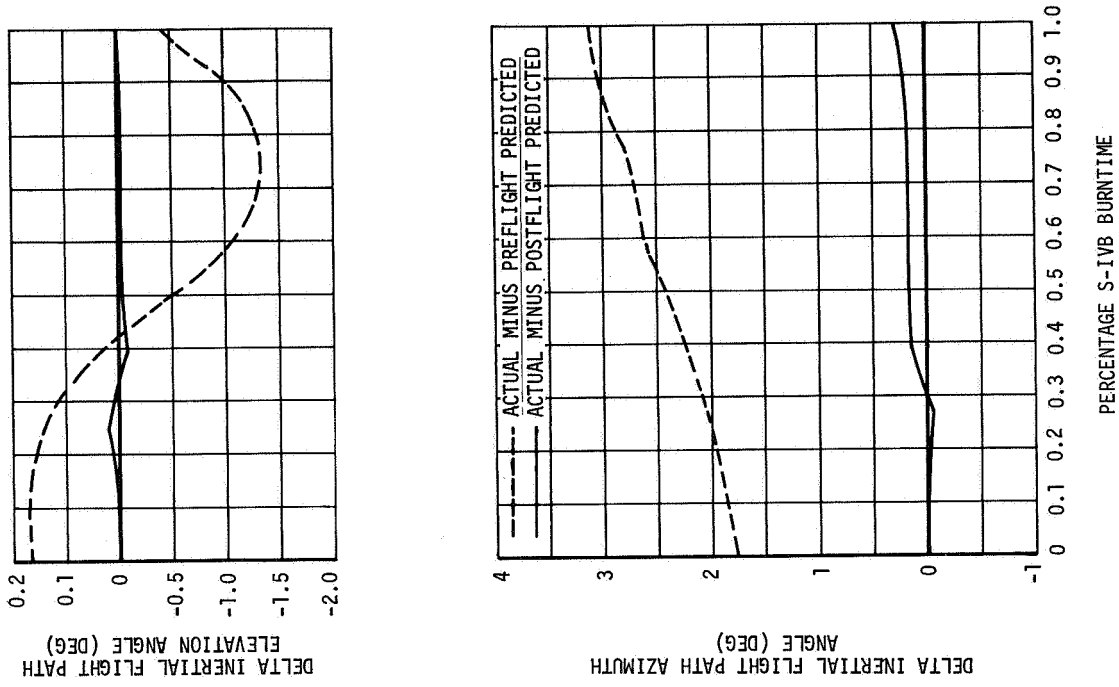


Figure 8-29. Inertial Flight Path Elevation and Azimuth Angle Difference Histories

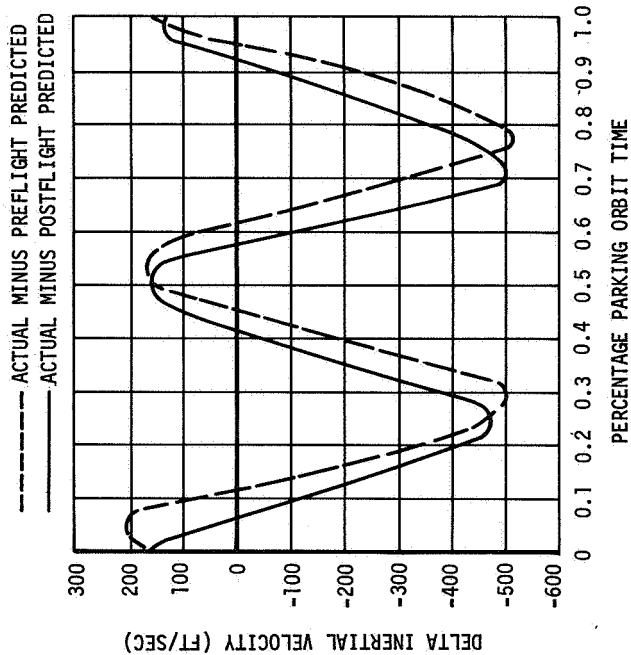
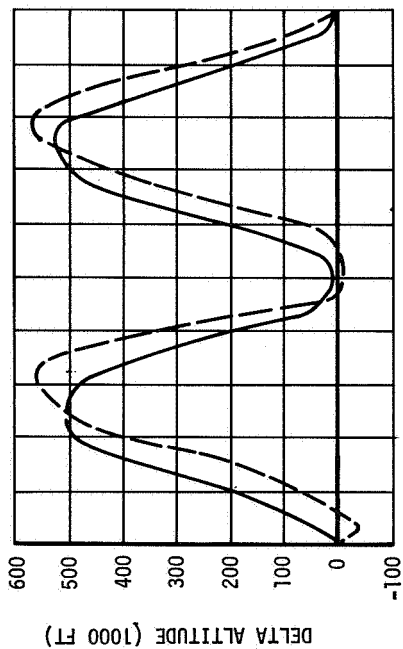
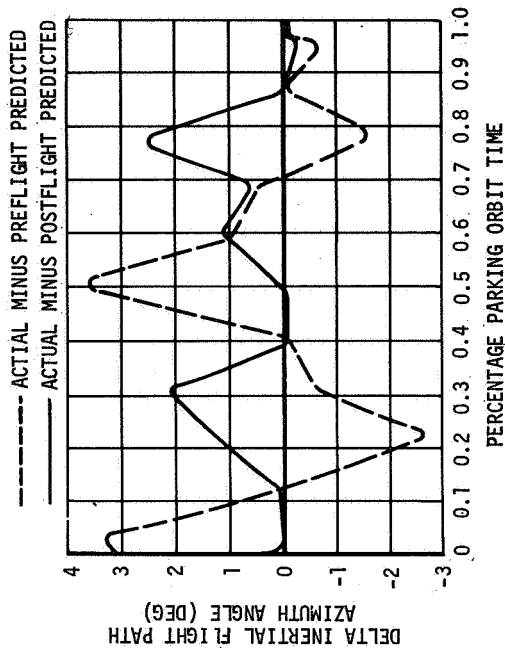
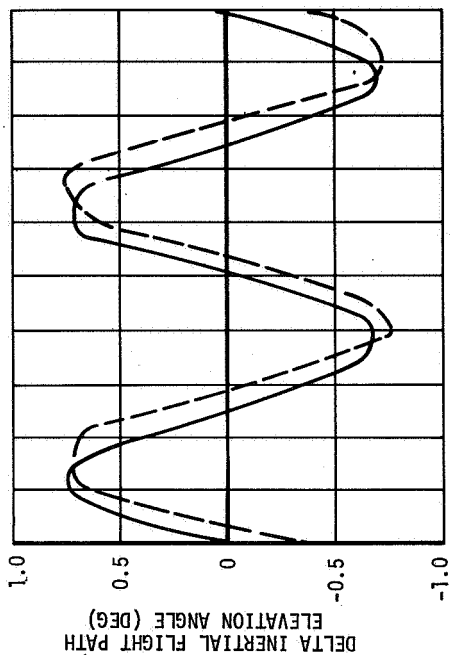


Figure 8-31. Parking Orbit Inertial Flight Path Elevation and Azimuth Angle Difference Histories

Figure 8-30. Parking Orbit Altitude and Inertial Velocity Difference Histories

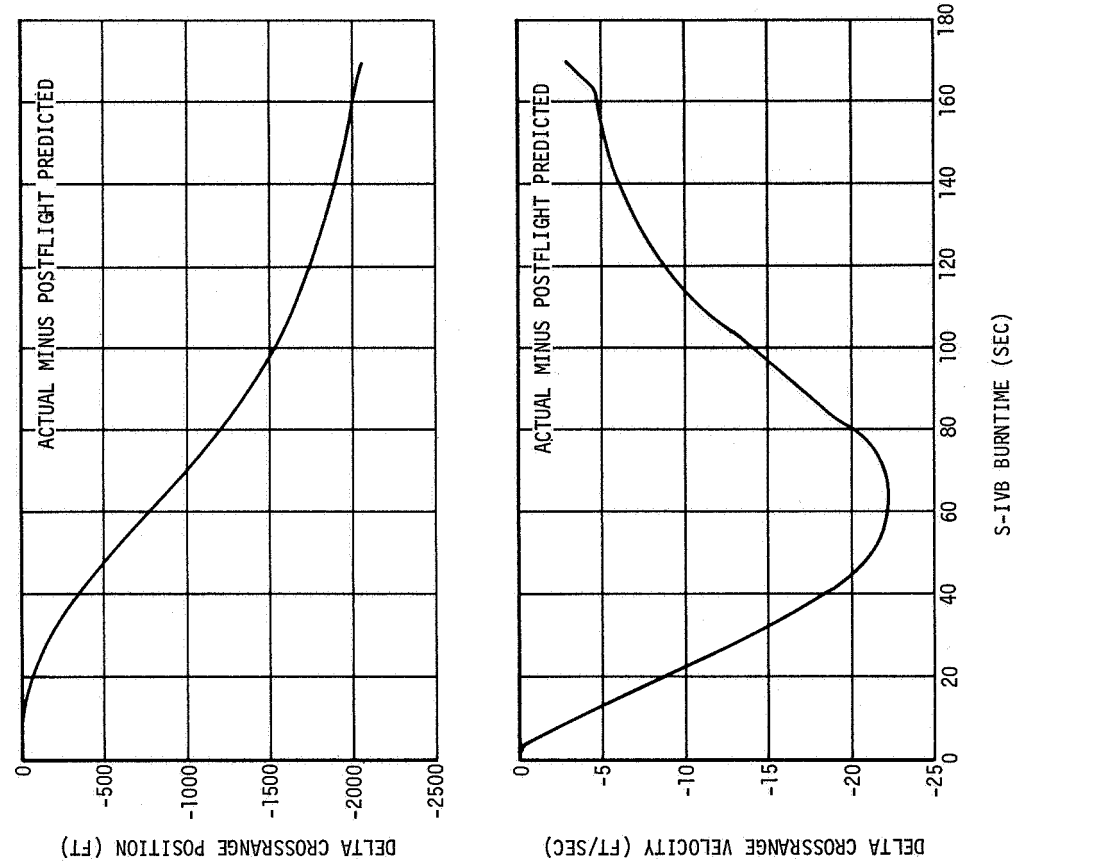


Figure 8-32. Altitude and Range Difference Histories Between Postflight Predicted and Actual Trajectories

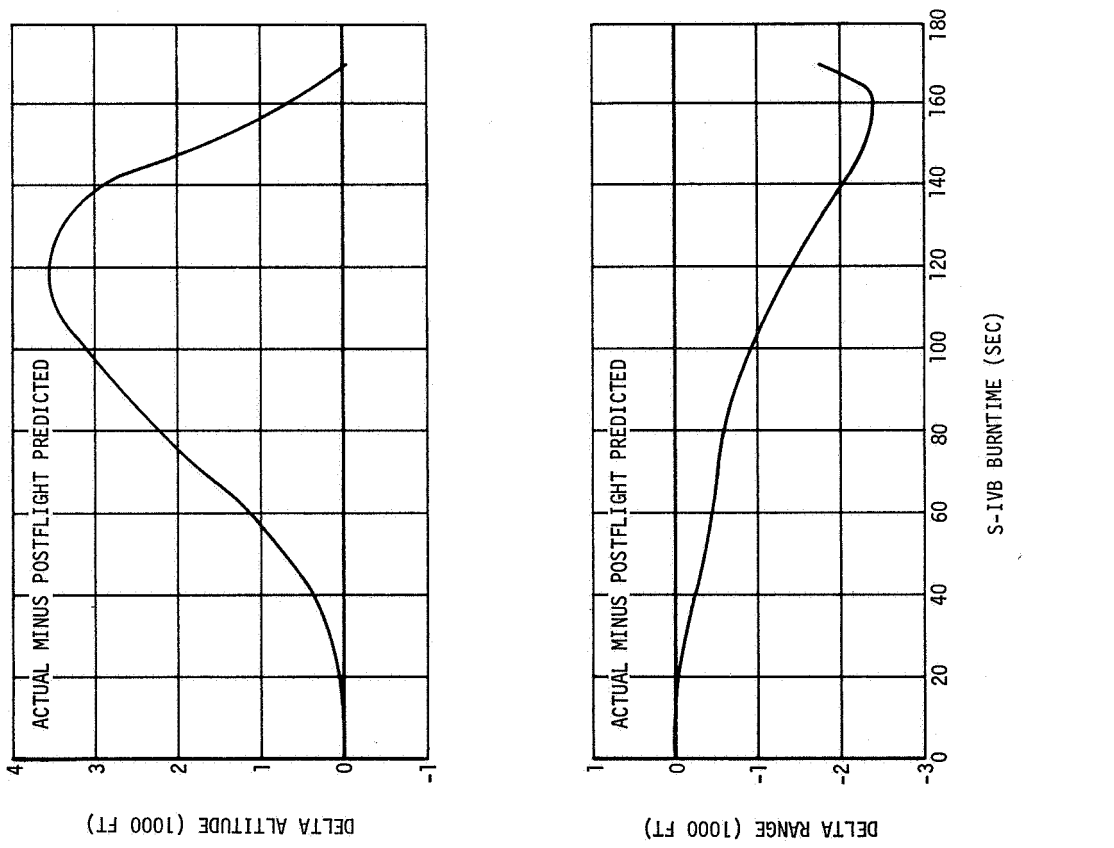


Figure 8-33. Crossrange Position and Velocity Difference Histories Between Postflight Predicted and Actual Trajectories

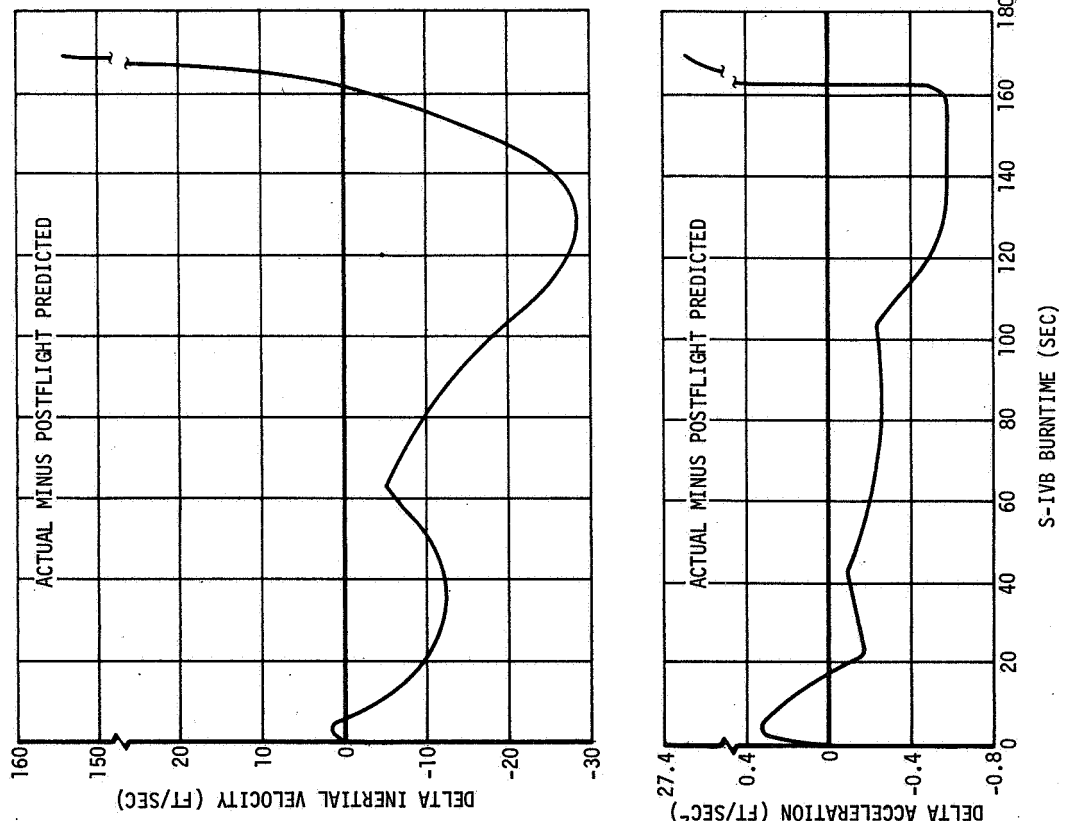


Figure 8-34. Inertial Velocity and Acceleration, Actual Minus Predicted Trajectories

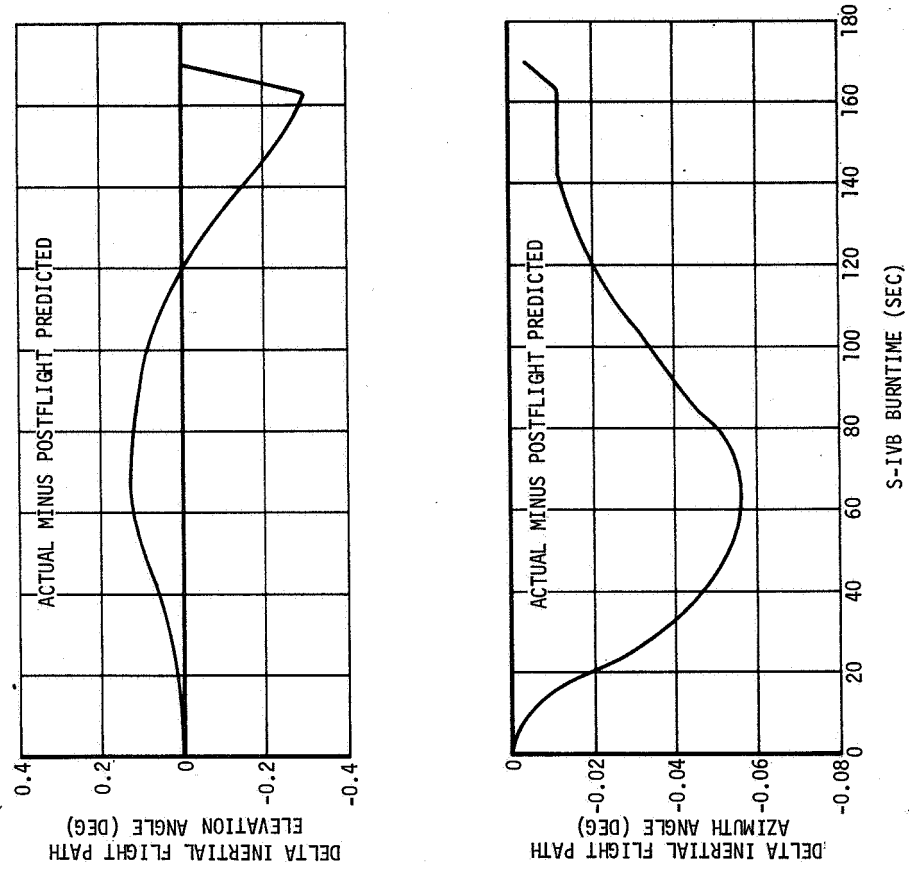
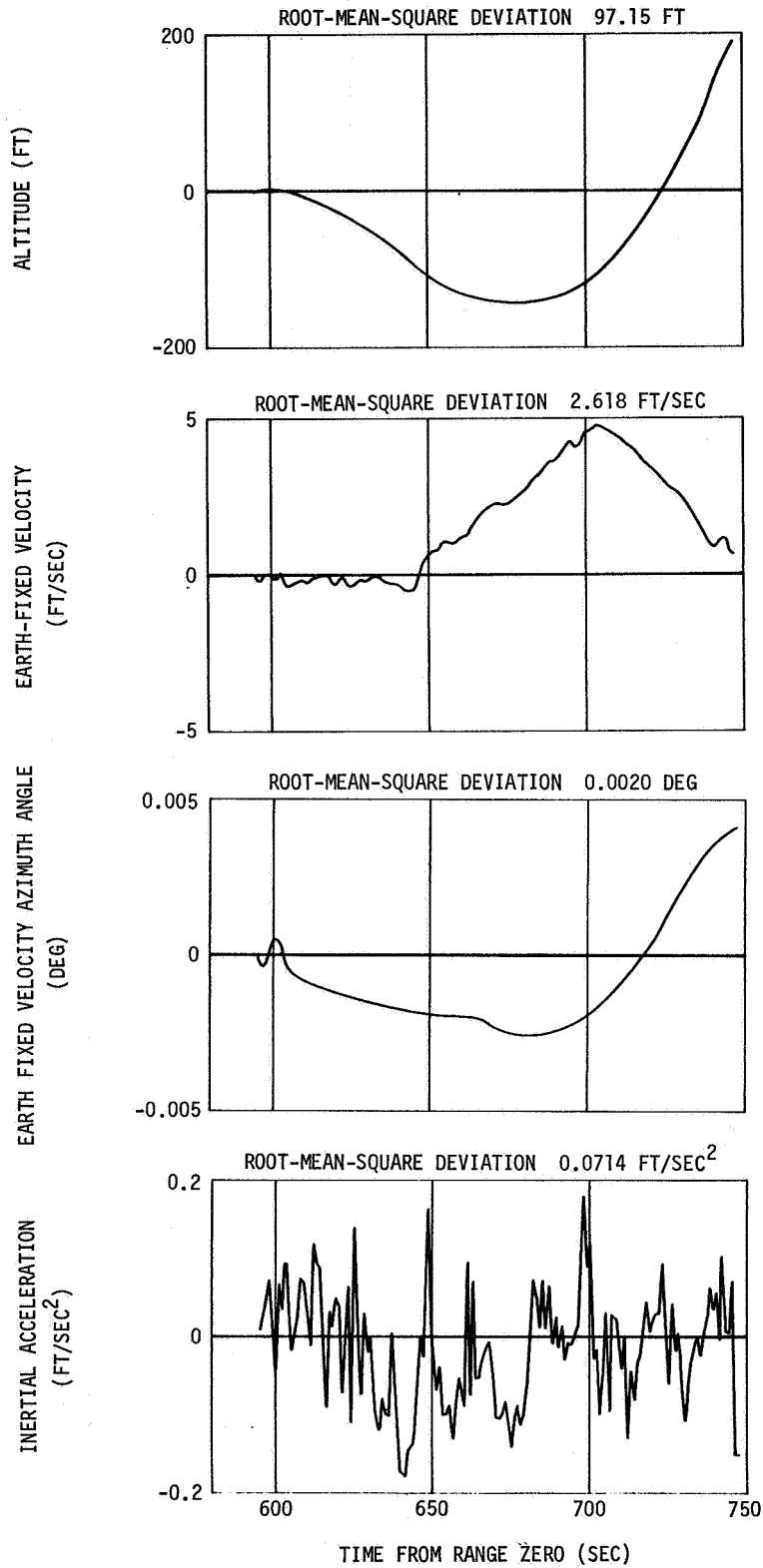


Figure 8-35. Inertial Flight Path Angle, Actual Minus Predicted Trajectories



NOTE: DATA IS ACTUAL MINUS SIMULATED

Figure 8-36. Trajectory Reconstruction Simulation Deviations from Observed Mass Point Trajectory

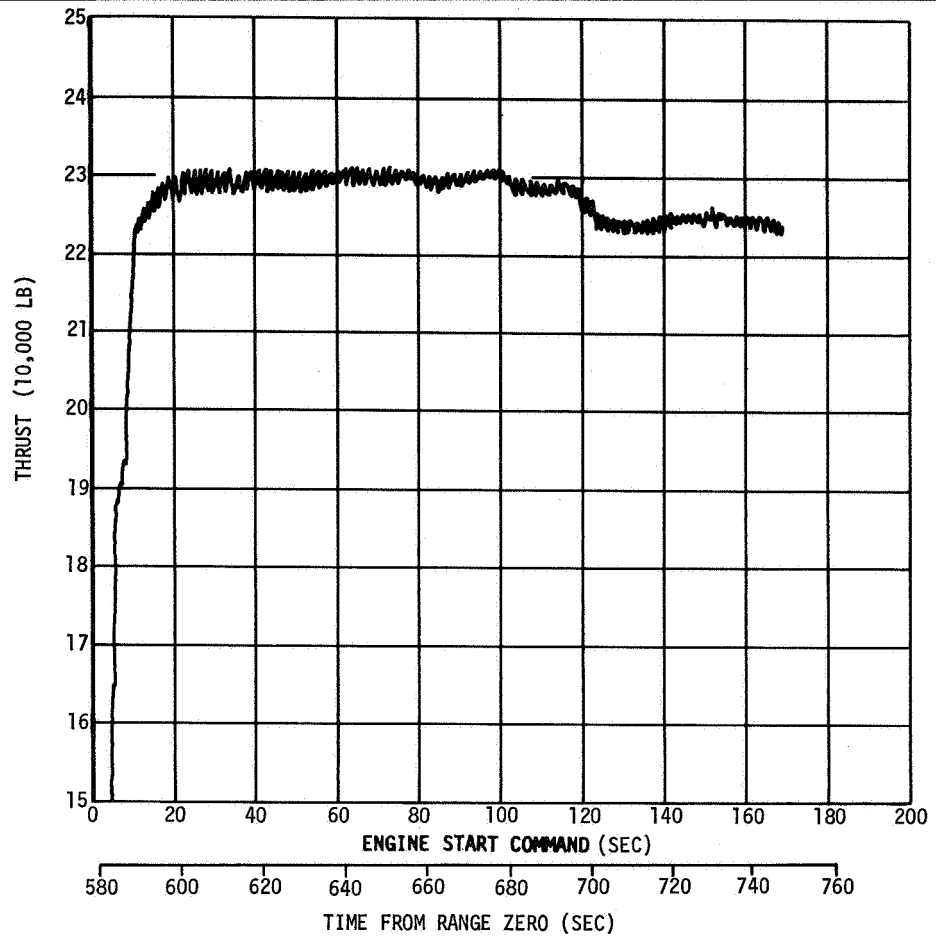


Figure 8-37. Thrust History from Engine Analysis

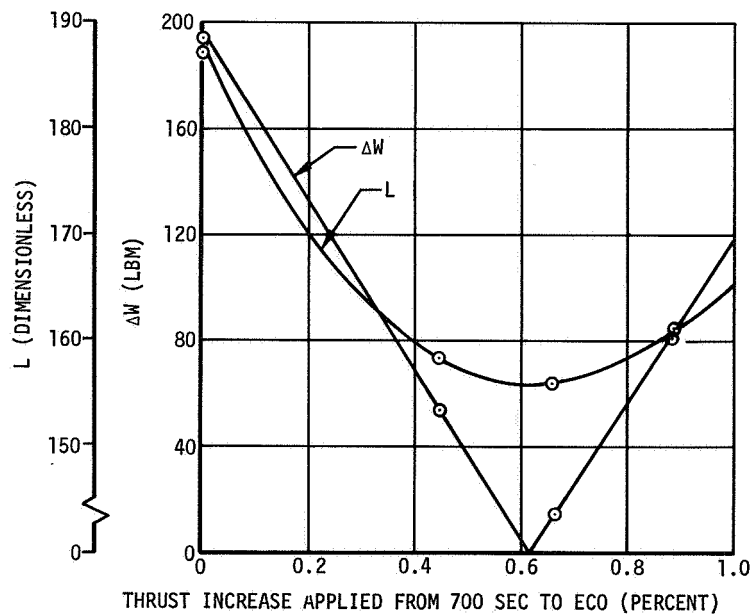


Figure 8-38. Effect of Magnitude of the Performance Shift on the Trajectory and Weight Estimate Fits

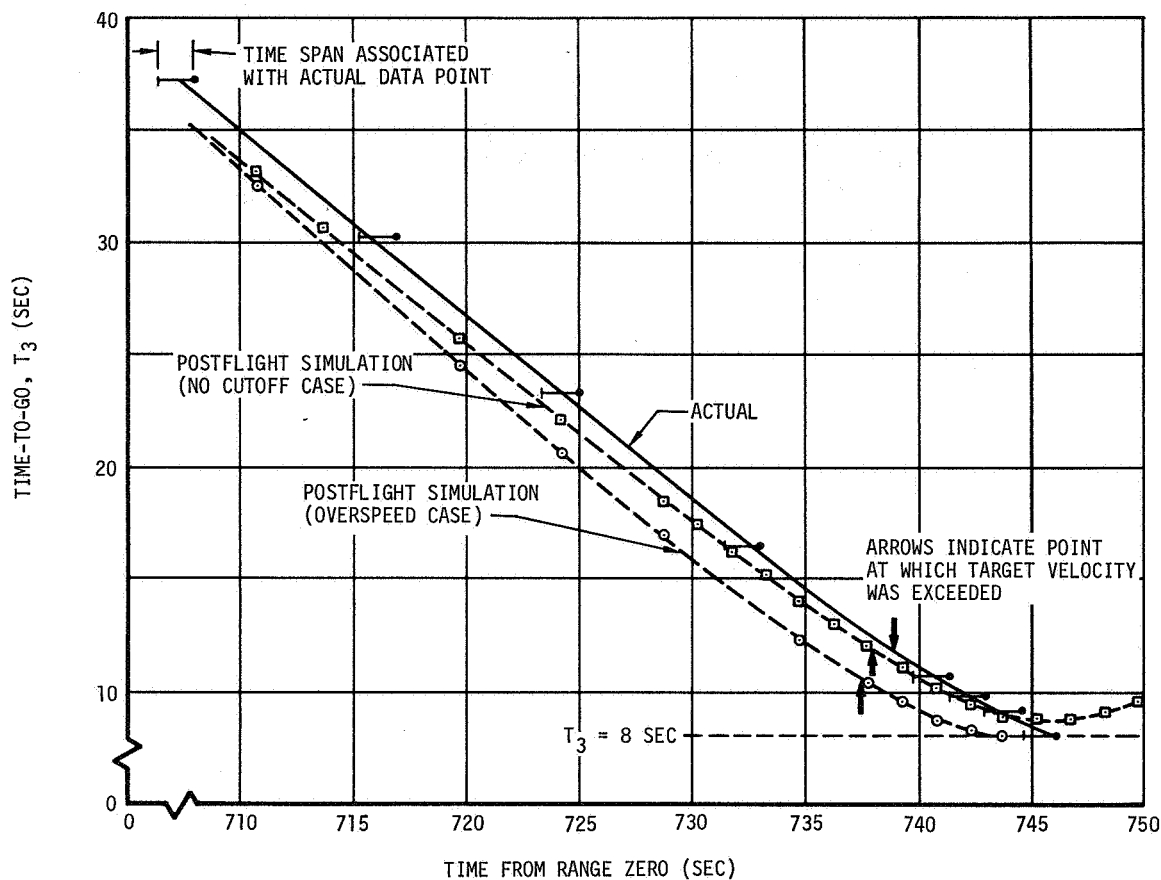


Figure 8-39. Guidance Time-to-Go for Actual, Overspeed, and No Cutoff Trajectories

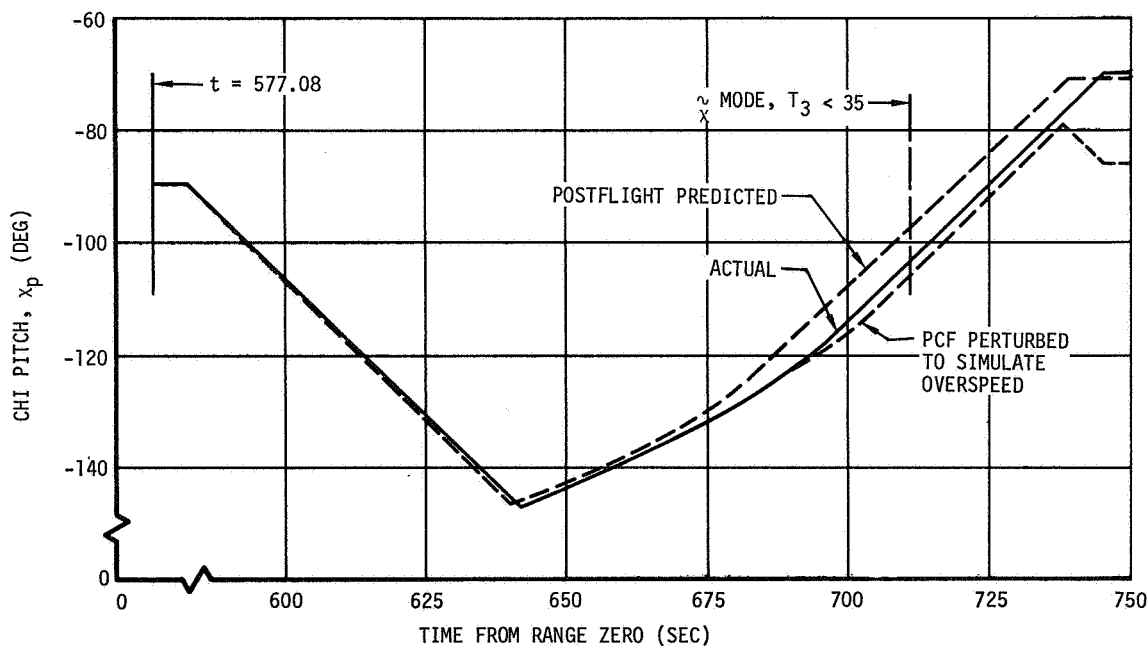


Figure 8-40. Commanded Pitch Attitude Angle for Actual, Postflight Predicted, and Overspeed Trajectories

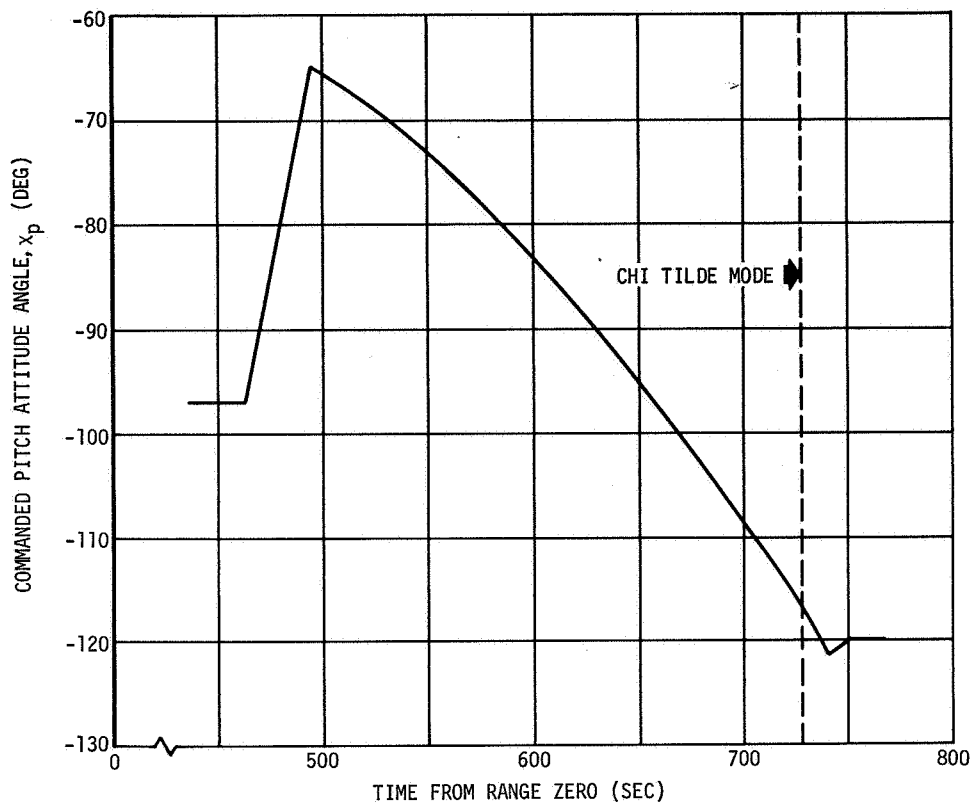


Figure 8-41. Comanded Pitch Attitude History for Direct Staging After Second S-II Engine Shutdown

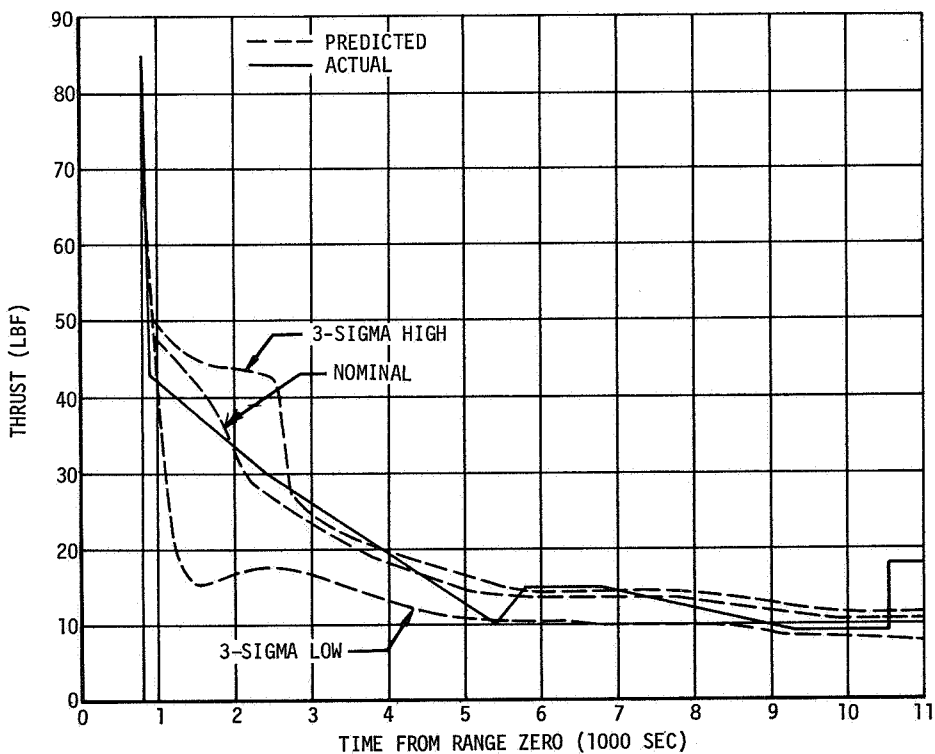


Figure 8-42. Predicted and Best Actual CVS Thrust - Orbital Coast

4

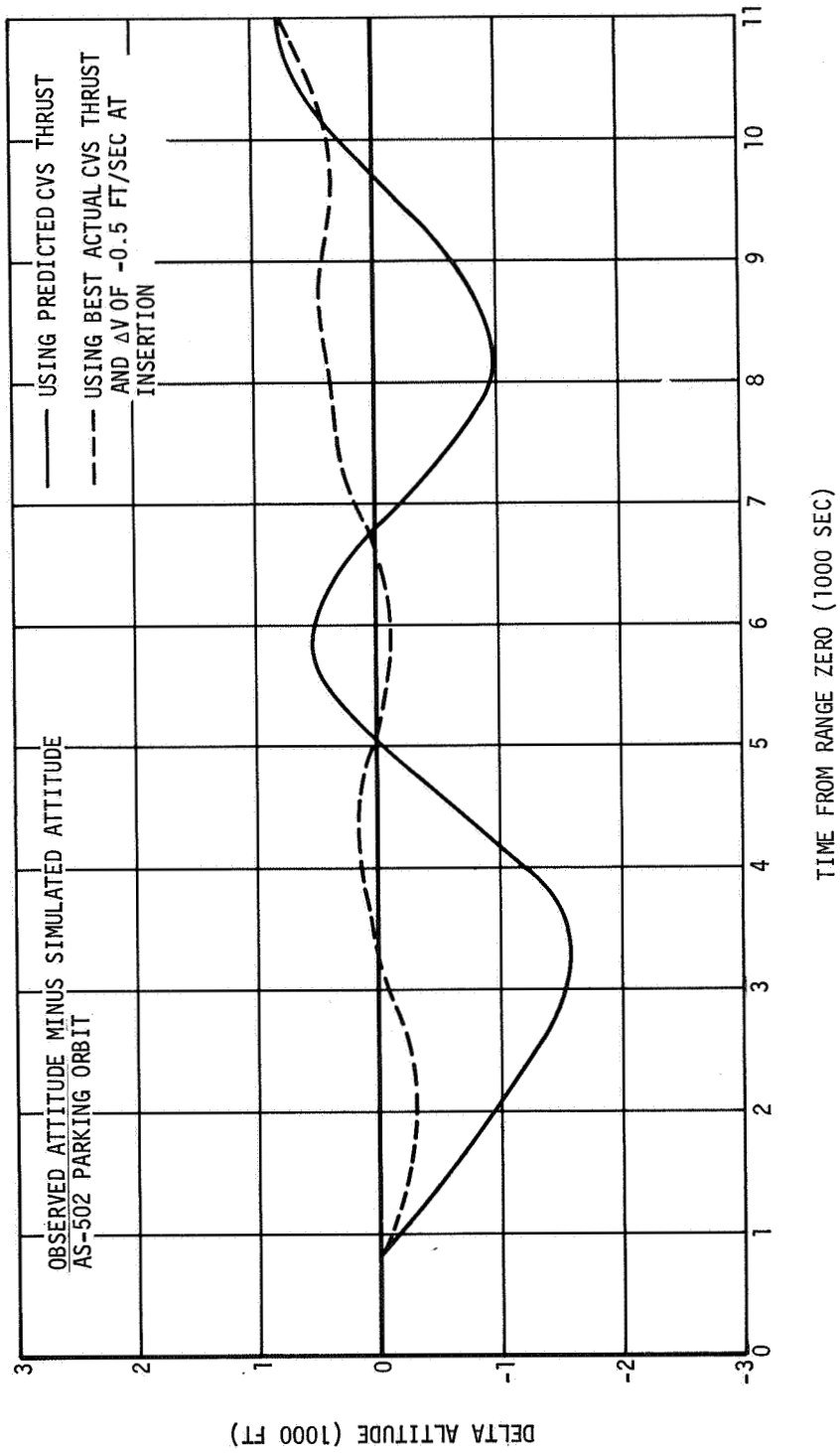


Figure 8-43. Altitude Residual Using Best Estimate of CVS Thrust

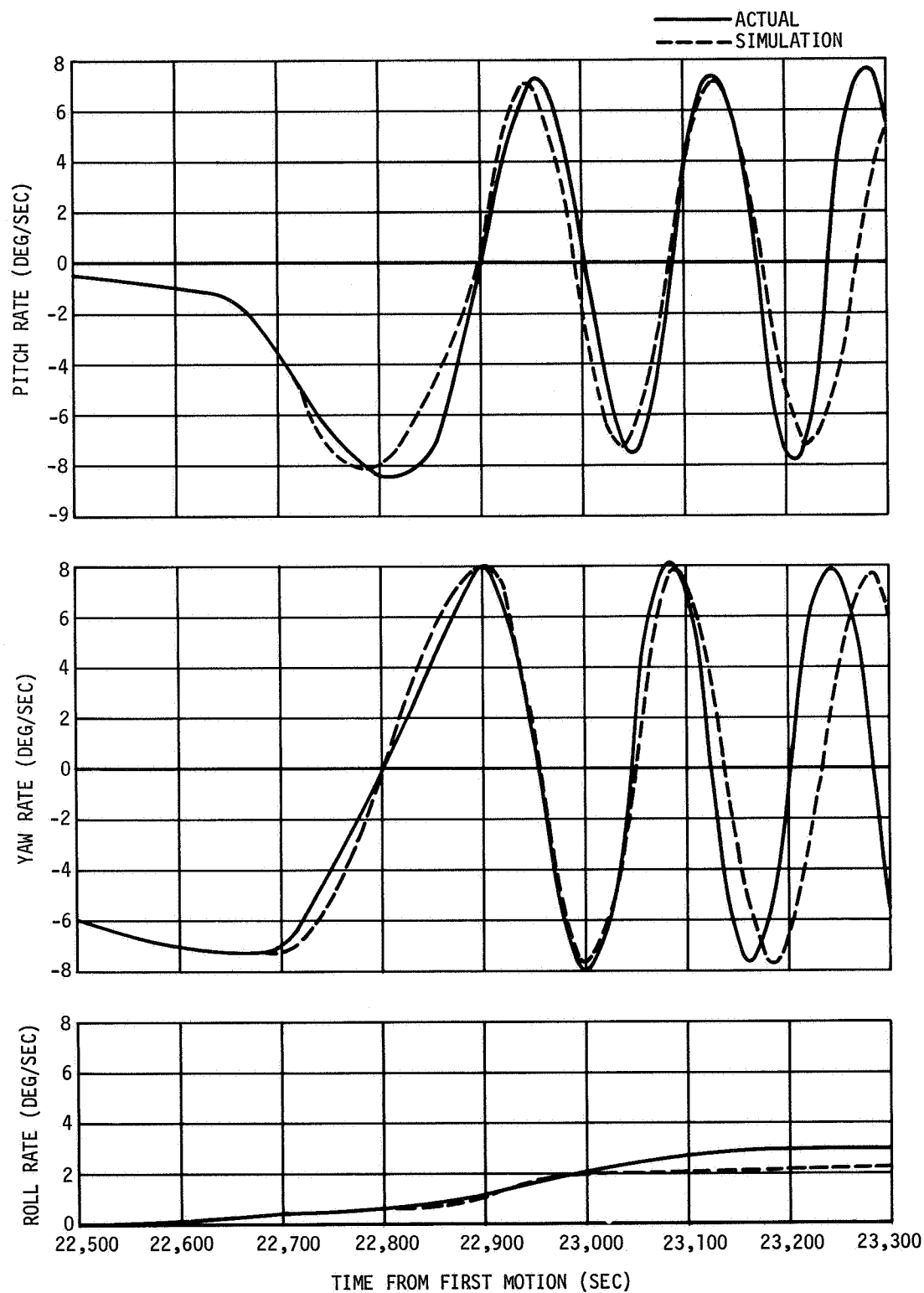


Figure 8-44. Tumbling Rates following APS Depletion

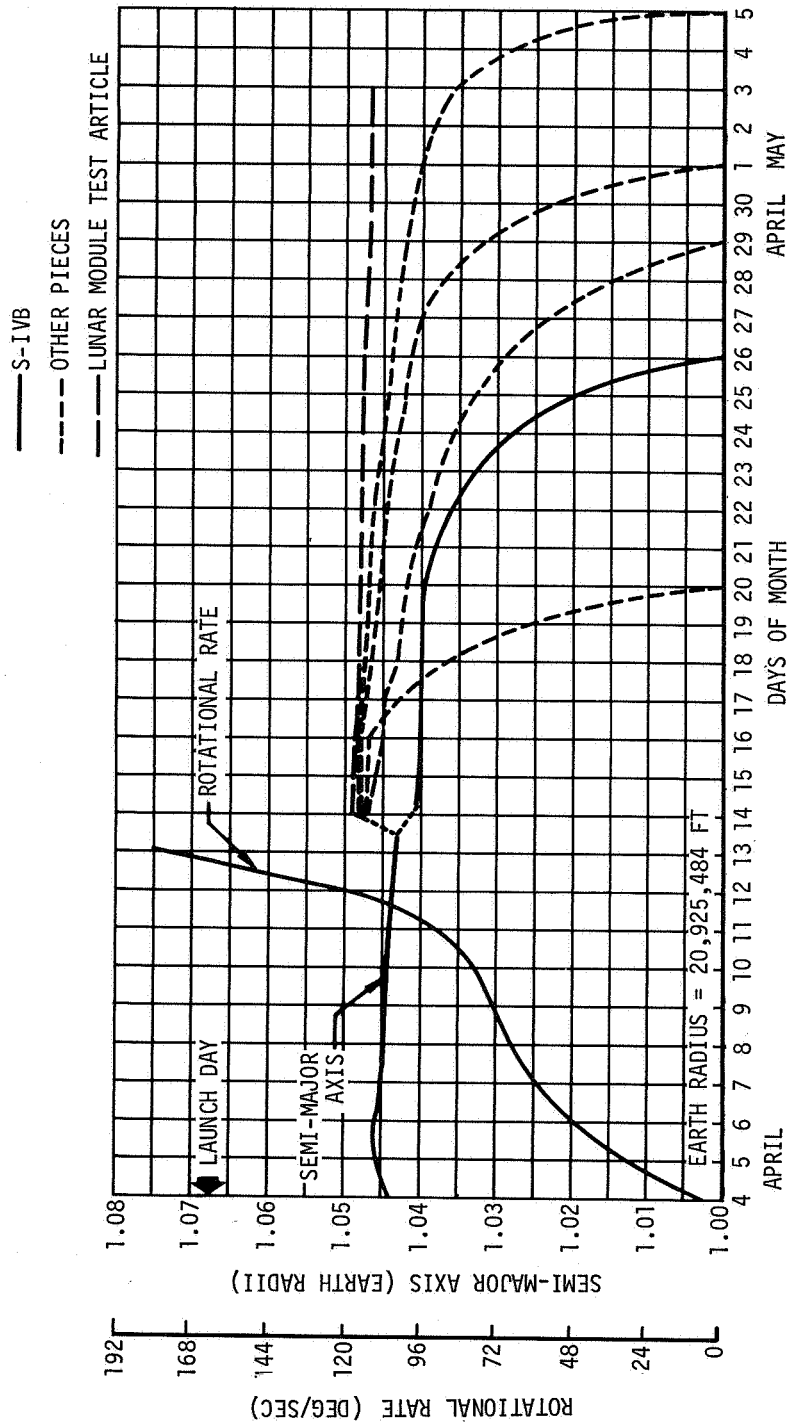


Figure 8-45. Orbit Radii and Rotational Rates

SECTION 9

MASS CHARACTERISTICS

9. MASS CHARACTERISTICS

9.1 Mass Characteristics Summary

The AS-502 third flight stage (S-IVB, IU, and Payload) mass summary presented in table 9-1, and the mass characteristics presented in appendix 1 are best estimate mass characteristics up to, and including first burn engine cutoff. Orbital boiloff and restart attempt mass losses do not represent values derived from statistical analysis.

9.2 Mass Properties Dispersion Analysis

Figures 9-1 through 9-4 present a comparison of the predicted vehicle mass characteristics and three-sigma dispersions, versus postflight actual vehicle mass characteristics during S-IVB first burn. The comparison for second burn is not shown. Figures 9-2 and 9-4 show that the actual longitudinal center of gravity and the pitch and yaw moment of inertia, respectively, were less than the minimum predicted three-sigma dispersions. The cause of this was a change in payload mass distribution which was not included in the predicted values. Had the payload mass distribution change been incorporated in the predicted values the actual values would have been well within the predicted three-sigma dispersions, and would have compared favorably with the predicted nominal values.

The predicted dispersions were determined from a statistical analysis component mass properties uncertainties and are referenced relative to time from Engine Start Command.

9.3 Third Flight Stage Best Estimate Ignition and Cutoff Masses

The best estimate method is a three dimensional statistical analysis of data from five mass measurement systems. This method develops a joint probability density function from which the most probable values and accuracies for ignition and cutoff masses are determined.

Three measurement systems provide unique values for ignition and cutoff masses while two systems provide linear relationships between cutoff and ignition mass. The best estimate method combines the unique values with the linear relationships to compute the most probable value for ignition and cutoff mass.

The five measurement systems used in determining the best estimate masses are: (1) PU indicated corrected (2) flight flow integral (3) PU volumetric (4) level sensors and (5) trajectory reconstruction. A brief description of each measurement system is given in section 16.

Figure 9-5 is a graphical presentation of the best estimate analysis for ignition and cutoff mass. The third flight stage ignition mass was 354,232 \pm 476 lbm and the cutoff mass was 265,234 \pm 400 lbm.

9.3.1 Best Estimate Program Input

Table 9-2 presents a summary of the values used in determining the best estimate ignition and cutoff mass. For the unique measurement systems, the LOX, LH2, and non-propellant mass values and their predicted dispersions are presented in addition to the total mass values and dispersions used for computation. The linear relationship slope, intercept, and dispersion values are presented as utilized for the best estimate analysis.

Section 9
Mass Characteristics

TABLE 9-1
MASS SUMMARY

| EVENT | S-IC LIFT- OFF | S-II/ S-IVB SEPAR. | S-IVB FIRST ESC | END FUEL LEAD | FIRST 90 PCT THRUST | S-IVB FIRST ECC | S-IVB FIRST ETD | BEGIN RESTART PREFS. | S-IVB SECOND ESC | END FUEL LEAD | S-IVB SECOND ECC | CSM SEPAR- ATION |
|-------------------------------|----------------------|--------------------------|-----------------------|---------------------|---------------------------|-----------------------|-----------------------|----------------------------|------------------------|---------------------|------------------------|------------------------|
| LAUNCH ESCAPE | 8,886 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FROST | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEPARATION PKG | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ULLAGE ROCKETS | 253 | 250 | 244 | 153 | 135 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COMMAND MODULE | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 12,543 | 0 |
| SERVICE MODULE | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 9,836 | 0 |
| SM PROPELLANT | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 32,785 | 0 |
| ADAPTER RING | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 0 |
| ADAPTER (SLA) | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 | 3,795 |
| LUNAR MODULE | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 | 26,001 |
| VEH INSTR UNIT | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 | 4,874 |
| S4B502 DRY SIG | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 | 26,253 |
| LOX IN TANK | 193,773 | 193,768 | 193,768 | 193,768 | 193,470 | 118,769 | 118,609 | 118,378 | 118,378 | 118,378 | 116,685 | 116,685 |
| LOX ULLAGE GAS | 28 | 33 | 33 | 34 | 35 | 187 | 187 | 418 | 423 | 423 | 423 | 345 |
| LOX BELOW TANK | 367 | 367 | 367 | 367 | 397 | 397 | 367 | 367 | 367 | 367 | 397 | 367 |
| LH2 IN TANK | 42,400 | 42,400 | 42,400 | 42,392 | 42,278 | 28,436 | 28,407 | 25,383 | 25,383 | 25,098 | 24,863 | 24,863 |
| LH2 ULLAGE GAS | 78 | 78 | 78 | 79 | 80 | 160 | 160 | 405 | 448 | 448 | 448 | 448 |
| LH2 BELOW TANK | 48 | 48 | 48 | 53 | 58 | 58 | 48 | 48 | 48 | 56 | 58 | 48 |
| COLD HELIUM | 332 | 332 | 332 | 331 | 330 | 274 | 274 | 203 | 201 | 200 | 199 | 198 |
| APS PROP FP 1 | 314 | 314 | 314 | 314 | 314 | 311 | 311 | 189 | 102 | 100 | 98 | 88 |
| APS PROP FP 3 | 315 | 315 | 315 | 315 | 315 | 312 | 312 | 240 | 139 | 136 | 134 | 122 |
| GH2 IN STRTANK | 5 | 5 | 5 | 3 | 1 | 7 | 7 | 7 | 7 | 2 | 1 | 1 |
| HELIUM-REPRESS | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 30 | 30 | 30 | 30 |
| SERVICE ITEMS | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 |
| TOTAL MASS | 363,279 | 354,239 | 354,233 | 354,138 | 353,742 | 265,240 | 265,010 | 261,967 | 261,777 | 261,489 | 259,586 | 204,190 |
| TIME FROM RANGE ZERO (sec) | 0.690 | 577.079 | 577.280 | 580.280 | 582.788 | 747.032 | 747.432 | 11,287.733 | 11,614.667 | 11,623.239 | 11,630.320 | 11,666.100 |

TABLE 9-2
BEST ESTIMATE PROGRAM INPUT VALUES

UNIQUE MEASUREMENT SYSTEMS

| EVENT | MEASUREMENT SYSTEM | LOX (lbm) | | LH2 (lbm) | | NON-PROPELLANT (lbm) | | TOTAL (lbm) | |
|-------|------------------------|-----------|--------|-----------|-------|----------------------|-------|-------------|--------|
| | | VALUE | ERROR | VALUE | ERROR | VALUE | ERROR | VALUE | ERROR |
| ESC | PU VOLUMETRIC | 194,122 | +965 | 42,214 | +271 | 117,649 | +231 | 353,985 | +1,029 |
| | PU INDICATED CORRECTED | 193,272 | +1,380 | 42,430 | +354 | 117,649 | +231 | 353,351 | +1,443 |
| | POINT LEVEL SENSORS | 194,893 | +954 | 42,569 | +251 | 117,649 | +231 | 355,111 | +1,013 |
| ECC | PU VOLUMETRIC | 119,145 | +670 | 28,265 | +214 | 117,574 | +233 | 264,984 | +741 |
| | PU INDICATED CORRECTED | 118,235 | +844 | 28,542 | +238 | 117,574 | +233 | 264,351 | +907 |
| | POINT LEVEL SENSORS | 119,875 | +732 | 28,590 | +153 | 117,574 | +233 | 266,039 | +783 |

LINEAR RELATIONSHIPS

| EVENT | MEASUREMENT SYSTEM | SLOPE | INTERCEPT (lbm) | ERROR (lbm) |
|------------------|---------------------------|---------|-----------------|-------------|
| ESC TO ECC | FLOW INTEGRAL | 1.0 | 88,952 | +544 |
| | TRAJECTORY RECONSTRUCTION | 1.33501 | 0 | +1,770 |

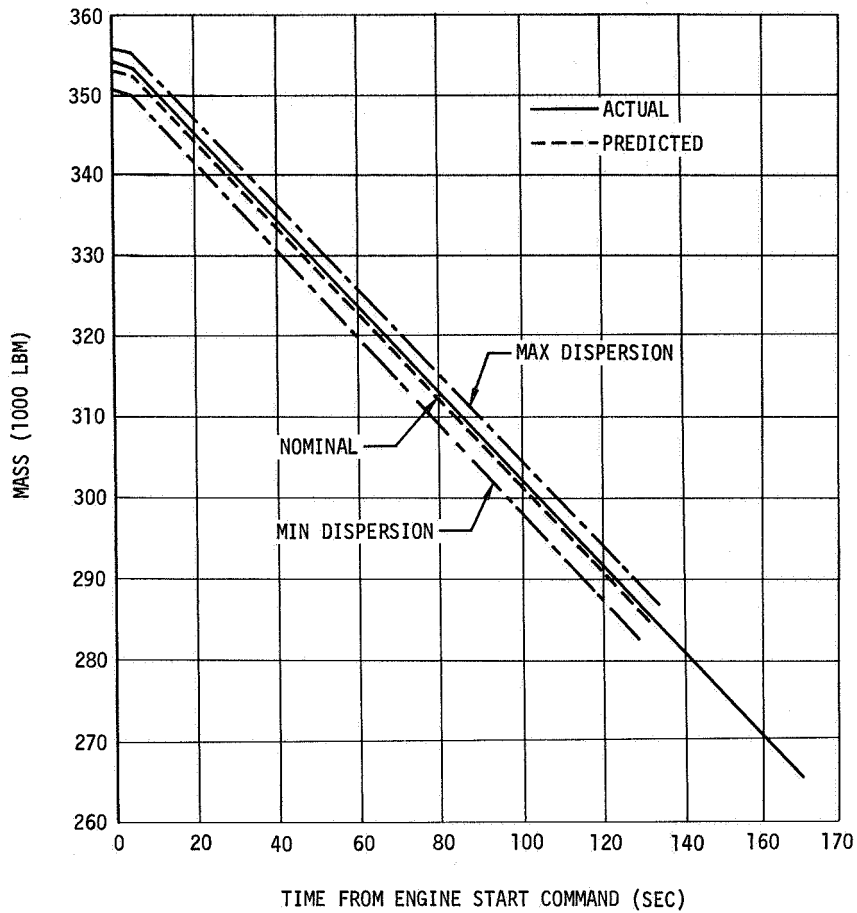


Figure 9-1. Third Flight Stage Vehicle Mass - First Burn

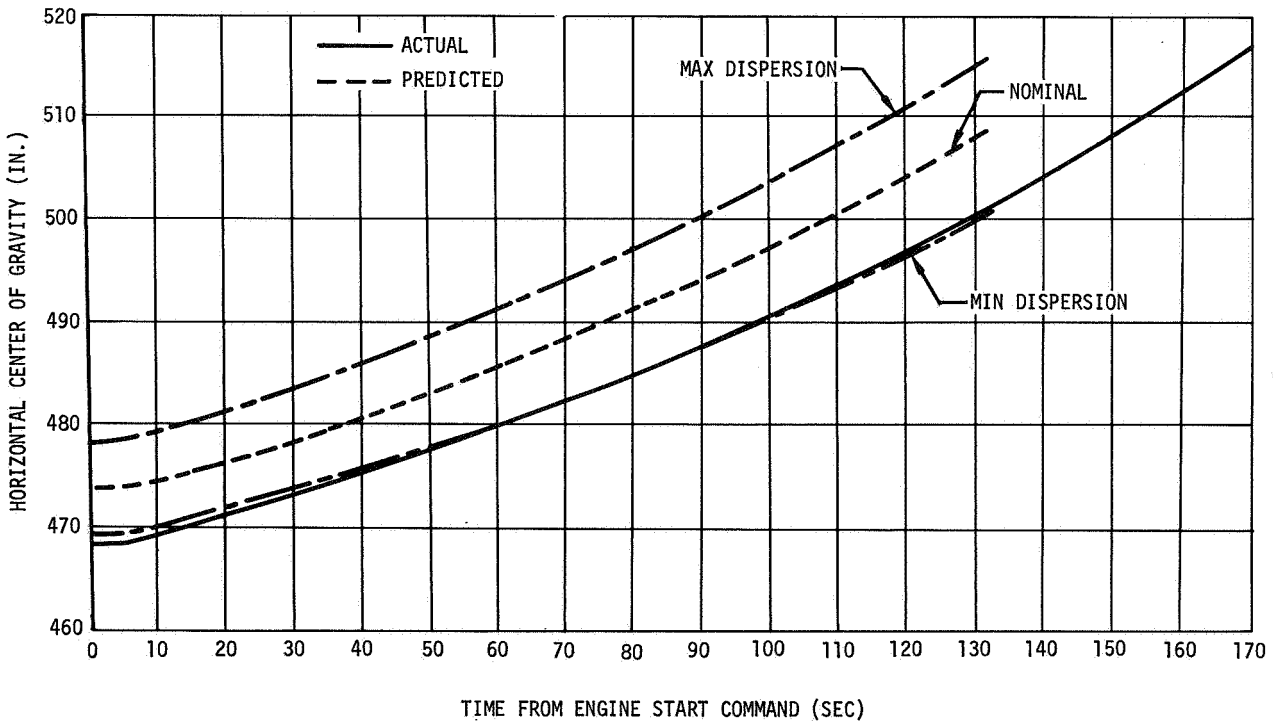


Figure 9-2. Third Flight Stage Vehicle Horizontal Center of Gravity - First Burn

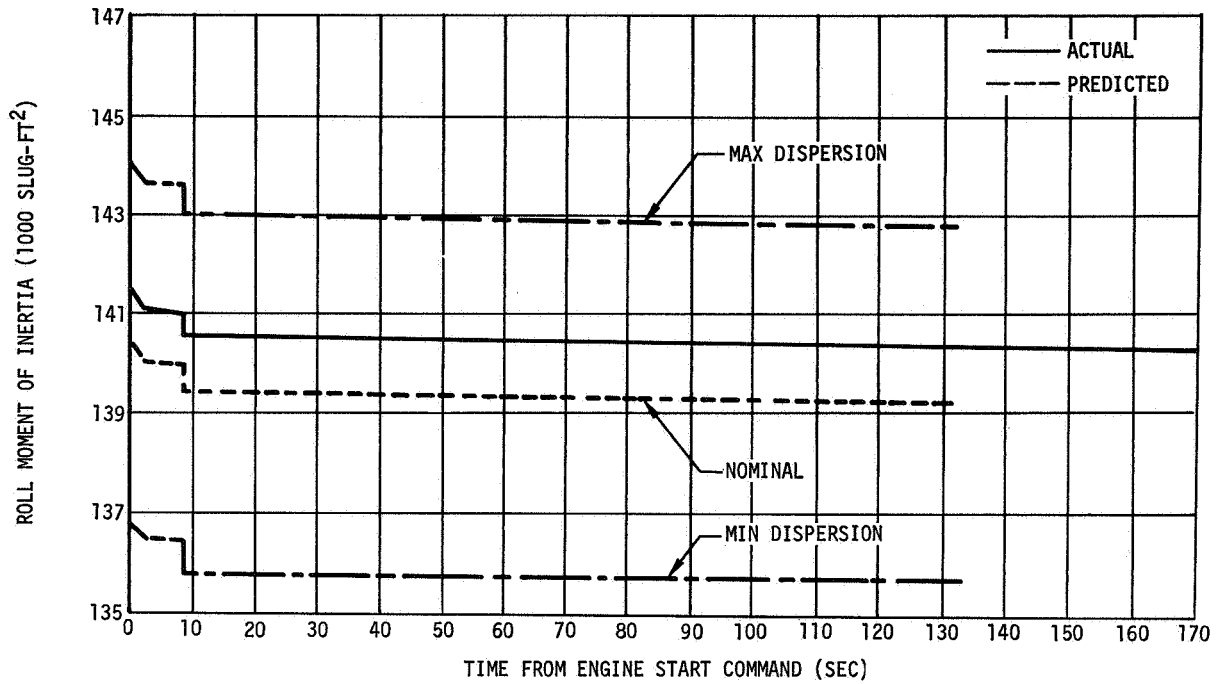


Figure 9-3. Third Flight Stage Vehicle Roll Moment of Inertia - First Burn

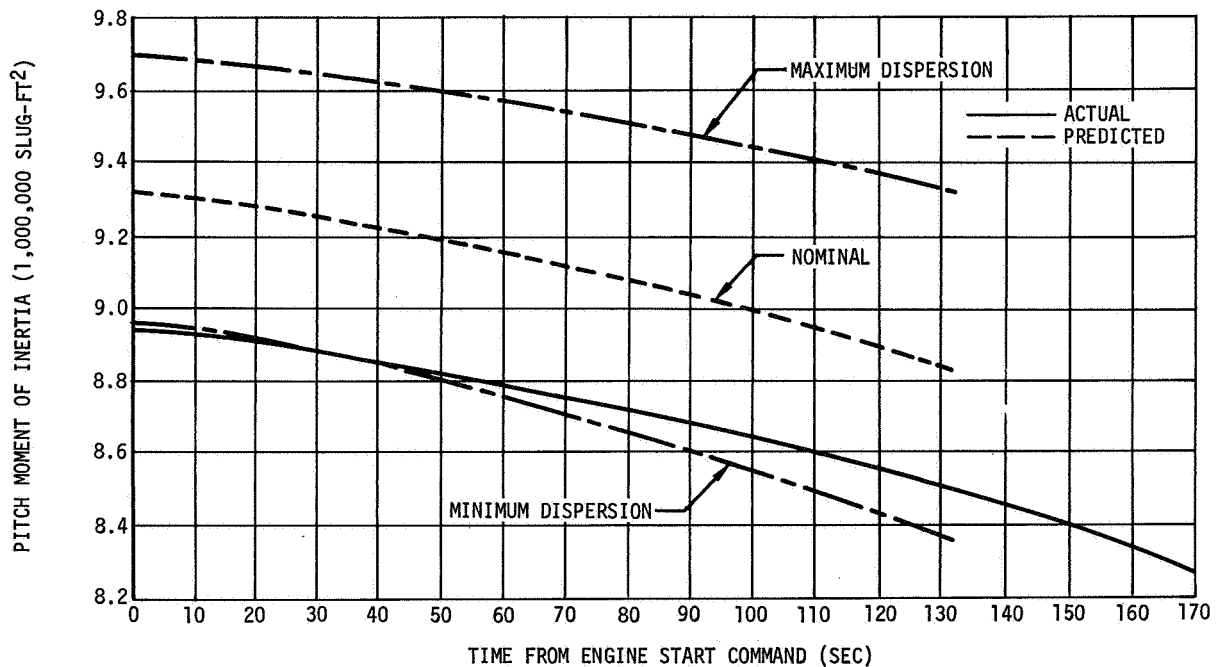
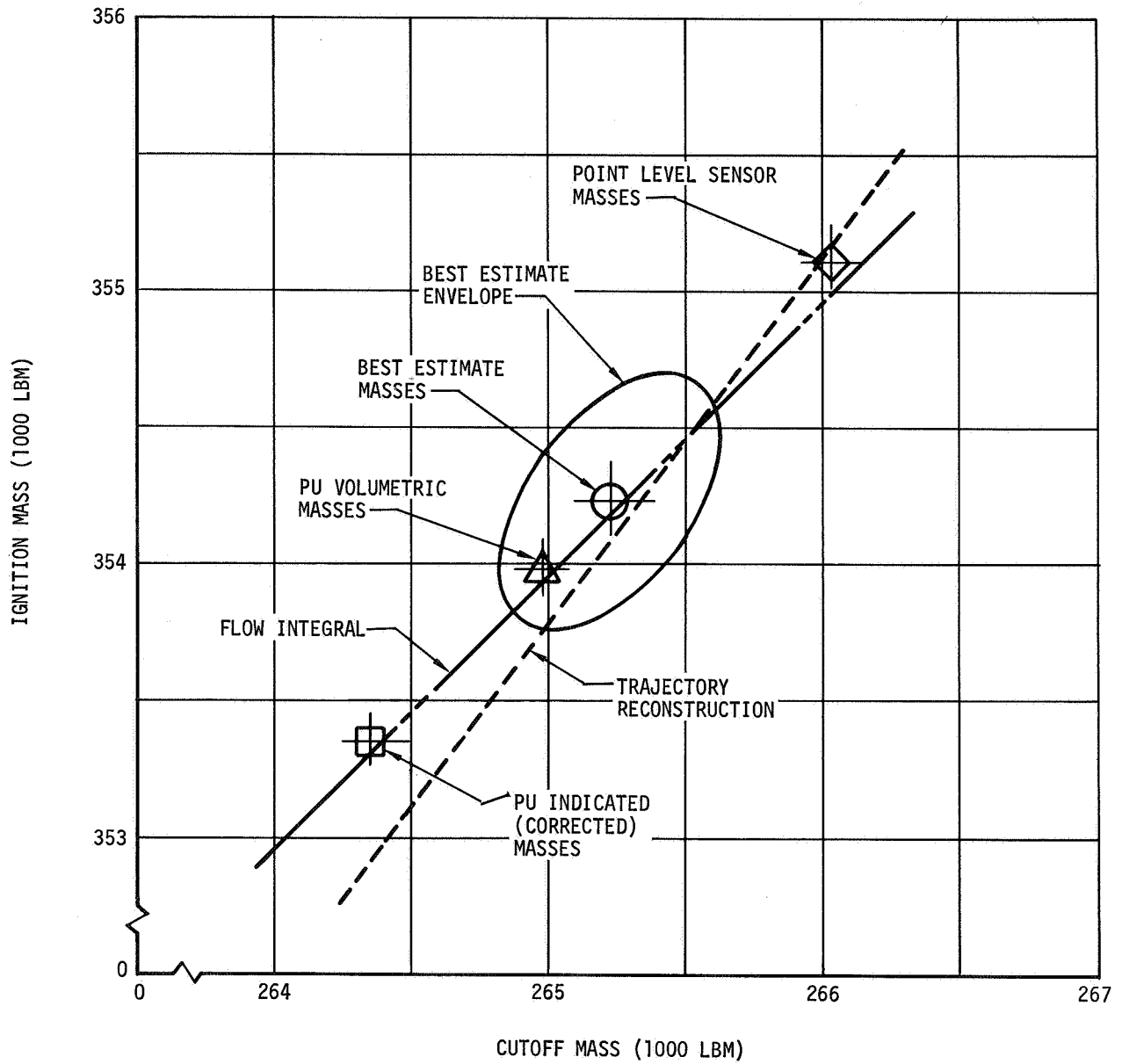


Figure 9-4. Third Flight Stage Vehicle Pitch Moment of Inertia - First Burn



AT IGNITION 354,232 \pm 476 LBM
AT CUTOFF 265,234 \pm 400 LBM

Figure 9-5. Third Flight Stage Best Estimate Masses

SECTION 10

ENGINE SYSTEM

10. ENGINE SYSTEM

The main propulsion system of the S-IVB stage of the AS-502 launch vehicle consisted of a Rocketdyne J-2 engine (S/N J-2042) shown schematically in figure 10-1, associated propellant ducting, and conditioning systems. The engine was rated at 225,000 lbf thrust. As a result of the analysis of the engine and stage acceptance tests, the following 60-sec tag values were established with the engine constants presented:

Tag Values

| | |
|----------------------------|-------------|
| Thrust | 228,980 lbf |
| Engine mixture ratio (EMR) | 5.480 |
| Specific impulse (Isp) | 424.77 sec |

Engine Constants

| | |
|--------------------------------|------------------------|
| LOX flowmeter | 5.5419 cycles/gal |
| LH2 flowmeter | 2.0270 cycles/gal |
| LOX boot strap orifice | 0.268 in. ² |
| LH2 boot strap orifice | 0.468 in. ² |
| Oxidizer turbine bypass nozzle | 1.202 in. ² |

The engine was equipped with a 0.640-sec start tank discharge valve (STDV) timer in the engine control circuit; however, actuation of the STDV, which determines the fuel lead duration, was controlled from the stage through the fuel injection temperature bypass circuit. With such control, the fuel leads were nominally 3 and 8 sec for the first and second burns, respectively.

10.1 Modifications

The engine was modified to improve restart capability. These modifications included retiming the main oxidizer valve (MOV) opening rate, reducing the augmented spark igniter (ASI) LOX orifice, and painting the crossover duct black. The stage propellant utilization (PU) system was modified to provide for a second burn engine start with the PU valve full open. A calibrated start tank vent and relief valve was installed to regulate the energy of the start tank, thereby controlling the pump spin up. Other modifications were made involving instrumentation or structures, but are not discussed here as they do not affect performance. Details of these modifications are presented in the Rocketdyne configuration report (R-5788).

10.2 Sequence of Events

Significant engine events during the S-IVB powered flight phase of the S-IVB-502 mission were as follows:

| <u>Event</u> | <u>From RO*</u> | <u>From ESC</u> | <u>Time (sec)</u> | |
|--|-----------------|-----------------|-------------------------------|------------------|
| | | | <u>Predicted From RO*</u> | <u>Deviation</u> |
| First Engine Start Command (ESC1) | 577.270 | 0.0 | 518.16 | + 59.51 |
| First Engine Cutoff Command (ECC1) | 747.036 | 169.366 | 657.12 | + 89.92 |
| Second Engine Start Command (ESC2) | 11,614.671 | 0.0 | 11,401.00 | +213.67 |
| Second Engine Cutoff Command (ECC2) | 11,630.397 | 15.726 | 11,725.56 | - 95.16 |

*Range Zero

NOTE: There are some differences in the sequence of events (section 5) and engine event times given in this section.

Engine events times are those received at the engine while the times listed in the sequence of events reflect switch selector or IU times. In addition, there is an inherent inaccuracy in both sources of data since neither is continuous.

Comparisons are made to the predicted propulsion system performance as published in memorandum M177-KKBA, dated 26 April 1968. Details of the sequence of events for the first and second starts are given in tables 10-1 and 10-2. Effects of these sequences on the start transients can be seen in figures 10-2 and 10-3.

10.3 Engine Chilldown Conditioning

10.3.1 Turbopump Chilldown

Chilldown of the engine LOX and LH2 turbopumps was adequate to provide the conditions required for proper engine start for both burns. Figure 10-4 shows the condition of the LOX pump. The pump performance is discussed in paragraph 10.5.2. The analysis and results of the chilldown operation at the engine/stage interface is presented in sections 12 and 13.

10.3.2 Thrust Chamber Chilldown

10.3.2.1 Ground Conditioning and Boost

Thrust chamber chilldown was initiated at RO -600 sec and terminated at RO -8.8 sec with a thrust chamber jacket temperature (C0199) of 241 deg R, thus satisfying the maximum allowable redline limit of 300 deg R. At first burn Engine Start Command, the temperature was 287 deg R (figure 10-5) which was within the requirement of 330 \pm 50 deg R.

For the S-IVB-502 flight, the thrust chamber conditioning time was decreased from the 15 min used for S-IVB-501 flight to 10 min, due to the lower than predicted heating during boost observed on the S-IVB-501 flight. The temperature rise rate at Engine Start Command was calculated to be 16.0 deg/min for S-IVB-502 flight and 22.5 deg/min for S-IVB-501 flight whereas the average temperature rise rate during boost was 48.5 deg R/min for S-IVB-502 flight and 54.3 deg R/min for S-IVB-501 flight.

10.3.2.2 Inflight Conditioning

Inflight conditioning of the thrust chamber is accomplished by the fuel lead which allows hydrogen to flow through the thrust chamber jacket prior to mainstage operation. The time used for this fuel lead period is defined as the time between Engine Start Command and STDV solenoid energize.

Fuel lead times were 3 and 8 sec respectively for the first and second burns. The conditions and characteristics of these fuel lead operations are summarized in table 10-3. Flight measurements are presented in figures 10-6 and 10-7.

Both fuel lead operations (first and second burns) were satisfactory. Engine performance during the fuel lead periods is presented in paragraphs 10.4.2.3 and 10.4.4.3.

10.3.3 Engine Start Sphere Chillydown and Loading

The GH2 start sphere was satisfactory at liftoff with 3.47 lbm of GH2 at 1,303 psia and 279 deg R as shown on figure 10-8. These conditions met the liftoff requirements shown in figure 10-9. Sphere conditions at liftoff are compared to S-IVB-501 flight and S-IVB-502 acceptance firing conditions in table 10-4. The sphere warmup rate from sphere pressurization to blowdown was 1.2 deg/min; the S-IVB-501 warmup rate was 0.9 deg/min. The difference between the GH2 start sphere and engine control helium sphere temperatures on S-IVB-502 and S-IVB-501 after pressurization was 27 deg R and 17 deg R, respectively. At liftoff, the respective differences had decreased to 11 and 9 deg R. The S-IVB-501 and S-IVB-502 warmup rates from pressurization to liftoff were 1.6 and 2.2 deg/min, respectively. From liftoff to sphere blowdown, the respective warmup rates were 0.6 and 0.7 deg/min. These warmup rates reflect the temperature differences before and after liftoff. From these data it can be seen that the greater warmup rate observed on S-IVB-502 was due to the greater temperature difference between the GH2 start sphere and the engine control helium sphere. This warmup rate is within the previous band of experience.

10.3.4 Engine Control Sphere Chillydown and Loading

The engine control helium sphere was satisfactorily loaded at liftoff with 1.87 lbm of helium at 2,963 psia and 290 deg R. These conditions met the liftoff requirements of 3,040 \pm 240 psia and 279 \pm 30 deg R, respectively. Control sphere performance data during loading is presented in figure 10-8. Control sphere conditions at liftoff are compared with S-IVB-501 flight and S-IVB-502 acceptance firing conditions in table 10-5.

10.4 Engine Performance

The J-2 engine did not meet all objectives during the AS-502 mission. After inserting the stage and payload into earth orbit, the engine failed to reignite for a second burn, thereby aborting the S-IVB mission. The failure was due to a rupture of the ASI feedline with possible ASI and injector damage during the first burn which prevented fuel from reaching the igniter during the second burn restart transient. The rupture allowed cold hydrogen gas to be sprayed into the thrust structure and engine area causing severe environmental changes for several components resulting in their inability to function properly. These malfunctions are discussed in the appropriate sections. All performance values were within the prediction accuracy of 1 percent prior to the rupture. The malfunction caused a performance degradation at approximately ESC +100 sec, and the 1 percent prediction limits were exceeded. As a result of this performance change and reduced performance in the lower stage, an extended first burn duration was required to achieve orbit.

Plots of selected data showing engine characteristics are presented in figures 10-10 through 10-21 for engine mainstage operation. The engine propellant inlet conditions are discussed in sections 12 and 13. The average stage performance and propellant consumption summary is presented in table 10-6.

10.4.1 Engine Performance Analysis Methods and Instrumentation

The performance of the engine start tank and helium control sphere was analyzed by applying thermodynamic relationships to the measured data. Start and cutoff transient thrust and impulse were determined by computer program PA53. Flowrates and consumption during the transients were determined by a manual count of the flowmeter cycle data. Computer program UT23A was used to investigate internal engine performance. Steady-state performance was calculated by use of computer program G105, which is considered to be the best current estimate of engine performance. The results of the G105 were also used in determining the best estimate of stage propellant consumption. Revised tag values, based on flight data, were generated by computer program G307 (Rocketdyne PAST640). A description of the program operation and a tabulation of the results is presented in table 10-7. Data inputs to the computer programs with the applicable biases are shown in table 10-8.

10.4.2 First Burn

10.4.2.1 Start Tank Performance

The engine start tank conditions at first S-IVB Engine Start Command and Engine Cutoff Command during the AS-502 flight, are shown on table 10-4. The deviations from predictions shown on table 10-9 were due to a higher than anticipated start tank temperature due to heat input from the control sphere which caused a higher flow through the relief valve thereby reducing the mass and pressure at Engine Start Command. The higher initial temperature was reflected throughout the first burn and was due to the heat transfer to the start tank from the control sphere which had not stabilized when the start tank vent was closed.

The STDV was commanded open at ESC1 +3.019 sec and the pressure decay initiated at ESC1 +3.219 sec. The blowdown was terminated by the STDV closure at ESC1 +3.821 sec. It was calculated that 2.839 lbm of GH2 were discharged during the 0.602 sec blowdown with

terminal conditions as shown on figure 10-22 at which time the start sphere began to refill with hydrogen from the fuel injection manifold and pump discharge.

A 0.055 in.² orifice in the line from the fuel pump discharge controlled the refill rate. The start sphere pressure increased to 793.4 psia at ESC1 +6.7 sec which terminated the gas portion of the refill as shown in figure 10-23. The figure also shows that, at that time, topping was initiated, which involves the flow from the fuel pump discharge only and is characterized by increasing pressure and decreasing temperature. The recharge capability of the start tank, as defined by Rocketdyne, was demonstrated (figure 10-24) at STDV +60 sec. The topping process was terminated at ESC1 +74.0 sec when the start tank pressure and pump discharge pressure were in equilibrium. The pressure and the temperature at this time were 1,185 psia and 187 deg R respectively with no further mass increase in the tank. Heat input from the system caused a temperature increase and a corresponding pressure increase along a constant mass line as shown in figure 10-22. At cutoff the start sphere pressure and temperature were 1,239 psia and 197 deg R, respectively. Cutoff conditions were within the safe engine restart envelope.

10.4.2.2 Engine Control Sphere Performance

The pressure and temperature in the engine control sphere at Engine Start Command were 3,000 psia and 288 deg R, respectively with a mass of 1.9 lbm as shown on table 10-5. Although the fuel lead time for the first burn engine start was 3.019 sec, the ignition phase control timer (0.450 ±0.033 sec) extended the period of high helium usage associated with the fuel lead to 3.480 sec which was normal. However, an additional extension of 0.65 sec was experienced due to the delay in the purge control valve closing. Delays as high as 0.7 sec have been experienced with this valve. As a result of this extension the control sphere pressure drop associated with the fuel lead was 662 psi as compared to the predicted value of 540 psi (figure 10-25). The indicated pressure drop of 1,334 psi from Engine Start Command to ECCL +1 sec was adjusted to 813 psi when the temperature was corrected to 290 deg R for comparison with specification values. The adjusted pressure was not within the required maximum ΔP (800 psi) due to the slow deactuation of the purge control valve. The performance during the first burn is also shown in figure 10-25. Consumption based on the indicated data was 0.39 lbm. However, when corrected for temperature the consumption was 0.405 lbm leaving 1.495 lbm in the sphere at orbital insertion. Barring any subsequent malfunction there was sufficient helium for the second burn.

10.4.2.3 Fuel Lead and Start Transient

Temperature and pressure data presented in figure 10-6 indicate that the first fuel lead was quite similar to AS-501. The temperature and pressures were also in close agreement with predictions. Flowrates, total flow, thrust, and impulse data in figure 10-26 were calculated using the flowmeter, temperature, and pressure data. All of these first burn fuel lead data appear normal.

The engine performance during the first burn start transient was satisfactory and is summarized in table 10-10. The thrust buildup occurred at a null PU valve position following the fuel lead. During the start transient, the PU valve position and MOV operation were satisfactory. Thrust buildup to the 90 percent performance level (STDV Command +2.5 sec by definition) was within the maximum and minimum thrust limits as shown in figure 10-27.

Thrust buildup was faster during flight than during the acceptance firing. This was largely due to the shorter first stage plateau time during MOV opening during flight. As a result of the shorter plateau time, LOX flowrate to the thrust chamber was higher during the early phases of thrust buildup during flight. The thrust and total impulse at the 90 percent performance level during flight were very similar to the S-IVB-501 flight values and were reasonably close to the log book values. They were considerably higher than the corresponding acceptance firing values due to the faster opening MOV on flight.

Figure 10-27 shows the thrust chamber pressure, the thrust buildup, and total impulse during the start transient. Figures 10-28 and 10-29 show the measured flowrates, consumptions, and pump speeds during the start transient.

10.4.2.4 Engine Steady-State Performance

Plots of selected data showing engine characteristics are presented in figures 10-10 through 10-15.

The PU valve was maintained at the full closed position during the mainstage period as planned. Burntime was 30.4 sec longer than predicted because the combined performance of both the S-II and S-IVB was much lower than expected. Although the overall performance level of the S-IVB was lower than predicted, the engine performance for the first 115 sec was satisfactory. At this time, the effects of a suspected ASI fuel line leak began to change the level of engine operation.

The significant effects of loss of fuel to the injector were to raise the mixture ratio at the injector and cause an increase in fuel injection temperature. However, the mixture ratio at the pumps did not change significantly because the leak occurred downstream of the pumps and flowmeters. Both fuel injection and fuel tank pressurization module temperatures increased 6.4 deg R and 12.5 deg R, respectively, which corresponds to a decrease in fuel flow of from 4.5 to 6 lb/sec.

At approximately ESC1 +127 sec, the engine performance began to stabilize at the lower level of operation. Chamber pressure exhibits the reduction in engine performance. A 17.5 psi drop in chamber pressure occurred due to a drop in total weight flow estimated at approximately 11.0 lb/sec, which was accomplished by a leak or combination of leaks. Gas generator (GG) performance was reduced due to the reduction in pump discharge pressures; however, the mixture ratio remained essentially constant.

Table 10-11 lists the steady-state average performance before and after the malfunction. Table 10-6 presents the average overall performance during the first burn period.

The composite values for standard altitude steady-state performance (engine tag values) with a comparison to the predicted at STDV +60 sec are shown in figures 10-30 and table 10-12.

Flow integral mass analysis indicated the following mainstage propellant consumptions by the engine during mainstage operation first burn: LOX 74,559 lbm, LH2 13,812 lbm.

Table 10-6 presents the total impulse generated during first burn mainstage operation.

Computed engine performance parameters of thrust, Isp, EMR, LOX flow, fuel flow, and total flow are shown in figure 10-31. The variation of Isp with EMR is presented on figure 10-32 which shows the performance shift.

The thrust variations from ESC1 +60 sec to engine cutoff of first burn are shown in figure 10-33. The thrust oscillations that occurred prior to and after the ASI fuel line failure are compared to the contract end item (CEI) specification in table 10-13. Prior to the failure, the thrust oscillations were within specification and would have remained so if the failure had not occurred.

The CEI specification states that if inflight engine performance shifts occur, the thrust variation limits may be exceeded, such was the case. The limits for the oscillations about mean thrust level and rate of change of thrust were exceeded due to the malfunction.

10.4.2.5 Cutoff Transient

The engine performance during the first burn engine cutoff transient was satisfactory. The time lapse between engine cutoff, as received at the engine, and thrust decrease to 11,250 lbf (5 percent of rated thrust) was within the maximum allowable time of 800 ms. Engine performance during the cutoff transient is shown in table 10-14.

The thrust decrease time during flight was greater than the log book value. This was probably due to a colder MOV actuator during flight which resulted in a longer valve closing time. First burn engine cutoff occurred with the PU valve in the closed position (high EMR).

The total cutoff impulse was greater than that of the S-IVB-501 flight and S-IVB-502 acceptance firing. This greater impulse was largely due to a colder MOV actuator temperature during the S-IVB-502 flight (282.5 deg R for -502 flight compared to 305 deg R for -501 flight). This resulted in a slower MOV closing time and increased cutoff impulse. The colder actuator temperature was most likely due to the presence of LH2 from the broken ASI line during the latter stages of first burn.

The flight total impulse can be compared to the log book value by adjusting the flight values to standard conditions (null PU valve position and 460 deg R MOV actuator temperature). The adjusted flight total impulse was in good agreement with the log book value. This indicated that the higher cutoff impulse during flight was due to the higher cutoff thrust and colder MOV actuator temperature during flight as compared to the nominal log book conditions.

The cutoff impulse to zero thrust as computed from MSFC trajectory data was 67,600 lb/sec as compared to a value of 59,376 lb/sec from engine analysis. The trajectory value exceeds the predicted three-sigma maximum cutoff impulse (66,350 lb/sec). This discrepancy remains unexplained as of this writing, but Douglas has a higher degree of confidence in the value derived from engine analysis which has been subjected to review and verification by Douglas.

Figure 10-34 shows the thrust chamber pressure, the thrust decrease, and total impulse during the cutoff transient. Figure 10-35 compares the velocity gain during the cutoff transient as computed by engine analysis and trajectory analysis with the predicted velocity gain.

Approximately 15 sec after first burn Engine Cutoff Command, a 25 psi spike was observed at the fuel pump discharge as shown in figure 10-34. A pressure rise was also manifested in the fuel pump interstage outlet pressure, fuel pump inlet pressure, and fuel pump balance piston cavity pressure. The fuel pump discharge temperature showed a corresponding rise. The most probable cause of the pressure spike was the sloshing or flow of liquid to the still spinning fuel pump from the main fuel supply. The magnitude of the pressure rise is a function of the opening time of the fuel bleed valve which allows the trapped gas at the pump discharge to relieve back to the fuel tank. This allows fuel to flow into the pump again, causing the rise in pump discharge pressure.

This phenomenon has been observed during several tests during the Arnold Engineering Development Center (AEDC) test series with both prevalues open and closed following engine cutoff. Present predicted maximum pressure rises at the pump discharge are expected to be 2,400 psi. Tests are currently underway at the AEDC facility to identify the magnitude of the pressure in the bleed return line with special instrumentation. The stage low pressure line is rated at approximately 100 psi; however, the bleed valve and associated hardware resistance may be sufficient to reduce the pressure to a safe level.

An increase in fuel turbine inlet temperature of approximately 90 deg was noted immediately after engine cutoff. This rise in temperature was attributed to a lack of GG purge, which is normally required 7 sec prior to engine cutoff. The purge was not supplied to the engine until 1 sec before cutoff because of instrument unit (IU) difficulty resulting from unexpected stage maneuvers as the required cutoff velocity was approached. The magnitude of the temperature rise was not great enough to cause any hardware damage, and the temperature returned to cutoff level within 20 sec.

10.4.3 First and Second Orbits

10.4.3.1 Start Tank Performance

Figure 10-36 shows a relatively large temperature change at Engine Cutoff Command with very little pressure change which is impossible without a corresponding mass loss. A similar deviation has been noted on AS-203 and AS-501. The resultant analysis concluded that, in the zero g environment, heat transfer becomes very localized because of the lack of free convection. Therefore, the location, installation technique, and type of transducer indicate that the start sphere temperature measurements during orbital coast are not

accurate; however correct interpretation of the data can now be made based on S-IVB-502 and previous flight experience. The pressure measurement can be used to obtain the temperature up to relief setting because the bottle mass is constant. Also, the temperature after the second burn start tank discharge (STD) should be valid due to convective currents set up by the blowdown. The temperature is assumed to be linear between the initiation of venting and second burn STD.

The anticipated temperature rise rate during orbital coast was 0.54 deg/min with a corresponding 2.3 psi/min pressure rise rate. With such rates the relief setting (1,290 psia) of the vent and relief valve would be reached at ECC1 +14 min. The actual relief time was ECC1 +23 min resulting from a mean pressure rise rate of 3.5 psi/min, which corresponds to an isochoric temperature rise rate of 0.561 deg/min compared to the indicated temperature rise rate of 2.5 deg/min. The vent and relief valve did not respond as predicted during orbit maintaining the pressure at 1,320 psia instead of 1,290 psia. This was apparently the effect of the environment change during the first burn and of the orbital maneuvers which varied the heat input into the start tank. The vehicle attitude experiment did not show any appreciable change in start bottle performance.

During the S-IVB-502 orbital coast (181 min) an estimated 0.87 lbm of GH2 was vented through the relief valve to maintain the pressure as indicated on figure 10-36.

10.4.3.2 Control Sphere Performance

The same environmental conditions which affect the start tank temperature effect the control sphere temperature to a lesser degree. The rate of increase agrees well with the predicted as shown on figure 10-37. The pressure and temperature data and temperatures calculated by using perfect gas laws are also shown on figure 10-37. There was no indication of leakage.

10.4.4 Second Burn

10.4.4.1 Start Tank Performance

The engine start sphere conditions, at Engine Start Command and Engine Cutoff Command during the AS-502 flight second burn, are shown on table 10-4. The deviations from normal after the blowdown were due to the malfunction which prevented the start tank from refilling.

The STDV was commanded open at ESC2 +8.007 sec and the pressure decay initiated at ESC2 +8.215 sec. The blowdown was terminated by STDV closure at ESC2 +8.800 sec. Approximately 3.17 lbm of GH2 were discharged during the 0.585 sec blowdown with the terminal conditions as shown on figure 10-38. The start sphere blowdown provided a turbine spin satisfactory for mainstage initiation. The lack of ignition in the thrust chamber prevented a successful mainstage and, although not required, the start tank did not refill as expected.

10.4.4.2 Control Sphere Performance

The pressure and temperature in the engine control sphere at Engine Start Command were 1,918 psia and 247 deg R, respectively, with a mass of 1.48 lbm as shown in table 10-5 and figure 10-39. Although the fuel lead time for the second burn start was 8 sec, the ignition phase timer (0.450 ± 0.033 sec) extended the period of high helium consumption associated with the fuel lead to 8.457 sec as anticipated. The fuel lead pressure drop was 740 psi as compared to a predicted value of 800 psi. Because of the failure to restart, comparisons with the prediction during mainstage were not possible; however, the cutoff usage was normal. The pressure profile is shown on figure 10-40.

10.4.4.3 Restart Attempt

The engine did not meet all objectives as second ignition failed to occur. Plots of selected data are presented in figures 10-16 through 10-21.

Second burn fuel lead measurements presented in figure 10-7 appear normal with two exceptions. Injector fuel temperature decreased somewhat faster than was expected and the injector fuel pressure measurement was lower than expected. Fuel injector pressure measurement (D0004) appeared to be erratic during the second burn fuel lead, as compared to D0104 which measures the pressure of the hydrogen bled from the engine for LH2 tank pressurization. These two pressure measurements usually correlate very well and analyses indicate that the tap off pressure was correct. The unusual reading of D0004 following the malfunction may have been caused by injector damage resulting from the ASI line failure discussed in paragraph 10.4.5.

Fuel lead thrust was determined from accelerometer measurement (A0006), and injector fuel pressure was calculated as a check on the validity of this measurement. The resulting pressure schedule is shown in the figure. Since the pressure calculated in this manner correlates reasonably well with the chilldown rates experienced and with the AS-501 chilldown, it is assumed to be valid.

The exceptionally rapid chilldown rate indicated in figure 10-8 is not greatly different than that during AEDC testing. The small differences in chilldown rates are logical considering the differences in bulk temperature and thermal distribution between test and flight. In addition, the possible effects of a general chilling of the area that could occur with an overboard hydrogen leak and a lack of combustion in the ASI are both indicative of an accelerated chilldown.

Second burn flowrates and fuel consumption thrust and total impulse are shown in figure 10-41 for the fuel lead. These are based on flowmeter (F0002) and temperature and pressure measurements. Injector pressure calculated from accelerometer data was used to calculate injector flow and engine thrust. Thrust, specific impulse and engine mixture ratio are shown in figure 10-41 also for the remainder of the restart attempt.

The S-IVB provided adequate conditioning of propellants to the J-2 engine for the restart attempt as discussed in sections 12 and 13. The engine start sphere was recharged properly and maintained sufficient pressure during coast. Although the engine control sphere gas usage was greater than predicted during the first burn, the sphere maintained sufficient system pressure for a proper restart.

All monitored events occurred as required and performance was as predicted until the end of the start bottle blowdown which occurred at approximately ESC2 +8.5 sec. At this time the main engine chamber pressure should have increased with opening of the MOV, and the GG should bootstrap to mainstage operation. However, the main engine chamber pressure did not rise and lack of ignition was indicated by the lack of increase in fuel injector temp C0200 (figure 10-20). The GG was ignited as shown by C0001 (figure 10-21). The temperature rose (see paragraph 10.5.4) just prior to Engine Cutoff Command and the GG chamber pressure increased slightly. This fact plus the absence of any unexplained vehicle moment during second burn suggests that the temperature spike did not burn through the GG combustor wall and that the GG performed satisfactorily.

The start bottle did not recharge due to a lack of system pressure buildup. Engine operation was terminated by instrument unit monitor of the mainstage OK pressure switches.

10.4.5 Malfunction Analysis

10.4.5.1 Failure to Restart

Failure to restart the engine was the major result of the malfunction that occurred during the flight. Proper electrical power was applied to the spark plugs but no ignition occurred. The subsequent failure of the IU to detect the mainstage pressure switch OK signal resulted in engine cutoff.

A failure of this type could only have occurred as a result of two possible malfunctions: (1) The destruction of both spark plugs due to an overtemperature in the ASI chamber which could have resulted from a flow reversal, or from an ASI fuel feedline anomaly which restricted fuel flow to the ASI chamber causing a high mixture ratio and thus extreme temperatures in the chamber shown schematically on figure 10-42; (2) A lack of one or both propellants in the ASI chamber. Since the start system has two independent spark exciters and igniters, a double failure would have been necessary to prevent ignition. A break in the LOX and/or ASI fuel lines was, therefore, considered most likely.

10.4.5.2 First Burn Anomalies

Investigation of pertinent parameters during first burn indicated deviations from normal operation as early as ESC1 +63 sec. Small leaks in the ASI lines, however, may actually have occurred earlier when abnormal engine vibration data was measured at ESC1 +20 sec.

10.4.5.3 Engine Abnormal Vibration

Abnormal engine vibration was indicated by the accelerometer data during first burn. The sensor on the LOX dome (E0209), failed completely at approximately RO +700 sec. The LOX pump exhibited normal vibrations (E0211) but shortly after engine start (ESC +20 sec), the LH2 pump vibration (E0210) indications deviated from normal (section 18). At approximately ESC1 +120 sec, the LH2 pump vibration indication returned to normal for the remainder of first burn. The abrupt changes in vibration indication levels appeared to correspond to engine temperature changes and engine performance levels; however, fuel pump performance was normal as discussed in paragraph 10.5.2. Sections 18 and 25 discuss the vibration effects.

10.4.5.4 Environment Temperatures

The engine area environmental temperature measurements indicated a malfunction as follows:

- a. A cooling trend began to appear at approximately RO +610 sec indicating a cryogenic fluid leak.
- b. A rapid heating trend was observed from RO +695 to RO +700 sec indicating that hot gas was escaping.
- c. After RO +700 sec, a general net cooling trend was again noted in the engine area.

These general trends are shown by a great number of environment temperature measurements. Some of them began showing cooling trends as early as RO +610 sec while some did not show any cooling until approximately RO +680 sec. At approximately RO +695 sec, most of the temperatures rose rapidly until approximately RO +700 sec and then began cooling again.

The GG fuel inlet line wall temperature indicates that the initial cold leak was probably a cryogenic fuel leak because of the temperature drop from 58 to 50 deg R. A temperature reduction at this level could not have been caused by expanding LOX because the temperature was too low. The discussion of the engine performance also points out the malfunction was most probably a failure of the ASI fuel line. Additional discussions of the engine area environment can be found in the thermodynamics section (section 26) of this report.

A few of the temperature measurements during the restart attempt indicated that a leak was present. At the end of fuel lead the thrust structure temperature and the engine main LOX pneumatic line surface temperature show cooling trends which are not normal. Also the gas generator fuel inlet line wall temperature shows a decrease immediately after the second burn Engine Start Command.

No leaks were indicated during the orbital coast period. Also, the roll maneuver during the orbital coast apparently had little effect on any temperatures. The changes in temperatures correlate with entering and leaving the shadow of the earth.

The location of each engine area environment temperature sensor is shown on figure 10-43 and the range is given in table 10-15. This table contains a detailed description of the temperatures and is supported by figures 10-43 through 10-53. The temperature measurements are discussed for the first burn, orbital coast, and second burn periods and are compared to AS-501 data where possible.

10.4.5.5 Engine Parameters

10.4.5.5.1 Fuel Lead

Figures 10-54 and 10-55 present special data particularly relevant to the engine failure that occurred during the first burn. This failure also apparently resulted in the failure of the engine to progress into mainstage operation during the restart attempt.

The figure shows the amount of hydrogen existing between the flowmeter and the injector plotted against injector temperature and against fuel lead time. Examination of this figure shows a degree of correlation between AS-501 and AS-502 first burns.

The second burn does not correlate as well. The AS-502 second burn shows a progressively increasing difference in the quantity of fuel in the thrust chamber compared to that in AS-501. Since AS-501 chilled only to 165 deg R, an extrapolation, shown by the dotted line in figure 10-54, is required to project this characteristic to a fully chilled condition. This curve shows that in the AS-502 chilldown, approximately 13.5 lbm of fuel existed in the thrust chamber at the time the fuel injection temperature reached 40 deg R. A quantity of 10.5 lbm is indicated for AS-501.

If similar conditions are assumed, this difference indicates that 3 lbm of hydrogen leaked from the system between the flowmeter and the injector during this period. This would be an average flowrate of 0.375 lbm/sec during the 8-sec fuel lead. A leakage rate of this magnitude projects, on the basis of percent average total fuel flowrate, to a mainstage leakage rate in the order of 8.6 lbm/sec. This flowrate is compared to the 2 to 11 lbm/sec leakage rate calculated for mainstage operation as discussed in paragraph 10.4.2.4.

Another indication of possible hydrogen leakage based entirely on flowmeter (F0002) data is given in figure 10-55 which shows that AS-502 used considerably more propellant than AS-501. However, it should be pointed out that AS-501 did not chill completely. Therefore some additional amount of propellant, possibly the amount shown by the dotted line in figure 10-54, should be allowed to complete the AS-501 chilldown. The thrust, engine mixture ratio (EMR), and specific impulse (Isp) that occurred between Engine Start Command and the IU commanded cutoff are also shown in the figure. It should be noted that thrust calculated from accelerometer data (A0006) correlates well with thrust calculated from chamber pressure (D0001). The specific impulse during fuel lead (the first 8 sec) was calculated from flowmeter and accelerometer thrust data. The specific impulse values shown are reasonable for a two-phase flow condition during this time. EMR is based entirely on flowmeter (F0001 and F0002) data.

10.4.5.5.2 Mainstage

The major engine parameter indicating the failure was the chamber pressure which began to drop noticeably at ESC1 +107 sec. The exact time was not distinguishable because a pressurization cycle was present at the time. A plot of chamber pressure corrected to exclude the effects of helium pressurization is presented in figure 10-56 which shows an initial decrease of 4 psia between ESC1 +107 and ESC1 +115 sec and a subsequent 12 psia drop during the following 10 sec. The reduction in measured chamber pressure, as indicated on figure 10-10 was validated by correlation with other major engine parameters. At the same time negligible changes were noted in the measured oxidizer and fuel flowrates (figure 10-12) indicating that a propellant loss had occurred at some point downstream of the flowmeters and upstream of the main chamber.

A second major indication of the malfunction can be seen in the fuel tank pressurization control module temperature data (figure 10-57). At ESC1 +50 sec the temperature began to deviate from the expected profile, resulting in a deviation of +4.5 deg R at ESC1 +118 sec. The deviation increased sharply to +12.5 deg R and remained at that value until engine cutoff. An increase of 7 to 10 deg R was also exhibited by the fuel injection temperature; however, this transducer had a much larger range and the control module temperature is considered more accurate. The control module temperature may be high, however, due to additional heatup in the line between the fuel injection and the module transducers.

Indications of the performance shift resulting from the malfunction are seen in most engine parameters and are discussed in the steady-state performance paragraph 10.4.2.4.

The initial 4 psi drop in chamber pressure and the subsequent 12 psi decrease, totaling 16 psi, corresponds to a flowrate decrease through the combustion chamber throat of approximately 11 lbm/sec.

The hydrogen pressurization module temperature which was 12.5 deg R higher than expected indicated that there was a 7 lbm/sec decrease in fuel flow through the engine thrust chamber tubes.

As ESC1 +115 sec the fuel flowrate, as shown by the LH2 flowmeter, increased approximately 0.3 lbm/sec. This indicates a decrease in flow resistance, downstream of the flowmeter. At approximately the same time, the LOX flowrate appeared to decrease 1 lbm/sec.

In order to verify the failure reconstruction, the summation of the flow losses must equal the decrease in engine flowrate as a result of the observed drop in chamber pressure. The various losses associated with a broken ASI fuel line are presented below and in table 10-14.

- a. As shown in figure 10-58 the loss of fuel from a broken ASI fuel line can vary from 2 to 11 lbm/sec, depending on the break location. The most likely point for the break would be in the vicinity of one of the three flex hose sections, probably at the first flex, resulting in a flow loss of 6 lbm/sec. This agrees within 1.0 lbm/sec of the fuel loss indicated by the increase in the fuel pressurization module temperature.

- b. An additional loss would result from the backflow of propellants and/or combustion gases from the combustion chamber. The flow is difficult to predict since injector erosion probably occurred and the temperature in the ASI chamber and degree of mixing cannot be determined. The range of flow, however, is approximately 0.1 to 1.5 lbm/sec.
- c. As mentioned previously the fuel pump flowrate increased and the LOX pump flowrate decreased.
- d. The final malfunction, which would lead to a loss of gas flow through the engine throat, is a burnthrough in the ASI chamber. The exact magnitude of the loss would, of course, depend on the severity of the erosion.

Considering all the propellant losses that would result from an ASI fuel line failure (table 10-16), it appears that a net loss between 2.8 and 13.2 lbm/sec is possible. The actual loss of 11 lbm/sec, indicated by the decrease in chamber pressure, is well within the range. The expected net loss if 7.7 lbm/sec, 3.2 lbm/sec lower than actual, which indicates that the ASI burned through and the main injector was eroded. The additional loss could result from combustion gases flowing through a hole less than 1 in.² of effective area.

10.4.5.6 Rocketdyne Failure Simulation

A J-2 engine was calibrated to match the engine used on the S-IVB. The S-IVB-502 failure was then simulated with this engine by slowly reducing the fuel flow to the ASI and then completely bypassing the fuel flow, thus simulating a leak and a subsequent break in the ASI fuel line. The engine was allowed to run for 29 sec following the elimination of fuel flow to the ASI. As a result the main injector was eroded, the ASI chamber was burned through, and the ASI fuel line was burned away along with the spark plug cable. This proved that the ASI could be burned through and severe engine damage caused by a fuel starvation to the ASI. The ASI LOX line was not damaged in the test, and thus helped to substantiate the theory that it had not broken during the flight.

A performance shift similar to that seen during the first burn of S-IVB-502 was noted, thus demonstrating that an ASI fuel line failure was responsible for producing effects seen on S-IVB-502.

Component testing on the upper flex section of the ASI line has been conducted at nominal ASI engine flowrates (0.8 to 1.2 lbm/sec). It has been demonstrated that these bellows sections can fail at near operational flowrates due to resonance under certain conditions. The precise conditions required to establish the resonant conditions are related to the bellows construction, internal flowrate, and external environment as well as installation configuration.

Results to date indicate the following:

- a. Bellows supplied from two independent sources resonate at different flowrates. The configuration installed on S-IVB-502 was of the type most susceptible to resonance.
- b. Fatigue failures have been demonstrated in short periods at operational flowrates in a vacuum environment.

- c. External environment such as air can provide enough damping due to liquefaction within the convolutions to preclude a fatigue failure that might have occurred in a vacuum under the same internal flowrates.

10.4.5.7 Suspected Failures

Suspected engine failures are as follows:

- a. The spark plugs were suspected of being damaged by an overtemperature in the ASI chamber due to a leak in the ASI fuel line. This may have been the case; however, an ASI fuel line leak would not account for the high propellant loss encountered.
- b. The two-stage increase in the fuel tank pressurization control module temperature strongly indicates that the ASI fuel line leaked for 68 sec and then broke completely at ESC1 +118 sec. A leak from the ASI fuel line would have reduced flow to the ASI resulting in an increase in the mixture ratio in the ASI chamber along with the temperature.
- c. An ASI LOX line failure is considered a possibility because this alone or in conjunction with an ASI fuel line failure would have prevented restart. However, a break in the line upstream of the orifice would have resulted in a LOX loss which, in addition to the fuel loss, would have produced a net loss much greater than that experienced. Although a break downstream of the orifice is feasible, the line should not be subject to failure since it is a relatively short line with no flexible sections.
- d. High temperatures in the ASI chamber may have induced internal erosion and possible damage to main engine LOX and fuel injectors, other adjacent engine hardware, and the ASI injector and body. A burnthrough could, therefore, have occurred leading to the loss of combustion gases and propellants from the main chamber.

10.4.5.8 Most Probable Failure

Environment temperatures and engine parameters indicate that the failure occurred as follows: During first burn a leak developed in the ASI fuel line. The leak increased with time resulting in a decrease in fuel flowrate to the engine and ASI chamber. This resulted in a decreasing chamber pressure and an increase in ASI mixture ratio until the pressure at the break decreased to a point where backflow could occur. At this time the ASI fuel line was severed and the flowrate to the engine decreased markedly. The ASI and main injector probably suffered erosion and burnthrough, allowing LOX from the ASI feed, propellants from the main injectors, and chamber gases from the injector face, to flow out. After the initial outflow of hot gases from the ASI chamber, a net cooling trend was apparent in environmental temperature. It is therefore concluded that hot gases from the combustion chamber were being cooled by mixing with the ASI LOX and possibly the injector-supplied fuel entering the ASI chamber. They then expanded into a vacuum environment already being cooled by fuel from the broken ASI line, and an effective cooling trend was established. The temperature of the escaping gases is difficult to determine since the degree of injector erosion is impossible to predict. The extent of any burnthroughs in the ASI can, likewise, not be predicted.

10.4.5.9 Corrective Action

Redesign of the ASI fuel line to a rigid 1/2 in. diameter, one piece, butt welded unit has been initiated and will be installed on future flight vehicles. The ASI LOX supply line has likewise been redesigned with the orifice moved to the ASI LOX valve flange. Analytical studies and tests have been made on all critical bellows installations in the engine to determine their susceptibility to failure.

10.5 Component Operation

10.5.1 Main LOX Valve

The main LOX valve performed satisfactorily during the first burn period and the restart attempt as indicated in table 10-17 and figure 10-59. The flight data acquisition accuracy of ± 85 ms is considered to be responsible for the apparent deviation of the flight values from the acceptance firing values. This accuracy level is the result of the 10 sample/sec data sampling rate.

The engine MOV actuator skin temperature (G2003) began to decrease at ESC1 +62 sec. This lowered actuator temperature is attributed to the ASI fuel line failure and subsequent LH2 cryogenic spray. The effect of this lower MOV temperature is discussed in paragraph 10.4.2.3.

10.5.2 Pumps and Turbines

The LH2 pump performance was satisfactory during the first burn start transient and the restart attempt with no indication of stall (figure 10-60). These data indicate that both thrust chamber chilldown operations were adequate to prevent excessive fuel pump back pressure. Further information on the chilldown operation and GSE supply system is presented in sections 6, 12, and 13.

The performance of the LH2 and LOX pumps and turbines was satisfactory during the first burn and the restart attempt. Pump speeds, discharge pressures, and temperatures, responded to perturbations and to engine inlet conditions as expected. Pressure and temperature increases across the pumps were satisfactory.

10.5.3 PU Valve

The PU valve control during first burn was as expected. Engine start occurred with the PU valve in the null position (5.0 EMR). At ESC1 +8 sec, PU Activate Command was given, and the valve moved to the full closed position (5.5 EMR) in approximately 1 sec, as predicted. The valve maintained the full closed position for the remainder of the first burn. A history of the valve position is shown in figure 10-11.

Prior to second burn Engine Start Command the PU valve was positioned in the full open position (4.5 EMR) and remained there until PU activate time (ESC2 +13 sec).

After system activation at ESC2 +13 sec, the valve moved to the LOX-rich (high EMR) position as shown on figure 10-17 due to the PU system malfunction as discussed in section 15.

10.5.4 Gas Generator

The GG performance was satisfactory during both the first burn and the restart attempt. The GG performance was noted to shift at the time of the ASI fuel line failure (ESCI +115 sec). At this time the GG chamber pressure was observed to decrease approximately 20 psi because of the decreased LOX and fuel pump discharge pressures associated with the powering down effect of the ASI fuel line failure (figure 10-61).

During the start of the second burn, the GG temperature spiked (as indicated by the fuel turbine inlet temperature bulb), to 2,300 deg R, the upper limit of the temperature bulb, but an expanded plot of fuel turbine inlet temperature suggests the spike actually reached as high as 2,500 deg R. The spike resulted from a high start mixture ratio in the GG which in turn was caused by the failure of the main chamber pressure to rise above the 40 psia idling pressure it reached during the second burn. With a low main chamber pressure, most of the flow destined for the GG follows the lower pressure drop path to the main chamber, resulting in a low GG total flowrate. However, because the start load of the oxidizer pump is lower than that of the fuel pump, the initial oxidizer flow is less affected than the fuel flow. Thus, as noted in figures 10-21 and 10-61, the GG chamber pressure, a function of both total flowrate and mixture ratio, is low; whereas, the fuel turbine inlet temperature, a function only of GG mixture ratio, is high.

At Engine Cutoff Command, the GG chamber pressure was observed to rise slightly. This fact plus the absence of any unexplained vehicle moment during second burn provides evidence that the temperature spike did not burn through the GG chamber wall.

10.5.5 Engine Drive Hydraulic Pump

The engine-driven hydraulic pump performed satisfactorily during the first burn. The average power required by the pump was 4.67 hp. The auxiliary and main hydraulic pumps failed during and preceding second burn due to cavitation resulting from frozen hydraulic fluid believed to have been a result of the cryogenic leak that occurred during the first burn. A comprehensive analysis of the hydraulic system performance can be found in section 22.

10.6 Powered Flight Simulated Trajectory Evaluation

Using a five-degrees-of-freedom trajectory simulation program, propulsion system parameter histories were adjusted so that an S-IVB trajectory could be generated to closely match the observed trajectory (appendix 5). The simulation program employed uses a differential correction technique which determines the necessary adjustments to thrust and weight flow from the engine analysis and pitch and yaw/engine thrust misalignment angles from the control system analysis to match the observed trajectory. These adjustments were determined by minimizing in a least-squares sense the weighted differences in altitude, earth-fixed velocity, earth fixed velocity azimuth angle, and inertial acceleration between the observed and simulated trajectories.

To obtain a match of the observed trajectory it was necessary to adjust the level of the weight flow and to make separate adjustments to the levels of thrust before and after the performance shift. This is discussed more fully in paragraph 8.4. The weight flow determined by engine analysis was decreased by 0.11 percent. The thrust was increased by 0.30 percent before the performance shift and by 1.41 percent after the performance shift. The corresponding adjustments to the specific impulse were an increase of 0.49 percent before the performance shift and 1.27 percent following the performance shift. The averages of thrust, weight flow, and specific impulse from 90 percent thrust to Engine Cutoff Command were adjusted by +0.56 percent, -0.11 percent, and +0.67 percent, respectively, from the values determined by engine analysis. These averages are compared with predicted and engine analysis values in paragraph 8.4.

Section 10
Engine System

TABLE 10-1 (Sheet 1 of 2)
FIRST BURN ENGINE SEQUENCE

| CONTROL EVENTS | | CONTINGENT EVENTS | | NOMINAL TIME FROM SPECIFIED REFERENCE | ACTUAL TIME (ms) | |
|------------------|--|-------------------|---|---------------------------------------|------------------|--------------------------|
| MEAS NO. | EVENT AND COMMENT | MEAS NO. | EVENT AND COMMENT | | FROM ESC | FROM SPECIFIED REFERENCE |
| K0021 (K0021) | *Engine Start Command P/U | | | 0 | 0 | 0 |
| | | K0007 (K0531) | Helium Control Solenoid Enrg P/U | Within 10 ms of K0021 | 0 | 0 |
| | | K0010 (K0454) | Thrust Chamber Spark on P/U | Within 10 ms of K0021 | 011 | 011 |
| | | K0011 (K0455) | Gas Generator Spark on P/U | Within 10 ms of K0021 | 011 | 011 |
| | | K0006 (K0535) | Ignition Phase Control Solenoid Enrg P/U | Within 20 ms of K0021 | 020 | 020 |
| | | K0126 (K0558) | LOX Bleed Valve Closed P/U | Within 130 ms of K0007 | 068 | 068 |
| | | K0127 (K0557) | LH2 Bleed Valve Closed P/U | Within 130 ms of K0007 | 151 | 151 |
| | | K0020 (K0627) | ASI LOX Valve Open P/U | Within 20 ms of K0006 | 112 | 092 |
| | | K0119 (G0506) | Main Fuel Valve Closed D/O | 60 \pm 30 ms from K0006 | 072 | 052 |
| | | K0118 (G0506) | Main Fuel Valve Open P/U | 80 \pm 50 ms from K0119 | 095 | 023 |
| K0021 (K0021) | **Engine Start D/O | | | Approx 3200 ms from K0021 P/U | 3201 | 3201 |
| K0096 (K0536) | †Start Tank Disc Control Solenoid Enrg | | | 3,000 \pm 40 ms from K0021 P/U | 3019 | 3019 |
| | | K0123 (G0508) | Start Tank Disc Valve Closed D/O | 100 \pm 20 ms from K0096 | 3162 | 153 |
| | | K0122 (G0508) | Start Tank Disc Valve Open P/U | 105 \pm 20 ms from K0123 | 3245 | 083 |
| K0005 (K0538) | Mainstage Control Solenoid Enrg | | | 450 \pm 30 ms from K0096 | 3480 | 461 |
| | | K0096 (K0536) | Start Tank Disc Control Solenoid Enrg D/O | 450 \pm 30 ms from K0096 | 3469 | 450 |
| | | K0121 (G0507) | Main LOX Valve Closed D/O | 50 \pm 20 ms from K0005 | 3570 | 090 |
| | | K0116 (G0509) | Gas Generator Valve Closed D/O | 140 \pm 10 ms from K0005 | 3571 | 091 |
| | | K0122 (G0508) | Start Tank Disc Valve Open D/O | 95 \pm 20 ms from K0096 | 3612 | 143 |
| | | K0117 (G0509) | Gas Generator Valve Open P/U | 50 \pm 30 ms from K0116 | 3698 | 127 |
| | | K0124 (G0510) | LOX Turbine Bypass Valve Open D/O | | 3720 | |
| | | K0123 (G0508) | Start Tank Disc Valve Closed P/U | 250 \pm 40 ms from K0122 | 3821 | 209 |

(K0XXX) Actual number from acceptance firing event recorder.

*Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 \pm 30 ms timer which controls energizing of the start tank discharge solenoid valve (K0096).

**This signal drops out after a time sufficient to lock in the engine electrical.

†An indication of fuel injection temperature of -150 \pm 40 deg F (or simulation) is required before this command will be executed. This command also actuates a 450 \pm 30 ms timer which controls the start of mainstage.

P/U - Pickup D/O - Dropout

TABLE 10-1 (Sheet 2 of 2)
FIRST BURN ENGINE SEQUENCE

| CONTROL EVENTS | | CONTINGENT EVENTS | | NOMINAL TIME FROM SPECIFIED REFERENCE | ACTUAL TIME (ms) | |
|----------------|--|-------------------|---|---------------------------------------|------------------|--------------------------|
| MEAS NO. | EVENT AND COMMENT | MEAS NO. | EVENT AND COMMENT | | FROM ESC | FROM SPECIFIED REFERENCE |
| | | K0125 (G0510) | ^{††} LOX Turbine Bypass Valve Closed P/U | | 3944 | |
| K0158 (K0572) | Mainstage Press Switch #1 Depress D/O | | | | 4850 | |
| K0159 | Mainstage Press Switch #2 Depress D/O | | | | 4919 | |
| | | K0120 (G0507) | Main LOX Valve Open P/U | 2,435 \pm 145 ms from K0005 | 5660 | 2180 |
| | | K0010 (K0454) | Thrust Chamber Spark on D/O | 3,300 \pm 200 ms from K0005 P/U | 6745 | 3265 |
| | | K0011 (K0455) | Gas Generator Spark on D/O | 3,300 \pm 200 ms from K0005 P/U | 6745 | 3265 |
| K0013 (K0522) | Engine Cutoff P/U (New time reference) | | | 0 | 0 | 0 |
| | | K0005 (K0538) | Mainstage Control Solenoid Enrg D/O | Within 10 ms of K0013 | 002 | 002 |
| | | K0006 (K0535) | Ignition Phase Control Solenoid Enrg D/O | Within 10 ms of K0013 | 018 | 018 |
| | | K0020 (K0622) | ASI LOX Valve Open D/O | | 087 | |
| | | K0120 (G0507) | Main Oxidizer Valve Open D/O | 50 \pm 15 ms from K0005 | 109 | 107 |
| | | K0117 (G0509) | Gas Generator Valve Open D/O | 75 \pm 25 ms from K0006 | 145 | 127 |
| | | K0118 (G0506) | Main Fuel Valve Open D/O | 90 \pm 25 ms from K0006 | 167 | 149 |
| | | K0121 (G0507) | Main Oxidizer Valve Closed P/U | 120 \pm 15 ms from K0120 | 235 | 126 |
| | | K0116 (G0509) | Gas Generator Valve Closed P/U | 500 ms from K0006 | 217 | 199 |
| | | K0119 (G0506) | Main Fuel Valve Closed P/U | 225 \pm 25 ms from K0118 | 419 | 252 |
| K0158 (K0572) | *Mainstage Press Switch A Depress P/U | | | | 233 | |
| K0159 (K0573) | Mainstage Press Switch B Depress P/U | | | * | 233 | |
| K0007 (K0531) | Helium Control Solenoid Enrg D/O | | | 1,000 \pm 110 ms from K0013 | 999 | 999 |
| | | K0125 (G0510) | Oxidizer Turbine Bypass Valve Closed D/O | | 285 | |
| | | K0124 (G0510) | Oxidizer Turbine Bypass Valve Open P/U | 10,000 ms from K0005 | 883 | 881 |
| K0126 (K0558) | LOX Bleed Valve Closed D/O | | | 30,000 ms from K0005 | 3709 | 3707 |
| K0127 (K0557) | LH2 Bleed Valve Closed D/O | | | 30,000 ms from K0005 | 3626 | 3624 |

^{††} Within 5,000 ms of K0005 (Normally = 500 ms)

*Signal drops out when pressure reaches 425 \pm 25 psig.

P/U - Pickup D/O - Dropout

TABLE 10-2 (Sheet 1 of 2)
SECOND BURN ENGINE SEQUENCE

| CONTROL EVENTS | | CONTINGENT EVENTS | | NOMINAL TIME FROM SPECIFIED REFERENCE | ACTUAL TIME (ms) | |
|------------------|---|-------------------|---|---------------------------------------|------------------|--------------------------|
| MEAS NO. | EVENT AND COMMENT | MEAS NO. | EVENT AND COMMENT | | FROM ESC | FROM SPECIFIED REFERENCE |
| K0021 (K0021) | *Engine Start Command P/U | | | 0 | 0 | 0 |
| | | K0007 (K0531) | Helium Control Solenoid Enrg P/U | Within 10 ms of K0021 | 0 | 0 |
| | | K0010 (K0454) | Thrust Chamber Spark on P/U | Within 10 ms of K0021 | 010 | 010 |
| | | K0011 (K0455) | Gas Generator Spark | Within 10 ms of K0021 | 010 | 010 |
| | | K0006 (K0535) | Ignition Phase Control Solenoid Enrg P/U | Within 20 ms of K0021 | 010 | 010 |
| | | K0126 (K0558) | LOX Bleed Valve Closed P/U | Within 130 ms of K0007 | 152 | 152 |
| | | K0127 (K0557) | LH2 Bleed Valve Closed P/U | Within 130 ms of K0007 | 152 | 152 |
| | | K0020 (K0627) | ASI LOX Valve Open P/U | Within 20 ms of K0006 | 112 | 102 |
| | | K0119 (G0506) | Main Fuel Valve Closed D/O | 60 <u>+30</u> ms from K0006 | 062 | 052 |
| | | K0118 (G0506) | Main Fuel Valve Open P/U | 80 <u>+50</u> ms from K0119 | 085 | 023 |
| K0021 (K0021) | **Engine Start D/O | | | Approx 8,200 ms from K0021 P/U | 9609 | 9609 |
| K0096 (K0536) | †Start Tank Disc Control Solenoid Enrg | | | 8,000 <u>+40</u> ms from K0021 | 8007 | 8007 |
| | | K0123 (G0508) | Start Tank Disc Valve Closed D/O | 100 <u>+20</u> ms from K0096 | 8154 | 147 |
| | | K0122 (G0508) | Start Tank Disc Valve Open P/U | 105 <u>+20</u> ms from K0123 | 8245 | 091 |
| K0005 (K0538) | Mainstage Control Solenoid Enrg | | | 450 <u>+30</u> ms from K0096 | 8457 | 450 |
| | | K0096 (K0536) | Start Tank Disc Control Solenoid Enrg D/O | 450 <u>+30</u> ms from K0096 | 8457 | 450 |
| | | K0121 (G0507) | Main LOX Valve Closed D/O | 50 <u>+20</u> ms from K0005 | 8562 | 105 |
| | | K0116 (G0509) | Gas Generator Valve Closed D/O | 140 <u>+10</u> ms from K0005 | 8584 | 127 |
| | | K0122 (G0508) | Start Tank Disc Valve Open D/O | 95 <u>+20</u> ms from K0096 | 8595 | 138 |
| | | K0117 (G0509) | Gas Generator Valve Open P/U | 50 <u>+30</u> ms from K0116 | 8700 | 116 |
| | | K0124 (G0510) | LOX Turbine Bypass Valve Open D/O | | 8675 | |
| | | K0123 (G0508) | Start Tank Disc Valve Closed P/U | 250 <u>+40</u> ms from K0122 | 8795 | 200 |

(K0XXX) Actual number from acceptance firing event recorder.

*Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 +30 ms timer which controls energizing of the start tank discharge solenoid valve (K0096).

**This signal drops out after a time sufficient to lock in the engine electrical.

†An indication of fuel injection temperature of -150 +40 deg F (or simulation) is required before this command will be executed. This command also actuates a 450 +30 ms timer which controls the start of mainstage.

P/U - Pickup D/O - Dropout

TABLE 10-2 (Sheet 2 of 2)
SECOND BURN ENGINE SEQUENCE

| CONTROL EVENTS | | CONTINGENT EVENTS | | NOMINAL TIME FROM SPECIFIED REFERENCE | ACTUAL TIME (ms) | |
|----------------|---------------------------------------|-------------------|--|---------------------------------------|------------------|--------------------------|
| MEAS NO. | EVENT AND COMMENT | MEAS. NO. | EVENT AND COMMENT | | FROM ESC | FROM SPECIFIED REFERENCE |
| | | K0125 (G0510) | ++ LOX Turbine Bypass Valve Closed P/U | | 8900 | |
| K0158 (K0572) | Mainstage Press Switch #1 Depress D/O | | | | | Did Not Occur |
| K0159 | Mainstage Press Switch #2 Depress D/O | | | | | Did Not Occur |
| | | K0120 (G0507) | Main LOX Valve Open P/U | 2,435 +145 ms from K0005 | 10525 | 2068 |
| | | K0010 (K0454) | Thrust Chamber Spark on D/O | 3,300 +200 ms from K0005 P/U | 11725 | 3268 |
| | | K0011 (K0455) | Gas Generator Spark on D/O | 3,300 +200 ms from K0005 P/U | 11725 | 3268 |
| K0013 (K0522) | Engine Cutoff PU (New time reference) | | | 0 | 0 | |
| | | K0005 (K0538) | Mainstage Control Solenoid Enrg D/O | Within 10 ms of K0013 | 006 | 006 |
| | | K0006 (K0535) | Ignition Phase Control Solenoid Enrg D/O | Within 10 ms of K0013 | 008 | 008 |
| | | K0020 (K0622) | ASI LOX Valve Open D/O | | 053 | |
| | | K0120 (G0507) | Main Oxidizer Valve Open D/O | 50 +15 ms from K0005 | 074 | 068 |
| | | K0117 (G0509) | Gas Generator Valve Open D/O | 75 +25 -35 ms from K0006 | 124 | 116 |
| | | K0118 (G0506) | Main Fuel Valve Open D/O | 90 +25 ms from K0006 | 133 | 125 |
| | | K0121 (G0507) | Main Oxidizer Valve Closed P/U | 120 +15 ms from K0120 | 211 | 137 |
| | | K0116 (G0509) | Gas Generator Valve Closed P/U | 500 ms from K0006 | 183 | 175 |
| | | K0119 (G0506) | Main Fuel Valve Closed P/U | 225 +25 ms from K0118 | 360 | 227 |
| K0007 (K0531) | Helium Control Solenoid Enrg D/O | | | 1,000 +110 ms from K0013 | 1000 | 1000 |
| SS-22 K0507 | PU Activate Switch D/O | | | N/A | | |
| | | K0125 (G0510) | Oxidizer Turbine Bypass Valve Closed D/O | | 244 | |
| | | K0124 (G0510) | Oxidizer Turbine Bypass Valve Open P/U | 10,000 ms from K0005 | 574 | 568 |
| K0126 (K0558) | LOX Bleed Valve Closed D/O | | | 30,000 ms from K0005 | 3592 | 3586 |
| K0127 (K0557) | LH2 Bleed Valve Closed D/O | | | 30,000 ms from K0005 | 3592 | 3586 |

++ Within 5,000 ms of K0005 (Normally = 500 ms)

P/U - Pickup D/O - Dropout

TABLE 10-3
FUEL LEAD CONDITIONS

| ITEM | UNIT | S-IVB-501 FLIGHT | | S-IVB-502 FLIGHT | |
|---|-----------|------------------|--------------|------------------|--------------|
| | | FIRST START | SECOND START | FIRST START | SECOND START |
| Estimated thrust chamber bulk temperature* at fuel lead start | (deg R) | 242 | 443 | 265 | 411 |
| Fuel lead duration | (sec) | 3 | 8 | 3 | 8 |
| Fuel temperature at the injector at fuel lead termination | (deg R) | 40 | 165 | 55 | 34 |
| Fuel passing through MFV during fuel lead | (lbm) | 15 | 25 | 14 | 39 |
| Fuel between injector and MFV at fuel lead termination | (lbm) | 4 | 8 | 4.5 | 14.5 |
| Fuel passing through injector during fuel lead | (lbm) | 11 | 17 | 9.5 | 24.5 |
| Total effective impulse during fuel lead | (lbf-sec) | 1,400 | 3,200 | 1,250 | 3,050 |

*Average of three temperature measurements: jacket temperature C0199 and exit skin temperatures C0385 and C0386.

TABLE 10-4
ENGINE START SPHERE CONDITIONS

| PARAMETER | TEMPERATURE (°R) | | | PRESSURE (psia) | | | MASS (lbm) | | |
|-------------------------------------|------------------|------------|-----------|-----------------|------------|-----------|-----------------|------------|-----------|
| | 502 FLIGHT | 501 FLIGHT | 502 ACCPT | 502 FLIGHT | 501 FLIGHT | 502 ACCPT | 502 FLIGHT | 501 FLIGHT | 502 ACCPT |
| Liftoff | 279 | 262 | 260 | 1303 | 1294 | 1270 | 3.47 | 3.65 | 3.64 |
| Liftoff requirement | See Liftoff Box | | | See Liftoff Box | | | See Liftoff Box | | |
| First Engine Start Command | 284 | 266 | 272 | 1267 | 1270 | 1335 | 3.31 | 3.53 | 3.64 |
| After first start sphere blowdown | 180 | 171 | 180 | 120 | 100 | 150 | 0.50 | 0.49 | 0.66 |
| First Engine Cutoff Command | 197 | 187 | 225 | 1242 | 1166 | 1255 | 4.75 | 4.74 | 4.18 |
| Total GH2 usage during first start | - | - | - | - | - | - | 2.84 | 3.04 | 2.98 |
| Second Engine Start Command | 253 | 246 | 263 | 1327 | 1286 | 1320 | 3.88 | 3.84 | 3.70 |
| After second start sphere blowdown | - | 170 | 178 | - | 140 | 165 | - | 0.68 | 0.73 |
| Second Engine Cutoff Command | 162 | 170 | 227 | 182 | 1185 | 1286 | 0.89 | 5.37 | 4.21 |
| Total GH2 usage during second start | - | - | - | - | - | - | - | 3.16 | 2.97 |

TABLE 10-5
CONTROL SPHERE DATA

| PARAMETER | TEMPERATURE (deg R) | | | PRESSURE (psia) | | | MASS (lbm)** | | |
|---------------------------------|---------------------|---------------|----------------|---------------------|------------|----------------|--------------|------------|----------------|
| | 502 FLIGHT | 501 FLIGHT | 502 ACCEPTANCE | 502 FLIGHT | 501 FLIGHT | 502 ACCEPTANCE | 502 FLIGHT | 501 FLIGHT | 502 ACCEPTANCE |
| Required at liftoff | 279 \pm 30* | 262 \pm 30* | 260 \pm 30* | 2,800 to 3,200 psia | | | - | - | - |
| Actual at liftoff | 290 | 271 | 283 | 2,963 | 3,010 | 3,260 | 1.87 | 2.01 | 2.07 |
| Before first burn engine start | 288 | 271 | 286 | 3,000 | 3,075 | 3,345 | 1.90 | 2.03 | 2.11 |
| After first burn engine cutoff | 210 | 216 | 246 | 1,679 | 1,989 | 2,450 | 1.51 | 1.56 | 1.79 |
| Before second burn engine start | 247 | 239 | 276 | 1,918 | 1,878 | 2,764 | 1.48 | 1.48 | 1.84 |
| After second burn engine cutoff | 186 | 172 | 236 | 903 | 735 | 1,925 | 0.97 | 0.80 | 1.52 |
| Mass used - first burn | - | - | - | - | - | - | 0.39 | 0.51 | 0.32 |
| Mass used - second burn | - | - | - | - | - | - | 0.37 | 0.68 | 0.32 |

*Actual requirement is start sphere temperature \pm 30 deg R.

**As calculated from measured temperature and pressure.

TABLE 10-6
ENGINE PERFORMANCE*

| PARAMETER | UNIT | CLOSED PU VALVE OPERATION | | | OVERALL PERFORMANCE 90 PERCENT THRUST TO ECC | | |
|----------------------|---------|---------------------------|-----------|-------------------|---|-----------|-------------------|
| | | ACTUAL | PREDICTED | PERCENT DEVIATION | ACTUAL | PREDICTED | PERCENT DEVIATION |
| Thrust | lbf | 227,101 | 230,524 | -1.48 | 226,293 | 229,832 | 1.54 |
| Total flowrate | lbm/sec | 539.42 | 542.52 | -0.57 | 537.21 | 540.50 | 0.61 |
| LOX flowrate | lbm/sec | 455.93 | 459.15 | -0.70 | 453.82 | 457.24 | 0.75 |
| LH2 flowrate | lbm/sec | 83.49 | 83.37 | +0.14 | 83.39 | 83.26 | +0.16 |
| Engine mixture ratio | | 5.461 | 5.507 | -0.83 | 5.441 | 5.491 | -0.91 |
| Specific impulse | sec | 421.01 | 424.91 | -0.92 | 421.29 | 425.27 | -0.94 |

| PARAMETER | UNIT | MAINSTAGE | | | TO DEPLETION** |
|-------------|---------|-------------------------|-------------------------|-------------------|----------------|
| | | ACTUAL | PREDICTED | PERCENT DEVIATION | |
| Burntime | | 163.866 | 133.5 | +22.75 | |
| Consumption | | | | | |
| LOX | lbm | 74,559 | 61,083 | +22.06 | |
| LH2 | lbm | 13,812 | 11,200 | +23.32 | |
| Impulse | lbf/sec | 37.08 x 10 ⁶ | 30.68 x 10 ⁶ | +20.86 | |

*All engine performance values are first burn only.

**Depletion figures were considered meaningless as there was no mainstage performance during second burn on which to base calculations.

TABLE 10-7
COMPARISON OF COMPUTER PROGRAM RESULTS

| PROGRAM | INPUT | METHOD | RESULTS |
|----------------|---|--|---|
| G105 Mode 1 | LOX and LH2 flowmeters, pump discharge pressures and temperatures, chamber pressures, chamber thrust area | Flowrates are computed from flowmeter data and propellant densities. The C_F is determined from equation $C_F = f(P_C, MR)$ and thrust is calculated from equation $F = C_F A_t P_C$. | $F = 230,343$ $\dot{W}_T = 541.233$ $I_{sp} = 425.59$ $MR = 5.505$ |
| G307 | Pump inlet and outlet conditions, PU valve position, chamber pressure, turbine inlet and outlet conditions, flowmeter speed | Math models of rocket engine components are linked together by the program which iterates among the component models until an operating point is reached where the power required by the pumps balances the power available from the turbines. | $F = 230,113$ $\dot{W}_T = 541.62$ $I_{sp} = 424.8$ $MR = 5.52$ |
| F839 | Thrust chamber pressure, chamber throat area | The C_F is computed from equation $C_F = f(P_C)$ and thrust is computed from equation $F = C_F A_t P_C$. The impulse is determined from integrated thrust. | Refer to paragraphs 10.4.2.3 and 10.4.2.5 |

TABLE 10-8
DATA INPUTS TO COMPUTER PROGRAMS

| PARAMETER | PROGRAM | SELECTION | BIAS | REASON |
|---------------------------------|----------|---------------|----------|--|
| Chamber Pressure | G105-1 | D0001 (TM/FM) | -15 | Rocketdyne estimation of purge effect |
| | PA53 | D0001 (TM/FM) | +4.887 | Correct for non-zero indication of transducer at ESC |
| | (Start) | | 97.51% | Variable bias -0 at ESC and -15 at ESC +60 sec |
| | (Cutoff) | D0001 (TM/FM) | +(6.412) | Correct for non-zero indication of transducer at end of thrust decay |
| | | | 97.27% | Variable bias -0 at end of thrust decay and -15 at ECC |
| LOX Flowrate | G105-1 | F0001 | None | |
| Fuel Flowrate | G105-1 | F0002 | None | |
| LOX Pump Discharge Temperature | G105-1 | C0133 | None | |
| Fuel Pump Discharge Temperature | G105-1 | C0134 | None | |
| LOX Pump Discharge Pressure | G105-1 | D0009 | None | |
| Fuel Pump Discharge Pressure | G105-1 | D0008 | None | |
| Fuel Turbine Inlet Temperature | G105-1 | C0001 | None | |
| Gas Generator Chamber Pressure | G105-1 | D0010 | None | |
| | G307 | | | |

TABLE 10-9
START TANK PERFORMANCE

| TIME | PRESSURE | | TEMPERATURE | | PREDICTED | ΔM | ACTUAL | ΔM |
|----------------------------------|-----------|---------|-------------|--------|-----------|--------|--------|--------|
| | PREDICTED | ACTUAL | PREDICTED | ACTUAL | | | | |
| First Burn Engine Start Command | 1,290 | 1,266.5 | 275 | 284.4 | 3.575 | | 3.31 | |
| STDV 1 | 1,290 | 1,265 | 275 | 284.4 | 3.575 | 0 | 3.31 | 0 |
| End of blowdown 1 | 175 | 117.6 | 178 | 190.3 | 0.749 | -2.826 | 0.471 | -2.839 |
| End of refill 1 | 825 | 793.4 | 226 | 236.4 | 2.78 | +2.039 | 2.56 | +2.089 |
| End of topping 1 | 1,115 | 1,184.9 | 178 | 186.8 | 4.77 | +1.99 | 4.83 | +2.27 |
| First Burn Engine Cutoff Command | 1,260 | 1,238.8 | 195 | 196.8 | 4.91 | +0.14 | 4.75 | -0.08 |
| Second Burn Engine Start Command | 1,285 | 1,327 | 230 | 252.8 | 4.25 | -0.66 | 3.88 | -0.87 |

TABLE 10-10
FIRST BURN START TRANSIENT

| PARAMETER | UNIT | ENGINE LOG BOOK | 501 FLIGHT FIRST BURN | 502 ACCEPT FIRST BURN | 502 FLIGHT FIRST BURN |
|--|--------------|-----------------|-----------------------|-----------------------|-----------------------|
| Time of STDV Command | sec from ESC | 1.0 | 3.008 | 0.629 | 3.019 |
| Thrust at 90 percent performance level* | lbf | 189,580** | 185,599 | 156,200 | 188,171 |
| Total Impulse from Engine Start Command to 90 percent performance level* | lb-sec | --- | 188,864 | --- | 190,543 |
| Total impulse from STDV Command to 90 percent performance level* | lb-sec | 197,707** | 187,464 | 135,931 | 189.158 |

*Defined as STDV Command +2.5 sec

**Based on stabilized thrust at null PU and standard altitude conditions.

TABLE 10-11
STEADY-STATE ENGINE PERFORMANCE

| PARAMETER | UNIT | 90 PERCENT THRUST TO 115 SEC | PERCENT DEVIATION FROM PREDICTED | 120 SEC TO C/O | PERCENT DEVIATION FROM PREDICTED |
|------------------|---------|------------------------------|----------------------------------|----------------|----------------------------------|
| Thrust | lbf | 227,032 | -1.21 | 224,579 | -2.29 |
| Mixture Ratio | | 5.44 | -0.93 | 5.45 | -0.75 |
| LOX Flowrate | lbm/sec | 452.61 | -1.01 | 456.6 | -0.14 |
| LH2 Flowrate | lbm/sec | 83.21 | -0.06 | 83.8 | +0.65 |
| Specific Impulse | sec | 423.7 | -0.37 | 415.6 | -2.27 |

TABLE 10-12
FLIGHT 60-SEC TAG COMPARISON

| PARAMETERS | UNIT | PREDICTED | ACTUAL | DEVIATION |
|------------------|--------|----------------|---------|-----------|
| Thrust | lbf | 228,980 +2,901 | 228,804 | -176 |
| EMR | | 5.4804 +0.09 | 5,485 | +0.0046 |
| Specific Impulse | sec | 424.765 +2.7 | 425.0 | +0.235 |
| LOX Flowrate | lb/sec | 455.889 +5.34 | 455.30 | -0.589 |
| LH2 Flowrate | lb/sec | 83.185 +1.35 | 83.01 | -0.175 |

TABLE 10-13
THRUST OSCILLATION SUMMARY

| DURING PU VALVE HARDOVER OPERATION | UNIT | CEI SPEC LIMIT | PRIOR TO MALFUNCTION | ACTUAL INCLUDING MALFUNCTION |
|--------------------------------------|-------------|----------------|----------------------|------------------------------|
| Variation in mean thrust level | lbf | <u>+5,000</u> | -1,100 | -3,500 |
| Oscillations about mean thrust level | lbf | <u>+2,500</u> | <u>+1,000</u> | 3,400 |
| Rate of change of thrust | lbf/sec | <u>+500</u> | +134, -133 | +134, -632 |
| Thrust acceleration | lbf/sec/sec | <u>+125</u> | +69 | +48 |

TABLE 10-14
FIRST BURN CUTOFF TRANSIENT

| PARAMETER | UNIT | J-2 ENGINE LOG BOOK | 501 FLIGHT FIRST BURN | 502 FLIGHT FIRST BURN | 502 FLIGHT RESULTS | |
|--|--------|---------------------|-----------------------|-----------------------|---------------------------------|-----------------------|
| | | | | | ENGINE PERFORMANCE CALCULATIONS | FD AND C (AERO) CALC. |
| Time for Thrust to Decrease to 11,250 lbf* | ms | 349 | 444 | 451 | 464 | --- |
| Thrust at Engine Cutoff Command | lbf | 202,651 | 223,122 | 230,525 | 224,576 | --- |
| Total Impulse to 5 percent Thrust | lb-sec | 38,031 | 48,101 | 48,808 | 53,177 | --- |
| Total Impulse to Zero Thrust | lb-sec | --- | 54,949 | --- | 59,376 | 67,600 |
| MOV Actuator Temperature at Engine Cutoff | °R | 460 | 304.9 | --- | 282.5 | --- |
| PU Valve Position at Engine Cutoff | deg | 0 | 33.3 | --- | 32.7 | --- |
| Total Impulse to 5 percent Thrust Adjusted to Null PU and 460°R Main Oxidizer Valve Actuator Temperature | lb-sec | 38,031 | --- | --- | 39,005 | --- |

*5 percent rated thrust

TABLE 10-15 (Sheet 1 of 3)
ENGINE AREA ENVIRONMENT TEMPERATURES

| TEMPERATURE | MEAS. NO. | RANGE | FIGURE NO. | DISCUSSION |
|--|-----------|--------------|------------|--|
| GG Fuel Inlet Line Wall | C0146 | 35 to 300°R | 10-43 | At approximately RO +685 sec this measurement began dropping from 58 deg R until it reached 50 deg R at RO +725 sec. It then increased slightly until engine cutoff. This temperature response indicates that fuel must have been spraying on the line because the temperature level is too low for LOX to cause such a reaction. The AS-501 data does not show any temperature change during the first burn. No unusual temperature changes occur during the orbital coast, although the level is approximately 50 deg R lower than on AS-501. Prior to second start the temperature increased to the same level as on AS-501. Immediately after the second burn Engine Start Command, the temperature dropped to the same level it reached during the first burn again indicating a fuel leak. |
| GG LOX Inlet Temp | C2035 | 100 to 610°R | 10-44 | At approximately RO +660 sec this temperature stopped increasing at 180 deg R and dropped to 160 deg R at RO +695 sec. It remained constant at this level until engine cutoff. During the second orbit of the coast period, the measurement went off-scale-high at RO +10,400 sec and remained there for the remainder of the mission. This measurement was not on AS-501; therefore, no comparison is possible. |
| Main LOX Valve Pneumatic Line Surface Temp | C2005 | 210 to 560°R | 10-46 | The temperature was normal until RO +650 sec when it dropped rapidly from 395 deg R to offscale at RO +720 sec. The temperature came back on scale after engine cutoff. The AS-501 continued to increase somewhat all during the first burn. The temperature during orbital coast appeared to be normal, although approximately 50 deg R lower than AS-501. At the end of fuel lead for the second start, it again dropped very rapidly approximately 45 deg R from 370 deg R. The AS-501 data increased during the second burn, similar to the first burn profile. |
| Main LOX Valve Actuator Skin Temp | C2003 | 110 to 560°R | 10-46 | During the first burn, the temperature dropped from 333 deg R at RO +640 sec to 280 deg R at engine cutoff with a slight discontinuity between RO +695 and RO +700 sec. On AS-501, this temperature decreased very slightly all during the first burn, but not nearly as much as it did on AS-502. Again, nothing unusual happened during orbital coast. During the period of the second burn the temperature was approximately 30 deg R lower on AS-502 than on AS-501 and showed evidence of a cooling trend following the restart attempt. |
| GG Bootstrap Line Temp No. 1 | C2037 | 100 to 610°R | 10-27 | The temperature appeared to be normal until approximately RO +675 sec when it dropped about 5 deg R. At RO +695 sec, it rose very sharply from 165 to 193 deg R and then cooled until cutoff. The temperature appeared to behave as expected during the orbital coast period and the restart attempt. This measurement was not on AS-501 and no comparison is possible. |
| GG Bootstrap Line Temp No. 2 | C2036 | 100 to 610°R | 10-47 | This temperature, which was not on AS-501, appeared normal throughout the mission. No abnormal temperature increases or decreases were present. |

TABLE 10-15 (Sheet 2 of 3)
ENGINE AREA ENVIRONMENT TEMPERATURES

| TEMPERATURE | MEAS. NO. | RANGE | FIGURE NO. | DISCUSSION |
|---|-----------|--------------|------------|--|
| Main Hydraulic Pump Discharge Line Temp | C2029 | 360 to 610°R | 10-48 | This thermocouple was not on AS-501. The temperature appeared to be normal until approximately RO +685 sec when it stopped increasing and remained near 570 deg R until engine cutoff. Nothing unusual appeared in this temperature for the remainder of the mission from a propulsion view point. It is mentioned, however, due to the hydraulic system anomaly which is discussed in section 22. |
| Crossover Duct Wall Temp No. 1 | C2015 | 0 to 2000°R | 10-49 | Compared to the AS-501 data, the temperature appeared to be normal until it went offscale at 718 sec. During the orbital coast, the temperature came back on scale for a short time at approximately the correct level. The thermocouple appears to have short circuited. |
| Crossover Duct Wall Temp No. 2 | C2016 | 0 to 2000°R | 10-49 | This temperature was normal until RO +625 sec when the rate of increase was greatly reduced. The AS-501 data shows the temperature increasing throughout the first burn. The low heat uprate present on AS-502 must be due to external cooling because there was no decrease of the gas temperature in the crossover duct. The temperature was normal and very close to AS-501 during the orbital coast. Because of the failure to start the second time, the temperature did not reach its normal level. |
| Engine Area Ambient | C0010 | 260 to 960°R | 10-50 | AS-502 data showed a gradual cooling trend somewhat similar to AS-501. However, at RO +650 sec the cooling rate increased until, at RO +695 sec, a heat spike occurred from about 365 deg R to 422 deg R and then at RO +700 sec dropped completely offscale. This entire cycle of increased cooling rate at RO +650 sec and the heat spike at RO +695 sec are entirely different from AS-501 data. The measurement remained offscale all during orbital coast and the restart attempt. It is concluded that this transducer or its electrical connections failed at RO +700 sec due to the engine malfunction. |
| Oxidizer Main Supply Line Wall Temp | C0153 | 160 to 450°R | 10-51 | The data for AS-501 and AS-502 are similar until approximately RO +690 sec where a rapid heating trend occurs in the AS-502 data. This heating trend peaks out at RO +700 sec and 178 deg R after an increase in temperature of 10 deg. At RO +700 sec it gradually decreases until engine cutoff at which time it begins to heat up again. During orbital coast a linear cooling trend is shown until RO +3,600 sec. At this time the reading dropped offscale and remained there for the duration of the flight. The location of C0153 is on the main LOX line itself while C0010 is on the flange supporting the LOX line. The main difference in the two readings is that while C0010 showed a gradual cooling trend starting at RO +650 sec before the heat spike, C0153 revealed no corresponding cooling trend. |

TABLE 10-15 (Sheet 3 of 3)
ENGINE AREA ENVIRONMENT TEMPERATURES

| TEMPERATURE | MEAS. NO. | RANGE | FIGURE NO. | DISCUSSION |
|--|-----------|--------------|------------|---|
| Oxidizer Main Supply Line Flange Wall Temp | C0152 | 160 to 370°R | 10-51 | The main supply line flange wall temperature (C0152) was similar to data from AS-501 until RO +675 sec. At this time the cooling rate increased similar to C0010 but continued for approximately 20 sec. At RO +695 sec the transducer went offscale for the duration of the flight. As shown in figure 10-43 the C0152 sensor is located between C0010 and C0153 sensors on the flange near the main LOX line. However, its data is more like the data from C0010 located farther back on the flange away from the LOX line. This leads to the conclusion that the initial cold leak occurred in an area somewhere to the inside of the main LOX line. Escaping hot gas could easily engulf all three sensors and probably did at approximately RO +695 sec since all these readings were definitely affected radically at this time. In conclusion, these three sensors indicate that the general environment became cooler in the area of the flange supporting the main LOX line. This cooling tendency did not occur in the area of C0153 shown in figure 10-43. Therefore, the hydrogen leak was probably to the inside of the main LOX line and accessible to the flange supporting the line. Two of the sensors (C0010 and C0153) showed a heat spike at RO +695 sec. |
| Interstage Area 7 Gas Temperature | C0275 | 160 to 660°R | 10-52 | The gas interstage area 7 temperature begins a rapid cooling trend at approximately RO +650 sec. This cooling continued until approximately RO +695 sec. A 505 to 575 deg R heat spike occurred at RO +700 sec. The heat spike peaked out and a rapid temperature drop occurred. |
| Thrust Structure Temp No. 1 | C0087 | 310 to 885°R | 10-53 | This measurement showed a cooling trend starting at RO +610 sec. This cooling trend continued until RO +700 sec and dropped a total of 10 deg R. At RO +700 sec a heat spike of 30 deg R occurred followed by an immediate temperature drop of 72 deg. During orbital coast the temperature trend for AS-502 is somewhat similar to AS-501 except that AS-502 temperatures are cooler. |
| Thrust Structure Temp No. 2 | C0088 | 310 to 385°R | 10-53 | The thrust structure No. 2 temperature exhibited a gradual cooling trend starting at approximately RO +680 sec. At RO +695 sec a rapid temperature increase occurred followed by another cooling trend. The temperature increase was 8 deg and much less exaggerated than the C0087 measurement. The two sensors are in the same general location but they are separated by a flange which could have shielded the C0088 sensor from the temperature extremes experienced by C0087. During orbital coast and restart attempt, the C0088 data is the same general pattern as AS-501 except that it is slightly cooler. In the AS-501 data, there is a gradual increase in temperature at approximately RO +2,000 sec followed by a cooling aid that is not seen in the AS-502 data. All of these sensors (C0275, C0088, and C0087) show a gradual cooling followed by an increase in temperature at approximately RO +700 sec. They are all located on the thrust structure itself. C0088 showed less irregularity in the data than the other two but the flange near it could easily have acted as a shield to protect it from the temperature extremes. |

TABLE 10-16
PROPELLANT LOSSES DUE TO FAILURE

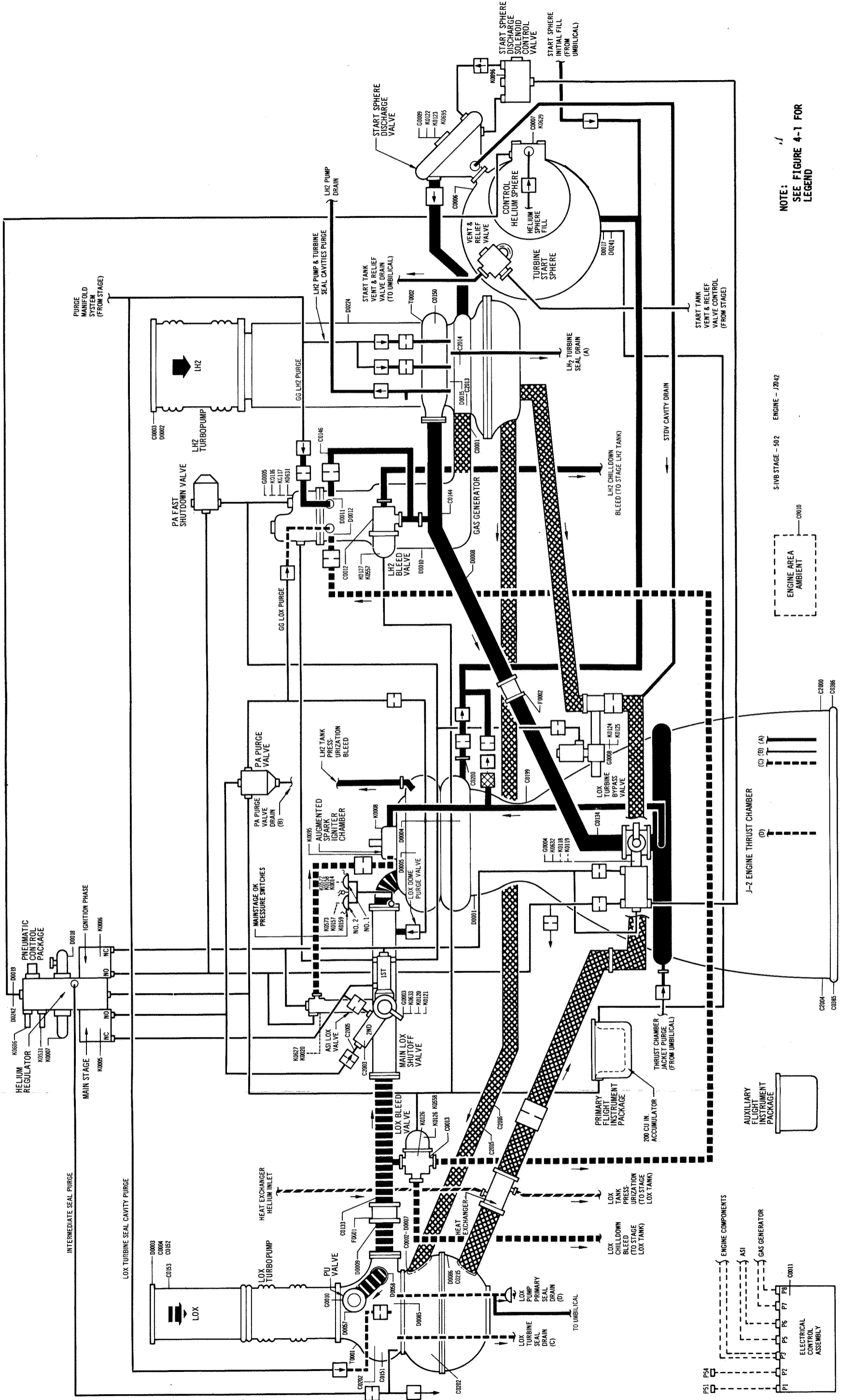
| | | MAXIMUM | MINIMUM | MOST PROBABLE |
|--|---------|-------------------------|---------|---------------|
| Total propellant loss indicated by chamber pressure | lbm/sec | | | -11 |
| Fuel loss from a broken ASI fuel line | lbm/sec | -11.0 | -2.0 | -6.0 |
| Backflow of gases from ASI chamber | lbm/sec | -1.5 | -0.1 | -1.0 |
| Fuel flowrate change--flowmeter | lbm/sec | | | +0.3 |
| LOX flowrate change--flowmeter | lbm/sec | | | -1.0 |
| LOX loss from a broken ASI LOX line | lbm/sec | -13.0 | -1.3 | 0 |
| Backflow of gases through a burnthrough in the ASI chamber | | Depends on size of hole | | -3.3* |
| Net loss | | -26.2 | -4.1 | -11.0 |
| Net loss excluding a broken ASI LOX line | | -13.2 | -2.8 | -11.0 |

*This is the additional flow required to produce a net loss of 11 lbm/sec.

TABLE 10-17
MAIN LOX VALVE OPENING TIMES

| SECTION | NOMINAL TIME (ms) | ACCEPTANCE FIRST START (ms) | FLIGHT FIRST BURN (ms) | ACCEPTANCE SECOND START (ms) | FLIGHT SECOND BURN (ms) |
|---------------------|-------------------|-----------------------------|------------------------|------------------------------|-------------------------|
| First stage travel | 50 \pm 26 | 60 | 150 | 70 | 165 |
| First stage plateau | 480 \pm 120 | 540 | 315 | 570 | 395 |
| Second stage travel | 1,825 \pm 75 | 1,890 | 2,030 | 2,110 | 1,800 |
| Total | 2,355 \pm 220 | 2,490 | 2,495 | 2,750 | 2,360 |

Section 10
Engine System



NOTE:
SEE FIGURE 4-1 FOR
LEGEND

S-1WB STAGE - 502 ENGINE - J2042

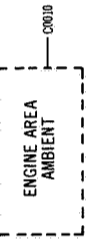


Figure 10-1. J-2 Engine System and Instrumentation

FOLDOUT FRAME

FOLDOUT FRAME

FOLDOUT FRAME

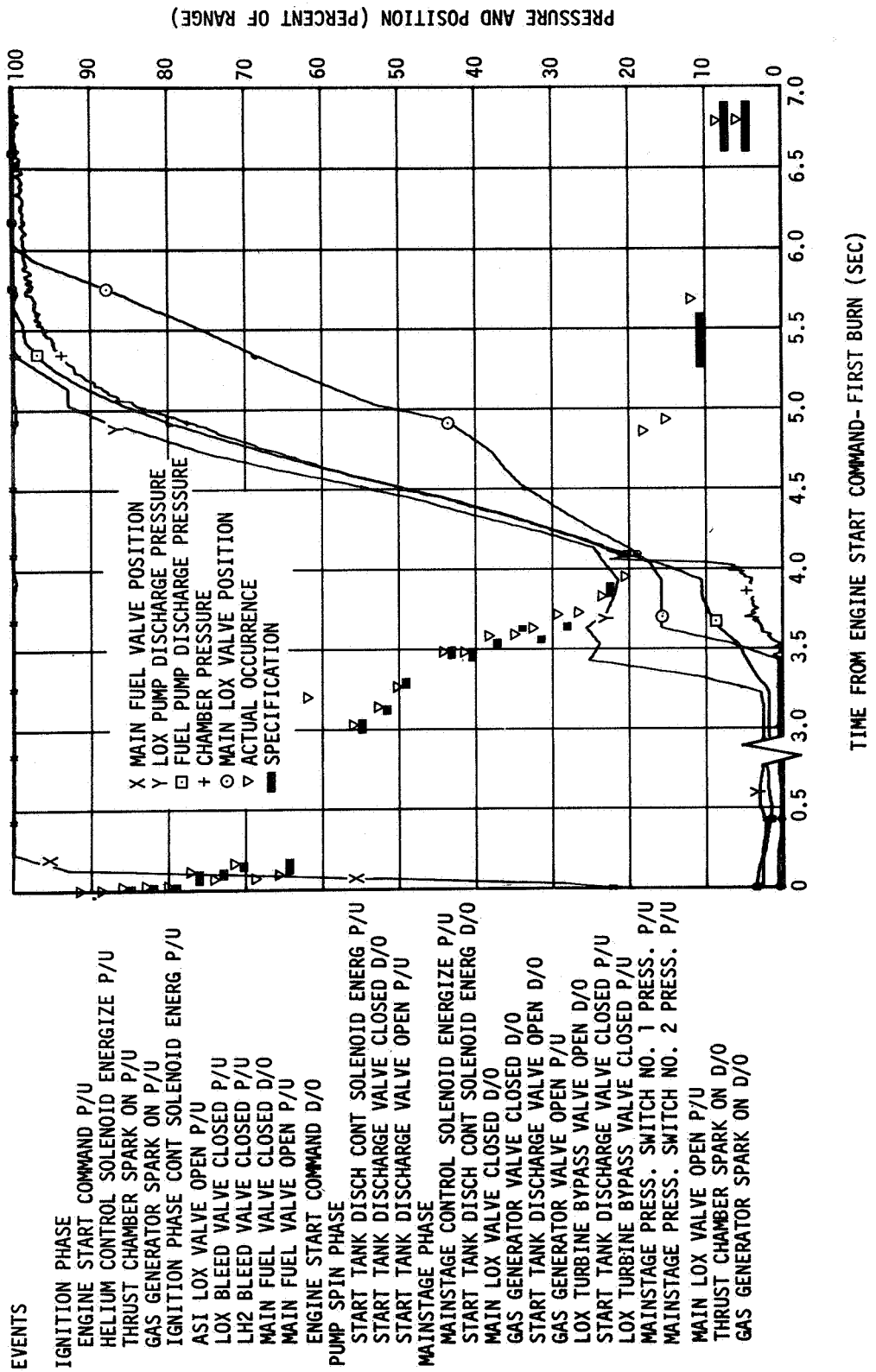


Figure 10-2. Engine Start Sequence - First Burn

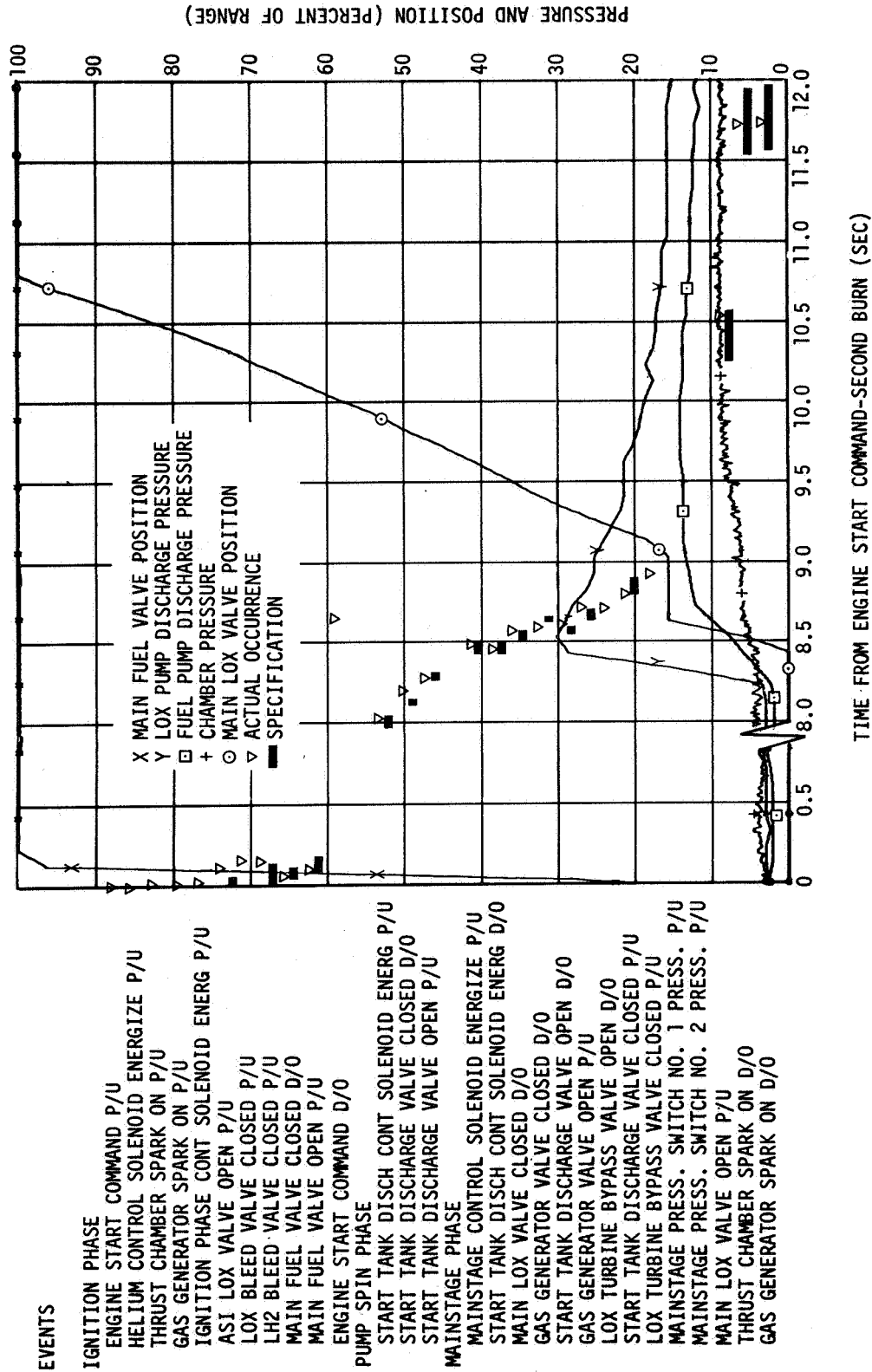


Figure 10-3. Engine Start Sequence - Second Burn

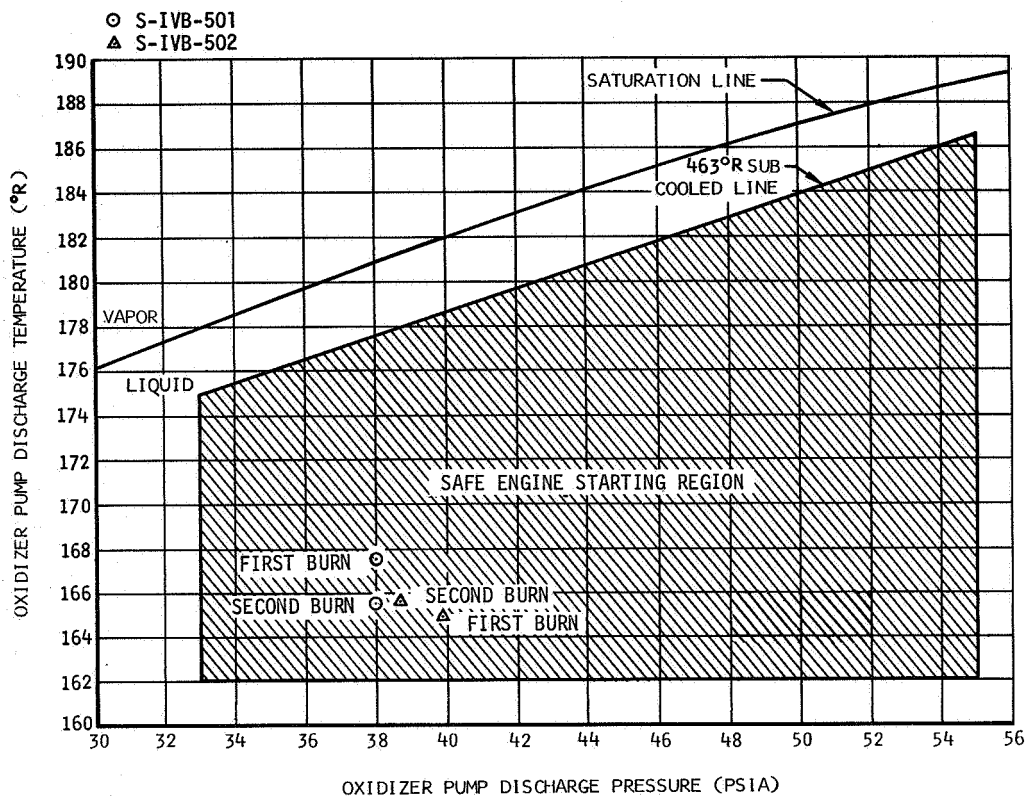


Figure 10-4. Oxidizer Pump Discharge Pressure Versus Temperature

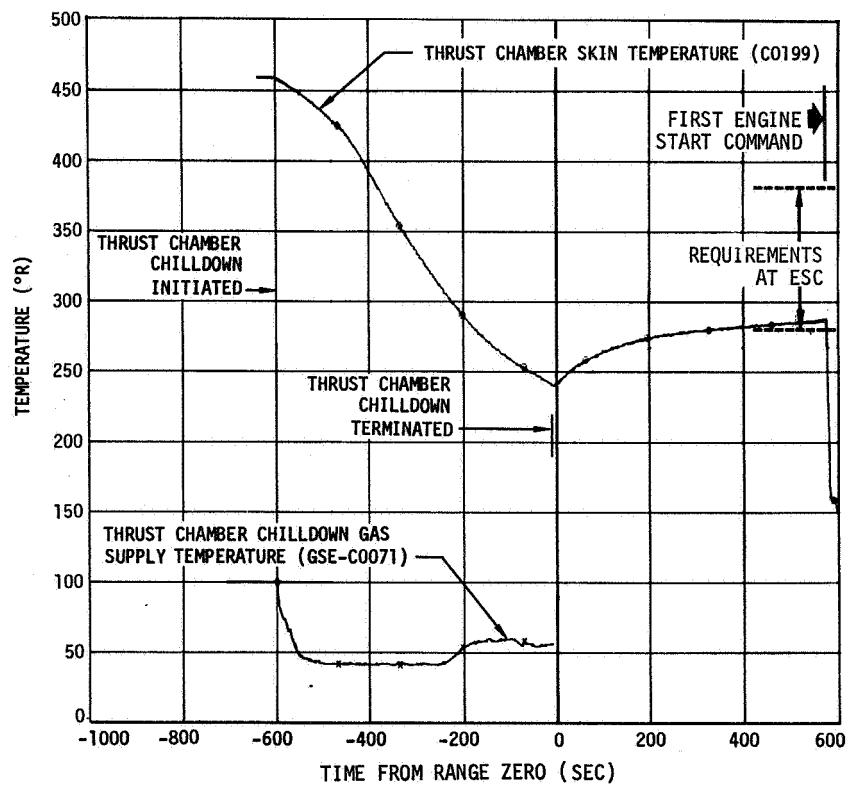


Figure 10-5. Thrust Chamber Chilldown - First Burn

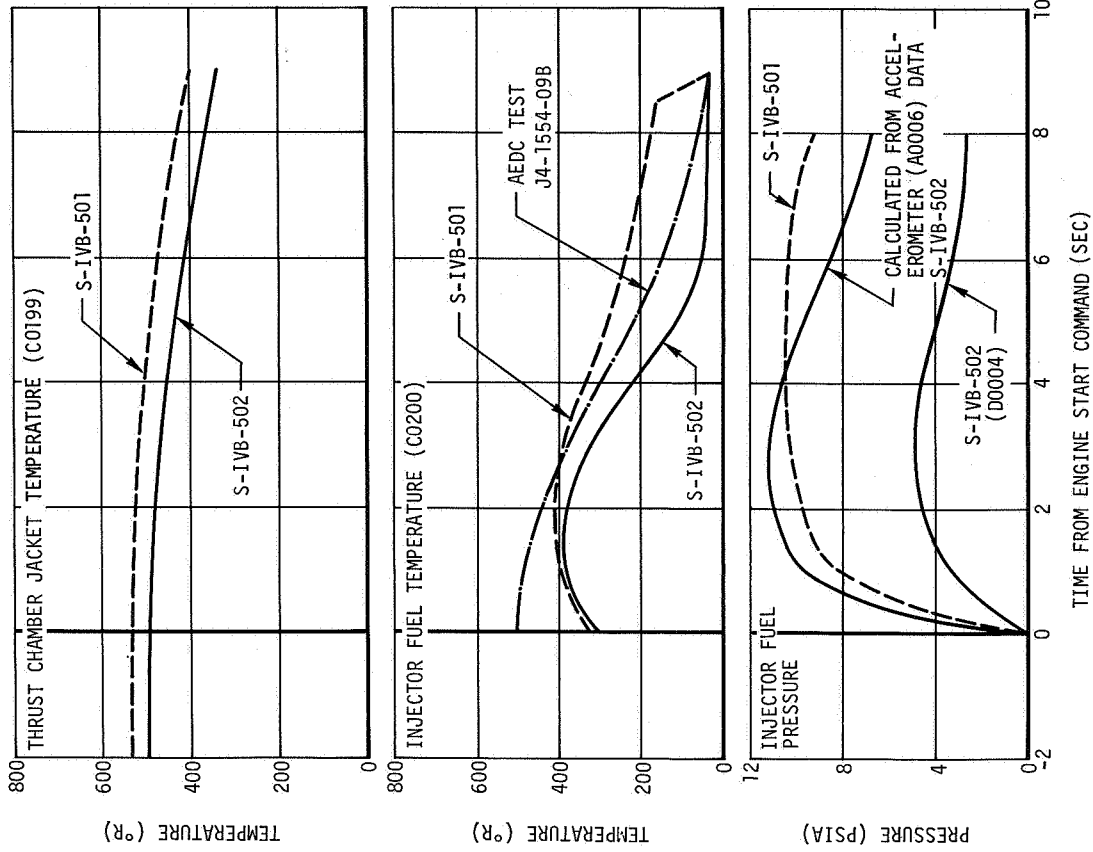


Figure 10-7. Fuel Lead - Second Burn

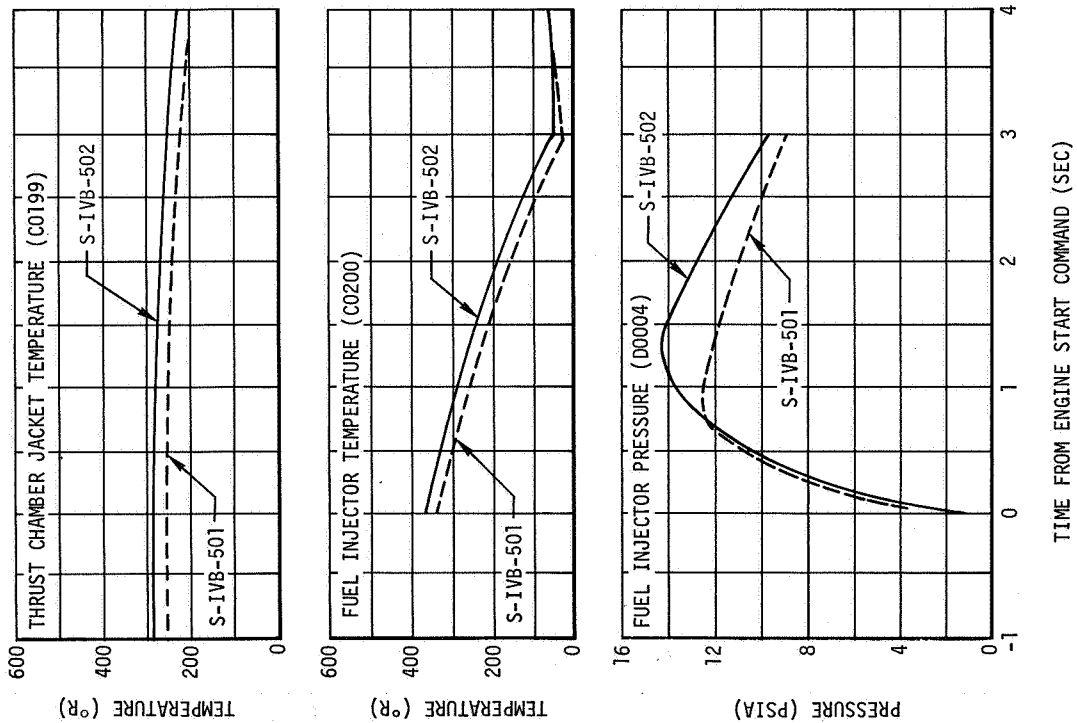


Figure 10-6. Fuel Lead - First Burn

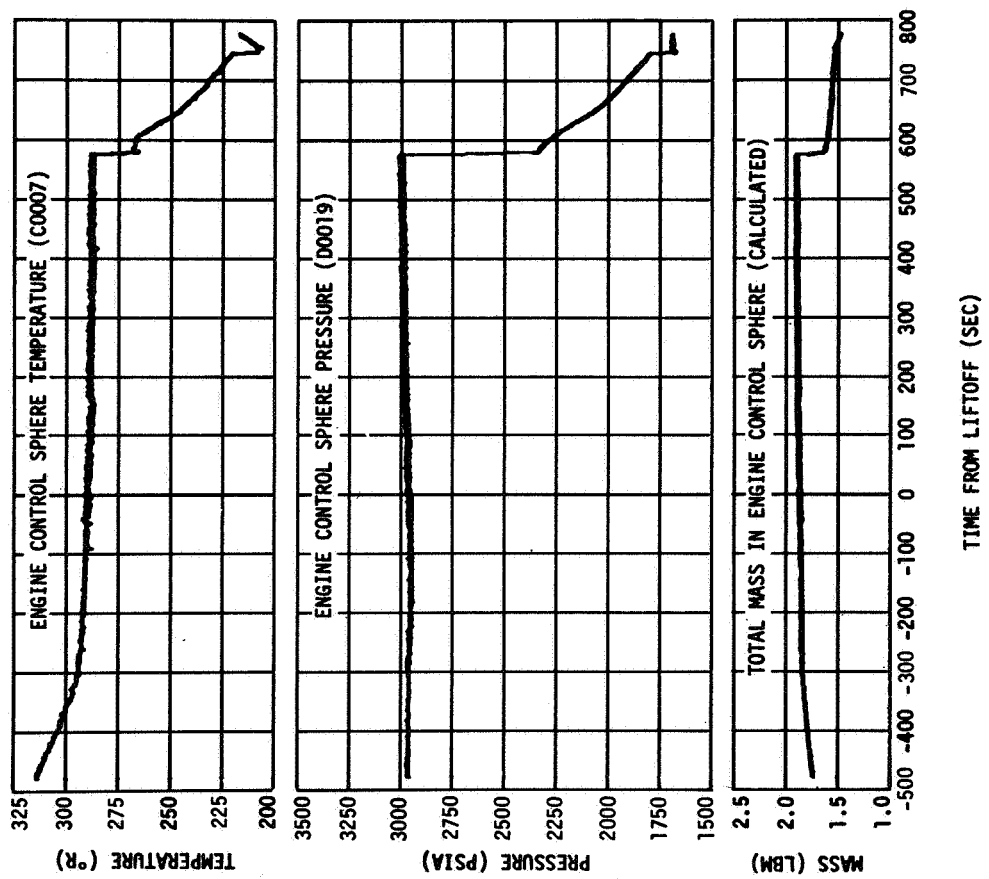
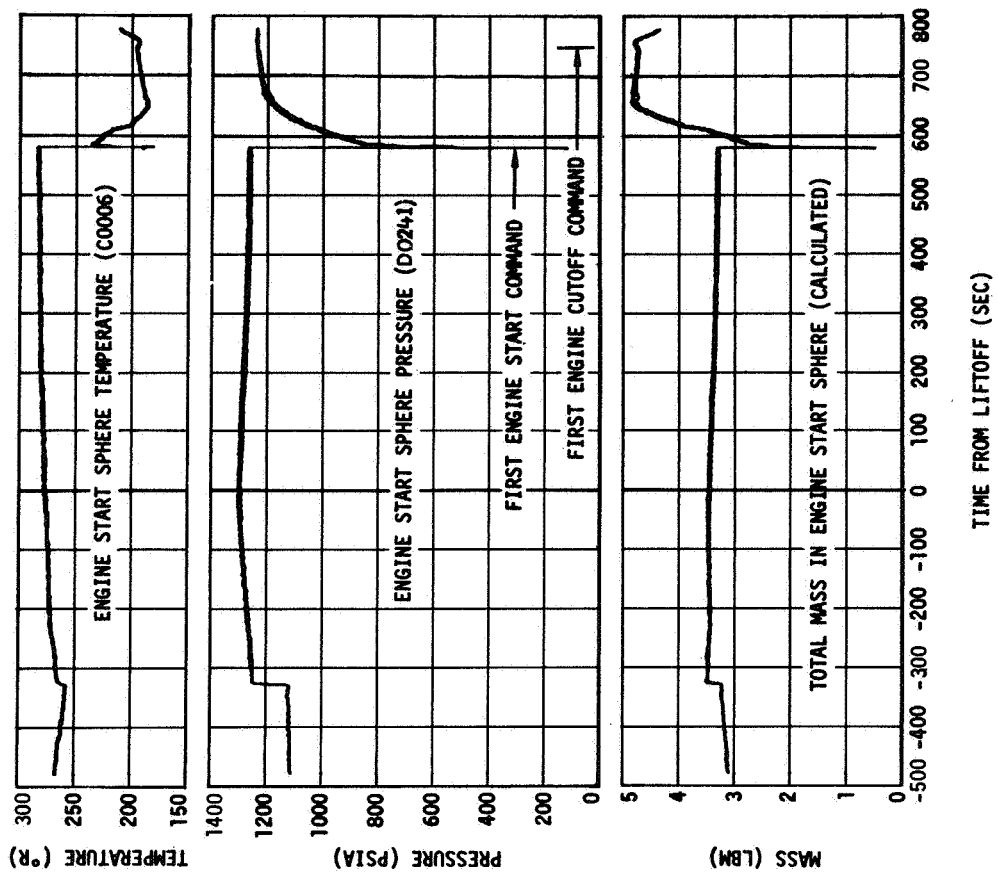


Figure 10-8 Engine Start and Control Sphere Performance - First Burn

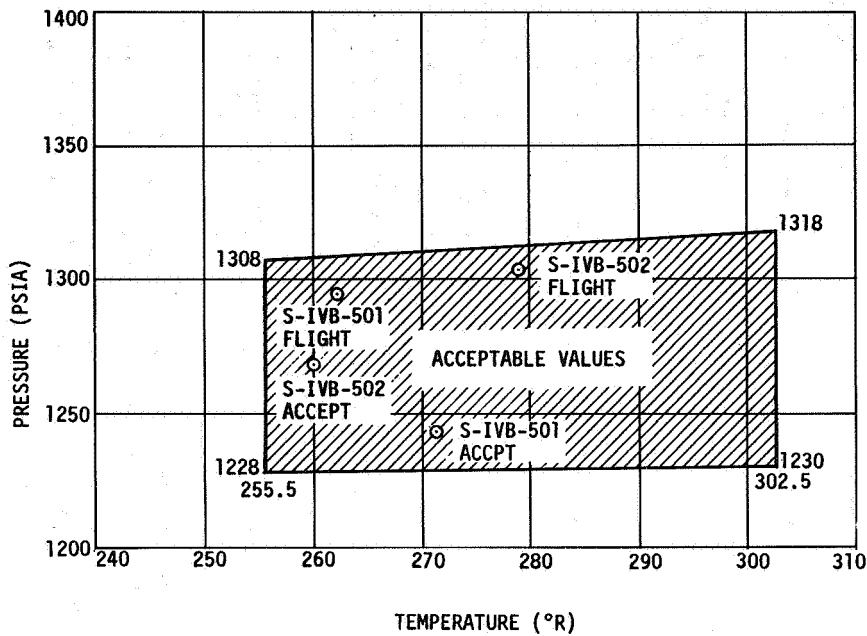


Figure 10-9. GH2 Start Sphere Critical Limits at Liftoff

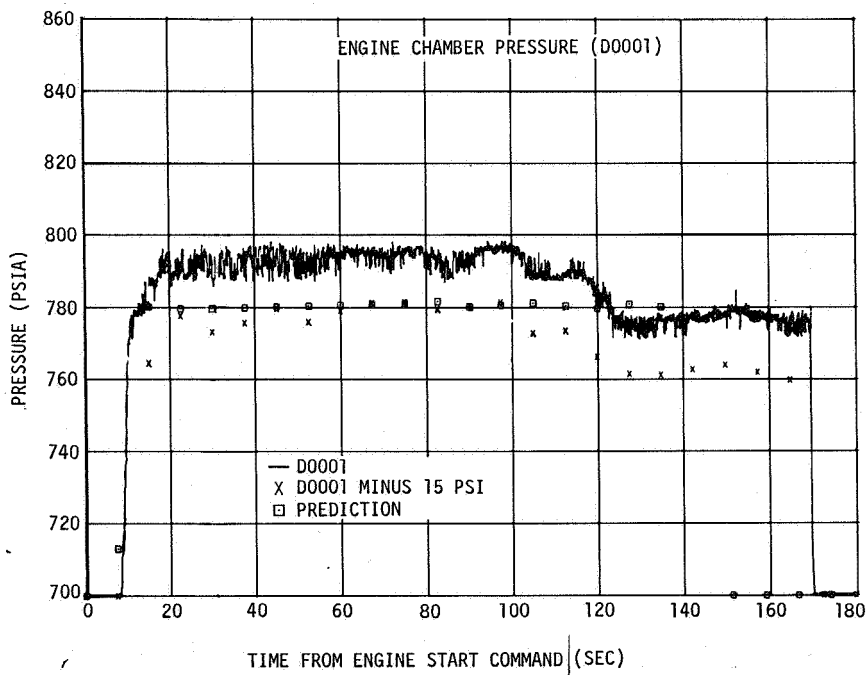


Figure 10-10. J-2 Engine Chamber Pressure - First Burn

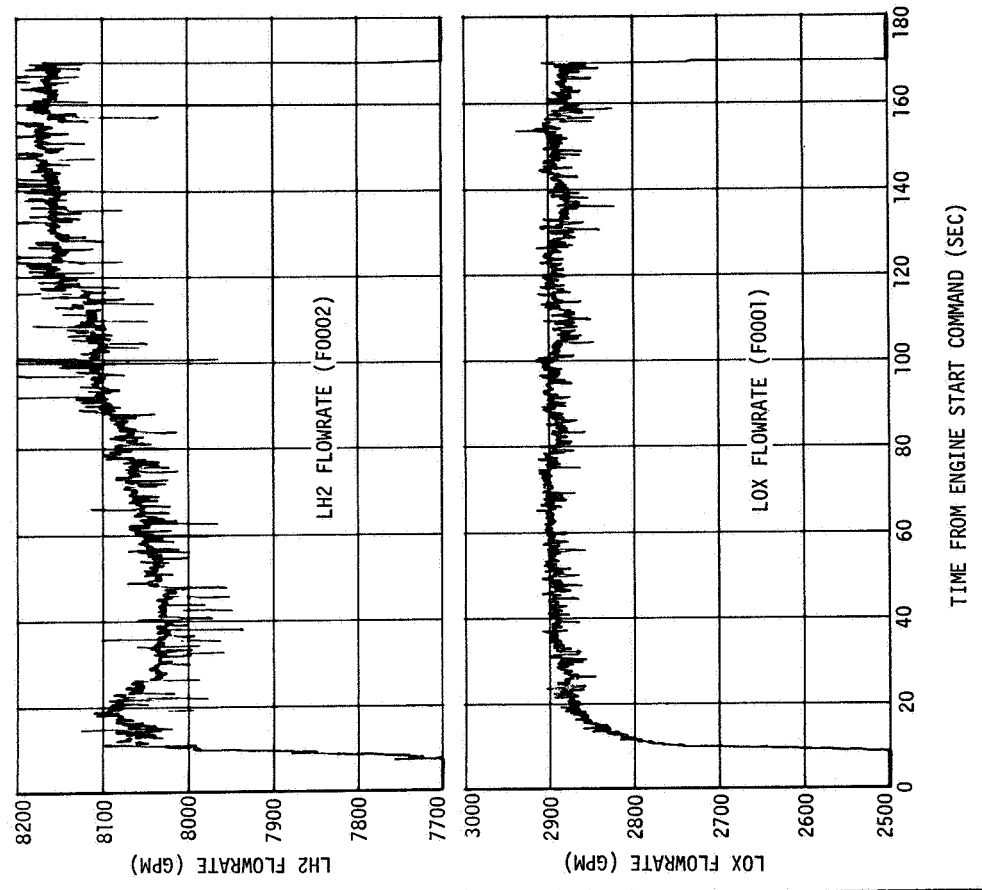


Figure 10-12. J-2 Engine Pump Flowrates - First Burn

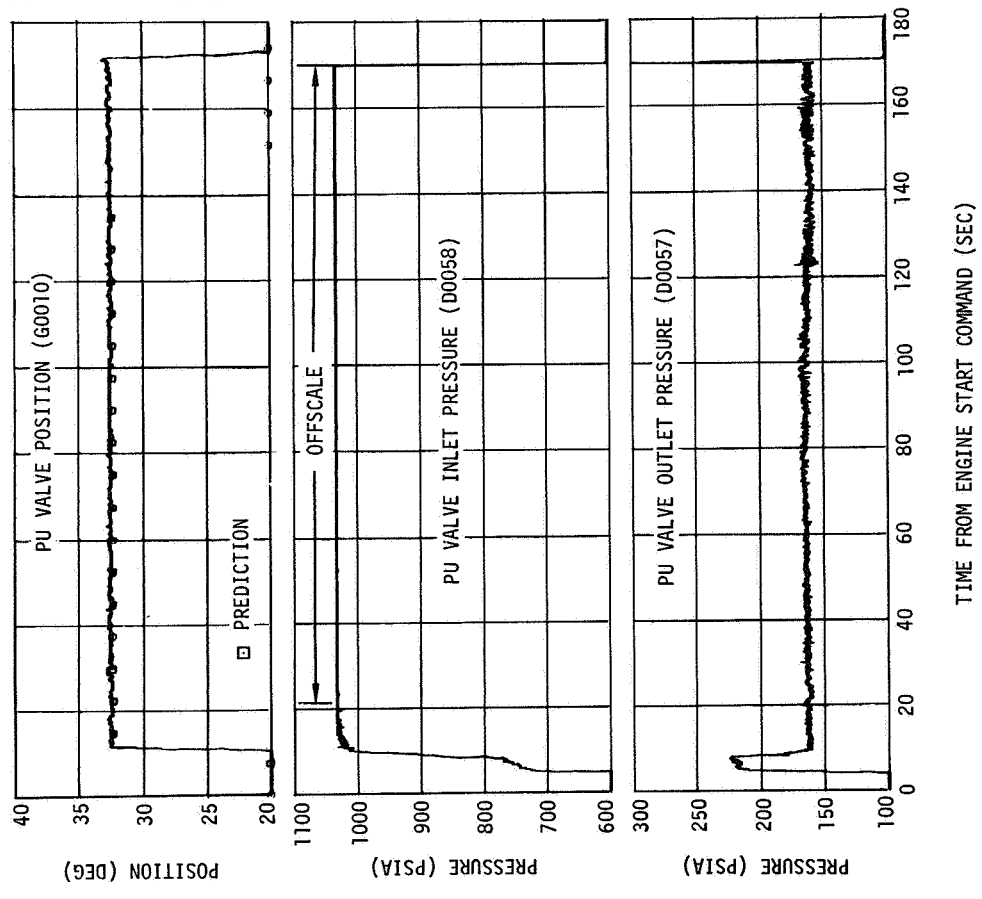


Figure 10-11. PU Valve Operation - First Burn

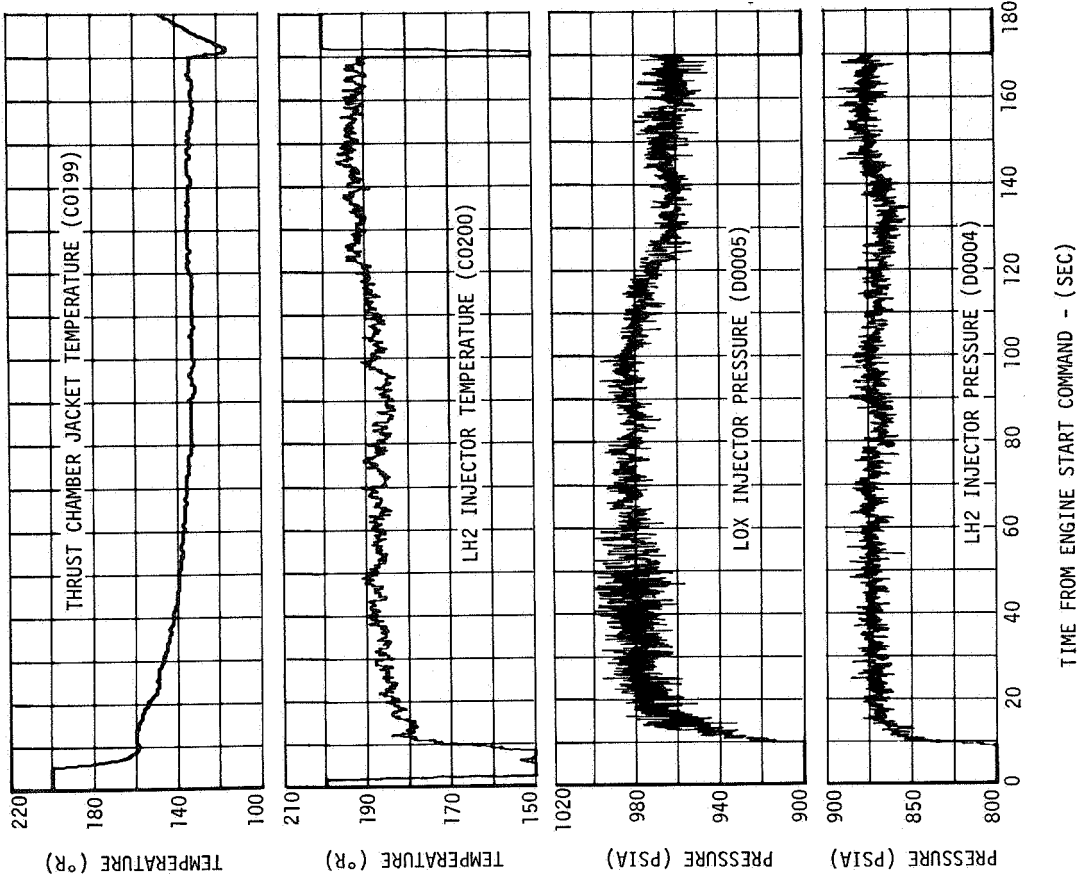


Figure 10-14. J-2 Engine Injector Supply Conditions - First Burn

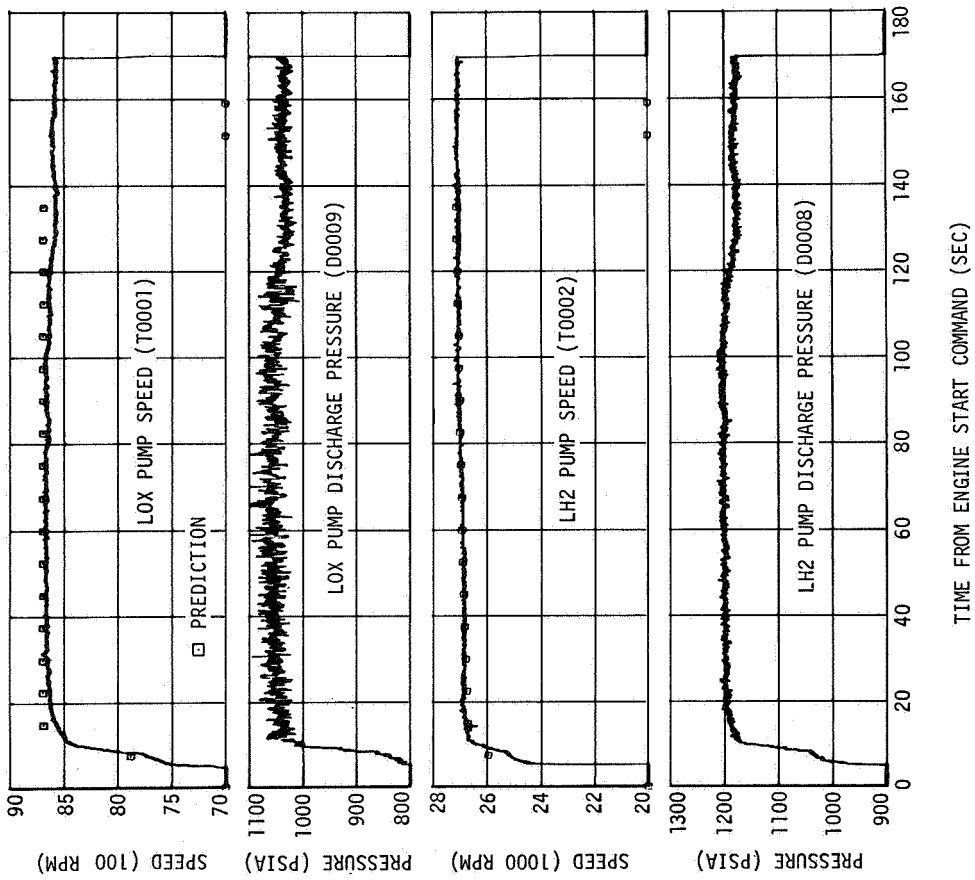


Figure 10-13. J-2 Engine Pump Operating Conditions - First Burn

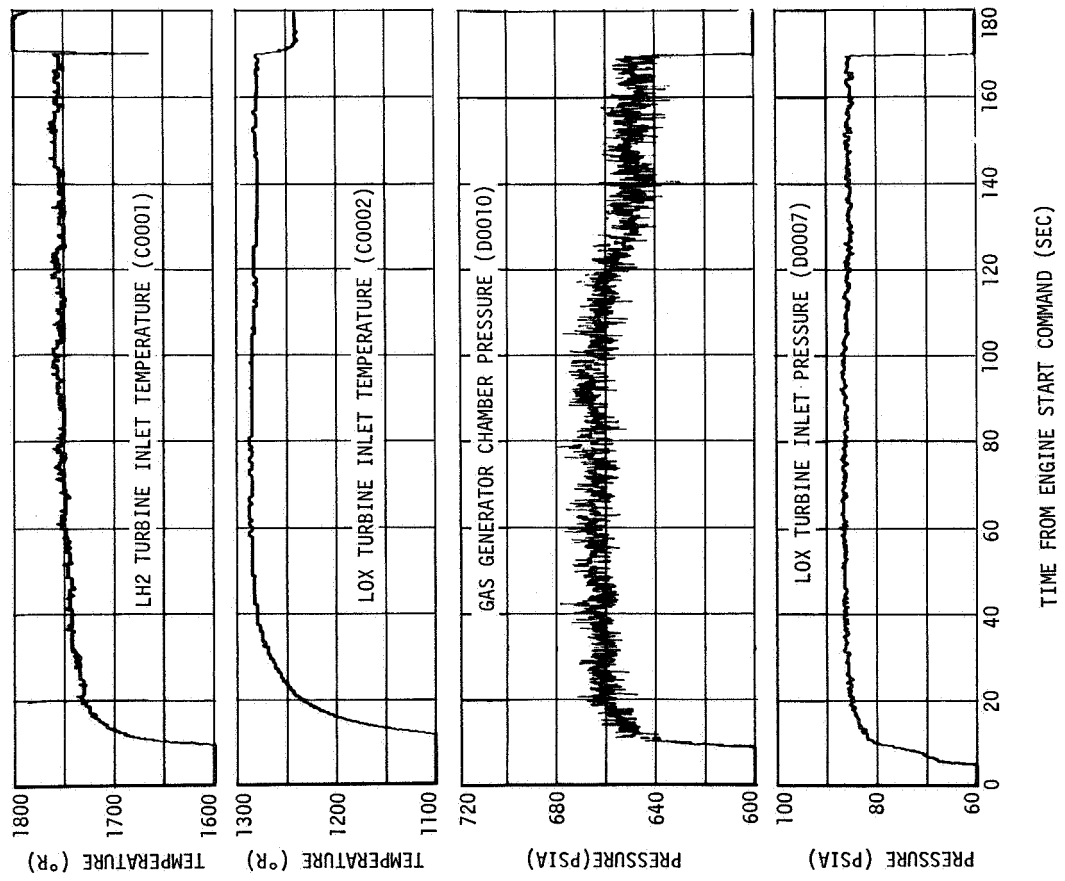


Figure 10-15. Turbine Inlet Operating Conditions - First Burn

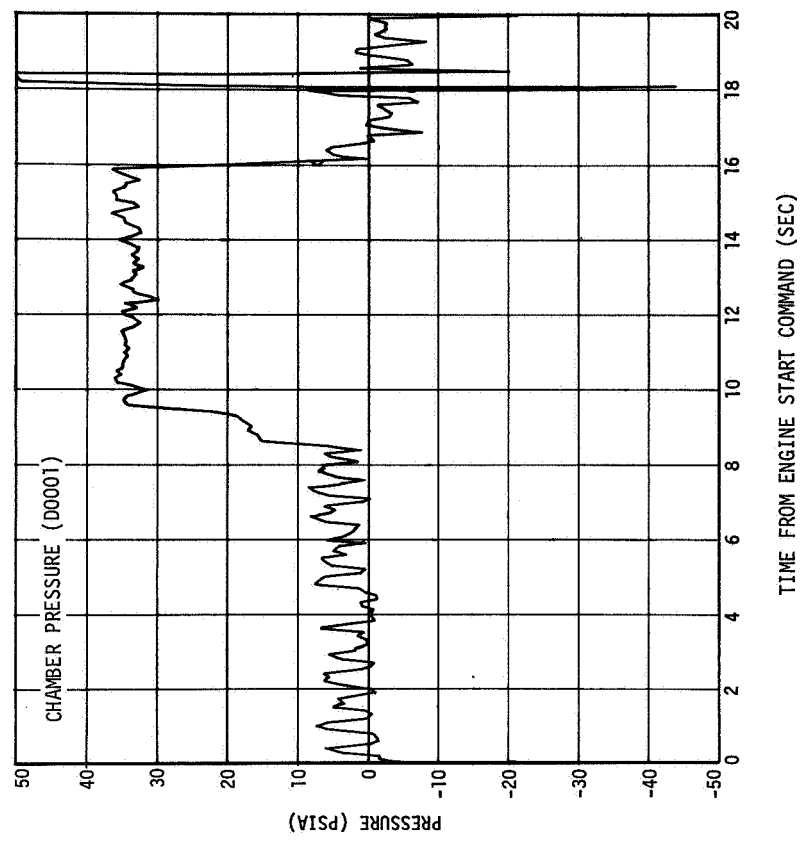


Figure 10-16. Engine Chamber Pressure - Second Burn

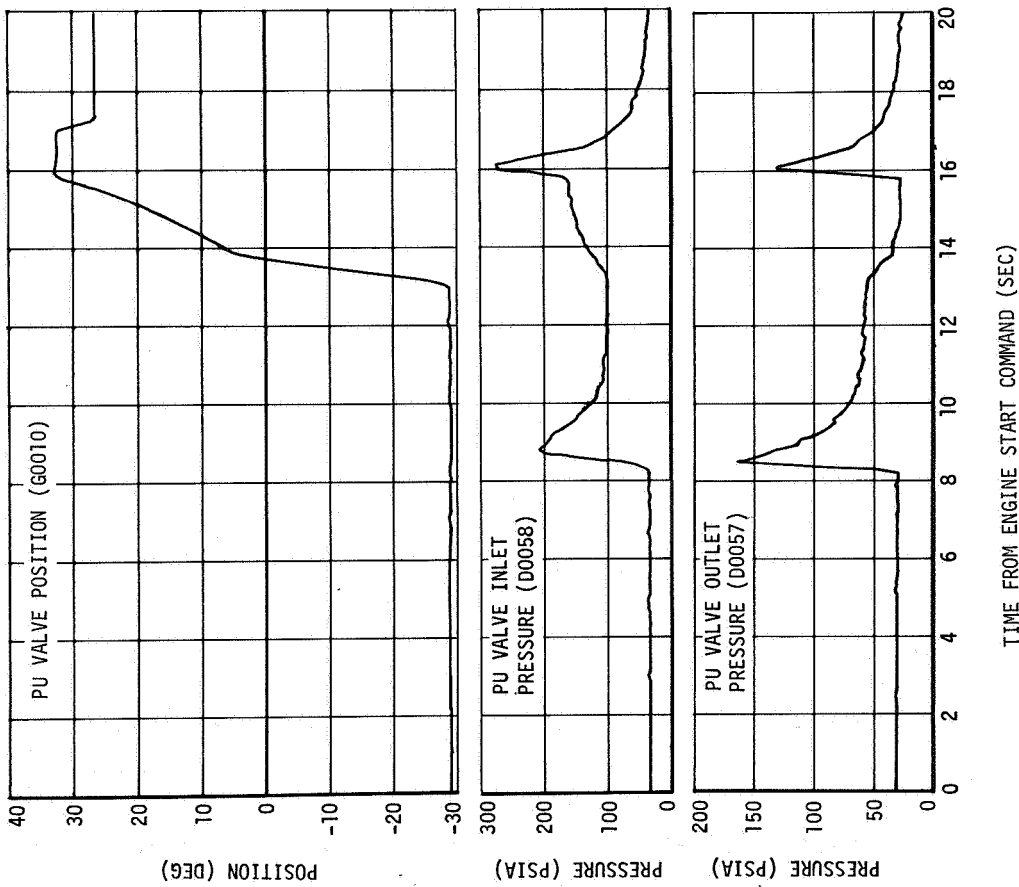


Figure 10-17. PU Valve Operation - Second Burn

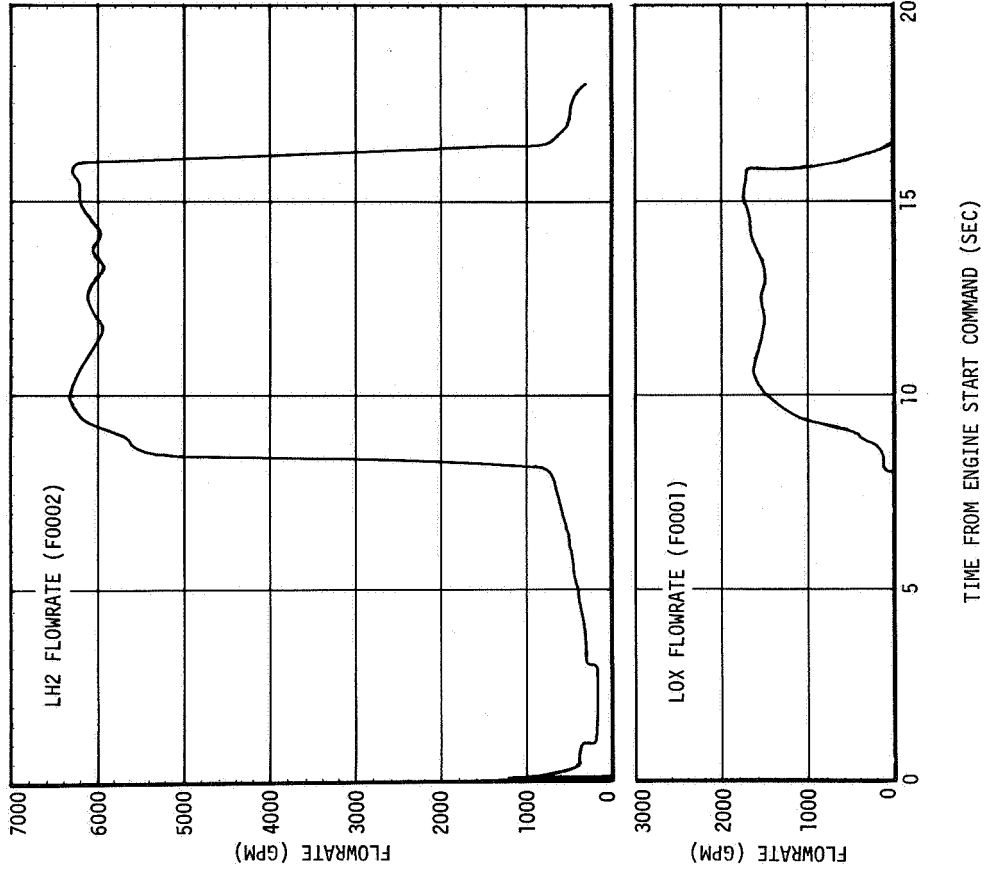


Figure 10-18. J-2 Engine Pump Flowrate - Second Burn

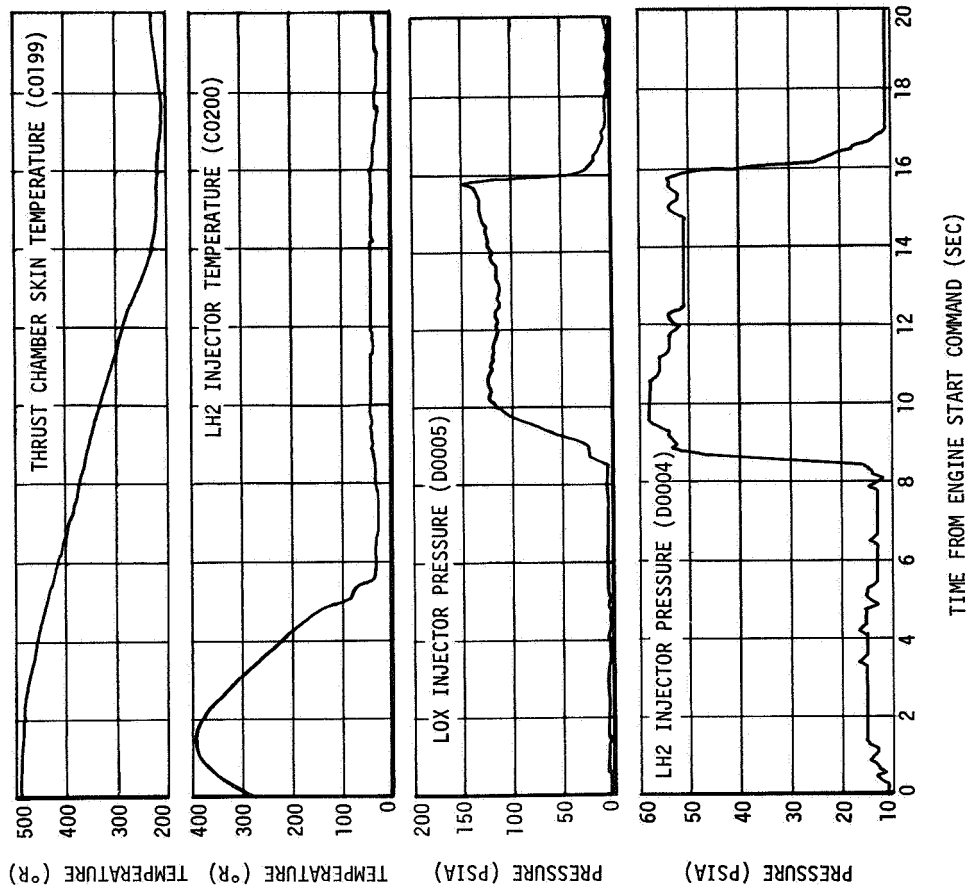


Figure 10-19. J-2 Engine Pump Operating Conditions - Second Burn

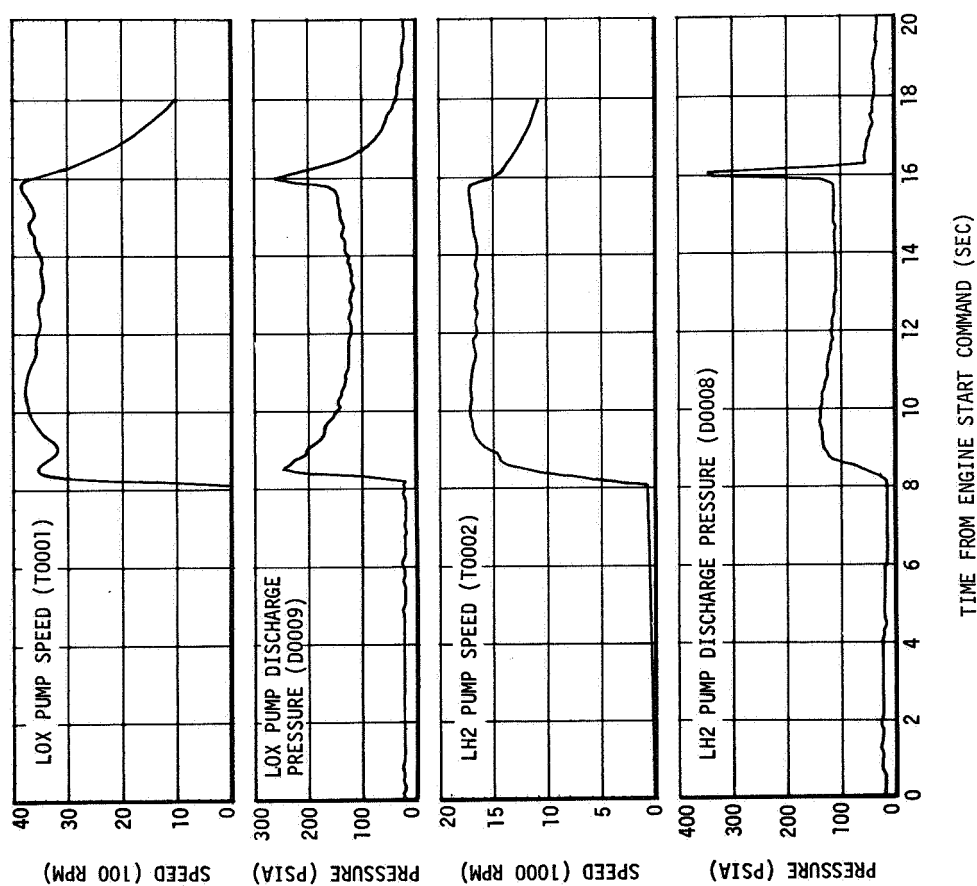


Figure 10-20. J-2 Engine Injector Supply Conditions - Second Burn

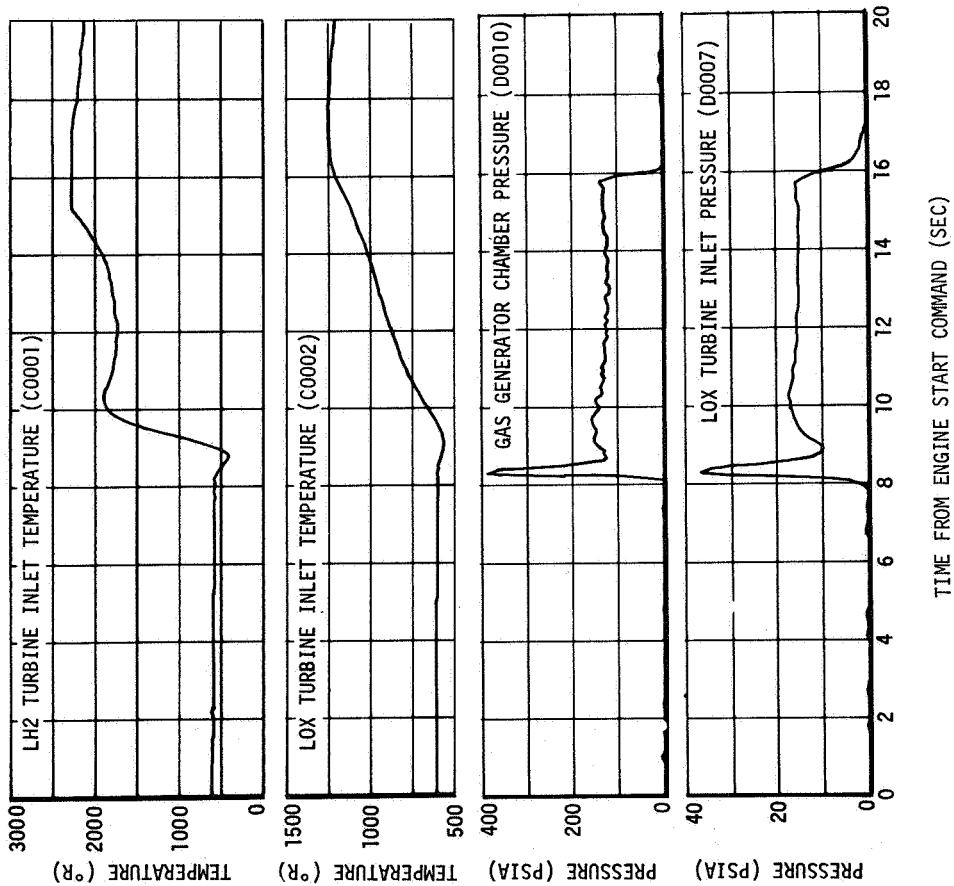


Figure 10-21. Turbine Inlet Operating Conditions - Second Burn

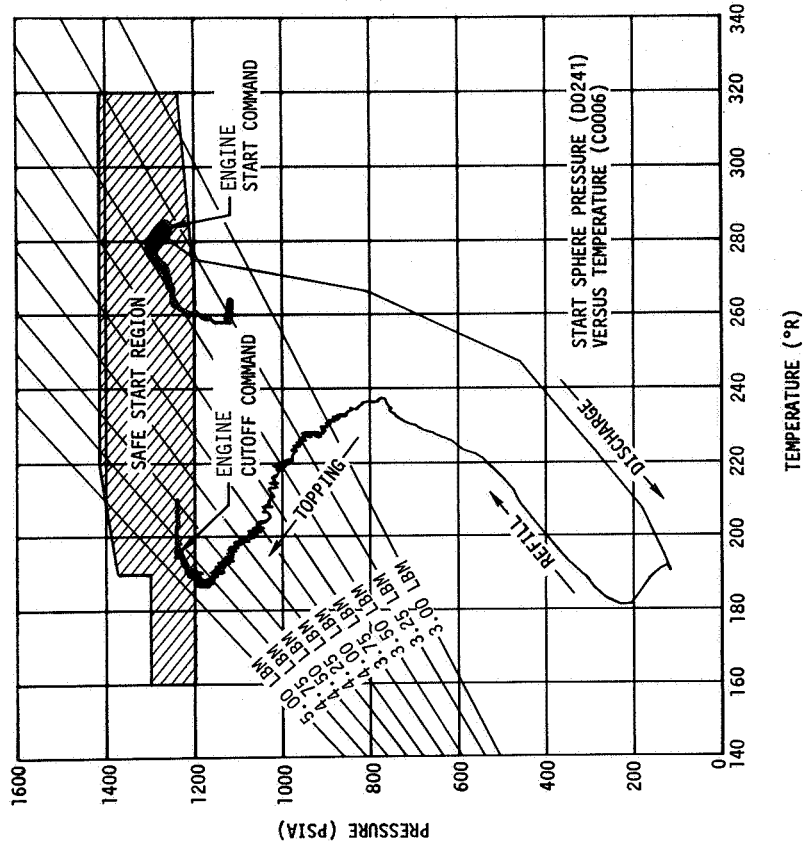


Figure 10-22. Start Sphere Refill Performance - First Burn

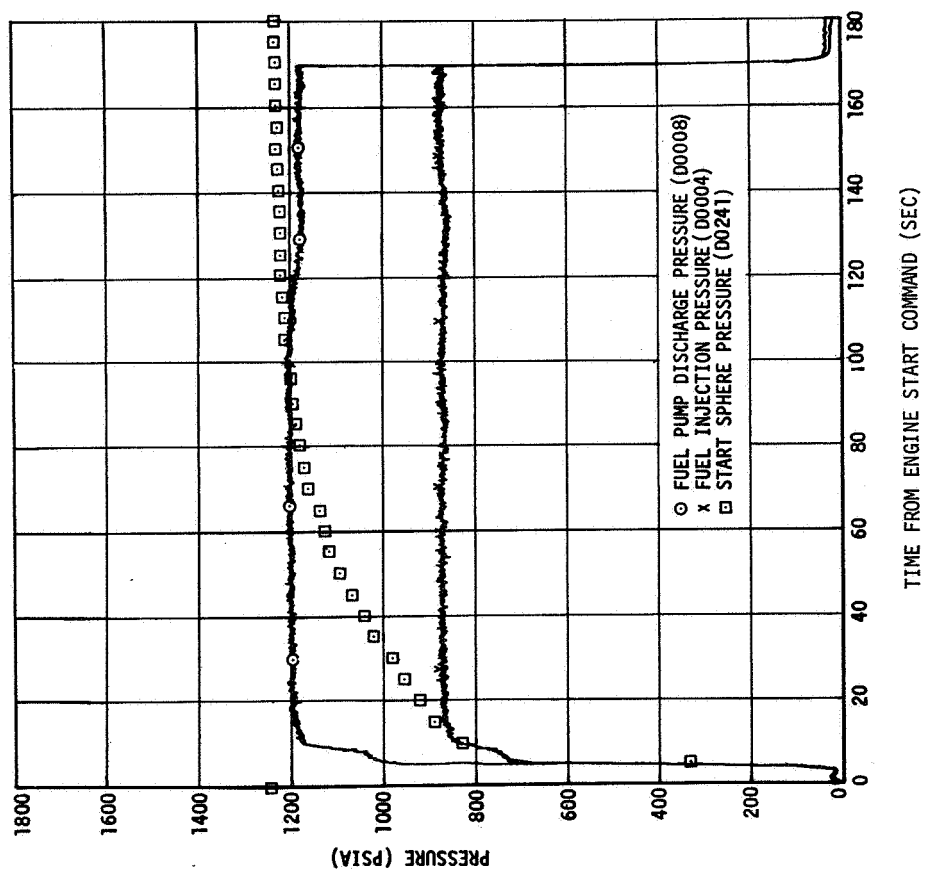
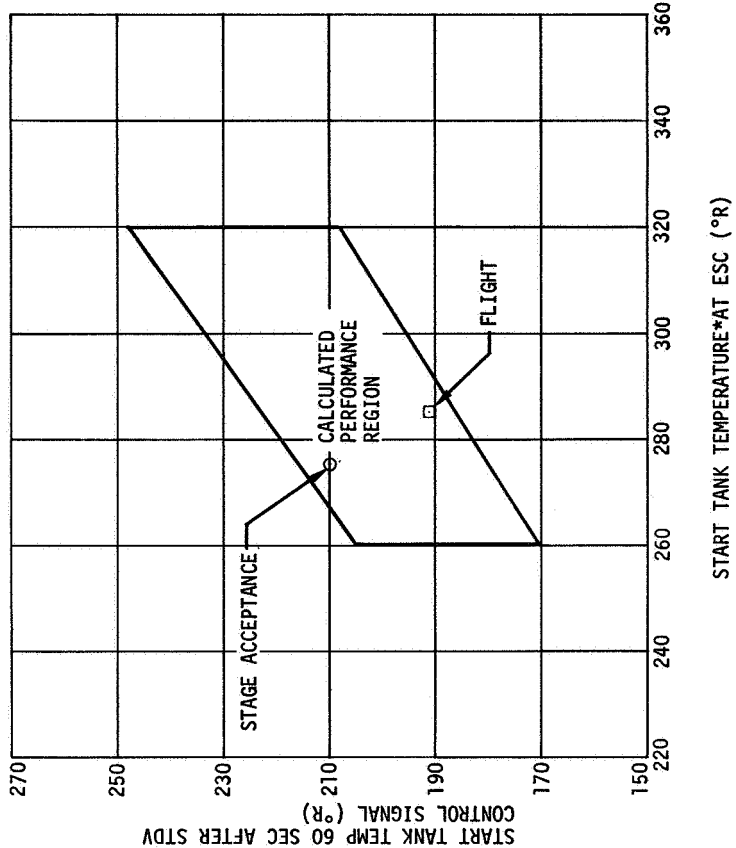


Figure 10-23. Start Sphere Refill



* DATA CORRECTED TO ZERO DIFFERENTIAL WITH RESPECT TO HELIUM TANK TEMPERATURE. PU VALVE WAS CLOSED 5.0 SECONDS FROM STDV COMMAND.

Figure 10-24. Start Tank Recharge Capability

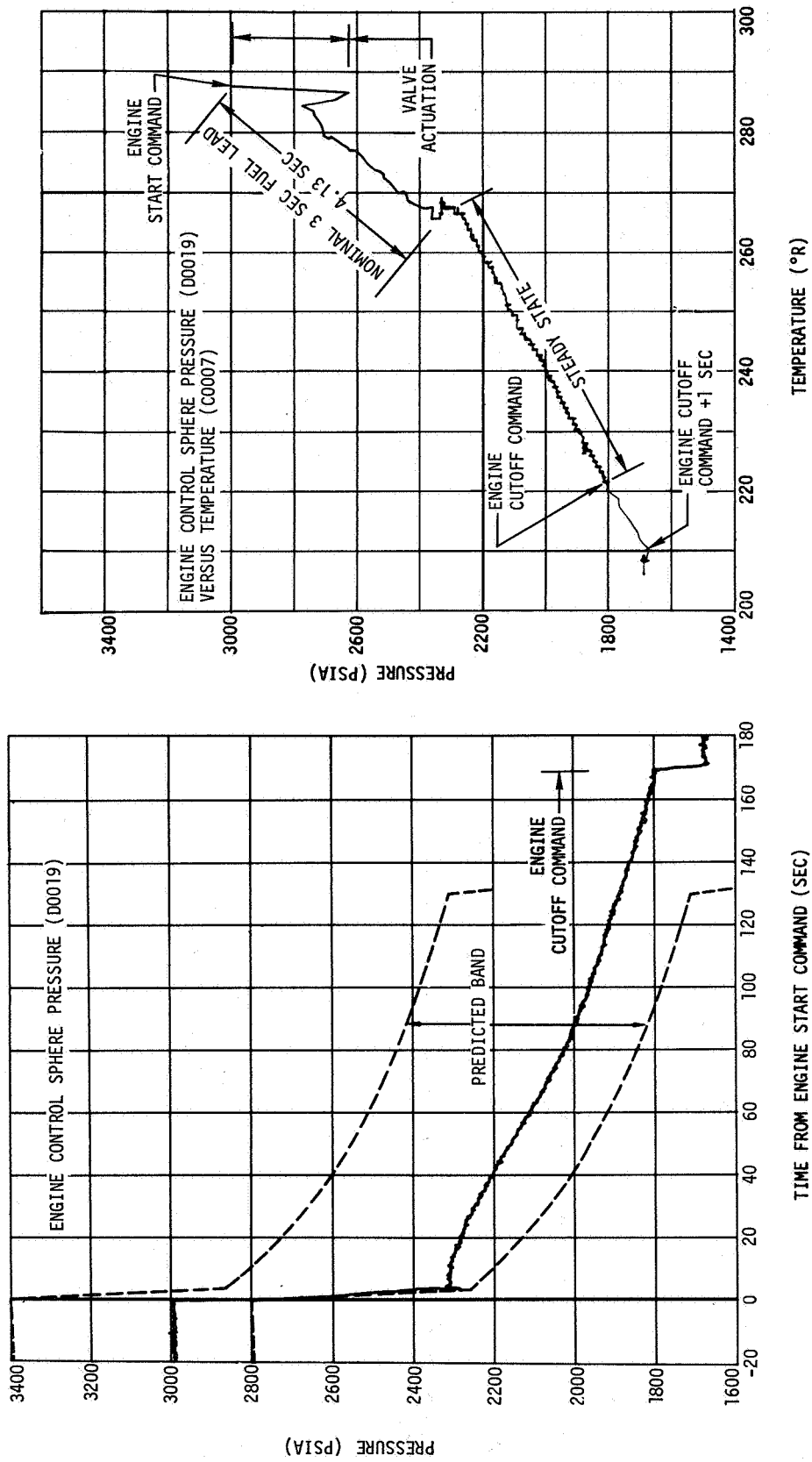


Figure 10-25. Engine Control Sphere Conditions - First Burn

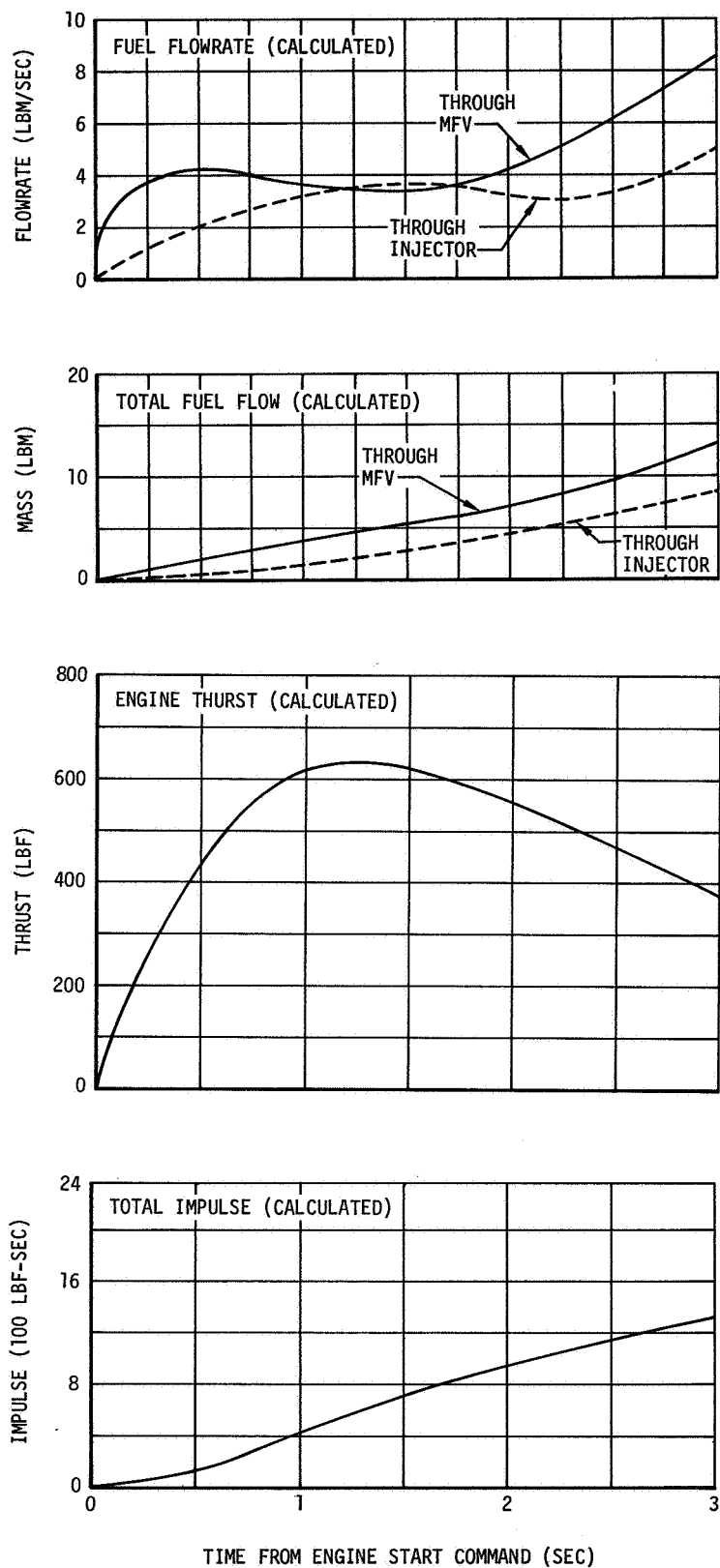


Figure 10-26. Fuel Lead Conditions - First Burn

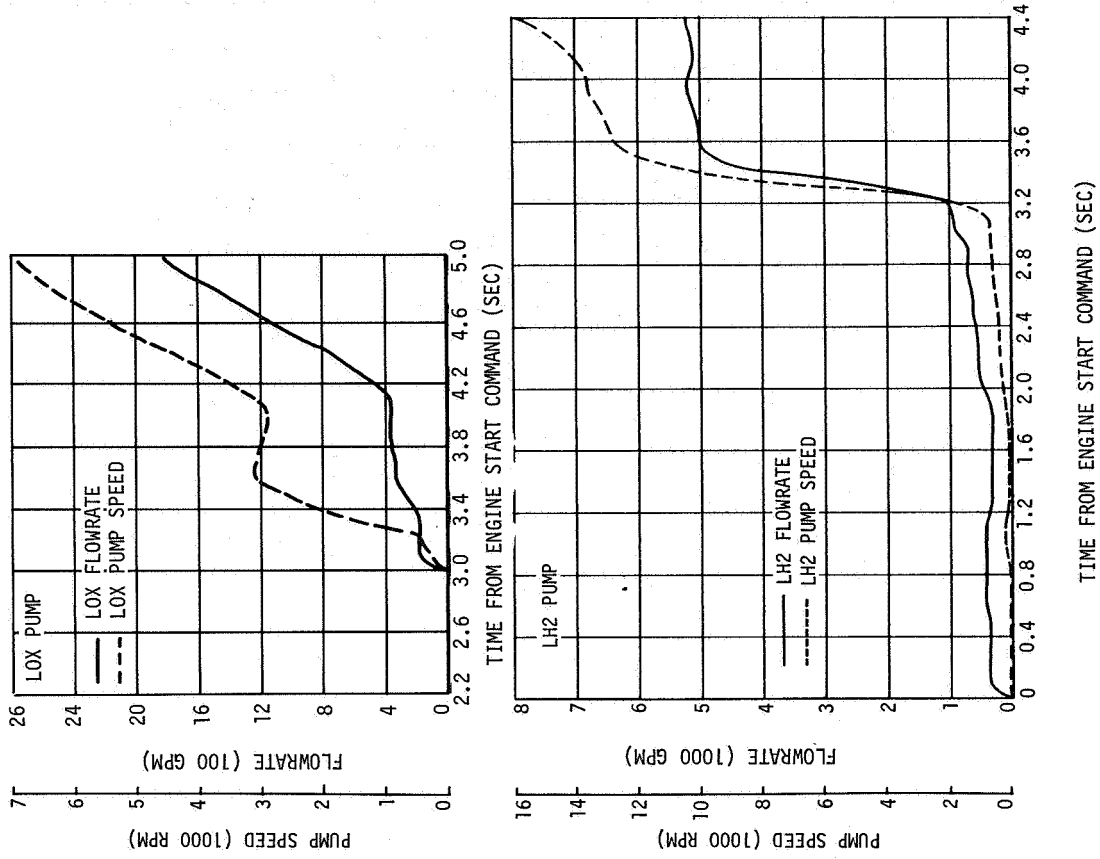


Figure 10-27. Engine Start Transient Characteristics - First Burn

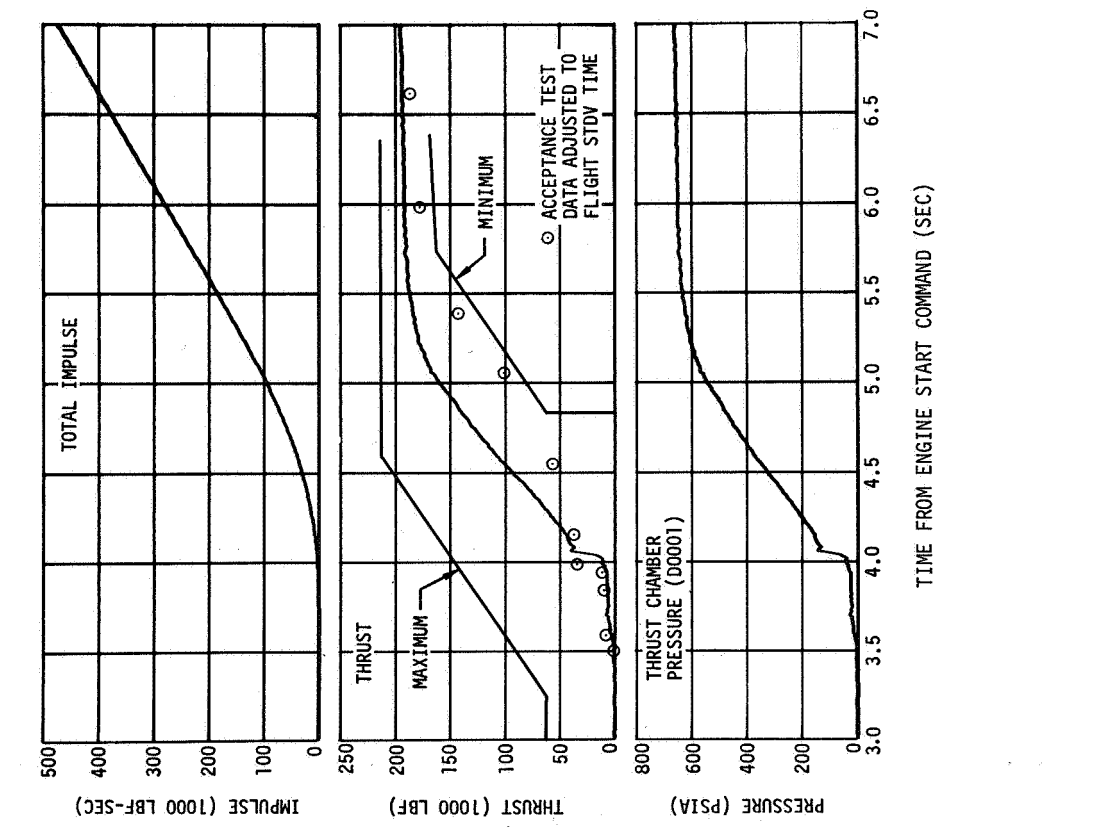


Figure 10-28. LOX and LH2 Pump Performance - First Burn

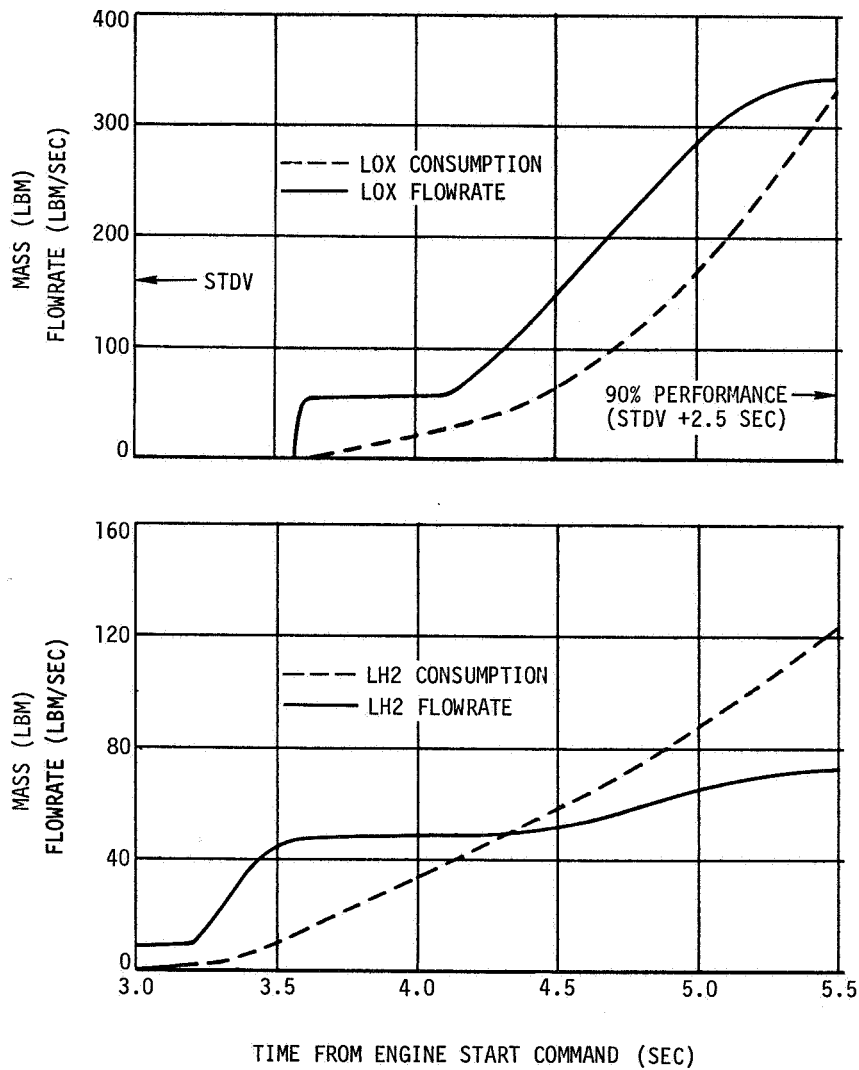


Figure 10-29. LOX and LH2 Consumption - First Burn Start Transient

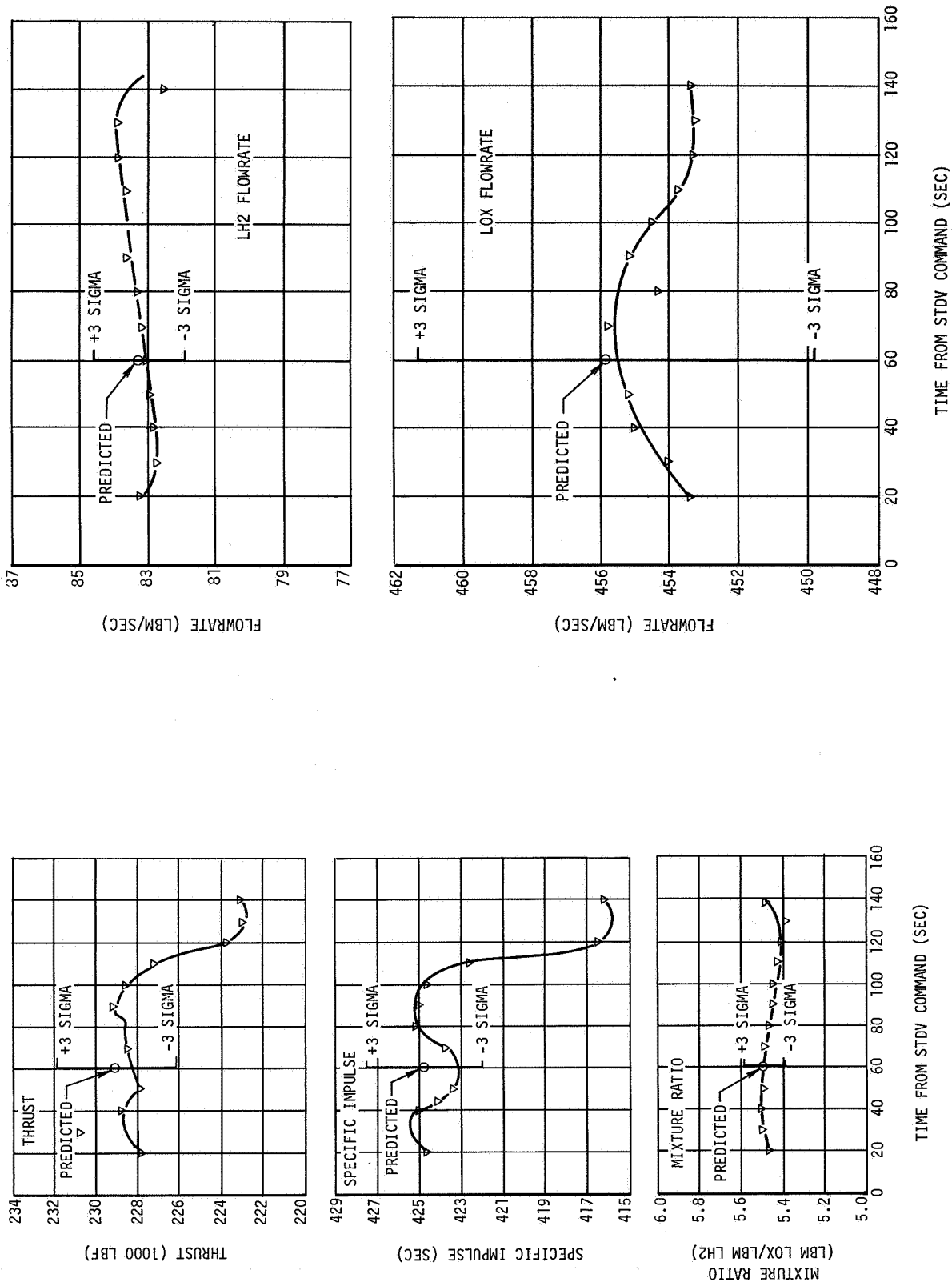


Figure 10-30. First Burn Engine Tag Values at Standard Altitude Conditions

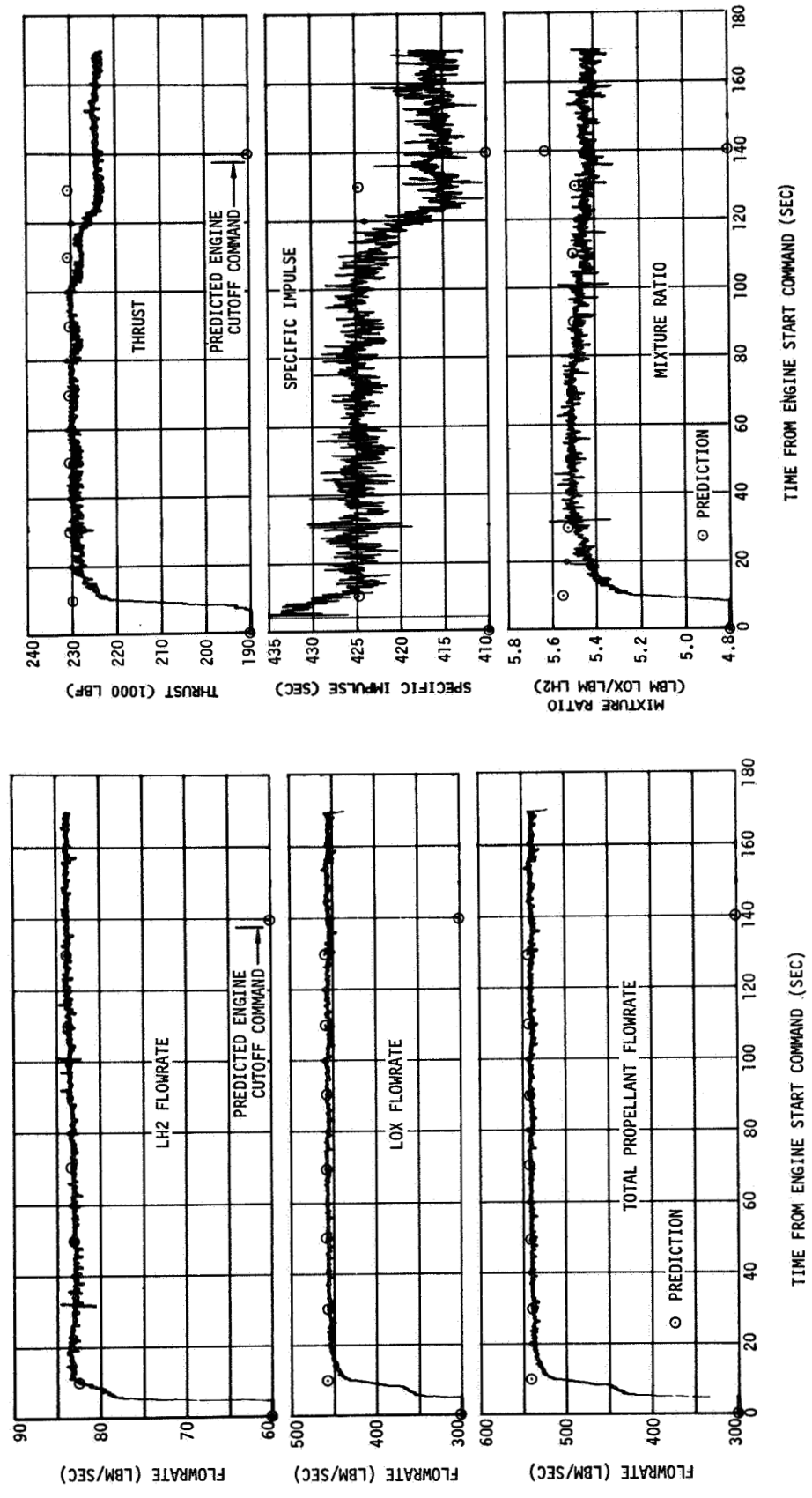


Figure 10-31. Engine Steady-State Performance - First Burn (Sheet 1 of 2)

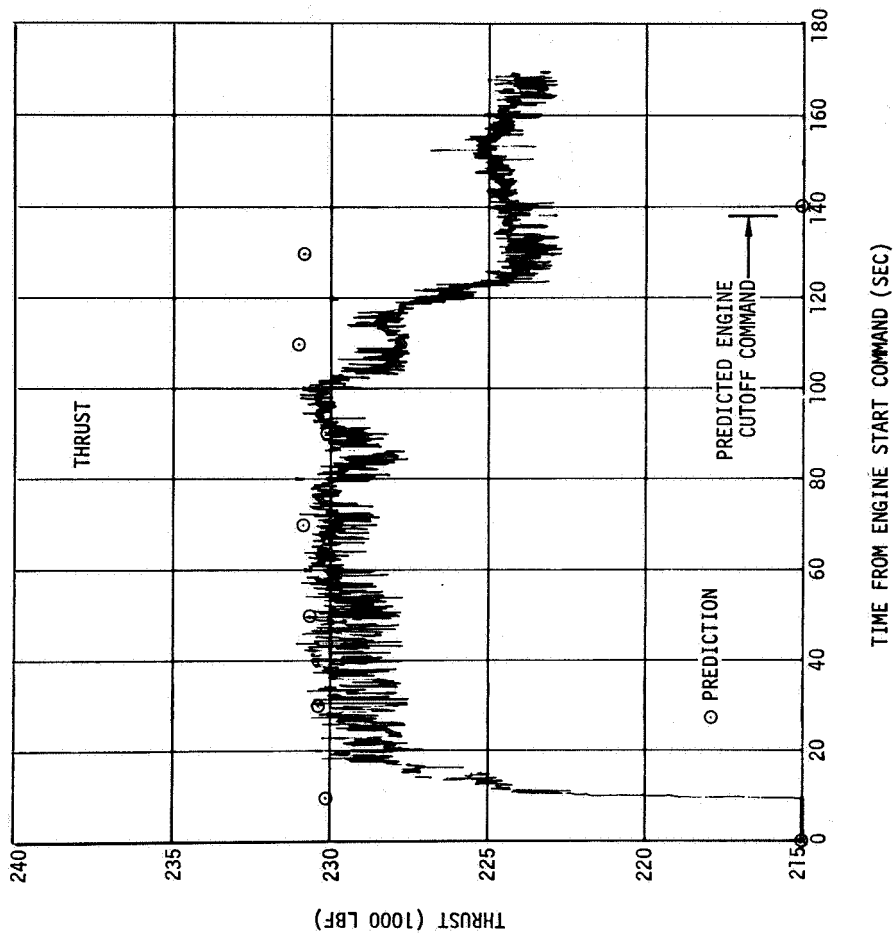


Figure 10-31. Engine Steady-State Performance - First Burn (Sheet 2 of 2)

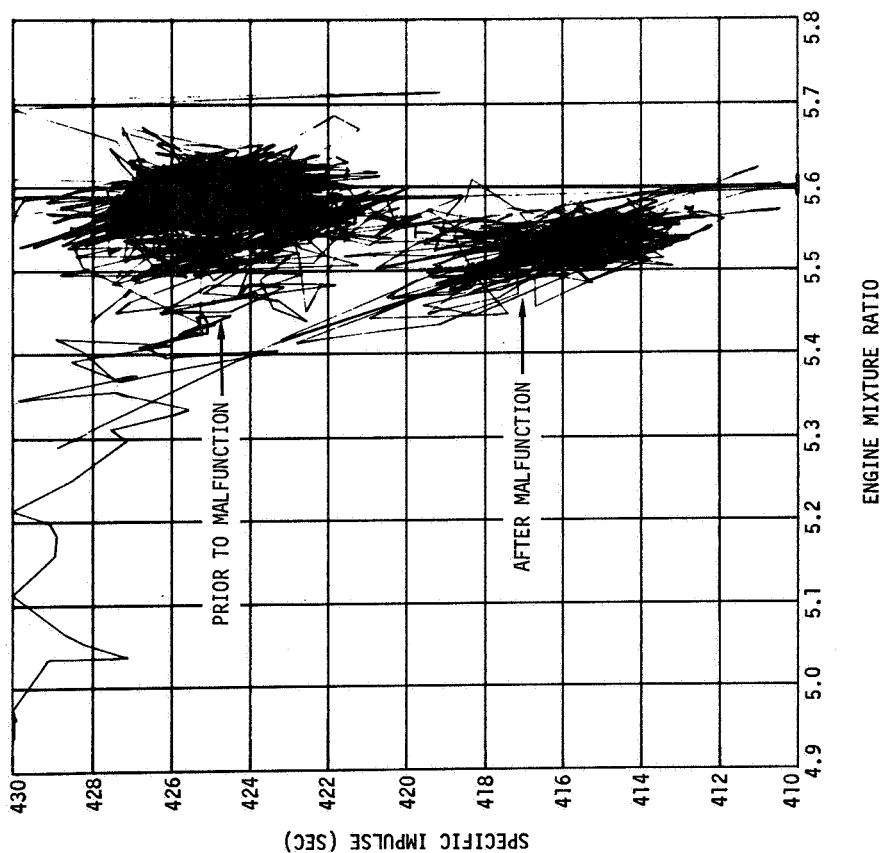
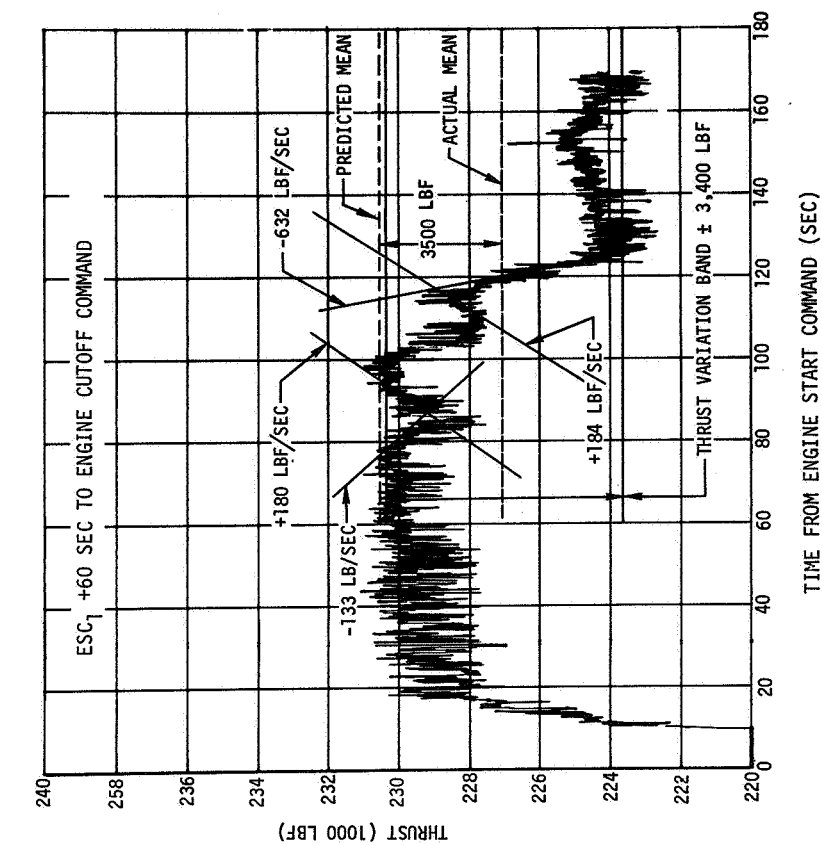


Figure 10-33. Thrust Variation - First Burn

Figure 10-32. Specific Impulse Versus Engine Mixture Ratio - First Burn

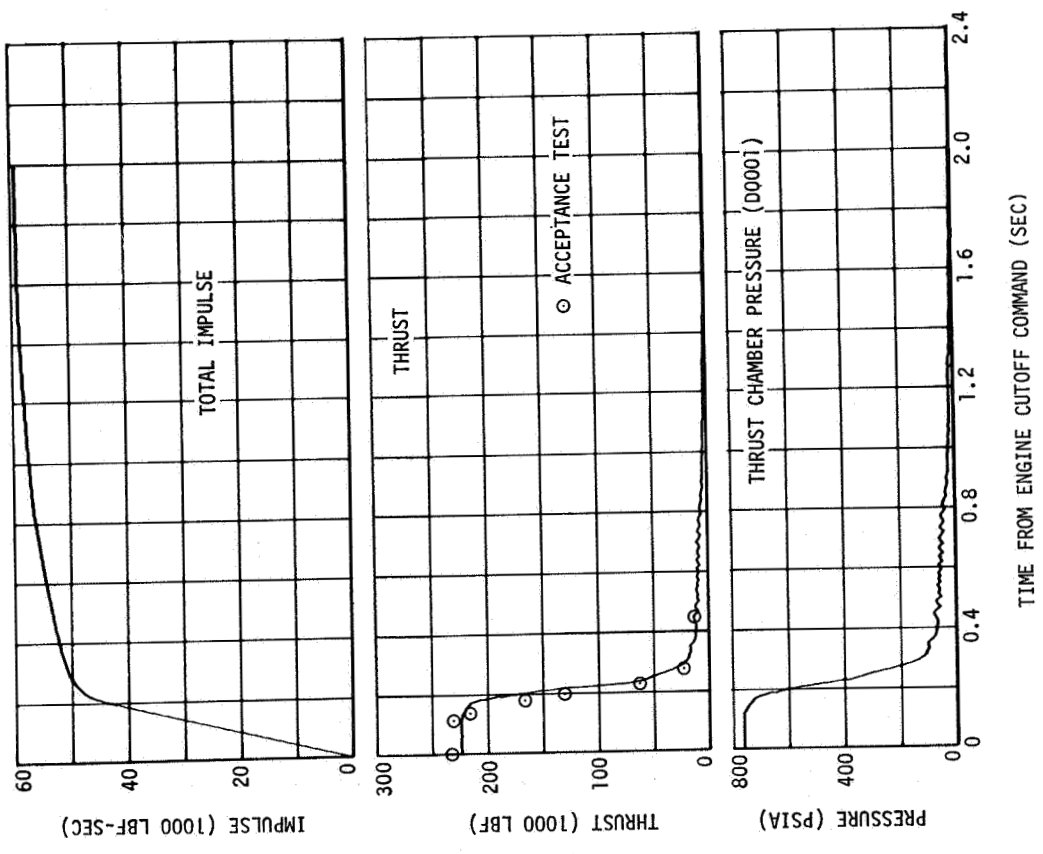
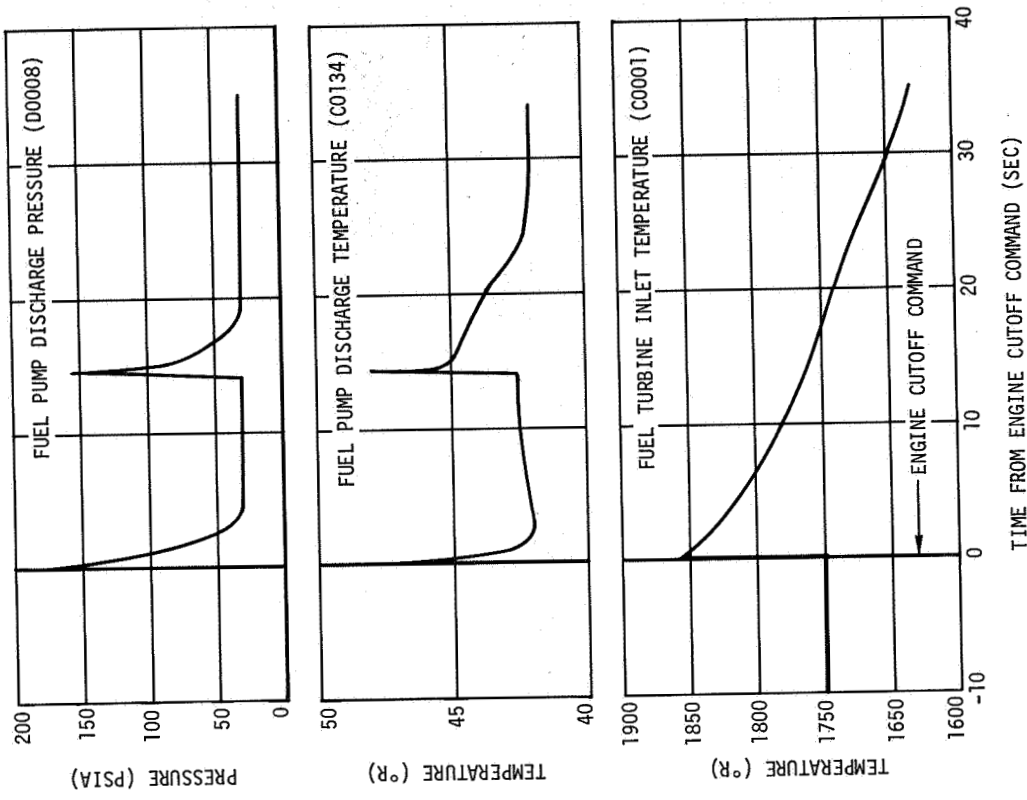


Figure 10-34. Engine Cutoff Transient Characteristics - First Burn

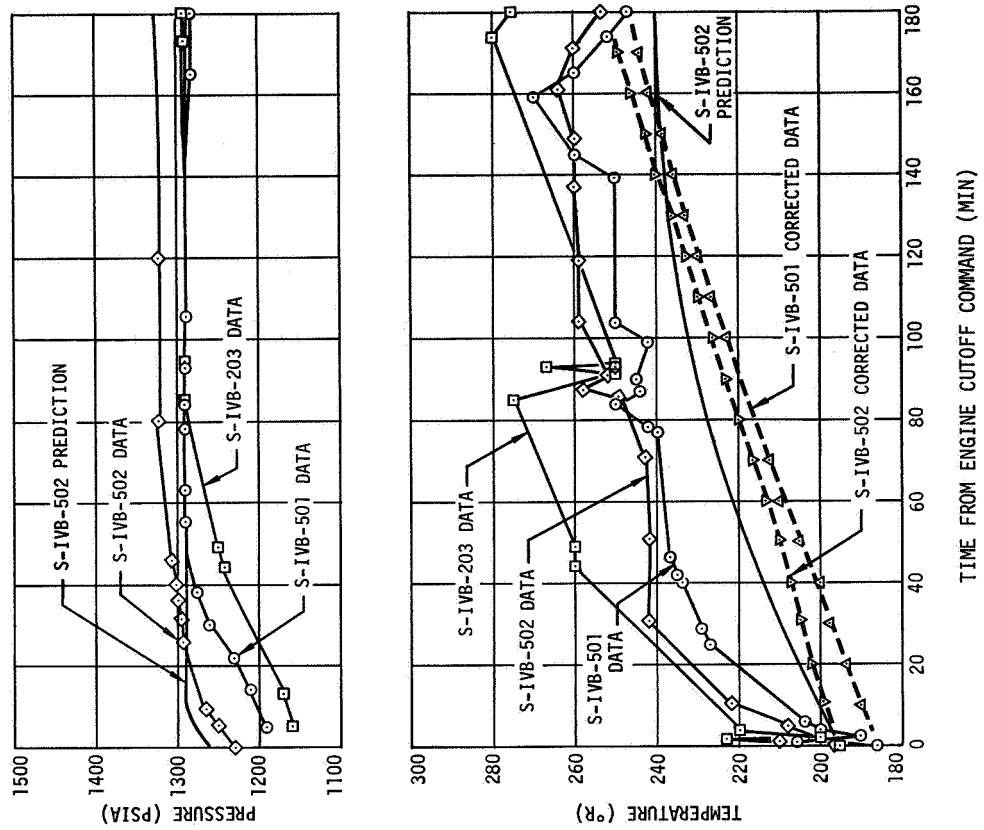


Figure 10-36. Start Sphere Conditions - First and Second Orbits

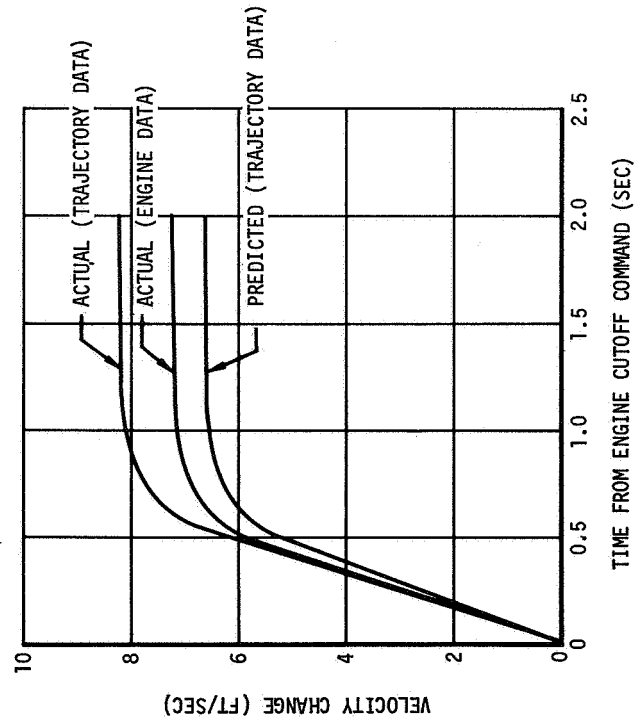


Figure 10-35. Change in Velocity Due to Cutoff Impulse - First Burn

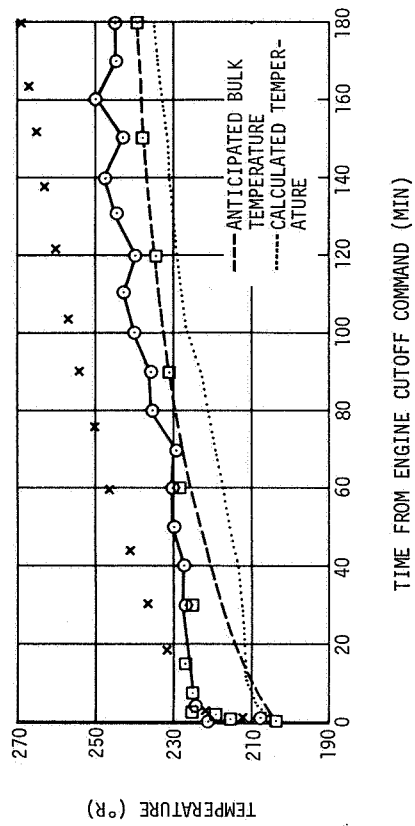
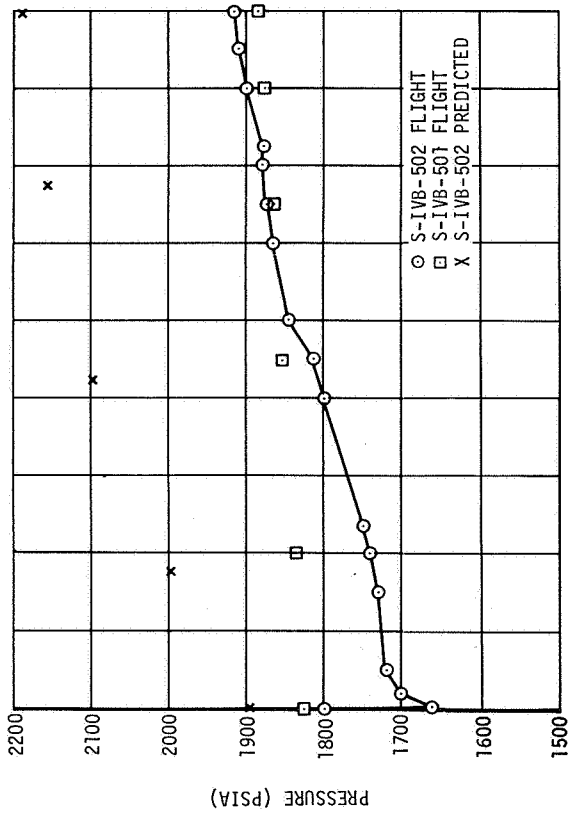


Figure 10-37. Engine Control Sphere Performance - First and Second Orbit

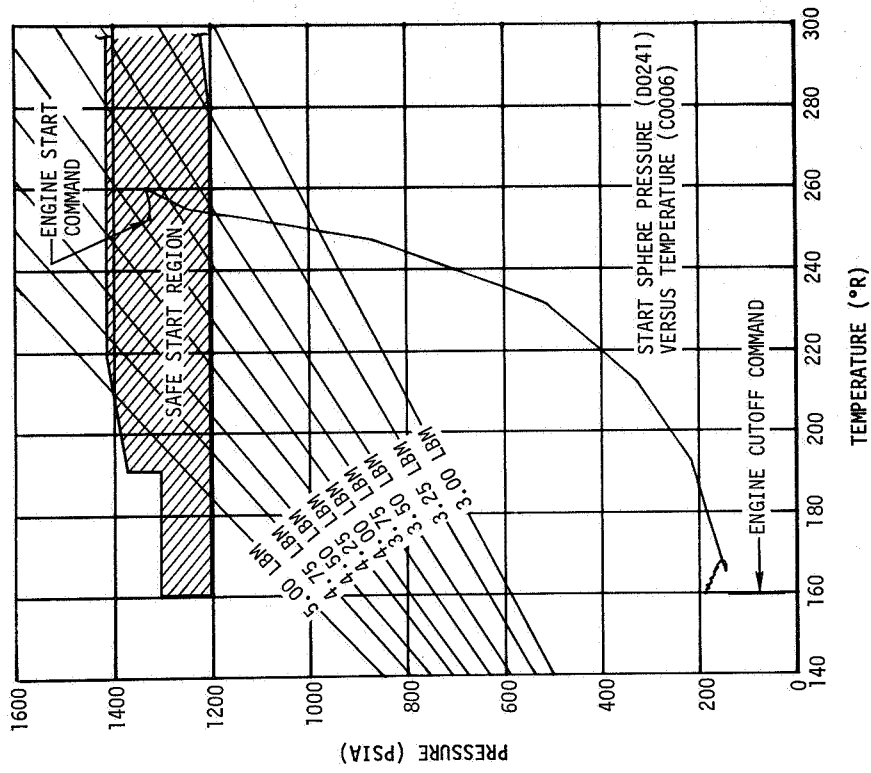


Figure 10-38. Start Sphere Blowdown - Second Burn

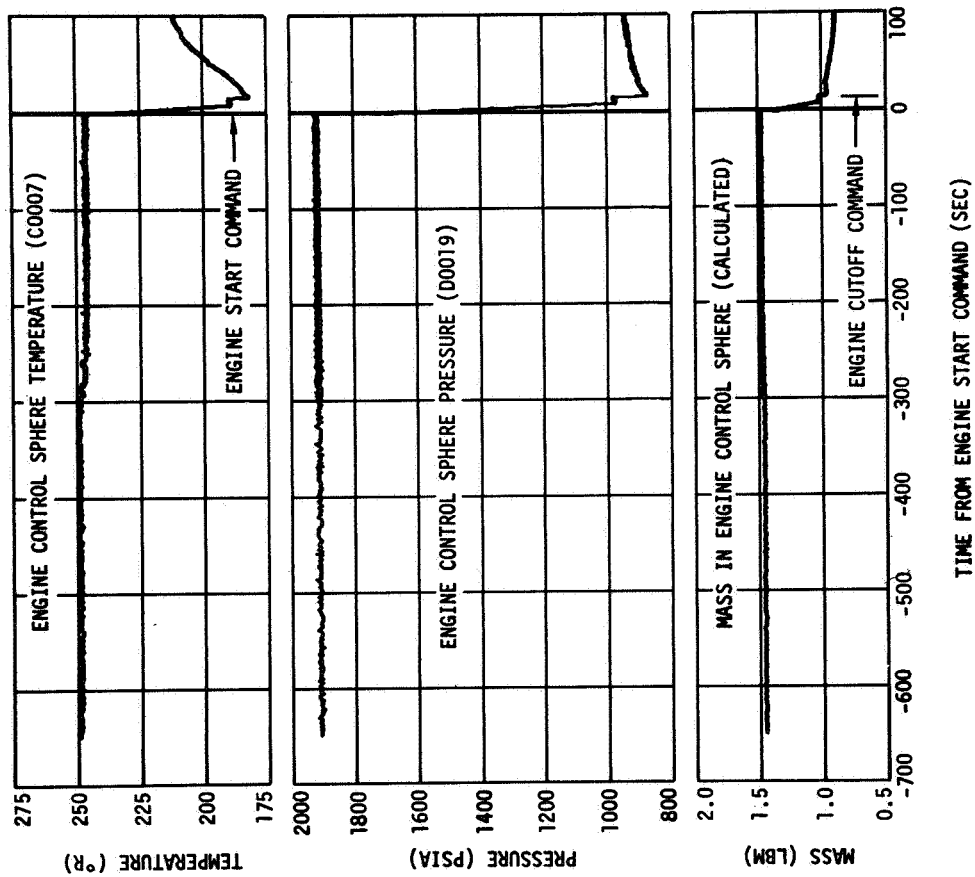
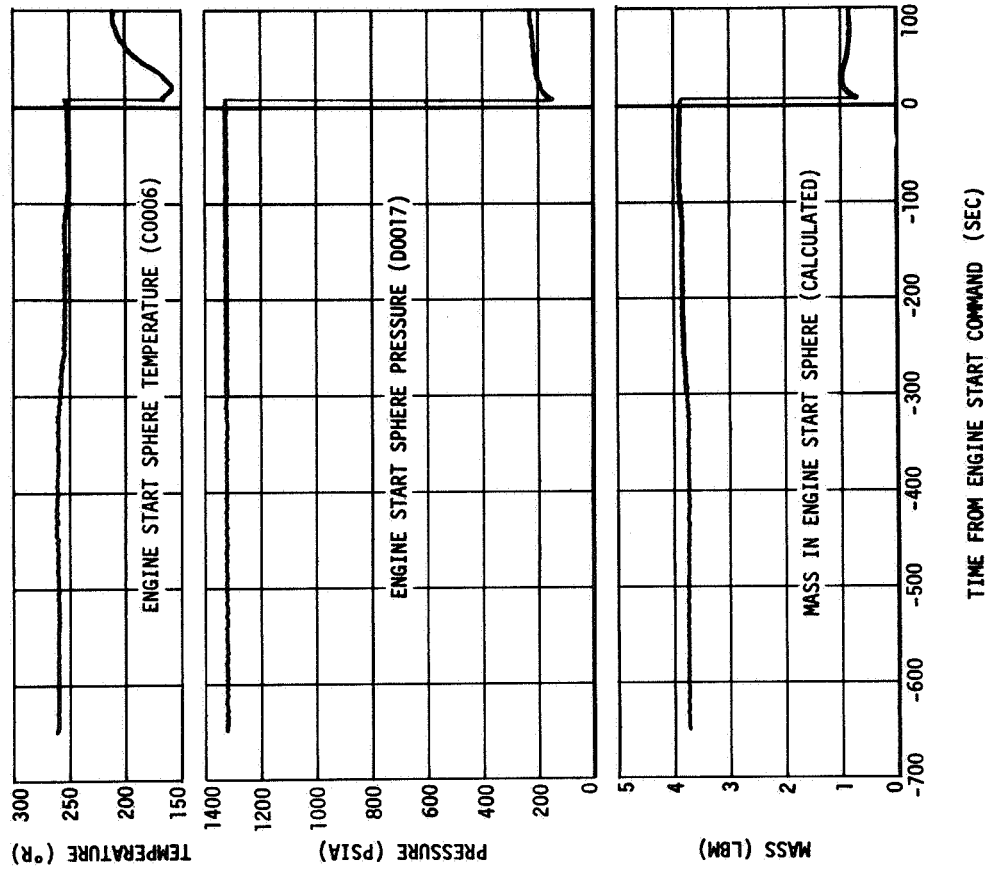


Figure 10-39. Engine Start and Control Sphere Operation - Second Burn

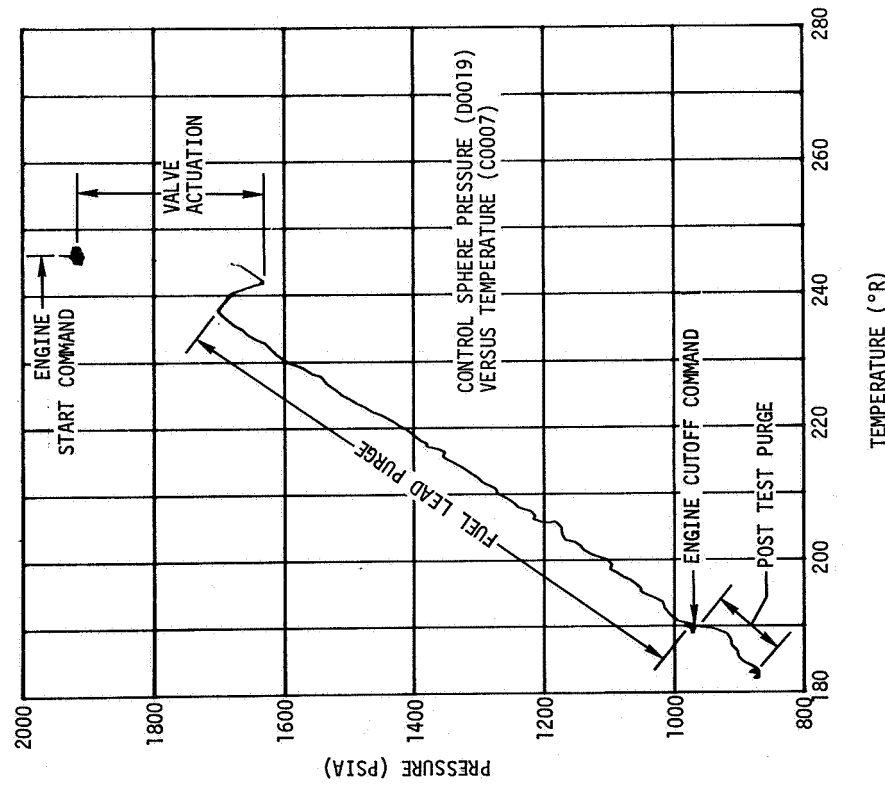
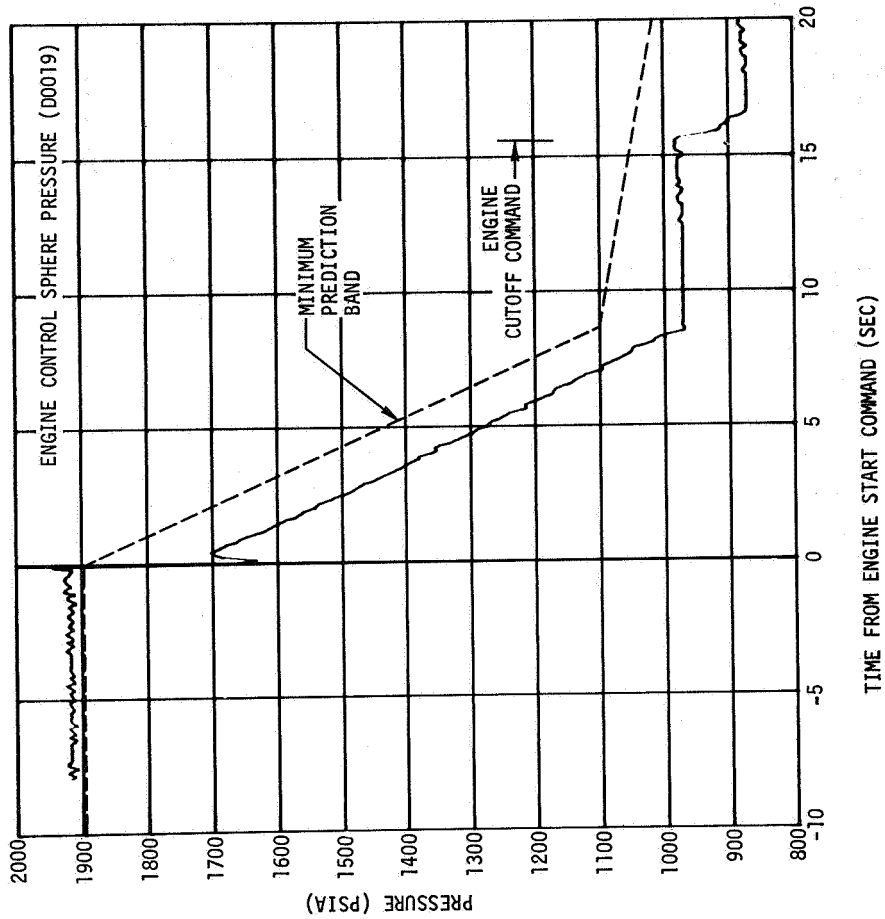


Figure 10-40. Control Sphere Performance - Second Burn

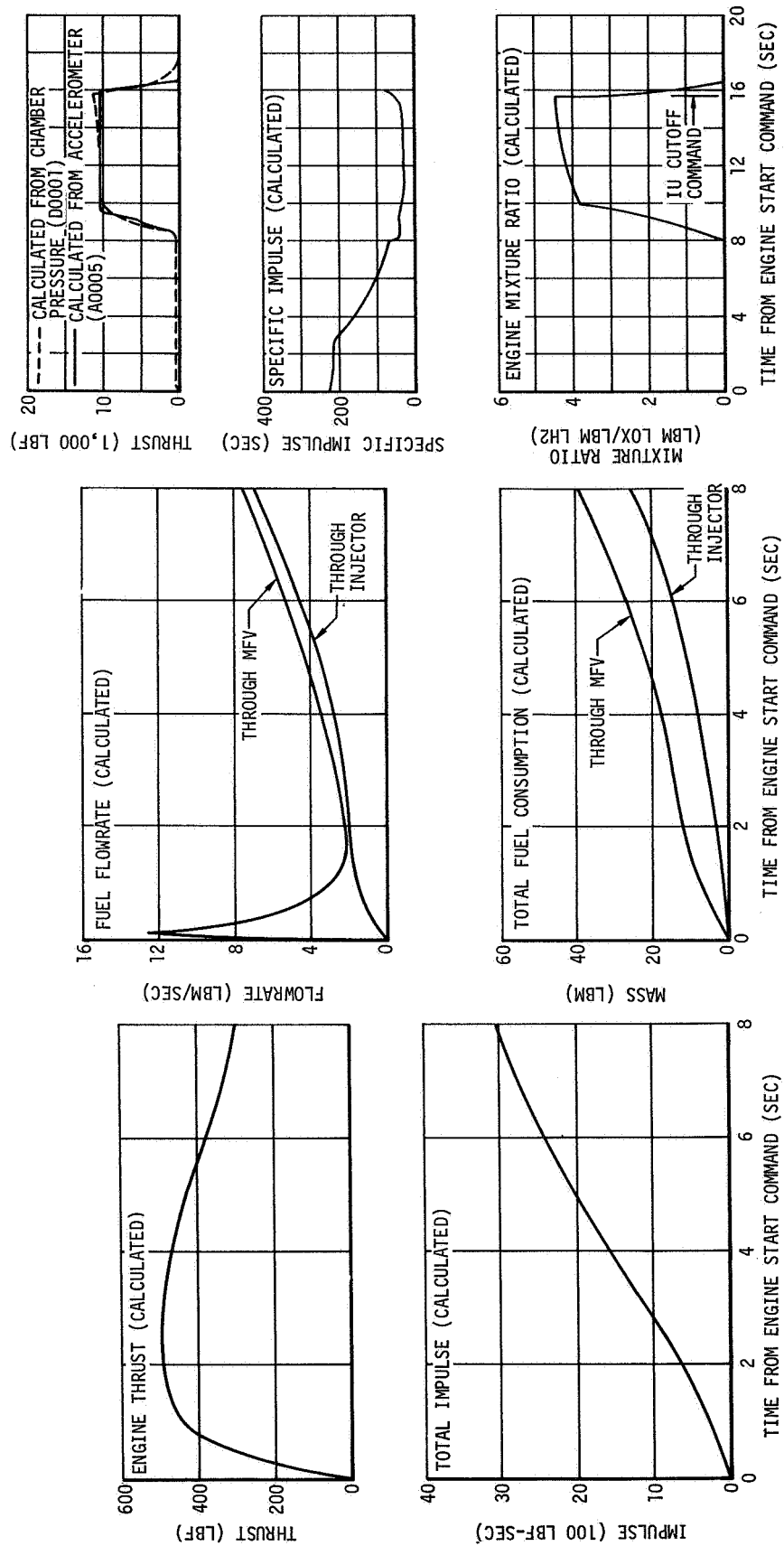


Figure 10-41. Engine Performance During Attempted Second Burn

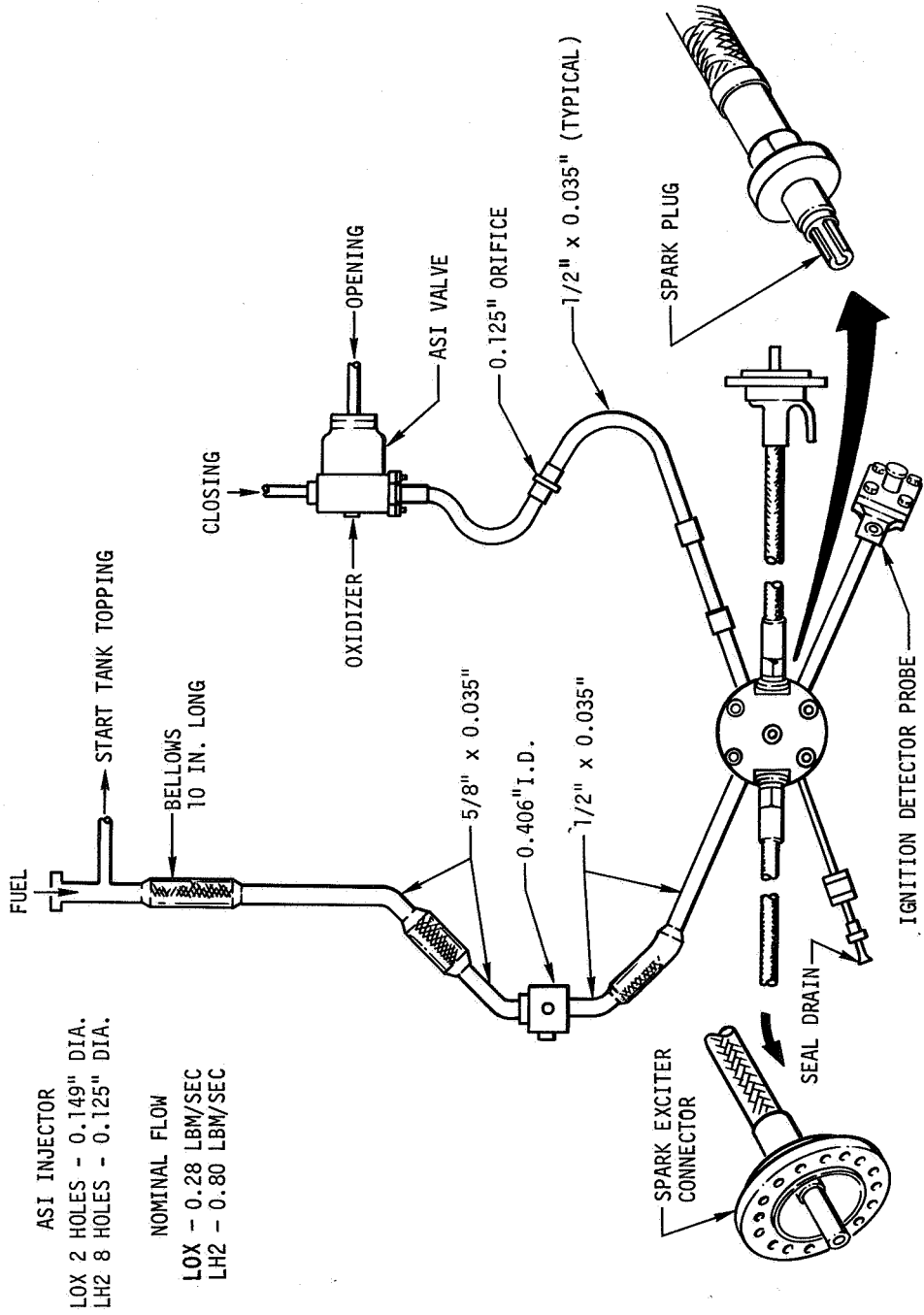


Figure 10-42. ASI Ignition System Schematic

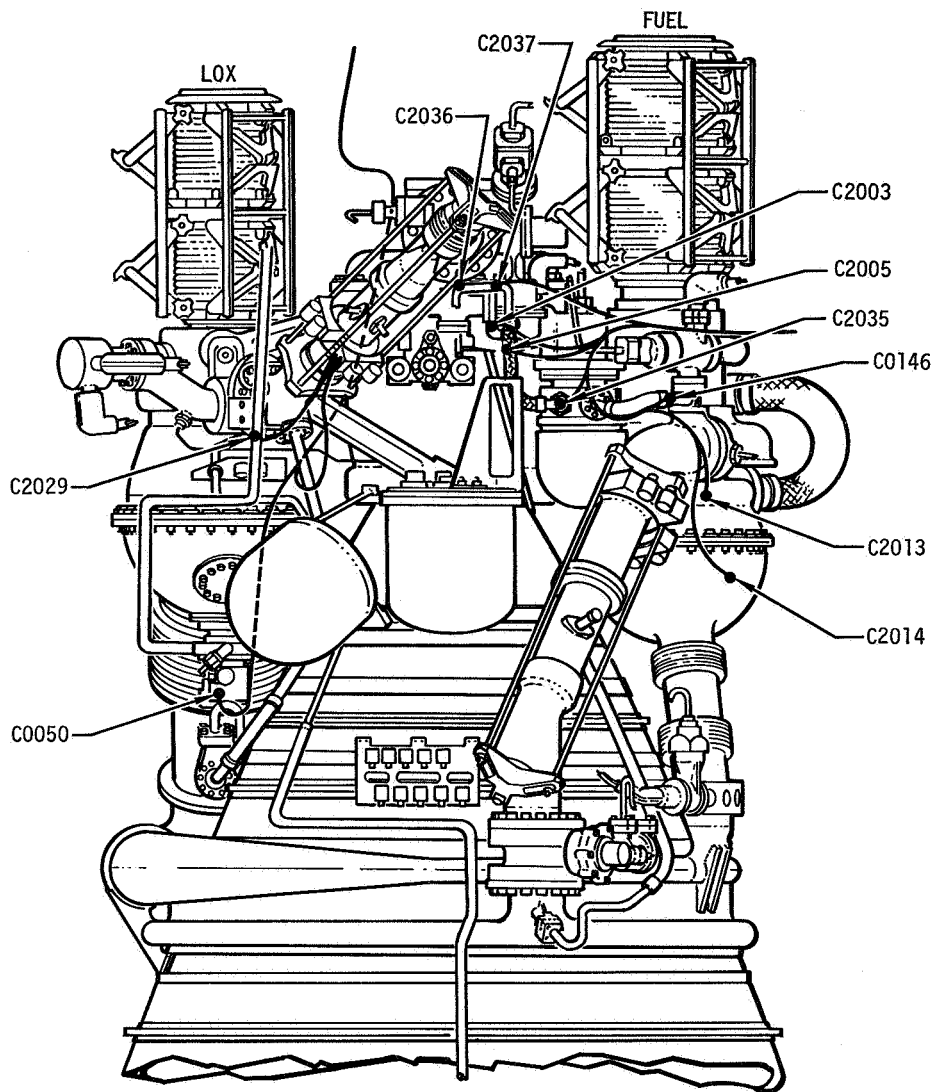


Figure 10-43. Engine Area Transducer Locations (Sheet 1 of 3)

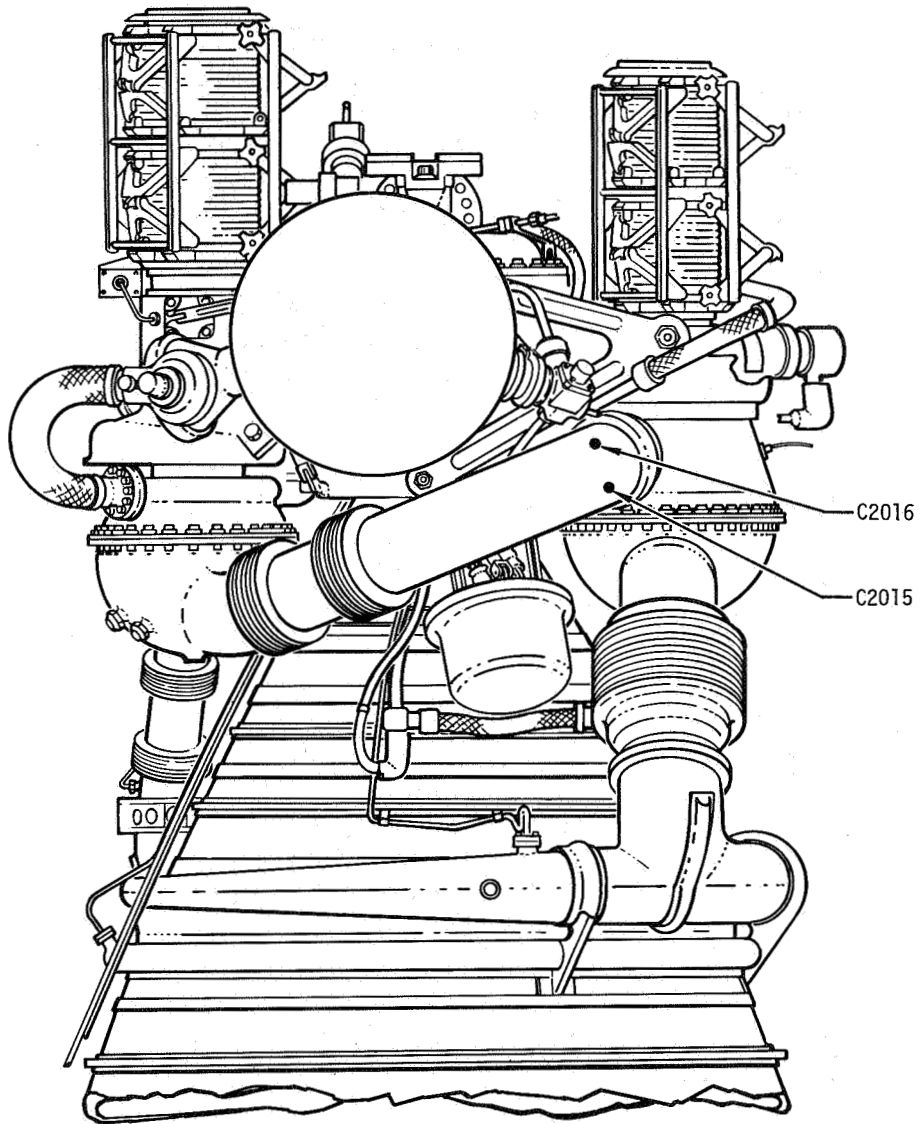


Figure 10-43. Engine Area Transducer Locations (Sheet 2 of 3)

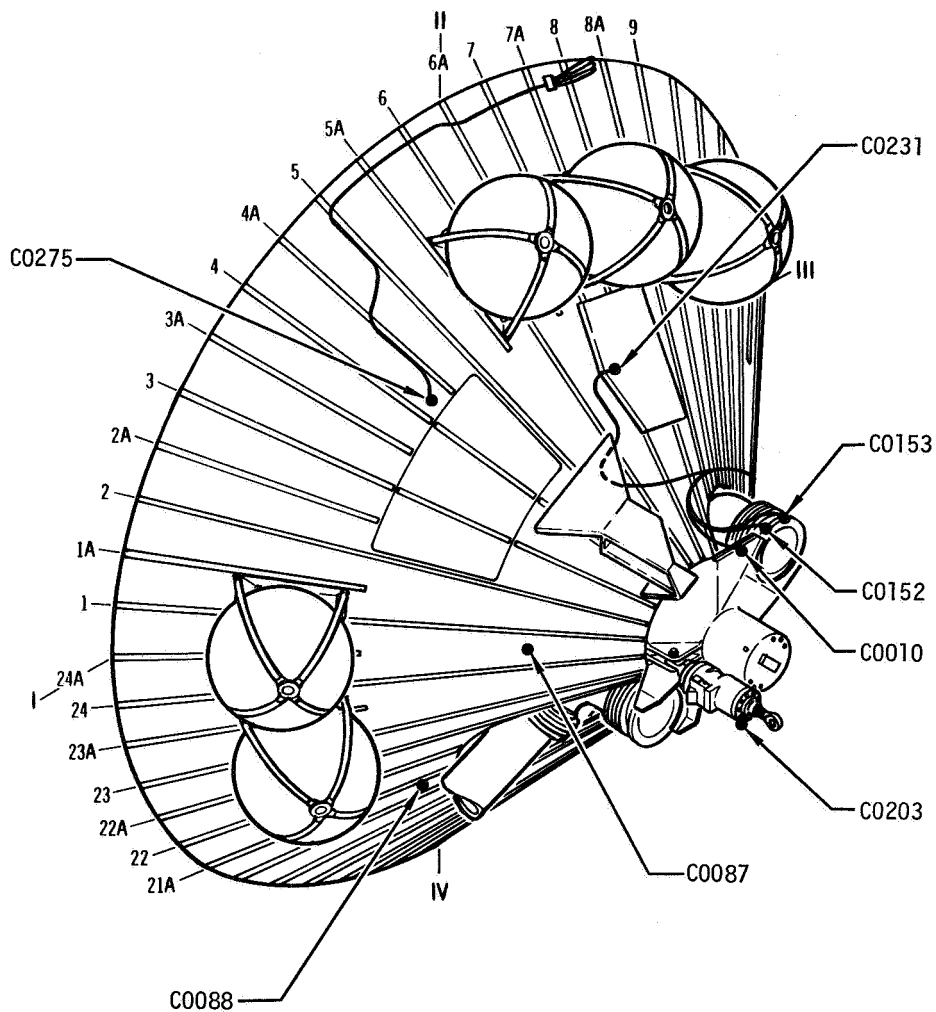


Figure 10-43. Engine Area Transducer Locations (Sheet 3 of 3)

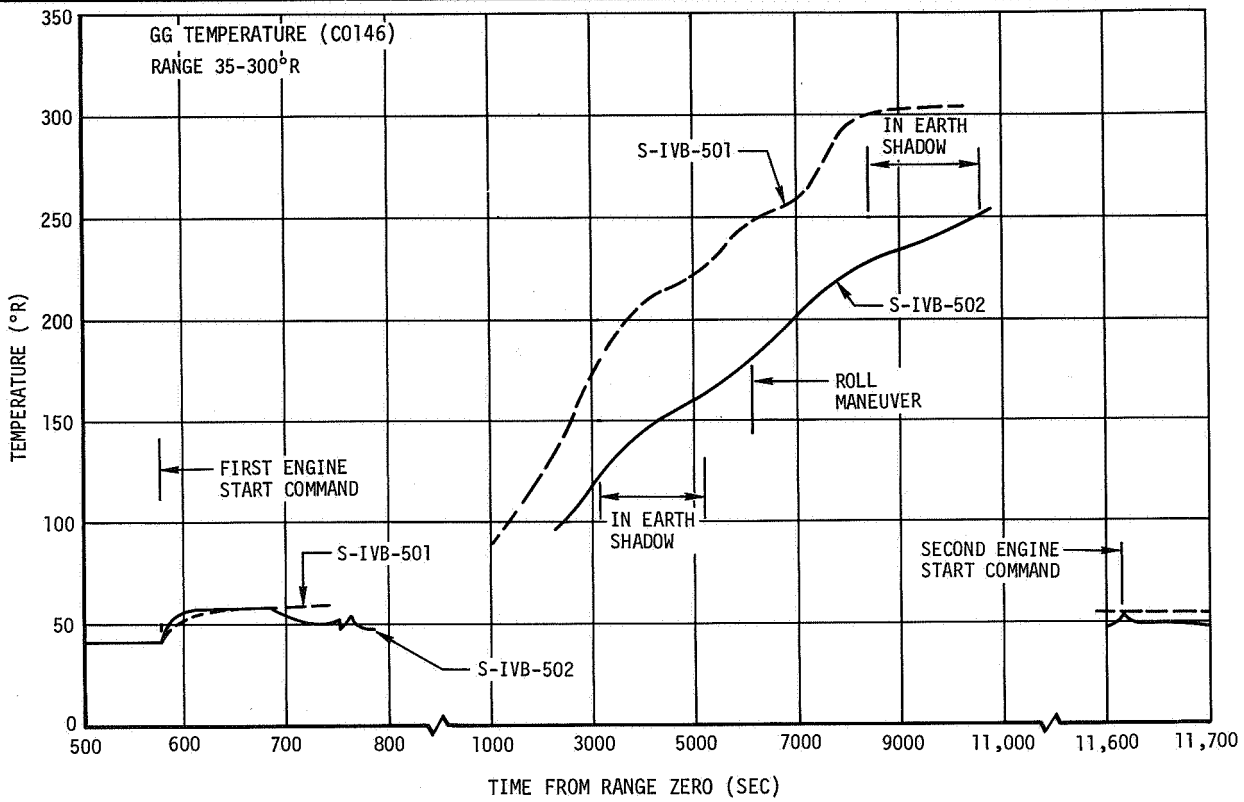


Figure 10-44. Gas Generator LH2 Inlet Line Wall Temperature

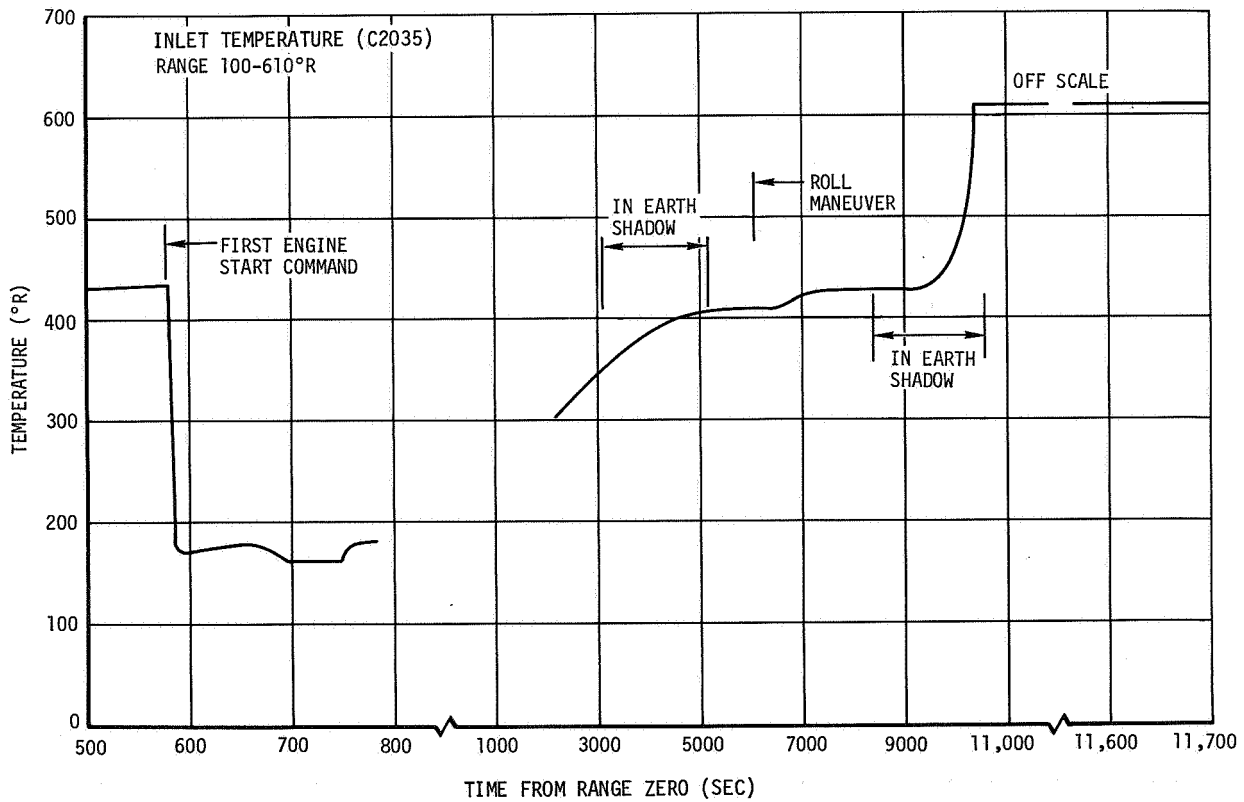


Figure 10-45. Gas Generator LOX Inlet Temperature

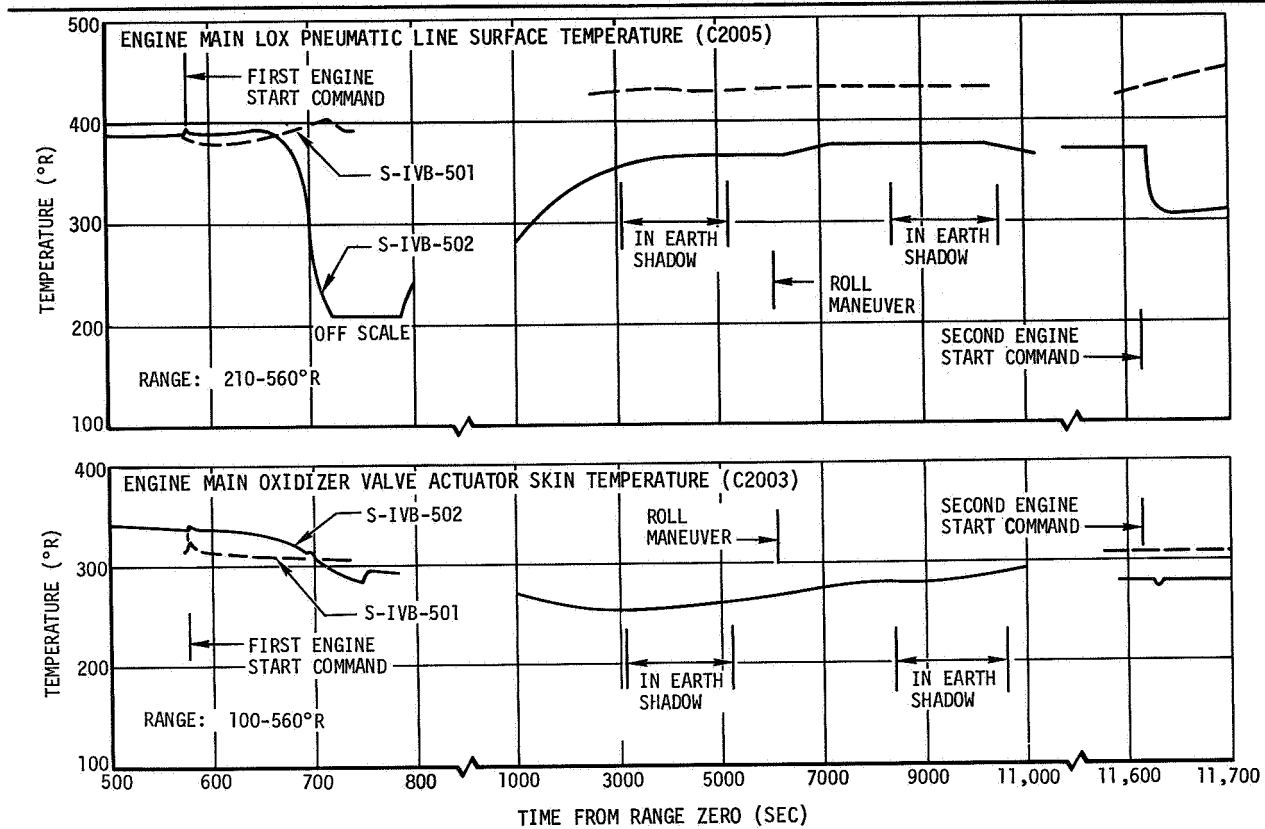


Figure 10-46. Environmental Effects

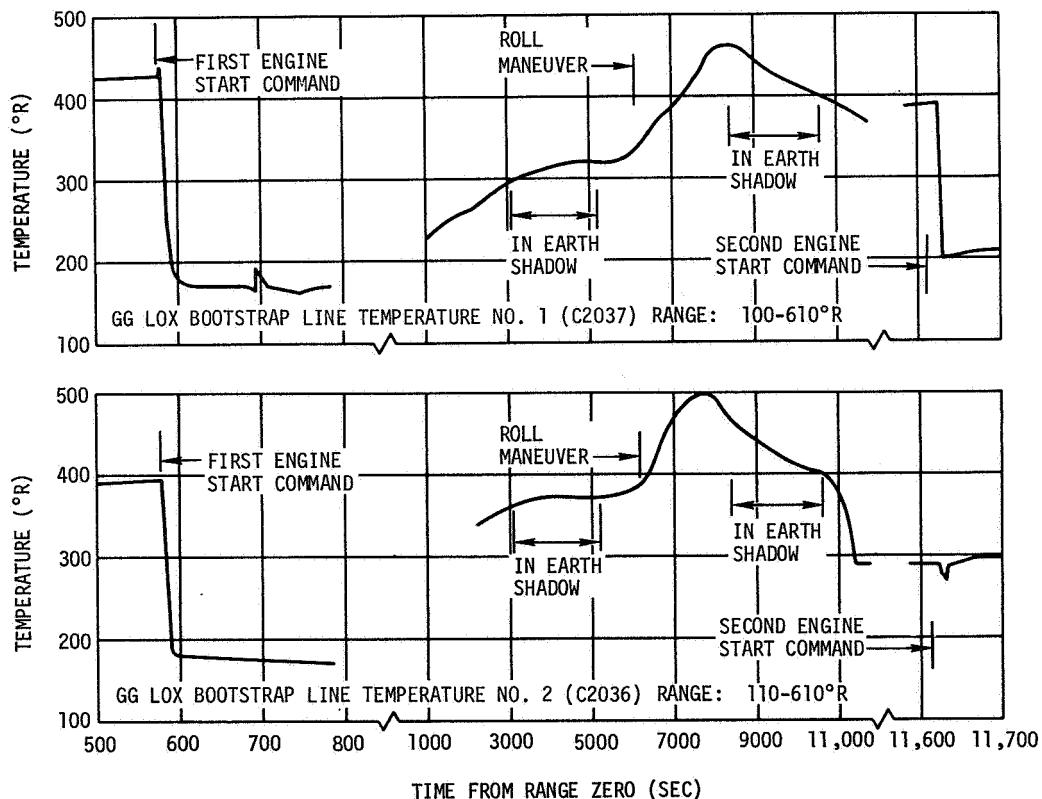


Figure 10-47. Gas Generator LOX Bootstrap Line Temperatures

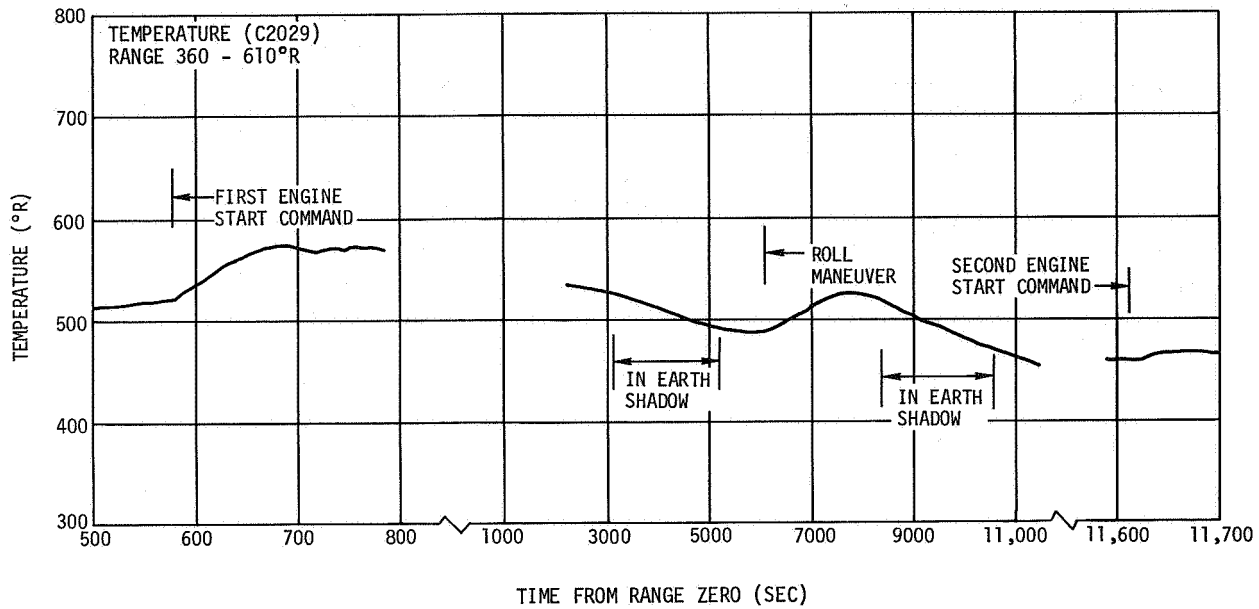


Figure 10-48. Main Hydraulic Pump Discharge Line Temperature

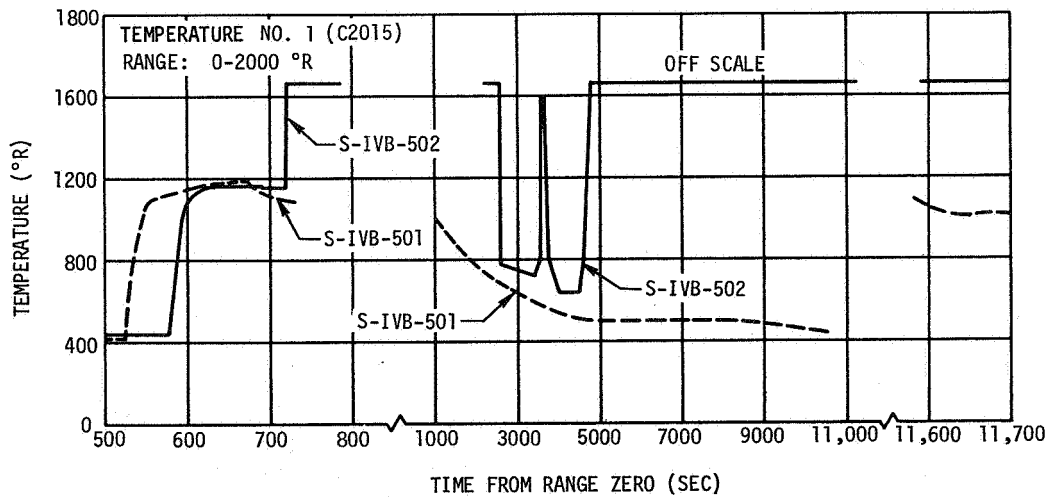
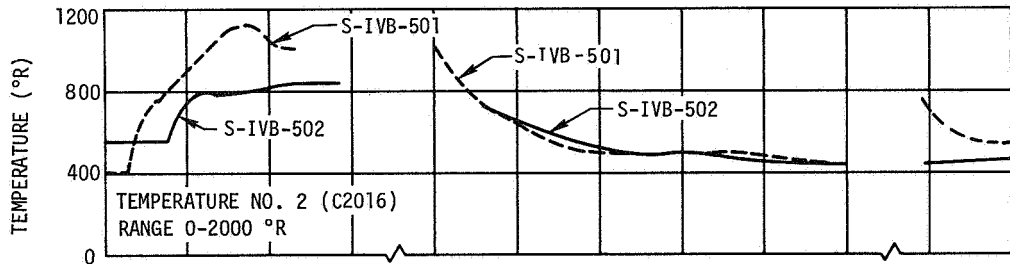


Figure 10-49. Crossover Duct Exterior Wall Temperatures

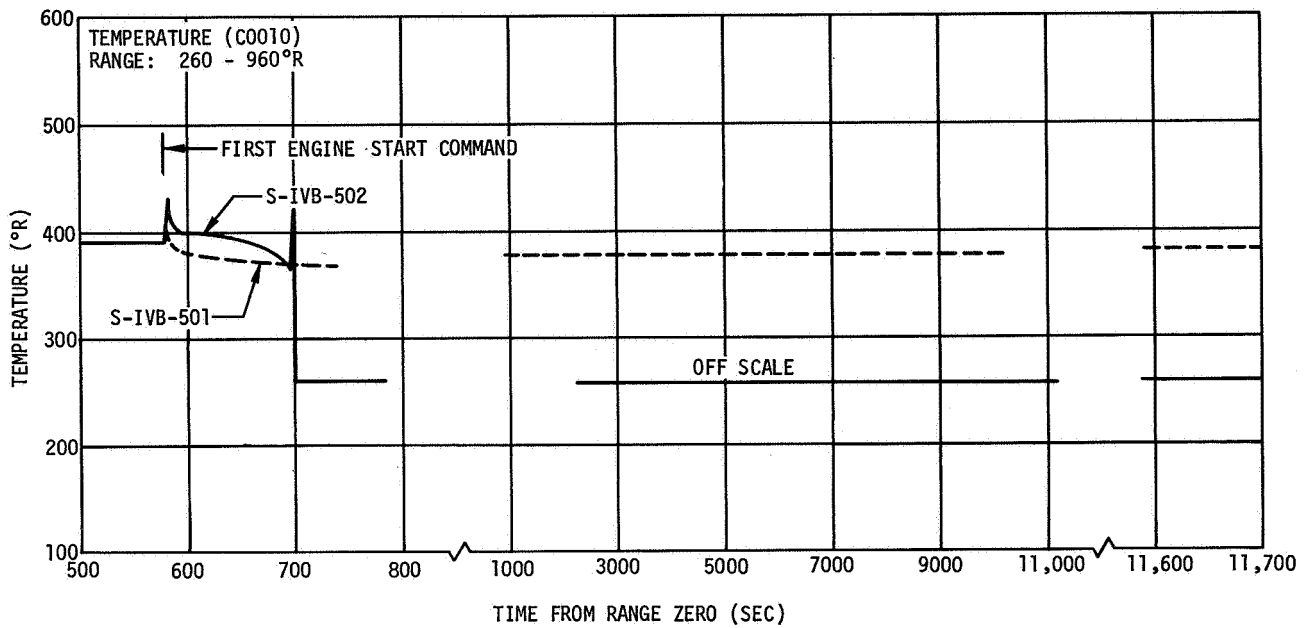


Figure 10-50. Engine Area Ambient Temperature

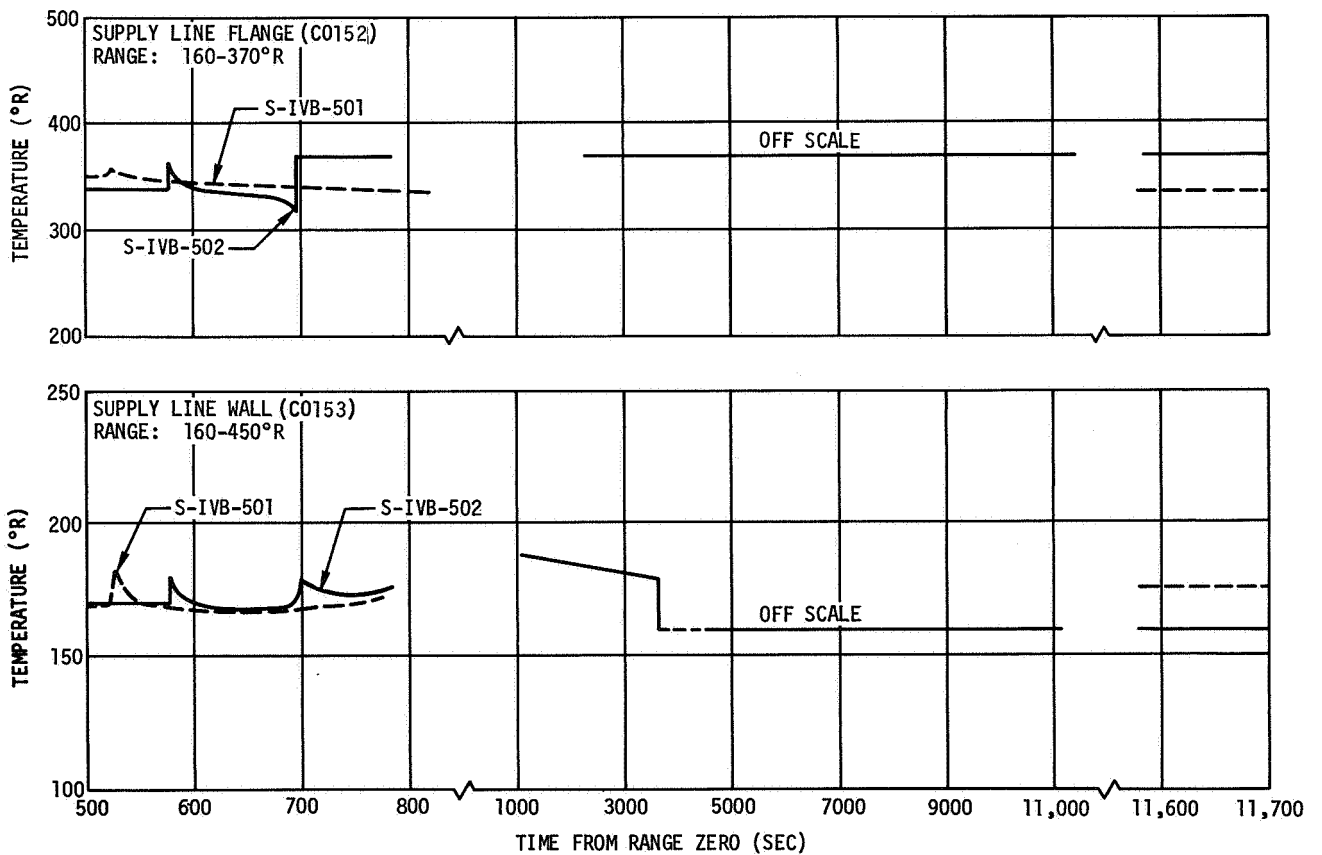


Figure 10-51. Main Oxidizer Supply Line Temperatures

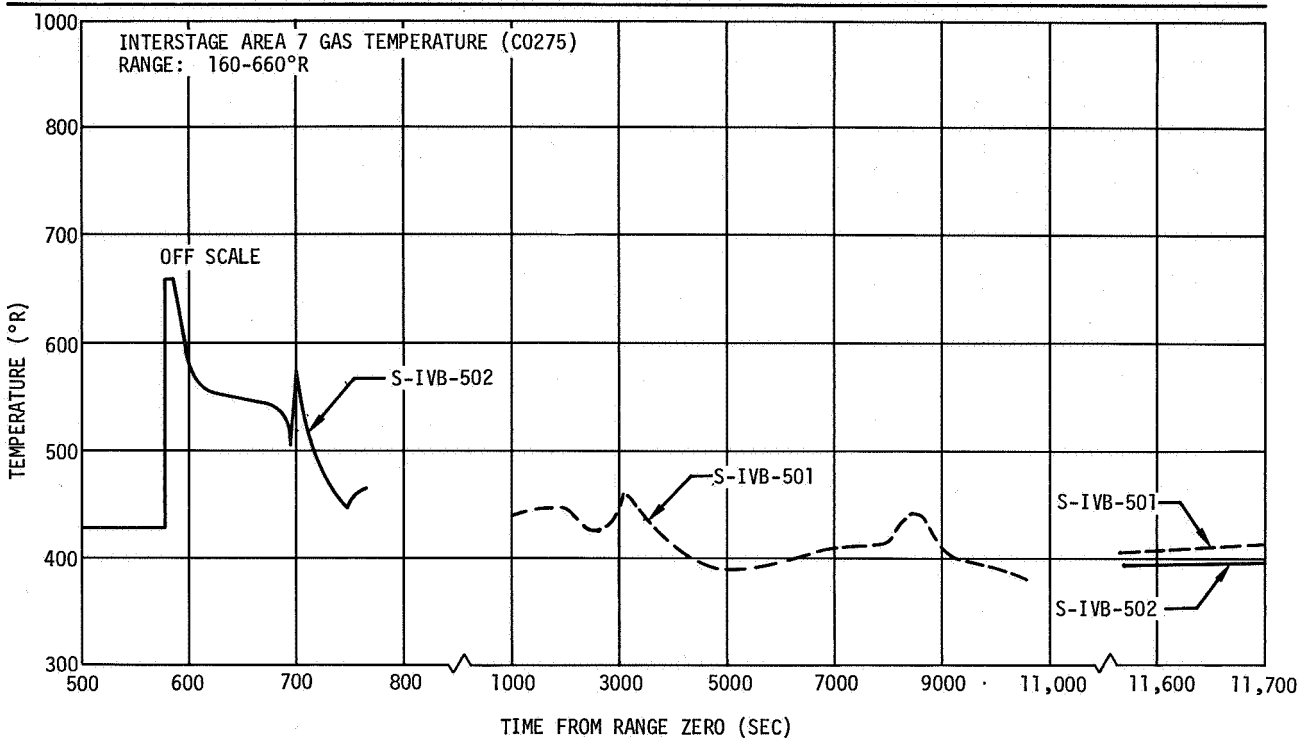


Figure 10-52. Interstage Area 7 Gas Temperature

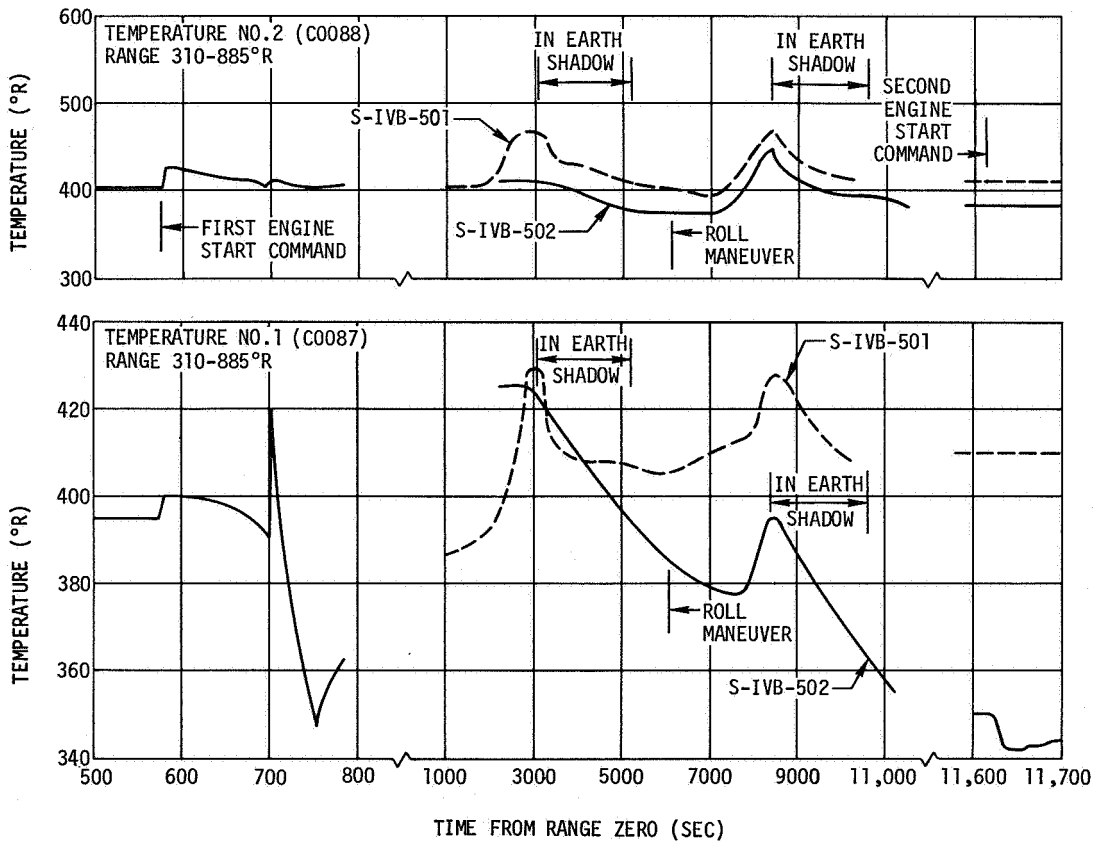


Figure 10-53. Thrust Structure Temperatures

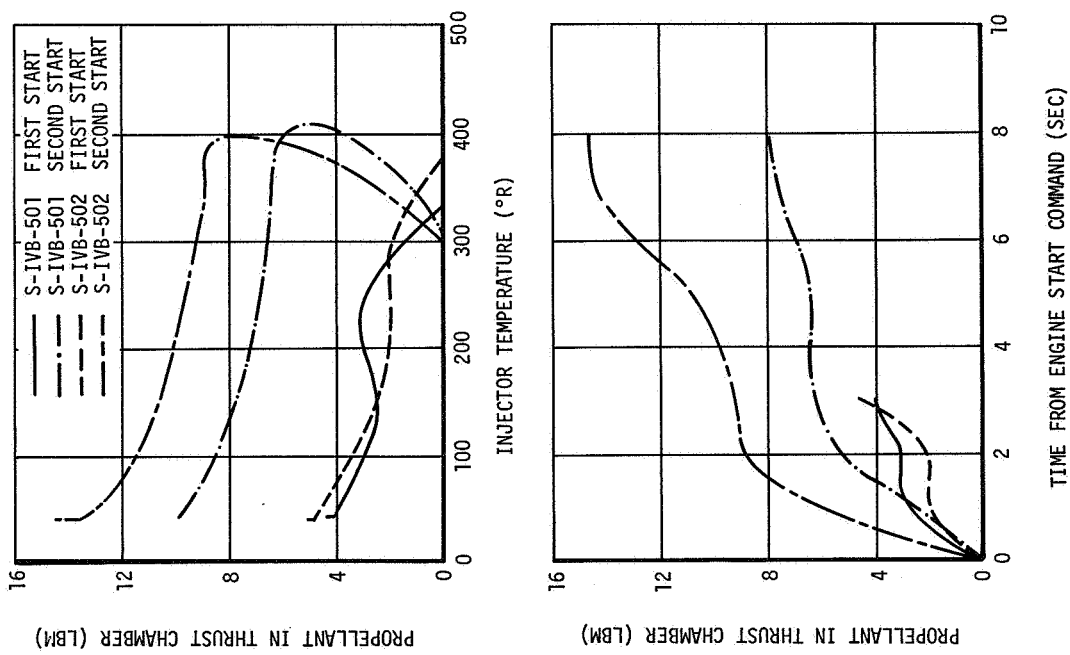


Figure 10-54. Propellant in Thrust Chamber During Fuel Lead

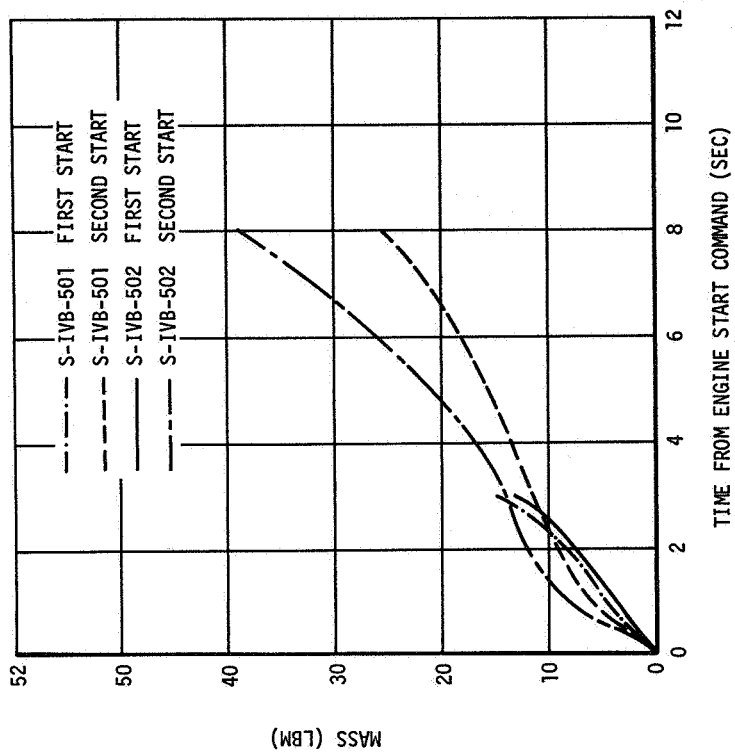


Figure 10-55. Total LH2 Flow Through Main Fuel Valve During Fuel Lead

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Engine System

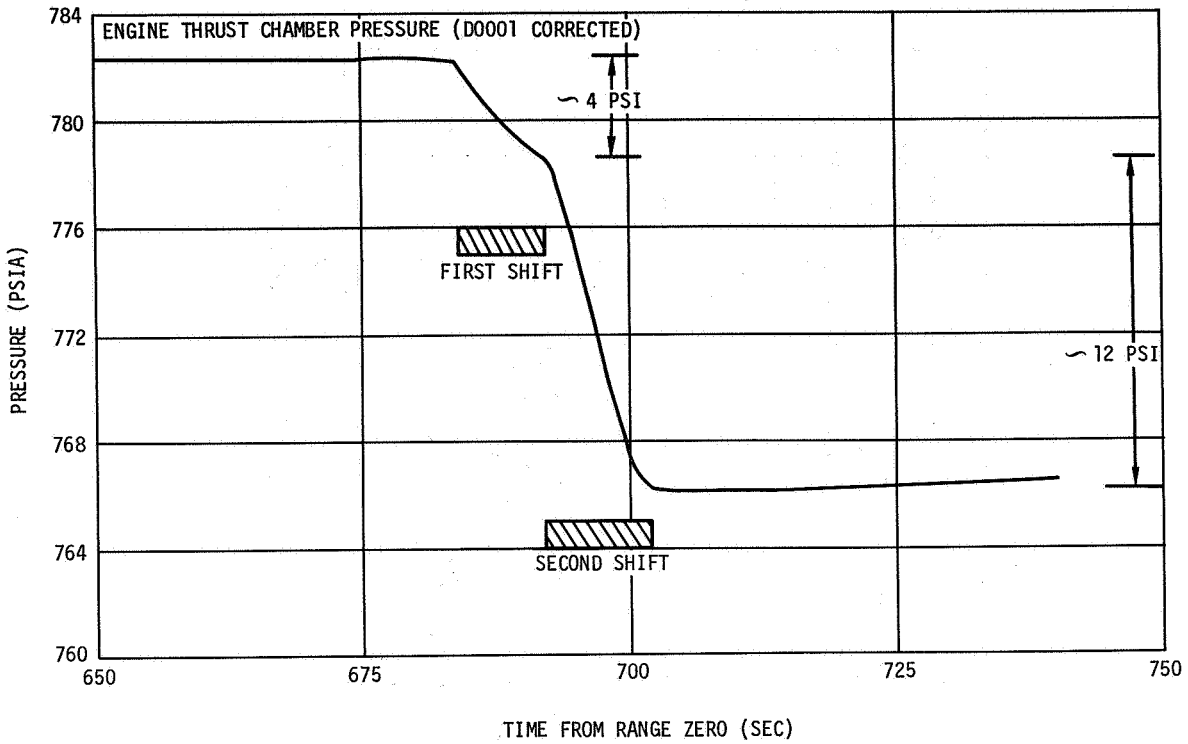


Figure 10-56. Thrust Chamber Pressure Corrected to Constant Heat Exchanger Operation (Reference Rocketdyne)

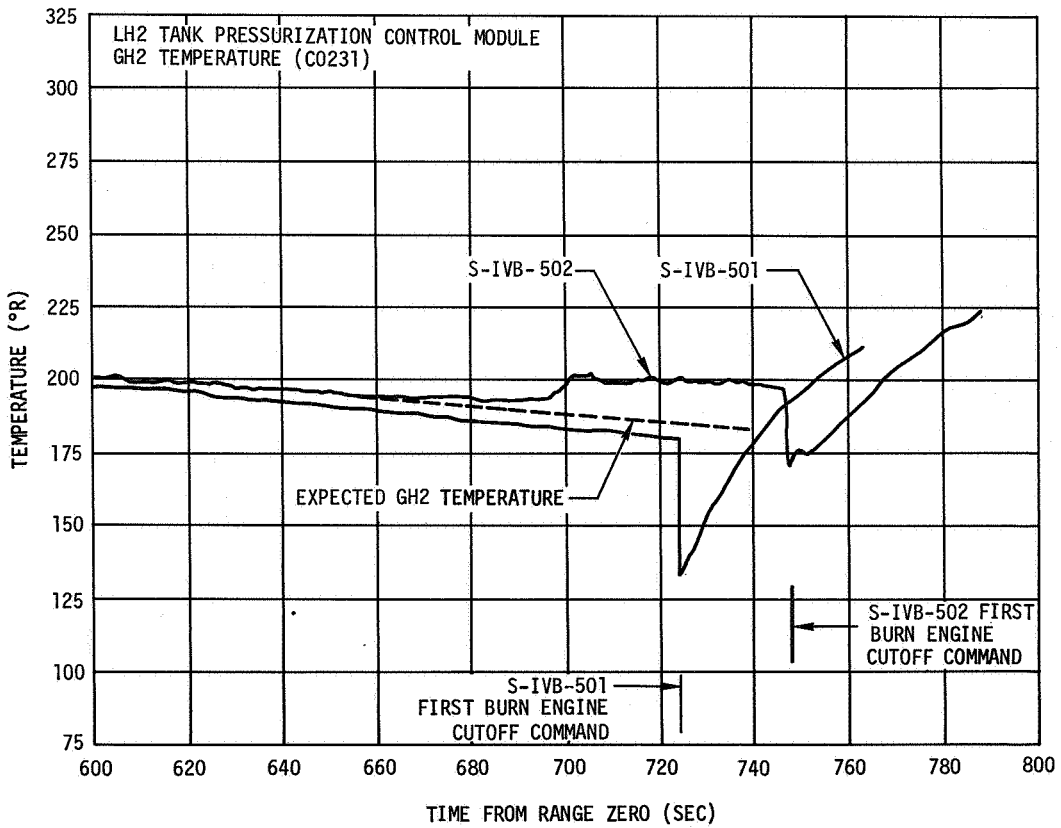


Figure 10-57. Response of LH2 Tank Pressurization GH2 Temperature

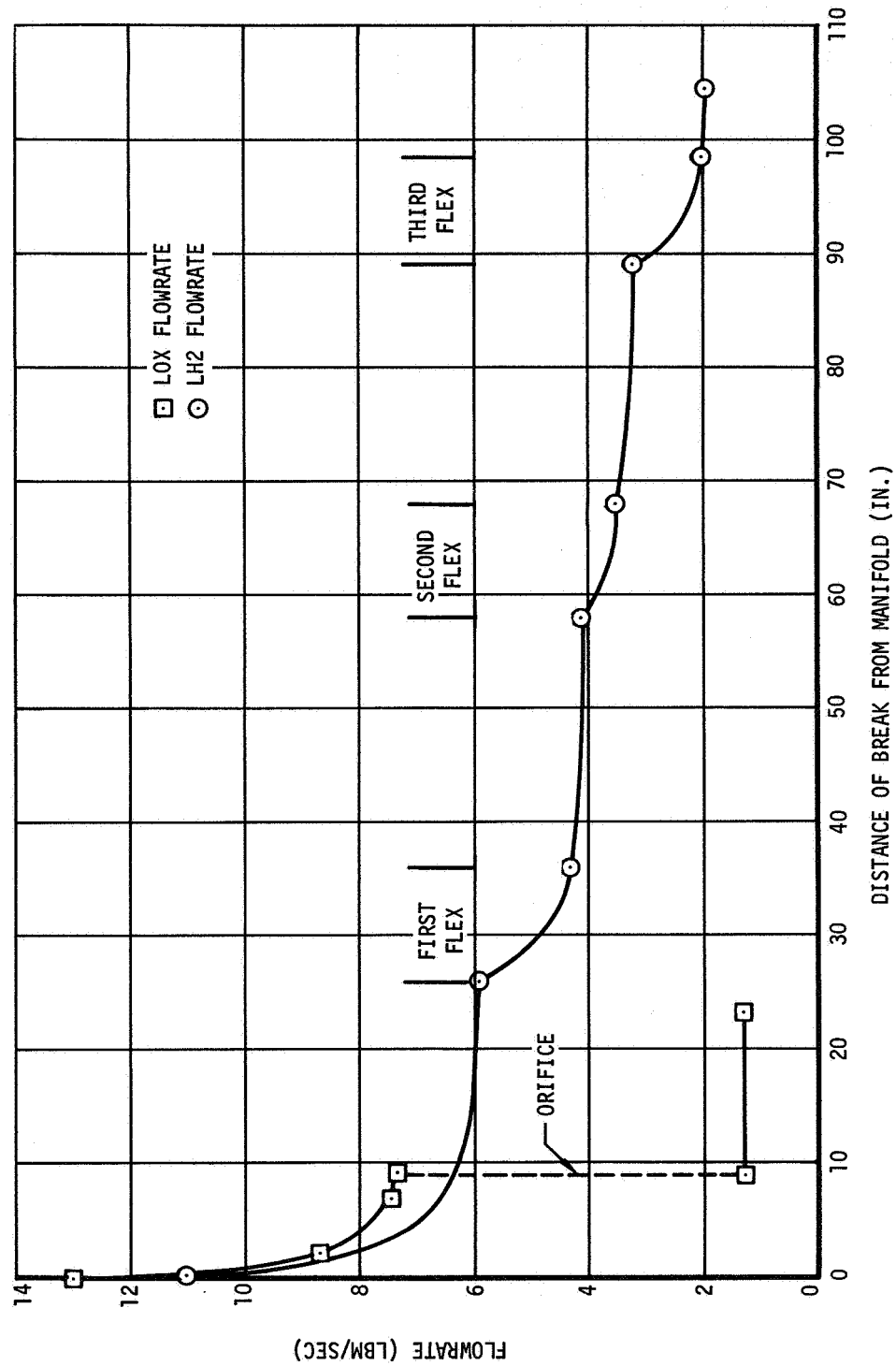


Figure 10-58. Flowrates From Broken ASI Lines

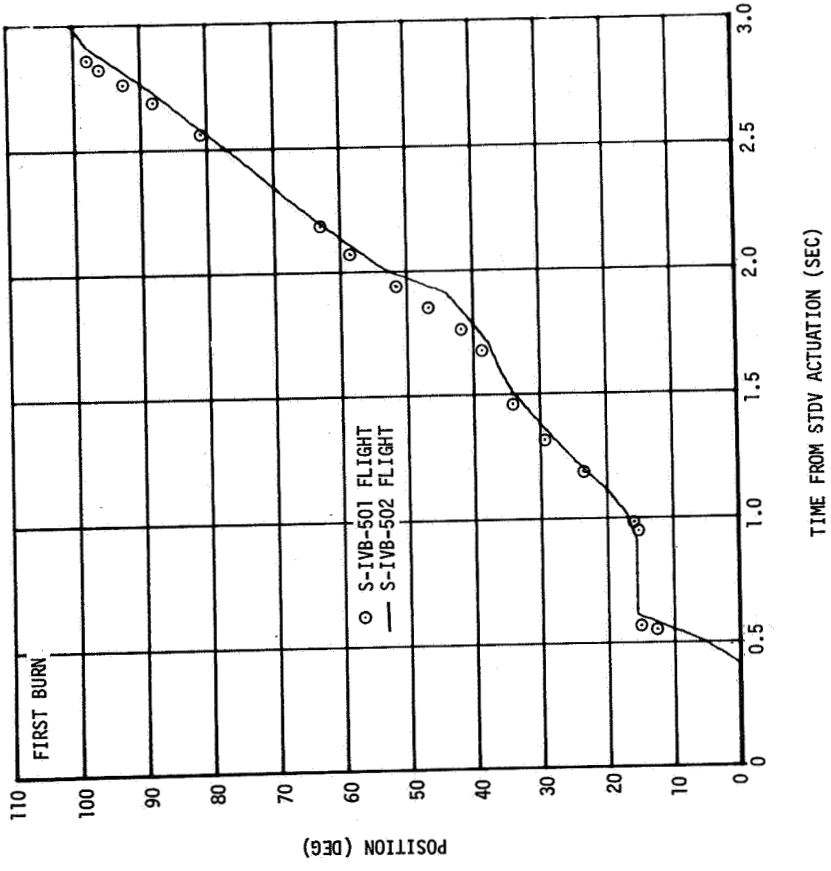
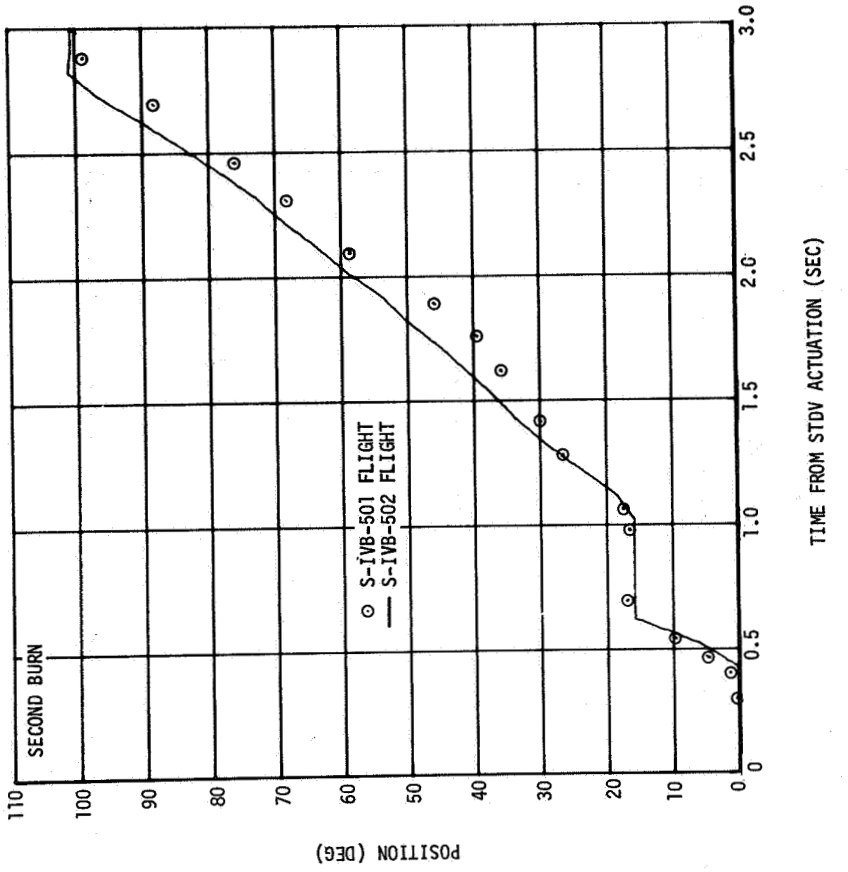


Figure 10-59. Main Oxidizer Valve Position

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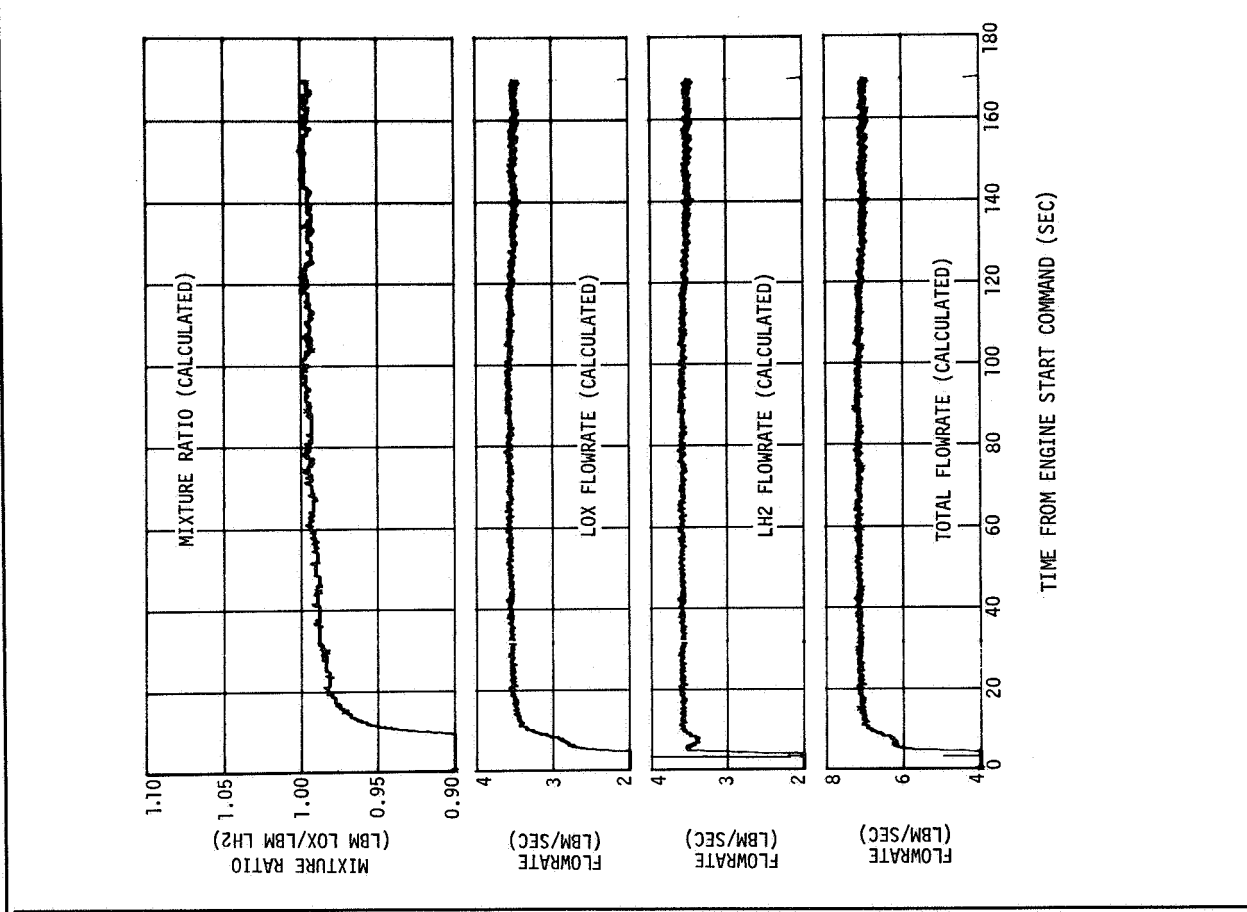


Figure 10-61. Gas Generator Performance - First Burn

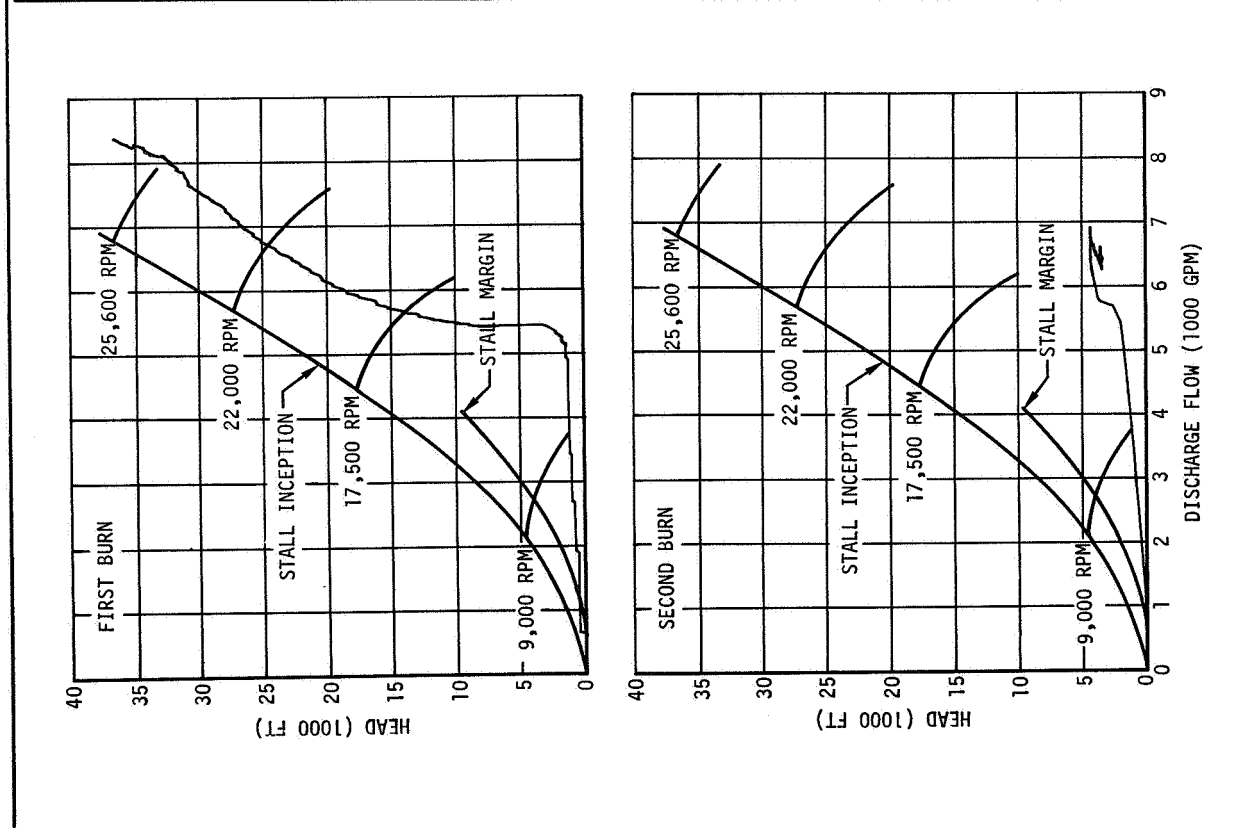


Figure 10-60. LH2 Pump Performance - Engine Start

SECTION 11

SOLID ROCKETS

11. SOLID ROCKETS

The solid rocket motors on the S-II and S-IVB stages performed satisfactorily and accomplished their intended purpose. The S-II was separated from the S-IVB by the retro-rockets, and the S-IVB propellants were settled prior to engine ignition by the ullage rockets.

11.1 Retrorockets

The four retrorockets mounted on the S-II performed satisfactorily and separated the S-II from the S-IVB. The ignition command time was not available as it is not transmitted on an S-IVB data link; however, the pressure buildup for all four retrorockets began within 0.02 sec of each other at RO +577.10 sec. The thrust and chamber pressure profiles for the four rockets were very similar and the maximum difference in burntimes was 0.04 sec. Prior to the flight, a correlation between thrust and chamber pressure had been obtained from previous ground tests of similar retrorockets. This correlation was used in a computer program to determine the retrorocket thrust from the chamber pressure data during the AS-502 flight. Table 11-1 presents the performance parameters for the individual rocket motors. All parameters were within the nominal performance limits except for the burntime total impulse for motor A (D0153) which was slightly greater than the nominal maximum value. This had no detrimental effect on motor performance. The chamber pressure data for motor D (D0156) was reading zero before burn and approximately 80 psia after burn, indicating a data shift during burn. A linear skew bias was applied to the data to correct for this shift. The corrected thrust and chamber pressure profiles for the retrorockets are presented in figure 11-1.

11.2 Ullage Rockets

Ullage rocket performance was satisfactory. The Ullage Rocket Ignition Command was given at RO +576.971 sec, with the Jettison Command at RO +589.066 sec. These times, relative to Engine Start Command, were very close to predicted. Table 11-2 presents the individual rocket motor performance parameters as defined in the Thiokol Chemical Company model specification SP-544A, dated November 29, 1965. A comparison of these data with nominal performance limits indicates that both motors performed within design specifications. Figure 11-2 presents the thrust profiles during burn.

Section 11
Solid Rockets

TABLE 11-1
RETROCKET PERFORMANCE

| Parameter | Units | Motor A (Pos IV-I, D0153) | Motor B (Pos II-III, D0154) | Motor C (Pos I-II, D0155) | Motor D (Pos III-IV, D0156) | Average | Nominal Performance Limits | |
|------------------------------------|---------|---------------------------------|-----------------------------------|---------------------------------|-----------------------------------|---------|----------------------------|---------|
| | | | | | | | Maximum | Minimum |
| Burntime* | sec | 1.55 | 1.51 | 1.51 | 1.52 | 1.52 | 1.67 | 1.38 |
| Maximum Chamber Pressure | psia | 1,930 | 1,855 | 1,865 | 1,920 | 1,893 | 2,258 | 1,822 |
| Average Burn Time Chamber Pressure | psia | 1,734 | 1,720 | 1,715 | 1,745 | 1,729 | 1,875 | 1,545 |
| Maximum Thrust | lbf | 40,800 | 39,800 | 39,300 | 41,000 | 40,225 | 43,420 | 34,200 |
| Average Burn Time Thrust | lbf | 36,371 | 35,623 | 35,356 | 36,241 | 35,898 | 39,435 | 30,190 |
| Burntime Total Impulse | lbf-sec | 56,375 | 53,791 | 53,387 | 55,086 | 54,660 | 56,300 | 52,290 |

*The interval between the time at which the pressure attains 10 percent of the maximum pressure during the buildup portion of the pressure curve; and the time at which the bisector of an angle (formed by the intersection of a line tangent to the pressure curve just prior to decay and a line tangent to the descending portion of the pressure curve) intersects the pressure curve.

TABLE 11-2
AS-502 ULLAGE ROCKET PERFORMANCE

| Parameter | Units | Motor A (Pos II-III, D0216) | Motor B (Pos IV-I, D0217) | Nominal Performance Limits | |
|--------------------------------------|---------|-----------------------------------|---------------------------------|----------------------------|---------|
| | | | | Maximum | Minimum |
| Action Time* | sec | 5.80 | 5.77 | 6.08 | 5.01 |
| Burntime** | sec | 3.81 | 3.80 | 4.10 | 3.54 |
| Maximum Chamber Pressure | psia | 1,016 | 1,031 | 1,220 | 900 |
| Maximum Ignition Chamber Pressure | psia | 1,081 | 1,076 | 1,470 | ---- |
| Average Action Time Chamber Pressure | psia | 739 | 758 | 880 | 680 |
| Average Burntime Chamber Pressure | psia | 975 | 1,001 | 1,100 | 890 |
| Maximum Thrust | lbf | 3,526 | 3,578 | 4,150 | 2,600 |
| Maximum Ignition Thrust | lbf | 3,751 | 3,734 | 5,100 | ---- |
| Average Action Time Thrust | lbf | 2,564 | 2,630 | 3,045 | 2,345 |
| Average Burntime Thrust | lbf | 3,383 | 3,473 | 3,786 | 3,090 |
| Action Time Total Impulse | lbf-sec | 14,871 | 15,175 | 15,595 | 14,335 |
| Burntime Total Impulse | lbf-sec | 12,889 | 13,197 | 13,590 | 12,500 |

*The time interval between 10 percent of maximum chamber pressure during the start transient and 10 percent of maximum chamber pressure during the cutoff transient.

**The time interval between 10 percent of maximum chamber pressure during the start transient and 75 percent of maximum chamber pressure during the cutoff transient.

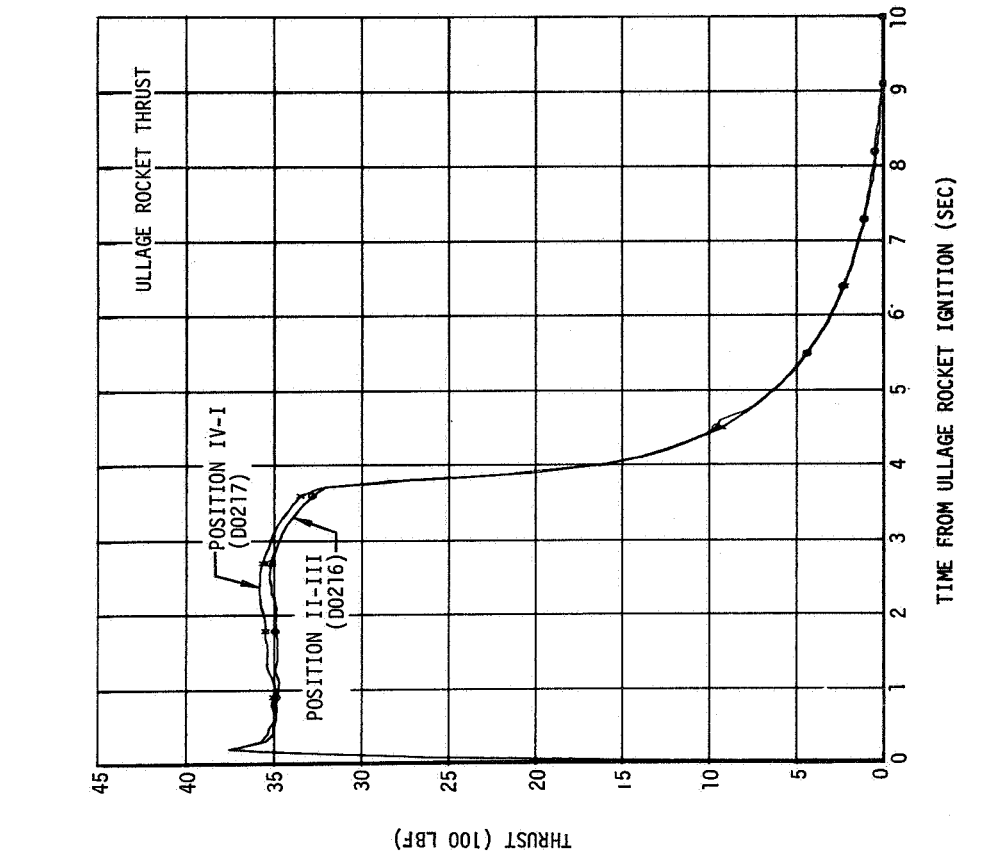


Figure 11-2. Ullage Rocket Performance

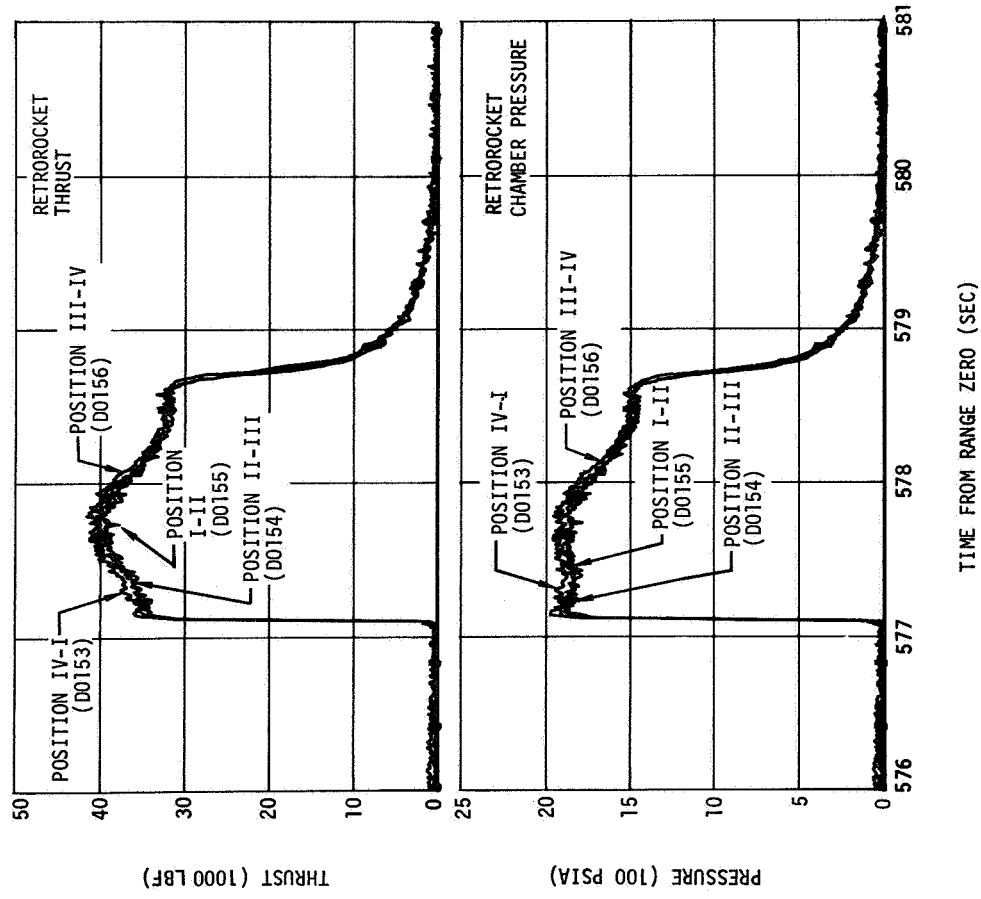


Figure 11-1. Retrorocket Performance

SECTION 12

OXIDIZER SYSTEM

12. OXIDIZER SYSTEM

The oxidizer system performed adequately, supplying LOX to the engine pump inlet within the specified operating limits throughout J-2 engine operation. The available NPSP at the LOX pump inlet exceeded the engine manufacturer's minimum requirement at all times.

12.1 LOX Tank Pressurization Control

The LOX tank pressurization systems (figure 12-1) satisfactorily controlled pressure in the LOX tank during all periods of the flight. The cold helium supply was adequate during boost and first burn and would have been sufficient for second burn if the restart had been successful. A significant cold helium leak occurred during orbit but adequate helium was available. The LOX pressurization module regulator performed as expected. The ambient helium repressurization system performed nominally during the restart preparations. Safing of the LOX tank was adequately accomplished subsequent to the aborted second burn.

12.1.1 First Burn

12.1.1.1 Prepressurization and Boost

LOX tank prepressurization started at R0 -167 sec and increased the LOX tank ullage pressure from 15.3 to 40.5 psia within 17 sec (figure 12-2). Two makeup cycles were required to maintain the LOX tank ullage pressure above 38.5 psia before the ullage temperature stabilized. At R0 -96 sec, the ullage pressure began increasing from 39.6 to 43.1 psia as a result of stage geometric change during LH2 prepressurization, with a minor contribution from the LOX vent valve purge and the LOX pressure sense line purge. At 43.1 psia the vent/relief valve cracked and dropped the ullage pressure to 42.1 psia where it remained until liftoff. Table 12-1 compares prepressurization data from the S-IVB-501 flight and the S-IVB-502 acceptance tests to that of the S-IVB-502 flight.

During the first 10 sec after liftoff (ESC -577 to ESC -567 sec) the ullage pressure decayed 1.4 psi to 40.7 psia. The pressure continued to decay at a lesser rate of 1.75 psi/min throughout S-IC boost, necessitating two makeup cycles from the cold helium spheres to maintain the ullage pressure above the lower pressure switch setting of 38.7 psia. At S-IC engine cutoff two sharp pressure rises occurred corresponding to S-IC inboard and outboard engines off; at S-II engine start the pressure was 42.0 psia. During S-II boost, the ullage pressure decayed at a constant rate of 0.37 psi/min until the S-II engines two and three cut off, at which time the pressure sharply increased 0.3 psi. The pressure then decayed at a constant rate of 0.18 psi/min until S-II engine cutoff when it again rose sharply (from 39.8 to 40.4 psia).

The rate of pressure decay during the various periods is approximately proportional to the rate of increase in axial acceleration during that period $\left(\frac{dp}{dt} \approx 60 \frac{da}{dt}\right)$. Correspondingly, the ullage pressure rise at the various engine cutoffs is proportional to the decrease in acceleration at that time ($\Delta P \approx -0.4 [\Delta A]$). In addition, the tank ullage temperature data do not indicate the temperature decay which would necessarily accompany the pressure drop if it were caused by an ullage collapse; there is also no temperature response to the pressure

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increase at the various engine cutoffs. The conclusion to be drawn from this information is that the ullage pressure decay and subsequent increases are a result of LOX tank ullage volume changes resulting from acceleration forces. Calculations based on ullage conditions indicate a decrease in ullage volume of 4.8 ft³ as a result of the 4.9 g decrease in acceleration at S-IC engine cutoff. This delta volume is consistent with predictions developed by the Saturn Weights Section in support of PU system performance. This change in LOX tank geometry as a result of stage axial acceleration was not noted on the AS-501 flight. The explanation for this discrepancy is not presently understood and is under investigation.

When the ullage pressure decayed below 38.7 psia during S-IC boost (at ESC -497.6 and ESC -449.1 sec), the tank pressure switch commanded the cold helium shutoff valves open until the pressure had been raised to 40.6 psia (figure 12-2). Each makeup cycle required approximately 1.1 sec and a total of 0.38 lbm of cold helium was added to the LOX tank.

Temperature data at the LOX tank diffuser (C0229) and the LOX pressurization line inlet to the vent line (C0016) suggest a flow out of the LOX tank through the vent line at two different periods during boost. Immediately after liftoff (ESC -577 sec) these two measurements show a rapid temperature drop for 10 sec followed by a gradual warming (figure 12-2). This corresponds to the period of initial rapid ullage pressure decay. (This was also noted on the AS-501 launch.) Later in the boost, at approximately ESC -472 sec, the rates of decrease for both C0016 and C0229 showed an increase; in each measurement the temperature dropped below its previous steady-state level. This rapid temperature decay was interrupted by the second makeup cycle at ESC -449 sec but continued after that cycle until approximately ESC -427 sec (S-IC engine cutoff). At that time C0016 began warming asymptotically to its previous steady-state level, and C0229, which coincidentally was at its previous steady-state level, began following the ullage temperatures (figure 12-2).

It is apparent that these temperature profiles could have been produced by cold gas flowing through the LOX vent line. Since the cold helium shutoff valves are closed during these times and the pressurization system still contains sensible heat, as demonstrated during both makeup cycles, the source of the cold gas could not have been through the pressurization system. The tank ullage temperatures during this period make it evident that the vent line temperature responses could have been caused by ullage gas flowing out through the LOX vent line. This would indicate a loss of ullage gas during the S-IC boost.

Unfortunately, the data are not adequate to precisely determine the mass of ullage gas; however, rough calculations indicate approximately 0.4 lbm of gas lost during the S-IC boost.

Loss of ullage gas in this manner, i.e., by flowing out through the tank vent line, would require flow through the LOX tank vent/relief and/or relief valves. These valves are not at their respective relief settings during these periods and should not have opened. The vent/relief valve talkbacks did not indicate a loss of the closed position (the relief valve has no talkbacks); however, this valve is capable of opening as much as 0.030 in. without affecting the microswitch. The only relevant phenomenon which is common to these two time periods is a longitudinal oscillation of approximately 5 cps.

Since there is no other logical explanation for the preceding data, it is felt that the data are indicative of leakage through the relief and/or vent/relief valve caused in all probability by the 5 cps longitudinal oscillation. The amount of leakage was not excessive from a pressurization aspect. It was, coincidentally, approximately equal to the mass of gas added during the two boost makeup cycles.

12.1.1.2 Pressurization

The LOX tank ullage pressure and temperature and the pressurant flowrate are shown in figure 12-3. The ullage pressure was 40.3 psia at first burn Engine Start Command, satisfying the engine start requirements, and was sufficient throughout S-IVB powered flight to meet the minimum NPSP requirement. During the start transient, the ullage pressure decreased to a minimum of 35.2 psia before the pressurant flowrate became large enough to increase the ullage pressure. During the burn the ullage pressure cycled between the upper and lower pressure settings approximately as predicted, although four overcontrol cycles were required versus the predicted three because the control band was smaller than that used for the prediction, and the burntime was longer.

The ullage pressure increased slightly during the first few seconds after first burn Engine Start Command because the pressurization system was activated at first burn engine start +2.8 sec and allowed the pressurant to flow into the tank for approximately 3 sec before the LOX flow out of the tank attained its steady-state level.

Due to the failure of the cold helium regulator discharge plenum pressure measurement (D0105) and the heat exchanger helium inlet temperature measurement (C0008), these parameters were reconstructed based on available data and relationships developed on past tests. The heat exchanger outlet pressure (D0161) was also biased by +6 psi in order to make it consistent with remaining system data under ambient conditions.

Utilizing this data the LOX tank pressurant flowrate varied from 0.20 to 0.41 lbm/sec during overcontrol system operation, and from 0.25 to 0.31 lbm/sec during undercontrol. This variation is normal because the heat exchanger bypass orifice inlet temperature changes as the system chills down. During S-IVB first burn, 54.7 lbm of helium were used; 332 lbm had been loaded. Table 12-2 compares the pressurization system data from S-IVB-502 flight to that from S-IVB-502 acceptance firing and S-IVB-501 flight tests.

The pressurization system showed no effects from the engine anomaly, as the system is almost independent of the engine. However, both the heat exchanger discharge pressure (D0161) and overcontrol valve inlet pressure (D0225) throughout the burn indicated pressures approximately 30 psi lower than was noted on either the S-IVB-502 acceptance firing or the S-IVB-501 acceptance firing or flight test. There was no system design change to account for this change in operating level; however, the LOX pressurization regulator had been replaced by a later configuration after the acceptance firing. Unfortunately, the failure of D0105 makes it quite difficult to determine whether the lower pressures were the result of regulator performance or of some unusual system condition. These data are undergoing continuing evaluation.

12.1.1.3 Cold Helium Supply

The cold helium supply was adequate to meet boost and first-burn flight requirements. The cold helium supply system data are presented in table 12-3 and figure 12-4. Two makeup cycles, using a total of approximately 0.4 lbm of cold helium, were required during boost. During burn, mass calculations based upon sphere temperatures and pressure agreed closely with the results obtained from flow integration.

12.1.1.4 J-2 Heat Exchanger

The J-2 heat exchanger performance data are presented in figure 12-5 and compared to S-IVB-501 flight and S-IVB-502 acceptance firing data in table 12-4. The failure of the heat exchanger helium inlet temperature (C0008) makes a precise comparison of performance to previous tests impossible; however, the available data indicate that performance was nominal. The effects of the engine anomaly were not reflected in the heat exchanger performance. The heat exchanger outlet temperature had increased to 965 deg R by the end of 50 sec of engine operation and continued to increase to a maximum of 1,005 deg R at ESC1 +115 sec. The flowrate through the heater was relatively constant at the values given in the table.

12.1.2 Second Burn Attempt

12.1.2.1 Repressurization

Ambient helium repressurization of the LOX tank in preparation for second burn engine start was satisfactorily accomplished. Repressurization was initiated at ESC2 -227 sec (figure 12-6) and raised the ullage pressure from 37.4 psia to 40.0 psia in 19.7 sec. Helium supply pressure dropped from 3,095 to 1,925 psia, and 5.2 lbm of helium were utilized. The ullage pressure stabilized at 40.0 psia until ESC2 -100 sec at which time it began to increase. The pressure was 41.6 psia at second burn Engine Start Command, completely satisfying all requirements. The pressure rise from ESC2 -100 sec is discussed in paragraph 12.2.1.

12.1.2.2 Pressurization

The LOX tank pressurization system operated nominally during the second burn attempt. Regulator discharge pressure rose rapidly to approximately 400 psi and remained at that level until the system was deactivated at ESC2 +16.2 sec. Contrary to first burn, when it was off-scale-high, the regulator discharge measurement (D0105) provided good data beginning during the second orbit and continuing through repressurization and second burn. Comparison with other system data verifies its level as correct during these periods.

Because the ullage pressure was above the pressure switch setting, the pressurization system was in the undercontrol mode during the entire 8.4 sec of activation. The ullage pressure was 42.1 psia at engine cutoff; cold helium usage was 2.95 lbm (figure 12-7).

12.1.2.3 Cold Helium Supply

Although orbital leakage (figure 12-8) dropped the cold helium sphere pressure from 1,378 psia at first burn engine cutoff to 860 psia at restart attempt, the cold helium supply would have been adequate for normal second-burn operations. Table 12-3 presents the cold helium supply system data at restart and cutoff; the system was activated for approximately 8 sec. Following the restart attempt the sphere pressure continued to decay, reaching 550 psia by the beginning of the cold helium dump (paragraph 12.2.3).

12.2 Pressurization System Conditions during Orbit

12.2.1 LOX Tank Conditions during Orbit

Evaluation of the LOX tank temperature and pressure data during the first and second orbits is difficult due to the lack of data at some times and the accuracy and response characteristics of the tape recorded data at other times. In general, however, the ullage gas temperatures appear to drop to liquid temperatures at engine cutoff because of liquid diffused through the ullage by the cutoff transients. Throughout the remainder of the orbital period the ullage temperatures appeared to very gradually become progressively colder toward the forward end of the tank (figure 12-9). During the same period the LOX liquid changed from uniform temperatures throughout the tank at engine cutoff to a profile that became progressively warmer toward the bottom of the tank. At no time, however, were liquid saturation temperatures indicated. With the common bulkhead exposed to LH2 and the aft bulkhead, thrust cone, and all of the attached hardware exposed to radiation heating in space, this profile would appear to be reasonable. The gradually decreasing trend of the ullage pressure during this period is consistent with the cooling trend in the ullage temperature.

At three times during orbit (approximately RO +3,275, RO +5,450, and RO +11,520 sec), the trends previously described were interrupted (figure 12-9). All of the temperature probes in the tank, both liquid and gas, converged rapidly on a common temperature of 164 to 165 deg R. Beginning at the same time, the ullage pressure increased 1 to 2 psi over an approximate 125-sec period. In each case, the change in the trend of the ullage data was preceded (100 to 300 sec) by a stage attitude pitch maneuver. Although no temperature data are available, at approximately RO +16,150 sec another ullage pressure rise occurred that was also preceded by an attitude pitch maneuver.

While the data and supporting analysis are not conclusive, the temperature and pressure responses are presently explained as follows: the ullage achieved a condition in which the proportion of GOX in the ullage gas assumed a gradient along the longitudinal axis as a function of the ullage temperature gradient. The partial pressure of GOX, and consequently the mass, was defined by the saturated vapor pressure at the local temperature.

The execution of the pitch maneuver under very low g conditions abruptly changed the orientation of the LOX in the tank in a manner that resulted in a slosh wave and surface agitation of the liquid. This exposed all of the ullage gas to direct contact with LOX and resulted in warming all of the ullage to LOX temperatures of 164 to 165 deg R. The GOX

in the ullage gas consequently was no longer saturated, and evaporation occurred until the GOX component of the ullage was again at a saturation condition. The rise in temperature and increase in ullage mass caused the noted ullage pressure rise.

Analysis of the data is continuing in an effort to develop a quantitative method of evaluation and prediction of this phenomenon.

12.2.2 LOX Tank Venting during Orbit

The automatic cutoff sequence immediately following the abortive restart attempt incorporated a 10-sec LOX tank vent during which the ullage pressure dropped from 42 to 33 psia. Tank ullage data are presented in figure 12-7. Tank ullage conditions indicate a homogeneous two-gas mixture in the ullage prior to the vent. Calculations based on these tank conditions indicate that 191 lbm of gas were vented including 27 lbm of helium. At the termination of the vent the ullage consisted of 41 lbm of helium and 355 lbm of LOX. The thrust level of the propulsive vent outlet averaged 900 lbf with a total impulse of 8,852 lbf-sec.

At approximately R0 +22,022 sec, the LOX tank vent and cold helium shutoff valves were commanded open in order to gain additional information relative to stage safing. The tank temperatures and pressure during the subsequent blowdown are presented in figure 12-10. The ullage pressure dropped rapidly from 34.5 to 24.0 psia within 24 sec and then stabilized for 14 sec before resuming the decay. At R0 +22,090 sec with the pressure at approximately 18 psia, the ullage pressure decay rate changed from a rapid blowdown to a gradual decay that followed the vapor pressure for the cooling LOX bulk. The pressure had decayed to 10.5 psia by R0 +23,000 sec and to 1.0 psia by 33,000 sec when data were finally lost.

Due to the simultaneous cold helium dump through the same vent valve and line coupled with the lack of instrumentation situated advantageously for this operation, the LOX tank vent flowrate and LOX boiloff have not yet been accurately reconstructed. With the exception of the 14 sec ullage pressure plateau, however, this ullage pressure appeared to follow a normal blowdown profile until the tank pressure reached the vapor pressure of the liquid bulk. At this point (R0 +22,090 sec) pronounced boiloff began, as evidenced by the liquid temperatures which began decreasing at this time. Calculations based on LOX mass and the temperature decay rate indicate an initial boiloff rate of approximately 8 to 10 lbm/sec. Since this is the approximate flow capacity of the LOX vent valve and line at the 18 psi ullage pressure, the rate of boiloff, at least initially, was obviously being controlled by the vent system flow capacity. In spite of the limited data available, a review of the excessively long blowdown period (more than 11,000 sec were required to drop the ullage pressure to 1.0 psia), indicates that boiloff is capable of maintaining tank pressure at the vapor pressure level indefinitely. The high rate of boiloff, when compared to the vent flowrate, also tends to confirm that there was no restriction of the vent line or valve.

A thorough analysis of the available LOX tank and pressurization system data has failed to provide a conclusive explanation for the 14-sec plateau in the ullage pressure. Pressurization system parameters show no reflection of this phenomenon, indicating that the cold helium dump flowrate was not affected. A possible cause, and the only one advanced which is

consistent with the data, is blockage of the vent line by liquid oxygen. If this were the case, the ullage volume would be effectively isolated from the vent, and the pressure would show a very small decay over a short period of time.

This liquid blockage of the vent line might well have been caused by a slosh wave in the tank which immersed the LOX vent line inlet as a result of the unbalanced 700-lbf thrust at the LOX vent outlet. As the thrust continued and the stage settled into a stable tumbling pattern, centrifugal force would quickly settle the LOX into the bottom of the tank and vent inlet would be uncovered, allowing the ullage gas to begin venting again.

12.2.3 Cold Helium Supply System during Orbit

Cold helium sphere conditions during orbit are shown in figure 12-8. Following first burn engine cutoff the cold helium sphere pressure (D0016) decreased steadily, dropping from 1,378 psia at cutoff to 860 psia at the restart attempt and to 550 psia by the beginning of the cold helium dump. In addition, the cold helium sphere temperatures were abnormally low during orbit. Both of these trends are indicative of a significant cold helium leak. The fact that D0016 appears somewhat inaccurate (the data approached -200 psia instead of 0 psia in the latter stages of the cold helium dump) does not account for this anomaly. It is therefore concluded that 50 to 75 lbm of cold helium were lost between first burn engine cutoff and second burn restart attempt, with an additional 35 to 58 lbm lost from the restart attempt to the beginning of the cold helium dump. The exact mass loss cannot be determined because of the possible 200 psi error in D0016.

The source of this leakage is not known. However, the curvature of the sphere pressure data indicates the leak was from an unregulated source upstream of the shutoff valves in the LOX pressurization control module. Possible leakage sources include (1) the conoseals at the eight spheres and at the inlet flange of the LOX pressurization control module, (2) the cold helium dump module, (3) the cold helium fill umbilical disconnect, and (4) the pipe joints. Based upon past experience, the conoseals and pipe joints appear to be the most likely sources. All future stages will have improved teflon-coated conoseals at all conoseal joints. Also, in the future all pipe joints and conoseal joints will be torque-checked after each cryogenic loading.

At the beginning of the fifth orbit (RO +22,023 sec) an experimental cold helium dump was initiated by opening the cold helium shutoff valves and the LOX tank vent valve; these valves were still open when loss of telemetry data occurred two orbits later. Significant parameters for the first 20 min of dump are shown in figure 12-11. As shown, the cold helium sphere pressure data (D0016) dropped toward an indicated level of approximately -200 psia, rather than 0 psia. This discrepancy is under investigation. Approximately 144 sec after dump initiation, the LOX pressurization system data indicated a reduction of cold helium flow, as evidenced by the drop in the system pressure levels and the rise in temperature; the flow recovered 76 sec later, as the pressures rose and the temperature decreased. At dump initiation +680 sec the cold helium flow again diminished. These variations in flow were apparently caused by variations of flow area within the LOX pressurization module. This change in flow area may have been caused by movement of the poppet within the cold helium regulator, partial closure of the cold helium shutoff valves, or an interaction of these. This phenomenon is still being investigated.

12.3 LOX Pump Chilldown

12.3.1 First Burn

The LOX pump chilldown system performed adequately. At Engine Start Command, the pump inlet conditions of 41.7 psia and 164.7 deg R were sufficient to produce an NPSP of 24.9 psi, thus satisfying the requirement of 12.8 psi minimum (table 12-5). At this time, the pump inlet pressure was 1.4 psia higher than the ullage pressure because of the slow prevalve opening.

Recirculation chilldown started at R0 -284 sec and continued until R0 +576.6 sec when the prevalve started to open with the pump still running. The chilldown system fluid temperature decreased during the first minute of chilldown, then remained relatively constant until prepressurization (figures 12-12 and 12-13) when the LOX became subcooled throughout the recirculation system. The engine pump inlet pressure was constructed for the period from liftoff to R0 +145 sec because acceleration caused it to go off-scale high. The pump inlet and return line pressures increased and decreased with acceleration until the prevalve was opened and the chilldown pump developed head was lost. The chilldown pump was cut off at approximately R0 +576.8 sec; the prevalve full open signal was received at R0 +579.4 sec. The pump inlet pressure then decreased to equal the ullage pressure.

The chilldown flowrate was 39.5 gpm prior to prepressurization and 42.5 gpm afterwards, with a pressurized frictional pressure drop of 11.5 psi through the system. The flow coefficient, a measure of the flow resistance, was calculated from these flowrate and pressure drop values to be $18.3 \text{ sec}^2/\text{in.}^2\text{-ft}^3$ for pressurized chilldown.

Three of the chilldown system parameters (C0013, C0159, and D0061) showed a change in level at or near the engine performance shift that occurred during first burn. The primary measurement indicating a change is the LOX bleed valve temperature. The temperature started a 0.6 deg R increase at R0 +695 sec and reached a maximum at R0 +700 sec. At this time the temperature started a decrease to 169.5 deg R which was 0.2 deg R higher than the steady-state temperature prior to the engine performance shift.

The change in the steady-state temperature level seems to be due to a small change in the LOX gas generator (GG) bleed flow. The temperature change at R0 +695 sec was apparently due to heating of the GG bleed valve and the LOX chilldown return line. This heating caused some of the liquid near the valve to vaporize and traverse through the return line to the tank. As the slug of vapor and liquid passed the chilldown return line temperature probe, the indicated temperature dropped from 179.4 deg R to approximately 172 deg R. It then increased to 182.4 deg R, indicating the slug had passed the probe. The higher return line temperature after the slug passed the probe was due to and coincidental with the pressure in the return line reaching its relief level which corresponds to the ullage pressure plus head pressure.

12.3.2 Second Burn

The second burn chilldown was initiated at R0 +10,872.2 sec, the predicted time. The total chilldown period was approximately 180 sec longer than predicted due to an LVDC time update resulting in a later than expected second burn Engine Start Command.

The LOX pump chilldown system performed satisfactorily (figures 12-14 and 12-15). At second burn Engine Start Command, the pump inlet pressure of 41.6 psia and temperature of 165 deg R were within the start requirements. The NPSP at engine start was 24.7 psi, which was 11.9 psi above the required minimum of 12.8 psi. Significant data are presented in table 12-5.

Due to vehicle position at initiation of the chilldown, many of the parameters required to perform an adequate chilldown analysis were not available. When sufficient data were available (ESC2 -650 sec) the chilldown pump differential pressure, flowrate, and engine LOX pump pressure and temperature had reached steady conditions. At this time the chilldown pump differential pressure was 12 psi, the flowrate was approximately 43 gpm, and the engine pump inlet pressure and temperature were 49.7 psia and 165.9 deg R, respectively. When the prevalve was opened at ESC2 -9.3 sec, the engine LOX pump inlet pressure dropped from 53.4 psia to 44.37 psia. The engine pump inlet temperature went from 165.4 deg R to 165 deg R between the time the prevalve opened and Engine Start Command. The engine pump outlet temperature increased from 165.3 deg R to 165.4 deg R during the same period.

12.4 Engine LOX Supply

The engine LOX supply system (figure 12-16) delivered the necessary quantity of LOX to the engine during first burn. During the restart attempt, the system performed adequately and reasonably in view of system boundary conditions.

12.4.1 First Burn

The NPSP at the engine interface (figure 12-17) was calculated to be 24.9 psi at first burn Engine Start Command. The NPSP then decreased and after 26 sec of powered flight reached a minimum value of 21.1 psi which was 0.8 psi above the 20.3 psi required at the interface at that time. During the remainder of the burn, the NPSP remained between 24.2 and 26.5 psi as it followed the ullage pressure. At the end of first burn the NPSP was 25.3 psi which was 5.1 psi higher than required at that time.

The interface static pressure and temperature are shown in figure 12-17. The interface pressure was 41.7 psia at Engine Start Command and reached a minimum of 34.9 psia after 26 sec of engine operation. The pressure increased to 40.0 psia and then cycled between 38.5 and 41.0 psia as it followed the ullage pressure. The LOX pump interface static pressure became significantly erratic commencing at approximately R0 +700 sec. Related system parameters and performance levels indicate the occurrence of this erratic behavior to be external of the LOX feed system. It is believed the behavior is a result of the J-2 failure which produced severe environmental changes which affected the instrumentation. The interface pressure at Engine Cutoff Command was 29.5 psia. The pump interface temperature was 164.7 deg R at Engine Start Command and Engine Cutoff Command.

The LOX pump inlet pressure and temperature were plotted in the LOX pump operating region (figure 12-18) and indicated that the LOX pump interface conditions were met satisfactorily throughout the first period of powered flight. The pump interface temperature was plotted against the mass remaining in the LOX tank during engine operation and is shown in figure 12-19. Table 12-6 compares the LOX supply parameters to those of the AS-501 flight and S-IVB-502 acceptance firing.

12.4.2 Second Burn

The LOX pump NPSP at the engine interface (figure 12-20) was calculated to be 24.7 psi at second burn Engine Start Command. At the end of fuel lead, the LOX NPSP increased rapidly to 25.5 psi. At Engine Cutoff Command, the NPSP was 25.5 psi which was 4.5 psi above the minimum required at that time.

The LOX pump interface static pressure transducer (D0003) was inoperative after first burn, and thus the inlet pressures were calculated from LOX tank conditions. The interface pressure was 41.6 psia at Engine Start Command and at the end of fuel lead; it was 42.0 psia at Engine Cutoff Command.

The interface temperature at Engine Start Command and at the end of fuel lead was 165 deg R; at Engine Cutoff Command it was 165.2 deg R.

The LOX pump interface pressure and temperature were plotted in the engine operating region (figure 12-21) and indicated that the engine LOX pump interface conditions were met satisfactorily during the restart attempt. The S-IVB-502 flight data are compared to the S-IVB-501 flight and the S-IVB-502 acceptance firing data in table 12-6.

TABLE 12-1
LOX TANK PREPRESSURIZATION DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | S-IVB-501 FLIGHT | S-IVB-502 ACCEPT |
|---|---------|---------------------|---------------------|---------------------|
| Prepressurization duration | sec | 17 | 15 | 19 |
| Number of makeup cycles | | 4* | 2 | 1 |
| Prepressurization helium | | | | |
| Flowrate | lbm/sec | 0.28 | 0.26 | 0.321 |
| Mass added to LOX tank during prepressurization | lbm | 4.8 | 3.7 | 6.1 |
| Mass added to LOX tank during makeup cycles | lbm | 1.28* | 0.39 | 0.57 |
| Ullage pressure | | | | |
| At prepressurization initiation | psia | 15.2 | 15.1 | 14.7 |
| At prepressurization termination | psia | 40.5 | 40.5 | 40.3 |
| At liftoff** | psia | 42.1 | 42.4 | |
| At Engine Start Command | psia | 40.3 | 40.2 | 36.8 |
| Events (from liftoff**) | sec | | | |
| Prepressurization initiation | | -167 | -167 | -163 |
| Prepressurization termination | | -150 | -152 | -144 |
| Engine Start Command | | 577.3 | 520.7 | 511.0 |

*0.9 lbm of helium were added to the tank during two GSE-supplied makeup cycles on the ground. Two cold-helium-sphere-supplied makeup cycles during S-IC boost added 0.38 lbm more.

**Liftoff is simulated during acceptance firing.

TABLE 12-2
LOX TANK PRESSURIZATION DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|---|---------|--------------------|-------------|--------------------|--------------------|--------------------|--------------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| Number of secondary flow intervals | | 4 | N/A | 6 | 3 | 3 | 3 |
| Pressure control band | | | | | | | |
| Minimum | psia | 38.6 | N/A | 39.0 | 38.9 | 38.0 | 38.0 |
| Maximum | psia | 40.3 | N/A | 40.0 | 40.0 | 39.7 | 39.8 |
| Ullage pressure | | | | | | | |
| At Engine Start Command | psia | 40.3 | 41.6 | 40.2 | 42.6 | 38.0 | 35.0 |
| Minimum during start transient | psia | 35.2 | N/A | 35.8 | 38.8 | 33.8 | 34.6 |
| At Engine Cutoff Command | psia | 39.0 | 42.1 | 40.0 | 39.0 | 35.6 | 39.5 |
| Pressurant total flowrate | | | | | | | |
| During undercontrol | lbm/sec | 0.25 to 0.31 | N/A | 0.25 to 0.30 | 0.28 to 0.33 | 0.26 to 0.28 | 0.28 |
| During overcontrol | lbm/sec | 0.37 to 0.41 | N/A | 0.38 to 0.42 | 0.40 to 0.46 | 0.38 to 0.40 | 0.40 to 0.41 |
| Maximum LOX tank vent inlet temperature | °R | 506 | N/A | 495 | 420 | 550 | 540 |

N/A Not applicable

TABLE 12-3
COLD HELIUM SUPPLY DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|---|-------|------------------|-------------|------------------|-------------|------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| <u>Pressure</u> | | | | | | | |
| At liftoff | psia | 2,966 | N/A | 2,910 | N/A | 3,280 | N/A |
| At Engine Start Command | psia | 2,939 | 860 | 2,910 | 1,430 | 3,200 | 2,425 |
| At Engine Cutoff Command | psia | 1,378 | 830 | 1,570 | 800 | 1,670 | 1,090 |
| <u>Average Temperature</u> | | | | | | | |
| At liftoff | deg R | 38.9 | N/A | 41.0 | N/A | 41.0 | N/A |
| At Engine Start Command | deg R | 39.1 | 35.3 | 40.0 | 38.5 | 40.0 | 56.0 |
| At Engine Cutoff Command | deg R | 30.8 | 34.8 | 32.5 | 35.0 | 31.5 | 44.0 |
| <u>Helium Mass</u> | | | | | | | |
| At Engine Start Command | lbm | 332 | 201.0 | 332 | 252 | 345 | 282 |
| At Engine Cutoff Command | lbm | 275 | 198.5 | 294 | 190 | 295.2 | 192 |
| Usage calculated from sphere conditions | lbm | 57 | 2.5 | 38 | 62 | 50 | 90 |
| Usage calculated by integration of flowrate | lbm | 55 | 2.9 | 47 | 95 | 50.2 | 105.5 |

N/A Not applicable

TABLE 12-4
J-2 HEAT EXCHANGER PERFORMANCE DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|------------------------------------|---------|------------------|-------------|------------------|-------------|------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| Flowrate through heat exchanger | lbm/sec | 0.185 | N/A | 0.2 | 0.22 | 0.20 | 0.21 |
| During overcontrol | lbm/sec | 0.065 | N/A | 0.073 | 0.074 | 0.075 | 0.075 |
| During undercontrol | | | | | | | |
| Heat exchanger inlet temperature | deg R | * | N/A | 50 | 50 | 75 | 70 |
| During overcontrol | deg R | * | N/A | 60 | 63 | 100 | 90 |
| During undercontrol | deg R | * | N/A | 45 | 39 | 70 | 75 |
| Minimum | | | | | | | |
| Heat exchanger outlet temperature | deg R | 965 | N/A | 925 | 940 | 960 | 940 |
| At end of 50-sec transient | deg R | 990 | N/A | ** | 930 | 985 | 915 |
| During overcontrol | deg R | 1,005 | N/A | ** | 985 | 1,000 | 940 |
| During undercontrol | deg R | 1,000 | N/A | 990 | 985 | 995 | 950 |
| At Engine Cutoff Command | | | | | | | |
| Heat exchanger outlet pressure | psia | 330 | N/A | 350 | 360 | 360 | 350 |
| During overcontrol | psia | 380 | N/A | 410 | 418 | 420 | 420 |
| During undercontrol | | | | | | | |
| Average LOX vent inlet pressure | psia | 69 | N/A | 67 | 65 | 64 | 64 |
| During overcontrol | psia | 52 | N/A | 52 | 50 | 47 | 47 |
| During undercontrol | deg R | 506 | N/A | 495 | 420 | 550 | 540 |
| Maximum LOX vent inlet temperature | | | | | | | |

*Measurement failed.

**Temperature did not stabilize.

N/A Not applicable

TABLE 12-5
LOX CHILLDOWN SYSTEM PERFORMANCE DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|---------------------------------------|--|------------------|-------------|----------------------|-------------|------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| NPSP | | | | | | | |
| At Engine Start Command* | | | | | | | |
| With chilldown pump head | psi | 24.9 | N/A | 36.9 | N/A | N/A | N/A |
| Without chilldown pump head | psi | 22.8 | 24.7 | 23.8 | 25.0 | 27.6 | 22.8 |
| Minimum required at engine start | psi | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 |
| At opening of prevalve | psi | 42.23 | 27.1 | 45.5 | 34.0 | 36.0 | 31.5 |
| Pump inlet conditions | | | | | | | |
| Pressure at Engine Start Command ** | | | | | | | |
| With chilldown pump head | psia | 41.7 | N/A | 50.3 | N/A | N/A | N/A |
| Without chilldown pump head | psia | 40.3 | 41.6 | 40.2 | 42.6 | 44.8 | 40.2 |
| Temperature at Engine Start Command | deg R | 164.7 | 165.0 | 164.5 | 165.75 | 165.4 | 165.4 |
| Average flow coefficient | sec ² / in. ² ft ³ | 18.3 | 18.2 | 25.0 | 25.0 | 14.4 | 13.27 |
| Heat absorption rate (Btu/hr) | | | | | | | |
| Section 1 (tank to pump inlet) | | 500 | ~500 | 500 | 500 | 2,900 | 4,110 |
| Section 2 (pump inlet to bleed valve) | | 4,000 | ~100 | 3,500 | 4,000 | 13,600 | 24,570 |
| Section 3 (bleed valve to tank inlet) | | ~500 | 0 | 3,500 | 2,000 | 4,400 | 6,120 |
| Total | | 5,000 | ~600 | 7,500 | 6,500 | 20,900 | 34,800 |
| Chilldown flowrate | | | | | | | |
| Unpressurized | gpm | 39.5 | N/A | 33.5 | N/A | 38.7 | 38.6 |
| Pressurized | gpm | 42.5 | 42.5 | 35.0 | 37.0 | 40.9 | 40.9 |
| Chilldown system pressure drop | | | | | | | |
| Unpressurized | psi | 10.0 | N/A | 9.2 | N/A | 6.6 | 6.6 |
| Pressurized | psi | 11.5 | 12.4 | 11.0 | 10.5 | 8.3 | 7.7 |
| Events*** | | | | | | | |
| Chilldown initiation | sec | -284.152 | -742.466 | -278.9 | -562.7 | -203.8 | -719.7 |
| Prevalve closed | | -274.909 | -727.446 | -272.5 | -552.0 | -- | -- |
| Prepressurization initiation | | -166.602 | -227.001 | -166.7 | -326.0 | -159.5 | -700.4 |
| Prevalve open command | | 576.596 | -10.79 | 520.0 | -10.8 | 509.37 | -3.14 |
| Prevalve closed signal dropout | | 577.596 | -9.256 | 520.9 | -9.8 | 510.31 | -2.12 |
| Prevalve open signal pickup | | 579.421 | -7.117 | 522.5 | -7.9 | 511.59 | -0.91 |
| Chilldown pump off | | 576.872 | -0.602 | 520.3 | -0.60 | 511.00 | -1.6 |
| Chilldown shutoff valve closed | | N/A | N/A | 625.298 [†] | Not Sent | 511.1 | -1.7 |
| Engine Start Command | | 577.270 | 0 | 520.7 | 0 | 511.9 | 0 |

*During acceptance testing, liftoff is simulated.

**The NPSP and pump inlet pressures are high at this time because the prevalues were slow in opening.

***All first burn data are referenced to liftoff (or simulated liftoff); all second burn data are referenced to second burn Engine Start Command.

[†]LOX chilldown valve closed switch (K0139) failed before liftoff (open dropout used).

N/A Not applicable.

TABLE 12-6
LOX PUMP INLET CONDITION DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|--|--------------|------------------|-------------|------------------|-------------|------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| Pump Inlet Conditions | | | | | | | |
| Static pressure at Engine Start Command* | | | | | | | |
| With chilldown pump head | psi | 41.7 | N/A | 50.3 | N/A | N/A | N/A |
| Without chilldown pump head | psi | 40.3 | 41.6 | 40.2 | 42.6 | 44.8 | 40.2 |
| Temperature at Engine Start Command | °R | 164.7 | 165.0 | 164.5 | 165.75 | 165.4 | 165.4 |
| Temperature at Engine Cutoff Command | °R | 164.7 | 165.2 | 164.5 | 165.75 | 165.0 | 169.2 |
| NPSP Requirements | | | | | | | |
| Minimum at Engine Start Command | psi | 12.77 | 12.77 | 12.8 | 12.8 | 12.8 | 12.8 |
| At high EMR | psi | 20.96** | 20.96** | 20.8 | 20.8 | 20.8 | 20.8 |
| After EMR cutback | psi | 14.93** | 14.93** | N/A | 14.95 | 14.95 | 14.95 |
| NPSP Available | | | | | | | |
| At Engine Start Command* | psi | | | | | | |
| With chilldown pump head | psi | 24.9 | N/A | 36.9 | N/A | N/A | N/A |
| Without chilldown pump head | psi | 22.8 | 24.7 | 23.8 | 25.0 | 27.6 | 22.8 |
| At Start Tank Discharge Valve OPEN Command | psi | 23.4 | 25.5 | 23.6 | 25.0 | 29.0 | 23.5 |
| Maximum during firing | psi | 27.3 | 25.7 | 27.5 | 28.0 | 29.0 | 25.0 |
| Time of maximum | sec from ESC | 5.7 | 15.1 | 15.0 | 8.5 | 4.0 | 118.0 |
| Minimum during firing | psi | 21.1 | 24.6 | 22.5 | 24.2 | 20.2 | 17.5 |
| Time of minimum | sec from ESC | 26.0 | 3.3 | 20.0 | ECC | ECC | ECC |
| At Engine Cutoff Command | psi | 25.3 | 25.5 | 26.0 | 24.2 | 20.2 | 17.5 |
| LOX Feed Duct | | | | | | | |
| At high EMR | | | | | | | |
| Pressure drop | psi | 2.0 | 0.8 | 1.9 | 1.8 | 2.6 | 2.3 |
| Flowrate | lbm/sec | 453 | 250 | 448 | 453 | 462 | 462 |
| After EMR cutback | | | | | | | |
| Pressure drop | psi | N/A | N/A | N/A | 1.8 | N/A | 1.6 |
| Flowrate | lbm/sec | N/A | N/A | N/A | 381 | N/A | 400 |

*The NPSP and pump inlet pressure are high at this time because the prevalues were slow in opening.

**These requirements are variable with acceleration. The values presented are maximum. Figures 12-10 and 12-11 graphically display the requirement.

N/A Not applicable.

Section 12 Oxidizer System

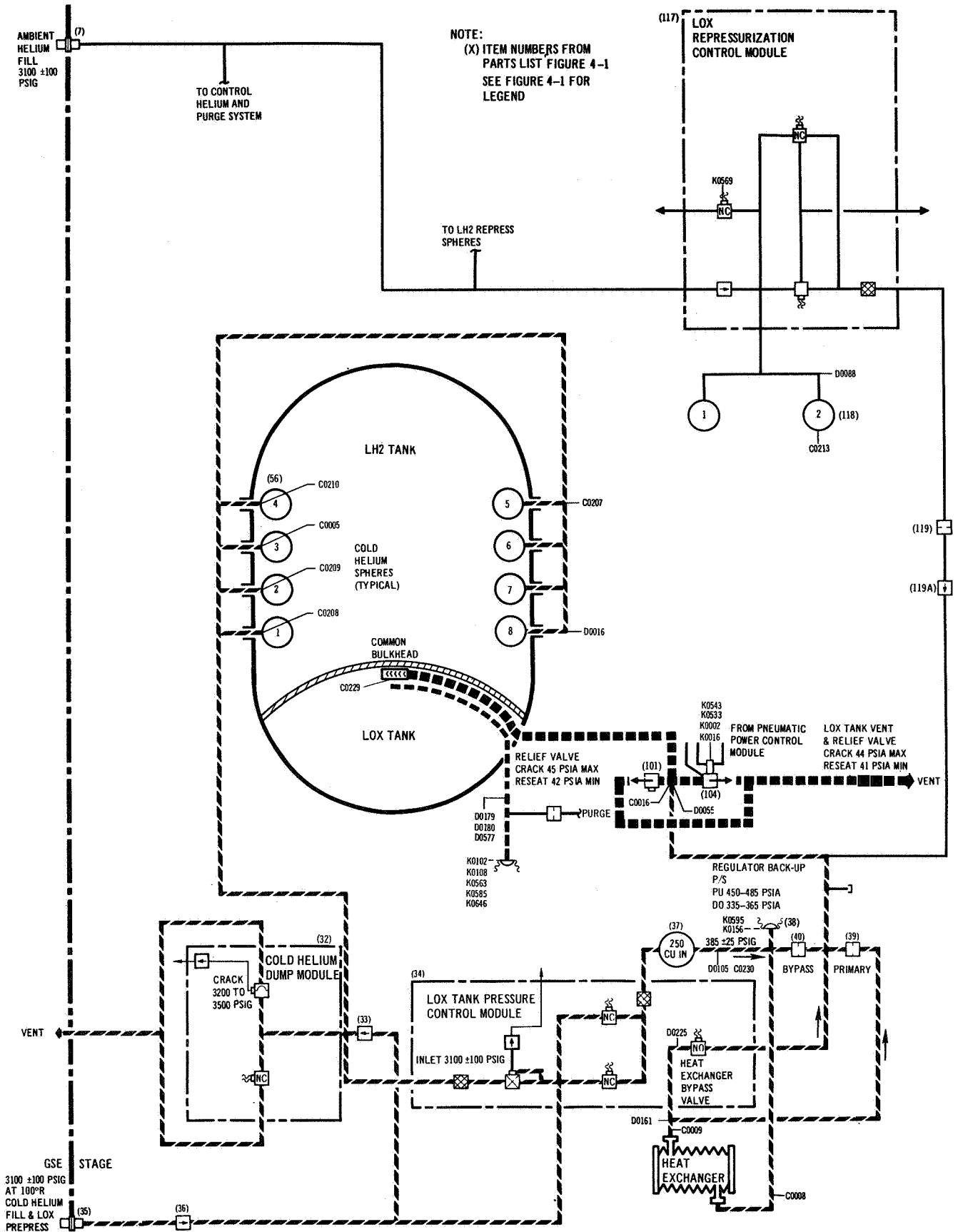


Figure 12-1. LOX Tank Pressurization System

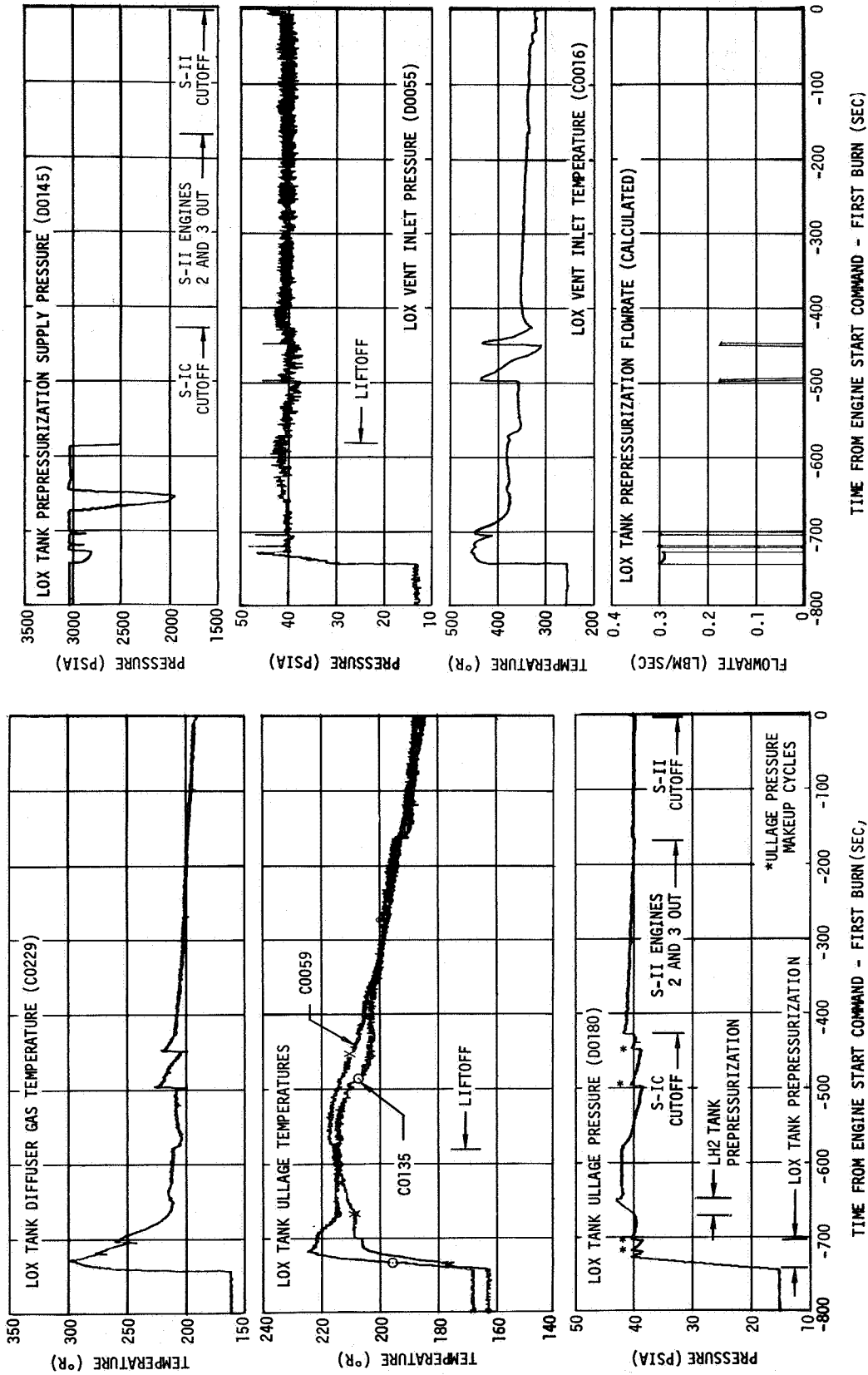


Figure 12-2. LOX Tank Conditions - Prepressurization and Boost

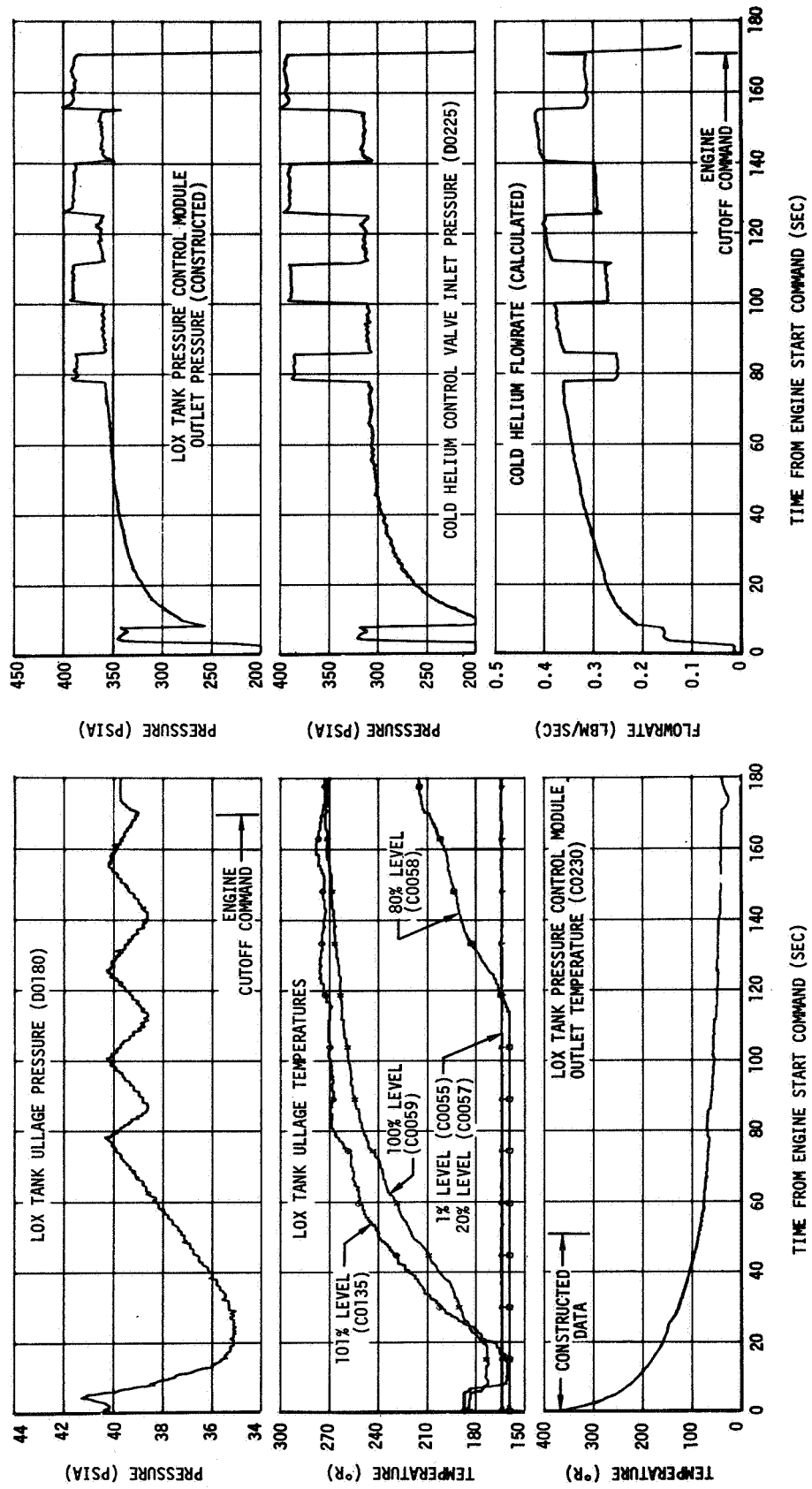


Figure 12-3. LOX Tank Pressurization System Performance - First Burn

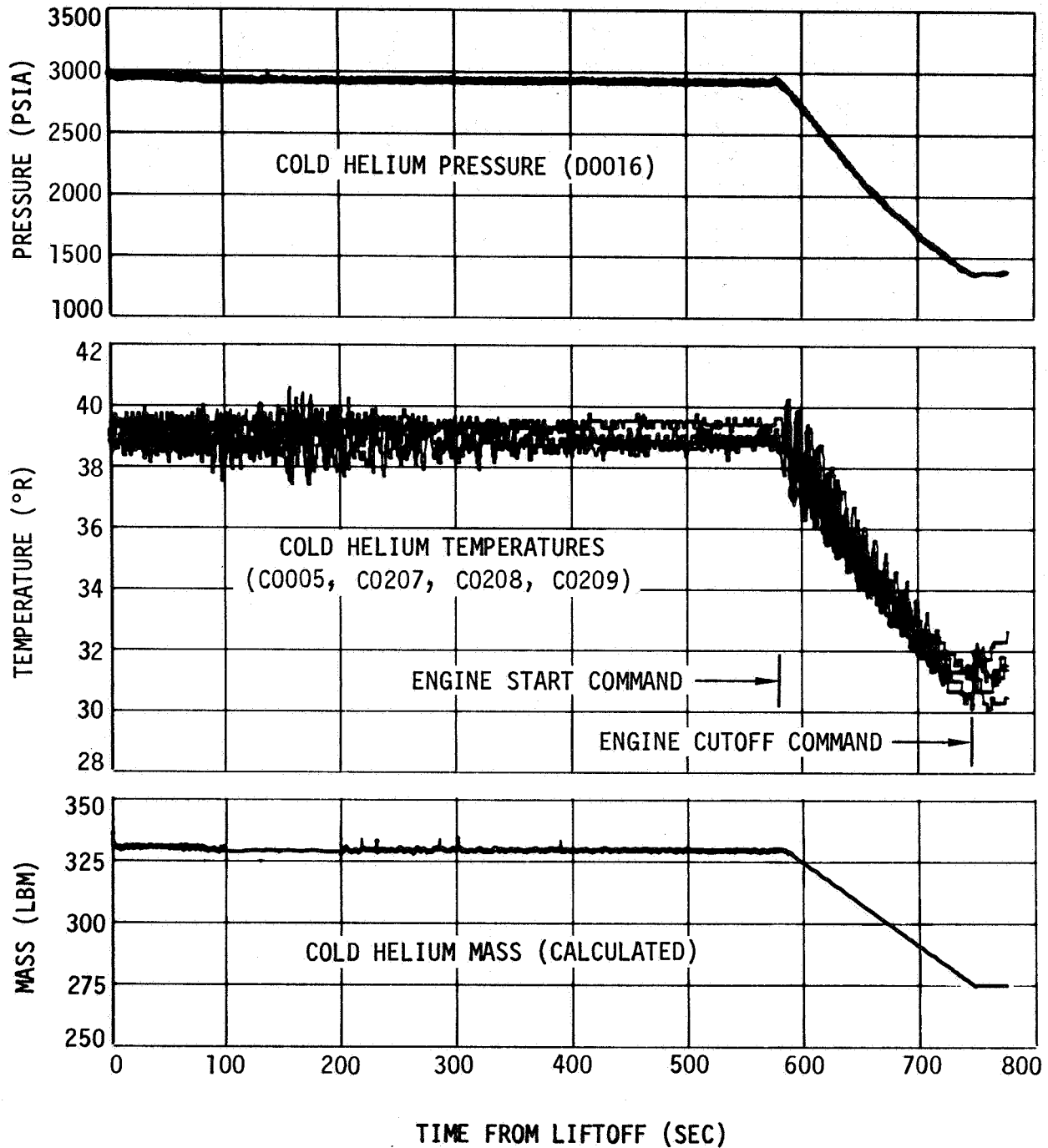


Figure 12-4. Cold Helium Supply - Boost and First Burn

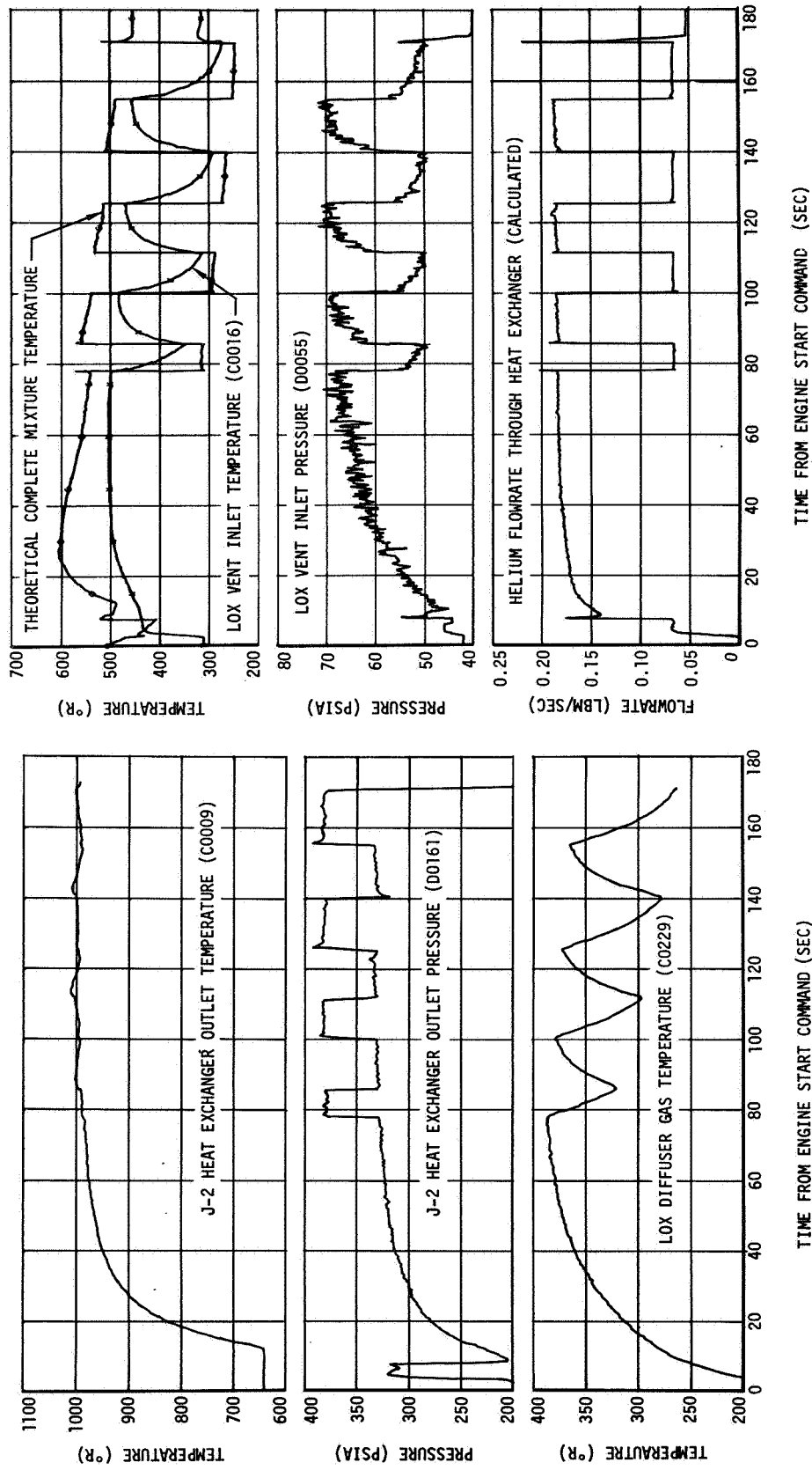


Figure 12-5. J-2 Heat Exchanger Performance - First Burn

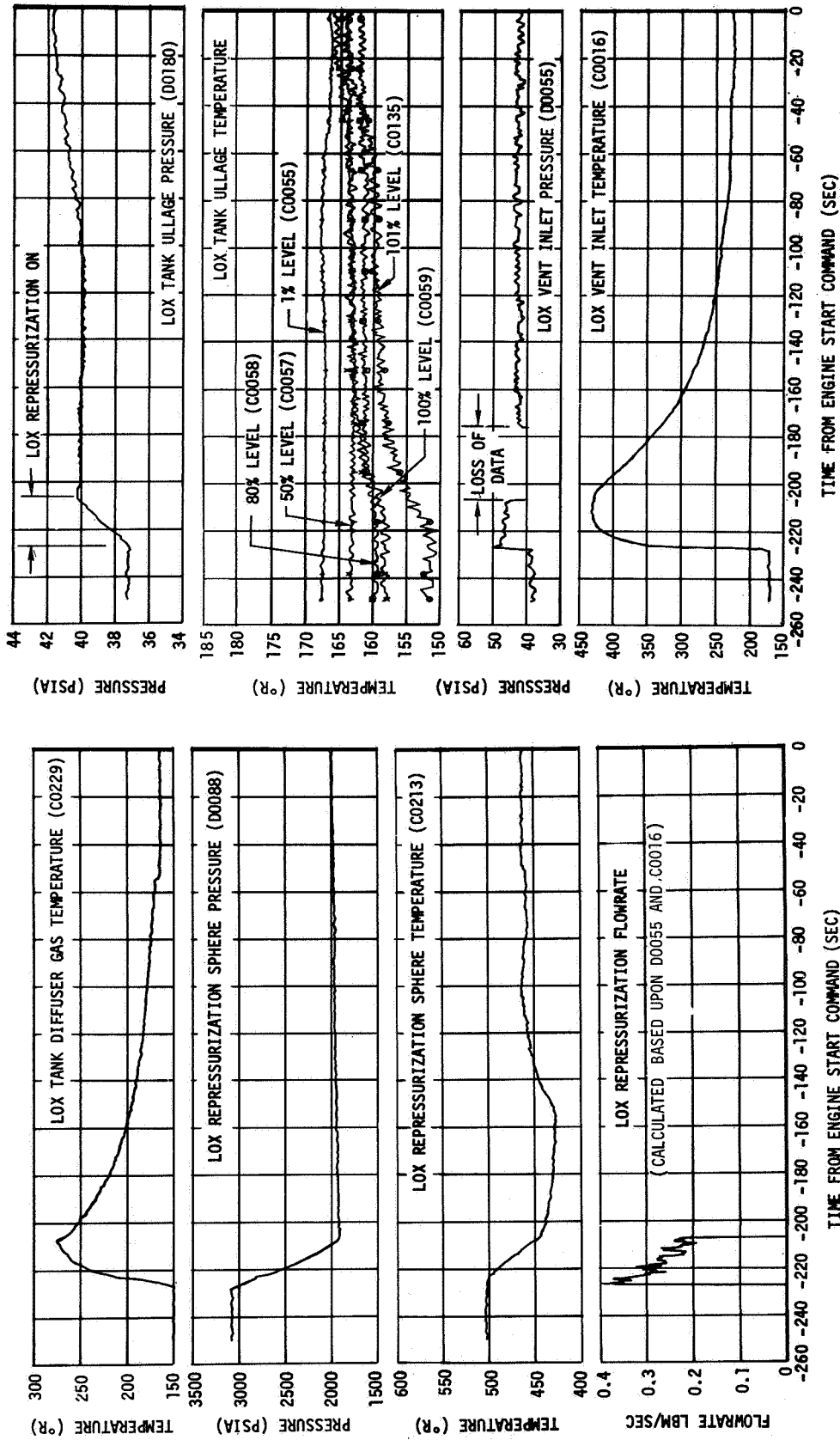


Figure 12-6. LOX Tank Conditions During Repressurization Period - Second Burn

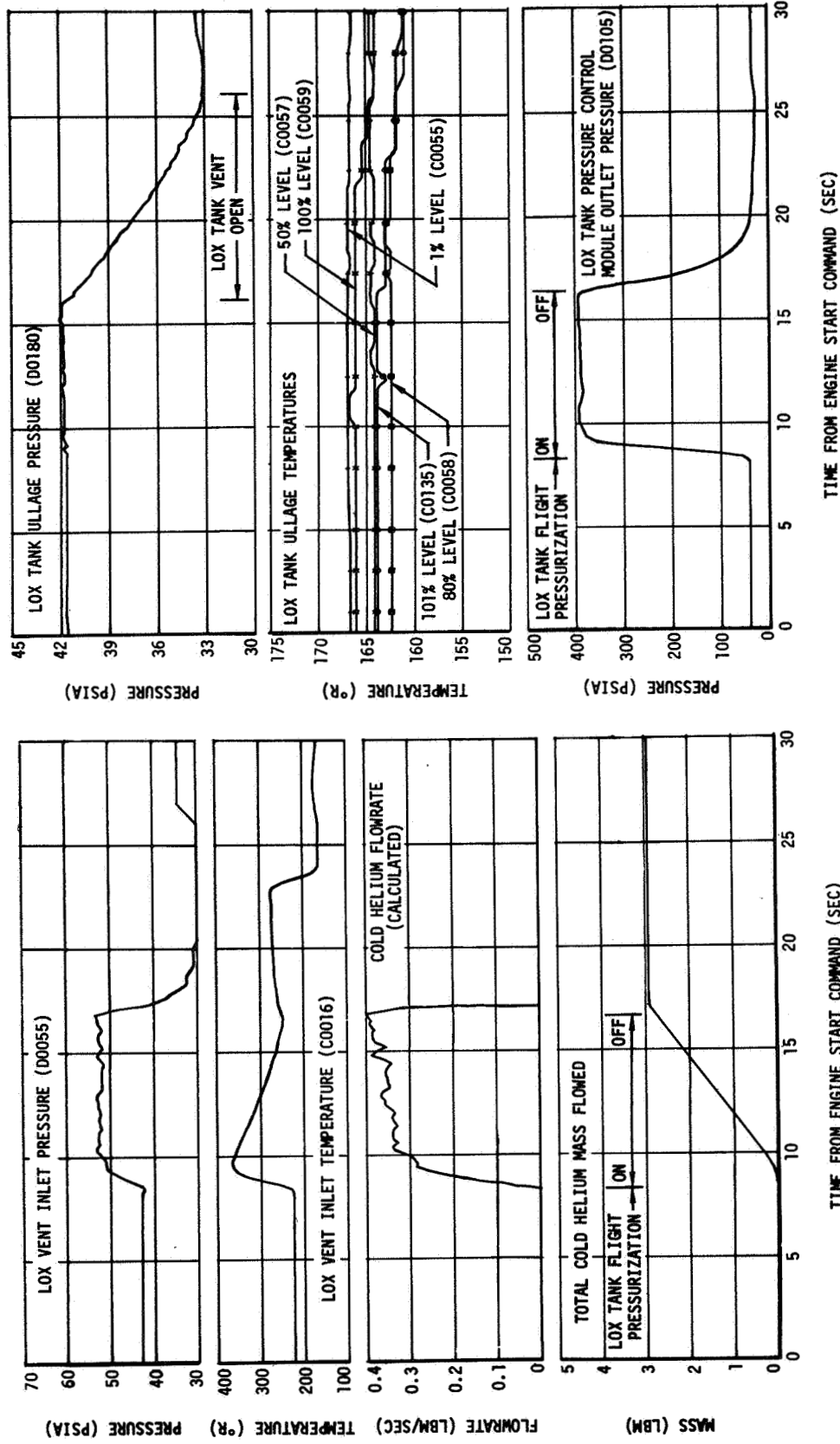


Figure 12-7. LOX Tank Pressurization System Performance - Second Burn

Section 12
Oxidizer System

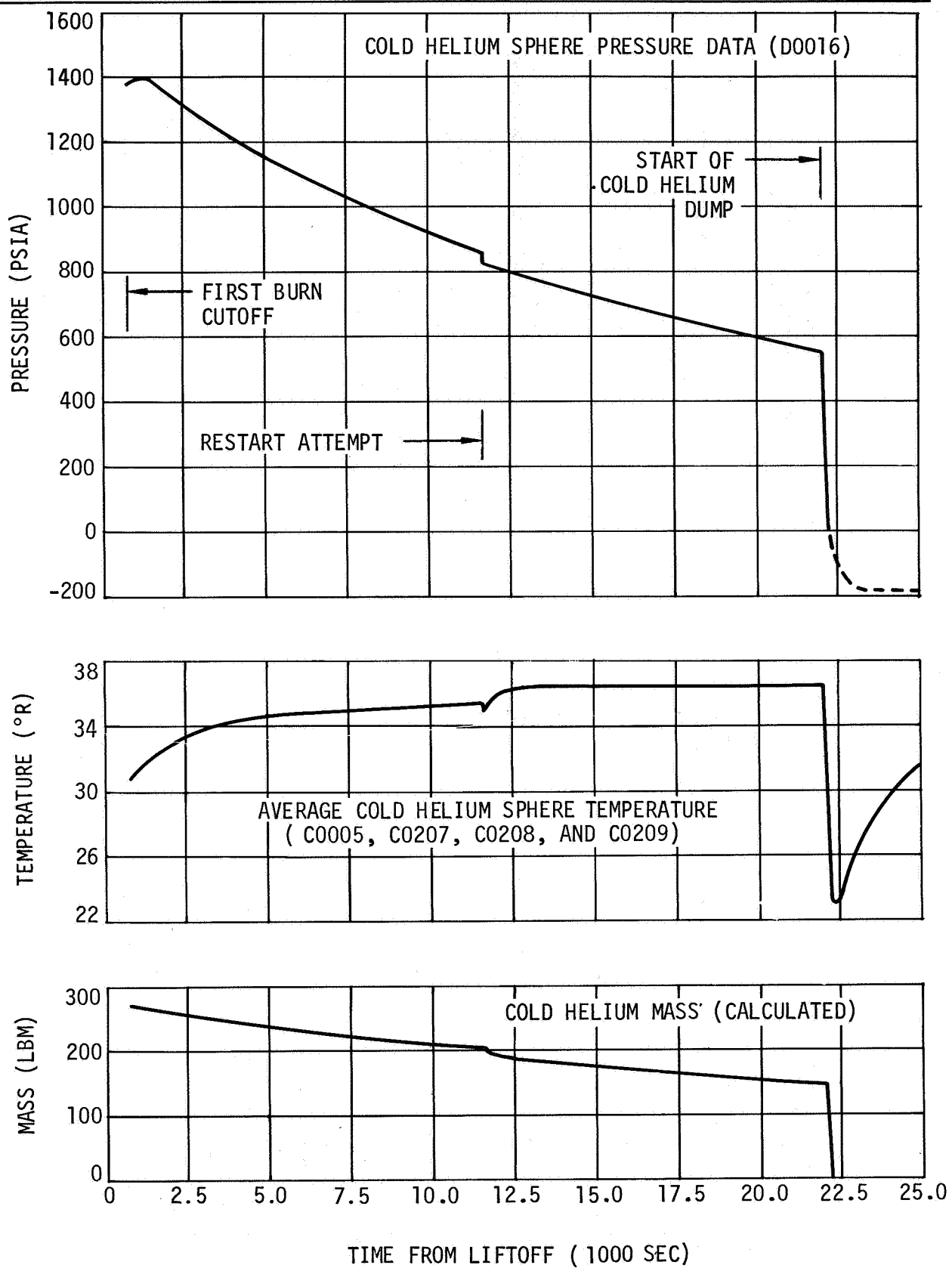


Figure 12-8. Cold Helium Supply - Orbit

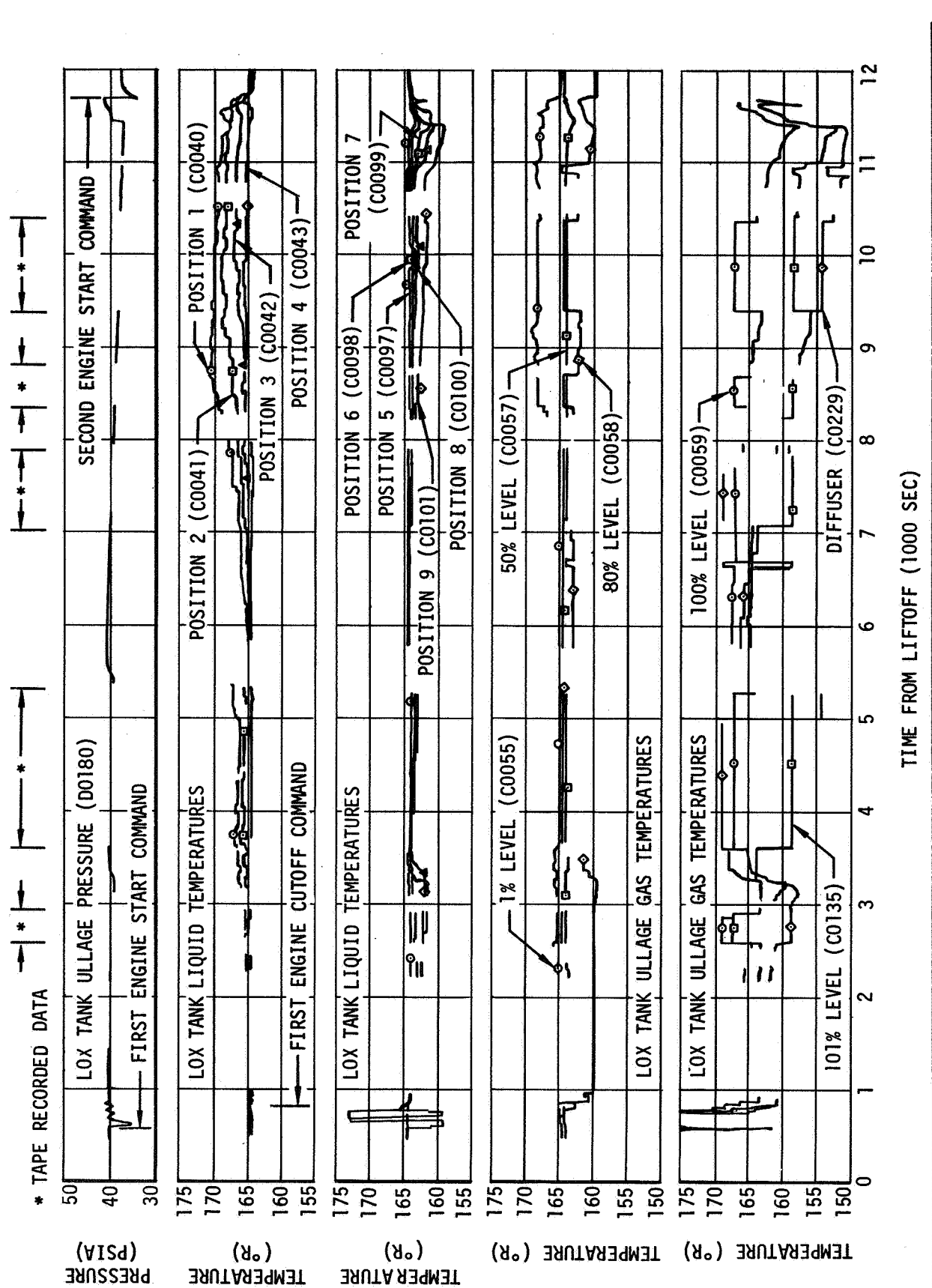


Figure 12-9. LOX Tank Conditions - First and Second Orbits

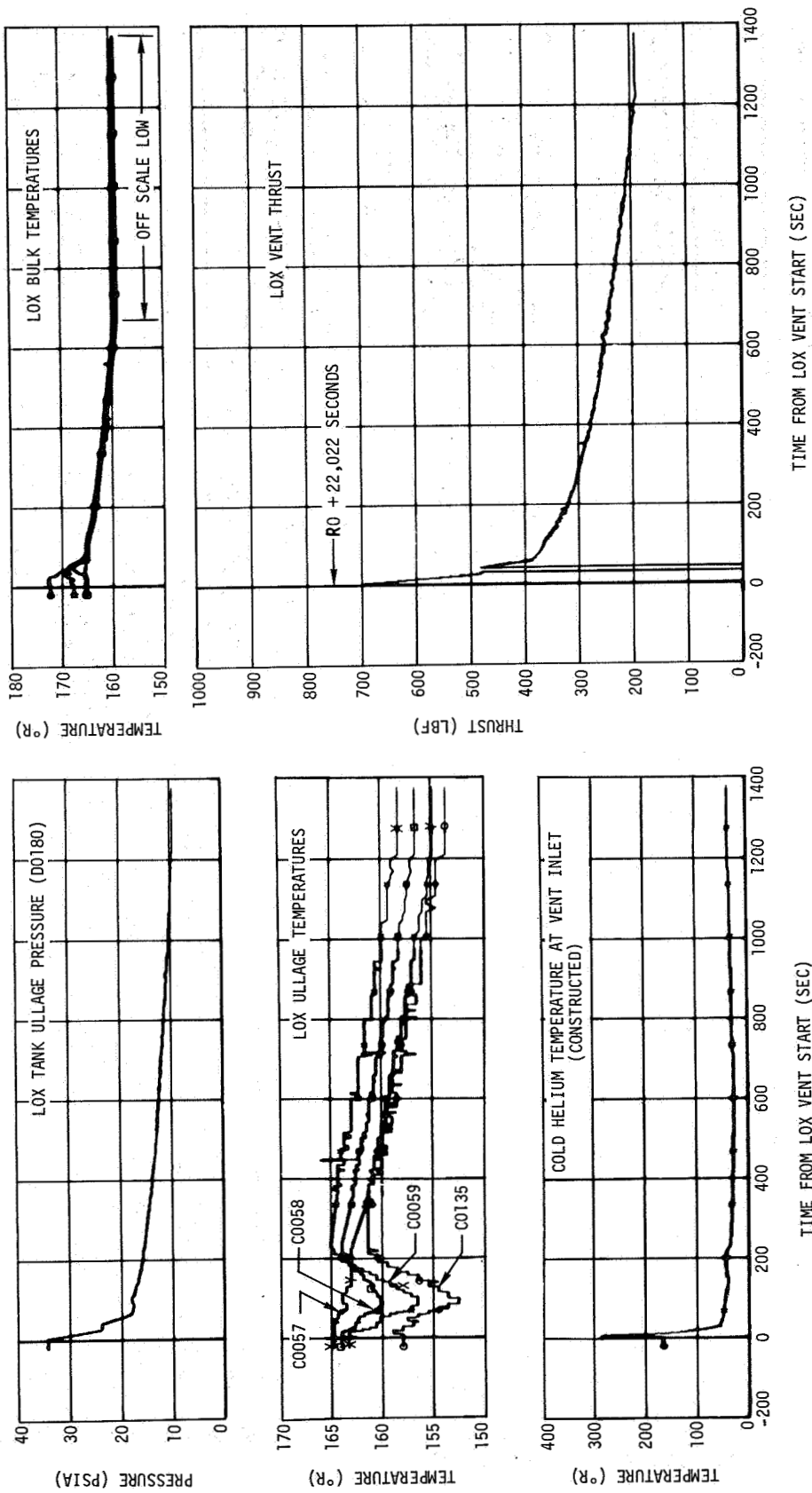


Figure 12-10. LOX Tank Conditions During LOX Tank Cold Helium Vent

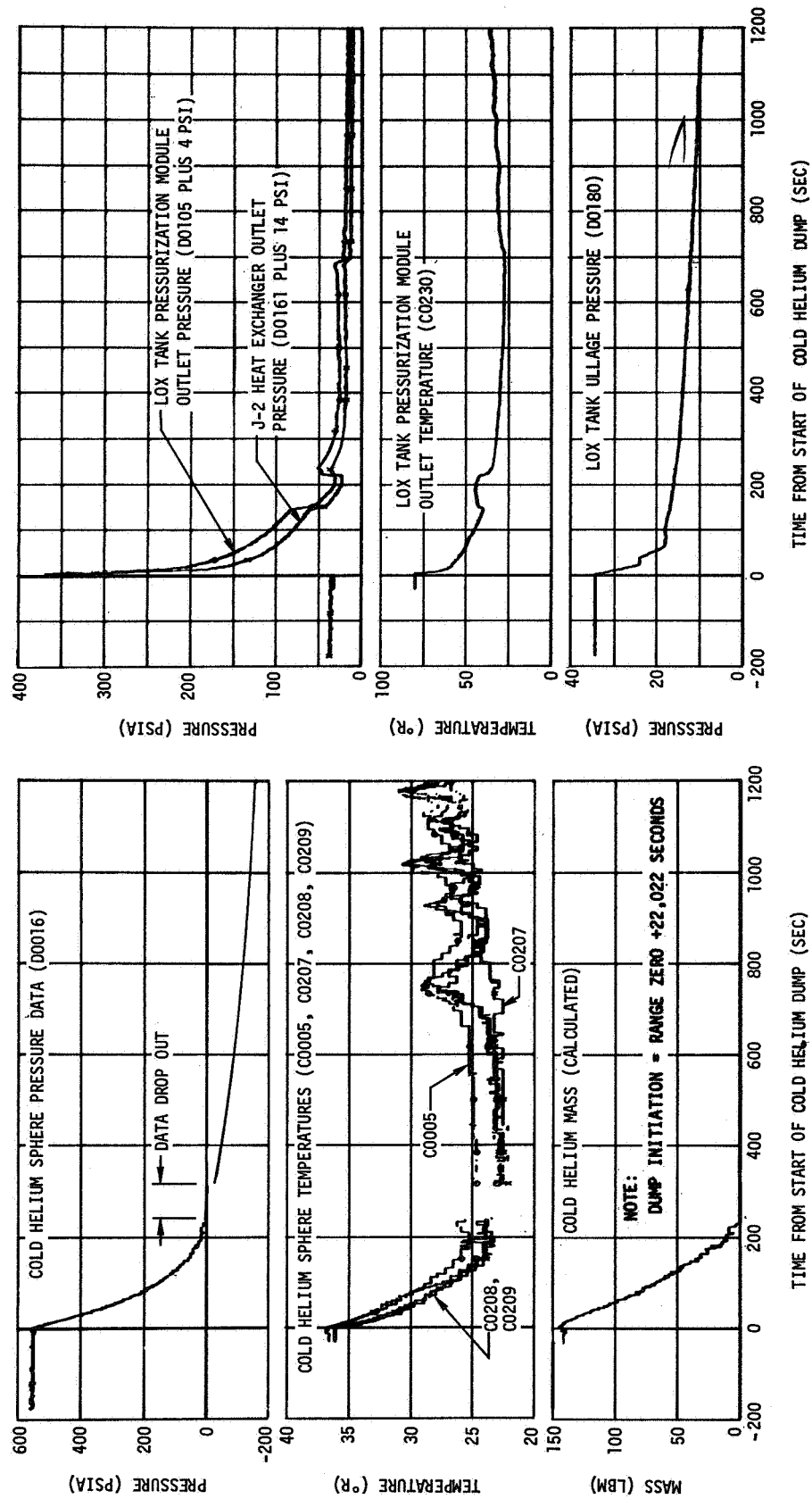


Figure 12-11. LOX Pressurization System Conditions - Cold Helium Dump

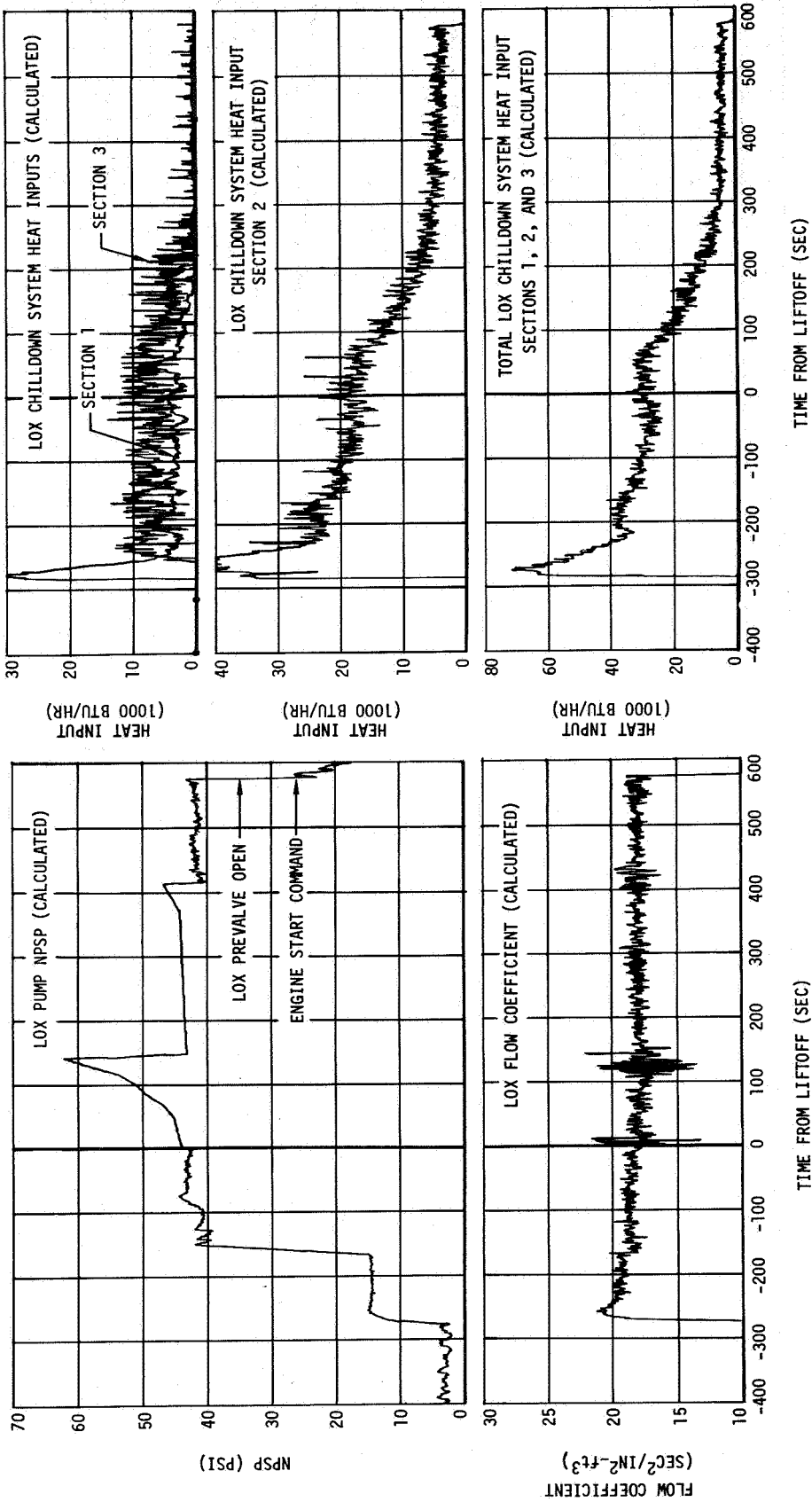


Figure 12-12. LOX Pump Chilldown System Performance - First Burn

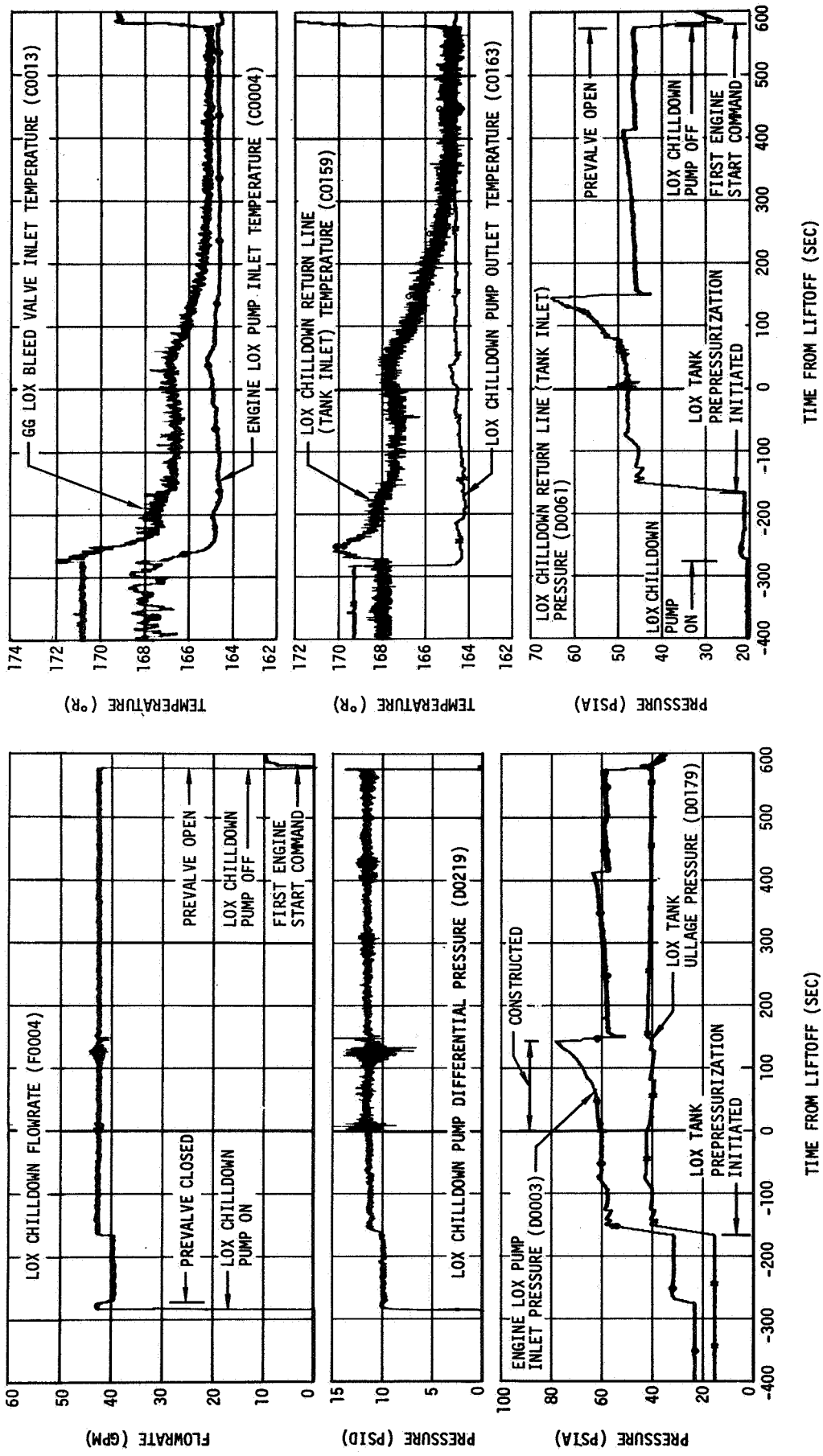


Figure 12-13. LOX Pump Chilldown System Operation - First Burn

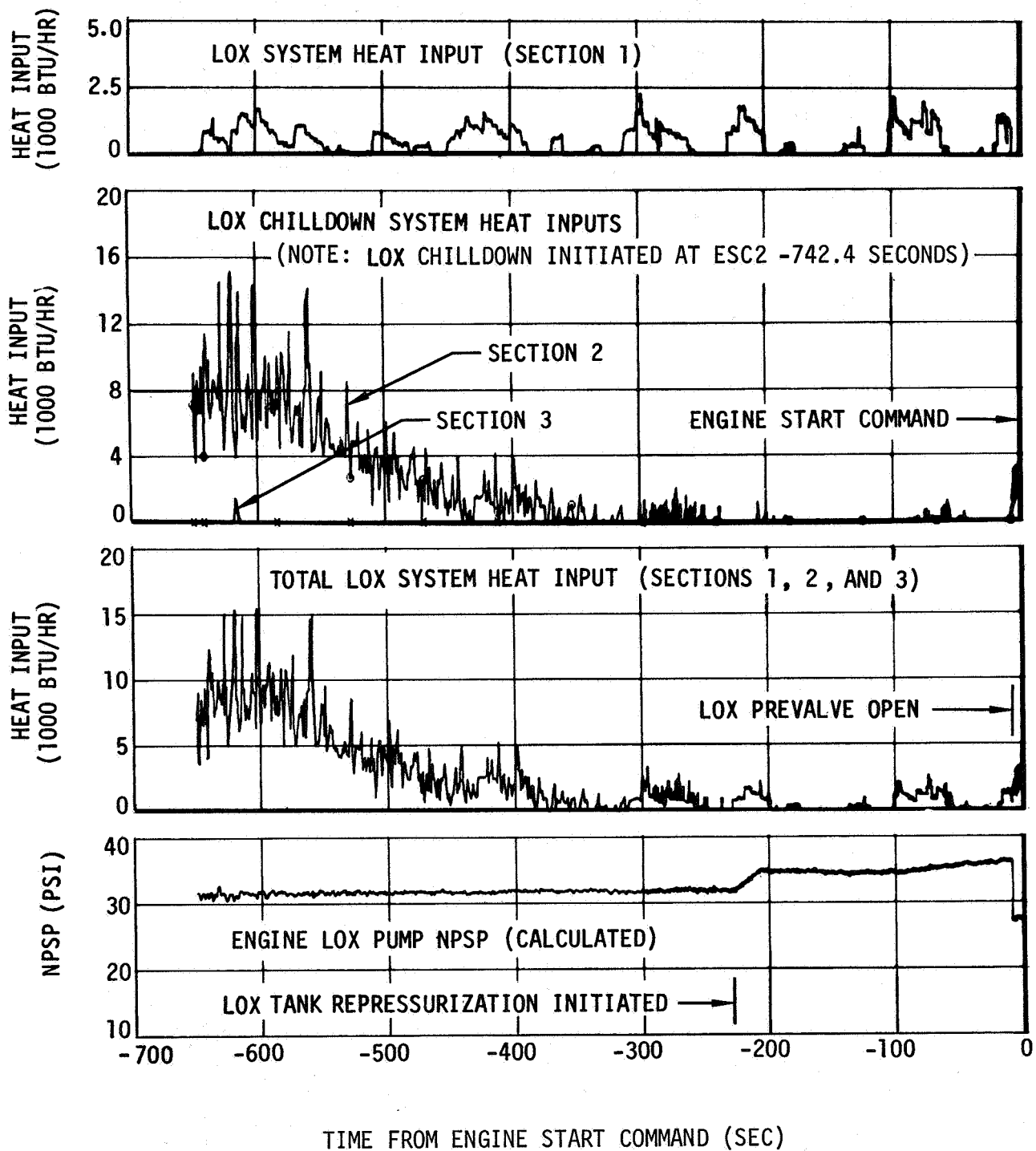


Figure 12-14. LOX Pump Chilldown System Performance - Second Burn

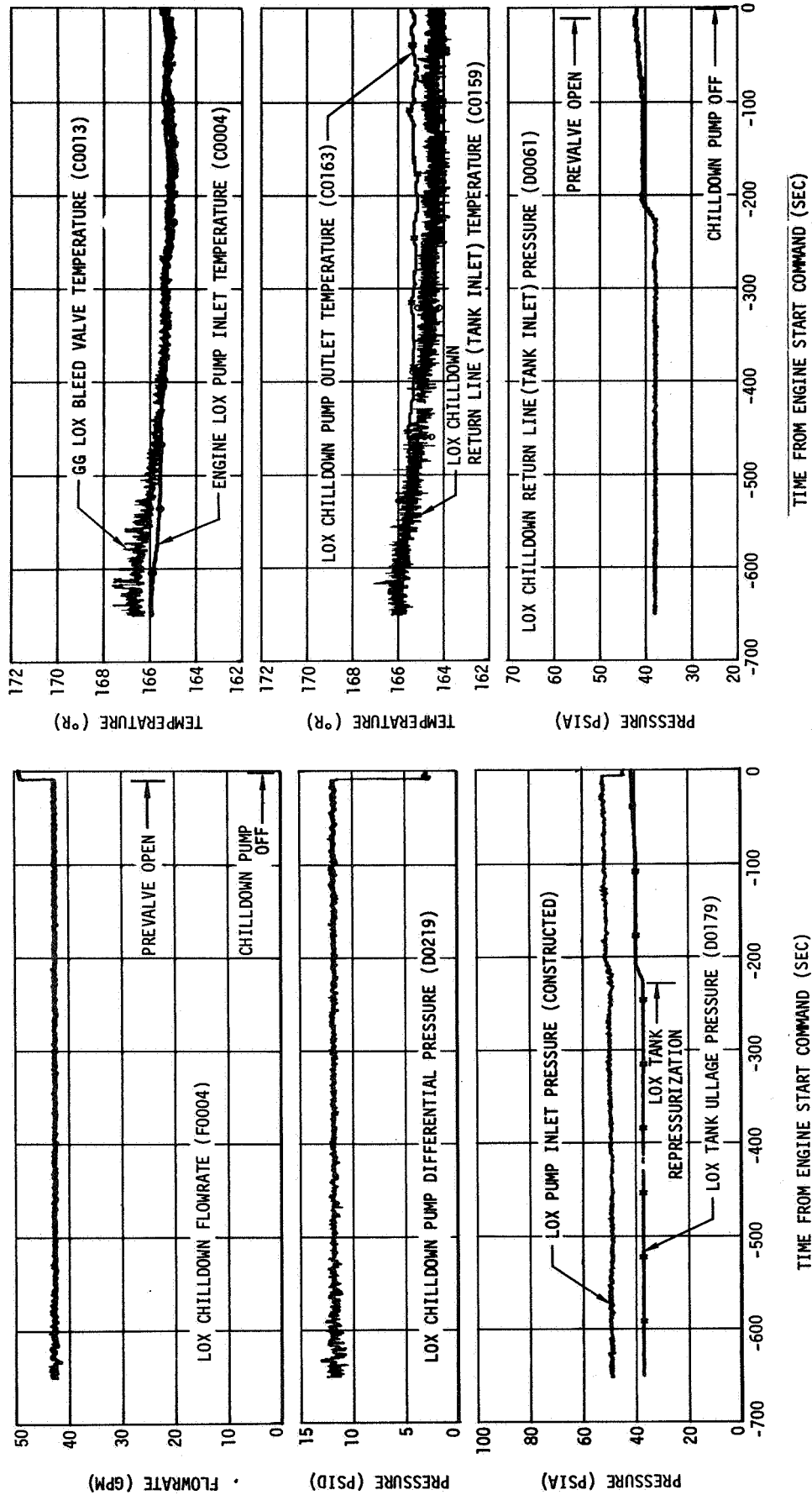


Figure 12-15. LOX Pump Chilldown System Operation - Second Burn

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Oxidizer System

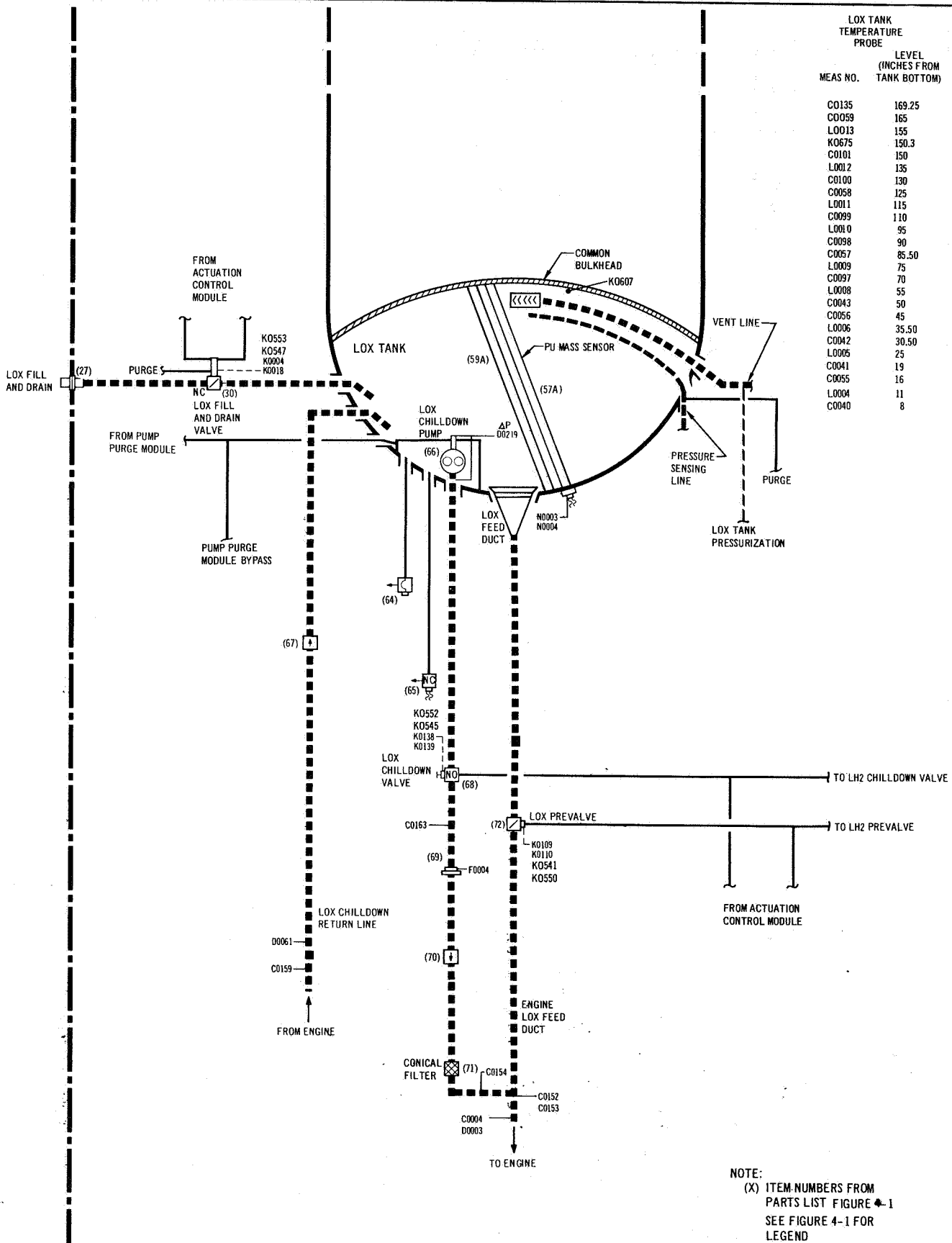


Figure 12-16. LOX Supply System

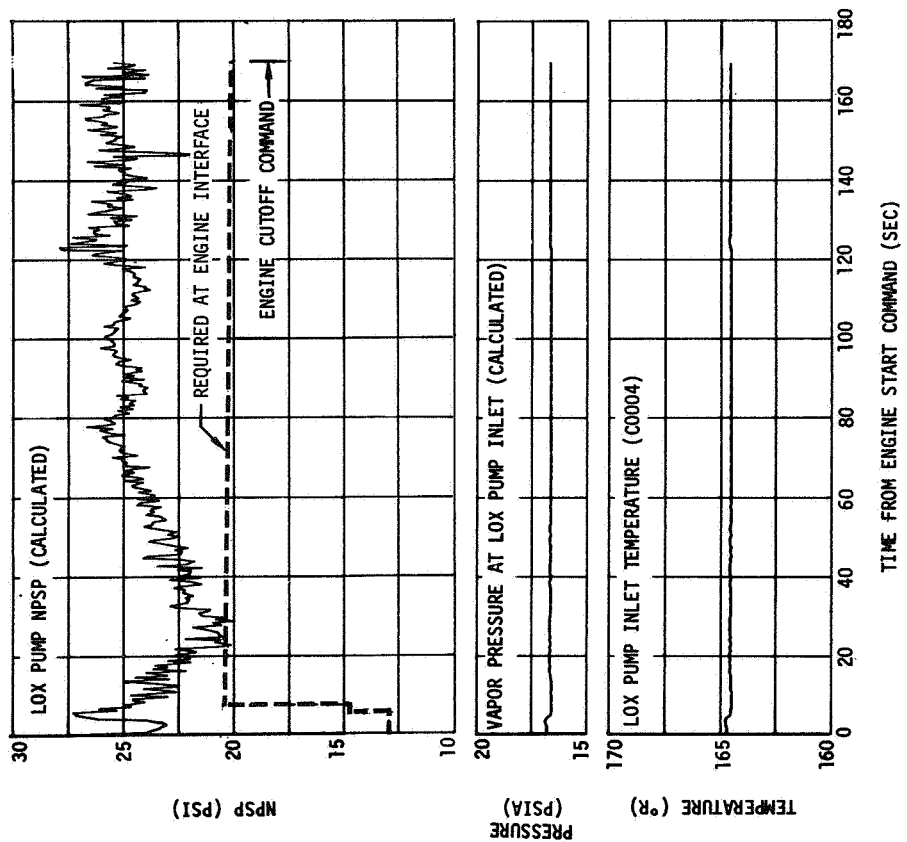
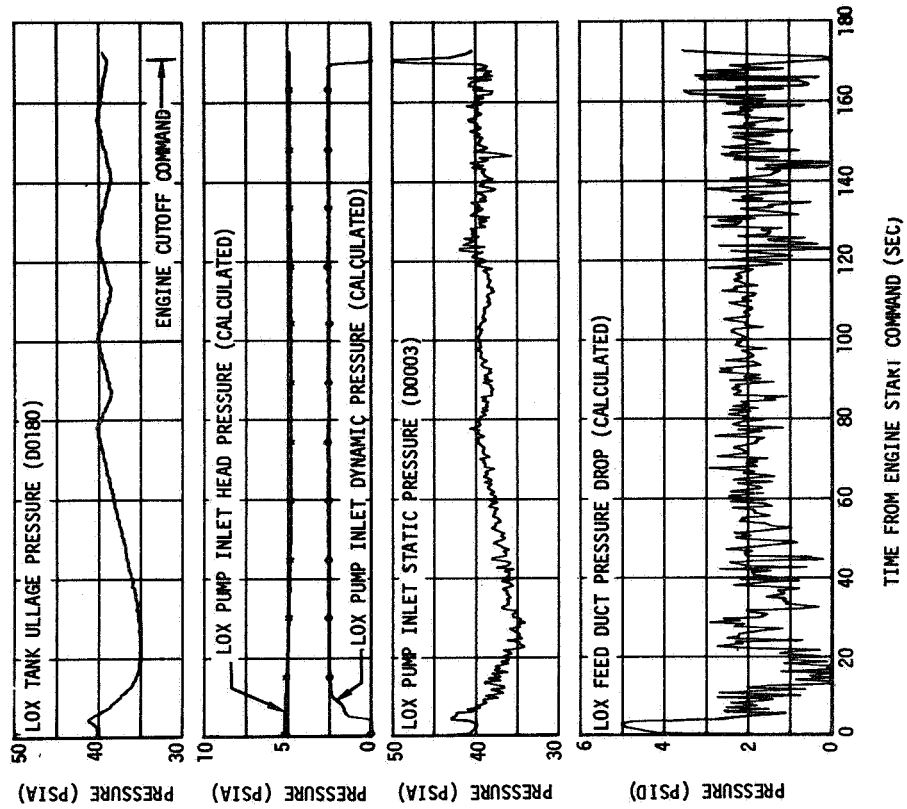


Figure 12-17. LOX Pump Inlet Conditions - First Burn

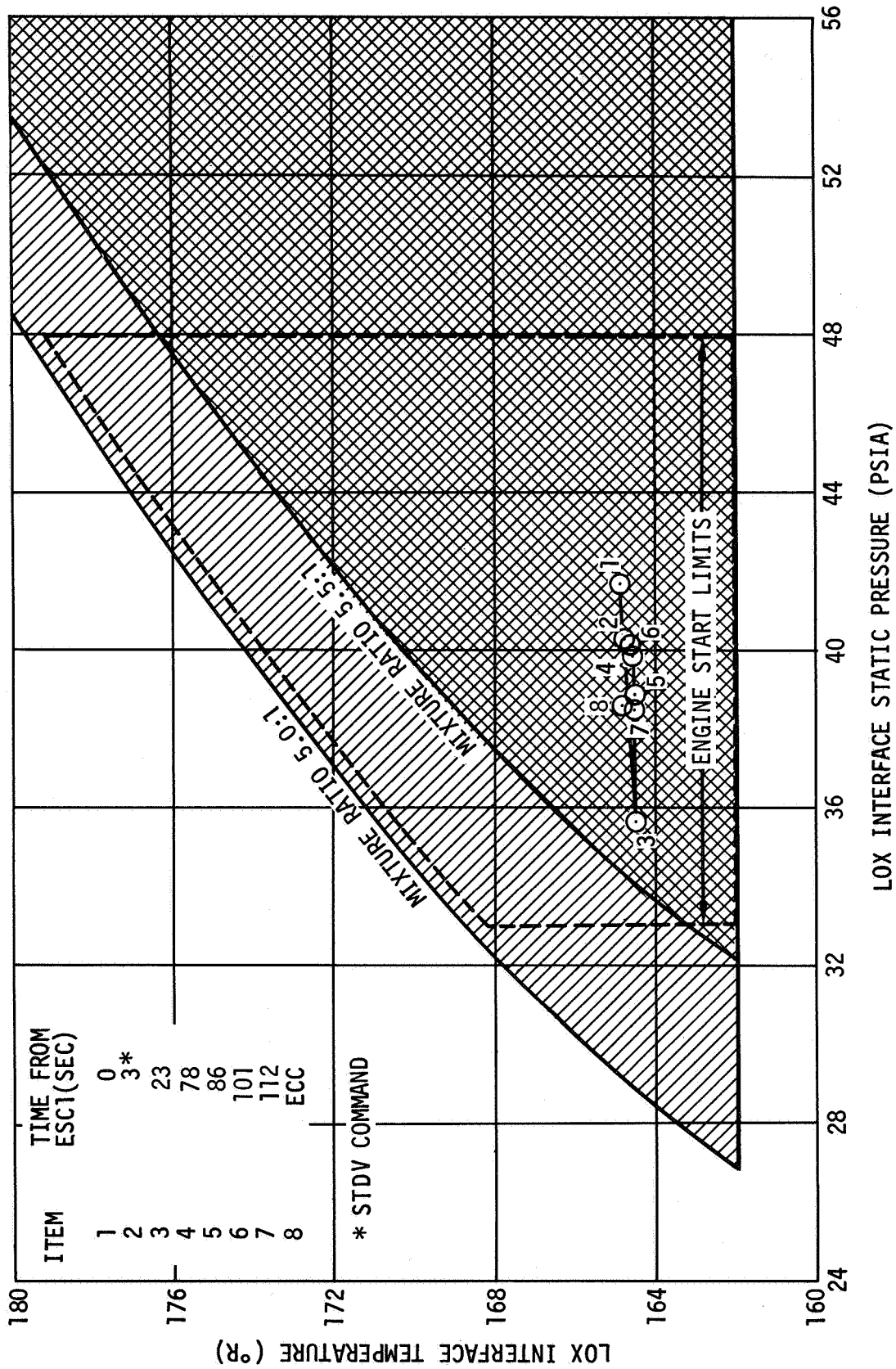


Figure 12-18. LOX Pump Interface Conditions - First Burn

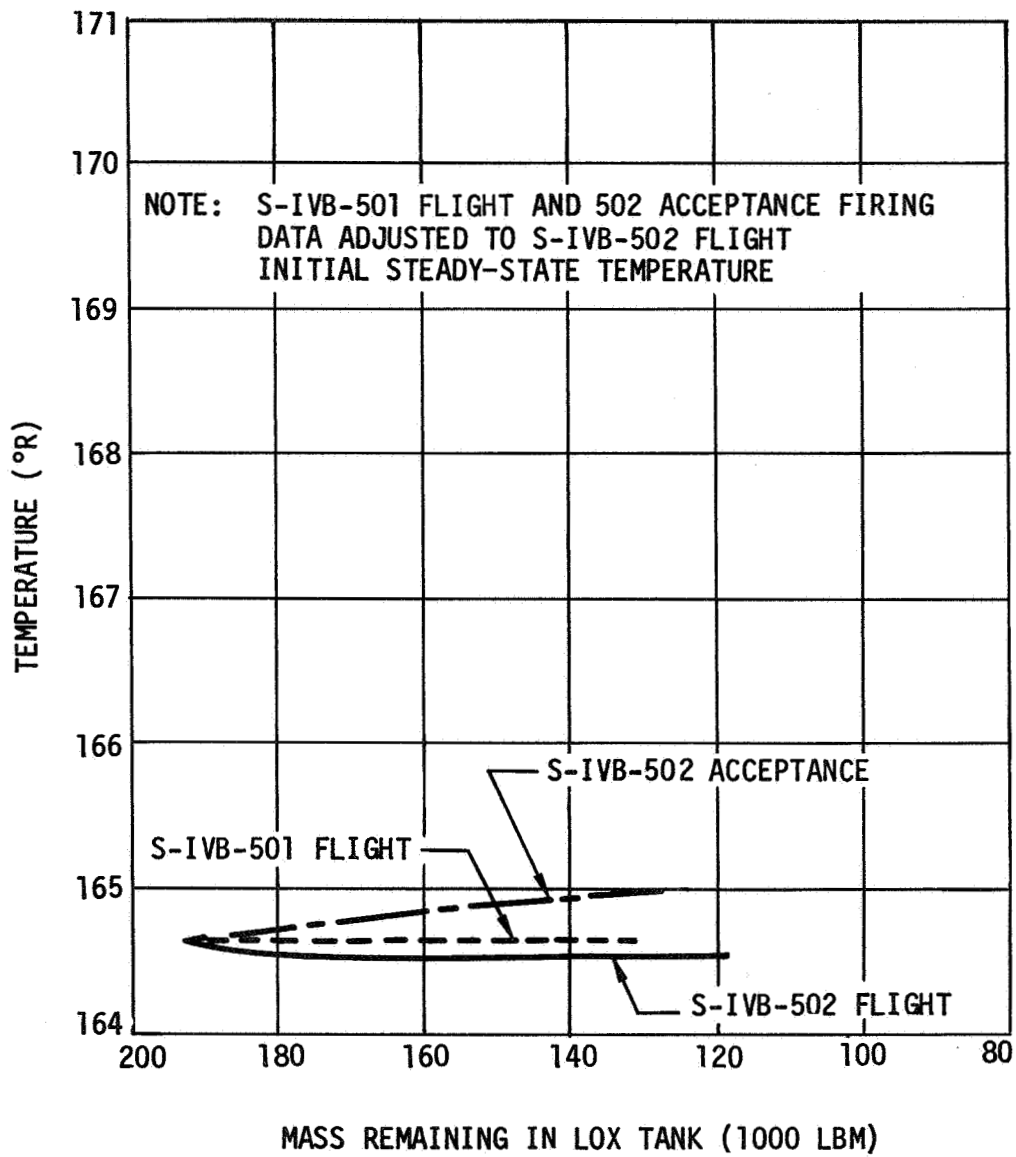


Figure 12-19. Effect of LOX Mass Level on LOX Pump Interface Temperature - First Burn

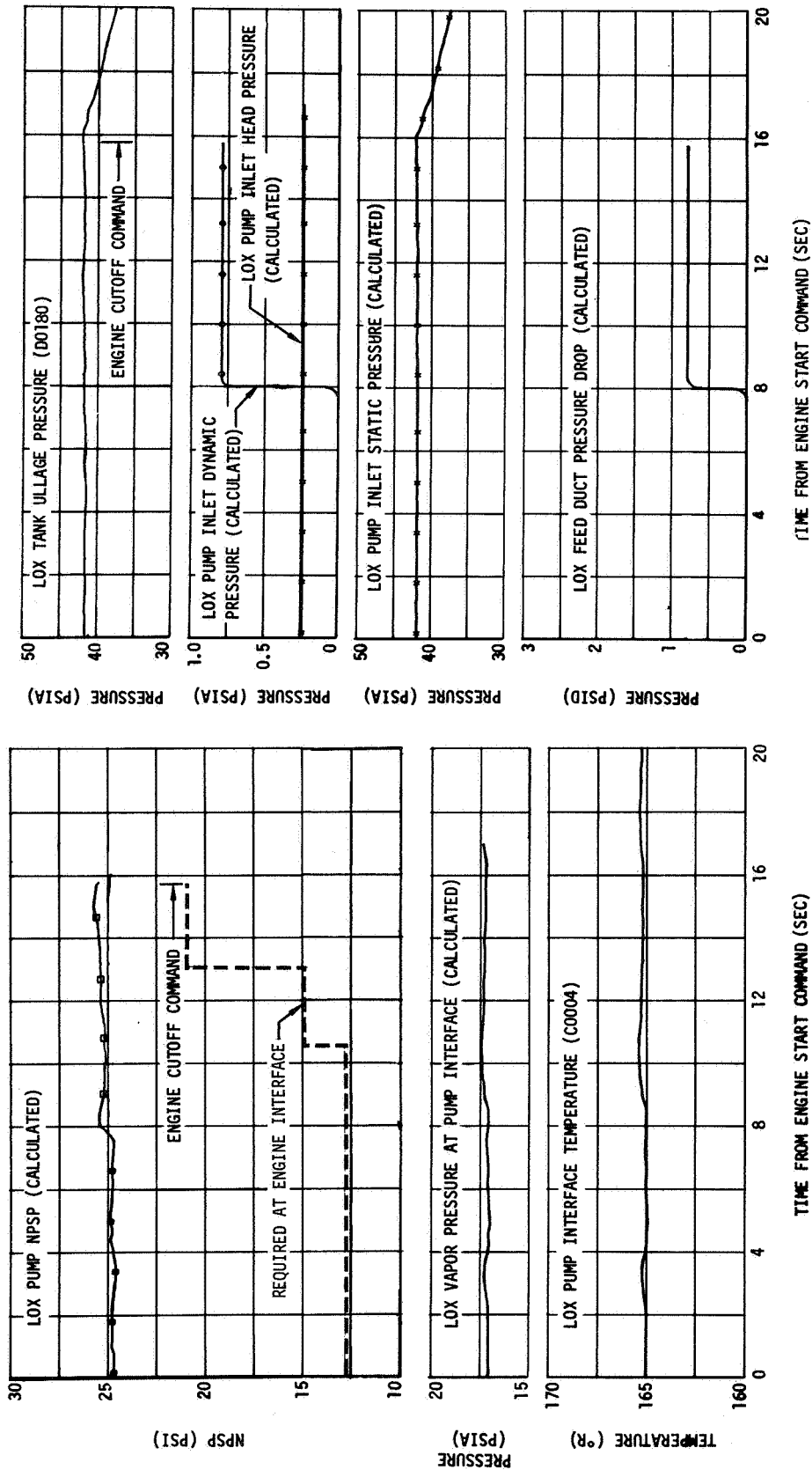


Figure 12-20. LOX Pump Inlet Conditions - Second Burn

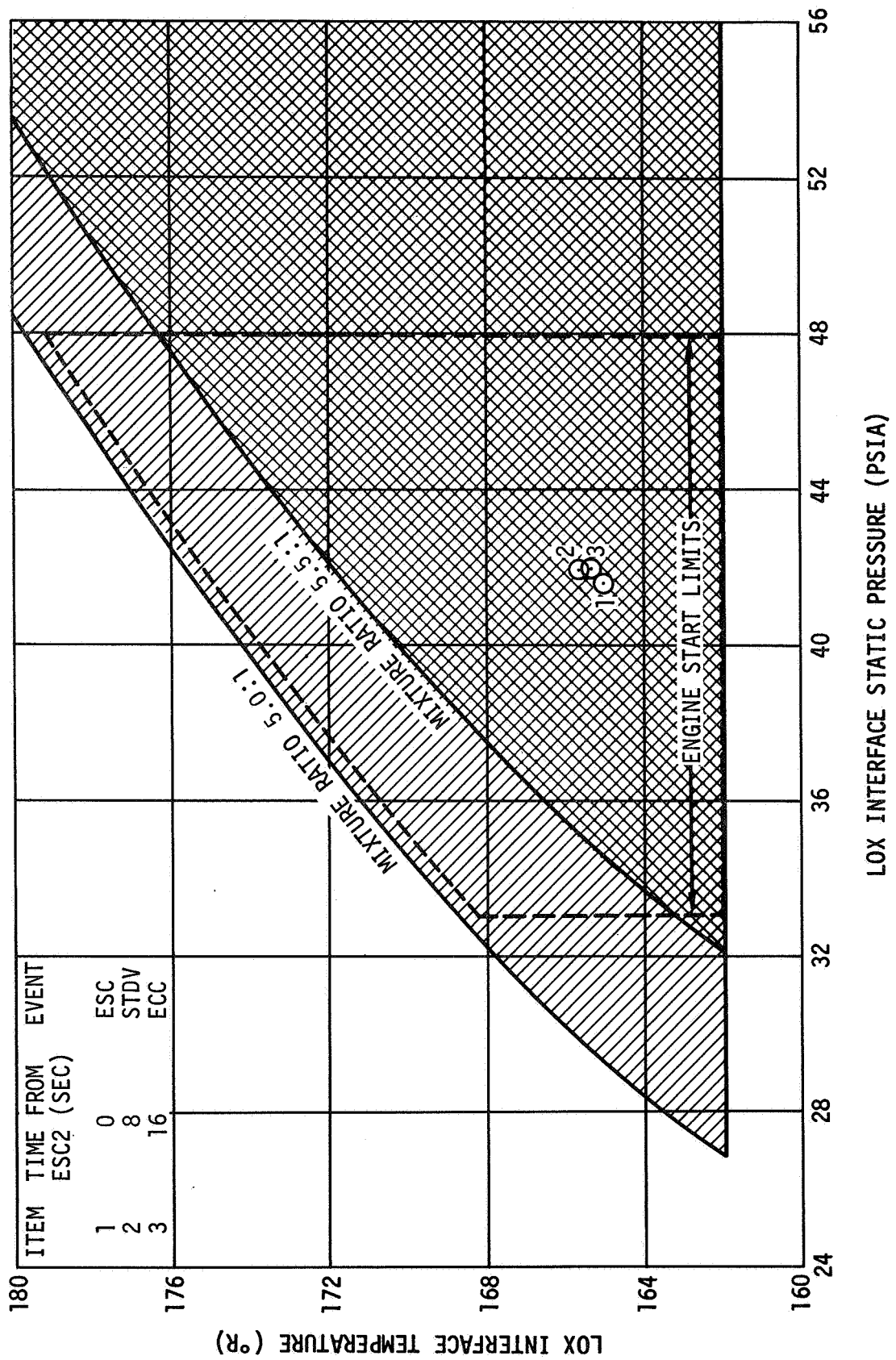


Figure 12-21. LOX Pump Interface Conditions - Second Burn

SECTION 13

FUEL SYSTEM

13. FUEL SYSTEM

The fuel system supplied LH2 to the engine as designed, and the NPSP exceeded minimum requirements at all times.

13.1 Pressurization Control

The LH2 tank pressurization system (figure 13-1) satisfactorily accomplished prepressurization, first burn GH2 pressurization, and second burn ambient helium repressurization. The system did not indicate any GH2 pressurization malfunction during the second burn restart attempt.

13.1.1 First Burn

13.1.1.1 Prepressurization

The LH2 tank conditions prior to prepressurization were 37 deg R and 16 psia. The LH2 prepressurization command was received at R0 -96.3 sec, and the LH2 tank pressurized signal was received 21.3 sec later when the LH2 tank ullage pressure reached 33.8 psia. The ullage pressure continued to increase as the ullage warmed, reaching the relief setting of 36.2 psia by liftoff.

Approximately 7.1 lbm of helium were added during prepressurization. Considering the relative ullage volumes, this agrees well with the 8.8 lbm of helium required during the AS-501 flight prepressurization. Conditions from prepressurization to first burn Engine Start Command are summarized in figure 13-2 and compared with S-IVB-501 flight and S-IVB-502 acceptance firing data in table 13-1.

A minor decay and subsequent recovery in LH2 tank ullage pressure occurred immediately following liftoff. This decay, which may have been the result of ullage gas cooling due to sloshing, was probably aggravated by the small initial LH2 ullage volume (719 ft³). A similar decay followed AS-203 flight liftoff (with an initial ullage volume of 750 ft³). There was no discernible decay following AS-501 flight liftoff (with an initial ullage volume of 1,019 ft³). A second ullage pressure decay resulted from a 10-sec LH2 relief vent period beginning at R0 +120 sec which was followed by recovery. A short vent occurred at R0 +180 sec, when the ullage pressure exceeded the vent relief setting. The relief vent then appears to have feathered with the LH2 ullage pressure at 36.2 psia until first burn Engine Start Command. Approximately 7 lbm of mixed GH2 and helium were vented from the LH2 ullage during the boost period.

13.1.1.2 Pressurization

At first burn Engine Start Command (ESC1) the LH2 tank ullage pressure was 36.2 psia. Between first engine start (which occurred at R0 +577.3 sec) and approximately ESC +4.8 sec, the primary, control, and step pressurization orifices were open to provide a high GH2 pressurant flowrate to the LH2 tank during engine start. From ESC1 +4.8 sec until first burn Engine Cutoff Command (ECC1) at ESC1 +169.8 sec, the control and step pressurization orifices were closed, thus limiting the pressurization flow to the primary orifice. The

ullage pressure decreased normally and reached 32.6 psia at engine cutoff command. The ullage pressure profile was somewhat lower than expected, but was higher than the S-IVB-501 flight first burn pressure profile. The higher pressure was the result of the use of a larger undercontrol orifice (effective area of 0.0726 in.² on S-IVB-502 flight compared to 0.0606 in.² on S-IVB-501 flight). Minor ullage energy collapse may have occurred during first burn; however, the magnitude of the calculated collapse is of the same order as the error in the method of calculation. If energy collapse actually occurred, it was probably the result of heat loss from the warm ullage gases to the cold tank walls and/or liquid bulk/ullage gas interaction produced by the significant pitch maneuvers occurring throughout first burn. The actual pressure profile, although slightly lower than expected, was satisfactory.

The engine performance shift occurring at approximately ESC1 +120 sec resulted in an increase in LH2 tank inlet and LH2 tank pressurization module temperatures, and in a decrease in LH2 tank pressurization module pressure. These changes reflected similar changes (or shifts) in the LH2 injector temperature and pressure. The changes in pressurization module conditions resulted in a downward shift in LH2 pressurization flowrate. The timing and magnitude of the shift were such that there was no significant effect on the LH2 tank ullage pressure profile.

An LH2 tank vent occurred at ESC1 +7 sec, resulting in the loss of approximately 0.8 lbm of ullage gas. The GH2 pressurization flowrate was approximately 0.62 lbm/sec, providing a first burn total flow of 102 lbm. Conditions during first burn LH2 tank pressurization are summarized in figure 13-3 and compared with S-IVB-501 flight and S-IVB-502 acceptance firing data in table 13-2.

13.1.2 Second Burn

13.1.2.1 Repressurization

The LH2 tank was repressurized with ambient helium from seven repressurization spheres (4.5 ft³ each). A 199 sec period of self-pressurization due to continuous vent system (CVS) closure preceded repressurization. Repressurization was initiated 127 sec before second burn Engine Start Command (ESC2), with the LH2 tank ullage pressure at 20.8 psia. The first repressurization cycle was terminated at ESC2 -90 sec when the ullage pressure upper switch setting of 33.8 psia was reached. By ESC2 -16 sec the ullage pressure had collapsed to the lower switch setting of 31.4 psia. At this time a makeup cycle was initiated, increasing the LH2 ullage pressure to 32.8 by ESC2 -1 sec when repressurization was automatically terminated. The ambient helium usage was 35.8 lbm during the first repressurization cycle and 8.1 lbm during the makeup cycle.

Reconstruction of the repressurization performance indicates that the initial repressurization cycle was nearly adiabatic and that most of the energy loss during repressurization (approximately 4,500 Btu) occurred during the subsequent pressure decay and makeup cycle. Liquid level measurements indicate that the 200 sec of ullaging prior to LH2 repressurization was successful in removing most of the subsurface GH2 bubbles. This is further substantiated by the lack of significant energy loss during the initial repressurization cycle

(the period during which the greatest loss due to bubble collapse would occur). Therefore the probable cause of the energy loss during the repressurization period was liquid bulk/ ullage gas interaction resulting from the stage maneuver which began at the initiation of LH2 repressurization. This conclusion is supported by the temperature sensors which indicated some liquid disturbances prior to Engine Start Command.

Significant pressurization data are presented in figure 13-4 and compared to S-IVB-501 flight and S-IVB-502 acceptance firing data in table 13-3.

13.1.2.2 Pressurization

The LH2 tank ullage pressure at second burn Engine Start Command (RO +11,614.7 sec) was 32.8 psia. As a result of the failure of the engine to ignite, the LH2 tank pressurization GH2 flowrate (which is tapped off of the engine GH2 injector manifold) was negligible, and the LH2 ullage pressure consequently decayed rapidly as LH2 was drained from the tank, dropping to 30 psia by second burn Engine Cutoff Command (ESC2 +15.7 sec). There was no indication of any malfunction by the LH2 pressurization system during the restart attempt.

Second burn cutoff was immediately followed by a 2-min LH2 tank vent which brought the ullage pressure back down to the CVS operational pressure (approximately 20 psia). Significant pressurization data are presented in figure 13-5 and compared to S-IVB-501 flight and S-IVB-502 acceptance firing data in table 13-2.

13.2 Pressurization System Conditions During Orbit

13.2.1 LH2 Tank Nonpropulsive Vent and Relief Valve Operation

The nonpropulsive vent (NPV) and relief valve operated satisfactorily. During boost, the relief valve opened twice (paragraph 13.1.1) and apparently feathered to maintain the ullage pressure at 36.2 psia between the second vent and first burn Engine Start Command. The valve opened again at 36.2 psia at ESC1 +7 sec.

After second burn cutoff, the NPV valve was opened for 120 sec, dropping the ullage pressure from 30.0 to 20.4 psia (figure 13-6). The LH2 tank then self-pressurized to 22.7 psia by RO +12,830 sec, when the continuous vent valve was opened. The ullage pressure remained below the relief setting throughout the orbital portions of the mission.

At RO +22,024 sec, the valve was opened again, dropping the ullage pressure to approximately 0 psia by RO +27,600 sec.

13.2.2 LH2 Tank Continuous Vent System Performance

The CVS performed satisfactorily, maintaining the LH2 tank ullage pressure at an average level of 19.7 psia and providing an average acceleration of 5×10^{-5} g for propellant settling during coast. The LH2 disturbances caused by the 20-deg pitch maneuvers at RO +3,213 and RO +5,428 sec were settled by the CVS acceleration before fuel tank repressurization.

Continuous venting was initiated at RO +806 sec as evidenced by the almost instantaneous increase in nozzle pressures, the decrease in nozzle temperatures, and the rapid decay of ullage pressure (figure 13-7). Two data problems encountered on the AS-501 flight were resolved by the relocation of the nozzle pressure transducers. After continuous venting was terminated, both nozzle pressures, unlike the S-IVB-501 nozzle pressures, dropped to and remained at approximately 0 psia (figure 13-8). Also unlike the S-IVB-501 nozzle pressures, the S-IVB-502 nozzle pressures were generally in good agreement (within 1 psi) during periods of good data.

The nozzle temperatures were lower on S-IVB-502 than on S-IVB-501. This resulted from the lower ullage temperatures, which were caused by the attitude maneuvers. The nozzle temperatures were cycling about a level which caused the tape recorder to alternately pick up and drop a data bit. The nozzle temperature transducer calibration curve was such that the alternate gain and loss of the data bit resulted in an erroneous indicated temperature cycling between approximately 7 and 48 deg R. Since the tape recorded data comprised a significant portion of the data for the first two orbits, only an approximate calculation of 2,870 lbm for the total vented mass was possible. CVS operation and performance are shown in figures 13-7 and 13-9, respectively, for the first and second orbits.

At RO +12,830 sec, following the nonpropulsive venting, continuous venting was initiated again and continued until RO +21,830 sec. During this time, the ullage pressure was maintained at an average pressure of 19.7 psia (figure 13-10).

During the third and fourth orbits, data were available only over ground stations. System operation parameters and system performance calculations are shown for the available third and fourth orbit data in figures 13-10 and 13-11, respectively. Extrapolating between station data yielded a total vented mass of 1,993 lbm during the third and fourth orbits.

13.2.3 LH2 Tank Conditions During Orbit

13.2.3.1 LH2 Tank Conditions During First and Second Orbits

LH2 tank conditions during the first and second orbits are shown in figures 13-7 and 13-8. The ullage temperatures were similar to those observed on S-IVB-501. Except for the 101 percent probe (C0039), the temperature probes indicated an environment which could have been either gaseous or liquid during most of the first two orbits. Prior to the start of ullaging, the forward dome liquid-vapor sensors indicated mainly dry, with erratic wetting, down to S-IVB sta 548. The erratic wetting indicates possible LH2 entrapment under the deflector.

Rapid drying of the S-IVB sta 528 level sensors (C2028 and C2026) occurred during ullaging. A comparison of these levels with those expected from the LH2 mass at first burn cutoff minus the calculated boiloff indicates as much as 1,300 ft³ of gas were entrapped in the liquid prior to the start of ullaging. Considering meniscus and liquid disturbance effects, an entrapped gas volume of approximately 1,000 ft³ may be more realistic. Using the first burn cutoff LH2 mass and the CVS vented mass, an approximate boiloff of 3,024 lbm was calculated.

13.2.3.2 LH2 Tank Conditions During Third and Fourth Orbits

Within 50 sec after second burn Engine Start Command, most liquid sensors were wet. This indicates that large liquid disturbances were caused by the restart attempt, venting, and launch vehicle/spacecraft separation. The NPV was opened for 120 sec immediately after the restart attempt and vented a calculated 299 lbm. The nozzle temperatures decreased rapidly, then leveled out at an indicated 39 deg R. Although this is above the saturation temperature, the temperature profile (figure 13-10) indicates that saturated gas was flowing through the vent. The difference between the indicated temperature and saturation temperature is well within transducer accuracy. During the third and fourth orbits only the 101 percent temperature probe occasionally indicated above 60 deg R (figure 13-10). This indicates that conditions in the tank during the third and fourth orbits were similar to the tank conditions during the first and second orbits.

13.2.3.3 LH2 Tank Passivation

LH2 tank passivation was initiated at RO +22,024 sec by opening the nonpropulsive vent. The LH2 tank ullage pressure decayed rapidly until saturated conditions were attained approximately 14 sec later (figure 13-12). Subsequent to this time, the pressure decay rate decreased because of LH2 flashoff. At RO +22,205 sec, the ullage pressure decay rate decreased again while the NPV nozzle pressure decay rate increased sharply. This phenomenon may be explained by a decrease in the quality of the fluid flowing through the NPV lines. Subsequent data indicate that the flow out of the tank was only slightly more than enough to overcome self-pressurization by LH2 boiloff.

Based on nozzle conditions and the assumption of gas flow only, the flowrate through the NPV system would have been 1.9 lbm/sec. Heat input to the tank and the heat available from the liquid bulk as the pressure decreased were sufficient to boil off only 0.35 lbm/sec. These conflicting calculations indicate either that the flow area in the NPV system was restricted or that the fluid flowing through the system was two-phase or liquid. Since the nozzle pressure data do not indicate a restriction in flow area, the two-phase or liquid flow is more probable. This theory is consistent with the indications discussed in the preceding paragraph.

Effective stage attitude control was lost at RO +22,030 sec, and the thrust from the LOX vent caused the stage to tumble. The internal tank temperatures indicated that the centrifugal force developed from this motion could have forced the LH2 to the top of the tank and, thus, over the LH2 vent inlet. This condition would allow only two-phase or liquid flow through the NPV and could provide an explanation for the observed phenomenon. With a flow coefficient calculated for the post restart attempt all-gas blowdown, a liquid flowrate was calculated to be 14.8 lbm/sec. This flowrate would remove most of the liquid from the tank in 1,500 sec; a flow with the quality of 0.01 would deplete the tank sufficiently to uncover the vent in approximately 1,800 sec, and a blowdown of the tank ullage would then be expected. At RO +24,170 sec, when data were recovered after a dropout, a blowdown was occurring. Extrapolating the pressure profile back, the blowdown would have started at approximately RO +23,950 sec, thus indicating approximately 1,700 sec of liquid and/or two-phase flow.

Some liquid would be expected to remain in the tank after the blowdown began. As the tank pressure dropped below the triple point (1.02 psia), solidification and then sublimation would occur. At RO +27,600 sec, after a data dropout, two low-range temperature transducers (C0052 and C0053) were off-scale-low (below 35 deg R), while all other transducers were off-scale-high. The high range transducers indicated from 80 to 115 deg R and were increasing. By RO +33,300 sec, after another data dropout, C0053 was also off-scale-high (about 47 deg R); and C0052 was the only transducer in the LH2 tank indicating cold temperatures. These data suggest that solid hydrogen had formed at the lower end of the instrumentation probe and was slowly sublimating.

13.3 LH2 Pump Chilldown

13.3.1 First Burn

The LH2 pump chilldown system performed adequately. The LH2 chilldown was initiated at RO -299 sec and was continuous until RO +577.4 sec when the LH2 prevalve was opened. The chilldown pump was turned off at RO +578.5 sec. The engine pump inlet pressure and temperature were 42.5 psia and 38.3 deg R at first burn Engine Start Command. Table 13-4 compares significant LH2 chilldown system performance data with S-IVB-501 flight data and S-IVB-502 acceptance firing data. The chilldown system temperatures, pressures, and calculated performance are presented in figures 13-13 and 13-14.

The unpressurized chilldown flowrate stabilized at 92 gpm after the start transients subsided and the prevalve closed. After prepressurization the flowrate was 133 gpm until first engine start. All heat inputs during pressurized chilldown were lower in flight than during acceptance testing. The total rate was constant at 17,000 Btu/hr for 30.0 sec before first engine start as compared to 56,000 Btu/hr during acceptance testing.

During unpressurized chilldown, the LH2 pump inlet was slightly subcooled; immediately following pressurization, the temperature decreased to a minimum of 38 deg R as the flowrate increased. By Engine Start Command, the LH2 pump inlet temperature had increased to 38.3 deg R reflecting the LH2 bulk warming. All chilldown system temperatures reflected this warming.

The bleed valve and return line temperature increased sharply at the initiation of prepressurization because all of the heat input went into heating the pressurized fluid and no vaporization occurred. The LH2 entered the system sufficiently subcooled to absorb all the heat input to the system without reaching saturation temperature. After pressurization the ullage pressure was constant but the pump inlet pressure increased and decreased with acceleration until the prevalve was opened and allowed essentially all flow to return to the LH2 tank through the prevalve with no flow through the chilldown system. The pump inlet pressure then decreased (because of loss of pump head) to 35.9 psia.

The NPSP at the pump inlet followed the ullage pressure during pressurization and reached a maximum of 29 psi when maximum acceleration was reached at S-IC cutoff. The NPSP dropped at S-IC cutoff and increased with S-II acceleration. With the loss of two S-II engines the

NPSP dropped from 25.8 psi to 24.8 psi and maintained that level until S-II cutoff. When the S-IVB LH2 prevalve was opened, the NPSP dropped to 15.9 psi because of the loss of pump head.

The LH2 prevalve was somewhat slow in opening during S-IVB first burn. No opening requirement exists for the prevalve per se, but the prevalve is required to be open to allow a 3-sec fuel lead prior to the start tank discharge valve (STDV) opening. Under the current sequence, the prevalve open command was given 0.672 sec prior to first burn Engine Start Command. The valve started to move 0.187 sec after engine start, as indicated by the drop-out of the closed position microswitch. The full open prevalve position was received 2.418 sec after engine start, and STDV command occurred 0.616 sec later. Investigation is continuing to determine the cause of the valve opening slowly and its effects on the fuel lead.

The flow coefficient was calculated from flowrate and chilldown system pressure drop data to be $19.0 \text{ sec}^2/\text{in.}^2\text{-ft}^3$, which was within the range calculated for previous S-IVB stages. The coefficient was used to compute the average fluid quality during the unpressurized phase of the chilldown.

Prior to prepressurization, two-phase flow existed in section 2 (engine pump inlet to the bleed valve) and in section 3 (engine bleed valve to tank inlet); the average fuel quality was 0.046 lbm gas/lbm mixture. The quality decreased to zero during prepressurization when the fluid in the system became subcooled. The LH2 chilldown system pressure drop was relatively steady during the unpressurized and pressurized operations at 9.0 psi and 6.4 psi, respectively.

13.3.2 Second Burn

The LH2 pump chilldown for second burn differed from that for first burn in that it started with no indication of liquid at the engine inlet. The chilldown was initiated at RO +10,877.2 sec, the predicted time. The total chilldown period was approximately 180 sec longer than predicted due to a launch vehicle digital computer time update resulting in a later than expected second burn Engine Start Command.

The recirculation chilldown system performed satisfactorily. At second engine start, the pump inlet pressure and temperature of 32.6 psia and 39.4 deg R were within the engine start requirements. The pump inlet NPSP at Engine Start Command was 9.5 psi, which was 3.2 psi above the required minimum limit of 6.3 psi (figure 13-15 and 13-16).

The LH2 chilldown pump was started at ESC2 -737.4 sec with the LH2 tank pressure being maintained by the continuous vent regulator. At ESC2 -325.8 sec the CVS was terminated allowing the tank to self pressurize until ESC2 -127 sec when the LH2 tank was pressurized. The Prevalve OPEN Command was issued at ESC2 -10.79 sec with the valve starting to open at ESC2 -9.824 sec. The full open position was attained at ESC2 -5.909 sec.

Before termination of the CVS, chilldown was marked by small pressure and flow fluctuations caused by the rapid vaporization of LH2 as it entered the system and came in contact with the warm hardware. This cycling is reflected throughout the system in the pressure and temperature data. The magnitude of the cycling decreased with time during the unpressurized chilldown period as the system hardware was cooled.

After the termination of the CVS, the cyclic action of the system flowrate, pressures, and temperatures stopped due to subcooled liquid caused by the slight self pressurization of the tank. During the tank self pressurization period, the chilldown flowrate increased from 100 to 128 gpm, and the pump inlet temperature and pressure decreased from 39.02 deg R and 27.5 psia to 38.8 deg R and 27.3 psia, respectively. A comparison of the mass of LH2 entering the chilldown system is presented in figure 13-17.

When the LH2 tank was pressurized for second burn at ESC2 -127 sec the chilldown flowrate increased from 128 gpm to 133 gpm. The NPSP dropped from 16.94 psi when the prevalve was commanded open at ESC2 -10.79 sec to 11.24 psi when the prevalve reached the full open position. At second burn Engine Start Command the pump inlet temperature and pressure were 39.4 deg R and 32.6 psia yielding an NPSP of 9.5 psi which is 3.2 psi above the required minimum of 6.3 psi. Figure 13-18 compares the total heat input rate to those obtained from S-IVB-501 and S-IVB-203 flights.

13.4 Engine LH2 Supply

13.4.1 First Burn

The LH2 supply system (figure 13-19) delivered the necessary quantity of LH2 to the engine pump inlet throughout first burn and maintained the pressure and temperature within a range that provided an LH2 pump NPSP that was at least 5.4 psi above the minimum requirement. The data and calculated performance are presented in figure 13-20. Table 13-5 compares the S-IVB-502 flight data with that from previous stages.

The LH2 pump inlet temperature and pressure during engine operation were plotted in the engine operating region in figure 13-21 which shows that conditions were met satisfactorily throughout first burn.

Figure 13-22 is a plot of the pump inlet temperature as a function of the propellant mass remaining within the LH2 tank and includes previous stage data for comparison. As the figure shows, the data from the three tests agree closely.

13.4.2 Second Burn

The NPSP, LH2 pump interface static pressure, and LH2 pump interface temperature during second burn attempt are shown in figure 13-23. The NPSP at second burn Engine Start Command was 3.2 psi above the minimum required.

The fuel pump inlet pressure and temperature were plotted in the second start region (figure 13-24) and indicate that the engine fuel pump inlet conditions were satisfactorily met. Table 13-5 compares the LH2 supply data with that from S-IVB-501 flight and S-IVB-502 acceptance firing.

TABLE 13-1
LH2 TANK PREPRESSURIZATION DATA

| PARAMETER | UNIT | S-IVB-502 FLIGHT | S-IVB-501 FLIGHT | S-IVB-502 ACCEPT |
|--|-------------------|---------------------|---------------------|---------------------|
| Prepressurization duration | sec | 21.3 | 21.5 | 41.0 |
| Ullage volume | cu ft | 719.0 | 1,019.0 | 1,174.0 |
| Helium mass added | lbm | 7.1 | 8.8 | 17.4 |
| Ullage pressure | | | | |
| At prepressurization initiation | psia | 16.0 | 17.5 | 15.3 |
| At prepressurization termination | psia | 33.8 | 33.8 | 33.6 |
| At liftoff* | psia | 36.2 | 35.9 | 35.0 |
| At Engine Start Command | psia | 36.2 | 35.9 | 36.0 |
| Rate of increase after prepressurization | psi/min | 1.5 | 1.0 | 1.3 |
| Events | sec from liftoff* | | | |
| Prepressurization initiation | | -96.3 | -96.5 | -114.0 |
| Prepressurization termination | | -75.0 | -75.0 | -73.0 |
| Engine Start Command | | 577.3 | 520.7 | 511.0 |

*During acceptance testing, liftoff is simulated.

TABLE 13-2
LH2 TANK PRESSURIZATION DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|--------------------------|---------|---------------------|-----------------|---------------------|----------------|---------------------|----------------|
| | | FIRST BURN | SECOND* BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| Pressure switch setting | | | | | | | |
| Lower | psia | 28.7 | 32.2 | 28.0 | 31.6 | 29.2 | 30.1 |
| Upper | psia | 30.2 | 33.8 | 30.5 | 33.6 | 31.5 | 34.3 |
| Ullage pressure | | | | | | | |
| At Engine Start Command | psia | 36.2 | 32.8 | 35.9 | 27.8 | 36.2 | 33.5 |
| At Engine Cutoff Command | psia | 32.6 | 30.0 | 29.0 | 31.9 | 28.7 | 32.8 |
| GH2 pressurant flowrate | | | | | | | |
| Undercontrol--high EMR | lbm/sec | 0.62 | -- | 0.50 | -- | 0.50 | 0.50 |
| Undercontrol--low EMR | lbm/sec | -- | -- | -- | -- | -- | 0.47 |
| Overcontrol--high EMR | lbm/sec | -- | -- | -- | 0.75 | -- | -- |
| Overcontrol--low EMR | lbm/sec | -- | -- | -- | 0.70 | -- | 0.72 |
| Total GH2 added | lbm | 102 | -- | 70.1 | 206 | 76 | 161.8 |

*GH2 pressurant flowrate during S-IVB-502 restart attempt was negligible.

TABLE 13-3
LH2 TANK REPRESSURIZATION DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | S-IVB-501 FLIGHT | S-IVB-502* ACCEPT |
|---|---------------|---------------------|---------------------|----------------------|
| Repressurization duration | sec | 52** | 80 | 279 |
| Helium usage from repressurization spheres during repressurization | lbm | 43.9*** | 47 | 40.5 |
| Ullage | | | | |
| Volume | cu ft | 4,451 | 4,260 | 4,780 |
| Pressure at repressurization initiation | psia | 20.8 | 19.7 | 15.5 |
| Pressure at repressurization termination | psia | 32.8 | 32.0 | 32.9 |
| Events | sec from ESC2 | | | |
| Repressurization initiation | | -127 | -325 | -322 |
| Repressurization termination | | -1 | -245 | -43 |

*The repressurization system was supplemented by the auxiliary pressurization system.
This is not accounted for in mass calculations.

**This includes 37 sec during the first repressurization cycle and 15 sec during the
makeup cycle.

***This includes 35.8 lbm used during the first repressurization cycle and 8.1 lbm used
during the makeup cycle.

TABLE 13-4 (Sheet 1 of 2)
LH2 CHILLDOWN SYSTEM PERFORMANCE DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 ACCEPT | |
|---|--|------------------|-------------|------------------|-------------|------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| NPSP | | | | | | | |
| At Engine Start Command* | psi | | | | | | |
| With Chill Pump Head | | 22.8 | N/A | 21.5 | N/A | N/A | N/A |
| Without Chill Pump Head | | 15.9 | 9.5 | 13.41 | 0.17 | 14.3 | 10.5 |
| Minimum required at engine start | psi | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 |
| Maximum during chilldown | psi | 29.0 | 18.9 | 27.3 | 16.5 | 25.6 | 18.6 |
| Average flow coefficient | sec ² /in. ² ft ³ | 19.0 | 19.0 | 16.5 | 16.5 | 18.8 | 18.8 |
| Fuel quality in sections** 2 and 3 | | | | | | | |
| Maximum during unpressurized chilldown | lb gas/ lb mixture | 0.0495 | N/A | 0.023 | N/A | 0.049 | 0.29 |
| At prepressurization | | 0.045 | N/A | 0.020 | N/A | 0.042 | 0.065 |
| Fuel pump inlet conditions | | | | | | | |
| Static pressure at Engine Start command* | psi | | | | | | |
| With Chill Pump Head | | 42.5 | N/A | 43.9 | N/A | N/A | N/A |
| Without Chill Pump Head | | 35.6 | 32.6 | 35.8 | 28.0 | 38.2 | 35.1 |
| Temperature at Engine Start Command | deg R | 38.3 | 39.4 | 38.9 | 40.7 | 39.6 | 39.8 |
| Amount of subcooling at engine start (deg below saturation at pump inlet) | deg R | 5.7 | 2.5 | 3.6 | 0.08 | 3.7 | 2.7 |
| Heat absorption rate during unpressurized chilldown | | | | | | | |
| Section 1** | Btu/hr | 22,000 | 0.0† | 8,200 | N/A | 19,000 | 21,000 |
| Sections 2 and 3** | Btu/hr | 29,000 | 28,000† | 27,500 | N/A | 25,000 | 35,000 |
| Total | Btu/hr | 51,000 | 28,000† | 35,700 | N/A | 44,000 | 56,000 |

*The S-IVB-501 flight and S-IVB-502 flight first burn NPSP's and pump inlet pressure's are high at this time as the prevalves were slow in opening.

**Section 1 is tank to pump inlet; section 2 is pump inlet to bleed valve; section 3 is bleed valve to tank.

†Values at repressurization initiation.

N/A = Not Applicable

TABLE 13-4 (Sheet 2 of 2)
LH2 CHILLDOWN SYSTEM PERFORMANCE DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502* ACCEPT | |
|---|--------|------------------|-------------|------------------|-------------|-------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| Heat absorption rate during pressurized chilldown | | | | | | | |
| Section 1† | Btu/hr | 2,500 | 500 | 100 | 3,500 | 13,500 | 19,000 |
| Section 2† | Btu/hr | 7,000 | | 12,000 | | 18,000 | 21,000 |
| Section 3† | Btu/hr | 7,500 | 23,000 | 1,500 | 11,500 | 24,500 | 15,000 |
| Total | Btu/hr | 17,000 | 23,500 | 13,600 | 15,000 | 56,000 | 55,000 |
| Chilldown flowrate | | | | | | | |
| Unpressurized | gpm | 92 | 10 to 100 | 115 | 32 to 95 | 91 | 82 |
| Pressurized After CVS closure | | N/A | 125 | N/A | N/A | N/A | N/A |
| Pressurized After repressurization | gpm | 133 | 134 | 143 | 143 | 135 | 133 |
| Chilldown pump pressure differential | | | | | | | |
| Unpressurized | psi | 9.0 | 2 to 8.5 | 8.7 | 2 to 16.5 | 8.8 | 9.1 |
| Pressurized | psi | 6.4 | 7.4 | 7.4 | 7.8 | 7.5 | 7.3 |
| Events | | | | | | | |
| | sec†† | | | | | | |
| Chilldown initiation | | -299.008 | -737.446 | -302.8 | -567.7 | -200.7 | -716.9 |
| Prevalve closed | | -275.076 | -727.446 | -272.8 | -551.9 | -197.0 | -744.5 |
| CVS closed | | N/A | -325.696 | N/A | -325.8 | N/A | N/A |
| Prepressurization | | -96.506 | -126.993 | -96.5 | -326.2 | -111.5 | -323.3 |
| Prevalve OPEN Command | | 576.596 | -10.79 | 520.0 | -10.8 | N/A | N/A |
| Prevalve closed signal dropout | | 577.429 | -9.839 | 520.9 | -9.8 | N/A | N/A |
| Prevalve open signal pickup | | 579.671 | -5.909 | 522.8 | -7.2 | 511.3 | -0.8 |
| Chilldown pump off | | 578.470 | -0.791 | 521.9 | -0.8 | 510.9 | -0.9 |
| Chilldown pump off | | Not Sent | Not Sent | 625.5 | Not Sent | 511.5 | -0.5 |
| Engine Start Command | | 577.270 | 0 | 520.7 | 0 | 511.9 | 0 |

*During acceptance testing, liftoff is simulated.

†Section 1 is tank to pump inlet; section 2 is pump inlet to bleed valve; section 3 is bleed valve to tank.

††All first burn data are referenced to liftoff (or simulated liftoff); all second burn data are referenced to ESC2

N/A = Not Applicable

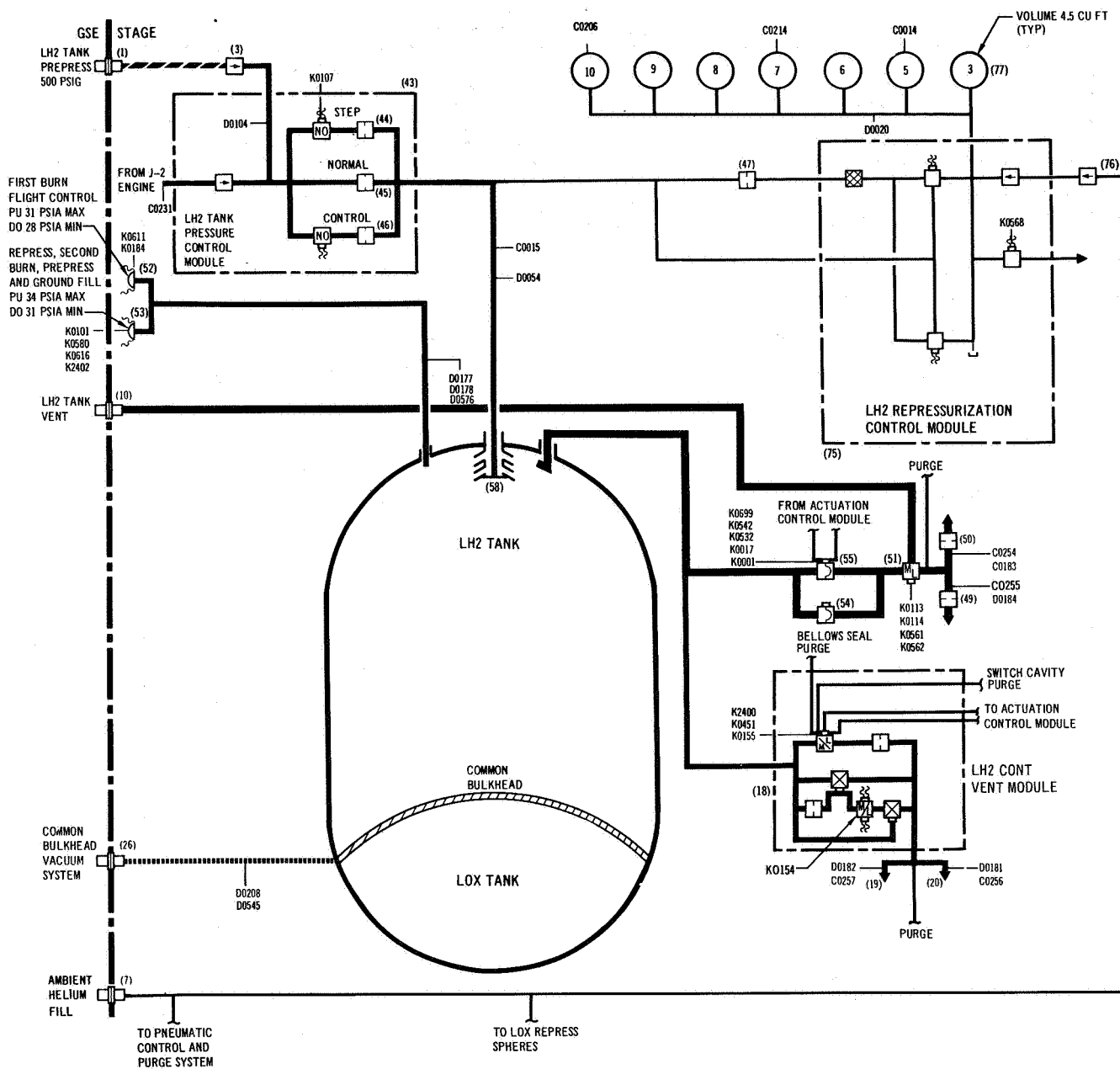
TABLE 13-5
LH2 PUMP INLET CONDITION DATA

| PARAMETER | UNITS | S-IVB-502 FLIGHT | | S-IVB-501 FLIGHT | | S-IVB-502 FLIGHT | |
|--|---------|------------------|-------------|------------------|-------------|------------------|-------------|
| | | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN | FIRST BURN | SECOND BURN |
| <u>Pump Inlet Conditions</u> | | | | | | | |
| Static pressure at Engine Start Command | psia | | | | | | |
| With chilldown head* | | 42.5 | N/A | 43.89 | N/A | N/A | N/A |
| Without chilldown head | | 35.6 | 32.6 | 35.8 | 28.0 | 38.2 | 35.1 |
| Static pressure at engine cutoff | psia | 30.5 | 28.2 | 27.5 | 31.0 | 27.0 | 30.8 |
| Temperature at engine start | deg R | 38.3 | 39.4 | 38.9 | 40.7 | 39.6 | 39.8 |
| Temperature at engine cutoff | deg R | 38.5 | 38.5 | 38.8 | 39.45 | 38.0 | 39.0 |
| <u>NPSP Requirements</u> | | | | | | | |
| Minimum at Engine Start Command | psi | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 |
| At high EMR | psi | 6.37 | 6.37 | 6.3 | 6.3 | 6.3 | -- |
| After EMR cutback | psi | N/A | 5.8 | N/A | 5.8 | 5.8 | 5.8 |
| <u>NPSP Available</u> | | | | | | | |
| At Engine Start Command | psi | | | | | | |
| With chilldown head* | | 22.8 | N/A | 21.5 | N/A | N/A | N/A |
| Without chilldown head | | 15.9 | 9.5 | 13.41 | 0.17 | 14.3 | 10.5 |
| At Start Tank Discharge Valve Open Command | psi | 16.5 | 11.2 | 15.1 | 5.8 | 17.2 | 16.0 |
| Maximum during engine burn | psi | 16.5 | 11.5 | 16.0 | 11.0 | 17.8 | 16.0 |
| Minimum during engine burn | psi | 11.8 | 7.7 | 7.5 | 0.17 | 9.5 | 10.0 |
| At Engine Cutoff Command | psi | 11.8 | 7.7 | 7.5 | 8.75 | 9.5 | 10.0 |
| <u>LH2 Feed Duct</u> | | | | | | | |
| At high EMR | | | | | | | |
| Pressure drop | psi | 1.0 | 1.25 | 1.0 | 0.5 | 1.0 | 1.8 |
| Flowrate | lbm/sec | 82.5 | 60 | 81 | 80 | 79.5 | 78.5 |
| After EMR cutback | | | | | | | |
| Pressure drop | psi | N/A | N/A | N/A | 0.5 | N/A | 1.7 |
| Flowrate | lbm/sec | N/A | N/A | N/A | 77 | N/A | 76.3 |

*The NPSP and pump inlet pressure are high at this time because the prevalves were slow in opening.

N/A = Not Applicable

Section 13
Fuel System



NOTE:
(X) ITEMS
PARTS LIST FIGURE 4-1
SEE FIGURE 4-1 FOR
LEGEND

Figure 13-1. LH2 Tank Pressurization System

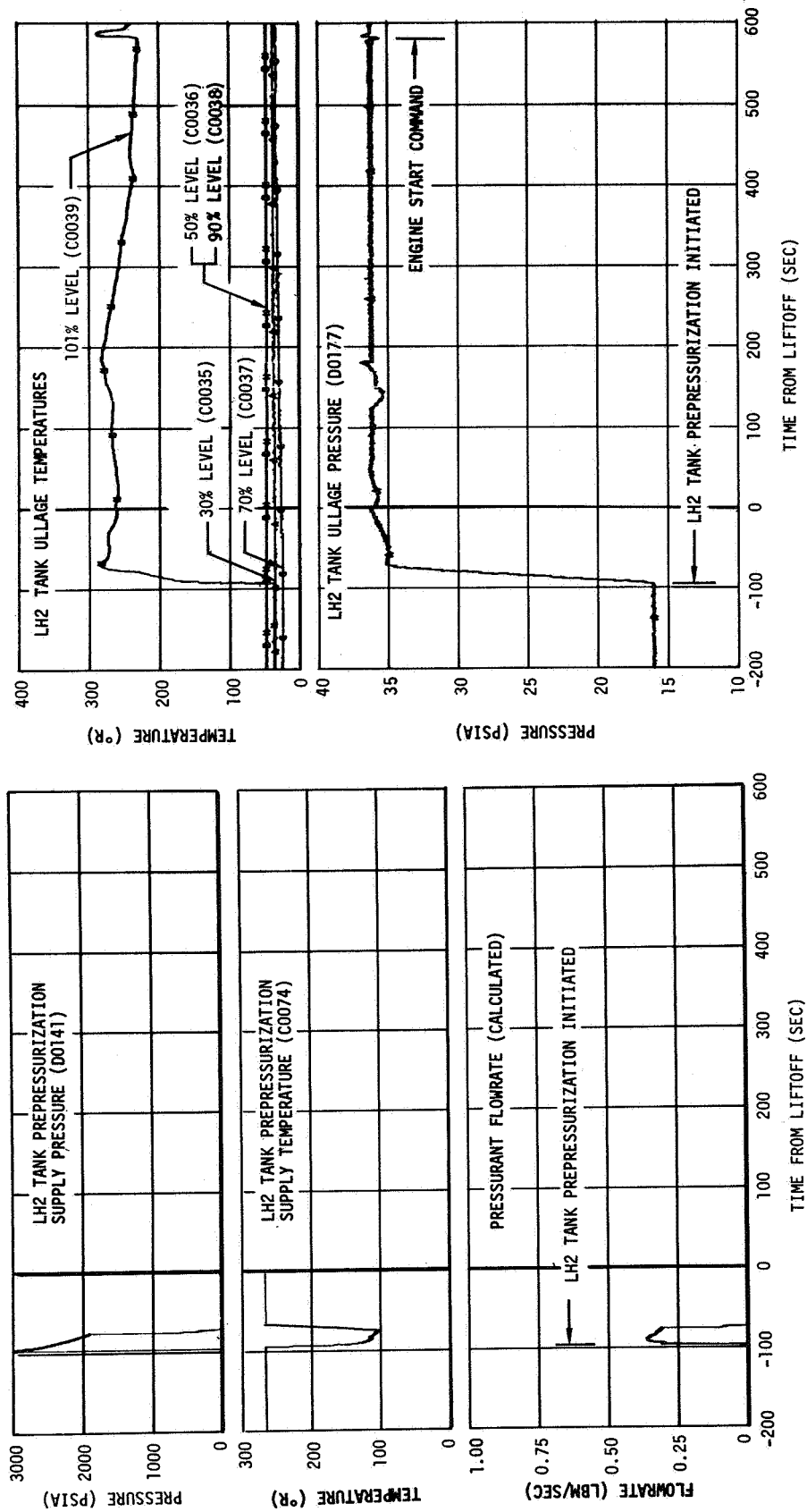


Figure 13-2. LH2 Tank Pressurization System Performance

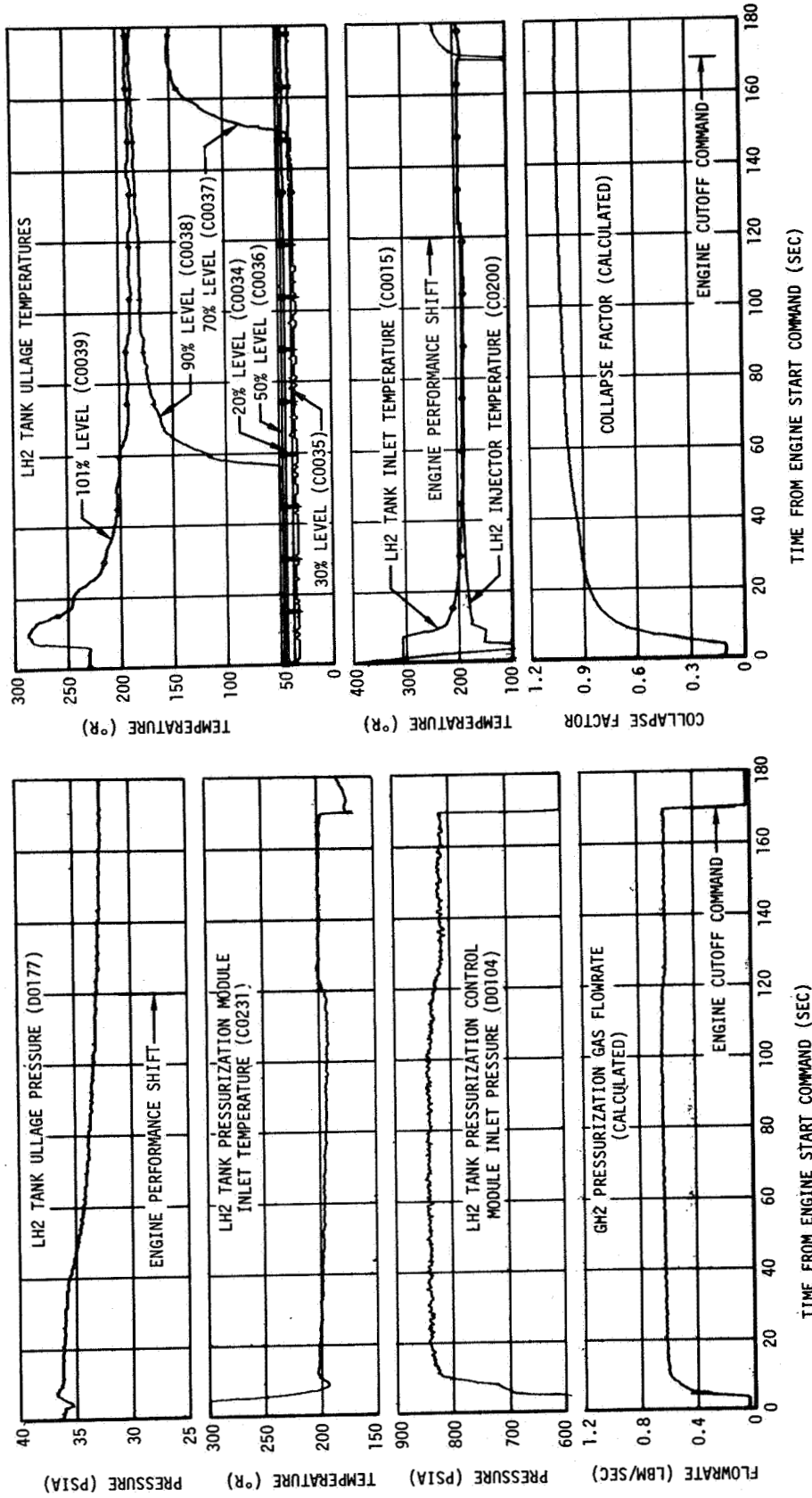


Figure 13-3. LH2 Tank Pressurization System Performance - First Burn

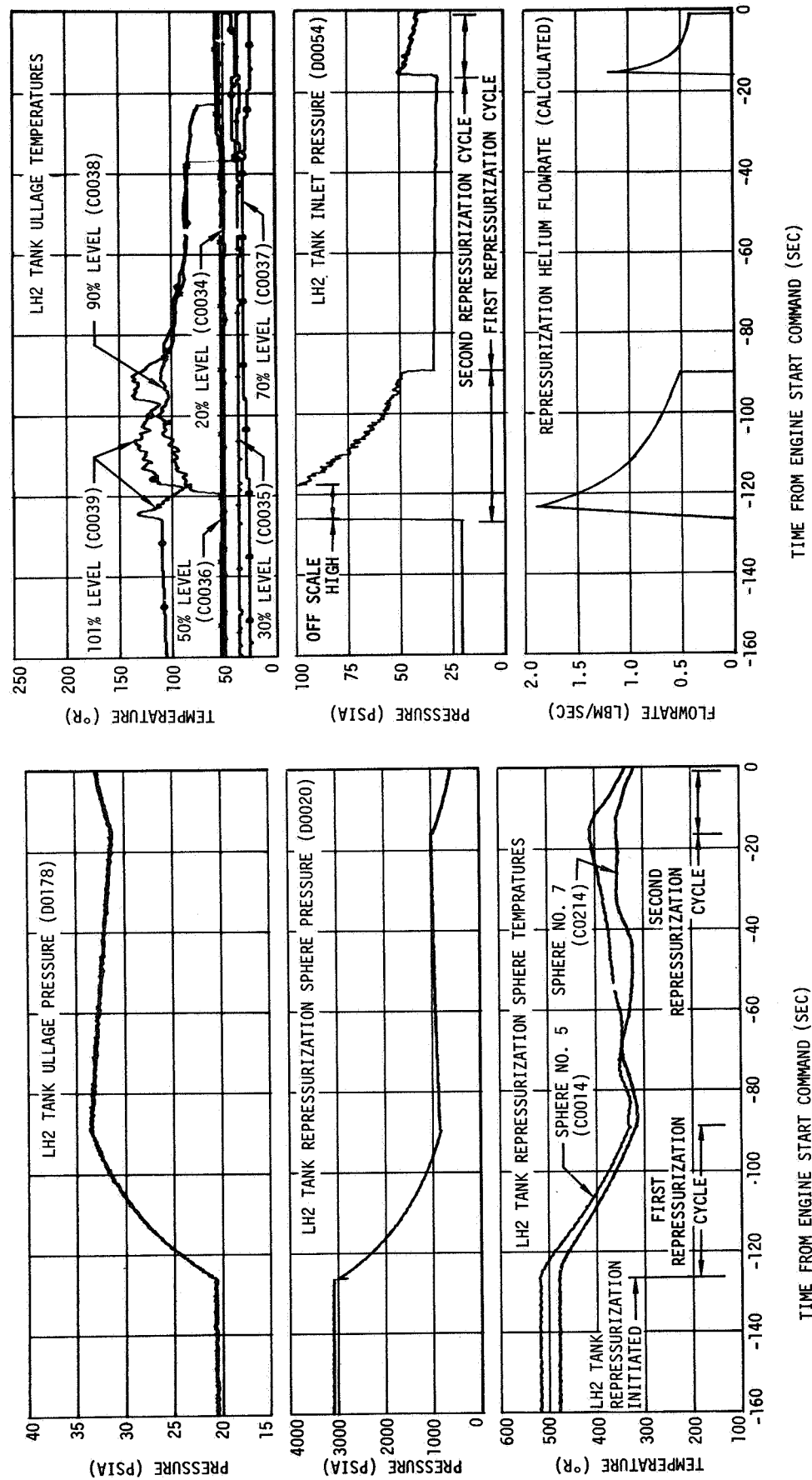


Figure 13-4. LH2 Tank Ambient Repressurization Performance - Second Burn

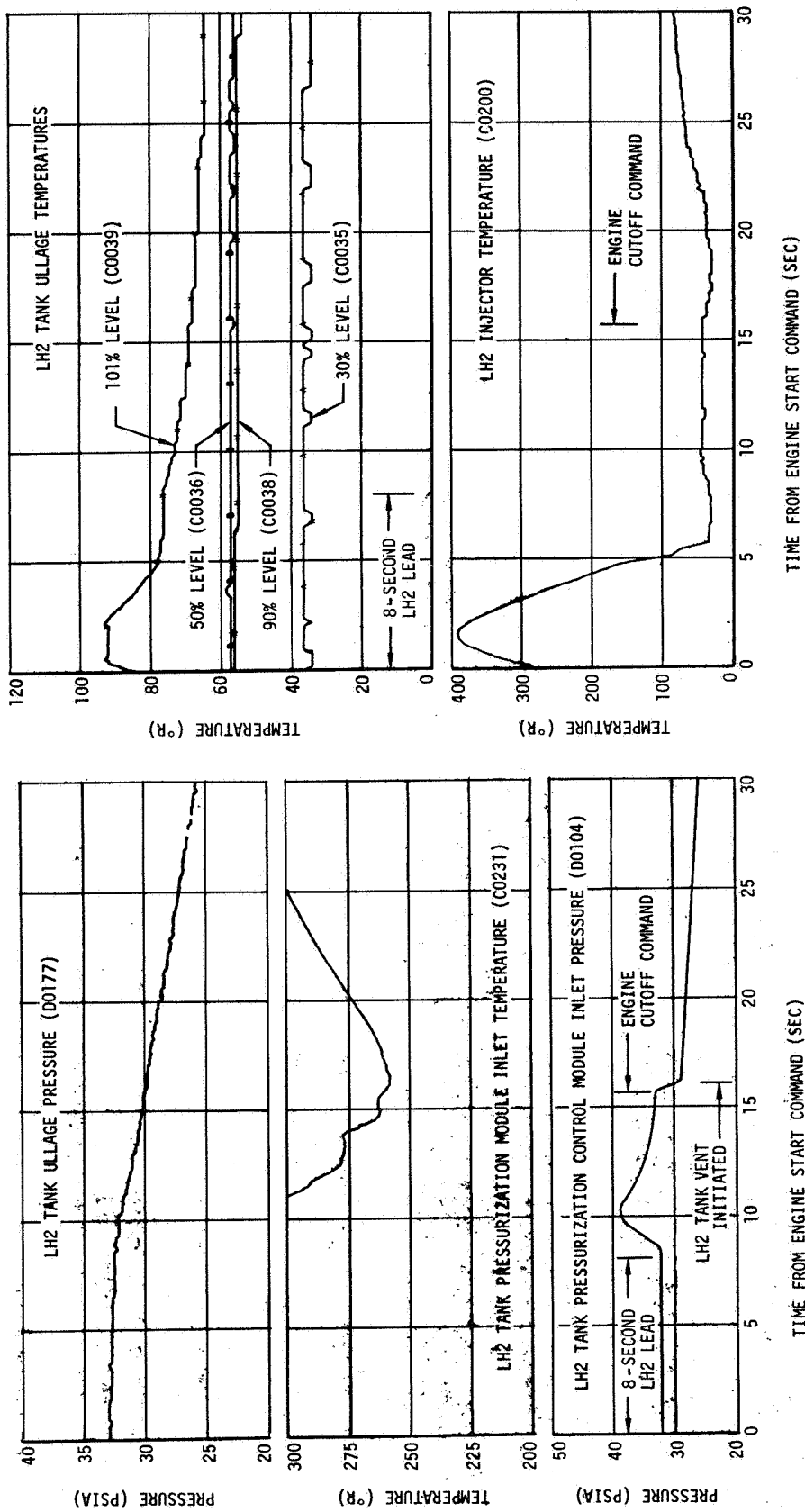


Figure 13-5. LH2 Tank Pressurization System Performance - Second Burn

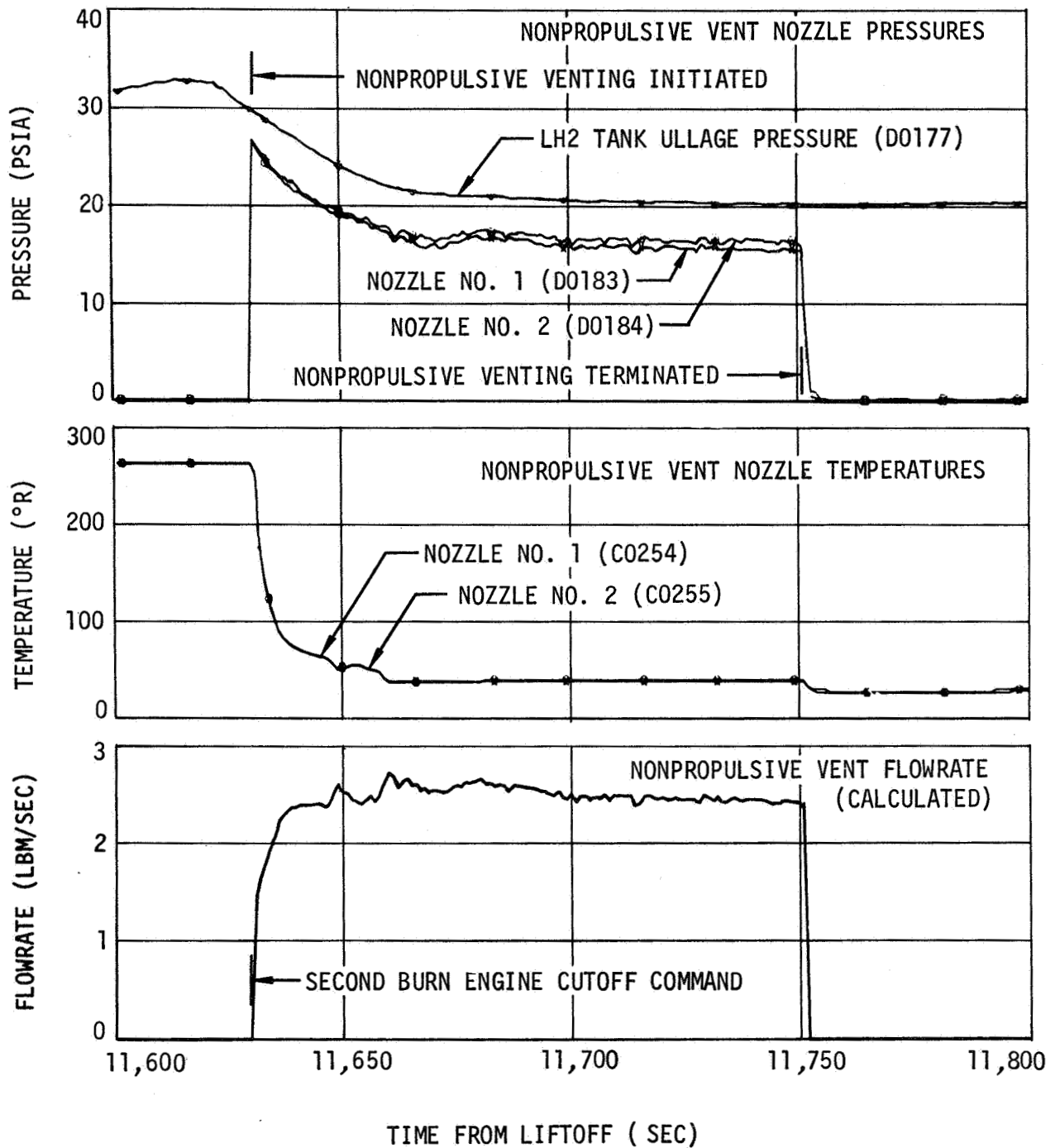


Figure 13-6. Nonpropulsive Vent System Performance

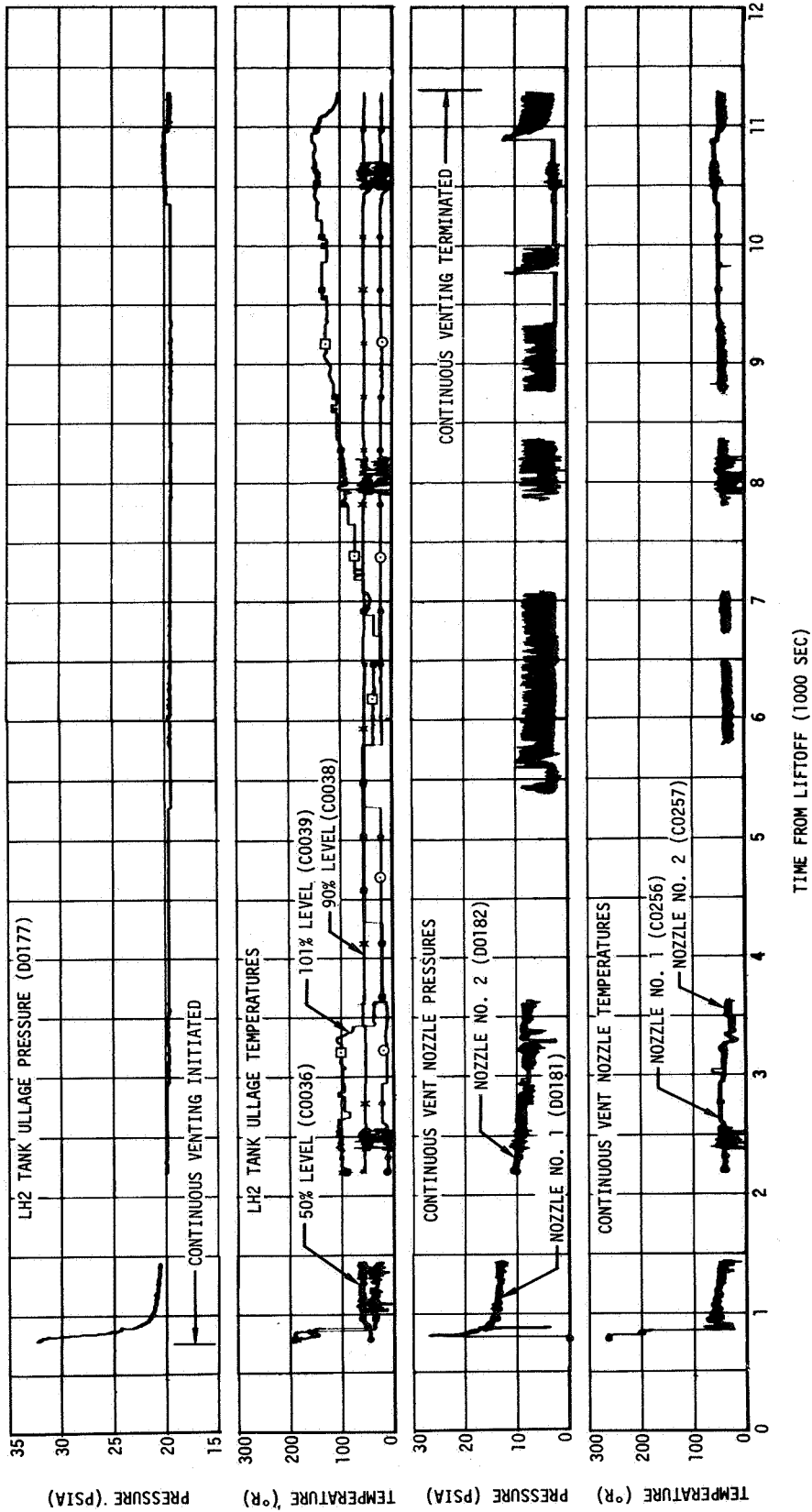


Figure 13-7. LH2 Continuous Vent System Operation - First and Second Orbits

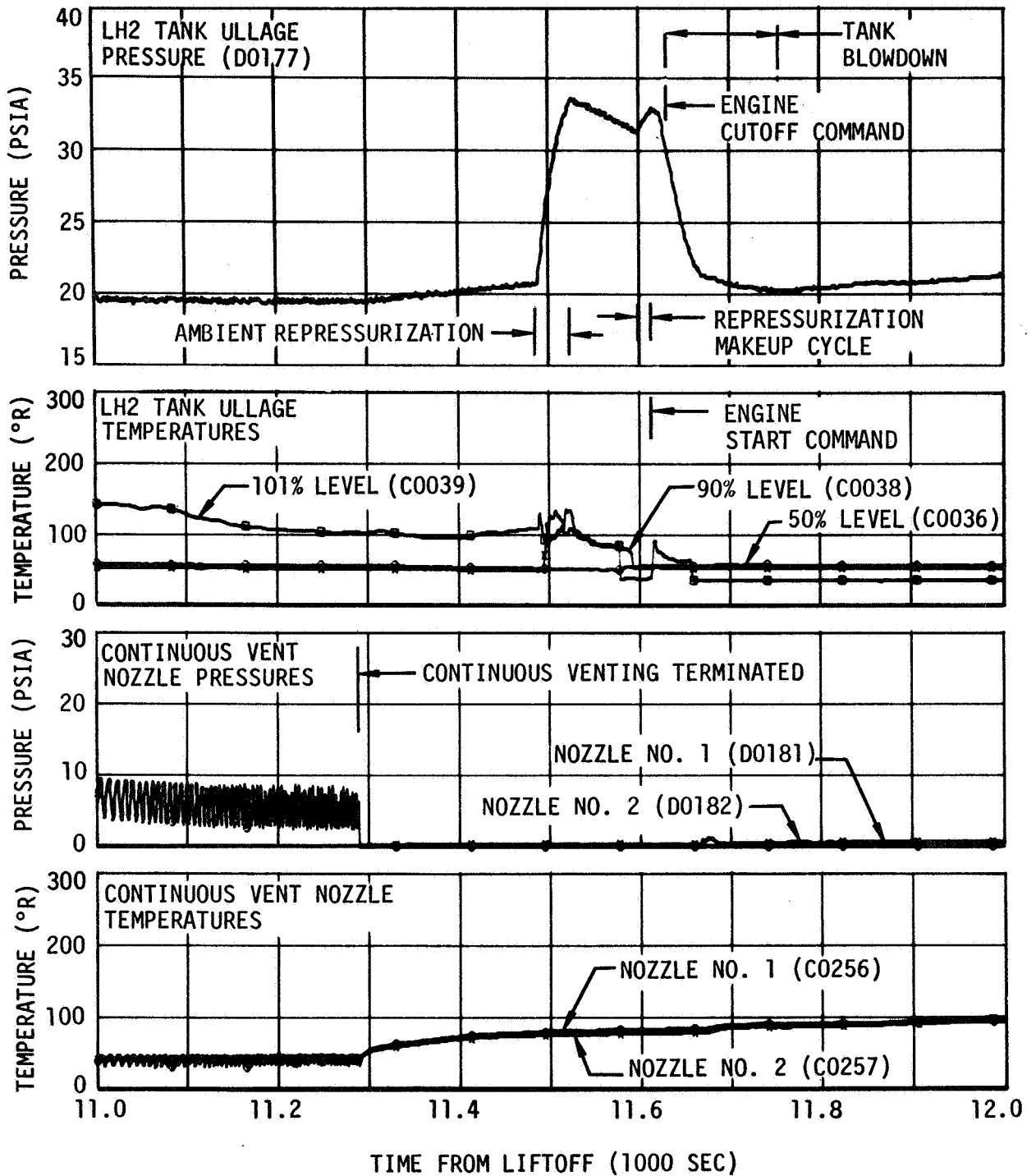


Figure 13-8. LH2 Tank Continuous Vent System Operation - Restart Preparations and Second Burn

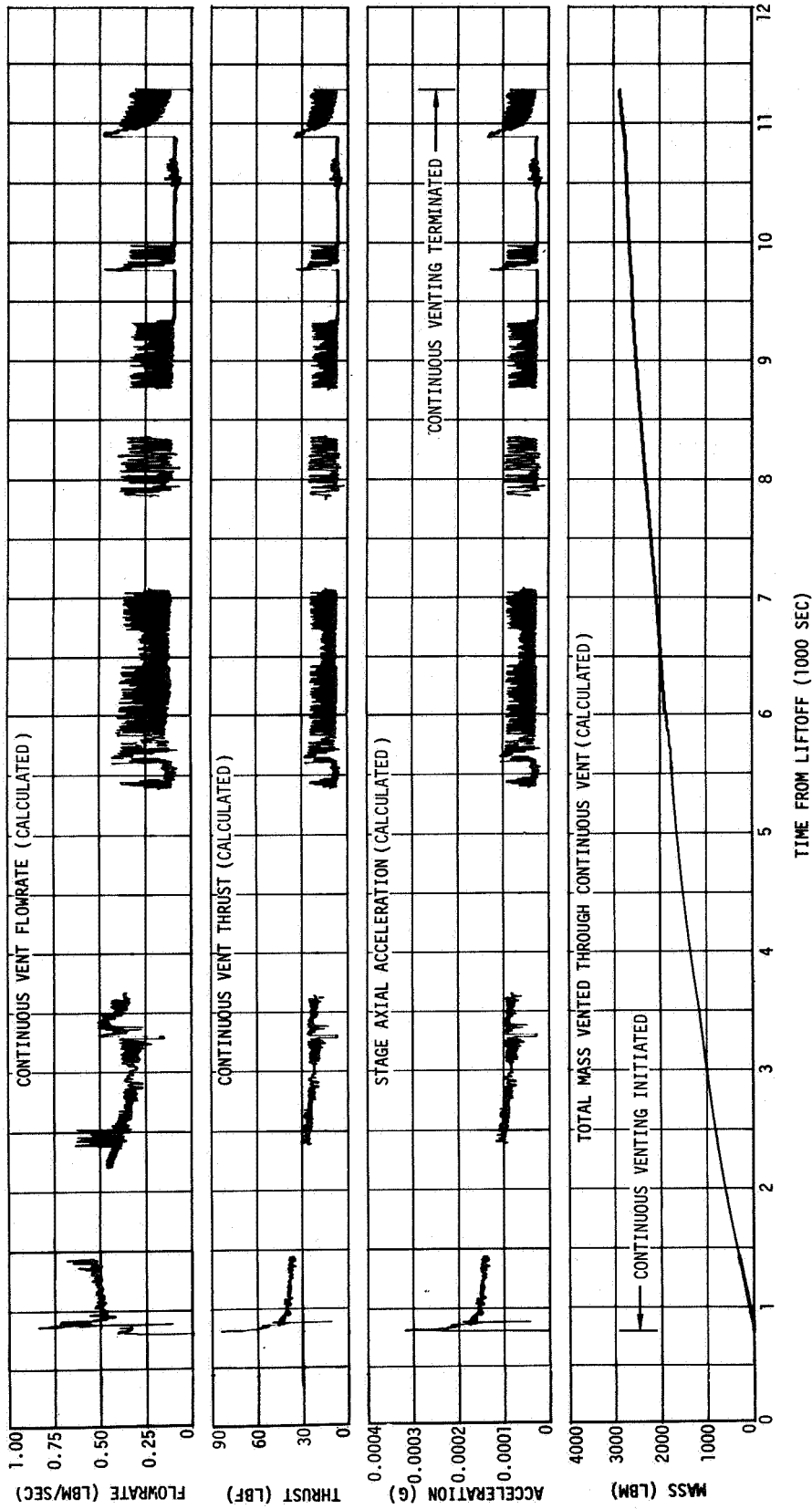


Figure 13-9. LH2 Continuous Vent System Performance - First and Second Orbits

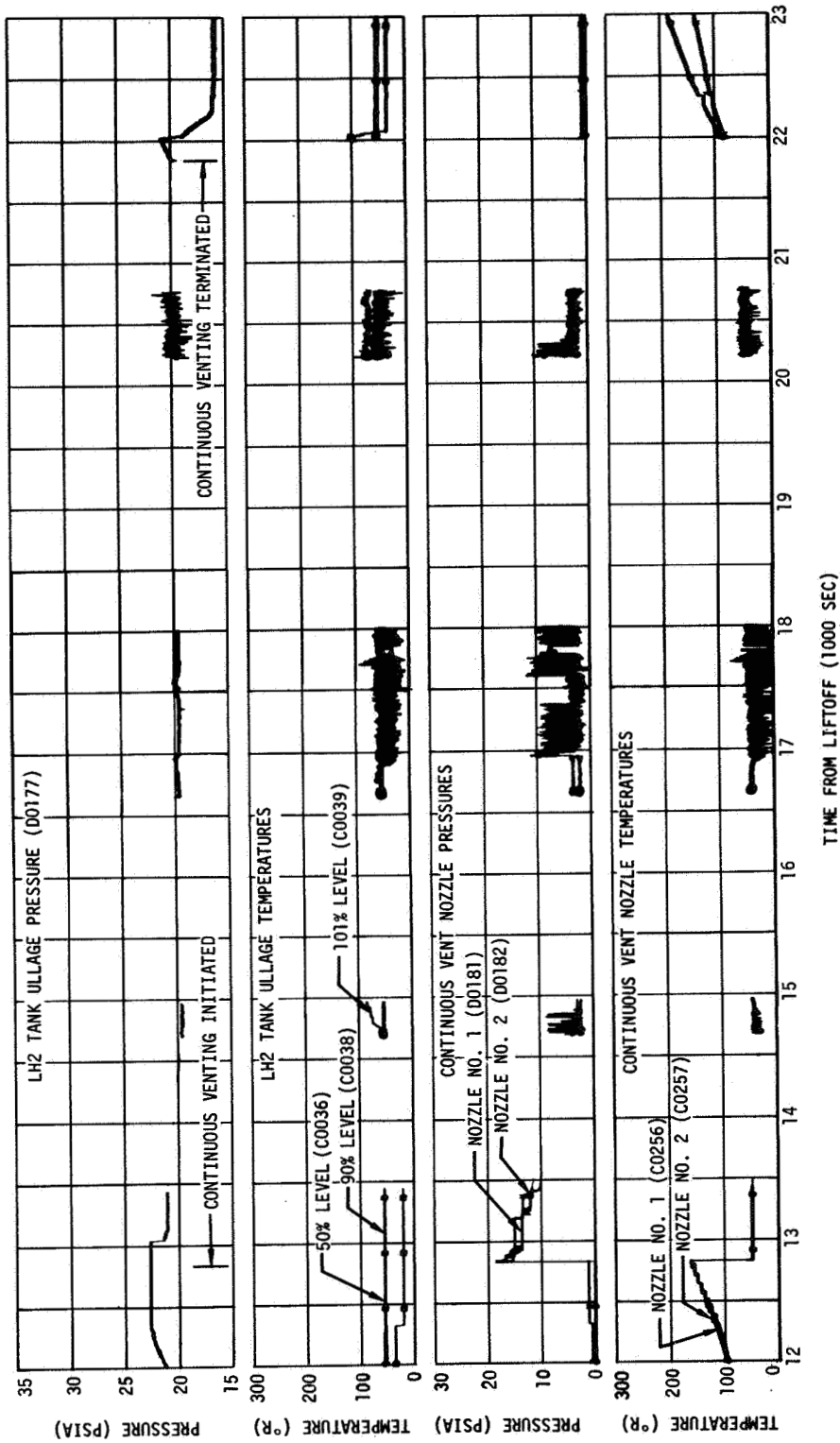


Figure 13-10. LH2 Tank Continuous Vent System Operation - Third and Fourth Orbits

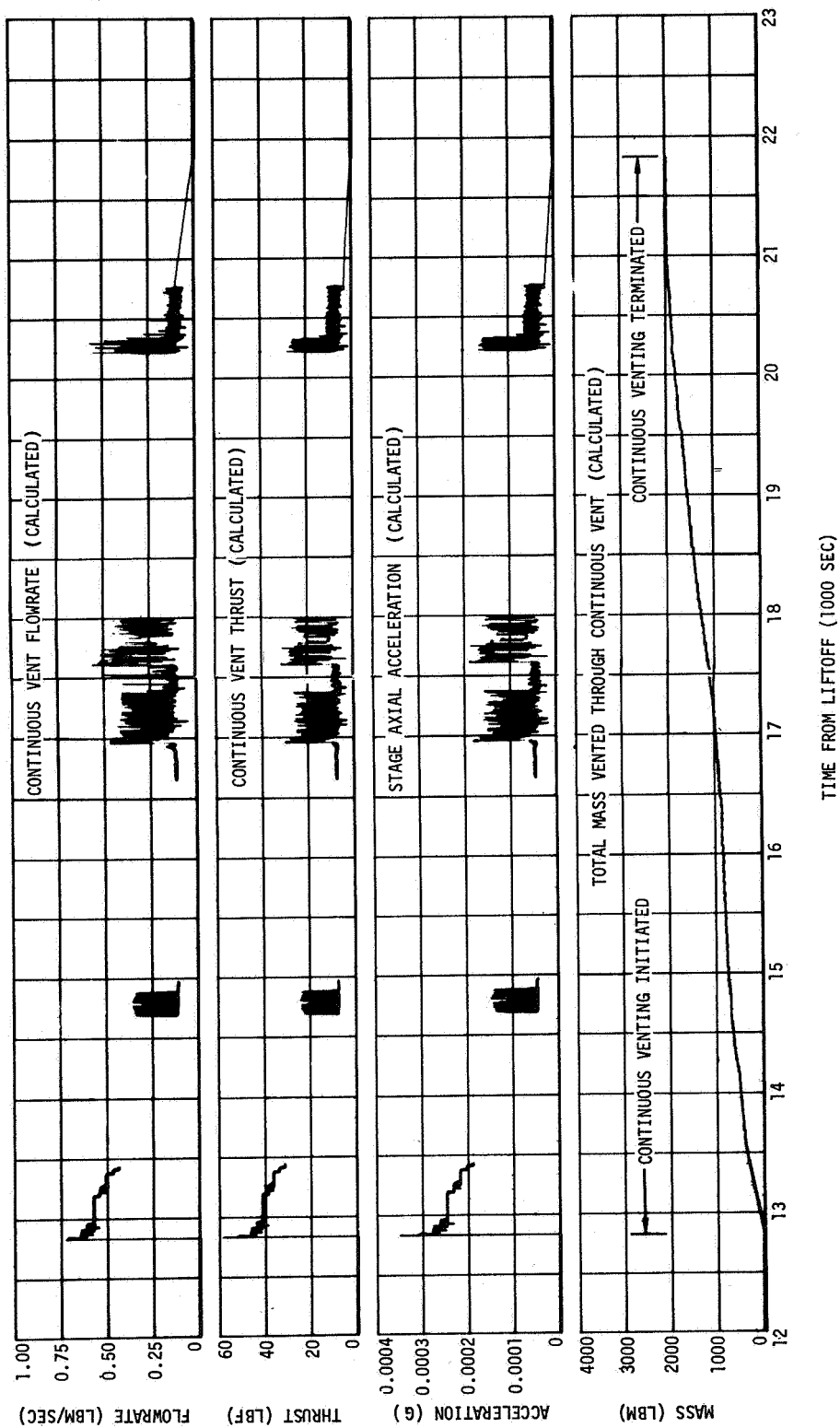


Figure 13-11. LH2 Continuous Vent System Performance - Third and Fourth Orbits

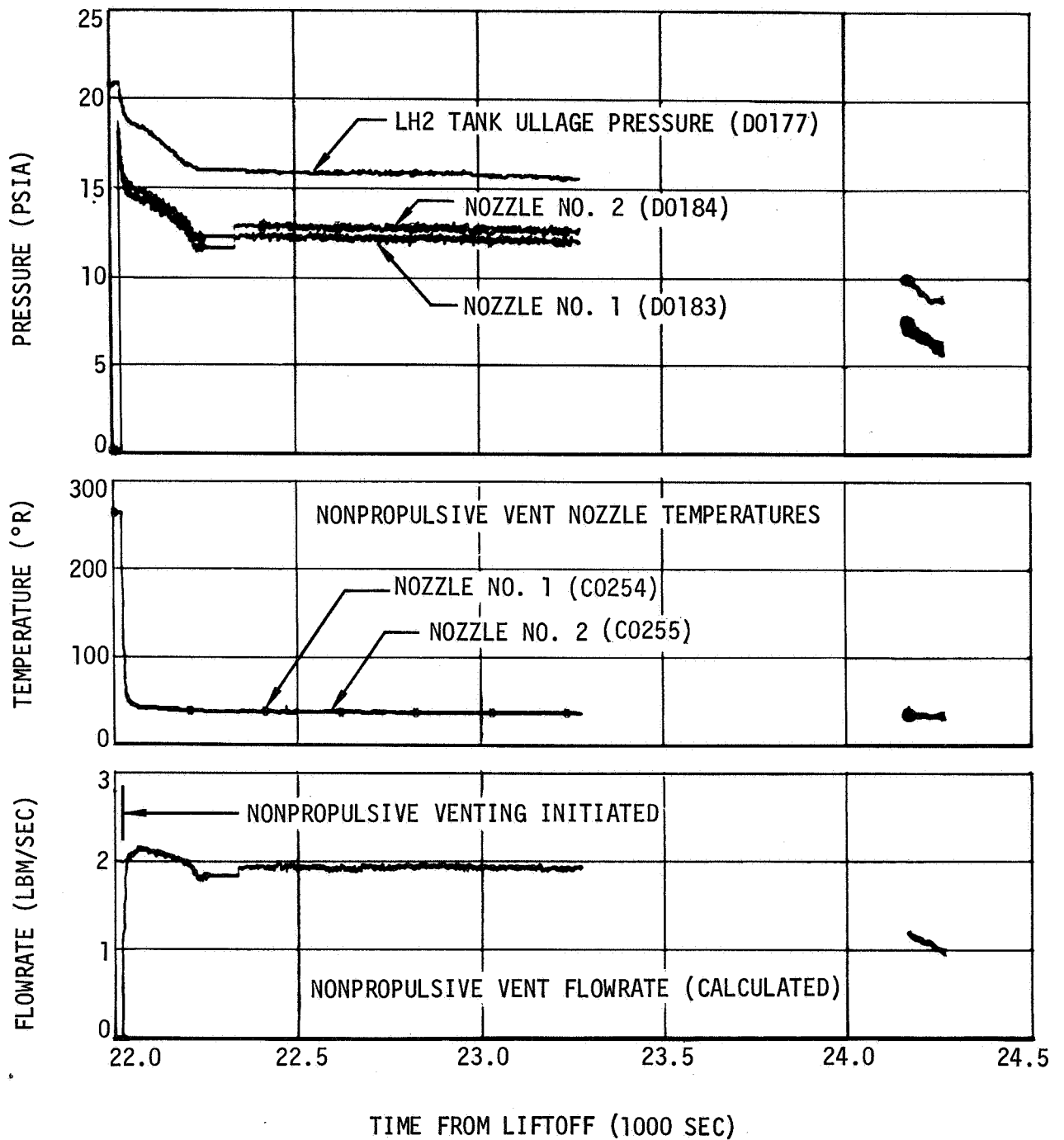


Figure 13-12. Nonpropulsive Vent System Performance - LH2 Tank Passivation

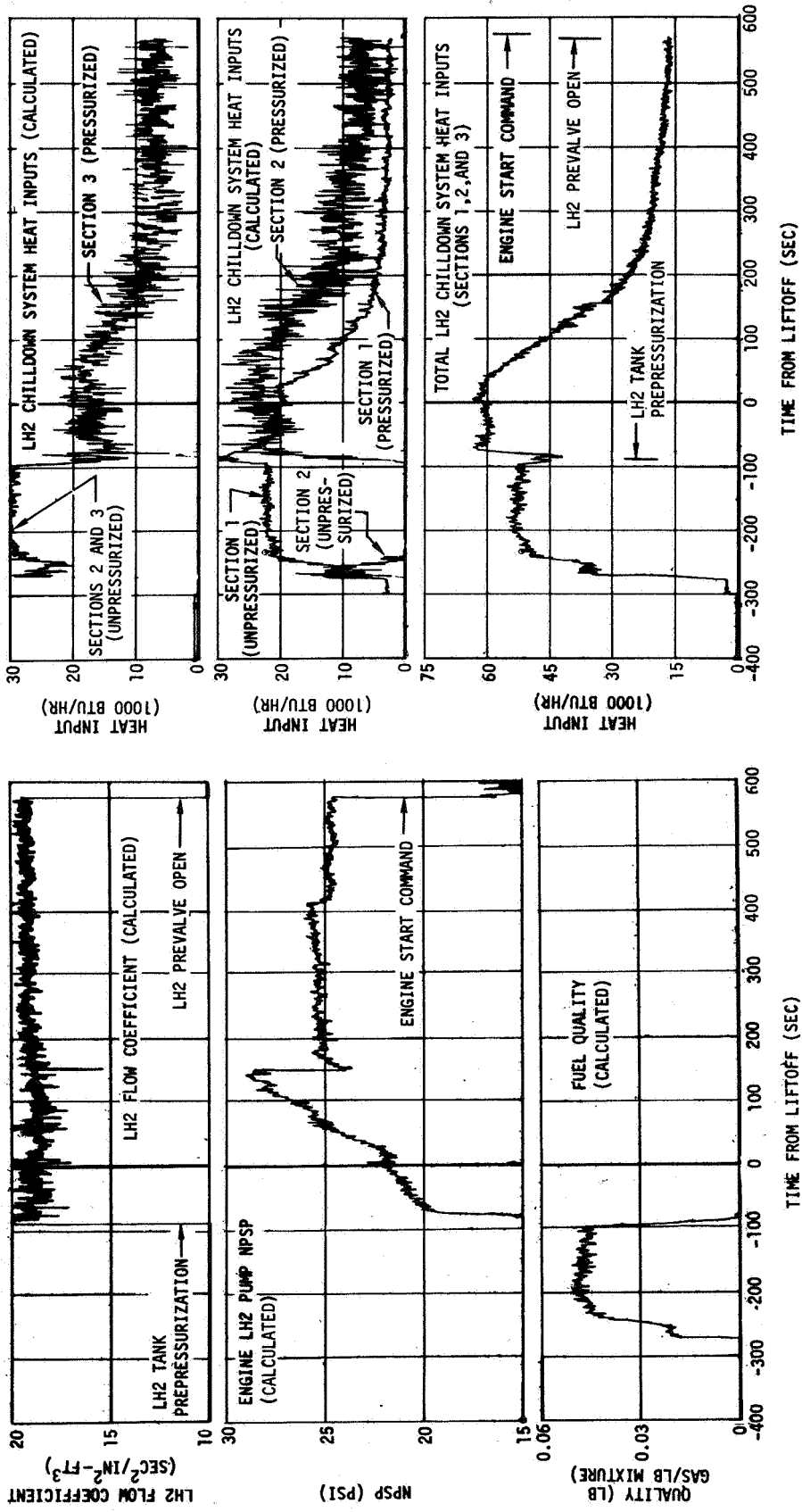


Figure 13-13. LH2 Pump Chilldown Conditions - First Burn

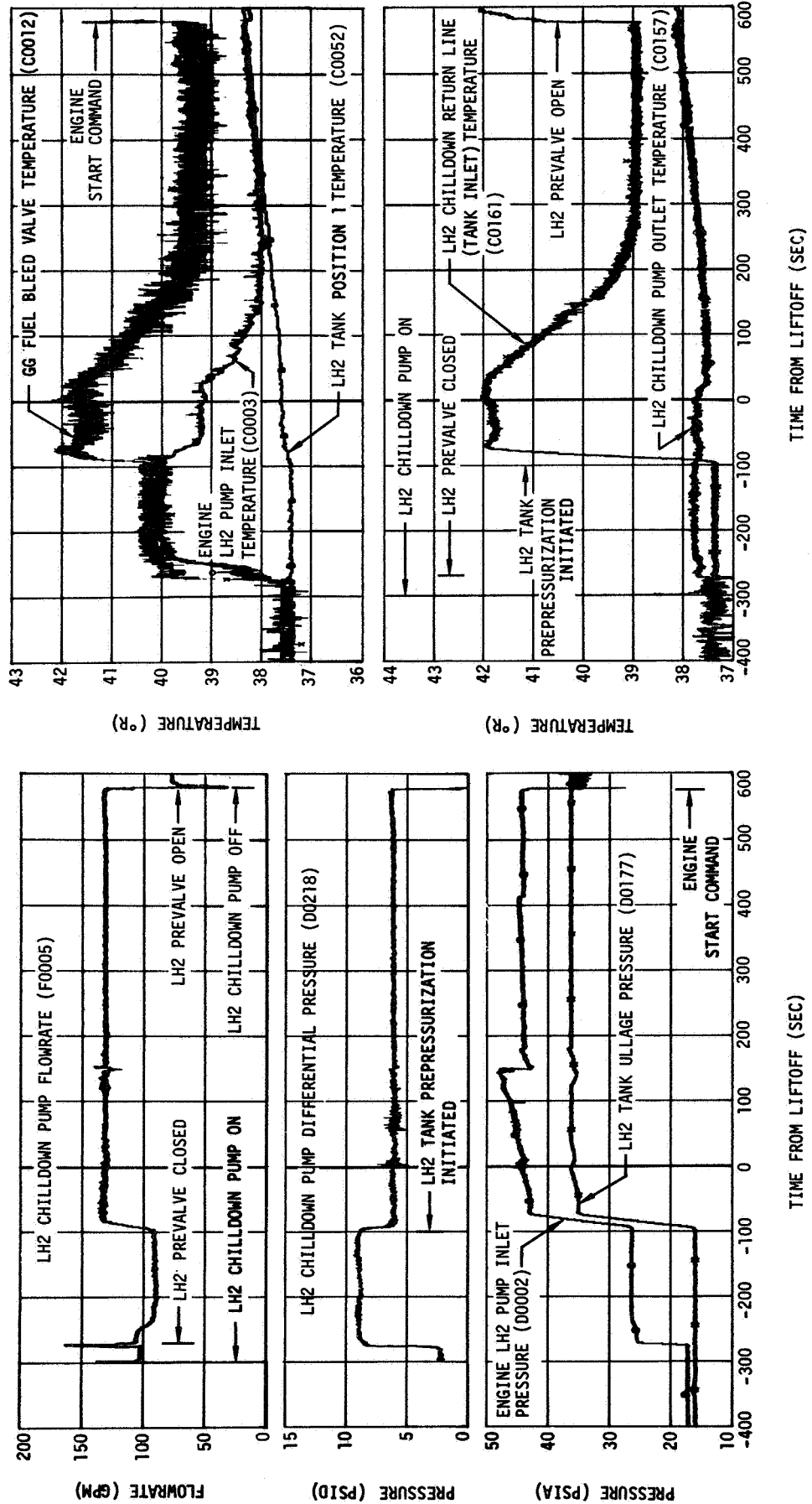


Figure 13-14. LH2 Pump Chilldown - First Burn

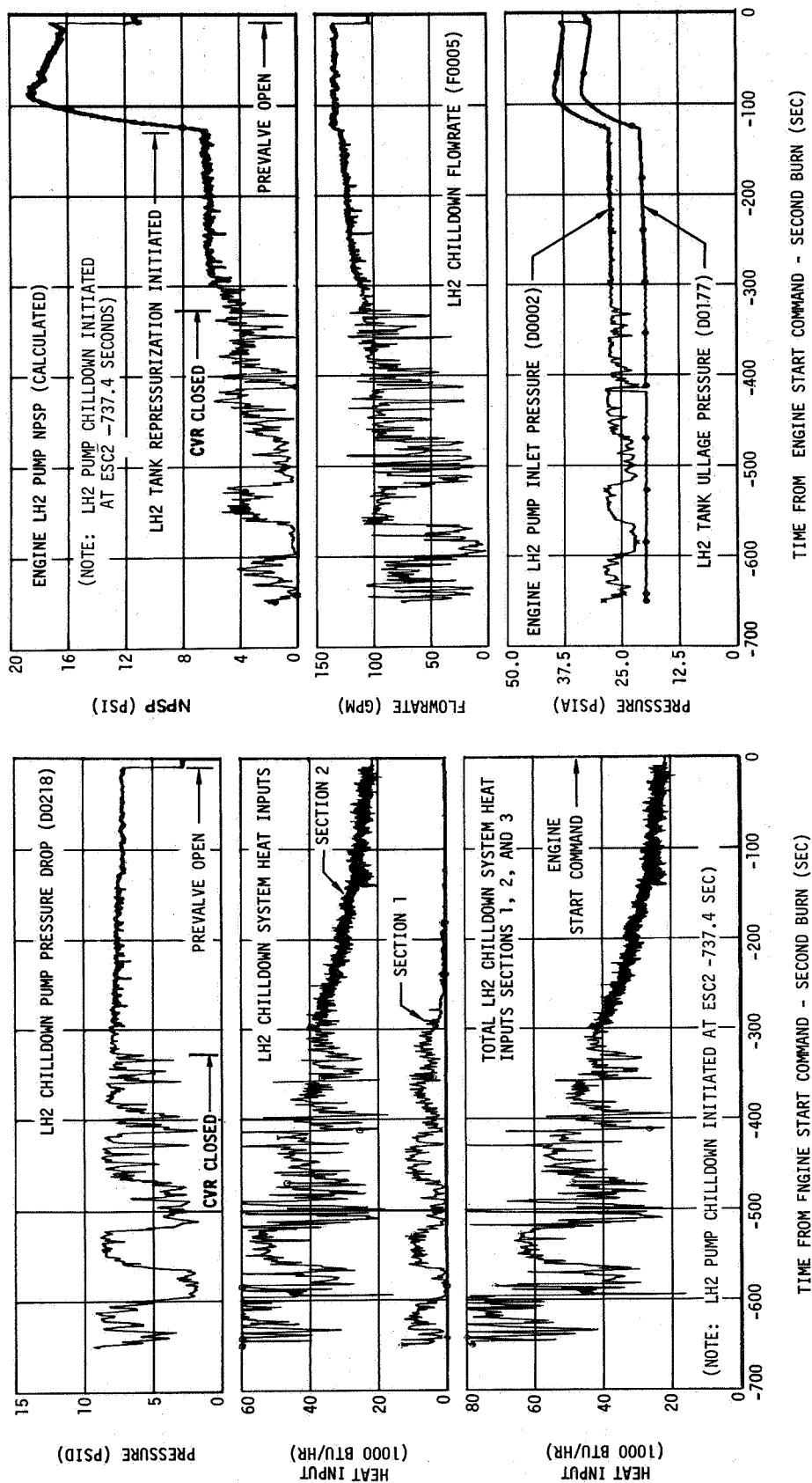


Figure 13-15. LH2 Pump Chilldown Characteristics - Second Burn

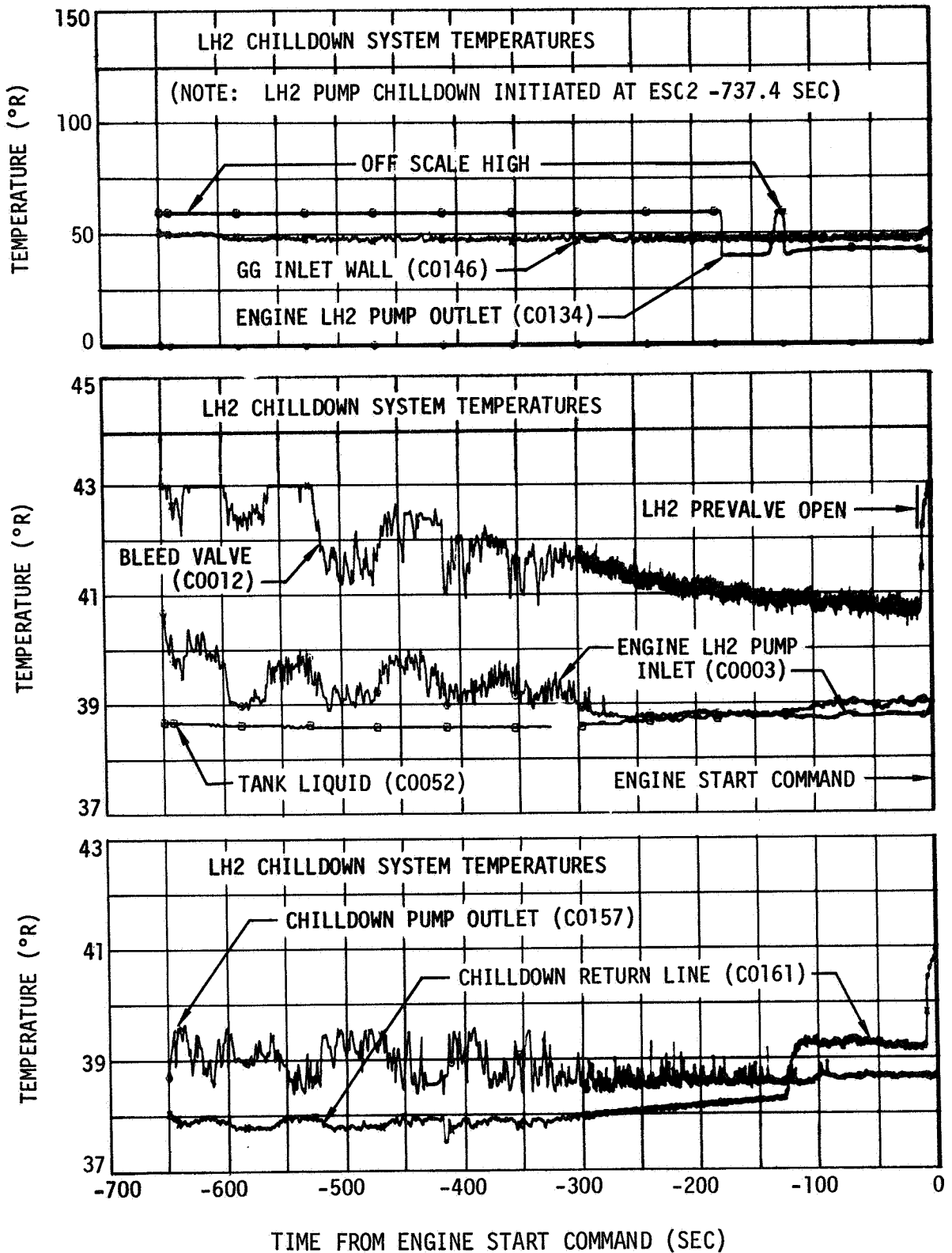
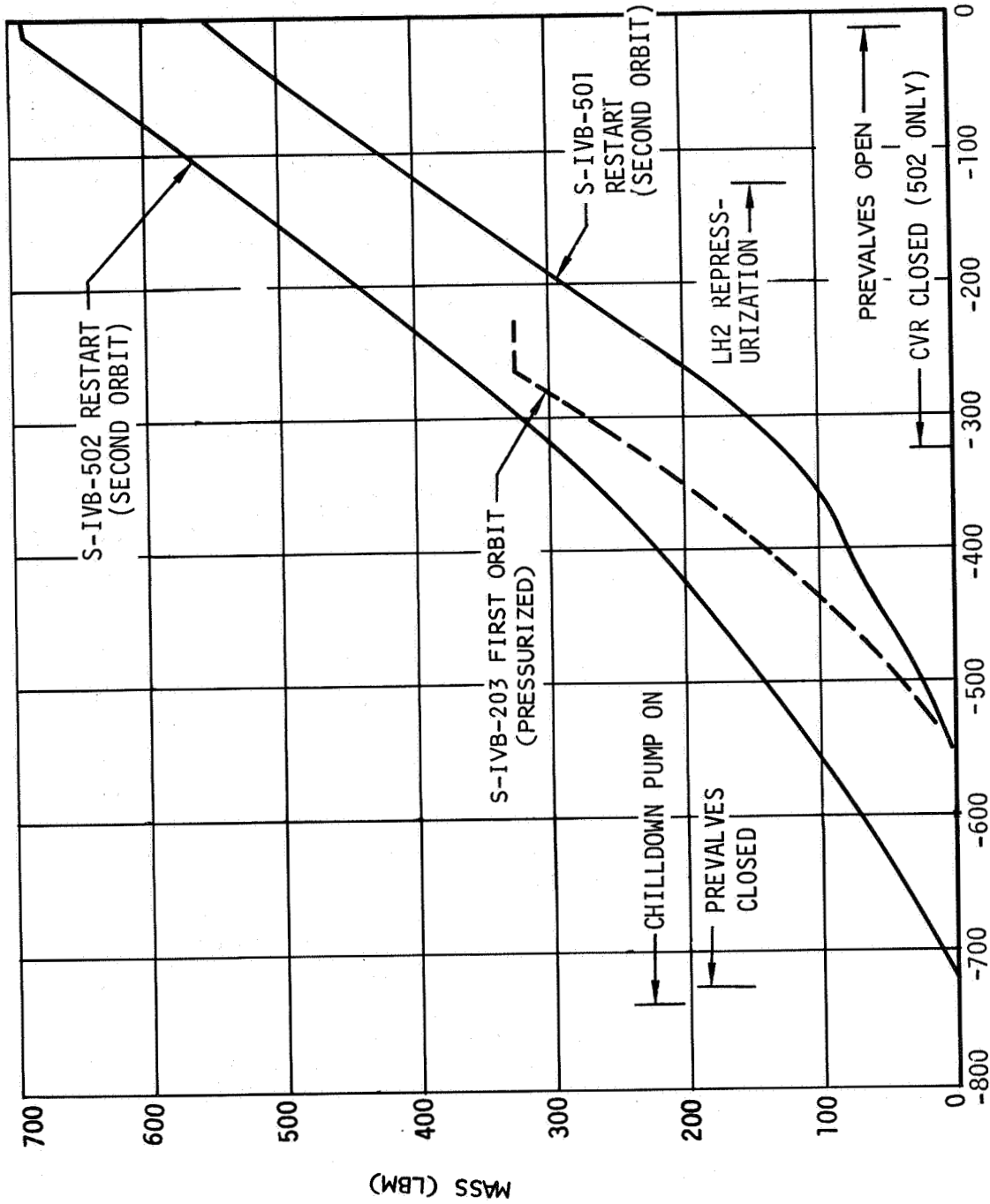


Figure 13-16. LH2 Pump Chilldown - Second Burn



TIME FROM ENGINE START COMMAND - SECOND BURN (SEC)

Figure 13-17. Comparison of LH2 Mass Entering Chilldown System

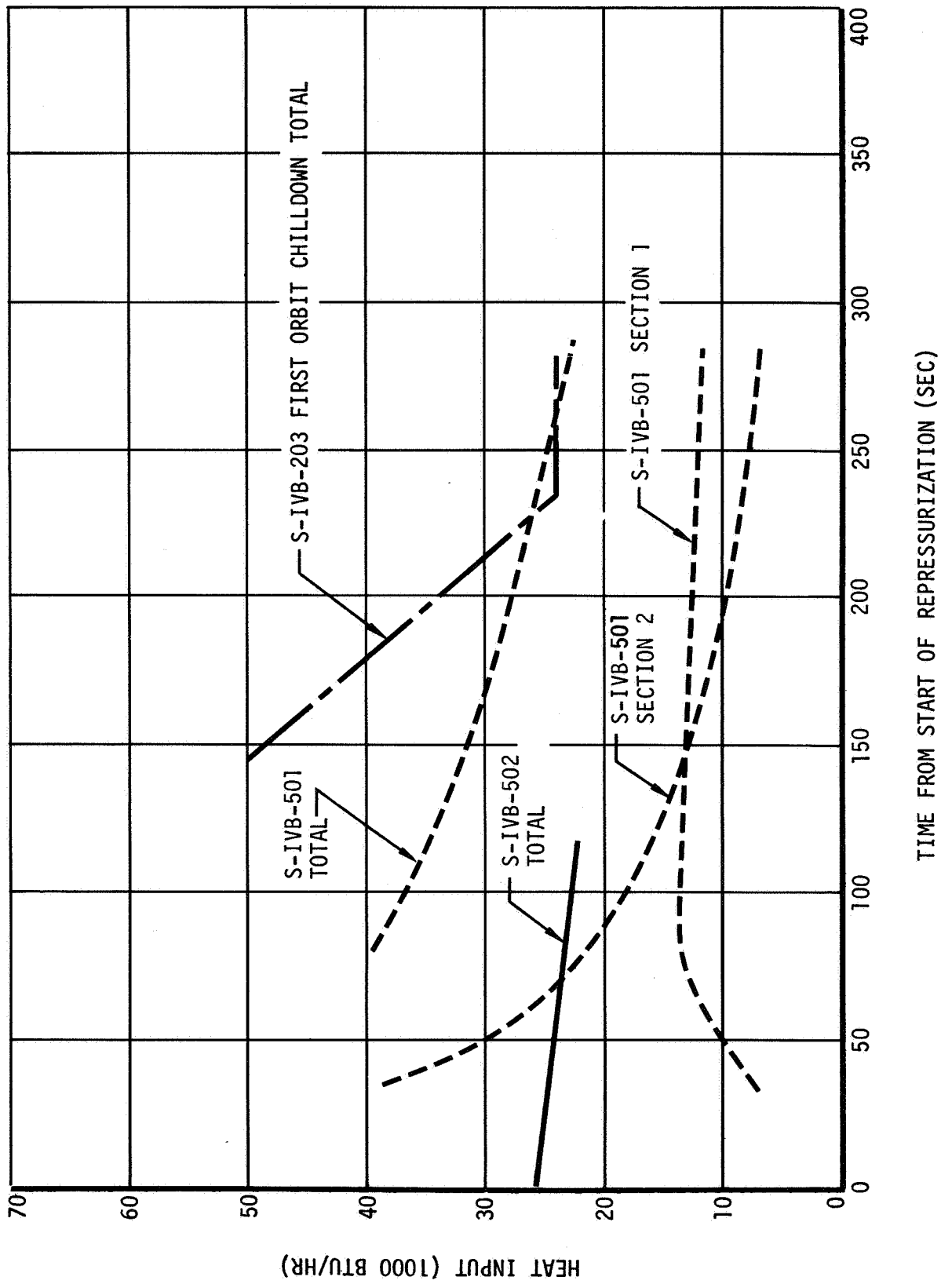


Figure 13-18. Comparison of Heat Input Rates During Flight

Section 13
Fuel System

NOTE:
(X) ITEM NUMBERS FROM
PARTS LIST FIGURE 4-1
SEE FIGURE 4-1 FOR
LEGEND

LH2 TANK
TEMPERATURE PROBE

| MEAS NO. | LEVEL (INCHES FROM TANK BOTTOM) |
|----------|---------------------------------|
| N0021 | 431 |
| C0039 | 417 |
| N0022 | 401 |
| C0068 | 395 |
| K0676 | 383.14 |
| N0023 | 370 |
| C0038 | 350 |
| N0024 | 340 |
| C0067 | 333 |
| N0025 | 309 |
| C0066 | 303 |
| C0037 | 288 |
| N0026 | 279 |
| C0065 | 273 |
| N0027 | 248 |
| C0036 | 227 |
| N0028 | 218 |
| C0064 | 212 |
| N0029 | 187 |
| C0063 | 180 |
| C0035 | 166 |
| N0030 | 157 |
| C0062 | 152 |
| N0031 | 126 |
| C0034 | 105 |
| N0032 | 96 |
| C0054 | 87 |
| L0002 | 60 |
| C0053 | 55 |
| L0001 | 28.5 |
| C0052 | 20 |

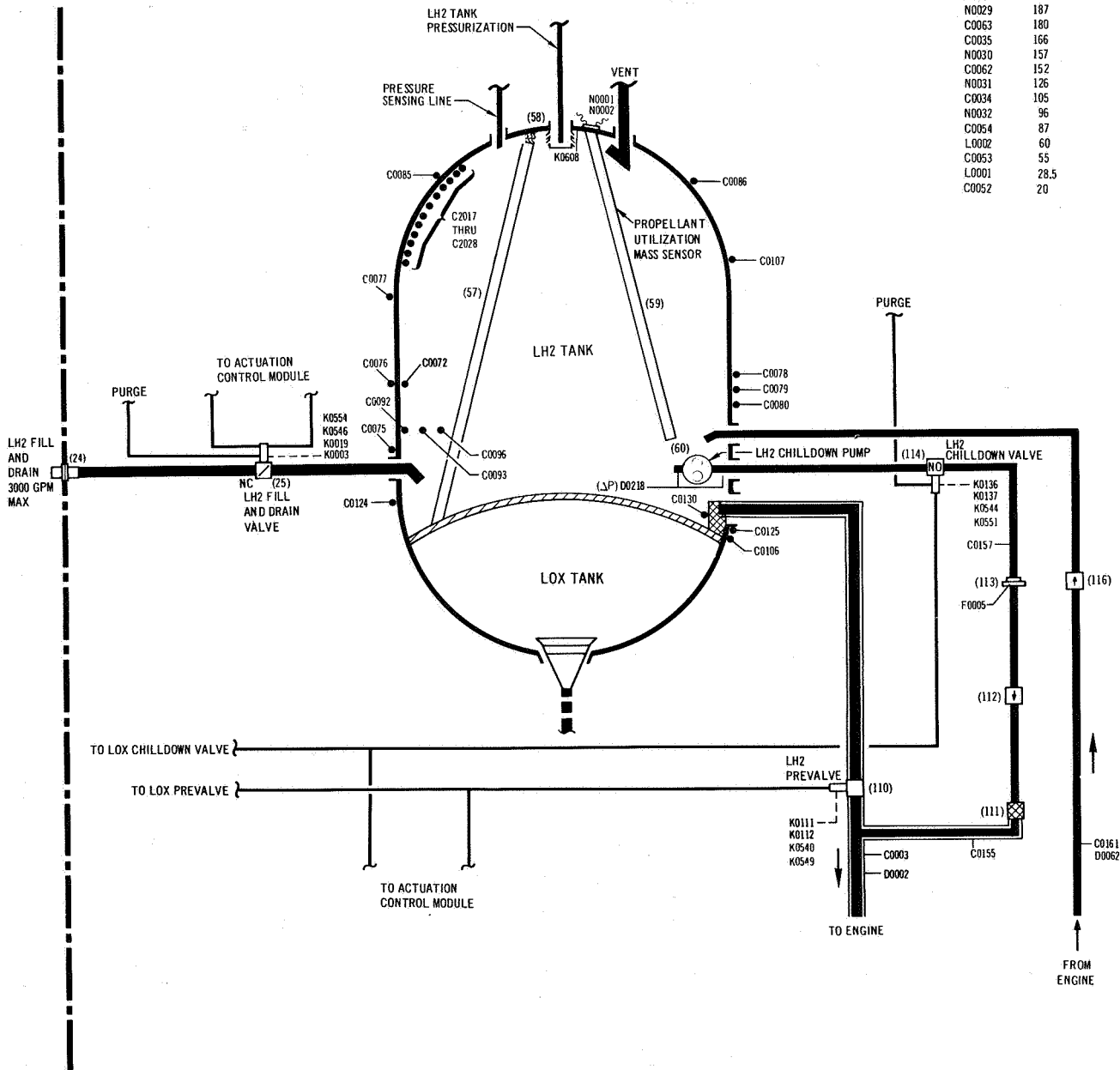


Figure 13-19. LH2 Supply System

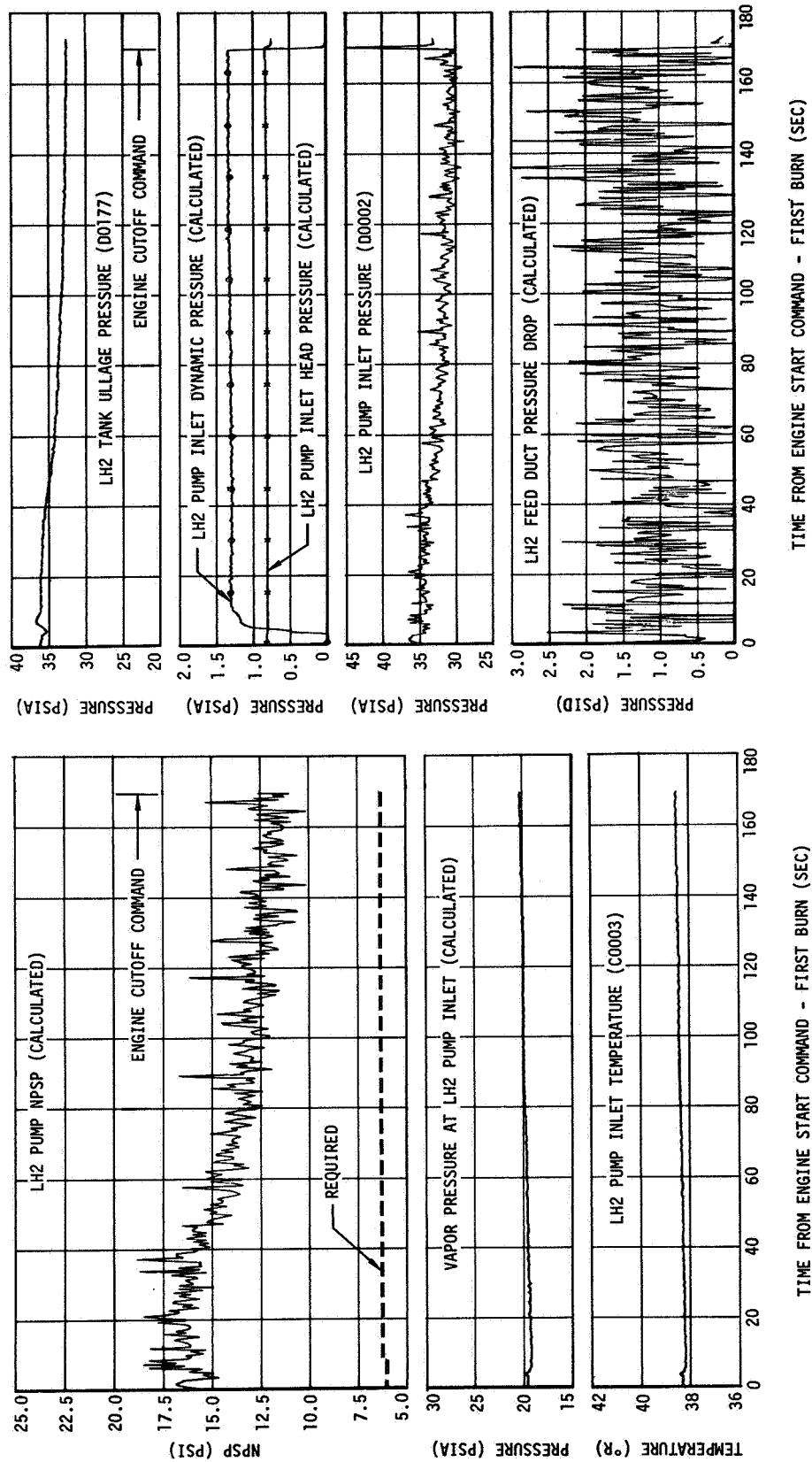
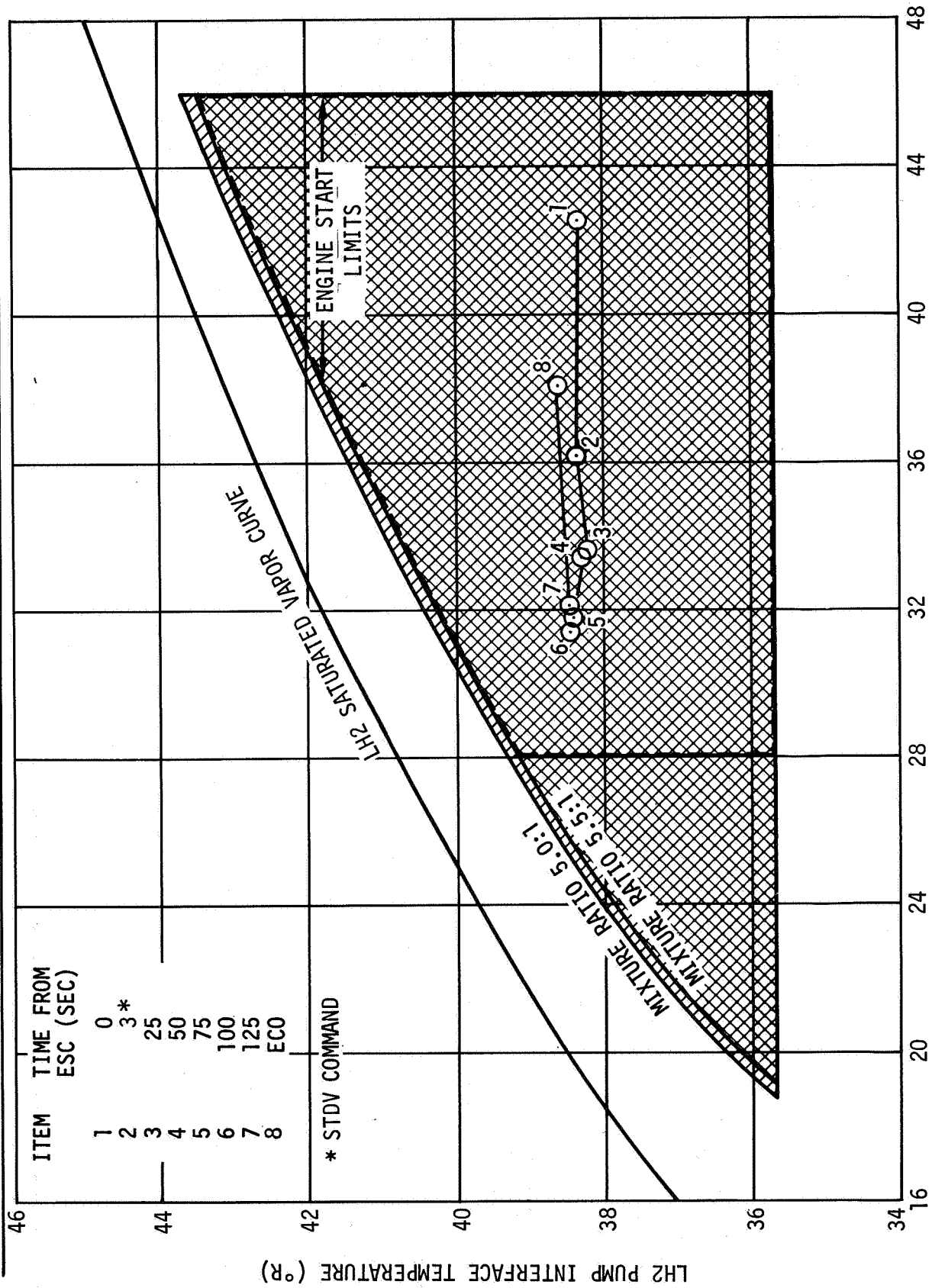


Figure 13-20. LH2 Pump Inlet Conditions - First Burn



LH2 PUMP INTERFACE PRESSURE (PSIA)

Figure 13-21. LH2 Pump Interface Conditions - First Burn

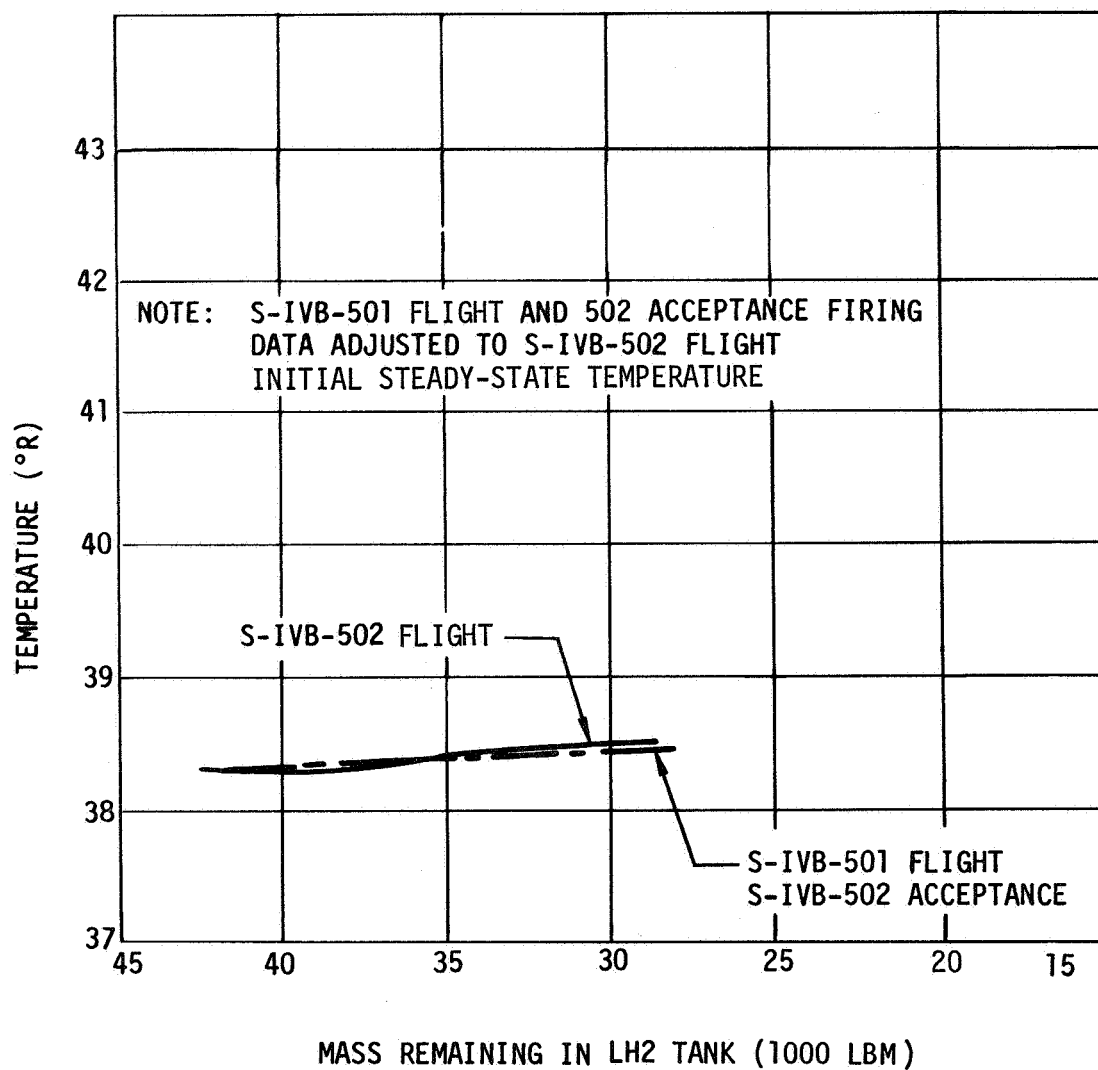


Figure 13-22. Effect of LH2 Mass Level on LH2 Pump Inlet Temperature

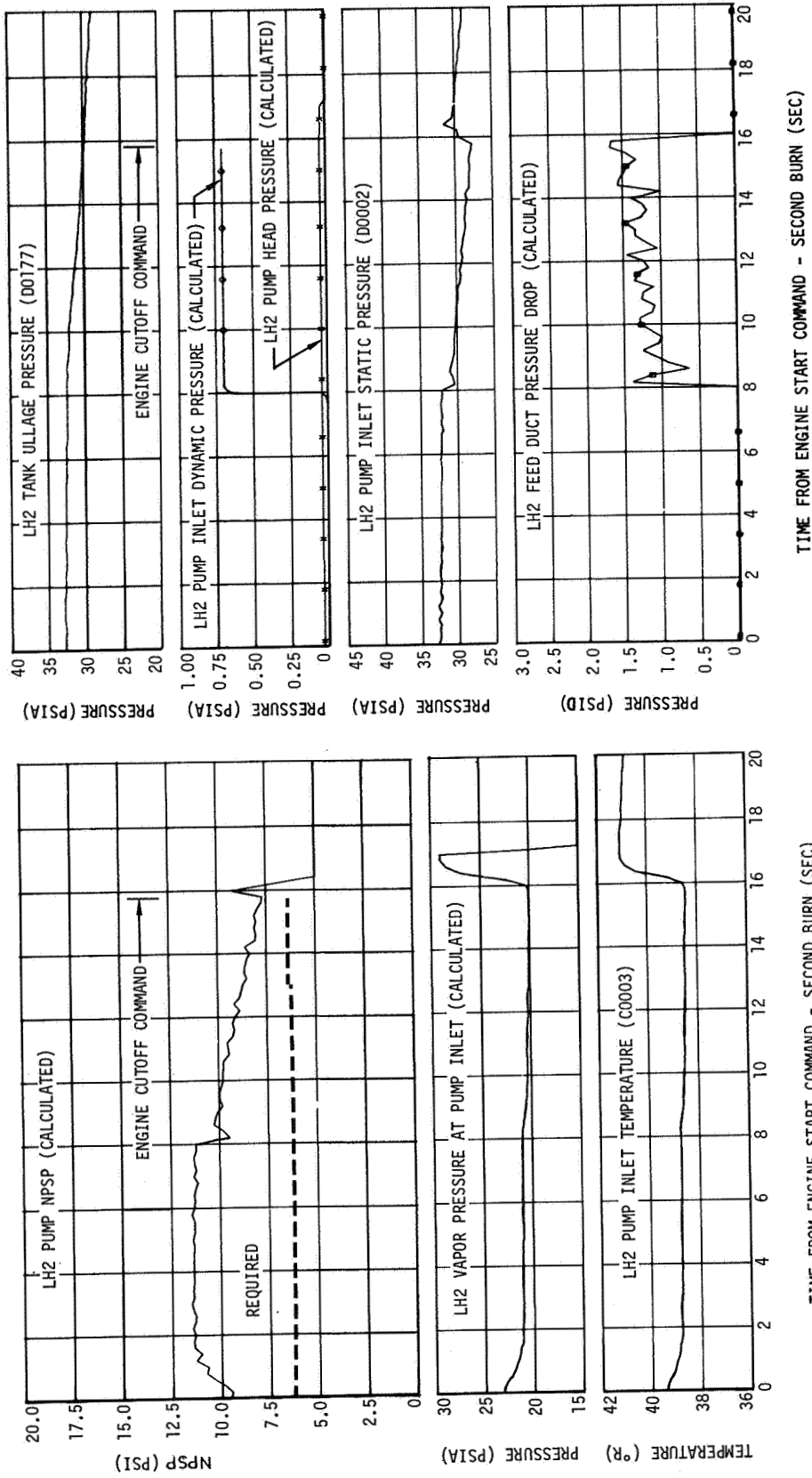


Figure 13-23. LH2 Pump Inlet Conditions - Second Burn

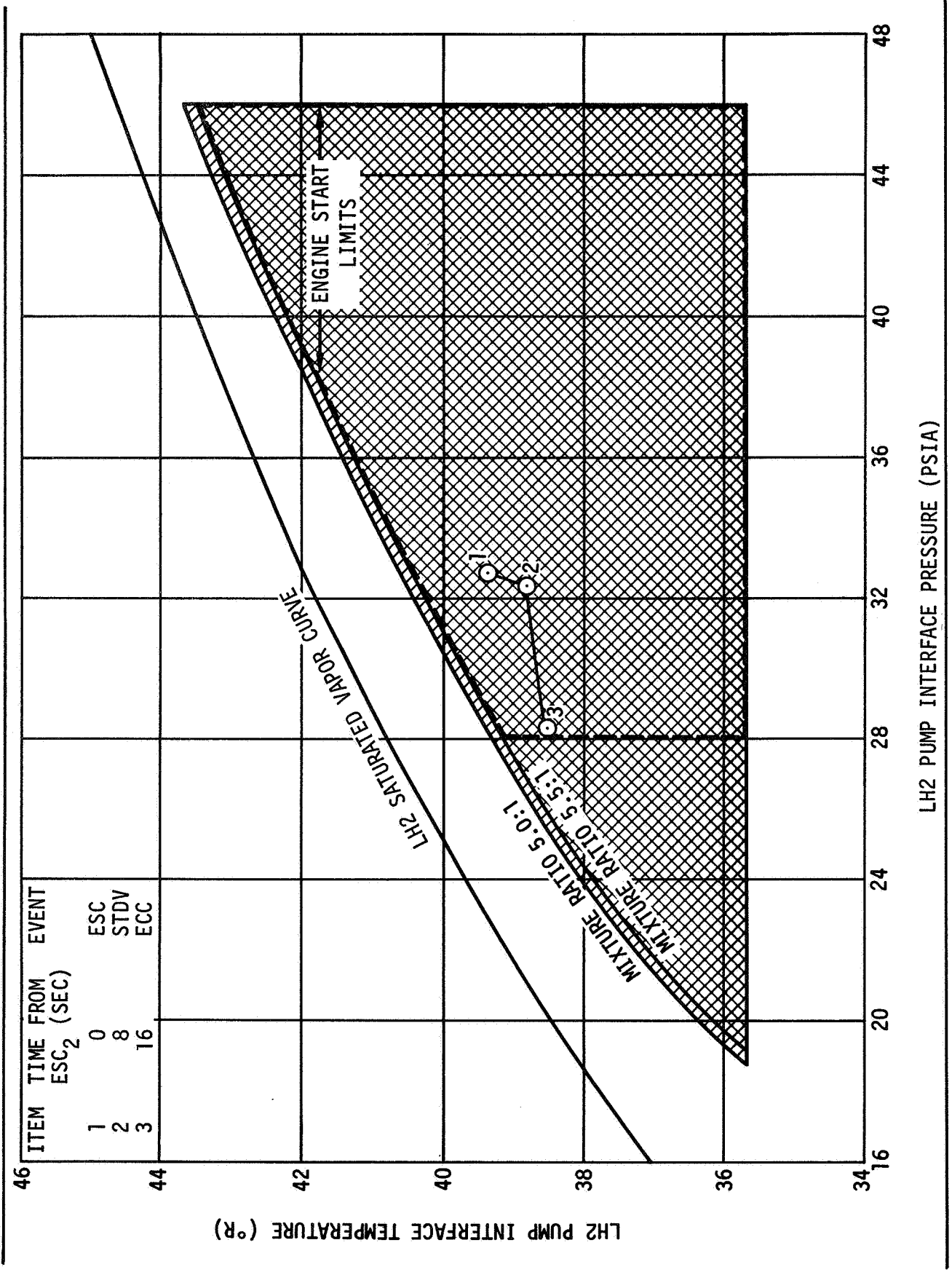


Figure 13-24. LH2 Pump Interface Conditions - Second Burn

SECTION 14

AUXILIARY PROPULSION SYSTEM

14. AUXILIARY PROPULSION SYSTEM

The attitude of the S-IVB is controlled by two auxiliary propulsion system (APS) modules (figure 14-1) mounted 180 deg apart on the aft skirt of the stage. Each module is a self-contained unit composed of four basic systems: (1) Oxidizer system; (2) fuel system; (3) helium pressurization system; and (4) the engines. The instrumentation unit, mounted above the S-IVB, provides signals for operation of the APS modules.

Each module contains two 150-lbf engines which provide roll control during S-IVB powered flight, and yaw and roll control during the coast periods. A third 150-lbf engine in each module provides pitch control during the coast periods. Each module also contains a 72-lbf engine to provide thrust for LOX and LH2 tank ullage control after first burn and during restart preparation.

14.1 APS Flight Operation

The APS operation was adequate to fulfill the attitude control, maneuvering, and ullaging requirements of the mission until APS propellant depletion. The APS propellant usage was greater than predicted as a result of the booster problems encountered during the mission. A discussion of usage is presented in the module 1 oxidizer paragraph 14.2.2.

The pitch engine of each module exhibited reduced chamber pressure at specific times during the mission as shown in figures 14-2, 14-3, and 14-4. The reason for the low chamber pressure is explained in the engine performance paragraph 14-4.

14.1.1 APS Flight Objectives

All objectives of the flight with respect to the APS modules were accomplished. These were as follows:

- a. To evaluate APS operation under actual flight conditions
- b. To better substantiate APS requirements
- c. To evaluate the ability of the APS to fulfill the attitude control, maneuvering, and ullaging requirements.

14.1.2 APS Flight Description

Approximately 1 sec after S-II engine cutoff, the APS was activated to provide roll control during first burn.

Following first burn engine cutoff, APS pitch and yaw control was activated to maintain the vehicle in the desired attitude. The APS ullage engines fired for 88 sec following J-2 first burn to provide slosh control and propellant settling.

Approximately 330 sec prior to restart the APS ullage engines were again ignited to provide ullage control during restart preparations. The ullage engines were shut off 3 sec after second burn Engine Start Command.

Section 14
Auxiliary Propulsion System

During the restart attempt the APS pitch and yaw control was deactivated and the APS provided roll control only. When the J-2 engine failed to restart, APS pitch and yaw control was reactivated. The APS maintained pitch, yaw, and roll control of the stage until module 1 propellant depletion at approximately RO +22,030 sec. At this time the signal from the IU was activating the valves of engine 1-1 continuously, attempting to maintain control.

14.2 APS Module No. 1

The operation of the helium pressurization system of module No. 1 was as expected. The propellant supply system pressure levels and the propellant temperatures measured in the propellant control module were in the expected range.

The performance of the module 1 engines was satisfactory throughout the mission with the exception of the pitch engine which had low chamber pressure at various times during the mission.

14.2.1 Helium Pressurization System - Module 1

The module No. 1 helium pressurization system operation was normal with no problems encountered throughout the flight. Prior to APS activation, the helium bottle pressure was 3,120 psia and the temperature was 558 deg R yielding an initial mass in the bottle of 1.015 lbm.

Figure 14-5 shows the helium temperature, pressure, and mass as a function of mission time. The nominal and three-sigma predictions are included for comparison. The mass of helium remaining in the bottle at module 1 propellant depletion was 0.470 lbm. This corresponds to a helium temperature of 552 deg R and a pressure of 1,330 psia.

Figure 14-5 shows that the module 1 helium usage was greater than nominal but was still less than the three-sigma prediction prior to second ullage burn. However the disturbances resulting from the failure of the J-2 to restart resulted in more propellant usage than predicted.

Following propellant depletion, the helium bottle mass leveled off at approximately 0.45 lbm indicating no leakage in the pressurization system.

The helium regulator outlet pressure was maintained at approximately 192 psia throughout APS operation. The propellant tank ullage pressures were 188 psia, which is on the low end of the expected range of 188 to 203 psia.

14.2.2 APS Oxidizer System - Module 1

The oxidizer manifold supply pressure of module 1 was as expected during the flight. The pressure was approximately 188 psia during APS operation. The oxidizer temperature measured at the propellant control module was also in the expected range. The maximum temperature recorded was 570 deg R. Evaluation of the data indicates that the oxidizer bulk temperature (in the tank) remained near the liftoff value of 557 deg R.

The oxidizer remaining in the APS is shown as a function of mission time in figure 14-6. The nominal and three-sigma predictions are included for comparison. The initial oxidizer load of module 1 was 188.6 lbm. The oxidizer consumption exceeded the predicted immediately following the stage first burn. This was due to a 43-sec steady-state burn by the module 1 pitch engine followed by approximately 43 sec of rapid pulsing. The excessive pitch engine firing was required to correct for an unusually high guidance-induced pitch rate at engine cutoff. Following this attitude correction the oxidizer consumption rate was close to the predicted rate until the restart attempt. When the APS pitch-yaw control was reactivated after the restart attempt, engine 1-3 fired steady-state for 18 sec followed by approximately 30 sec of rapid pulsing. Within the next 300 sec, steady-state pulses of 26 and 34 sec were fired on engine 1-2. These firings were required to correct for error rates induced by the J-2 engine and to perform commanded maneuvers. Because of the large LH2 and LOX residual, the moment of inertia of the vehicle was larger than predicted, and the center of gravity (CG) lower. The low CG resulted in shorter APS pitch and yaw moment arms resulting in the large quantity of propellant usage at this time. Table 14-1 shows the propellant consumption during significant periods of the flight. The oxidizer in module 1 was depleted at RO +22,053 sec after liftoff. The time of depletion was determined by examining the oxidizer manifold pressure. Figure 14-7 shows the oxidizer manifold pressure drop at RO +22,053 sec after liftoff.

14.2.3 APS Fuel System - Module 1

The fuel system of module 1 performed as expected during the flight. The fuel manifold supply pressure remained at approximately 190 psia. The fuel temperature measured at the propellant control module remained below 566 deg R. Again, the data indicate that the fuel bulk temperature remained near the liftoff value of 555 deg R (figure 14-6).

The fuel remaining in module 1 during the mission is shown in figure 14-6. The liftoff value was nominal at 124.4 lbm. Like the oxidizer the fuel consumption exceeded predicted usage immediately following stage first burn for the reason mentioned in the oxidizer section. After the attitude control engine burned to correct for guidance-induced vehicle disturbances, the fuel consumption rate was near nominal. Following the restart attempt, the fuel consumption greatly exceeded that predicted for the reasons mentioned in the oxidizer section. The fuel was depleted at RO +21,953 sec. The time of depletion was determined by examining engine chamber pressure data and fuel manifold pressure. Figure 14-7 shows the decrease in engine 1-2 chamber pressure starting at 21,953 sec. The fuel manifold pressure data were not obtained at this time; however, the drops in pressure can be seen with each pulse after RO +21,993 sec. No problems resulted from the fuel being depleted first. The fuel consumption during significant portions of the flight is presented in table 14-1.

14.3 APS Module No. 2

The operation of APS module 2 was satisfactory. As in module 1 low pitch engine chamber pressures were recorded at various times in the mission. Also as in module 1 the propellant usage was greater than predicted. Module 2 propellant depletion occurred approximately 600 sec after module 1 depletion.

14.3.1 Helium Pressurization System - Module 2

The module No. 2 helium pressurization system operation was normal with no problems encountered throughout the flight. Prior to APS activation, the helium bottle pressure was 3,100 psia and the temperature was 545 deg R. The mass of helium in the bottle was 1.035 lbm. Figure 14-5 shows the helium temperature, pressure, and mass as a function of mission time. The nominal and three-sigma predictions are included for comparison.

Figure 14-5 shows that the module 2 helium usage was close to nominal until after the restart attempt. At this time the APS burn requirements greatly exceeded predicted for the reason mentioned in paragraph 14.2.2.

Following propellant depletion the helium bottle mass leveled off at approximately 0.45 lbm indicating no leakage in the pressurization system.

The helium regulator outlet pressure was maintained at 193 to 195 psia throughout APS operation. The propellant ullage pressures were 192 psia.

14.3.2 APS Oxidizer System - Module 2

The oxidizer system of module 2 performed as expected during the flight. The manifold supply pressure was approximately 193 psia. The oxidizer temperature (measured at the propellant control module) remained in the expected range throughout the APS operation. The maximum temperature recorded was 561 deg R. As with module 1, the data indicate that the oxidizer bulk temperature (in the tank) remained near the liftoff temperature of 546 deg R.

The oxidizer remaining in the APS as a function of mission time is presented in figure 14-6. The initial oxidizer load was 189.4 lbm. The oxidizer quantity prior to restart attempt was within the three-sigma predicted range. For the reasons mentioned in paragraph 14.2.2 the oxidizer consumption exceeded predicted following the restart attempt. Engine 2-1 was fired steady-state for 31 sec, and engine 2-2 had two long steady-state burns of 69 and 64 sec. Table 14-1 shows the propellant consumption during significant periods of the flight. The oxidizer in module 2 was depleted at RO +22,634 sec. The time of oxidizer depletion was determined from the oxidizer manifold pressure. Figure 14-8 shows the drop in manifold pressure at the time of depletion.

14.3.3 APS Fuel System - Module 2

The fuel system of module 2 performed as expected during the flight. The fuel manifold supply pressure was approximately 193 psia throughout the flight. The fuel temperature measured at the propellant control module remained in the expected range throughout the APS operation. The data indicate that the bulk temperature remained near 545 deg R throughout the flight.

The quantity of fuel remaining in the APS is presented as a function of mission time in figure 14-6. The quantity of fuel in the module 2 APS at liftoff was 124.7 lbm. The fuel usage was slightly less than nominal until the restart attempt. At this time, as in the case of the oxidizer, the fuel consumption exceeded prediction. Table 14-1 shows the fuel consumption during significant portions of the mission. The fuel was depleted at RO +22,602 sec. The time of fuel depletion was determined from the drop in fuel manifold

pressure and the decrease in chamber pressure. As in module 1 the fuel was depleted prior to the oxidizer without any detrimental effects on the module. The fuel was depleted first in both modules because the propellants were loaded for an attitude control engine EMR of 1.65 to 1, while the attitude control engines operate at an EMR of approximately 1.60 to 1 during minimum pulsing of which a large portion of the mission is composed. Another reason for the fuel to deplete first was an apparently reduced oxidizer flow at various times during the mission. This is explained in greater detail in the following paragraphs.

14.4 Engine Performance

The performance of the APS engine was adequate to fulfill the attitude control and ullaging requirements until APS propellant depletion. The two pitch engines, 1-2 and 2-2, had low chamber pressures at various times during the mission. The ullage engine in module 2 had a slightly extended chamber pressure tail-off after the second ullage engine burn.

Low chamber pressure (85 psia) was first observed at RO +5,565 sec on engine 1-2. This was the first pulse of a series on this engine after not having fired for approximately 100 sec. Prior to this, the firing on this engine was quite extensive. The chamber pressure increased with each successive pulse. The second pulse in the series had a chamber pressure of 92 psia, while the third was 94 psia. Figure 14-4 shows the chamber pressure increase in a series of pulses on the module 2 pitch engine later in the mission. The chamber pressure of the initial pulse was 55 psia, but by the seventeenth pulse the chamber pressure was up to 92 psia. This engine had two steady-state firings of 69 and 64 sec as well as extensive pulsing prior to this time. In figures 14-2 and 14-3 the engine chamber pressures, injector temperature, and propellant temperature are presented as functions of mission time. The propellant temperatures measured in the propellant control module remained within the acceptable region throughout the mission. A correlation, however, can be made between the low chamber pressure of the module 2 pitch engine and the injector temperature. Figure 14-3 shows that as the engine injector temperature increases the engine chamber pressure decreases. A similar correlation could not be made directly on the module 1 pitch engine because module 1 injector temperature data were not obtained after RO +2,500 sec. Because of the extensive firing on engine 1-2 prior to the times when low chamber pressures were observed, it is very likely that the injector temperature was high.

The following conclusions have been reached in regard to the low chamber pressures obtained during the flight. Extensive attitude control engine firing as a result of the booster problems caused high engine injector temperatures. Heat soak back from the engines during the off periods increased the injector temperature and propellant temperatures in the lines near the injector. When the engine valves were opened the drop in line pressure caused oxidizer vaporization and helium liberation. The vapor and gas in the lines reduced the oxidizer flow and resulted in the lower chamber pressure during the initial pulses in a series. As the series of pulses continued the cooler propellants, which were not affected by the high engine temperature, entered the injector and decreased the injector temperature. The oxidizer vaporization was reduced and the oxidizer mass flow increased. This resulted in the chamber pressure increase with successive pulses as shown in figure 14-4.

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Auxiliary Propulsion System

The total APS impulse for the attitude control engines in each module is presented as a function of mission time in figure 14-9. Module 1 had supplied a total impulse of 53,830 lbf-sec for attitude control when the propellants were depleted. The quantity of propellant used for attitude control was approximately 201 lbm. Therefore, the average specific impulse for the module attitude control engines was 268 sec. The module 2 attitude control total impulse at propellant depletion was 55,959 lbf/sec. The quantity of propellant used by module 2 for attitude control was 202 lbm. Therefore, the average specific impulse of the module 2 attitude control engines was 277 sec.

The APS engine total impulse is presented in figure 14-10 as a function of pulse width. The total impulse was obtained by integrating the chamber pressure and multiplying the integral by the thrust coefficient (C_F) and the throat area (A_t). The TRW plus and minus two-sigma impulse variation for single and multiple pulses are included in this figure for comparison purposes. The data points below the TRW two-sigma line are the low performance pulses on the two pitch engines and the pulses which occurred on the engines after the fuel had depleted.

The APS engine average thrust is presented as a function of mission time in figure 14-11. The average thrust of each pulse was determined by dividing the total impulse by the pulse width. TRW nominal plus and minus two-sigma thrust value lines have been included in this figure for comparison. The points which are below the minus two-sigma line are the low thrust values on the pitch engines and the pulses which occurred after fuel depletion.

The slightly extended tail-off (1 sec) of the module No. 2 ullage engine at the end of the second ullage burn is presented in figure 14-12. The module 1 ullage engine chamber pressure is presented for comparison. No tail-off was observed on this engine after the first ullage burn. This slight tail-off is not seen as a problem.

TABLE 14-1
APS PROPELLANT USAGE DURING FLIGHT

| Events | Module No. 1 | | | | Module No. 2 | | | |
|--|----------------|---------|------------|---------|----------------|---------|------------|---------|
| | Oxidizer Usage | | Fuel Usage | | Oxidizer Usage | | Fuel Usage | |
| | lbm | percent | lbm | percent | lbm | percent | lbm | percent |
| Initial load | 188.6 | | 124.4 | | 189.4 | | 124.7 | |
| First burn roll control | 1.6 | 0.8 | 1.0 | 0.8 | 1.6 | 0.8 | 1.0 | 0.8 |
| Engine cutoff to end of first APS ullaging | 28.1 | 14.9 | 21.6 | 17.4 | 14.5 | 7.7 | 11.1 | 8.9 |
| Limit cycle operation | 45.3 | 24.0 | 28.2 | 22.7 | 28.7 | 15.2 | 18.0 | 14.4 |
| Restart preparation (Including second ullage engine burn) | 50.5 | 26.8 | 37.4 | 30.1 | 51.5 | 27.2 | 38.1 | 30.6 |
| Restart attempt to propellant depletion | 63.1 | 33.5 | 36.2 | 29.0 | 93.1 | 49.1 | 56.5 | 45.3 |
| Total usage | 188.6 | 100 | 124.4 | 100 | 189.4 | 100 | 124.7 | 100 |

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Auxiliary Propulsion System

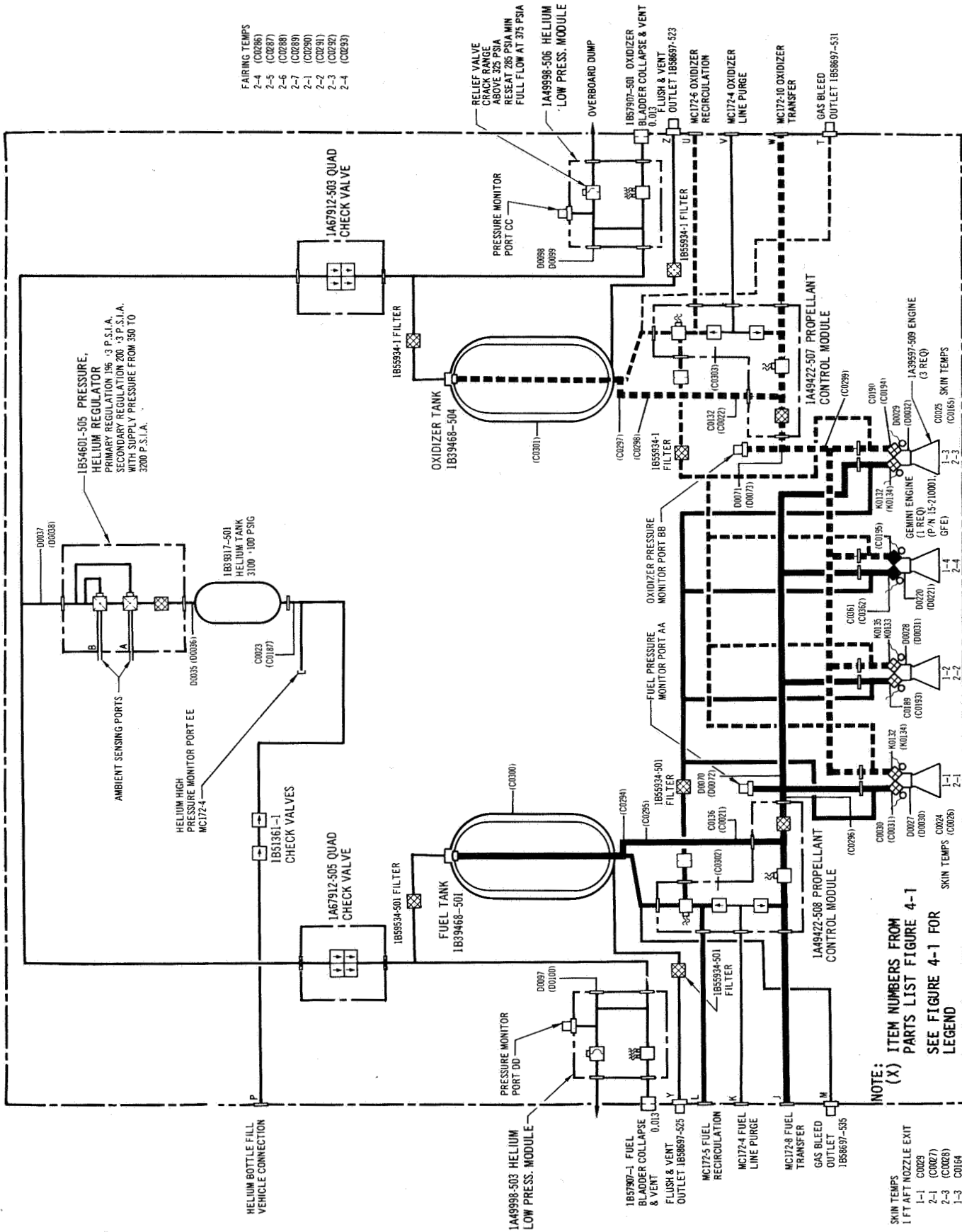


Figure 14-1. Auxiliary Propulsion System and Instrumentation

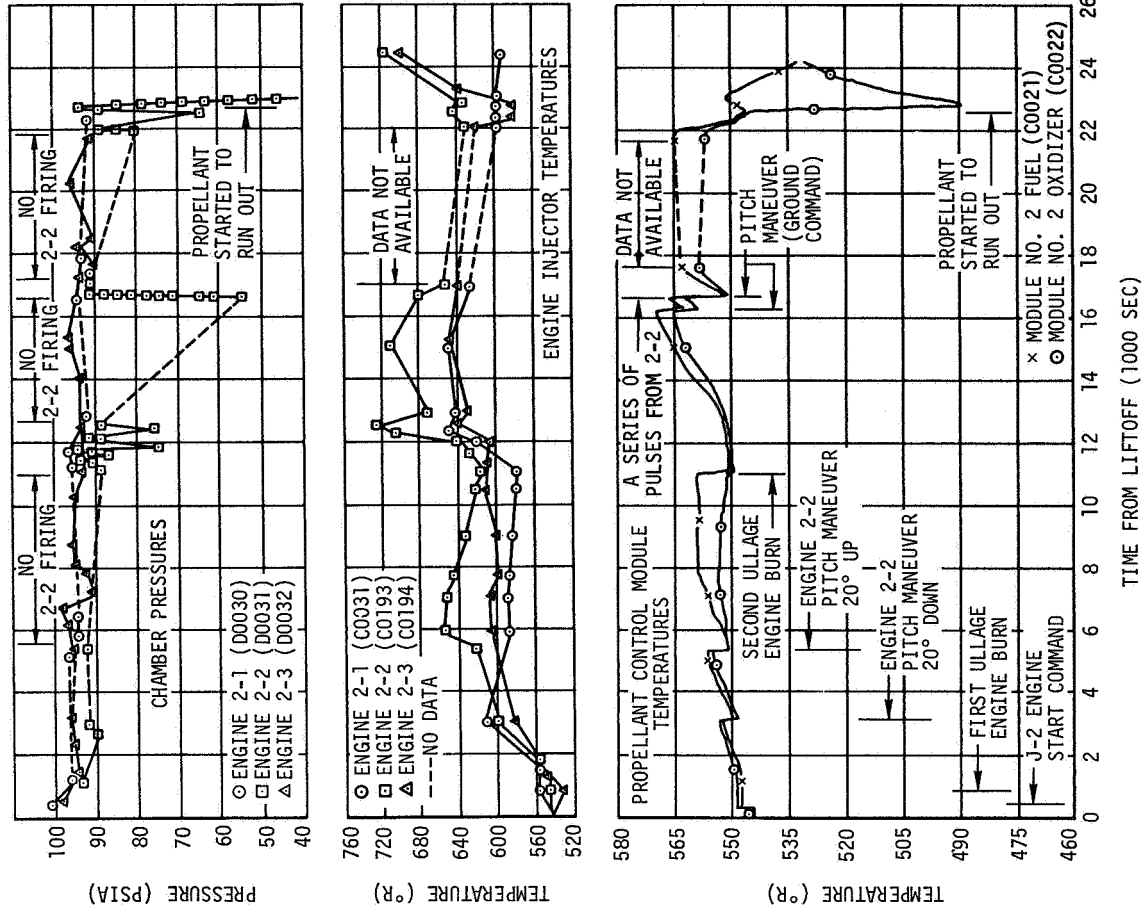


Figure 14-2. Module 1 Performance Correlation

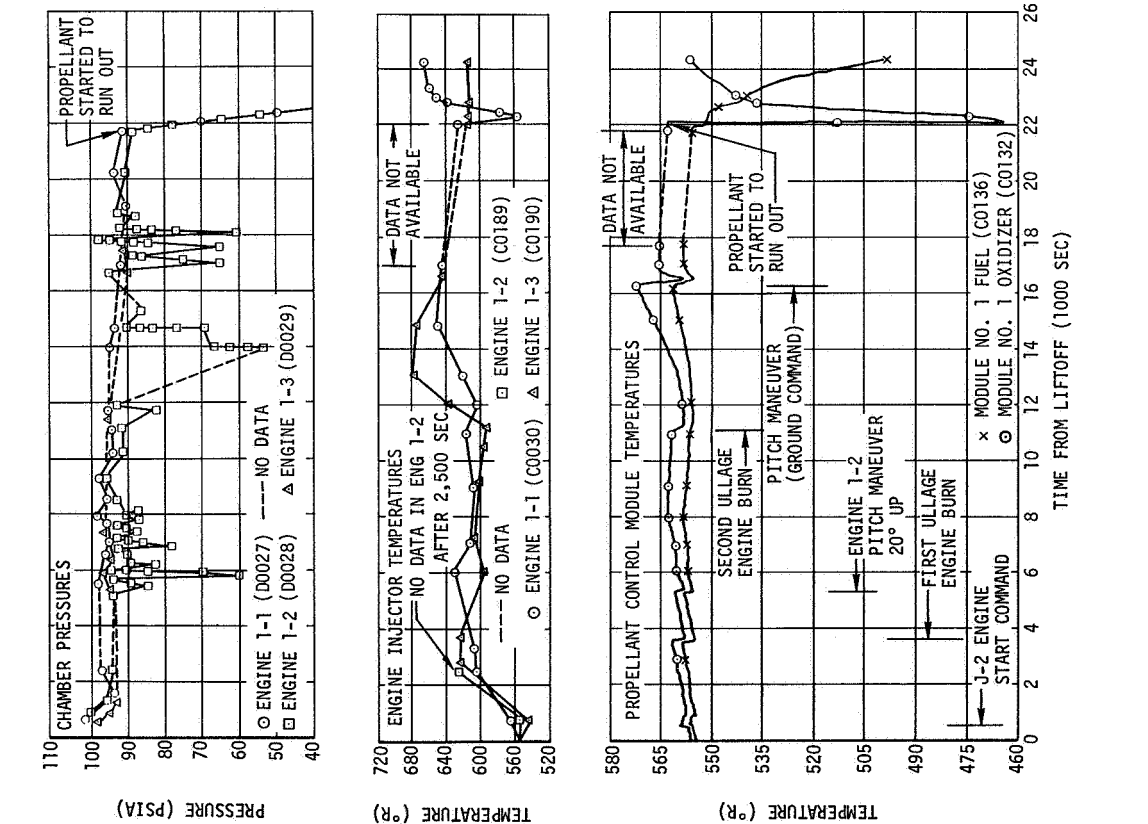


Figure 14-3. Module 2 Performance Correlation

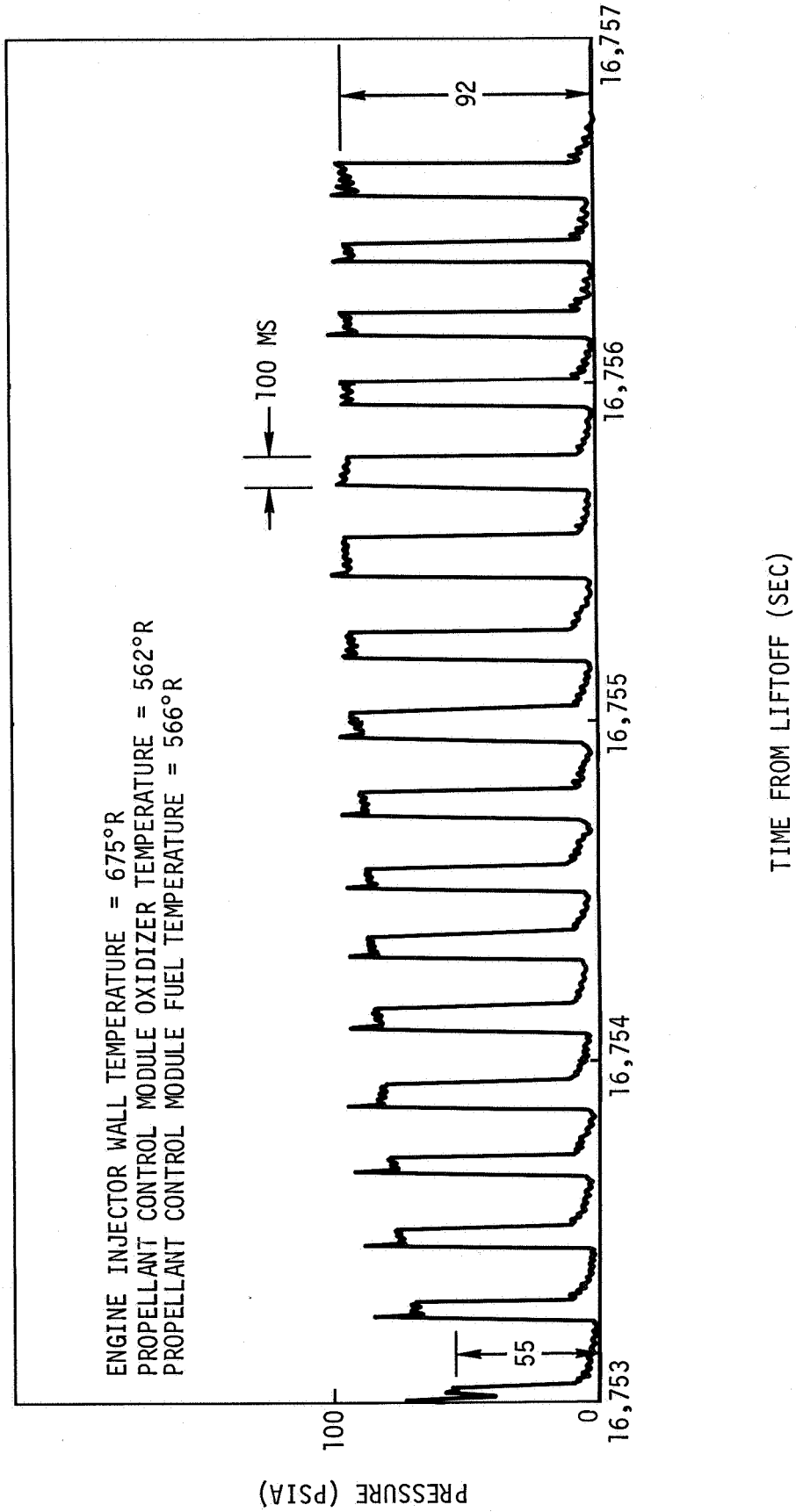


Figure 14-4. Module 2 Pitch Engine 2-2 Chamber Pressure

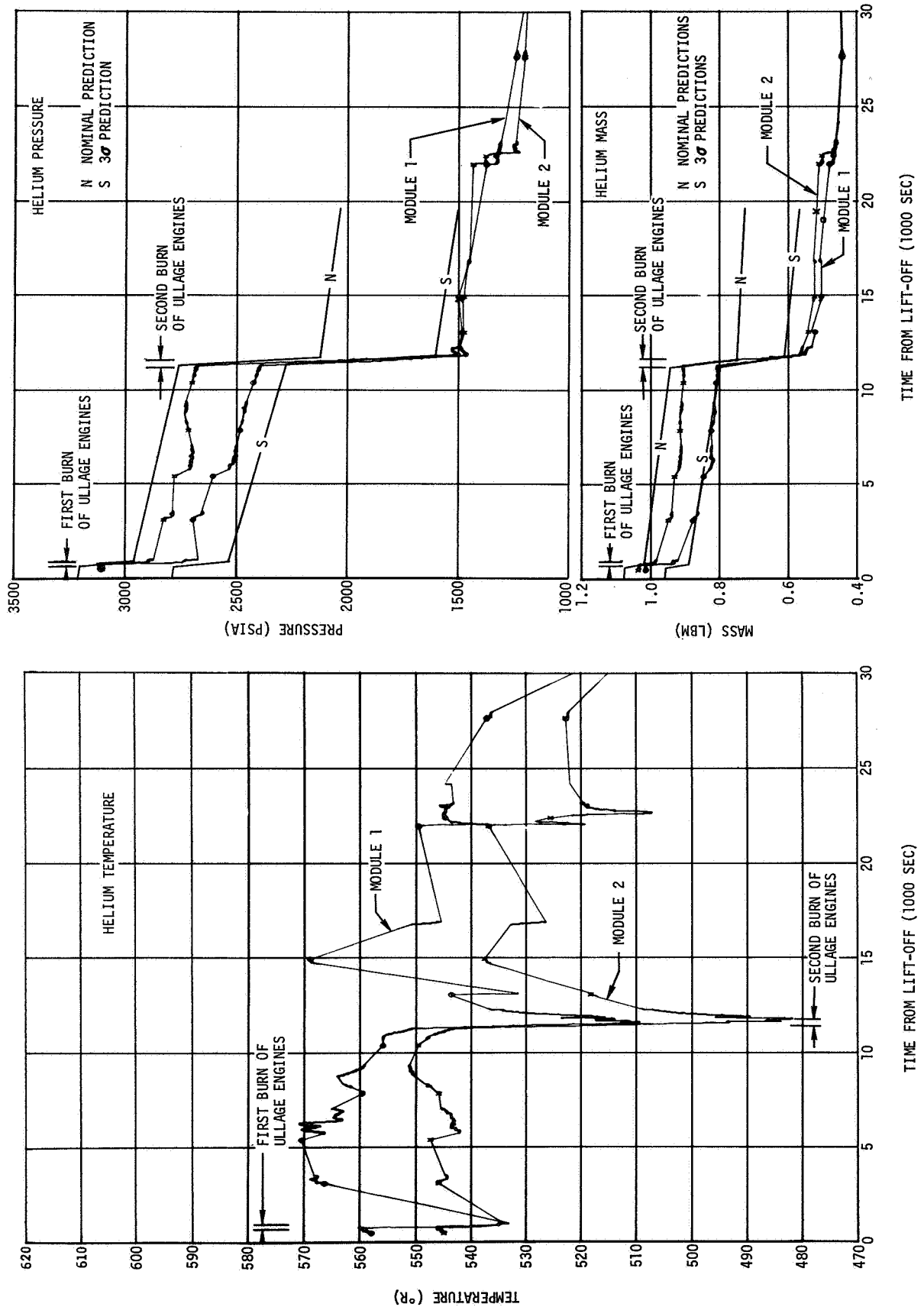


Figure 14-5. Helium Bottle Conditions

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 Auxiliary Propulsion System

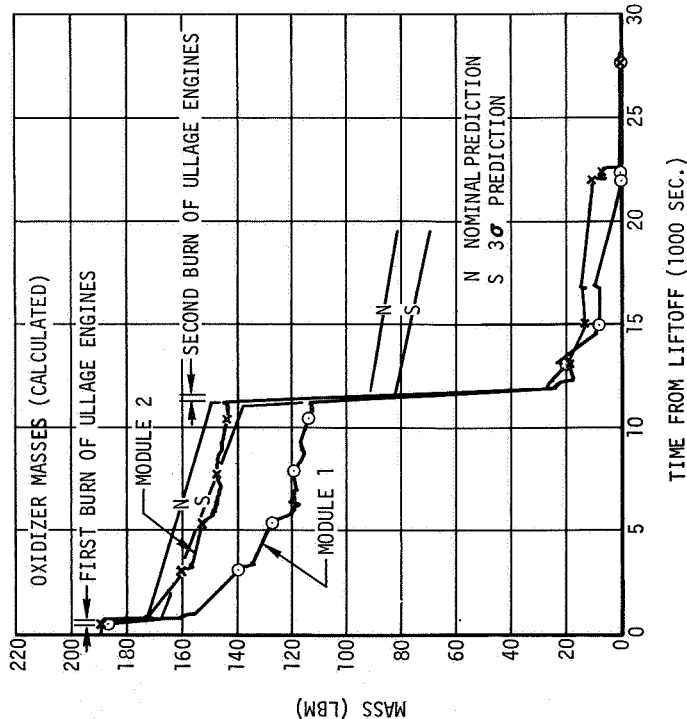
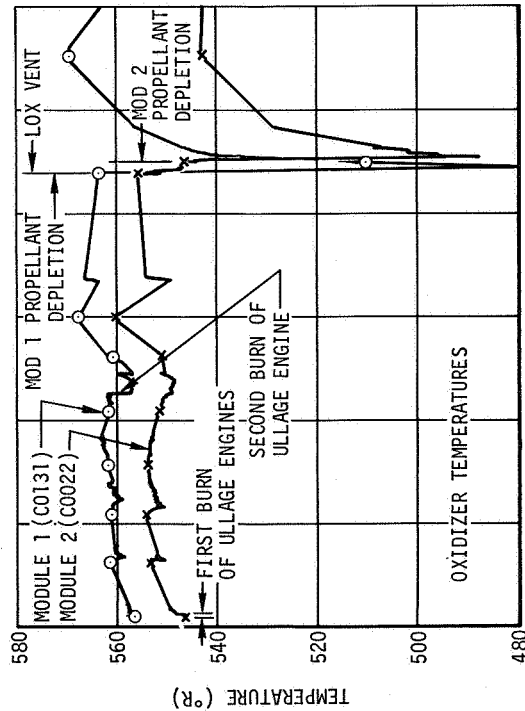
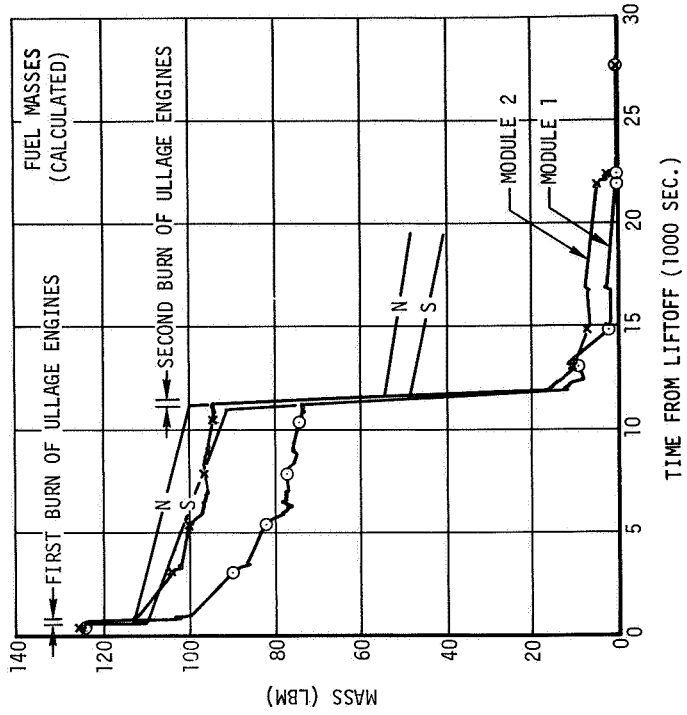
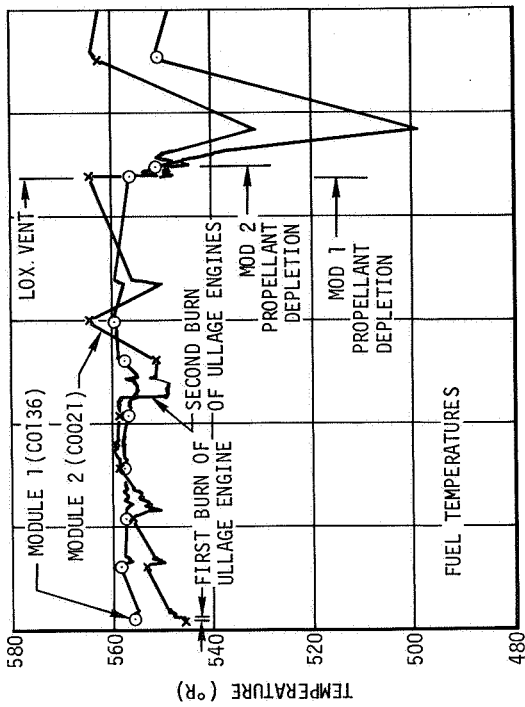


Figure 14-6. APS Propellant Conditions

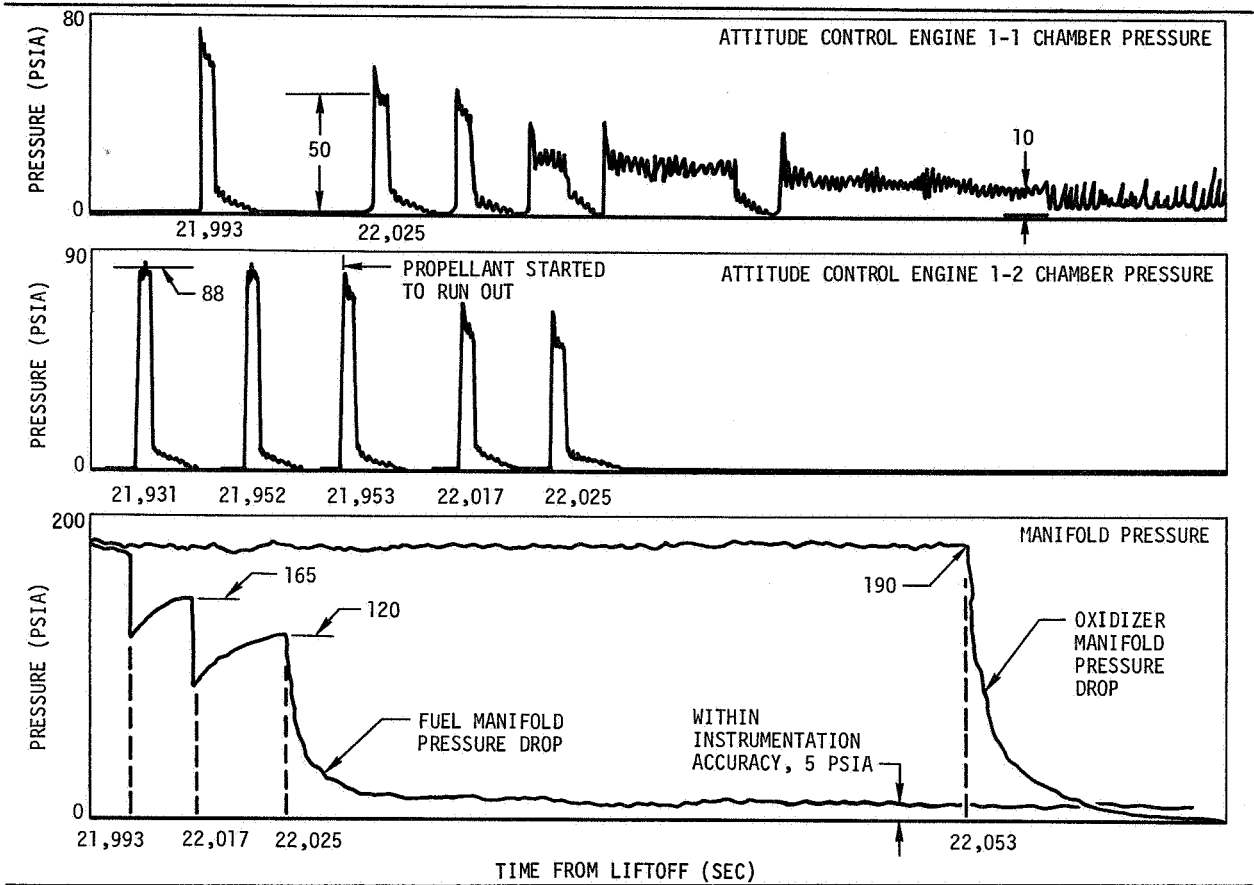


Figure 14-7. APS Module No. 1 Propellant Depletion History

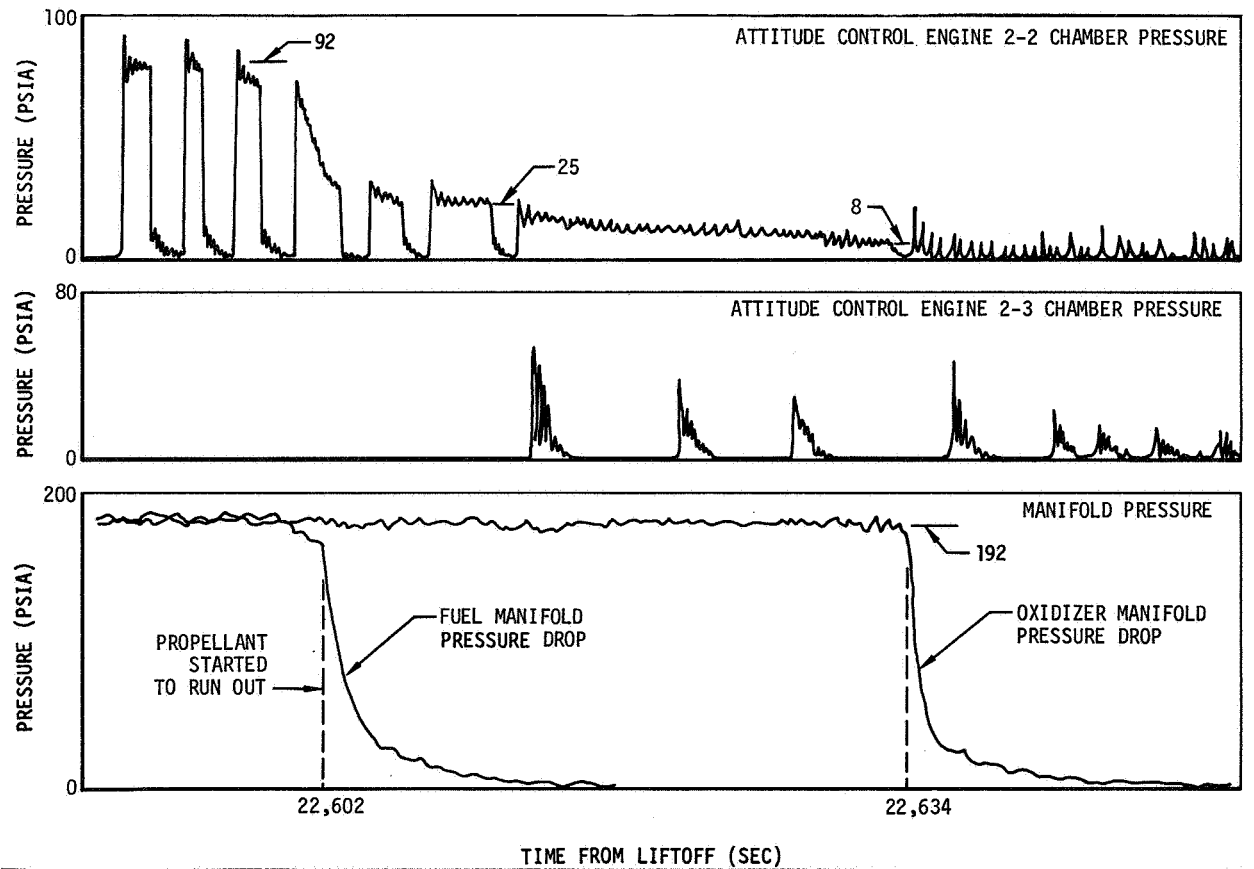


Figure 14-8. APS Module No. 2 Propellant Depletion History

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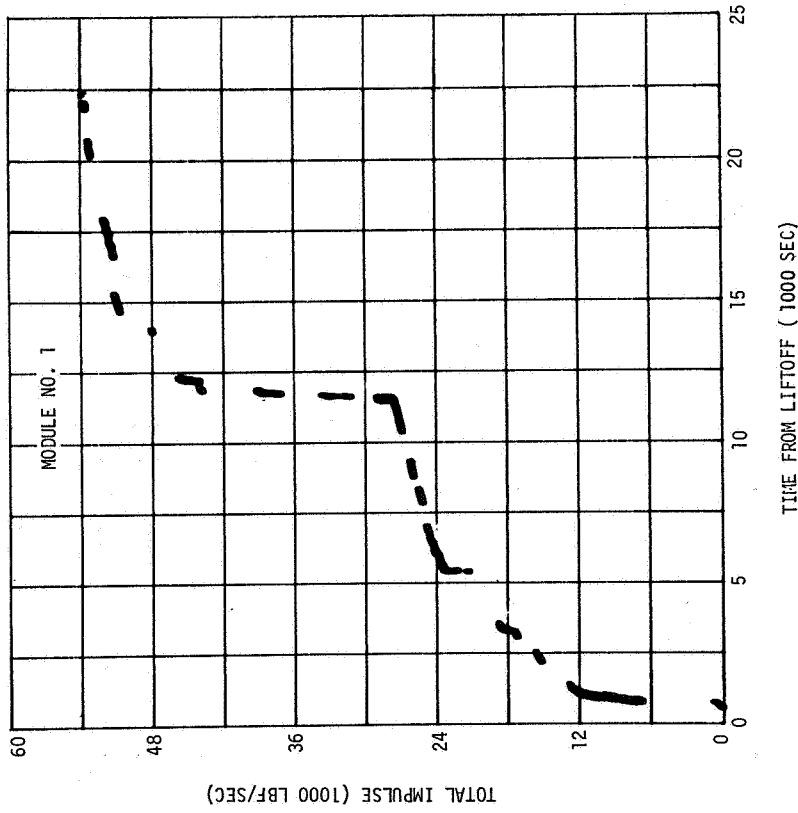
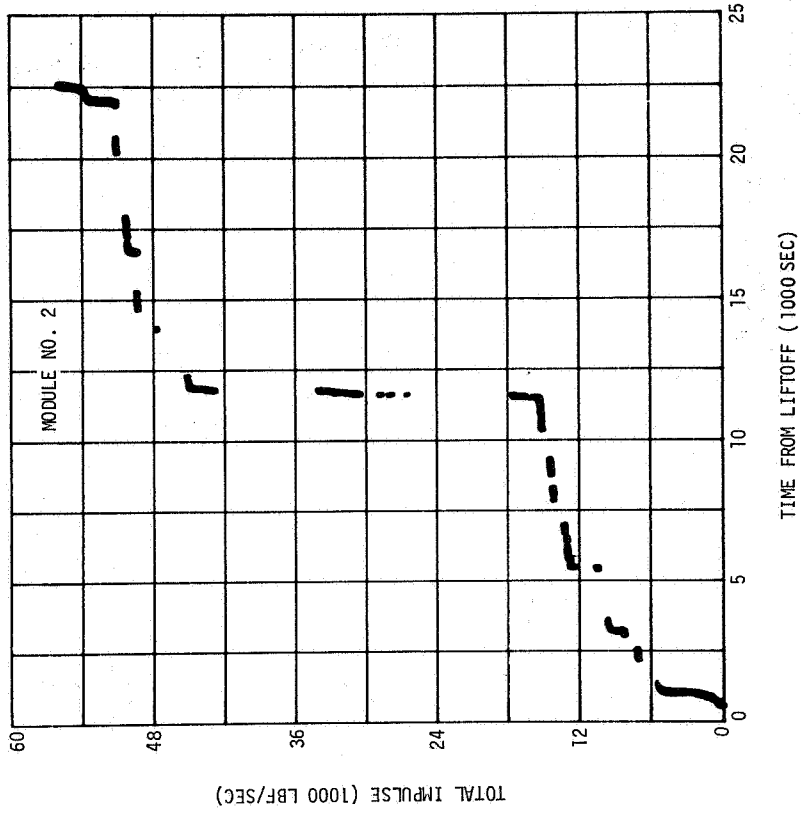


Figure 14-9. APS Total Impulse

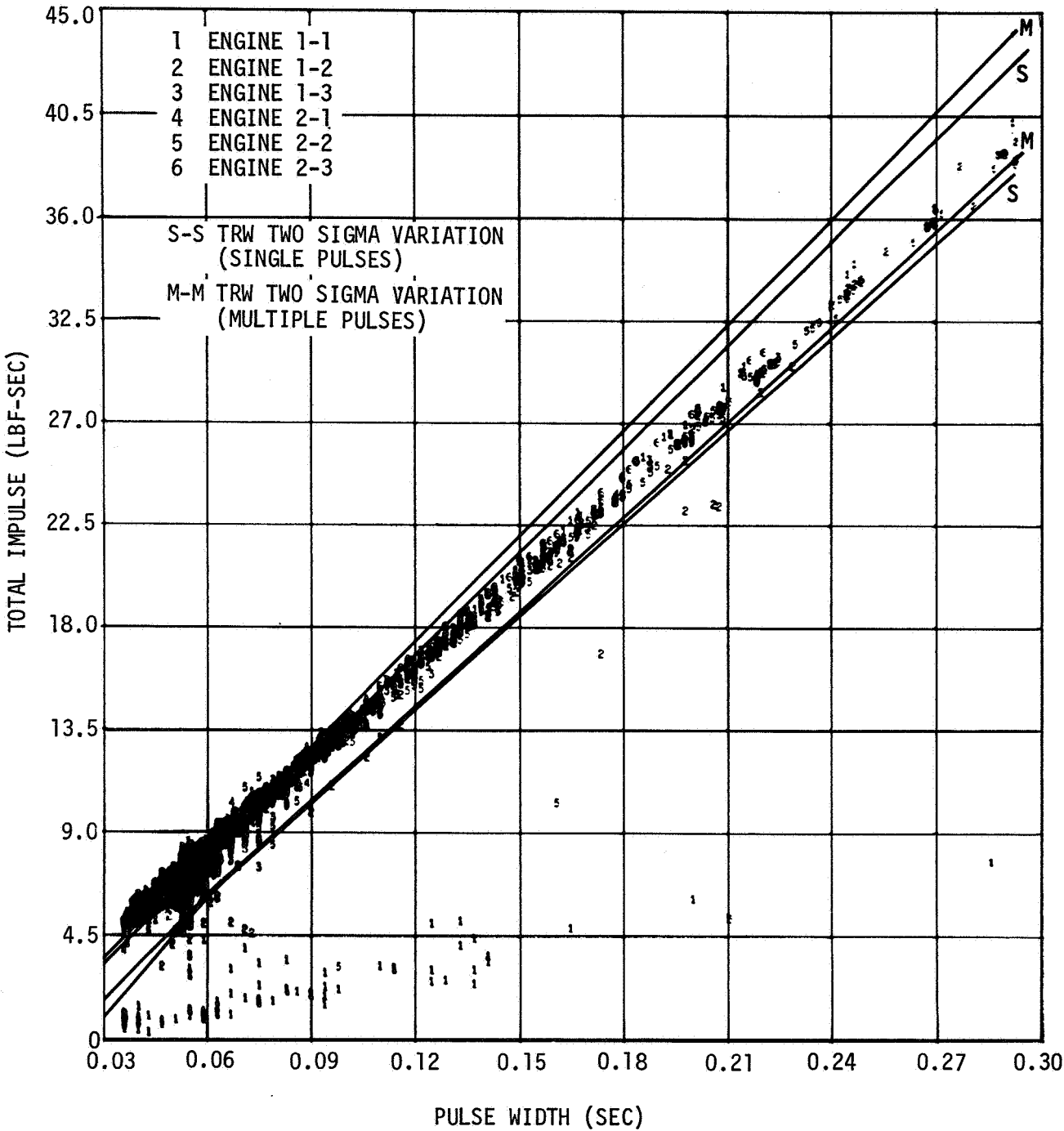


Figure 14-10. APS Total Impulse Per Pulse

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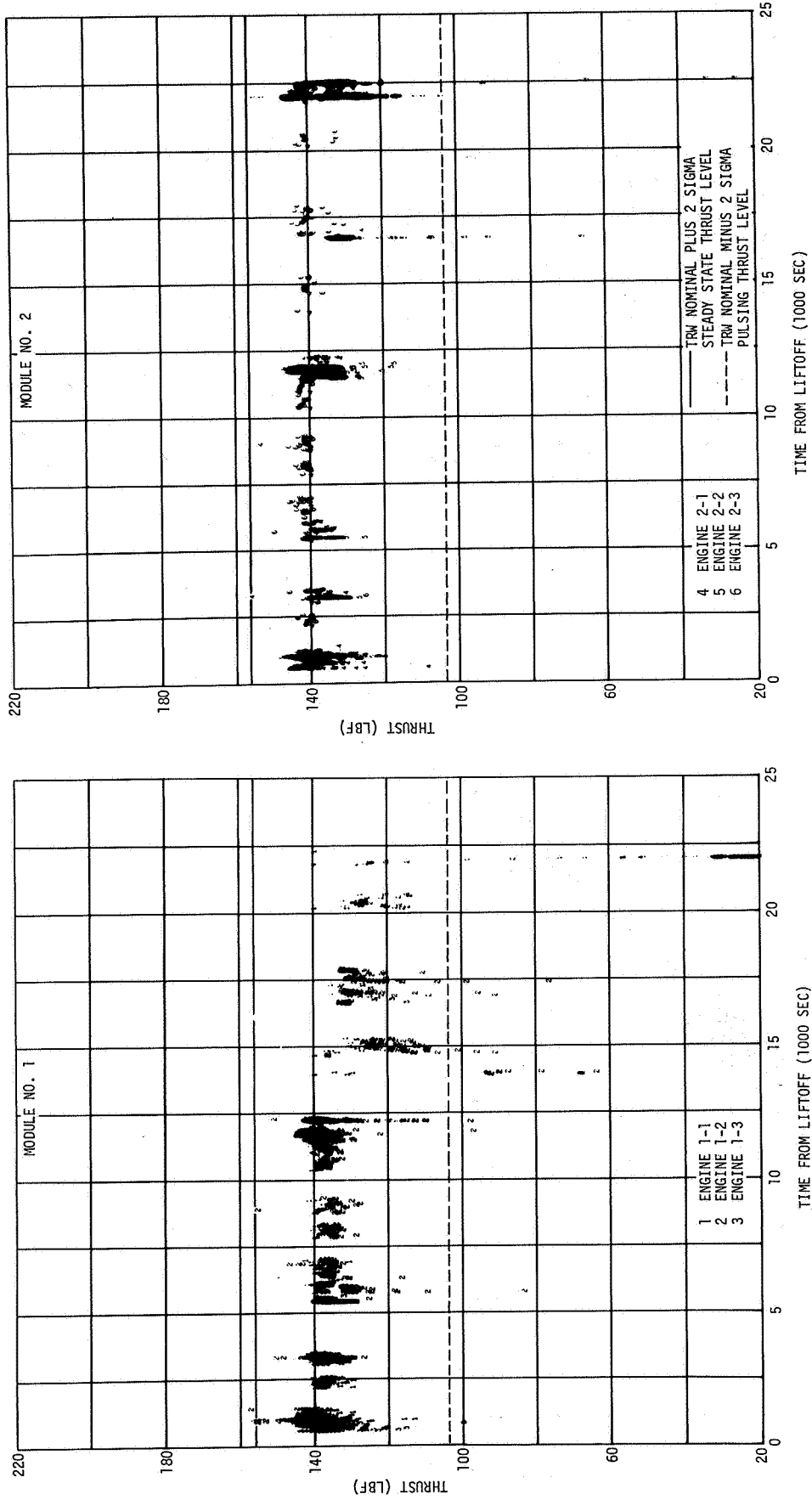


Figure 14-11. APS Thrust

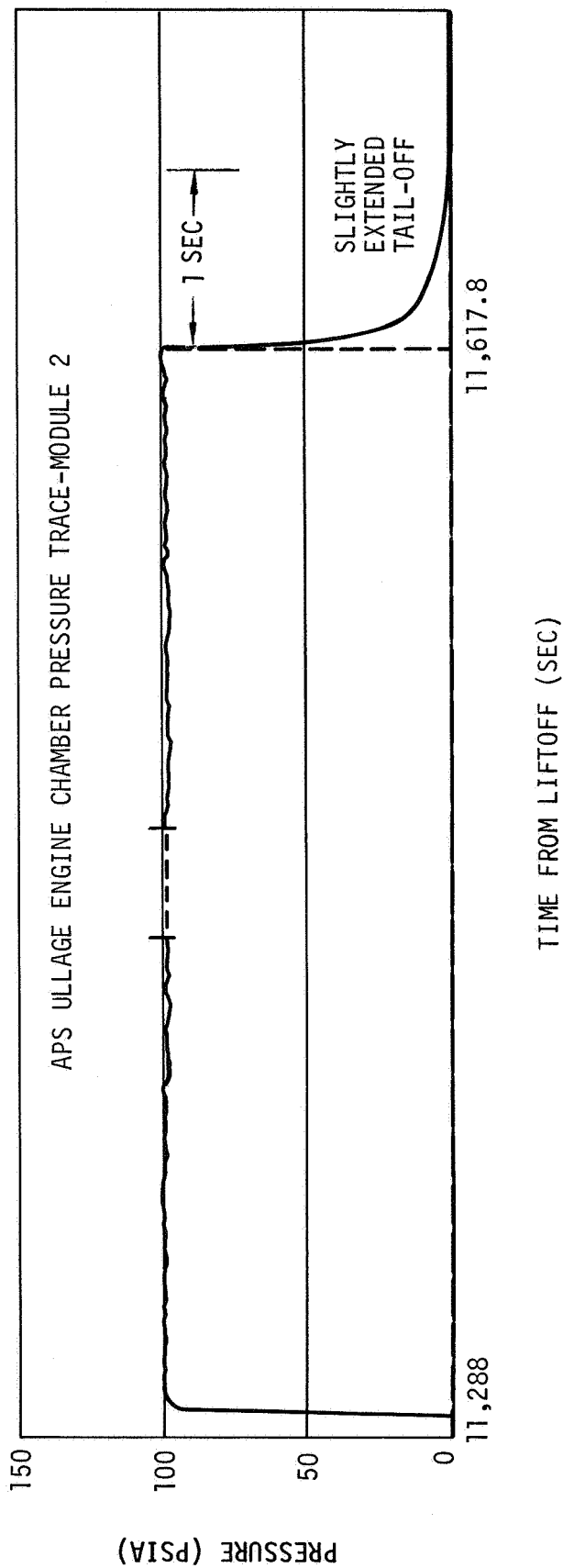
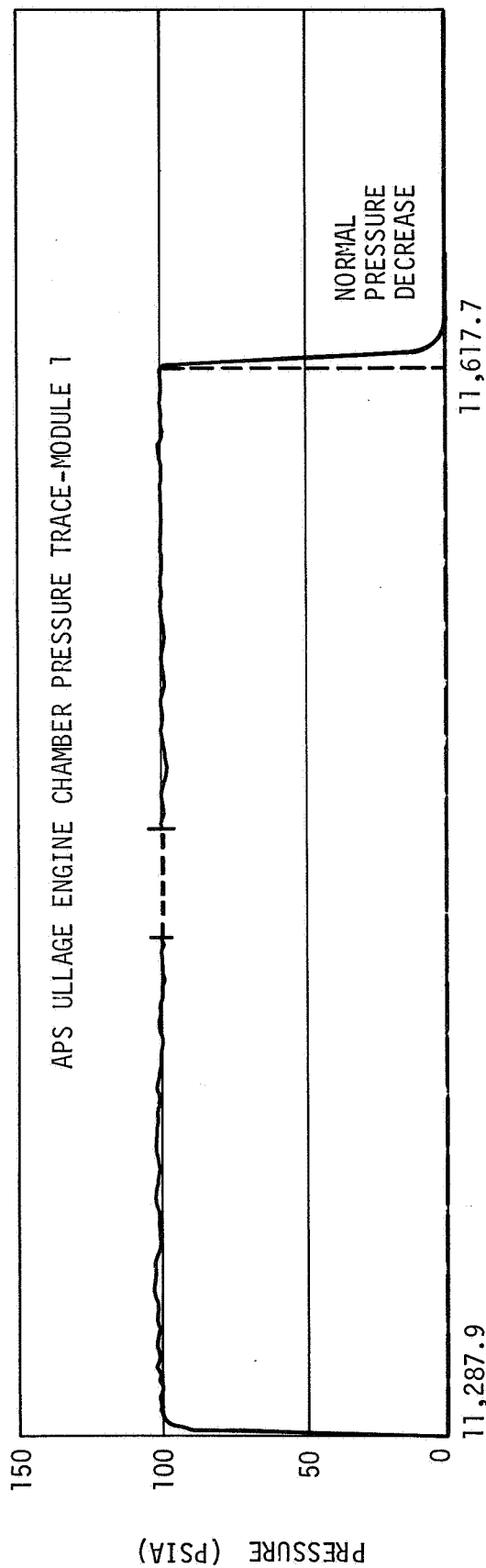


Figure 14-12. APS Ullage Engine Chamber Pressure - Second Burn

SECTION 15

PNEUMATIC CONTROL AND PURGE SYSTEM

15. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 15-1) performed satisfactorily throughout the flight. The helium supply was adequate to meet all mission requirements and to accomplish all purges. The S-IVB-502 was the first to incorporate Sterer actuation control modules, and the modules performed satisfactorily. The orbital leakage rate was near zero.

15.1 Ambient Helium Supply

The pneumatic supply was adequate, and only one deviation in system operation occurred during the flight. The engine pump purge was initiated approximately 0.1 sec before engine cutoff (approximately 7 sec late), and the purge pressure was near operating level within 1.5 sec. This purge initiation is required a minimum of 5 sec before Engine Cutoff Command to ensure that the required conditions are present at the customer connect panel within 0.2 sec of Engine Cutoff Command. The purge is conducted to purge the oxidizer turbine seal, fuel turbine seal, and fuel turbopump primary seal cavities of moisture; to clear the gas generator (GG) combustor of combustion products; and to maintain an inert moisture-free atmosphere at the GG injector face. The only problems likely to be caused by a purge delay are blockage, or partial blockage, of the GG LH2 injector and freezing, or sticking, of the GG LH2 valve poppet. Since the GG was successfully restarted during the second burn attempt, these problems did not occur; therefore, the purge delay had no detrimental effect. The delay was caused by an error in the launch vehicle digital computer (LVDC) time to go equations and was not a fault of pneumatic system components. It is understood that the LVDC contractor is presently studying means to prevent recurrence of this problem.

During the AS-502 countdown demonstration test, the LOX chilldown pump motor container purge pressure (D0103) reached the vent setting (86 psia) before chilldown was initiated and remained at 86 psia throughout the test. The container pressure during the flight showed a similar profile and is compared with the S-IVB-501 flight in figure 15-2. The lower prelaunch container pressure on S-IVB-501 indicates that the prelaunch static leakage was greater on S-IVB-501. The increases in D0103 during the S-IVB-501 chilldowns occurred because the motor seals were dynamic seals which leak less when the pump is running. During engine burn on S-IVB-501, the chilldown pumps were stopped, resulting in an increased leakage rate. This accounts for the decreases in D0103 during both engine burns.

On S-IVB-502 the D0103 pressure decay, which began at liftoff, indicated an increased leakage rate that could have resulted from poor sealing due to vibration or to a chipped seal. Also, tests have shown that seals can change sealing characteristics during the wearing in process, and that they can seal differently at different speeds. On S-IVB-502 and subsequent stages, the chilldown shutoff valves are normally left open during engine

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Pneumatic Control and Purge System

burn, allowing sufficient flow (approximately 10 gpm) to spin the chilldown pump at low speed. Good sealing at slow speed could account for the low leakage rates observed during the S-IVB-502 flight first engine burn.

Therefore, the difference in seal boundary conditions between S-IVB-501 and -502 during boost (S-IVB-502 experienced significant 5 cps longitudinal vibration) and the variance in system configuration (chilldown shutoff valve closed on S-IVB-501 during burn) support the indicated behavior of the system levels.

15.2 Pneumatic Control

Significant valve actuations through the end of first burn and their respective demands on the system are shown in figure 15-3. The control helium regulator discharge pressure (D0014) responded to the J-2 engine anomaly at R0 +700 sec by increasing from 550 to 554 psia, but pneumatic control system performance was not affected by this indicated change in pressure. The control sphere temperature (C0205) during the last half of the engine pump purge was obtained from less accurate tape recorder data, but an extrapolation of the valid data indicated an average mass usage rate of 5.9 scfm, which is near prediction of 6 to 8 scfm. After the engine pump purge was terminated, the mass loss rate was insignificant until R0 +10,877 sec when the prevalues were closed for orbital chilldown (figure 15-4). During the period of prevalue closure the average mass usage rate was 1.7 scfm which agrees very well with predictions. The pneumatic system performance parameters during the restart attempt and during the third and fourth orbits are shown in figures 15-5 and 15-6, respectively. During periods of no pneumatic actuations, the mass loss rate continued to be insignificant (approximately zero).

Pneumatic system performance data at significant times are compared with S-IVB-501 flight and S-IVB-502 acceptance firing data in table 15-1.

TABLE 15-1
PNEUMATIC CONTROL AND PURGE SYSTEM DATA

| Parameter | Units | S-IVB-502 Flight | | S-IVB-501 Flight | | S-IVB-502 Accept | |
|---|-------|------------------|-------------|------------------|-------------|------------------|-------------|
| | | First Burn | Second Burn | First Burn | Second Burn | First Burn | Second Burn |
| <u>Sphere Volume</u> | cu ft | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| <u>Sphere Pressure</u> | | | | | | | |
| At liftoff | psia | 3,063 | -- | 2,921 | -- | 3,205 | -- |
| At Engine Start Command | psia | 3,003 | 2,429 | 2,892 | 1,474 | 3,220 | 2,640 |
| At Engine Cutoff Command | psia | 3,010 | 2,429 | 2,932 | 1,515* | 3,110 | 2,640 |
| <u>Sphere Temperature</u> | | | | | | | |
| At liftoff | deg R | 545 | -- | 547 | -- | 555 | -- |
| At Engine Start Command | deg R | 541 | 496 | 543 | 461 | 549 | 545 |
| At Engine Cutoff Command | deg R | 541 | 496 | 552 | 473* | 549 | 546 |
| <u>Helium Mass</u> | | | | | | | |
| At liftoff | lbm | 8.54 | -- | 8.19 | -- | 9.75 | -- |
| At Engine Start Command | lbm | 8.49 | 7.56 | 8.17 | 5.08 | 8.98 | 7.39 |
| At Engine Cutoff Command | lbm | 8.49 | 7.56 | 8.14 | 5.08* | 8.76 | 7.36 |
| Usage during engine operation | lbm | 0.0 | 0.0 | 0.03 | 0* | 0.22 | 0.03 |
| Usage during 10-min postfiring engine pump purge | lbm | 0.72 | -- | 0.62 | -- | 0.84 | -- |
| <u>Regulator Outlet Pressure</u> | | | | | | | |
| Maintained pressure band | psia | 525 to 560 | 525 to 560 | 520 to 555 | 520 to 540 | 515 to 545 | 515 to 545 |
| Minimum system pressure during start and cutoff transient | psia | 510 | 483 | 420 | 415 | 425 | 425 |
| <u>Average LOX chilldown motor container purge pressure</u> | psia | 42 | 43 | 65 | 59 | 41 | 41 |

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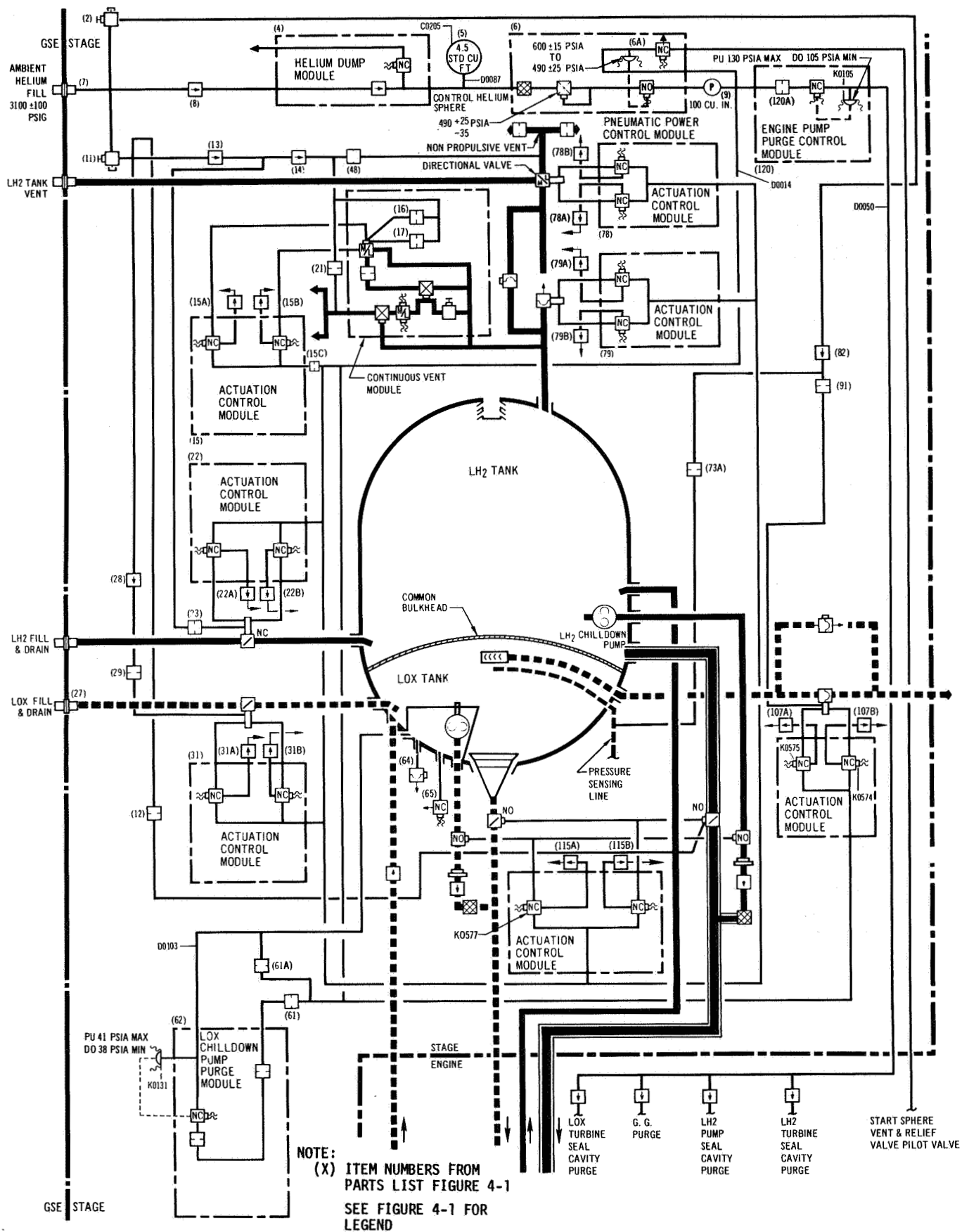


Figure 15-1. Pneumatic Control and Purge System

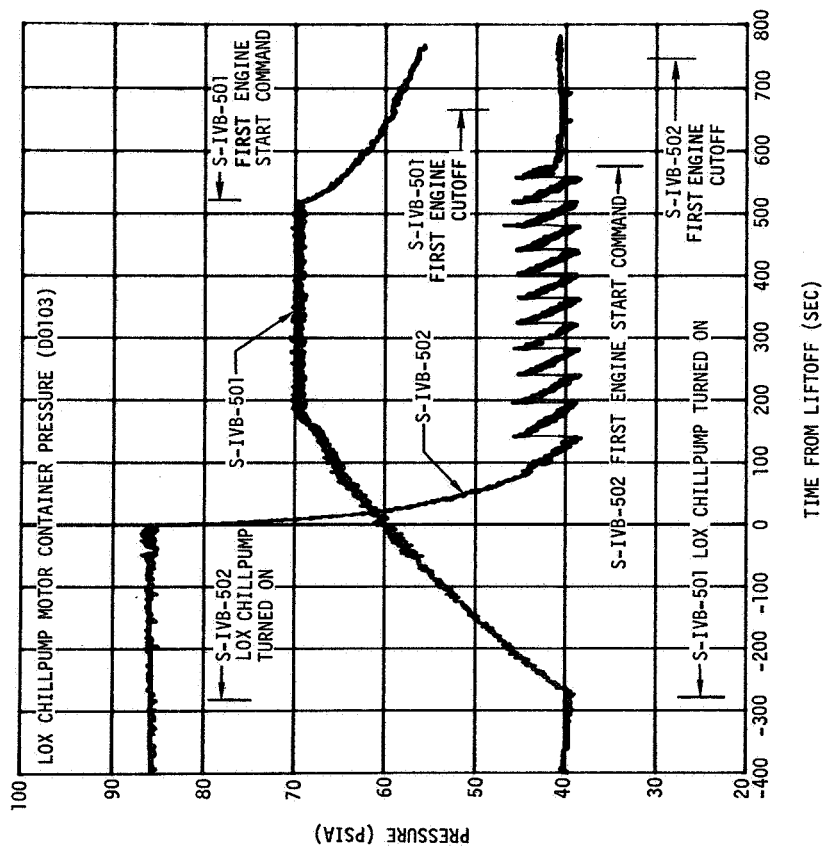
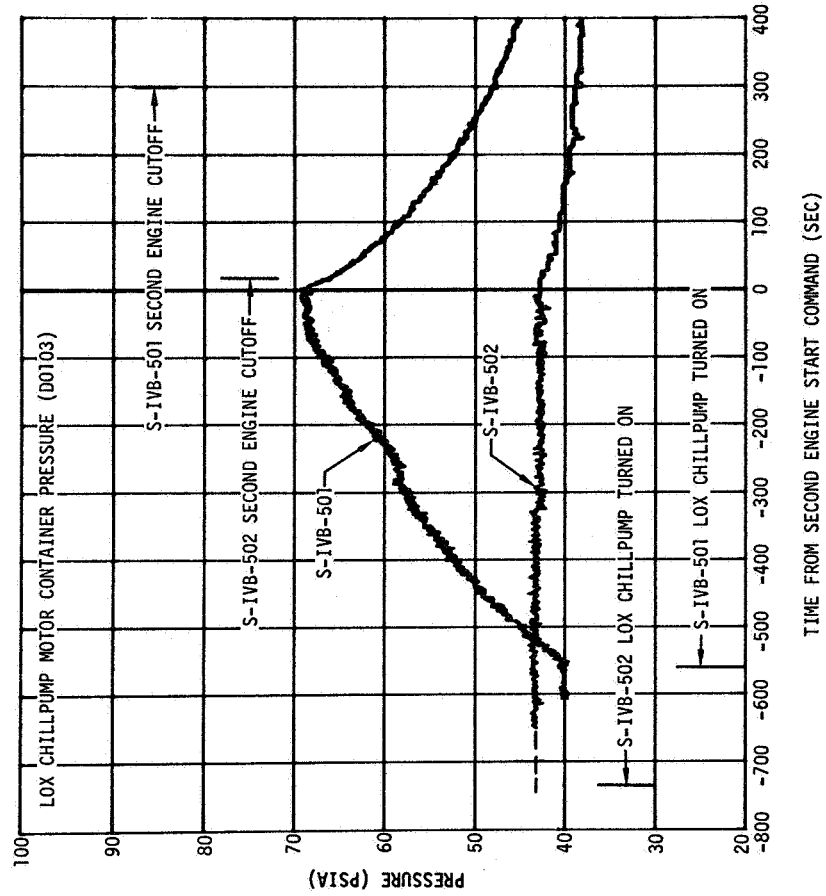


Figure 15-2. LOX Chilldown Motor Container Purge Performance

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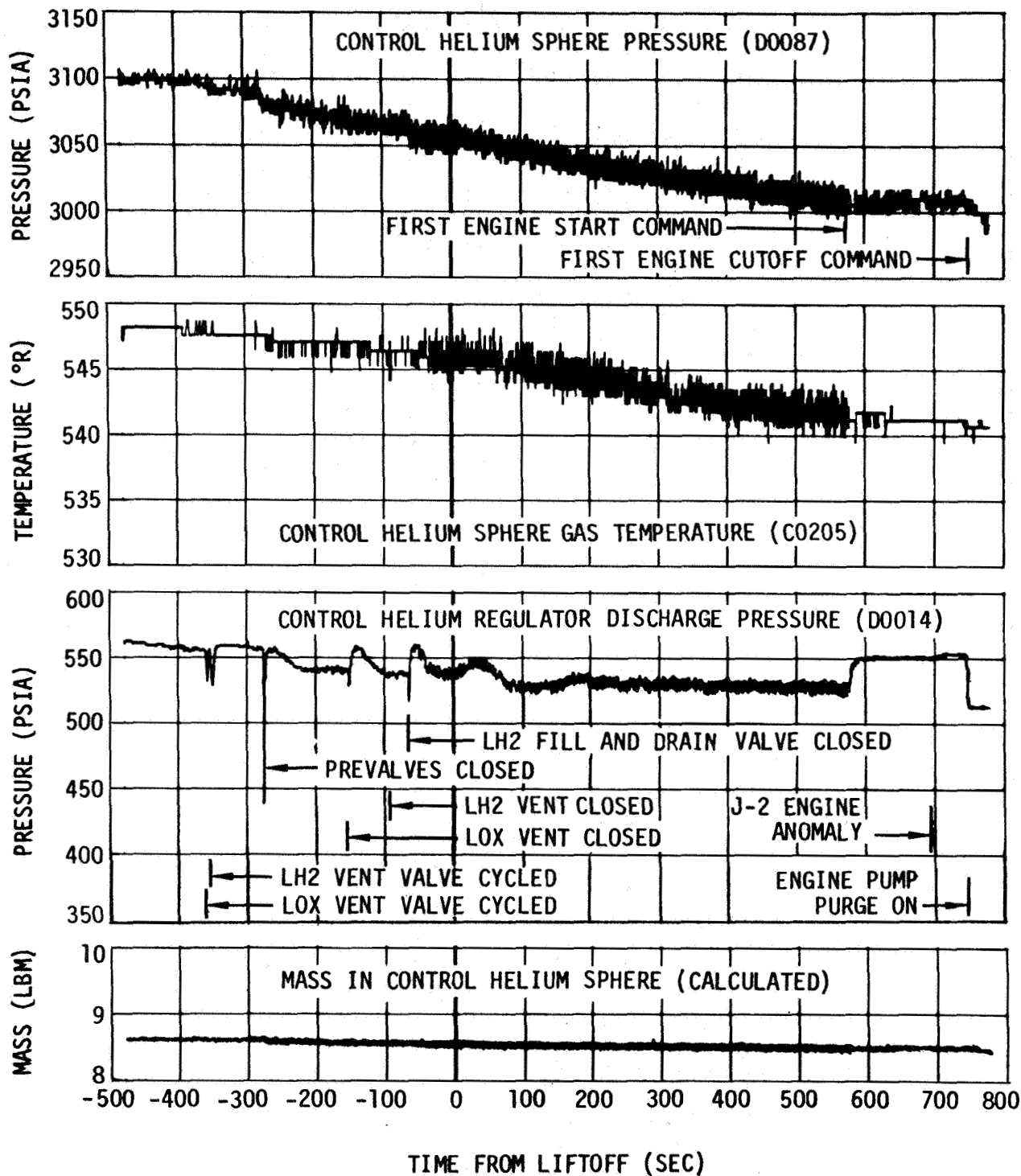


Figure 15-3. Pneumatic Control and Purge System Performance - Boost and First Burn

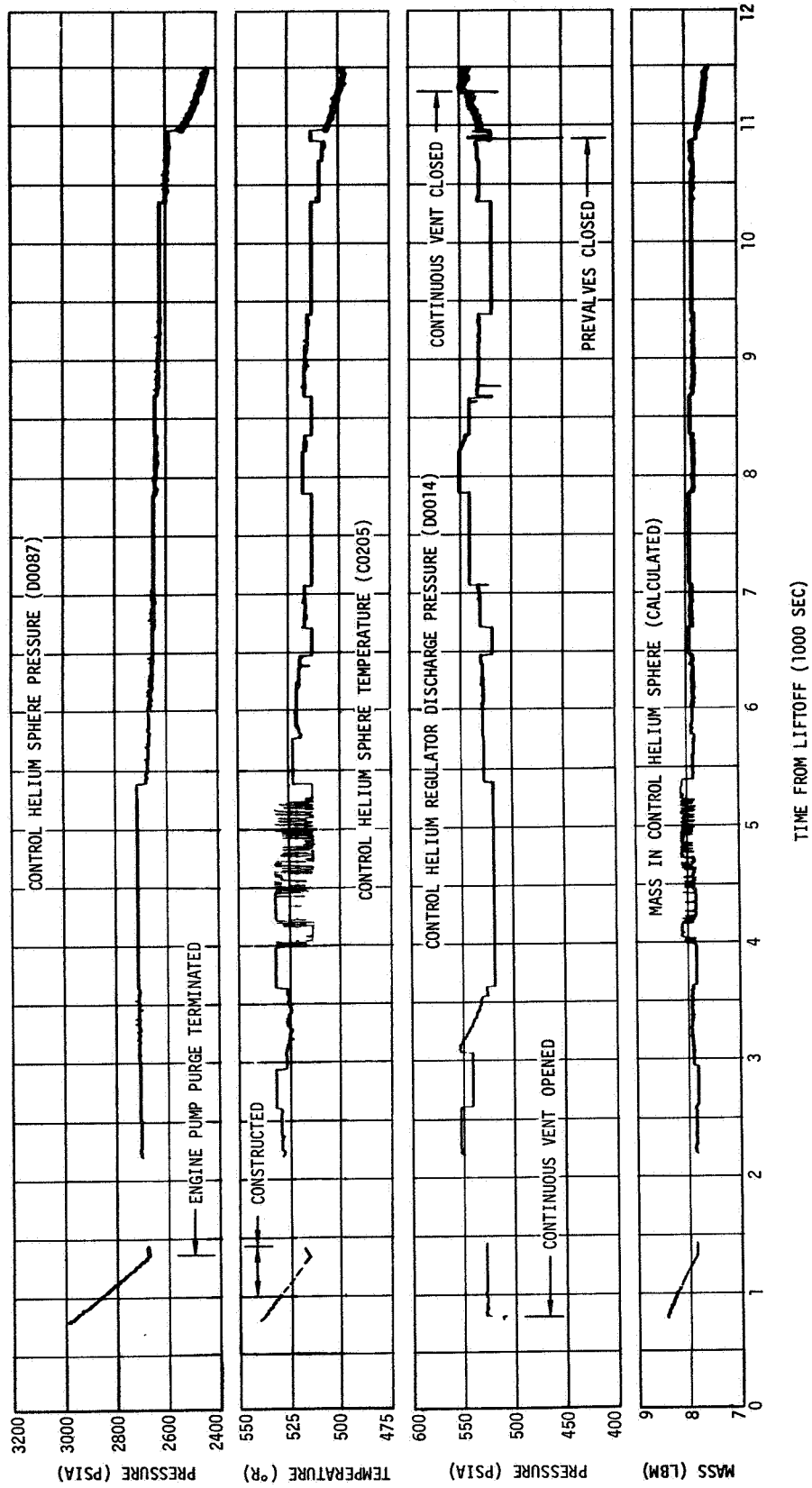


Figure 15-4. Pneumatic Control and Purge System Performance During First and Second Orbits

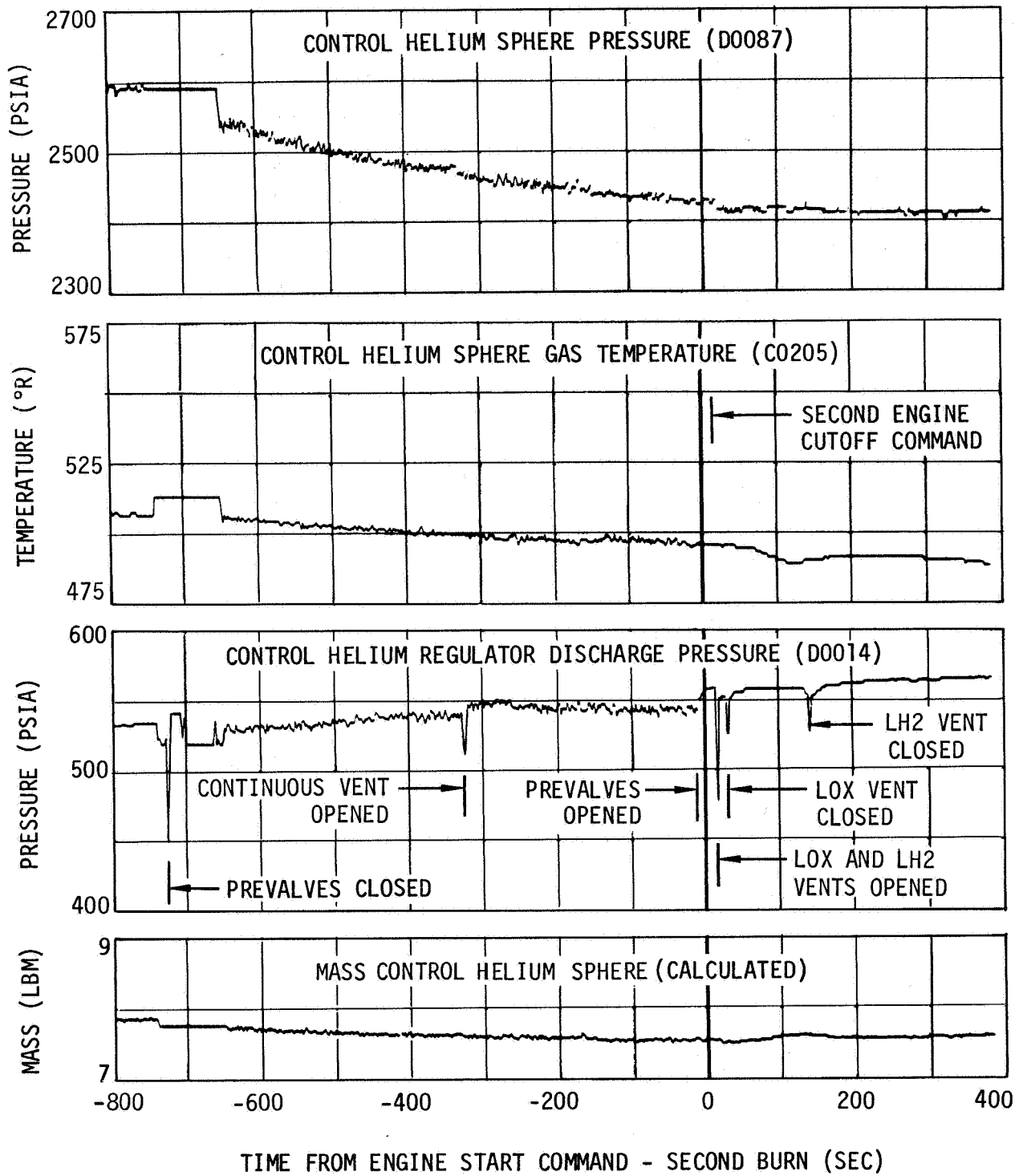


Figure 15-5. Pneumatic Control and Purge System Performance - Second Burn

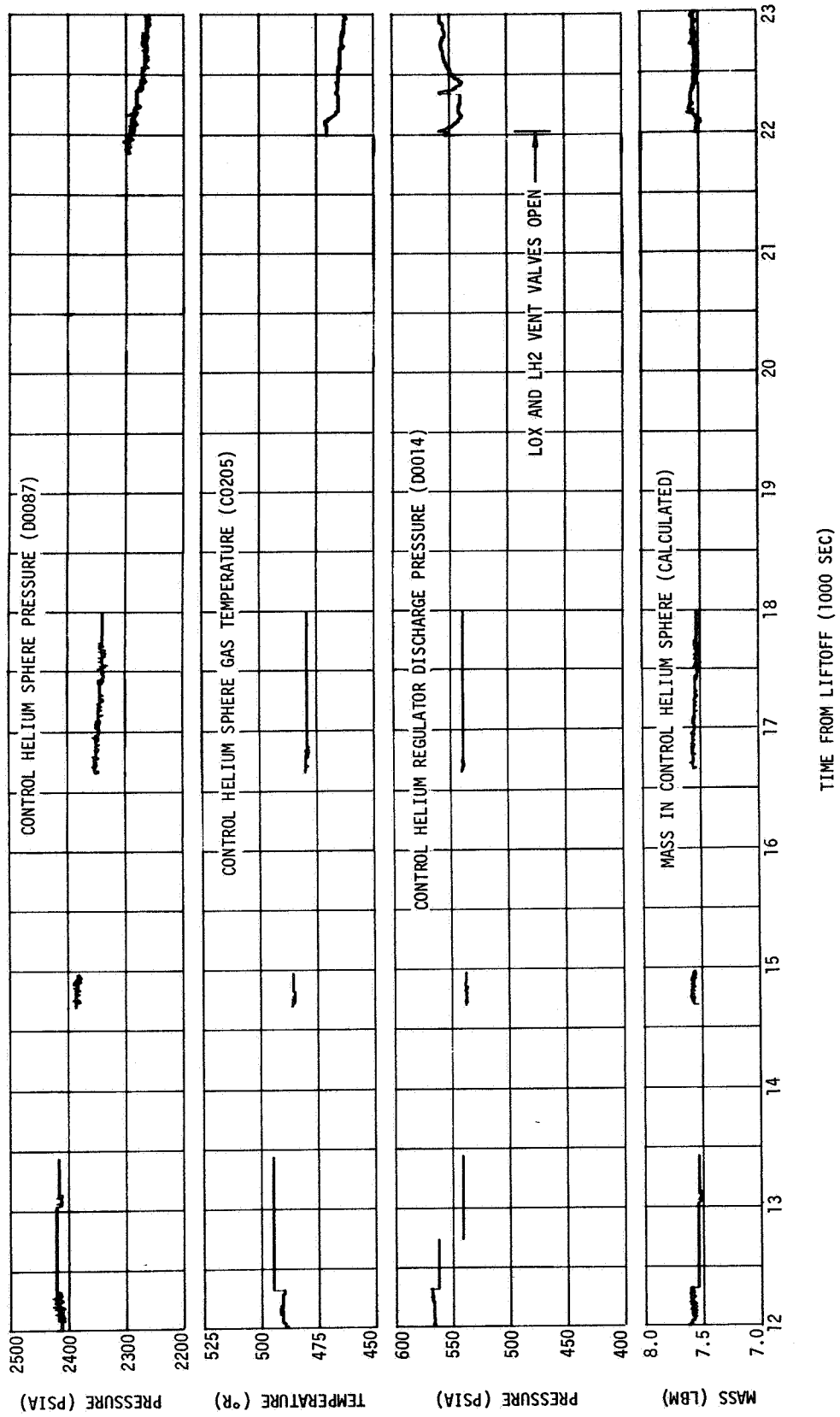


Figure 15-6. Pneumatic Control and Purge System Performance During Third and Fourth Orbits

16. PROPELLANT UTILIZATION

The propellant utilization (PU) system successfully accomplished the requirements associated with propellant loading and first burn propellant management. A LOX mass measurement system malfunction prior to the attempted restart might have prevented proper operation of the PU system during second burn operation, had restart been achieved.

Loading computer indicated full load propellant values at liftoff were 100.07 and 99.88 percent of the desired indicated values for LOX and LH2, respectively. The actual best estimate propellant mass values at liftoff were 194,140 lbm LOX and 42,448 lbm LH2 as compared to the desired mass values of 193,273 lbm LOX and 42,493 lbm LH2. These values are well within the required +1.39 percent stage loading accuracy.

The PU valve slewed to the LOX rich (full closed) position after PU activate and remained in that position for the duration of the extended first burn. Second burn PU valve operation, through restart attempt, was consistent with proper sequencing followed by a response to a LOX mass measuring system anomaly.

Similar to the flight of AS-501 the rising of propellants within the sensors due to capillary action was noted during the low acceleration coast period. During the orbital coast period a malfunction of the LOX mass measuring system occurred, resulting in an indication of a LOX tank overfilled condition. Since restart was not achieved the effect of capillary action on the hydrogen mass probe was not completely removed.

Propellant slosh experienced by the stage had no effect on PU operation during first burn because of the high engine mixture ratio (EMR) operation.

Several tests are in progress to further define the PU system failures mode as well as to evaluate proposed fixes and/or product improvement. The results of these studies are not available for inclusion in this report. However, it should be noted that the aft section of the stage was subjected to a high temperature environment which may have degraded the LOX probe wiring during first burn.

16.1 PU Mass Sensor Calibration

The preflight propellant masses at the desired full load calibration point were determined by extrapolating the S-IVB-502 acceptance firing full load data. S-IVB-502 acceptance firing full load data was determined by the flow integral analysis method.

The propellant masses at the lower calibration point were computed from unique tank volumes and predicted propellant density data. The corresponding capacitance values were determined by adding a mean delta capacitance based on measured data to the S-IVB-502 vendor air capacitance values.

The following table presents a summary of the PU mass sensor calibration data:

| SENSOR | FULL POINT | | EMPTY POINT | |
|--------|------------|------------------|-------------|------------------|
| | MASS (lbm) | CAPACITANCE (pf) | MASS (lbm) | CAPACITANCE (pf) |
| LOX | 193,273 | 412.94 | 1291 | 282.33 |
| LH2 | 42,493 | 1180.29 | 202 | 974.31 |

16.2 Propellant Mass History

The predicted, measured, and best estimate propellant masses at significant flight events are presented in table 16-1. The best estimate propellant masses are derived by subtracting nonpropellants (dry stage, ullage gases, etc.) from AS-502 third flight stage best estimate masses presented in section 9. The remaining propellant mass is then divided into LOX and LH2 according to the prevailing mixture ratio at the specific flight event time.

The propellant mass measurement systems represented in table 16-1 are (a) PU indicated corrected (b) flight flow integral (c) PU volumetric (d) level sensors, and (e) trajectory-reconstruction. A brief description of each measurement system is as follows:

- a. The PU indicated corrected method measures propellant mass from raw PU probe output which is reduced according to the preflight flow integral calibration slope and adjusted for acceptance firing flow integral nonlinearity and PU flight dynamics effects.
- b. The flight flow integral method consists of determining the LOX and LH2 mass flowrates and integrating as a function of time to obtain total consumed propellant masses during engine burn. The flow integral propellant masses at Engine Start Command (ESC) are determined by adding propellant at Engine Cutoff Command (ECC) to the total propellant consumed by the engine, the fuel pressurant added to the ullage, and the propellant lost to boiloff.
- c. The PU volumetric masses are derived from raw PU probe output data which is reduced according to volumetric calibration slopes and adjusted for flight dynamics effects and volumetric tank to sensor mismatch. The calibration slopes (pounds per picofarad) were computed from the capacitance-propellant mass relationships at the upper and lower probe active element extremities. Propellant masses at the extremities were calculated from unique tank volume determined from tank measurements and propellant density.
- d. The level sensor system measures propellant mass at sensor activation and these masses are extrapolated to ignition or cutoff masses by the flight flow integral data. Data was obtained from three level sensors in the LOX tank and four level sensors in the LH2 tank.
- e. The trajectory reconstruction method determines vehicle mass changes from thrust/acceleration relationships.

The results of the five methods of propellant mass evaluation are presented in table 16-1. The flight flow integral, the PU volumetric, and the trajectory reconstruction total propellant masses agree very closely to the best estimate propellant masses. The PU indicated corrected total propellant masses are 881 and 883 lbm less at Engine Start Command and Engine Cutoff Command, respectively, than the best estimate. The level sensor total propellant masses are 879 and 805 lbm more at Engine Start Command and Engine Cutoff Command, respectively, than the best estimate. Propellant consumption values from the various measurement systems agreed favorably with the best estimate consumption values. The maximum deviation in propellant consumption between all measurement systems was 314 lbm.

16.2.1 Propellant Loading

Table 16-2 presents a tabulation of the LOX, LH2, and total propellant masses at liftoff. The desired, measured, and best estimate masses are presented and the deviations of the desired and measured values from the best estimate are shown. The best estimate liftoff propellants are derived from the AS-502 third flight stage best estimate masses presented in section 9 and from the S-IVB stage propellant mass history presented in paragraph 16.2.

The best estimate total propellant liftoff mass was 822 lbm (0.347 percent) greater than desired; the LOX mass was 867 lbm greater and the LH2 mass was 45 lbm less than desired. Both LOX and LH2 loaded masses were well within the specified loading accuracy.

16.2.2 Orbital Boiloff

LOX loss between first burn Engine Cutoff Command and second burn restart preparations was 343 lbm including first burn engine thrust decay and orbital boiloff.

The LH2 boiloff between first burn Engine Cutoff Command and second burn restart preparations was 3,024 lbm. This value was determined by analysis of the LH2 tank ullage gas and continuous vent system (CVS) flowrate analysis (section 13).

16.2.3 PU Nonlinearity Analysis

A comparison of the LOX and LH2 mass sensor nonlinearities as determined by the PU volumetric and flow integral methods is presented in figure 16-1. The volumetric nonlinearities were obtained by normalizing the volumetric total flight corrections to the observed flight full propellant load and propellant sensor empty point. The predicted flow integral nonlinearity was obtained from smoothed acceptance firing data and predicted inflight dynamics effects. The flow integral actual data are smoothed nonlinearities from the flight flow integral analysis, which inflight dynamics effect.

The total correction to the indicated PU mass for volumetric analysis is the sum of the PU flight dynamics correction, propellant tank to sensor mismatch, and the difference in preflight flow integral and volumetric calibration slopes. A discussion of corrections applied are given in paragraphs 16.2.3.1 and 16.2.3.2.

The deviation of the volumetric derived actual nonlinearity from the predicted (volumetric) is less than 50 lbm for both LOX and LH2.

The magnitude of the flow integral nonlinearities compare favorably with predictions. The maximum deviation of flow integral LOX mass sensor nonlinearity from predicted is 180 lbm. The LH2 flow integral mass history demonstrates good agreement with the prediction except at engine start when the LH2 mass nonlinearity deviates by approximately 210 lbm. This condition demonstrates the effects of the LH2 propellant tilt which had resulted from the launch vehicle response to the S-II engine malfunctions.

16.2.3.1 Inflight Dynamics Effects

The PU mass sensor corrections, due to inflight dynamics, are shown in figure 16-2 for the LH2 and LOX tanks. These corrections are the sum of the tank deflection and CG offset corrections as described in the following paragraphs.

The propellant tank deflection correction to the PU indicated mass is caused by tank skin temperature variations and differential tank pressure difference from those experienced during acceptance firing.

Figure 16-3 and 16-4 present a comparison of the predicted and actual flight tank deflection corrections for the LOX and LH2 mass sensors. The predicted LOX correction shows good agreement with the actual postflight evaluation. The slightly lower actual correction for the LH2 sensor was attributed to a lower skin temperature than predicted prior to the flight. Consequently the actual postflight correction due to this effect was 38 lbm less than predicted at S-IVB Engine Start Command.

The offset correction is caused by tilting of the propellant level due to the engine thrust vector passing through the vehicle cg when the cg is displaced from the longitudinal centerline.

Figure 16-5 and 16-6 present the predicted versus the flight evaluation center of gravity offset correction for the LOX and LH2 mass sensors. The difference between the actual and predicted values is due to a MSFC change in the payload distribution prediction. The payload distribution change was not reflected in the predicted values.

16.2.3.2 Volumetric Propellant Tank to Sensor Mismatch

The volumetric propellant tank to sensor mismatch nonlinearity was computed from the vendor's sensor data and measured unique tank volume-height data. The vendor's raw manufacturing nonlinearity was smoothed for the sensor discontinuity introduced during the test procedure. The smoothed S-IVB volumetric tank to sensor mismatch nonlinearity is presented in figures 16-7 and 16-8 for LOX and LH2 respectively. The nonlinearity was normalized to the sensor active element extremities.

16.2.4 Comparison of Level Sensors and Volumetric PU Mass at Level Sensor Activation

Table 16-3 presents the level sensor mass and volumetric PU mass at each level sensor activation during flight. The level sensor masses were computed from propellant volume at the level sensor height location and propellant density at the level sensor activation time.

Figures 16-9 and 16-10 show the deviations between level sensor and volumetric PU mass at level sensor activation times for acceptance firing, countdown demonstration test (CDDT) and flight. In order to compare the level sensor data to the PU data for the three tests, the PU masses for the acceptance firing were recomputed based upon the pounds per picofarad flight calibration slope. This procedure normalizes the volume data so that the differences between level sensor and PU mass for the three tests (acceptance firing, CDDT, and flight) are a measure of system repeatability.

The general trend and magnitude of the deviations for both the LOX and LH2 tanks are approximately the same as experienced for the S-IVB-501. During first burn, there is good agreement between the CDDT and flight data although the magnitude of the deviations are greater than the acceptance firing data. Further analysis will be conducted in view of the similarity between the S-IVB-501 and S-IVB-502 data and the greater than expected mass deviations.

16.3 PU System Response

The first burn PU valve position is illustrated in figure 16-11. During first burn, the PU valve was positioned at null for start and remained there until PU activate at first burn ESC +8 sec. The PU valve was then commanded to the fully closed (high EMR) position at activation and remained there until ESC +171.9 sec, at which time the PU system was deactivated. The extended burntime resulting from the early shutdown of two of the S-II engine caused 30.7 sec of additional S-IVB operation at the LOX-rich stop.

The actual second burn PU valve position is presented in figure 16-12. At RO +11,574.7 sec (40 sec prior to second burn Engine Start Command) the PU valve low hardover command was issued; 0.8 sec later, the PU valve reached the low stop and remained there until ESC +13 sec, at which time PU activate was commanded by the IU. Following PU activate the valve travelled to the high stop in 3 sec, and remained there until PU deactivate (1 sec later). Following PU deactivate, the valve started back toward null but the removal of the PU system power left the valve at 26.7 deg. Had the power not been shut off, the PU valve would have returned to null.

Had restart been achieved, with a normal LOX mass system operation, it is highly probable the PU system would have described the revised second burn prediction (figure 16-13). This prediction is based on the actual S-IVB first burn and coast data which included the initial LOX overload, extended S-IVB first burn operation, and boiloff data.

During the second revolution, the LOX mass bridge experienced disturbances on nine different occasions which caused the LOX bridge to slew toward the full stop. On each occasion the bridge subsequently recovered except for the last disturbance at RO +11,091 sec of flight when the LOX mass bridge slewed to the full mechanical stop and remained there for the remainder of the S-IVB mission.

Had second burn been sustained with the PU system in the malfunctioned mode, the engine would have operated in the high EMR mode until velocity cutoff. In that mode, guidance cutoff is predicted to occur at second burn ESC +263 sec. In the high EMR hardover malfunction mode, propellant depletion would occur at second burn ESC +265 sec.

16.4 PU System Anomalies

PU system operation was normal during the CDDT and during propellant loading for the S-IVB-502 flight. AS-502 liftoff was at 12:00:01 and first burn engine cutoff occurred approximately 747 sec after liftoff. During this period, PU system operation was normal as shown in figure 16-14. The EMR valve was positioned at 5.5:1 to provide the high thrust required during this initial portion of flight. Some time after engine cutoff, the PU electronics indicated the expected capillary action on both the LOX and LH2 PU probes.

Data is available for the periods: RO +5,400 to RO +6,300 sec, RO +10,300 to RO +10,800 sec, and RO + 10,960 sec up to and including the restart attempt. Figure 16-15 shows that data available for the period RO +10,960 sec through restart. Prior to RO +10,610 sec, the LOX mass bridge indicated that the probe was completely filled with propellant. The PU electronic assembly calibration for the S-IVB would allow the coarse mass indication to read approximately 4.5 vdc and the fine mass indication to indicate approximately 2.2 vdc when the probe is completely filled.

At RO +10,610 and RO +10,635 sec into flight, the LOX bridge began to slew at the maximum rate toward the full stop. The bridge recovered each time within 1 sec and operation returned to normal. At RO +10,660 sec, the LOX bridge again slewed at maximum rate to the full stop indicating an over-full indication. The LOX bridge remained in this position until data dropout, which occurred at RO +10,880 sec. The next available data beginning at RO +10,960 sec shows the bridge had recovered at some period during data dropout.

At RO +10,967 sec into flight, the LOX bridge again slewed at the maximum rate indication an over-full condition. The bridge recovered within 3 sec and operation returned to normal. At RO +11,066, RO +11,072, RO +11,087, and RO +11,090 sec the fine mass again indicated an anomaly by starting to slew towards the full stop at the maximum rate. Each of these malfunctions were of less than 1 sec duration. At RO +11,091 sec the bridge slewed at maximum rate and this time reached the full mechanical stop of the output potentiometer. The bridge did not recover from this position for the remainder of the S-IVB mission.

16.4.1 Failure Analysis

The PU system is an inflight, closed-loop, propellant-mass-ratio control system consisting of two capacitance mass probes, an electronics assembly, and a liquid oxygen flow-control valve with valve-positioning assembly.

The PU system provides continuous 0-5 vdc analog output signals of the propellant masses. These outputs are obtained from the coarse and fine mass telemetry potentiometers and are sent to the stage telemetry system for transmission to the ground station.

In operation, indicated LOX mass is compared to the product of indicated LH2 mass times the predetermined propellant mass-ratio reference. The difference between the actual and predetermined propellant mass is then used to proportionally control the LOX pump bypass flowrate, thereby altering the EMR. A change in the EMR produces a change in the remaining propellant mass ratio.

The LOX mass bridge is a servo balanced capacitance type which converts changes in propellant mass to a proportional output voltage. The bridge consists of a capacitance mass probe in one leg, a stable reference capacitor mounted in a temperature controlled oven in another leg, and transformer voltage sources in the third and fourth leg. Figure 16-16 is a schematic diagram of the servo balanced bridge.

The capacitance of the mass probe changes in direct proportion to the variations in propellant mass. This change in capacitance will unbalance the bridge, resulting in an output signal to the bridge amplifier, which in turn drives the servomotor and rebalance potentiometer to seek a null condition. When rebalance occurs, no output is developed by the bridge network, and therefore, the motor and potentiometer will remain in that position.

In order for the capacitance bridge to slew at maximum rate toward the full stop, it is necessary to have a condition which causes the bridge to unbalance so that the rebalance potentiometer will attempt to null at or past the full stop.

In order to create such a condition in the PU electronics assembly, an open circuit is required in the full adjust potentiometer, rebalance potentiometer, or reference capacitor. These open circuits are indicated by X's on the schematic diagram shown in figure 16-16.

The over-full condition could also be caused by the LOX mass probe or its associated cabling. Figure 16-17 indicates the failure modes of the capacitance probe. Summarized below are the four probe and/or cabling failures which could cause the bridge to slew to the full stop.

a. The Inner Element Shorted to Ground

This will cause the bridge to slew at a slow rate to the full stop.

b. The Inner Element Shield Shorted to the Outer Element

This will cause the bridge to slew at maximum rate to the full stop if the short is no greater than 2K ohms.

c. Inner Element Shield Open

This will cause the bridge to slew at maximum rate to the full stop.

d. The Inner Element Shorted to the Outer Element

This will cause the bridge to slew at maximum rate to the full stop.

The intermittent operation of the LOX bridge prior to restart tends to indicate a condition which eliminates component failures such as resistors, transistors, capacitors, etc. The anomaly appears to be of the type present with either an open wire/cable shield or a short between probe elements.

16.4.2 Anomaly Conclusions

At this time there appears to be two possible causes for the PU system anomaly noted during the S-IVB flight. These causes are:

- a. An intermittent cable shield between the mass probe and the PU electronics assembly.
- b. Metallic debris of some type in the LOX tank which caused a short between the inner and outer elements of the LOX PU probe.

PU system operation was normal during first burn and the first appearance of the bridge anomaly occurred during orbiting conditions. Debris in the tank during orbital conditions could be distributed anywhere in the tank and possibly lodge between the probe elements. As the PU system operation was normal during powered flight while the LOX mass probe, its associated cable and PU electronics assembly, were under the highest vibration levels experienced during flight, the possibility of an intermittent cable shield appears to be remote. Therefore, the most probable cause of the PU system anomaly was metallic debris in the LOX tank shorting the inner and outer element of the LOX probe, thus causing the LOX bridge to slew at a maximum rate to the over-fill condition.

Figure 16-18 shows the slew rates of the LH2 bridge during the failure that occurred on the S-IVB-503N at Sacramento, the slew rate of the LOX bridge during the S-IVB-502 flight, and the lab test data obtained on a PU system breadboard at Space Systems Center, Huntington Beach, when a LOX mass probe failure was simulated by shorting the elements of a simulated mass probe.

TABLE 16-1
PROPELLANT MASS HISTORY

| EVENT | PREDICTED MASS (lbm) | PU INDICATED MASS (lbm) | PU INDICATED CORRECTED MASS (lbm) | FLIGHT FLOW INTEGRAL MASS (lbm) | PU VOLUMETRIC MASS (lbm) | LEVEL SENSOR MASS (lbm) | TRAJECTORY RECONSTRUCTION MASS (lbm) | BEST ESTIMATE MASS (lbm) |
|---|-------------------------------------|------------------------------|-----------------------------------|---------------------------------|------------------------------|------------------------------|--------------------------------------|--------------------------------|
| LIFTOFF (RO +0) | 193,273 42,493 235,766 | 193,412 42,442 235,854 | 193,412 42,482 235,894 | 194,097 42,440 236,537 | 194,272 42,266 236,538 | 194,893 42,569 237,462 | -- -- 236,526 | 194,140 42,448 236,588 |
| ESC 1 (RO +577.28) | 193,273 42,493 235,766 | 193,136 42,154 235,290 | 193,272 42,430 235,702 | 194,097 42,440 236,537 | 194,122 42,214 236,336 | 194,893 42,569 237,462 | -- -- 236,526 | 194,135 42,448 236,583 |
| ECC 1 (RO +747.30) | 132,047 31,185 163,232 | 119,991 28,580 148,571 | 118,551 28,542 147,093 | 119,166* 28,494* 147,660 | 119,145 28,265 147,410 | 119,875 28,590 148,465 | -- -- 147,726 | 119,166* 28,494* 147,660 |
| CONSUMPTION (ESC 1 TO ECC 1) | 61,226 11,308 72,534 | 73,145 13,574 86,719 | 74,721 13,888 88,609 | 74,931 13,946 88,877 | 74,977 13,949 88,926 | 75,018 13,979 88,997 | 74,869 13,931 88,800 | 74,969 13,954 88,923 |
| ORBITAL BOILOFF (ECC 1 TO RE-START PREPS) | LOX 120 LH2 2,964 TOTAL 3,084 | -- -- -- | -- -- -- | 343 3,024 3,367 | -- -- -- | -- -- -- | -- -- -- | -- -- -- |
| ESC 2 (RO +11,614.67) | 131,402 28,168 159,570 | -- -- -- | -- -- -- | 118,723 25,470 144,193 | -- -- -- | -- -- -- | -- -- -- | -- -- -- |
| ECC 2 (RO +11,630.32) | LOX N/A LH2 N/A TOTAL N/A | -- -- -- | -- -- -- | 117,030 24,950 141,980 | -- -- -- | -- -- -- | -- -- -- | -- -- -- |

*Best estimate residual propellants

Section 16
Propellant Utilization

TABLE 16-2
PROPELLANT LOADING SUMMARY

| ITEM | LOX (lbm) | LH2 (lbm) | TOTAL (lbm) |
|-------------------------------------|---------------|---------------|----------------|
| PROPELLANT LOAD | | | |
| Desired | 193,273 | 42,493 | 235,766 |
| PU indicated | 193,412 | 42,442 | 235,854 |
| PU indicated (corrected) | 193,412 | 42,482 | 235,894 |
| Flight flow integral | 194,097 | 42,440 | 236,537 |
| PU volumetric | 194,272 | 42,266 | 236,538 |
| Level sensor | 194,893 | 42,569 | 237,462 |
| Trajectory reconstruction | -- | -- | 236,526 |
| Best estimate | 194,140 | 42,448 | 236,588 |
| DEVIATION FROM BEST ESTIMATE | | | |
| Desired | -867(-0.447%) | +45(+0.106%) | -822(-0.348%) |
| PU indicated | -728(-0.375%) | -6(-0.014%) | -734(-0.310%) |
| PU indicated (corrected) | -728(-0.375%) | +34(+0.080%) | -694(-0.293%) |
| Flight flow integral | -43(-0.022%) | -8(-0.019%) | -51(-0.022%) |
| PU volumetric | +132(+0.068%) | -182(-0.429%) | -50(-0.021%) |
| Level sensor | +753(+0.388%) | +121(+0.285%) | +874(+0.369%) |
| Trajectory reconstruction | -- | -- | -62(-0.026%) |

TABLE 16-3
LEVEL SENSOR AND VOLUMETRIC PU MASS AT
LEVEL SENSOR ACTIVATION DURING FLIGHT

| LEVEL SENSOR | ACTIVATION TIME (sec) FROM RO | LEVEL SENSOR MASS (lbm) | VOLUMETRIC PU MASS (lbm) | DEVIATION LEVEL SENSOR-PU (lbm) |
|-------------------|-------------------------------------|----------------------------------|--------------------------------|---------------------------------------|
| (LOX TANK) | | | | |
| L0013 | 586.2 | 193,508 | 192,906 | +602 |
| L0012 | 626.1 | 174,946 | 174,491 | +455 |
| L0011 | 687.1 | 147,354 | 146,761 | +593 |
| (LH2 TANK) | | | | |
| N0023 | 596.4 | 141,349 | 40,994 | +355 |
| N0024 | 637.8 | 37,800 | 37,450 | +350 |
| N0025 | 685.6 | 33,809 | 33,437 | +372 |
| N0026 | 731.8 | 29,898 | 29,580 | +318 |

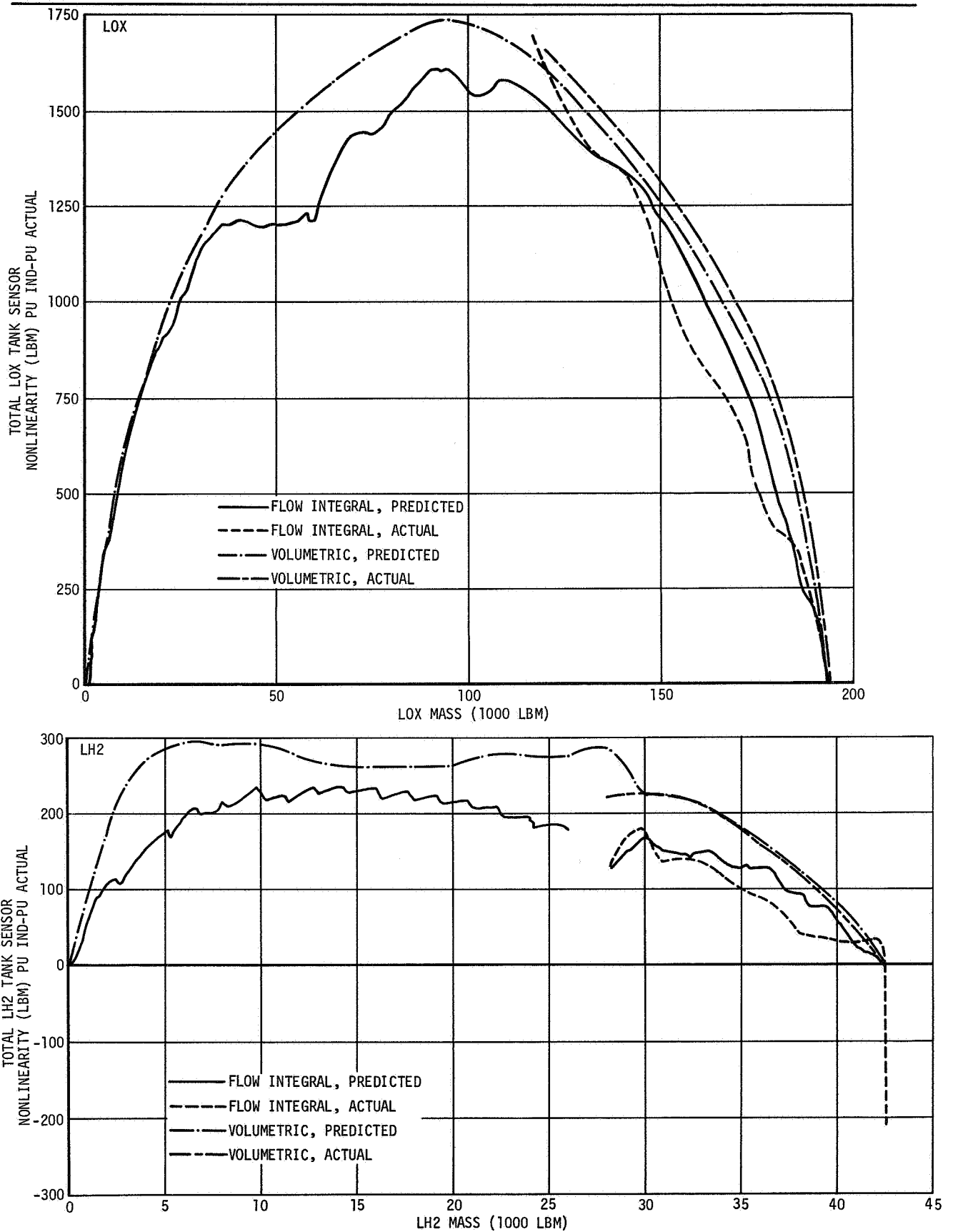


Figure 16-1. Total Mass Sensor Flight Nonlinearity

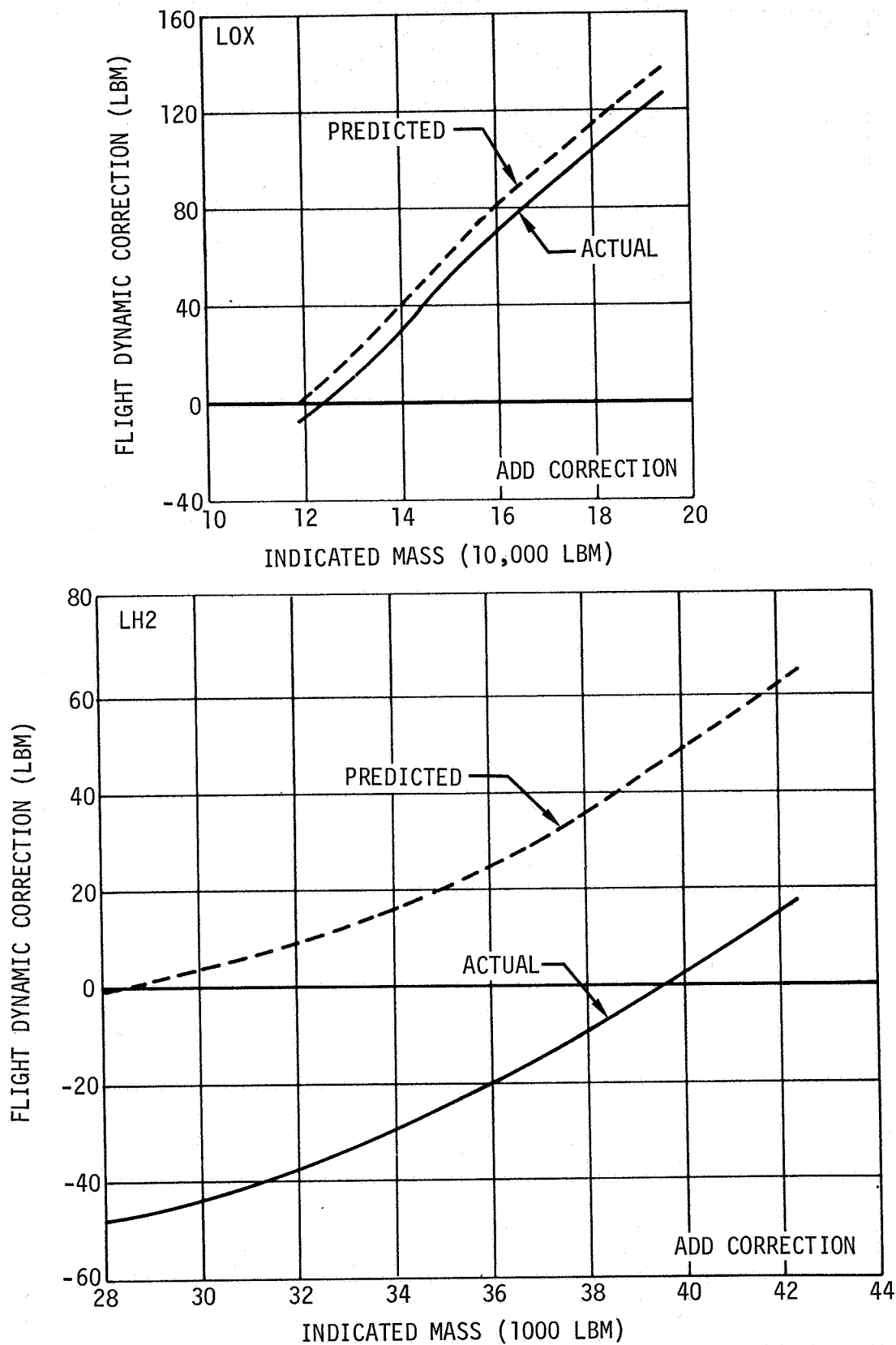


Figure 16-2. PU Mass Sensor Correction Due to Flight Dynamic Effect - CG Offset and Tank Deflection

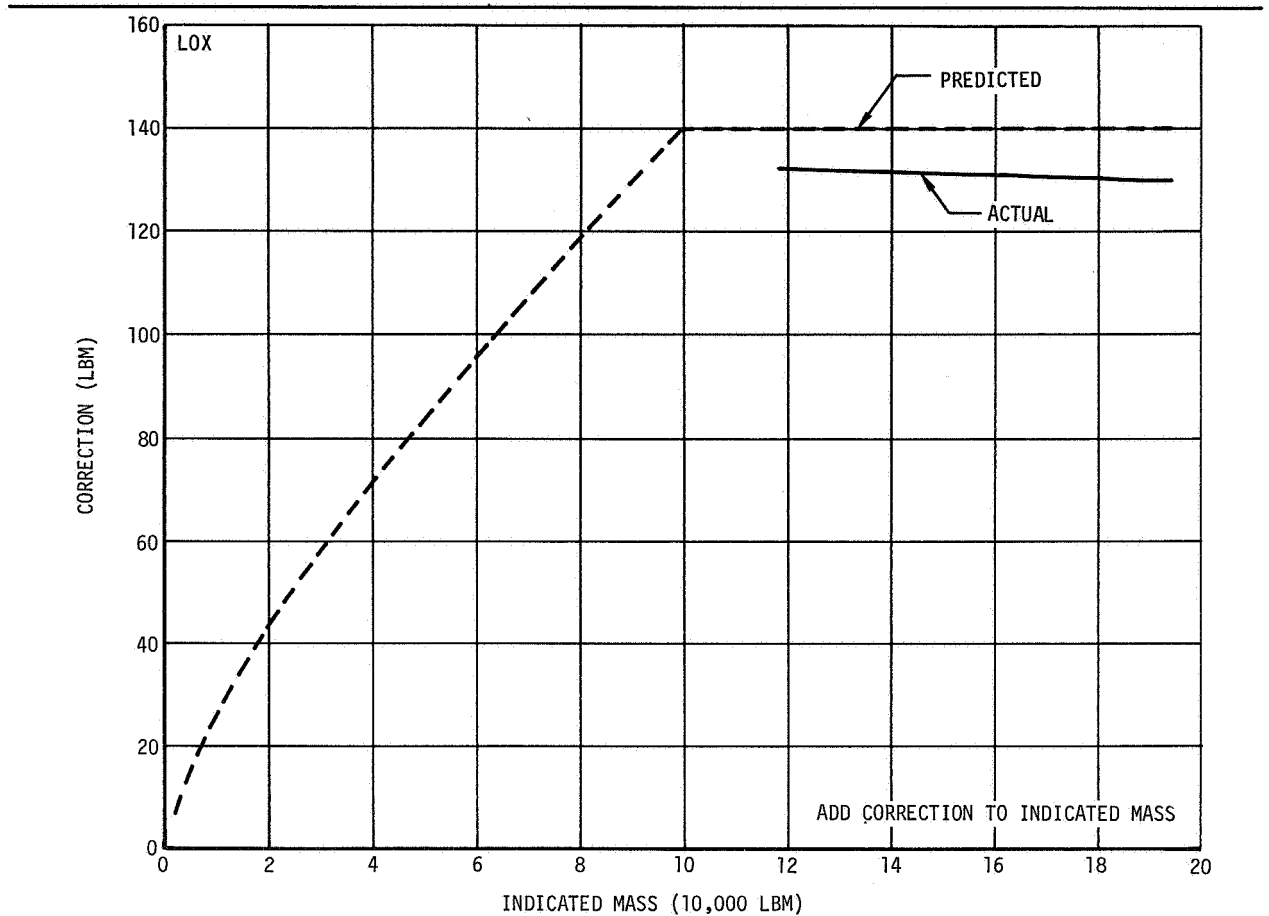


Figure 16-3. Flight PU Correction Due to LOX Tank Deflection

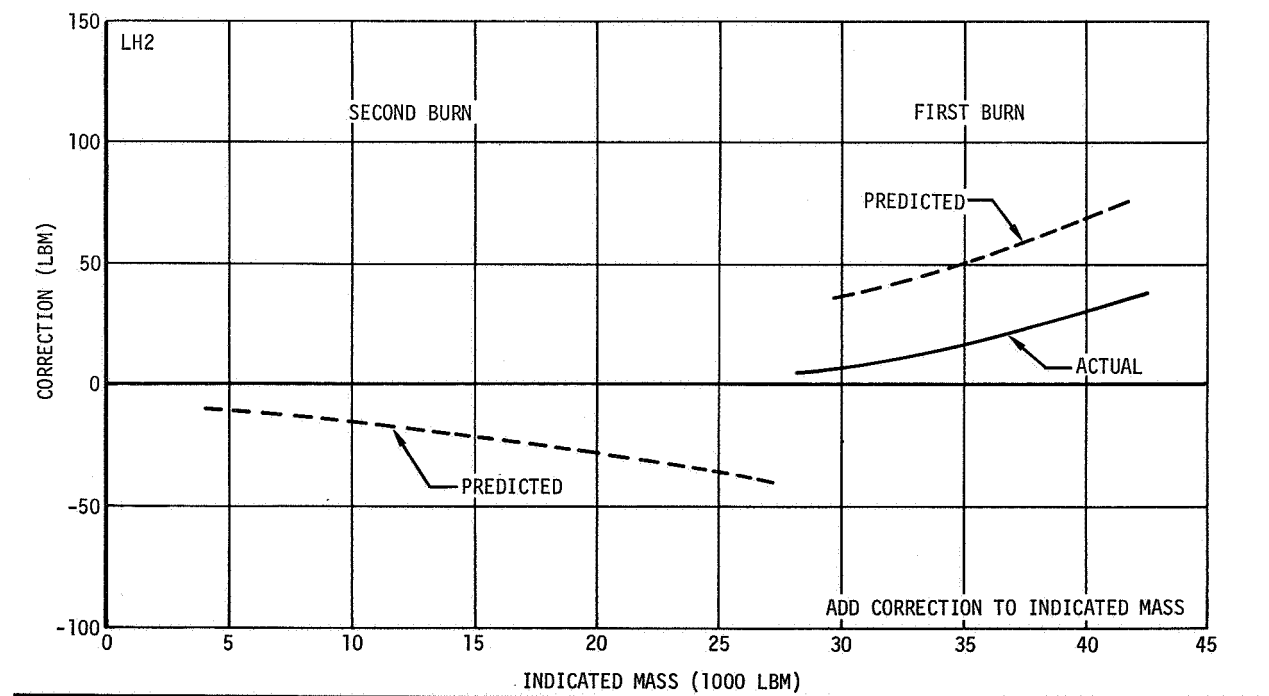


Figure 16-4. Flight PU Correction Due to LH2 Tank Deflection

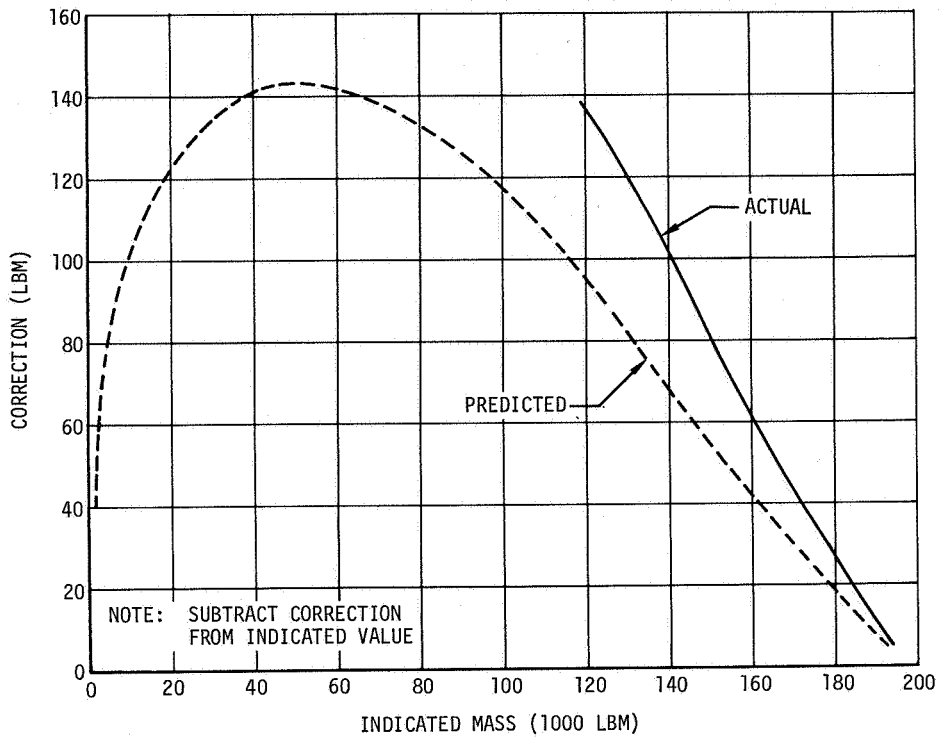


Figure 16-5. LOX PU Mass Sensor Correction Due to CG Offset

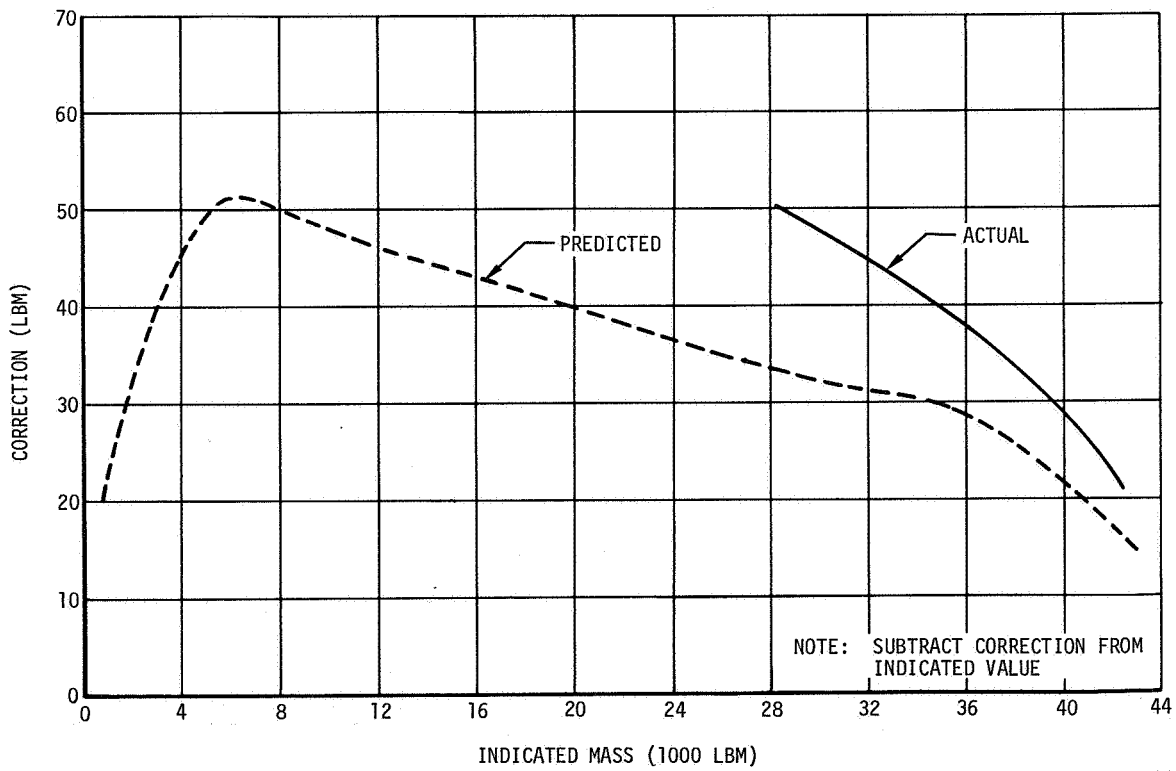


Figure 16-6. LH2 PU Mass Sensor Correction Due to CG Offset

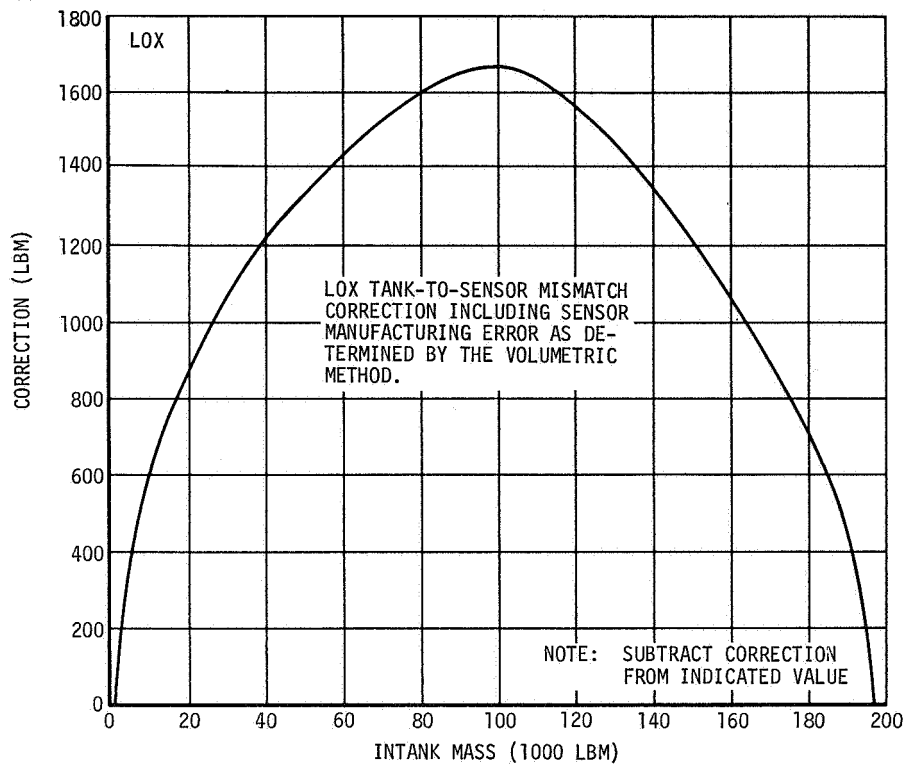


Figure 16-7. Volumetric LOX Tank-to-Sensor Mismatch Correction

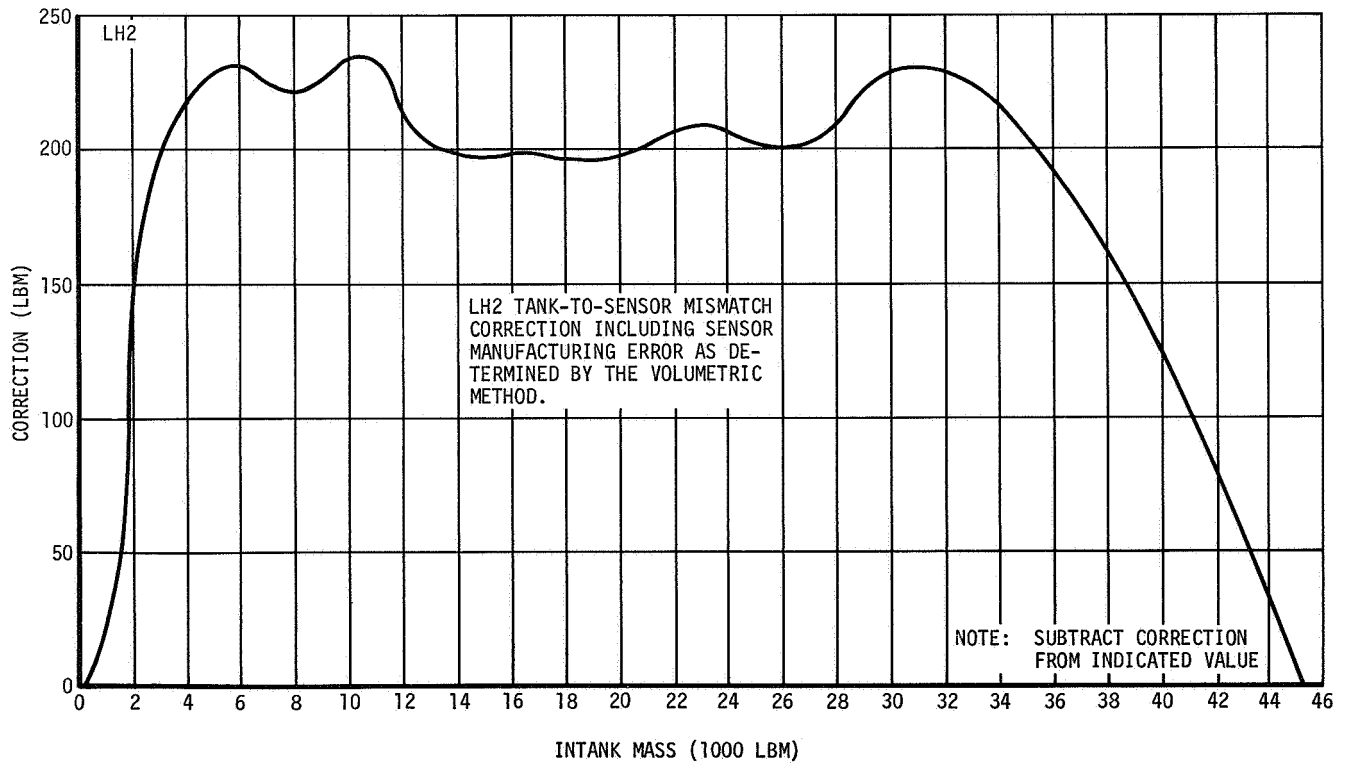


Figure 16-8. Volumetric LH2 Tank-to-Sensor Mismatch Correction

Section 16
Propellant Utilization

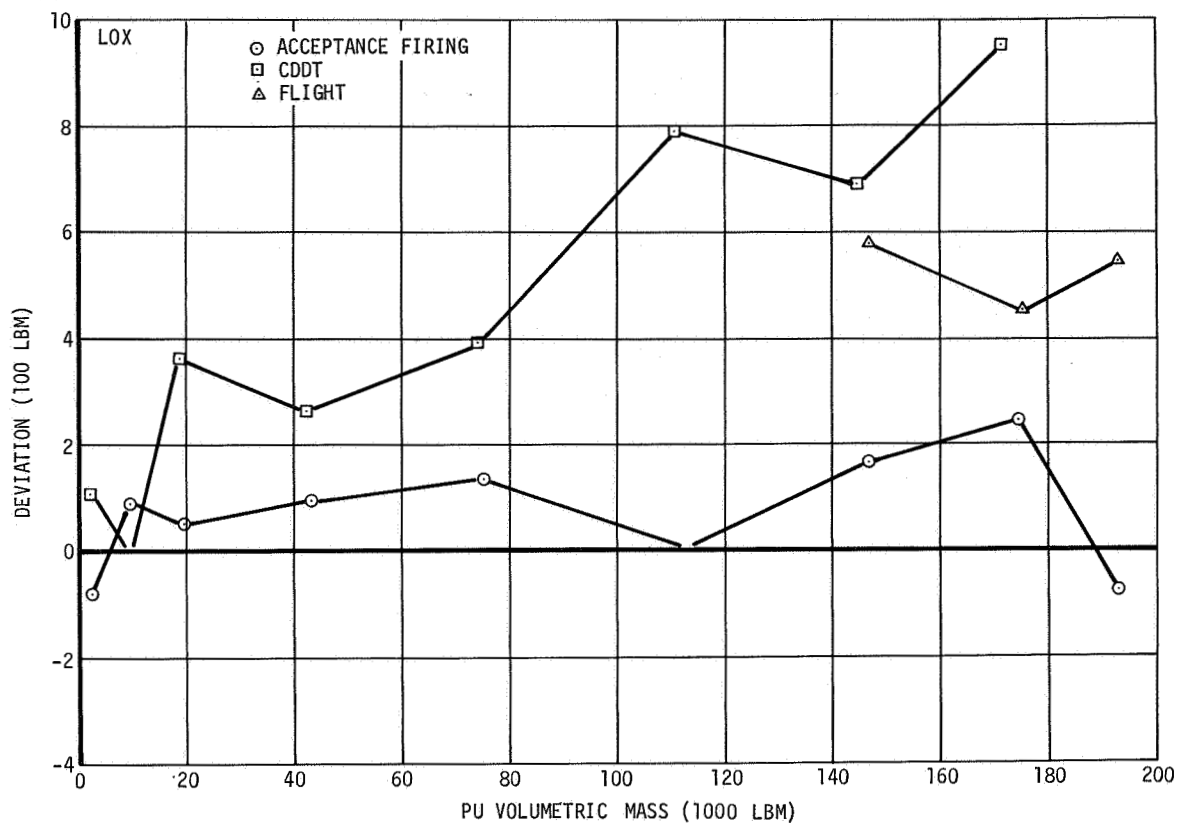


Figure 16-9. Level Sensor and Volumetric PU Mass Comparison - LOX Tank

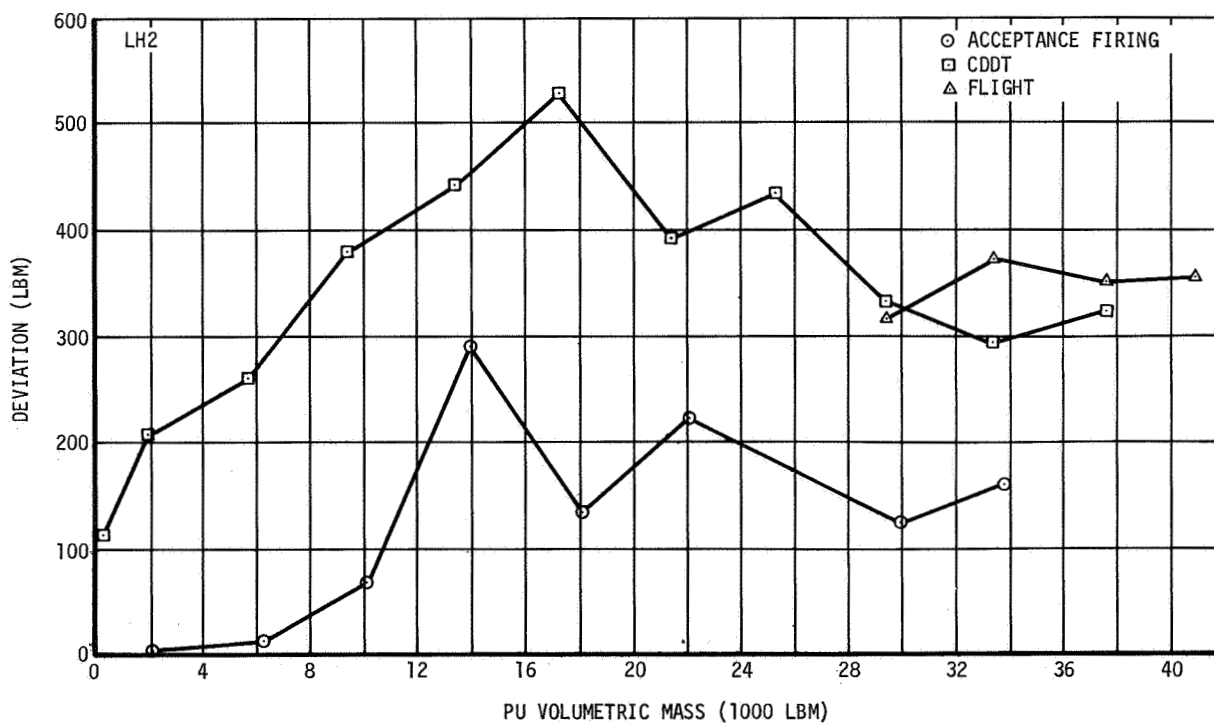
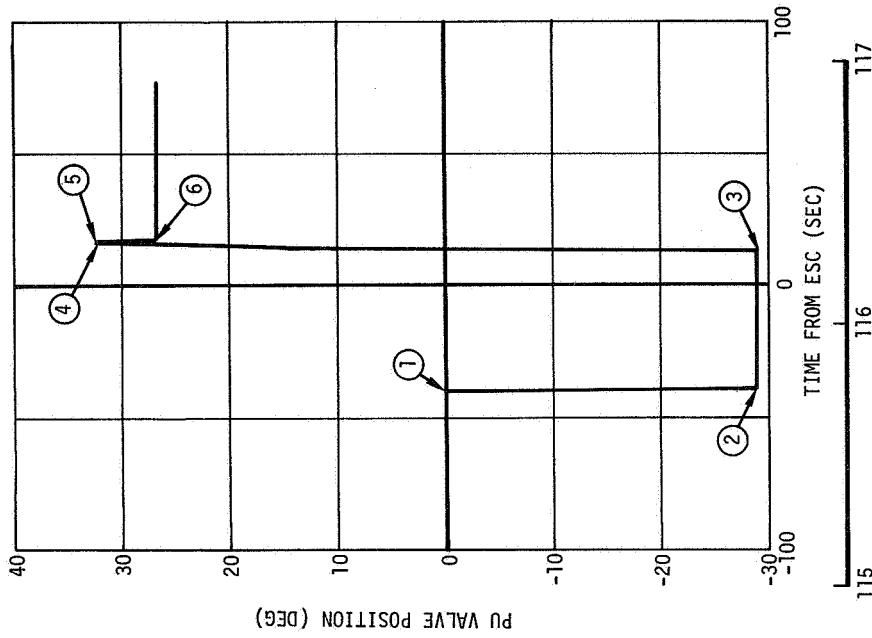


Figure 16-10. Level Sensor and Volumetric PU Mass Comparison - LH2 Tank



NOTE: VALVE POSITION REMAINED AT 26.6 DEG AFTER PU POWER WAS SHUT OFF.

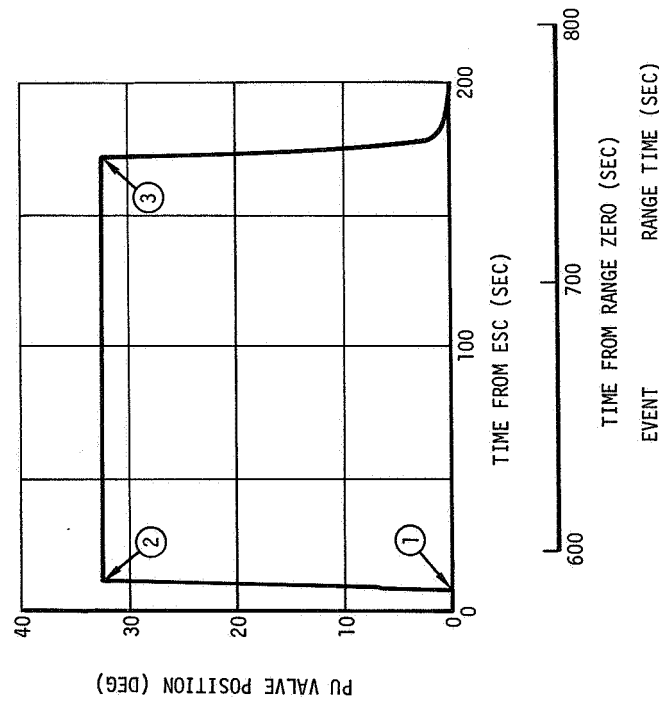


Figure 16-11. PU Valve Position - First Burn

Figure 16-12. PU Valve Position - Second Burn

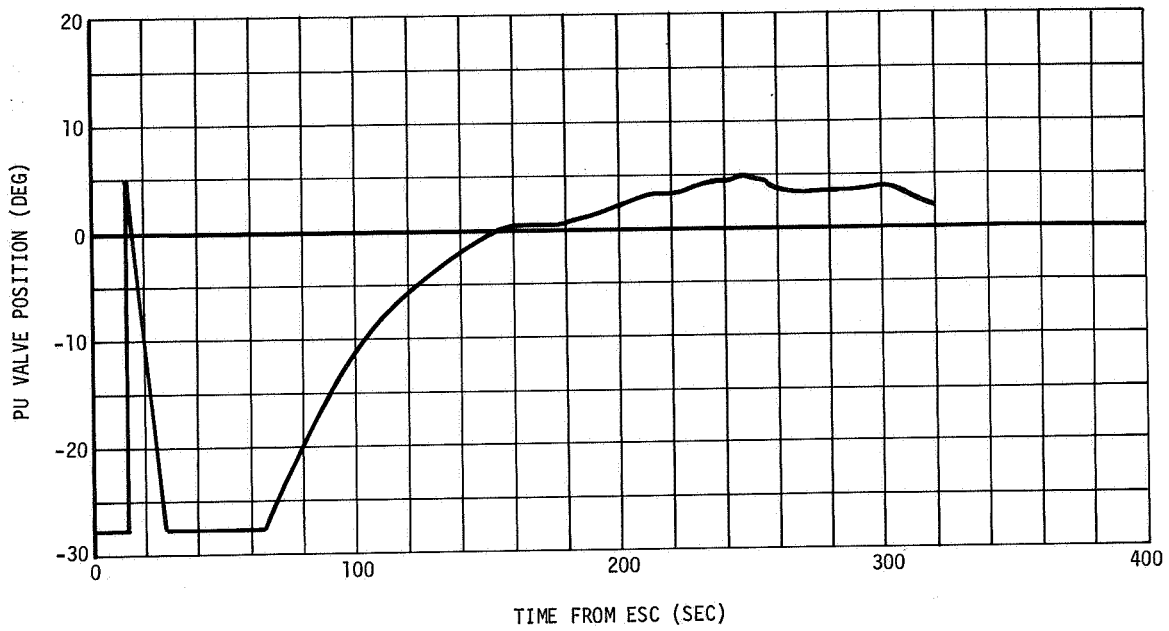


Figure 16-13. Revised Prediction No LOX Measuring System Anomaly - Second Burn

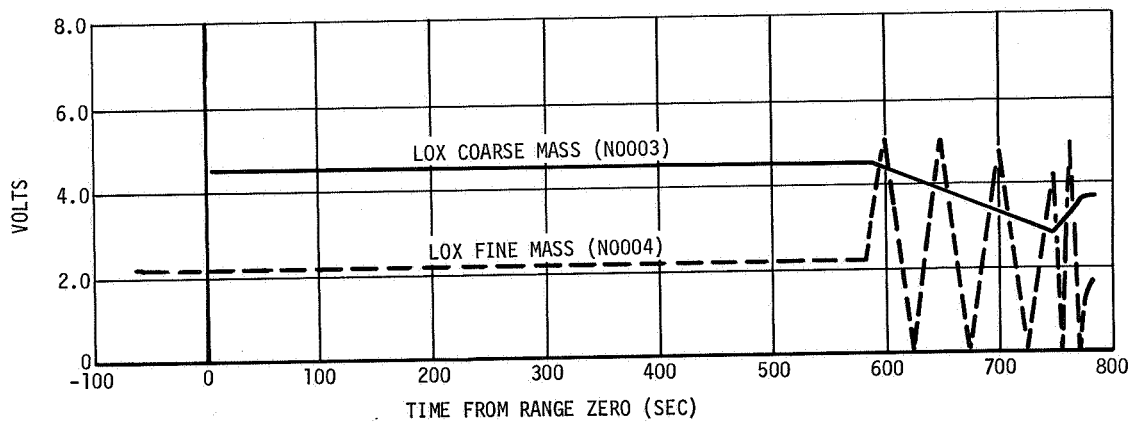


Figure 16-14. LOX Mass History - First Burn

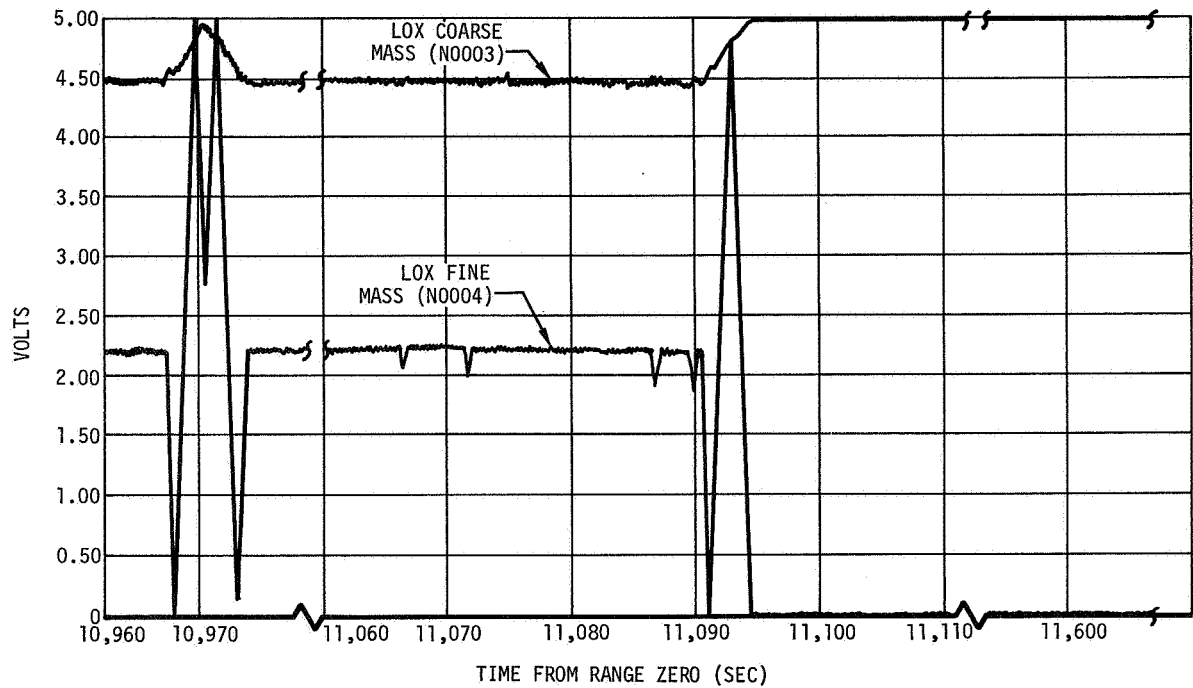


Figure 16-15. LOX Mass History - Restart Preparations

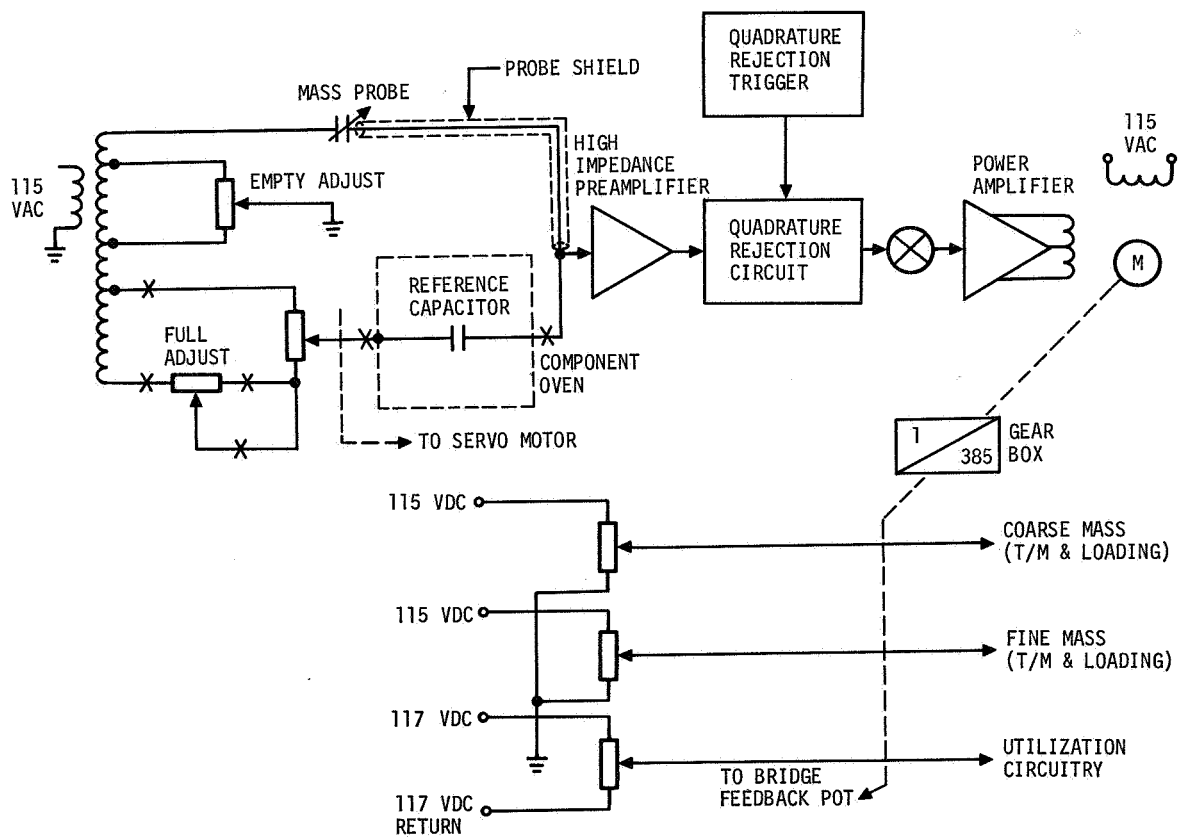


Figure 16-16. Servo Bridge

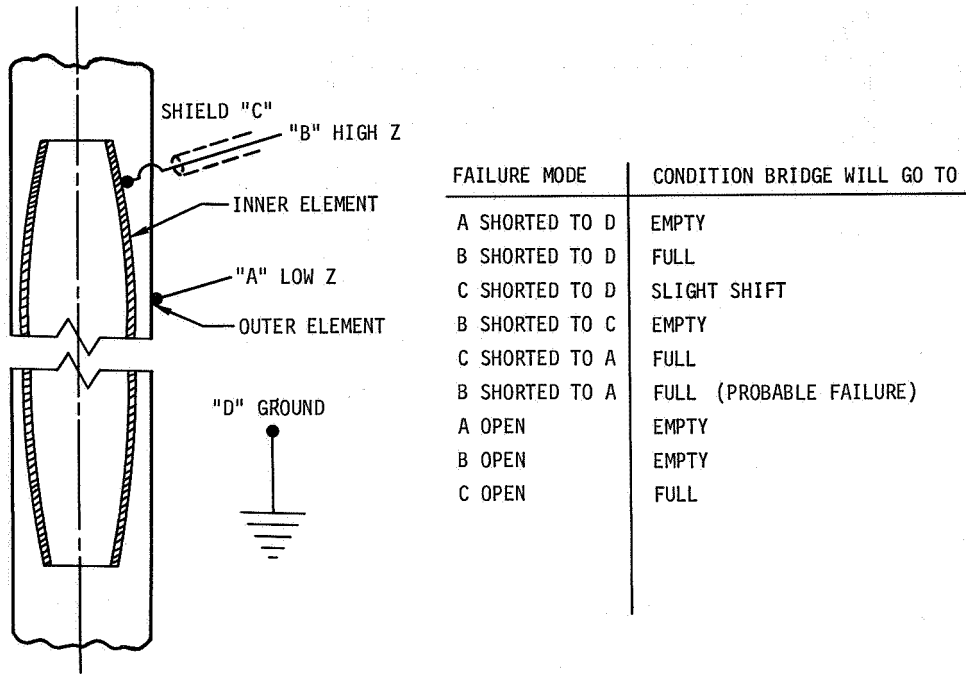


Figure 16-17. Failure Modes of PU Probes

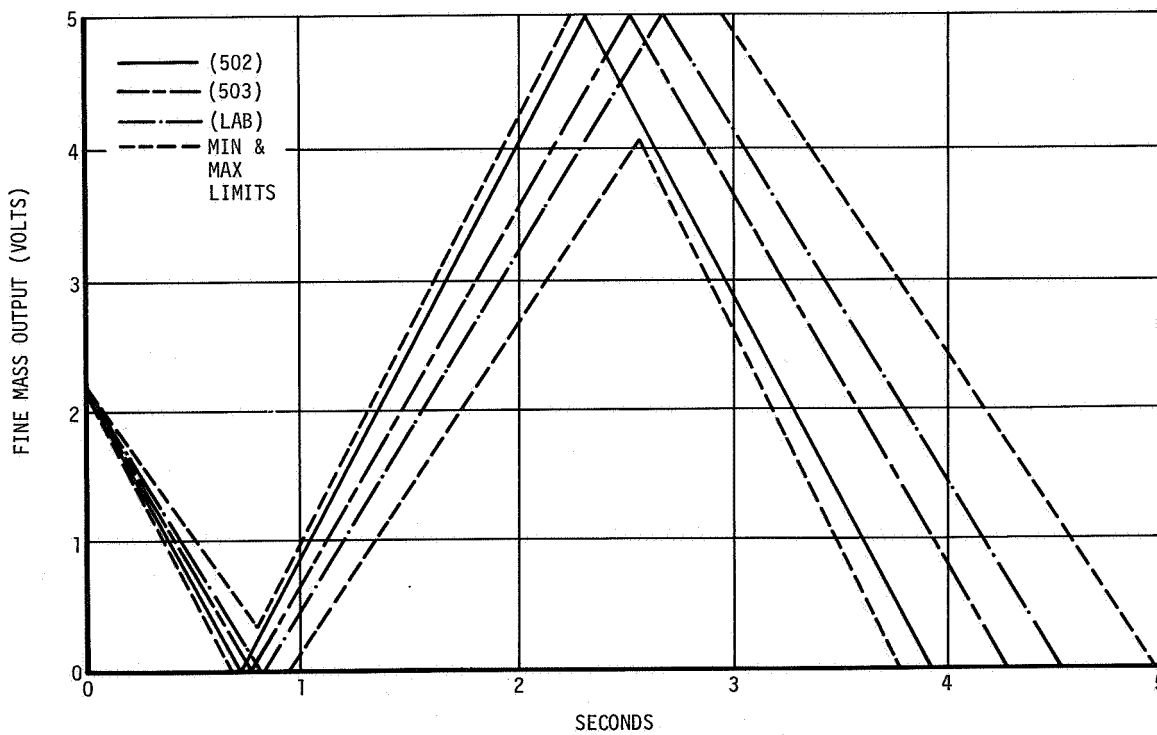


Figure 16-18. PU Bridge Slew Rate

SECTION 17

S-II/S-IVB SEPARATION

17. S-II/S-IVB SEPARATION

Separation of the S-IVB from the S-II was accomplished faster than predicted for a nominal separation by 0.07 sec. This was caused by lower than nominal S-II tail-off thrust level due to two engines out. First axial motion between the stages occurred 0.049 sec after the Separation Command (established from extensometer data). Due to engines two and three being out on the S-II a resultant unbalanced moment is introduced on the S-II causing a positive S-II pitch rate making the critical separation point on position I side of the S-IVB thrust structure. The clearance distance used for separation was approximately 6.7 in. in the direction of position I. In addition, approximately 12 in. were used due to engine gimbal position at the time of separation.

Table 17-1 contains significant times and events for S-II/S-IVB separation.

Figure 17-1 presents the axial separation history of the S-II/S-IVB separation. Also included in this figure are the predicted and actual S-IVB-501 separation histories.

Figure 17-2 shows the longitudinal accelerations for the S-II and S-IVB. The reconstructed acceleration histories were obtained from S-II and S-IVB accelerometer data. A time base was applied to these acceleration histories to compensate for the time lag inherent in the accelerometer data. Retrorocket chamber pressure data was used to determine the time bias.

Figure 17-3 presents the lateral accelerations for the S-II and S-IVB. The S-II pitch acceleration varied between 0.65 ft/sec^2 to -0.4 ft/sec^2 and the yaw acceleration varied between 0.5 ft/sec^2 and -0.4 ft/sec^2 . The S-IVB lateral accelerations were for pitch $\pm 0.6 \text{ ft/sec}^2$ and yaw $\pm 0.2 \text{ ft/sec}^2$.

The angular velocity for both the S-II and S-IVB is presented in figure 17-4. The S-II rates were all approximately zero at first motion. The S-II pitch rate increased to approximately 2 deg/sec by the end of separation. The yaw rate increased to 0.95 deg/sec by the end of separation and the roll rate remained approximately zero throughout separation. The increase in both the S-II pitch and yaw rates after first motion were caused by the combination of two engines out on the S-II and retrorocket misalignment of approximately 0.1 deg. The S-IVB rates were all small with pitch and yaw rates remaining below 0.2 deg/sec and the roll rate remaining below 0.5 deg/sec.

The path of the interstage lip during separation is shown in figure 17-5. The closest approach point was a point on the S-IVB engine bell at position I. During separation 6.7 in. of lateral clearance was utilized. The S-IVB engine was in a hardover (6.7 deg) position in the direction of position I but a clearance of approximately 64 in. still remained.

Figure 17-6 presents the relative velocity between the two stages during separation.

Section 17
 S-II/S-IVB Stage Separation

TABLE 17-1
 SEQUENCE OF EVENTS DURING S-II/S-IVB SEPARATION

| EVENT | TIME FROM RANGE ZERO | TIME FROM SEPARATION COMMAND | |
|---------------------------|----------------------|------------------------------|-----------|
| | | ACTUAL | PREDICTED |
| S-II ECC | +576.327 | -0.766 | -0.8 |
| Ullage rocket ignition | +576.956 | -0.12 | -0.1 |
| 75% ullage thrust | +577.07 | -0.006 | - |
| Separation Command | +577.079 | 0.0 | 0.0 |
| S-II retrorocket ignition | +577.076 | 0.0 | 0.0 |
| 10% retrorocket thrust | +577.11 | 0.034 | |
| First axial motion | +577.125 | 0.049 | 0.075 |
| 90% retrorocket thrust | +577.13 | 0.054 | - |
| S-IVB ESC | +577.268 | 0.192 | 0.2 |
| Separation complete | +578.066 | 0.99 | 1.06 |

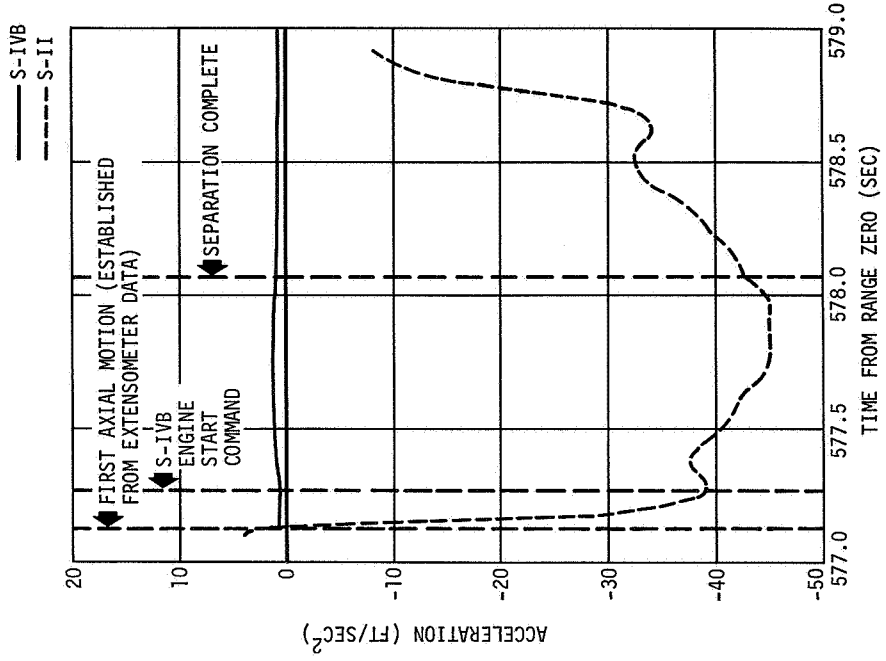


Figure 17-2. Longitudinal Acceleration

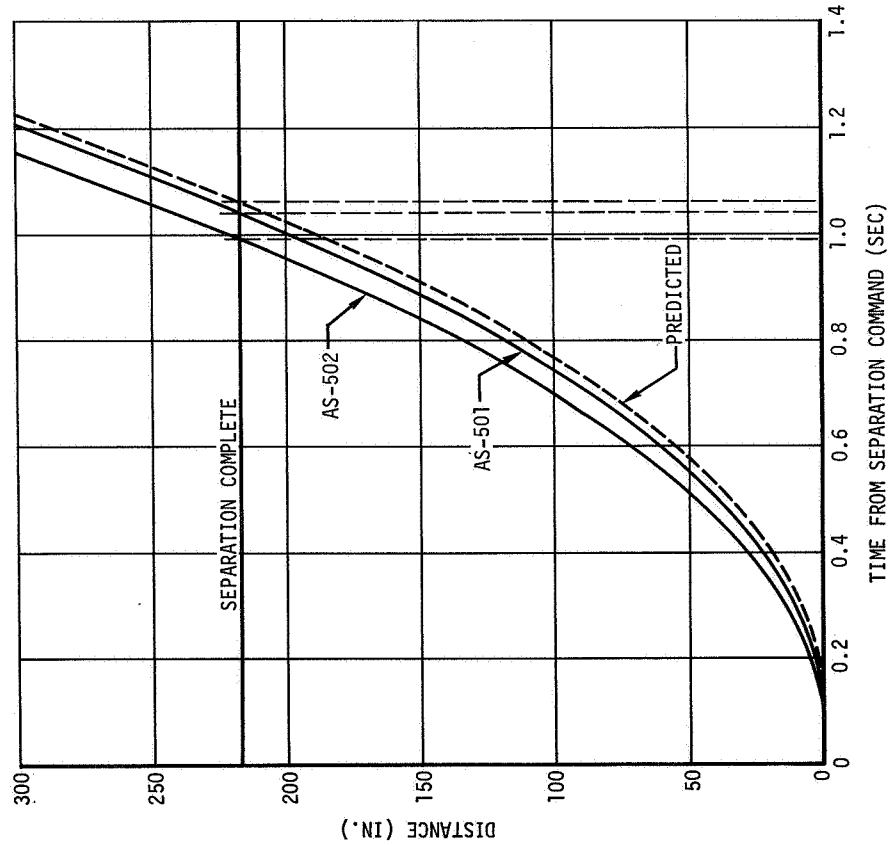


Figure 17-1. Axial Separation History

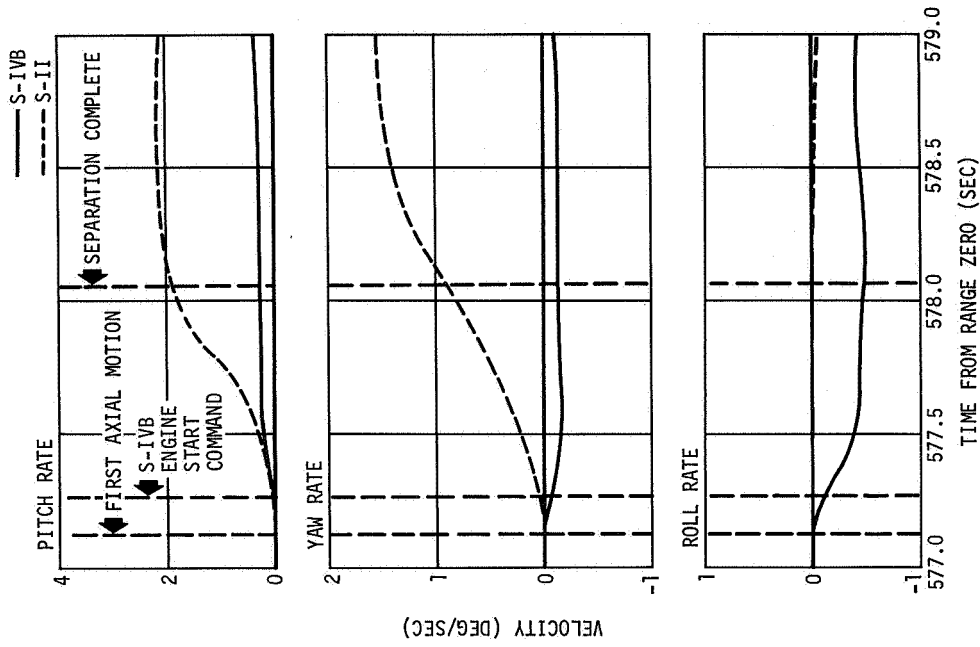


Figure 17-3. Lateral Acceleration

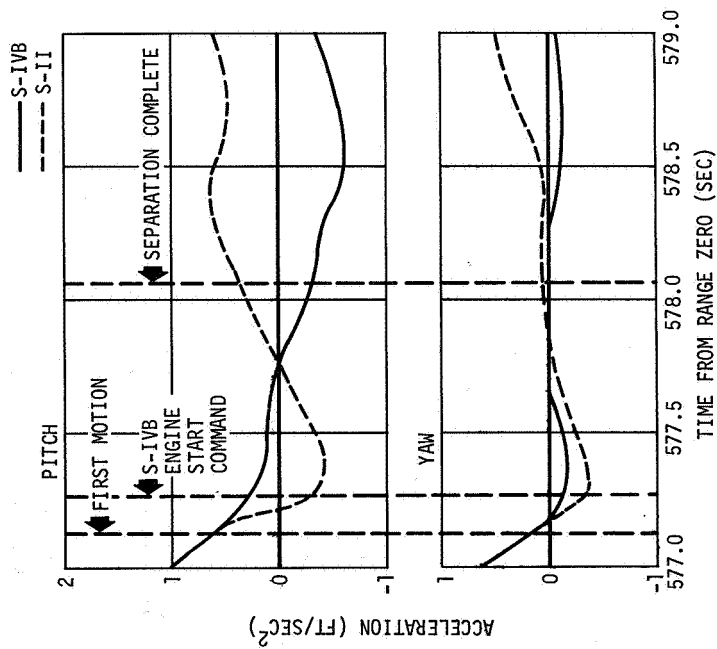


Figure 17-4. Angular Velocity

NOTE: DURING SEPARATION A POINT ON THE S-IVB ENGINE BELL AT POSITION I UTILIZED 6.7 IN. OF THE AVAILABLE 83 IN. (WHEN THE ENGINE IS IN THE NULL POSITION) OF LATERAL CLEARANCE.

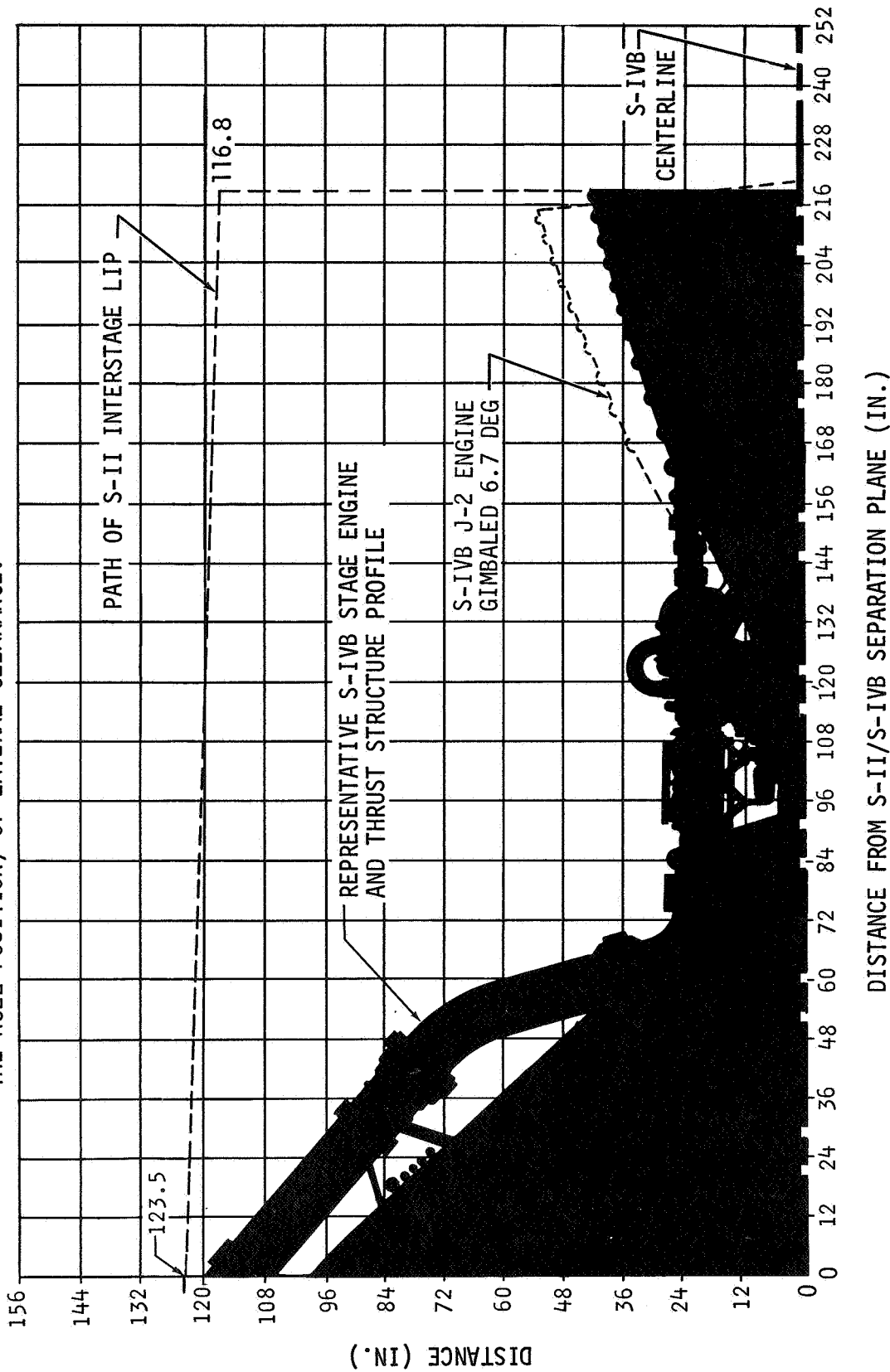


Figure 17-5. S-II Interstage Lip Path - S-II/S-IVB Separation

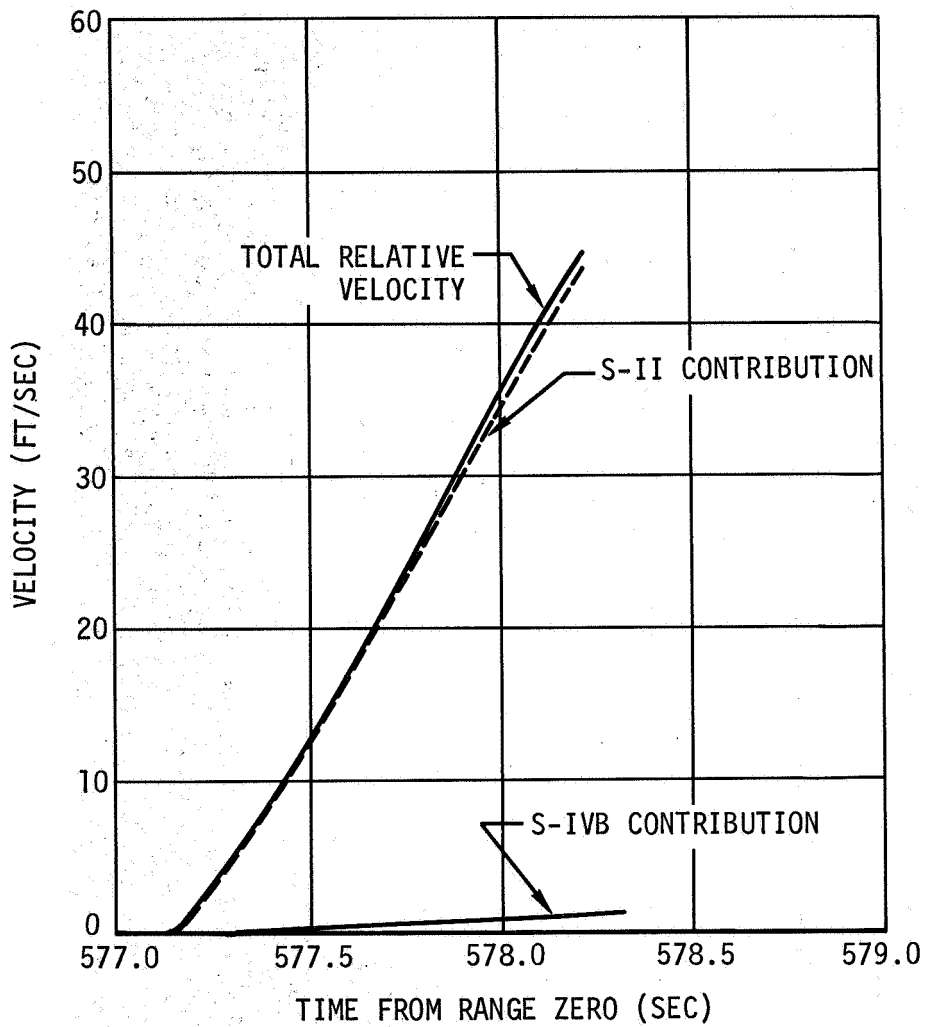


Figure 17-6. S-II/S-IVB Relative Velocity History

SECTION 18

DATA ACQUISITION SYSTEM

18. DATA ACQUISITION SYSTEM

18.1 Data Acquisition System Objective

The objective of the data acquisition system was to gather information describing the performance of stage systems and environments. The measurements collected are specified in the Douglas Drawing 1B43567, "AL" change Instrumentation Program and Components List (IP&CL). The information acquired from the measurements was converted into telemetry format and transmitted to ground stations located throughout the flight path. The final data were processed to conform with the requirements of the measurement requirement drawings.

Data shall be evaluated to requirements specified in the IP&CL, from automatic sequence start through S-IVB Command Service Module separation.

18.2 Summary of Performance

The performance of the data acquisition system was excellent throughout the flight mission. All systems performed as designed, and there were no system malfunctions. The number of measurement failures was low for the two evaluation phases of the AS-502 mission as summarized below:

| | |
|---|--------------|
| Measurements assigned | 616 |
| Measurements monitored by S-II | 4 |
| Measurements inoperative due to stage configuration | 1 |
| Checkout measurements | 11 |
| Measurements deleted prior to flight | 9 |
| Measurements prevented from being transmitted | |
| Phase I | 0 |
| Phase II | 3 |
| Measurements active for flight | |
| Phase I | 591 |
| Phase II | 588 |
| Phase I measurement failures | 10 |
| Phase I measurement efficiency | 98.3 percent |
| Phase II measurement failures | 14 |
| Phase II measurement efficiency | 97.6 percent |

A detailed presentation status for the flight mission is presented in table 18-1. The nine deleted measurements prior to the flight are described in table 18-2. The three measurements prevented from being transmitted for phase II are elaborated on in table 18-3.

18.3 Instrumentation System Performance

The performance of the instrumentation system was satisfactory throughout the AS-502 mission. Ten measurements were considered phase I failures (liftoff to first S-IVB engine cutoff +10 sec). An additional four measurements failed after phase I to give a total of 14 phase II measurement failures. Table 18-4 elaborates on each measurement failure. Measurements which were not failures but considered as questionable, are covered in table 18-5.

Section 18
Data Acquisition System

The remote automatic checkout system (RACS) calibration levels were evaluated at R0 -1,161 sec (11:40:40 hr GMT). Three measurements exceeded the 3 percent level tolerance. D0031-415 (Press - APS Chamber 2-2), D0206-404 (Press Int, Aft Skirt, Loc 1), and S0092-426 (Strain - Dyn, Fwd Skirt, Pnl 55). The following list delineates the measurements that exceeded 2 percent.

| <u>Measurement No. and Title</u> | <u>RACS Level</u> | <u>PCM Bit Count</u> | <u>Percent from Nominal</u> |
|--------------------------------------|-----------------------|--------------------------|---------------------------------|
| D0031-415 | High | (FM) | -3 |
| Press - APS Chamb 2-2 | Low | (FM) | -3 |
| D0206-404 | High | 787 | -1.7 |
| Press - Int, Aft Skt, Loc 1 | Low | 188 | -3.2 |
| S0092-426 | High | (FM) | -3 |
| Strain - Dyn, Fwd Skt, Pnl 55 | Low | (FM) | -1 |
| D0192-426 | High | 827 | +2.7 |
| Press - Ext, Aft Intrstg, Loc 14 | Low | 246 | +2.8 |
| D0196-419 | High | 786 | -1.8 |
| Press - Ext, Aft Intrstg, Loc 18 | Low | 197 | -2.6 |
| D0198-419 | High | 788 | -1.6 |
| Press - Ext, Aft Intrstg, Loc 2 | Low | 194 | -2.6 |
| D0199-419 | High | 795 | -0.9 |
| Press - Ext, Aft Intrstg, Loc 21 | Low | 198 | -2.2 |
| D0201-427 | High | 826 | +2.3 |
| Press - Ext, Aft Skt, Loc 5 | Low | 243 | +2.5 |
| D0210-402 | High | 783 | -2.2 |
| Press - Int, Intrstg, Loc 6 | Low | 199 | -2.1 |

18.4 Telemetry System Performance

The telemetry system performance was within expected nominals. No deviation from the normal was observed.

18.4.1 Pulse Code Modulation Subsystem

All analog multiplexers were properly synchronized with respect to their pulse code modulation (PCM) assemblies. The PCM wave train was properly serialized and sync words properly coded. Analog-to-digital conversion appears uniform throughout the life of the stage.

PCM was utilized as the prime data source for sampled data.

18.4.2 Pulse Amplitude Modulation Subsystem

PAM was the secondary data source for sampled data; therefore, all channels were not reduced for evaluation. However, from the limited reduced data and the PCM/PAM comparison data, the pulse amplitude modulation (PAM) systems appear normal. Higher data noise was observed on PAM as compared to PCM; however, this was expected and is inherent in PAM systems.

18.4.3 Frequency Modulation Subsystem

The frequency characteristic for individual subcarrier oscillators (SCO) are listed in table 18-6. All SCO's were within band tolerances. System calibrations were verified whenever commanded by the switch selector. All calibration levels were present and easily distinguishable.

18.4.4 Single Sideband Subsystem

Data from the single sideband system verified the proper sampling of the 245 multiplexer. The 1,700 Hz calibration signal was actually 1,713 Hz, which was well within the calibrating tolerance. The presence of the calibration signal was verified whenever calibration was commanded.

The system was commanded OFF/ON/OFF at RO +296, RO +11,496, and RO +11,640 sec, respectively. System operation was verified by the presence of the SS/FM transmitter RF output power.

18.4.5 Tape Recorder

The critical data loss period at S-IC/S-II separation was not recovered due to the insufficient preprogrammed playback time that resulted from the over-burn of the S-II flight phase.

The tape recorder was commanded to fast record at RO +135 to RO +160 sec to recover data during S-IC/S-II separation. The second fast record, programmed to recover data during the time of S-II/S-IVB separation, was commanded to fast record at RO +483 sec (TB4 +335 sec) and was not commanded to stop recording until RO +597 sec (TB5 +21 sec). The total time for the second recording was 114 sec. Upon insertion, the tape recorder was commanded to play back at RO +835 sec for the preprogrammed time of 73 sec. This playback time was not sufficient to completely play back the second recording phase.

The short playback from the launch phase fast recording that resulted in an incomplete rewinding of the recorder tape, equivalent to 528 sec of slow recording, was not detrimental to the programmed recovery of out-of-range orbital data.

Except for difficulties in timing correlation due to the abnormal orbit trajectory, all orbital recordings were successfully recovered and reduced.

The evaluation of the fast operation period indicated an average speed of 29.99 in./sec with a wow amplitude of 0.24 in./sec² peak to peak (P-P) at the rate of 15.5 Hz and a flutter amplitude of 0.45 in./sec² P-P at the rate of 4,690 Hz. The tape recorder required 2.11 sec to attain speed stability in the fast operation mode.

18.4.6 Calibration Subsystem

The remote automatic checkout system (RACS), used for instrumentation system evaluation, was exercised at RO -1,161 sec. High mode was initiated at RO -1,161 sec, low mode at RO -1,144 sec, and returned to run mode at RO -1,130 sec. RACS levels were verified on all channels.

Telemetry system calibration was sent to the voltage controlled oscillator assemblies in the proper sequence and all calibration levels were present.

18.5 Radio Frequency System

The performance of the RF system was within expected nominal as shown in table 18-7. The performance figures were taken at four different places because of data drifts encountered during the launch period. The selected times are: Prelaunch (R0 -1 sec), prior to first burn (R0 +500 sec), post first burn when single sideband was OFF (R0 +780 sec), and prior to second burn (R0 +11,600 sec). Major drifting of the detectors occurred at liftoff and max q; stability was attained by R0 +600 sec.

The transmitter output power of FM/FM 2, FM/FM 3, and SSB/FM was higher than specified by specifications; however, detrimental effects were not observed. The high power output was confirmed during detector calibration.

The RF system blackout period during S-IC/S-II separation was not evaluated because the tape recorder playback data were not recovered. Data loss was observed at R0 +149.23 sec for 0.83 sec. Flame attenuation was not observed during S-II/S-IVB separation.

Good system performance was verified until R0 +33,000 sec when degradation of performance was observed due to the depletion of the electrical power source.

18.6 Signal Strength

Based upon available data reviewed, it is concluded that overall flight coverage was good as indicated by data recovery. The received signal levels were generally as expected when the antenna radiation patterns are considered with respect to the attitude and range of the vehicle.

Figures 18-1 and 18-2 show the signal strength level received at the noted ground stations from the S-IVB-502 PCM telemetry link. The time periods shown were selected to depict the prime interest areas of the first burn (R0 +577 to R0 +747 sec) and second burn (R0 +11,615 to R0 +11,630 sec) portions of the flight. Both left hand circular polarized (LHCP) and right hand circular polarized (RHCP) are shown except for the Tel 4 ground station from R0 +11,500 to R0 +11,980 sec, for which there was no RHCP data available. The derived signal levels shown are theoretical levels expected at the ground stations, computed from the actual flight trajectory.

There were two sets of data received for MILA-CIF RHCP from R0 to R0 +570 sec; one set showed a received signal strength approximately 10 db lower than the other. Figure 18-1 shows the lower level set of signal strength data. However, the signals received at MILA-CIF, both RHCP and LHCP, were approximately 40 db greater than expected throughout the acquisition period. The signal level received at Bermuda for approximately 75 sec starting at R0 +490 sec varied from 10 to 40 db lower than expected. At present, investigation is still in progress to determine the correct level of MILA-CIF RHCP and the reasons for the received signal strength transients.

18.7 Electromagnetic Compatibility

An electromagnetic compatibility (EMC) review of the S-IVB-502 prime flight data disclosed two measurements with marginal noise content. Measurements M0069-404 and M0070-404 displayed between 2 and 2-1/2 percent peak to peak (P-P) noise during chilldown for both burns.

Douglas Report No. SM-47376, Test Plan for the Electromagnetic Compatibility Test of S-IVB/V Systems Saturn S-IVB-501 and Subsequent, limits long term (over 1 sec) variations to 2 percent P-P.

ECP 10012 will reroute wiring in order to eliminate this noise problem on S-IVB-504N and subs.

TABLE 18-1 (Sheet 1 of 2)
MEASUREMENT STATUS

| | | |
|----|---|-----|
| 1. | <u>Measurements Assigned by IP&CL</u> | 616 |
| 2. | <u>Measurements Not Flight Active</u> | 12 |
| | <u>Landline Measurements Available Prior to Liftoff Only -(3)</u> | |
| | D0545-407 Press - Common Bulkhead Int - H/W | |
| | D0576-408 Press - Fuel Tank Ullage Umb - H/W | |
| | D0577-406 Press - Oxid Tank Ullage Umb - H/W | |
| | <u>Inactive Measurement</u> | |
| | K0152-404 Event - Rt Gyro Whl Speed OK Ind | |
| | <u>Measurements Used for Checkout and Prelaunch Only -(8)</u> | |
| | K0141-411 Event - R/S 1 Pulse Sensor | |
| | K0142-411 Event - R/S 2 Pulse Sensor | |
| | K0149-404 Event - Ullage Rocket Jettison 1 P/S | |
| | K0150-404 Event - Ullage Rocket Jettison 2 P/S | |
| | K0168-404 Event - Switch Selector Register Test | |
| | K0169-404 Event - EBW Pulse Sensor OFF Ind | |
| | K0176-404 Event - Ullage Rkt Ign P/S 1 Ind | |
| | K0177-404 Event - Ullage Rkt Ign P/S 2 Ind | |
| 3. | <u>S-IVB-502 Measurements Monitored by S-II Stage</u> | 4 |
| | D0153-423 Press - Chamber Retro Rocket Pos IV - I | |
| | D0154-421 Press - Chamber Retro Rocket Pos II - III | |
| | D0155-420 Press - Chamber Retro Rocket Pos I - II | |
| | D0156-422 Press - Chamber Retro Rocket Pos III - IV | |
| 4. | <u>Measurements Waived from Flight Active List</u> | 9 |
| | C0041-406 Temp - LOX Tank, Posit 2 | |
| | C0056-406 Temp - LOX Tank Ullage Gas, 20% | |
| | C0150-401 Temp - Eng LH2 Pump Surface | |
| | C0155-404 Temp - LH2 Prevalve Bypass Line | |
| | C0205-403 Temp - He Prepress Sphere, No. 4 Gas | |
| | C0301-415 Temp - APS Oxid, Tank 2 | |
| | D0018-401 Press - Eng Reg Outlet | |
| | D0058-401 Press - PU Valve Inlet | |
| | S0087-426 Strain - Dyn, Fwd Skirt, Pnl 17 | |
| 5. | <u>Measurements Prevented from being Transmitted</u> | |
| | Phase I | 0 |
| | Phase II | 3 |
| | C0010-403 Temp - Engine Area Ambient | |
| | C0152-403 Temp - LOX Main Line Flg Wall | |
| | E0209-401 Vib - Combustion Chamb Dome, Long | |
| 6. | <u>Net Measurements Available for Flight Test</u> | |
| | Phase I | 591 |
| | Phase II | 588 |

TABLE 18-1 (Sheet 2 of 2)
MEASUREMENT STATUS

7. Measurement Failures

Phase II 14

C0189-414 Temp - APS Inj Wall, Eng 1-2
C2015-401 Temp - Crossover Duct Ext Wall 1
D0003-403 Press - LOX Pump Inlet
D0224-401 Press - LH2 Pump Intrstg Outlet

Phase I 10

B0023-404 Acoustic - Aft (2400 - 4800), Int
C0008-403 Temp - Heat Exch He Inlet
C0049-405 Temp - Electrical Tunnel, Loc 1
C0058-406 Temp - LOX Tank Ullage, 80 percent
C0111-426 Temp - Fwd Skirt, Loc 8
C0151-401 Temp - LOX Pump Surface
C0286-415 Temp - APS Fairing 2-4
D0105-403 Press - LOX Tank Press Mod, He Gas
E0114-411 Vib - Fwd Skirt, EBW R/S Pnl, Radial
E0210-401 Vib - LH2 Turbopump - Lateral

8. Partially Successful

C0274-403 Temp - Gas, Intrstg Area, Loc 6
C0305-418 Temp - Aft, Intrstg, Loc 7
D0002-403 Press - LH2 Pump Inlet
D0055-424 Press - LOX Tank Inlet
E0117-411 Vib - Fwd Skirt, Battery 1 and 2, Tan

9. Aberrant Measurements

C0037-408 Temp - LH2 Tank Ullage, 70 percent
C0153-403 Temp - Oxid Main Supply Line Wall
C0205-403 Temp - He Repress Sphere 4
C2035-401 Temp - Gas Generator LOX Inlet
D0016-425 Press - Cold Helium Sphere
D0018-401 Press - Engine Reg Outlet
D0071-414 Press - APS Oxid Sup Manf, Mod 1
D0073-415 Press - APS Oxid Sup Manf, Mod 2
K0008-401 Event - Ignition Detector
M0069-404 Volt - Aft T/M Full Scale Ref
M0070-404 Volt - Aft T/M Zero Volt Ref
N0012-411 Misc - RF Power, T/M Ant 2, Fwd
N0015-411 Misc - RF Power, FM/FM 1 Transmitter
N0016-411 Misc - RF Power, FM/FM 2 Transmitter
N0017-411 Misc - RF Power, FM/FM 3 Transmitter
N0019-411 Misc - RF Power, SS/FM Transmitter
N0033-411 Misc - RF Power, T/M Ant 3, Fwd
N0036-411 Misc - RF Power, T/M Ant 4, Refl
S0054-426 Strain - Axial, Fwd Skirt Loc 10A
S0055-426 Strain - Axial, Fwd Skirt Loc 10B
S0062-426 Strain - Axial, Fwd Skirt Loc 14A
S0063-426 Strain - Axial, Fwd Skirt Loc 14B
S0086-426 Strain - Dyn, Fwd Skirt, Pnl 13
S0087-426 Strain - Dyn, Fwd Skirt, Pnl 17
S0088-426 Strain - Dyn, Fwd Skirt, Pnl 26
S0089-426 Strain - Dyn, Fwd Skirt, Pnl 33
S0090-426 Strain - Dyn, Fwd Skirt, Pnl 40
S0091-426 Strain - Dyn, Fwd Skirt, Pnl 46
S0092-426 Strain - Dyn, Fwd Skirt, Pnl 55
S0093-426 Strain - Dyn, Fwd Skirt, Pnl 61
S0094-426 Strain - Dyn, Fwd Skirt, Pnl 69
S0095-426 Strain - Dyn, Fwd Skirt, Pnl 76
S0096-426 Strain - Dyn, Fwd Skirt, Pnl 80
S0097-426 Strain - Dyn, Fwd Skirt, Pnl 87
S0098-426 Strain - Dyn, Fwd Skirt, Pnl 94
S0099-426 Strain - Dyn, Fwd Skirt, Pnl 101
S0100-426 Strain - Dyn, Fwd Skirt, Pnl 108
S0101-426 Strain - Dyn, Fwd Skirt, Pnl 7

TABLE 18-2 (Sheet 1 of 2)
MEASUREMENT DELETIONS

C0041-406 Temp - LOX Tank, Posit 2

The level prior to liftoff was 6 deg R higher than nominal LOX temperatures. At liftoff, the level abruptly decreased to nominal LOX temperatures and subsequently proper operation was verified. The erroneous temperature data prior to liftoff was probably due to a high resistance contact in the sensor resistance system. The reason for the resistance changes at liftoff (change in acceleration) is presently under investigation.

C0056-406 Temp - LOX Tank Ullage Gas, 20%

The measurement was deleted from the flight list because of its erratic behavior during countdown demonstration test (CDDT) detanking process. During terminal countdown the measurement was off-scale-low. At RO +70 sec, the measurement abruptly came on-scale at the proper LOX temperature. It exhibited good data until RO +575 sec when it suddenly decreased to off-scale-low and remained there throughout the remainder of the mission.

Since the RACS were within specifications, the amplifier/bridge system was operating properly. The characteristic of the data indicates a short circuited sensor; however, the location of the malfunction is still under study.

C0150-401 Temp - Engine LH2 Pump Surface

The data remained in the off-scale-high state throughout the flight test. A debonded temperature sensor is suspected, possibly an open circuit resulted from the debonding. This transducer was bonded using the newer installation method. However, the malfunction was probably the result of improper technique.

C0155-404 Temp - LH2 Pre-Valve Bypass Line

The data level was off-scale-high prior to launch and remained off-scale through the mission. Since the upper end of the temperature range was 460 deg R, it was expected, even if a debonded condition occurred, the temperature indication would be in-range sometime during flight. It is, therefore, suspected that a similar condition to measurement C0150 occurred, i.e., debonding with an open-circuit sensor.

C0205-403 Temp - He Repress Sphere No. 4 Gas

This measurement was deleted from the flight test list, however, good data was received throughout the mission. The measurement was deleted because of intermittent operation during prelaunch countdown.

C0301-415 Temp - APS, Oxid Tank 2

The measurement indicated off-scale-high prior to liftoff and throughout the mission. The malfunction is characteristic of a debonded temperature transducer that resulted in an open circuit sensor. The transducer was bonded using a method that is susceptible to debonding under environmental conditions.

D0018-401 Press - Engine Regulation Outlet

The measurement presented valid data during the flight test. The measurement was deleted because of an off-scale-low indication during CDDT. During launch countdown the pressure indication was at normal ambient.

TABLE 18-2 (Sheet 2 of 2)
MEASUREMENT DELETIONS

D0058-401 Press PU Valve Inlet

The measurement was deleted because of erratic variations of 40 psi during CDDT. The erratic condition persisted during launch, S-IC, and S-II flight phases. The erratic phenomenon was not exhibited after the initial pressure increase at S-IVB ignition. Data during the attempted restart was good. It was surmised that a restriction in the pressure monitoring line was present which was cleared after the initial pressure surge at S-IVB ignition.

S0087-426 Strain - Dyn, Fwd Skirt, Pnl 17

This measurement could not be calibrated during CDDT and was deleted prior to initiation of the automatic sequence. Evaluation of the preflight RACS indicated the high level was 8.5 percent low and the low level was 2.5 percent low. It appears that the gain setting of the amplifier was 0.87 of the nominal gain. It was not determined if the amplifier gain setting was at its maximum position. The balance adjustment was slightly lower than nominal. However, since the data level was on-scale, no detrimental effects were introduced. The response of the measurement during launch appears normal except for possible amplitude suppression; the measurement could be classified as trend.

TABLE 18-3
DEGRADED MEASUREMENTS PREVENTED FROM BEING TRANSMITTED

The following measurements have been deleted from the Phase II measurement efficiency baseline. The failure of these measurements have been attributed to the rupture of the ASI fuel feedline and the abnormal conditions existing (beyond design limitations) as a result. Since these transducers were subjected to conditions beyond their design limits, it does not reflect on the instrumentation system performance and therefore cannot be considered as instrumentation failures.

C0010-403 Temp - Engine Area Ambient

The measurement failed at RO +699 sec. The transducer was initially subjected to a very high temperature as shown by a 100 deg temperature rise in 3 sec. It then short-circuited indicating an off-scale-low condition. The malfunction was probably caused by excessive heating to the temperature probe and its associated wiring, causing an apparent short circuit to the sensor element.

C0152-403 Temp - LOX Main Line Flange Wall

The measurement failed in the off-scale-high mode at RO +696 sec. The transducer was subjected to a high temperature at RO +695 sec prior to the failure. The failure was probably caused by excessive heat deforming the bonding material that subsequently resulted in an open-circuit sensor.

E0209-401 Vib - Combustion Chamber Dome, Long

The measurement ceased to display valid data at RO +694 sec. The erratic data during the malfunction appears as a coaxial cable problem. It has been surmised that the initial malfunction was caused by a short circuit of the coaxial cable outer conductor to the inner conductor then, due to vibration, an electrical discontinuity occurred. The failure was initiated by the abnormal environment in the engine area.

TABLE 18-4 (Sheet 1 of 3)
MEASUREMENT FAILURES

PHASE I FAILURES

Liftoff to first burn Engine Cutoff Command (ECC) +10 sec.

B0023-404 Acoustic - Aft (2400 - 4800), Int

The measurement did not respond to sound pressures. Some indication of sound pressures was expected at liftoff and max q as extrapolated from measurements B0022 and B0024 in the same area. A redundant transmission of this channel digital in nature indicated some increase of noise quantity during the time of interest; however, the noise was much lower than the expected sound pressure levels. It is suspected that the transducer experienced an input signal adjustment change or an erroneous sound pressure calibration.

C0008-403 Temp - Heat Exchanger, He Inlet

The data exhibited off-scale-high condition throughout the flight test. The temperature was expected to be on-scale during cold helium flow at LOX tank pressurization. Since the RACS levels were within proper limits, the off-scale condition was due to an open circuit sensor.

C0049-405 Temp - Electrical Tunnel, Loc 1

The data indicated a sharp increase to off-scale-high at RO +70 sec. The off-scale condition was probably caused by an open circuit transducer. This temperature sensor was a patch type bonded by a method that was susceptible to debonding under max q conditions.

C0058-406 Temp - LOX Tank Ullage, 80%

The temperature indicated a decrease at liftoff 5 deg R lower than nominal LOX temperature. The measurement performance characteristics appear normal; the probe uncovering characteristics were similar to those recorded for the S-IVB-501. At the present time, investigation is being conducted to determine the LOX tank influence on electrical components at liftoff.

C0111-426 Temp - Forward Skirt, Loc 8

The measurement did not display valid data during the region of max q. The data appears normal except from liftoff to RO +148 sec when it was off-scale-high, from RO +525 to RO +557 sec when erratic data increases were noted, and after RO +664 sec when the temperature started increasing until it was off-scale-high at RO +712 sec. The malfunction was caused by a debonded temperature sensor exhibiting erratic discontinuities and high resistance interface connections. The bonding method was a type susceptible to debonding under environmental conditions.

C0151-401 Temp - LOX Pump Surface

The data indicated off-scale-high condition throughout the flight test. The malfunction was probably caused by a debonded sensor. The debonding could have also caused an open circuit sensor. Since preflight RACS levels were within nominal levels, sensor connections were intact.

C0286-415 Temp - APS Fairing 2-4

The measurement response was very slow with respect to other similar fairing temperatures. The characteristic appears as a partially debonded transducer. The bonding method was a type susceptible to debonding under environmental conditions.

TABLE 18-4 (Sheet 2 of 3)
MEASUREMENT FAILURES

D0105-403 Press - LOX Tank Press Mod He Gas

The measurement displayed invalid data during S-IVB first burn. The data increased to off-scale-high at RO +92 sec and did not return to nominal level until RO +7,260 sec and subsequently presented valid data.

E0114-411 Vib - Fwd Skirt, EBW R/S Pnl, Rad

The vibration data was erratic during the presence of stage vibration. The malfunction appears to be a loosened coaxial connection that was susceptible to vibration causing discontinuity of the accelerometer output signal. The vibration spectral power density plots indicate excessive low frequency components, which confirms disturbance from a low response source.

E0210-410 Vib - LH2 Turbopump, Lat

The data indicated very high levels between RO +667 and RO +695 sec, and higher than nominal levels at other turbopump operating times. The vibration characteristic appears good with higher than nominal levels at engine start as compared to AS-501. At the RO +667 sec sample, the level was very high; the peaks were clipped by amplifier limiting. At RO +699 sec, after three samples, the level decreased to a nominal level. Due to the nature of the data during this period, the measurement did not provide usable information for the purpose of defining the vibration environment and is classified a failure for phase I. However, investigation of the measurement subsequent to the failure indicate that there is sufficient intelligence in the data to provide information useful in correlating engine performance. Total loss of measurement response was observed to occur at RO +11,625 sec.

Extensive laboratory tests and analyses performed in the investigation of the measurement failure indicate that severe overdriving of the amplifier from high vibration levels at low frequencies can result in the duplication of the flight data observed on AS-502. The vibration transducer is mounted on a block with the block bolted to the turbopump. It is suspected that a problem may exist in the mounting method. Resolution of the problem is under study and the implementation of Change Order 1789 and 1796 is expected to include corrective action.

PHASE II FAILURES - LIFTOFF TO PLANNED LV/SC SEPARATION

C0189-414 Temp - APS Injector Wall, Eng 1-2

The measurement failed in the off-scale-high mode at approximately RO +2,400 sec. The failure occurred during the first revolution coast period where the APS was enabled. The continual temperature variation associated with APS firings probably caused debonding of the transducer and subsequently open circuited the sensor continuity. The bonding method was a type susceptible to debonding under environmental conditions.

C2015-401 Temp - Crossover Duct, Ext Wall, Loc 1

The data was off-scale-high during the attempted restart. The initial indication of failure occurred at RO +722 sec when an off-scale-high response was observed. During coast mode the temperature appeared to return to scale. Several erratic temperature rises were noted, then at RO +4,700 sec it finally remained off-scale-high. Since the upper end of the range was 1,660 deg R, and off-scale-high condition during orbital coast phase seems unlikely.

The malfunction was probably due to a temperature patch debonding causing an intermittent high resistance contact of the sensor wiring. This temperature measurement was installed by Rocketdyne on the J-2 engine.

TABLE 18-4 (Sheet 3 of 3)
MEASUREMENT FAILURES

D0003-403 Press - LOX Pump Inlet

The data indicated off-scale-high subsequent to RO +5,400 sec. The expected pressure was approximately the LOX ullage pressure. This transducer was a potentiometer type transducer. At the present time definite cause of the malfunction has not been determined; however, some possibilities are presented here:

- a. Potentiometer deterioration - Deterioration of the potentiometer winding caused by rapid pressure variations as seen between RO +696 and engine cutoff.
- b. Diaphragm damage - Overpressurizing at engine cutoff caused over-flexing of the mechanical diaphragm.
- c. Internal pressure relief - Loss of internal pressure to reduce the diaphragm backpressure.
- d. LOX ingestion - LOX entering the sense tube causing internal damage.

At RO +33,500 sec the data abruptly came on scale to the 47 psia level, still approximately 46 psia above the ullage pressure. This phenomenon is also unexplained.

D0224-401 Press - LH2 Pump Interstage Outlet

The data decreased abruptly from 20 psia to below zero psia. The malfunction occurred at RO +2,730 sec during the coast mode. The data level was approximately 2 percent through the remainder of the mission. The malfunction is still under investigation; the pressure sensing system and the output connector discontinuity are the prime suspects.

TABLE 18-5 (Sheet 1 of 3)
QUESTIONABLE MEASUREMENTS

Partially Successful

C0274-403 Temp - Gas Interstage Area, Loc 6

The measurement abruptly increased to off-scale-high at S-II/S-IVB separation and remained in that state for the duration of the mission. The malfunction occurred after the period of interest. The off-scale-high condition indicates an open circuit of the sensor or to its associated wiring probably caused by temperature shock at S-II/S-IVB separation.

C0305-419 Temp - Aft Interstage, Loc 7

The temperature indication from RO +90 to RO +117 sec increased abnormally rapid with respect to other aft interstage temperatures. The response resembles a partially debonded sensor subjected to localized heating. The sensor eventually reseated itself (due to bond stress or aerodynamic pressures) at RO +117 sec and cooled to ambient skin temperature at RO +119 sec. The bonding method used was a type susceptible to debonding under environmental conditions.

D0002-403 Press - LH2 Pump Inlet

The data level indicated 2.5 psia (4 percent) above ullage pressure during the coast phase. The pressure during this phase was expected to be very close to the ullage pressure because of the very low axial acceleration level. The transducer malfunction occurred at RO +762 sec when a high pressure surge was observed. This pressure surge damaged the pressure sensor and offset its calibration +4 percent. Data were recoverable by a manual calibration shift.

D0055-424 Press - LOX Tank Inlet

Invalid data indication of zero pressure areas from RO +11,410 to RO +11,430 sec and subsequent to RO +11,730 sec was observed. The probable malfunction was the lifting of the potentiometer wiper from the winding in the vicinity of excessive wear. The invalid areas were not detrimental to the evaluation of the LOX pressurization system.

E0117-411 Vib - Fwd Skirt, Battery 1 and 2, Tan

Erratic vibration data were displayed except during liftoff and max q. The malfunction appears to be due to a loose coaxial cable connector. This measurement was not continually monitored (multiplexed); therefore, transition from good to invalid data was not definitely discernable. The malfunction probably occurred just after liftoff, then at max q, good data were obtained for one sample. The spectral power density plots at liftoff and max q appear similar to AS-501.

Aberrant:

C0037-408 Temp - LH2 Tank Ullage, 70 Percent

The temperature level indication was far below LH2 boiling point, and the level changed in irregular steps. The range of this measurement was intended to measure both liquid and gas temperatures. The calibration curve is linear until close to the liquid temperature where it is then exponential. The accuracy of the measurement is markedly degraded by the exponential portion of the curve and cannot be precisely represented by the computer calibration program.

C0153-403 Temp - Oxid Main Supply Line Wall

The measurement reflected a cooling trend during the coast period through RO +3,600 sec. At RO +5,400 sec, which was the next available data period, the measurement indicated off-

TABLE 18-5 (Sheet 2 of 3)
QUESTIONABLE MEASUREMENTS

scale-low and remained there for the duration of flight. Since the measurement was partially successful in phase II with failure occurring between RO +3,600 and RO +5,400 sec, it was considered good for phase II in accordance with the evaluation ground rules.

C0205-403 Temp - He Repress Sphere 4

This measurement was deleted prior to flight test; however, the flight data appear valid.

C2035-401 Temp - Gas Generator LOX Inlet

The measurement went off-scale-high at RO +10,230 sec. A patch-type transducer is utilized and it is suspected that debonding occurred. Since the measurement was partially successful in phase II, it was considered good for phase II in accordance with the evaluation ground rules.

D0016-425 Press - Cold Helium Sphere

The measurement was off-scale-low at RO +22,375 sec, after cold helium dump, on the data plots. Digital data showed the pressure to be below zero at -175 psia. RACS were verified to be within tolerance and the pressure at liftoff was within 50 psia of the ground supply pressure; however, investigation into the measurement history indicates the pressure to be lower than the ambient expected. It is believed that an ambient calibration degradation exists and the problem is being investigated further to correct the lower end point of calibration.

D0018-401 Press - Engine Reg Outlet

This measurement was deleted prior to flight test. It responded properly during flight.

D0071-414 Press - APS Oxid Supply Manf, Mod 1
D0073-415 Press - APS Oxid Supply Manf, Mod 2

Appearance of activity during liftoff, mach 1, and max q was indicated, although no activity was expected. These transducers are potentiometer type pressure transducers which are known to be susceptible to a high vibration environment.

K0008-401 Event - Ignition Detected

No activity was expected from this measurement. A dummy probe was installed for flight test.

M0069-404 Volt - Aft T/M Full Scale Ref
M0070-404 Volt - Aft T/M Zero Volt Ref

These measurements were susceptible to noise created by the chardown inverters. The noise quantity was discernable; however, it was not detrimental to the telemetry system. Noise in these measurements was observed on previous tests.

N0012-411 Misc - RF Power, T/M Ant 2, Fwd
N0015-411 Misc - RF Power, FM/FM 1 Transmitter
N0017-411 Misc - RF Power, FM/FM 3 Transmitter
N0019-411 Misc - RF Power, SS/FM Transmitter
N0033-411 Misc - RF Power, T/M Ant 3, Fwd
N0036-411 Misc - RF Power, T/M Ant 4, Refl

These measurements indicated drifting characteristics which were quite pronounced during the launch phase. These drifting responses were of a random nature that could not be attributed to the change of RF power. The drifting characteristic manifested itself as an

TABLE 18-5 (Sheet 3 of 3)
QUESTIONABLE MEASUREMENTS

increasing or decreasing step shift at liftoff. After liftoff they slowly increased or decreased to some peak value, then stabilized at a nominal level. The drifts did not exceed system requirements, and they were used for system evaluation. It appears the detectors were sensitive to vibration and temperature changes. Similar characteristics were observed on the S-IVB-501 flight.

N0016-411 Misc - RF Power, FM/FM 2 Transmitter

The measurement indicated a loss of output power at RO +27,950 sec. No telemetry data loss was observed, and the antenna powers did not decrease. Thus, a measurement loss was experienced. Probably a detector loss of sensitivity was incurred.

S0054-426 Strain - Axial, Fwd Skirt Loc 10A

S0055-426 Strain - Axial, Fwd Skirt Loc 10B

S0062-426 Strain - Axial, Fwd Skirt Loc 14A

S0063-426 Strain - Axial, Fwd Skirt Loc 14B

These measurements show polarity reversals. There is no degradation of data and the measurements have been used in analyses of static strain.

S0086-426 Strain - Dyn, Fwd Skirt, Pnl 13

to

S0101-426 Strain - Dyn, Fwd Skirt, Pnl 7

All dynamic strain measurements were inadvertently displayed with their calibration header inverted. Dynamically, the direction of deflection was not critical; however, for static deflection, correction should be applied.

S0100-426 Strain - Dyn, Fwd Skirt, Pnl 108

S0101-426 Strain - Dyn, Fwd Skirt, Pnl 7

These strain measurements indicated behavior questioned by Acoustics and Structural Dynamics. S0101-426 and S0100-426 showed higher than expected data amplitudes between RO +79.5 and RO +82.5 sec, and between RO +84.5 and RO +87.5 sec, respectively. At RO +91.5 sec, S0101-426 showed a dc shift from 52 percent to 70 percent of the measurement range and maintained the dc offset for two data samples. After the return of the data level of S0101-426 to approximately 42 percent of range, S0100-426 exhibited level variations during one sample period of approximately 10 percent from RO +109 sec.

Investigation and analysis of possible electrical malfunctions to the measurements did not produce evidence of electrical failures which would account for the anomalous behavior of the data during the periods specified above. Singular failure modes which can exhibit the type of data observed were investigated and analyzed but no reasonable singular failure mode could be determined. In view of the electrical characteristics, multiple failures of two separate measurements, over a coincident period of time, is possible but is considered unlikely. No laboratory testing was performed since simulation of flight conditions is considered impractical.

TABLE 18-6 (Sheet 1 of 3)
SUBCARRIER OSCILLATOR FREQUENCY

| IRIG CHANNEL | NOMINAL | | PRELAUNCH (RO -1,266) | | POST RESTART (RO +11,634) | |
|--------------|----------------|-----------------|--------------------------|-----------------|------------------------------|-----------------|
| | F _c | f _{BE} | F _c | f _{BE} | F _c | f _{BE} |
| FM SYSTEM 1 | | | | | | |
| 5 | 1300 | 1398 1202 | 1301 | 1400 1202 | 1300 | 1400 1202 |
| 6 | 1700 | 1828 1572 | 1699 | 1826 1569 | 1695 | 1815 1572 |
| 7 | 2300 | 2473 2127 | 2305 | 2466 2132 | 2296 | 2468 2135 |
| 8 | 3000 | 3225 2775 | 2993 | 3217 2768 | 2988 | 3190 2784 |
| 9 | 3900 | 4193 3607 | 3867 | 4190 3607 | 3891 | 4183 3596 |
| 10 | 5400 | 5805 4995 | 5396 | 5804 4989 | 5385 | 5783 4977 |
| 11 | 7350 | 7901 6799 | 7346 | 7899 6797 | 7332 | 7878 6778 |
| 12 | 10500 | 11288 9712 | 10505 | 11299 9709 | 10484 | 11267 9681 |
| 13 | 14500 | 15588 13412 | 14488 | 15572 13406 | 14459 | 15530 13369 |
| 14 | 22000 | 23650 20350 | 21980 | 23632 20341 | 21944 | 23576 20290 |
| 15 | 30000 | 32250 27750 | 29964 | 32229 27722 | 29928 | 32144 27656 |
| FM SYSTEM 2 | | | | | | |
| 3 | 730 | 785 675 | 729 | 784 674 | 730 | 783 674 |
| 6 | 1700 | 1828 1572 | 1700 | 1831 1571 | 1701 | 1831 1571 |
| 7 | 2300 | 2473 2127 | 2301 | 2477 2126 | 2303 | 2479 2129 |
| 8 | 3000 | 3225 2775 | 3001 | 3225 2776 | 3004 | 3230 2778 |

TABLE 18-6 (Sheet 2 of 3)
SUBCARRIER OSCILLATOR FREQUENCY

| IRIG CHANNEL | NOMINAL | | PRELAUNCH (RO -1,266) | | POST RESTART (RO +11,634) | |
|--------------|----------------|-----------------|--------------------------|-----------------|------------------------------|-----------------|
| | F _c | f _{BE} | F _c | f _{BE} | F _c | f _{BE} |
| 9 | 3900 | 4193 3607 | 3906 | 4197 3611 | 3905 | 4201 3611 |
| 10 | 5400 | 5805 4995 | 5395 | 5798 4989 | 5407 | 5813 5000 |
| 11 | 7350 | 7901 6799 | 7351 | 7904 6805 | 7364 | 7921 6807 |
| 12 | 10500 | 11288 9712 | 10500 | 11289 9710 | 10514 | 11307 9722 |
| 13 | 14500 | 15588 13412 | 14510 | 15610 13412 | 14526 | 15626 13429 |
| 14 | 22000 | 23650 20350 | 21990 | 23644 20344 | 22027 | 23699 20376 |
| 15 | 30000 | 32250 27750 | 29969 | 32211 27715 | 30032 | 32302 27780 |
| 16 | 40000 | 43000 37000 | 39996 | 43000 37027 | 40020 | 43033 37022 |
| 17 | 52500 | 56440 48560 | 52487 | 56424 48560 | 52522 | 56469 48616 |
| 18 | 70000 | 75250 64750 | 70089 | 75350 64848 | 70122 | 75453 64837 |
| FM SYSTEM 3 | | | | | | |
| 6 | 1700 | 1828 1572 | 1699 | 1828 1571 | 1701 | 1830 1572 |
| 7 | 2300 | 2473 2127 | 2299 | 2474 2126 | 2302 | 2475 2127 |
| 8 | 3000 | 3225 2775 | 3000 | 3224 2774 | 3003 | 3228 2777 |
| 9 | 3900 | 4193 3607 | 3898 | 4190 3605 | 3900 | 4194 3611 |
| 10 | 5400 | 5805 4995 | 5399 | 5803 4990 | 5402 | 5806 4995 |
| 11 | 7350 | 7901 6799 | 7346 | 7895 6794 | 7353 | 7907 6802 |

TABLE 18-6 (Sheet 3 of 3)
SUBCARRIER OSCILLATOR FREQUENCY

| IRIG CHANNEL | NOMINAL | | PRELAUNCH (RO -1,266) | | POST RESTART (RO +11,634) | |
|--------------|----------------|-----------------|--------------------------|-----------------|------------------------------|-----------------|
| | F _c | f _{BE} | F _c | f _{BE} | F _c | f _{BE} |
| 12 | 10500 | 11288 9712 | 10505 | 11298 9708 | 10514 | 11304 9714 |
| 13 | 14500 | 15588 13412 | 14485 | 15567 13399 | 14499 | 15586 13409 |
| 14 | 22000 | 23650 20350 | 21970 | 23632 20331 | 22006 | 23663 20354 |
| 15 | 30000 | 32250 27750 | 30004 | 32238 27766 | 30032 | 32271 27801 |

TABLE 18-7
RF SYSTEM PERFORMANCE SUMMARY

LAUNCH TIME

| | RO -1 | RO +500 | RO +780 | RO +11,600 |
|---|--------|---------|---------|------------|
| <u>Transmitter output (watts) (min 15w)</u> | | | | |
| FM/FM 1 (N15) | 21.2 | 20.2 | 20.0 | 22.2 |
| FM/FM 2 (N16) | 25.2 | 25.2 | 25.2 | 25.2 |
| FM/FM 3 (N17) | 27.2 | 27.6 | 27.6 | 29.6 |
| PCM/FM (N18) | 22.6 | 23.0 | 23.0 | 24.0 |
| SS/FM (N19) | 26.4 | 25.4 | 0 | 23.8 |
| <u>Antenna Power (watts)</u> | | | | |
| Ant 1 (N1) | 10.0 | 9.8 | 9.8 | 10.6 |
| Ant 2 (N12) | 9.8 | 9.4 | 9.8 | 11.6 |
| Ant 3 (N33) | 20.2 | 19.4 | 13.8 | 20.8 |
| Ant 4 (N35) | 17.4 | 17.2 | 11.6 | 17.8 |
| <u>Antenna VSWR (max 1.7:1)</u> | | | | |
| Ant 1 | 1.19:1 | 1.69:1 | 1.69:1 | 1.54:1 |
| Ant 2 | 1.37:1 | 1.47:1 | 1.47:1 | 1.44:1 |
| Ant 3 | 1.11:1 | 1.12:1 | 1.06:1 | 1.56:1 |
| Ant 4 | 1.13:1 | 1.63:1 | 1.44:1 | 1.41:1 |
| <u>Insertion Loss (max 7.5 db) (At RO +500)</u> | | | | |
| Ant 1 | | 6.88 db | | |
| Ant 2 | | 7.07 db | | |
| Ant 3 | | 5.79 db | | |
| Ant 4 | | 6.31 db | | |

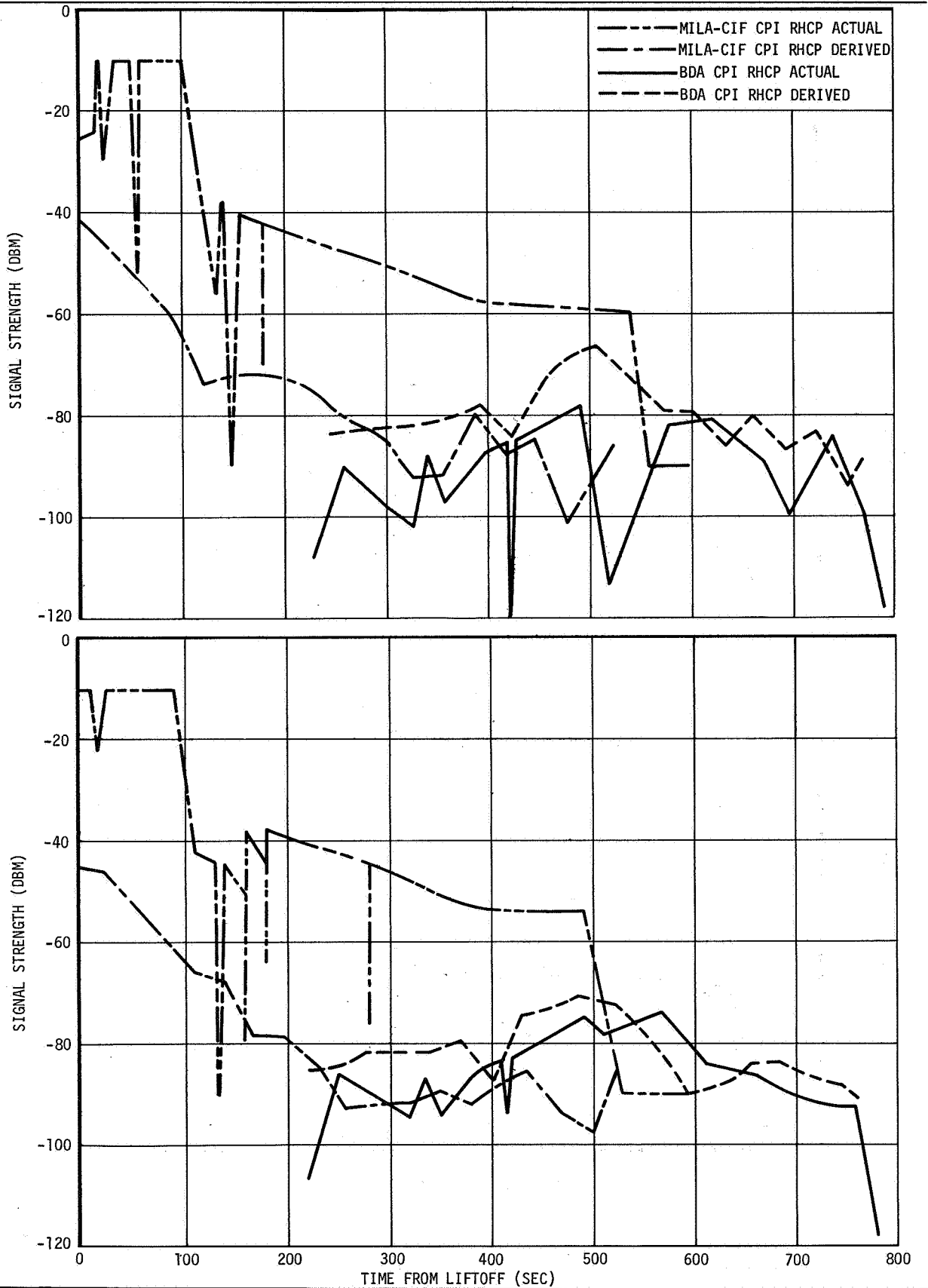


Figure 18-1. Telemetry Signal Strength - MILA and BDA

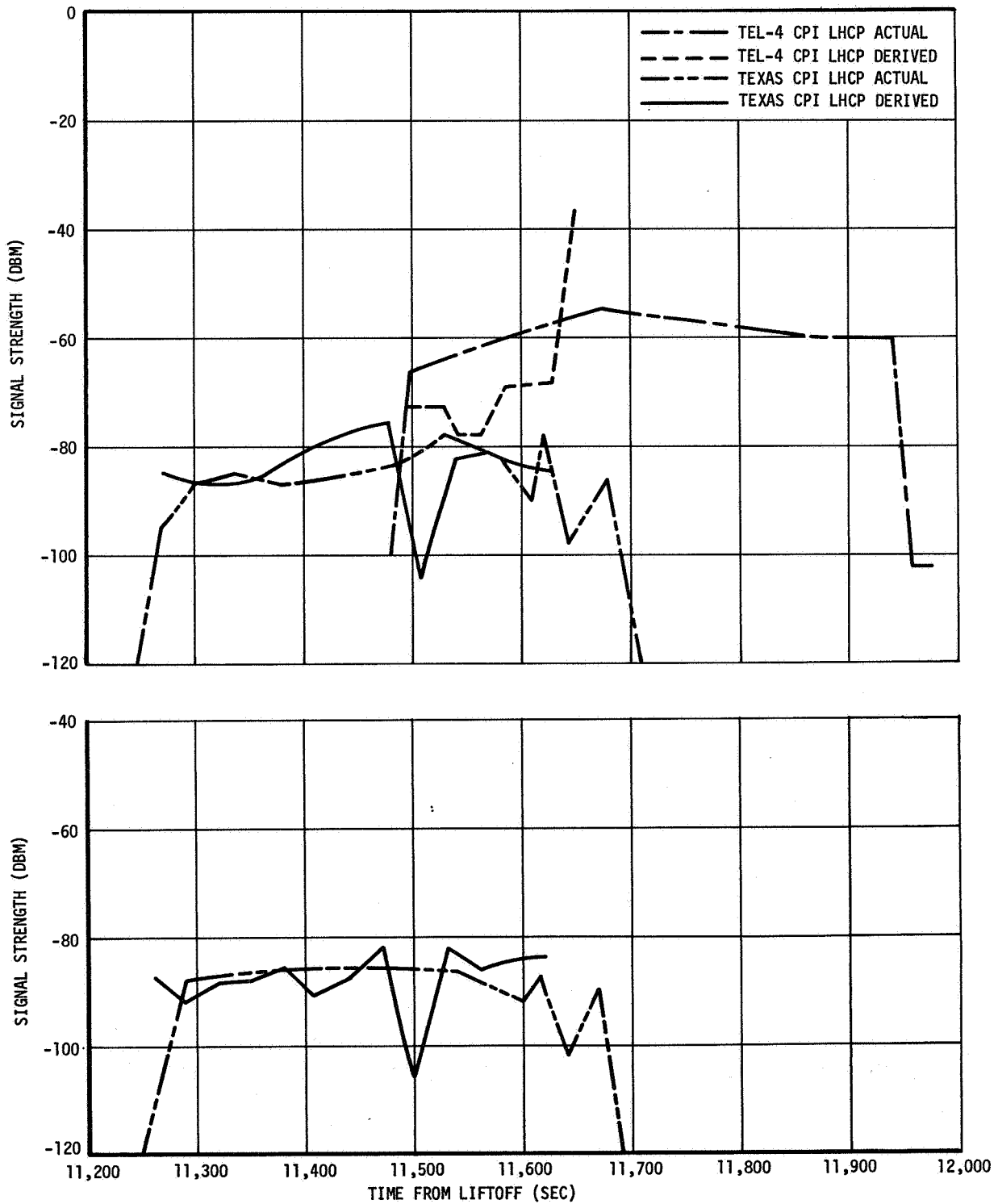


Figure 18-2. Telemetry Signal Strength - Tel 4 and Texas

SECTION 19

ELECTRICAL SYSTEMS

19. ELECTRICAL SYSTEMS

The electrical control system, with the exception of the PU system, and the electrical power system performed satisfactorily throughout phases I and II of the AS-502 flight as defined in Douglas Report No. DAC-56610A, S-IVB-502 Stage Technical Performance Criteria Document, revised March 1968. Although the propellant utilization (PU) system performed satisfactorily throughout phase I, LOX mass measurements went to a LOX tank mass-full condition during re-start preparation of phase II, indicating possible PU system malfunction. Subsequent investigation verified the PU system malfunction, and the analysis is delineated in section 16.

Evaluation of the electrical system performance during the critical analysis period of RO +133 sec did not disclose any electrical system malfunction.

19.1 Electrical Control System

The operational integrity of the electrical control system is verified in the sequence of events in section 5 of this evaluation. All responses to switch selector commands were satisfactory. Seventeen nonprogrammed commands were initiated to command the S-IVB from Carnarvon, Hawaii, and Guaymas ground stations. These commands are included in the sequence of events.

19.1.1 J-2 Engine Control System

All event measurements verified that the engine control system had responded properly to the Engine Start Command and Engine Cutoff Command given for first burn and for the engine restart attempt. First burn engine start was initiated at RO +577.268 sec with engine cutoff being initiated at RO +747.032 sec, resulting in a total engine first burn time of 169.764 sec. Second burn engine start was initiated at RO +11,614.667 sec. Due to the failure of the S-IVB engine to restart, the mainstage OK pressure switches did not pick up and engine cutoff was initiated at RO +11,630.394 sec. All telemetry event measurements of engine performance occurred in the proper sequential order.

19.1.2 Control Pressure Switches

A review of the event and pressure measurements associated with the control pressure switches verified that each switch functioned properly. The following paragraphs list these measurements and delineate the performance of each pressure switch.

The engine pump purge control module pressure switch regulates the pressure of the helium gas in the pump purge line to stay between 105 and 130 psia when the Engine Pump Purge Control Valve Enable ON Command is given. Data from the following measurements showed that purge pressure never reached the actuation limit (130 psia) and that the pressure switch, therefore, remained in the de-energized position (105 psia).

K0105-404 Event - Pump Purge Regulator Backup Pressure Switch De-en

D0050-403 Press - Engine Pump Purge Regulator

Section 19
Electrical System

The LH2 tank first burn flight control pressure switch actuates the first burn bypass control valve so that tank ullage pressure is maintained between 28 and 31 psia during the time that the first burn relay is on. The fuel tank was pressurized to 35 psia prior to first burn and never decreased below 32 psia during mainstage. Therefore, the pressure switch remained in the actuate (31 psia) position during this time. The following measurements verified these conditions.

K0184-404 Event - Fuel Tank Flight Control Pressure Switch
K0107-404 Event - LH2 Tank Step Pressure Valve En
D0177-410 Press - Fuel Tank Ullage EDS 1
D0178-410 Press - Fuel Tank Ullage EDS 2

The LH2 tank prepress, repress, and second burn flight control pressure switch actuates at 34 psia and deactuates at 31 psia. It controls the LH2 repress control valves during the LH2 Repress Control Valve Open ON Command and the LH2 tank step pressurization control valve during the time that the second burn relay is on. During repressurization, the switch allowed ullage pressure to increase from 20 to 34 psia at which time it closed the repress control valves. Prior to the second burn attempt, ullage pressure decreased sufficiently to allow deactuation of the switch. During the second burn attempt the pressure did not reach the actuation limit of the switch before the engine was cut off.

These conditions are verified by the following measurements:

K0101-404 Event - LH2 Repress Control Switch De-en
K0107-404 Event - LH2 Step Pressure Valve En
D0177-410 Press - Fuel Tank Ullage EDS 1
D0178-410 Press - Fuel Tank Ullage EDS 2

The LOX tank prepress and flight control pressure switch regulates the cold helium shutoff valves during the OFF portion of the LOX tank flight pressure system command and the heat exchanger bypass valve during the ON portion of this command. Actuation and deactuation of the switch occurs, respectively, at 41 and 38 psia of LOX ullage pressure. The pressure switch also controls the LOX tank repress control valves after the LOX Tank Repress Control Valve Open ON Command is given. Data from the following measurements verified that the switch responded properly to ullage pressure changes throughout flight.

K0102-404 Event - LOX Prepress Flight Switch En
K0108-404 Event - LOX Prepress Flight Switch De-en
D0179-424 Press - Oxid Tank Ullage EDS 1
D0180-424 Press - Oxid Tank Ullage EDS 2

The LOX chilldown pump purge pressure switch actuates at 41 psia and deactuates at 38 psia of pressure in the pump purge line. It controls the LOX chilldown pump purge control valve

when the LOX Chilldown Pump Purge Control Valve Enable ON Command is given prior to LOX loading. The pressure switch responded to pressure fluctuations in the pump purge line throughout flight as is verified by the following measurements.

K0131-403 Event - LOX Chilldown Purge Switch De-en

D0103-403 Press - Helium Pressure to LOX Motor Control

The control helium regulator backup pressure switch is employed in the pneumatic power control module as a redundant control of the helium line pressure should the module regulator fail for some reason. The switch actuates at 600 \pm 15 psia and deactuates at 490 \pm 25 psia. Pressure measurement D0014 showed that the regulator kept the line pressure below the actuation limit of the pressure switch during flight.

D0014-403 Press - Control Helium Regulator Discharge

The operation of the LOX tank regulator backup pressure switch is redundant to that of the cold helium pressure regulator in the LOX tank pressure control module. If the regulator fails, the pressure switch can actuate (450-485 psia) and close the cold helium supply shutoff valves thereby regulating the cold helium supply line pressure. Since the regulator functioned properly, the pressure switch remained in the de-energize (335-370 psia) position during flight. Proper operation was verified by the following measurements.

K0156-404 Event - LOX Tank Regulator Backup Pressure Switch En

D0225-403 Press - Cold Helium Control Valve Inlet

The LOX and LH2 translunar vent termination pressure switches were installed but were not operational for flight.

19.1.3 APS Electrical Control System

A review of the APS feed valve data verified that the APS electrical control system performed within prescribed limitations.

K0132-404 Event - APS Eng 1-1/1-3 Fd Vlv - Op

K0133-404 Event - APS Engine 1-2 Fd Vlv - Open

K0134-404 Event - APS Engine 2-1/2-3 Fd Vlv - Op

K0135-404 Event - APS Engine 2-2 Fd Vlv - Open

19.1.4 Chilldown Shutoff Valves

The LOX and LH2 chilldown shutoff valves responded to the chilldown shutoff pilot valve commands and operated properly.

K0136-409 Event - Fuel SOV Chill System - Cl

K0137-409 Event - Fuel SOV Chill System - Op

K0138-424 Event - Oxid SOV Chill System - Op

K0139-424 Event - Oxid SOV Chill System - Cl

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Electrical System

19.1.5 Vent Valves

A review of the following measurements indicated that the LOX and LH2 vent valves responded to their respective commands and operated properly.

K0001-410 Event - Fuel Tank Vent Valve - Cl
K0002-424 Event - Oxid Tank Vent Valve - Cl
K0016-404 Event - Oxid Tank Vent Valve 1 - Op
K0017-410 Event - Fuel Tank Vent Valve 1 - Op

19.1.6 Fill and Drain Valves

The LOX and LH2 fill and drain valves were commanded closed through the umbilical prior to liftoff and remained closed throughout flight.

K0003-427 Event - Fuel Fill Valve - Closed
K0004-404 Event - Oxid Fill Valve - Closed

19.2 Electrical Power System

The electrical power system performed satisfactorily in meeting electrical load requirements throughout phase I and the restart attempt of phase II.

19.2.1 Flight Batteries

All batteries performed within the expected limits as verified from the load profiles and temperature data shown in figures 19-1 through 19-4.

19.2.2 Chiltdown Inverters

The chiltdown inverters performed satisfactorily during phases I and II of the flight evaluation period. The inverters reacted to the load change demands of the chiltdown pumps without difficulties. The operating temperature of the inverters prior to liftoff was 515 deg R. The LOX chiltdown inverter temperature increased to 524 deg R and the LH2 chiltdown inverter temperature increased to 527 deg R at turnoff. Both the LOX and LH2 chiltdown inverter temperatures were at 499 deg R at turnon after the coast period and increased to 511 deg R and 515 deg R respectively at turnoff before the restart attempt.

| <u>MEASUREMENT NUMBER</u> | <u>MEASUREMENT NOMENCLATURE</u> | <u>ACCEPTABLE RANGE</u> | <u>ACTUAL VALUE</u> |
|-------------------------------|--|-----------------------------|-------------------------|
| M0026-404 | Volt-Phase A-B Fuel Chilldown Inverter | 56 <u>+4</u> vac | 57.0 vac |
| M0027-404 | Volt-Phase A-B LOX Chilldown Inverter | 56 <u>+4</u> vac | 56.0 vac |
| M0028-404 | Freq-Fuel Chilldown Inverter | 400 <u>+10</u> Hz | 401.0 Hz |
| M0029-404 | Freq-Oxid Chilldown Inverter | 400 <u>+10</u> Hz | 402.0 Hz |
| M0040-404 | Volt-Phase A-C LOX Chilldown Inverter | 56 <u>+4</u> vac | 57.0 vac |
| M0041-404 | Volt-Phase A-C Fuel Chilldown Inverter | 56 <u>+4</u> vac | 57.0 vac |
| M0044-404 | Volt-Phase A1-B1, LOX Chilldown Inverter | 56 <u>+4</u> vac | 58.0 vac |
| M0045-404 | Volt-Phase A1-C1, LOX Chilldown Inverter | 56 <u>+4</u> vac | 58.0 vac |
| M0046-404 | Volt-Phase A1-B1, LH2 Chilldown Inverter | 56 <u>+4</u> vac | 57.0 vac |
| M0047-404 | Volt-Phase A1-C1, LH2 Chilldown Inverter | 56 <u>+4</u> vac | 58.0 vac |

19.2.3 5 Volt Excitation Modules

Both 5 v excitation modules performed satisfactorily. The output values are listed below:

| <u>MEASUREMENT NUMBER</u> | <u>MEASUREMENT NOMENCLATURE</u> | <u>ACCEPTABLE RANGE</u> | <u>ACTUAL VALUE</u> |
|-------------------------------|-------------------------------------|-----------------------------|-------------------------|
| M0024-411 | Volt-5 Volt Excitation Mod Fwd | 5.00 <u>+0.025</u> vdc | 5.01 vdc |
| M0025-404 | Volt-5 Volt Escitation Mod Aft | 5.00 <u>+0.025</u> vdc | 5.00 vdc |
| M0042-404 | Freq-5 Volt Excitation Mod Aft | 2,000 <u>+200</u> Hz | 2,000 Hz |
| M0043-411 | Freq-5 Volt Excitation Mod Fwd | 2,000 <u>+200</u> Hz | 2,000 Hz |

19.2.4 Static Inverter Converter

The static inverter converter operated within design limits with the exception of the 5 vdc output, measured by measurement M0004-411 (Static Inverter Converter, 5 vdc) which was 30 mv higher than the tolerance limit during normal PU operation and 90 mv out of tolerance when the PU Valve Hardover Command was acted upon. The 5 vdc output being out of tolerance does not affect the operation of the PU control system since it is used for telemetry excitation of the mass potentiometers only. No error is introduced into propellant mass calculations since ratios of voltage levels are utilized in evaluating mass potentiometer data.

The inverter frequency went to 406.2 Hz when the PU Valve Hardover Command was given at second burn Engine Start Command. The shift in frequency is expected at the PU Hardover Command, and there is no degradation in the operation of the PU system.

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 Electrical System

The minimum temperature was 541 deg R at liftoff. At inverter power turnoff, the temperature was 546 deg R.

| <u>MEASUREMENT NUMBER</u> | <u>MEASUREMENT NOMENCLATURE</u> | <u>ACCEPTABLE RANGE</u> | <u>ACTUAL VALUE</u> |
|-------------------------------|---|------------------------------|-------------------------|
| M0001-411 | Volt-Static Inverter Converter | 115 \pm 3.45 vrms | 114.5 vrms |
| M0004-411 | Volt-Static Inverter Converter | 5.00 \pm 0.10 -0.55 vdc | 5.130 vdc 5.190 vdc* |
| M0012-411 | Freq-Static Inverter Converter | 400 \pm 6 Hz | 402 Hz 406.2 Hz* |
| M0023-411 | Volt-Static Inverter Converter, 21 vdc | 21.0 \pm 1.5 -1.0 vdc | 21.80 vdc |

*Levels during PU hardcover period.

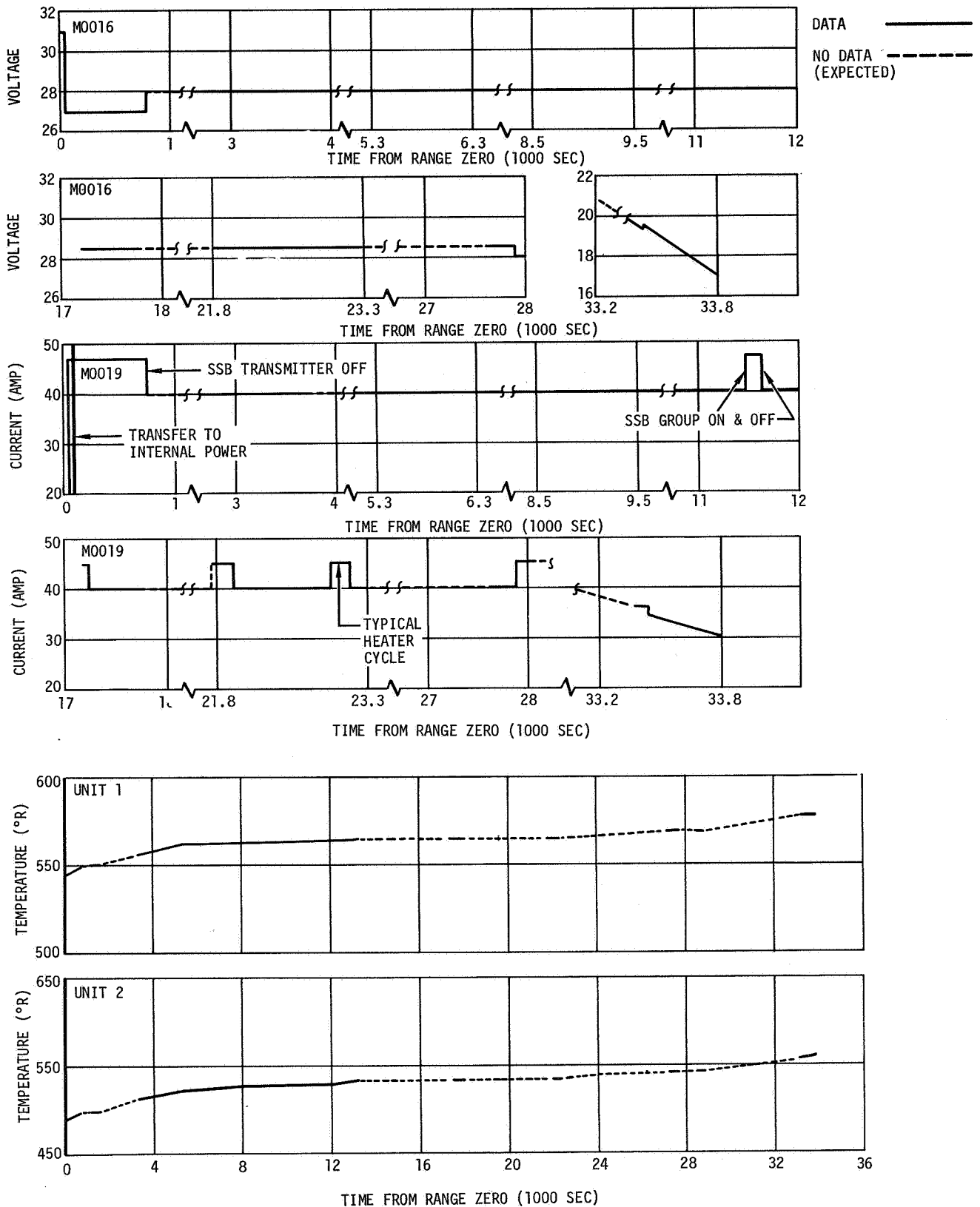


Figure 19-1. Forward Battery No. 1 Performance

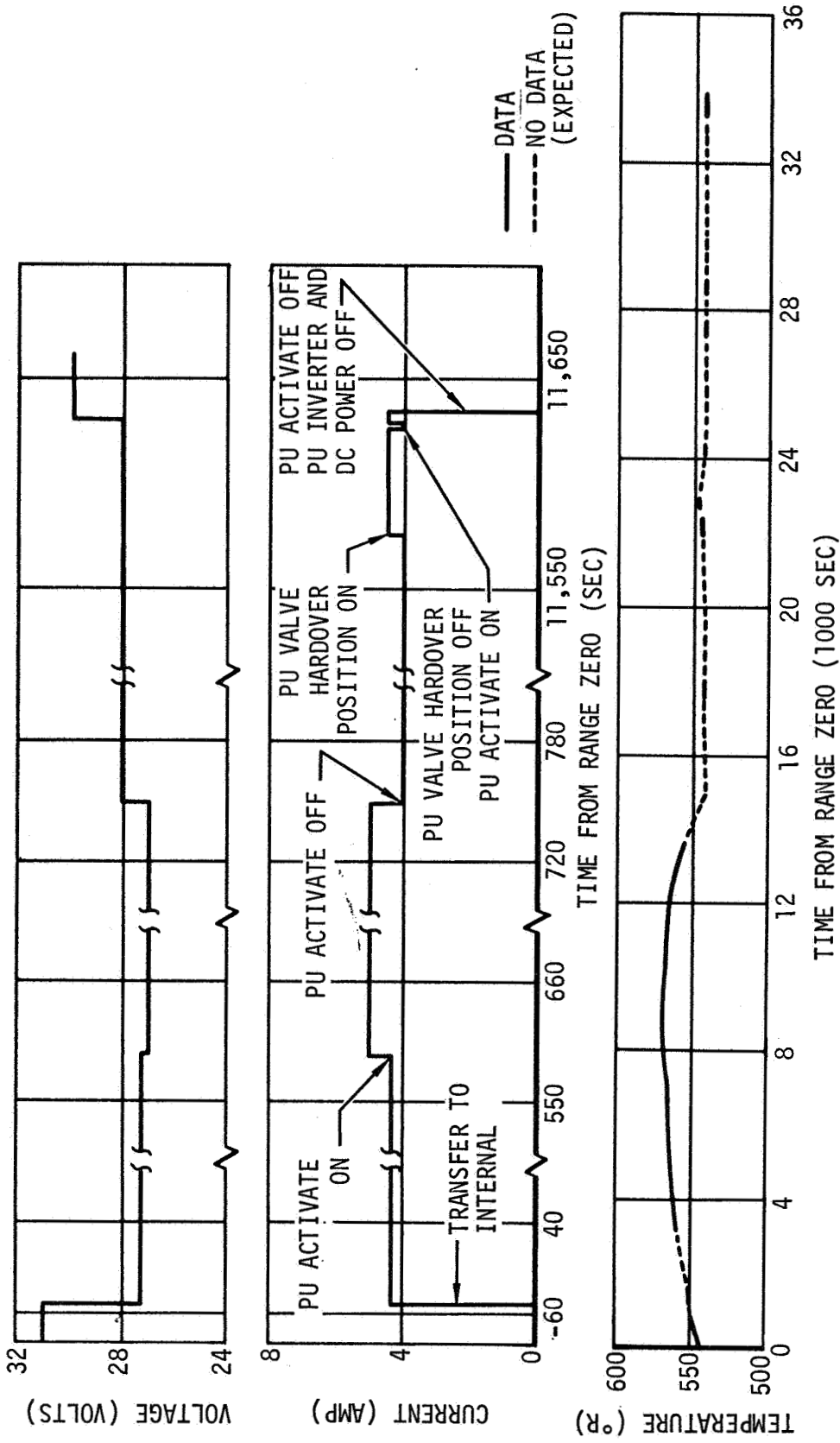


Figure 19-2. Forward Battery No. 2 Performance

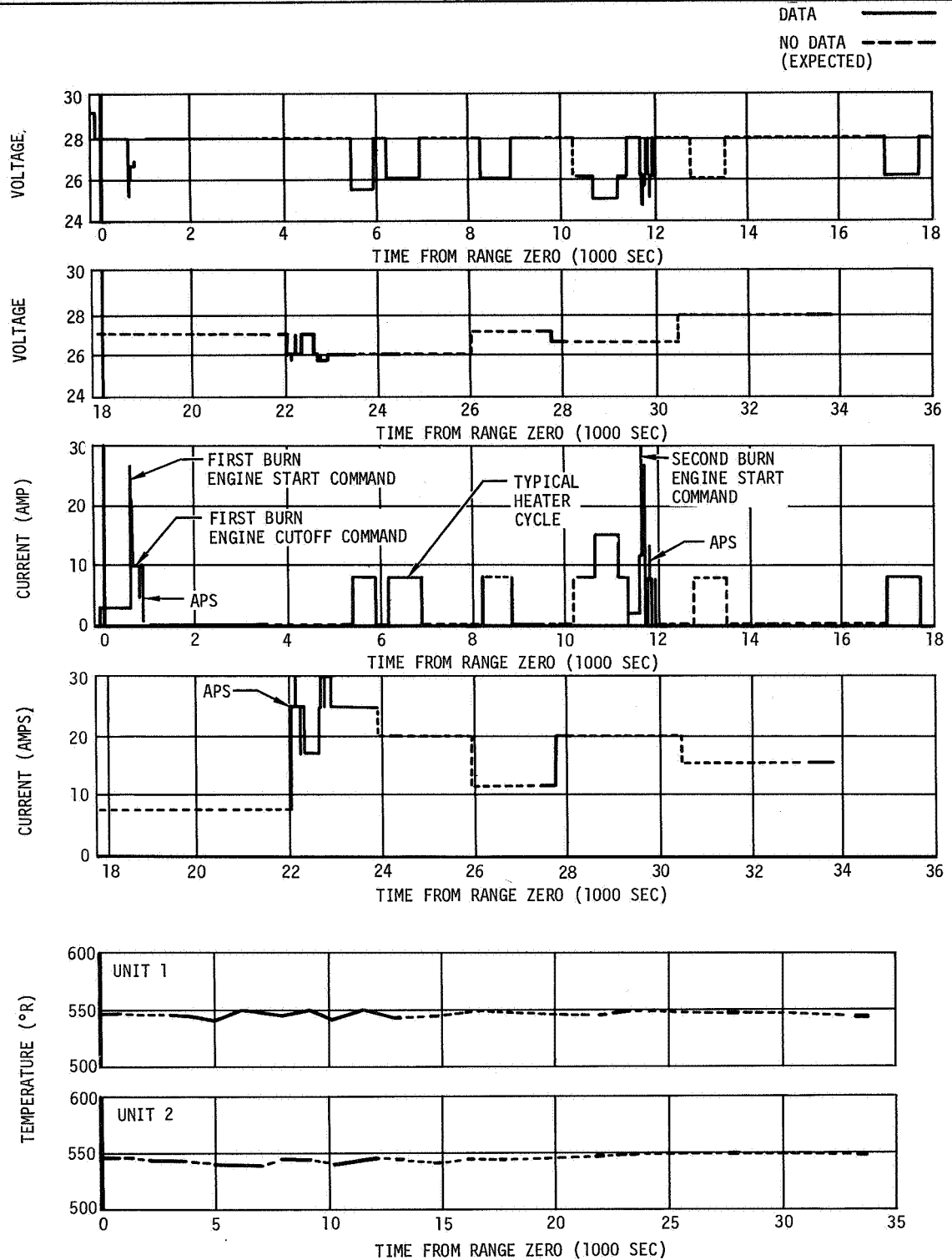


Figure 19-3. Aft Battery No. 1 Performance

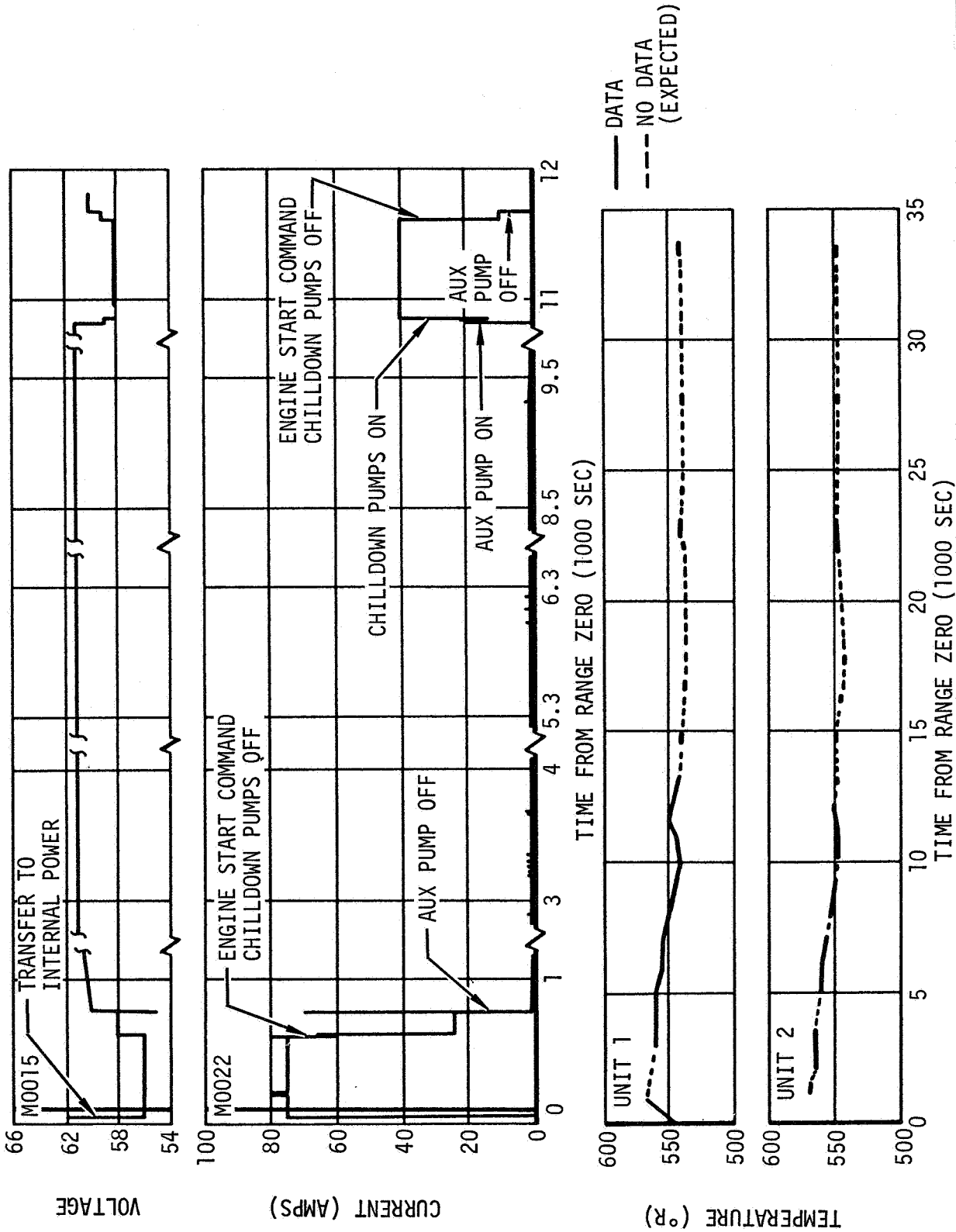


Figure 19-4. Aft Battery No. 2 Performance

SECTION 20

RANGE SAFETY SYSTEM

20. RANGE SAFETY SYSTEM

The range safety system was not required for propellant dispersion during the flight. All indications are that it operated properly and would have satisfactorily terminated an erratic flight.

20.1 Controllers

The controllers are designed to distribute command signals for engine cutoff, exploding bridgewire (EBW) charge and fire, and to distribute power to the range safety components. No abnormal conditions were evident.

20.2 Firing Unit Monitors

The following measurements indicate that the firing units were not charged throughout the flight.

M0030-411 Volt - F/U 1 EBW Range Safety

M0031-411 Volt - F/U 2 EBW Range Safety

20.3 Receivers Signal Strength

The signal strength monitors indicate that the range safety system was on at loss of data at RO +785 sec. Although safe commands were sent from Bermuda during the orbital insertic phase of flight, the range safety system did not respond since the flight vehicle was out of range of the range safety transmitter. This is due to the extended burn times of the S-II and S-IVB stages resulting from the S-II engines-out conditions. The safe command was sent from Bermuda on the first orbital pass and the following measurements verified that the range safety system was safed at RO +5,889 sec.

N0056-411 Misc - Sec R/S Rcvr 2 H/L Sig Str

N0057-411 Misc - Sec R/S Rcvr 1 L/L Sig Str

N0062-411 Misc - Sec R/S Rcvr 2 L/L Sig Str

SECTION 21

FLIGHT CONTROL

21. FLIGHT CONTROL

The thrust vector control system (TVCS) responded satisfactorily to instrument unit (IU) command signals providing pitch and yaw control during S-IVB first burn. The separation transient in the pitch plane was considerably larger than that experienced on previous flights. The maximum pitch engine deflection following S-II/S-IVB separation was approximately 6.7 deg which is near the maximum design engine deflection of 7 deg. This large separation transient was attributed to a large pitch attitude error (7.6 deg) existing at S-II/S-IVB separation. The TVCS responded normally during this interval and provided adequate control following S-II/S-IVB separation. Additional control system transients were experienced during guidance mode changes and first burn engine cutoff. These transients were expected and were well within the capabilities of the control system.

Inadequate hydraulic system supply pressure prior to restart prevented the J-2 engine from being centered at the time of Engine Start Command (ESC). The engine position at Engine Start Command was approximately 1.5 deg in pitch and -2.3 deg in yaw. Disturbances, experienced during the restart interval, resulted in pitch and yaw angular rates of -0.5 deg/sec and 0.45 deg/sec at the time of Engine Cutoff Command. The TVCS did not respond normally to control system commands during this interval because of insufficient hydraulic pressure.

The auxiliary attitude control system (AACS) provided satisfactory roll stabilization during powered flight and satisfactory pitch, yaw, and roll control during orbit. During S-II/S-IVB separation, a 0.3 sec pitch AACS firing (engine I_p) occurred commencing with the S-II/S-IVB Separation Command and terminating with the S-IVB Burn Mode ON Command. The design characteristics of the flight control computer (FCC) resulted in a temporary transfer of attitude control to the S-IVB coast mode following the S-II/S-IVB Separation Command which was terminated by the S-IVB Burn Mode ON Command. The noted temporary S-IVB coast mode and subsequent pitch AACS firing, although undesirable because of unnecessary use of AACS propellants, was not detrimental.

All orbital maneuvers were accomplished as planned, and vehicle attitude control was verified until approximately R0 +22,040 sec, at which time the yaw angular rate diverged attaining a maximum angular rate of -7.5 deg/sec followed by an oscillatory vehicle motion. AACS propellant depletion in module 1 (oxidizer - R0 +22,053 sec) and a LOX vent (R0 +22,020 sec) accounted for the diverging angular rate at this time. Depletion of the AACS propellants and subsequent loss of attitude control at this time is much earlier than expected for a nominal mission; however, this is reasonable when considering the relatively large and unexpected demands on the control system, particularly due to high initial angular rates at first and second burn engine cutoff, large propellant masses remaining following second engine cutoff, and an early LV/SC separation. Although depletion was earlier than expected, attitude control was maintained beyond the time period necessary to meet mission requirements.

LOX and LH2 propellant sloshing during powered flight was comparable to that experienced on previous flights. A large LH2 slosh wave occurred at S-II/S-IVB separation due to the large control system transient experienced at that time, however, the LH2 sloshing was rapidly damped by the LH2 deflector and baffle. LOX and LH2 sloshing did not have an appreciable effect on the control system during first burn.

21.1 Attitude Control - Powered Flight

The TVCS and AACS responded normally to guidance commands during first burn and provided satisfactory control in the pitch and yaw axes and roll axis respectively.

21.1.1 Thrust Vector Control System Performance - First Burn

A large pitch attitude error (7.6 deg) existing at S-II/S-IVB separation resulted in a significant control system transient (6.7 deg engine deflection) following transfer of attitude control from the S-II to the S-IVB (RO +577.4 sec). The large attitude error at S-II/S-IVB separation is attributed primarily to S-II engine trim (engines 1 and 4) required to compensate for the loss of two control engines (engines 2 and 3). These engines are shown in conjunction with the vehicle coordinate system and polarities in figure 21-1. The separation transient was considerably larger than that experienced on any previous flight, however, the control system operation appeared normal during this interval. TVCS capability was demonstrated for the engine in a near hardover position at the time of initial J-2 engine thrust buildup. A sequence of events related to attitude control during powered flight is presented in table 20-1. Maximum values of significant control system parameters are presented in table 20-2.

Following guidance initiation (third phase iterative guidance mode [IGM]) at RO +582.5 sec, the guidance system commanded the S-IVB to pitch nose down at a limited rate of 1 deg/sec to correct for nonoptimum trajectory conditions existing at S-II/S-IVB separation. Discussion of the trajectory conditions existing at S-II/S-IVB separation are presented in sections 8 and 17. Approximately RO +645 sec, the guidance system commanded the S-IVB nose up to achieve the desired target flight path angle at S-IVB engine cutoff. This maneuver became rate limited at 1 deg/sec near the end of S-IVB burn. The S-IVB inertial attitude (θ_y) at first burn engine cutoff was -71 deg, approximately 50 deg above the local horizontal.

Pitch and yaw guidance commands and actual vehicle attitudes (platform gimbal angles) during first burn are shown in figure 21-2. The actual vehicle attitude correlates well with the commanded attitude indicating normal control system operation.

Pitch attitude error, angular rate, and actuator position during first burn are presented in figure 21-3. The corresponding parameters in the yaw plane are shown in figure 21-4. The maximum angular rates experienced during first burn occurred during the interval of S-II/S-IVB separation and initiation of the third phase IGM. The maximum pitch and yaw

angular rates were -3.5 deg/sec and 1 deg/sec, respectively. The separation/guidance initiation transient decayed by approximately 30 sec after activation of the S-IVB attitude control system. The steady-state pitch attitude error during the pitch-down maneuver at 1 deg/sec was 1.5 deg. Following the pitch up maneuver at R0 +645 sec, the pitch attitude error shifted from 1.5 deg to -0.3 deg and gradually increased to -1 deg at approximately R0 +705 sec. At this time the pitch angular rate attained the rate limit of 1 deg/sec and the pitch attitude error remained constant at approximately -1 deg until first burn engine cutoff. The yaw attitude error was approximately -0.9 deg throughout flight. The steady-state attitude errors experienced during powered flight resulted from a combination of constant vehicle angular rates and/or effective thrust vector misalignment. The effective thrust vector misalignment includes the thrust vector misalignment with respect to the J-2 engine centerline, actuator tolerances, engine/stage misalignment, and system electrical biases. The effective pitch and yaw thrust vector misalignments determined for first burn were 0.25 deg and -0.4 deg respectively. These values are comparable to those experienced on previous flights.

LVDC Guidance commands were frozen (chi freeze) approximately 0.9 sec prior to guidance cutoff. Guidance commands are frozen to minimize disturbances at S-IVB cutoff. Immediately following chi freeze, the pitch attitude error became positive and increased as the vehicle attitude deviated from the frozen guidance commands due to angular rates at the time of chi freeze. The pitch actuator retracted responding to attitude control signals to remove the angular rate and resulting attitude error until R0 +750.7 sec at which time the FCC was switched to coast mode enabling the pitch and yaw channels of the AACS. Both pitch and yaw actuators returned to null as expected following activation of coast mode control.

The attitude control system response during first burn was simulated to determine the nature of experienced disturbances and to verify satisfactory control system operation. Initial conditions and constant parameter values required in the simulation are presented in table 21-4. A comparison of actual and simulated pitch and yaw attitude errors, angular rates and actuator positions are shown in figures 21-3 and 21-4, respectively. The results indicate that the TVCS responded normally to attitude control signals.

21.1.2 Auxiliary Attitude Control System

The AACS operation for roll stabilization during S-IVB powered flight appeared normal. During S-II/S-IVB separation a 0.3 sec pitch AACS firing (engine I_p) occurred commencing with the S-II/S-IVB Separation Command and terminating with the S-IVB Burn Mode ON Command. The sequence of events and noted AACS engine firing immediately following S-II/S-IVB separation are shown in figure 21-6. The roll control system is activated by the S-IVB Burn Mode ON Command. This command also enables the TVCS for pitch and yaw control with the J-2 engine during powered flight. Investigation of design characteristics of the FCC

Section 21
Flight Control

indicate that the attitude control system is temporarily in coast mode operation during the time interval between the S-II/S-IVB Separation Command and the S-IVB Burn Mode ON Command (0.3 sec). As a result, the appropriate initial conditions (attitude errors and angular rates) at S-II/S-IVB separation can induce pitch, yaw, or roll AACS firings during this interval. An initial pitch attitude error of 7.6 deg at S-II/S-IVB separation induced the noted AACS pitch firing. The S-IVB coast mode operation at S-II/S-IVB separation, although undesirable due to unnecessary use of AACS propellants, was not detrimental. Employment of alternate sequence TB4a would place the FCC in coast mode operation for 4.4 sec as opposed to 0.3 sec which was observed during the AS-502 mission. This may result in the unnecessary use of as much as 3 lbm of AACS propellants from one module.

Attitude control system firings during the separation interval have been experienced on one previous flight. During the AS-501 S-II/S-IVB separation, engine I_{IV} pulsed before the FCC was switched to S-IVB burn mode. This pulse is again attributed to attitude control signals commanding engine firings while the FCC was temporarily in coast mode operation.

Roll control during first burn appeared normal. The roll attitude error, angular rate, and attitude control system engine firings required for roll stabilization are shown in figure 21-5. Significant roll disturbances were observed during the interval from S-II/S-IVB separation to guidance initiation and following a change in pitch guidance commands at approximately R0 +645 sec. The roll disturbances experienced at S-II/S-IVB separation and guidance initiation were induced by a combination of ullage rocket misalignment (Flight Test Data indicated that the effective ullage rocket misalignment was approximately 0.6 deg), J-2 engine exhaust gas swirl, and coupling resulting from the engine pitch and yaw deflections. The roll disturbance experienced during the change in pitch guidance commands was induced by the pitch transient which occurred at this time.

The frequency of AACS roll engine firings during powered flight was higher than that experienced on previous flights. This is attributed to a higher steady-state roll torque (approximately 40 ft-lbf in a clockwise direction), resulting from J-2 engine exhaust gas swirl. The highest steady-state roll torque experienced previously was 27 ft-lbf (AS-204). AACS engines I_{III} and III_{IV} fired to correct for disturbances resulting from the steady-state roll torque. Propellant requirements and impulse usage for roll control during first burn were approximately 2.8 lbm and 620 lbf-sec for module 1 and 2.6 lbm and 570 lbf-sec for module 2. The propellant usage was determined using impulse data derived from integration of engine thrust data and assuming an Isp of 230 sec. A summary of AACS impulse is presented in table 21-5. The difference in AACS impulse requirements between module 1 and module 2 is attributed primarily to the pitch firing from module 1 (40 lbf-sec) during the separation sequence and also to AACS engine performance variations. The AACS propellant usage for roll control during first burn was higher than expected. The expected propellant usage ranged

between 0.8 and 2.0 lbm. The higher than expected usage is attributed primarily to the roll induced disturbances resulting from the large separation transient and to the relatively high steady-state roll torque.

Investigation of rate gyro data indicated the presence of low amplitude oscillations (17 to 22 cps) similar to that experienced on AS-204. These oscillations were noted primarily on the pitch and roll rate gyros during S-II/S-IVB separation. The amplitude and duration of these oscillations on AS-502 were much less than that experienced on AS-204, and no apparent effect on the attitude control system was noted.

21.2 Attitude Control - Orbit

The AACS responded normally to guidance commands during orbit and provided satisfactory attitude control during orbital disturbances, limit cycle operation, and maneuvering periods. The attitude control system engine firing history during orbit is shown in figure 21-7.

Loss of normal attitude control was evidenced at RO +22,040 sec as the yaw angular rate diverged to approximately -7.5 deg/sec followed by an oscillatory vehicle motion. The large yaw angular rate is attributed to termination of AACS engine firings in module 1 due to AACS propellant depletion (see section 14) and a LOX vent initiated at RO +22,023 sec. AACS propellant depletion of module 2 occurred approximately RO +22,630 sec. Depletion of the AACS propellants occurred earlier than expected for a nominal mission but is reasonable when considering the relatively large and unexpected demands on the control system, particularly during the intervals following first burn engine cutoff and second burn engine cutoff. Attitude control was maintained beyond the required period as covered in section 7 of this report.

21.2.1 First Burn Engine Cutoff

Launch Vehicle Digital Computer (LVDC) guidance commands were frozen approximately 0.9 sec prior to S-IVB engine cutoff. This is normally referred to as chi freeze and is implemented to minimize disturbances at engine cutoff. The guidance commands remained frozen until approximately 15 sec after cutoff at which time guidance commands were issued to align the S-IVB with the local horizontal.

The S-IVB attitude at cutoff was approximately 50 deg above the local horizontal. Initial conditions at first burn engine cutoff are summarized as follows:

| | |
|--------------------------------|----------------------------------|
| Pitch Attitude Error - 0.9 deg | Pitch Angular Rate - 0.7 deg/sec |
| Yaw Attitude Error - 0.8 deg | Yaw Angular Rate - 0.04 deg/sec |
| Roll Attitude Error - 0.35 deg | Roll Angular Rate - 0.07 deg/sec |

These conditions resulted from guidance operation during S-II and S-IVB burn phases (see section 8). The AACS pitch and yaw channels were activated approximately 3.5 sec after engine cutoff. Following activation of the AACS, pitch engine I_p came full on for

approximately 43 sec to reduce the initial positive rate (0.7 deg/sec) and establish the maneuvering rate of -0.3 deg/sec to align the vehicle with the local horizontal. Prior to achieving the local horizontal, the vehicle was commanded to roll 180 deg (counterclockwise looking forward) to position I up. This command was initiated at RO +837 sec with a maneuvering rate of -0.5 deg/sec.

The attitude control system operation appeared normal following engine cutoff. AACS propellant usage following engine cutoff was higher than expected and is attributed primarily to the initial pitch rate existing at engine cutoff. Actual and commanded vehicle attitudes following first burn engine cutoff are shown in figure 21-8. The corresponding pitch, yaw and roll control system response following engine cutoff are shown in figures 21-9, 21-10, and 21-11.

21.2.2 20 Deg Pitch Down Maneuver

A 20 deg pitch down maneuver was initiated at RO +3,207 sec for the purpose of evaluating propellant slosh dynamics. Propellant behavior is presented in paragraph 21.4.4. AACS engine III_p fired to establish the required maneuvering rate of +0.3 deg/sec (nose down) which was maintained until the vehicle attitude approached the commanded attitude; engine I_p then fired to reduce the angular rate to the desired orbital pitch rate. The commanded and actual vehicle attitudes during this maneuver are shown in figure 21-12. The corresponding attitude errors, angular rates and AACS engine firings are shown in figures 21-13, 21-14, and 21-15 for pitch, yaw, and roll, respectively. The AACS response appeared normal during this maneuver.

Low amplitude oscillations at 19.5 to 22 cps (see figure 21-15) were observed on the pitch and roll rate gyro signals beginning at RO +3,311 sec and terminating approximately 15 sec later. This time correlates with the time period of an AACS engine firing frequency of approximately 5 to 6 firings per sec required to terminate the pitch maneuver. The noted oscillations appeared to terminate as the AACS engine firing frequency was reduced to less than 4 firings per sec. Correlation of the noted oscillations and AACS firings indicates that the oscillations are related to the AACS engine firings. The oscillations appear to be similar to that experienced on previous flights and during other intervals of the AS-502 mission. The observed oscillations were not of sufficient magnitude to effect attitude control system operation.

21.2.3 20 Deg Pitch Up Maneuver

A 20 deg pitch up maneuver to the local horizontal was initiated at RO +5,427 sec. (An evaluation of propellant sloshing during this maneuver is presented in paragraph 21.4.4) AACS pitch engine I_p fired to remove the existing orbital pitch rate and established a

maneuvering rate of -0.3 deg/sec (nose up). As the actual vehicle attitude approached the commanded attitude, AACS engine III_p fired to remove the maneuver rate and establish an orbital pitch rate (nose down). High frequency oscillations were also observed during this maneuver, particularly on the pitch and roll rate gyros. Again, these oscillations existed during intervals of high frequency AACS engine firings (approximately 5 firings per sec). The attitude control system operation appeared normal during the 20 deg pitch up maneuver.

The commanded and actual vehicle attitudes during this maneuver are shown in figure 21-16. The corresponding attitude errors, angular rates and AACS engine firings are presented in figures 21-17, 21-18, and 21-19 for pitch, yaw, and roll, respectively.

Impulse requirements to initiate and terminate the pitch up maneuver were much larger than for the pitch down maneuver. This is normal since the orbital pitch rate contributes to the maneuvering rate during the pitch down maneuver and opposes the maneuvering rate during the pitch up maneuver. As a result, additional impulse is required to complete the pitch up maneuver. APS impulse requirements to initiate and terminate each of the pitch maneuvers was as follows:

Pitch Down Maneuver

Initiation 1,060 lbf-sec (module 2)
Termination 1,130 lbf-sec (module 1)

Pitch Up Maneuver

Initiation 2,270 lbf-sec (module 1)
Termination 2,220 lbf-sec (module 2)

21.2.4 180 Deg Roll Maneuver (Counterclockwise Looking Forward) Position I Down

A 180 deg counterclockwise roll maneuver was initiated approximately $R0 +5,787$ sec to rotate position I down. AACS engine III_{IV} fired to establish the required maneuvering rate of -0.5 deg/sec and the attitude error limited at 3.5 deg as expected. The attitude error remained limited until approximately $R0 +6,090$ sec at which time the actual vehicle attitude approached the commanded attitude and AACS engines I_{IV} and III_{II} fired to reduce the maneuvering rate. The attitude control system response appeared normal during this maneuver. The commanded and actual vehicle attitudes are shown in figure 21-20. The corresponding attitude errors, angular rates, and AACS engine firings are presented in figures 21-21, 21-22, and 21-23 for pitch, yaw, and roll, respectively.

21.2.5 Restart Orientation Maneuver to Spacecraft Separation

21.2.5.1 Restart Orientation Maneuver

Restart preparations were initiated at $R0 +11,287.6$ sec (TB6). Shortly after this time,

the APS ullage engines were commanded ON to provide acceleration to settle the propellants for restart. During ullaging, a small nose down disturbance was observed with a resulting rate of approximately -0.01 deg/sec which corresponds to an effective ullage thrust unbalance of approximately 0.6 lbf. This effective unbalance was probably a combination of a small ullage engine misalignment and thrust unbalance.

A restart orientation maneuver was initiated at RO +11,488 sec to position the vehicle in the desired attitude for restart. The commanded pitch attitude was approximately 10 deg below the local horizontal. Upon attainment of this attitude, the pitch guidance commands were frozen resulting in a pitch attitude of approximately 4 deg below the local horizontal at the time of Engine Start Command (RO +11,614.7 sec). The yaw and roll guidance commands at initiation of the restart orientation maneuver were +0.9 deg (nose right) and 0 deg respectively. The restart orientation maneuver was performed satisfactorily and the attitude control system response appeared normal. The commanded and actual vehicle attitudes during this maneuver are shown in figure 21-24. The corresponding attitude errors, angular rates, and AACS engine firings are presented in figures 21-25, 21-26, and 21-27, for pitch, yaw, and roll, respectively.

21.2.5.2 Restart

The FCC was transferred from the S-IVB coast mode to the S-IVB burn mode at RO +11,622.3 sec to provide pitch and yaw attitude control with the J-2 engine during second burn. Insufficient hydraulic system pressure (see section 22) prevented the main engine from providing satisfactory pitch and yaw control during this interval. The engine position at Engine Start Command was 1.5 deg in pitch and -2.3 deg in yaw. Disturbances experienced during the restart interval resulted in pitch and yaw angular rates of -0.5 deg/sec and 0.45 deg/sec at Engine Cutoff Command. These rates resulted from the inability of the TVCS to respond normally to control signals due to inadequate supply pressure. The LVDC issued TB7 after failure to restart. The AACS pitch and yaw channels were activated 3.5 sec after initiation of TB7. Roll control during the S-IVB burn mode on phase was minimal and appeared normal. Pitch and yaw attitude errors, angular rates, and actuator positions during the interval are shown in figures 21-28, and 21-29. The roll attitude error, angular rate, and AACS firing history are shown in figure 21-30.

21.2.5.3 Cutoff

Following engine cutoff and initiation of TB7, the pitch, yaw, and roll guidance commands (χ_y , χ_z , and χ_x) were set equal to the stable platform gimbal angles (θ_y , θ_z , and θ_x) and an inertial hold commanded until TB7 +20 sec, at which time the spacecraft separation orientation maneuver was initiated. Noticeable decreases in the pitch, yaw, and roll attitude errors were experienced at the time the guidance commands were set equal to the platform gimbal angles (figures 21-28, 21-29, and 21-30). This change in attitude error is normal.

Prior to engine cutoff, pitch and yaw angular rates increased to approximately -0.5 deg/sec (nose up) and 0.45 deg/sec (nose right). These angular rates at second burn engine cutoff are attributed to inadequate thrust vector control during the restart interval. Following second burn engine cutoff, the attitude error limits and command rate limits are changed to reconfigure for coast mode control (table 21-6). The attitude control system gains are changed (table 21-7) and the pitch and yaw channels of the AACS are activated approximately 3.5 sec after TB7. At this time, AACS engines III_p , I_{II} , and III_{II} came full on to reduce existing initial rates. Pitch and yaw attitude errors, angular rates and actuator positions following second burn engine cutoff are shown in figures 21-28 and 21-29. The roll attitude error, angular rate and AACS engine firing history during this interval is presented in figure 21-30.

21.2.5.4 Launch Vehicle/Spacecraft Separation Maneuver

The pitch and yaw attitude error limits and command rate limits were changed again at TB7 +15 sec (table 21-6) to provide increased maneuvering capability during the spacecraft separation orientation maneuver. Normal step changes in the pitch and yaw attitude error were observed at this time (see figures 21-28 and 21-29).

The launch vehicle/spacecraft (LV/SC) separation maneuver was initiated at TB7 +20 sec. The attitude commands during this maneuver were χ_y (pitch) +158 deg (nose up), χ_z (yaw) -5.5 deg (nose left), and χ_x (roll) 180 deg (clockwise looking forward). The maximum maneuvering rate in all three axes was +1.2 deg/sec. Commanded and actual vehicle attitudes during the LV/SC separation maneuver are shown in figure 21-31. The corresponding attitude errors angular rates, and AACS engine firings are presented in figures 21-25, 21-26, and 21-27.

21.2.5.5 LV/SC Separation

The LV/SC separation was programmed to occur at TB7 +180 sec; however, due to the restart failure, a ground command was issued to initiate LV/SC separation at RO +11,666.1 sec (TB7 +35.8 sec). At this time the vehicle attitude was θ_y -128.9 deg (0.2 deg below the local horizontal), θ_z -2.6 deg, and θ_x 15.0 deg. Pitch, yaw, and roll angular velocities were 0.4, -0.9, and 1.3 deg/sec, respectively. The first detectable disturbances resulting from the LV/SC separation occurred at RO +11,667.85 sec.

Telemetry data from both the CSM, and the S-IVB IU indicated unexpected disturbances were applied to both vehicles during the separation interval. The following information was obtained from available flight data:

- a. The spacecraft pitch rate increased by 1.53 deg/sec (from 0.3 to 1.83 deg/sec in the nose up direction) (figure 21-32) over a period of 0.1 sec immediately following physical separation which occurs 1.7 sec after initiation of the LV/SC separation sequence.

- b. The S-IVB pitch rate decreased by approximately 0.3 deg/sec (from 0.38 deg/sec to 0.1 deg/sec nose up) (figure 21-32), in a similar interval immediately following physical separation.
- c. The S-IVB pitch rate abruptly increased by approximately 0.3 deg/sec (from 0.1 to 0.4 deg/sec nose up) at 1.0 sec following physical CSM separation.
- d. Longitudinal acceleration impulses in the aft direction were detected by the IU accelerometer at the time of physical separation and 1.0 sec later.
- e. Additional data relating to the noted disturbance were also evaluated and correlated with the above data.

The following phenomena were considered as possible causes of the observed disturbances:

- a. A shift in position of a large mass, such as the LM, on the launch vehicle.
- b. Unbalanced forces from Spacecraft Lunar Module Adapter (SLA) panel separation ordnance (MDF).
- c. CSM RCS (Command service module reaction control system) thrust.
- d. CSM RCS plume impingement on the launch vehicle.
- e. S-IVB APS thrust.
- f. Launch vehicle venting thrust.
- g. A momentary interference or hangup between a SLA panel and the CSM.
- h. Failure of one or more SLA panels to deploy properly.

Of the phenomena evaluated as possible sources of the moments required to cause the separation disturbances, the following were ruled out as primary causes of the disturbances.

- a. A shift of a large mass on the launch vehicle such as the LM was ruled out because it could not contribute to the CSM disturbances, and the sequence of events connected with the launch vehicle behavior is not consistent with a shifting mass.
- b. Unbalanced SLA ordnance (MDF) forces during separation could not account for the S-IVB disturbances 1 sec after physical separation.
- c. RCS thrust moments were too small to account for CSM rate changes.
- d. RCS plume impingement forces on the launch vehicle were too small to account for the observed rate changes, and the pulsing history did not correlate with the observed rate changes.
- e. S-IVB APS moments were too small to account for the observed rapid rate changes and the thrusting history did not correlate with the observed rate changes.

- f. Launch vehicle venting could not cause the CSM disturbances. Potential venting moments applied to the S-IVB (even with worst case asymmetry) are too small to account for the observed rate changes, and the actual venting history did not correlate with the observed rate changes.

From analysis of the data it was concluded that the primary cause of the disturbances noted previously can be explained by:

- a. A momentary interference or hangup between the SLA panel on position I and the CSM during the 0.1 sec following actual separation, which induced the CSM disturbance which resulted in the angular rate change of 1.53 deg/sec.
- b. The asymmetrical forces and moments applied to the S-IVB by the acceleration of the SLA panel on position III and the failure to accelerate the SLA panel on position I coupled with the CSM interference during deployment could account for the first observed S-IVB rate change of approximately 0.3 deg/sec.
- c. Action of the ordnance at separation can account for the first noted longitudinal acceleration pulse.
- d. Deceleration of the SLA panel on position III during panel arrestment without a corresponding deceleration of the SLA panel on position I accounts for the observed S-IVB rate change of approximately 0.3 deg/sec.
- e. The second observed longitudinal acceleration pulse can be accounted for by deceleration of SLA panels on positions II, III, and IV.

From evaluation of the observed data it was concluded that a momentary interference or hangup occurred between the launch vehicle and spacecraft preventing normal deployment of the SLA panel on position I. The momentary interference or hangup temporarily affected the motion of both the launch vehicle and spacecraft, however, the spacecraft separated successfully and the launch vehicle and spacecraft each recovered from the momentary attitude deviation.

21.2.6 Loss of Attitude Control

Orbital attitude control was verified until approximately R0 +22,040 sec (Hawaii fourth revolution) at which time the yaw angular rate started to diverge attaining an angular rate of -7.5 deg/sec followed by an oscillatory motion. Two factors were conducive to producing the initial yaw attitude divergence:

- a. A LOX vent initiated at R0 +22,023 sec
- b. AACS propellant depletion (module 1) at R0 +22,053 sec (section 14).

Since the LOX vent is oriented approximately 14.5 deg off of position IV toward position III, venting disturbances were experienced primarily in the yaw plane. AACS engine III_{IV} fired

to correct for the resulting yaw disturbance but introduced a negative roll angular rate and attitude error. Since yaw/roll signal mixing is employed in the FCC during orbital control, engine III_{IV} terminated yaw correction firings (RO +22,227 sec) when the roll angular rate and attitude error increased to a sufficient magnitude to require AACS engine III_{II} to fire for roll attitude correction. Approximately RO +22,112 sec, the yaw platform gimbal angle reached its physical limit (61.3 deg) causing loss of the platform inertial reference. AACS propellants in module 2 were depleted at approximately RO +22,630 sec.

AACS propellant depletion and subsequent loss of attitude control, although earlier than expected for a normal mission, was reasonable when considering control system requirements due to initial angular rates existing at first and second burn engine cutoff, large propellant mass remaining following second burn engine cutoff, and an early spacecraft separation. Commanded and actual vehicle attitudes following loss of attitude control are shown in figure 21-33. The vehicle dynamics and control system response during this interval are shown in figures 21-34 through 21-39.

21.3 Propellant Sloshing During S-IVB Powered Flight

Propellant utilization (PU) system sensor fine mass data was utilized to determine LH2 and LOX slosh frequencies and amplitudes during S-IVB first burn. LH2 and LOX slosh frequencies and amplitudes are shown in figures 21-40 and 21-41, respectively. The LH2 probe sensor data indicated a large slosh wave occurring at S-II/S-IVB separation which has been attributed to the large control system transient experienced at that time. This slosh wave appeared to be rapidly damped by the LH2 deflector. Increased LH2 slosh activity was also indicated at approximately RO +645 sec which coincides with the time of the vehicle pitch maneuver. This sloshing was rapidly damped. LOX slosh amplitudes and frequencies were comparable to those experienced on previous flights. Propellant sloshing did not significantly affect control operation during first burn.

21.4 Propellant Behavior During Orbit

The dynamic behavior of the LH2 and LOX aboard the S-IVB has been evaluated using data from instrumentation inside the tanks, flight AACS impulse usage, attitude error data and angular rate data. The results of this evaluation for the time period between J-2 first burn engine cutoff and restart attempt are presented in this section of the flight evaluation report.

The LH2 behavior was evaluated using data obtained from the internal sensors, but LOX sloshing could not be evaluated during orbit using the tank sensor data. The LOX sensors are mounted internally to the hollow instrumentation probe. For periods of low g coast, capillary action in this probe preclude an accurate evaluation of LOX behavior in the tank.

LOX sloshing behavior has been determined during the orbital maneuver from AACs firings, attitude error data and angular rate data.

21.4.1 Tank Instrumentation

The locations of the sensors in the LH2 tank from which data on propellant behavior has been obtained are shown in figure 21-42. Three types of sensors are used. These are: (1) wall temperature patches, (2) instrumentation probe temperature sensors, and (3) liquid/gas differentiators located on both the tank wall and instrumentation probe. Data from these sensors have been converted into charts (figures 21-43 through 21-46) presenting a continuous display of liquid or vapor condition.

The criteria used to discriminate between liquid and vapor conditions for the various temperature sensors are as follows:

- a. Liquid Condition
Temperature at or below saturation temperature.
- b. Vapor Condition
Temperature above saturation temperature.
- c. Transition Condition
Temperature changing from or to a steady-state condition indicating liquid.

The liquid/gas differentiators give a simple high or low capacitance reading, which indicates vapor or liquid, respectively.

During boost and S-IVB powered flight phase of operation, the various sensors performed satisfactorily. Both the wall temperature patch and instrumentation probe data show a progressive transition from liquid to vapor conditions as the propellant surface level dropped during S-IVB burn. Figure 21-43 shows a comparison between the surface level indicated by the PU probe data and the transition time for the various sensors. This comparison demonstrates that these sensors were operational and performing satisfactorily during high g vehicle operation.

During the orbital coast period data from the wall temperature patches appear to give an accurate indication of the presence of liquid propellant at the sensor. It has been found relatively easy to differentiate between liquid and vapor conditions. When the patches were immersed in the LH2, the data indicated liquid conditions. When the patches were surrounded by vapor, the data indicated a temperature even higher than that of the vapor. This is due to the low heat transfer between the patch and vapor compared with the relatively high thermal conductivity between the patch and the tank wall. Hence, the wall patch temperature data was considered to be giving an accurate differentiation between liquid and vapor conditions.

The instrumentation probe sensors are considered less reliable than the wall temperature patches during orbit coast. After orbital injection and activation of the CVS, the ullage temperature decreases to the liquid hydrogen temperature. Therefore, the probe temperature sensor data cannot be used to differentiate between liquid and vapor conditions. The liquid/gas differentiators have shown a tendency to be sensitive to condensation and globules on the sensor. Therefore, one of these sensors could be indicating liquid propellant due to small amounts of liquid trapped on the sensor, even though the sensor is well above the liquid level. However, the converse of this does not apply. When these liquid/gas differentiators indicate vapor, the data is considered reliable, since it does not appear to be probable that a submerged sensor would be surrounded by a single large vapor bubble.

21.4.2 LH2 Slosh Behavior at First Burn Engine Cutoff

A baffle and deflector are installed in the LH2 tank of all S-IVB/V vehicles to:

- a. Minimize the slosh amplitude at J-2 engine cutoff
- b. Increase slosh damping during orbital coast
- c. Minimize the amount of liquid which travels into the forward dome area of the LH2 tank.

Slosh amplification during the J-2 engine thrust termination and ullage thrusting could have caused high amplitude sloshing early in the coast period. To minimize the amount of this slosh amplification, the ullage thrusting sequence for the S-IVB was carefully timed. The theoretical maximum possible slosh wave amplification with this thrust sequencing has been determined to be 39. With the slosh wave indicated in the LH2 tank at the time of engine cutoff (less than 1 in.) the theoretical maximum slosh wave due to amplification would have been less than 40 in.

Immediately after engine cutoff, a number of events occurred (rocket ignition and cutoff, CVS activation, pitch down maneuver, and 180 deg roll maneuver) which could have had a significant effect upon propellant behavior. Because of the number and close proximity of these events, it is very difficult to establish a cause/effect relationship for these events and slosh amplification with the attendant propellant behavior.

Within 20 sec after S-IVB first burn engine cutoff, all of the wall sensors in the pitch plane indicated liquid propellant. The same type of response was noted in the yaw plane approximately 20 sec later. The data (figures 21-4 and 21-44) showed that these sensors continued to indicate liquid for quite a time (greater than 7000 sec), unlike data from S-IVB-203 and S-IVB-501 which indicated the liquid motion transients had subsided within 300 sec after engine cutoff. The instrumentation probe data indicate that liquid propellant inundated the probe sensors between 100 and 140 sec after engine cutoff. Unlike S-IVB-501 and S-IVB-203 data, sensors on the instrumentation probe above the level of the deflector (N0023, C0068, N0022, C0039 and N0021) indicated liquid at this time. Hence, the propellant

dynamics at engine cutoff appeared to have been more severe than that indicated on the previous flights. This increased slosh activity could have been the result of a combination of slosh amplification at engine cutoff and attitude control system engine firings. Attitude control system firings were required to remove a high initial pitch rate and maneuver the vehicle to the local horizontal.

21.4.3 LH2 Slosh Behavior During Orbital Coast

The wall sensor data during the orbital coast period (except for that from C2020 and C2021) continuously indicated liquid conditions until approximately R0 +8,200 sec. Starting at this time, a number of sensors in both the pitch and yaw planes indicated a transition from liquid to vapor conditions. The nature of the change in readings for these sensors does not indicate either sloshing or bubble formation (as was postulated in the S-IVB-501 flight evaluation). The topmost sensor in both planes (sta 605) continued to indicate liquid even though sensors lower on the probe indicated vapor.

One possible explanation for the response of these sensors is that after engine cutoff (where large propellant motion was indicated) a substantial amount of propellant became trapped between the tank wall and the bottom of the deflector due to surface tension effects. However, the amount of trapped liquid was greater than could be sustained indefinitely by these surface tension forces and liquid moved down the wall toward the main bulk of LH2 until the volume of this trapped liquid reached a steady-state condition. In the steady-state condition, the sensors above the surface level and below the trapped liquid would become exposed to vapor. This explanation would correlate the wall temperature sensor data to propellant behavior.

If the propellant configuration postulated above is correct, then the propellant would appear to have been settled prior to TB6 and the surface level as determined from wall sensor data would have been between sta 530 and 545.

Data obtained from temperature sensors on the instrumentation probe during orbital coast indicates liquid conditions at all sensors below sta 660. This was not unexpected, since on previous flights data from these sensors did not indicate transition from liquid to vapor conditions during orbital coast periods. This can be attributed to the sensor peculiarities noted in paragraph 21.4.1. Therefore, this data does not necessarily discredit the surface level indicated by the wall patch sensors.

21.4.4 LOX and LH2 Slosh Behavior During Pitch Maneuvers

Two 20 deg pitch maneuvers were performed during the orbital coast in order to assess propellant slosh dynamics resulting from vehicle maneuvers. Propellant slosh behavior resulting from these maneuvers have been determined through comparison of AACS flight data with predictions.

The flight impulse data for both maneuvers were compared to the predicted (dynamic model) impulse requirements and rigid body impulse requirements. The predicted impulse requirements

were obtained from an analog simulation of the S-IVB AACS and included the effects of propellant sloshing. The rigid body impulse requirements were analytically determined and represent the amount of impulse required to start or stop the desired maneuver rate excluding the effects of propellant sloshing. The AACS impulse usage requirements from modules 1 and 2 for the 20 deg pitch down and pitch up maneuvers are given in figures 21-47 and 21-48. The 20 deg pitch down maneuver was initiated by engine firings from module 2 (III_p) and terminated by engine firings from module 1 (I_p). For the 20 deg pitch up maneuver engine firings from module 1 (I_p) initiates the maneuver and firings from module 2 (III_p) terminates the maneuver.

Comparison of actual AACS impulse and calculated rigid body impulse requirements (figures 21-47 and 21-48) during the noted maneuvers indicate the existence of relatively large LOX slosh disturbances following initiation and termination of each maneuver. The actual impulse data, however, did not indicate sustained slosh activity. This was evidenced by the lack of periodic impulse usage following each maneuver. This is also evidenced in the pitch attitude error and angular rate data (figures 21-13 and 21-17) which do not indicate any significant interaction between propellant sloshing and the AACS as would be expected if sustained slosh activity had occurred. As discussed in paragraph 21.4.2, LH2 wall temperature sensor data indicate a wet condition before and during both pitch maneuvers. Therefore, LH2 sloshing during this time cannot be determined.

An investigation of actual impulse usage during these maneuvers is being continued in order to evaluate and improve, if necessary, the existing slosh model used in control system simulations.

21.4.5 LH2 Slosh Behavior During Restart Preparations

Prior to the engine restart attempt, a number of events occurred (ullage rocket ignition, LH2 repressurization, and APS firing to realign the vehicle) which would effect propellant slosh dynamics. The LH2 tank sensor data and the sequence of events related to restart preparation are given in figures 21-45 and 21-46.

After the application of ullage thrust, a number of sensors on the instrumentation probe indicated a transition from liquid to vapor conditions (figure 21-45). The sensors indicating this trend were both temperature sensors (C0068 and C0069) and liquid/gas differentiators (N0022, N0023, and N0024). This transition would correspond either to the expulsion of entrained vapor from the liquid bulk or to the draining of liquid attached to the probe and sensors. Since these sensors are reliable when indicating vapor conditions, data from these sensors give a sound indication that the liquid surface level at Engine Start Command was below sta 550. Within 20 sec after Engine Start Command, sensors N0025 and N0026 also showed a transition from liquid to vapor conditions. Hence, the surface level at that time was below sta 524. This would indicate that the propellant was settled with very little entrained vapor in the bulk at this time.

The wall temperature patch data (figure 21-46) for this same time period (around Engine Start Command) indicated liquid conditions existed as high as sta 605. The discrepancy in the propellant surface level as indicated by instrumentation probe data and wall sensor data must be explained in order to positively establish the propellant configuration at Engine Start Command. The wall temperature patch data in both planes indicated that the sensors became wet during the restart preparation period. The order in which these sensors became wet indicated propellant motion downward along the tank wall. This could be attributed to increased acceleration during ullaging causing the unsettling of propellant which had become trapped between the LH2 deflector and the tank wall during orbit. Hence, wall temperature sensors above the propellant surface level could have been indicating liquid propellant. Therefore, the wall sensor data does not discredit the validity of the surface level postulated from instrumentation probe data prior to engine restart.

Approximately 100 sec after the initiation of repressurization and the attitude realignment maneuver, instrumentation probe sensors high in the tank (N0021 and C0039) indicated the presence of liquid. This phenomenon appears to be quite similar to that experienced on S-IVB-501. Although it is not possible to determine the amount of propellant that reached the forward dome area, the duration of the liquid indication by the sensors would tend to indicate that this response resulted from a small amount of splash.

The repressurization difficulties encountered on S-IVB-501 were not encountered on S-IVB-502. This appears to be the result of the revised restart preparation sequence which employs ullaging prior to repressurization. This sequence appears to have contributed to better propellant control during repressurization and the restart orientation maneuver than on AS-501.

On the S-IVB-501 the realignment maneuver and repressurization occurred immediately after ullage engine ignition. On S-IVB-502 these two events took place about 200 sec after the initiation of ullage thrust. As a result of the duration of this thrust period, a substantial amount of entrained vapor appears to have been purged from the liquid; hence, lowering the surface level as indicated by probe data. At the time of the attitude realignment maneuver this surface was much nearer the level of the slosh baffle, thereby increasing baffle effectiveness for propellant control during restart preparations.

21.4.6 Conclusions

LH2 wall temperature sensor data indicated that LH2 sloshing following first burn engine cutoff was greater than that experienced on S-IVB-501. Propellant sloshing following engine cutoff has been attributed to a combination of slosh amplification and the pitch down maneuver. LH2 slosh amplitudes prior to engine cutoff were greater on S-IVB-502 than S-IVB-501 (0.7 in. compared to 9.1 in.). As a result, the LH2 slosh wave resulting from slosh amplification could be higher on S-IVB-502, depending on the phase angle of the propellant surface. In addition, control system activity following S-IVB-502 engine cutoff was much more severe than that experienced on S-IVB-501, due primarily to a high initial

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pitch rate at engine cutoff (approximately 1 deg/sec). The larger LH2 sloshing experienced after engine cutoff on S-IVB-502 is, therefore, attributed to the increased control system activity in conjunction with the initial slosh conditions.

Propellant sloshing activity during the two 20 deg pitch maneuvers remained within acceptable levels. Although there was a relatively large initial LOX slosh wave excited by each maneuver, sustained sloshing was not evident.

During the first portion of the orbital coast, LH2 wall temperature sensor data indicated liquid conditions in both pitch and yaw as high as S-IVB sta 605. Late in the orbital coast, a number of these sensors indicated a transition from liquid to vapor. Because of the manner of this transition, it was postulated that LH2 was trapped in the corner between the wall and the bottom of the deflector and that the propellant surface level was below sta 545 prior to TB6.

The S-IVB-502 data during TB6 indicates conditions in the LH2 tank more conducive to a successful restart than that of S-IVB-501. Instrumentation probe data indicated a surface level in the vicinity of that which would be expected under high acceleration. This would place the LH2 surface level near the baffle, thus increasing the effectiveness of the slosh baffle for propellant control during restart preparations. Since S-IVB-501 restart was successfully completed, the more favorable conditions in the LH2 tank on S-IVB-502 should have enhanced a successful restart.

For additional information concerning propellant behavior refer to paragraph 26.4.

TABLE 21-1
SEQUENCE OF EVENTS RELATED TO ATTITUDE CONTROL
DURING POWERED FLIGHT

| EVENT | TIME FROM RANGE ZERO (sec) |
|---------------------------------------|----------------------------|
| Guidance reference release | -16.84 |
| S-II/S-IVB separation | 577.12 |
| Engine Start Command | 577.27 |
| S-IVB Burn Mode ON | 577.40 |
| Guidance initiation | 582.50 |
| End of artificial tau guidance | 593.90 |
| Chi freeze | 746.10 |
| S-IVB first burn engine cutoff (TB5) | 747.03 |
| S-IVB Burn Mode OFF | 750.76 |
| Time base 6 | 11,287.73 |
| Ullage engines ON | 11,287.89 |
| Engine Start Command | 11,614.67 |
| S-IVB Burn Mode ON | 11,622.29 |
| Guidance initiation | 11,627.73 |
| S-IVB second burn engine cutoff (TB7) | 11,630.32 |
| S-IVB Burn Mode OFF | 11,633.78 |
| LV/SC separation | 11,667.80 |

TABLE 21-2
MAXIMUM VALUES OF CRITICAL FLIGHT CONTROL PARAMETERS

| | UNITS | SEPARATION, GUIDANCE INITIATION AND ARTIFICIAL TAU | CHI TILDE | S-IVB C/O |
|-------------------------|---------|---|--------------|--------------|
| Pitch attitude error | deg | 7.6 | -1.0 | -0.9 |
| Yaw attitude error | deg | -2.4 | -0.9 | -0.8 |
| Roll attitude error | deg | -1.0 | 0.3 | 0.4 |
| Pitch rate | deg/sec | -3.5 | 1.1 | 1.0 |
| Yaw rate | deg/sec | 1.0 | -0.2 | -0.1 |
| Roll rate | deg/sec | -0.6 | 0.5 | 0.0 |
| Pitch actuator position | deg | 6.7 | 0.2 | 0.2 |
| Yaw actuator position | deg | -1.3 | -0.5 | -0.6 |

TABLE 21-3
ORBITAL MANEUVERS

| COMMANDED MANEUVER | INITIATION TIME (sec) | COMMANDED ATTITUDE PRIOR TO INITIATION OF MANEUVER (deg) | | | COMMANDED ATTITUDE AT TERMINATION OF MANEUVER (deg) | | |
|---|-----------------------|--|----------------|----------------|---|----------------|----------------|
| | | X _y | X _z | X _x | X _y | X _z | X _x |
| Maneuver to local horizontal following S-IVB cutoff | TB5 +15 (754) | -70.17 | .67 | 0 | -131* | +0.05 | -47 |
| Roll 180° CCW position I up | TB5 +90 (837) | -99 | +0.1 | 0 | -145.94 | 0.11 | 180 |
| Pitch 20° nose down | TB5 +2460 (3,207) | 74.6 | -0.9 | +180 | 51.1* | -0.9 | +180 |
| Pitch 20° nose up | TB5 +4680 (5,427) | -91 | 0.8 | 0 | -74* | 1.0 | 0 |
| Roll 180° CCW position I down | TB5 +5040 (5,787) | -95 | 0.8 | 180 | -115.6 | 0.59 | 0.0 |
| Restart orientation maneuver | TB6 +0.0 (11,288) | -115.6 | +0.75 | 0.0 | -128.0 | +1.5 | 0.0 |
| S-IVB second burn engine cutoff | TB7 +0.0 (11,630) | -128.0 | -1.51 | 0 | -129.99(x) | 4.57(x) | 0.47(x) |
| Spacecraft separation maneuver | TB7 +20 (11,650) | -129.99 | 4.57 | 0.47 | 28.02(x) | -0.85(x) | 178.73(x) |
| Post separation maneuver | TB7 +600 (12,230) | ND | ND | ND | ND | ND | ND |
| Maneuver to local horizontal (ground command) | TB7 +7200 (16,201) | ND | ND | ND | ND | ND | ND |

ND - No data X_y - Pitch X_z - Yaw X_x - Roll (x) - Chi freeze
* - Establish orbital pitch rate

TABLE 21-4
Simulation Initial Conditions and Constant Parameter Values

| | |
|--|--------------|
| Initial pitch attitude error - positive nose up | 7.21 deg |
| Initial yaw attitude error - positive nose right | 0 deg |
| Initial roll attitude error - positive clockwise looking forward | -0.2 deg |
| Initial pitch angular velocity - positive nose up | 0.2 deg/sec |
| Initial yaw angular velocity - positive nose right | -0.1 deg/sec |
| Initial roll angular velocity - positive clockwise looking forward | 0 deg/sec |
| Initial pitch engine position | 0 deg |
| Initial yaw engine position | 0 deg |
| Initial slosh parameters | 0 deg |
| Initial pitch angle of attack - positive nose up | 0 deg |
| Initial yaw angle of attack - positive nose right | 0 deg |
| Effective pitch thrust vector misalignment | -0.25 deg |
| Effective yaw thrust vector misalignment | 0.418 deg |
| Steady-state roll torque - positive clockwise looking forward | 40 ft-lbf |

FIGURE 21-5
APS IMPULSE SUMMARY

| | UNITS | MODULE 1 | MODULE 2 | APS ENGINE | | | | | |
|--|-----------------|----------------------|-----------------------|--------------------|---------------------|---------------------|---------------------|----------------------|--------------------|
| | | | | I _{IV} | I _P | I _{II} | III _{II} | III _P | III _{IV} |
| Powered Flight: Separation, guidance initiation, and ullage RKT jettison; R0 +577 to R0 +600 sec. | 1b-sec N-sec | 365.5 1,625.8 | 318.4 1,416.3 | 216.7 963.9 | 38.3 170.4 | 110.5 491.5 | 207.7 923.9 | 0 0 | 110.7 492.4 |
| Limit cycle operation for remainder of first burn; R0 +600 to R0 +747 sec. | 1b-sec N-sec | 253.9 1,129.4 | 251.6 1,119.2 | 23.9 106.3 | 0 0 | 229.9 1,022.6 | 22.6 100.5 | 0 0 | 229.0 1,018.6 |
| Initial recovery after first burn and alignment to local horizontal including pitch and 180° roll maneuver plus settling usage; CVS ON; *R0 +750 to R0 +1,230 sec. | 1b-sec N-sec | 11,726.0 52,159.8 | 4,914.4 21,860.3 | 1,449.0 6,445.5 | 9,144.5 40,676.7 | 1,132.7 5,038.5 | 1,363.4 6,064.7 | 2,333.8 10,381.2 | 1,217.3 5,414.8 |
| Pitch down 20° below local horizontal; CVS is ON; R0 +3,210 to R0 +3,475 sec. | 1b-sec N-sec | 1,334.3 5,935.2 | 1,206.3 5,365.9 | 111.5 496.0 | 1,222.7 5,438.8 | 0 0 | 30.5 135.7 | 1,062.8 4,727.6 | 113.0 502.6 |
| Pitch up maneuver to align with local horizontal; CVS is ON; R0 +5,426 to R0 +5,520 sec. | 1b-sec N-sec | 2,099.6 9,339.5 | 2,313.4 10,290.5 | 6.7 29.8 | 2,092.8 9,309.2 | 0 0 | 0 0 | 2,283.6 10,158.0 | 29.8 132.6 |
| Roll 180° to fin position I down; CVS is ON; R0 +5,786 to R0 +6,110 sec. | 1b-sec N-sec | 560.7 2,494.1 | 199.8 888.8 | 146.1 649.9 | 354.3 1,576.0 | 60.3 268.2 | 52.0 231.3 | 0 0 | 147.8 657.4 |
| Pitch and yaw maneuver for restart orientation; R0 +11,485 to R0 +11,600 sec. | 1b-sec N-sec | 1,413.3 6,286.7 | 2,147.4 9,552.1 | 97.7 434.6 | 1,266.0 5,631.4 | 49.6 220.6 | 29.6 131.7 | 2,022.1 8,994.7 | 95.8 426.1 |
| Recovery following second burn attempt, maneuver to spacecraft separation attitude, spacecraft separation and settling; 10 sec LOX tank venting, 120 sec LH2 tank venting; R0 +11,630 to R0 +11,970 sec. | 1b-sec N-sec | 14,930.1 66,412.4 | 27,318.6 121,519.1 | 1,615.9 7,187.9 | 8,320.5 37,011.4 | 4,993.7 22,213.1 | 5,034.0 22,392.3 | 20,819.8 92,611.0 | 1,464.8 6,515.8 |

*Does not include R0 +965 to R0 +1,010 sec because data is not available.

TABLE 21-6
ATTITUDE CONSTANTS

| TIME OF CHANGE | LADDER RATE LIMIT (-deg/minor loop) | | | LADDER MAGNITUDE LIMIT (-deg) | | | ATTITUDE COMMAND RATE LIMIT (-deg/sec) | | |
|--------------------|-------------------------------------|------|-------|-------------------------------|------|-------|--|------|-------|
| | YAW | ROLL | PITCH | YAW | ROLL | PITCH | YAW | ROLL | PITCH |
| 0 (Initial Values) | 0.48 | 0.48 | 0.48 | 15.3 | 15.3 | 15.3 | 1.0 | 1.0 | 1.0 |
| TB4 +0 | 0.48 | 0.48 | 0.48 | 15.3 | 15.3 | 15.3 | 1.0 | 1.0 | 1.0 |
| TB5 +0 | 0.48 | 0.48 | 0.48 | 2.5 | 15.3 | 2.5 | 0.4 | 0.6 | 0.4 |
| TB5 +100 | 0.24 | 0.24 | 0.24 | 2.5 | 15.3 | 2.5 | 0.4 | 0.6 | 0.4 |
| TB6 +0* | 0.48 | 0.48 | 0.48 | 2.5 | 15.3 | 2.5 | 0.4 | 0.6 | 0.4 |
| TB6 +327 | 0.48 | 0.48 | 0.48 | 15.3 | 15.3 | 15.3 | 1.0 | 1.0 | 1.0 |
| TB7 +0 | 0.48 | 0.48 | 0.48 | 2.5 | 15.3 | 2.5 | 0.4 | 0.6 | 0.4 |
| TB7 +15 | 0.24 | 0.24 | 0.24 | 7.0 | 7.0 | 7.0 | 1.44 | 1.44 | 1.44 |
| TB7 +600 | 0.24 | 0.24 | 0.24 | 2.5 | 15.3 | 2.5 | 0.4 | 0.6 | 0.4 |

*This change should be made when switchover from orbit to boost navigation occurs.

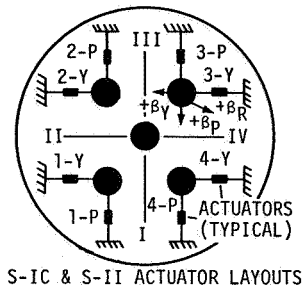
TABLE 21-7
ATTITUDE CONTROL SYSTEM GAINS

| TIME (sec) | PITCH AND YAW | | ROLL | |
|------------|--|--|--|--|
| | $A_0 \left(\frac{\text{deg}}{\text{deg}} \right)$ | $A_1 \left(\frac{\text{deg}}{\text{deg/sec}} \right)$ | $A_0 \left(\frac{\text{deg}}{\text{deg}} \right)$ | $A_1 \left(\frac{\text{deg}}{\text{deg/sec}} \right)$ |
| TB4 +1.1 | 0.809 | 0.97 | 1.0 | 5.0 |
| TB5 +3.7 | 1.0 | 5.0 | 1.0 | 5.0 |
| TB6 +334.6 | 0.809 | 0.97 | 1.0 | 5.0 |
| TB6 +597* | 0.809 | 0.698 | 1.0 | 5.0 |
| TB7 +3.7 | 1.0 | 5.0 | 1.0 | 5.0 |

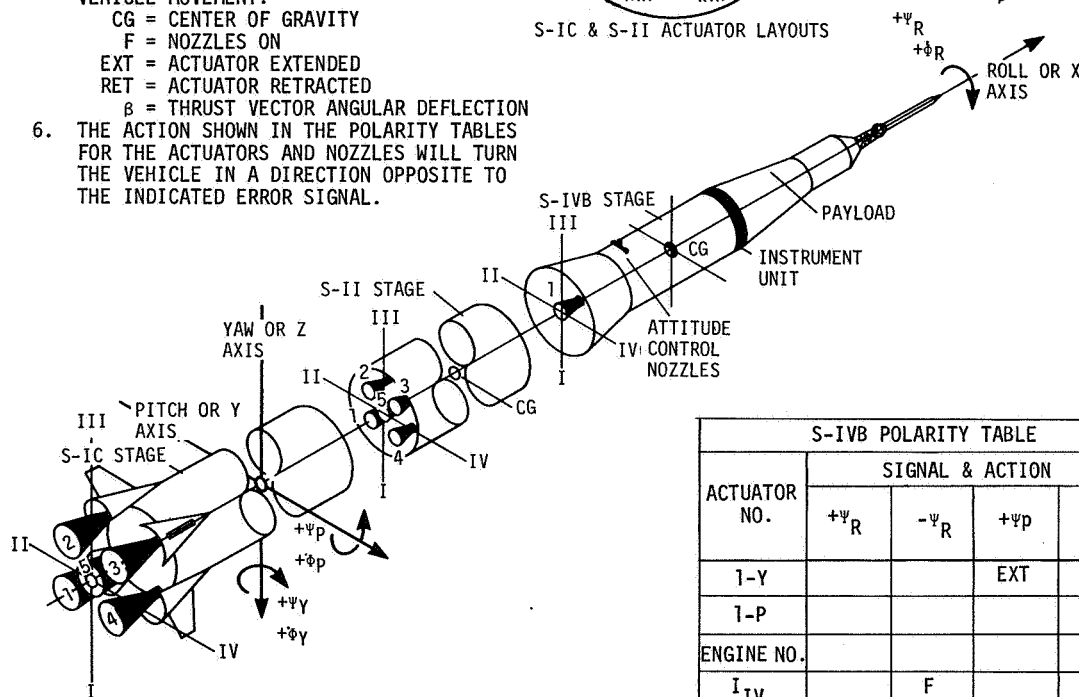
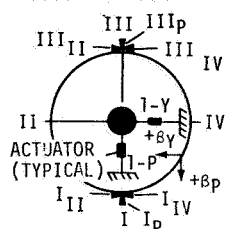
*Did not occur due to restart failure

NOTES:

1. ALL SIGNAL ARROWS INDICATE POSITIVE VEHICLE MOVEMENTS.
2. VEHICLE PITCHES OVER POSITION 1.
3. ENGINE ACTUATOR LAYOUTS SHOWN AS VIEWED FROM AFT END OF VEHICLE.
4. DIRECTIONS AND POLARITIES SHOWN ARE TYPICAL FOR ALL STAGES.
5. $+\beta$ INDICATES ENGINE DEFLECTION REQUIRED TO CORRECT FOR POSITIVE VEHICLE MOVEMENT.
CG = CENTER OF GRAVITY
F = NOZZLES ON
EXT = ACTUATOR EXTENDED
RET = ACTUATOR RETRACTED
 β = THRUST VECTOR ANGULAR DEFLECTION
6. THE ACTION SHOWN IN THE POLARITY TABLES FOR THE ACTUATORS AND NOZZLES WILL TURN THE VEHICLE IN A DIRECTION OPPOSITE TO THE INDICATED ERROR SIGNAL.



S-IVB ACTUATOR AND NOZZLE LAYOUT



| S-IC & S-II POLARITY TABLE | | | |
|----------------------------|-------------------|-----------------|-----------------|
| ACTUATOR NO. | ACTUATOR MOVEMENT | | |
| | $+\dot{\phi}_R$ | $+\dot{\phi}_Y$ | $+\dot{\phi}_P$ |
| 1-Y | RET | RET | |
| 1-P | EXT | | RET |
| 2-Y | EXT | RET | |
| 2-P | RET | | EXT |
| 3-Y | RET | EXT | |
| 3-P | EXT | | EXT |
| 4-Y | EXT | EXT | |
| 4-P | RET | | RET |

| S-IVB POLARITY TABLE | | | | | | |
|-------------------------|-----------------|-----------|-----------|-----------|-----------|-----------|
| ACTUATOR NO. | SIGNAL & ACTION | | | | | |
| | $+\psi_R$ | $-\psi_R$ | $+\psi_P$ | $+\psi_Y$ | $+\psi_D$ | |
| 1-Y | | | EXT | | | |
| 1-P | | | | | RET | |
| ENGINE NO. | | | | | | |
| I _{IV} | | F | | | | |
| I _p | | | | | F | |
| I _{II} | F | | | | | |
| III _{II} | | F | | | | |
| III _p | | | | | | |
| III _{IV} | F | | | | | |
| CONDITIONS DURING COAST | | | | | | |
| | $+\psi_R$ | $-\psi_R$ | $+\psi_Y$ | $-\psi_Y$ | $+\psi_P$ | $-\psi_D$ |
| I _{IV} | | F | | F | | |
| I _p | | | | | F | |
| I _{II} | F | | F | | | |
| III _{II} | | F | F | | | |
| III _p | | | | | | F |
| III _{IV} | F | | | F | | |

Figure 21-1. Saturn V Coordinate System and Polarities

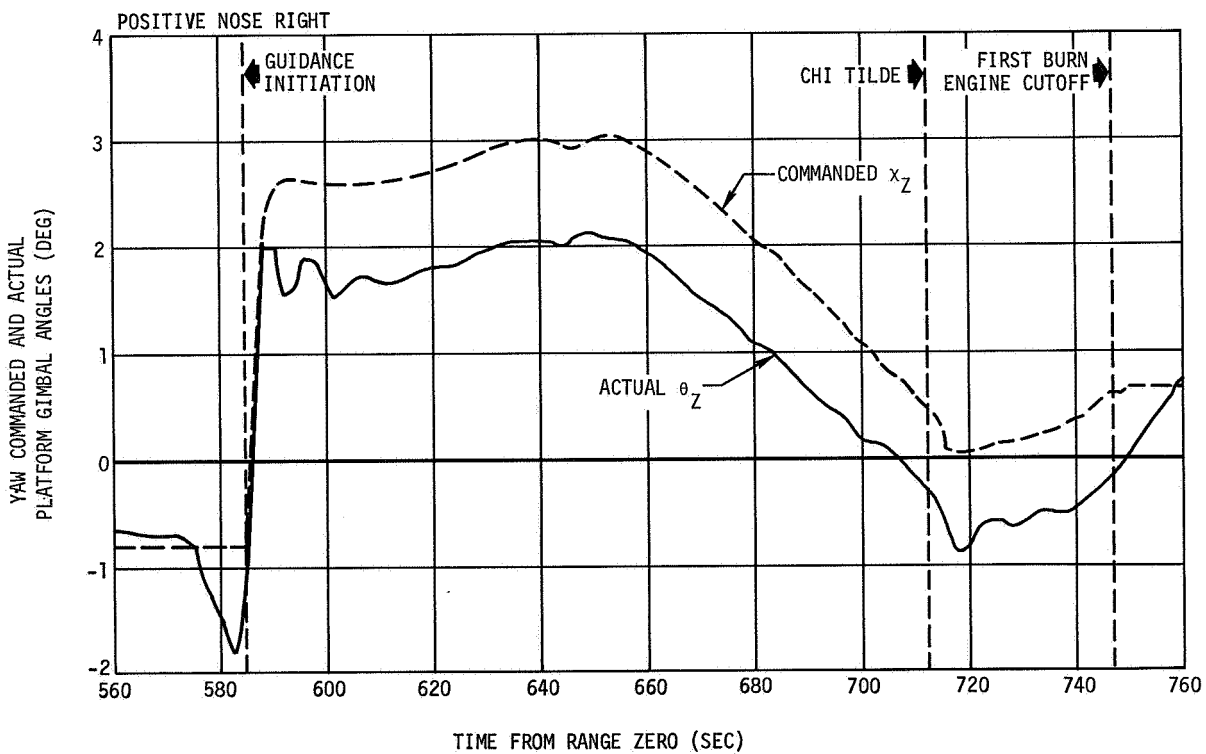
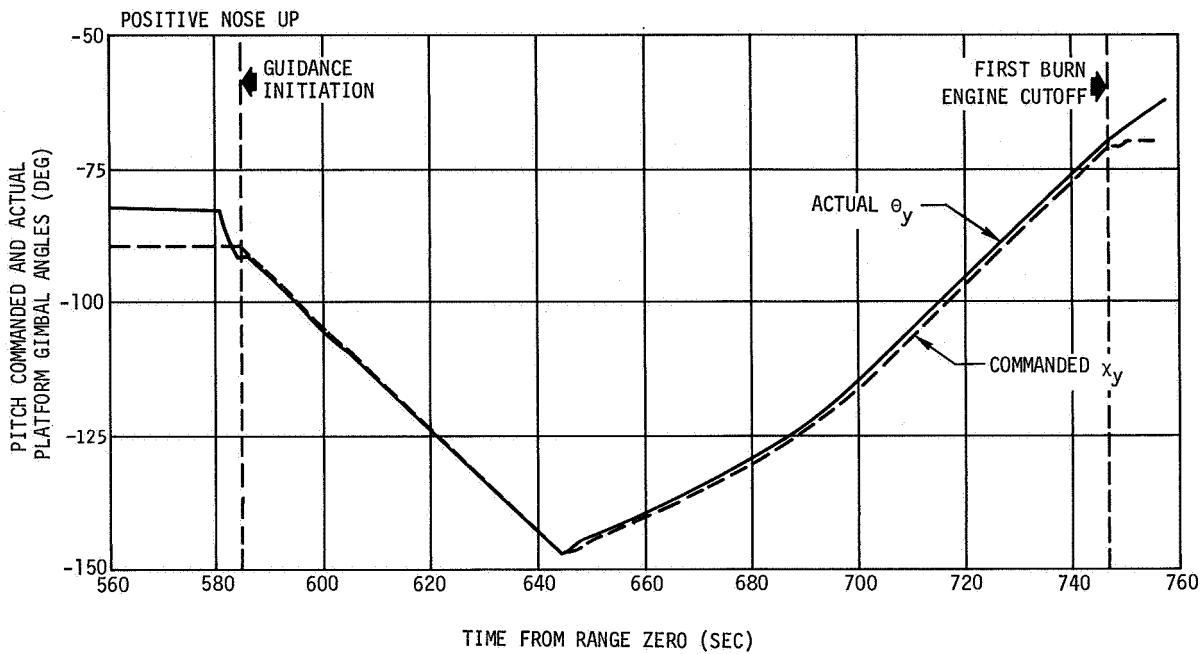
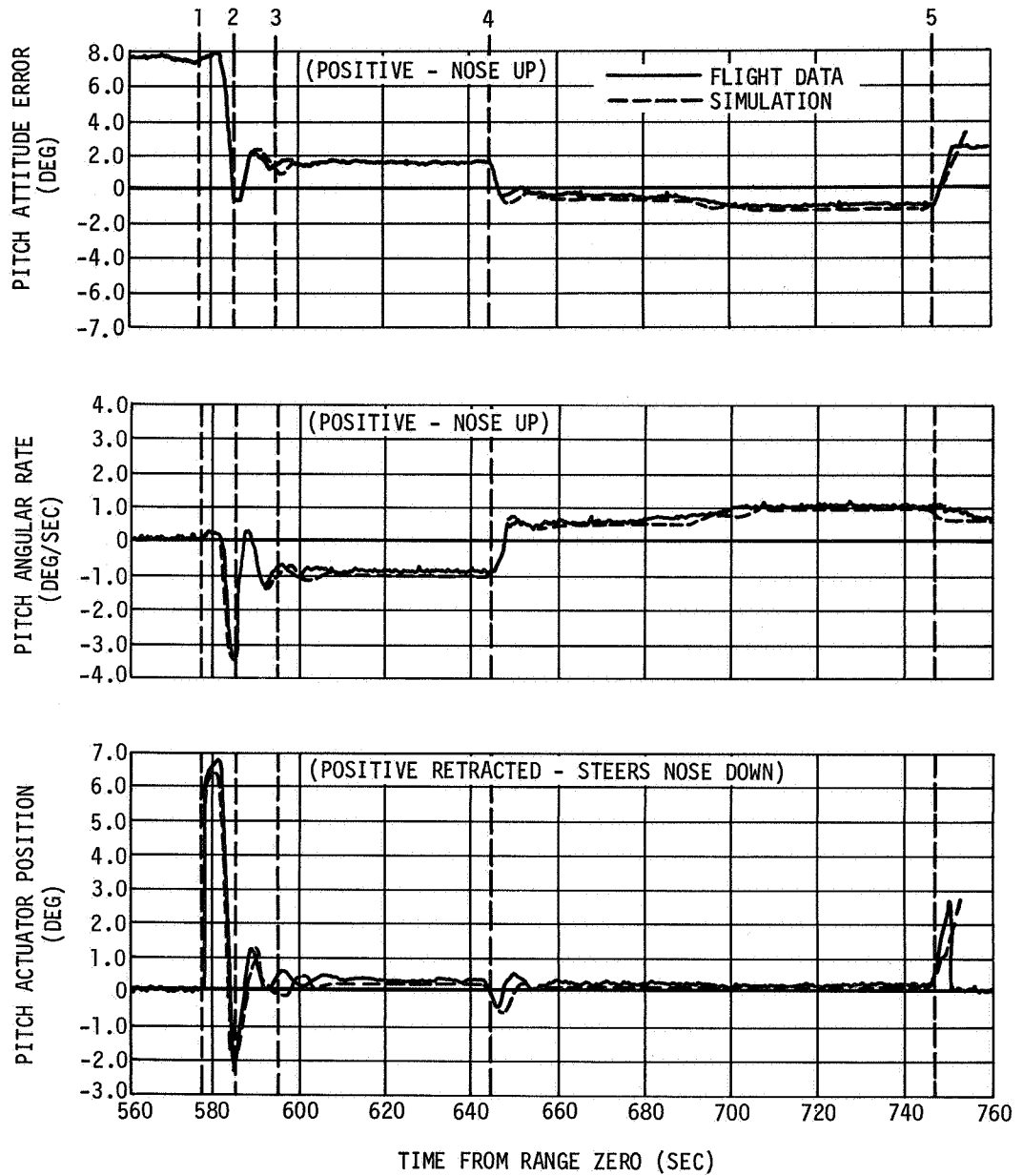
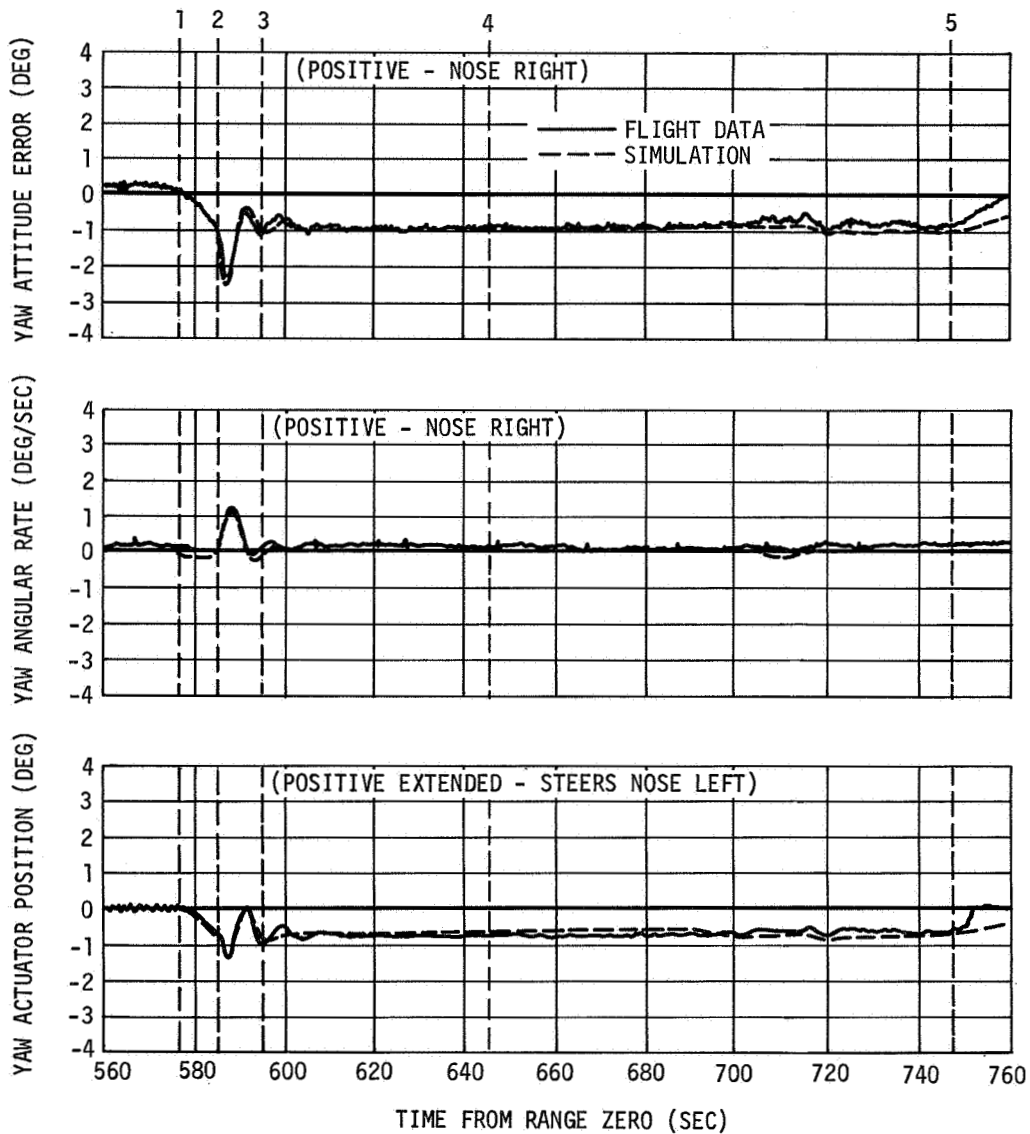


Figure 21-2. Pitch and Yaw Commanded and Actual Vehicle Attitude - S-IVB Powered Flight



1. ENGINE START COMMAND
2. GUIDANCE INITIATION
3. END ARTIFICIAL TAU GUIDANCE MODE
4. PITCH COMMAND TO NOSE UP ATTITUDE
5. CHI FREEZE AND ENGINE CUTOFF

Figure 21-3. Pitch Attitude Control - First Burn



1. ENGINE START COMMAND
2. GUIDANCE INITIATION
3. END ARTIFICIAL TAU GUIDANCE MODE
4. PITCH COMMAND TO NOSE UP ATTITUDE
5. CHI FREEZE AND ENGINE CUTOFF

Figure 21-4. Yaw Attitude Control - First Burn

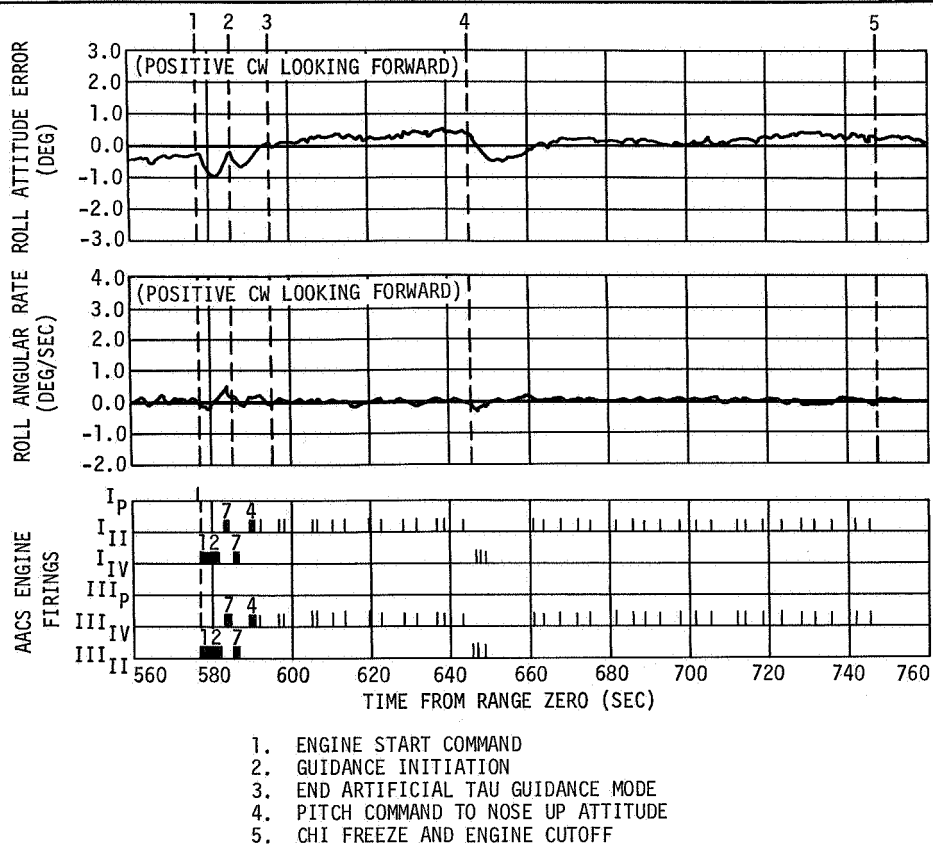


Figure 21-5. Roll Attitude Control - First Burn

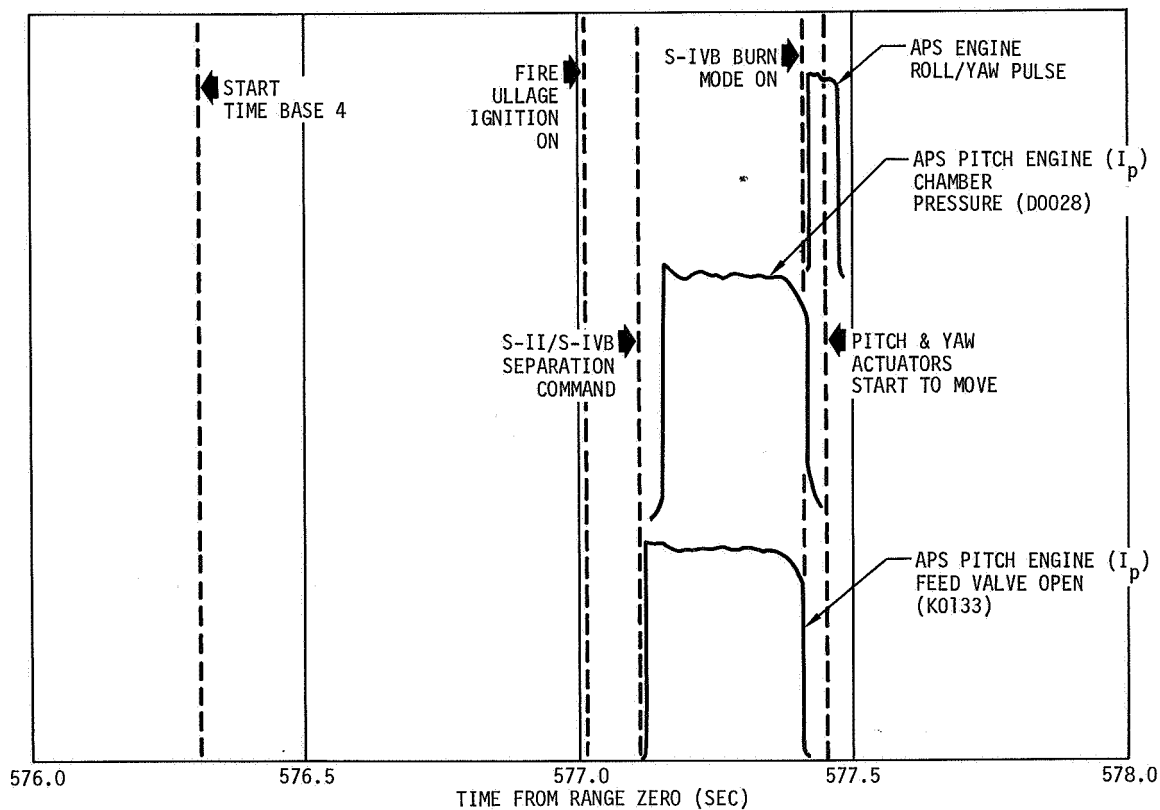
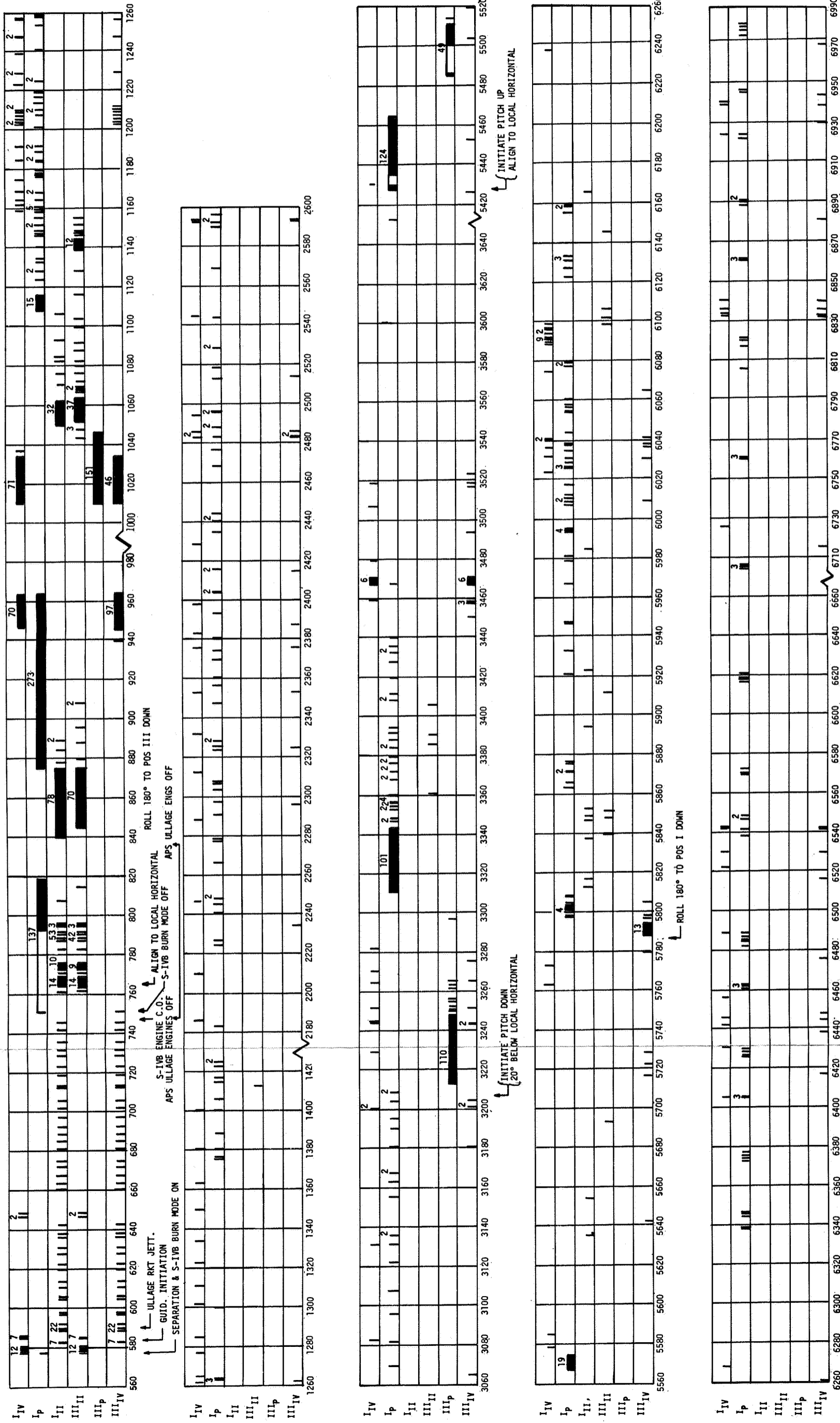


Figure 21-6. Pitch AACS Engine Firing and Related Sequence of Events - S-II/S-IVB Separation

Section 21
Flight Control



* INDICATES * INDIVIDUAL PULSES
 [Solid Bar] INDICATES CONTINUOUS FIRING

Figure 21-7. Auxiliary Attitude Control System Firing History (Sheet 1 of 3)

FOLDOUT FRAME

FOLDOUT FRAME

FOLDOUT FRAME 2

Section 21
Flight Control

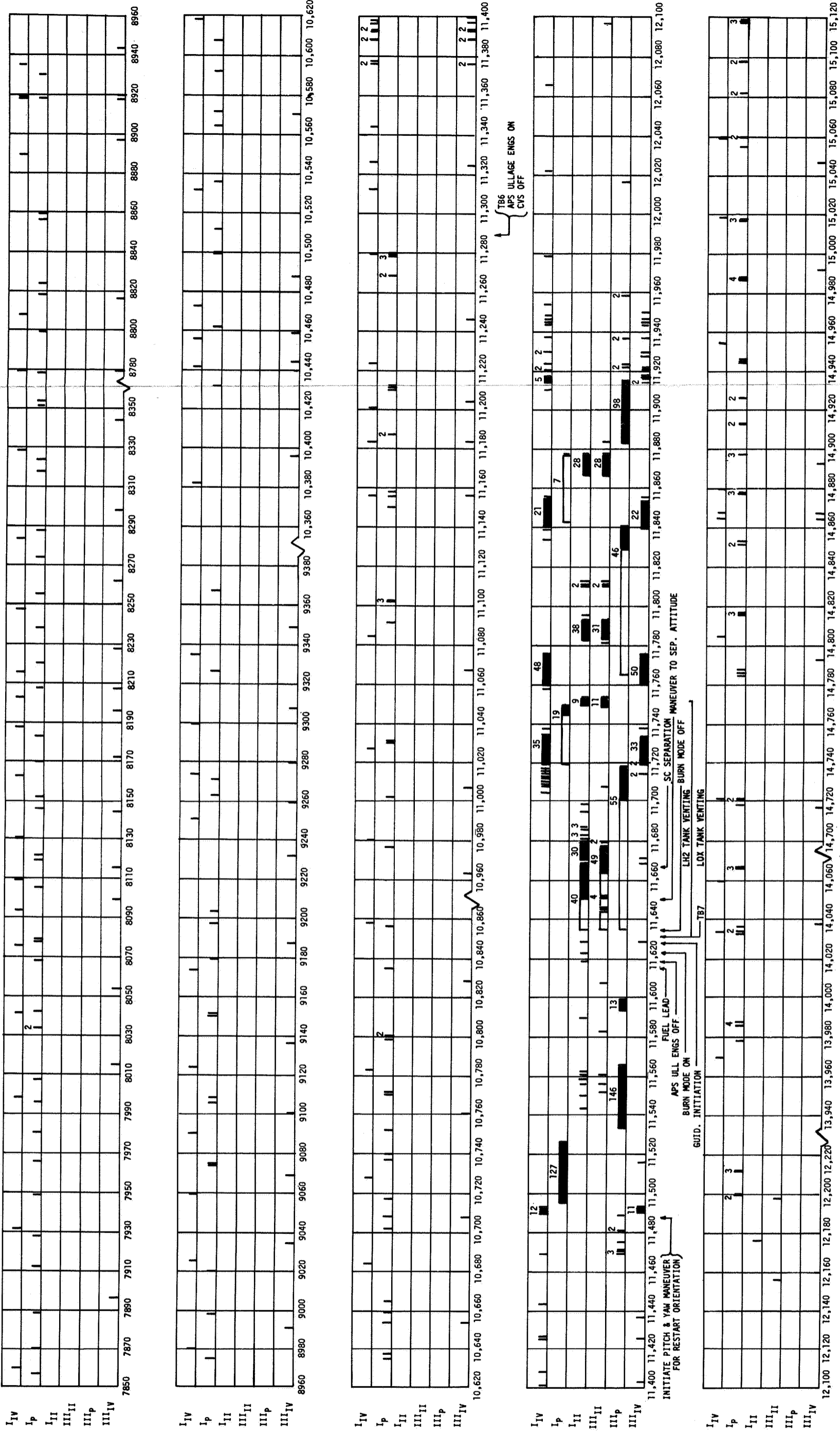
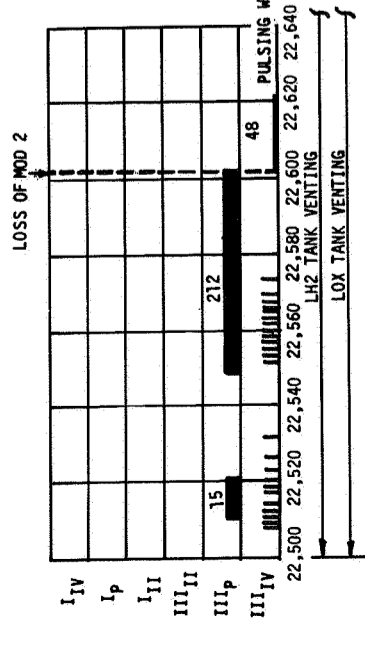
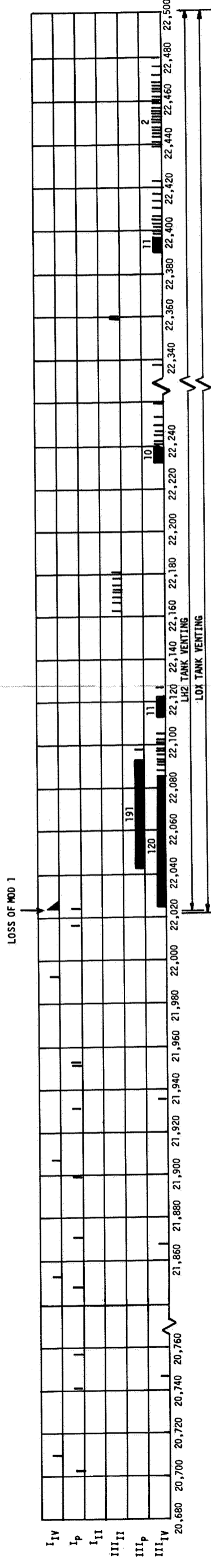
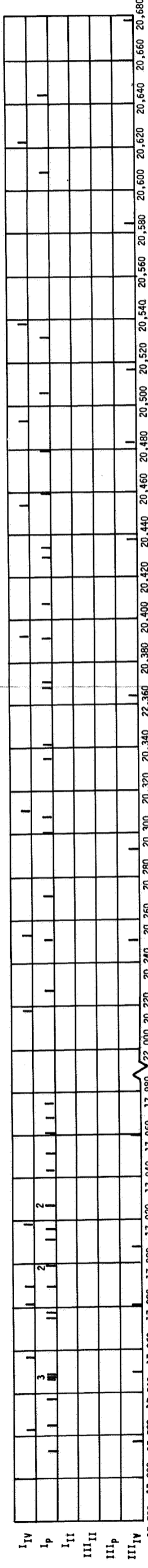
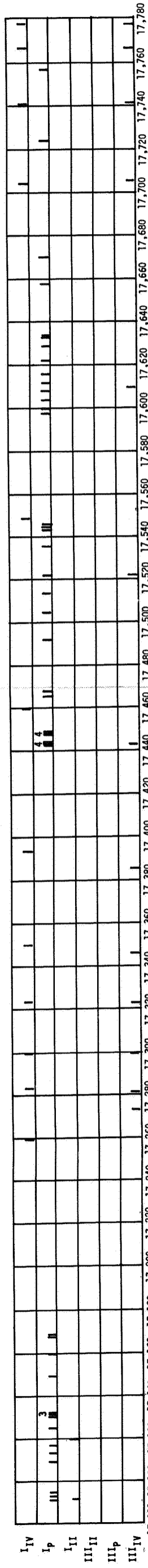
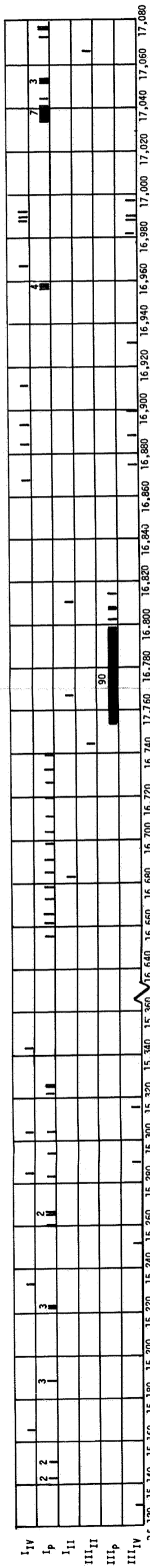


Figure 21-7. Auxiliary Attitude Control System Firing History (Sheet 2 of 3)

FOLDOUT FRAME 1

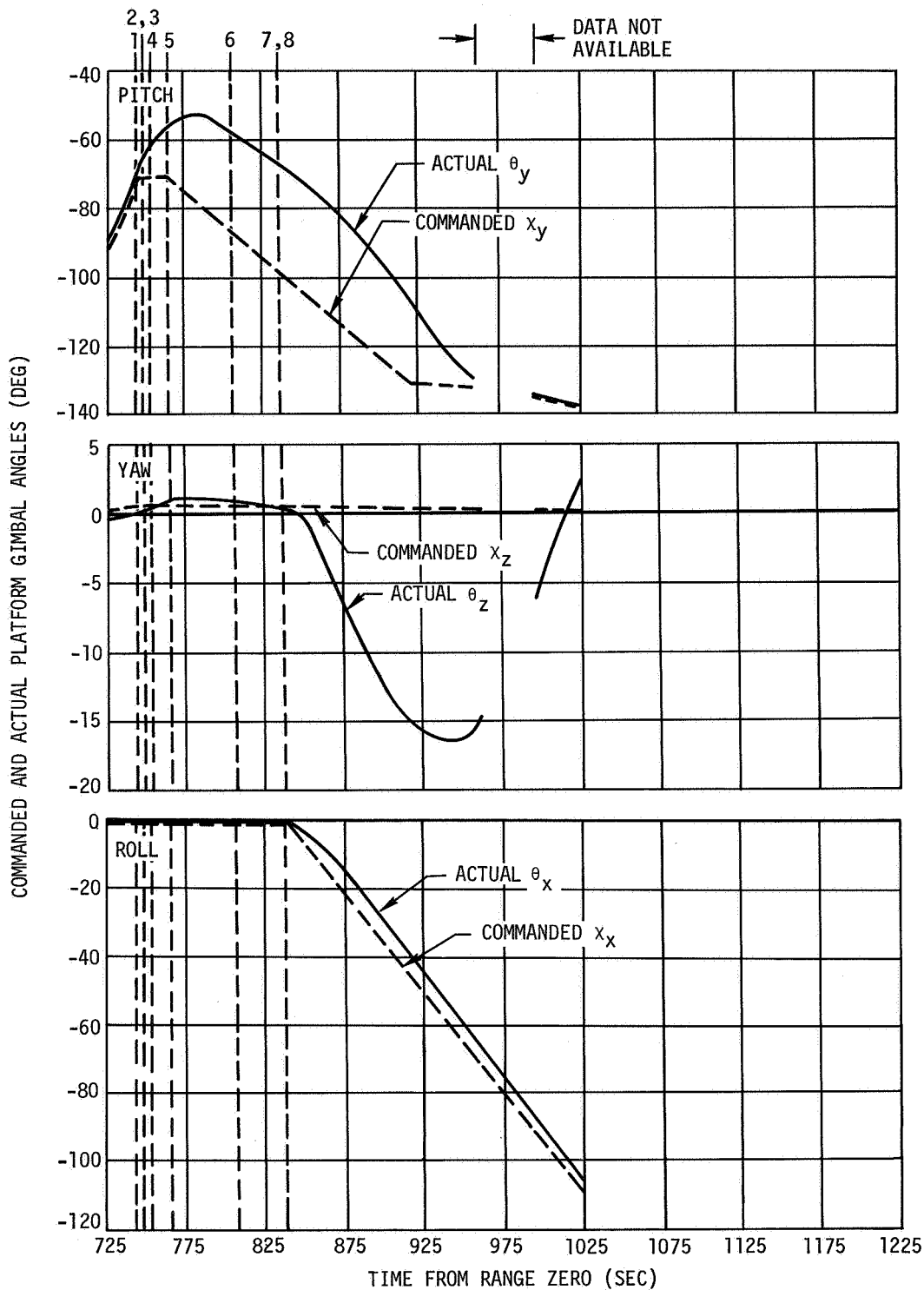
FOLDOUT FRAME 2

Section 21
Flight Control



* INDICATES * INDIVIDUAL PULSES
 □ INDICATES CONTINUOUS FIRING

Figure 21-7. Auxiliary Attitude Control System Firing History (Sheet 3 of 3)



- | | |
|------------------------------|--|
| 1. COMMAND FREEZE | 5. COMMAND LOCAL HORIZONTAL |
| 2. FIRST S-IVB ENGINE CUTOFF | 6. LH2 CVS ON |
| 3. ULLAGE ENGINES ON | 7. ULLAGE ENGINES OFF |
| 4. APS ACTIVATE | 8. COMMAND -180° ROLL POSITION III TOWARD EARTH |

Figure 21-8. Commaned and Actual Pitch, Yaw and Roll Attitudes following First Burn

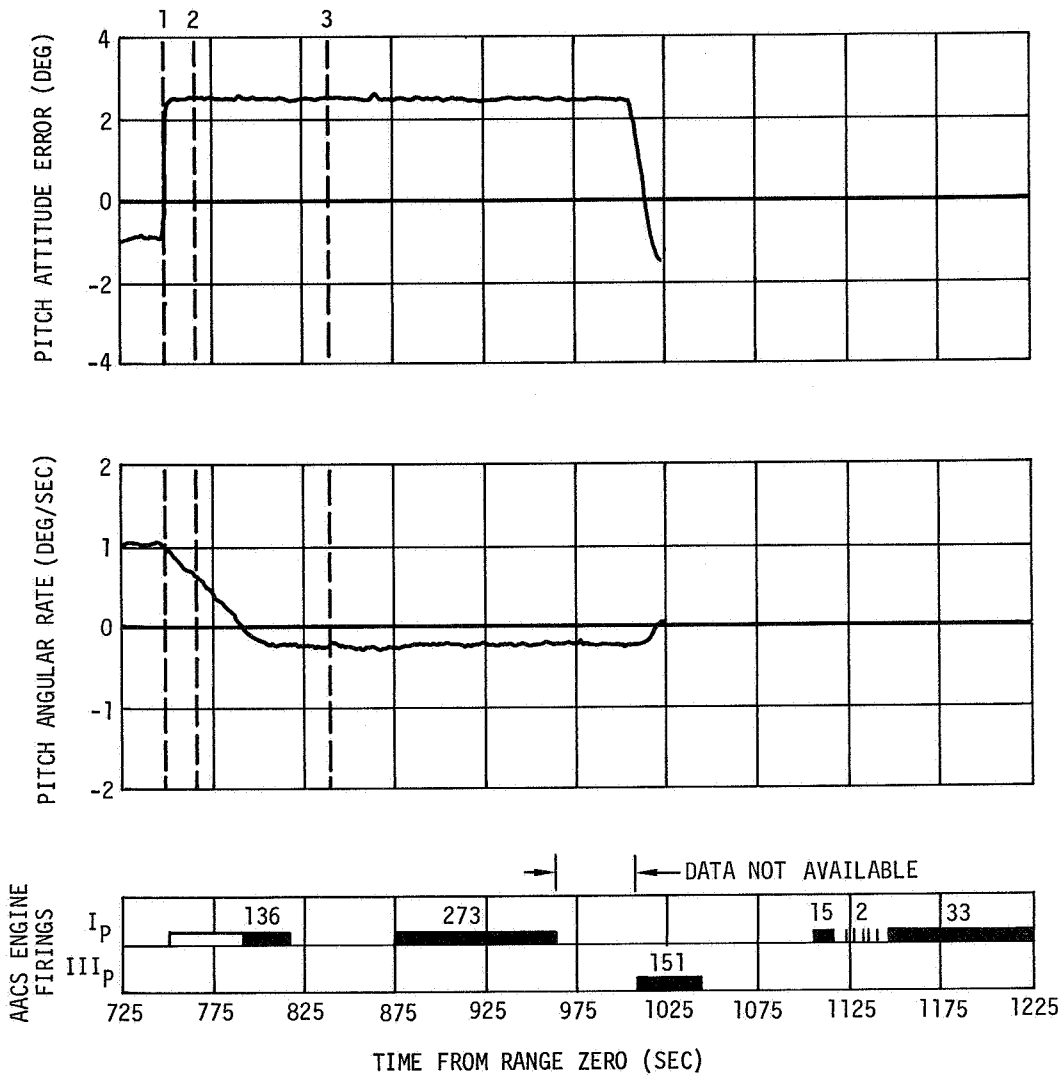


Figure 21-9. Pitch Attitude Control following Engine Cutoff

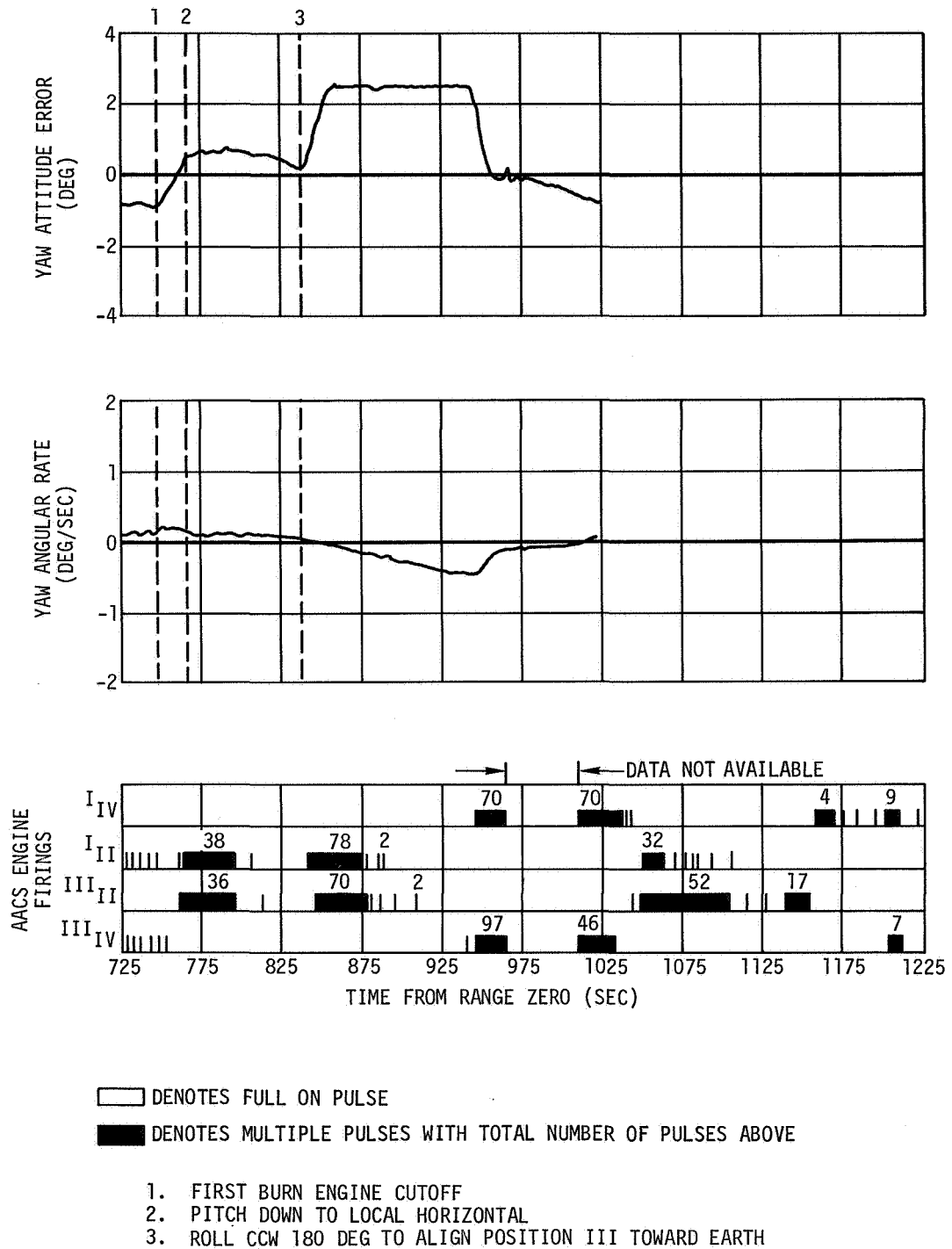


Figure 21-10. Yaw Attitude Control following Engine Cutoff

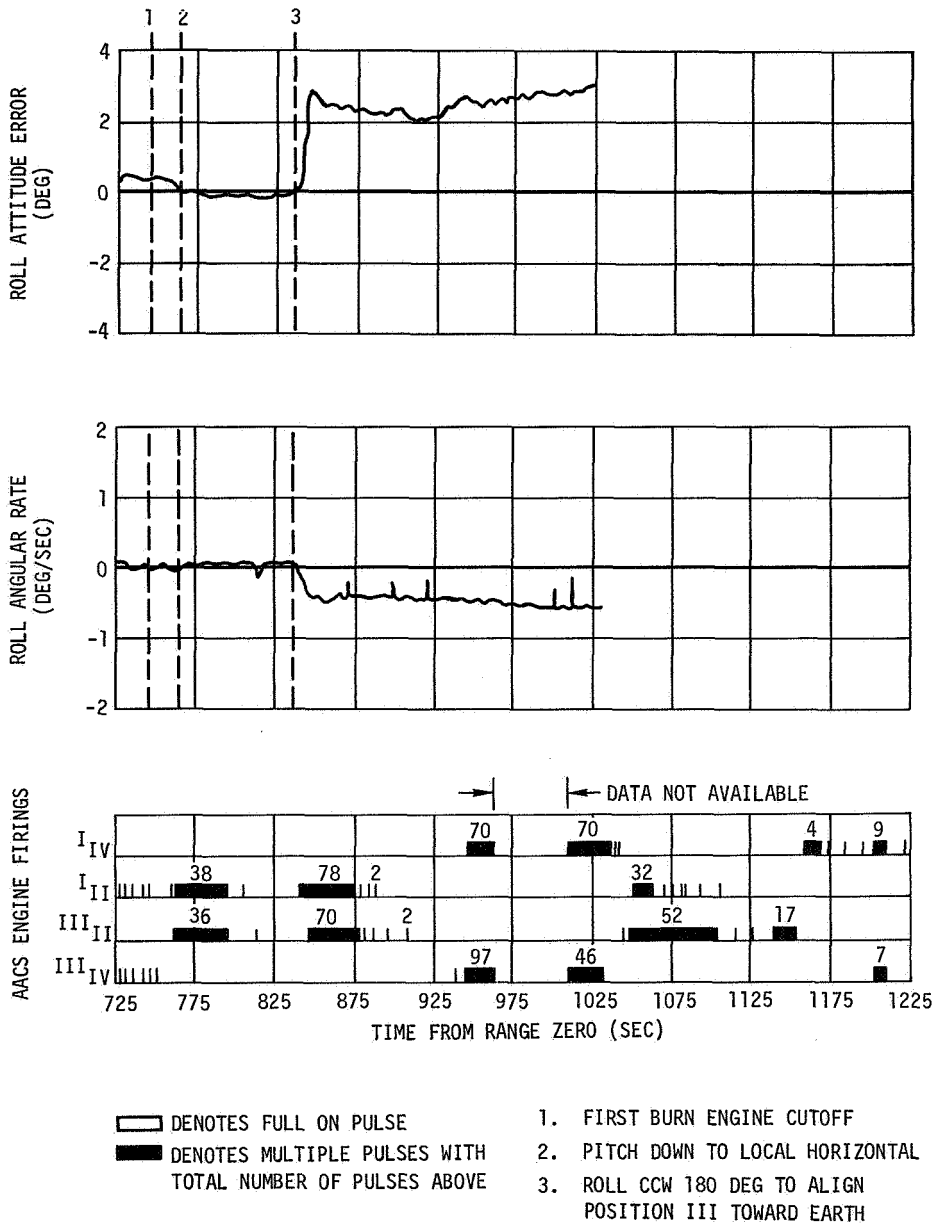


Figure 21-11. Roll Attitude Control Following Engine Cutoff

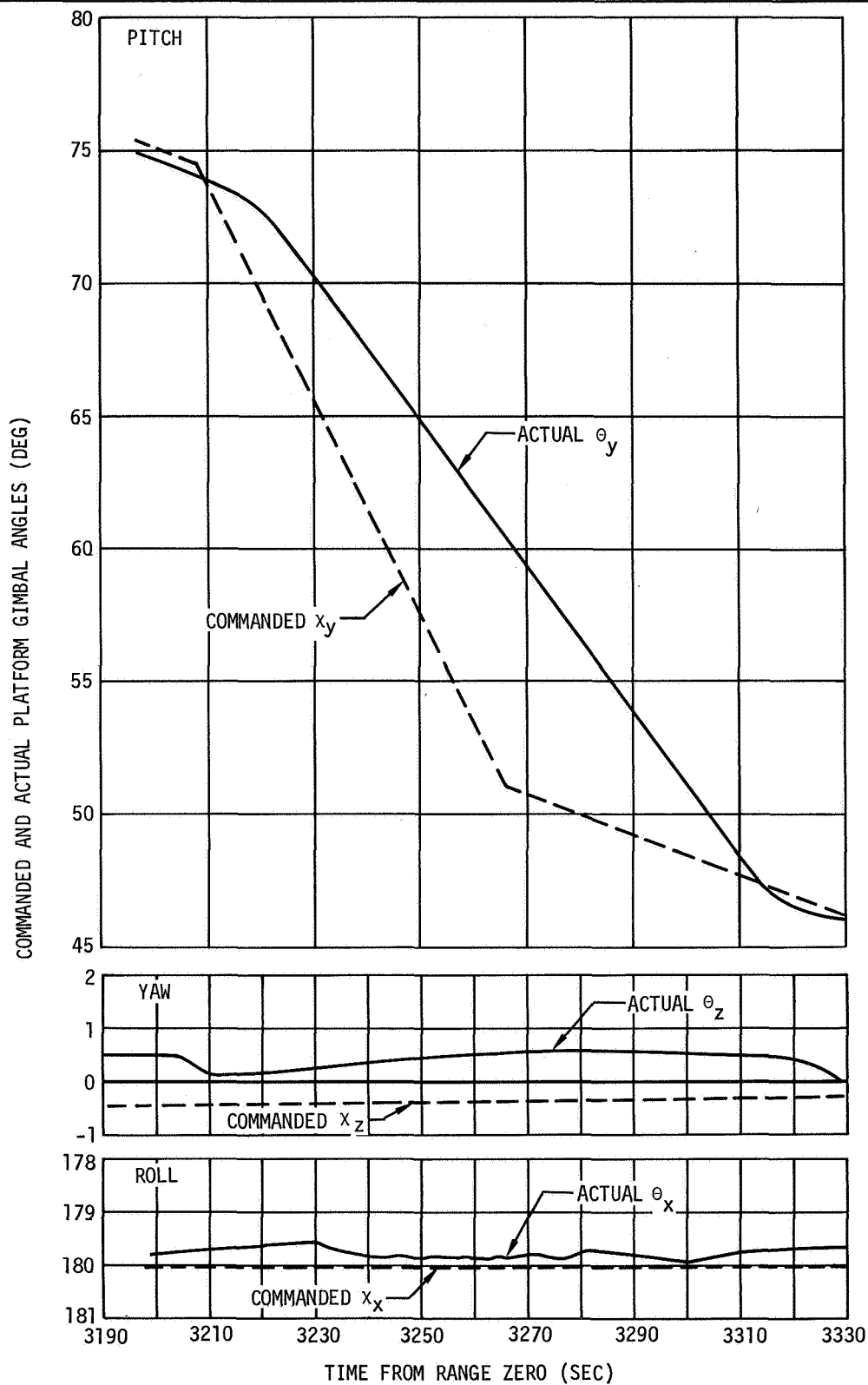


Figure 21-12. Commanded and Actual Vehicle Attitudes - Pitch Down Maneuver

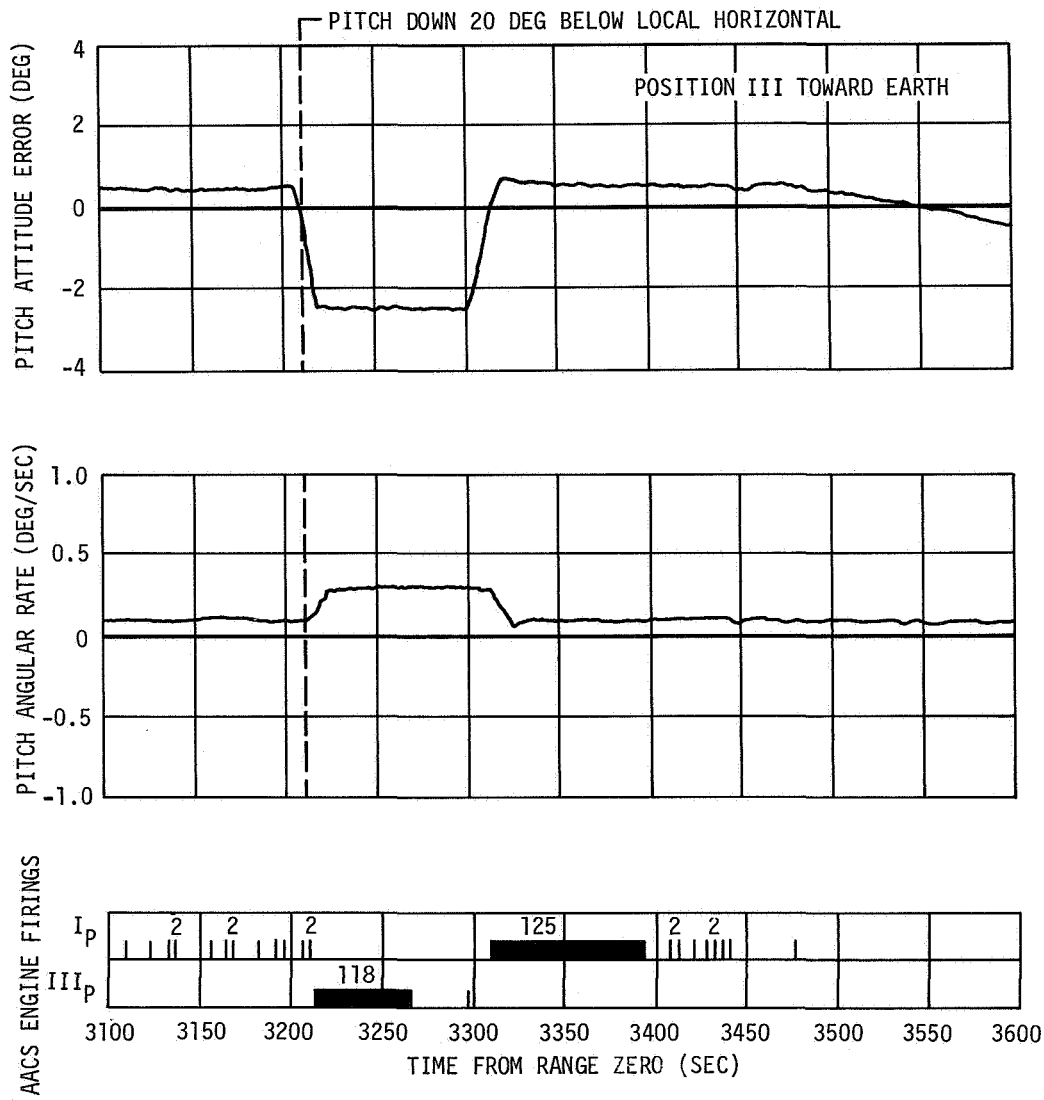


Figure 21-13. Pitch Attitude Control - Pitch Down Maneuver

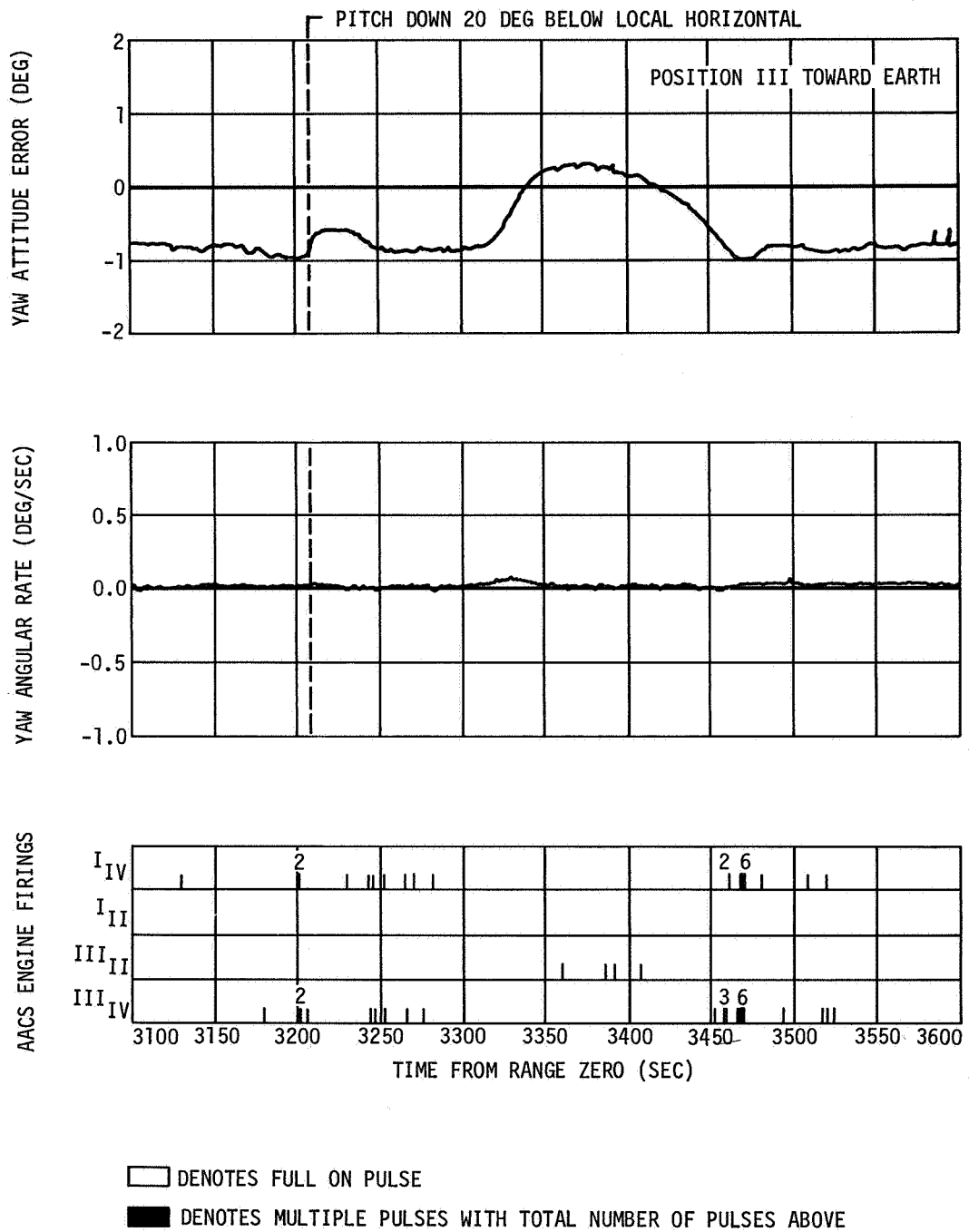


Figure 21-14. Yaw Attitude Control - Pitch Down Maneuver

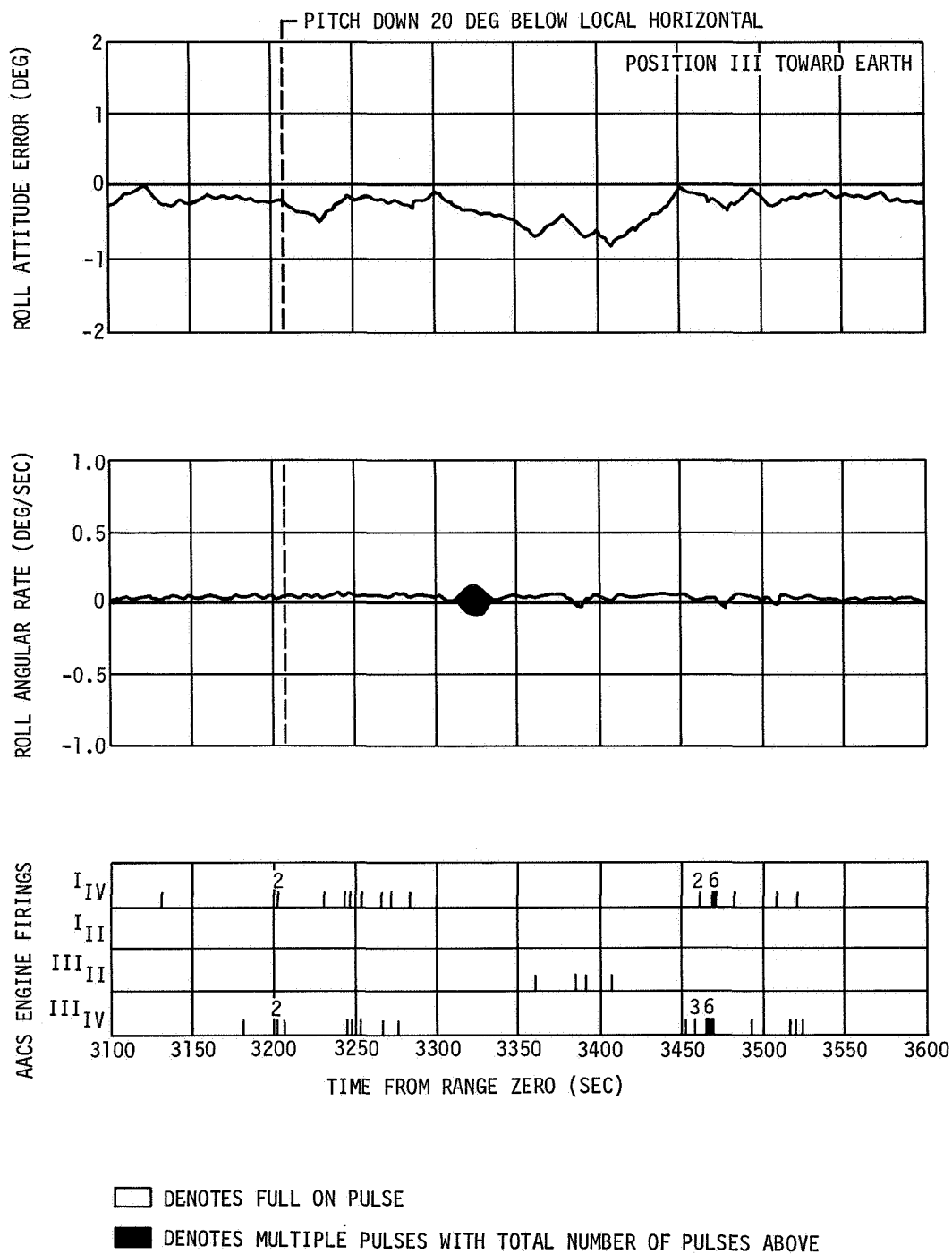


Figure 21-15. Roll Attitude Control - Pitch Down Maneuver

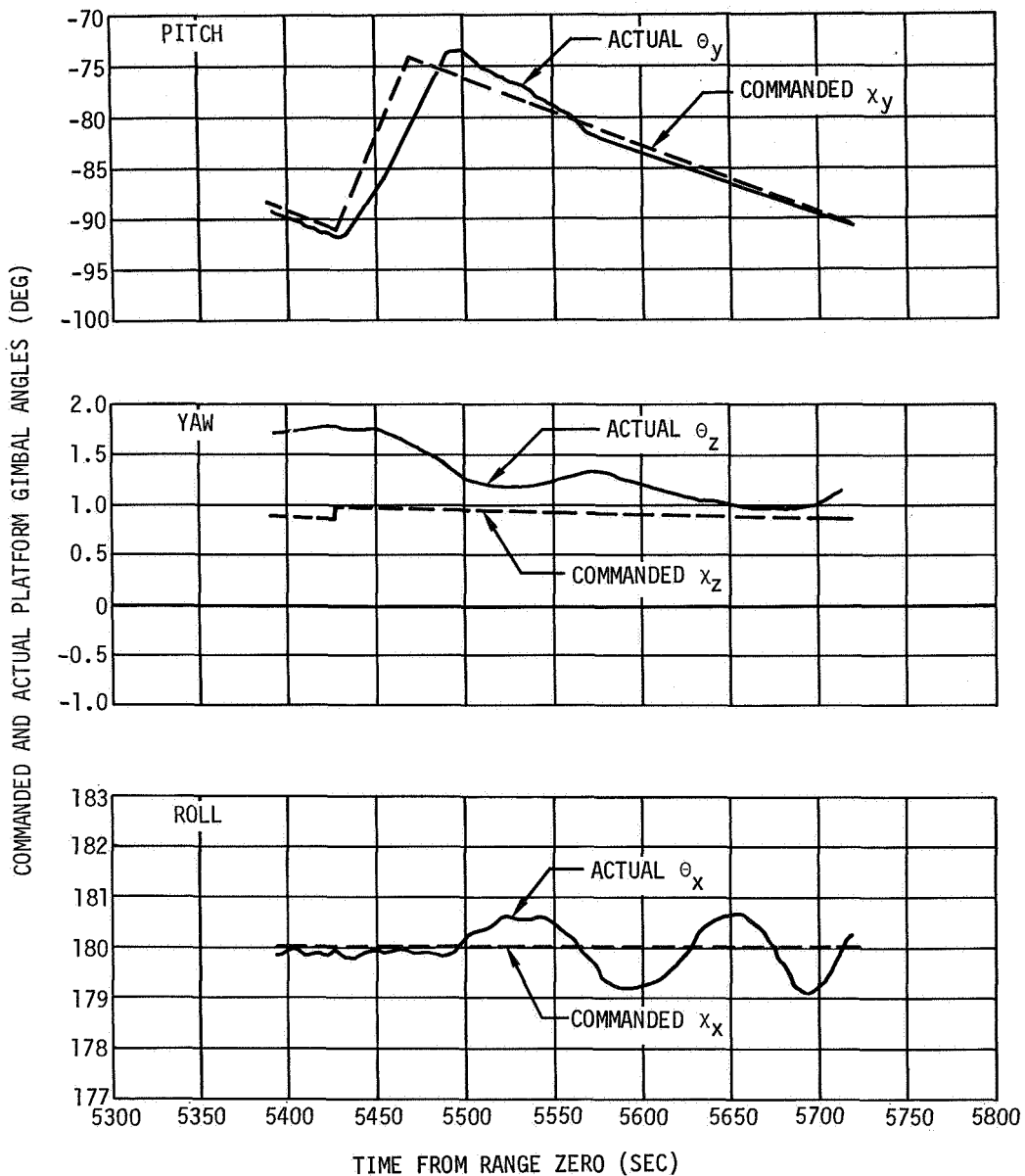
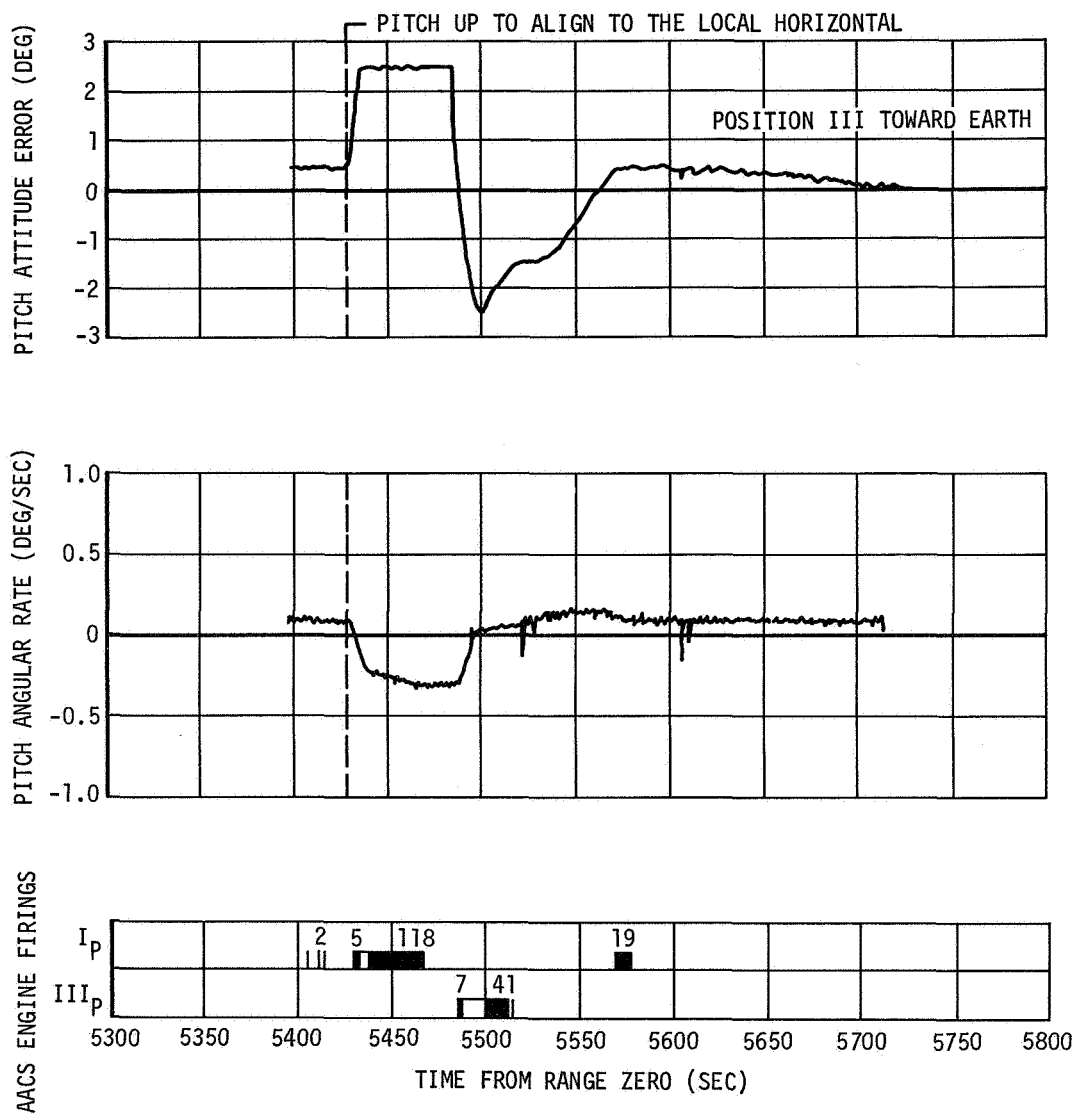
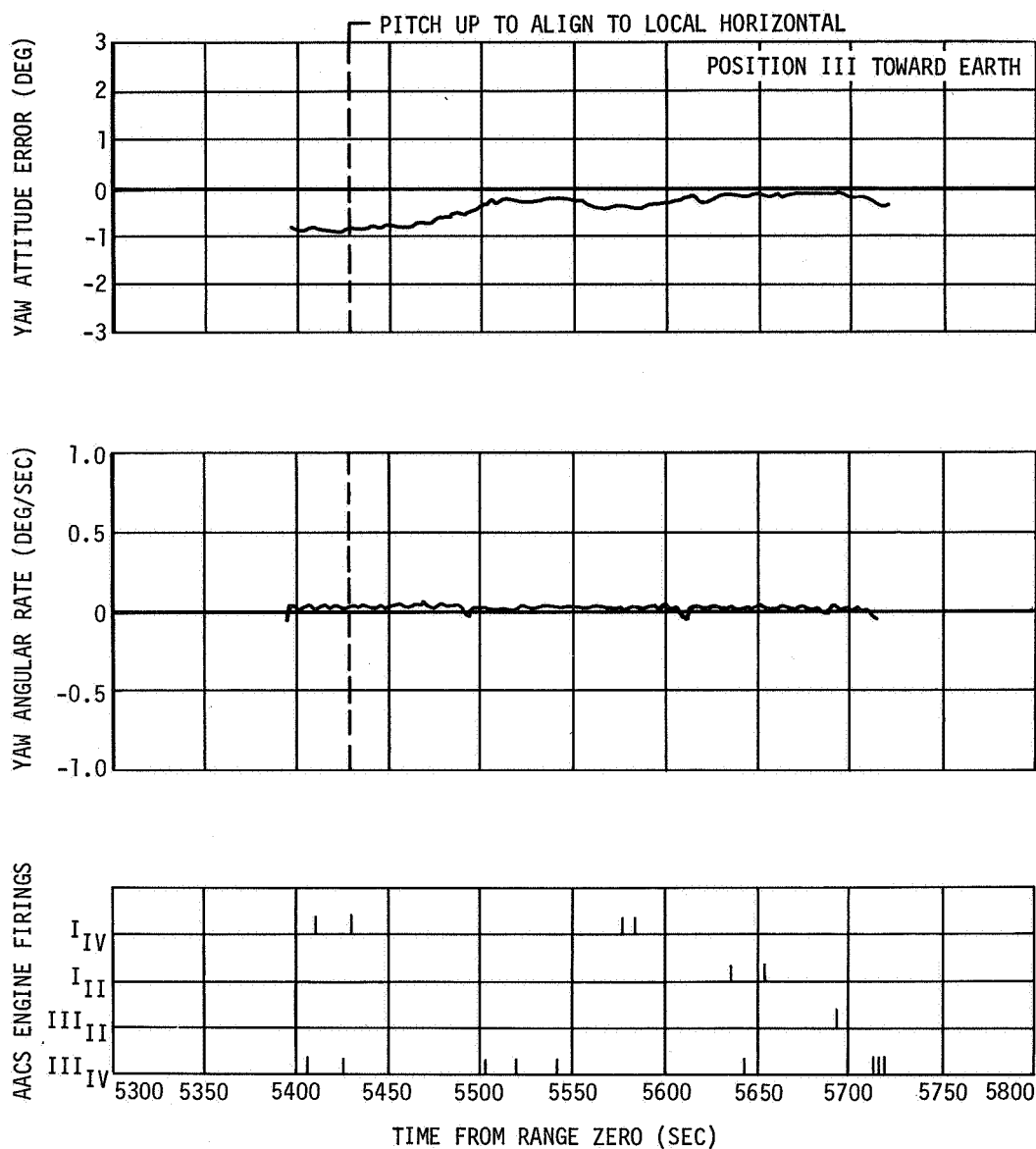


Figure 21-16. Commanded and Actual Vehicle Angles - Pitch Up Maneuver



DENOTES FULL ON PULSE
 DENOTES MULTIPLE PULSES WITH TOTAL NUMBER OF PULSES ABOVE

Figure 21-17. Pitch Attitude Control - Pitch Up Maneuver



□ DENOTES FULL ON PULSE

■ DENOTES MULTIPLE PULSES WITH TOTAL NUMBER OF PULSES ABOVE

Figure 21-18. Yaw Attitude Control - Pitch Up Maneuver

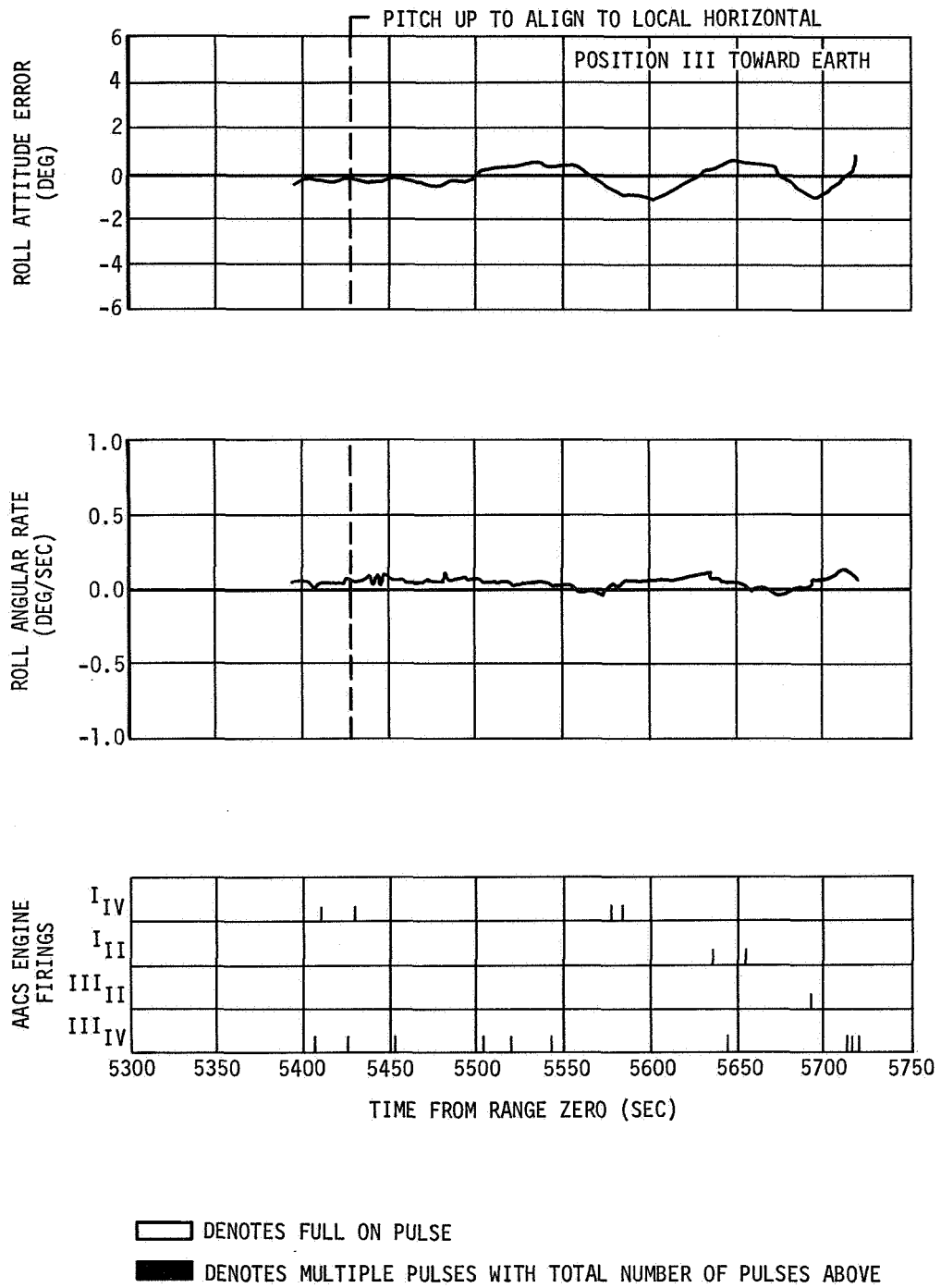


Figure 21-19. Roll Attitude Control - Pitch Up Maneuver

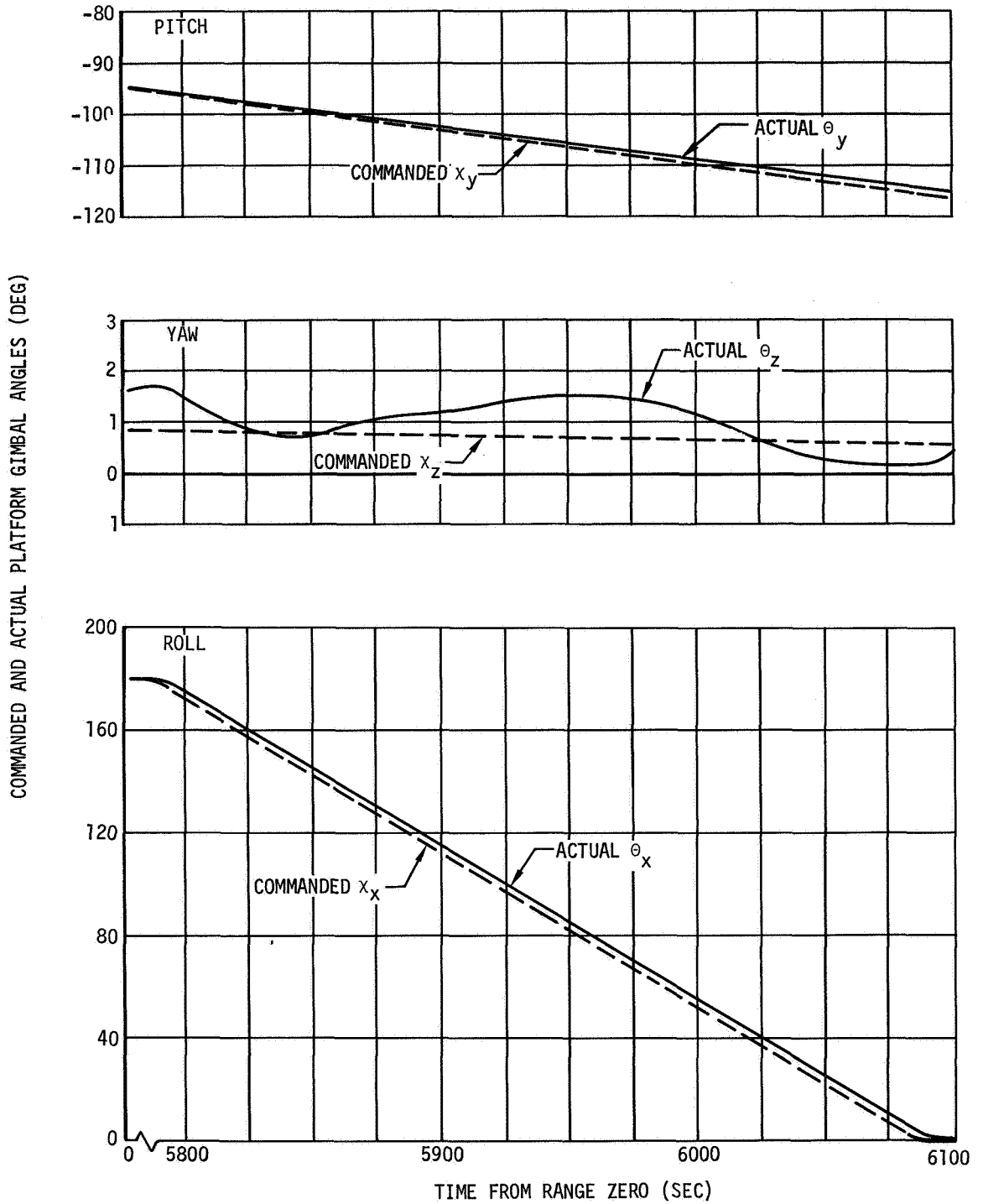
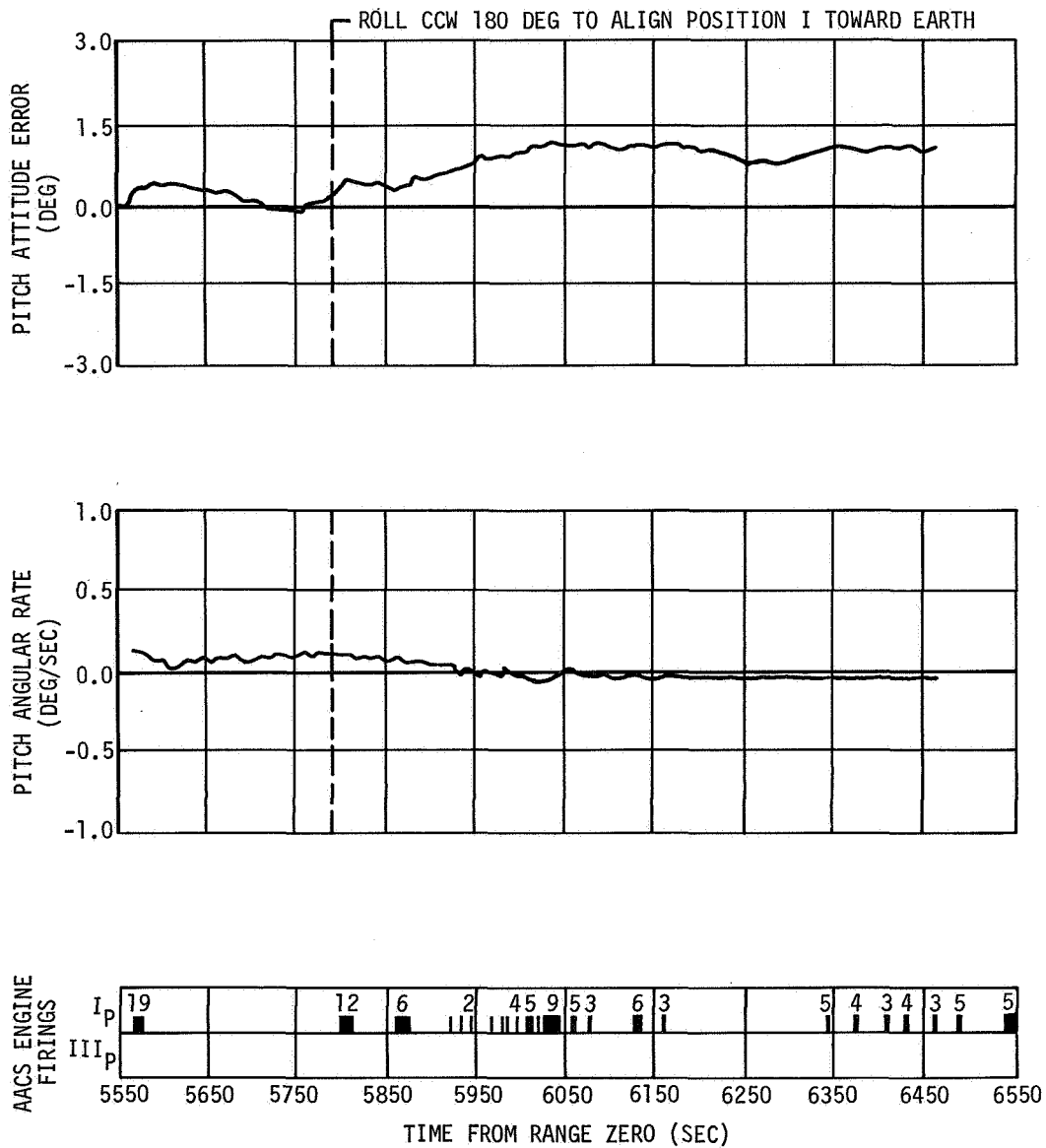


Figure 21-20. Commanded and Actual Vehicle Attitudes - 180 deg Roll Maneuver (CCW Position I Down)



DENOTES FULL ON PULSE
 DENOTES MULTIPLE PULSES WITH TOTAL NUMBER OF PULSES ABOVE

Figure 21-21. Pitch Attitude Control - 180 deg Roll Maneuver (CCW Position I Down)

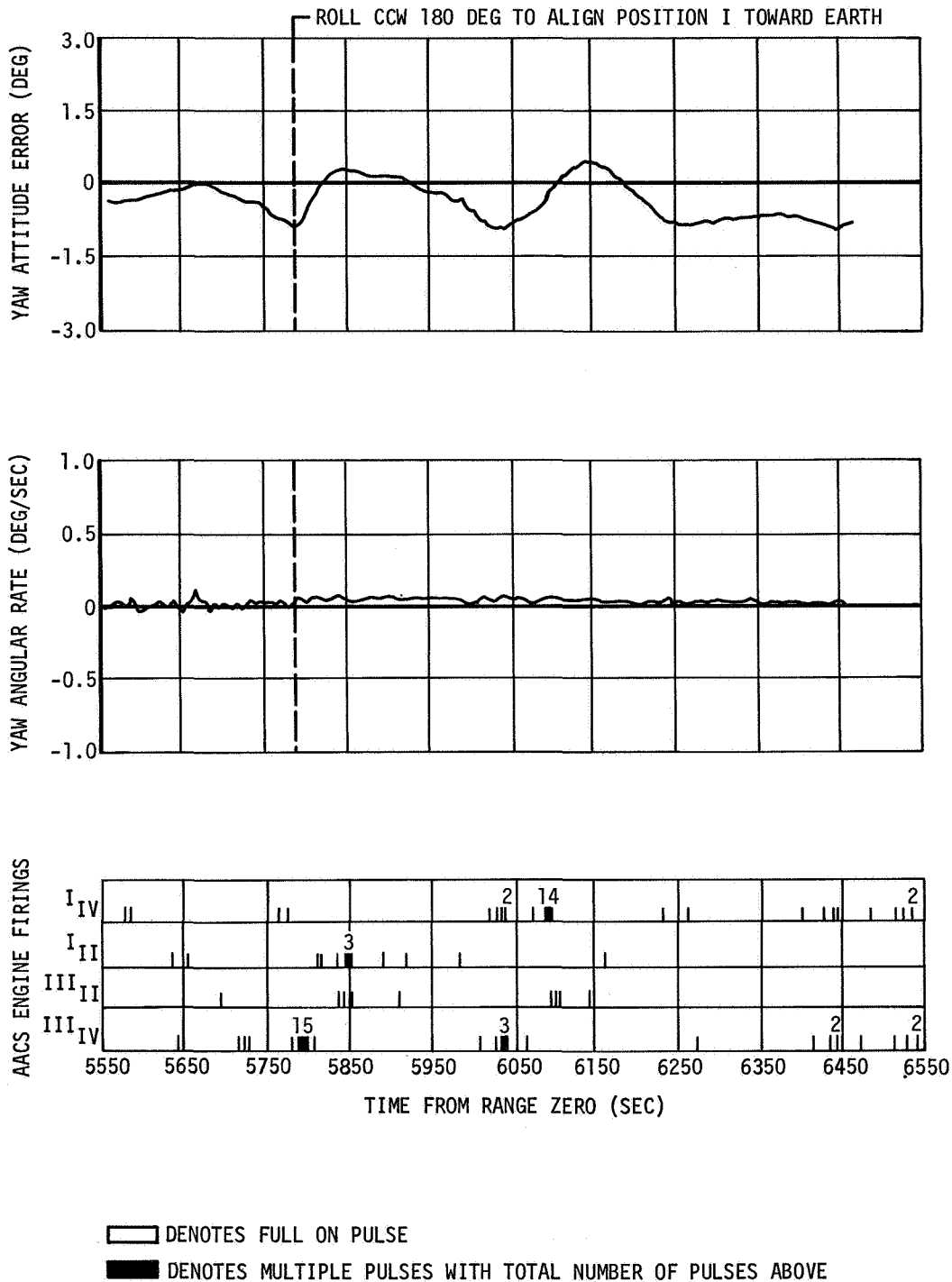


Figure 21-22. Yaw Attitude Control - 180 deg Roll Maneuver (CCW Position I Down)

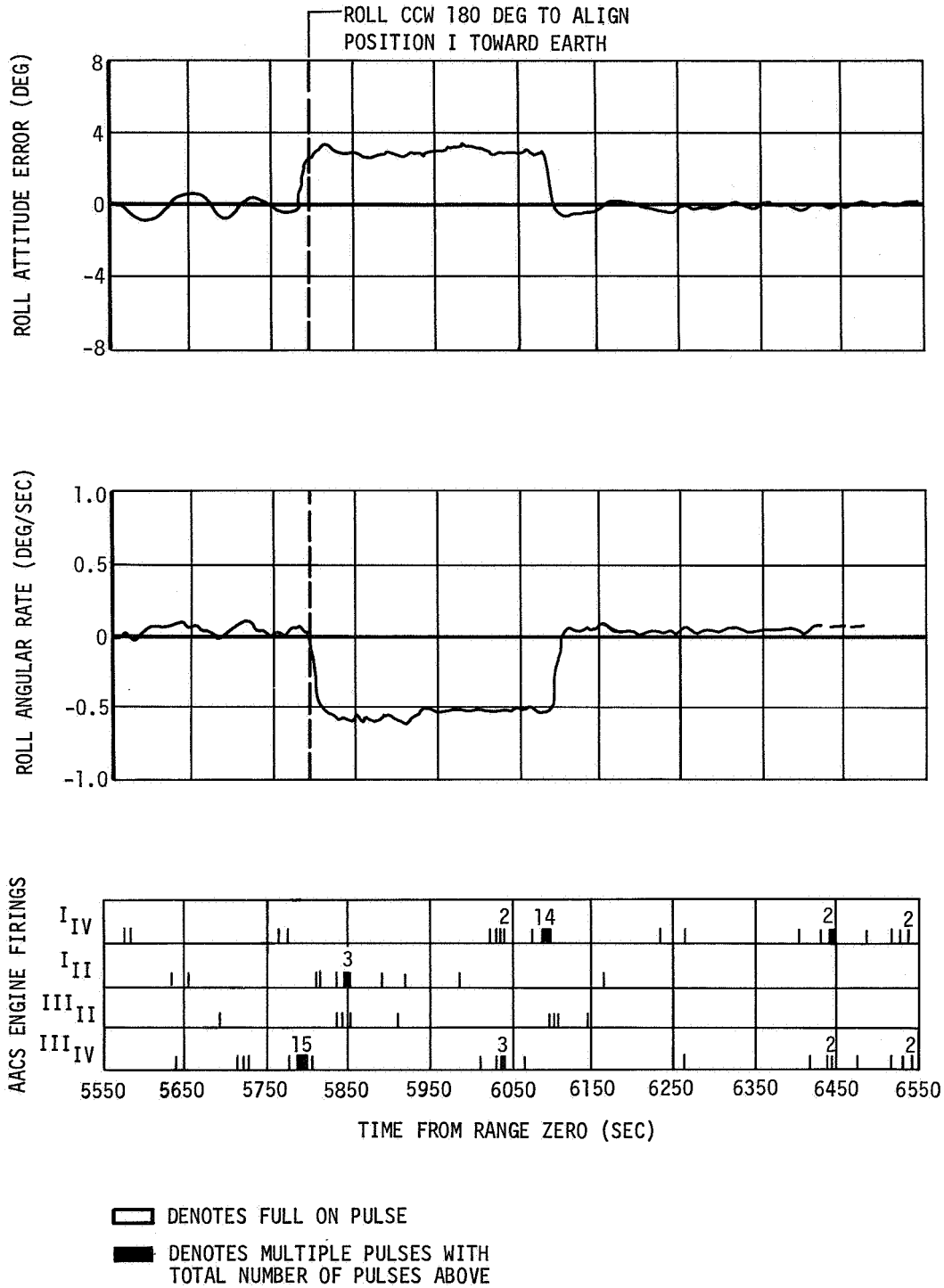


Figure 21-23. Roll Attitude Control - 180 deg Roll Maneuver (CCW Position I Down)

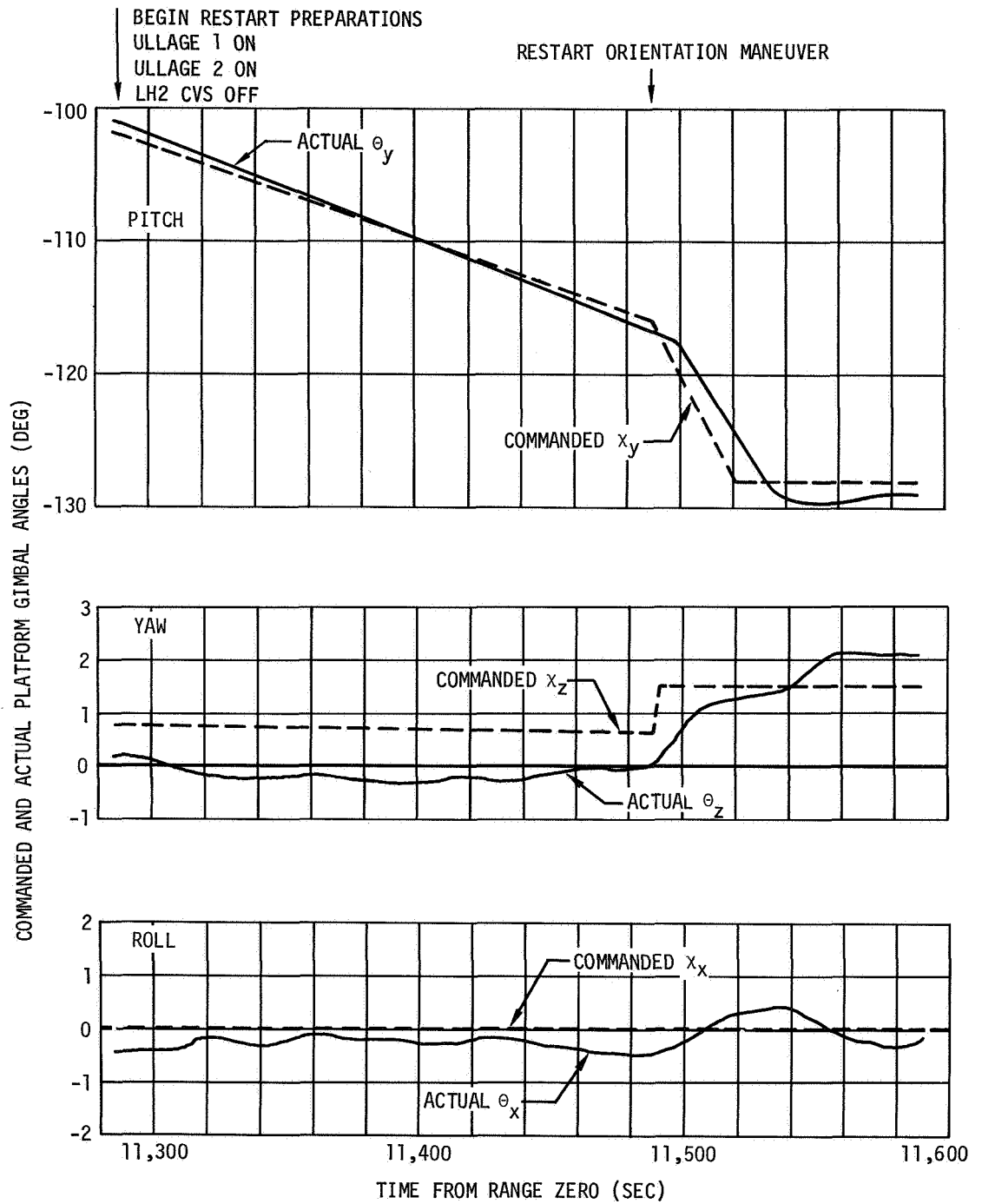


Figure 21-24. Commanded and Actual Vehicle Attitudes - Restart Orientation Maneuver

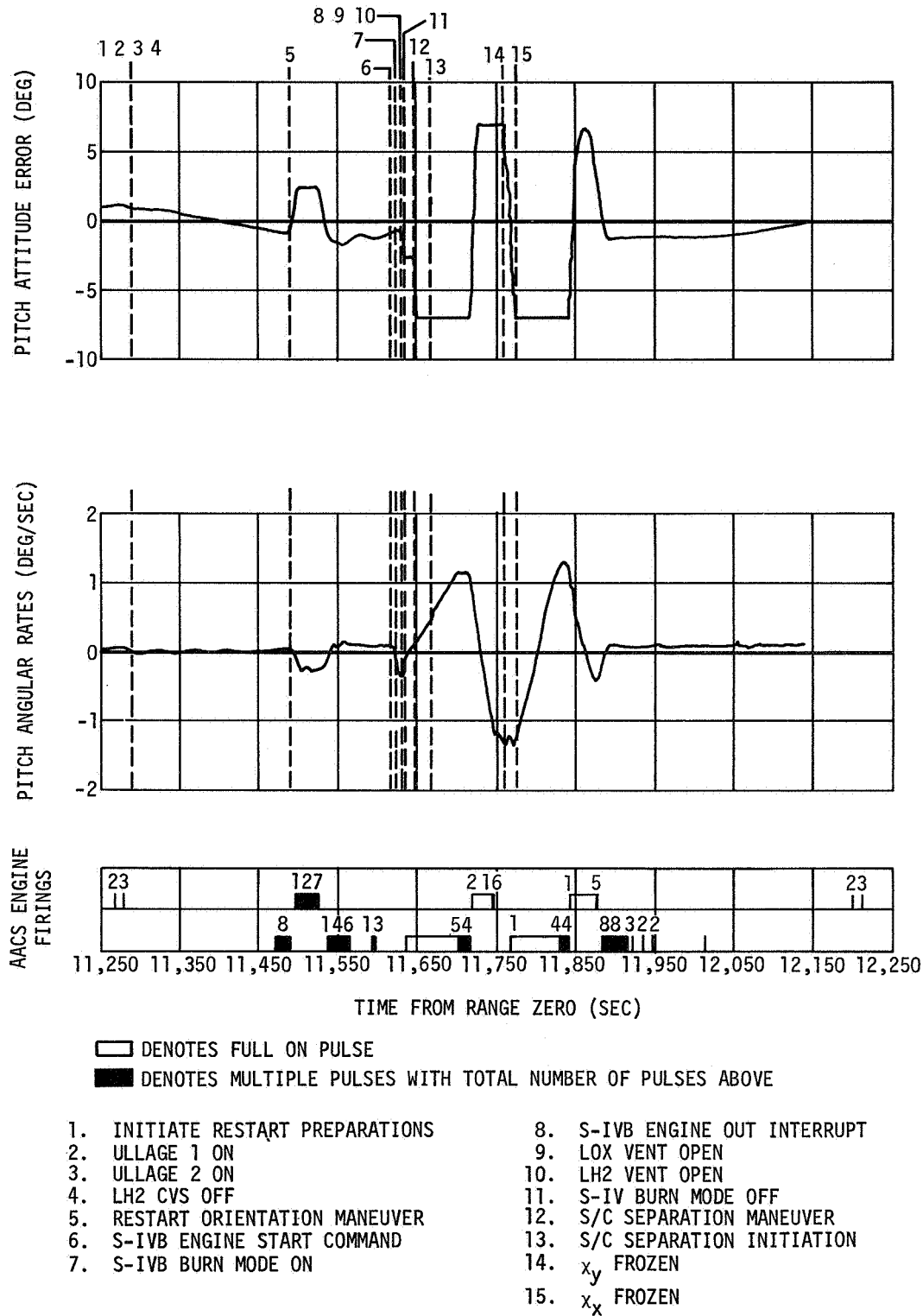


Figure 21-25. Pitch Attitude Control - Restart Orientation Maneuver and Restart Attempt

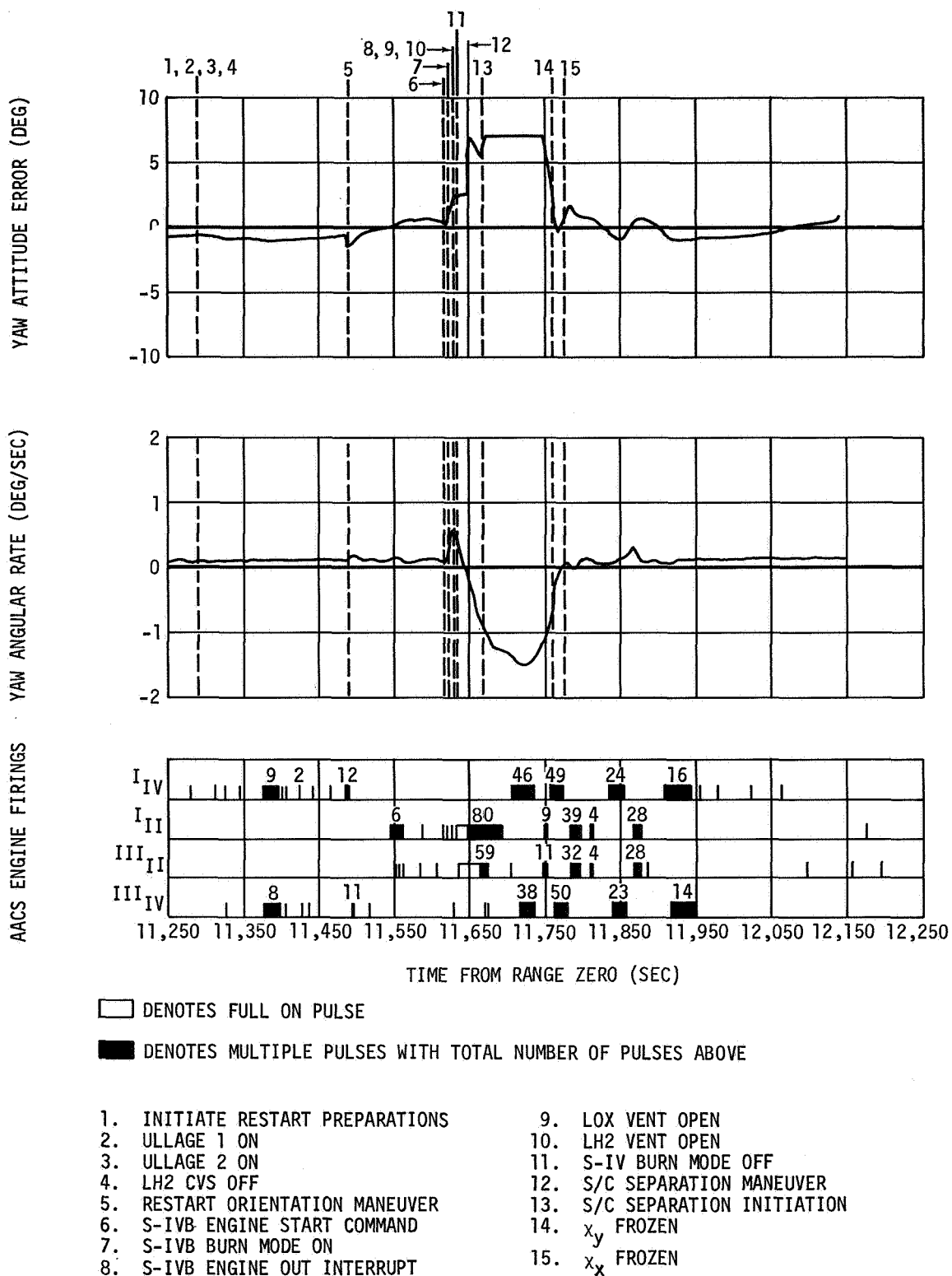


Figure 21-26. Yaw Attitude Control - Restart Orientation Maneuver and Restart Attempt

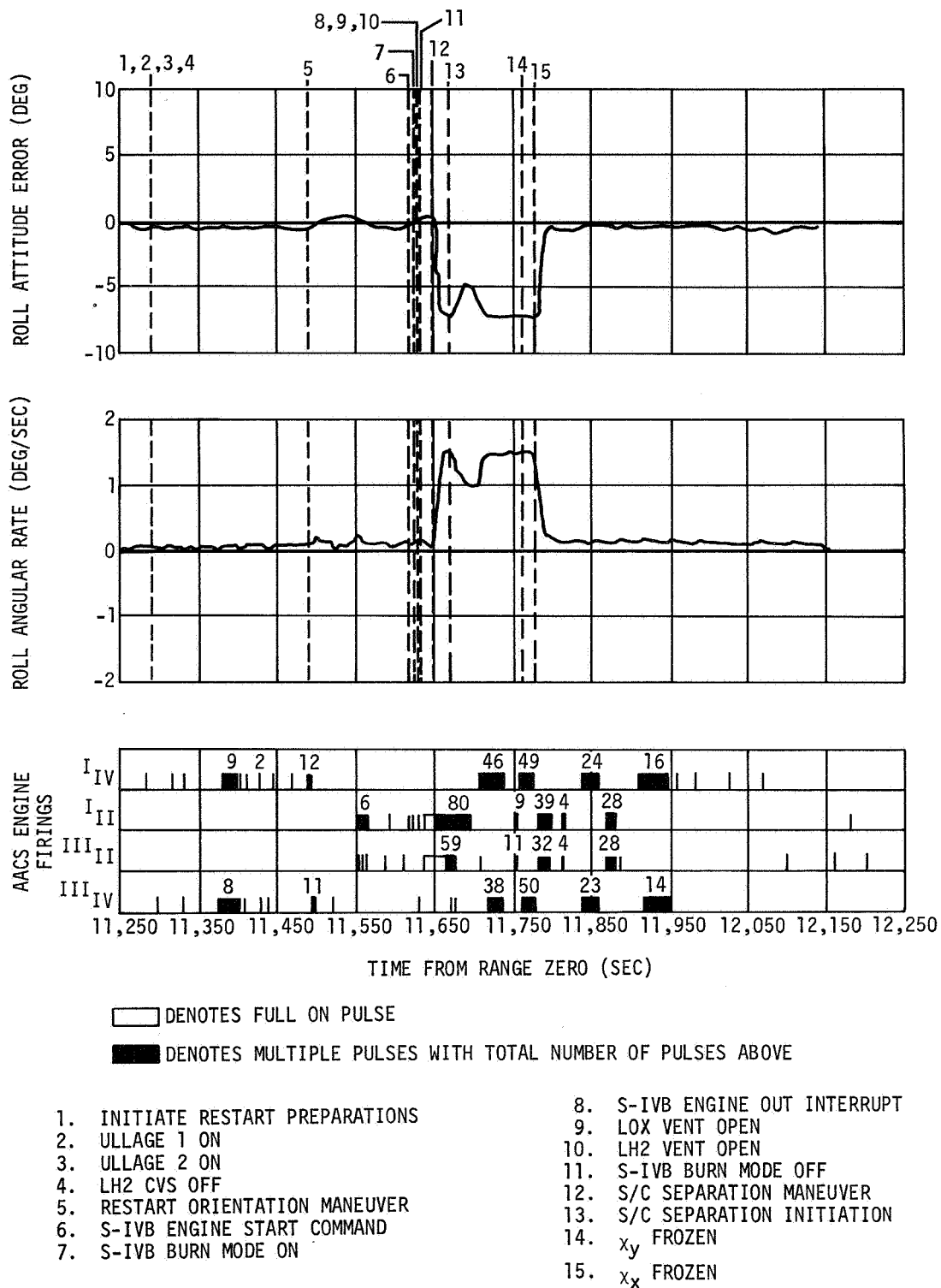
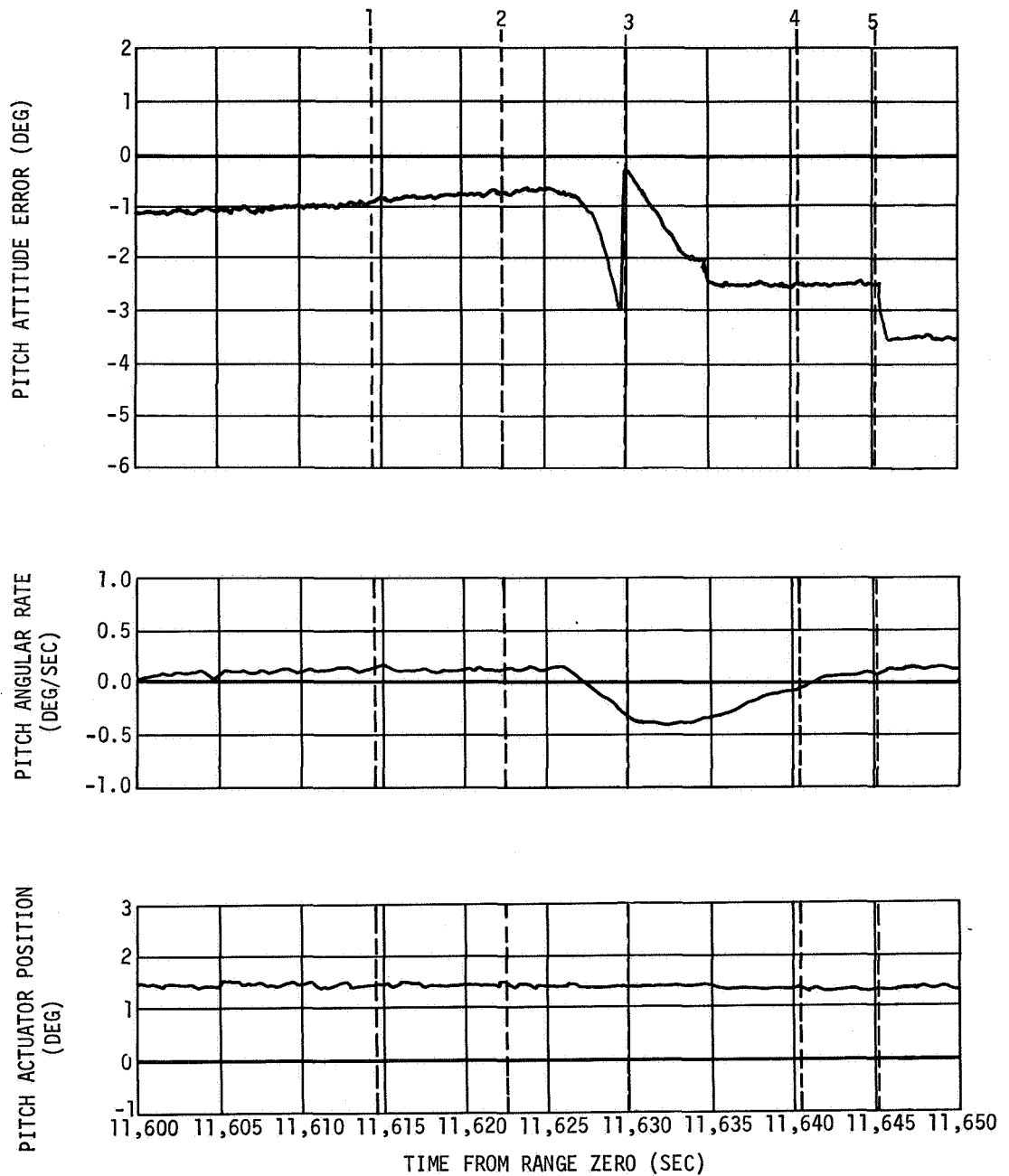
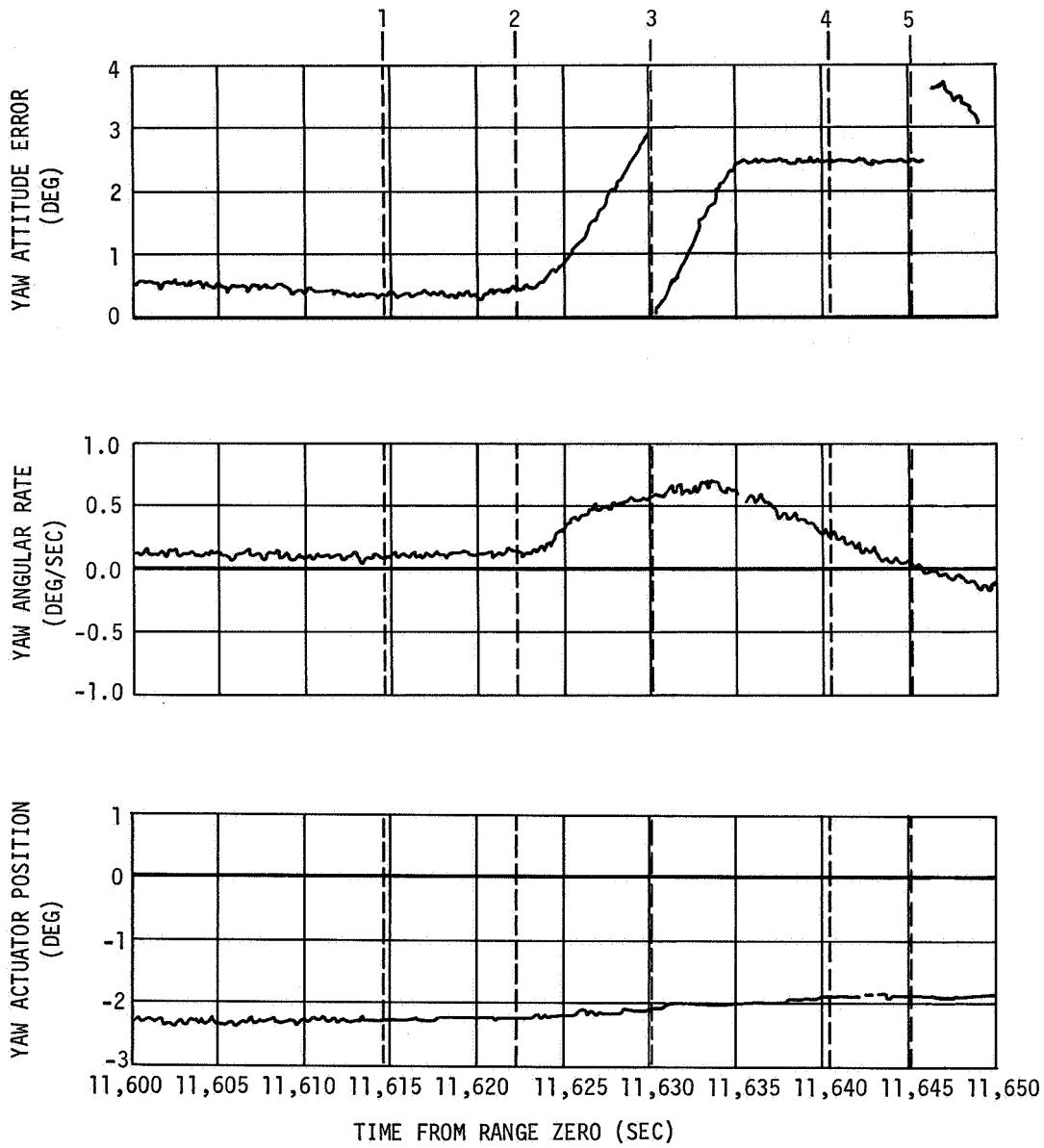


Figure 21-27. Roll Attitude Control - Restart Orientation Maneuver and Restart Attempt



1. ENGINE START COMMAND
2. S-IVB BURN MODE ON
3. S-IVB CUTOFF, LOX VENT OPEN, LH2 VENT OPEN
4. LOX VENT CLOSE
5. ATTITUDE ERROR LIMIT CHANGE

Figure 21-28. Pitch Attitude Control - Restart Attempt



1. ENGINE START COMMAND
2. S-IVB BURN MODE ON
3. S-IVB CUTOFF, LOX VENT OPEN, LH2 VENT OPEN
4. LOX VENT CLOSE
5. ATTITUDE ERROR LIMIT CHANGE

Figure 21-29. Yaw Attitude Control - Restart Attempt

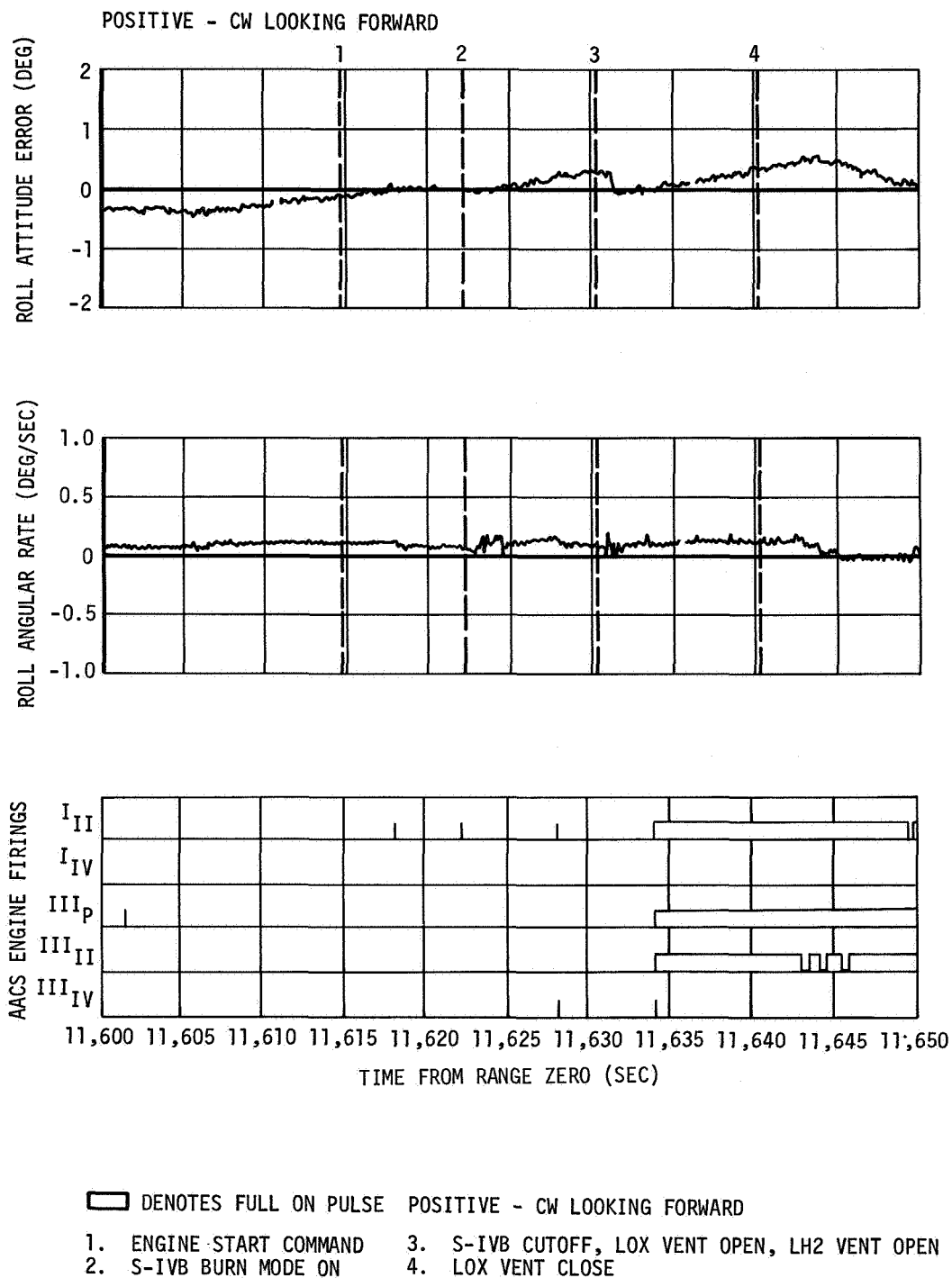


Figure 21-30. Roll Attitude Control - Restart Attempt

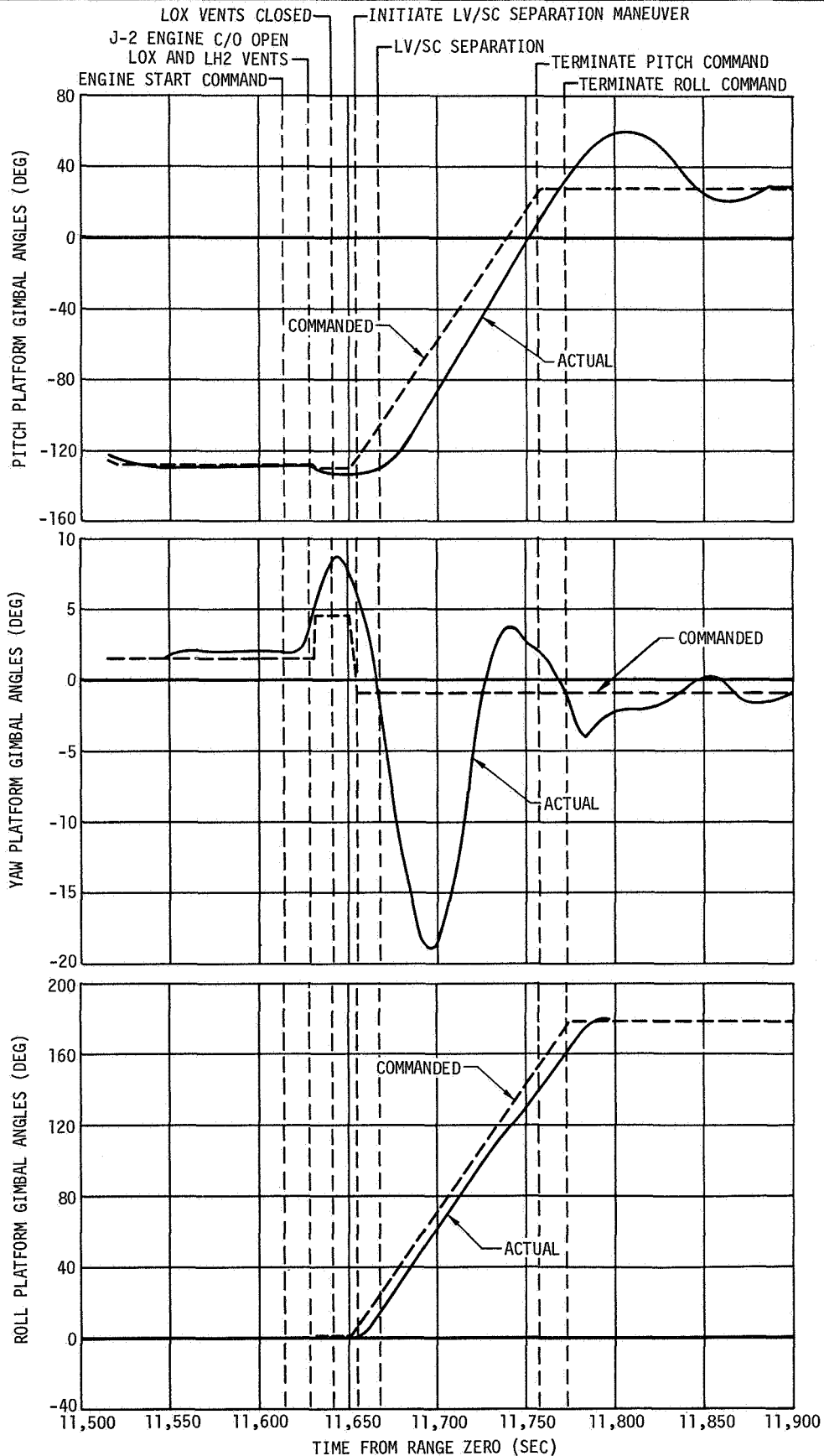


Figure 21-31. Pitch, Yaw, and Roll Commanded and Actual Vehicle Attitudes following Attempted Restart

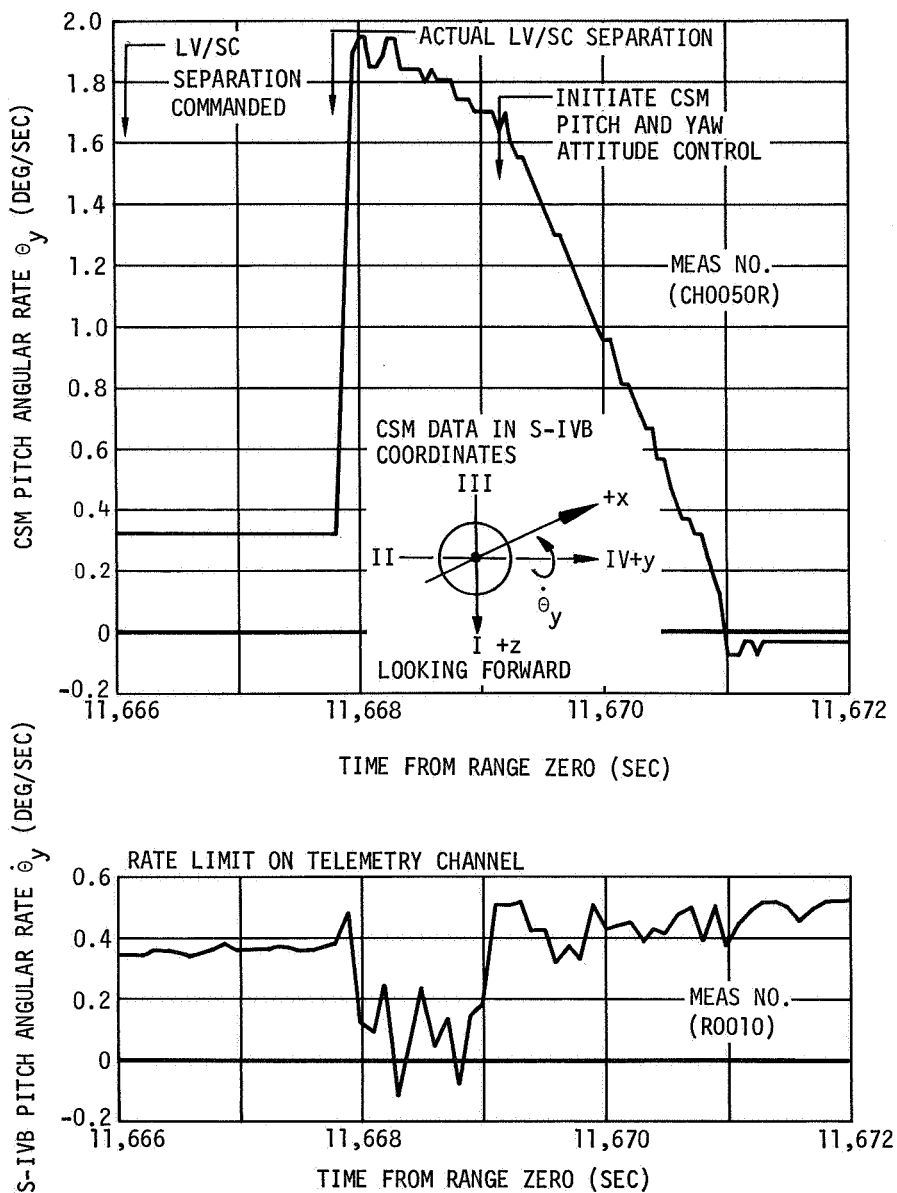


Figure 21-32. LV/SC Pitch Angular Rates at Separation

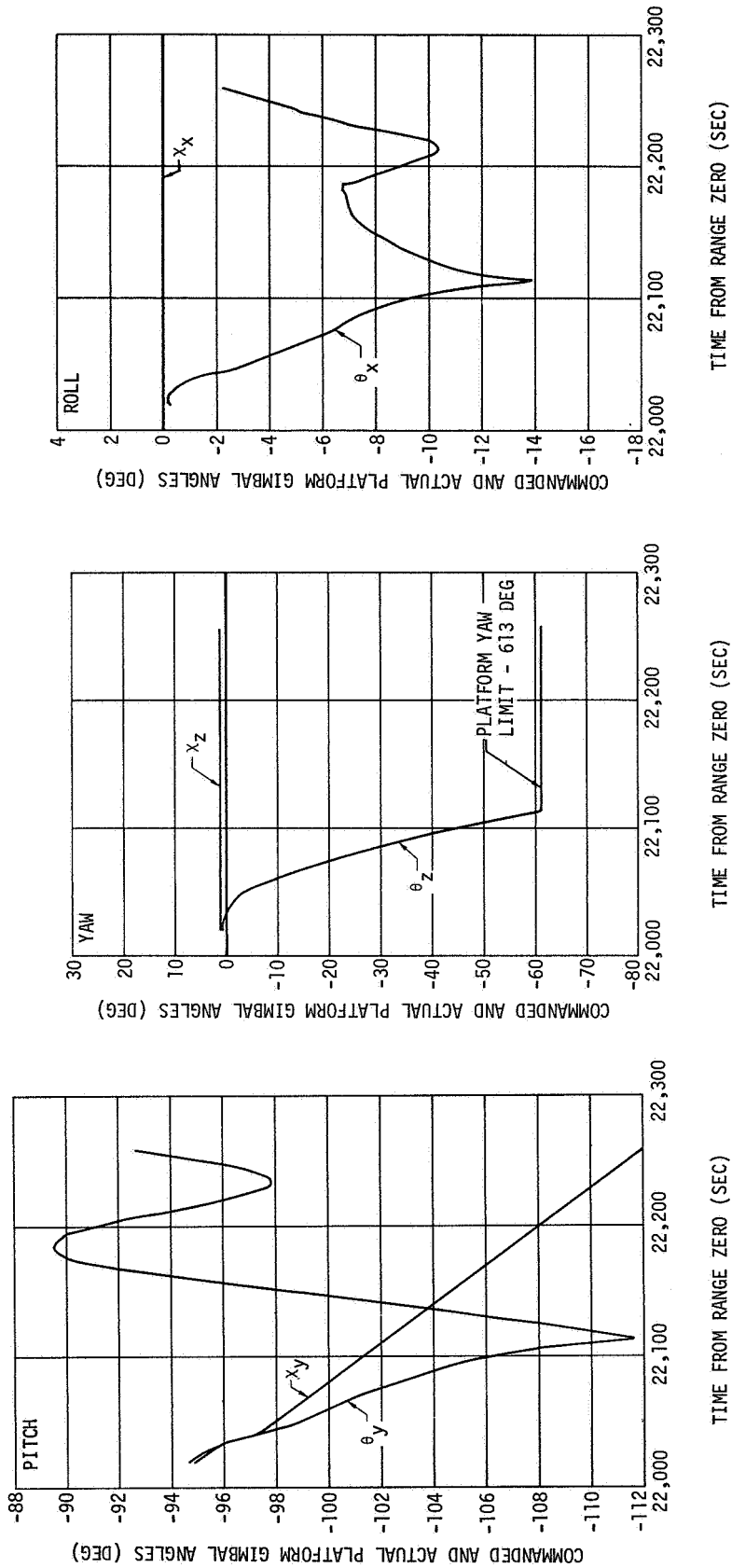
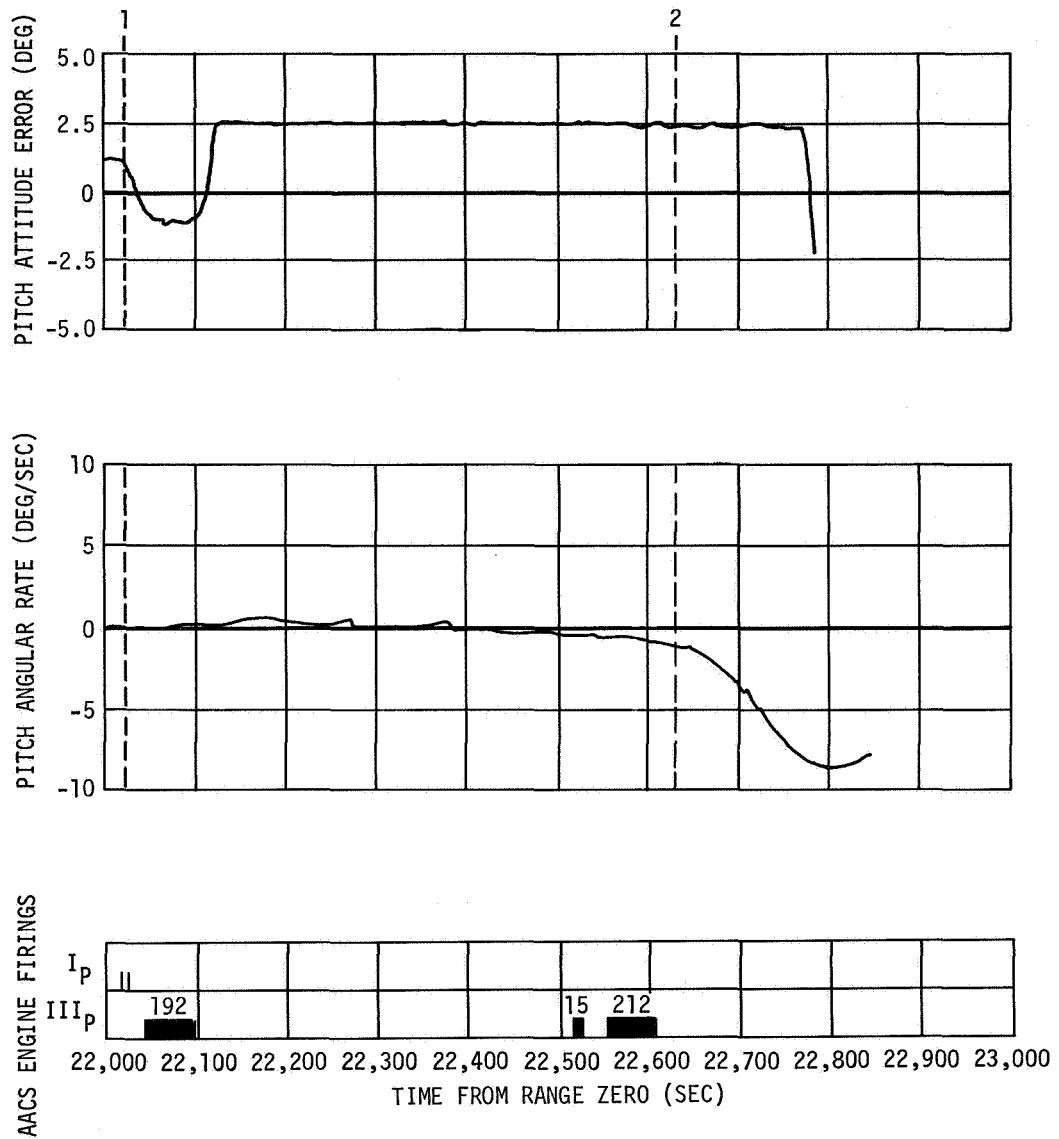


Figure 21-33. Commanded and Actual Vehicle Attitudes at Loss of Attitude Control (Hawaii - Revolution 4)



DENOTES FULL ON PULSE
 DENOTES MULTIPLE PULSES WITH
 TOTAL NUMBER OF PULSES ABOVE

1. LOSS OF APS MODULE 1
2. LOSS OF APS MODULE 2

Figure 21-34. Pitch Axis Parameters at Loss of Attitude Control

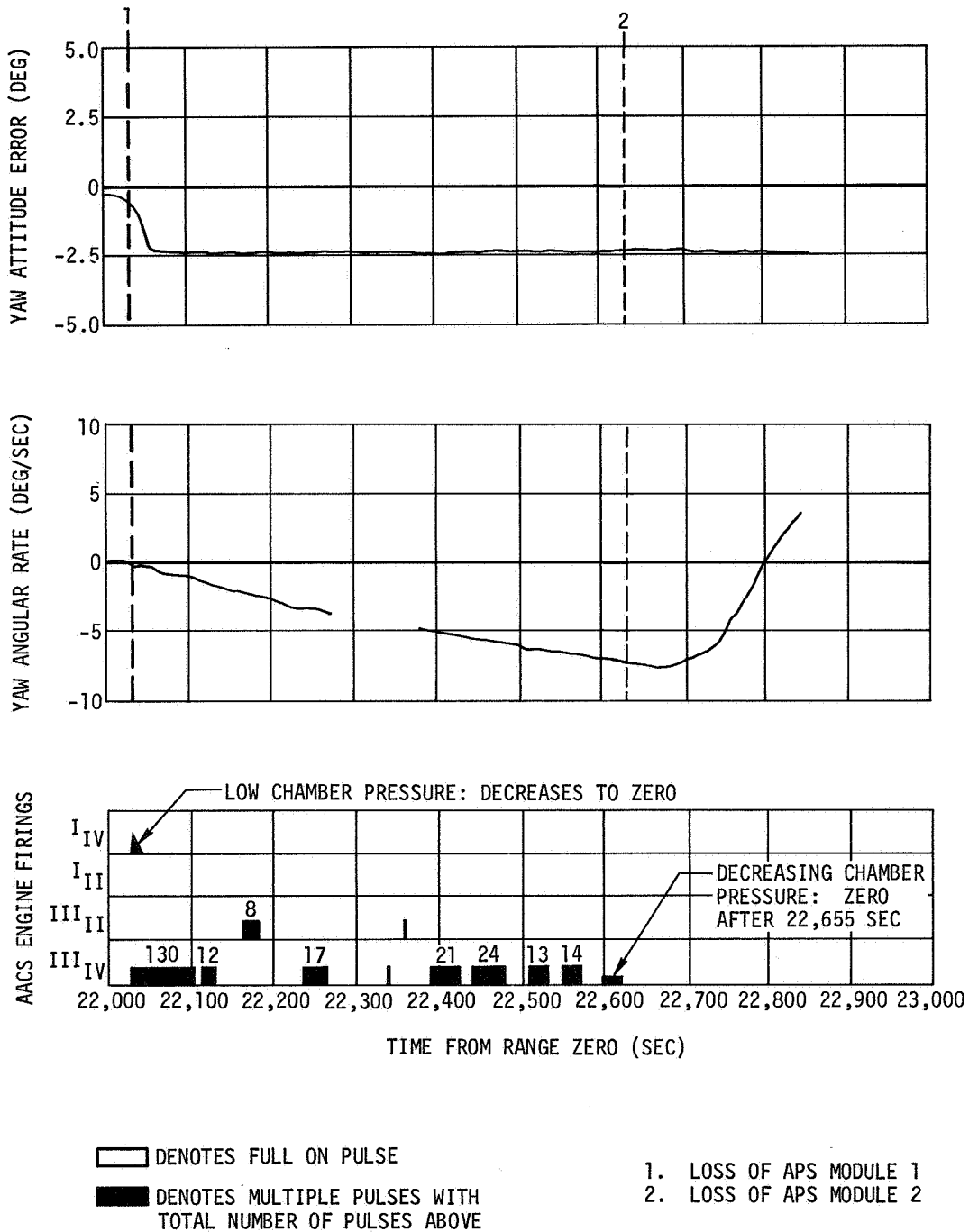


Figure 21-35. Yaw Axis Parameters at Loss of Attitude Control

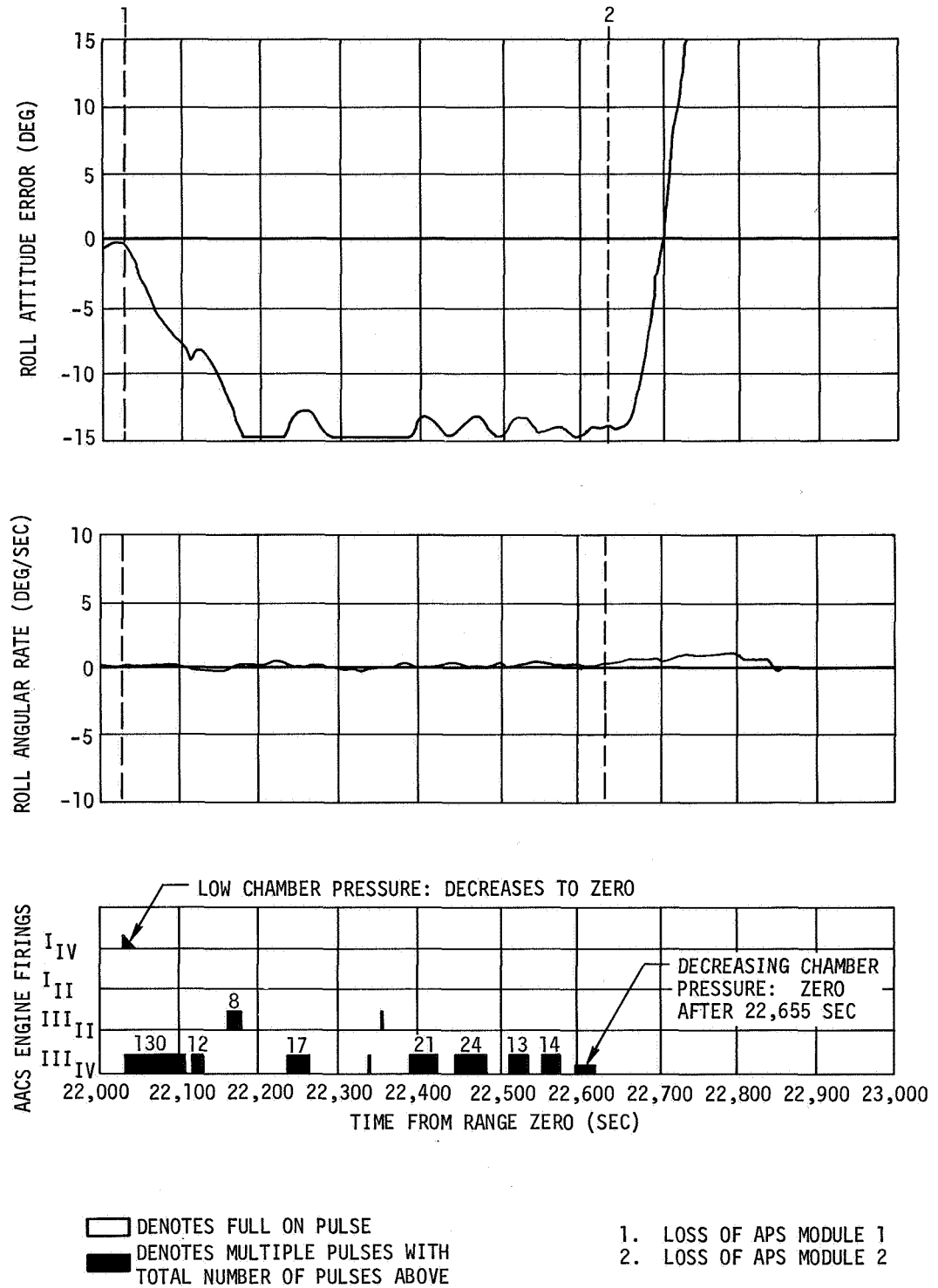


Figure 21-36. Roll Axis Parameters at Loss of Attitude Control

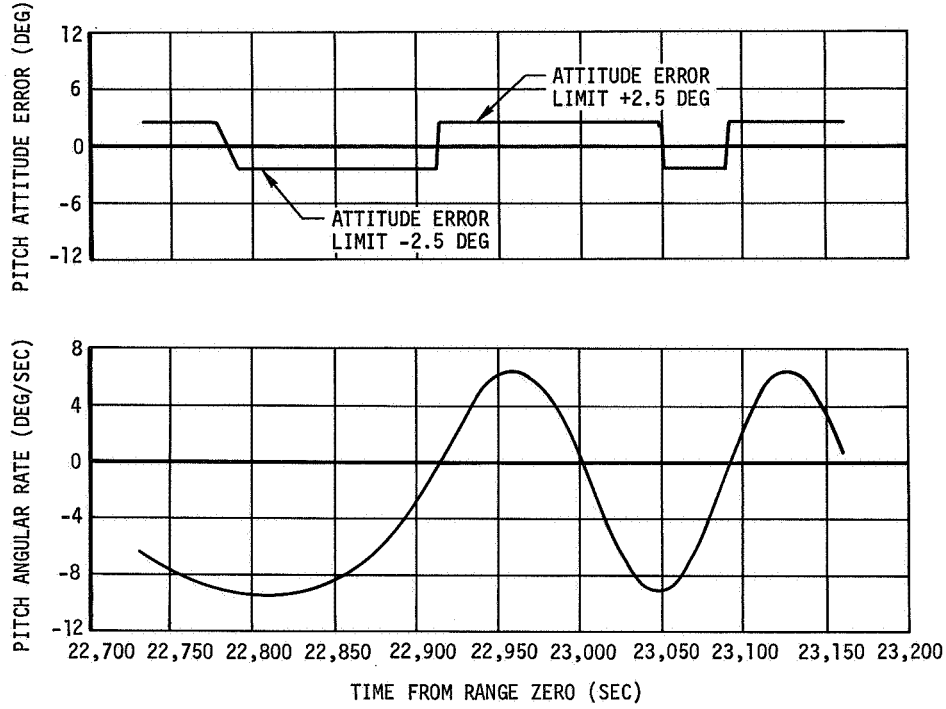


Figure 21-37. Pitch Axis Parameters After Loss of Attitude Control

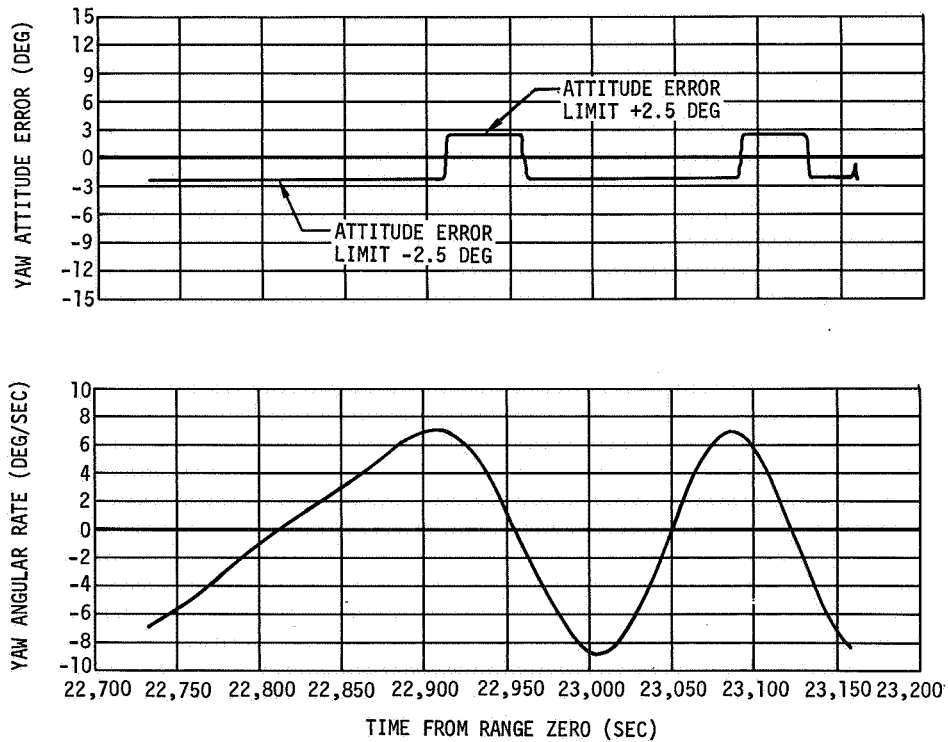


Figure 21-38. Yaw Axis Parameters After Loss of Attitude Control

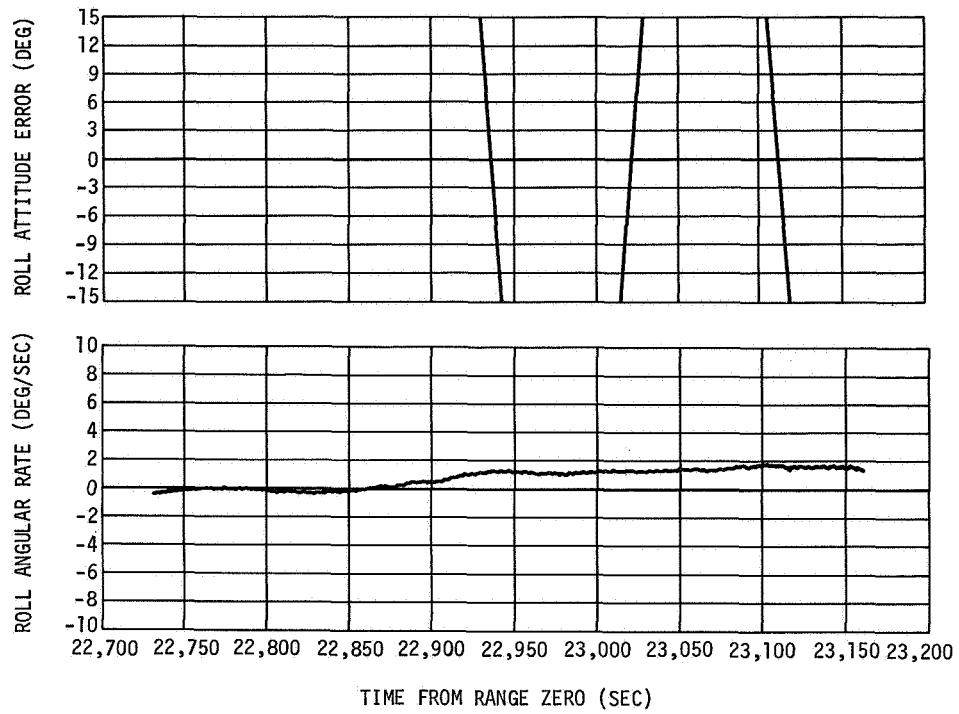


Figure 21-39. Roll Axis Parameters After Loss of Attitude Control

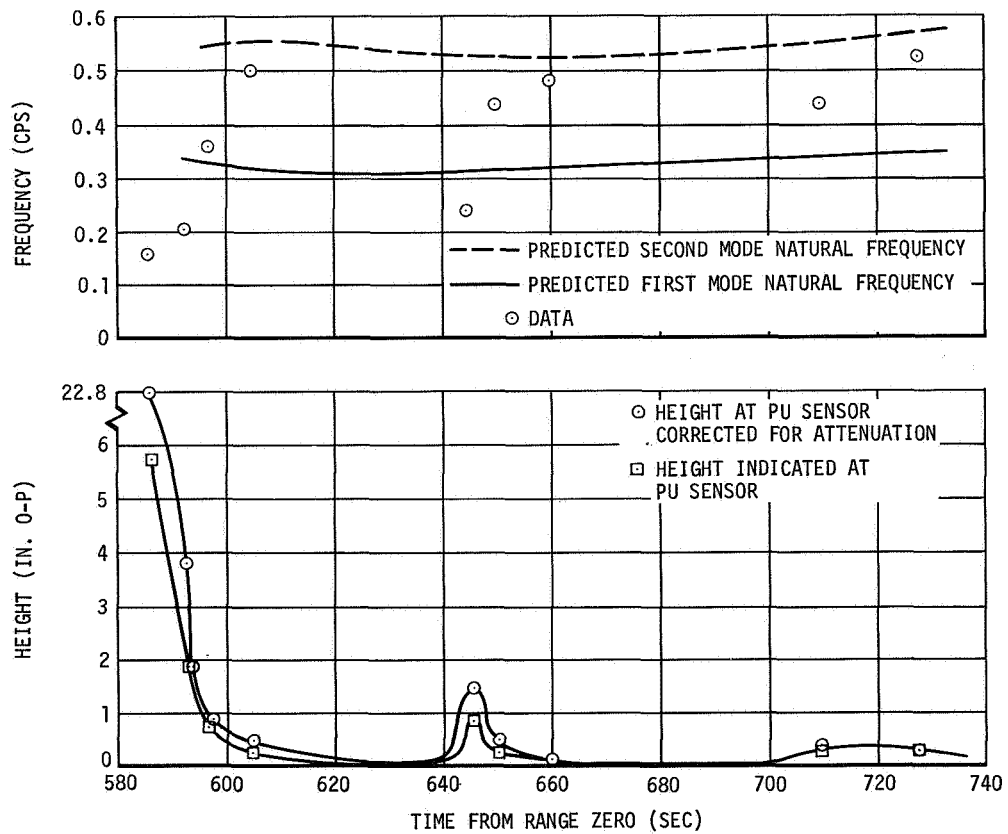


Figure 21-40. LH2 Slosh Frequencies and Amplitudes - First Burn

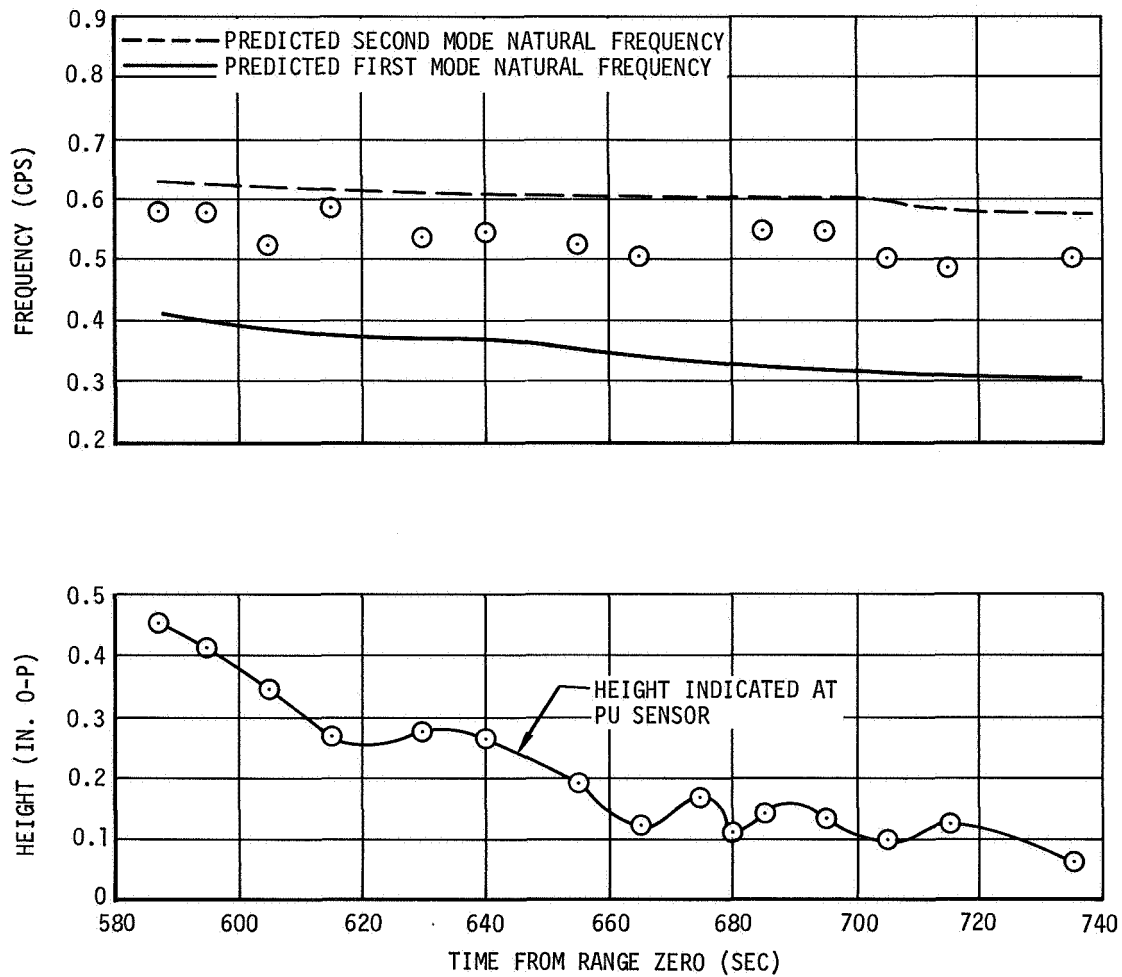


Figure 21-41. LOX Slosh Frequencies and Amplitudes - First Burn

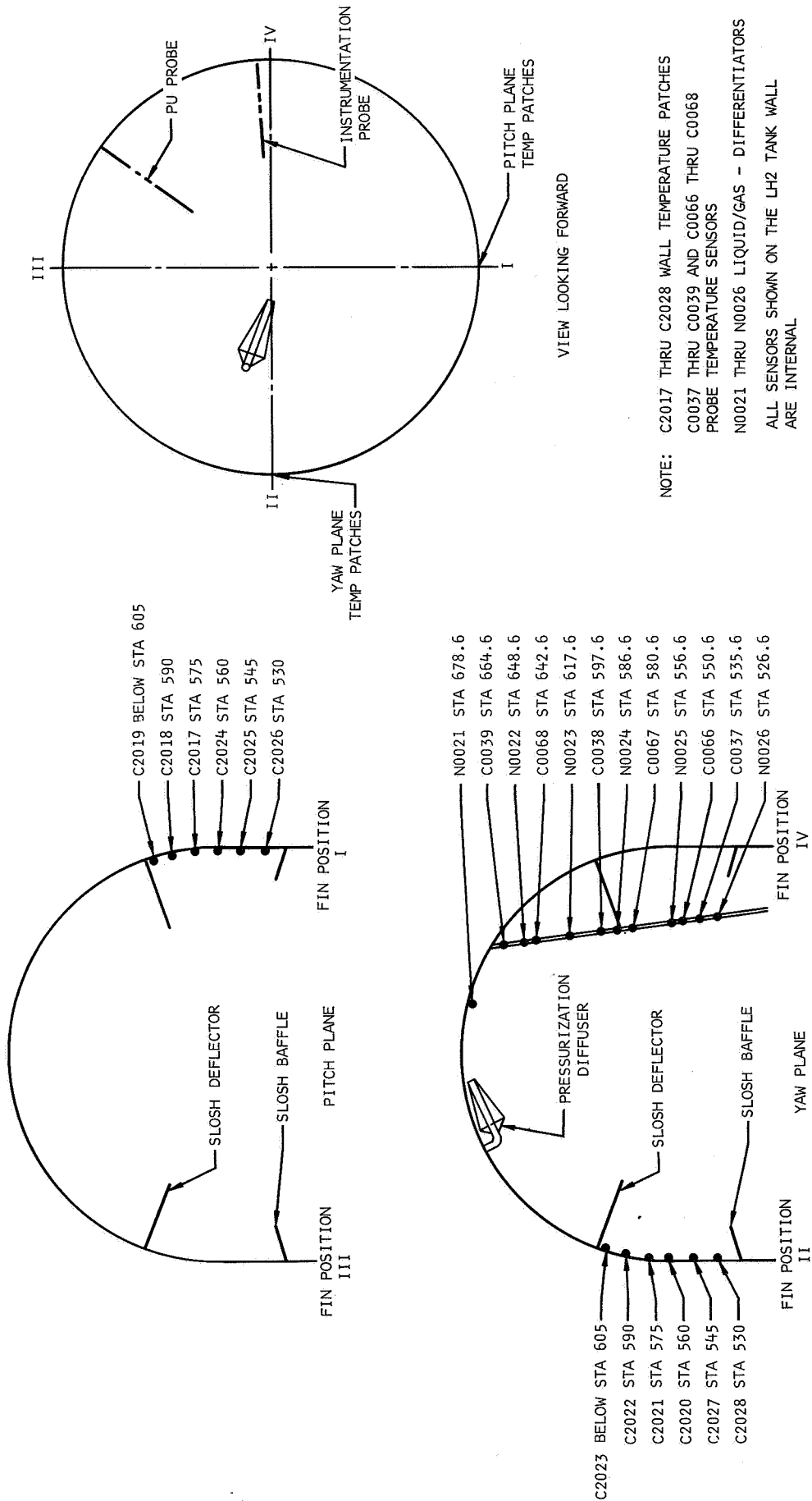


Figure 21-42. LH2 Instrumentation Location in Forward Dome Area

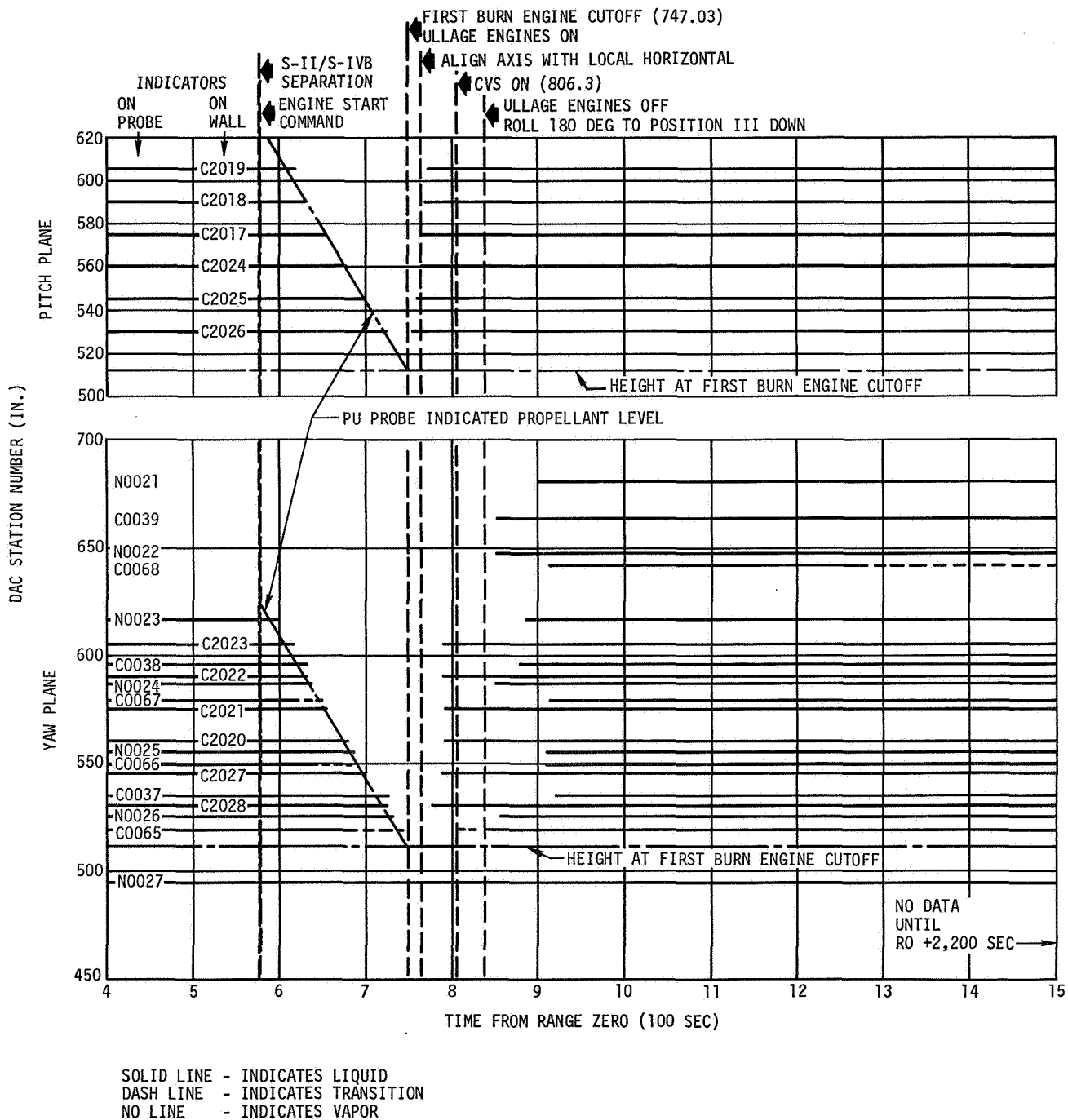


Figure 21-43. LH2 Sensor Data - S-IVB First Burn and Engine Cutoff

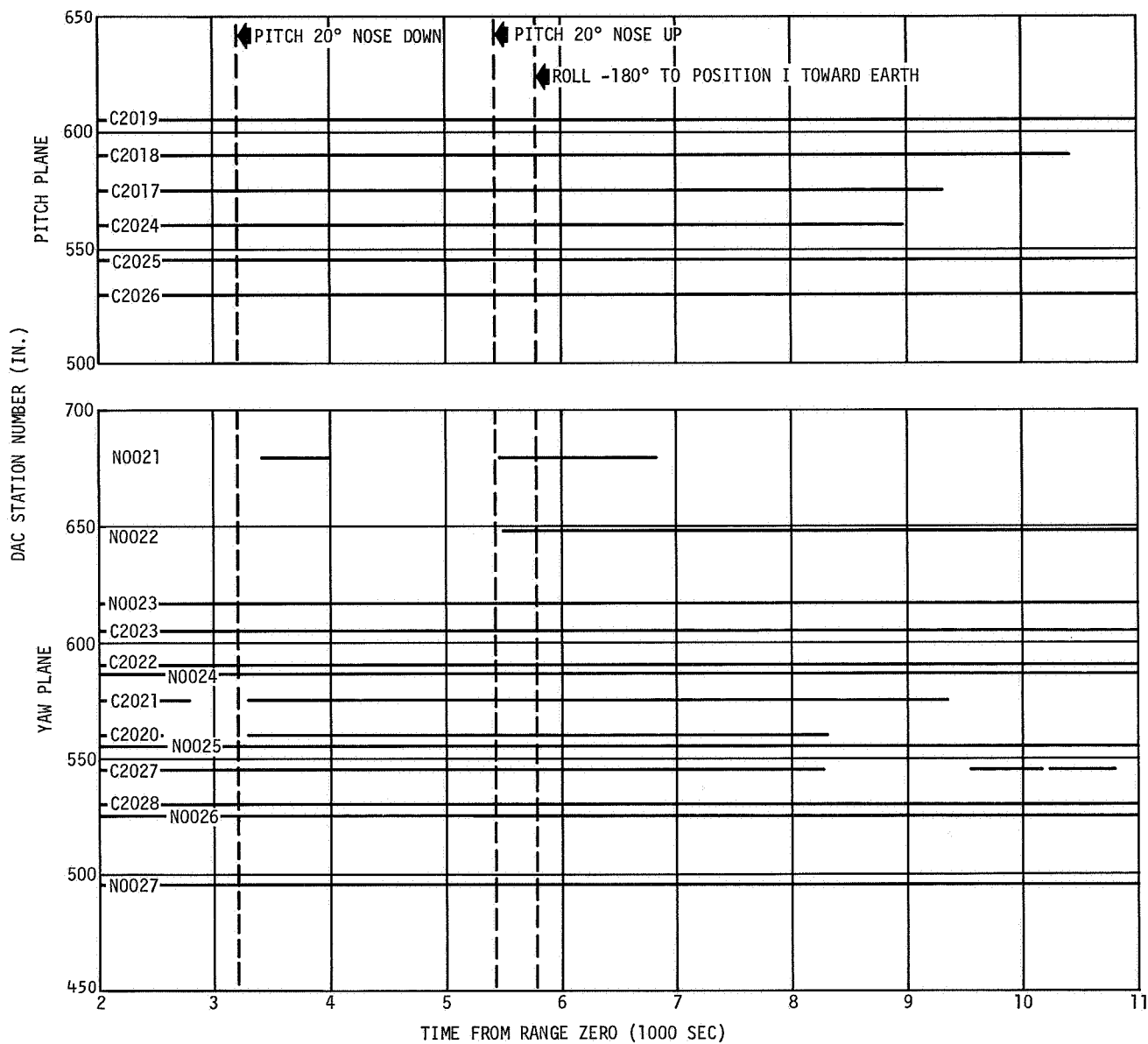
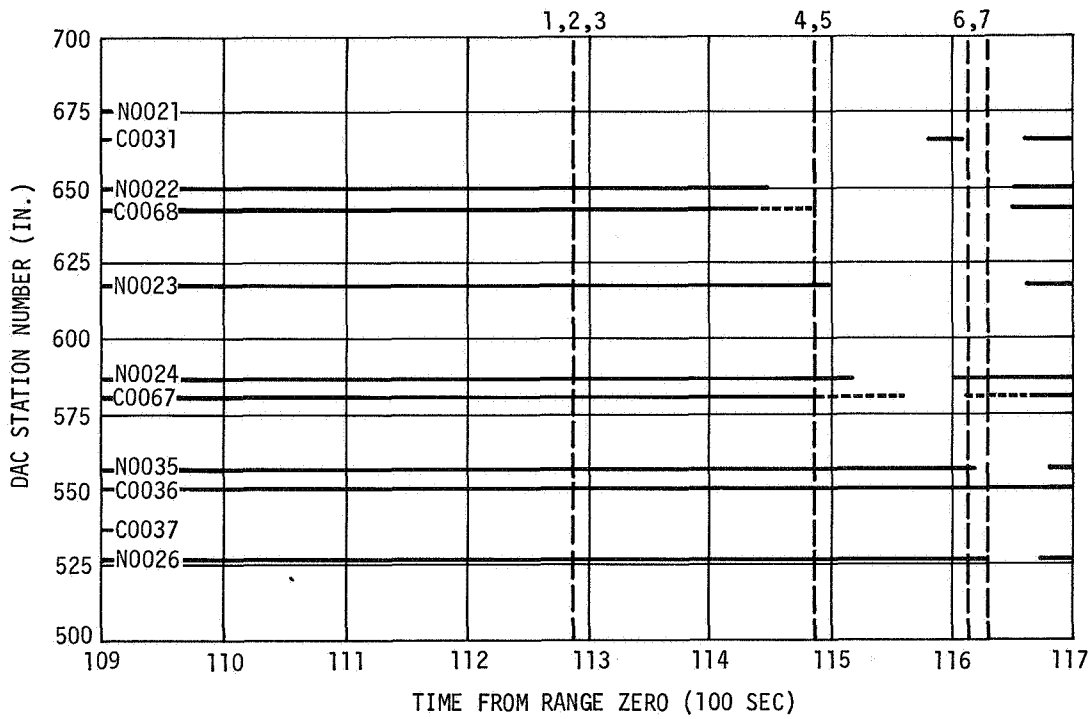


Figure 21-44. Sensor Data - Orbital Coast

1. TB6 BEGIN RESTART PREPARATIONS
2. ULLAGE ENGINES ON
3. LH2 CVS OFF
4. RESTART ORIENTATION MANEUVER
5. LH2 TANK REPRESSURIZATION
6. ENGINE START COMMAND
7. ENGINE CUTOFF COMMAND



SOLID LINE - SENSOR INDICATES LIQUID
 NO LINE - SENSOR INDICATES VAPOR
 DOTTED LINE - SENSOR INDICATES TRANSITION

Figure 21-45. Instrumentation Probe Sensor Data - Prior to Restart

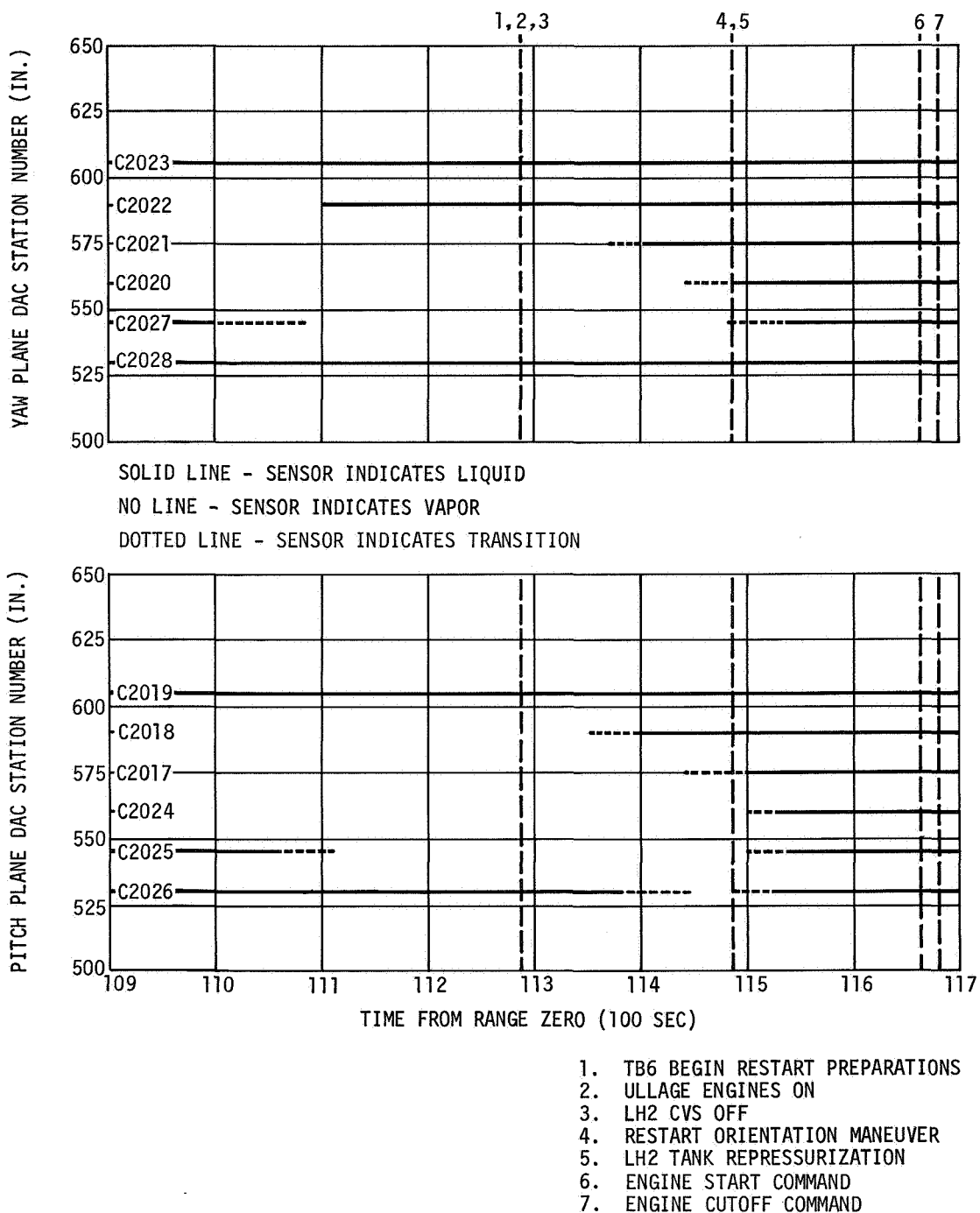


Figure 21-46. Tank Wall Temperature Sensor Data - Prior to Restart

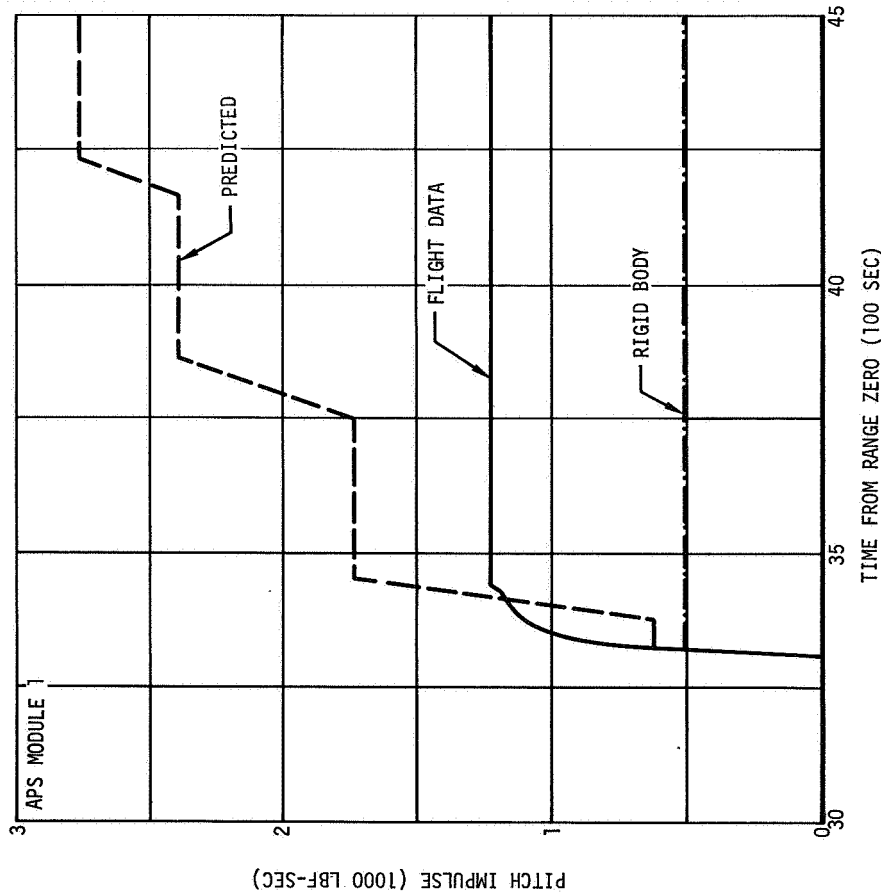
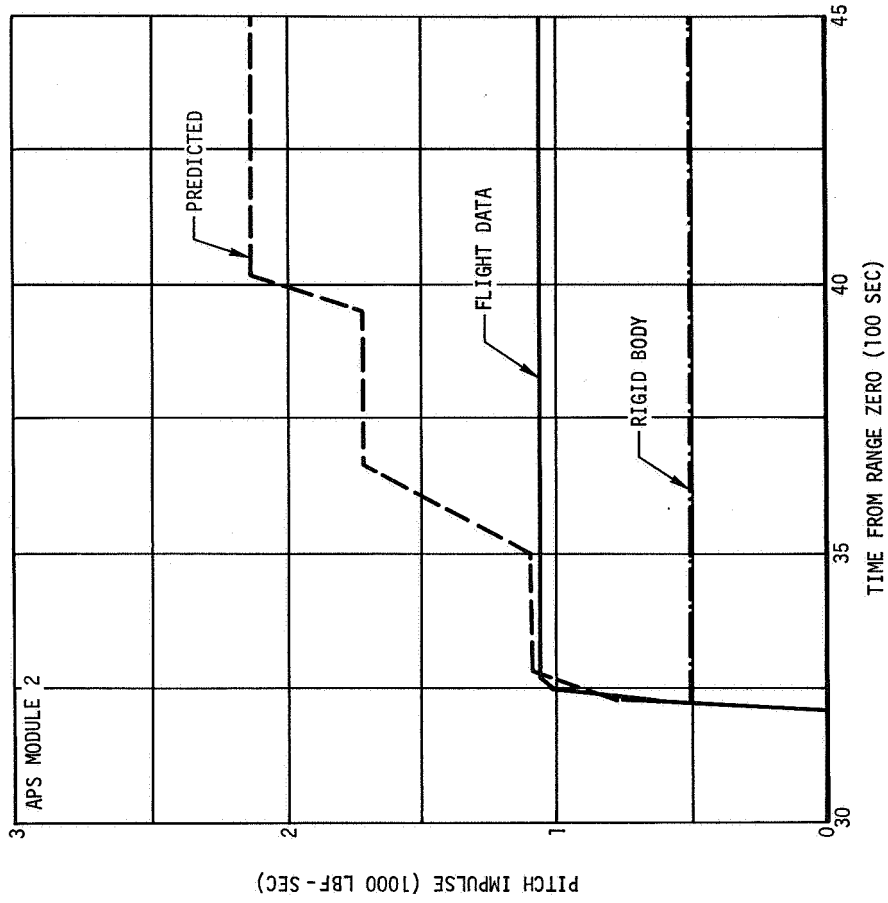


Figure 21-47. APS Impulse Requirements for 20 deg Pitch Down Maneuver

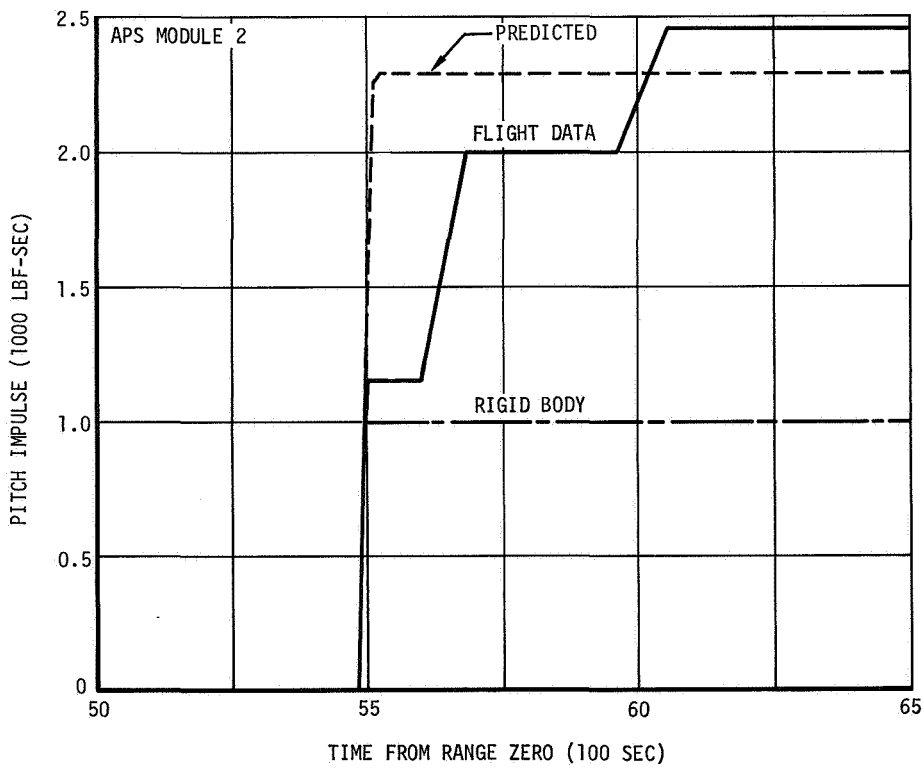
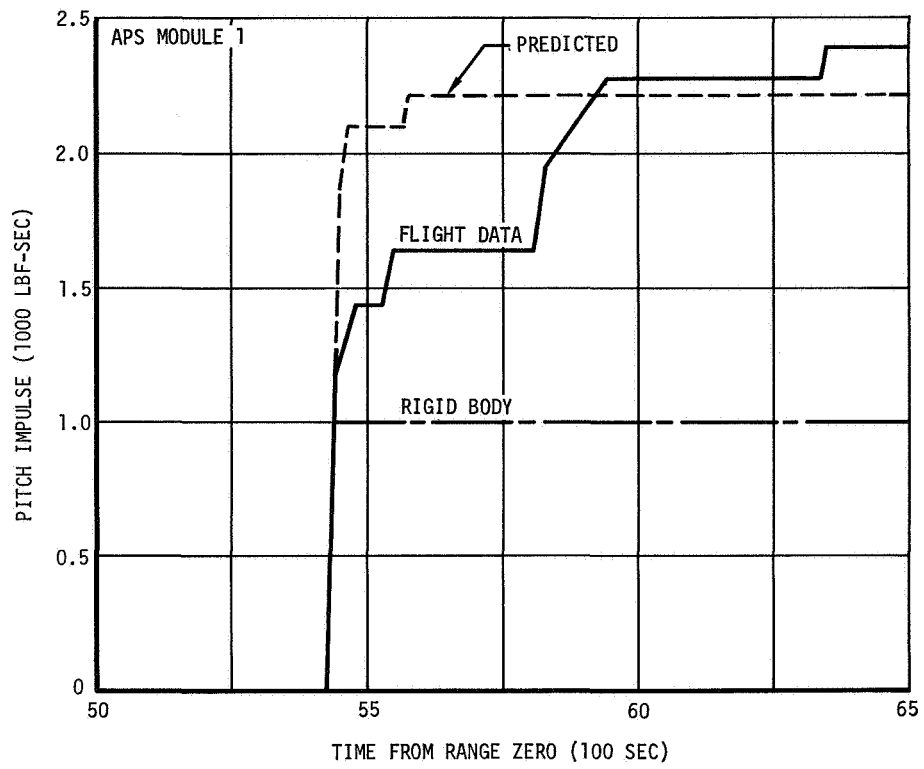


Figure 21-48. APS Impulse Requirements for 20 deg Pitch Up Maneuver

SECTION 22

HYDRAULIC SYSTEM

22. HYDRAULIC SYSTEM

The S-IVB hydraulic system performance was within predicted limits and the entire system operated satisfactorily during liftoff and first burn. There was no loss of system fluid due to overboard venting as a result of reservoir fluid thermal expansion. System internal leakage was 0.64 gpm which is within the 0.4 to 0.8 gpm allowable range. The hydraulic pump required 5.6 hp from the engine during first burn.

Both the auxiliary and main hydraulic pumps failed to develop pressure in the period preceding and during second burn. It is believed that the pumps were cavitating due to an obstruction of frozen hydraulic fluid in the pump suction line between the reservoir and main pump. Flight data indicated that the freezing was in a localized area and possibly caused by fluid impingement from a leaking cryogenic fuel line. Reservoir fluid level, temperature and pressure levels were normal during this time period.

A summary of system pressure measurements obtained during various phases of flight is presented in table 22-1. Figures 22-1 through 22-5 graphically depict various system parameters plotted against time from liftoff.

22.1 Prelaunch

During countdown the auxiliary hydraulic pump was switched to coast thermal mode ON at R0 -6.5 hr, just prior to start of propellant loading. The accumulator was precharged to 2,200 psia at 40 deg F. Reservoir fluid level (auxiliary pump OFF) was 78.5 percent at 26 deg F. There were no thermal cycles prior to launch.

The auxiliary hydraulic pump was switched to flight mode ON, coast mode OFF at R0 -8.5 min (11:51:20 GMT). After stabilization the following measurements were recorded:

| | |
|---------------------------------------|------------|
| System pressure (D0041): | 3,600 psia |
| Reservoir pressure (D0042): | 170 psia |
| Pump inlet fluid temperature (C0050): | 52 deg F |
| Reservoir fluid temperature (C0051): | 45 deg F |
| Reservoir fluid level (L0007): | 17 percent |

22.2 Boost and First Burn Phases

During boost the pump inlet and reservoir fluid temperatures rose steadily as auxiliary pump operation warmed the fluid. Accumulator gas and actuator cylinder temperatures remained low during boost but started to rise as soon as the engine driven pump started.

The pitch actuator differential pressure recorded a 5.5 cps pressure oscillation between R0 +121.5 to R0 +135.0 sec. The maximum amplitude recorded was 400 psi (peak to peak). The yaw actuator differential pressure did not show a change in pressure during this interval of time. These oscillations occurred when the maximum S-IC stage pogo effect was taking place.

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Hydraulic System

System temperatures did not rise normally during first burn. The following characteristics have not been experienced on previous flights:

- a. At Engine Start Command (ESC) +111 sec (RO +688 sec) the yaw actuator suddenly started to lose temperature at the rate of approximately 0.3 deg F/sec.
- b. At ESC +124 sec (RO +701 sec) the pump inlet fluid temperature suddenly jumped 30 deg F in 14 sec and then decreased 12 deg F at cutoff.
- c. The main pump discharge line temperature rose normally from the start of engine burn. At ESC +107 sec (RO +684 sec) it suddenly started to drop and then leveled off at engine cutoff.

Engine deflections in the pitch plane exceeded previously observed excursions on other Saturn flights by a considerable amount. The deflections in the yaw plane were much less than those encountered in the pitch plane throughout first burn. The large amount of pitch actuator activity was due to abnormal SII/S-IVB separation transients caused by engines No. 2 and 3 on the S-II cutting off earlier than scheduled during the S-II boost portion of the powered flight. These engines are symmetrical about the S-IVB pitch plane.

Prior to the event Flight Control Computer S-IVB Burn Mode ON, the pitch and yaw actuator positions (G0001 and G0002) were at null. During S-IVB first burn, their average offset values were +0.37 and -0.75 deg respectively. At engine cutoff after the event Flight Control Computer S-IVB Burn Mode OFF, the actuators returned to their original null positions. The actuators were offset from null during powered flight due to the displacement of the vehicle's center of gravity off the vehicle's longitudinal axis, and due to J-2 engine installation tolerances, thrust misalignment, and uncompensated gimbal clearances and thrust structure compression effects.

The pitch actuator's first movement at separation occurred at RO +577.5 sec, the yaw actuator at RO +577.9 sec. A maximum deflection of 6.69 deg occurred in the pitch plane due to separation transients at RO +580.9 sec; thus the displacement of the engine from its offset during this portion of powered flight was 6.32 deg. The maximum slew rate of the engine was 15.1 deg/sec. This rate falls within the hydraulic servo flow limit of 10.5 \pm 1.5 gal/min. The actuator did not retract to its limit since full differential pressure was not developed. The engine responded to pitch guidance commands at RO +643.8 sec and moved to -0.437 deg, or 0.807 deg from the offset position. At RO +747.30 sec, the S-IVB engine cutoff signal was received. At this time, the pitch attitude rate signal was causing the pitch actuator to retract at a rate of 0.68 deg/sec. The vehicle could not respond to the guidance signals since engine thrust was cutoff. The actuator continued to move and reached +2.79 deg. At RO +750.76 sec the guidance signal was removed. This caused the engine to null at a rate of 16.3 deg/sec. The actuator was able to return to null since hydraulic pressure was still on the system. The yaw actuator experienced its maximum deflection of -1.35 deg at RO +586.0 sec which is 0.6 deg from its offset position. The maximum pitch and yaw actuator differential pressures during first burn were -800 psi at

RO +577.6 sec and -650 psi at RO +585.3 sec respectively. This is equivalent to 25.7 and 18.9 percent of the respective actuator's maximum torque capability at that particular time. A differential pressure bias of -200 psi existed in both planes at the beginning of powered flight. A differential pressure of +900 psi was developed in the pitch actuator at RO +750.76 sec when guidance was removed. This is equivalent to 26.2 percent of the actuator's maximum torque capability.

Actuator separation transient loads were not considered excessive. Proper operation of the actuator dynamic pressure feedback mechanism is indicated by noting the damping of the pitch and yaw actuator differential pressure traces. The hydraulic servoactuators responded properly to the guidance signals.

Figure 22-1 shows the activity of various system measurements during this phase of flight.

22.3 Parking Orbit

After engine cutoff the pump inlet fluid temperature continued to rise as heat was transferred from the LOX turbine dome to the pump manifold. It rose to a peak of 185 deg F at RO +8,300 sec and then started to decrease at a rate of 0.39 deg F/min. Reservoir fluid temperature dropped approximately 30 deg F during orbital coast prior to second burn. The pitch actuator temperature fell off very sharply. Just prior to restart it was -60 deg F. The yaw actuator was at -28 deg F prior to restart. The pump discharge line declined to a minimum of 2 deg F at restart.

The auxiliary hydraulic pump was commanded to coast mode ON (thermal switch control) after engine cutoff. There were no thermal cycles during the coast phase.

At RO +10,822 sec the pump was commanded to flight mode ON and coast mode OFF but the pump failed to produce any discernable hydraulic pressure. There was an increase in current draw to the pump motor of 12 amp which is an indication that the pump was cavitating. Normal motor current is 45 amp. A 10 psi reservoir pressure increase occurred approximately 250 sec later but this was of short duration.

Flight history during this phase is shown on figures 22-2 through 22-4.

22.4 Second Burn

After second burn Engine Start Command, the main engine driven hydraulic pump failed to produce any measurable hydraulic system pressure. Flight data was carefully analyzed at RO +11,622 sec which corresponds to start of LOX turbine spin after second burn Engine Start Command. At this time there was a small fluctuation in reservoir oil pressure, the actuators moved slightly and there was 27 deg F momentary drop in pump inlet fluid temperature. This indicated that the main pump was turning and moving fluid but unable to develop system pressure.

It has been concluded that both the auxiliary and main hydraulic pumps did not produce pressure preceding and during second burn due to cavitation. Since the reservoir fluid level

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Hydraulic System

and pressure were normal it is believed that the condition was caused by localized freezing of the pump suction line hydraulic fluid by an unusual source such as fluid impingement from a leaking cryogenic fuel line. The pump suction line runs across the gimbal plane in line with position III between the accumulator reservoir on the thrust structure and the main hydraulic pump on the LOX turbine dome. If this line is subjected to cryogenic freezing, a blockage of fluid would result in the line (pour point of MIL-H-5606 is -90 deg F) which would prevent reservoir fluid from reaching the inlets of both pumps.

The pitch and yaw hydraulic actuators were offset from null +1.2 and -3.0 deg respectively at RO +10,822.83 sec when the hydraulic auxiliary pump was commanded ON for second burn. The actuators attempted to center the engine, however, since hydraulic system pressure was not sufficiently developed nor sustained they were only able to move to +0.9 and -2.1 deg positions. At RO +11,070 and RO +11,500 sec both actuators attempted to center and at RO +11,620 sec the yaw actuator again moved indicating some hydraulic pressure activity. Other hydraulic parameters also indicated activity at these times. The pitch and yaw actuators were unable to respond to the incoming IU signals. Their differential pressures were zero during this portion of the flight.

Two attempts were made to start the auxiliary hydraulic pump by ground command but with no success. The pump inlet and reservoir fluid temperatures continued to sink at approximately the same rates. The pump discharge line temperature measurement which was located near the system thermal switch, apparently varied with exposure to solar radiation or earth's shadow. Curve plots of flight measurements during attempted second burn are shown in figures 22-2 through 22-5.

TABLE 22-1
HYDRAULIC SYSTEM PERFORMANCE

| PRESSURES | PREDICTED DURING PUMP OPERATION (psia) | LIFTOFF (psia) | FIRST BURN (psia) | PARKING ORBIT (psia) | SECOND BURN (psia) |
|----------------------------|--|-------------------|----------------------|-------------------------|-----------------------|
| System fluid (D0041) | 3,500 to 3,650 | 3,600 | 3,600 | - | - |
| Accumulator gas (D0043) | 3,500 to 3,650 | 3,610 | 3,610 | 2,370* | 2,380* |
| Reservoir fluid (D0042) | 165 to 185 | 170 | 172 | 67 | 62 |
| Aux pump air tank (D0223) | 250 to 450 | 425 | 430 | 430 | 425 |
| Aux pump motor air (D0209) | 15 to 35 psig | 20 psig | 36 psig | 35 psig | 36 psig |
| RESERVOIR FLUID LEVEL | PREDICTED (percent) | LIFTOFF (percent) | FIRST BURN (percent) | PARKING ORBIT (percent) | SECOND BURN (percent) |
| Pump ON | 20 to 25 | 18 | 21 | - | - |
| Pump OFF | 80 to 90 | - | - | 82 | 83 |

*Corrected to 68 deg F

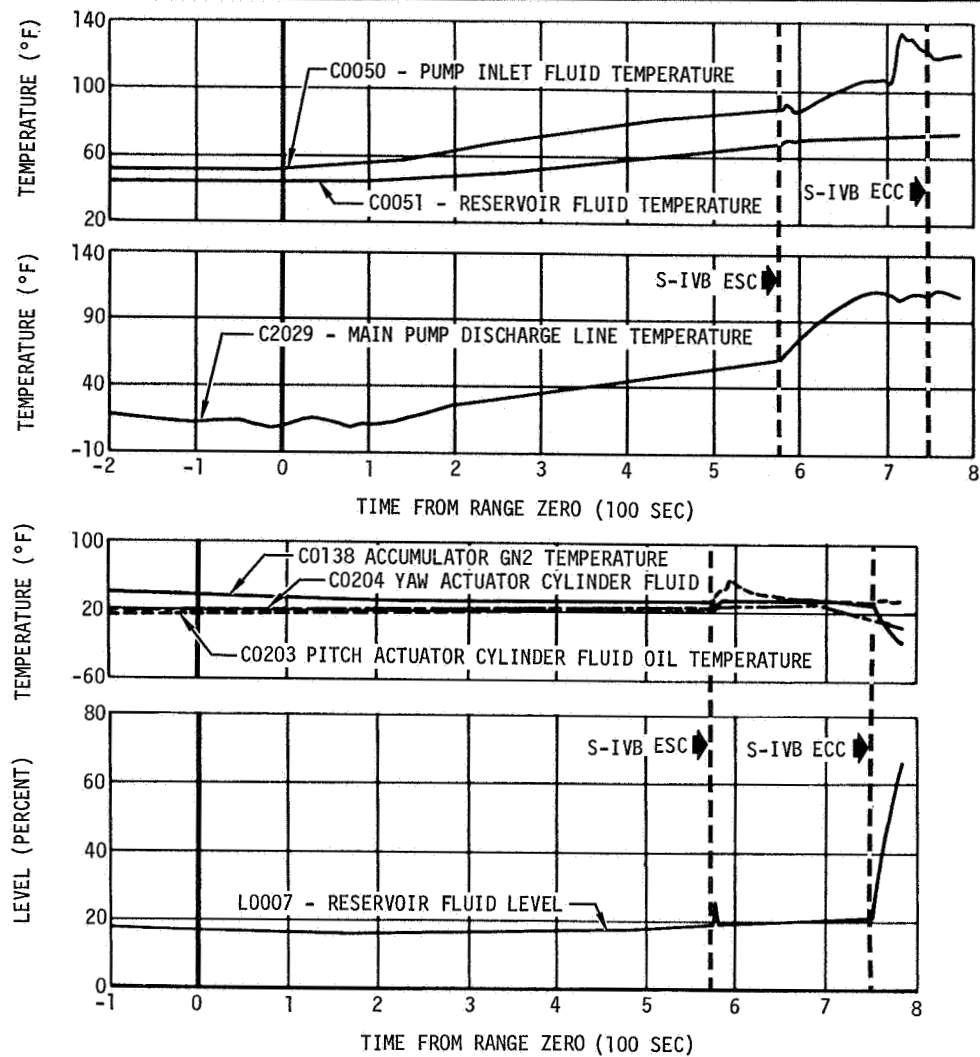


Figure 22-1. Hydraulic System Temperature and Reservoir Fluid Level - Boost and First Burn

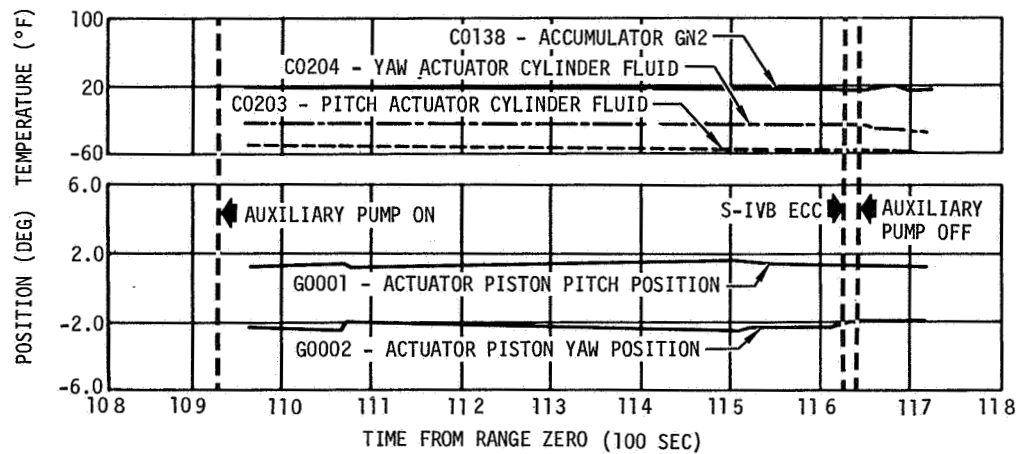


Figure 22-2. Hydraulic System Temperature and Actuator Piston Position - Restart

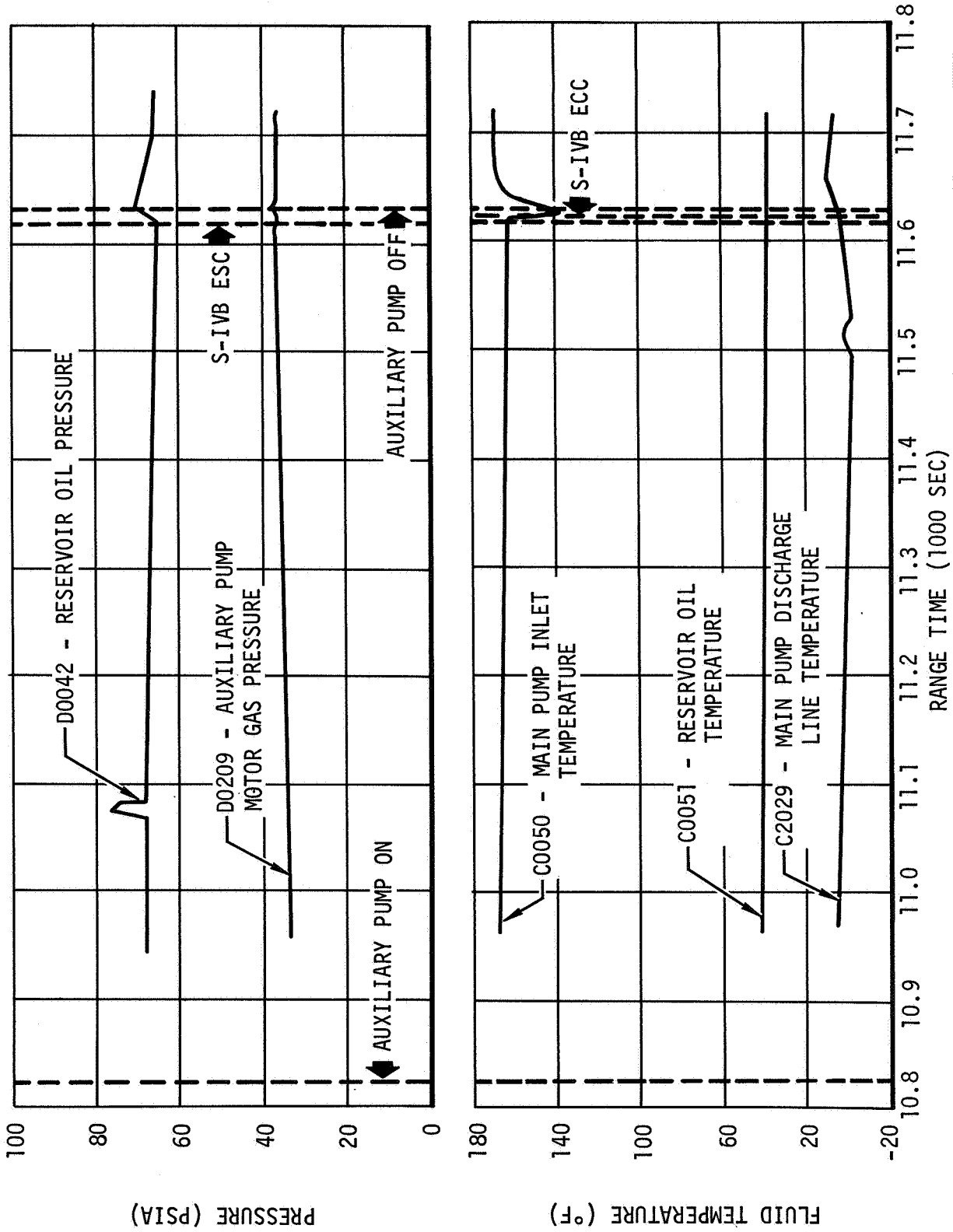


Figure 22-3. Hydraulic System Pressures and Fluid Temperatures - Restart

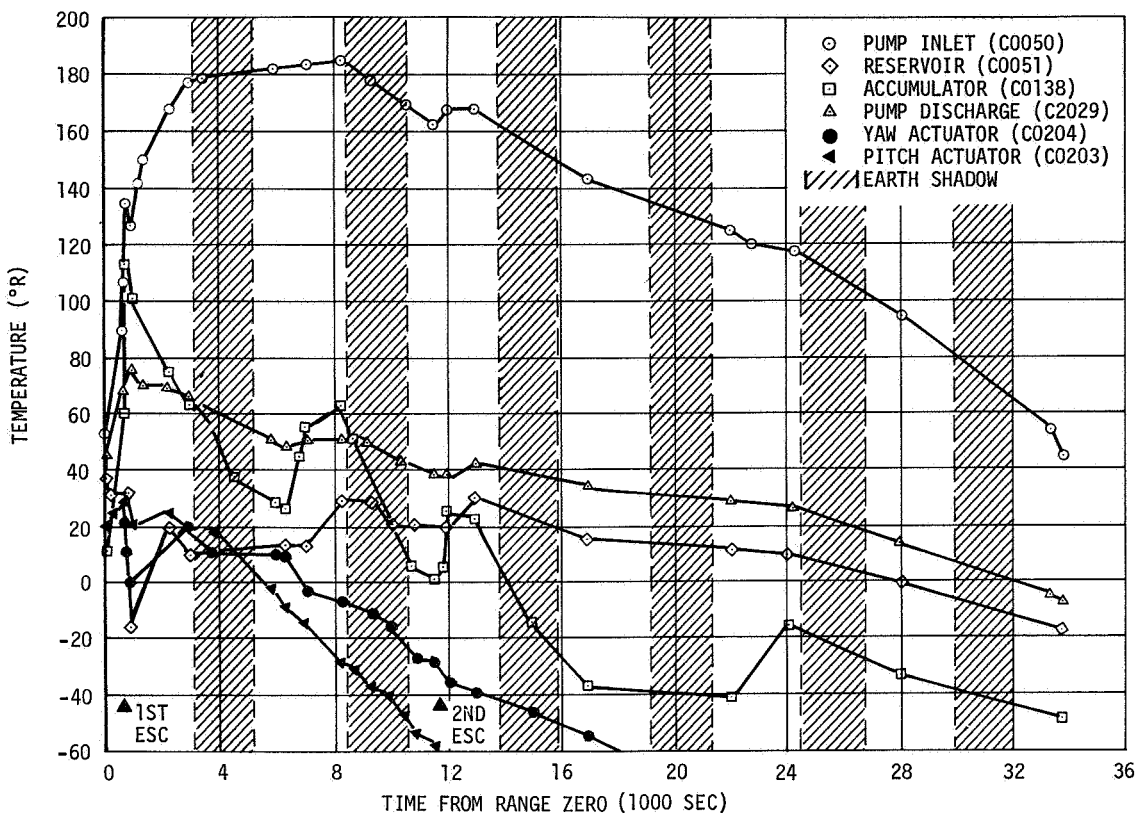


Figure 22-4. Hydraulic System Temperatures - First Burn to End of Data

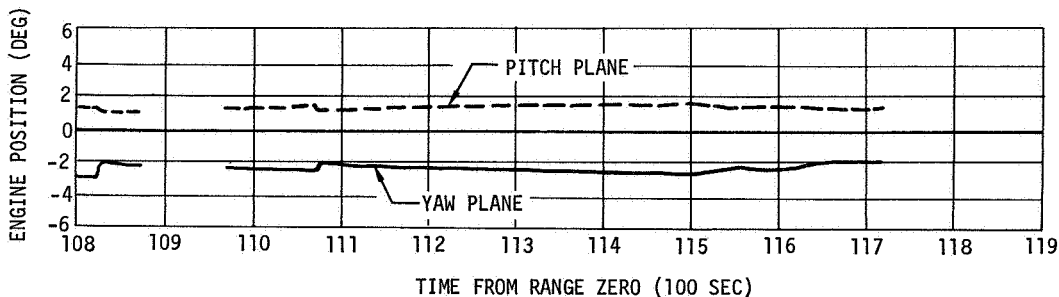
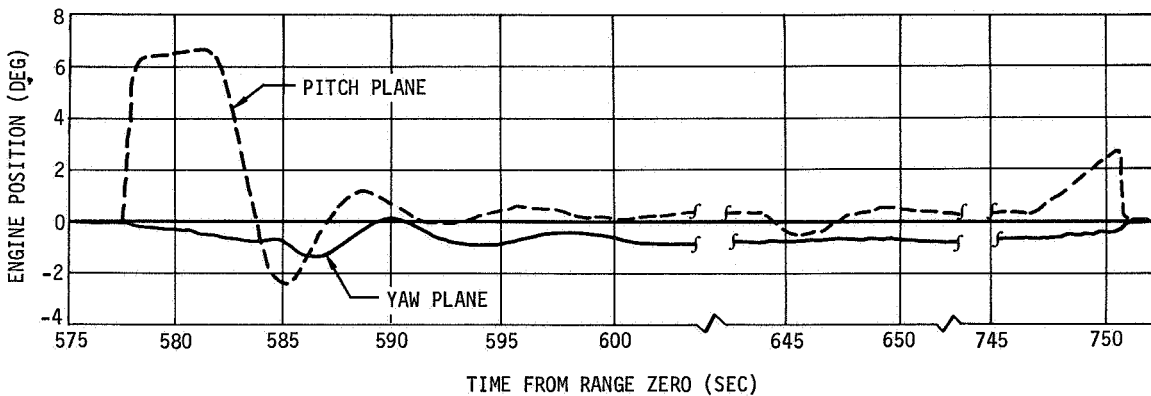


Figure 22-5. Engine Position

23. STAGE STRUCTURE AND ENVIRONMENT

23.1 Flight Load Conditions and Structural Integrity

An evaluation of strain, acceleration, pressure, and temperature data from the S-IVB for the AS-502 trajectory indicated adequate structural strength existed in the stage for the conditions encountered.

The flight environment of the S-IVB deviated from expected conditions in two structurally significant respects. First, during S-IC boost, the AS-502 vehicle and spacecraft experienced relatively severe 5 1/2 cps longitudinal vibrations as reported in section 25. Second, during S-IC boost at RO +133 sec, the S-IVB experienced an unusual load redistribution in the forward skirt as indicated by strain gage measurements at skirt stringers. This load redistribution was evident throughout the remainder of the high axial loads of first stage boost to center engine cutoff (CECO) at RO +144 sec. The combined loads from the load redistribution and the longitudinal vibrations were within the structural capability of the S-IVB forward skirt.

The load distribution to the aft skirt was normal, which indicates the propellant tank structure was effective in uniformly distributing the unusual axial load distributions of the forward skirt to the aft skirt.

The flight test data indicate that the sudden change in axial load distribution through the S-IVB forward skirt at RO +133 sec resulted from changes in structure located above the forward skirt. The character of these structural changes and their causes were investigated by an engineering task group at NASA Manned Spacecraft Center, Houston, Texas. The results of that investigation are to be published in a NASA/MSC report entitled, Anomaly Report No. 6 - Unexpected Structural Indications During Launch Phase, unpublished as of this writing.

Body bending moments and skin differential pressures were less than the maximum predicted values due to comparatively moderate wind shears and gusts. Vehicle axial accelerations were close to predicted values which verified the computed preflight axial loads for the S-IVB, except for the structurally noncritical anomaly of two S-II engines cutting out prematurely at about RO +414 sec. Axial loads computed from flight strain gage aft skirt data are in agreement with preflight computed axial loads from liftoff to approximately RO +60 sec. Beyond this flight time, the axial loads computed from stringer strain gage data appeared to be low apparently due to thermal effects on the structure from aerodynamic heating and to an approximate integration resulting from the limited number of instrumented stringers.

Recorded maximum temperatures of the S-IVB structure subjected to aerodynamic heating indicated the flight temperatures did not exceed maximum predicted temperatures.

The LH2 and LOX tank ullage pressures did not exceed corresponding design ullage pressures. The differential tankage pressures acting on the common bulkhead were as expected. The internal pressure of the common bulkhead remained substantially constant at less than 1 psia as predicted.

23.1.1 Body Strains and Stringer Loads

Thirty-two axial strain gages were installed on external hat stringers of the S-IVB. The gages were located at vehicle sta 3145 of the forward skirt and sta 2821 of the aft skirt. Eight measurement locations at each station were approximately equally spaced around the circumference. Two strain gages were installed at each measurement location, of which one gage was mounted to the side of the stringer near the neutral axis, and the other to the top of the stringer. The dual stringer strain gage installation permitted the evaluation of strains at the stringer neutral axis and hence more accurate calculations of stringer axial loads and body bending moments. The dual gage installations also provided data from which stringer internal bending moments could be evaluated. All strain gages were temperature compensated.

The recorded data from the strain gages were determined to be valid by the S-IVB-502 Data Qualification Review Board. These data were reviewed thoroughly and in detail and no electrical anomalies were detected. In particular, the unusual strain changes which occurred at R0 +133 sec and which remained through CECO at approximately R0 +144 sec were found to be valid by the Review Board. An analytical calculation at S-II engine ignition indicated that measured thrust computed from S-IVB strain measurements and predicted thrust were within 3 percent, and that the strain gages at that later time were performing normally.

The strain histories for the 16 gages on the aft skirt are presented in figure 23-1, and those for the 16 gages on the forward skirt are shown in figure 23-2. At R0 -10 sec all measured strains have been adjusted to the computed correct strain corresponding to the 1 g axial load condition. This adjustment was necessary since the initial strain readings had drifted considerably due to the combined effects of added payload and propellant weights, propellant cryogenic temperatures, and ullage pressurizations. The adjustment to each measured strain at liftoff was applied uniformly to the corresponding measured strain trace throughout flight, so that measured strain increments during flight were not affected. The increments of strain on the S-IVB due to bending moments from ground winds were computed and found to be relatively small. Ground wind strains have been neglected in the adjustments to corrected strains at liftoff.

The maximum and minimum strain envelopes shown in figures 23-1 and 23-2 were calculated from design conditions and include the effects of maximum expected aerodynamic gusts and wind shears. The envelope also includes the tolerances of ± 7 percent for the telemetry system and ± 3 percent for predicted engine thrust. The predicted strains for the top mounted gages were computed using coefficients obtained from the AS-501 vehicle calibration conducted 19 April 1967.

The stringer side mounted gages on the aft skirt (figure 23-1) provided strain histories substantially as predicted except at times approaching CECO and outboard engines cutoff (OECO). At these flight times, airloads should be nearly non-existent and body bending negligible. Hence, the side gage strain traces ideally would converge approximately to

a common value at OECO. The non-convergence of the measured strains after RO +80 sec is apparently due in part to differential structural expansion or contraction from aerodynamic heating. However, the heating did not significantly affect the evaluation of flight body bending moments which peaked at approximately RO +68 sec. Also, the aerodynamic heating influence was minimized in the evaluation of maximum axial loads at CECO by using differential strains referenced to zero thrust strains at S-IC separation.

The stringer top mounted gages on the aft skirt (figure 23-1) provided strain data having less convergence at OECO than in the side gage data. The top gages were displaced from the stringer neutral axis and were sensitive to local stringer bending. These data were useful in analyzing the stringers for local bending. The strains from the top gages, like those from the side gages, were less than the maximum design strains shown in the figures. It is to be noted that the aft skirt strain traces indicate no unusual strain changes at RO +133 sec, such as subsequently will be discussed for the forward skirt. It appears that the propellant tankage structure distributed axial loads from the forward skirt uniformly to the aft skirt.

Figure 23-3 illustrates the effect of aerodynamic heating on stringer strains. The strain data from gages No. 70 and No. 74 have been plotted to show typical trends for side mounted gages, and the broken line curves show the traces adjusted to remove temperature effects. The adjustments result from the assumption that without aerodynamic heating, the measured strain traces would ideally decrease to zero strain (zero thrust) at S-IC separation (RO +148 sec). However, the actual measured strain traces, after correction to the 1 g condition, did not decrease to zero strains at RO +148 sec and the residual strains were assumed to be measurements of thermally induced strains. Residual compressive strains at RO +148 sec were subtracted from measured strains at CECO (RO +144 sec) to show flight strains independently of temperature effects. Similarly, residual tension strains were additive to show flight strains without internal temperature effects. These adjustments were assumed constant from CECO (RO +144 sec) back to RO +120 sec, and to decrease linearly to zero strain adjustment at RO +60 sec. This strain adjustment distribution corresponds with the aerodynamic heating which began at approximately RO +60 sec and stabilized at higher temperatures near RO +120 sec. These adjustments to remove temperature effects were applied to all side gage strain data to allow more accurate calculations of body bending moments and stage axial loads. However, thermally induced strains were reacted internally by the structure, and hence these increments of strain were included in detailed stringer stress analyses.

The strain histories (figure 23-2) for the 16 forward skirt strain gages indicate greater aerodynamic heating effects than occurred in the aft skirt. It is also seen that a number of strain measurements experienced load shifts at RO +133 sec, and that these shifts were retained throughout the remainder of S-IC powered flight. These strain shifts at RO +133 sec are summarized in the polar bar chart of figure 23-4. In the chart, negative values indicate increases in compression and positive values indicate decreases in

Section 23
Stage Structure and Environment

compression. Figure 23-4 includes identification of gage or measurement numbers, skirt stringer numbers, vehicle position numbers (I through IV), and values of strain changes in micro inches per inch. The strain shift at the side gage of stringer No. 81 was 0.00115 in./in. which corresponds to an increase of the stringer axial compression load of approximately 4,800 lbf. Stringers No. 95 and No. 27 experienced much smaller increases in compression. Stringers No. 14, 27, 54, 81, 95 and 108 experienced relatively small changes in strain at the top mounted gages. These gages reflected the combined effects of axial loads, local stringer bending, and shifts of the locations of the applied axial stringer loads. Changes in readings of the stringer top mounted gages and side mounted gages could result from changes in stiffnesses or load paths of structure above the S-IVB forward skirt.

The sudden change in stringer axial loads is further illustrated by figure 23-5 which shows polar plots at RO +132 sec compared to RO +134 sec for the S-IVB-502 forward skirt. The large change is evident at stringer No. 81. For purposes of comparison, a similar plot is shown for the S-IVB-501 forward skirt at RO +135.5 sec. Only the S-IVB-502 plots have been adjusted to represent the total axial load.

The strain changes at RO +133 sec in the S-IVB forward skirt stringers appear to be due to a change in load path through the skirt apparently caused by a load path shift in structure above the skirt. This conclusion resulted after it was determined that the gross loads on the vehicle were normal, that the temperatures of the forward skirt were normal, and that the forward skirt stringer strain gage data were valid throughout powered flight. The indicated load change in stringer No. 81 from strain measurements was 4,800 lbf at the g loading of RO +133 sec, or about 1,200 lbf when related to a 1 g weight condition. Assuming several stringers adjacent to stringer No. 81 were also affected, then the total load change may have been of the order of approximately 2,500 lb or more related to the 1 g condition. The largest single weight in the S-IVB forward skirt was 100 lb and the largest in the instrument unit (IU) was approximately 150 lb. In contrast, the LM weighed 26,000 lb and the weight above the service lunar adapter panels was 64,000 lb. Hence, the large load change in the load path at stringer No. 81 evidently resulted from load redistribution from the large weights above the forward skirt rather than from any failure of supports for the relatively small weights in the skirt. A detailed postflight stress analysis of the forward skirt using measured strains throughout flight indicated that there was no stringer buckling and that positive margins of safety existed for the skirt. The strain gage data showed increasing compressive stringer loads with increasing axial load factors after the anomaly at RO +133 sec thereby providing supporting evidence that skirt stringer buckling did not occur. Thus, it appears evident that the forward skirt structural integrity was maintained and that a change in load path originated in structure above the S-IVB stage forward skirt.

The strain changes at RO +133 sec involved eight strain gages. However, at RO +107 sec there was an indication of a similar sudden shift of increased compressive strain from the

single measurement of side gage No. 66 at stringer No. 95. This strain shift is shown in figure 23-2. This single strain shift may have been the result of a preliminary change in structure above the S-IVB forward skirt preceding the more pronounced structural changes at RO +133 sec. Further details of the anomalies, including considerations of the structure above the forward skirt, are presented in the Anomaly Report No. 6 referenced in paragraph 23.1.

The local stringer bending moments and axial loads for the aft and forward skirts at respective strain measurement sta 2821 and 3145 are shown in table 23-1. The table compares the maximum flight loads derived from strain gage data to the corresponding stringer local design loads. For the aft skirt, the critical maximum αq condition design loads were not exceeded, and including temperature effects a positive margin of safety existed. The forward skirt flight moments and axial loads calculated from measured strains exceeded design values. The results of the corresponding postflight stress analysis are presented in table 23-2. Stringer No. 95 was critical and the corresponding minimum margin of safety was +97 percent.

23.1.2 Axial Loads

The strain data measured for sta 2821 and 3145 during flight were used for computing axial load histories as presented in figures 23-6 and 23-7. The measured strain data were converted to stringer neutral axis strains, and adjusted to remove the internal strains induced by differential expansions and contractions from aerodynamic heating. From these adjusted data, the axial flight loads at the respective stations were computed. These axial load histories are shown compared to preflight computed axial loads. The divergence of the flight measured plots above RO +60 to RO +80 sec is attributed to thermal effects on the structure from aerodynamic heating and to the limited number of instrumented stringers which prevents a full integration of stringer loads.

Axial load factors measured during powered flight are presented in table 23-3. The maximum acceleration of 4.78 g occurred at S-IC CECO. This was slightly higher than the 4.73 g predicted value, and greater than the design limit axial load factor of 4.68 g at CECO as expected. Detailed stress analysis, including the effects of S-IVB flight measured temperatures, indicated positive margins of safety for the 4.78 g axial load condition.

23.1.3 Body Bending Moments

The strain data measured during flight was also used in computing bending moment histories, as shown in figure 23-8 for the aft skirt and figure 23-9 for the forward skirt. In each case, the measured strain data at three stringer locations was converted to stringer neutral axis strains, and adjusted to remove internal strains induced by aerodynamic heating. From these adjusted data, the maximum bending moments at the respective stations from flight loads were computed. In the figures, the computed flight moment histories are shown compared to preflight computed design limit moments. The design curve is a partial

envelope covering the time of maximum αq and showing the total effect of discrete wind shears and gusts occurring at each time point. The curves show the S-IVB was subjected to relatively moderate aerodynamic loading as compared to maximum design values.

During S-II powered flight, two adjacent outboard engines cut out inadvertently at about RO +414 sec (reference figure 8-6). The bending moment at sta 2821 of the aft skirt was computed using flight measured strains. The resulting moment was 9,600,000 in.-lb which was only about one-sixth of the limit design maximum bending moment, indicating ample margin of safety for the S-IVB with this anomalous condition.

23.1.4 Pressures - Skirts and Interstage

For the forward skirt of the S-IVB, no pressure measurements were taken because of confidence in prediction methods gained from S-IVB/IB flight test experience.

For the aft skirt and interstage, the maximum calculated bursting pressure during flight, based on pressure sensor measurements was 2.9 psid at RO +75 sec. This was less than the maximum limit design bursting pressure of 3.9 psid at RO +73 sec. The peak flight measured differential crushing pressure was -0.80 psid at RO +60 sec, which compares favorably to the maximum limit design crushing pressure of -1.66 psid at RO +58 sec.

23.1.5 Temperatures

A summary of maximum measured temperatures for the major structural assemblies subject to aerodynamic heating is given in table 23-4. The temperatures are shown separately for stringers and skin. Predicted maximum temperatures based on the maximum heating trajectory are also shown. A comparison of values shows flight temperatures did not exceed maximum predicted temperatures. This supports other evidence that S-IVB structural integrity was maintained.

23.1.6 LH2 and LOX Tank Ullage Pressures

The maximum LH2 ullage pressure recorded during prelaunch and through powered flight to S-IVB first burn engine cutoff was 37.0 psia. Subsequent ullage pressures during orbital coast reached a maximum of 34.0 psia. These values compare favorably with the limit design ullage pressure of 37.0 psia for the LH2 tank.

The limit design ullage pressure for the LOX tank is 44 psia, and the maximum ullage pressure recorded during prelaunch and powered flight through first burn was 43.0 psia. The maximum LOX tank ullage pressure recorded during orbital coast was 42.0 psia.

23.1.7 Common Bulkhead Pressure Environment

The S-IVB-502 ullage differential pressures on the common bulkhead during prelaunch, powered flight, and typical orbital coast are shown in figure 23-10. A positive differential pressure indicates the LOX tank ullage pressure exceeds the LH2 tank ullage pressure. At the apex of the common bulkhead these differential ullage pressures are the pressures across

the bulkhead after allowances for the liquid hydrogen head. Also included in the figures are curves showing the limit structural capability of the common bulkhead, and these limit curves have been calculated to include the liquid hydrogen head effects.

The maximum negative operational pressure during flight occurred due to a temporary decrease in LOX ullage pressure from 41.0 psid to 34.5 psid after S-IVB first burn ignition. The resultant negative differential pressure was -1.0 psid at RO +600 sec (figure 23-10). This applied pressure was well below the limit bulkhead capability of -24.2 psid corresponding to this period of flight.

The largest positive differential pressure occurred during initial pressurization of the LOX tank while the LH2 tank was vented and stabilized at a saturation pressure condition. The pressure obtained was +24.8 psid, and this was expected since the sequencing permits pressurization to the LOX tank vent and relief valve setting of 44 psia while the LH2 tank is unpressurized. The measured maximum positive differential pressure was below the corresponding bulkhead limit structural capability of 30.0 psid.

The ullage differential pressures at all other times were normal and also below the limit structural capability.

Common bulkhead internal vacuum pressure during prelaunch and through powered flight to first burn engine cutoff and through orbital coast did not exceed 0.3 psia. This favorably corresponds to expected values of less than 1.0 psia.

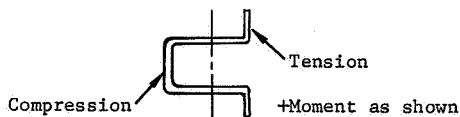
23.2 Explosive Ordnance Equipment

All exploding bridgewire initiated ordnance systems performed as required. The stage separation system, which utilizes a dual mild detonating fuse assembly, functioned on command and effected a complete disconnection of the S-IVB from the S-II. The two ullage rockets and four retrorockets fired, thus accomplishing a normal separation sequence.

Approximately 12 sec after separation, the two ullage rockets and their fairings were jettisoned. This has been verified by telemetry data. The jettison indication was a drop to zero of the chamber pressure transducer potentiometer excitation voltage.

The safety and arming device, an element of the range safety system, was cycled electrically from ARMED to SAFE position several times during terminal countdown and functioned as required.

TABLE 23-1
MAXIMUM LOCAL STRINGER BENDING MOMENTS AND AXIAL LOADS IN AFT AND FORWARD SKIRTS



Axial Load
- Compression
+ Tension

| SKIRT | STATION | CONDITION | MAX. FLIGHT LOAD (CALCULATED FROM TOP AND SIDE STRAIN GAGES) | | LOAD USED IN DESIGN ANALYSIS (LIMIT) | |
|-------|---------|----------------|--|--------------------|--|--------------------|
| | | | MOMENT (in.-lb) | AXIAL LOAD (lb) | MOMENT (in.-lb) | AXIAL LOAD (lb) |
| Aft | 2821 | Max α q | -1,364 | -7,319 | -6,800 | -14,168 |
| | | CECO | -2,611 | -13,047 | -5,700 | -11,756 |
| Fwd | 3145 | Max α q | +118 | -3,065 | +1,857 | -8,287 |
| | | CECO | -1,217 | -6,853 | +1,080 | -4,804 |

TABLE 23-2
FORWARD SKIRT LOCAL STRINGER LOADS AND MINIMUM MARGIN
OF SAFETY AT STA 3145 - CONDITION OF RO +144 SEC

| STRINGER NO. | GAGE* NO. | STRAIN** (micro in./in.) | STRINGER*** MOMENT (in.-lb) | STRINGER AXIAL LOAD (lb) | MINIMUM MARGIN OF SAFETY (percent) |
|-----------------|--------------|-----------------------------|-----------------------------------|-----------------------------------|---|
| 14 | 54 | -1,040 | -184 | -4,437 | -- |
| | 55 | -890 | | | |
| 27 | 56 | -560 | 719 | -3,319 | -- |
| | 57 | -1,210 | | | |
| 41 | 58 | -840 | -50 | -3,695 | -- |
| | 59 | -800 | | | |
| 54 | 60 | -600 | 127 | -2,794 | -- |
| | 61 | -700 | | | |
| 68 | 62 | -1,250 | -800 | -4,813 | -- |
| | 63 | -580 | | | |
| 81 | 64 | -1,810 | -925 | -6,785 | -- |
| | 65 | -1,010 | | | |
| 95 | 66 | -1,890 | -1,217 | -6,853 | +97.0 |
| | 67 | -830 | | | |
| 108 | 68 | -520 | 154 | -2,471 | -- |
| | 69 | -640 | | | |

*Even numbered gages were stringer side mounted, and odd numbered were top mounted.

**Measured strain values were adjusted to 1 g calculated conditions at RO -10 sec.

***Positive moment corresponds to tension in skin.

TABLE 23-3
AXIAL LOAD FACTORS - POWERED FLIGHT

| CONDITION | MAXIMUM MEASURED LOAD FACTOR (g) | FLIGHT TIME OF MEASUREMENT (sec) | PREDICTED LOAD FACTOR (g) | FLIGHT TIME OF PRED. L.F. (g) |
|--------------------|----------------------------------|----------------------------------|---------------------------|-------------------------------|
| S-IC Liftoff | 1.27 | 2.0 | 1.27 | 2.0 |
| *S-IC CECO | 4.78 | 144.7 | 4.73 | 143.4 |
| S-IC OECO | 3.98 | 148.4 | 3.96 | 148.4 |
| S-II ECO (Max g) | 1.58 | 410 | 2.02 | 515 |
| S-IVB (First Burn) | 0.85 | 747 | 0.84 | 660 |

*Condition S-IC CECO design load factor = 4.68 g

TABLE 23-4
MAXIMUM TEMPERATURES OF MAJOR STRUCTURAL ASSEMBLIES
SUBJECT TO AERODYNAMIC HEATING

| STRUCTURAL ASSEMBLY | MEASURED* MAX. TEMP. (deg F) | FLIGHT TIME OF MEASUREMENT (sec) | THERMAL DESIGN TRAJECTORY | | EXTERNALLY** INSULATED STRUCTURE |
|---------------------|------------------------------|----------------------------------|-----------------------------|---------------------------------|----------------------------------|
| | | | MAXIMUM TEMPERATURE (deg F) | FLIGHT TIME OF MAX. TEMP. (sec) | |
| <u>Stringers</u> | | | | | |
| Forward skirt | 220 | 150 | 320 | 150 | No |
| Aft skirt | 140 | 140 | 243 | 150 | Yes |
| Interstage | 191 | 160 | 248 | 150 | Yes |
| <u>Skin</u> | | | | | |
| Forward skirt | 286 | 160 | 389 | 150 | No |
| LH2 tank cyl. wall | 90 | 130 | 159 | 150 | No |
| Aft skirt | 176 | 130 | 258 | 150 | Yes |
| Interstage | 185 | 160 | 265 | 180 | Yes |

*Measured temperatures are adjusted for measurement lag due to mass of temperature sensors.

**At location of temperature sensor.

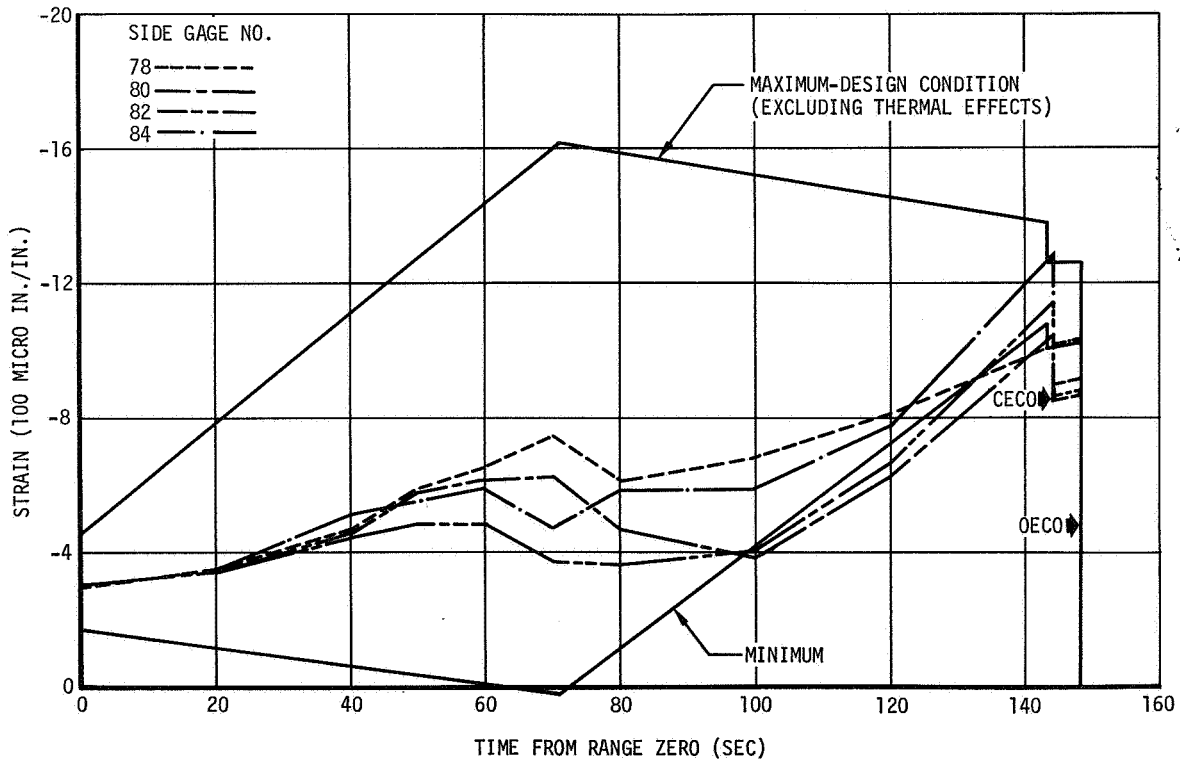
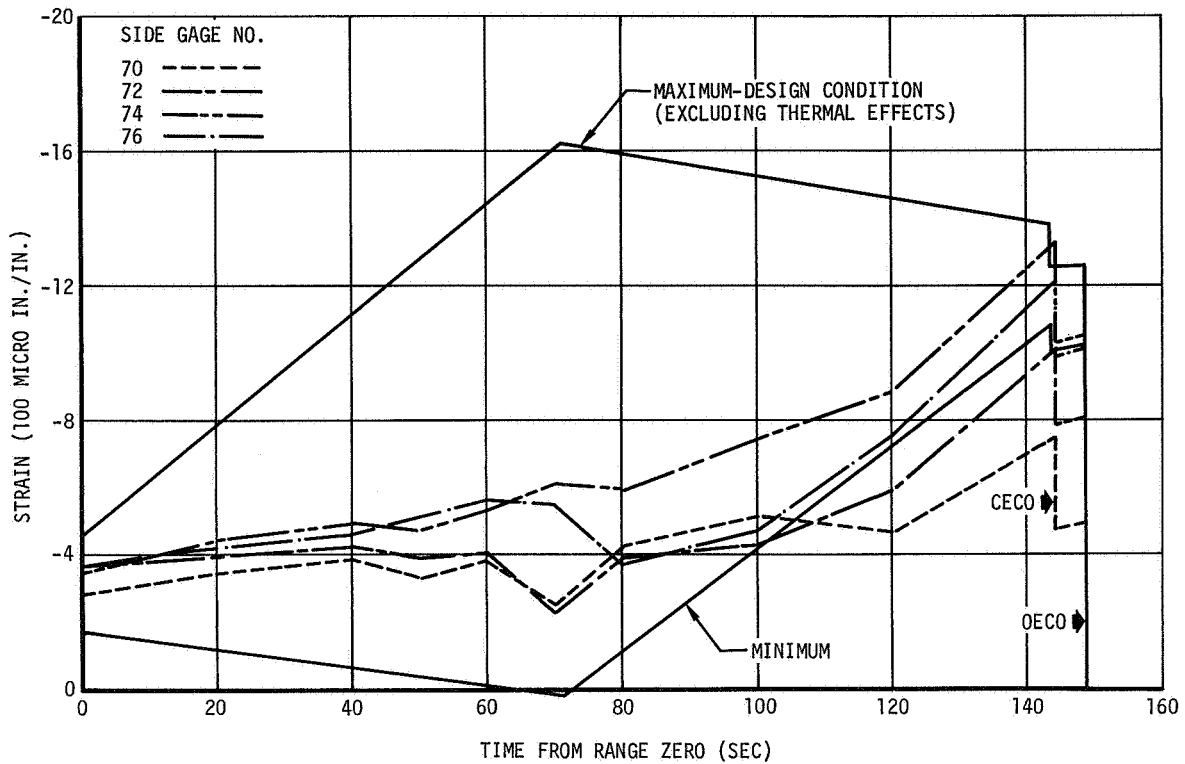


Figure 23-1. Flight Axial Strain vs Flight Time - Aft Skirt Sta 2821 (Sheet 1 of 2)

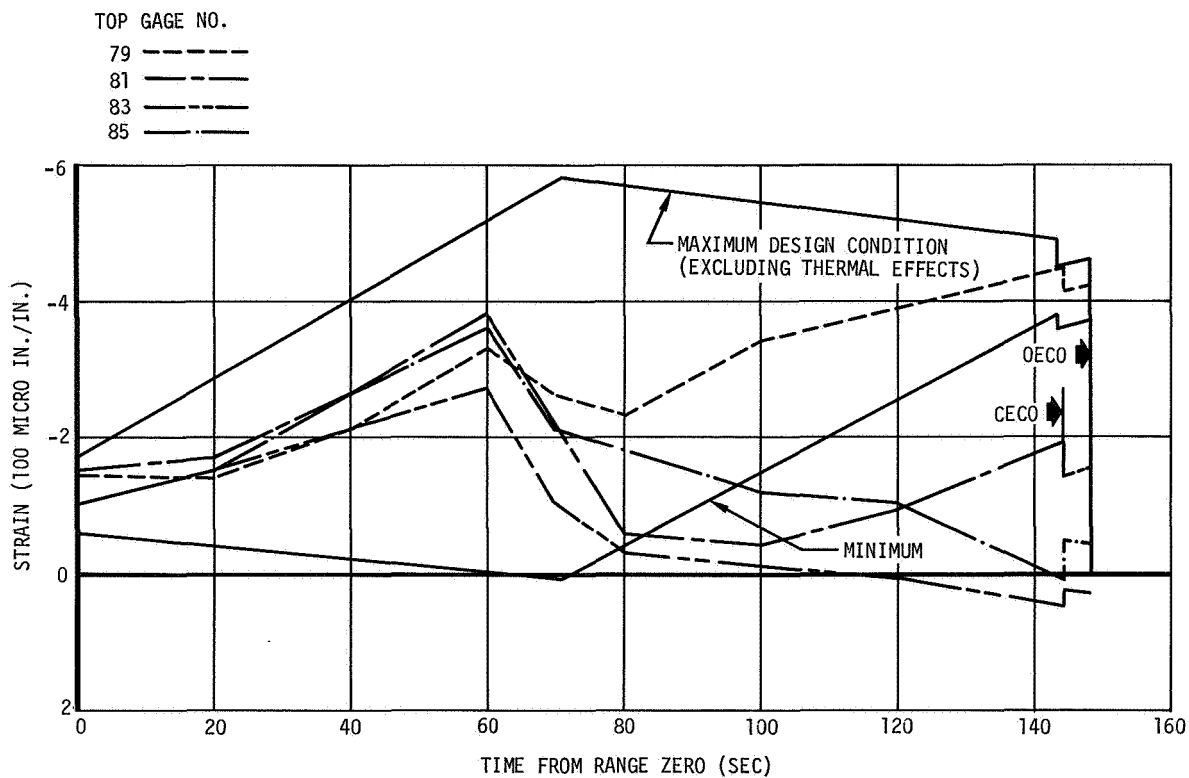
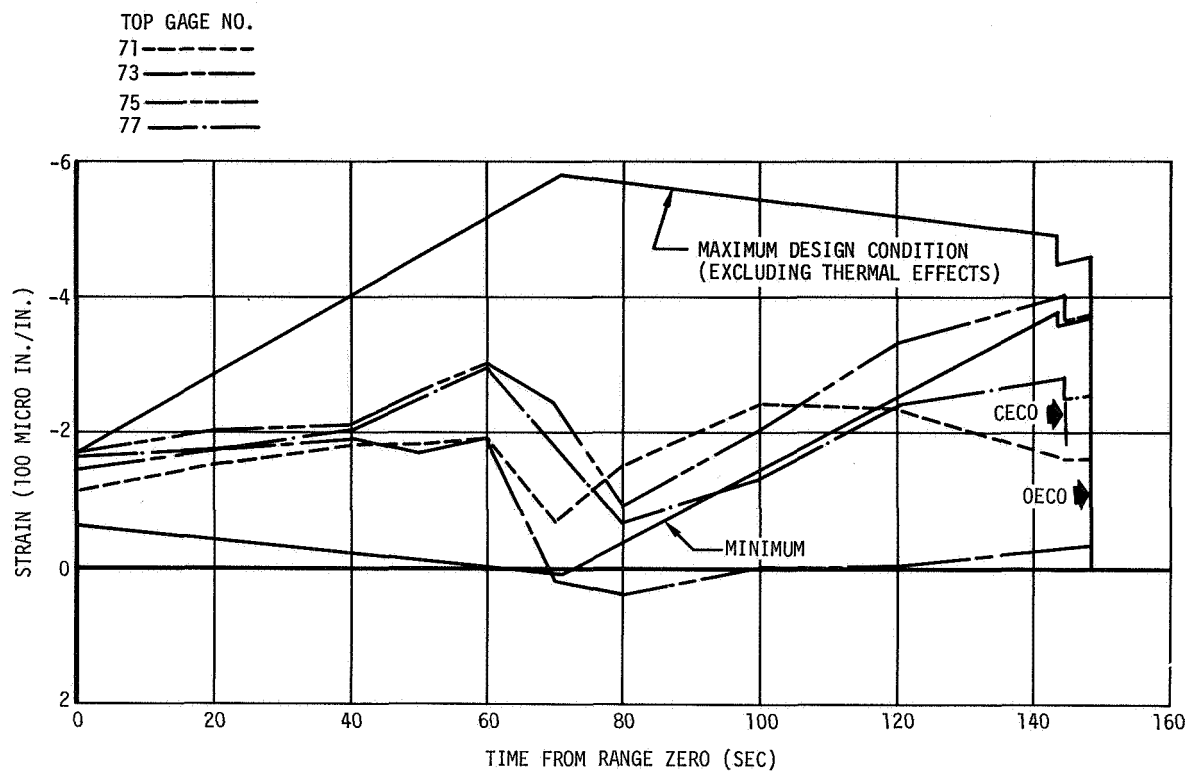


Figure 23-1. Flight Axial Strain vs Flight Time - Aft Skirt Sta 2821 (Sheet 2 of 2)

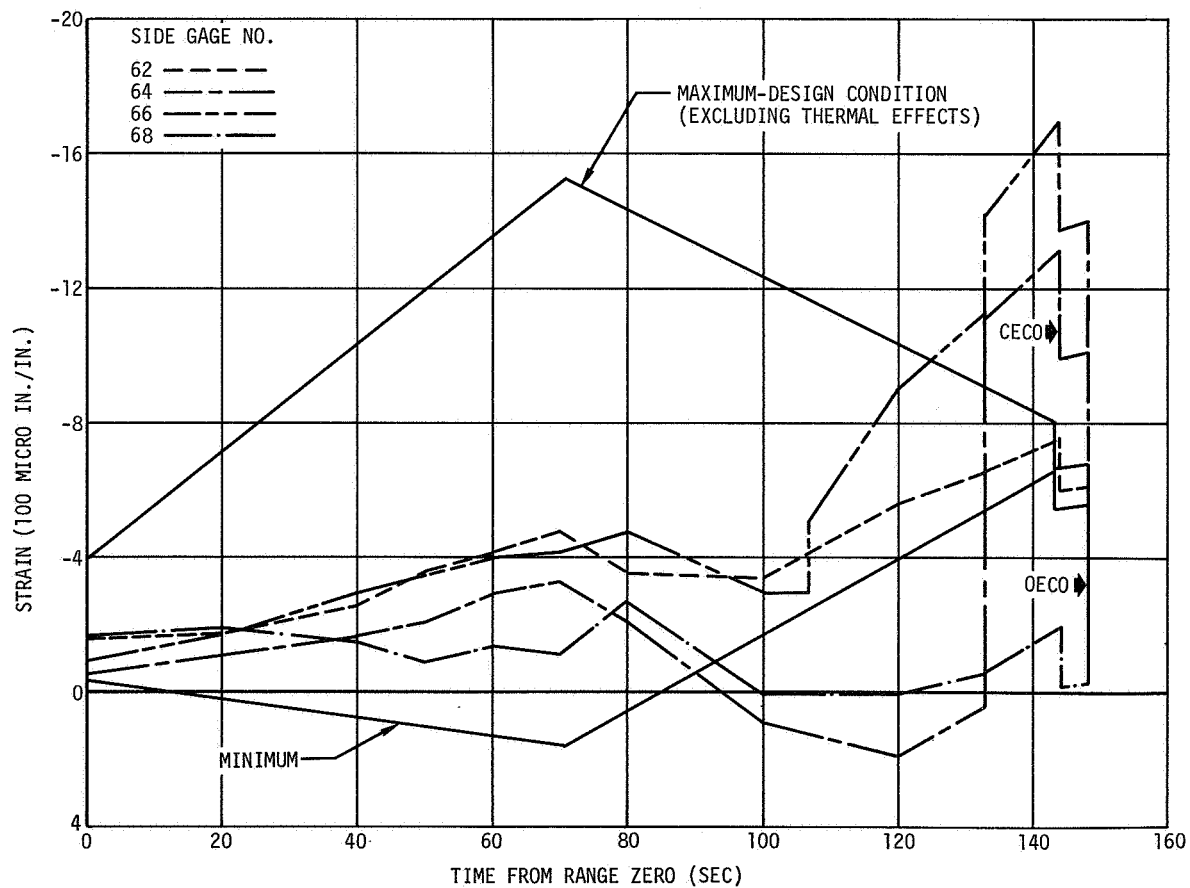
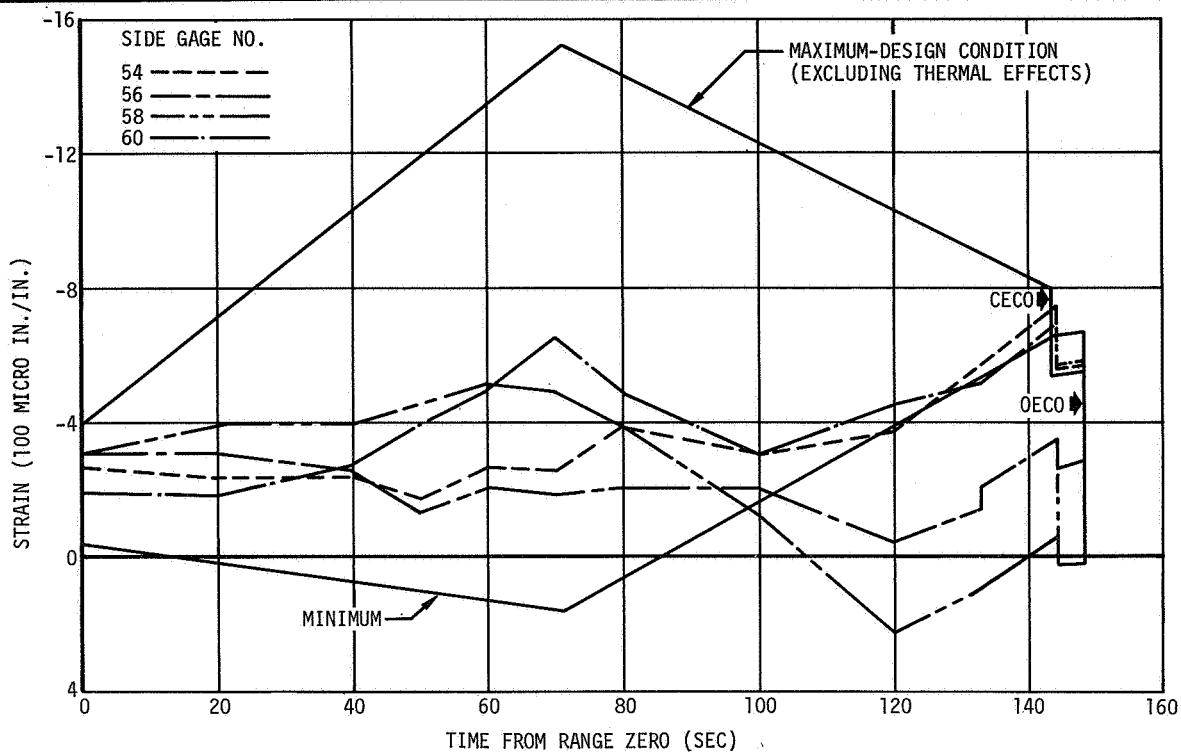


Figure 23-2. Flight Axial Strain vs Flight Time - Forward Skirt Sta 3145 (Sheet 1 of 2)

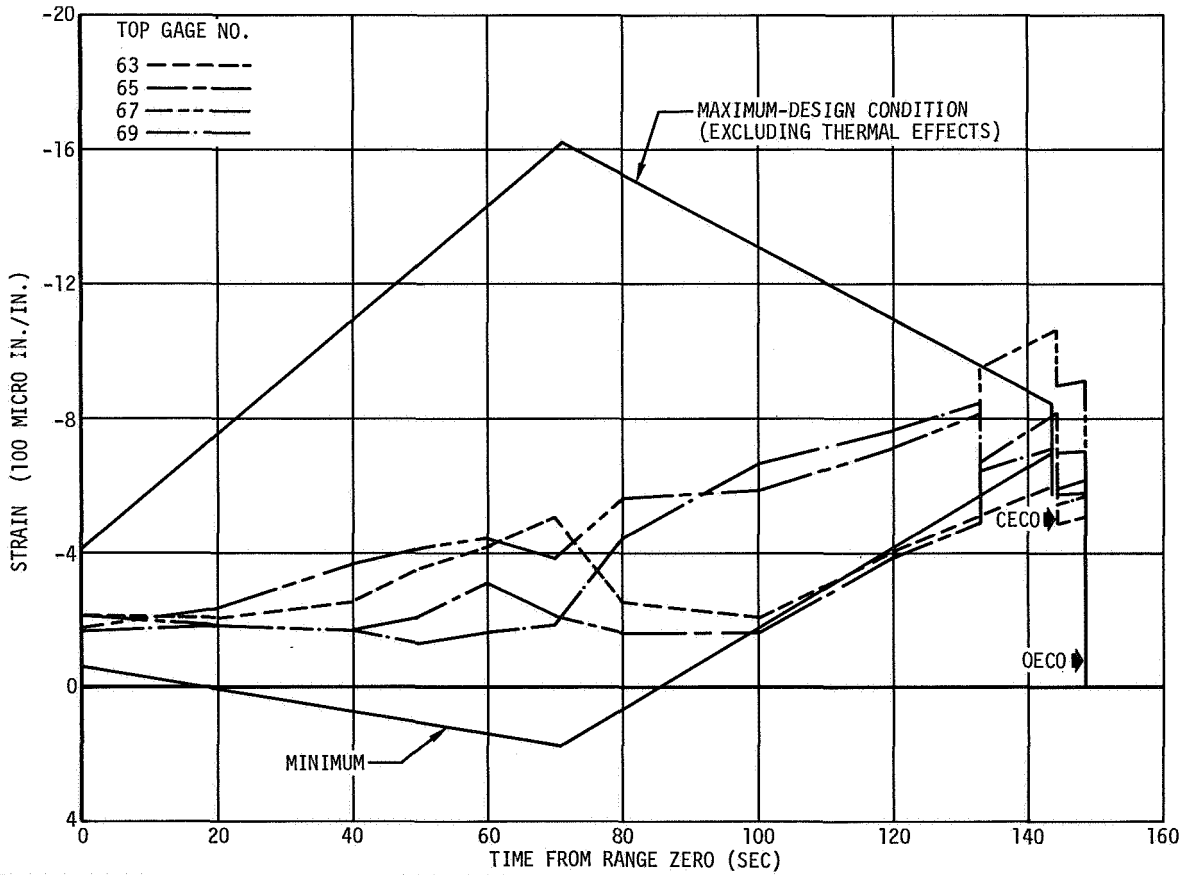
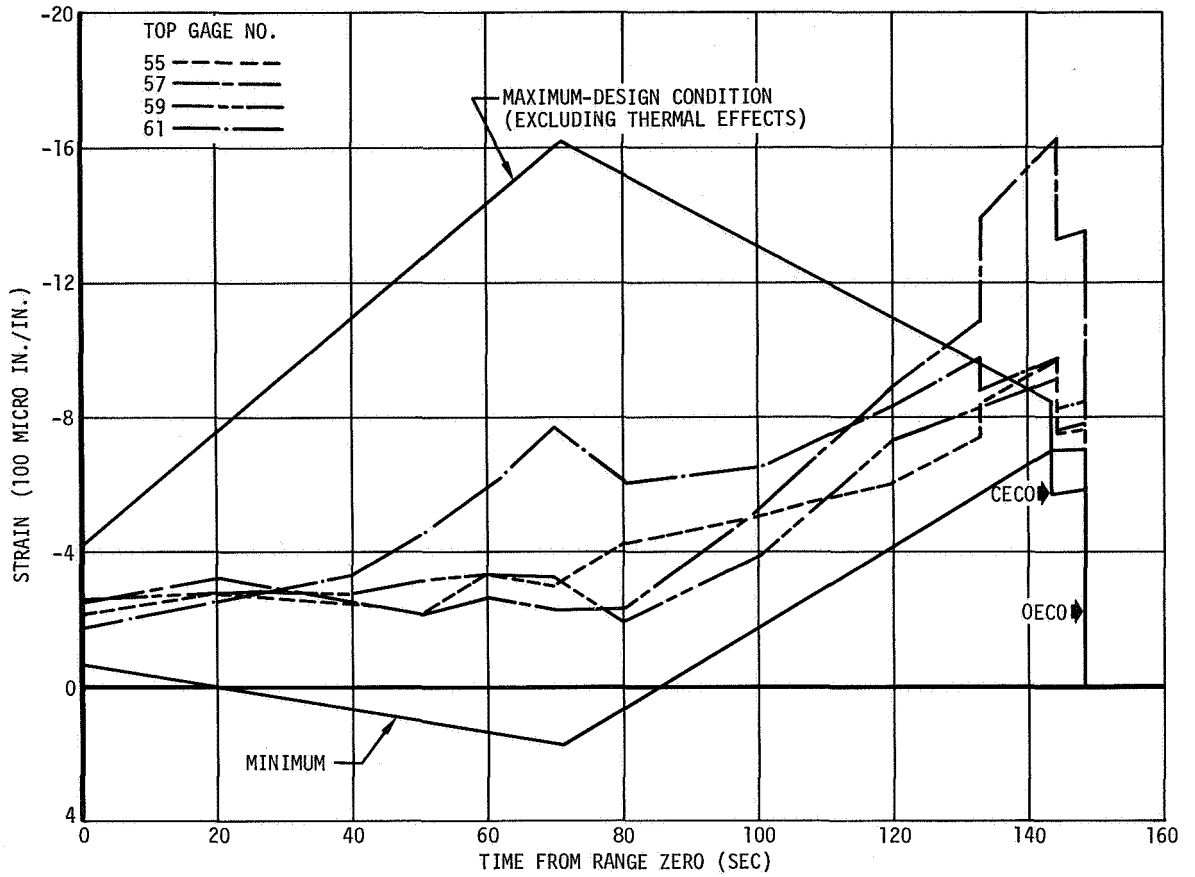


Figure 23-2. Flight Axial Strain vs Flight Time - Forward Skirt Sta 3145 (Sheet 2 of 2)

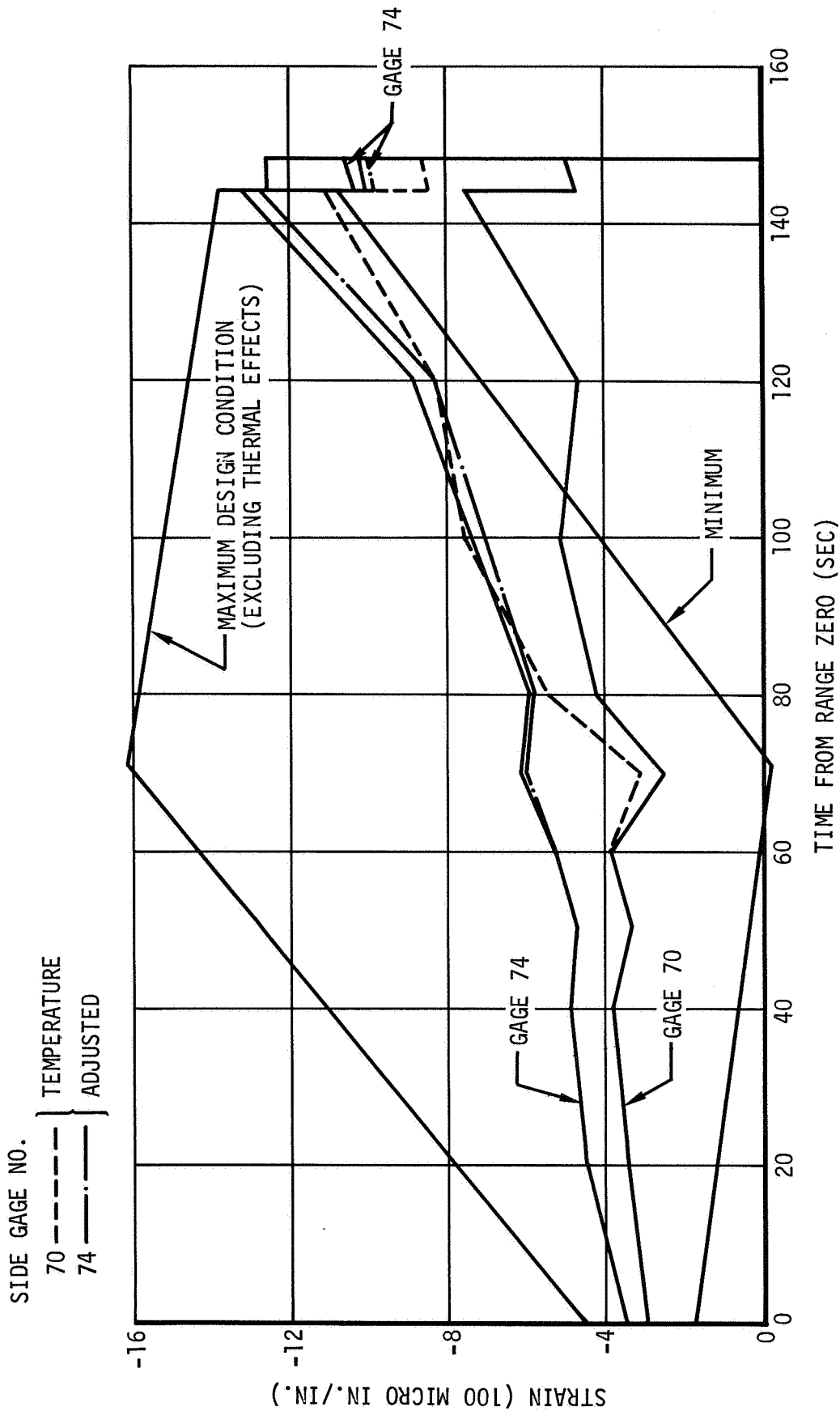
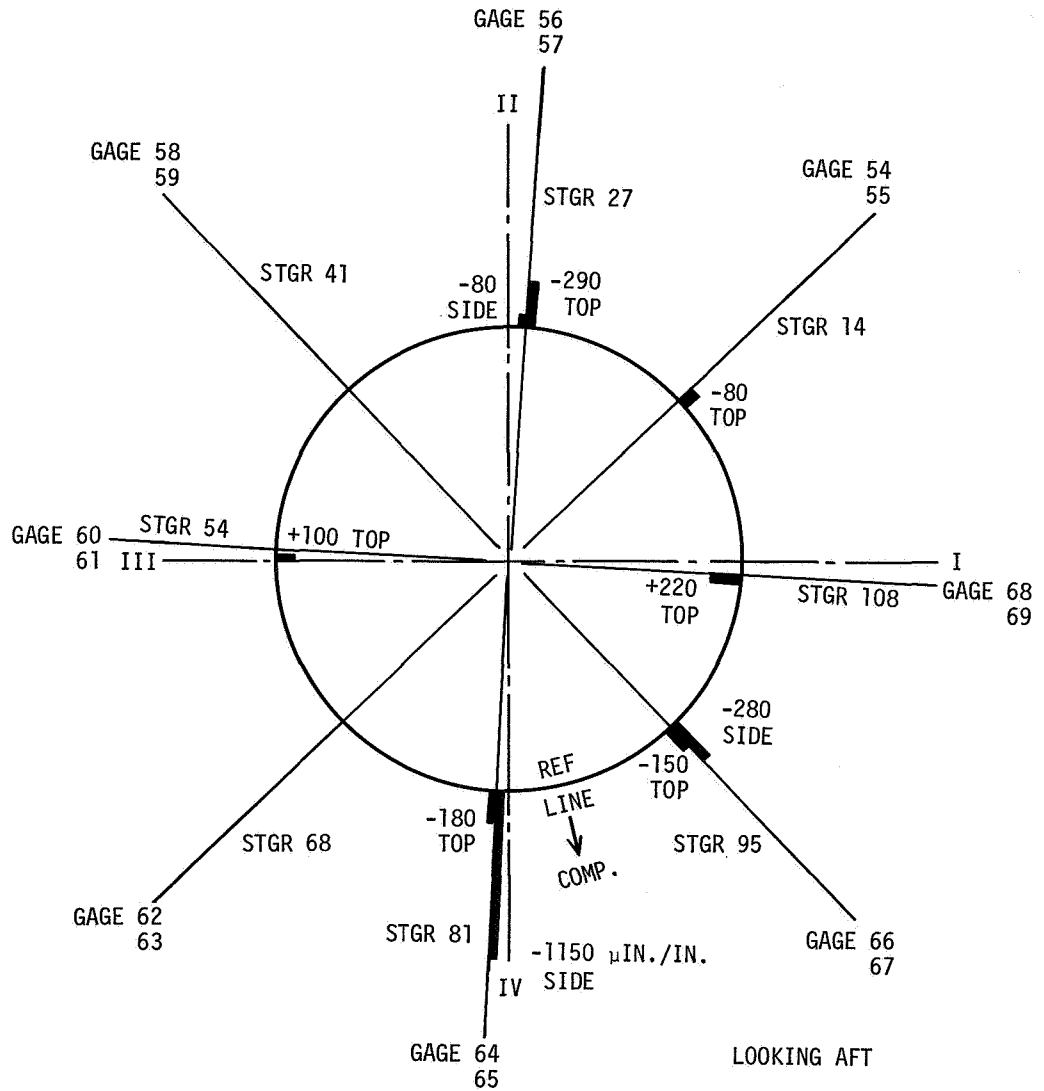


Figure 23-3. Flight Axial Strain vs Flight Time Including Temperature Adjustments - Aft Skirt Sta 2821

BAR CHART SHOWING STRAIN CHANGES AT RO +133 SEC



NOTE: THESE CHANGES HELD UNTIL CECO.
 BAR VALUES ARE STRAIN (MICRO
 INCHES PER IN.). NEGATIVE
 VALUES INDICATE INCREASES IN
 COMPRESSION. POSITIVE VALUES
 INDICATE DECREASES IN COMPRESSION

Figure 23-4. Forward Skirt Strains

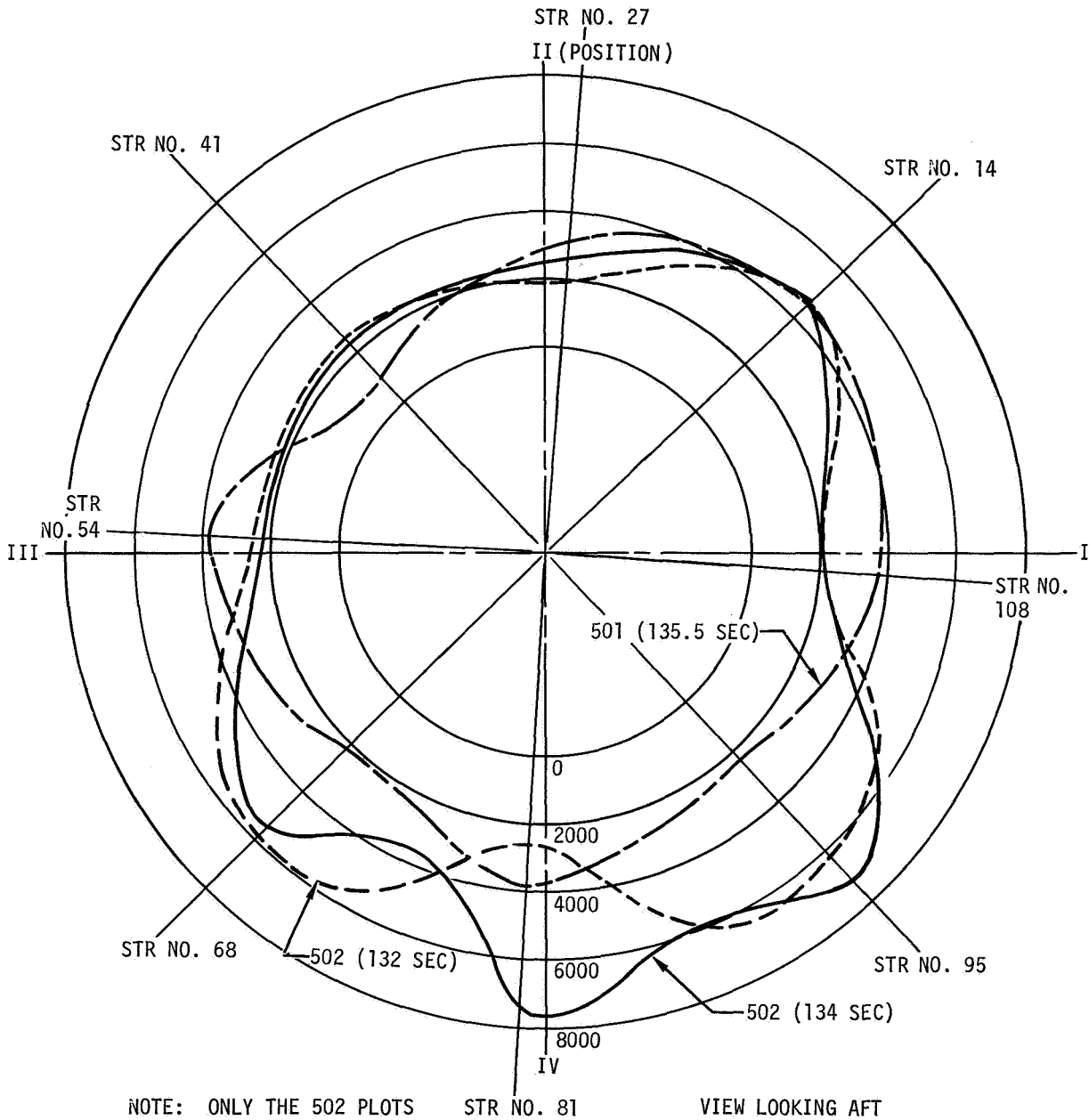


Figure 23-5. Forward Skirt Stringer Load

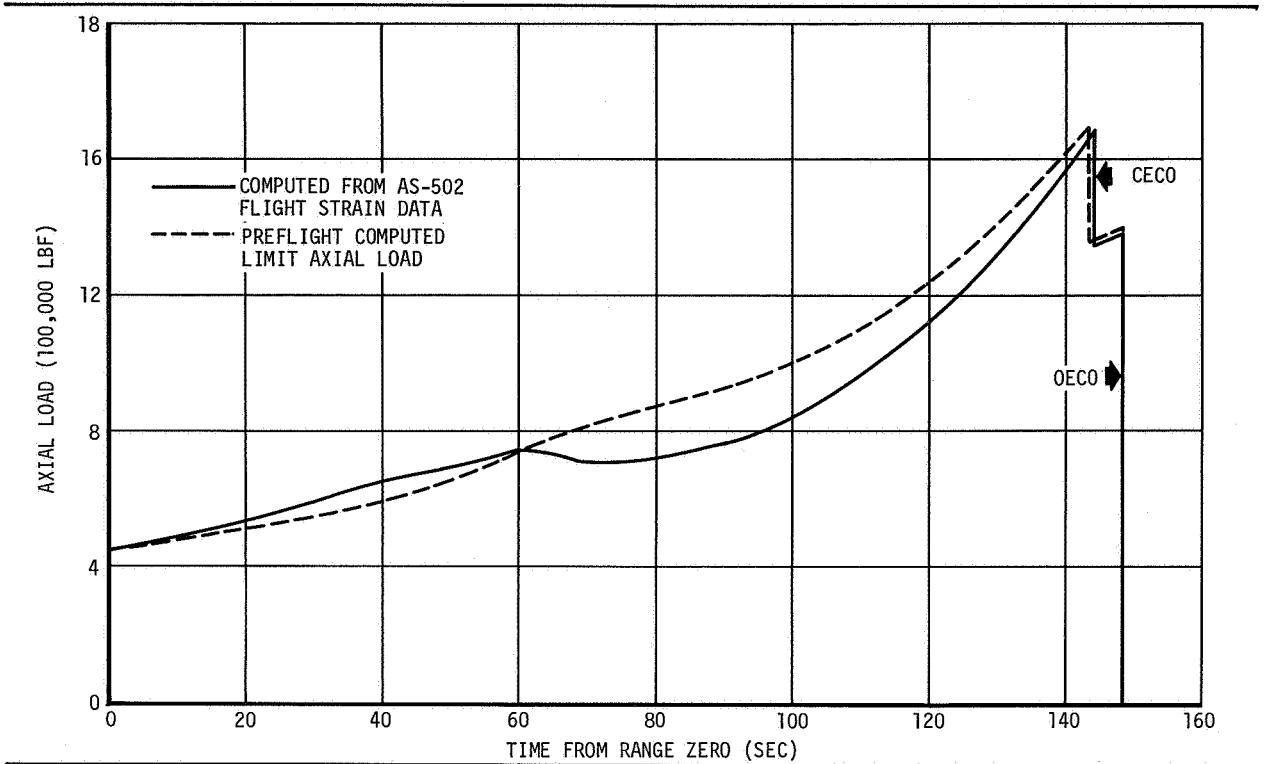


Figure 23-6. Flight Axial Load vs Time - Aft Skirt Sta 2821

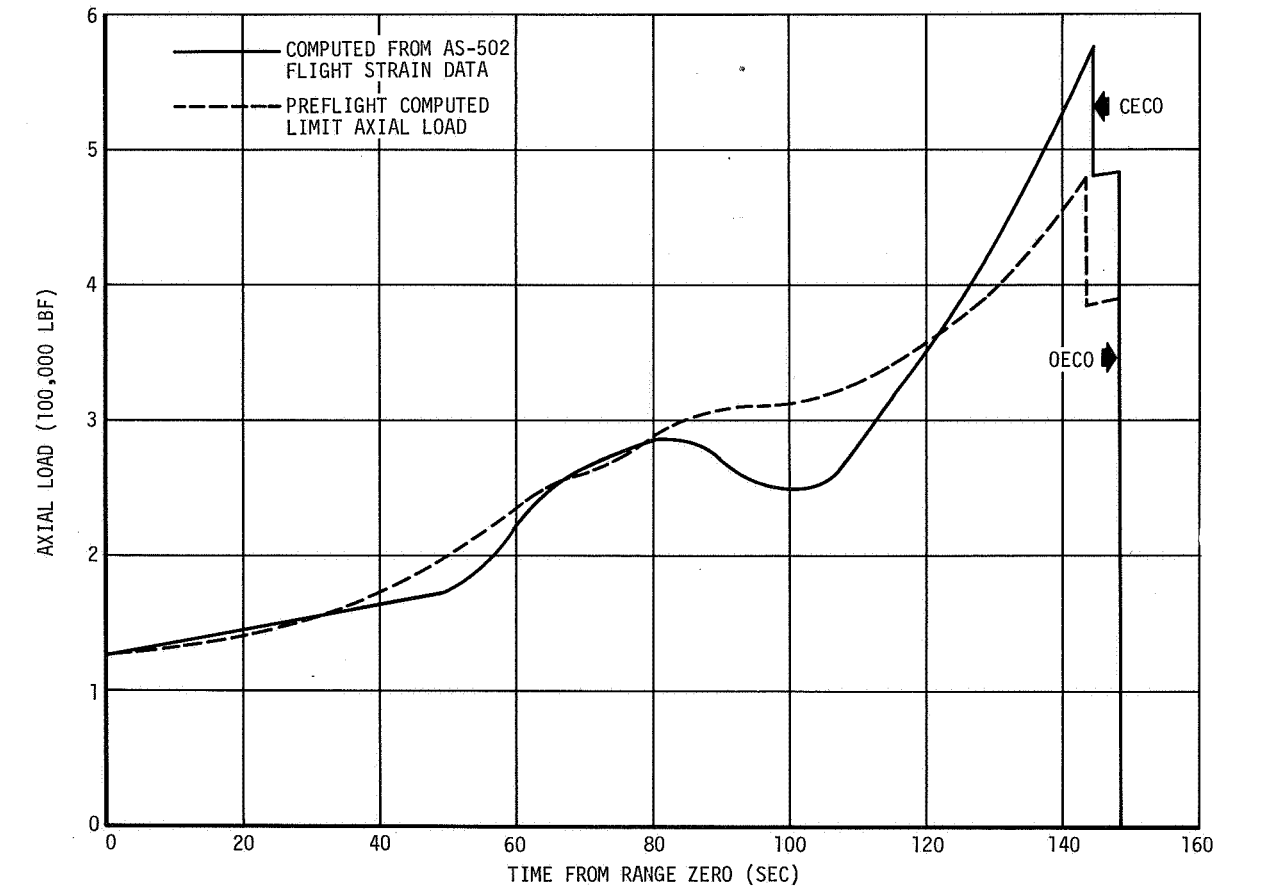


Figure 23-7. Flight Axial Load vs Time - Forward Skirt Sta 3145

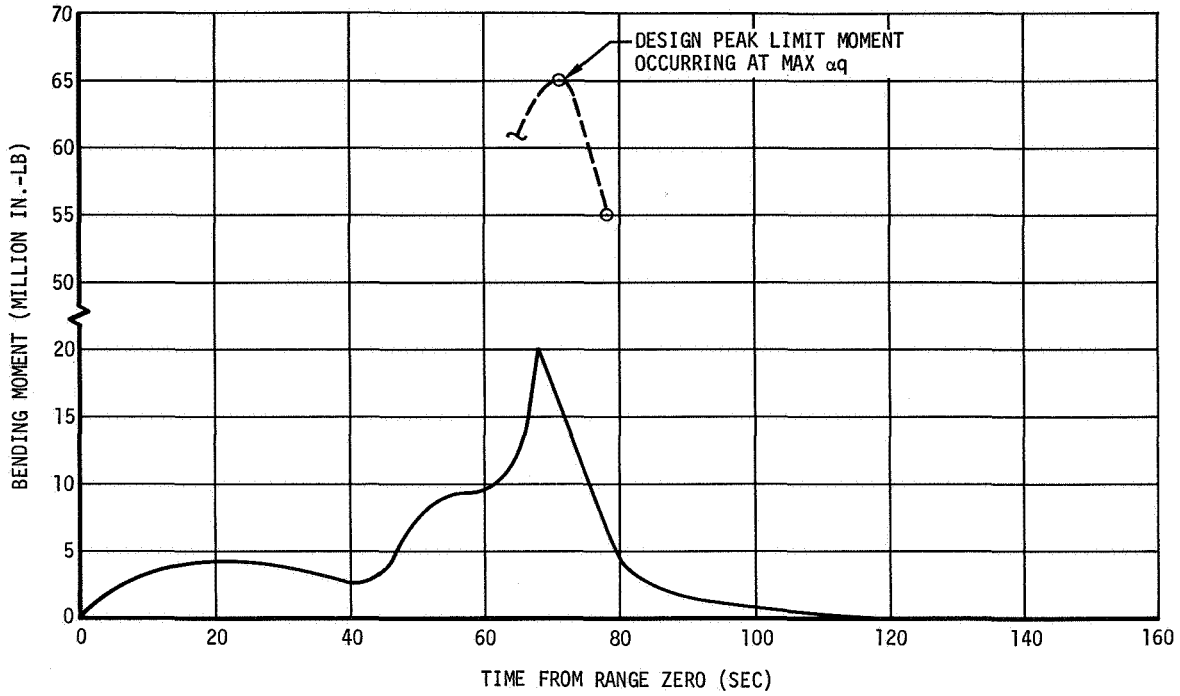


Figure 23-8. Flight Stage Bending Moment vs Time - Aft Skirt Sta 2821

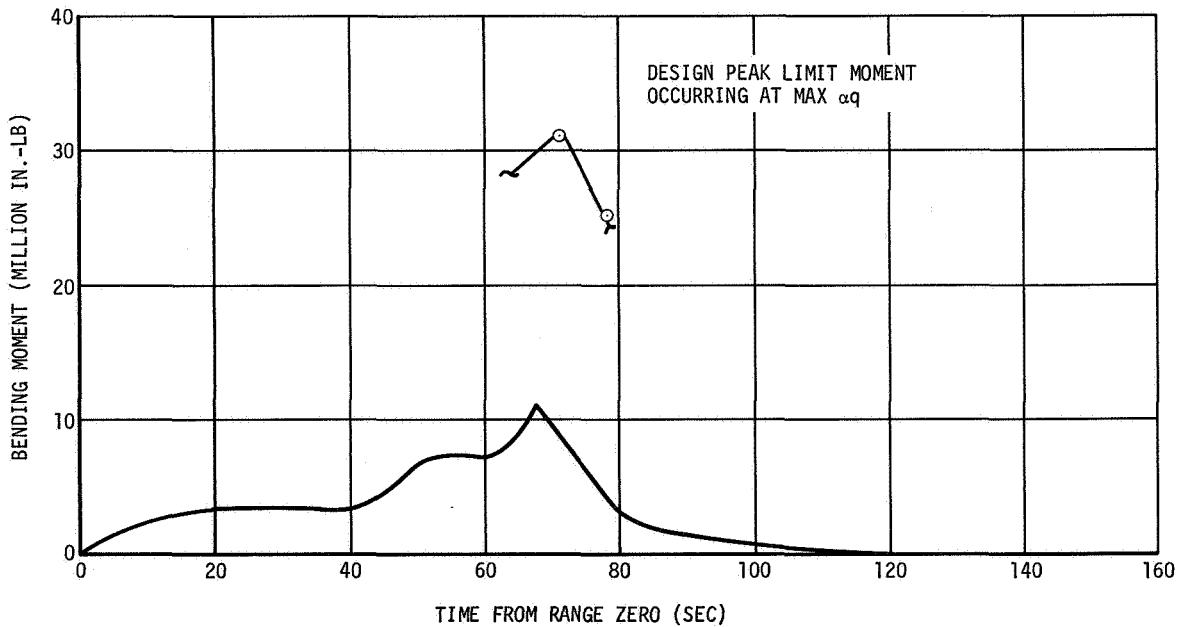


Figure 23-9. Flight Stage Bending Moment vs Time - Forward Skirt Sta 3145

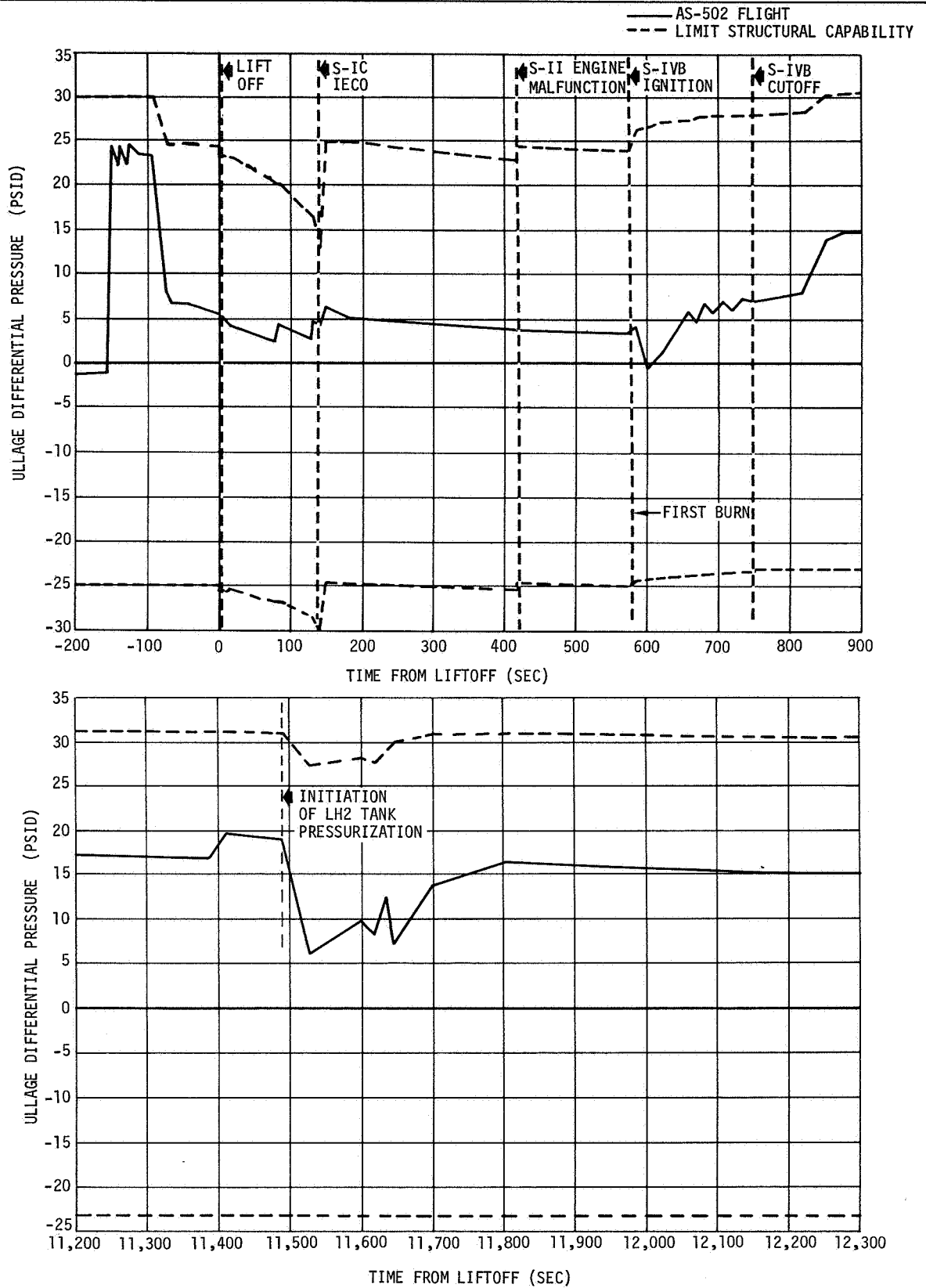


Figure 23-10. Ullage Differential Pressure vs Flight Time

FORWARD SKIRT THERMOCONDITIONING SYSTEM

24. FORWARD SKIRT THERMOCONDITIONING SYSTEM

The thermoconditioning system operated normally during flight. All parameters (temperature, pressure, and flowrate) were within their design limits.

24.1 Temperature

The methanol/water control temperature (C0015-601), which is the inlet temperature for the S-IVB thermoconditioning panel system, was 59.2 deg F at liftoff and increased to 63.5 deg F in 32 sec, decreased to 62.2 deg F by R0 +115 sec, increased to 66.4 deg F at R0 +496 sec, and decreased to 63.5 deg F at the end of first burn (approximately R0 +560 sec). During the remainder of the monitored flight periods, the control temperature varied between a minimum of 53 deg F and a maximum of 66 deg F. This temperature range is entirely within the acceptable inlet temperature range of 45 to 70 deg F.

The exit temperature from the S-IVB thermoconditioning system (C0026-601) was 62.2 deg F at liftoff and decreased to 60.8 deg F after 93 sec and increased to 66.9 deg F at R0 +560 sec. The exit temperature varied between a minimum of 53 deg F and a maximum of 66 deg F for the remainder of the monitored flight periods.

24.2 Pressure

The coolant manifold inlet pressure (D0017-601) was approximately constant at 41.3 psia during the first 560 sec of flight. The inlet pressure varied between 41 and 44 psia from R0 +560 sec until R0 +33,780 sec. These pressure levels are all below the maximum allowable operating pressure of 53 psia.

The coolant manifold exit temperature (D0018-601) increased from 26.8 psia at liftoff to 30.0 psia during the first 148 sec of flight. At 148 sec, there was a pressure drop from 30.0 to 26.8 psia. The pressure then gradually increased from 26.8 psia to 27.5 psia at R0 +400 sec. The pressure then decreased back to 26.8 psia at R0 +420 sec and stabilized for the remainder of the first 560 sec of flight. From R0 +560 sec until R0 +33,750 sec, the exit pressure remained between 26.5 and 28.0 psia.

24.3 Flowrate

The S-IVB coolant inlet flowrate (F0010-601) was 7.9 gal/min at liftoff and decreased to 7.8 gal/min at R0 +17 sec. It then increased to 8.0 gal/min at R0 +560 sec. From R0 +560 sec until R0 +33,780, the flowrate varied between 7.9 and 8.3 gal/min.

ACOUSTIC VIBRATION AND DYNAMIC
STRAIN MEASUREMENTS

25. ACOUSTIC, VIBRATION, AND DYNAMIC STRAIN MEASUREMENTS

A total of 65 acoustic, vibration and dynamic strain measurements were monitored on the S-IVB-502 stage. Four measurements did not provide data. In general, the acoustic and vibration environments were similar to those measured on the AS-501 flight. The dynamic strain levels were higher than those measured on the AS-204 flight; however, there were no indications of panel flutter. The fatigue life of the forward skirt skin panels, as demonstrated in the wind tunnel qualification test, was not impaired during the flight.

There were two unexpected dynamic occurrences noted on the S-IVB. The first was a 5.5 cps oscillation (POGO) during the latter period of S-IC powered flight and secondly a shock transient at approximately RO +133.3 sec. There were no adverse effects on the S-IVB due to these events.

25.1 Data Acquisition and Reduction

A list of the 37 vibration and 12 acoustic measurements is presented in table 25-1. The transducer locations are shown in figure 25-1. The 16 dynamic strain measurements are listed in table 25-2 and gage locations are detailed in paragraph 25.4. Overall levels during specific flight periods are also presented in both tables.

Three separate telemetry systems were used to acquire the data: PAM/FM, FM/FM, and SSB/FM. The PAM/FM system, in conjunction with a filtering and averaging circuit, was used to provide acoustical levels for frequencies above 2,400 cps. The FM/FM system was used to provide low frequency (5 to 220 cps) vibration data. Both systems provided extended frequency information to supplement the data from the SSB/FM system which has a nominal frequency range of 50 to 3,000 cps. The preflight sweep calibration showed the low frequency rolloff for this SSB set was not as severe as expected, and therefore, 30 cps information was recoverable on this flight. The FM/FM system was also used to provide the dynamic strain data (0 to 800 cps).

A time sharing arrangement was utilized to obtain more measurements than the number of allocated telemetry channels. This method of acquisition provided data for 3 or 6 sec for every 12 sec commutation period. Time sharing, however, prevented the acquisition of maximum response amplitudes and specific events (liftoff, separation, etc.) for some of the measurements. The time shared channels are reflected in the time-history plots by interpolated lines between the time intervals of the actual measured data.

The data from the SSB/FM and FM/FM measurements were corrected for data acquisition system and data reduction filter rolloff characteristics. The corrections were applied to the spectrum plots and to the overall levels in tables 25-1 and 25-2. Because there was no convenient way to correct the time-history plots, the levels shown may differ from the values in the tables. The levels below 40 cps in the power spectral density (PSD) plots from the SSB measurements are to be disregarded because the system did not provide valid data below this frequency.

Both analog and digital techniques were utilized in reducing the data. The final analysis consisted of both instantaneous and root-mean square (rms) composite time history, and one-third octave band and PSD spectrum plots (figures 25-2 through 25-57).

25.2 Vibration Environment

The S-IVB vibration environment was induced by acoustical noise, aerodynamic pressure fluctuations, and mechanical excitation. The predominant sources were the F-1 engine exhaust noise during launch, unsteady aerodynamic flow conditions during the transonic period of flight, boundary layer turbulence during the period of high dynamic pressures, J-2 engine combustion chamber processes during S-IVB powered flight, and staging transients at separation and S-IVB engine ignition and cutoff. Thirty-seven vibration pickups were located on the S-IVB to determine the response amplitudes of the stage structure and components to these excitation sources.

For discussion purposes, the measurements were grouped into engine, thrust structure, aft skirt and LH2 tank, and forward skirt measurements. Data from corresponding measurements from the AS-501 flight are presented for comparison purposes.

25.2.1 Engine Measurements

Vibration measurements were made on the combustion chamber dome in the thrust direction and on the flange above the turbopump housing, in the radial direction, of each main propellant pump. The data from the LH2 turbopump measurement were invalid. A detailed discussion of the problems associated with this measurement system is presented in section 18. Although the data were invalid for determining the LH2 turbopump vibration, the data were considered usable for trend purposes. The rms composite time-history (figure 25-2) showed changes in amplitude which correlate in time with other measurement anomalies. A discussion of the anomalous behavior is presented in section 2.

The vibration amplitudes on the combustion chamber dome and LOX turbopump were similar to those measured on the AS-501 flight (figures 25-3 and 25-4). Between R0 +685 and R0 +694 sec the measurement on the combustion chamber dome failed and did not provide data for the remainder of the flight. The failure appears to be related to other measurement anomalies noted during this time period (section 2).

25.2.2 Thrust Structure Measurements

The thrust structure measurements were located on the gimbal block and at the attach points of an ambient helium bottle and the LH2 feedline. Three measurements on the gimbal block were oriented in the thrust, pitch, and yaw directions. The data (figures 25-5, 6, and 7) showed the amplitudes were nearly identical in the three axes. The highest vibration levels occurred during S-IVB powered flight.

Three helium bottle measurements were located on the thrust structure at one of the tie-down straps and oriented in the thrust, pitch, and yaw directions. The measurement at the LH2 feedline was located on the thrust structure near the support bracket. The data from these measurements are shown in figure 24-8 through 24-11. The measured amplitudes during the flight were approximately 75 percent lower than those measured during acceptance firing. In general, the vibration energy was concentrated below 300 cps at liftoff and above 300 cps during S-IVB powered flight and acceptance firing.

25.2.3 Aft Skirt and LH2 Tank Measurements

The aft skirt measurements were monitored on the separation ring frame, at two vibration-isolated ambient panels, and at APS module No. 1. The measurement on the separation ring frame was located at position II and oriented in the thrust direction. The PSD levels (figures 25-12) were in good agreement with those measured on the AS-501 flight. The increased amplitude in the composite time-history at R0 +125 sec was due to a 5.5 cps longitudinal oscillation (POGO). The vibration level was approximately 70 percent higher than that measured on the AS-501 flight.

The ambient panel measurements provided the vibration input and response of the sequencer (panel No. 1) and switch selector (panel No. 2) panels. The data from these measurements are shown in figures 25-13 through 25-18. In addition, the PSD's from corresponding AS-501 flight measurements are shown. The comparisons show the peaks in the spectrum for the panel input data were at a lower frequency on this flight. However, the panel response data were in good agreement. Similar differences were noted in the acceptance firing data.

The measurements at the APS module monitored the vibration input to the module at the forward and aft attach points. The levels shown in figures 25-19, 20, and 21 show good agreement with those measured on the AS-501 flight.

There was one measurement located on the LH2 tank near the PU probe support structure. The maximum amplitude was measured during launch with most of the energy concentrated at approximately 100 cps (figure 25-22).

25.2.4 Forward Skirt Measurements

The vibration environment in the forward skirt was measured on the field splice, at two vibration-isolated cold plate panels, and at battery No. 1. Except for short duration transients at approximately R0 +133.3 sec and stage separation, the vibration amplitudes diminished to negligible values (less than 1 grms) after R0 +110 sec.

The measurements on the field splice were monitored near positions I and II. There were three measurements at each location monitored via SSB. The thrust measurement system at position I was also monitored on FM/FM to provide low frequency (figure 25-23) data. The 5.5 cps longitudinal oscillation noted on the aft skirt was also measured in the forward skirt. The maximum amplitude was ± 0.5 g, measured on both the aft and forward skirts.

The vibration amplitudes on the field splice were similar to those measured on the AS-501 flight (figures 25-24 through 25-28), except for measurement E0097-411 (figures 25-29). The AS-501 flight data were considerably higher due to a 700 cps peak which was absent in the AS-502 data. This difference in vibration response was also noticed during the acceptance firing.

The cold plate panel measurements provided the vibration input and response of the PU electronics (panel No. 9) and EBW range safety (panel No. 16) panels. The data from these measurements are shown in figures 25-30 through 25-34. In general, the amplitudes were in good agreement with those measured on the AS-501 flight.

The accelerometers at the battery were mounted on the structure adjacent to the battery support bracket. Rms time-history and PSD plots are presented in figures 25-35, 36, and 37. Measurement E0117-411 did not provide valid data throughout the flight due to an instrumentation malfunction (section 18). The vibration characteristics at the battery were similar to those measured at the cold plate panels.

A shock transient with four separate impulses within a time interval of 0.25 sec was noted at approximately R0 +133.3 sec. Due to time-sharing, only three forward skirt measurements were monitored at this time. The maximum measured level was ± 17 g which was slightly higher than that measured during stage separation. The transient was hardly noticeable on the aft skirt, thrust structure, or engine measurements. The R0 +133.3 sec incident is discussed in greater detail in section 2.

25.3 Acoustic Environment

The acoustic environment was produced by F-1 engine exhaust noise at launch, unsteady flow conditions during the transonic period of flight (near mach 1), and by boundary layer pressure fluctuations during the period of high dynamic pressures. There were four microphones on the S-IVB to measure this environment. Two (external and internal) were located on the aft skirt near position I, approximately 36 in. forward of the separation plane. The other two were located on the forward skirt near position I (external) and II (internal), approximately 6 in. aft of the field splice. Each transducer system had a multiple output capability with the data signal below 3,000 cps transmitted by SSB/FM and the data level for the 7th (2,400 to 4,800 cps) and 8th (4,800 to 9,600 cps) octave bands transmitted via PAM/FM.

Rms time-history and one-third octave band plots for these measurements are shown in figures 25-38 through 25-41. Data from similar AS-501 flight measurements are also presented. In general, the comparisons during selected flight periods were in reasonable agreement between flights.

One of the discrepancies noted in the AS-501 aft skirt acoustical data at liftoff was that the internal levels were higher than the external in the low frequencies. The internal levels on this flight were lower than the external throughout the spectrum.

No comparison was made of the forward skirt external data because the AS-501 flight measurement was located at a different location. The major difference noted on this flight was the increase in amplitude between R0 +85 to R0 +96 sec. This phenomenon correlates in time with the increased wind shear loading noted at this time and reported in appendices 3 and 5.

25.4 Dynamic Strain Measurements

Sixteen dynamic strain measurements were made to detect the possible existence and degree of skin panel flutter in the forward skirt during supersonic flight. The strain gages were installed on approximately every 7th panel at sta 3135, oriented in the thrust axis, located midway between stringers and 4 in. forward of the panel trailing edge. The installation was similar to AS-204. The gages were external to the skin and at the same location as the internal gages used in the panel flutter qualification test performed on a full scale segment of the S-IVB forward skirt in the Arnold Engineering Development Center transonic wind tunnel.

A location sketch and a comparison of rms composite time histories of the measurements are shown in figure 25-42. PSD plots, samples of the instantaneous wave forms and rms composite time histories are shown for selected flight periods in figures 25-43 through 25-57. The composite dynamic strain levels at liftoff, transonic, and supersonic periods of flight are presented in table 25-2.

One measurement, S0087, was found to be operating erratically prior to launch and was deleted. Two measurements, S0100 and S0101, were not found to be malfunctioning prior to launch; but the signals that they were sending back during launch and later in flight during periods of maxima cross winds aloft indicated high wide-band random noise levels on the channels, as well as a dc shift of approximately one volt which occurred on the channel of S0101 at 91.5 sec. The high wide-band random noise levels seemed to be a function of the high external excitation environments. The spectrum level over a broad frequency band was raised, which is not the expected response of a vibrating skin panel as shown in the other flight dynamic strain measurements. The noise levels dropped to satisfactory values during low external excitation. These two measurements were investigated for electrical malfunction and no single failure mode could be identified (see section 18, table 18-5) but because of their peculiar behavior, they have been classified as aberrant. The data from these measurements are included in this report, see figures 25-56 and 25-57.

The time history of the composite dynamic strain levels from most measurements followed a trend similar to the external acoustic levels measured on the forward skirt as shown in figure 25-40. The first maxima levels occurred at liftoff followed by lower levels during subsonic flight. The next maxima levels occurred during transonic flight followed by lower levels during low supersonic flight before maximum dynamic pressure. The flight vehicle then encountered transient air loads as it traversed the maxima cross winds aloft which ranged from approximately 50 to 80 ft/sec, between R0 +75 and R0 +85 sec, as shown in appendix 3 and appendix 5. During the period of cross winds the measured dynamic strain increased on individual panels then decreased as indicated in figure 25-42.

The dynamic strain transients during supersonic flight can be explained as follows: The wind tunnel tests showed that (with the Mach number, differential pressure, and dynamic pressure held constant) the dynamic strain levels due to the fluctuating pressures in the boundary layer increased as the compression loads applied to the skin panels were increased. The maximum dynamic strain levels occurred when the panel compression load was equal to or greater than the static buckling load. Similarly in flight the dynamic strain response increased as the static strain in the skin panel approached the critical buckling ratio. The critical buckling ratios during flight were estimated from the static strains measured on eight forward skirt stringers as a result of bending moments induced by the cross winds. The static strains, reported in section 23, were adjusted for this dynamic analysis to reflect the total load on each stringer, including the strain-effects due to loading the S-IVB with cryogenic fuels. The effects of differential pressure were included in the estimation of the static buckling load.

Section 25
Acoustic and Vibration Environment

The dynamic strain data were analyzed by high speed oscillograph traces and power spectral density analysis as shown in figures 25-43 through 25-57. Panel flutter, which was searched for, was to be distinguished by the sustained characteristic of a single dominant mode with a wave shape that was primarily periodic and of constant amplitude, significantly higher than the expected random and narrow band random vibration. No such dominant mode was found in the dynamic strain data during supersonic flight. Therefore, it is concluded that panel flutter did not occur. The predominant dynamic response was narrow band random vibration of two or more modes of the panels occurring simultaneously as shown in the figures. This dynamic response is typical of skin panel vibration response to acoustic noise or random pressure fluctuations in the aerodynamic boundary layer.

The composite dynamic strain levels which are tabulated in table 25-2 show that the aberrant measurements S0100 and S0101 indicated the highest values; 498 $\mu\text{in./in. rms}$ and 460 $\mu\text{in./in. rms}$, respectively. These values are approximately four times higher than the maxima values of rms strain measured on AS-204 but only approximately one-half of the maximum levels recorded in the wind tunnel panel flutter qualification testing. If the aberrant measurements are disregarded because of the peculiarities noted in this report, the highest dynamic strain during supersonic flight occurred on measurement S0092. The dynamic strain level would then be approximately 253 $\mu\text{in./in. rms}$, approximately twice as high as the maximum value measured on AS-204, and approximately one-third of the levels recorded in the wind tunnel panel flutter qualification testing.

The dynamic strains after 100 sec (figure 25-42) were all due to the predominantly low frequency (approximately 5.5 Hz) vibration which was attributed to POGO, (section 2). These dynamic strains were not due to random pressure fluctuations in the boundary layer.

In summary it is concluded that panel flutter did not occur and that the fatigue life of the forward skirt skin panels, as demonstrated in the wind tunnel qualification test, was not impaired by the dynamic strains measured during the AS-502 flight.

TABLE 25-1 (Sheet 1 of 2)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

| MEASUREMENT NO. | MEASUREMENT | DIRECTION | FREQUENCY RANGE (cps) | S-IC POWERED FLIGHT LEVELS | | S-II POWERED FLIGHT LEVELS | S-IVB POWERED FLIGHT LEVELS | MAX AS-501 FLIGHT LEVEL |
|-----------------|------------------------------|------------|-----------------------|----------------------------|--------------|----------------------------|-----------------------------|-------------------------|
| | | | | LIFTOFF | MAX INFLIGHT | | FIRST BURN | |
| | <u>Vibration</u> | | | | | | <u>Acceleration (grms)</u> | |
| E0041-403 | Helium Bottle, Thrust Struct | Thrust | 40 to 3,000 | 1.8 | 1.0 | NF | 1.8 | NM |
| E0042-403 | Helium Bottle, Thrust Struct | Pitch | 40 to 3,000 | 2.2 | 1.4 | NF | 2.2 | NM |
| E0043-403 | Helium Bottle, Thrust Struct | Yaw | 40 to 3,000 | 2.1 | 1.2 | NF | 2.1 | NM |
| E0061-403 | LH2 Feedline, Thrust Struct | Thrust | 40 to 3,000 | 2.2 | 1.4 | NF | 1.7 | NM |
| E0062-409 | PU Probe, LH2 Tank Cylinder | Radial | 40 to 3,000 | 6.8 | 4.6 | NF | 0.4 | NM |
| E0090-403 | Gimbal Point | Thrust | 40 to 3,000 | 0.4 | 0.3 | NF | 4.5 | 3.0 |
| E0091-411 | Field Splice Position I | Thrust | 10 to 220 | 0.7 | 0.4 | NF | NF | 1.1* |
| E0092-404 | Station 2748 Position II | Thrust | 10 to 220 | 0.8 | 0.5 | NF | NF | 0.9* |
| E0093-411 | Field Splice Position I | Thrust | 40 to 3,000 | 2.9 | 5.0 | NF | 0.2 | 4.8 |
| E0094-411 | Field Splice Position I | Pitch | 40 to 3,000 | 6.5 | 7.6 | NF | 0.2 | 8.2 |
| E0095-411 | Field Splice Position I | Yaw | 40 to 3,000 | 2.1 | 4.7 | NF | 0.2 | 2.7 |
| E0096-411 | Field Splice Position II | Thrust | 40 to 3,000 | 1.3* | 4.4 | NF | 0.2 | 5.0 |
| E0097-411 | Field Splice Position II | Pitch | 40 to 3,000 | 1.1 | 3.0 | NF | 0.1 | 5.7 |
| E0098-411 | Field Splice Position II | Yaw | 40 to 3,000 | 4.2 | 8.6 | NF | 0.2 | 7.2 |
| E0103-404 | Sequencer Panel | Thrust | 40 to 3,000 | 4.2 | 5.9 | NF | 0.4 | 6.3 |
| E0104-404 | Sequencer Assembly | Radial | 40 to 3,000 | 1.6 | 2.8 | NF | 0.3 | 3.5 |
| E0105-404 | Sequencer Panel | Radial | 40 to 3,000 | 4.4 | 7.8 | NF | 0.4 | 7.5 |
| E0106-404 | Switch Selector Panel | Thrust | 40 to 3,000 | 4.1 | 4.8 | NF | 0.4 | 10.9 |
| E0107-404 | Switch Selector Unit | Radial | 40 to 3,000 | 3.5 | 3.1 | NF | 0.3 | 3.6 |
| E0108-404 | Switch Selector Panel | Radial | 40 to 3,000 | 4* | 6.6 | NF | 0.4 | 8.1 |
| E0109-411 | PU Electronic Panel | Thrust | 40 to 3,000 | 3.2 | 4.3 | NF | 0.2 | 5.9 |
| E0110-411 | PU Electronic Assembly | Radial | 40 to 3,000 | 5.5 | 4.9 | NF | 0.2 | 3.5 |
| E0111-411 | PU Electronic Panel | Radial | 40 to 3,000 | 10.6 | 9.8 | NF | 0.3 | 9.0 |
| E0112-411 | EBW Range Safety Panel | Thrust | 40 to 3,000 | 1.3* | 3.2 | NF | 0.2 | 5.2 |
| E0113-411 | EBW Range Safety Unit | Radial | 40 to 3,000 | 2.2 | 1.6 | NF | 0.2 | 2.3 |
| E0114-411 | EBW Range Safety Panel | Radial | 40 to 3,000 | I | I | I | I | 8.1 |
| E0115-411 | Forward Skirt Battery 1 | Thrust | 40 to 3,000 | 1.0 | 2.1 | NF | 0.2 | 2.6 |
| E0116-411 | Forward Skirt Battery 1 | Radial | 40 to 3,000 | 3.2 | 4.2 | NF | 0.3 | 5.7 |
| E0117-411 | Forward Skirt Battery 1 | Tangential | 40 to 3,000 | 1.9 | I | I | I | 4.8 |

Section 25
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TABLE 25-1 (Sheet 2 of 2)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

| MEASUREMENT NO. | MEASUREMENT | DIRECTION | FREQUENCY RANGE (cps) | S-IC POWERED FLIGHT LEVELS | | S-II POWERED FLIGHT LEVELS | S-IVB POWERED FLIGHT LEVELS | MAX AS-501 FLIGHT LEVEL |
|-----------------|----------------------------|-----------|-----------------------|----------------------------|-------------|----------------------------|----------------------------------|-------------------------|
| | | | | LIFTOFF | MAX INFIGHT | | FIRST BURN | |
| | <u>Vibration</u> | | | | | | <u>Acceleration (grms)</u> | |
| E0118-427 | APS Mod 1 Aft Attach Point | Thrust | 40 to 3,000 | 0.8* | 2.8 | NF | 0.6 | 2.6 |
| E0119-427 | APS Mod 1 Aft Attach Point | Radial | 40 to 3,000 | 2.7 | 4.2 | NF | 0.4 | 4.5 |
| E0120-427 | APS Mod 1 Fwd Attach Point | Radial | 40 to 3,000 | 4.7 | 5.7 | NF | 0.8 | 5.5 |
| E0209-401 | Combustion Chamber Dome | Thrust | 40 to 3,000 | NF | NF | NF | 9.1 | 7.7 |
| E0210-401 | LH2 Turbopump | Radial | 40 to 3,000 | NF | NF | NF | I | I |
| E0211-401 | LOX Turbopump | Radial | 40 to 3,000 | NF | NF | NF | 21.0 | 28* |
| E0212-403 | Gimbal Point | Yaw | 40 to 3,000 | I | 0.3 | NF | 4.2 | NM |
| E0213-403 | Gimbal Point | Pitch | 40 to 3,000 | 0.7* | 0.4 | NF | 5.3 | NM |
| | <u>Acoustics</u> | | | | | | <u>Sound Pressure Level (db)</u> | |
| B0016-411 | Forward Skirt | Internal | 30 to 3,000 | 140.7 | 132.6 | NF | NF | 139.5 |
| B0017-411 | Forward Skirt | Internal | 2,400 to 4,800 | 111C | 121 | NF | NF | 126 |
| B0018-411 | Forward Skirt | Internal | 4,800 to 9,600 | 105C | 119.5 | NF | NF | 119 |
| B0019-427 | Aft Skirt | External | 30 to 3,000 | 151.9 | 150.2 | NF | NF | 150 |
| B0020-427 | Aft Skirt | External | 2,400 to 4,800 | 130C | 138 | NF | NF | 129C |
| B0021-427 | Aft Skirt | External | 4,800 to 9,600 | 120C | 133C | NF | NF | 130C |
| B0022-404 | Aft Skirt | Internal | 30 to 3,000 | 144.1 | 129.4 | NF | NF | 145 |
| B0023-404 | Aft Skirt | Internal | 2,400 to 4,800 | N | N | N | N | 110C |
| B0024-404 | Aft Skirt | Internal | 4,800 to 9,600 | 108C | 108C | NF | NF | 101C |
| B0025-426 | Forward Skirt | External | 30 to 3,000 | 152.0 | 151.8 | NF | NF | NM |
| B0026-426 | Forward Skirt | External | 2,400 to 4,800 | 130C | 138 | NF | NF | NM |
| B0027-426 | Forward Skirt | External | 4,800 to 9,600 | 123C | 134 | NF | NF | NM |

NF - System Noise Floor
 NM - Not Monitored
 * - Estimated Level
 I - Data Invalid
 N - No Data
 C - Data Corrected for System Noise

TABLE 25-2
COMPOSITE DYNAMIC STRAIN LEVELS

| MEASUREMENT NO. | MEASUREMENT | DIRECTION | FREQUENCY RANGE (cps) | S-IC POWERED FLIGHT LEVELS | | |
|-----------------|-------------------------|-----------|-----------------------|------------------------------|-----------|------------|
| | | | | STRAIN (μ in./in. rms)* | | |
| | | | | LIFTOFF | TRANSONIC | SUPERSONIC |
| S0086-426 | Forward Skirt Panel 13 | Thrust | 2 to 800 | 39.8K | 29.9 | 25.8 |
| S0087-426 | Forward Skirt Panel 17 | Thrust | 2 to 800 | D | D | D |
| S0088-426 | Forward Skirt Panel 26 | Thrust | 2 to 800 | 44**K | 40** | 28.6 |
| S0089-426 | Forward Skirt Panel 33 | Thrust | 2 to 800 | 30.1K | 30.6 | 25.8 |
| S0090-426 | Forward Skirt Panel 40 | Thrust | 2 to 800 | 144.0 | 73.7 | 112.3 |
| S0091-426 | Forward Skirt Panel 46 | Thrust | 2 to 800 | 60** | 93.2 | 66.7 |
| S0092-426 | Forward Skirt Panel 55 | Thrust | 2 to 800 | 80** | 100** | 252.6 |
| S0093-426 | Forward Skirt Panel 61 | Thrust | 2 to 800 | 67.1 | 36.2 | 106.8 |
| S0094-426 | Forward Skirt Panel 69 | Thrust | 2 to 800 | 115.3 | 77.6 | 182.5 |
| S0095-426 | Forward Skirt Panel 76 | Thrust | 2 to 800 | 40**K | 25.7 | 31.8 |
| S0096-426 | Forward Skirt Panel 80 | Thrust | 2 to 800 | 115.3K | 67.4 | 46.4 |
| S0097-426 | Forward Skirt Panel 87 | Thrust | 2 to 800 | 102.4 | 74** | 105.0 |
| S0098-426 | Forward Skirt Panel 94 | Thrust | 2 to 800 | 56.9 | 65.5 | 36.6 |
| S0099-426 | Forward Skirt Panel 101 | Thrust | 2 to 800 | 90** | 67.6 | 64.4 |
| S0100-426 | Forward Skirt Panel 108 | Thrust | 2 to 800 | 133.8A | 51.8A | 497.7A |
| S0101-426 | Forward Skirt Panel 7 | Thrust | 2 to 800 | 95.0A | 64.2A | 459.8A |

*The possible accumulated measurement error is ± 25 percent.

**Estimated level.

K = Panel either partially or completely coated with 0.010 in. thickness of Korotherm for thermal protection near protuberances.

A = Aberrant measurement.

D = Deleted prior to launch.

Section 25
Acoustic and Vibration Environment

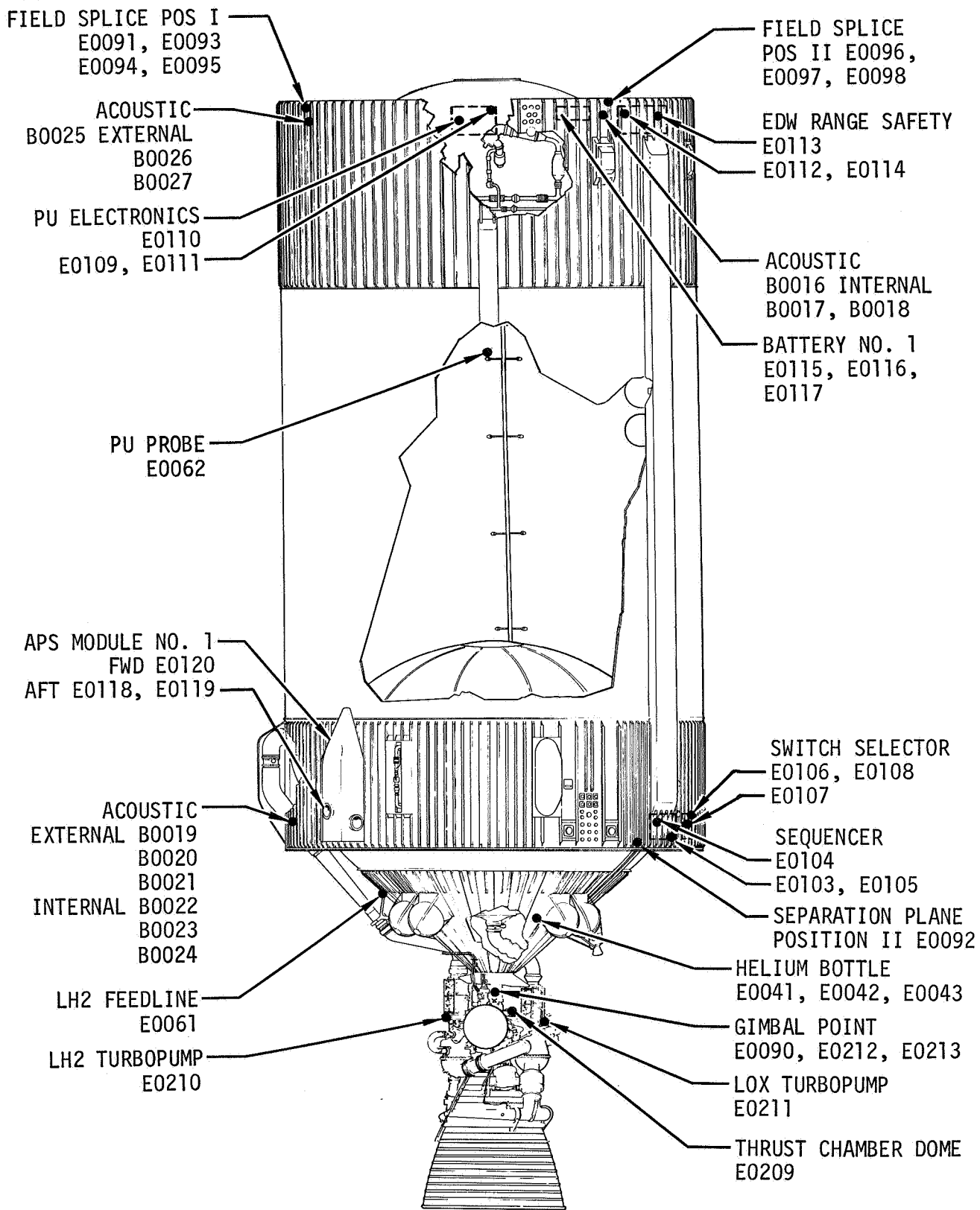


Figure 25-1. Acoustic and Vibration Measurement Locations

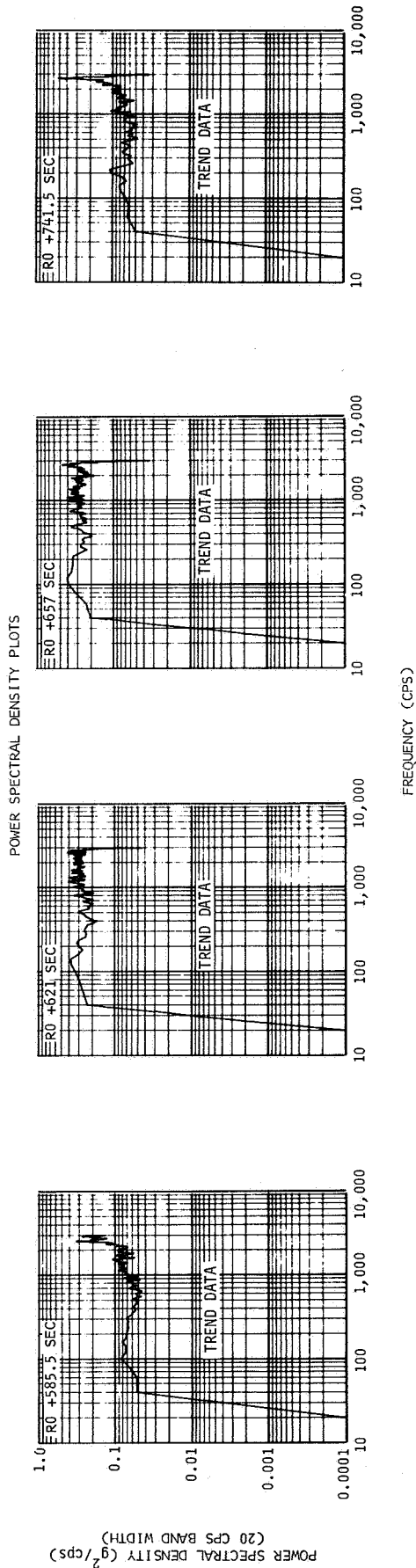
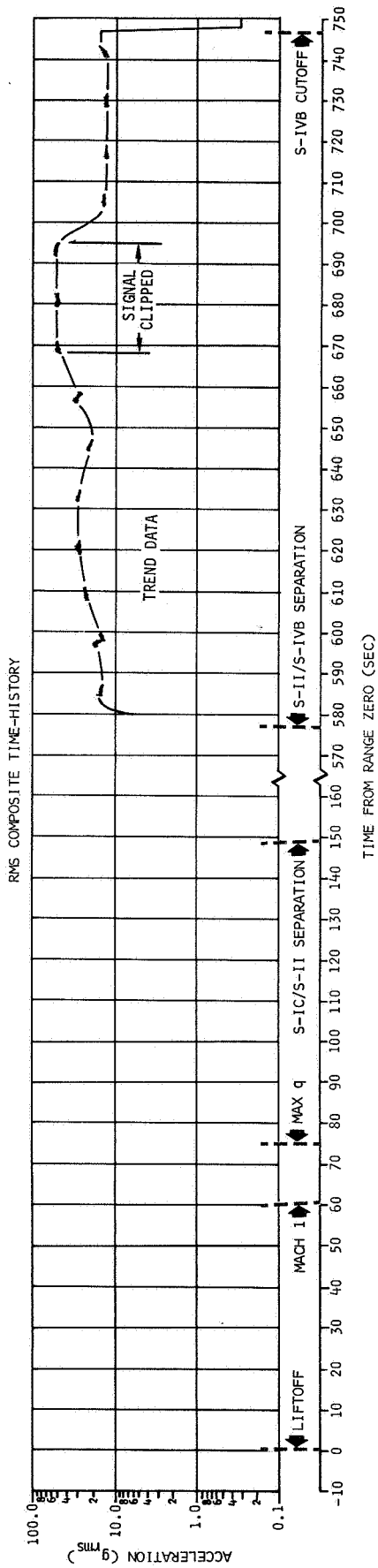
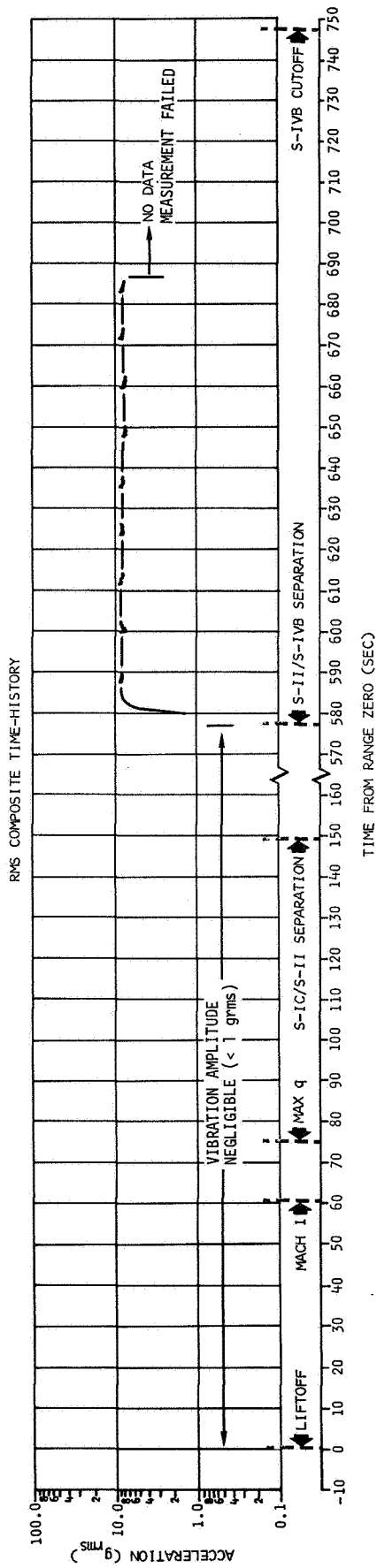


Figure 25-2. Vibration Measured at LH2 Turbopump, Radial Direction - E0210-401



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

— AS-502
* AS-501

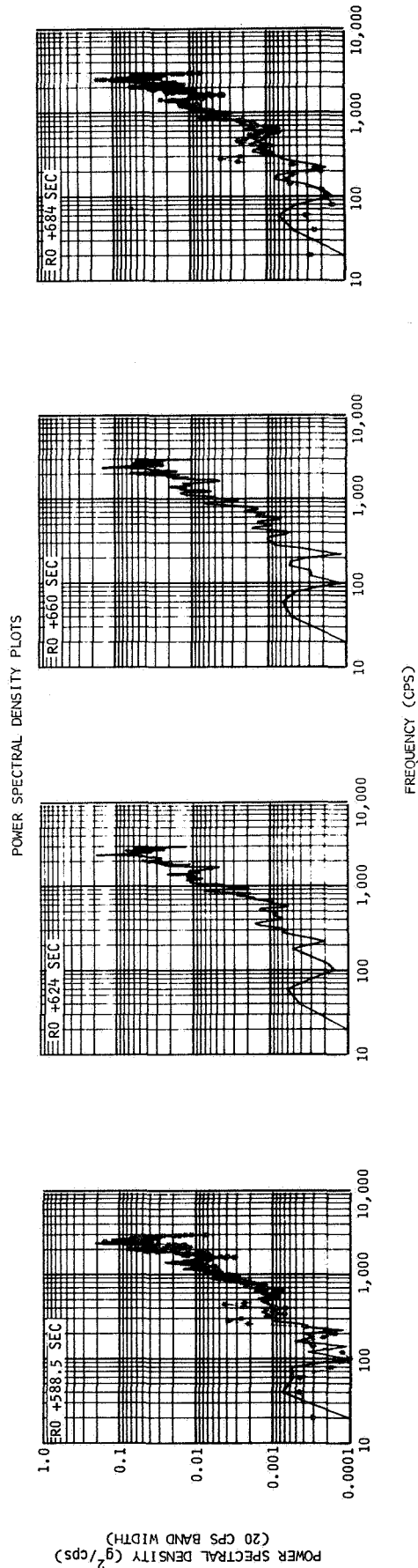
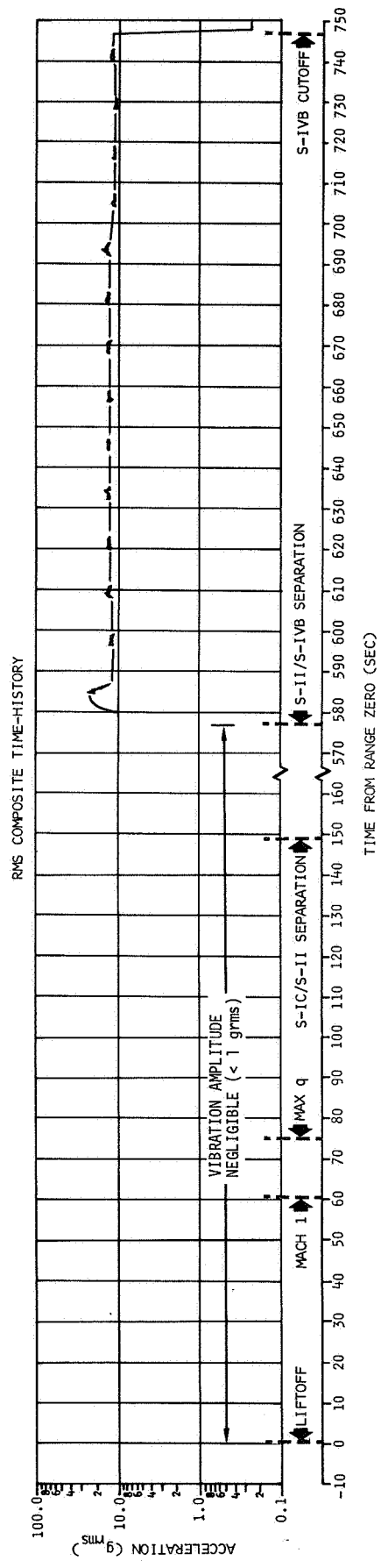


Figure 25-3. Vibration Measured on Combustion Chamber Dome, Thrust Direction - E0209-401



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

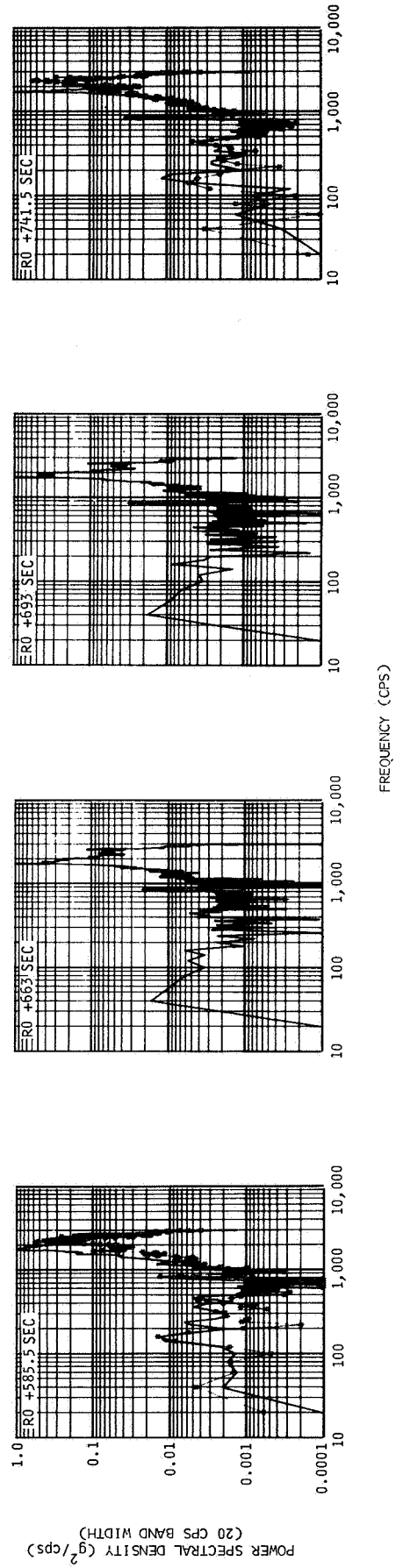
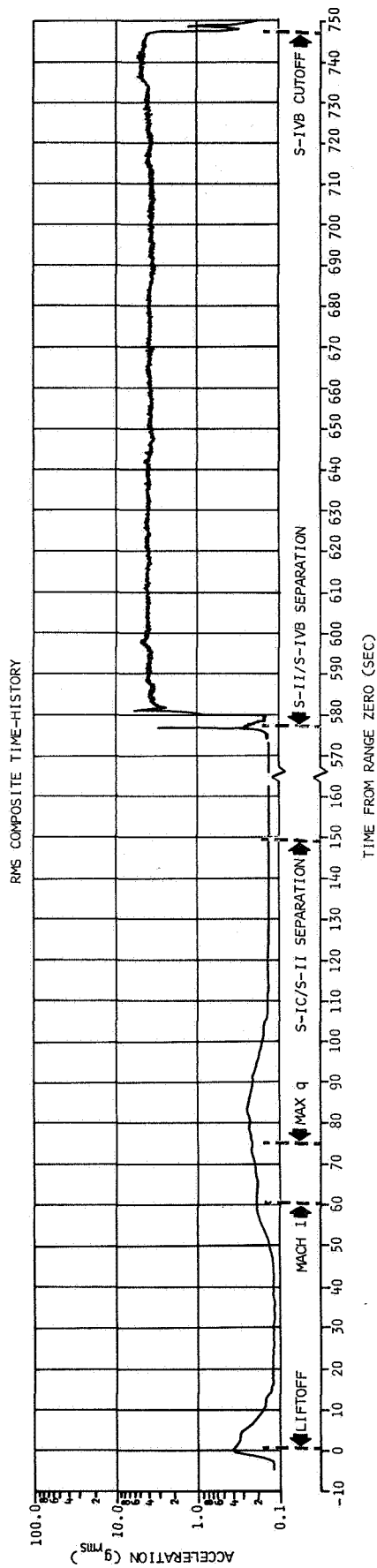


Figure 25-4. Vibration Measured at LOX Turbopump, Radial Direction - E0211-401



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

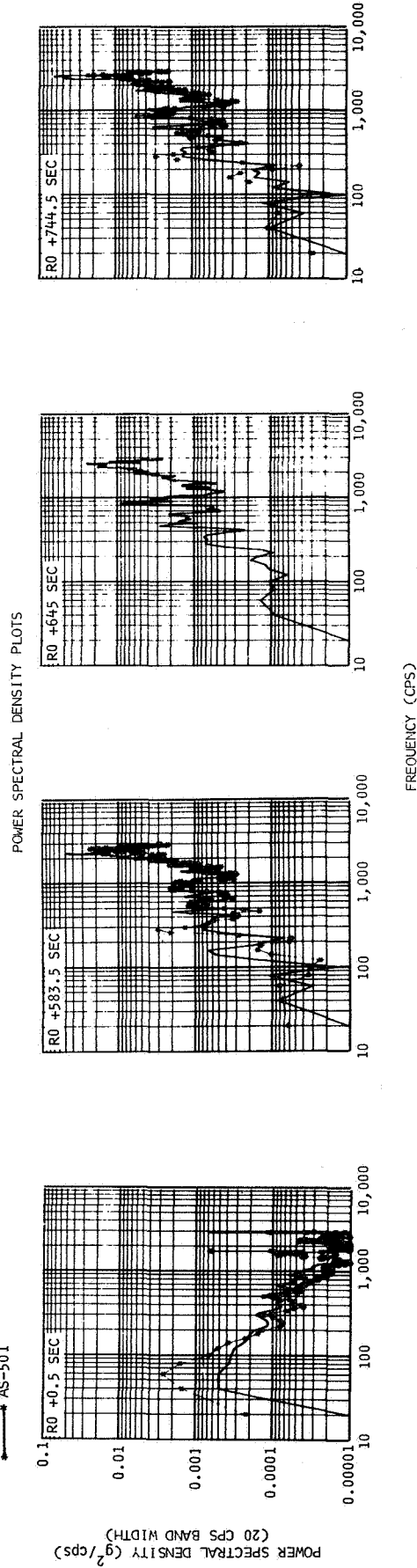
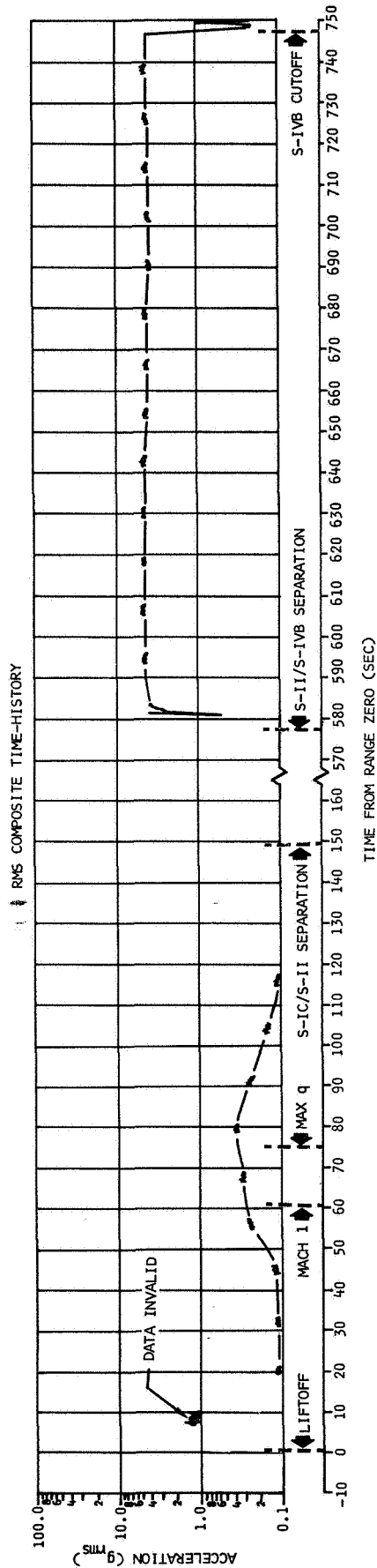


Figure 25-5. Vibration Measured on Gimbal Block, Thrust Direction - E0090-403



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

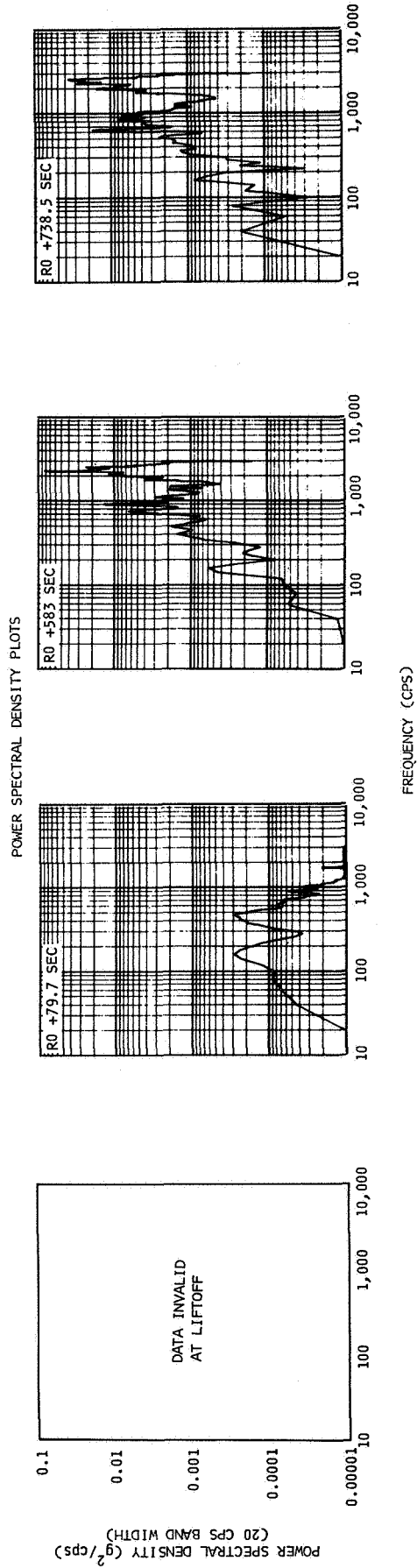
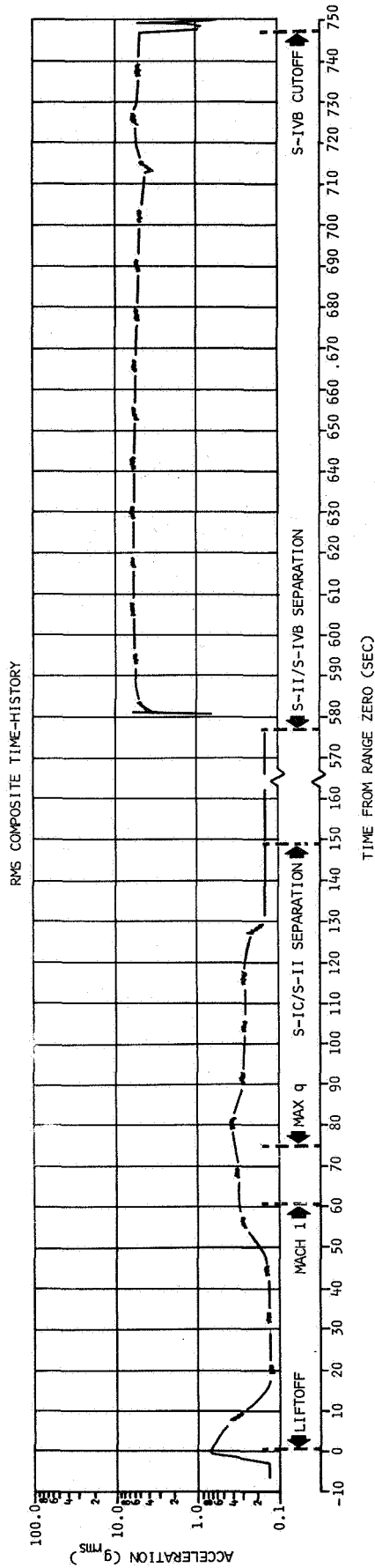


Figure 25-6. Vibration Measured on Gimbal Block, Yaw Direction - E0212-403



NOTE: DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

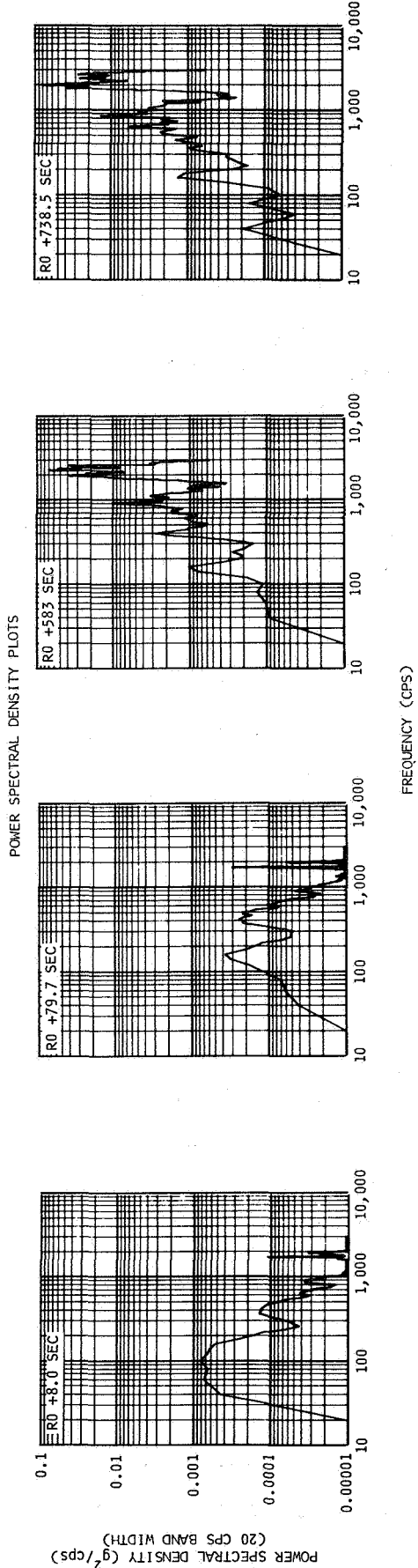
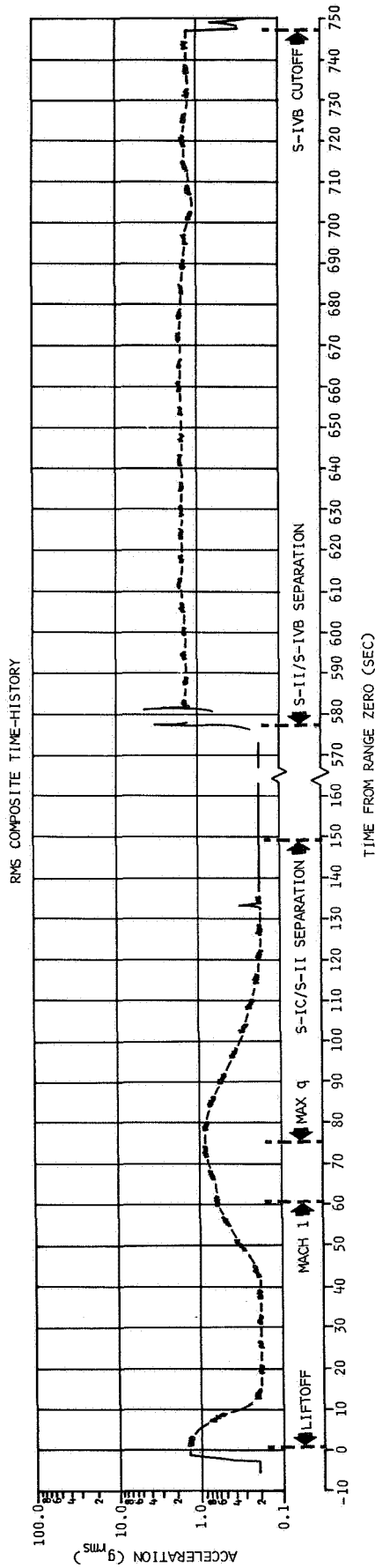


Figure 25-7. Vibration Measured on Gimbal Block, Pitch Direction - E0213-403



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

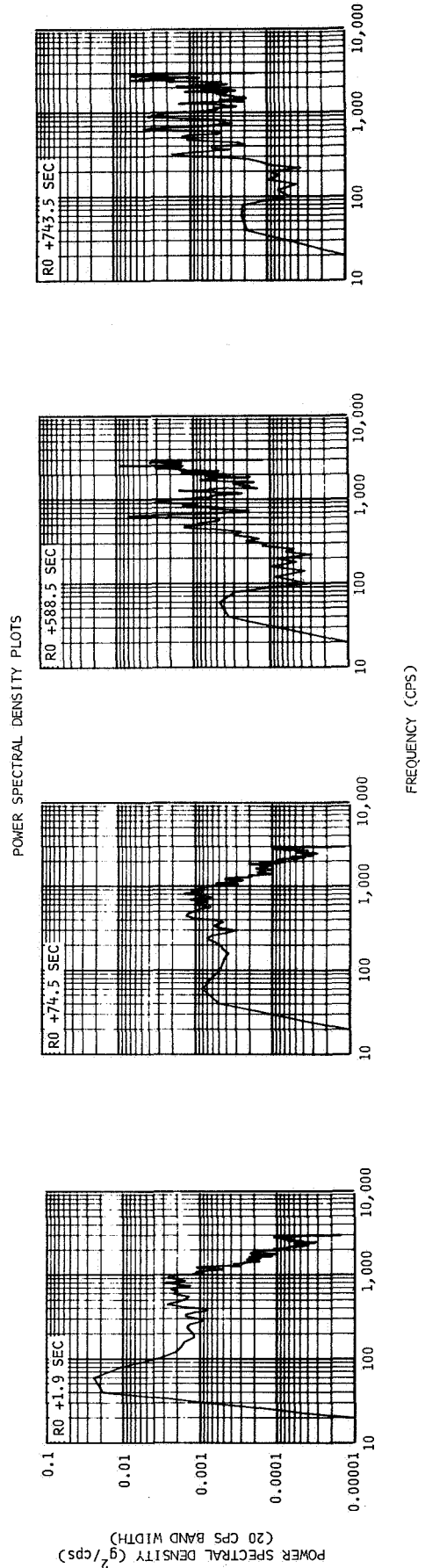
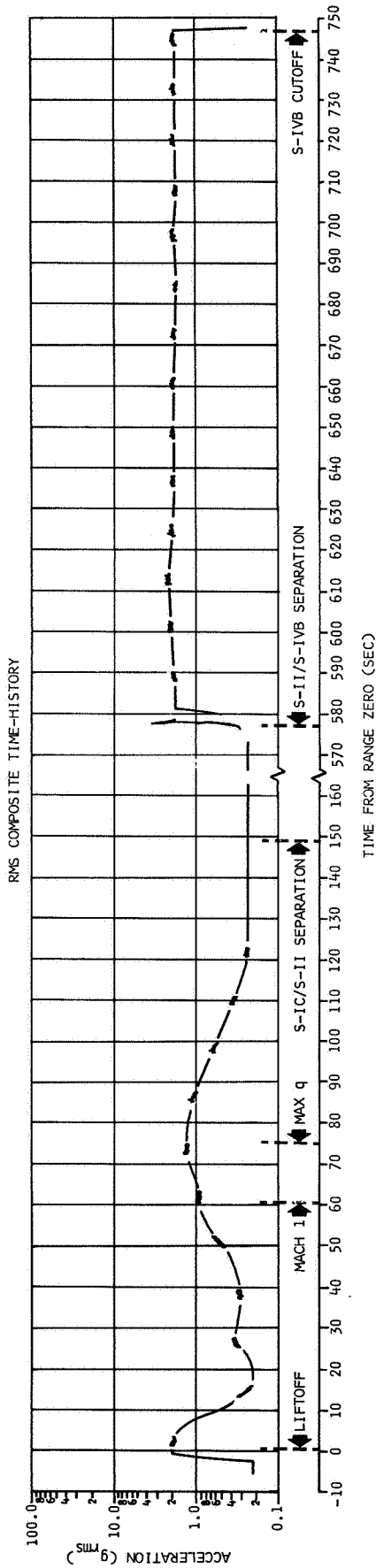


Figure 25-8. Vibration Measured at Input to Helium Bottle, Thrust Direction - E0041-403



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

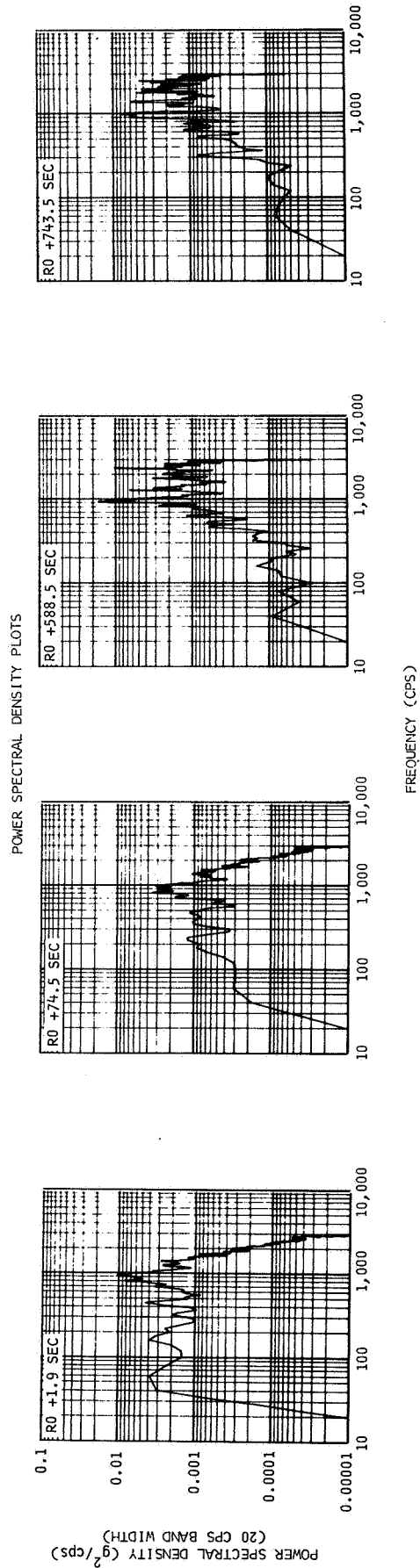
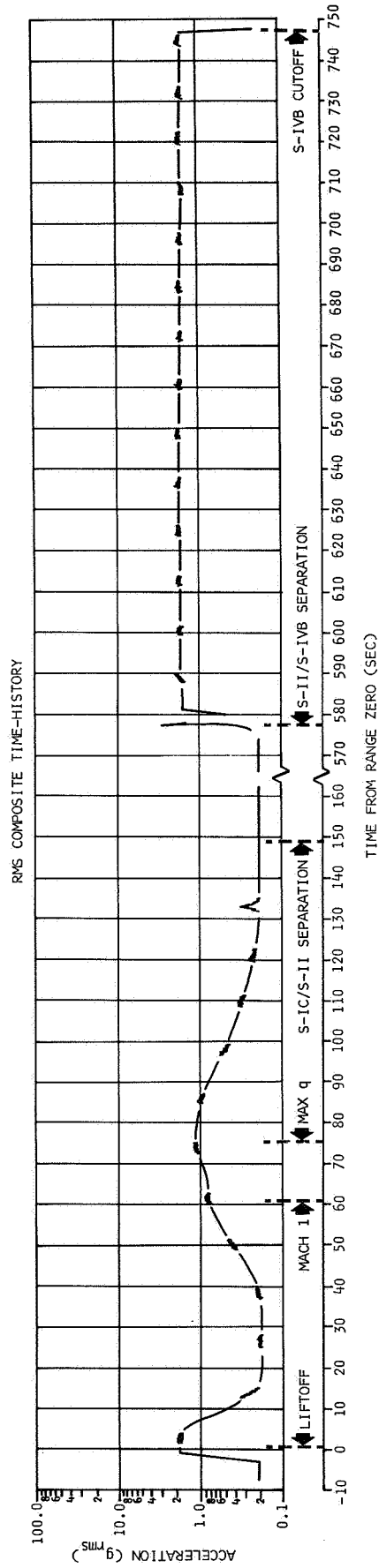


Figure 25-9. Vibration Measured at Input to Helium Bottle, Pitch Direction - E0042-403



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

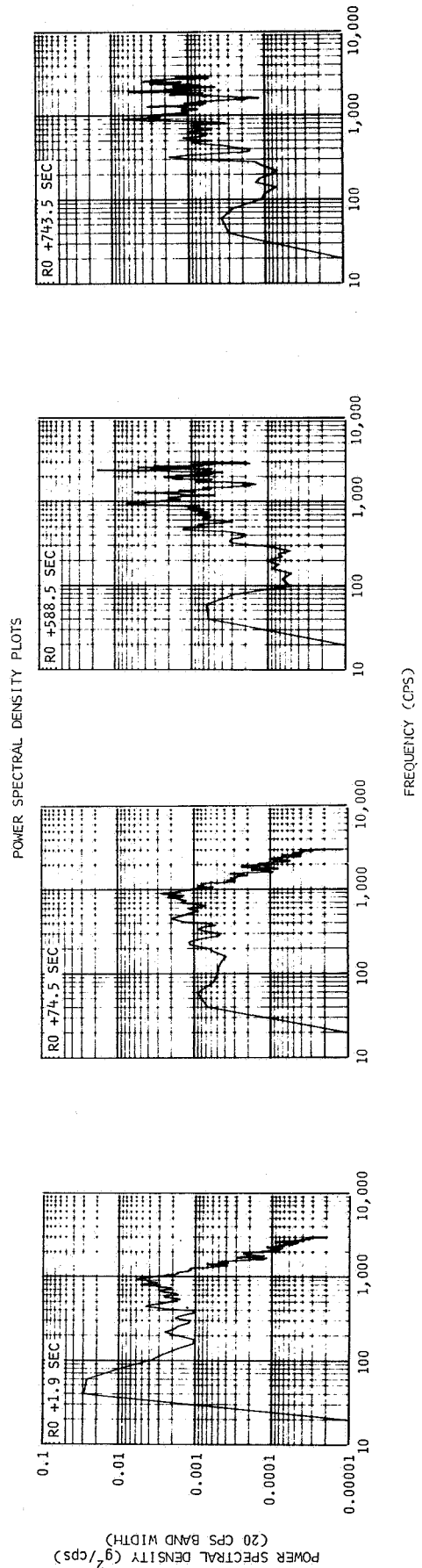
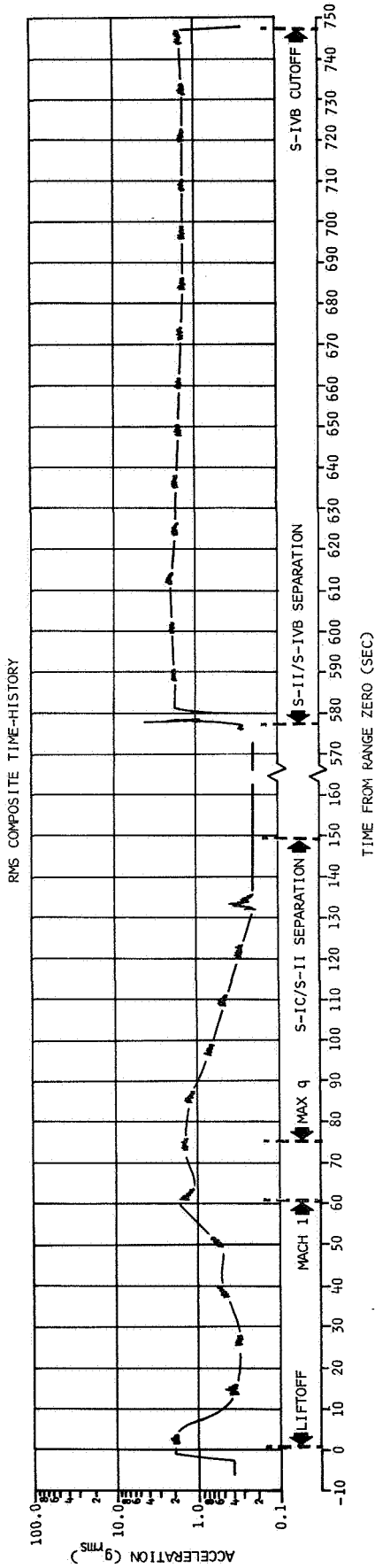


Figure 25-10. Vibration Measured at Input to Helium Bottle, Yaw Direction - E0043-403



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

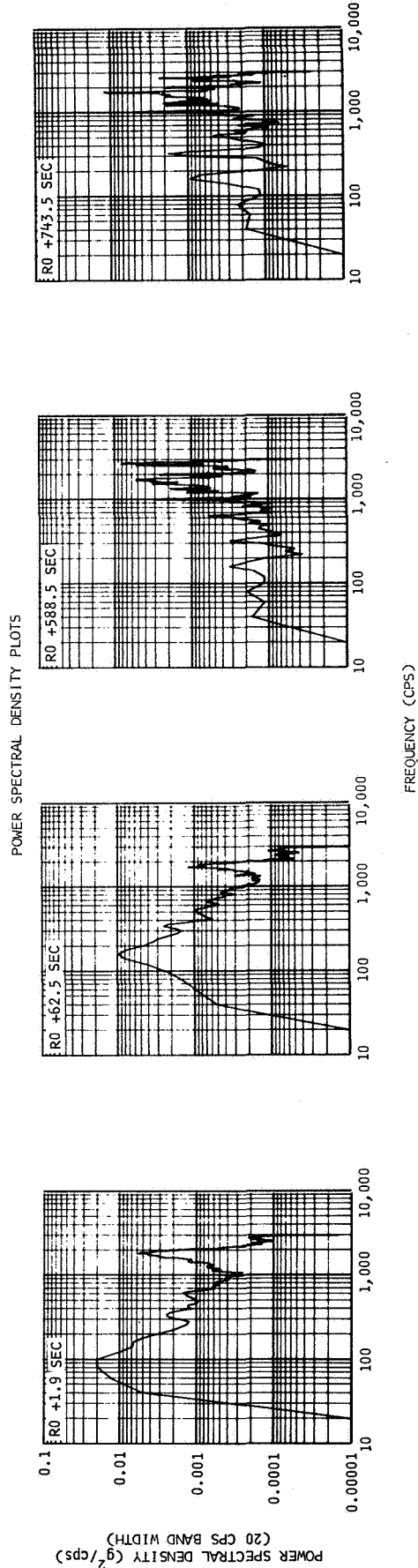


Figure 25-11. Vibration Measured at LH2 Feedline Attach Point on Thrust Structure, Thrust Direction - E0061-403

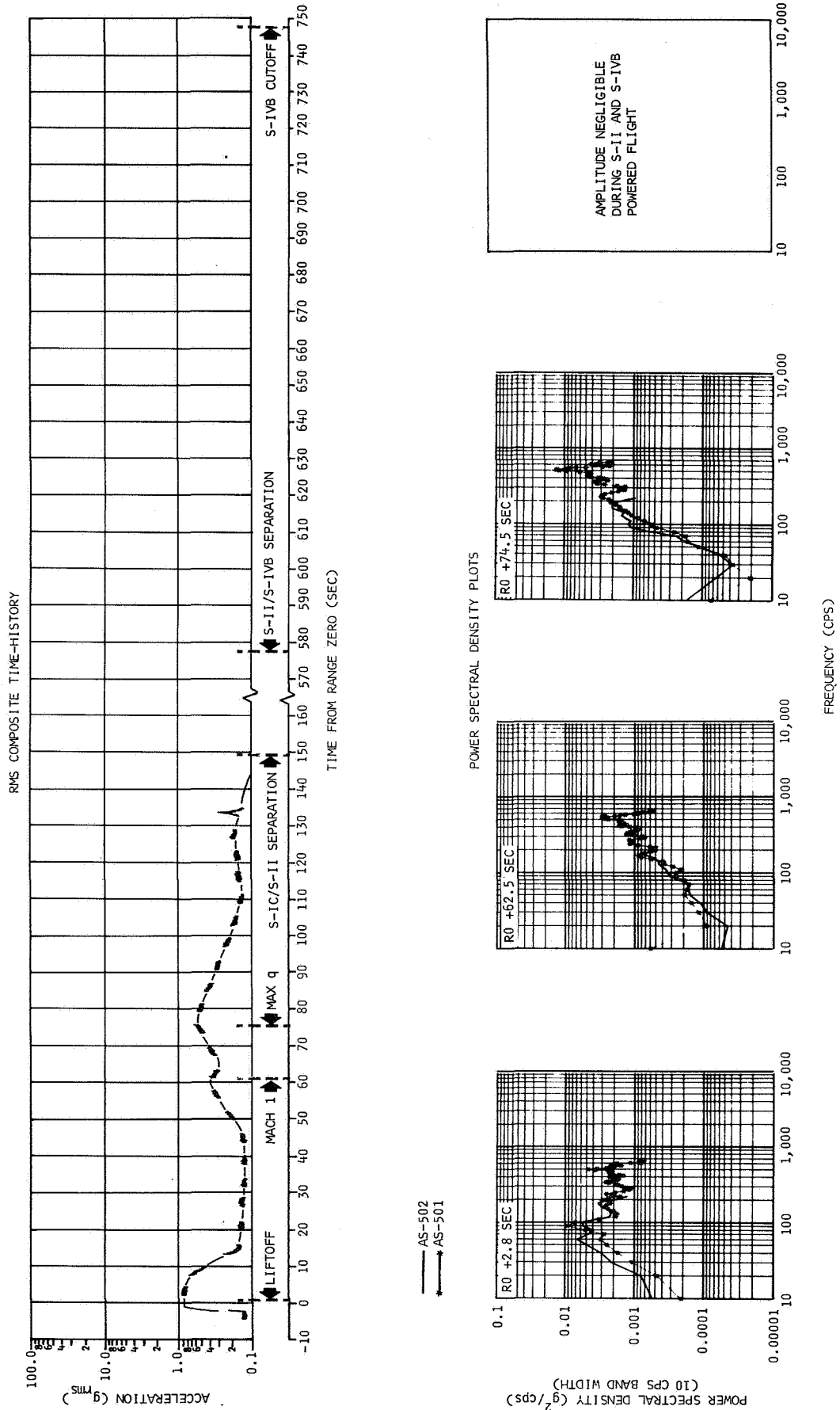
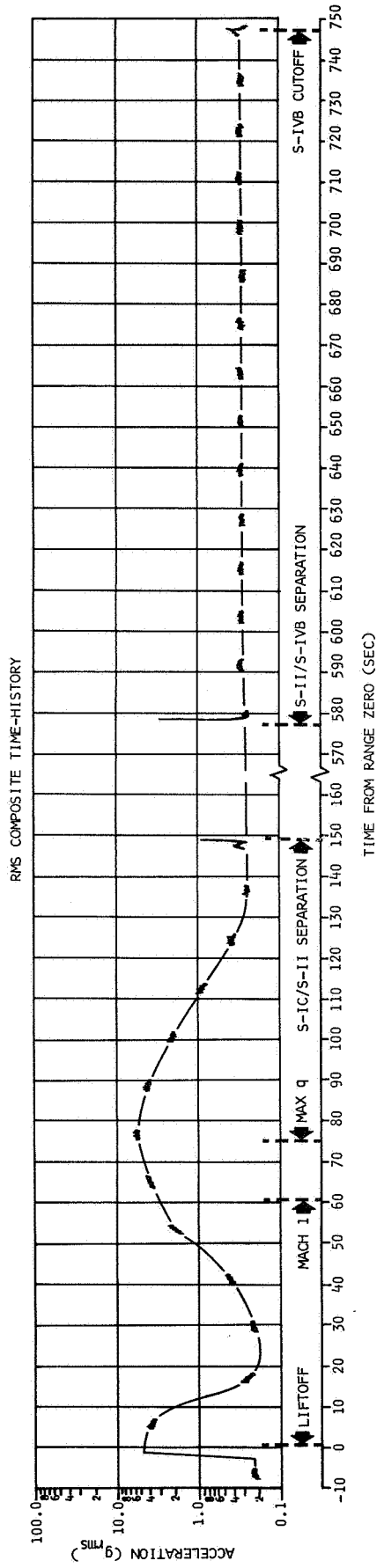


Figure 25-12. Vibration Measured on Separation Plane Position II, Thrust Direction - E0092-404



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

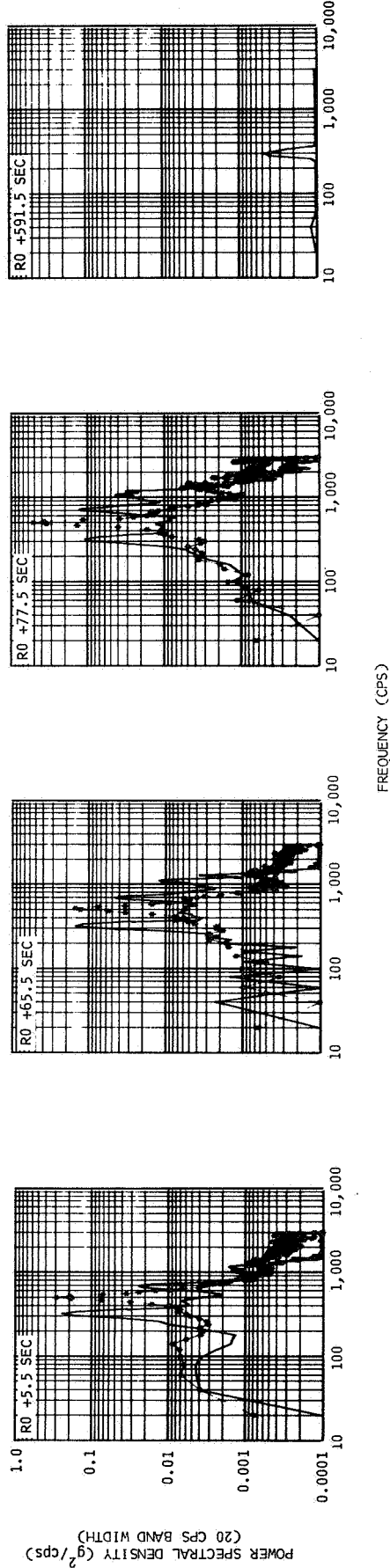
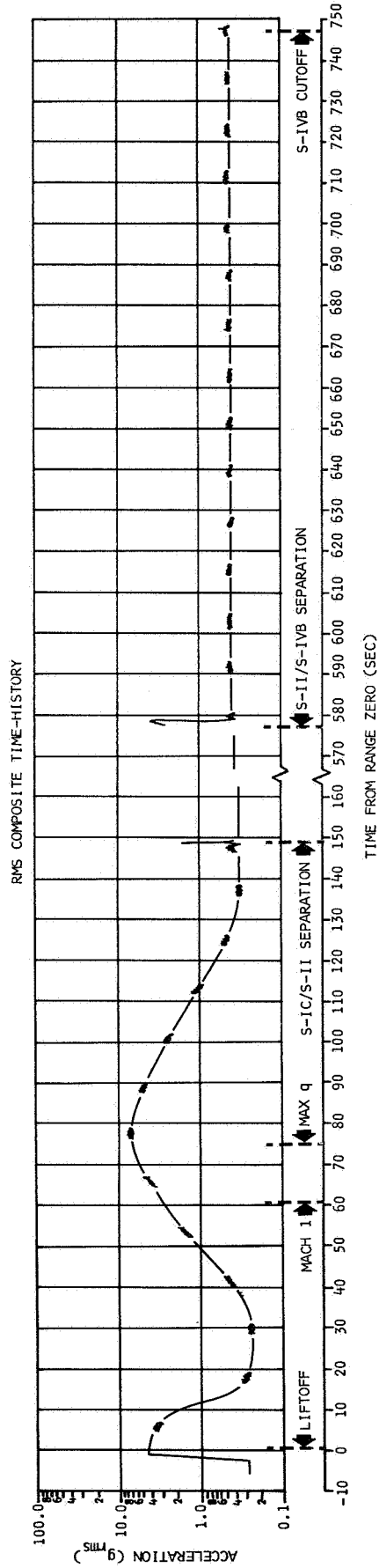


Figure 25-13. Vibration Measured at Input to Sequencer Panel, Thrust Direction - E0103-404



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

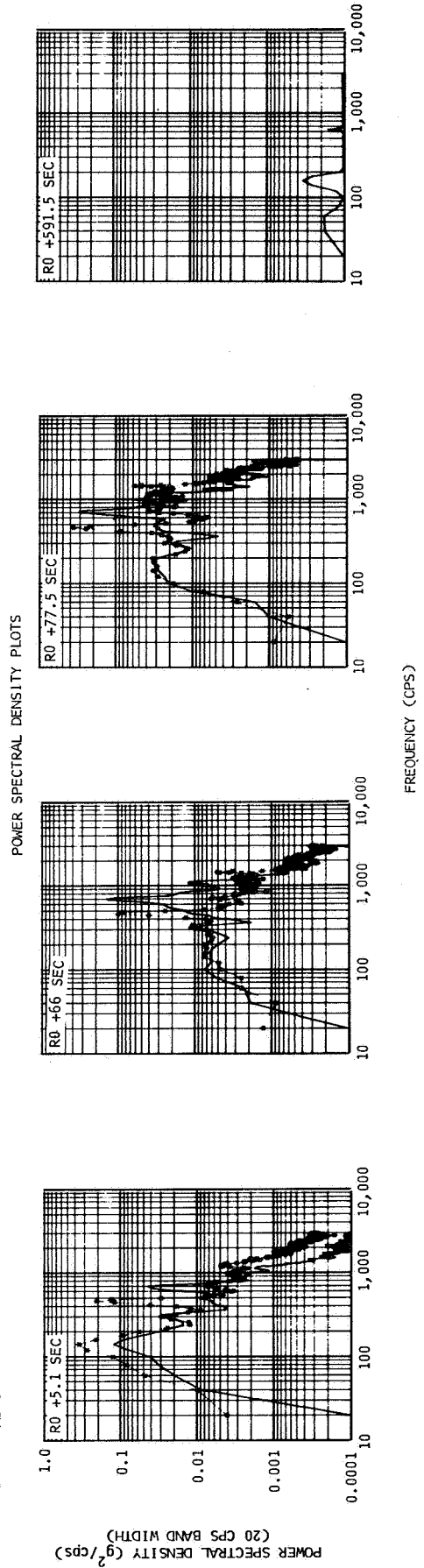


Figure 25-14. Vibration Measured at Input to Sequencer Panel, Radial Direction - E0105-404

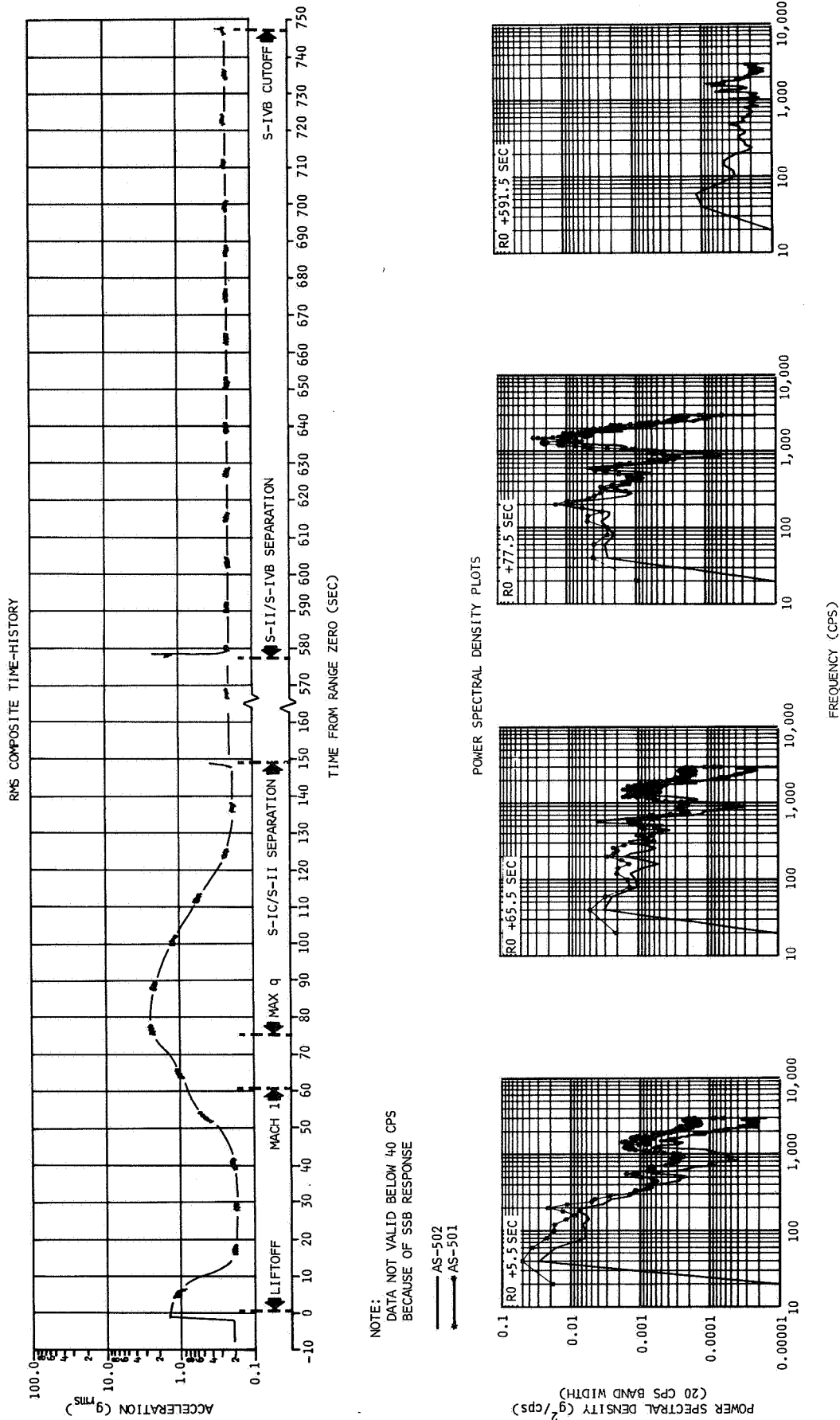
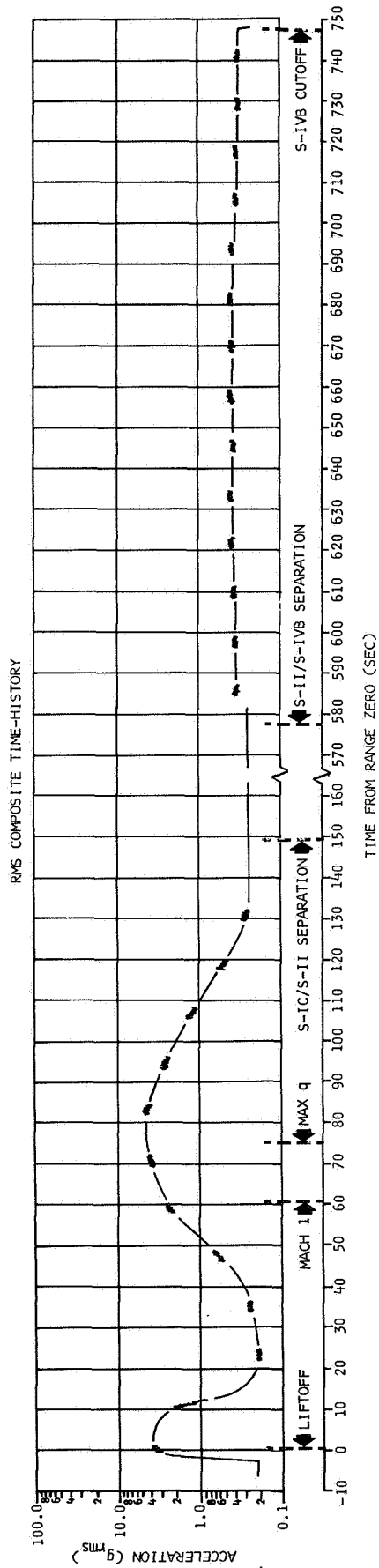


Figure 25-15. Vibration Measured at Input to Sequencer Assembly, Radial Direction - E0104-404



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

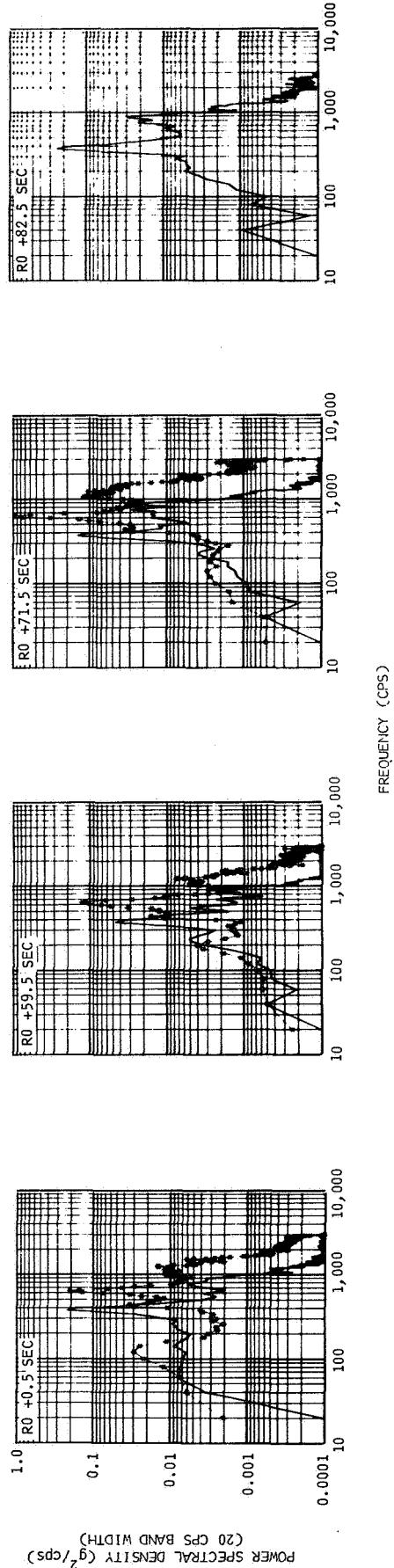


Figure 25-16. Vibration Measured at Input to Switch Selector Panel, Thrust Direction - E0106-404

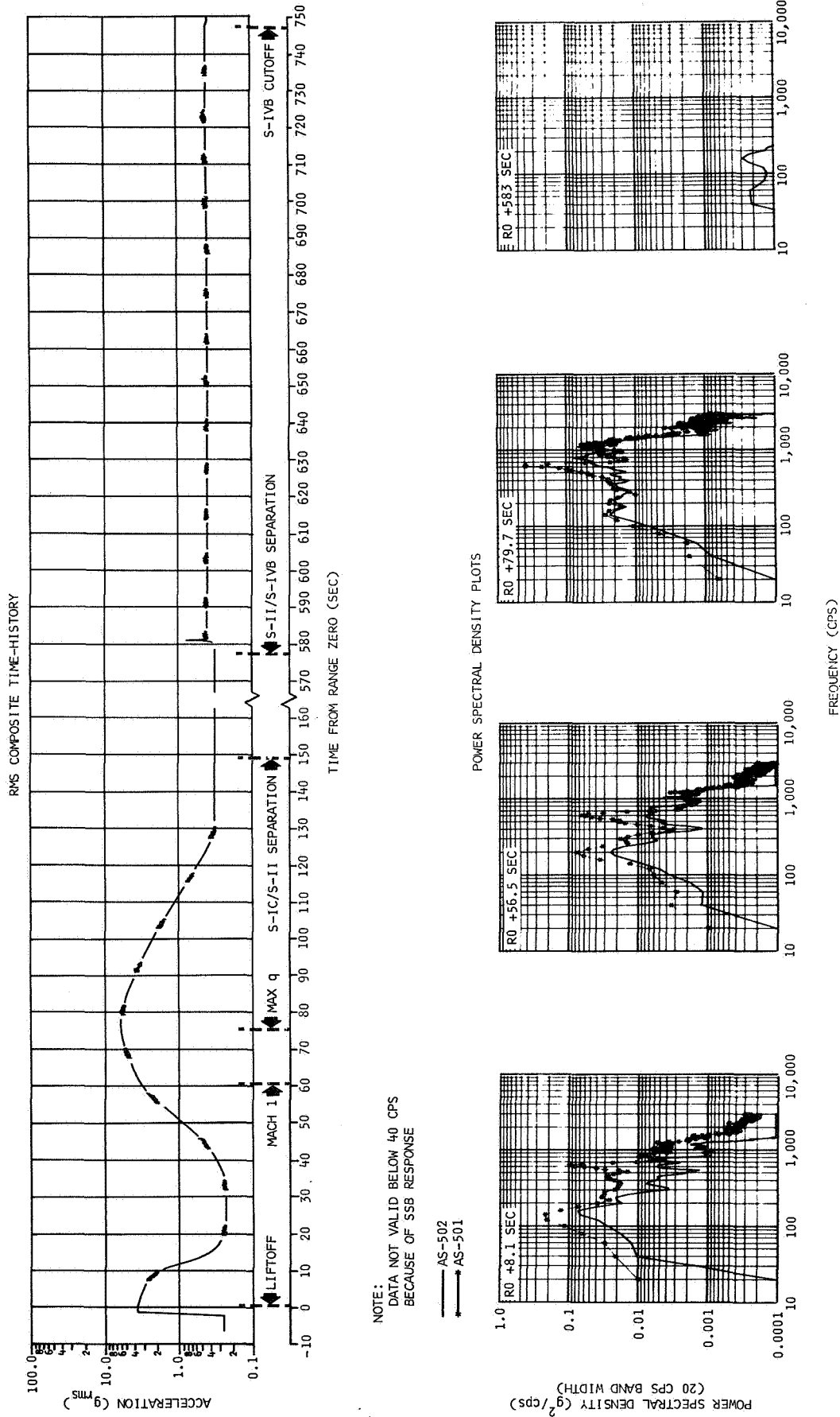
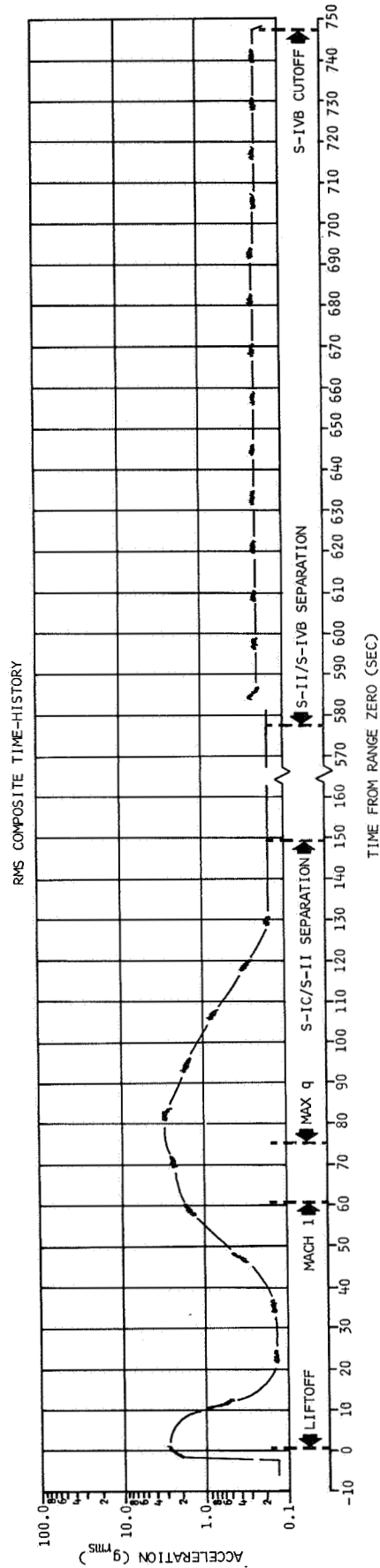


Figure 25-17. Vibration Measured at Input to Switch Selector Panel, Radial Direction - E0108-404



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

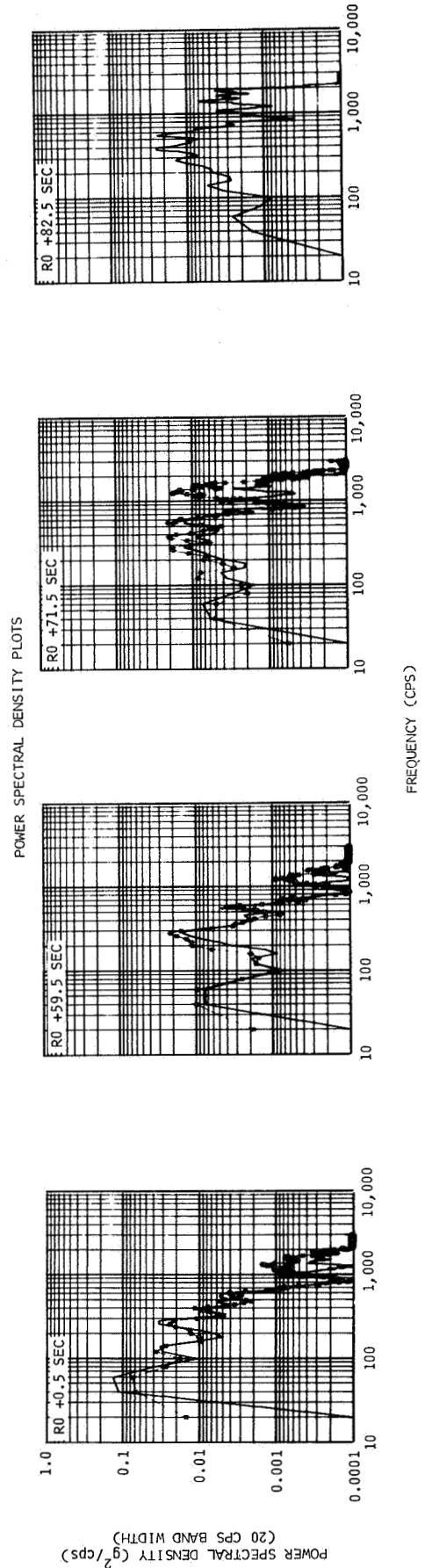
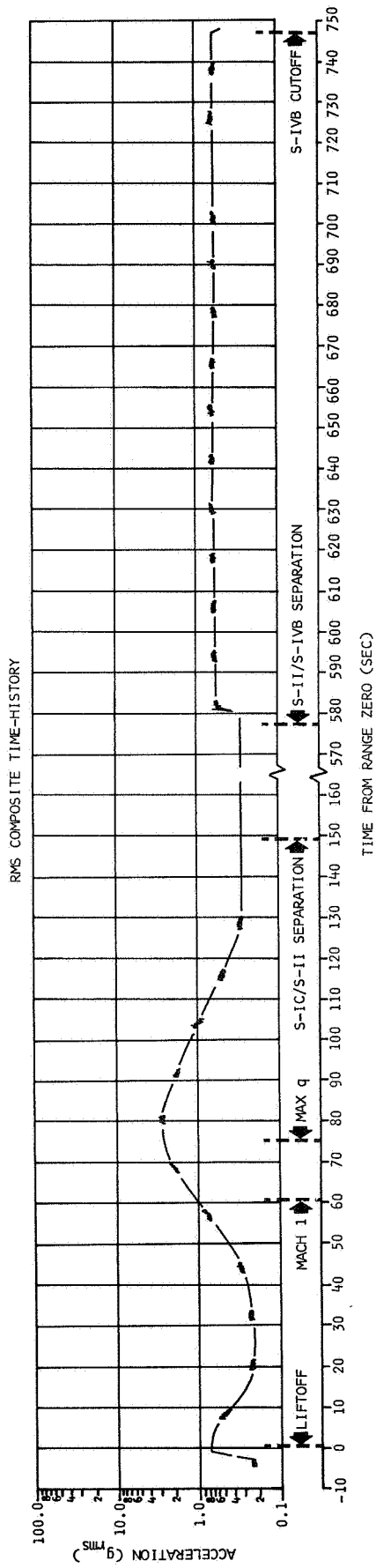


Figure 25-18. Vibration Measured at Input to Switch Selector Unit, Radial Direction - E0107-404



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

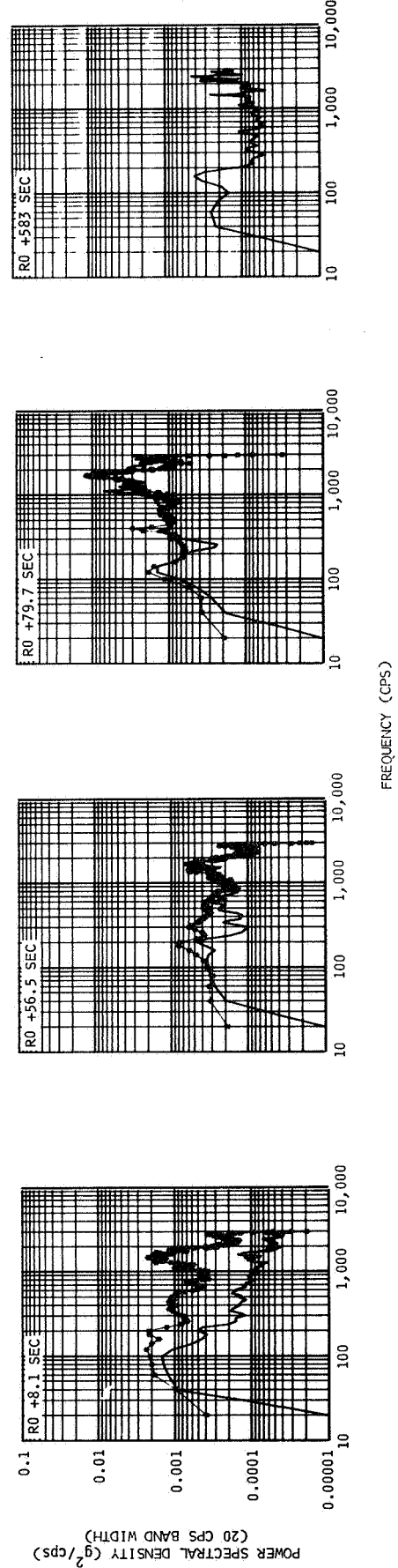
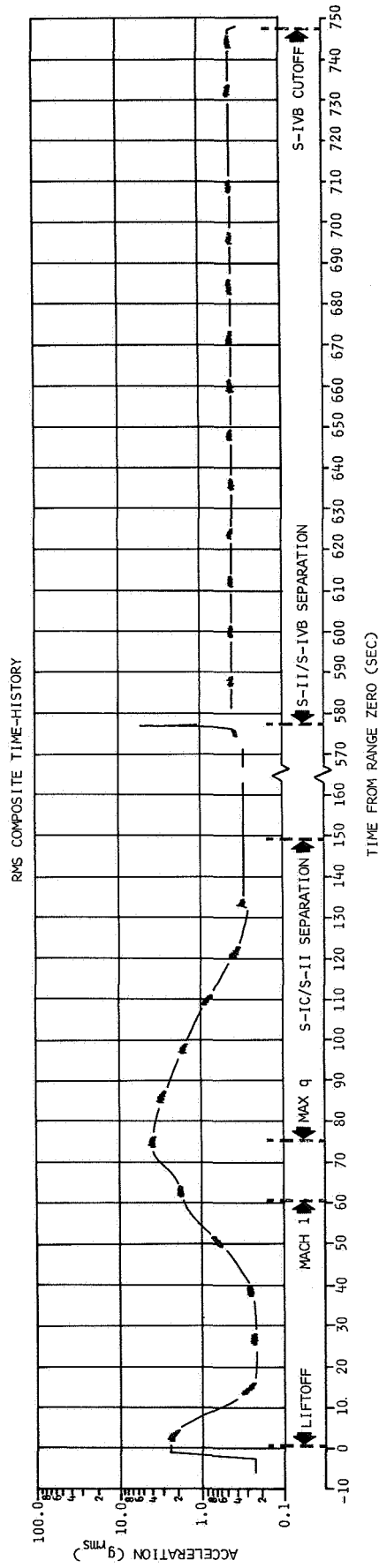


Figure 25-19. Vibration Measured at Aft Attach Point of APS Module 1, Thrust Direction - E0118-427



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

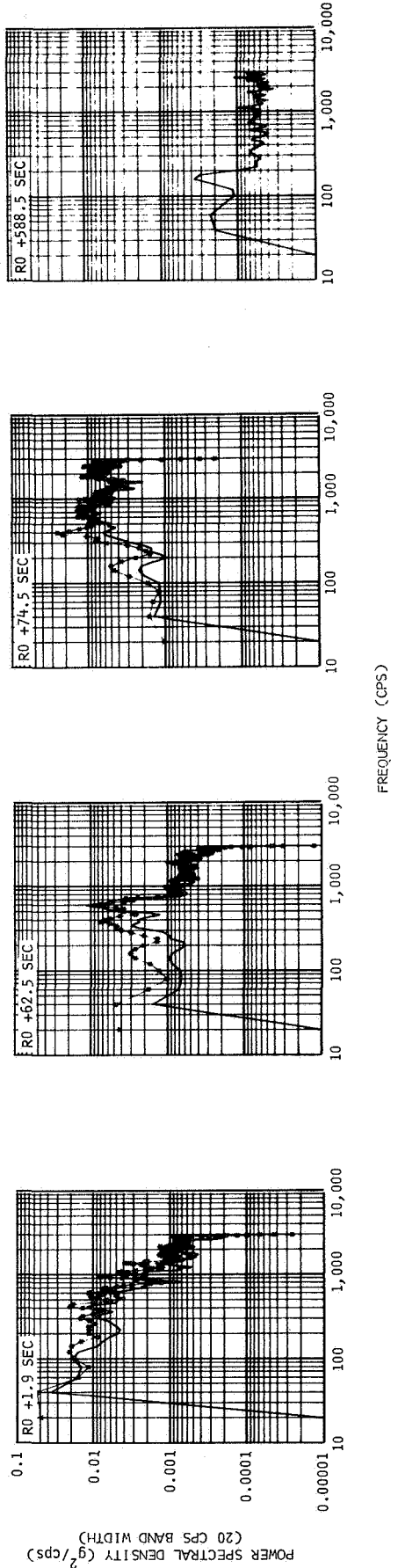
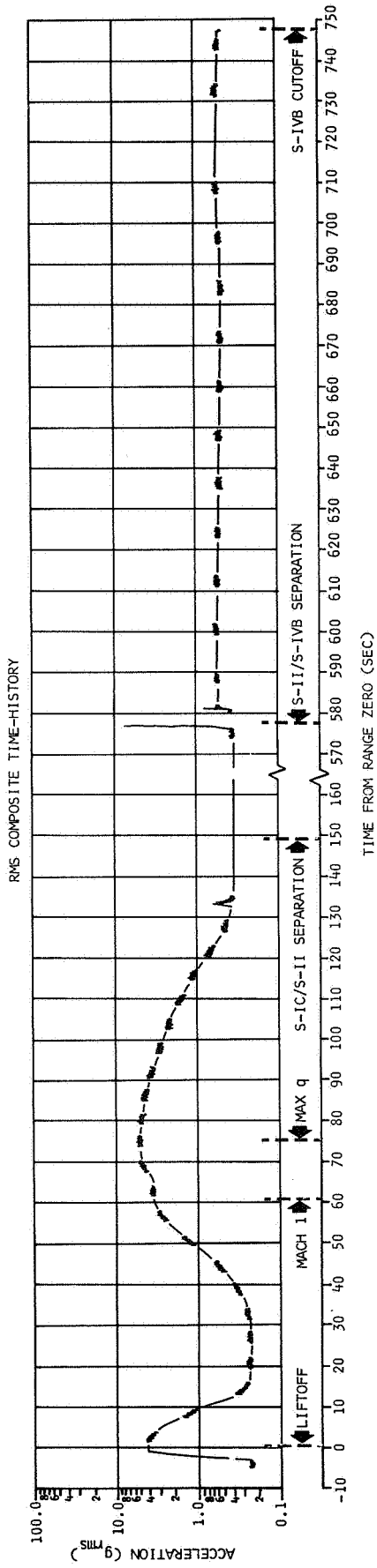


Figure 25-20. Vibration Measured at Aft Attach Point of APS Module 1, Radial Direction - E0119-427



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

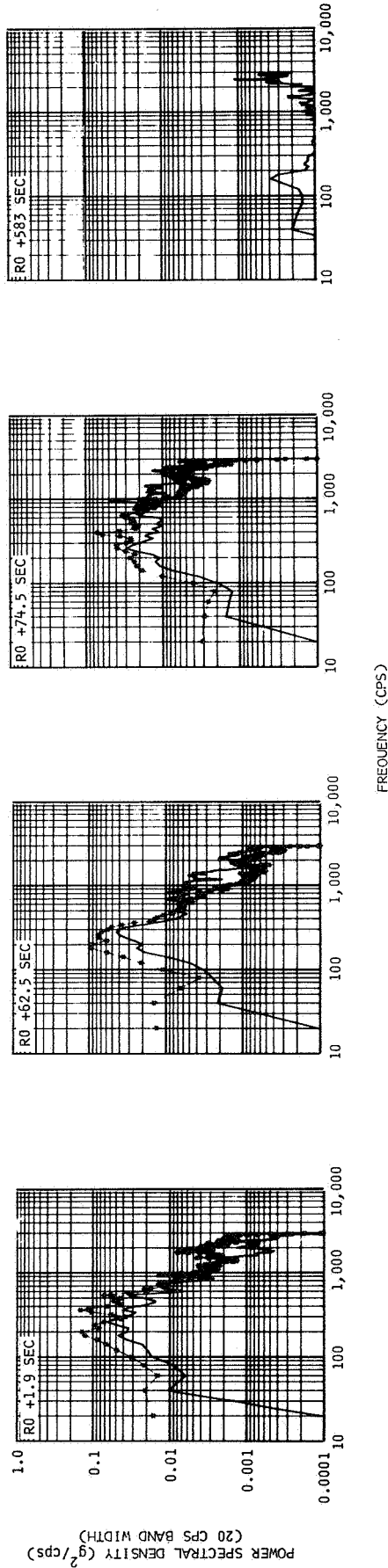
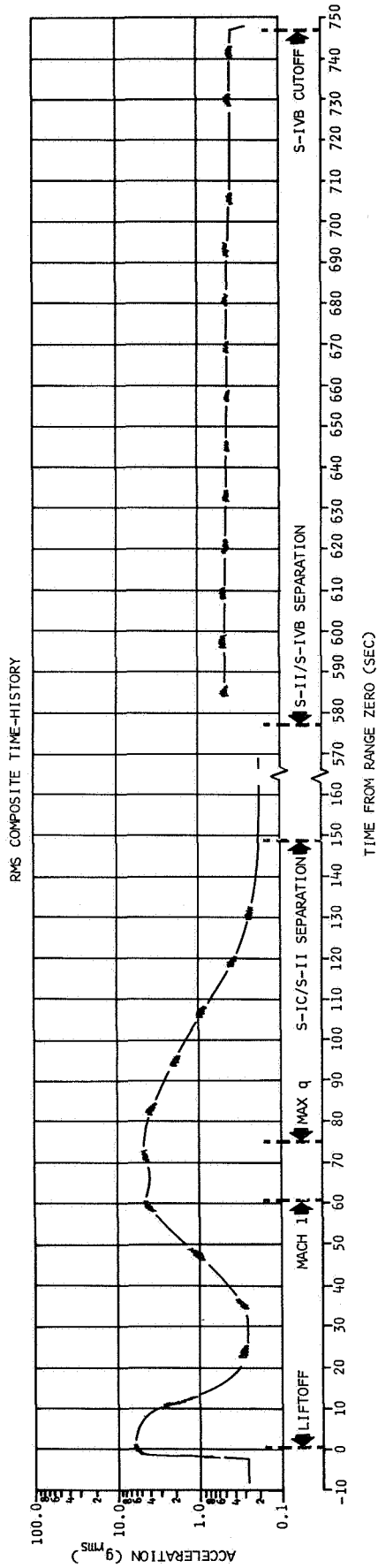


Figure 25-21. Vibration Measured at Forward Attach Point of APS Module 1, Radial Direction - E0120-427



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

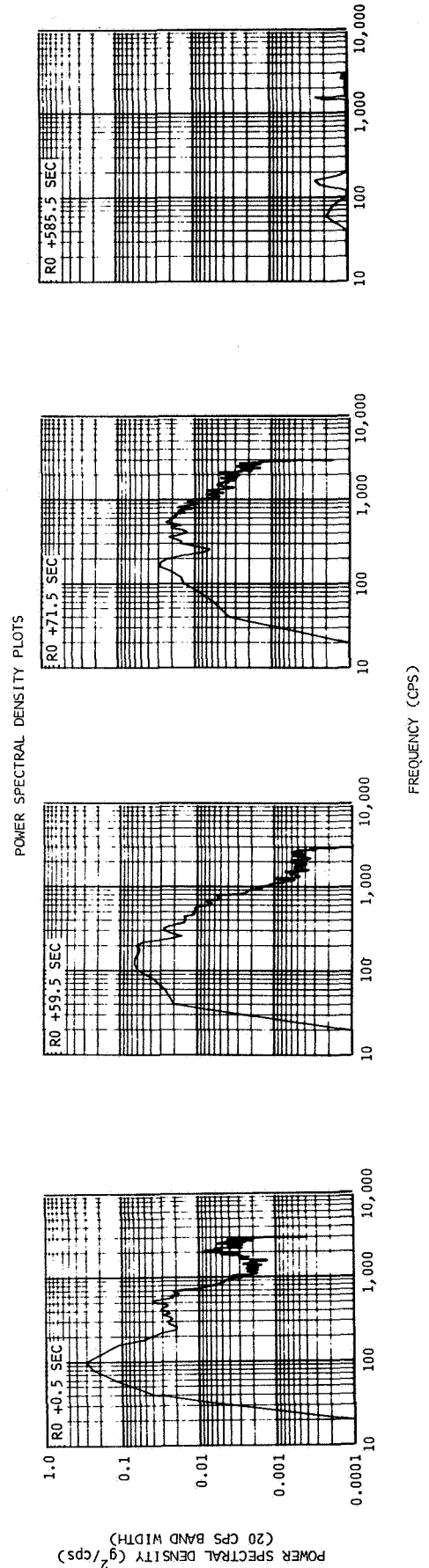


Figure 25-22. Vibration Measured at Input to LH2 PU Probe, Radial Direction - E0062-409

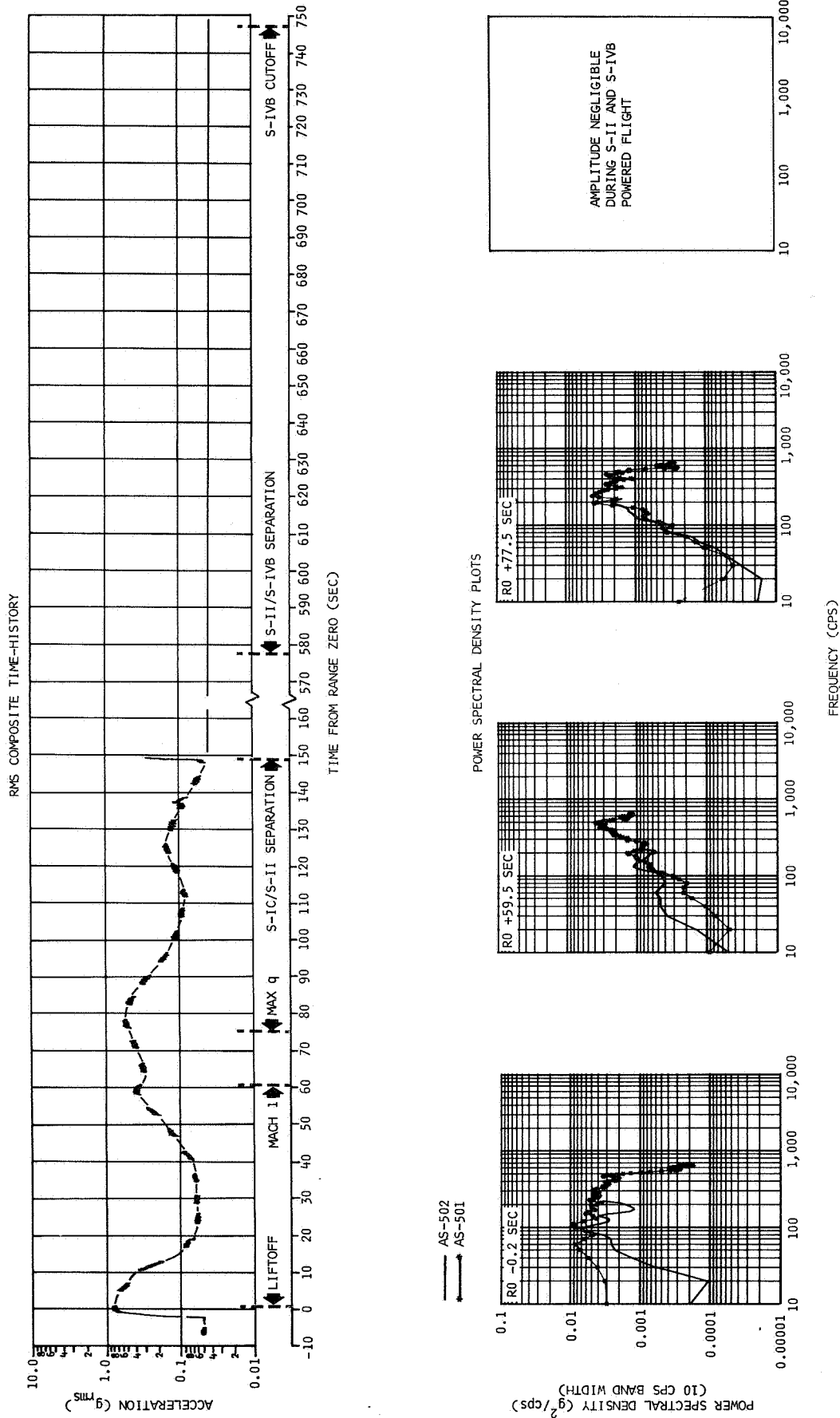
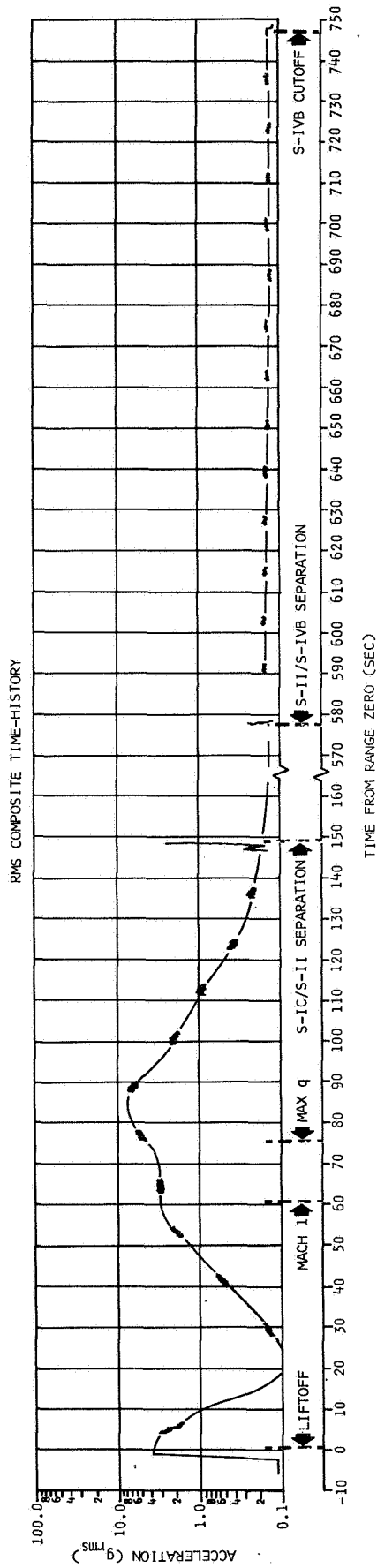


Figure 25-23. Low Frequency Vibration Measured on Field Splice Position I, Thrust Direction - E0091-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

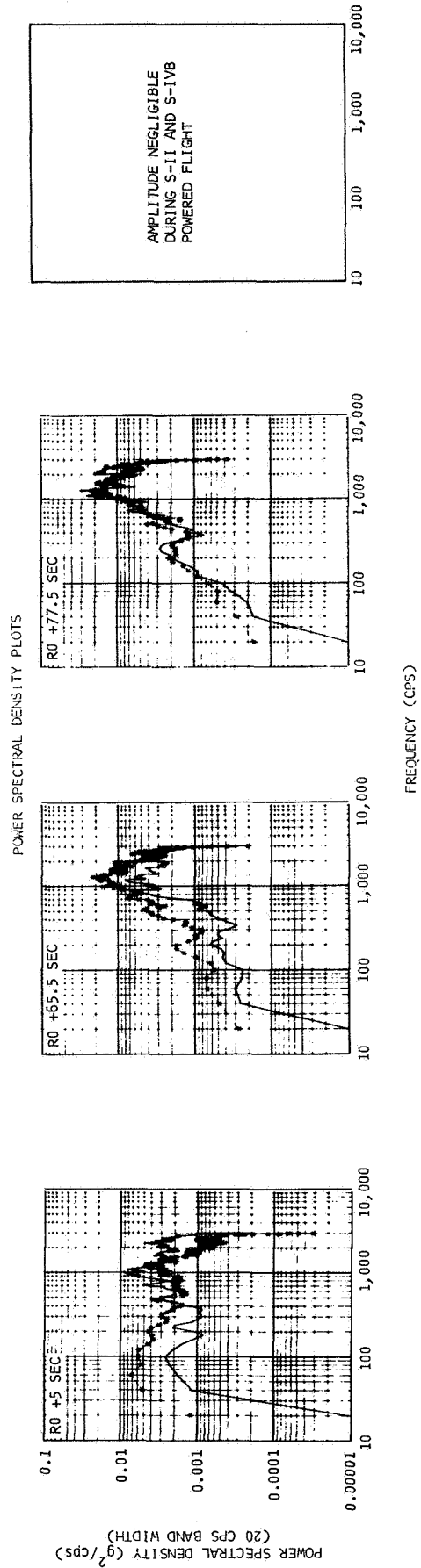


Figure 25-24. Vibration Measured on Field Splice Position I, Thrust Direction - E0093-411

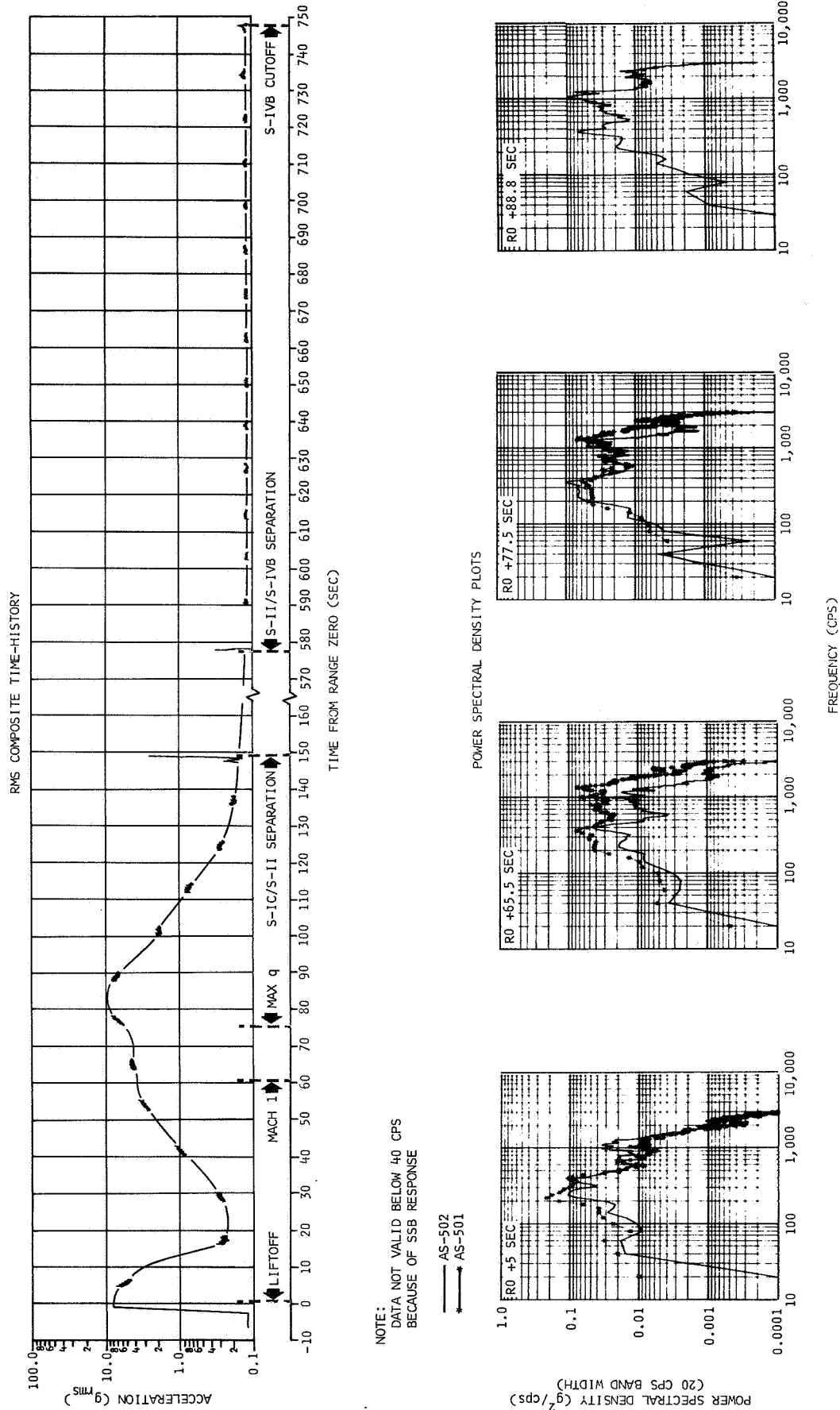
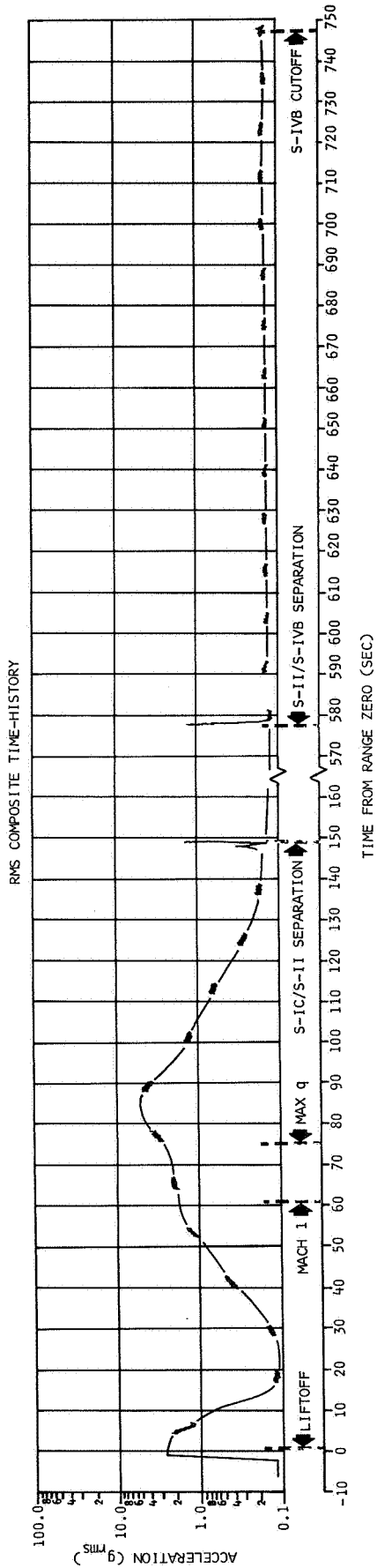


Figure 25-25. Vibration Measured on Field Splice Position I, Radial Direction - E0094-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

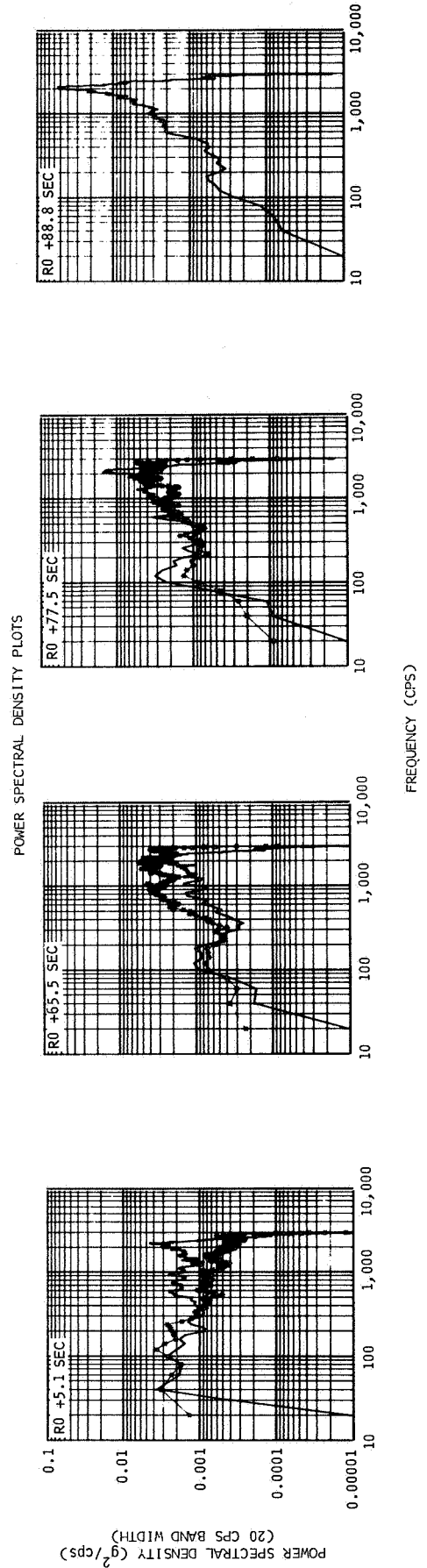


Figure 25-26. Vibration Measured on Field Splice Position I, Tangential Direction - E0095-411

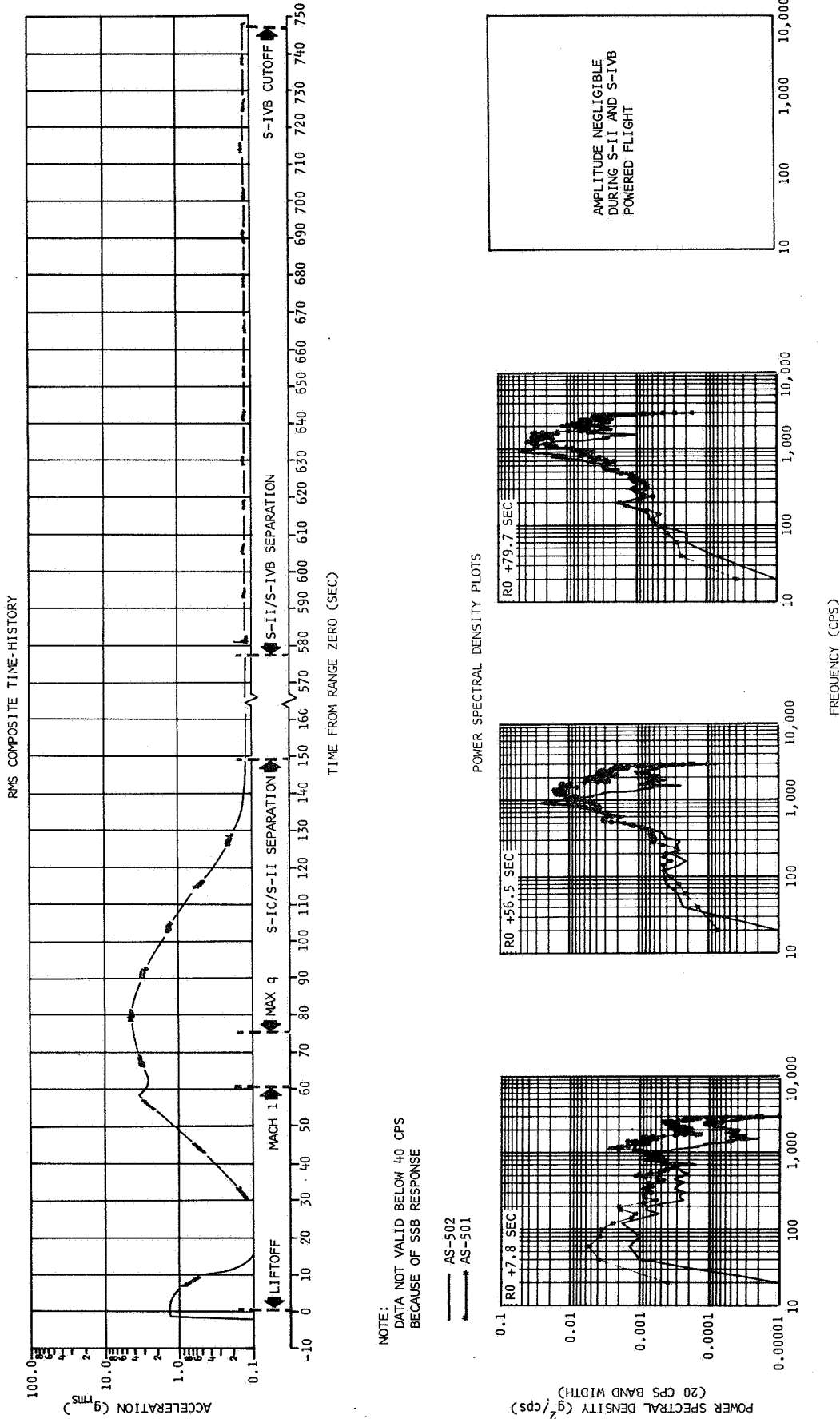
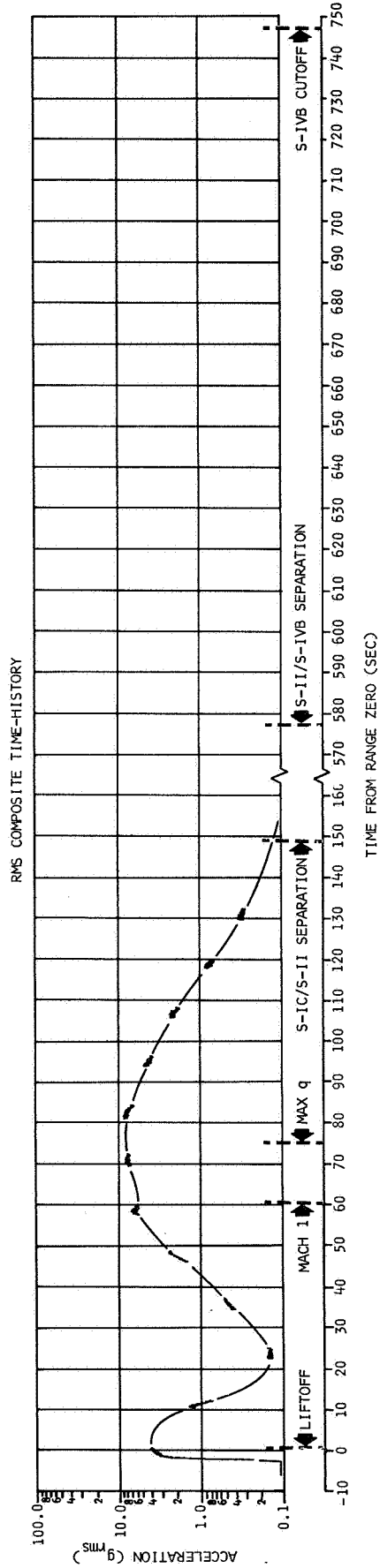


Figure 25-27. Vibration Measured on Field Splice Position II, Thrust Direction - E0096-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

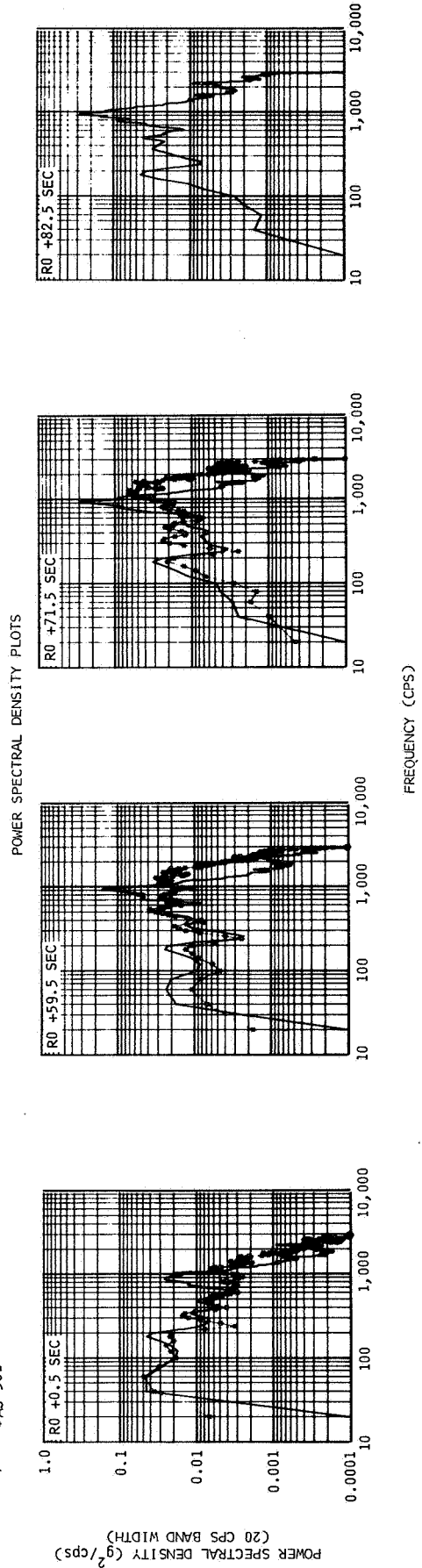
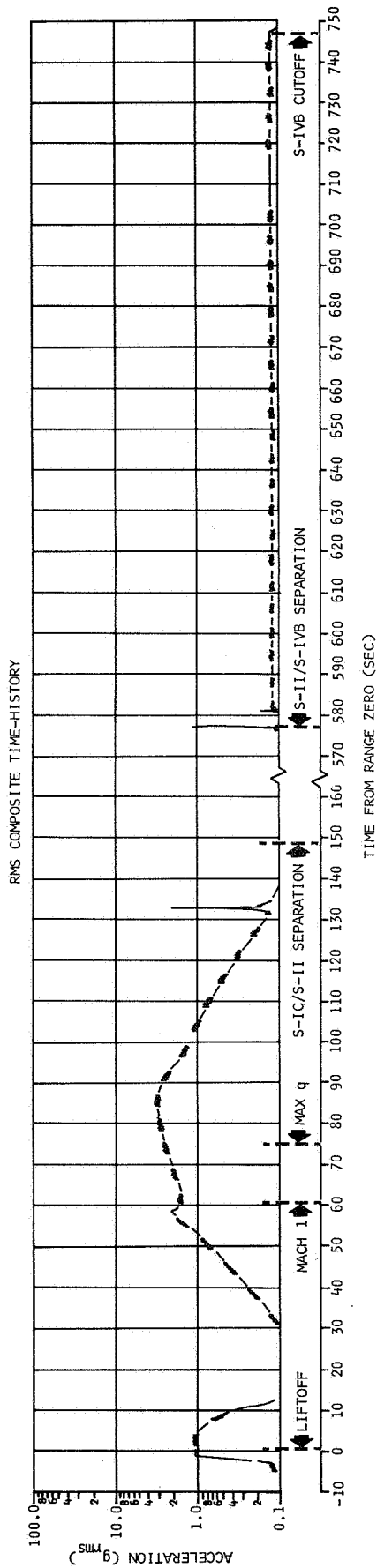


Figure 25-28. Vibration Measured on Field Splice Position II, Radial Direction - E0098-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

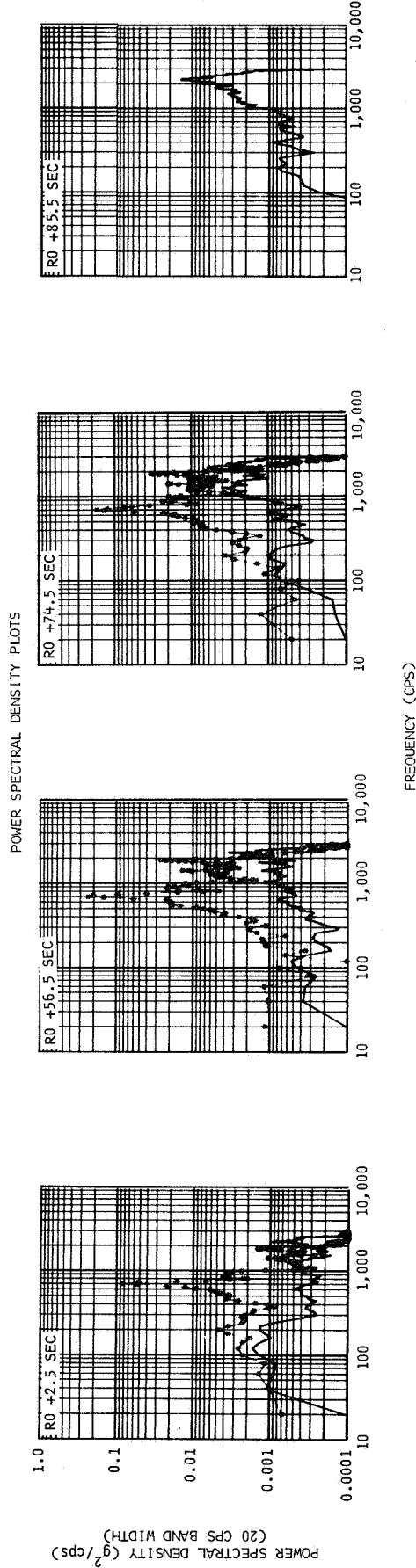
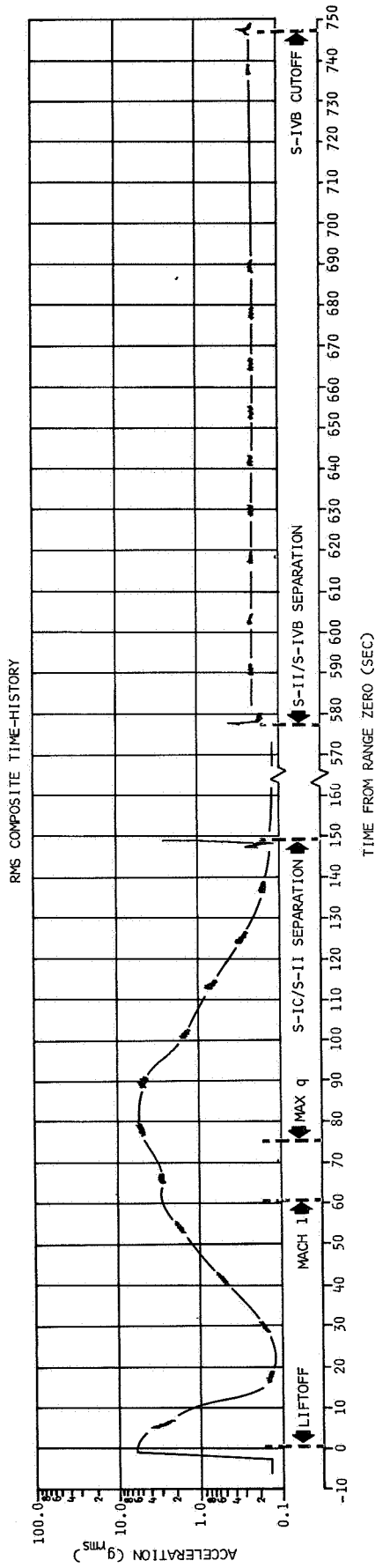


Figure 25-29. Vibration Measured on Field Splice Position II, Tangential Direction - E0097-411



NOTE:
DATA NOT VALID BELOW 40 CFS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

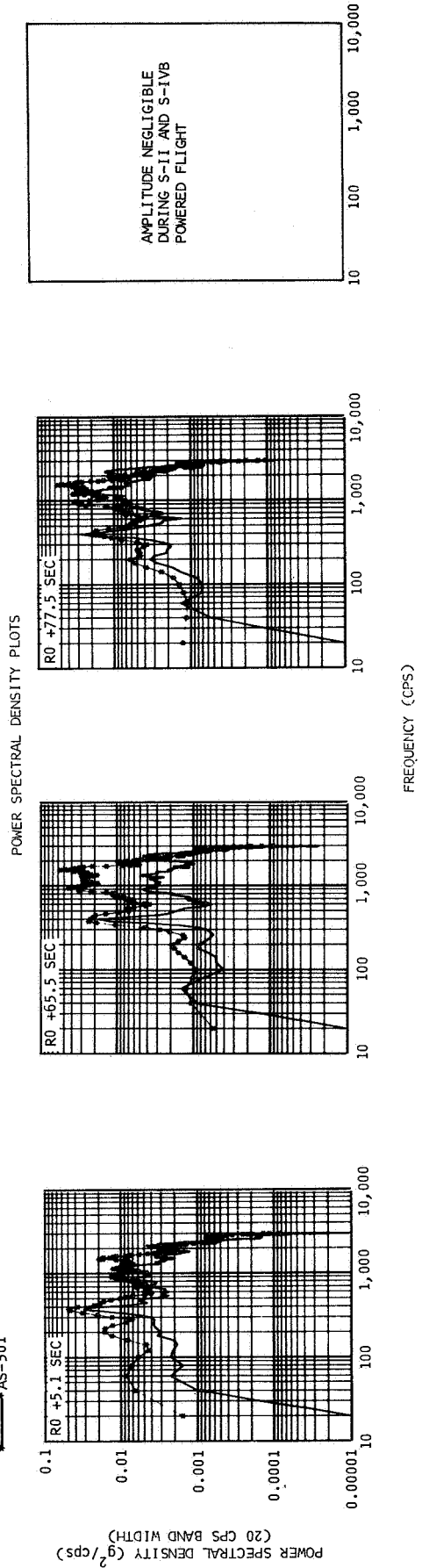
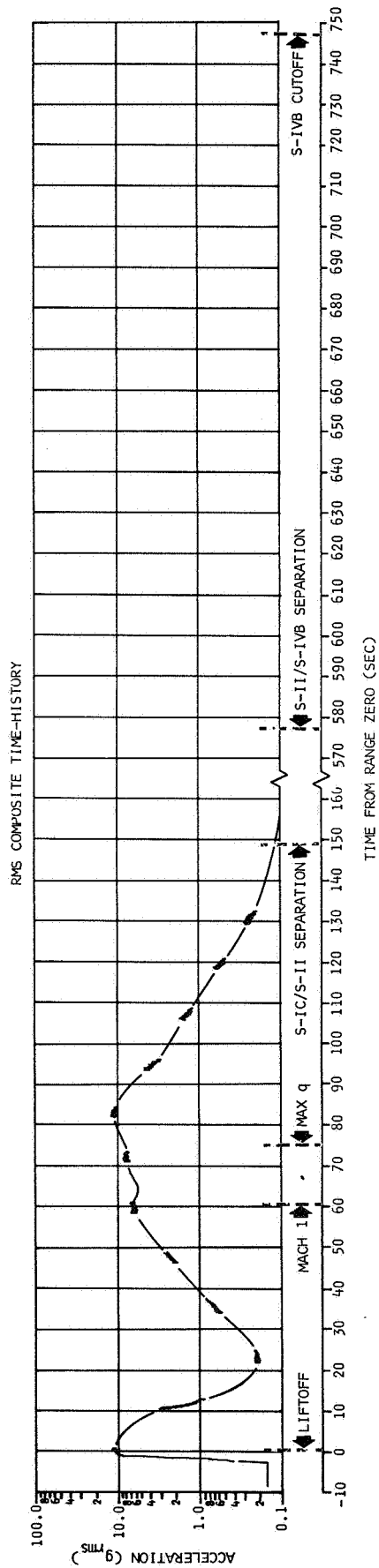


Figure 25-30. Vibration Measured at Input to PU Electronic Panel, Thrust Direction - E0109-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

— AS-502
* AS-501

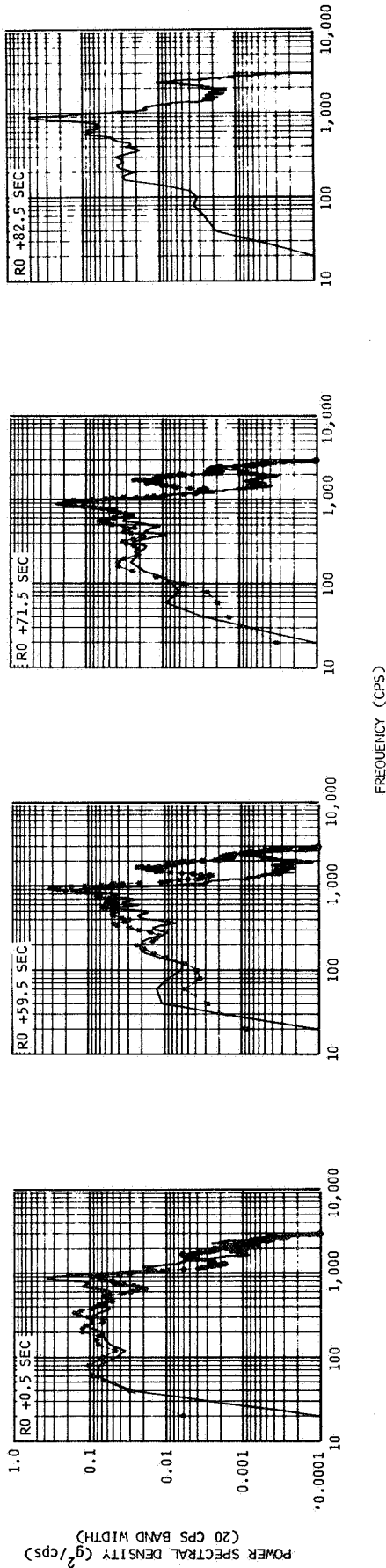
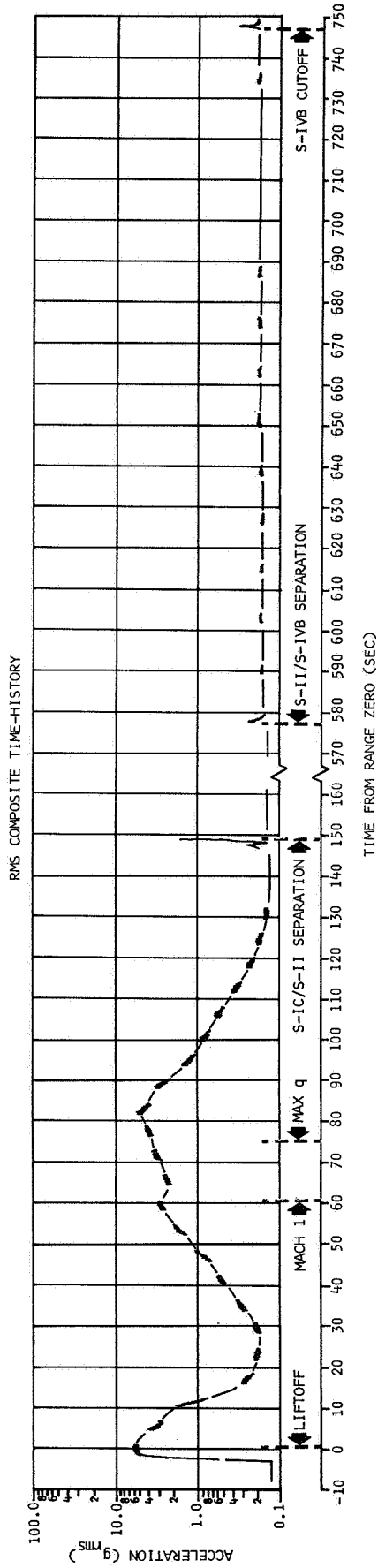


Figure 25-31. Vibration Measured at Input to PU Electronic Panel, Radial Direction - E0111-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

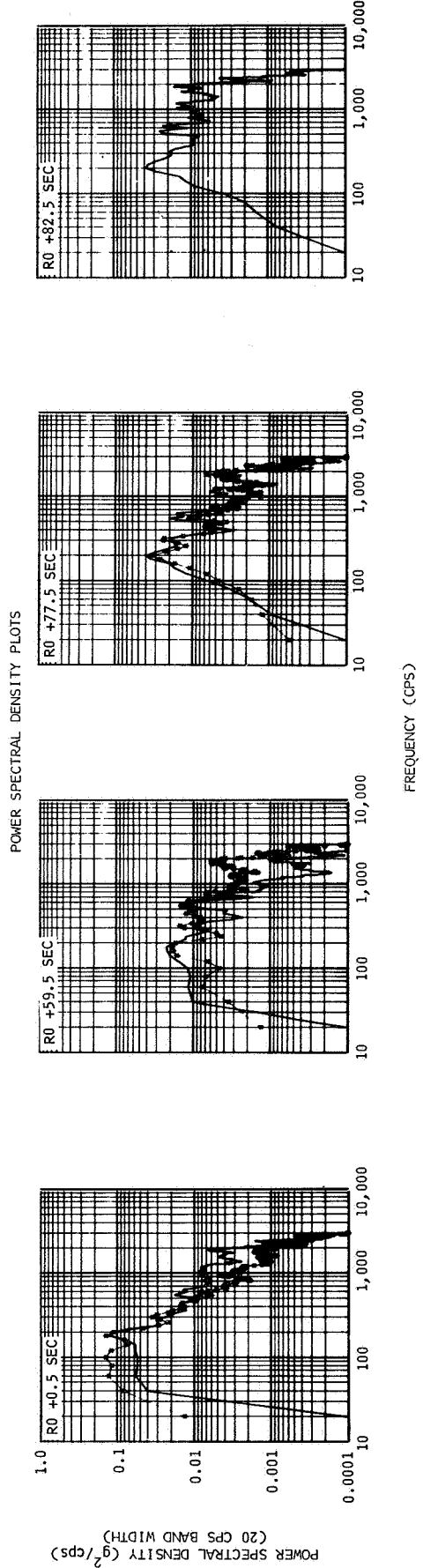
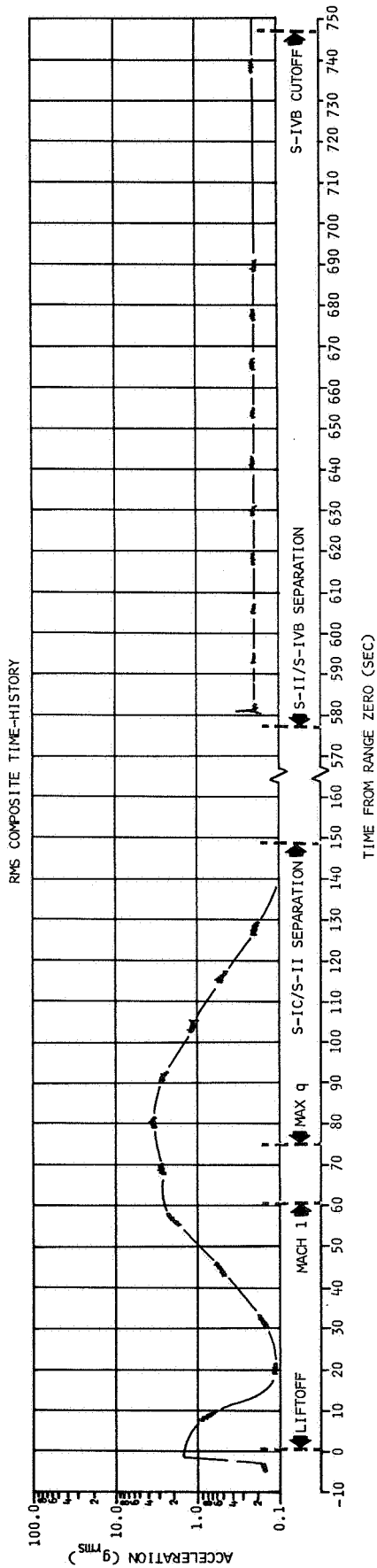


Figure 25-32. Vibration Measured at Input to PU Electronic Assembly, Radial Direction - E0110-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

— AS-502
— AS-501

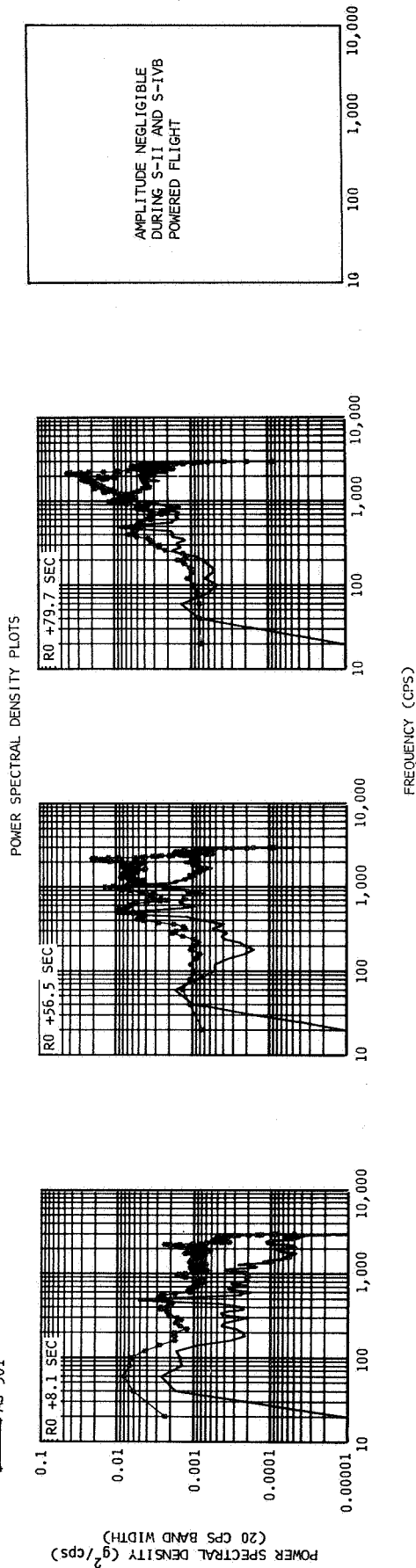
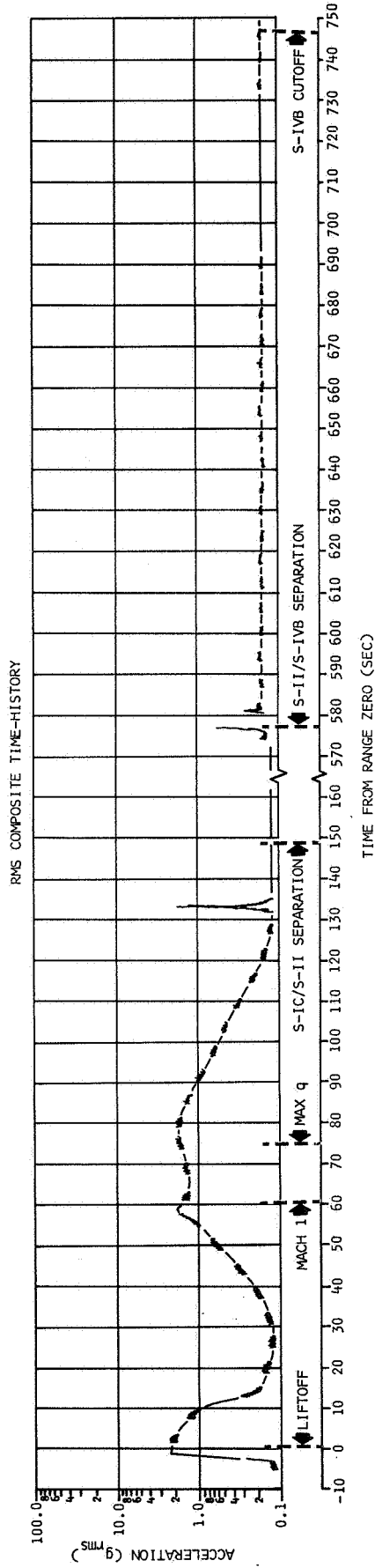


Figure 25-33. Vibration Measured at Input to EBW Range Safety Panel, Thrust Direction - E0112-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

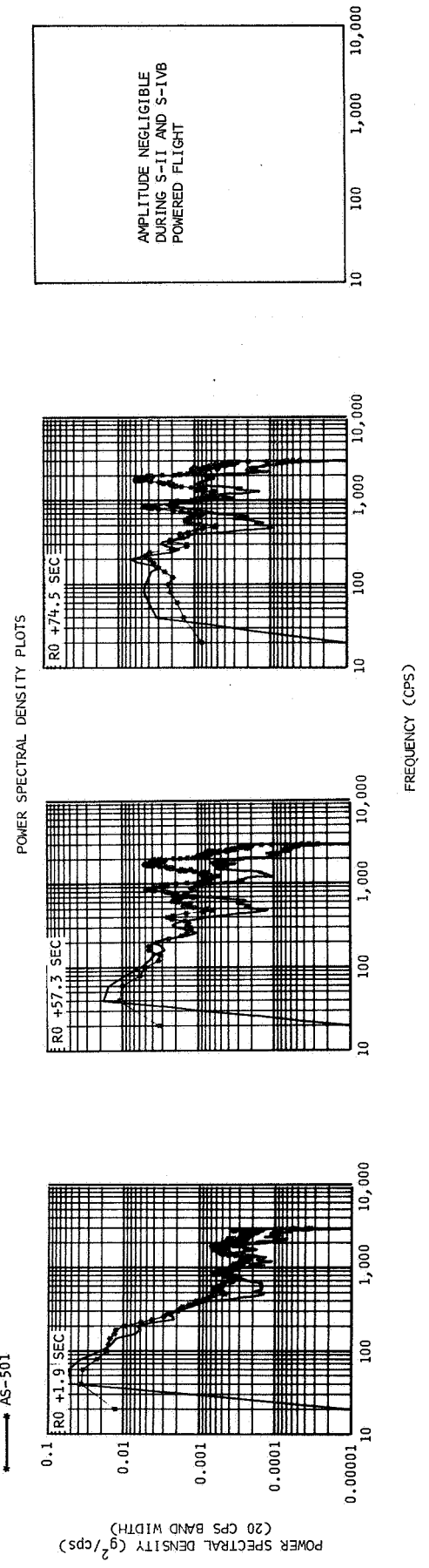


Figure 25-34. Vibration Measured at Input to EBW Range Safety Unit, Radial Direction - E0113-411

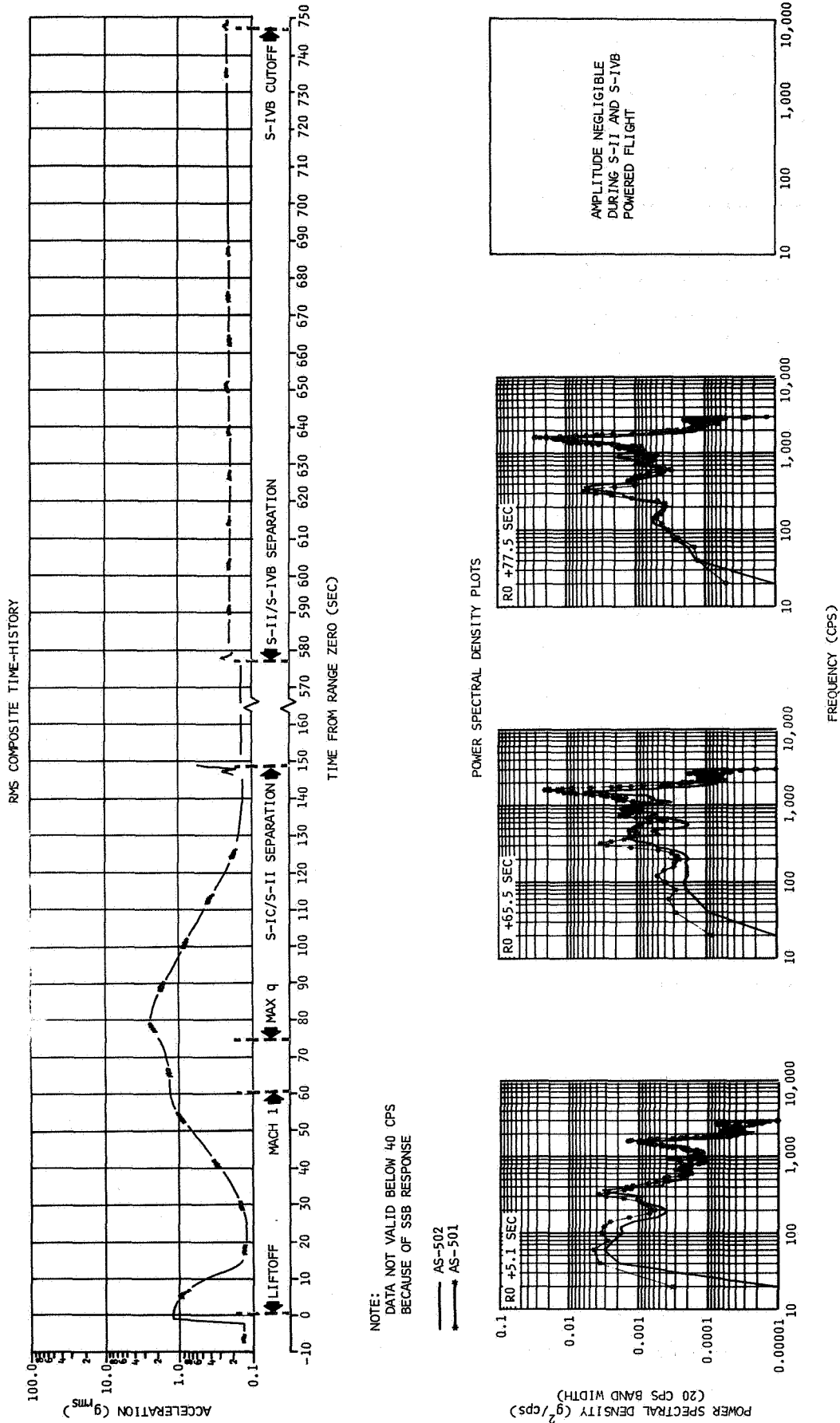
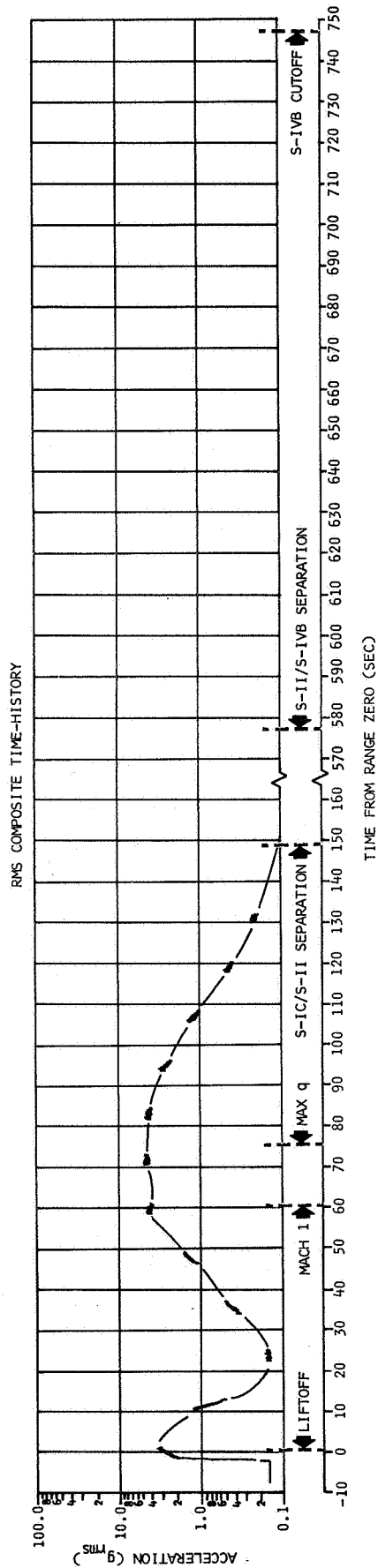


Figure 25-35. Vibration Measured at Input to Forward Skirt Battery No. 1, Thrust Direction - E0115-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

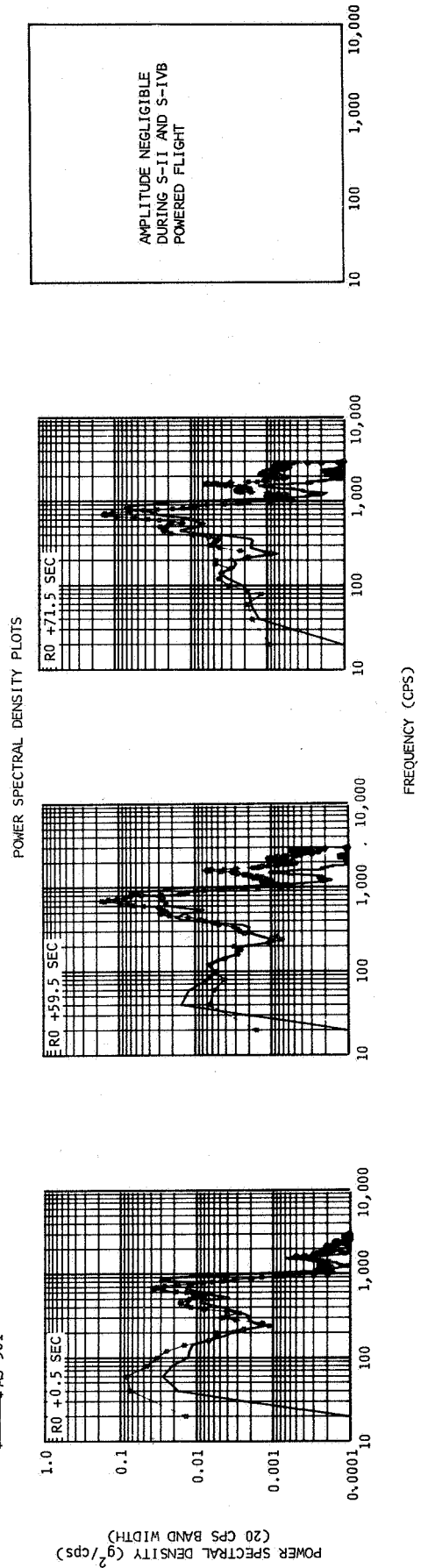
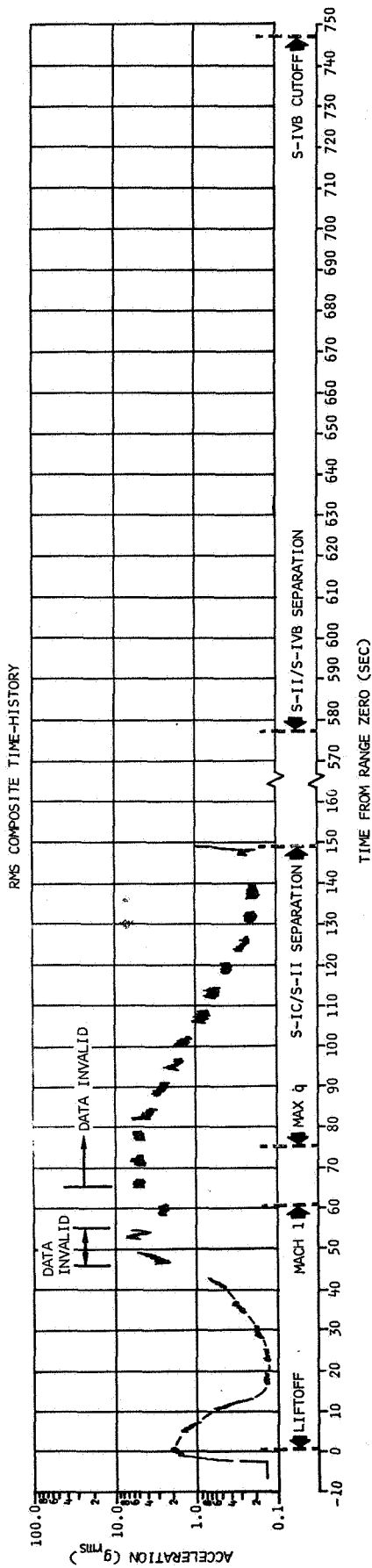


Figure 25-36. Vibration Measured at Input to Forward Skirt Battery No. 1, Radial Direction - E0116-411



NOTE:
DATA NOT VALID BELOW 40 CPS
BECAUSE OF SSB RESPONSE

— AS-502
— AS-501

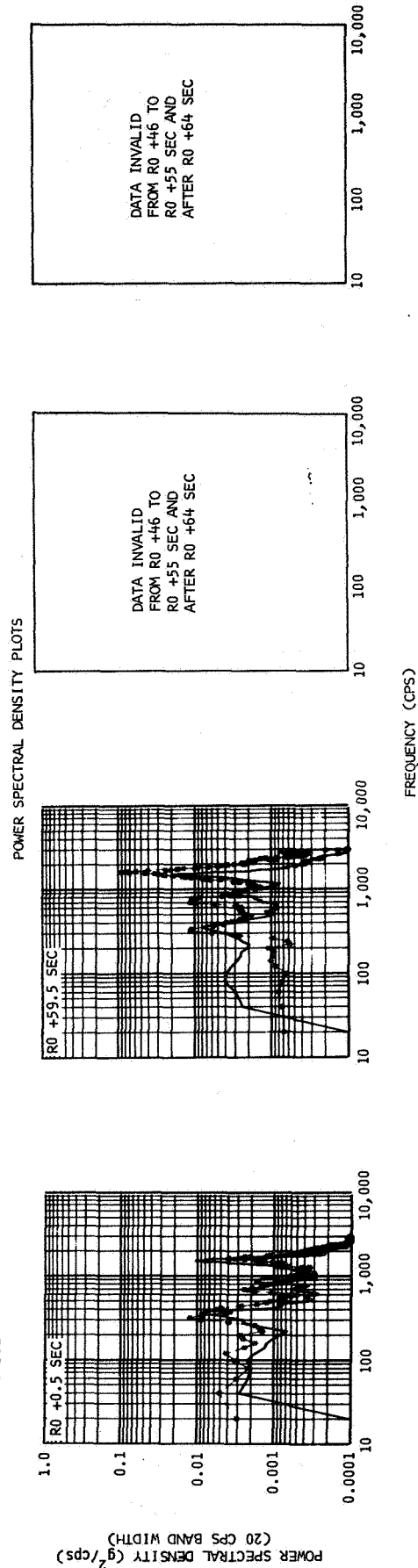
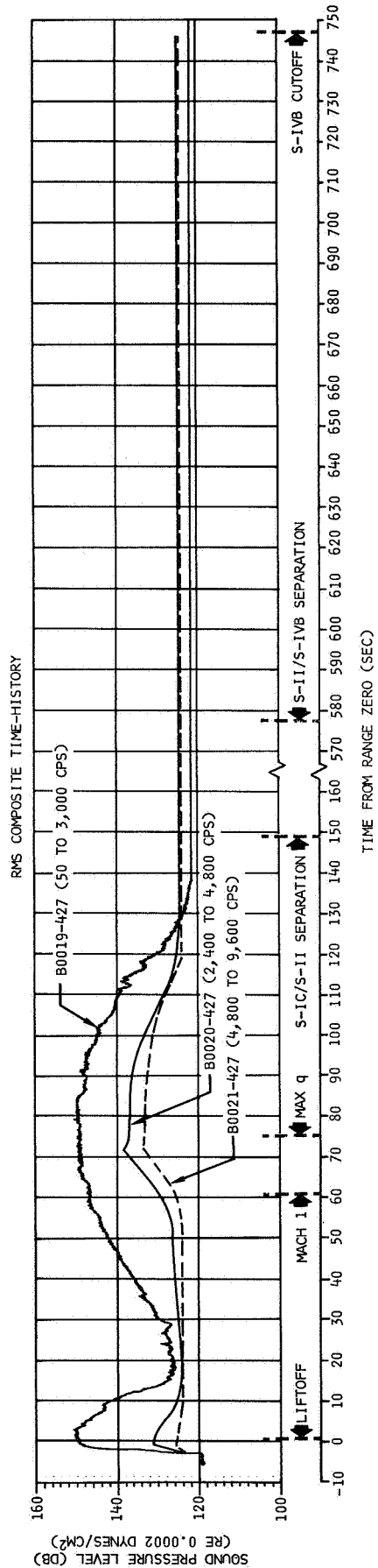


Figure 25-37. Vibration Measured at Input to Forward Skirt Battery No. 1, Tangential Direction - E0117-411



NOTE:
DATA NOT VALID BELOW 30 CPS
BECAUSE OF SSB RESPONSE

AS-502
AS-501

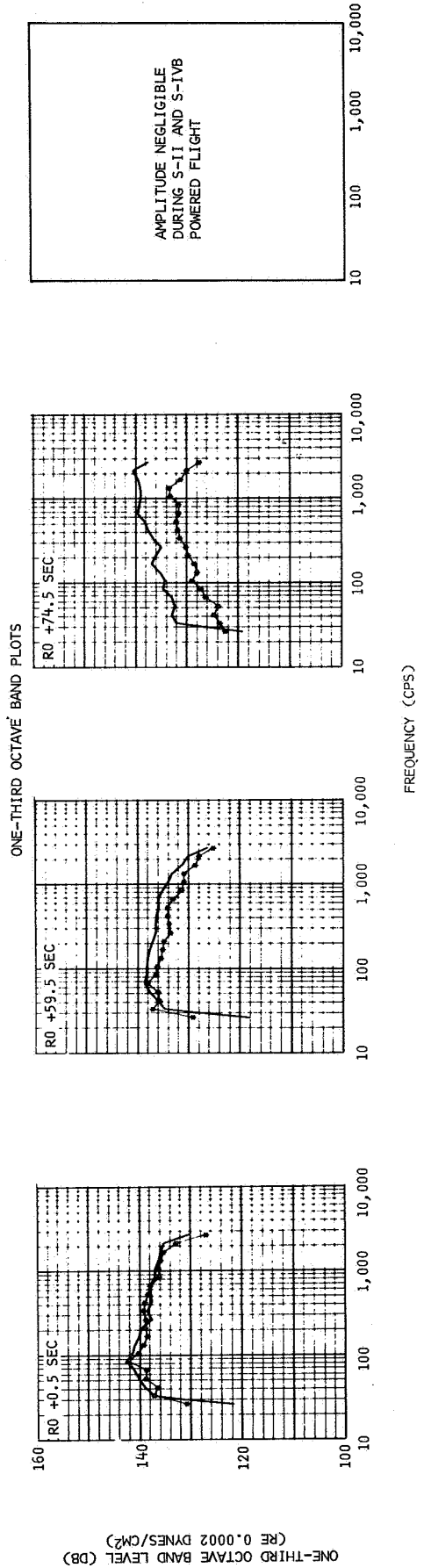


Figure 25-38. External Sound Pressure Levels Measured on Aft Skirt

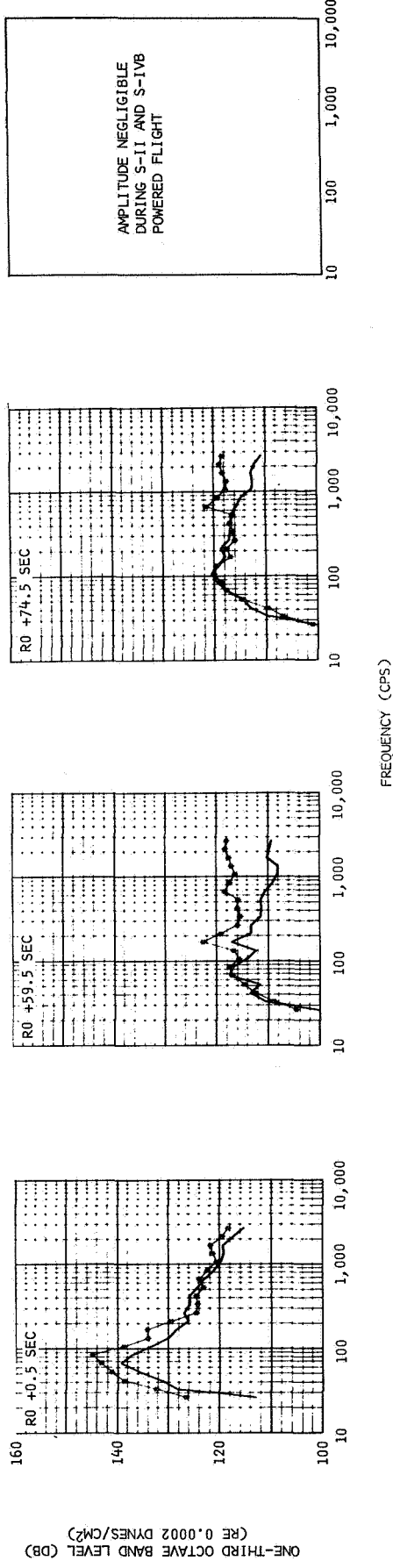
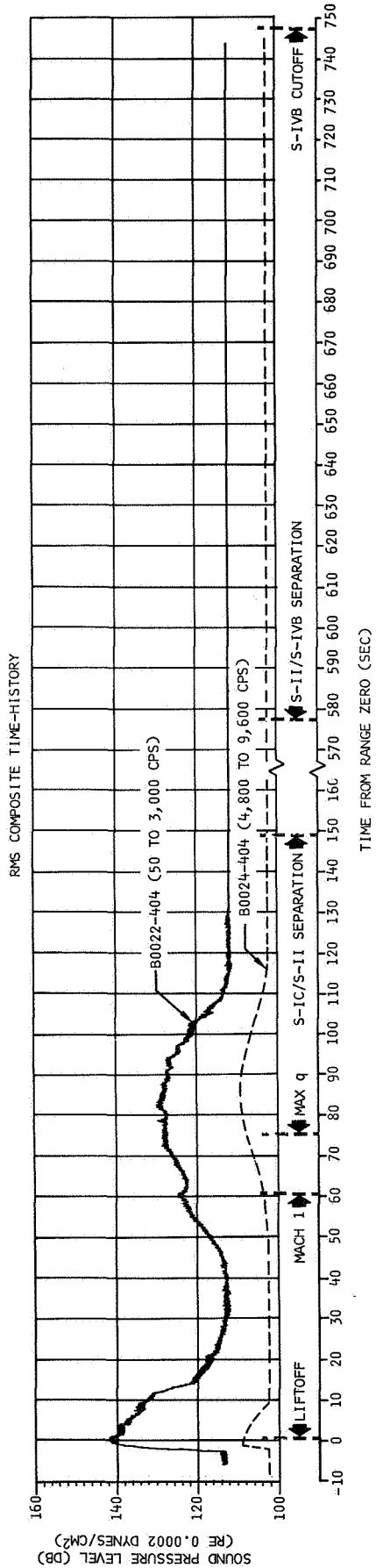
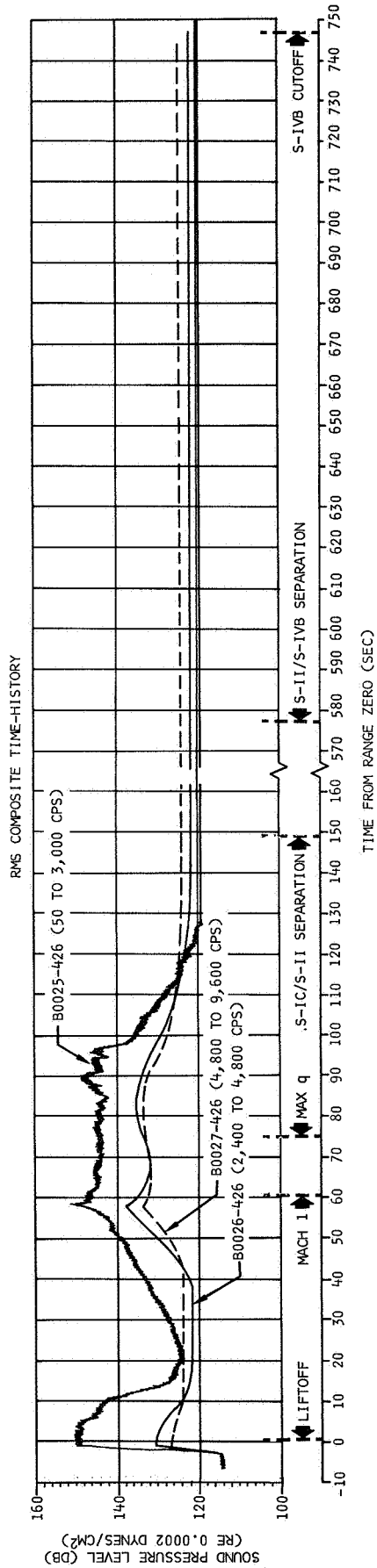


Figure 25-39. Internal Sound Pressure Levels Measured on Aft Skirt



NOTE:
DATA NOT VALID BELOW 30 CPS
BECAUSE OF SSB RESPONSE

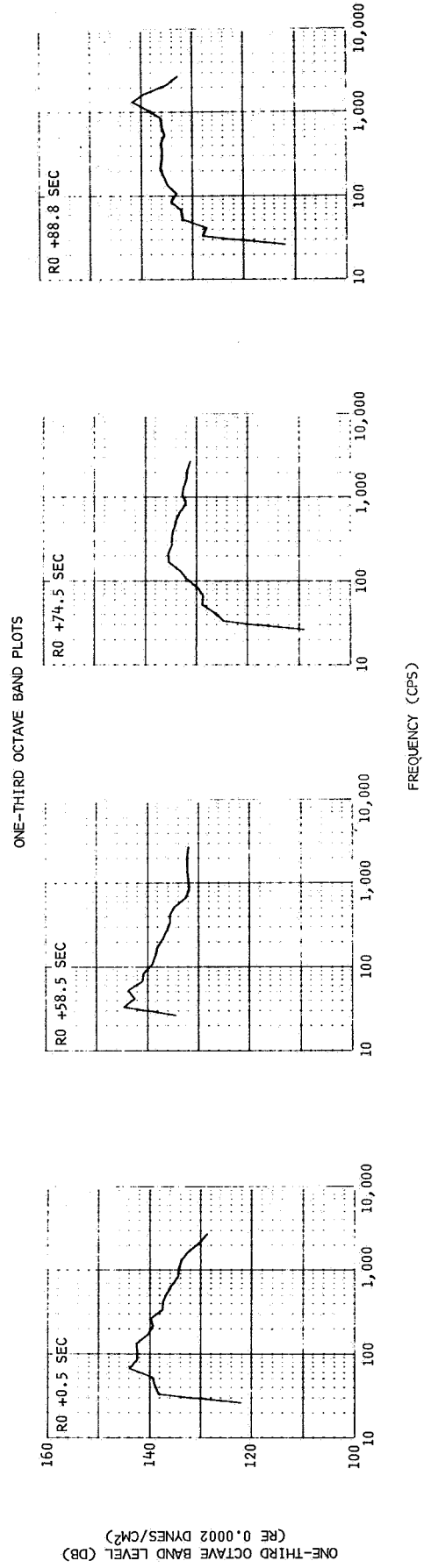


Figure 25-40. External Sound Pressure Levels Measured on Forward Skirt

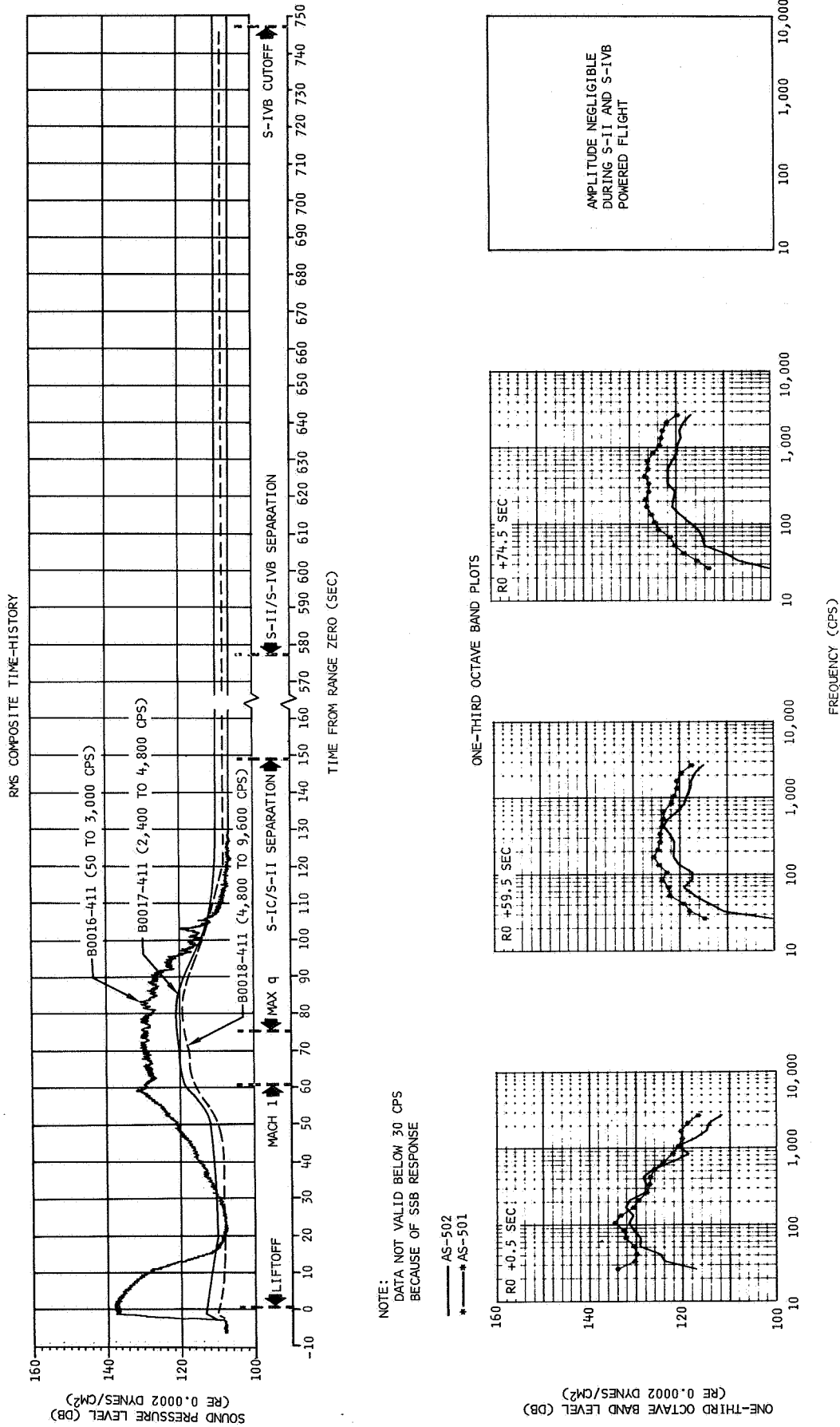


Figure 25-41. Internal Sound Pressure Levels Measured on Forward Skirt

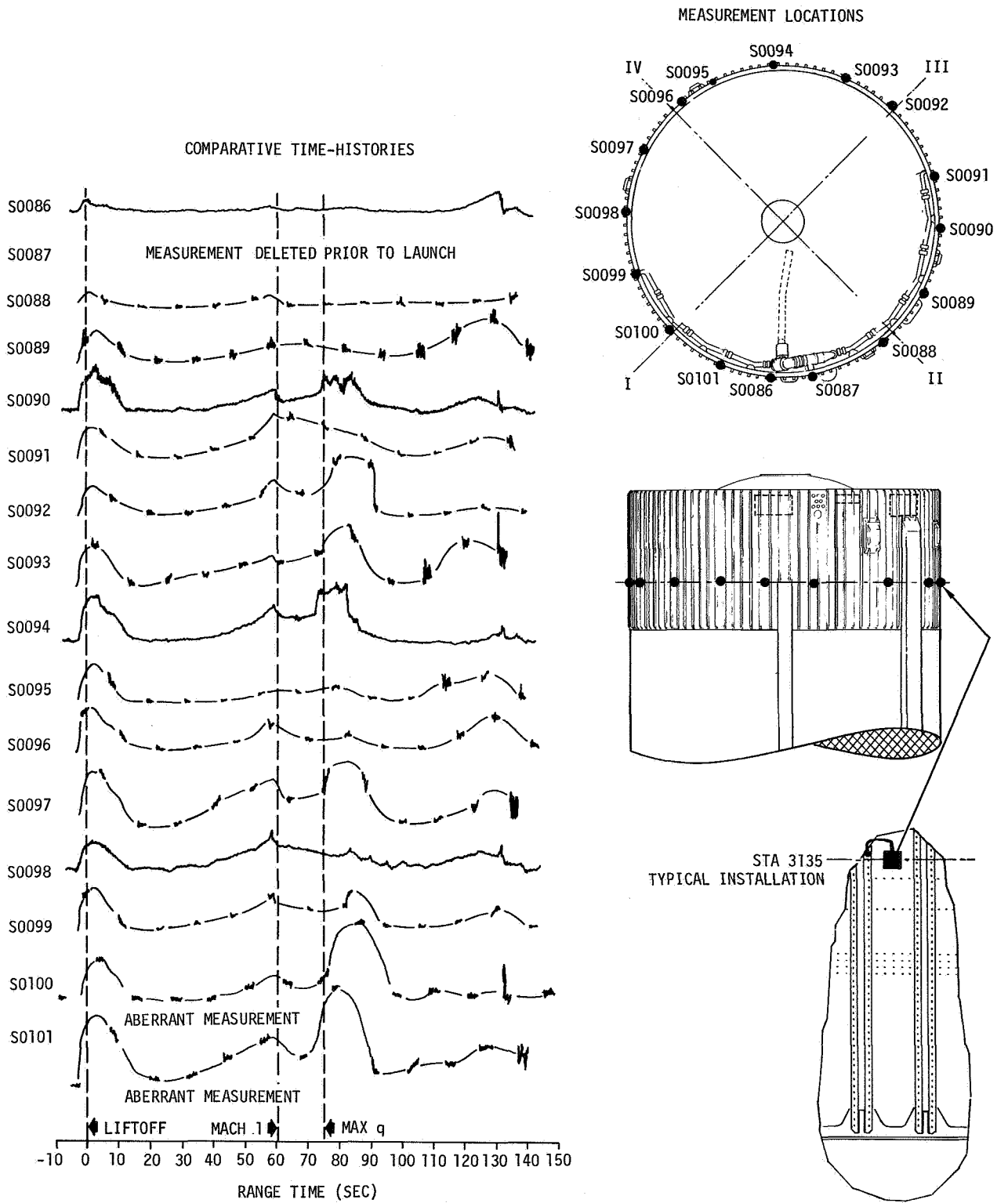


Figure 25-42. Forward Skirt Dynamic Strains

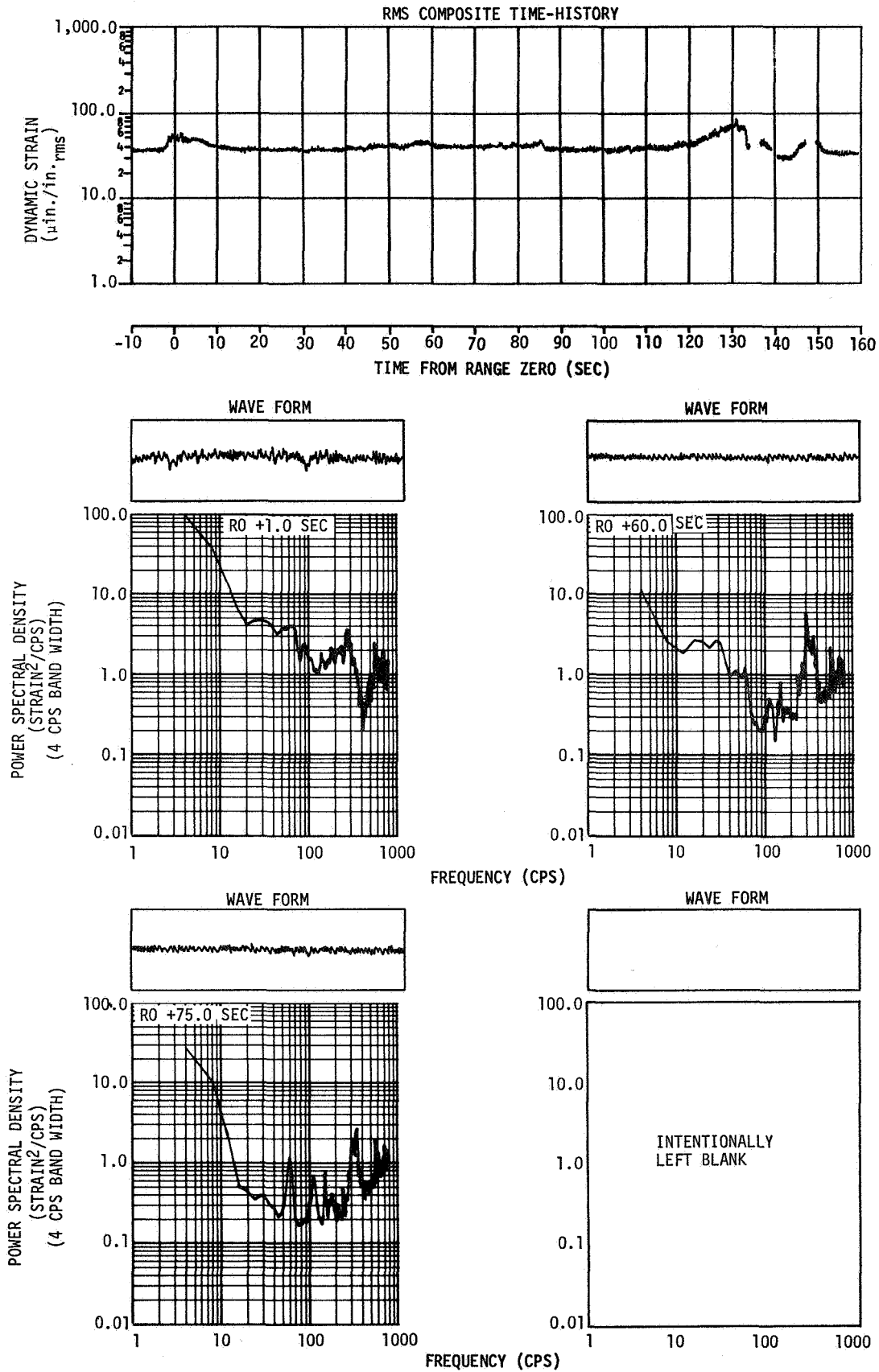


Figure 25-43. Dynamic Strain Measured on Forward Skirt Panel 13 - S0086-426

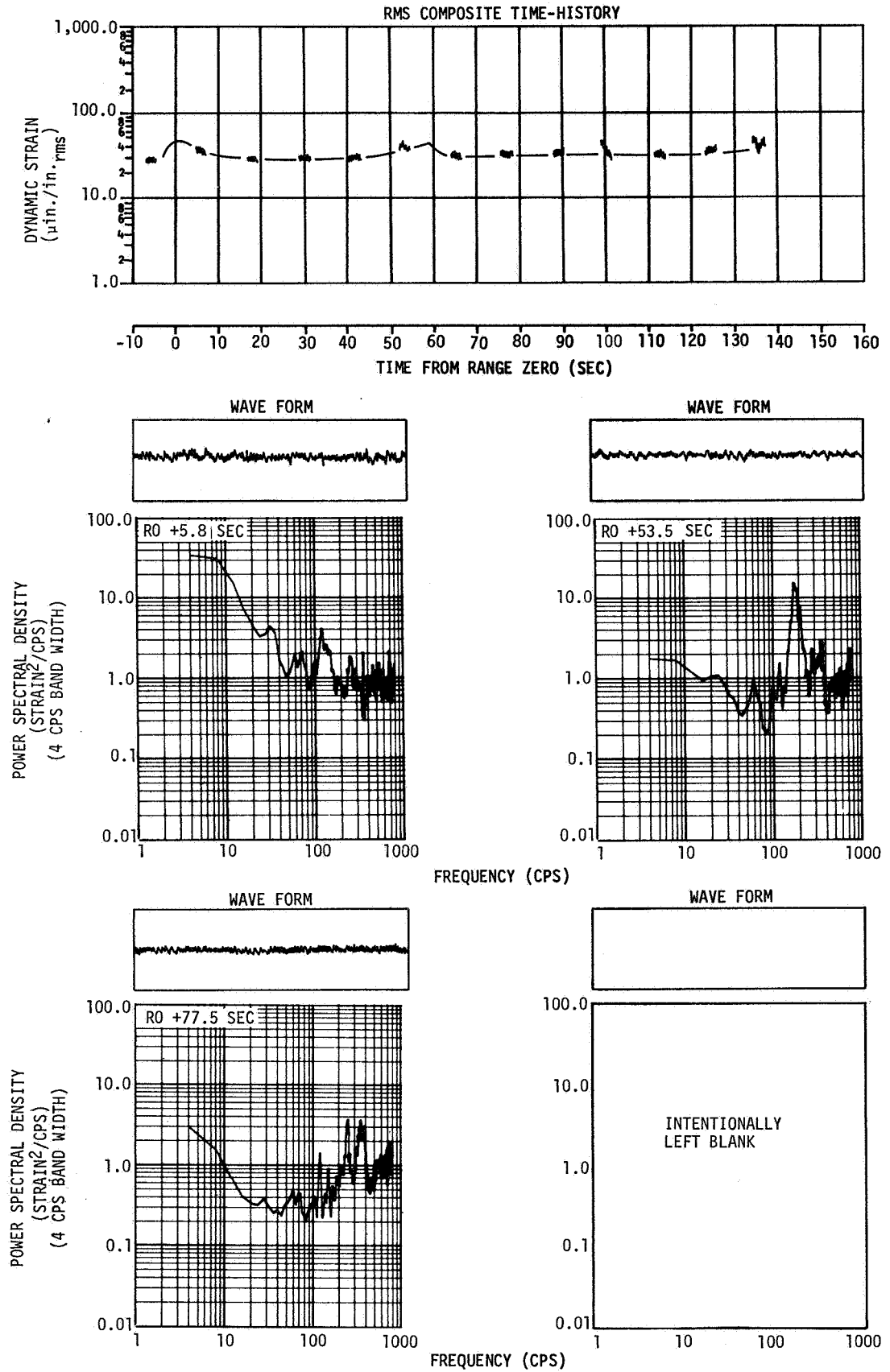


Figure 25-44. Dynamic Strain Measured on Forward Skirt Panel 26 - S0088-426

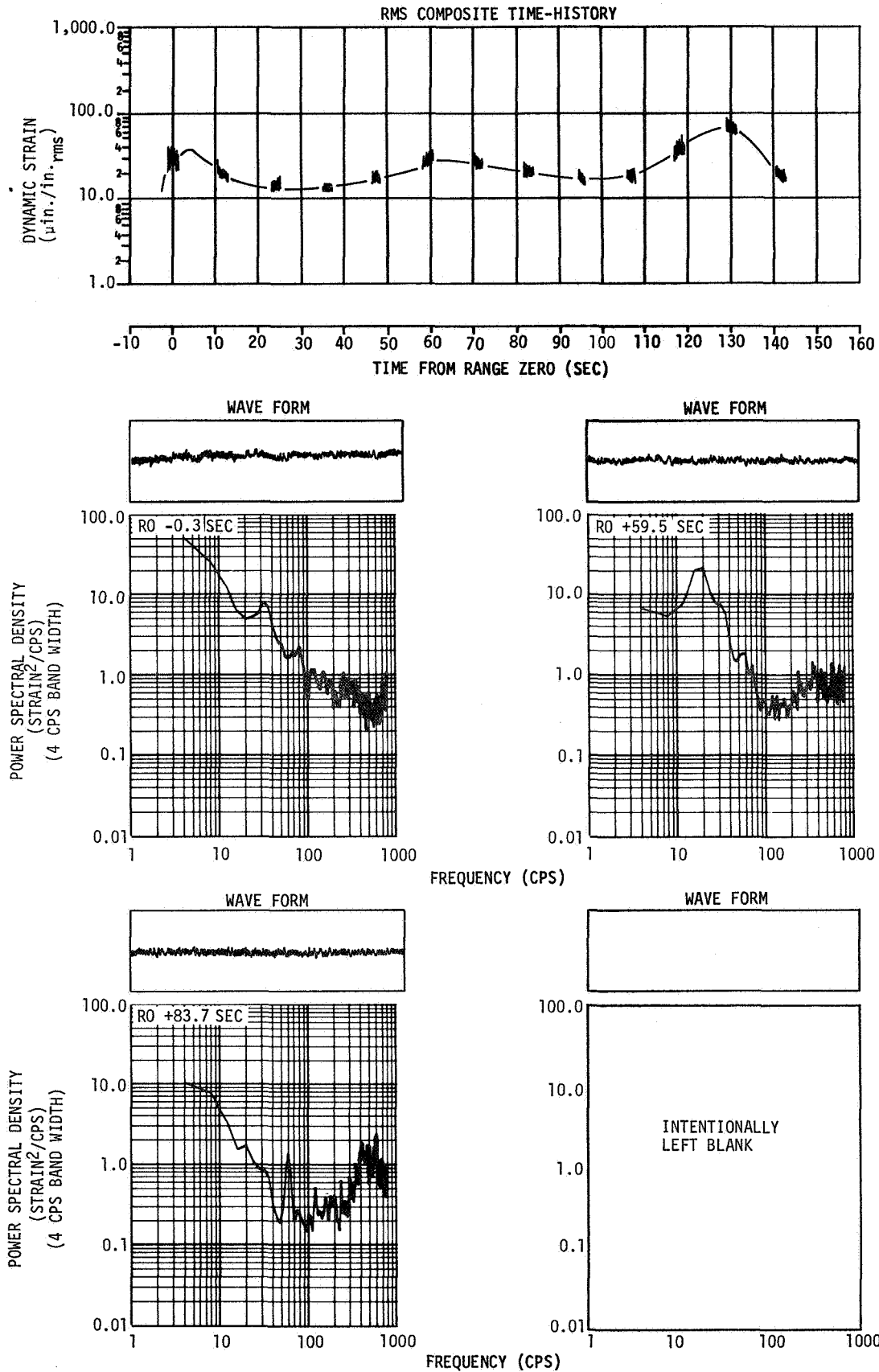


Figure 25-45. Dynamic Strain Measured on Forward Skirt Panel 33 - S0089-426

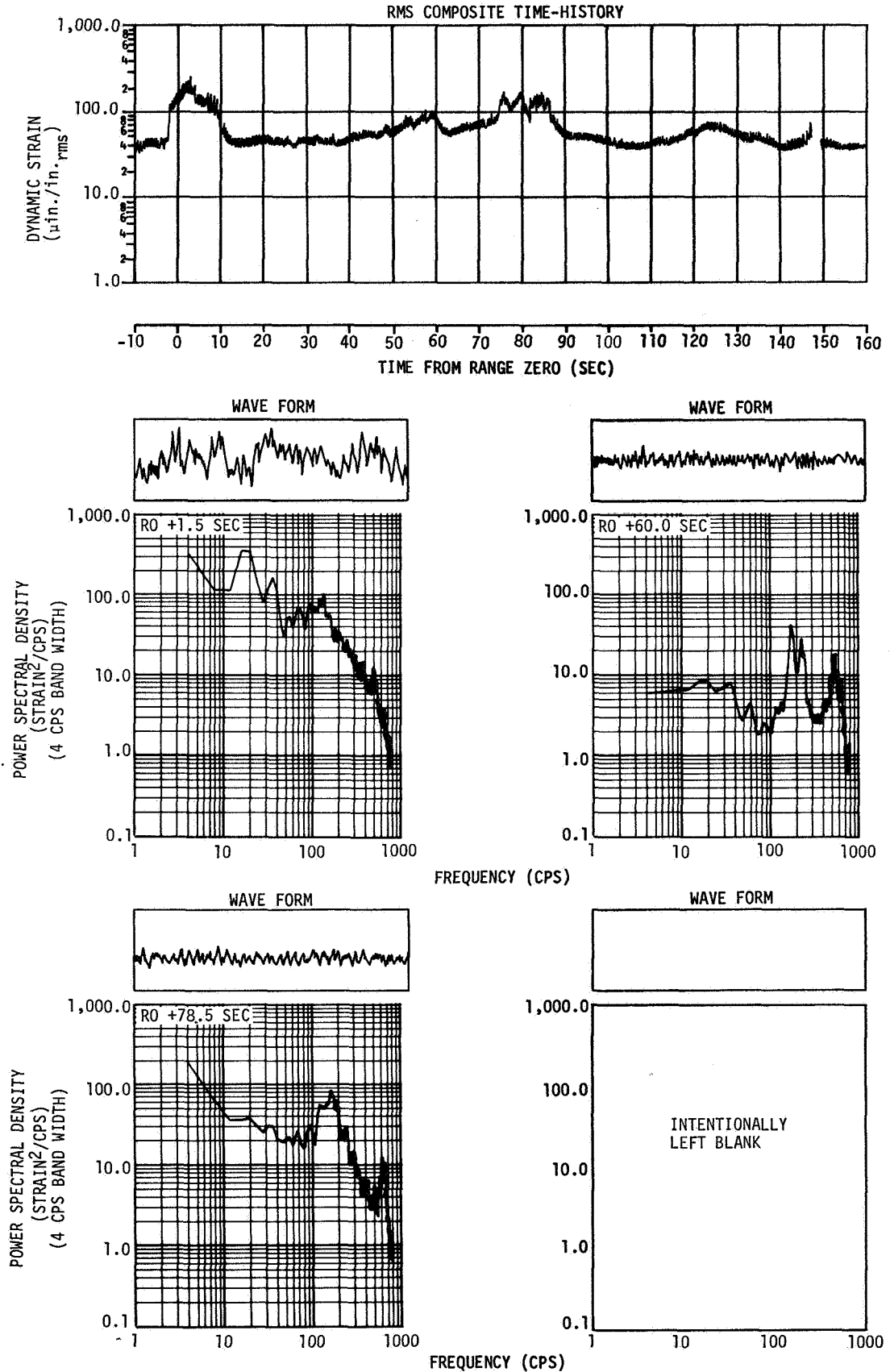


Figure 25-46. Dynamic Strain Measured on Forward Skirt Panel 40 - S0090-426

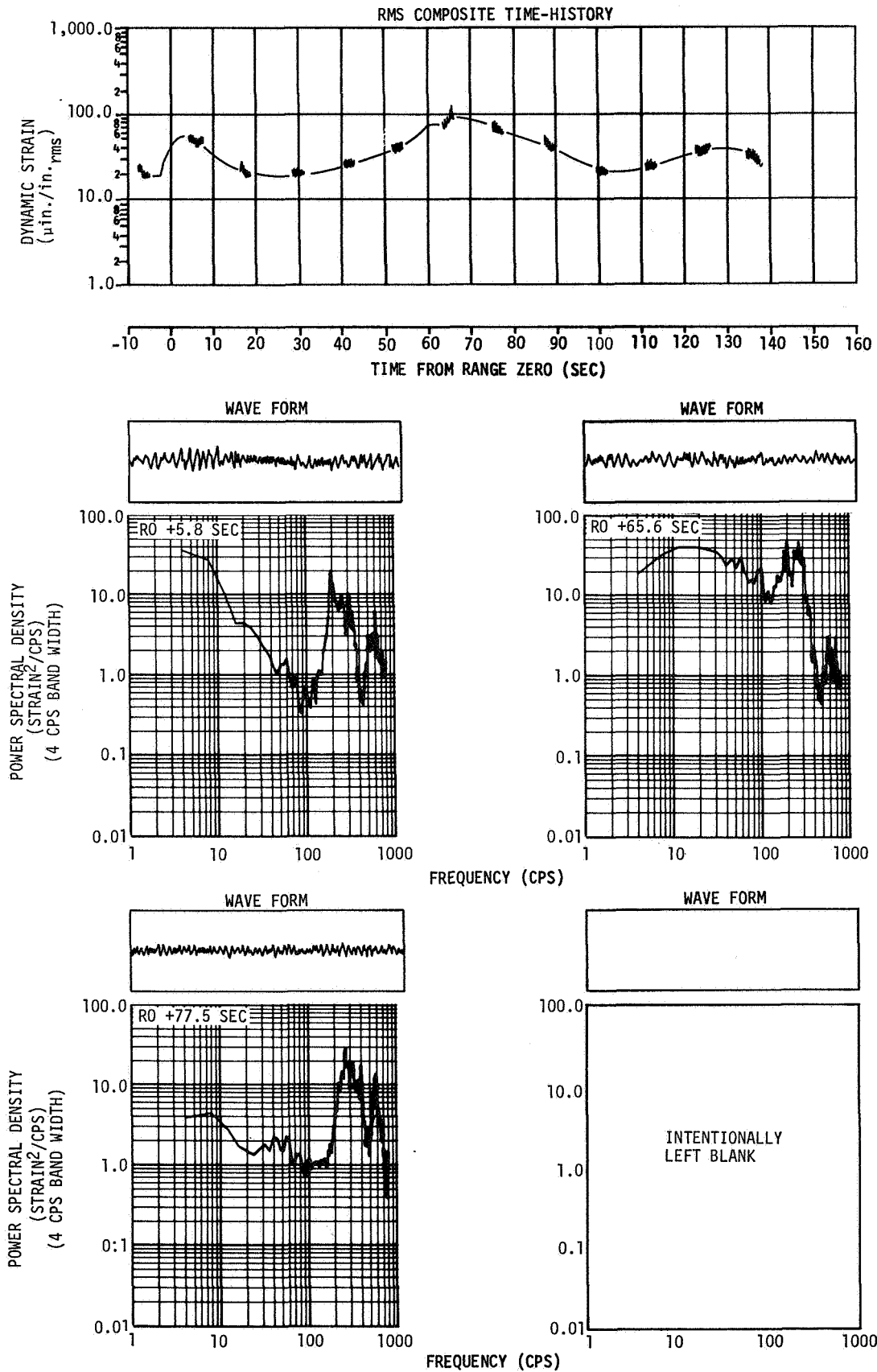


Figure 25-47. Dynamic Strain Measured on Forward Skirt Panel 46 - S0091-426

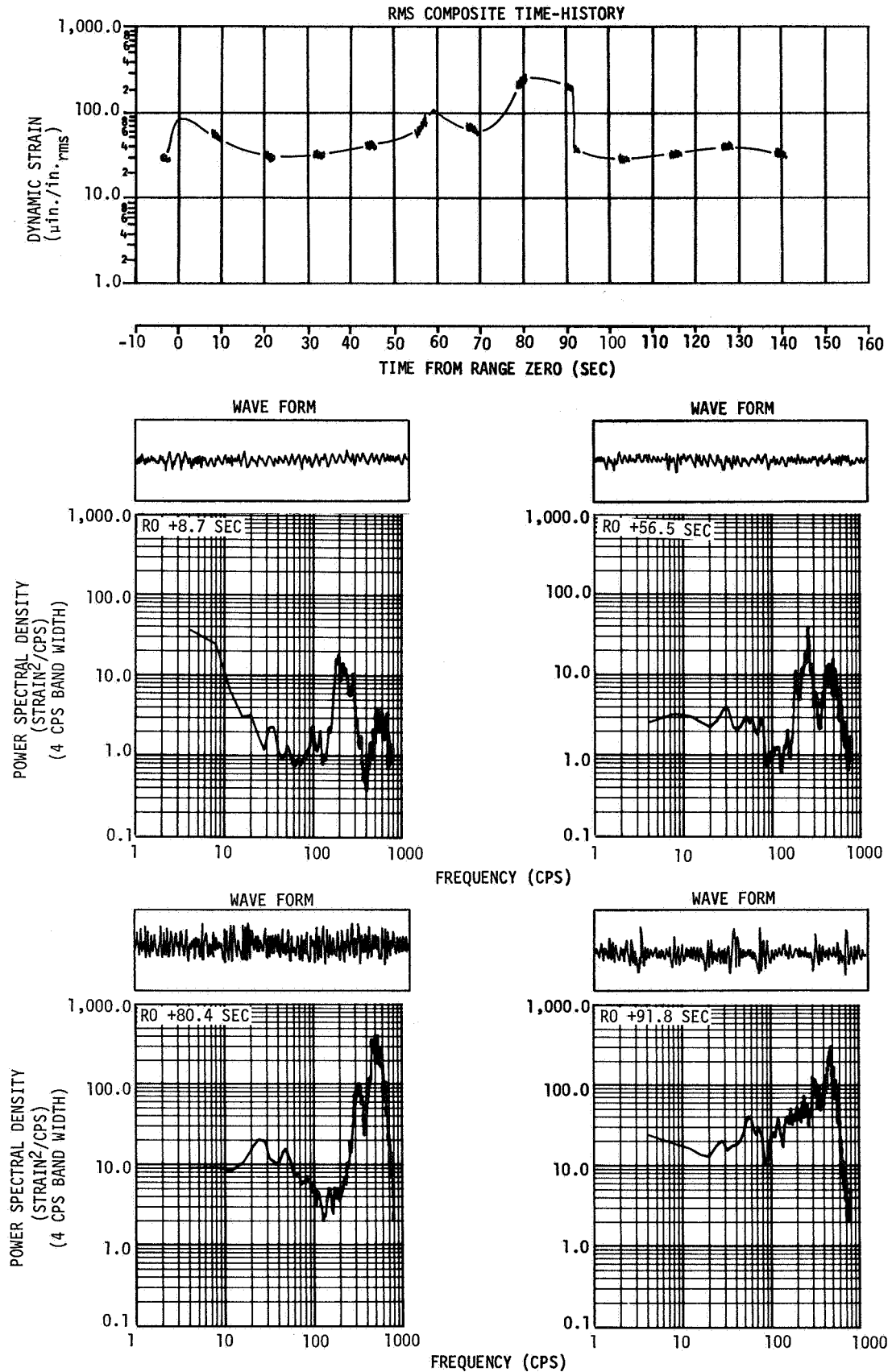


Figure 25-48. Dynamic Strain Measured on Forward Skirt Panel 55 - S0092-426

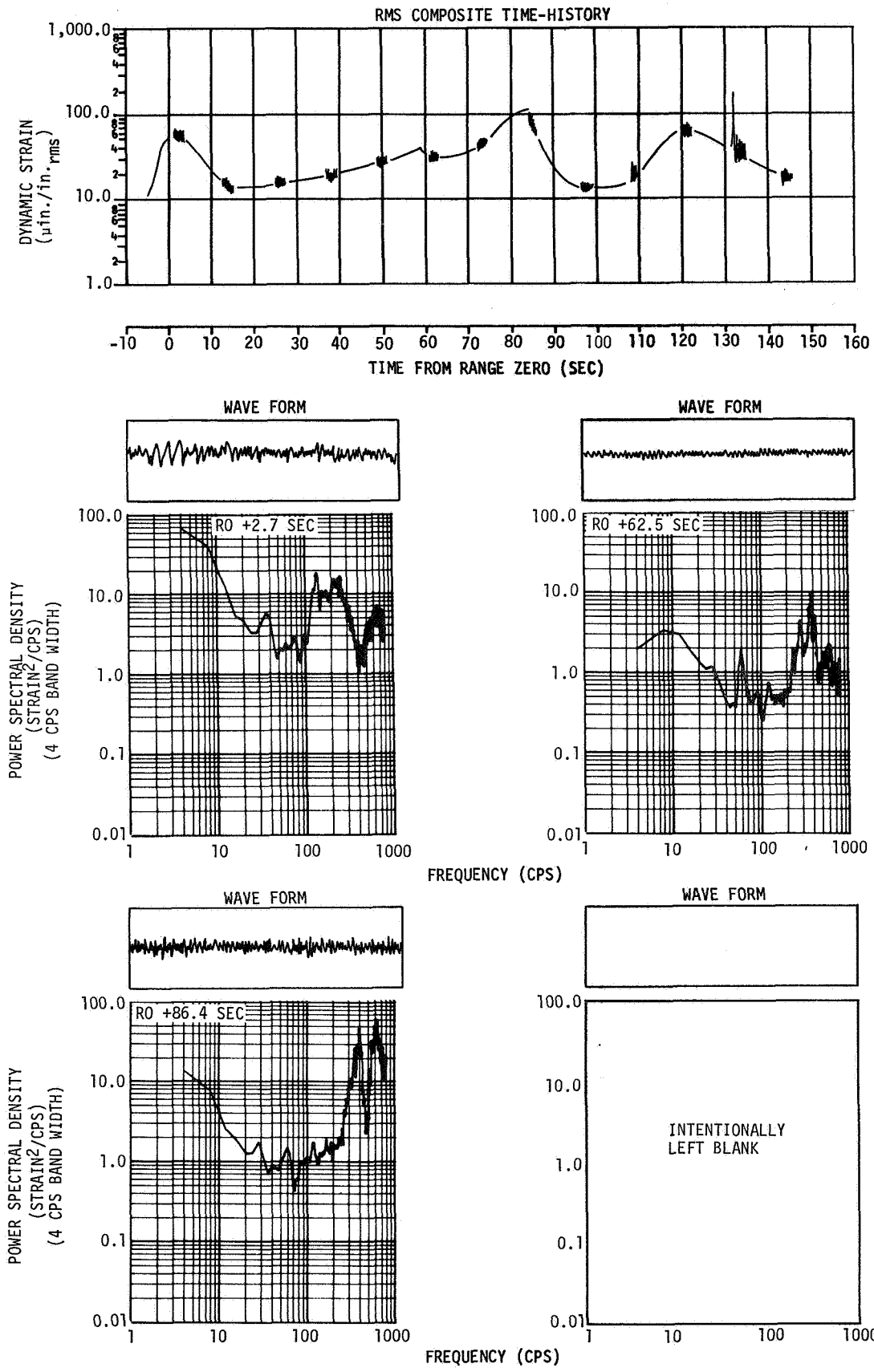


Figure 25-49. Dynamic Strain Measured on Forward Skirt Panel 61 - S0093-426

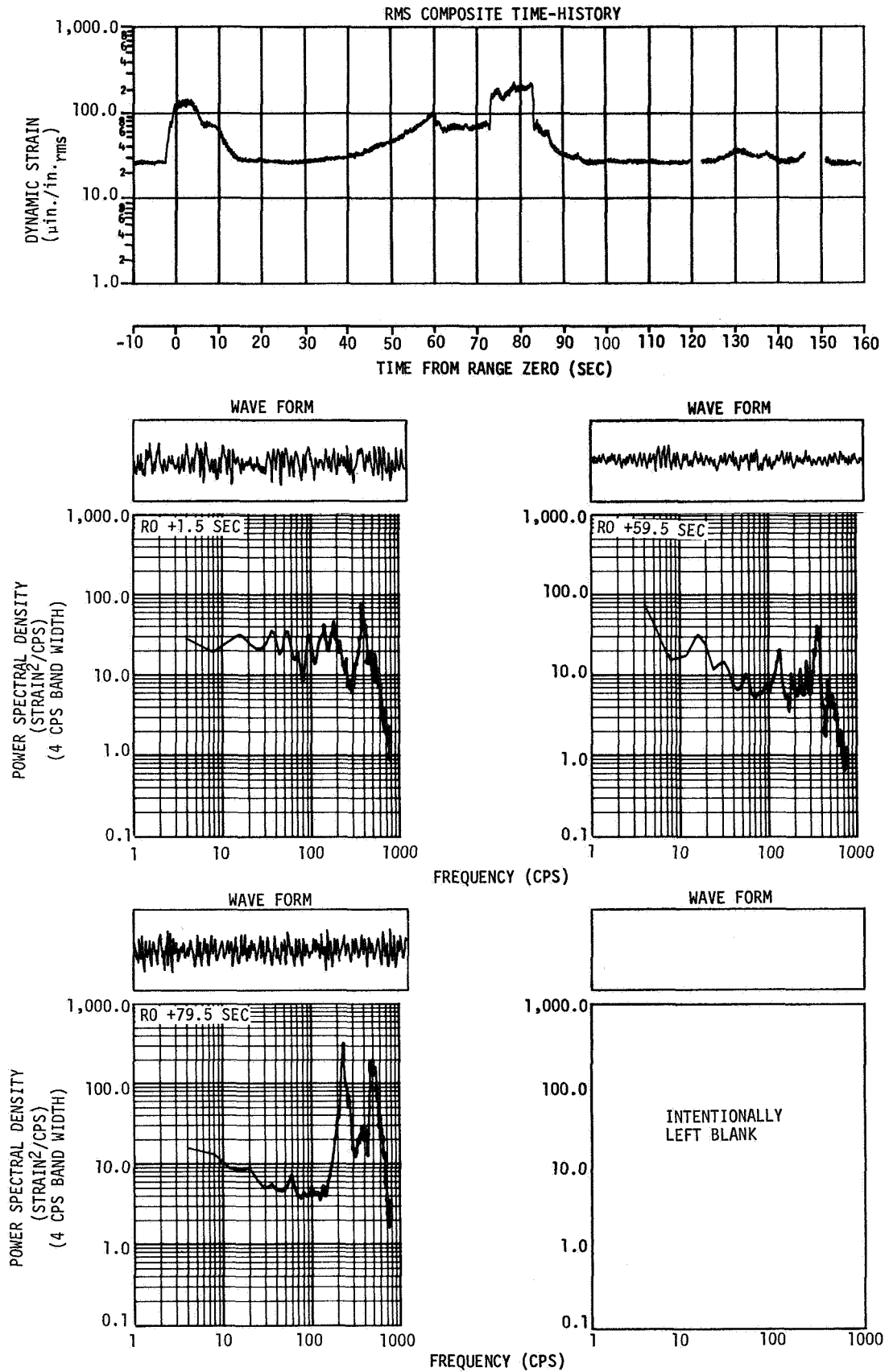


Figure 25-50. Dynamic Strain Measured on Forward Skirt Panel 69 - S0094-426

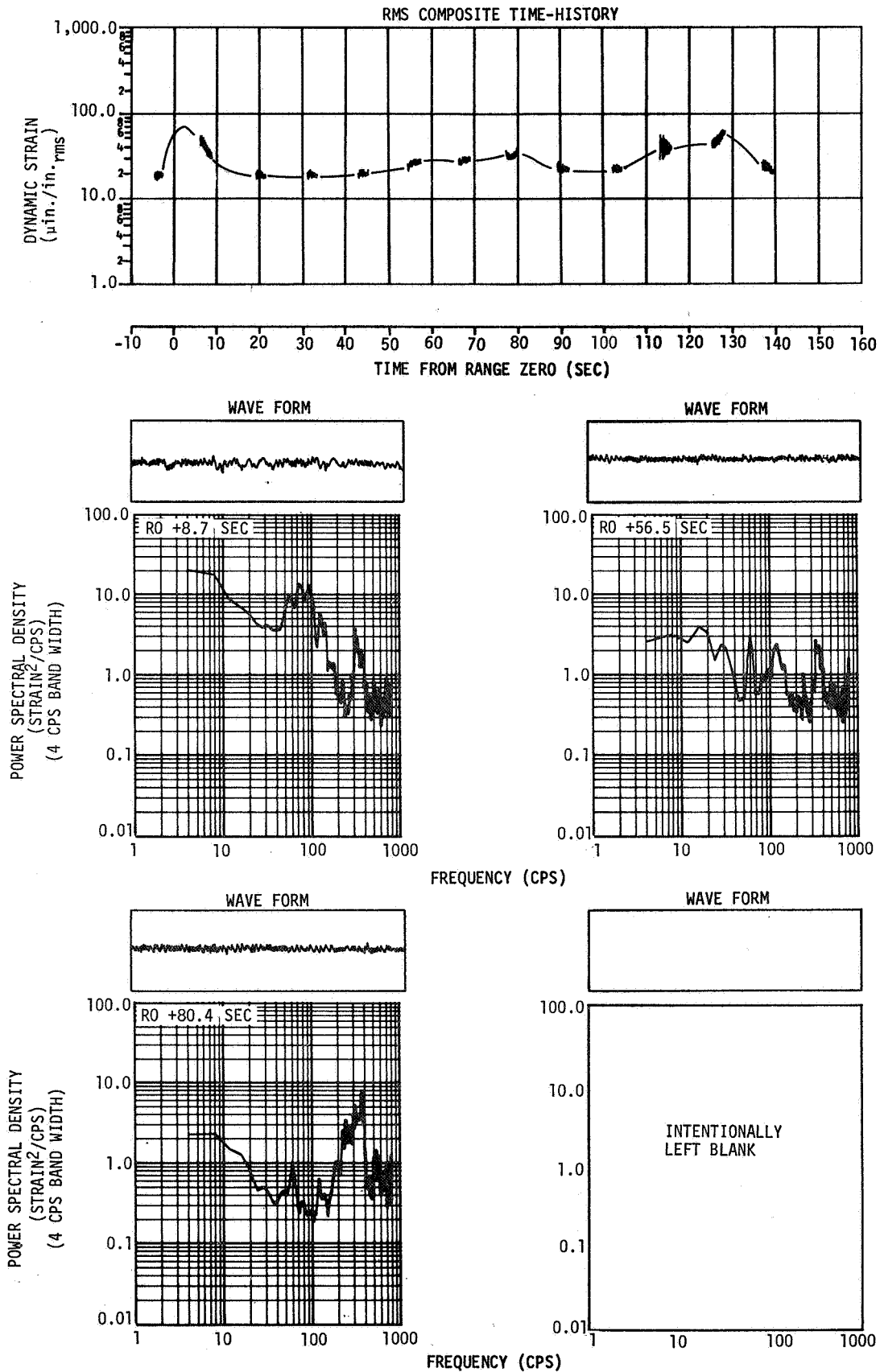


Figure 25-51. Dynamic Strain Measured on Forward Skirt Panel 76 - S0095-426

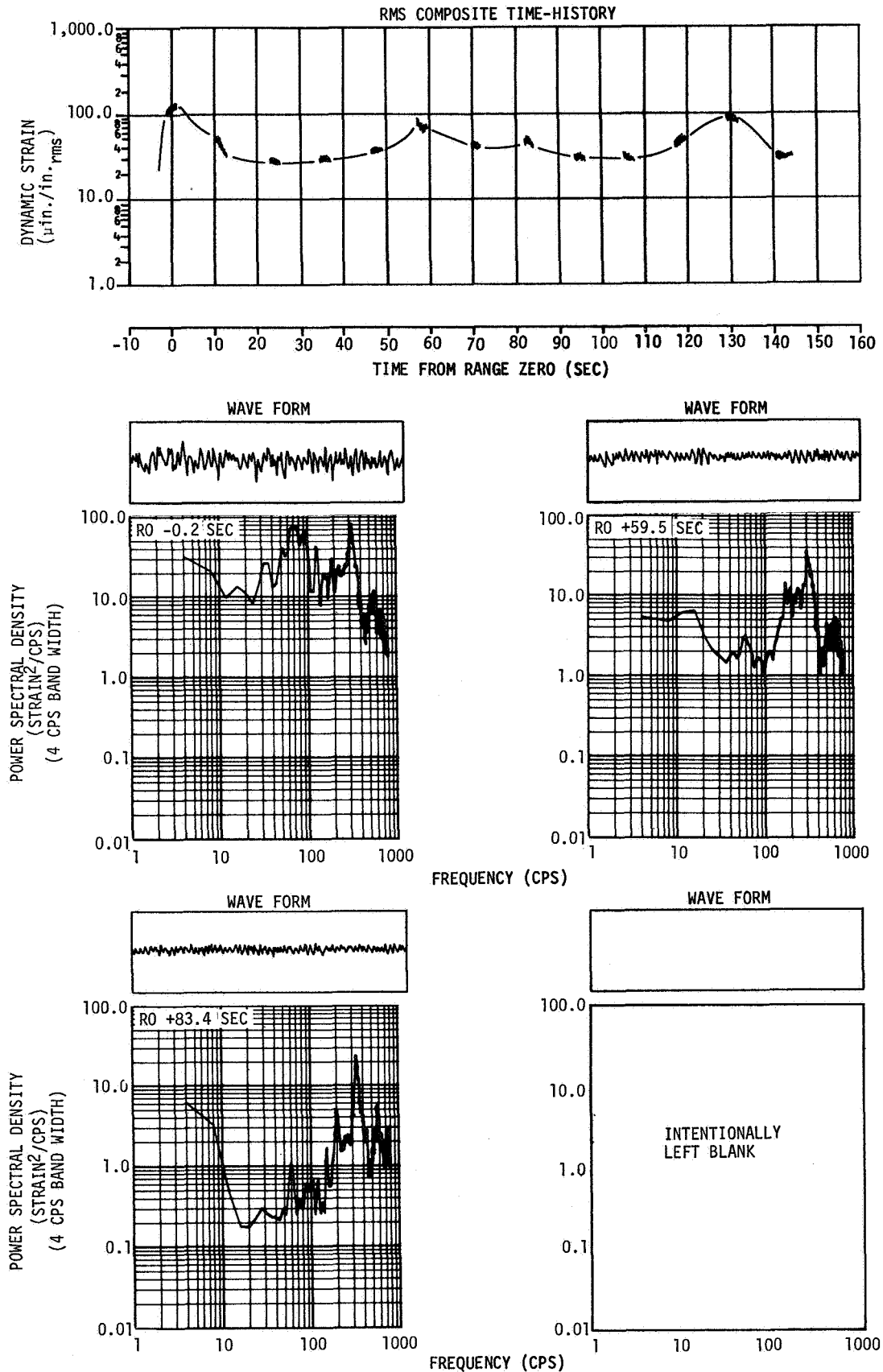


Figure 25-52. Dynamic Strain Measured on Forward Skirt Panel 80 - S0096-426

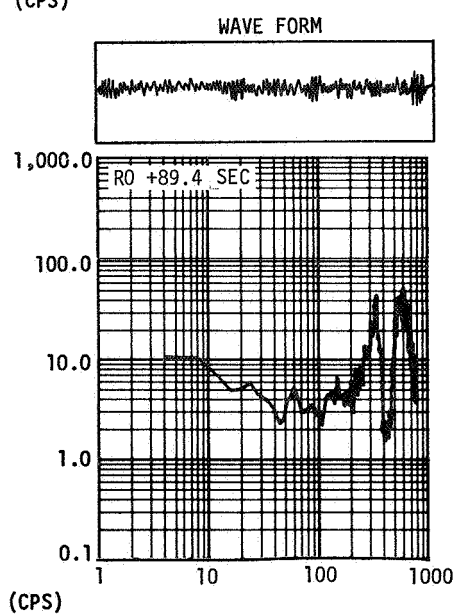
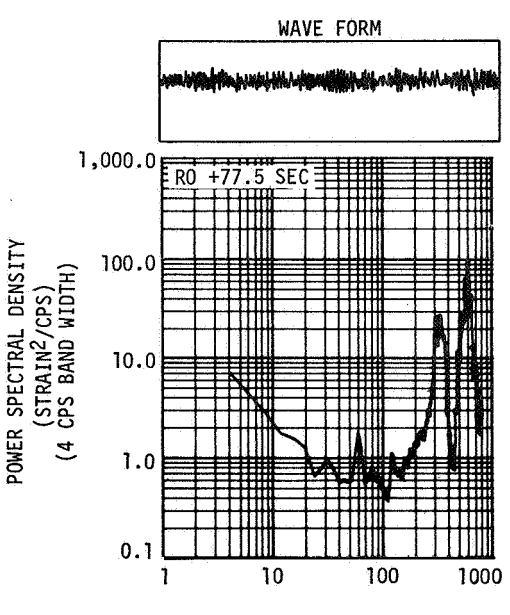
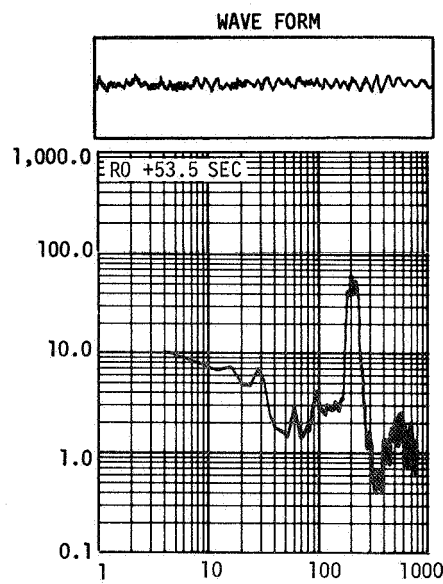
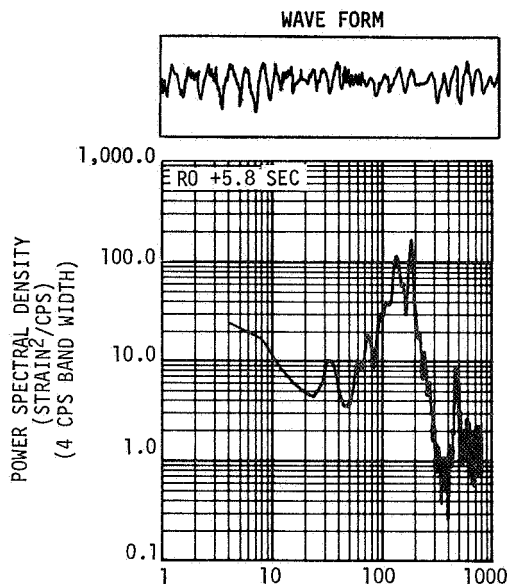
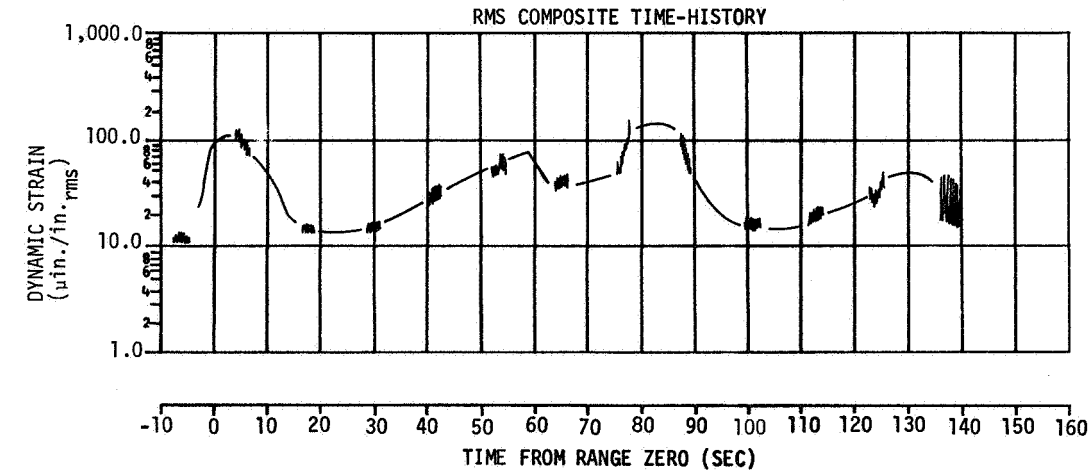


Figure 25-53. Dynamic Strain Measured on Forward Skirt Panel 87 - S0097-426

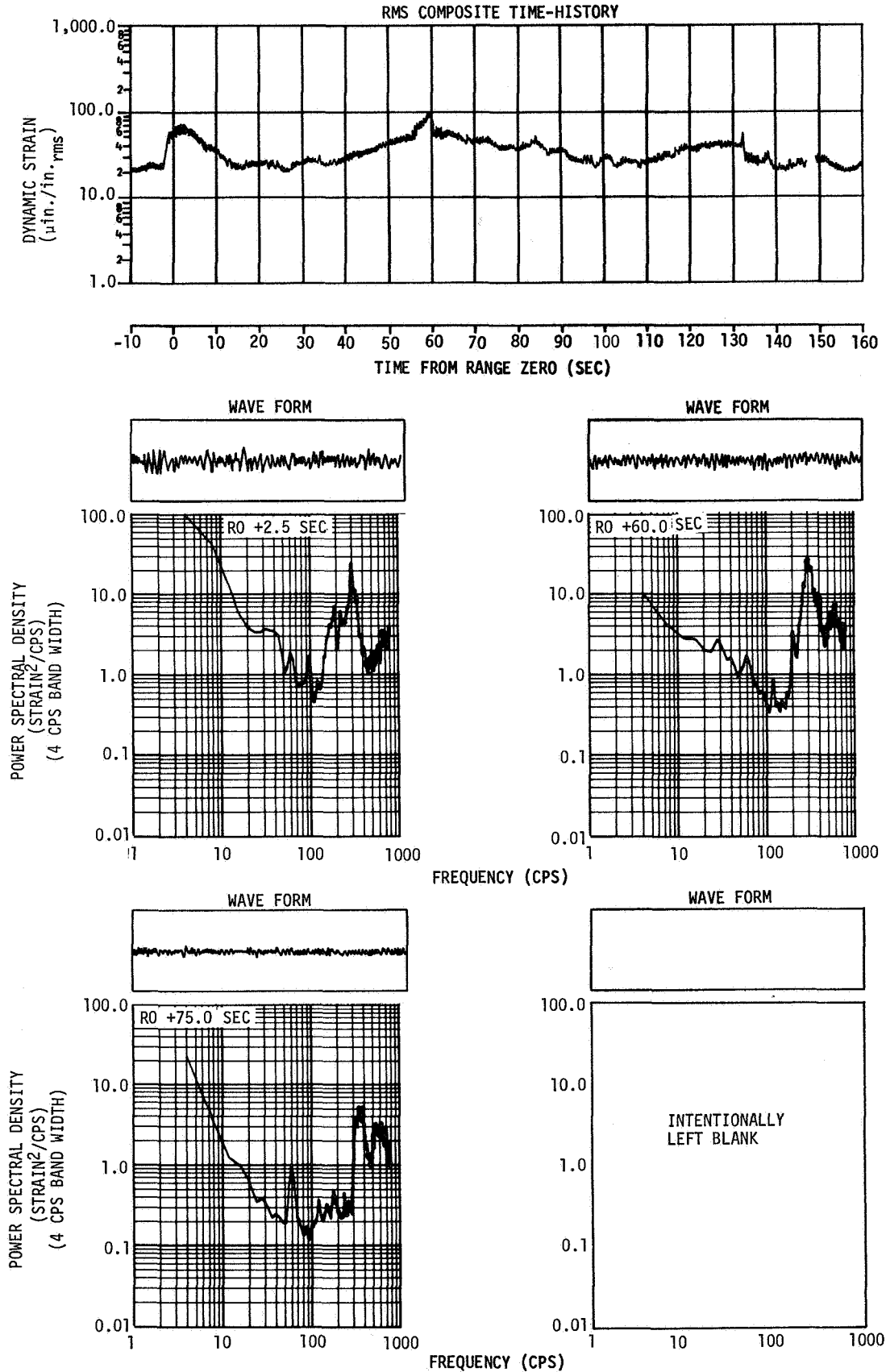


Figure 25-54. Dynamic Strain Measured on Forward Skirt Panel 94 - S0098-426

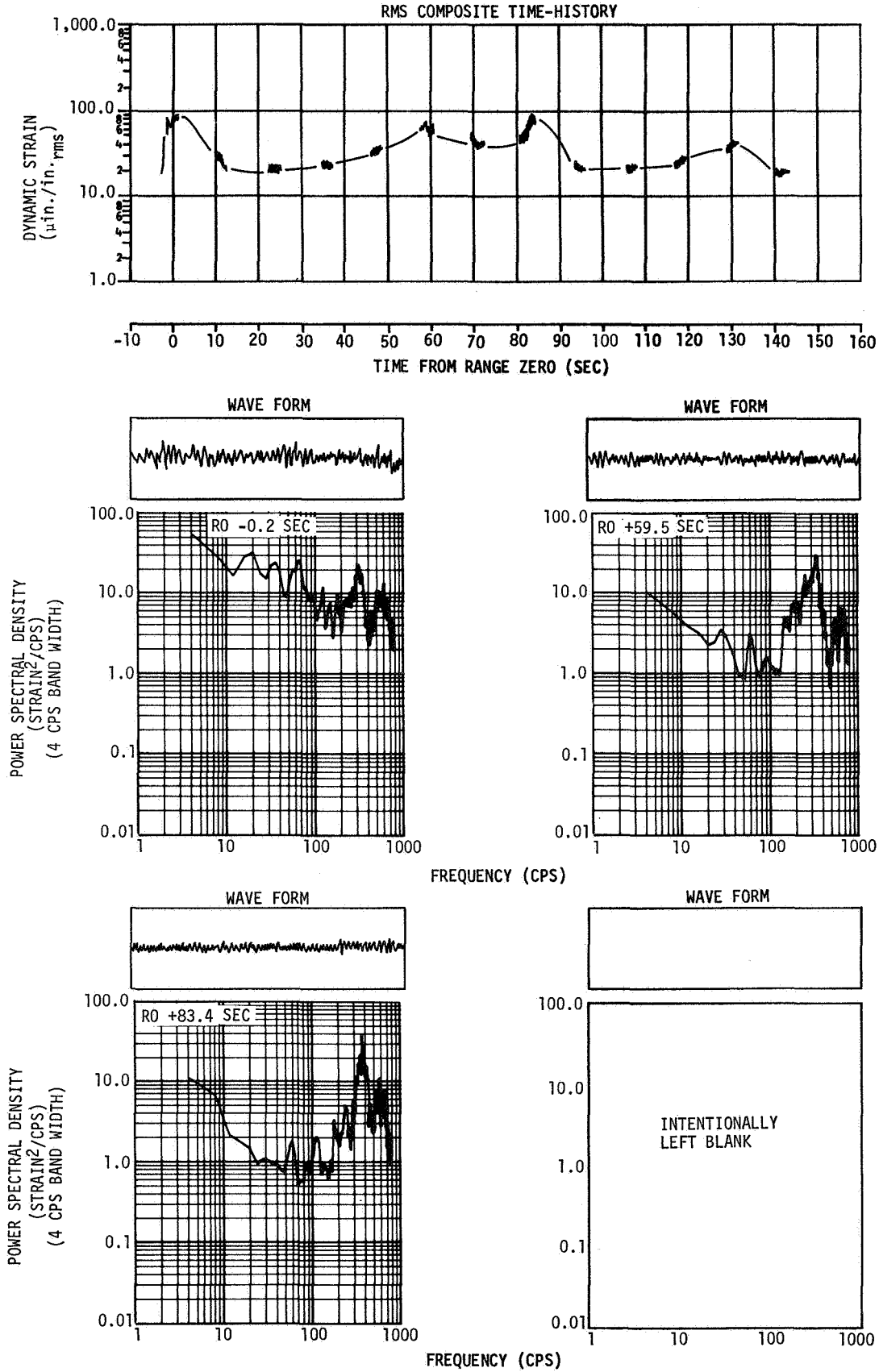


Figure 25-55. Dynamic Strain Measured on Forward Skirt Panel 101 - S0099-426

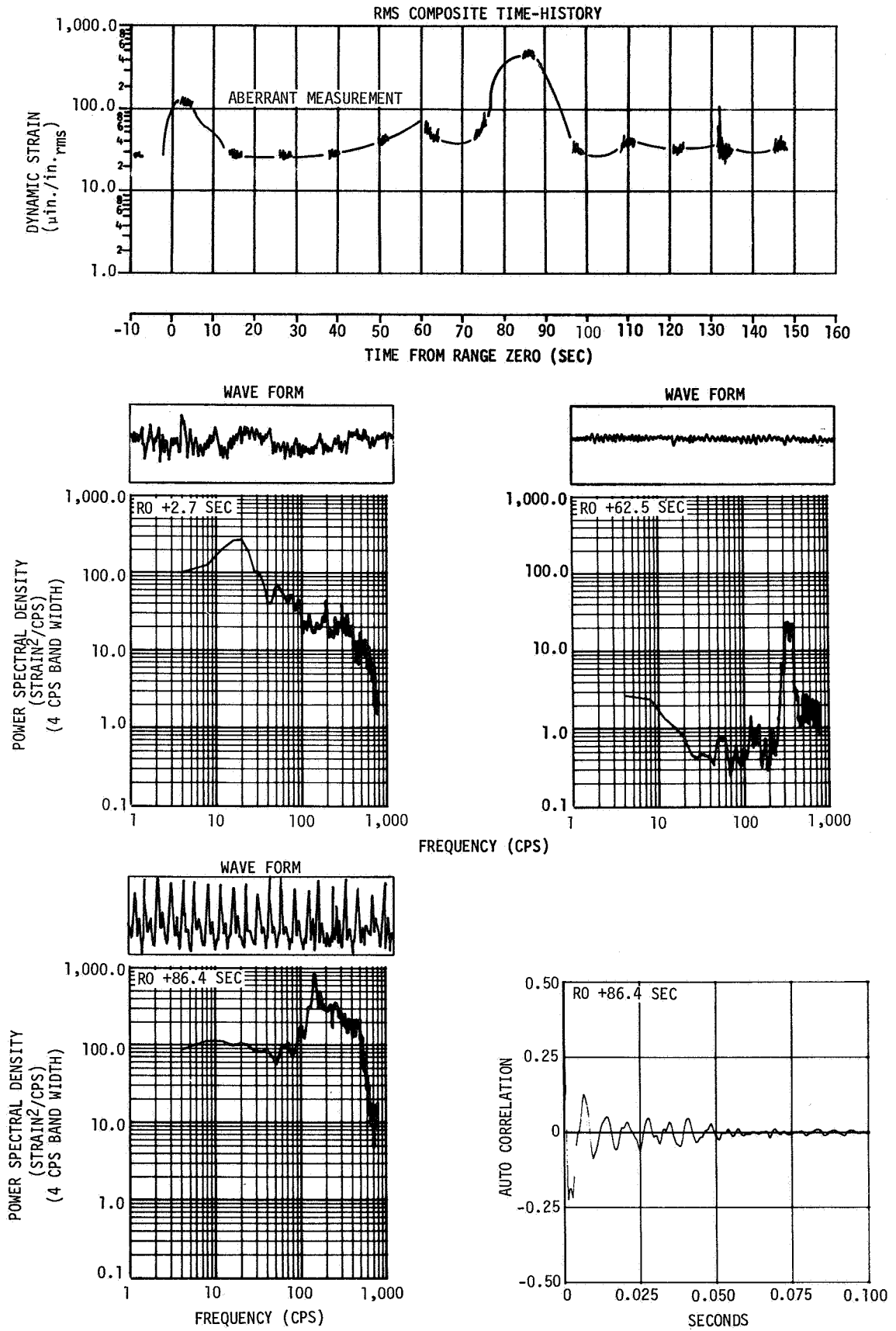


Figure 25-56. Dynamic Strain Measured on Forward Skirt Panel 108 - S0100-426

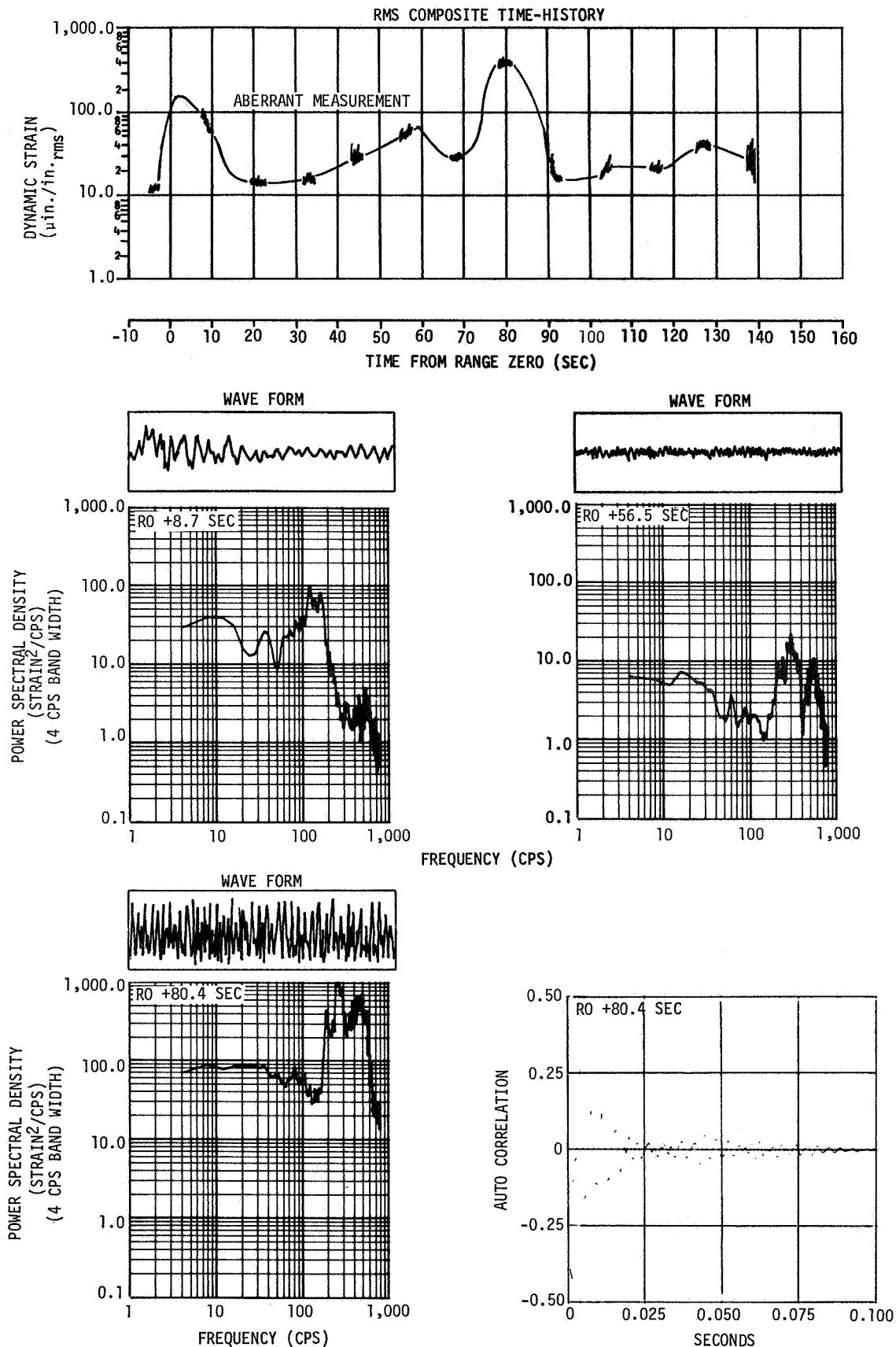


Figure 25-57. Dynamic Strain Measured on Forward Skirt Panel 7 - S0101-426

26. AERO/THERMODYNAMIC ENVIRONMENT

26.1 Surface Pressure and Compartment Venting

Pressures on the S-IVB were measured by 1 internal transducer in the forward compartment and 21 external and 3 internal measurements for the aft compartment.

Figure 26-1 shows the predicted internal minus ambient pressure differentials for the forward compartment together with flight data for both AS-501 and AS-502. The vent area for AS-502 was 150 sq in. as compared to 200 sq in. for AS-501. With the trajectories flown, the smaller vent area on AS-502 should have resulted in higher internal pressures than AS-501 and correspondingly higher pressure differentials. The lower internal pressures shown in figure 26-1 for the first 60 sec of the AS-502 flight (0.05 psid) are attributed to instrumentation accuracy (± 0.75 psi). Also, the fact that the AS-502 data exceed the predicted by a maximum of 0.08 psid is considered to be within the data accuracy.

Figure 26-2 shows pressure data for measurement D0051 at approximately R0 +133 sec. The pressure dropped approximately 0.2 psi. Tests conducted at Douglas to support the overall vehicle evaluation of unusual behavior at R0 +133 sec produced the following results:

- a. The maximum response time required to release the transducer mechanical static friction pressure buildup was 70 ms. The maximum response time for a sudden pressure drop from 0.2 psia to 0 psia was 180 ms. The flight data were recorded every 250 ms. Therefore, it was possible that either a pressure drop or a static friction release occurred during the flight since both responses occurred in less than 250 ms during the tests.
- b. Preflight and pretest calibrations on the flight and test transducers compared to test calibrations of the test transducers showed that ageing can increase the static friction buildup percentage. Based on test data and the latter fact, it was possible for the flight transducer to build up an indicated static friction pressure of 0.2 psi or greater.

It must, therefore, be concluded that the ground tests were inconclusive in showing whether a static friction release or an actual pressure drop of 0.2 psi occurred at R0 +133 sec.

Figures 26-3 and 26-4 show predicted and measured pressure differentials for the aft compartment as internal-minus-ambient and internal-minus-external, respectively. The flight data fall within the predicted band during the critical flight period and the maximum bursting and crushing pressures (2.9 psid and 0.8 psid, respectively) are well below the design values (4.69 psid and 2.24 psid).

26.2 Thermodynamic Environment

26.2.1 Structural Heating (Boost)

Figure 26-5 presents the vehicle geometry and indicates the locations of the temperature measurements used for the structural heating evaluation. All measured temperatures were below design temperatures as was expected from the relatively cool boost trajectory flown.

Table 26-1 tabulates the sensors liftoff temperatures, simulated maximum sensor and structural temperatures, AS-501 maximum measured sensor temperatures, AS-502 maximum measured sensor temperatures, and estimated maximum AS-502 structural temperatures. From table 26-1 it can be seen that the AS-502 flew a somewhat hotter trajectory than the AS-501 flight.

Comparisons between flight data and simulations are shown in figures 26-6 through 26-20. The simulations used the actual AS-502 flight trajectory and assumed boundary layer transition from turbulent to laminar flow at the time the wall-temperature-to-recovery-temperature ratio (T_w/T_r) equals 0.5. This method resulted in a closer simulation with measured data than the design method of analysis (using a transition Reynolds number of 500,000) and gave maximum simulated temperatures, with few exceptions, higher than the recorded flight data. The simulations matched the AS-502 flight data very well during the subsonic flight from RO to RO +60 sec.

26.2.1.1 Forward Skirt

The forward skirt temperature data are shown in figures 26-6 through 26-9, along with the sensor and structural temperature simulations. All of the sensors were located in regions unaffected by protuberance induced heating (i.e., $h/h_o = 1$). Good correlation between the sensor simulation and flight data is indicated. The maximum structural temperature simulations are found to be from 17 to 57 deg R higher than the maximum sensor simulated temperatures. The estimated maximum structural temperature was 746 deg R for the skin near sensor C0081, which is at the forward end of the skirt and positioned toward the sun.

26.2.1.2 LH2 Tank

The LH2 tank temperatures are shown in figure 26-10 along with the simulated sensor and skin temperatures. All of the sensors were located in regions unaffected by protuberance induced heating (i.e., $h/h_o = 1$). The simulations start at the liftoff sensor temperature, but do not consider the presence of frost and ice formation which was evident from the low liftoff temperatures (391 to 490 deg R). As a result, both sensor and skin temperature simulations gave much higher values than the recorded temperature. The estimated maximum structural temperature was 550 deg R based on sensor C0078. Only two sensors recorded temperatures higher than the freezing point of water and these were C0078 (541 deg R) and C0106 (497 deg R).

26.2.1.3 Aft Skirt

The aft skirt temperature data are shown in figures 26-11 through 26-16, along with the simulated sensor and structural temperatures. The estimated maximum structural temperature was 646 deg R based on sensor C0048 which was not insulated by Korotherm.

Figure 26-11 and 26-12 present the temperatures in the insulated (0.01 in. Korotherm) protuberance induced heating area adjacent to the APS. The simulations employ a disturbed aerodynamic heating rate 50 percent higher ($h/h_o = 1.5$) than experienced in undisturbed regions of the stage. This approach gives good simulation for the sensors in the higher heating areas (adjacent to the protuberance), and values as much as 100 deg R higher in the lower heating areas as seen for sensor C0291. The simulated skin temperatures were found

to be approximately the same as the simulated sensor temperatures. The maximum structural temperature in a protuberance induced heating area insulated with 0.01 in. of Korotherm was 636 deg R (sensor C0165).

Figures 26-13 and 26-14 present the temperatures in the insulated protuberance induced heating area adjacent to the LH2 feedline fairing (C0045, C0113, C0114, and C0115) and adjacent to the LOX vent (C0046). The simulations employed a disturbed heating rate factor, $h/h_o = 1.5$, which gave simulations up to 65 deg R higher than the data for the skin simulation and up to 30 deg R higher for the stringer simulation. The simulated structural temperatures were found to be nearly equal to the simulated sensor temperature. The low initial and maximum temperature recorded by C0046 were due to the influence of the LOX venting which was not considered in the simulation. The maximum temperature recorded for this sensor (C0046) was 562 deg R and was 92 deg R lower than the simulation.

Figure 26-15 presents the temperature data and simulations for the uninsulated aft skirt skin. Sensors C0047, C0048, C0116, and C0117 were located on the skin sufficiently removed from protuberances so as to require no insulation and the simulation employed a heating rate factor of $h/h_o = 1.0$. This approach gives excellent correlation and predicts temperatures from 0 to 15 deg R higher than the recorded temperatures. The estimated maximum structural temperature was 631 deg R based on sensor C0048.

26.2.1.4 Aft Interstage

Figure 26-16 presents the aft interstage temperature data and the sensor and structural temperature simulations. The temperature sensors on the aft interstage were covered with ablative insulation. The simulated temperatures were analyzed with $h/h_o = 1.0$ and boundary layer transition at the time $T_w/T_r = 0.5$. This method predicts temperatures slightly higher than the data with the simulation being 20 to 24 deg R higher for the stringers and 27 to 47 deg R higher for the skin. The estimated maximum structural temperature was 647 deg R based on skin sensor C0305.

26.2.1.5 LH2 Feedline Fairing

The temperature data and simulation of the LH2 feedline fairing forebody is presented in figure 26-17. For the simulation, local flow properties were assumed to be those for a 30 deg semi-apex angle cone. The simulated maximum skin temperature is seen to be 14 deg R higher than the maximum sensor temperature. The estimated maximum skin temperature is 754 deg R.

26.2.1.6 Main Tunnel

The main tunnel centerbody temperature data are shown in figure 26-18 with the simulated sensor and skin temperatures. The forebody sensor C0049 was listed as a failure during boost and therefore was not analyzed. The estimated maximum structural temperature was 685 deg R based on sensor C0227. Good correlation between data and simulated sensor temperatures is indicated.

26.2.1.7 APS Fairing

Figure 26-19 shows the temperature data of the APS centerbody with their corresponding simulated skin and sensor temperatures. Sensor C0288 is located on top of the fairing and sensors C0287 and C0289 are located approximately half way down either side of the fairing. As indicated in the data, there is little difference between the aerodynamic heating on the top or sides. The simulated sensor temperatures were found to match the recorded sensor temperature quite well. The simulated skin temperatures were found to be approximately 41 deg R higher than the simulated sensor temperatures. The maximum estimated structural temperature was 711 deg R based on sensor C0288.

26.2.2 Plume Impingement Heating

26.2.2.1 J-2 Engine Heat Flux - S-II/S-IVB Separation

The heat flux on the J-2 engine bell during retrorocket firing (RO +577.076 sec) was measured by calorimeters C2000 and C2004. The recorded heat flux histories are shown in figure 26-20 along with the simulated heat fluxes. Sensor C2000 indicated a maximum heat flux of 0.56 Btu/ft²-sec and sensor C2004 indicated a maximum heat flux of 1.13 Btu/ft²-sec. The simulation indicates no heating until the S-IVB was sufficiently separated from the S-II to orient the J-2 engine bell within the retrorocket flow field (approximately 1 sec after retrorocket start). The initial heating indicated by the data is due to retrorocket gases entering the aft compartment during initial separation whereas the predicted values are based only on flow impingement. The simulation also shows a maximum condition for sensor C2000 (with maximum heat flux equal to 2.29 Btu/ft²-sec) whereas the data indicate a maximum condition for sensor C2004. It is suspected that this is attributable to the simplified analysis method which does not consider flowfield interrelation between retrorockets as well as between retrorockets and ullage rockets.

26.2.2.2 APS Ullage Rocket Plume Impingement on J-2 Engine

Calorimeters C2000 and C2004 were also used for measuring the heating rates on the J-2 engine during the auxiliary propulsion system (APS) ullage rocket firing (initiated at RO +11,288 sec). The maximum increase in heat flux for these measurements during this time was 0.014 Btu/ft²-sec; however, the initial increase occurred approximately 40 sec prior to ullage ignition. Examination of the data from the previous orbit (RO +5,760 sec), when the ullage rockets were not firing, indicated similar trends with approximately the same (0.012 Btu/ft²-sec) heat flux. This would indicate that solar influences are the primary source of heating measured during the ullage rocket firing and the heating due to the APS ullage rocket plume impingement is much less than the design heat flux (0.15 Btu/ft²-sec).

26.2.3 Auxiliary Propulsion System

The orbital temperatures for the APS were determined by 10 sensors (C0294 through C0303) mounted internally to the APS fairing, on various components and propellant transfer lines,

and 4 sensors (C0286 through C0289) mounted on the fairing. One component measurement (C0303) and one fairing measurement (C0288) were selected for analytical correlation with the flight data. All measurements were evaluated with regard to their proper operation and whether the temperatures were within the allowable operational limits and the predicted range.

Sensor C0301 was found to be inoperable and was deleted prior to the flight. Sensor C0286 did not respond properly after liftoff and it is believed that this measurement partially debonded during the boost phase of the flight.

Table 26-2 lists the maximum and minimum temperatures during the flight for the APS measurements. The values for the AS-501 flight are also included for comparison. It can be seen that all components remained within their allowable limits with the exception of the propellant transfer lines. Four line measurements (C0294, C0295, C0297, and C0298) exceeded their maximum allowable temperature of 585 deg R because of extended APS engine firing resulting from failure of the engine to restart. Two measurements (C0295 and C0298) were within 5 deg R of the maximum allowable value, and two measurements (C0294 and C0297) were within 20 deg R of the maximum allowable value.

The excessive line temperatures were produced by radiation from the APS engines. The engines have a direct radiation path to the propellant transfer lines and components in the aft engine compartment. The effect of this radiation on the oxidizer control module can be seen in figure 26-21 where correlation of measurement C0303 is presented. The analytically predicted temperatures (which do not include the radiation effects of the abnormal engine temperatures) agree fairly well with the flight data until after restart attempt (approximately RO +11,615 sec). After this time, the flight data, although still well within the operational limits, exceed the analytically predicted values by as much as 20 deg R. The engines, which have a relatively large heat capacitance, retain the high temperatures until telemetry data drop out.

Figure 26-22 presents a comparison of the APS fairing orbital flight data with respect to the predicted design temperature envelope. The figure shows that the fairing flight data fall within the design limits and indicates that the high internal line and component temperatures were internally produced (i.e., due to the warmer than expected APS engines). If the increase in component temperature was a result of the external environment (through a change in vehicle orientation or a degradation of external surface optical properties) the fairing flight data would have reflected this condition. Figure 26-22, however, indicates that while the line and component temperatures were increasing in temperature after restart attempt, the APS fairings were decreasing in temperature. The fairing temperatures would need to be considerably outside the range of the maximum design temperature envelope to produce the response indicated by the flight data on the lines and components.

Figure 26-23 shows the correlation of measurement C0288 located on the APS fairing. This figure indicates that no appreciable change in optical properties occurred such as was encountered during the AS-501 flight. Fairly good correlation was achieved for the first two orbits. After this time, it is believed that the flight simulation parameters (e.g., inertial hold) used to establish the vehicle orientation did not match the actual flight parameters.

26.2.4 Propellant Heating

This section presents the LH2 and LOX tank heating values during boost and the first two orbits of the AS-502 flight.

26.2.4.1 LH2 Heating - Boost

The net heat transferred to the LH2 during boost was analytically determined by two methods. A comparison between the results obtained from these two methods and the maximum and minimum design heating values is shown in figure 26-24. Curve A is a simulation using the recovery temperature and tank wall heat transfer coefficient histories based on the flight trajectory. Initial LH2 tank skin temperatures from flight data were used. Maximum values of insulation thermal conductivity as a function of temperature as determined from S-IVB loading and acceptance firing test data were used. The heat transferred through heat shorts (i.e., heating paths other than the cylindrical tank) was taken from a recent S-IVB propellant heating analysis. Curve B was calculated by integrating LH2 bulk temperature change resulting from propellant heating during ascent. The LH2 heating values fall within the design range.

26.2.4.2 LH2 Heating - Orbit

The predicted LH2 heating values during the first two orbits were determined using the actual AS-502 orbital path. A comparison between the analysis results, the calculated maximum and minimum design heating values, and LH2 heating values obtained from LH2 boiloff data is shown in figure 26-25.

The heating values were based on the maximum values of internal insulation thermal conductivity discussed in paragraph 26.2.4.1. For the cylindrical tank optical properties, an average solar absorptivity (α) of 0.42 and infrared emissivity (ϵ) of 0.87 were used. These average values were determined by measurements taken on the LH2 tank a few days before the flight. (Design values for maximum heating were $\alpha = 0.40$ and $\epsilon = 0.87$.) The LH2 was assumed to be settled at the aft end of the tank with the effective liquid level at the deflector. This assumption was based at the liquid-vapor indications given by interior wall temperature sensors (C2017 to C2028).

The LH2 heating value derived from boiloff data is equivalent to 2,600 lbm of boiloff. This boiloff occurred during the period between first burn engine cutoff and second burn Engine Start Command and did not include the boiloff during blowdown. The LH2 evaporation which occurred during blowdown was the result of heat accumulated during boost and was subtracted from the total. As shown in figure 26-25, the calculated heating values agree well with each other and fall within the design range.

26.2.4.3 LOX Heating - Orbit

The predicted LOX heating values during the first two orbits were determined using the actual AS-502 orbital path. The LOX was assumed to be settled at the aft end of the tank with the effective liquid level at sta 256 (just above the common bulkhead joint). Heating of the LOX caused by the helium pressurant gas was considered negligible in the analysis. The results of this analysis are presented in figure 26-26. As shown, the total heat transferred to the LOX was approximately 2,800 Btu.

26.2.4.4 LH2 Tank External Temperatures - Orbit

Figure 26-27 compares the LH2 tank skin temperature histories for three tank regions during the second orbit. The figure shows the tank temperature at a point 30 deg from position I toward IV, position IV, and a point 30 deg from position III toward IV.

During most of the first orbit, the vehicle position III was facing the earth. At the end of the first orbit, the vehicle rolled 180 deg; thus, during the second orbit, vehicle position I was toward earth. For simplification, the initial temperature distributions for the simulated curves were estimated using flight temperature data. As shown in the figures, the simulated curves are slightly higher than the measured ones and account for the calculated heat input being slightly high.

26.3 Electronic Components Thermal Environment

The electronic component temperature data appear to be valid throughout the flight. The temperature extremes recorded during the first 33,800 sec of flight are presented in table 26-3.

The temperatures of the aft skirt components mounted on fiberglass panels ranged from 10 to 20 deg R cooler than those recorded on vehicle AS-501 at liftoff. The forward skirt components mounted on cold plates ranged up to 9 deg R warmer than those on vehicle AS-501. All temperatures at liftoff were well within the components' upper and lower temperature limits.

All components, except the chilldown inverters and the propellant utilization assembly, remained within their respective temperature limits throughout the flight. Ground hold and orbital data through the first 16,000 sec of flight are presented in figure 26-28 for the chilldown inverters. The results of the postflight analysis, simulating the environment experienced by the LOX inverter (C0139), are also presented. As indicated, there is satisfactory correlation between the flight data and the analytical results. The chilldown inverters (C0139 and C0140) exceeded their lower temperature limit at approximately RO +24,000 sec. The propellant utilization (PU) assembly exceeded its low temperature limit at 33,400 sec. Neither event is considered to be a problem because the normal operation period of both the chilldown inverters and the PU assembly extends only over the first 16,200 sec of a nominal Saturn V flight.

26.4 Propellant Behavior

Figure 26-29 shows the location of temperature sensors on the instrumentation probe, liquid-vapor sensors and temperature sensors attached to the insulation which were used to evaluate the propellant behavior immediately after orbital insertion. Only the sensors attached to the internal insulation were used to evaluate the propellant behavior during the orbital coast period. The temperature sensors on the instrumentation probe could not be used for liquid-vapor indication because the ullage temperature decreased to liquid hydrogen temperature after the initial phases of orbital coast. The liquid-vapor sensors could not be used because most of these sensors gave continuous liquid indications after the ullage

temperature decreased to liquid temperature level. This was probably caused by liquid droplet collection at the sensors. The wall temperature sensors gave very definite liquid-vapor indications. Since external tank heating creates a warm vapor layer at the tank wall, these sensors increased in temperature when the tank wall at the sensor location dried.

The wall temperature sensors became wet shortly after S-IVB engine cutoff and the sensors located on the instrumentation probe became wet approximately 100 sec later. At the time the wall temperature sensors became wet, the continuous venting system was still closed and the bulk of the liquid was in a subcooled state. Hence, boiling could not cause any significant disturbances and the wall sensor wetting was probably caused by propellant dynamic disturbances. Sensors on the instrumentation probe became wet after the pressure in the tank decreased below saturation pressure. Hence, boiling within the liquid bulk was a contributing factor to the propellant disturbances at this time. The sensor wetting could have been caused by either propellant disturbances or liquid level rise induced by propellant boiling.

All of the sensors remained wet during the first orbit. During the second orbit, some of the sensors became dry as shown in figure 26-30. The first sensors to dry were located between the nominal liquid level and the slosh deflector. As can be seen in figure 26-30, the sensors dried in the following sequence: C2024, C2017, C2018 and C2025 on position I, C2020, C2021, and C2022 on position II. Sensor C2027 fluctuated between liquid and vapor readings. A drying trend which goes up from the forward dome joint area towards the slosh deflector is indicated. Such behavior can be explained by assuming that the liquid height reached the deflector during the initial phases of the orbital coast period, then receded, leaving some of the liquid attached to the slosh deflector. The maximum volume of liquid that can be trapped under the slosh deflector cannot be calculated accurately. A stable configuration depends on the Bond number, based on a typical dimension of attached fluid. Hence, for any settling acceleration level, some fluid can be maintained under the slosh deflector.

The total liquid level rise depends on the volume of vapor generated during pressure decrease after orbital insertion and the vapor volume generated by boundary layer boiling caused by external tank heating. Since both the pressure decrease and the maximum propellant heating occur immediately after orbital insertion, the liquid level rise should reach a maximum early in the first orbit, then recede. Such behavior is indicated by the flight data.

Sensors C2017, C2018, C2021, and C2022 became wet again after the ullage rockets were fired as shown in figure 26-30. The sequence of wetting suggests that liquid was flowing from the top down the sidewall, first wetting the higher sensors. This lends support to the assumption that a liquid volume existed under the slosh deflector prior to the ullage rocket ignition.

At the time of ullage rocket ignition, the liquid level was close to sensors C2025 and C2027. This is indicated by continuous liquid readings recorded by sensors C2026 and C2028 and a fluctuation between liquid and vapor readings, recorded by sensor C2027. Such liquid height is equivalent to 1,300 ft³ of entrained vapor.

During the tank pressurization, all of the sidewall temperature sensors measured the saturation temperature corresponding to the tank pressure. This period is indicated by the shaded areas in figure 26-30. Such behavior is possible when a sensor is covered by a thin liquid film or is in the vicinity of a two phase system, such as a boiling boundary layer.

The decrease in pressure after the restart attempt caused the wetting of all temperature sensors. The sensors remained wet up to 17,700 sec or longer. At approximately 20,000 sec, sensors between the slosh deflector and the nominal liquid level were already dry. This is shown in figure 26-31. Data between 17,700 and 20,000 sec are not available; hence, it is not possible to determine the sequence of drying. The pattern of dry and wet sensors is very similar to that during the second orbit. It can be concluded, therefore, that after both the orbital insertion and the restart attempt, propellant behavior was very similar. In both cases at least one temperature sensor located under the slosh deflector remained wet indicating trapped liquid.

The propellant behavior results obtained during the flight indicate that the effective tank sidewall wetted area was much larger than the minimum possible area and this factor must be considered in such areas as the propellant heating analysis and the design of the pressurization system. The minimum wetted area is defined as the area for a completely settled propellant with no vapor entrained within the liquid, dry tank sidewalls in the ullage space, and zero meniscus height at the tank sidewall. The wetted area is very close to minimum in a 1 g environment, but deviates from the minimum considerably in a low gravity field, as indicated by the flight data.

For additional information concerning propellant behavior refer to paragraph 21.3 and 21.4.

26.5 Unusual Changes in Thermal Environment

26.5.1 First Burn Thermal Environment

Thrust structure and engine temperatures experienced an unexpected and significant change during boost beginning at approximately R0 +675 sec. The temperatures in the affected regions decreased at an abnormal rate for approximately 20 sec, underwent a 3 to 10 sec increase and, again, cooled at a rate higher than normal. A comparison of the rate of change of the affected S-IVB-502 temperatures with the temperatures experienced on S-IVB-501 for the same relative flight time is shown in figure 26-32. Sensors C0010 and C0275 are ambient gas temperature probes while C0203 and C0204 are hydraulic oil temperature probes. The remaining temperature sensors shown in the figures are external temperature patches installed on plumbing and structure.

The gas temperature probes show a high cooling rate (relative to S-IVB-501) indicating that convective cooling of the probes occurred at this time. A comparison of the rate of cooling of sensor C0087 with the temperature rise rate that occurred during S-IVB/S-II staging (retro-rocket plume impingement heating of 3 Btu/sec-ft^2) produces a thrust structure cooling rate of $0.25 \text{ Btu/sec-ft}^2$. This cooling rate is 20 times that possible due to radiation cooling. The response of sensor C0088 showed the same trends as C0087, but the temperature changes were less due to its location under the LH2 feedline.

The thrust structure temperature (C0087) increases at an average rate of 2.5 deg F/sec during this time. This rate is approximately one-half the rate that resulted from retro-rocket plume impingement. The maximum heating rate available from the natural environment and J-2 engine is approximately 30 percent of the heating rate required to produce the 2.5 deg F/sec temperature rise. Thus, to produce the observed temperature rise requires a heating environment other than the natural environment. The two gas temperature probes indicate convective heating is occurring at this time which indicates either plume impingement from a hot gas source or external combustion. Sensors C0204, C2005, C2013, C2014, and C2016 showed the initial cooling response, but did not increase in temperature at RO +695 sec. Except for C2016, all of the sensors that did not respond to heating were located between position I-IV and III-IV. C2015 showed little initial cooling, but responded with a rapid temperature rise approximately 22 sec after the other sensor responses.

Figure 26-32 shows the temperature decrease rates during the second cooling phase (RO +705 to RO +715 sec) that were two to six times as great as during the initial cooling phase that started at RO +675 sec. Comparing C0087 for the two cooling phases shows that the convective cooling environment was more severe (1.8 deg F/sec versus 0.35 deg F/sec) during the latter phase which indicates the possibility that either the initial gas mass flowrate has increased or that the flow had shifted direction.

26.5.2 Thermal Environment During Attempted Restart

The attempted restart (RO +11,614 sec) provided the next opportunity for the thrust structure and J-2 engine instrumentation to be subjected to a cold, gaseous environment. Figure 26-32 shows a comparison during restart of the rate of temperature change of selected instrumentation for both S-IVB-501 and S-IVB-502. In general, those sensors that responded to the cooling environment during boost responded during the attempted restart. The magnitude of the cooling rates was less than during boost except for C2005 (main oxidizer valve pneumatic line temperature). This measurement was very near the ASI LH2 line (suspected failure point) and was probably in the denser portion of the flow for both boost and restart.

TABLE 26-1
STRUCTURAL TEMPERATURES (BOOST)

| MEASUREMENT NUMBER AND LOCATION | LIFTOFF TEMPERATURE (deg R) | MAXIMUM INFLIGHT TEMPERATURE (deg R) | | | | | REMARKS |
|---|-----------------------------------|--------------------------------------|------|----------|--------|---------------------------|----------------------------|
| | | SIMULATED | | MEASURED | | TRUE STRUCTURE* AS-502 | |
| | | SENSOR | SKIN | AS-501 | AS-502 | | |
| Forward Skirt | | | | | | | |
| C0081 | 546 | 687 | 744 | 645 | 690 | 746 | |
| C0082 | 528 | 687 | 744 | 680 | 680 | 735 | |
| C0083 | 528 | 687 | 744 | 690 | 660 | 715 | |
| C0084 | 528 | 687 | 744 | 660 | 677 | 733 | |
| C0108 | 542 | 653 | 670 | 640 | 663 | 680 | Stringer adjacent to C0081 |
| C0109 | 525 | 692 | 745 | 599 | 663 | 713 | |
| C0110 | 528 | 653 | 670 | 610 | 618 | 635 | Stringer adjacent to C0109 |
| C0111 | 510 | 692 | 745 | 610 | Failed | | off-scale-high |
| C0112 | 490 | 690 | 735 | 492 | 624 | 664 | |
| C0239 | 530 | 658 | 673 | 610 | 650 | 665 | |
| C0240 | 496 | 631 | 620 | 540 | 538 | 528 | |
| LH2 Tank External | | | | | | | |
| C0075 | 436 | 560 | 565 | 550 | 468 | 475 | |
| C0076 | 476 | 570 | 575 | 510 | 490 | 495 | |
| C0077 | 451 | 565 | 572 | 475 | 475 | 482 | |
| C0078 | 490 | 573 | 582 | 505 | 541 | 550 | |
| C0079 | 422 | 560 | 565 | 490 | 465 | 470 | |
| C0080 | 460 | 565 | 572 | 490 | 478 | 485 | |
| C0106 | 480 | 570 | 575 | 480 | 497 | 502 | |
| C0107 | 391 | 550 | 560 | 480 | 470 | 480 | |
| Aft Skirt (Insulated with 0.01 in. Korotherm except as noted) | | | | | | | |
| C0024 | 533 | 670 | 669 | 595 | 588 | 588 | |
| C0025 | 534 | 670 | 669 | 633 | 634 | 634 | |
| C0026 | 530 | 686 | 685 | 625 | 628 | 628 | |
| C0027 | 526 | 686 | 685 | 590 | 588 | 588 | |
| C0028 | 530 | 686 | 685 | 590 | 593 | 593 | |
| C0029 | 534 | 670 | 669 | 615 | 615 | 615 | |
| C0045 | 527 | 660 | 659 | 595 | 595 | 595 | |
| C0046 | 503 | 654 | 652 | 480 | 562 | 562 | |
| C0047 | 518 | 600 | 630 | 593 | 590 | 625 | No insulation |
| C0048 | 528 | 600 | 630 | 593 | 601 | 631 | No insulation |
| C0113 | 528 | 626 | 626 | 585 | 600 | 600 | Stringer adjacent to C0045 |
| C0114 | 550 | 664 | 664 | 585 | 605 | 605 | |
| C0115 | 547 | 630 | 630 | 580 | 598 | 598 | Stringer adjacent to C0114 |
| C0116 | 522 | 600 | 630 | 580 | 597 | 627 | No insulation |
| C0117 | 511 | 600 | 630 | 485 | 585 | 615 | No insulation |
| C0164 | 531 | 686 | 685 | 583 | 591 | 591 | |
| C0165 | 534 | 686 | 685 | 620 | 636 | 636 | |
| C0291 | 495 | 654 | 652 | 570 | 565 | 565 | |
| C0292 | 470 | - | - | 465 | 480 | 480 | |
| C0293 | 515 | 634 | 644 | 608 | 613 | 622 | Covered by APS fairing |
| Aft Interstage (Insulated with 0.01 in. Korotherm) | | | | | | | |
| C0119 | 520 | 660 | 670 | 595 | 640 | 650 | Stringer adjacent to C0306 |
| C0120 | 520 | 660 | 670 | 592 | 636 | 646 | Stringer adjacent to C0121 |
| C0121 | 517 | 672 | 670 | - | 627 | 625 | |
| C0123 | 520 | 660 | 670 | 623 | 641 | 651 | Stringer adjacent to C0305 |
| C0305 | 518 | 672 | 670 | 617 | 647 | 645 | |
| C0306 | 520 | 672 | 670 | 575 | 628 | 626 | |
| LH2 Feedline Fairing | | | | | | | |
| C0091 | 505 | 740 | 754 | 670 | 740 | 754 | |
| Main Tunnel | | | | | | | |
| C0049 | - | - | - | 702 | Failed | | Off-scale-high |
| C0227 | 500 | 648 | 698 | 612 | 635 | 684 | |
| C0242 | 510 | 650 | 700 | 590 | 626 | 675 | |
| APS Fairing | | | | | | | |
| C0286 | - | - | - | 755 | Failed | | No response |
| C0287 | 547 | 665 | 706 | 657 | 665 | 706 | |
| C0288 | 540 | 665 | 706 | 655 | 670 | 711 | |
| C0289 | 544 | 665 | 706 | 641 | 653 | 694 | |

*True structural temperature was estimated from analysis by the temperature differences of the structure calculated with and without the sensor installation.

TABLE 26-2
APS ORBITAL TEMPERATURES

| MEASUREMENT NO. AND DESCRIPTION OR LOCATION | LIFTOFF TEMPERATURE (deg R) | | | INFLIGHT MAXIMUM TEMPERATURE (deg R) | | | | INFLIGHT MINIMUM TEMPERATURE (deg R) | | |
|---|--------------------------------|----------|--------|--|----------|--------|--------------------------|--|----------|--------|
| | EXPECTED | MEASURED | | MAX LIMIT | MEASURED | | EXCEED TIME* (sec) | MIN LIMIT | MEASURED | |
| | | AS-501 | AS-502 | | AS-501 | AS-502 | | | AS-501 | AS-502 |
| FAIRING | | | | | | | | | | |
| C0286 Forebody | | 533 | 533 | | 585 | 508** | | | 485 | 498 |
| C0287 Right side | | 542 | 546 | | 650 | 600 | | | 496 | 490 |
| C0288 Top | | 537 | 540 | | 610 | 582 | | | 507 | 505 |
| C0289 Left side | | 537 | 542 | | 505 | 540 | | | 465 | 475 |
| INTERNAL | | | | | | | | | | |
| C0294 Fuel line | 545 ±7 | 547 | 545 | 535 | 575 | 603 | 16,500 | 480 | 545 | 550 |
| C0295 Fuel inlet (right side) | 545 ±7 | 546 | 545 | 535 | 566 | 587 | 16,850 | 480 | 546 | 550 |
| C0296 Fuel inlet (left side) | 545 ±7 | 545 | 545 | 585 | 557 | 576 | | 480 | 540 | 548 |
| C0297 Ox line | 545 ±7 | 545 | 545 | 585 | 550 | 601 | 16,500 | 480 | 545 | 550 |
| C0298 Ox inlet (left side) | 545 ±7 | 545 | 545 | 585 | 559 | 590 | 16,850 | 480 | 544 | 548 |
| C0299 Ox inlet (right side) | 545 ±7 | 546 | 545 | 585 | 566 | 570 | | 480 | 543 | 550 |
| C0300 Fuel tank support | 545 ±7 | 545 | 548 | 585 | 563 | 560 | | 480 | 550 | 550 |
| C0301 Ox tank support | 545 ±7 | 545 | † | 585 | 555 | † | | 480 | 540 | † |
| C0302 Fuel cont mod | 545 ±7 | 545 | 546 | 585 | 570 | 563 | | 480 | 550 | 548 |
| C0303 Ox cont mod | 545 ±7 | 545 | 546 | 585 | 550 | 554 | | 480 | 528 | 548 |

*Time at which temperature limit was exceeded (available data)

**Apparent failure during boost

†No Data

TABLE 26-3
FORWARD AND AFT SKIRT COMPONENT TEMPERATURE*

| MEASUREMENT NO. AND DESCRIPTION OR LOCATION | LIFTOFF TEMPERATURE (deg R) | | | MAX FLIGHT TEMP (deg R) | | | MIN FLIGHT TEMP (deg R) | | | REMARKS |
|---|--------------------------------|----------|--------|----------------------------|----------|--------|----------------------------|----------|--------|---|
| | EXPECTED | MEASURED | | LIMIT | MEASURED | | LIMIT | MEASURED | | |
| | | AS-501 | AS-502 | | AS-501 | AS-502 | | AS-501 | AS-502 | |
| LOX CHILLDOWN INVERTER | | | | | | | | | | |
| C0139 | 495 - 540 | 530 | 515 | 610 | 536 | 523 | 470 | 500 | 435 | Exceeded minimum limit approximately 24,000 sec after liftoff |
| C2032 | 495 - 540 | - | 505 | - | - | 516 | - | - | 444 | |
| LH2 CHILLDOWN INVERTER | | | | | | | | | | |
| C0140 | 495 - 540 | 535 | 515 | 610 | 545 | 527 | 470 | 509 | 440 | Exceeded minimum limit approximately 24,000 sec after liftoff |
| C2033 | 495 - 540 | - | 505 | - | - | 516 | - | - | 447 | |
| BRIDGE MODULES | | | | | | | | | | |
| Forward | | | | | | | | | | |
| C0233 | 500 - 540 | 516 | 525 | 620 | 524 | 529 | 395 | 516 | 490 | |
| C0234 | 500 - 540 | 516 | 524 | 620 | 524 | 526 | 395 | 516 | 490 | |
| C0235 | 500 - 540 | 516 | 517 | 620 | 524 | 523 | 395 | 516 | 487 | |
| Aft | | | | | | | | | | |
| C0236 | 460 - 540 | 508 | 499 | 620 | 508 | 499 | 395 | 467 | 424 | |
| C0237 | 460 - 540 | 505 | 489 | 620 | 505 | 489 | 395 | 474 | 411 | |
| C0238 | 460 - 540 | 525 | 511 | 620 | 525 | 511 | 395 | 434 | 422 | |
| PU ASSEMBLY | | | | | | | | | | |
| C0017 | 500 - 560 | 528 | 527 | 570 | 537 | 530 | 500 | 521 | 493 | Exceeded minimum limit 33,400 sec after liftoff |
| STATIC INVERTER/ CONVERTER | | | | | | | | | | |
| C0061 | 500 - 560 | 533 | 541 | 570 | 537 | 546 | 500 | 515 | 505 | |

*During first 33,800 sec of flight.

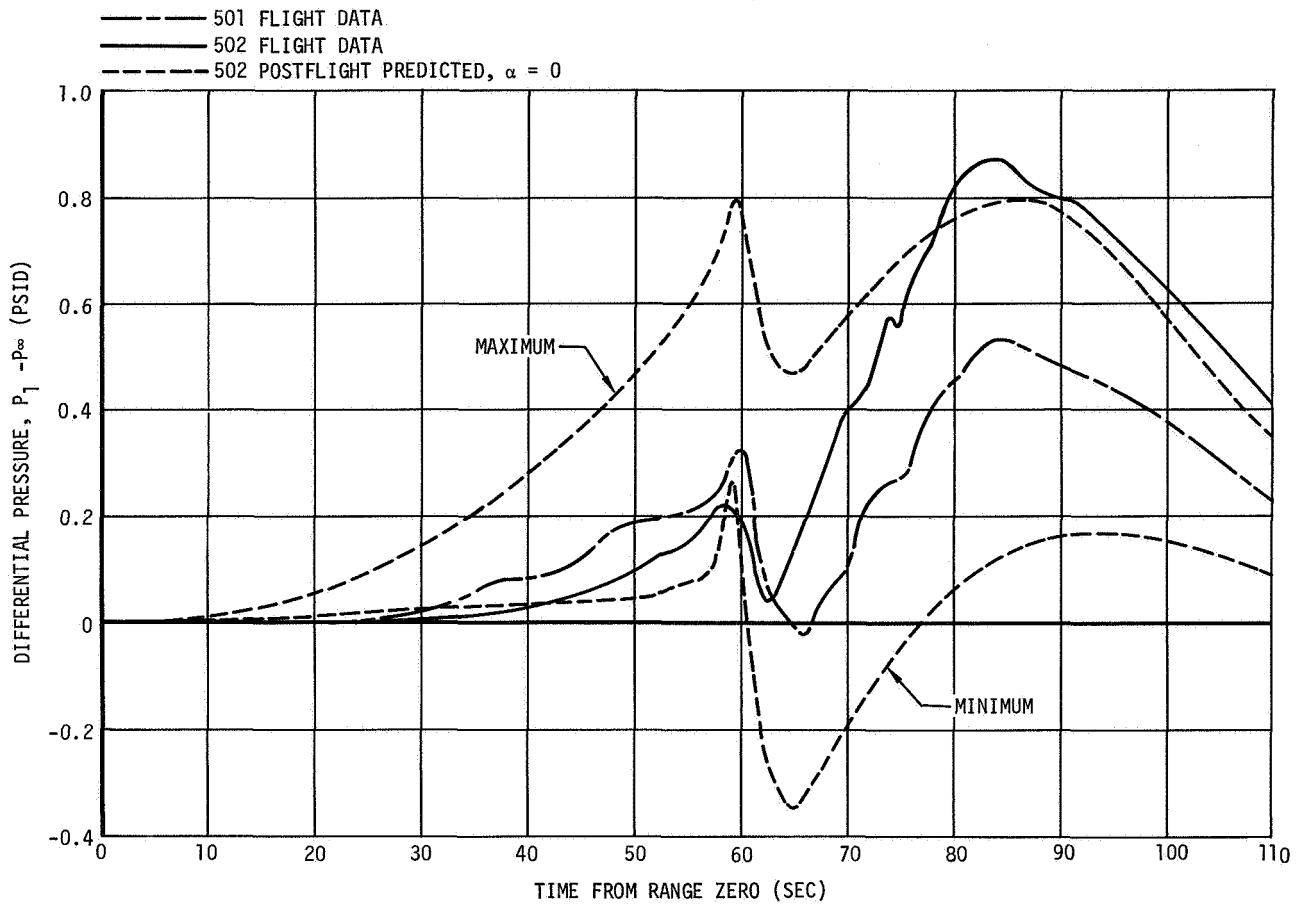


Figure 26-1. Forward Compartment Internal Pressure Minus Ambient Pressure

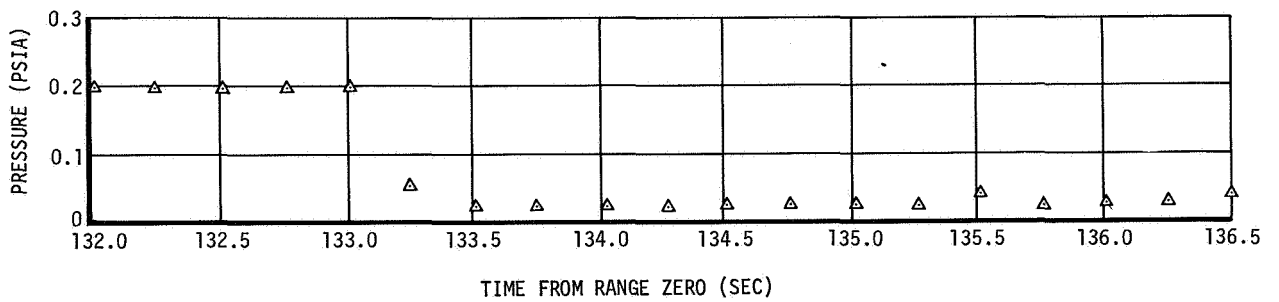


Figure 26-2. Raw Data Output From Measurement D0051

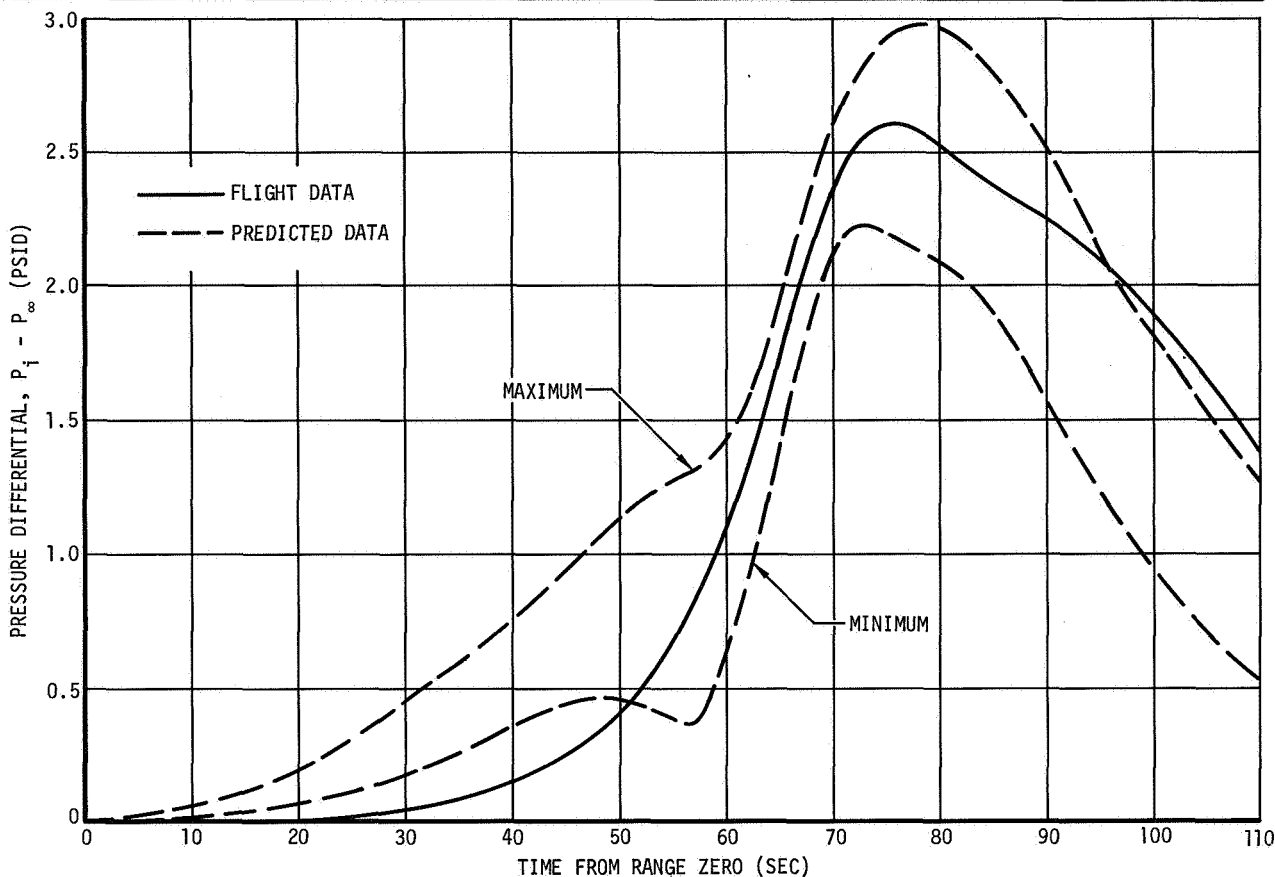


Figure 26-3. Aft Skirt and Interstage Internal Pressure Minus Ambient Pressure

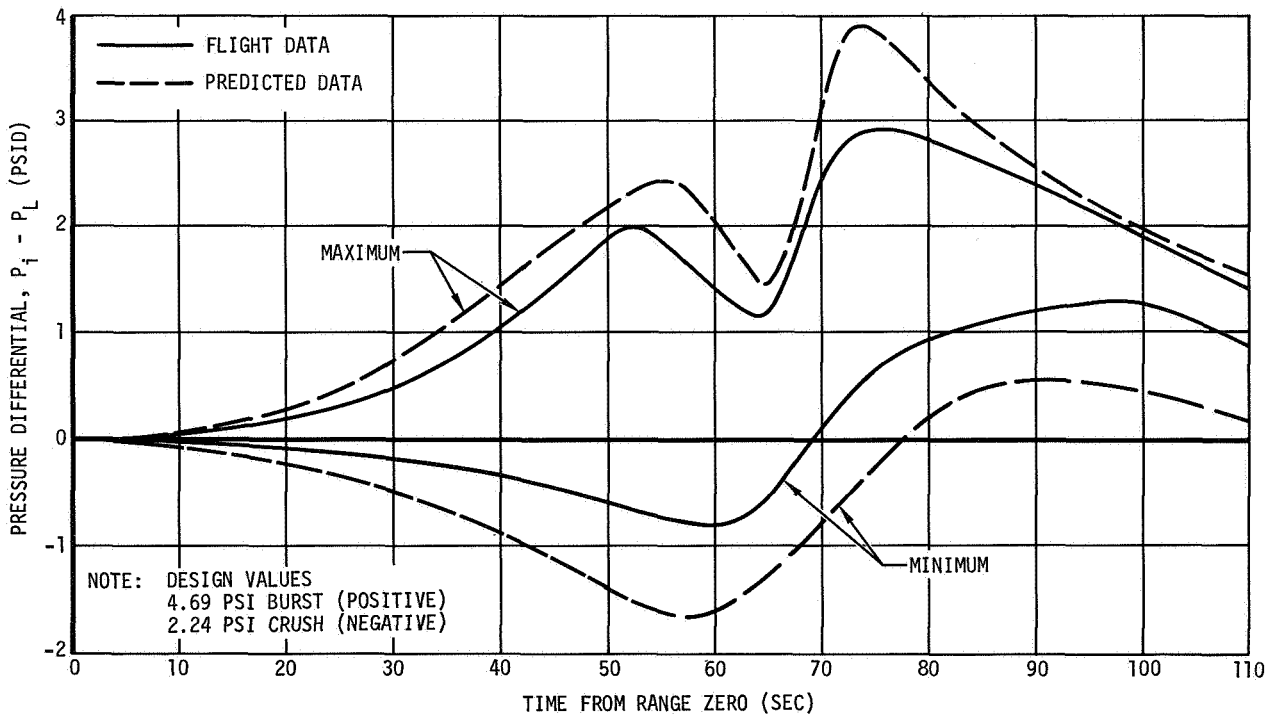


Figure 26-4. Aft Skirt and Interstage Internal Pressure Minus Local External Pressure

Section 26
Aero/Thermodynamic Environment

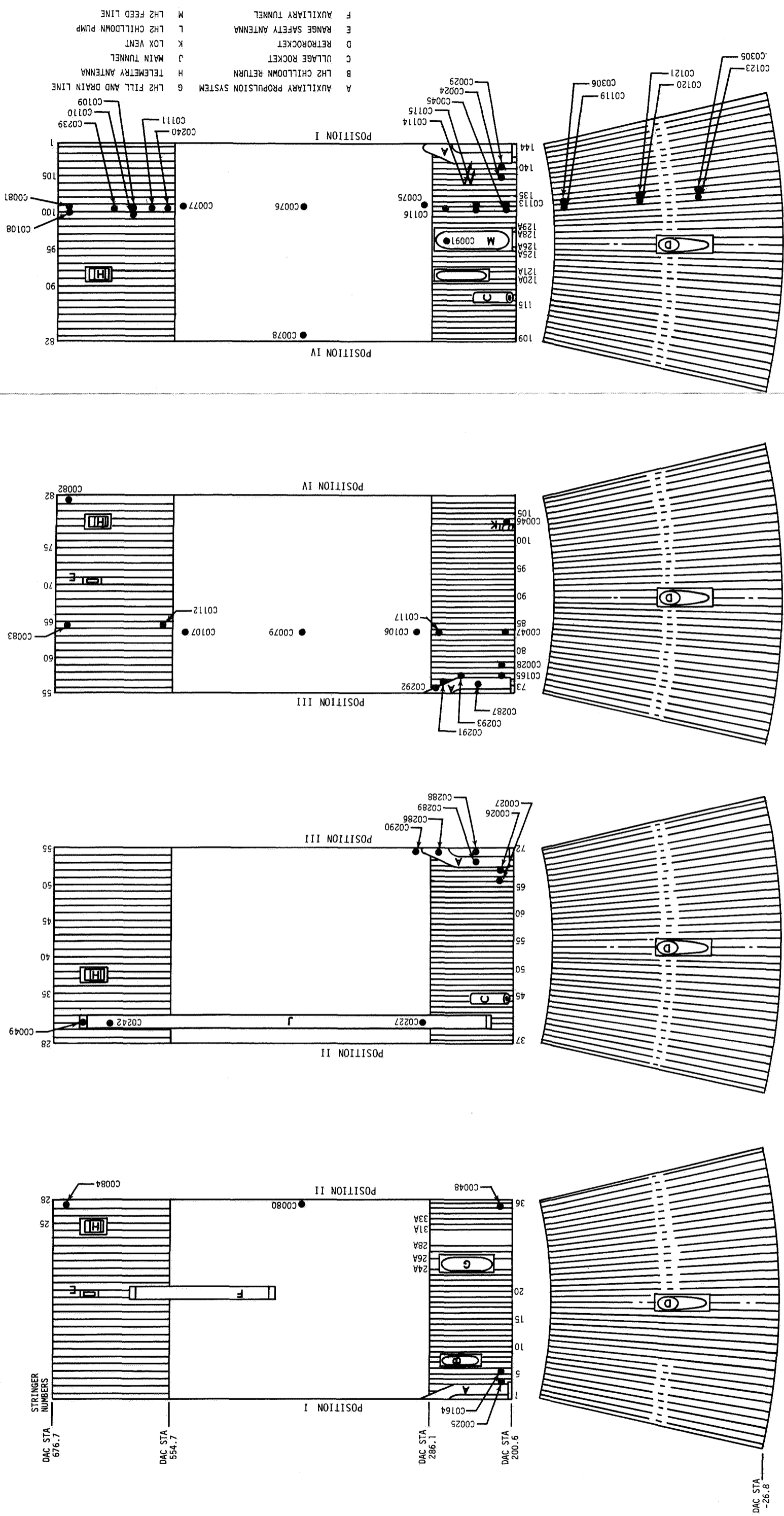


Figure 26-5. Temperature Sensor Locations

FOLDOUT FRAME 2

FOLDOUT FRAME 1

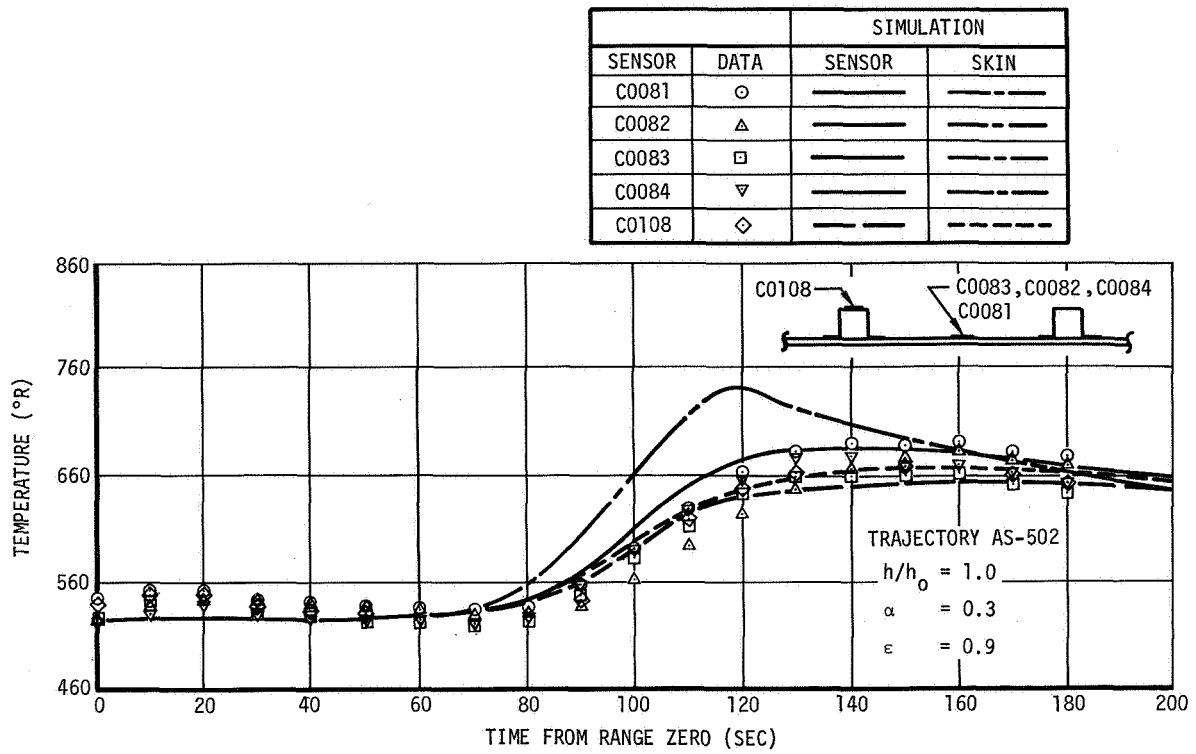


Figure 26-6. Forward Skirt Temperature Histories - Sta 670

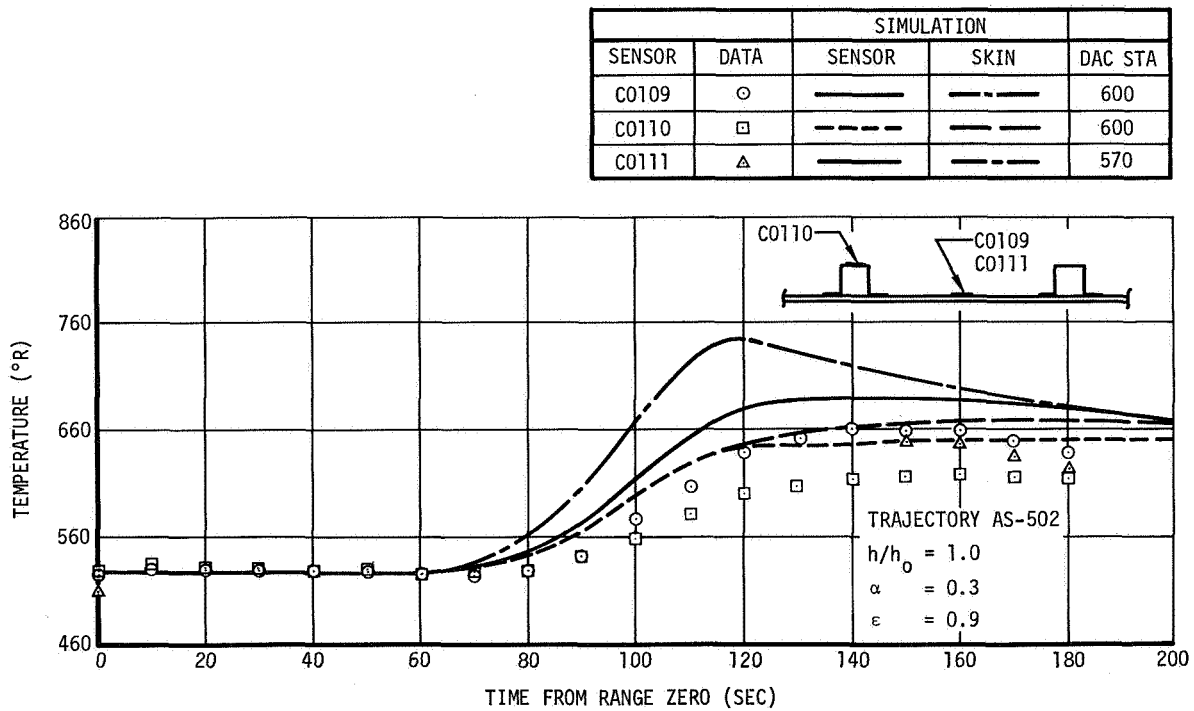


Figure 26-7. Forward Skirt Temperature Histories - Sta 600 and 570

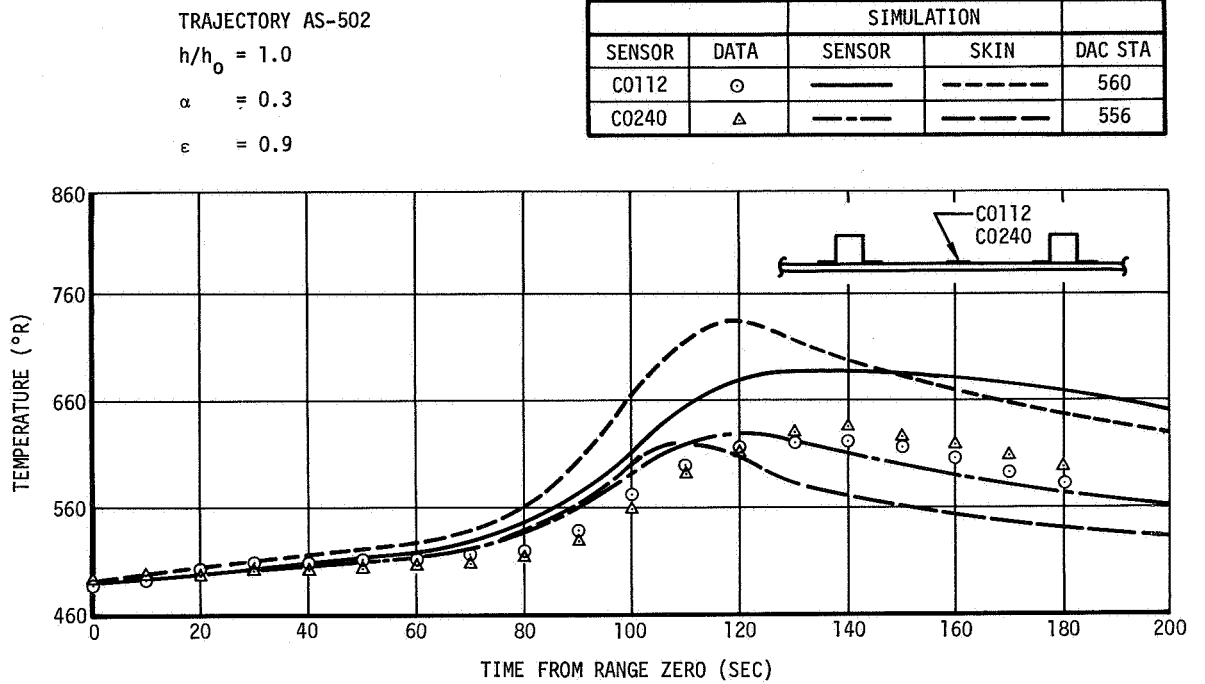


Figure 26-8. Forward Skirt Temperature Histories - Sta 556 & 560

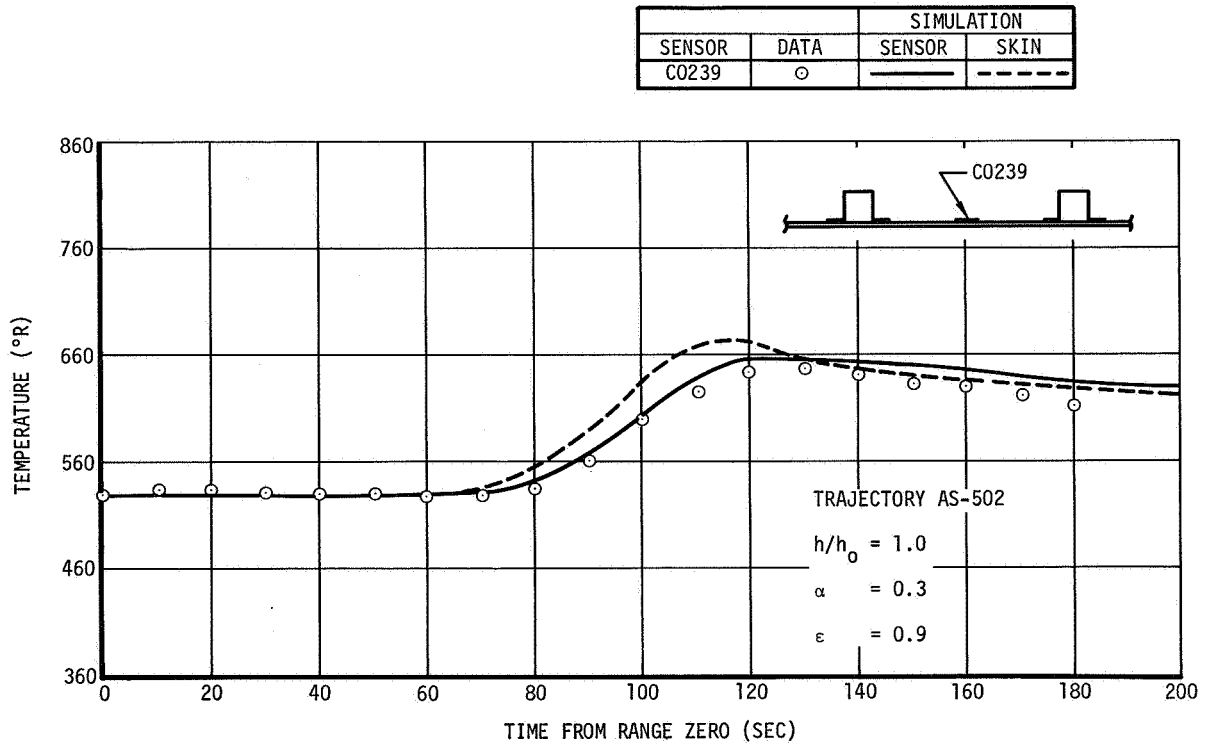


Figure 26-9. Forward Skirt Temperature History - Sta 615

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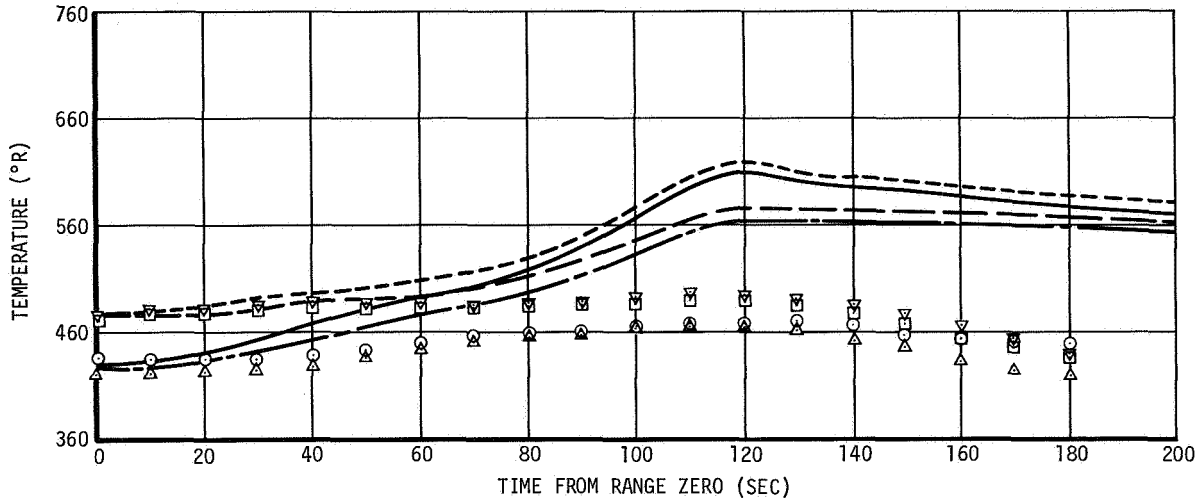
TRAJECTORY AS-502

$h/h_0 = 1.0$

$\alpha = 0.42$

$\epsilon = 0.87$

| SENSOR | DATA | SIMULATION | | DAC STA |
|--------|------|------------|-------|---------|
| | | SENSOR | SKIN | |
| C0075 | ○ | ———— | ----- | 296 |
| C0079 | △ | ———— | ----- | 421 |
| C0076 | □ | ----- | ———— | 421 |
| C0106 | ▽ | ----- | ———— | 296 |



TRAJECTORY AS-502

$h/h_0 = 1.0$

$\alpha = 0.42$

$\epsilon = 0.87$

| SENSOR | DATA | SIMULATION | | DAC STA |
|--------|------|------------|-------|---------|
| | | SENSOR | SKIN | |
| C0077 | ○ | ———— | ----- | 544 |
| C0080 | △ | ———— | ----- | 421 |
| C0078 | □ | ----- | ———— | 421 |
| C0107 | ▽ | ----- | ———— | 544 |

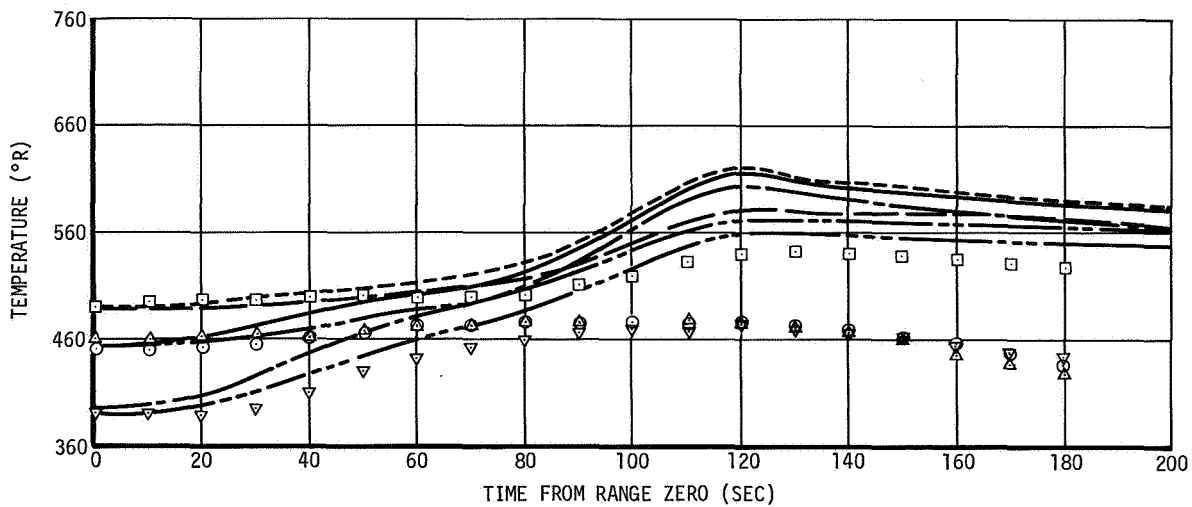


Figure 26-10. LH2 Tank Temperature Histories

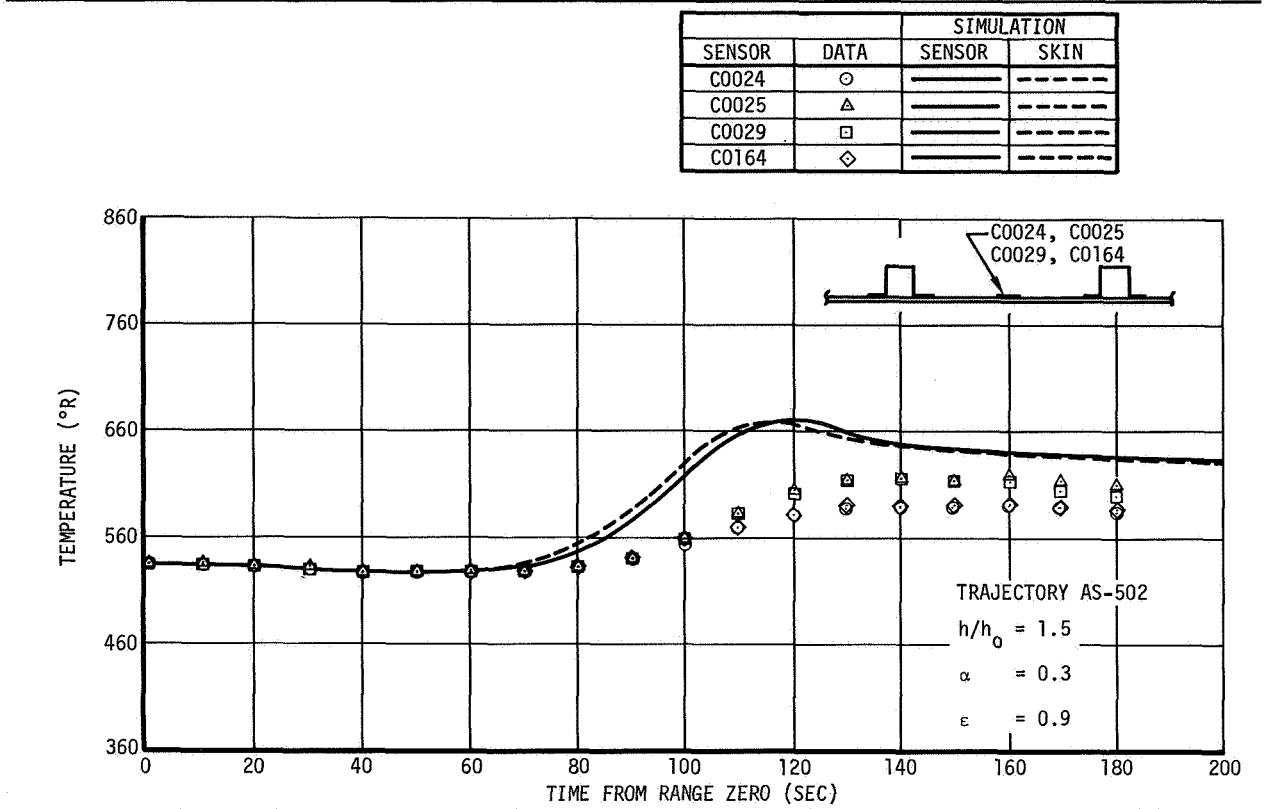


Figure 26-11. Aft Skirt Temperature Histories Near APS NO. 1 - Sta 215

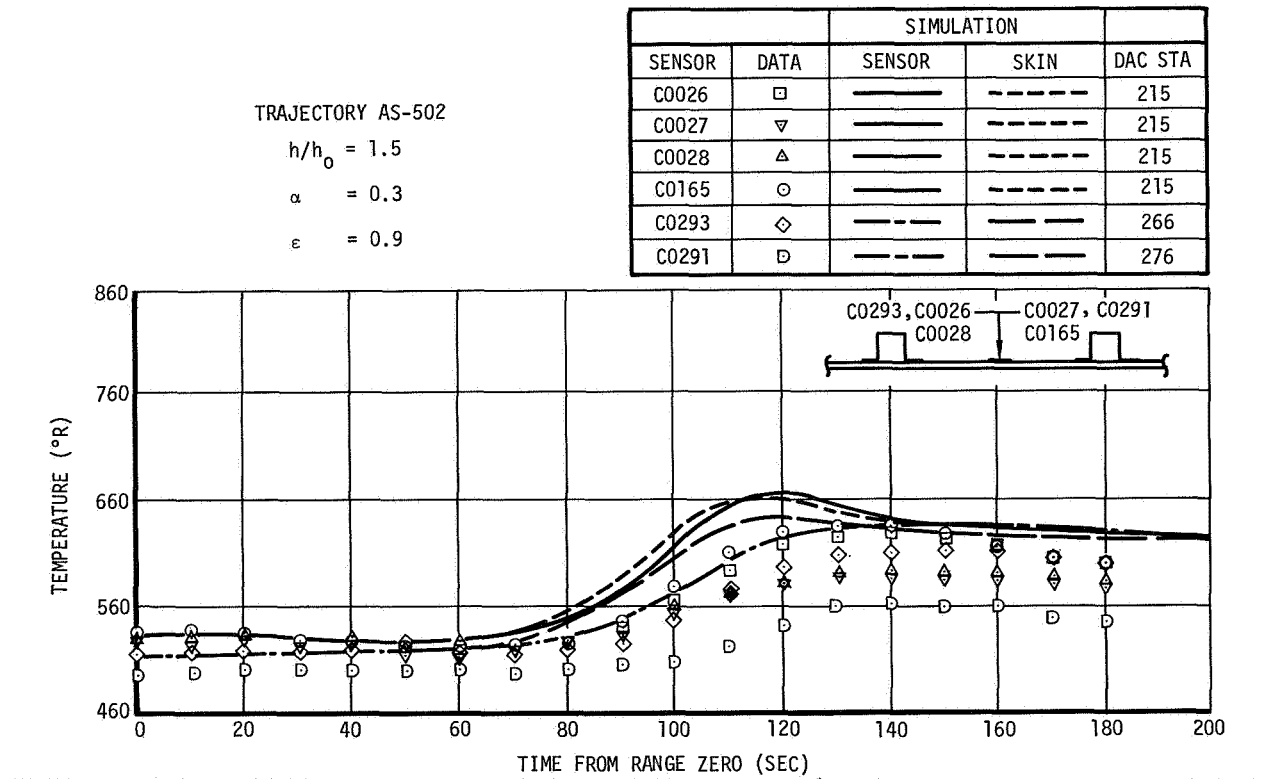


Figure 26-12. Aft Skirt Temperature Histories Near APS NO. 2

TRAJECTORY AS-502

$h/h_o = 1.5$

$\alpha = 0.3$

$\epsilon = 0.9$

| | | SIMULATION | |
|--------|------|------------|------|
| SENSOR | DATA | SENSOR | SKIN |
| C0045 | ○ | —— | ---- |
| C0113 | △ | ---- | ---- |
| C0046 | ◇ | —— | ---- |

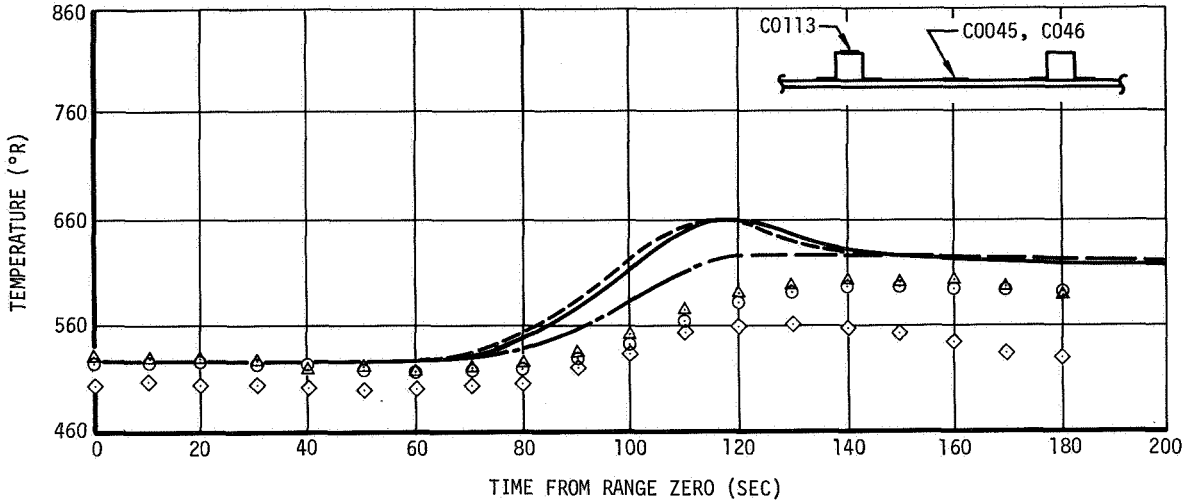


Figure 26-13. Aft Skirt Temperature Histories - Insulated (Sta 210.65)

| | | SIMULATION | |
|--------|------|------------|------|
| SENSOR | DATA | SENSOR | SKIN |
| C0114 | ○ | —— | ---- |
| C0115 | △ | ---- | ---- |

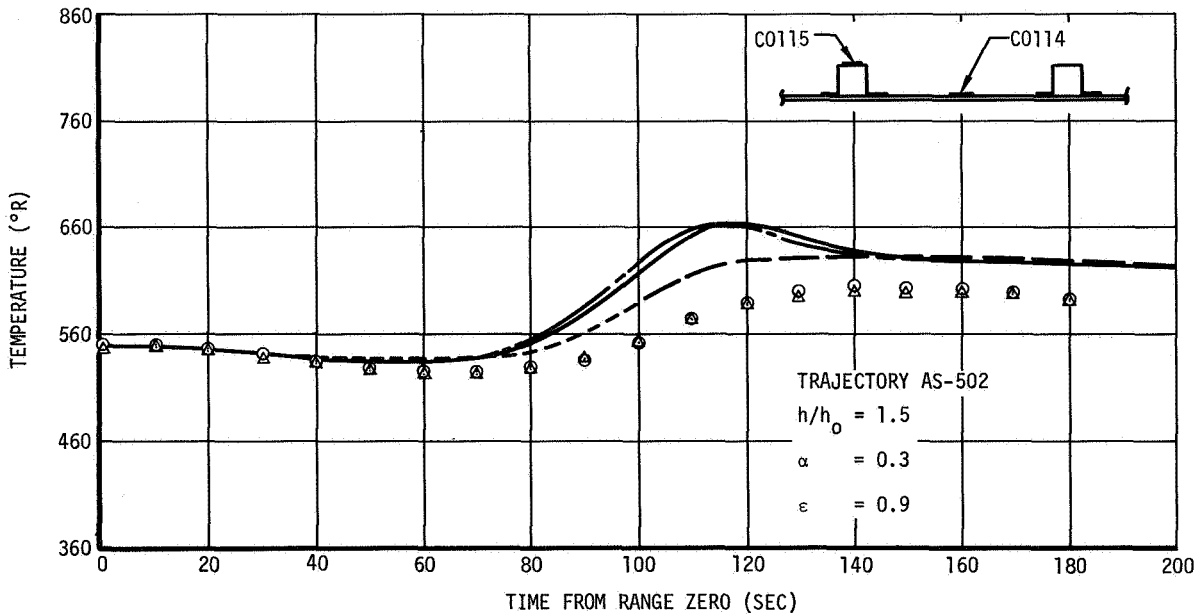


Figure 26-14. Aft Skirt Temperature Histories - Insulated (Sta 250)

TRAJECTORY AS-502

$h/h_0 = 1.0$

$\alpha = 0.3$

$\epsilon = 0.9$

| | | SIMULATION | | |
|--------|------|------------|-------|---------|
| SENSOR | DATA | SENSOR | SKIN | DAC STA |
| C0047 | ○ | ———— | ----- | 210 |
| C0048 | △ | ———— | ----- | 210 |
| C0116 | □ | ———— | ----- | 280 |
| C0117 | ▽ | ———— | ----- | 280 |

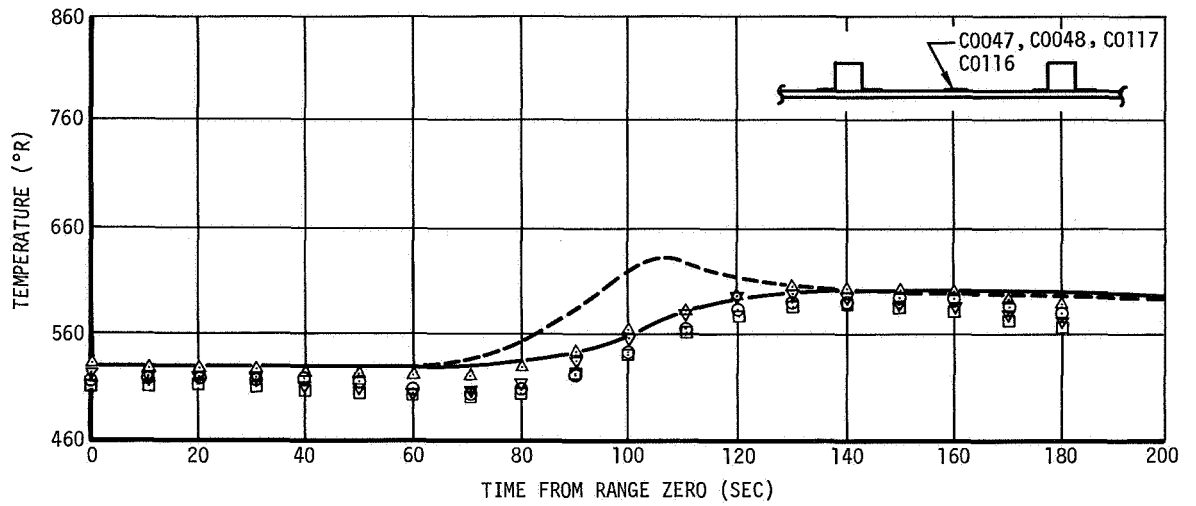


Figure 26-15. Aft Skirt Skin Temperature Histories - Uninsulated

TRAJECTORY AS-502

$h/h_0 = 1.0$

$\alpha = 0.3$

$\epsilon = 0.9$

| | | SIMULATION | | |
|--------|------|------------|-------|---------|
| SENSOR | DATA | SENSOR | SKIN | DAC STA |
| C0119 | □ | ———— | ----- | 192 |
| C0120 | ▽ | ———— | ----- | 156 |
| C0121 | ◇ | ----- | ----- | 156 |
| C0123 | ○ | ———— | ----- | 81 |
| C0305 | △ | ----- | ----- | 81 |
| C0306 | ◁ | ----- | ----- | 192 |

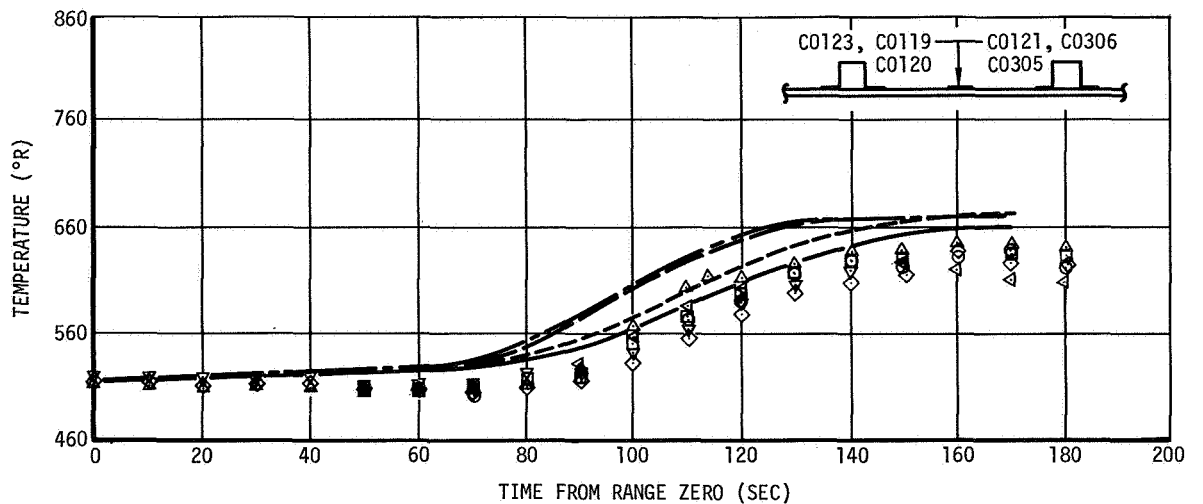


Figure 26-16. Aft Interstage Temperature Histories - Insulated

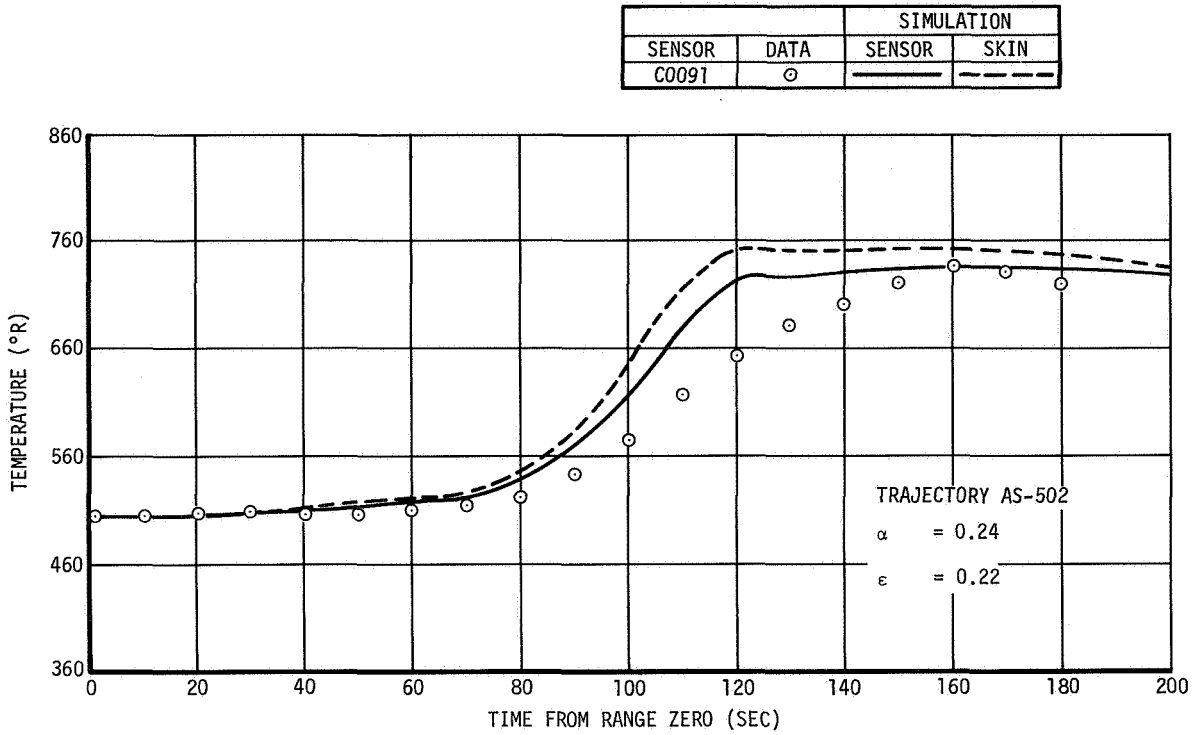


Figure 26-17. LH2 Feedline Fairing Temperature History

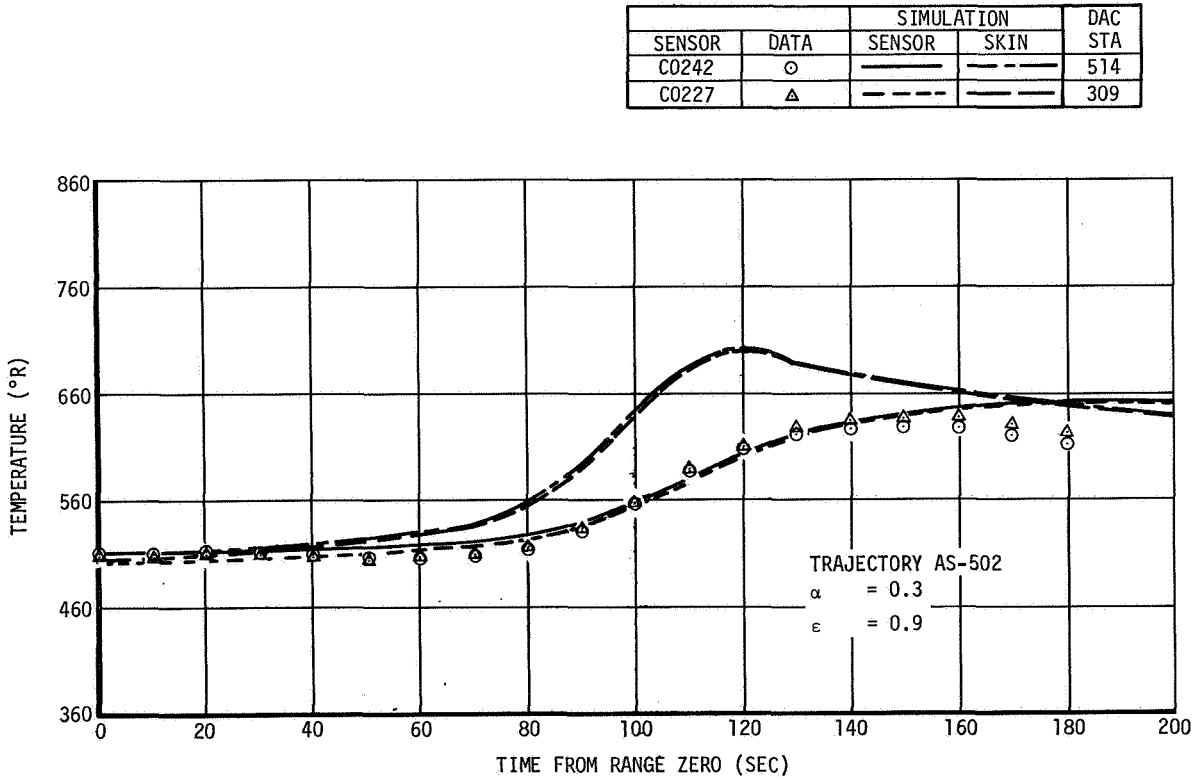


Figure 26-18. Main Tunnel Temperature Histories

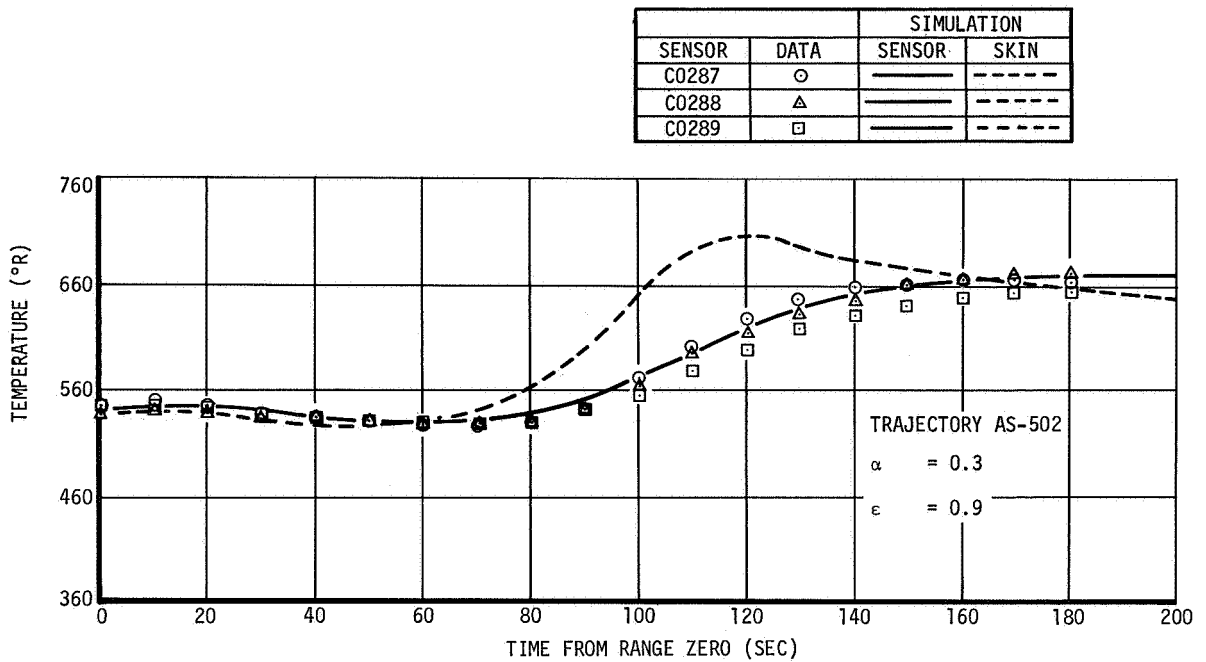


Figure 26-19. APS Centerbody Temperature Histories

| HEAT FLUX-BTU/SEC-FT ² | SENSOR | | 501 | 502 | |
|-----------------------------------|--------|-------------|-------------|------|--|
| ENGINE NOZZLE | C2000 | 6.2* (10)** | 0.4 (2.3)** | 0.55 | 45° FROM POSITION III TOWARD POSITION IV |
| HEAT FLUX | C2004 | 3.6* | 0.35(1.1)** | 1.10 | POSITION III |

* AS-202 FLIGHT DATA
** NUMBERS IN PARENTHESIS REPRESENT ANALYTICALLY PREDICTED MAXIMUMS

| SENSOR | DATA | SIMULATION |
|--------|------|------------|
| C2000 | △ | ———— |
| C2004 | ○ | ----- |

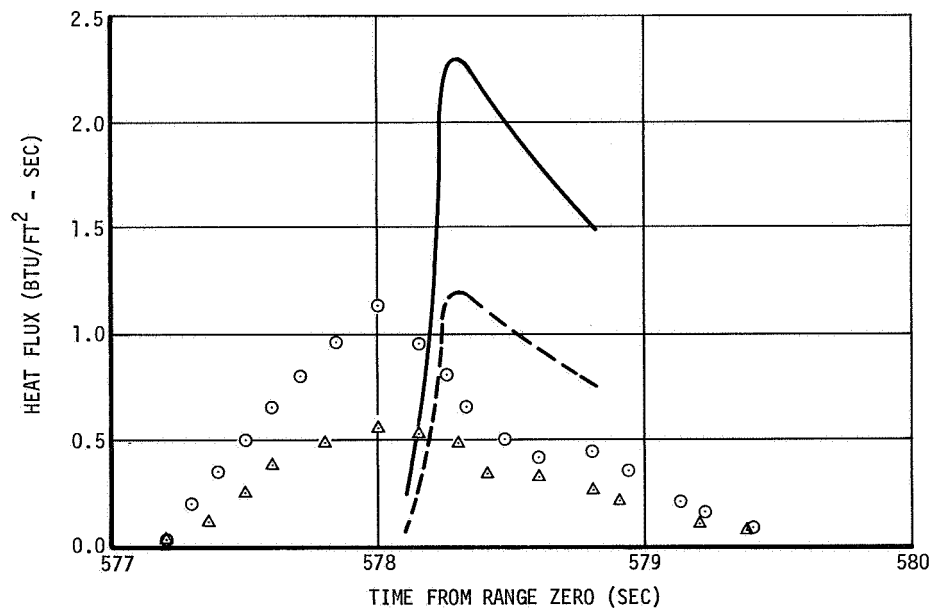


Figure 26-20. J-2 Engine Heat Flux Due to Retrorocket Impingement

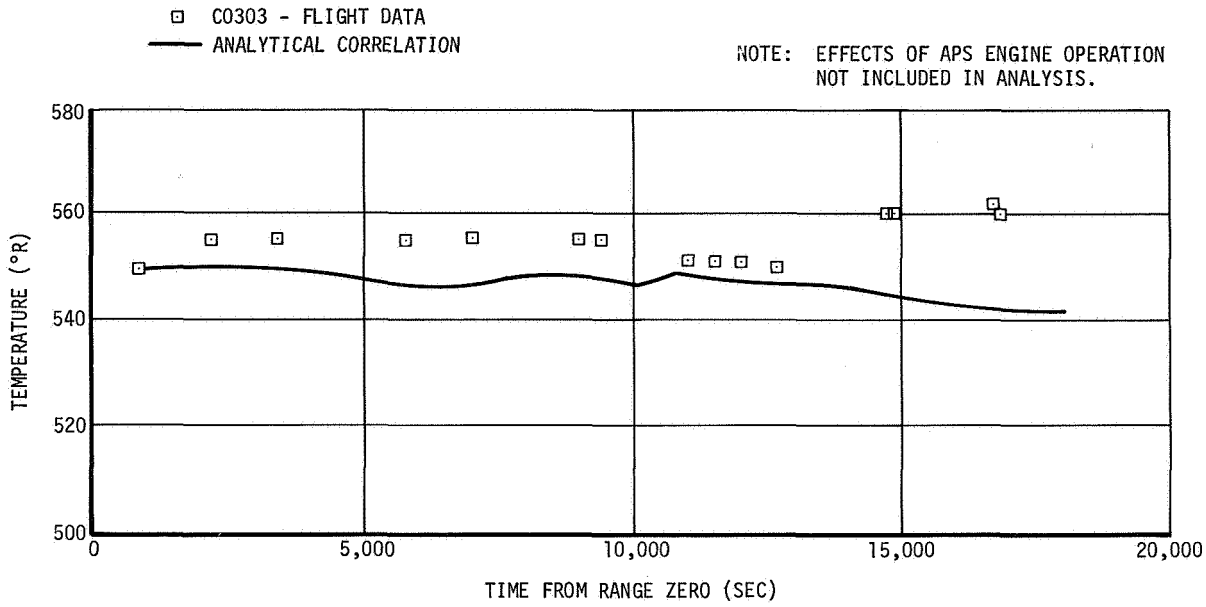


Figure 26-21. APS Oxidizer Control Module Temperature Correlation.

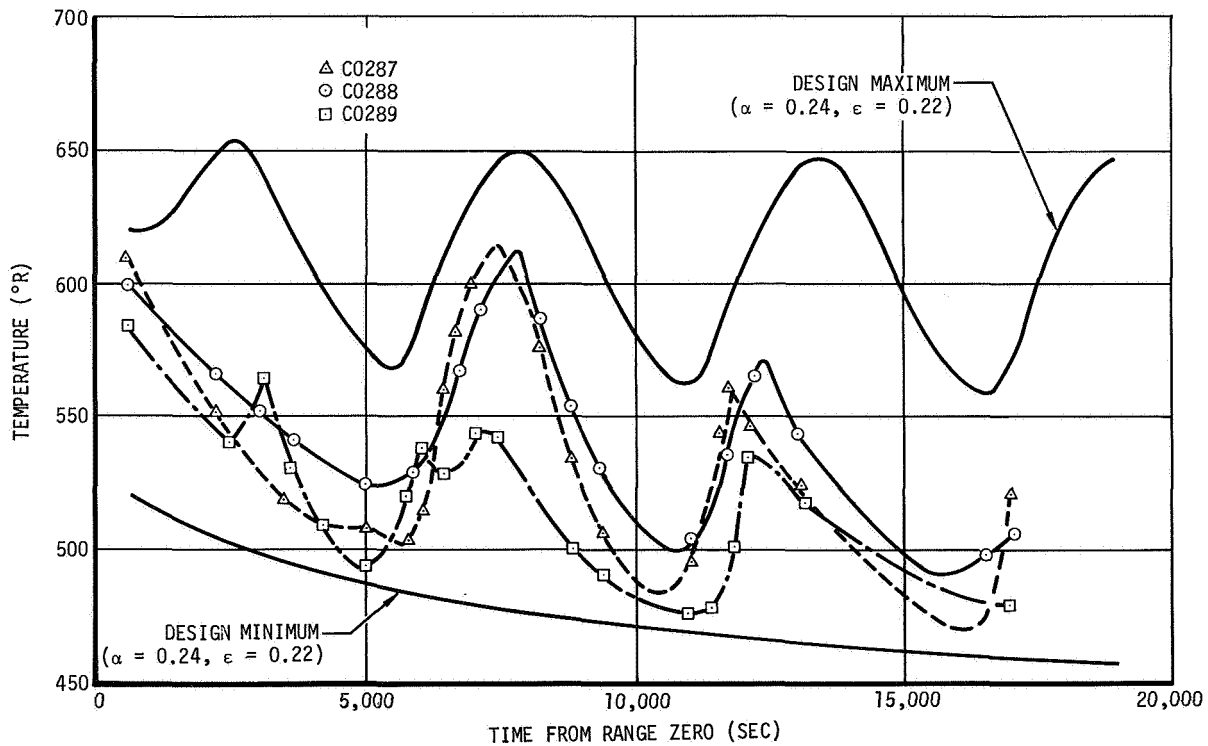


Figure 26-22. APS Fairing Temperature Comparison

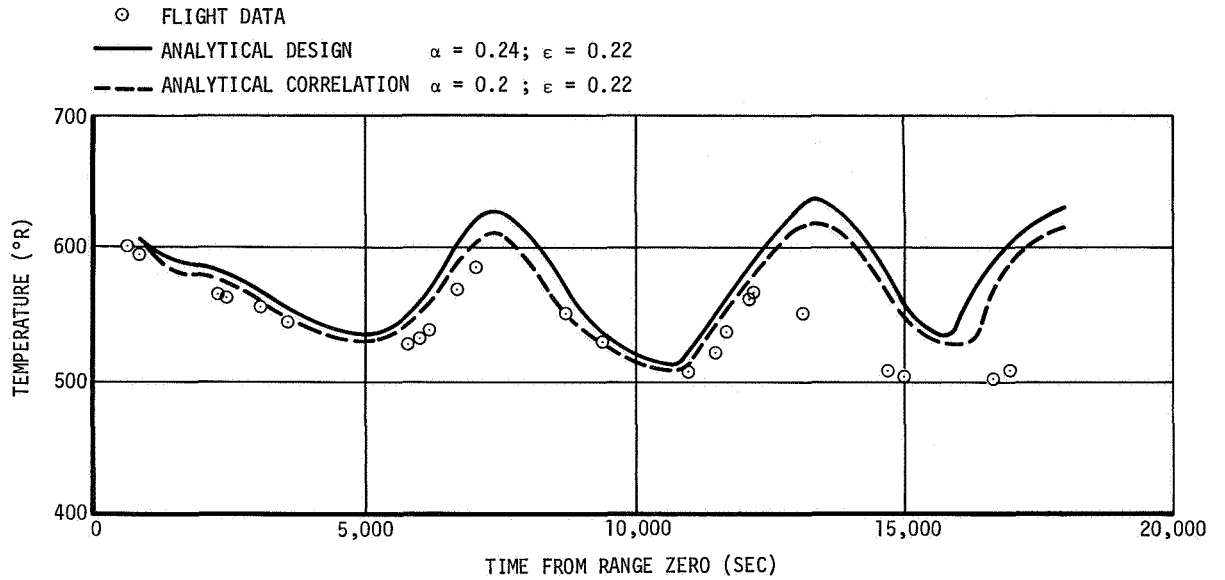


Figure 26-23. APS Fairing Temperature Correlation

NOTE: HEAT SHORTS INCLUDED IN CURVE A = 54,700 BTU
 DESIGN VALUES ARE BASED ON 180 SEC PREPRESSURIZATION
 AND 690 SEC BOOST PERIOD.

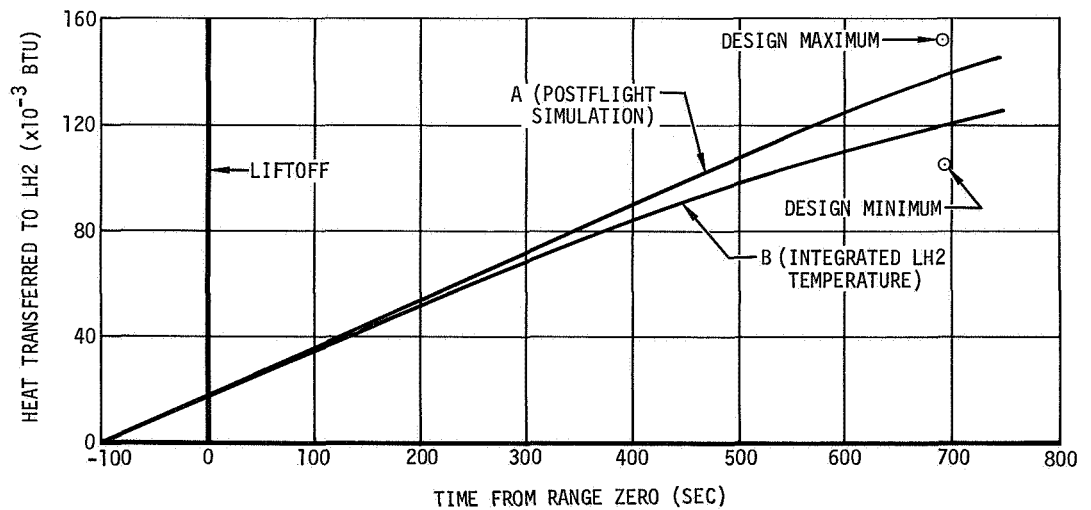


Figure 26-24. LH2 Heating - Boost

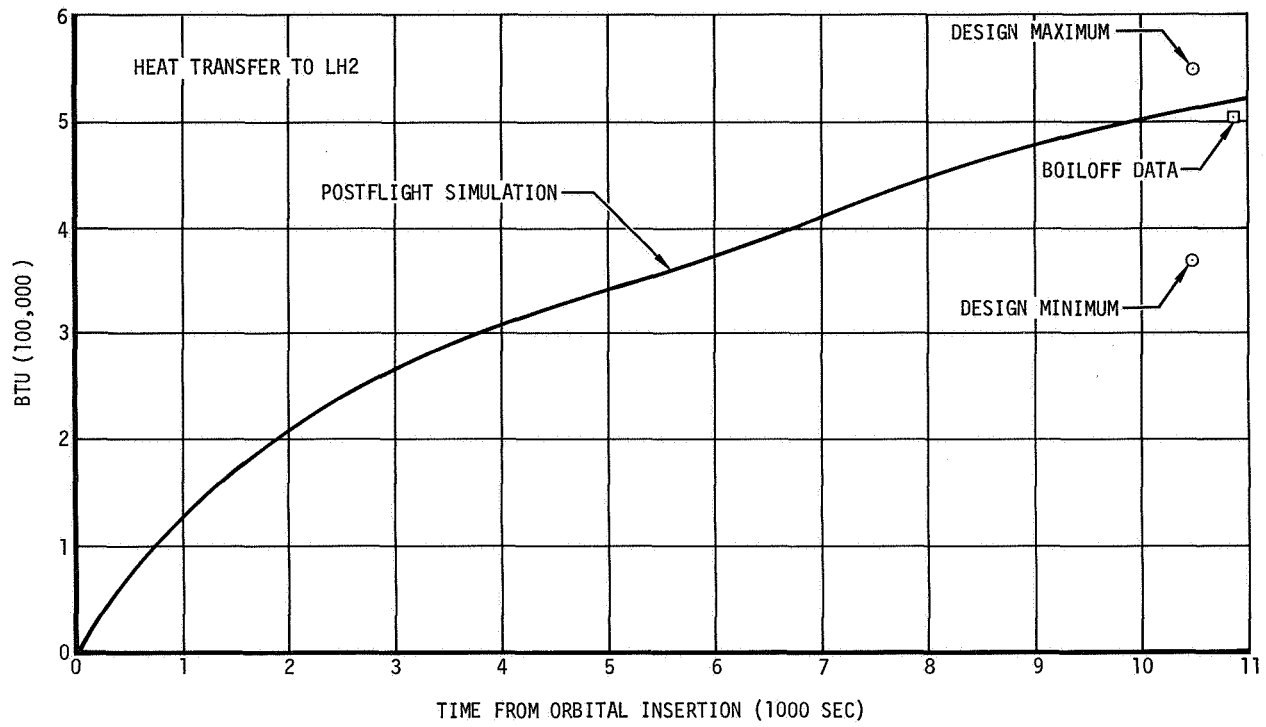


Figure 26-25. LH2 Heating - Orbit

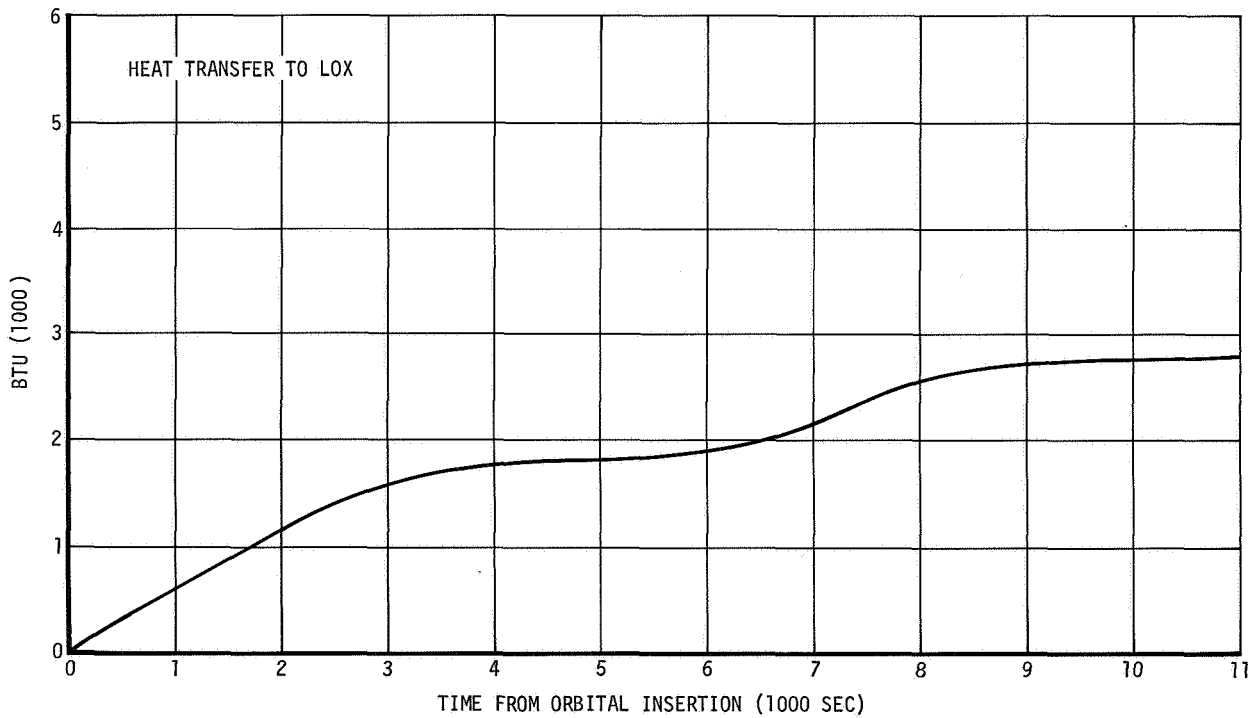


Figure 26-26. LOX Heating - Orbit

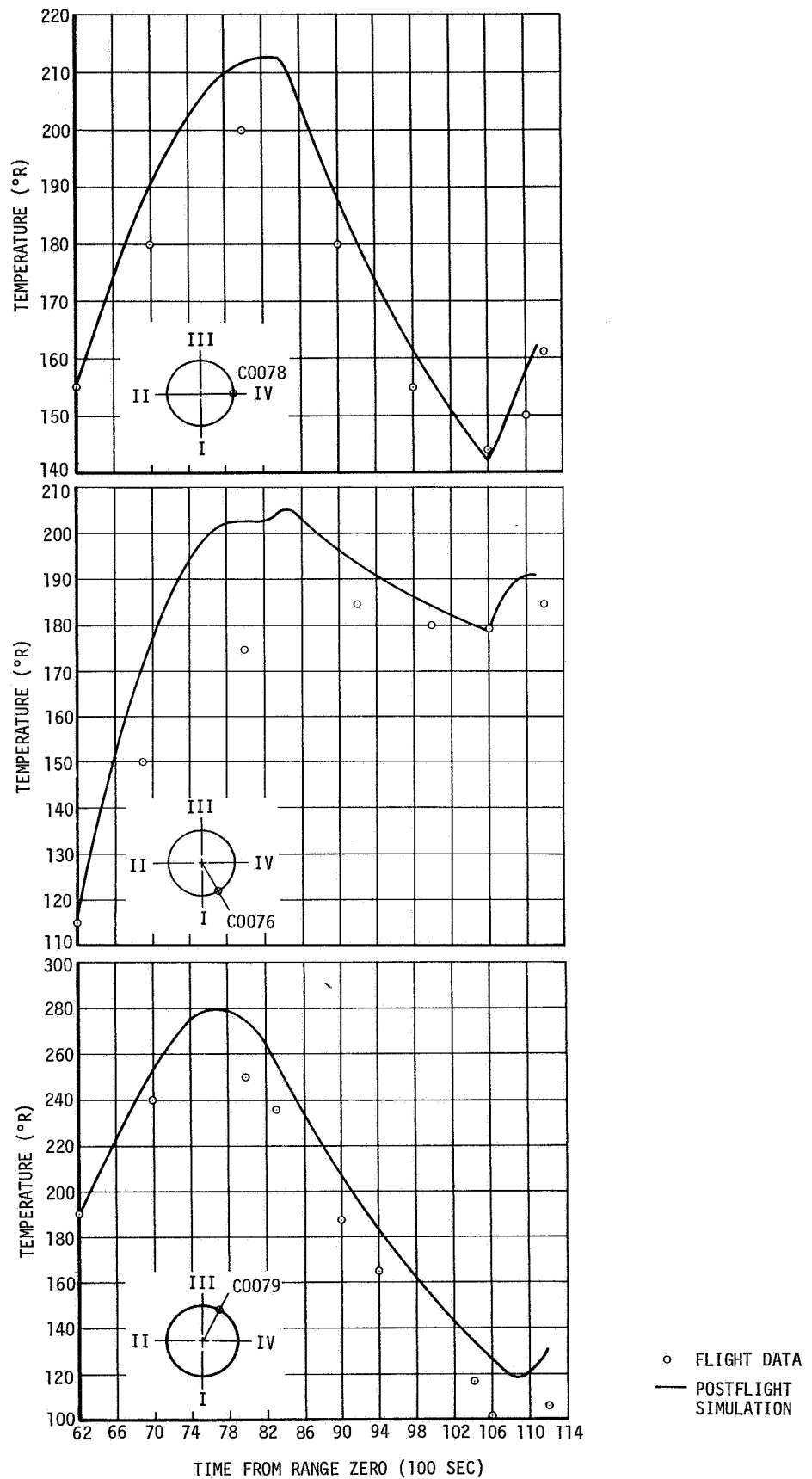


Figure 26-27. LOX and LH2 Chilldown Inverters Temperatures

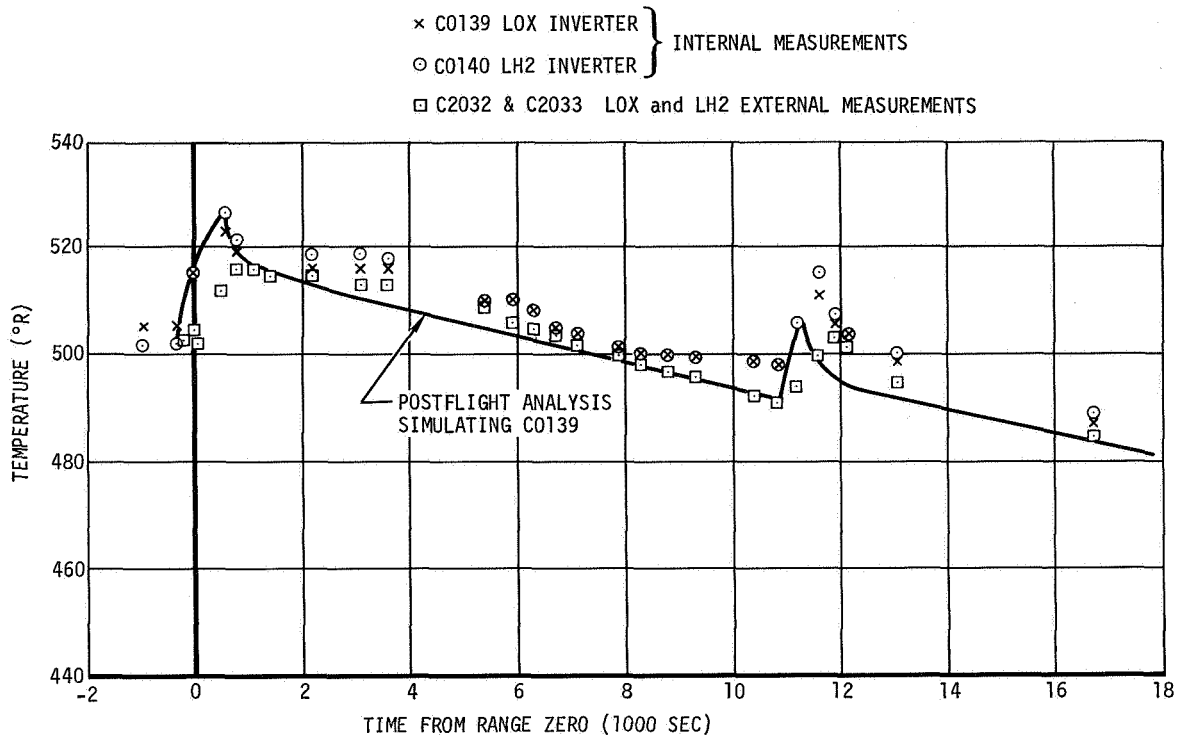


Figure 26-28. LOX and LH2 Chilldown Inverters Temperatures

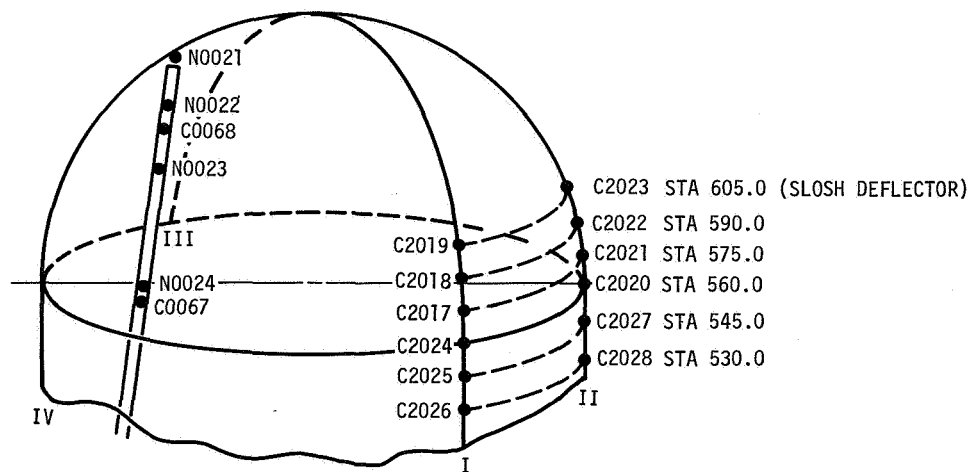


Figure 26-29. Ullage Space Instrumentation

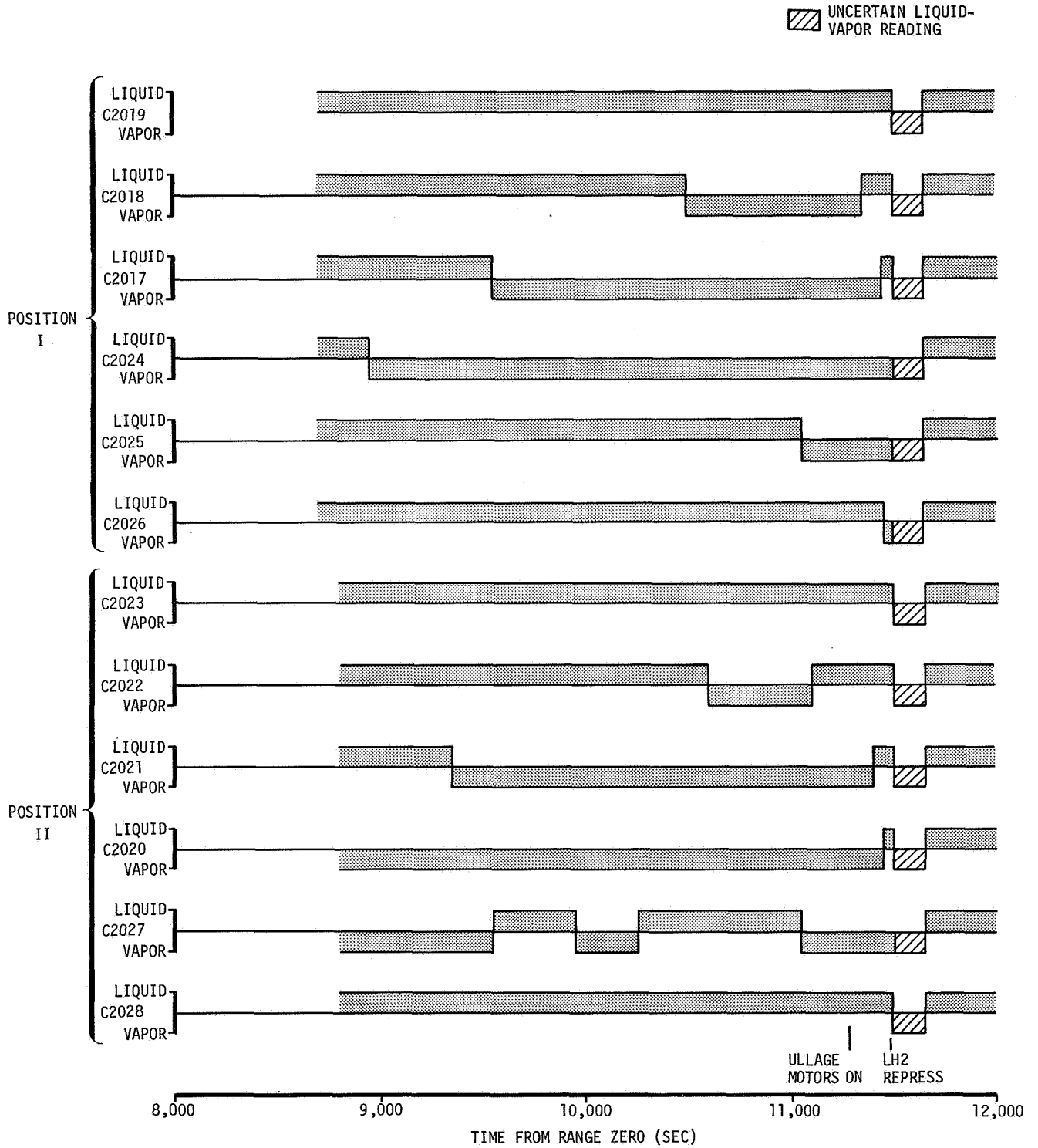


Figure 26-30. Wall Temperature Sensors Liquid-Vapor Indications - Second Orbit through Restart Attempt

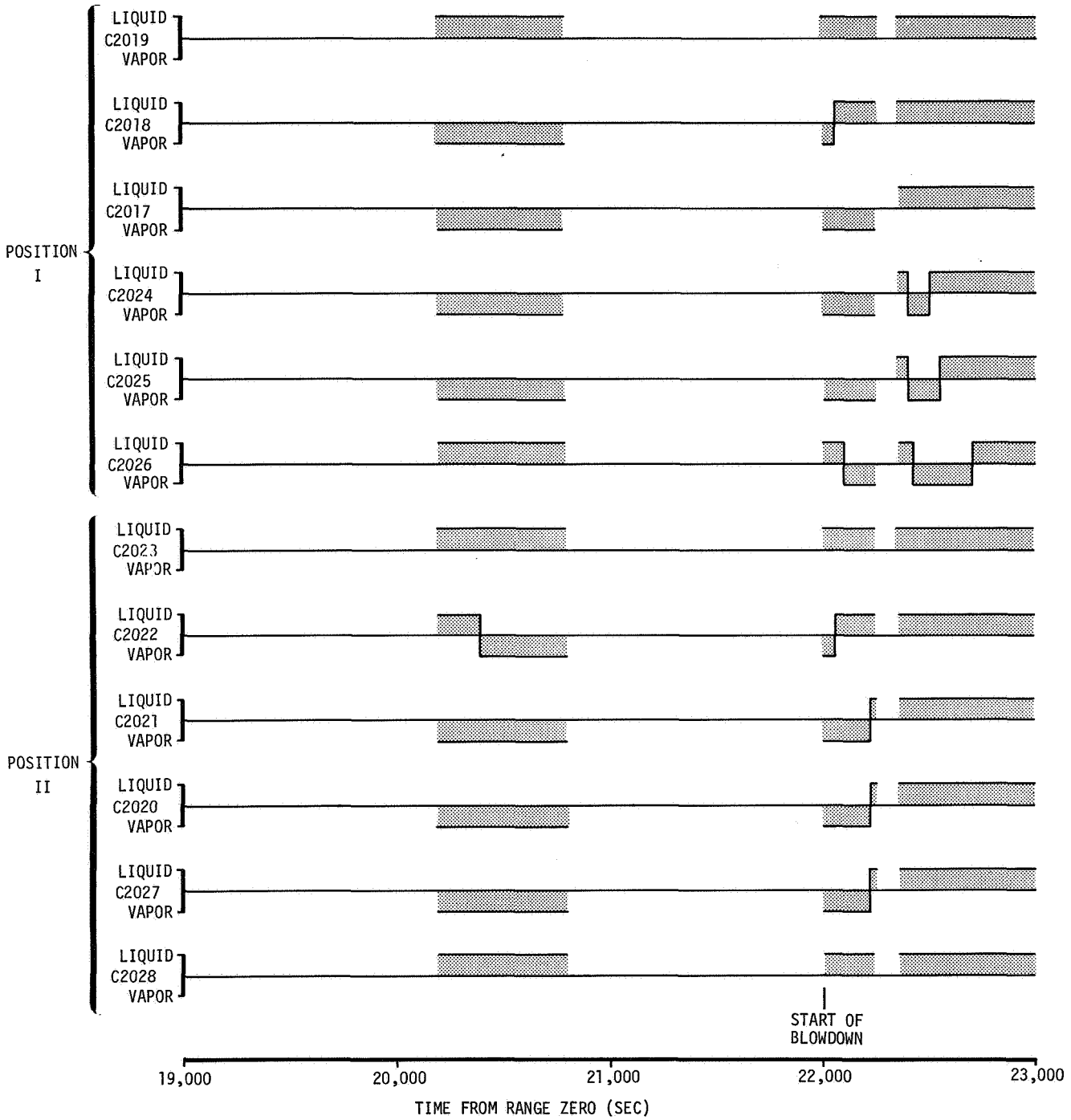
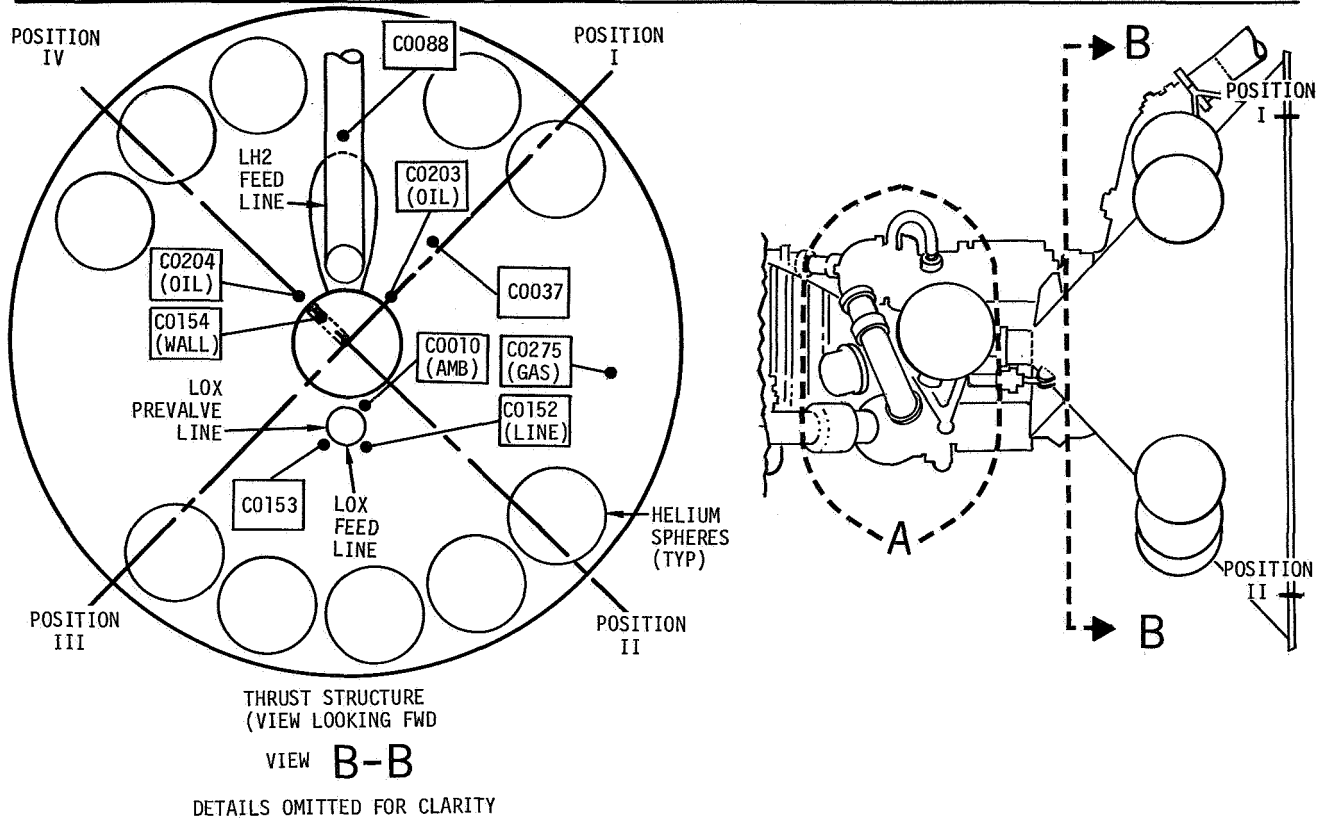
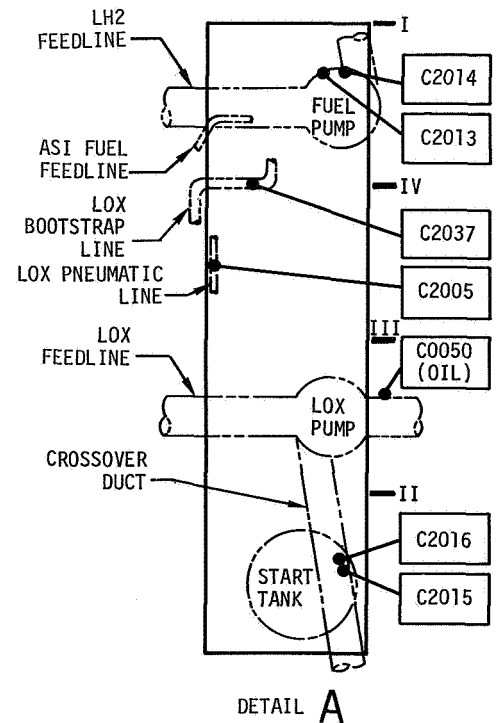


Figure 26-31. Wall Temperature Sensors Liquid-Vapor Indications - Fourth Orbit through Blowdown



| TEMPERATURE CHANGE RATES ($\Delta T/\Delta \theta$ DEG F/SEC) | | | | | | | | |
|--|----------------------------|--------|------------|--------|------------|--------|--------|-------|
| MEASUREMENT | TIME FROM RANGE ZERO (SEC) | | | | | | | |
| | 675 TO 695 | | 695 TO 705 | | 705 TO 715 | | 11,614 | |
| | 502 | 501 | 502 | 501 | 502 | 501 | 502 | 501 |
| C0204 (Oil) | -0.05 | 0 | -0.10 | 0 | -0.40 | 0 | -0.14 | 0 |
| C0154 (Wall) | 0 | +0.03 | +0.22 | +0.03 | -0.10 | +0.03 | +0.017 | 0 |
| C0153 | 0 | +0.05 | +0.78 | +0.05 | +0.41 | +0.05 | 0 | -0.05 |
| C0088 | -0.20 | -0.10 | +0.50 | 0 | -0.25 | 0 | 0 | 0 |
| C0087 | -0.35 | +0.05 | +2.5 | +0.05 | -1.8 | +0.05 | -0.78 | 0 |
| C0203 (Oil) | -0.05 | 0 | -0.05 | 0 | -0.10 | 0 | 0 | +0.05 |
| C0010 (Amb) | -0.80 | 0 | +30.7 | 0 | OSL | 0 | OSL | 0 |
| C0152 (Line) | -0.65 | -0.075 | OSH | -0.005 | OSH | -0.005 | OSH | 0 |
| C0275 (Gas) | -2.36 | -0.08 | +25.6 | -0.08 | -5.0 | -0.08 | +0.02 | 0 |
| C2014 | +5.5 | 0 | +4.0 | 0 | +3.0 | 0 | 0 | 0 |
| C2013 | +1.75 | +2.5 | +1.0 | +3.5 | +1.0 | +2.0 | +1.4 | +0.1 |
| C2037 | -0.46 | 0 | +16.7 | 0 | -0.21 | 0 | -1.0 | -- |
| C2005 | -6.4 | +0.2 | -7.1 | 0 | -5.0 | 0 | -5.0 | -0.1 |
| C0050 (Oil) | +0.05 | +0.13 | 0 | -0.3 | +2.9 | +0.3 | -15.0 | +0.07 |
| C2016 | +1.0 | -1.5 | +1.0 | -1.0 | +1.0 | -1.0 | +0.15 | +33.3 |
| C2015 | -0.40 | -1.2 | -0.20 | -1.0 | -0.50 | -1.0 | 0 | +4.76 |

NOTE: OSH - off-scale-high
OSL - off-scale-low



ENGINE CYLINDRICAL SECTION FLAT PATTERN DIAGRAM

Figure 26-32. Thrust Structure and Engine Instrumentation Temperature Change Rates

APPENDIX 1

MASS CHARACTERISTICS DATA (WS11)

1. MASS CHARACTERISTICS DATA (WS11)

This appendix presents the mass breakdown summary and the mass characteristics summary as calculated by the WS11 computer program for the AS-502 third flight stage (S-IVB stage, IU, spacecraft, lunar module, and the launch escape system).

Table AP 1-1 defines the terms and abbreviations used in the printouts.

The mass breakdown (table AP 1-2) is an itemized listing of major components (including all propellants, gases, etc) giving mass, center of gravity and moments of inertia including a summation for the indicated time. In addition to the above, a jettisoned item summary is presented at the appropriate time. The mass characteristics summary (table AP 1-3) is a time listing of the S-IVB-502 third flight stage mass characteristics.

All mass characteristics parameters are time referenced to AS-502 vehicle range zero and progress chronologically from range zero to LV/SC separation.

Figure AP 1-1 is a diagram of the coordinate system used in the WS11 computing program and S-IVB Douglas station numbers.

TABLE AP 1-1 (Sheet 1 of 2)
DEFINITIONS FOR MASS CHARACTERISTICS
COMPUTER PROGRAM WS11

| <u>Term</u> | <u>Definitions</u> | <u>Units</u> |
|---------------------|--|----------------------|
| Time | Time is referenced to range time. All computing was done in the pounds, inches, and pound inches squared system of units. (Items below the TOTAL REMAINING line were converted to other unit systems.) Pound mass is defined as 1/32.174 slugs. | Seconds |
| DAC Station | Distance along the H axis from an arbitrary S-IVB-502 stage reference zero. The ZERO station is located so that the S-IVB-502 stage engine gimbal point is station 100.0. Positive values increase in the forward direction and negative values are aft of station zero. | Inches |
| H Arm | Distance along the centerline of the S-IVB-502 stage from the center of gravity of the item under consideration to S-IVB-502 stage DAC station zero. | Inches |
| L Arm | Distance from the center of gravity of the item under consideration to the centerline of the S-IVB-502 stage along an axis perpendicular to the centerline and coinciding with position II and IV. Position II is negative and position IV is positive. | Inches |
| V Arm | Distance from the center of gravity of item under consideration to the centerline of the stage along an axis perpendicular to the H and L axes and coinciding with positions I and III. Position I is negative and position II is positive. | Inches |
| Pound Inches Square | Moment of inertia about the center of gravity of each item or total of items. | Lbm-In. ² |

TABLE AP 1-1 (Sheet 2 of 2)
 DEFINITIONS FOR MASS CHARACTERISTICS
 COMPUTER PROGRAM WS11

| <u>Term</u> | <u>Definitions</u> | <u>Units</u> |
|------------------|---|----------------------|
| Roll MOI | Moment of inertia of any item of total, about an axis through its own center of gravity and parallel to the H axis. | Lbm-In. ² |
| Pitch MOI | Moment of inertia of any item of total about an axis through its own center of gravity and parallel to the V axis. | Lb-In. ² |
| Yaw MOI | Moment of inertia of any item or total, about an axis through its own center of gravity and parallel to the L axis. | Lb-In. ² |
| Items Remaining | A listing of all items being considered at the current computing time that will be considered at the next computing time. | None |
| Total Remaining | A summation of the above. | None |
| Items Jettisoned | A listing of all items being considered at the current computing time that will not be considered at the next computing time. | None |
| Total Jettisoned | A summation of the items being jettisoned at the current computing time. | None |
| KGM | Kilograms | |
| SLG | Slugs | |
| VS | Vehicle station (when center of gravity is expressed in coordinates other than S-IVB-502 stage). | Inches |
| GS | Center of gravity expressed in terms of distance from engine gimbal point of the stage being considered. | Inches |
| SS | Center of gravity expressed in terms of stage coordinates when individual items are in another coordinate system. | Inches |
| SLF | Slug feet squared. | |
| KM ² | Kilogram meters squared. | |

TABLE AP 1-2 (Sheet 1 of 9)
MASS BREAKDOWN SUMMARY

S-IC LIFTOFF

TIME 0.690 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|-----------------|---------------|-------------------|-------------------|-------------------|----------------------------|----------------------------|----------------------------|
| LAUNCH ESCAPE | 8886.00 | 1510.50 | -.3 | -1.3 | .34206159+07 | .13915493+09 | .13904376+09 |
| FROST | 100.00 | 420.40 | .0 | .0 | .16926009+07 | .14472090+07 | .14472090+07 |
| SEPARATION PKG | 51.00 | 200.69 | .0 | .0 | .85792657+06 | .60659825+06 | .60659825+06 |
| ULLAGE ROCKETS | 253.20 | 223.50 | .0 | .0 | .49627200+07 | .51341386+06 | .44526262+07 |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825916+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 193773.00 | 241.92 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 28.00 | 318.61 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 42400.00 | 454.28 | .0 | .0 | .00000000 | .21238044+09 | .21238044+09 |
| LH2 ULLAGE GAS | 78.00 | 646.37 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 332.00 | 494.30 | 100.5 | -27.8 | .82139044+06 | .10579520+07 | .36220565+06 |
| APS PROP FP 1 | 314.00 | 246.20 | 1.8 | -140.3 | .13847400+06 | .11335400+06 | .11335400+06 |
| APS PROP FP 3 | 315.00 | 246.20 | -1.8 | 140.3 | .13891500+06 | .11371500+06 | .11371500+06 |
| GH2 IN STRTANK | 5.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 363279.00 | 493.70 | 1.6 | -.6 | .66495918+09 | .51025550+11 | .51036281+11 |
| | | | | | (SLUG=FT2) .14352483+06 | (SLUG=FT2) .11013358+08 | (SLUG=FT2) .11015674+08 |

S-II/S-IVB SEPARATION

TIME 577.079 SEC

ITEMS JETTISONED

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|------------------|---------------|-------------------|-------------------|-------------------|----------------------------|----------------------------|----------------------------|
| FROST | .00 | 420.40 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| SEPARATION PKG | 51.00 | 200.69 | .0 | .0 | .85792657+06 | .60659825+06 | .60659825+06 |
| TOTAL JETTISONED | 51.00 | 200.69 | .0 | .0 | .85792657+06 | .60659825+06 | .60659825+06 |
| | | | | | (SLUG=FT2) .18517493+03 | (SLUG=FT2) .13092823+03 | (SLUG=FT2) .13092823+03 |

S-II/S-IVB SEPARATION

TIME 577.079 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|-----------------|---------------|-------------------|-------------------|-------------------|----------------------------|----------------------------|----------------------------|
| ULLAGE ROCKETS | 249.94 | 223.50 | .0 | .0 | .48987310+07 | .50679393+06 | .43932142+07 |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825916+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 193768.03 | 241.92 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 33.00 | 318.60 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 42400.00 | 455.84 | .0 | .0 | .00000000 | .21945602+09 | .21945602+09 |
| LH2 ULLAGE GAS | 78.00 | 646.81 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 332.00 | 494.30 | 100.5 | -27.8 | .82139044+06 | .10579520+07 | .36220565+06 |
| APS PROP FP 1 | 314.00 | 246.20 | 1.8 | -140.3 | .13847400+06 | .11335400+06 | .11335400+06 |
| APS PROP FP 3 | 315.00 | 246.20 | -1.8 | 140.3 | .13891500+06 | .11371500+06 | .11371500+06 |
| GH2 IN STRTANK | 5.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 354238.76 | 468.45 | 1.6 | -.6 | .65888723+09 | .41468216+11 | .41478981+11 |
| | | | | | (SLUG=FT2) .14221427+06 | (SLUG=FT2) .89505026+07 | (SLUG=FT2) .89528261+07 |

TABLE AP 1-2 (Sheet 2 of 9)
MASS BREAKDOWN SUMMARY

| S-IVB FIRST ENGINE START COMMAND | | TIME 577.280 SEC | | | | ITEMS REMAINING | | |
|----------------------------------|------------|------------------|----------------|----------------|----------------------------|----------------------------|----------------------------|--|
| ITEM | MASS (LB#) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) | |
| ULLAGE ROCKETS | 243.86 | 223.50 | .0 | .0 | .47796312+07 | .49447258+06 | .42889962+07 | |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825316+08 | .22443064+08 | |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 | |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 | |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 | |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 | |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 | |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 | |
| S4B302 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 | |
| LOX IN TANK | 193768.03 | 241.92 | .0 | .0 | .00000000 | .00000000 | .00000000 | |
| LOX ULLAGE GAS | 33.00 | 318.60 | .0 | .0 | .00000000 | .00000000 | .00000000 | |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 | |
| LH2 IN TANK | 42600.00 | 455.84 | .0 | .0 | .00000000 | .21945845+09 | .21945845+09 | |
| LH2 ULLAGE GAS | 78.00 | 646.81 | .0 | .0 | .00000000 | .00000000 | .00000000 | |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23054514+06 | |
| COLD HELIUM | 332.00 | 494.30 | 100.5 | -27.8 | .82139044+06 | .10579520+07 | .36220565+06 | |
| APS PROP FP 1 | 314.00 | 246.20 | 1.8 | -140.3 | .13847400+06 | .11335400+06 | .11335400+06 | |
| APS PROP FP 3 | 315.00 | 246.20 | -1.8 | 140.3 | .13891500+06 | .11371500+06 | .11371500+06 | |
| GH2 IN STRTANK | 5.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 | |
| HELIUM=REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 | |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 | |
| TOTAL REMAINING | 354232.69 | 468.45 | 1.6 | -.6 | .65876811+09 | .41467842+11 | .41478513+11 | |
| | | | | | (SLUG=FT2) .14218856+06 | (SLUG=FT2) .89504219+07 | (SLUG=FT2) .89527251+07 | |

| END FUEL LEAD | | TIME 580.280 SEC | | | | ITEMS REMAINING | | |
|-----------------|------------|------------------|----------------|----------------|----------------------------|----------------------------|----------------------------|--|
| ITEM | MASS (LB#) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) | |
| ULLAGE ROCKETS | 153.17 | 223.50 | .0 | .0 | .30020592+07 | .31057541+06 | .26934922+07 | |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825316+08 | .22443064+08 | |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 | |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 | |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 | |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 | |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 | |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 | |
| S4B302 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 | |
| LOX IN TANK | 193768.00 | 241.92 | .0 | .0 | .00000000 | .00000000 | .00000000 | |
| LOX ULLAGE GAS | 34.09 | 318.60 | .0 | .0 | .00000000 | .00000000 | .00000000 | |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 | |
| LH2 IN TANK | 42392.00 | 455.82 | .0 | .0 | .00000000 | .21931984+09 | .21931984+09 | |
| LH2 ULLAGE GAS | 79.09 | 646.78 | .0 | .0 | .00000000 | .00000000 | .00000000 | |
| LH2 BELOW TANK | 53.45 | 148.00 | -39.2 | -42.5 | .65621854+05 | .26692375+06 | .25949953+06 | |
| COLD HELIUM | 330.98 | 494.30 | 100.5 | -27.8 | .81887195+06 | .10547082+07 | .36109509+06 | |
| APS PROP FP 1 | 313.95 | 246.20 | 1.8 | -140.3 | .13845069+06 | .11333492+06 | .11333492+06 | |
| APS PROP FP 3 | 314.95 | 246.20 | -1.8 | 140.3 | .13889169+06 | .11369592+06 | .11369592+06 | |
| GH2 IN STRTANK | 2.82 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 | |
| HELIUM=REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 | |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 | |
| TOTAL REMAINING | 354138.28 | 468.51 | 1.6 | -.6 | .65699850+09 | .41462398+11 | .41471649+11 | |
| | | | | | (SLUG=FT2) .14180660+06 | (SLUG=FT2) .89492467+07 | (SLUG=FT2) .89512433+07 | |

TABLE AP 1-2 (Sheet 3 of 9)
MASS BREAKDOWN SUMMARY

FIRST 90 PERCENT THRUST

TIME 582.788 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|------------|----------------|----------------|----------------|---|---|---|
| ULLAGE ROCKETS | 135.30 | 223.50 | .0 | .0 | .26518800+07 | .27434793+06 | .23793062+07 |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .30565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S48502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 193470.00 | 241.81 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 35.00 | 318.34 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 397.00 | 114.94 | 3.2 | 6.5 | .21441875+06 | .50201190+06 | .50483932+06 |
| LM2 IN TANK | 42278.00 | 455.37 | .0 | .0 | .00000000 | .21667198+09 | .21667198+09 |
| LM2 ULLAGE GAS | 80.00 | 646.07 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LM2 BELOW TANK | 58.00 | 148.00 | -39.2 | -42.5 | .71212492+05 | .28966642+06 | .28160793+06 |
| COLD HELIUM | 330.13 | 494.30 | 100.5 | -27.8 | .81676650+06 | .10519964+07 | .36016665+06 |
| APS PROP FP 1 | 313.90 | 246.20 | 1.8 | -140.3 | .13843121+06 | .11331897+06 | .11331897+06 |
| APS PROP FP 3 | 314.90 | 246.20 | -1.8 | 140.3 | .13887221+06 | .11367997+06 | .11367997+06 |
| GM2 IN STRTANK | 1.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 353742.03 | 468.57 | 1.6 | -.6 | .65667175+09 | .41457207+11 | .41466172+11 |
| | | | | | (SLUG=FT ²) .14173608+06 | (SLUG=FT ²) .89481264+07 | (SLUG=FT ²) .89500614+07 |

SUMMARY PRINTOUT

TIME 600.000 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|------------|----------------|----------------|----------------|---|---|---|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .30565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S48502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 185641.68 | 239.08 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 50.93 | 312.00 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 397.00 | 114.94 | 3.2 | 6.5 | .21441875+06 | .50201190+06 | .50483932+06 |
| LM2 IN TANK | 40827.42 | 449.63 | .0 | .0 | .00000000 | .18506171+09 | .18506171+09 |
| LM2 ULLAGE GAS | 88.38 | 637.31 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LM2 BELOW TANK | 58.00 | 148.00 | -39.2 | -42.5 | .71212492+05 | .28966642+06 | .28160793+06 |
| COLD HELIUM | 324.29 | 494.30 | 100.5 | -27.8 | .80231707+06 | .1033855+07 | .35379494+06 |
| APS PROP FP 1 | 313.60 | 246.20 | 1.8 | -140.3 | .13829748+06 | .11320950+06 | .11320950+06 |
| APS PROP FP 3 | 314.60 | 246.20 | -1.8 | 140.3 | .13873848+06 | .11357050+06 | .11357050+06 |
| GM2 IN STRTANK | 3.07 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 344347.76 | 471.72 | 1.7 | -.6 | .65390463+09 | .41250469+11 | .41257280+11 |
| | | | | | (SLUG=FT ²) .14113882+06 | (SLUG=FT ²) .89035041+07 | (SLUG=FT ²) .89049741+07 |

TABLE AP 1-2 (Sheet 4 of 9)
MASS BREAKDOWN SUMMARY

SUMMARY PRINTOUT

TIME 650.000 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|-----------------|------------|----------------|----------------|----------------|----------------------------|----------------------------|----------------------------|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LHX IN TANK | 162900.83 | 231.78 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LHX ULLAGE GAS | 97.20 | 299.29 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LHX BELOW TANK | 397.00 | 114.94 | 3.2 | 6.5 | .21441875+06 | .50201190+06 | .50483932+06 |
| LH2 IN TANK | 36613.57 | 433.40 | .0 | .0 | .00000000 | .11223433+09 | .11223433+09 |
| LH2 ULLAGE GAS | 112.74 | 615.22 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 58.00 | 148.00 | -39.2 | -42.5 | .71212492+05 | .28966642+06 | .28160753+06 |
| COLD HELIUM | 307.32 | 494.30 | 100.5 | -27.8 | .76036222+06 | .97932184+06 | .33528544+06 |
| APS PROP FP 1 | 312.72 | 246.20 | 1.8 | -140.3 | .13790899+06 | .11289148+06 | .11289148+06 |
| APS PROP FP 3 | 313.72 | 246.20 | -1.8 | 140.3 | .13836999+06 | .11325248+06 | .11325248+06 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 317448.89 | 483.03 | 1.8 | -.7 | .65356077+09 | .40504506+11 | .40511165+11 |
| | | | | | (SLUG=FT2) .14106461+06 | (SLUG=FT2) .87424953+07 | (SLUG=FT2) .87439325+07 |

SUMMARY PRINTOUT

TIME 700.000 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|-----------------|------------|----------------|----------------|----------------|----------------------------|----------------------------|----------------------------|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LHX IN TANK | 140159.96 | 224.99 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LHX ULLAGE GAS | 143.47 | 289.75 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LHX BELOW TANK | 397.00 | 114.94 | 3.2 | 6.5 | .21441875+06 | .50201190+06 | .50483932+06 |
| LH2 IN TANK | 32399.72 | 417.12 | .0 | .0 | .00000000 | .13788752+09 | .13788752+09 |
| LH2 ULLAGE GAS | 137.09 | 596.58 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 58.00 | 148.00 | -39.2 | -42.5 | .71212492+05 | .28966642+06 | .28160753+06 |
| COLD HELIUM | 290.36 | 494.30 | 100.5 | -27.8 | .71836738+06 | .92525818+06 | .31677594+06 |
| APS PROP FP 1 | 311.84 | 246.20 | 1.8 | -140.3 | .13752050+06 | .11257347+06 | .11257347+06 |
| APS PROP FP 3 | 312.84 | 246.20 | -1.8 | 140.3 | .13796150+06 | .11293447+06 | .11293447+06 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 290546.07 | 498.29 | 2.0 | -.7 | .65319806+09 | .39563227+11 | .39569722+11 |
| | | | | | (SLUG=FT2) .14098632+06 | (SLUG=FT2) .85393296+07 | (SLUG=FT2) .85407313+07 |

TABLE AP 1-2 (Sheet 5 of 9)
MASS BREAKDOWN SUMMARY

S-IVB FIRST ENGINE CUTOFF COMMAND

TIME 747.032 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|---------------|-------------------|-------------------|-------------------|---|---|---|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662342+10 |
| LOX IN TANK | 118769.00 | 218.67 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 187.00 | 282.07 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 397.00 | 114.94 | 3.2 | 6.5 | .21441875+06 | .50201190+06 | .50483932+06 |
| LH2 IN TANK | 28436.00 | 401.94 | .0 | .0 | .00000000 | .11776071+09 | .11776071+09 |
| LH2 ULLAGE GAS | 160.00 | 580.74 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 58.00 | 148.00 | -39.2 | -42.5 | .71212492+05 | .28966642+06 | .28160753+06 |
| COLD HELIUM | 274.40 | 494.30 | 100.5 | -27.8 | .67888416+06 | .87440374+06 | .29936316+06 |
| APS PROP FP 1 | 311.01 | 246.20 | 1.8 | -140.3 | .13715507+06 | .11227433+06 | .11227433+06 |
| APS PROP FP 3 | 312.01 | 246.20 | -1.8 | 140.3 | .13759607+06 | .11263533+06 | .11263533+06 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 265240.21 | 517.05 | 2.1 | -.8 | .65283617+09 | .38320220+11 | .38326547+11 |
| | | | | | (SLUG=FT ²) .14090864+06 | (SLUG=FT ²) .82710390+07 | (SLUG=FT ²) .82724045+07 |

S-IVB FIRST END OF THRUST DECAY

TIME 748.432 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|---------------|-------------------|-------------------|-------------------|---|---|---|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662342+10 |
| LOX IN TANK | 118609.00 | 218.62 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 187.00 | 282.02 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 28407.00 | 401.82 | .0 | .0 | .00000000 | .11764510+09 | .11764510+09 |
| LH2 ULLAGE GAS | 160.00 | 580.63 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 274.39 | 494.30 | 100.5 | -27.8 | .67884955+06 | .87435918+06 | .29934990+06 |
| APS PROP FP 1 | 310.51 | 246.20 | 1.8 | -140.3 | .13693504+06 | .11209422+06 | .11209422+06 |
| APS PROP FP 3 | 311.70 | 246.20 | -1.8 | 140.3 | .13745978+06 | .11252377+06 | .11252377+06 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 265010.39 | 517.27 | 2.1 | -.8 | .65275616+09 | .38303221+11 | .38309564+11 |
| | | | | | (SLUG=FT ²) .14089093+06 | (SLUG=FT ²) .82673700+07 | (SLUG=FT ²) .82687389+07 |

TABLE AP 1-2 (Sheet 6 of 9)
MASS BREAKDOWN SUMMARY

| SUMMARY PRINTOUT | | | | | ITEMS REMAINING | | |
|------------------|------------|----------------|----------------|----------------|----------------------------|----------------------------|----------------------------|
| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | .7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 118546.51 | 218.69 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 249.49 | 282.10 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 27588.90 | 398.82 | .0 | .0 | .00000000 | .11450271+09 | .11450271+09 |
| LH2 ULLAGE GAS | 226.28 | 577.63 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 247.19 | 494.30 | 100.5 | -27.8 | .61156201+06 | .78769273+06 | .26967835+06 |
| APS PROP FP 1 | 220.07 | 246.20 | 1.8 | -140.3 | .97049342+05 | .79444019+05 | .79444019+05 |
| APS PROP FP 3 | 258.45 | 246.20 | -1.8 | 140.3 | .11397458+06 | .93298919+05 | .93298919+05 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 264087.68 | 517.52 | 2.1 | .8 | .64951724+09 | .38287751+11 | .38296723+11 |
| | | | | | (SLUG=FT2) .14019185+06 | (SLUG=FT2) .82640307+07 | (SLUG=FT2) .82659675+07 |

| SUMMARY PRINTOUT | | | | | ITEMS REMAINING | | |
|------------------|------------|----------------|----------------|----------------|----------------------------|----------------------------|----------------------------|
| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | .7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 118467.61 | 218.79 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 328.39 | 282.21 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 26556.08 | 395.02 | .0 | .0 | .00000000 | .11084309+09 | .11084309+09 |
| LH2 ULLAGE GAS | 309.96 | 573.85 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 226.55 | 494.30 | 100.5 | -27.8 | .56050967+06 | .72193725+06 | .24716599+06 |
| APS PROP FP 1 | 205.52 | 246.20 | 1.8 | -140.3 | .90633896+05 | .74192373+05 | .74192373+05 |
| APS PROP FP 3 | 249.81 | 246.20 | -1.8 | 140.3 | .11016541+06 | .90180753+05 | .90180753+05 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM-REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 263094.71 | 517.71 | 2.1 | .8 | .64878108+09 | .38282438+11 | .38291722+11 |
| | | | | | (SLUG=FT2) .14003295+06 | (SLUG=FT2) .82628839+07 | (SLUG=FT2) .82648879+07 |

TABLE AP 1-2 (Sheet 7 of 9)
MASS BREAKDOWN SUMMARY

S-IVB SECOND ENGINE START COMMAND

TIME 10,800.000 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|---------------|-------------------|-------------------|-------------------|---|---|---|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 118388.71 | 218.88 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 407.29 | 282.31 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 25523.25 | 391.19 | .0 | .0 | .00000000 | .10746063+09 | .10746063+09 |
| LH2 ULLAGE GAS | 393.64 | 570.08 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 209.72 | 494.30 | 100.5 | -27.8 | .50895436+06 | .65553392+06 | .22443182+06 |
| APS PROP FP 1 | 190.97 | 246.20 | 1.8 | -140.3 | .84218450+05 | .68940727+05 | .68940727+05 |
| APS PROP FP 3 | 241.17 | 246.20 | -1.8 | 140.3 | .10633624+06 | .87062588+05 | .87062588+05 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM=REPRESS | 78.00 | 153.50 | .0 | .0 | .19500000+06 | .95550001+05 | .95550001+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 262101.55 | 517.92 | 2.1 | -.8 | .64804231+09 | .38276245+11 | .38285839+11 |
| | | | | | (SLUG=FT ²) .13987350+06 | (SLUG=FT ²) .82615475+07 | (SLUG=FT ²) .82636181+07 |

SUMMARY PRINTOUT

TIME 11,614.667 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|---------------|-------------------|-------------------|-------------------|---|---|---|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795.00 | 850.60 | 1.2 | -1.8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 118378.00 | 218.91 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 423.00 | 282.34 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 25383.00 | 390.69 | .0 | .0 | .00000000 | .10701311+09 | .10701311+09 |
| LH2 ULLAGE GAS | 448.00 | 569.58 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 201.00 | 494.30 | 100.5 | -27.8 | .49728759+06 | .64050710+06 | .21928716+06 |
| APS PROP FP 1 | 102.17 | 246.20 | 1.8 | -140.3 | .45037476+05 | .36883784+05 | .36883784+05 |
| APS PROP FP 3 | 138.56 | 246.20 | -1.8 | 140.3 | .61103367+05 | .50018856+05 | .50018856+05 |
| GH2 IN STRTANK | 7.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM=REPRESS | 30.00 | 153.50 | .0 | .0 | .75000000+05 | .36750000+05 | .36750000+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 261776.53 | 518.22 | 2.1 | -.8 | .64400397+09 | .38250674+11 | .38264004+11 |
| | | | | | (SLUG=FT ²) .13900186+06 | (SLUG=FT ²) .82560281+07 | (SLUG=FT ²) .82589053+07 |

TABLE AP 1-2 (Sheet 8 of 9)
MASS BREAKDOWN SUMMARY

END FUEL LEAN

TIME 11,623.239 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|---------------|-------------------|-------------------|-------------------|---|---|---|
| COMMAND MODULE | 12543,00 | 1249,90 | .3 | 6,7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836,00 | 1122,20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785,00 | 1111,50 | 11,3 | -4,8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91,00 | 1047,70 | .6 | -1,8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795,00 | 850,60 | 1,2 | -1,8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001,00 | 799,10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874,00 | 699,00 | -.7 | -10,8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252,80 | 325,46 | 6,2 | -2,8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 118378,00 | 218,91 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 423,00 | 282,34 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367,00 | 114,94 | 3,2 | 6,5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 25098,24 | 389,57 | .0 | .0 | .00000000 | .10614574+09 | .10614574+09 |
| LH2 ULLAGE GAS | 448,00 | 568,48 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 55,74 | 148,00 | -39,2 | -42,5 | .68440154+05 | .27838957+06 | .27064441+06 |
| COLD HELIUM | 199,63 | 494,30 | 100,5 | -27,8 | .49390046+06 | .63614447+06 | .21779355+06 |
| APS PROP FP 1 | 99,89 | 246,20 | 1,8 | -140,3 | .44059032+05 | .36061553+05 | .36061553+05 |
| APS PROP FP 3 | 135,90 | 246,20 | -1,8 | 140,3 | .59929859+05 | .49058229+05 | .49058229+05 |
| GH2 IN STRTANK | 2,35 | 88,40 | -22,0 | 14,6 | .00000000 | .00000000 | .00000000 |
| HELIUM=REPRESS | 30,00 | 153,50 | .0 | .0 | .73000000+05 | .36750000+05 | .36750000+05 |
| SERVICE ITEMS | 73,00 | 442,63 | 5,8 | 3,8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 261488,55 | 518,25 | 2,1 | -.8 | .64391777+09 | .38252087+11 | .38265500+11 |
| | | | | | (SLUG=FT ²) .13898326+06 | (SLUG=FT ²) .82563331+07 | (SLUG=FT ²) .82592282+07 |

S-IVB SECOND ENGINE CUTOFF COMMAND

TIME 11,630.320 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN ²) | IYY (LB-IN ²) | IZZ (LB-IN ²) |
|-----------------|---------------|-------------------|-------------------|-------------------|---|---|---|
| COMMAND MODULE | 12543,00 | 1249,90 | .3 | 6,7 | .30485636+08 | .27825516+08 | .22443064+08 |
| SERVICE MODULE | 9836,00 | 1122,20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785,00 | 1111,50 | 11,3 | -4,8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91,00 | 1047,70 | .6 | -1,8 | .52285323+06 | .26831259+06 | .25949196+06 |
| ADAPTER (SLA) | 3795,00 | 850,60 | 1,2 | -1,8 | .44519034+08 | .58881507+08 | .58186549+08 |
| LUNAR MODULE | 26001,00 | 799,10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874,00 | 699,00 | -.7 | -10,8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252,80 | 325,46 | 6,2 | -2,8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 116685,00 | 218,39 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 423,00 | 281,76 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 397,00 | 114,94 | 3,2 | 6,5 | .21441875+06 | .50201190+06 | .50483932+06 |
| LH2 IN TANK | 24863,00 | 388,65 | .0 | .0 | .00000000 | .10544098+09 | .10544098+09 |
| LH2 ULLAGE GAS | 448,00 | 567,57 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 58,00 | 148,00 | -39,2 | -42,5 | .71212492+05 | .28966642+06 | .28160753+06 |
| COLD HELIUM | 198,50 | 494,30 | 100,5 | -27,8 | .49110241+06 | .63254059+06 | .21655971+06 |
| APS PROP FP 1 | 98,01 | 246,20 | 1,8 | -140,3 | .43223284+05 | .35382325+05 | .35382325+05 |
| APS PROP FP 3 | 133,70 | 246,20 | -1,8 | 140,3 | .58960450+05 | .48264677+05 | .48264677+05 |
| GH2 IN STRTANK | 1,00 | 88,40 | -22,0 | 14,6 | .00000000 | .00000000 | .00000000 |
| HELIUM=REPRESS | 30,00 | 153,50 | .0 | .0 | .73000000+05 | .36750000+05 | .36750000+05 |
| SERVICE ITEMS | 73,00 | 442,63 | 5,8 | 3,8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 259586,01 | 519,96 | 2,2 | -.8 | .64383817+09 | .38141670+11 | .38155145+11 |
| | | | | | (SLUG=FT ²) .13896608+06 | (SLUG=FT ²) .82325007+07 | (SLUG=FT ²) .82354093+07 |

TABLE AP 1-2 (Sheet 9 of 9)
MASS BREAKDOWN SUMMARY

COMMAND SERVICE MODULE SEPARATION

TIME 11,667.820 SEC

ITEMS JETTISONED

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|------------------|---------------|-------------------|-------------------|-------------------|----------------------------|----------------------------|----------------------------|
| COMMAND MODULE | 12543.00 | 1249.90 | .3 | 6.7 | .30485636+08 | .27825516+08 | .22449064+08 |
| SERVICE MODULE | 9836.00 | 1122.20 | .1 | .5 | .29862195+08 | .50565793+08 | .49165147+08 |
| SM PROPELLANT | 32785.00 | 1111.50 | 11.3 | -4.8 | .74282940+08 | .87970022+08 | .11181521+09 |
| ADAPTER RING | 91.00 | 1047.70 | .6 | -1.8 | .52285323+06 | .26831259+06 | .25949196+06 |
| TOTAL JETTISONED | 55255.00 | 1144.72 | 6.8 | -1.2 | .13802856+09 | .34865249+09 | .36610768+09 |
| | | | | | (SLUG=FT2) .29792094+05 | (SLUG=FT2) .75253166+05 | (SLUG=FT2) .79020707+05 |

COMMAND SERVICE MODULE SEPARATION

TIME 11,667.820 SEC

ITEMS REMAINING

| ITEM | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (LB-IN2) | IYY (LB-IN2) | IZZ (LB-IN2) |
|-----------------|---------------|-------------------|-------------------|-------------------|----------------------------|----------------------------|----------------------------|
| ADAPTER (SLA) | 3795.00 | 836.80 | 4.6 | -3.5 | .10909879+09 | .89479114+08 | .85320414+08 |
| LUNAR MODULE | 26001.00 | 799.10 | .1 | .0 | .80089580+08 | .92050040+08 | .96749721+08 |
| VEH INSTR UNIT | 4874.00 | 699.00 | -.7 | -10.8 | .71596330+08 | .39831107+08 | .33173662+08 |
| S4B502 DRY STG | 26252.80 | 325.46 | 6.2 | -2.8 | .29793359+09 | .11660329+10 | .11662542+10 |
| LOX IN TANK | 116685.00 | 218.39 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX ULLAGE GAS | 345.00 | 281.76 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LOX BELOW TANK | 367.00 | 114.94 | 3.2 | 6.5 | .19821582+06 | .46407650+06 | .46669026+06 |
| LH2 IN TANK | 24863.00 | 388.65 | .0 | .0 | .00000000 | .10544025+09 | .10544025+09 |
| LH2 ULLAGE GAS | 448.00 | 567.57 | .0 | .0 | .00000000 | .00000000 | .00000000 |
| LH2 BELOW TANK | 48.00 | 148.00 | -39.2 | -42.5 | .58934476+05 | .23972394+06 | .23305451+06 |
| COLD HELIUM | 197.50 | 494.30 | 100.5 | -27.8 | .48864017+06 | .62936921+06 | .21547394+06 |
| APS PROP FP 1 | 88.05 | 246.20 | 1.8 | -140.3 | .38829084+05 | .31785260+05 | .31785260+05 |
| APS PROP FP 3 | 122.06 | 246.20 | -1.8 | 140.3 | .53826633+05 | .44062165+05 | .44062165+05 |
| GH2 IN STRTANK | 1.00 | 88.40 | -22.0 | 14.6 | .00000000 | .00000000 | .00000000 |
| HELIUM REPRESS | 30.00 | 153.50 | .0 | .0 | .75000000+05 | .36750000+05 | .36750000+05 |
| SERVICE ITEMS | 73.00 | 442.63 | 5.8 | 3.8 | .70984703+06 | .54597656+07 | .54290643+07 |
| TOTAL REMAINING | 204190.40 | 350.84 | 1.0 | -.7 | .56843321+09 | .10369130+11 | .10360643+11 |
| | | | | | (SLUG=FT2) .12269067+06 | (SLUG=FT2) .22380737+07 | (SLUG=FT2) .22362420+07 |

TABLE AP 1-3 (Sheet 1 of 2)
 MASS CHARACTERISTICS SUMMARY

| TIME (SEC) | MASS (LRM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (SLUG-FT ²) | IYY (SLUG-FT ²) | IZZ (SLUG-FT ²) |
|---------------|---------------|-------------------|-------------------|-------------------|--------------------------------|--------------------------------|--------------------------------|
| 0.690 | 363279.00 | 493.70 | 1.6 | -.6 | .14352483+06 | .11013358+08 | .11015674+08 |
| 184.766 | 363217.51 | 493.77 | 1.6 | -.6 | .14330012+06 | .11013225+08 | .11015541+08 |
| 184.766 | 354331.51 | 468.27 | 1.6 | -.6 | .14255396+06 | .89508000+07 | .89531346+07 |
| 300.000 | 354293.01 | 468.31 | 1.6 | -.6 | .14241329+06 | .89508924+07 | .89532269+07 |
| 576.971 | 354293.03 | 468.41 | 1.6 | -.6 | .14241329+06 | .89514659+07 | .89538004+07 |
| 577.079 | 354289.76 | 468.41 | 1.6 | -.6 | .14239947+06 | .89514227+07 | .89537463+07 |
| 577.079 | 354238.76 | 468.45 | 1.6 | -.6 | .14221427+06 | .89505026+07 | .89528261+07 |
| 577.280 | 354232.69 | 468.45 | 1.6 | -.6 | .14218856+06 | .89504219+07 | .89527251+07 |
| 580.280 | 354138.28 | 468.51 | 1.6 | -.6 | .14180660+06 | .89492467+07 | .89512435+07 |
| 580.871 | 354031.25 | 468.53 | 1.6 | -.6 | .14173220+06 | .89488001+07 | .89507365+07 |
| 582.788 | 353742.03 | 468.57 | 1.6 | -.6 | .14173608+06 | .89481264+07 | .89500614+07 |
| 589.066 | 350364.86 | 469.63 | 1.6 | -.6 | .14172707+06 | .89332543+07 | .89351855+07 |
| 589.066 | 350229.56 | 469.73 | 1.6 | -.6 | .14115460+06 | .89314246+07 | .89329012+07 |
| 590.000 | 349727.13 | 469.89 | 1.6 | -.6 | .14115326+06 | .89291394+07 | .89306155+07 |
| 600.000 | 344347.76 | 471.72 | 1.7 | -.6 | .14113882+06 | .89035041+07 | .89049741+07 |
| 610.000 | 338968.40 | 473.69 | 1.7 | -.6 | .14112429+06 | .88757345+07 | .88771980+07 |
| 620.000 | 333589.04 | 475.80 | 1.7 | -.6 | .14110963+06 | .88458014+07 | .88472584+07 |
| 630.000 | 328209.68 | 478.06 | 1.7 | -.6 | .14109486+06 | .88136636+07 | .88151143+07 |
| 632.788 | 326709.91 | 478.71 | 1.8 | -.6 | .14109073+06 | .88043060+07 | .88057551+07 |
| 640.000 | 322829.45 | 480.47 | 1.8 | -.6 | .14107984+06 | .87792455+07 | .87806898+07 |
| 650.000 | 317448.89 | 483.03 | 1.8 | -.7 | .14106461+06 | .87424953+07 | .87439325+07 |
| 660.000 | 312068.31 | 485.75 | 1.8 | -.7 | .14104925+06 | .87033477+07 | .87047781+07 |
| 670.000 | 306687.75 | 488.63 | 1.9 | -.7 | .14103375+06 | .86617164+07 | .86631397+07 |
| 680.000 | 301307.20 | 491.68 | 1.9 | -.7 | .14101810+06 | .86175013+07 | .86189178+07 |
| 690.000 | 295926.64 | 494.88 | 1.9 | -.7 | .14100229+06 | .85878519+07 | .85892609+07 |
| 700.000 | 290546.07 | 498.29 | 2.0 | -.7 | .14098632+06 | .85393296+07 | .85407315+07 |
| 710.000 | 285165.52 | 501.90 | 2.0 | -.7 | .14097016+06 | .84880123+07 | .84894067+07 |
| 720.000 | 279784.96 | 505.70 | 2.0 | -.7 | .14095382+06 | .84337542+07 | .84351408+07 |
| 730.000 | 274404.39 | 509.71 | 2.1 | -.8 | .14093728+06 | .83763925+07 | .83777715+07 |
| 740.000 | 269023.84 | 513.94 | 2.1 | -.8 | .14092054+06 | .83157529+07 | .83171236+07 |
| 747.032 | 265240.21 | 517.05 | 2.1 | -.8 | .14090864+06 | .82710390+07 | .82724045+07 |
| 747.556 | 265154.48 | 517.13 | 2.1 | -.8 | .14090324+06 | .82696716+07 | .82710373+07 |
| 748.432 | 265010.39 | 517.27 | 2.1 | -.8 | .14089093+06 | .82673700+07 | .82687389+07 |
| 835.210 | 264908.44 | 517.35 | 2.1 | -.8 | .14054955+06 | .82657798+07 | .82674786+07 |
| 1800.000 | 264623.31 | 517.41 | 2.1 | -.8 | .14043102+06 | .82652125+07 | .82669865+07 |
| 3074.000 | 264246.81 | 517.49 | 2.1 | -.8 | .14027452+06 | .82644509+07 | .82663240+07 |

TABLE AP 1-3 (Sheet 2 of 2)
MASS CHARACTERISTICS SUMMARY

| TIME (SEC) | MASS (LBM) | X ARM (STA-IN) | Y ARM (STA-IN) | Z ARM (STA-IN) | IXX (SLUG-FT ²) | IYY (SLUG-FT ²) | IZZ (SLUG-FT ²) |
|---------------|---------------|-------------------|-------------------|-------------------|--------------------------------|--------------------------------|--------------------------------|
| 3202.000 | 264207.79 | 517.49 | 2.1 | -.8 | .14025354+06 | .82643474+07 | .82662357+07 |
| 3300.000 | 264174.51 | 517.51 | 2.1 | -.8 | .14022283+06 | .82642019+07 | .82661160+07 |
| 3369.000 | 264151.39 | 517.51 | 2.1 | -.8 | .14020202+06 | .82640988+07 | .82660311+07 |
| 3600.000 | 264087.68 | 517.52 | 2.1 | -.8 | .14019185+06 | .82640307+07 | .82659675+07 |
| 5400.000 | 263591.24 | 517.61 | 2.1 | -.8 | .14011254+06 | .82634789+07 | .82654494+07 |
| 6000.000 | 263425.77 | 517.64 | 2.1 | -.8 | .14008611+06 | .82632861+07 | .82652675+07 |
| 7200.000 | 263094.71 | 517.71 | 2.1 | -.8 | .14003295+06 | .82628839+07 | .82648879+07 |
| 9000.000 | 262598.13 | 517.81 | 2.1 | -.8 | .13995323+06 | .82622426+07 | .82642799+07 |
| 10800.000 | 262101.55 | 517.92 | 2.1 | -.8 | .13987350+06 | .82615475+07 | .82636181+07 |
| 11287.733 | 261966.99 | 517.95 | 2.1 | -.8 | .13985189+06 | .82613499+07 | .82634293+07 |
| 11287.888 | 261966.95 | 517.95 | 2.1 | -.8 | .13985188+06 | .82613504+07 | .82634298+07 |
| 11288.867 | 261966.12 | 517.95 | 2.1 | -.8 | .13984942+06 | .82613384+07 | .82634203+07 |
| 11387.670 | 261908.62 | 518.01 | 2.1 | -.8 | .13960025+06 | .82601251+07 | .82624480+07 |
| 11487.678 | 261831.46 | 518.10 | 2.1 | -.8 | .13933659+06 | .82583092+07 | .82608763+07 |
| 11613.668 | 261777.26 | 518.22 | 2.1 | -.8 | .13900448+06 | .82560461+07 | .82589207+07 |
| 11614.486 | 261776.63 | 518.22 | 2.1 | -.8 | .13900232+06 | .82560308+07 | .82589074+07 |
| 11614.667 | 261776.53 | 518.22 | 2.1 | -.8 | .13900186+06 | .82560281+07 | .82589053+07 |
| 11623.239 | 261488.55 | 518.25 | 2.1 | -.8 | .13898326+06 | .82563331+07 | .82592282+07 |
| 11625.739 | 260836.84 | 518.82 | 2.2 | -.8 | .13898101+06 | .82486750+07 | .82515746+07 |
| 11630.320 | 259586.01 | 519.96 | 2.2 | -.8 | .13896608+06 | .82325007+07 | .82354093+07 |
| 11630.490 | 259584.54 | 519.96 | 2.2 | -.8 | .13896517+06 | .82324516+07 | .82353606+07 |
| 11635.320 | 259504.50 | 520.06 | 2.2 | -.8 | .13893919+06 | .82305829+07 | .82335041+07 |
| 11640.276 | 259462.01 | 520.10 | 2.2 | -.8 | .13892636+06 | .82300370+07 | .82329704+07 |
| 11667.720 | 259445.47 | 520.11 | 2.2 | -.8 | .13885556+06 | .82296961+07 | .82326955+07 |
| 11667.820 | 259445.41 | 519.91 | 2.2 | -.8 | .15280335+06 | .82289854+07 | .82312363+07 |
| 11667.820 | 204190.40 | 350.84 | 1.0 | -.7 | .12269067+06 | .22380737+07 | .22362420+07 |
| 11668.000 | 204190.30 | 350.84 | 1.0 | -.7 | .12269020+06 | .22380731+07 | .22362418+07 |

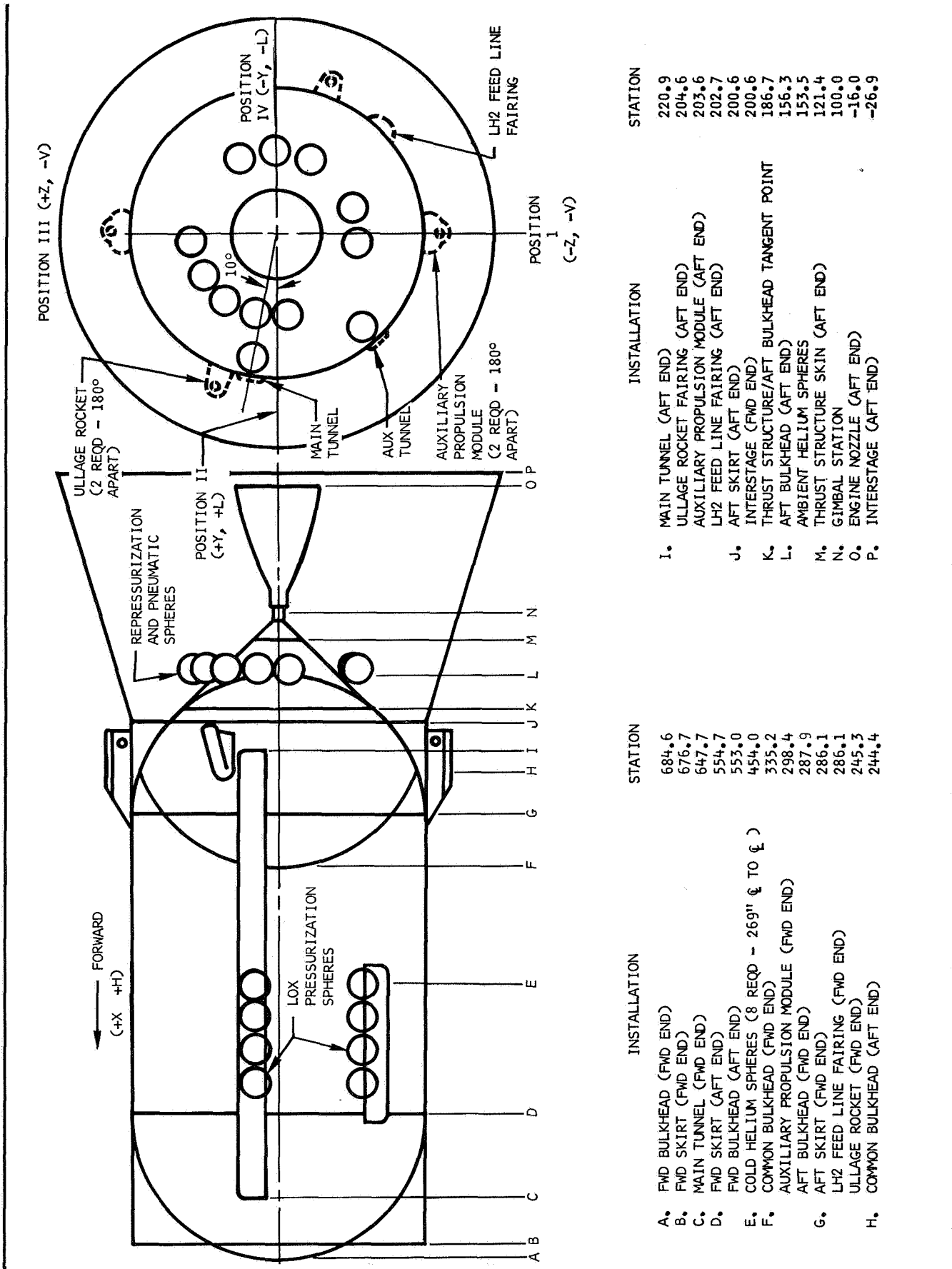


Figure AP 1-1. Saturn S-IVB/V Installation - Station List

| INSTALLATION | STATION | INSTALLATION | STATION |
|--|---------|--|---------|
| A. FWD BULKHEAD (FWD END) | 684.6 | I. MAIN TUNNEL (AFT END) | 220.9 |
| B. FWD SKIRT (FWD END) | 676.7 | J. ULLAGE ROCKET FAIRING (AFT END) | 204.6 |
| C. MAIN TUNNEL (FWD END) | 647.7 | K. AUXILIARY PROPULSION MODULE (AFT END) | 203.6 |
| D. FWD SKIRT (AFT END) | 554.7 | L. LH2 FEED LINE FAIRING (AFT END) | 202.7 |
| E. COLD HELIUM SPHERES (8 REQD - 269" ϕ TO ϕ) | 553.0 | M. AFT SKIRT (AFT END) | 200.6 |
| F. COMMON BULKHEAD (FWD END) | 454.0 | N. INTERSTAGE (FWD END) | 200.6 |
| G. AUXILIARY PROPULSION MODULE (FWD END) | 335.2 | O. THRUST STRUCTURE/AFT BULKHEAD TANGENT POINT | 186.7 |
| H. AFT BULKHEAD (FWD END) | 298.4 | P. AFT BULKHEAD (AFT END) | 156.3 |
| I. AFT SKIRT (FWD END) | 287.9 | | 153.5 |
| J. LH2 FEED LINE FAIRING (FWD END) | 286.1 | | 121.4 |
| K. ULLAGE ROCKET (FWD END) | 286.1 | | 100.0 |
| L. COMMON BULKHEAD (AFT END) | 245.3 | | -16.0 |
| | 244.4 | | -26.9 |

APPENDIX 2

ENGINE PERFORMANCE PROGRAM (PA49)

1. ENGINE PERFORMANCE PROGRAM (PA49)

This appendix contains the digital printout of computer program PA49 which is a compilation of computer programs G105 and AA89. These computer programs are employed in the propulsion system performance reconstruction of the S-IVB-502 stage flight. The performance analysis and associated plots are presented in section 10.

Table AP 2-1 defines the printout symbols; table AP 2-2 is the digital printout for S-IVB engine burn.

TABLE AP 2-1
PROGRAM PA49 PRINTOUT SYMBOLS

| | | | |
|--------|------------------------------------|--------|------------------------------------|
| FSUB1 | Stage thrust from G105 (lbf) | EMR 2 | Engine mixture ratio from AA89 |
| WDOTT1 | Total flowrate from G105 (lbm/sec) | ISP 2 | Specific impulse from AA89 (sec) |
| WDOTO1 | LOX flowrate from G105 (lbm/sec) | MSUBO2 | LOX mass on board from AA89 |
| WDOTF1 | LH2 flowrate from G105 (lbm/sec) | MSUBF2 | LH2 mass on board from AA89 (lbm) |
| EMR 1 | Engine mixture ratio from G105 | THRUST | Composite stage thrust (lbf) |
| ISP 1 | Specific impulse from G105 (sec) | T FLOW | Composite total flowrate (lbm/sec) |
| MSUBO1 | LOX mass on board from G105 (lbm) | O FLOW | Composite LOX flowrate (lbm/sec) |
| MSUBF1 | LH2 mass on board from G105 (lbm) | F FLOW | Composite LH2 flowrate (lbm/sec) |
| FSUB2 | Stage thrust from AA89 (lbf) | *EMR* | Composite engine mixture ratio |
| WDOTT2 | Total flowrate from AA89 (lbm/sec) | *ISP* | Composite specific impulse (sec) |
| WDOTO2 | LOX flowrate from AA89 (lbm/sec) | O MASS | Composite LOX mass on board (lbm) |
| WDOTF2 | LH2 flowrate from AA89 (lbm/sec) | F MASS | Composite LH2 mass on board (lbm) |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 1 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| TIME | FSUB 2 | THRUST | WDTT1 | WDTT2 |
|------------|------------|------------|------------|------------|
| FSUB 1 | WDTT1 | WDTT2 | W FLOW | WDTT1 |
| I FLOW | F FLTW | EMR 1 | EMR 2 | *EMR* |
| WDTT2 | ISP 2 | *ISP* | MSJB01 | MSJB02 |
| ISP 1 | MSJBF1 | MSJBF2 | F MASS | |
| U MASS | | | | |
| .000 | | | | |
| .000 | .000 | .000 | 1.029 | .000 |
| 1.029 | .000 | .000 | .000 | 1.029 |
| .000 | 1.029 | .000 | .000 | .000 |
| .000 | .000 | .000 | 193335.000 | 193273.000 |
| 193335.000 | 42470.001 | 42493.001 | 42470.001 | |
| 1.000 | | | | |
| .000 | 180.679 | .000 | .343 | 2.566 |
| .343 | .000 | .000 | .000 | .343 |
| 2.566 | .343 | .000 | .000 | .000 |
| .000 | 70.417 | .000 | 193334.630 | 193272.610 |
| 193334.630 | 42468.971 | 42490.473 | 42468.971 | |
| 2.000 | | | | |
| .000 | 180.711 | .000 | .338 | 2.566 |
| .338 | .000 | .000 | .000 | .338 |
| 2.566 | .338 | .000 | .000 | .000 |
| .000 | 70.422 | .000 | 193334.240 | 193272.220 |
| 193334.240 | 42467.941 | 42487.905 | 42467.941 | |
| 3.000 | | | | |
| .000 | 180.744 | .000 | 4.475 | 2.612 |
| 4.475 | .000 | .046 | .000 | 4.475 |
| 2.566 | 4.475 | .000 | .018 | .000 |
| .000 | 69.191 | .000 | 193333.850 | 193271.790 |
| 193333.850 | 42465.980 | 42485.337 | 42465.980 | |
| 4.000 | | | | |
| 5258.775 | 38871.720 | 5258.775 | 105.366 | 106.026 |
| 105.366 | 55.074 | 59.369 | 55.004 | 50.362 |
| 46.657 | 50.362 | 1.092 | 1.272 | 1.092 |
| 49.910 | 356.674 | 49.910 | 193315.660 | 193234.140 |
| 193315.660 | 42432.372 | 42456.556 | 42432.372 | |
| 5.000 | | | | |
| 155344.420 | 132585.030 | 155344.420 | 355.443 | 283.324 |
| 355.443 | 286.800 | 223.692 | 286.800 | 68.643 |
| 59.633 | 58.643 | 4.178 | 3.751 | 4.178 |
| 437.044 | 467.952 | 437.044 | 193182.200 | 193114.910 |
| 193182.200 | 42374.393 | 42404.085 | 42374.393 | |
| 6.000 | | | | |
| 188282.500 | 187957.900 | 188282.500 | 435.281 | 433.833 |
| 435.281 | 356.871 | 357.780 | 356.871 | 78.410 |
| 76.054 | 78.410 | 4.551 | 4.704 | 4.551 |
| 432.554 | 433.249 | 432.554 | 192842.820 | 192802.180 |
| 192842.820 | 42298.053 | 42334.162 | 42298.053 | |
| 7.000 | | | | |
| 191079.680 | 200737.010 | 191079.680 | 442.983 | 460.553 |
| 442.983 | 363.769 | 381.270 | 363.769 | 79.214 |
| 79.283 | 79.214 | 4.592 | 4.809 | 4.592 |
| 431.348 | 435.841 | 431.348 | 192482.520 | 192432.580 |
| 192482.520 | 42218.486 | 42255.492 | 42218.486 | |
| 8.000 | | | | |
| 193610.810 | 215768.340 | 193610.810 | 450.420 | 492.729 |
| 450.420 | 370.731 | 411.166 | 370.731 | 79.690 |
| 81.563 | 79.690 | 4.652 | 5.041 | 4.652 |
| 429.845 | 437.905 | 429.845 | 192115.370 | 192037.360 |
| 192115.370 | 42138.250 | 42174.363 | 42138.250 | |

TABLE AP 2-2 (Sheet 2 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 9.000 | | | | |
| 207081.360 | 229785.570 | 207081.360 | 483.593 | 527.740 |
| 483.593 | 402.361 | 445.144 | 402.361 | 81.232 |
| 82.596 | 81.232 | 4.953 | 5.383 | 4.953 |
| 428.214 | 435.414 | 428.214 | 191726.600 | 191610.430 |
| 191726.600 | 42057.193 | 42091.666 | 42057.193 | |
| 10.000 | | | | |
| 219319.260 | 230108.870 | 219319.260 | 515.356 | 541.606 |
| 515.356 | 432.687 | 458.968 | 432.687 | 82.669 |
| 82.638 | 82.669 | 5.234 | 5.554 | 5.234 |
| 425.568 | 424.854 | 425.568 | 191309.600 | 191158.030 |
| 191309.600 | 41974.785 | 42008.400 | 41974.785 | |
| 11.000 | | | | |
| 224239.840 | 230064.560 | 224239.840 | 524.820 | 541.517 |
| 524.820 | 441.071 | 458.832 | 441.071 | 83.749 |
| 82.685 | 83.749 | 5.267 | 5.549 | 5.267 |
| 427.270 | 424.852 | 427.270 | 190871.880 | 190698.730 |
| 190871.880 | 41891.237 | 41925.088 | 41891.237 | |
| 12.000 | | | | |
| 224689.260 | 230010.520 | 224689.260 | 528.406 | 541.417 |
| 528.406 | 444.855 | 458.700 | 444.855 | 83.951 |
| 82.717 | 83.951 | 5.324 | 5.545 | 5.324 |
| 425.221 | 424.831 | 425.221 | 190428.470 | 190239.560 |
| 190428.470 | 41807.146 | 41841.735 | 41807.146 | |
| 13.000 | | | | |
| 224727.270 | 229958.650 | 224727.270 | 531.064 | 541.308 |
| 531.064 | 447.825 | 458.571 | 447.825 | 83.239 |
| 82.738 | 83.239 | 5.380 | 5.542 | 5.380 |
| 423.164 | 424.820 | 423.164 | 189982.820 | 189780.530 |
| 189982.820 | 41723.103 | 41758.354 | 41723.103 | |
| 14.000 | | | | |
| 225955.790 | 229907.190 | 225955.790 | 531.683 | 541.193 |
| 531.683 | 448.123 | 458.442 | 448.123 | 83.560 |
| 82.752 | 83.560 | 5.363 | 5.540 | 5.363 |
| 424.982 | 424.815 | 424.982 | 189534.670 | 189321.610 |
| 189534.670 | 41639.094 | 41674.958 | 41639.094 | |
| 15.000 | | | | |
| 225195.370 | 230181.050 | 225195.370 | 532.408 | 541.449 |
| 532.408 | 449.456 | 458.666 | 449.456 | 82.952 |
| 82.782 | 82.952 | 5.418 | 5.541 | 5.418 |
| 422.975 | 425.121 | 422.975 | 189085.630 | 188852.670 |
| 189085.630 | 41554.923 | 41591.539 | 41554.923 | |
| 16.000 | | | | |
| 227513.710 | 230455.010 | 227513.710 | 534.223 | 541.704 |
| 534.223 | 450.676 | 458.891 | 450.676 | 83.547 |
| 82.813 | 83.547 | 5.394 | 5.541 | 5.394 |
| 425.877 | 425.426 | 425.877 | 188534.560 | 188403.490 |
| 188634.560 | 41470.921 | 41508.090 | 41470.921 | |
| 17.000 | | | | |
| 227524.850 | 230426.680 | 227524.850 | 535.569 | 541.607 |
| 535.569 | 452.182 | 458.787 | 452.182 | 83.386 |
| 82.820 | 83.386 | 5.423 | 5.540 | 5.423 |
| 424.829 | 425.450 | 424.829 | 188182.070 | 187944.250 |
| 188182.070 | 41386.727 | 41424.620 | 41386.727 | |
| 18.000 | | | | |
| 229049.990 | 230398.220 | 229049.990 | 535.963 | 541.505 |
| 535.963 | 452.372 | 458.683 | 452.372 | 83.591 |
| 82.822 | 83.591 | 5.412 | 5.538 | 5.412 |
| 427.362 | 425.477 | 427.362 | 187728.930 | 187485.110 |
| 187728.930 | 41302.516 | 41341.149 | 41302.516 | |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 3 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 19.000 | | | | |
| 228566.670 | 230369.770 | 228566.670 | 536.811 | 541.403 |
| 536.811 | 453.090 | 458.579 | 453.090 | 83.721 |
| 82.824 | 83.721 | 5.412 | 5.537 | 5.412 |
| 425.786 | 425.505 | 425.786 | 187275.100 | 187026.080 |
| 187275.100 | 41218.073 | 41257.674 | 41218.073 | |
| 20.000 | | | | |
| 229321.320 | 230341.310 | 229321.320 | 537.890 | 541.302 |
| 537.890 | 454.296 | 458.475 | 454.296 | 83.594 |
| 82.826 | 83.594 | 5.435 | 5.535 | 5.435 |
| 426.335 | 425.532 | 426.335 | 186820.870 | 186567.160 |
| 186820.870 | 41133.974 | 41174.197 | 41133.974 | |
| 21.000 | | | | |
| 228167.210 | 230331.380 | 228167.210 | 537.686 | 541.258 |
| 537.686 | 454.046 | 458.428 | 454.046 | 83.641 |
| 82.830 | 83.641 | 5.429 | 5.535 | 5.429 |
| 424.350 | 425.548 | 424.350 | 186366.390 | 186108.310 |
| 186366.390 | 41049.719 | 41090.717 | 41049.719 | |
| 22.000 | | | | |
| 229228.910 | 230321.440 | 229228.910 | 536.038 | 541.214 |
| 536.038 | 453.526 | 458.381 | 453.526 | 82.511 |
| 82.833 | 82.511 | 5.497 | 5.534 | 5.497 |
| 427.636 | 425.564 | 427.636 | 185911.530 | 185649.500 |
| 185911.530 | 40965.629 | 41007.235 | 40965.629 | |
| 23.000 | | | | |
| 230278.910 | 230332.490 | 230278.910 | 539.740 | 541.224 |
| 539.740 | 456.409 | 458.385 | 456.409 | 83.331 |
| 82.839 | 83.331 | 5.477 | 5.533 | 5.477 |
| 426.648 | 425.577 | 426.648 | 185455.710 | 185190.710 |
| 185455.710 | 40881.625 | 40923.748 | 40881.625 | |
| 24.000 | | | | |
| 227773.470 | 230343.620 | 227773.470 | 537.037 | 541.239 |
| 537.037 | 453.627 | 458.390 | 453.627 | 83.410 |
| 82.849 | 83.410 | 5.438 | 5.533 | 5.438 |
| 424.130 | 425.586 | 424.130 | 185000.480 | 184731.920 |
| 185000.480 | 40797.630 | 40840.253 | 40797.630 | |
| 25.000 | | | | |
| 229840.910 | 230341.610 | 229840.910 | 537.738 | 541.241 |
| 537.738 | 454.446 | 458.380 | 454.446 | 83.292 |
| 82.861 | 83.292 | 5.456 | 5.532 | 5.456 |
| 427.421 | 425.581 | 427.421 | 184545.340 | 184273.140 |
| 184545.340 | 40713.532 | 40756.747 | 40713.532 | |
| 26.000 | | | | |
| 230276.850 | 230339.590 | 230276.850 | 538.147 | 541.243 |
| 538.147 | 454.762 | 458.370 | 454.762 | 83.385 |
| 82.873 | 83.385 | 5.454 | 5.531 | 5.454 |
| 427.907 | 425.575 | 427.907 | 184090.260 | 183814.370 |
| 184090.260 | 40629.495 | 40673.228 | 40629.495 | |
| 27.000 | | | | |
| 229696.970 | 230343.160 | 229696.970 | 537.990 | 541.259 |
| 537.990 | 454.952 | 458.373 | 454.952 | 83.038 |
| 82.886 | 83.038 | 5.479 | 5.530 | 5.479 |
| 426.954 | 425.569 | 426.954 | 183636.670 | 183355.590 |
| 183636.670 | 40545.718 | 40589.697 | 40545.718 | |
| 28.000 | | | | |
| 228476.940 | 230346.720 | 228476.940 | 539.232 | 541.276 |
| 539.232 | 456.127 | 458.377 | 456.127 | 83.105 |
| 82.898 | 83.105 | 5.489 | 5.529 | 5.489 |
| 423.708 | 425.563 | 423.708 | 183181.300 | 182896.820 |
| 183181.300 | 40461.940 | 40506.154 | 40461.940 | |

TABLE AP 2-2 (Sheet 4 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 29.000 | | | | |
| 228190.080 | 230355,460 | 228190.080 | 539.756 | 541.305 |
| 539.756 | 456,528 | 458.393 | 456.528 | 83.229 |
| 82.912 | 83,229 | 5.485 | 5.529 | 5.485 |
| 422.765 | 425,556 | 422.765 | 182724.830 | 182438.040 |
| 182724.830 | 40378,110 | 40422.597 | 40378,110 | |
| 30.000 | | | | |
| 228057.880 | 230364,210 | 228057.880 | 538.315 | 541.335 |
| 538.315 | 455,604 | 458.410 | 455.604 | 82.711 |
| 82.925 | 82,711 | 5.508 | 5.528 | 5.508 |
| 423.651 | 425,549 | 423.651 | 182269.280 | 181979,240 |
| 182269.280 | 40294,320 | 40339.027 | 40294,320 | |
| 31.000 | | | | |
| 50421.930 | 230373,200 | 50421.930 | 541.025 | 541.365 |
| 541.025 | 457,903 | 458.426 | 457.903 | 83.122 |
| 82.939 | 83,122 | 5.509 | 5.527 | 5.509 |
| 93.197 | 425,542 | 93.197 | 181813.730 | 181520.420 |
| 181813.730 | 40210,596 | 40255.443 | 40210,596 | |
| 32.000 | | | | |
| 228138.250 | 230382,170 | 228138.250 | 536.046 | 541.395 |
| 536.046 | 452,954 | 458.442 | 452.954 | 83.091 |
| 82.953 | 83,091 | 5.451 | 5.527 | 5.451 |
| 425.595 | 425,535 | 425.595 | 181358.330 | 181061.590 |
| 181358.330 | 40127,604 | 40171,846 | 40127,604 | |
| 33.000 | | | | |
| 229481.950 | 230394,360 | 229481.950 | 540.318 | 541.439 |
| 540.318 | 457,160 | 458.472 | 457.160 | 83.159 |
| 82.967 | 83,159 | 5.497 | 5.526 | 5.497 |
| 424.716 | 425,522 | 424.716 | 180902.920 | 180602,730 |
| 180902.920 | 40043,685 | 40088.235 | 40043,685 | |
| 34.000 | | | | |
| 229914.460 | 230406,770 | 229914.460 | 539.851 | 541.484 |
| 539.851 | 456,509 | 458.502 | 456.509 | 83.342 |
| 82.982 | 83,342 | 5.478 | 5.525 | 5.478 |
| 425.885 | 425,510 | 425.885 | 180445.700 | 180143,840 |
| 180445.700 | 39960,004 | 40004,610 | 39960,004 | |
| 35.000 | | | | |
| 228067.200 | 230419,180 | 228067.200 | 540.507 | 541.529 |
| 540.507 | 457,351 | 458.533 | 457.351 | 83.156 |
| 82.996 | 83,156 | 5.500 | 5.525 | 5.500 |
| 421.950 | 425,498 | 421.950 | 179988.340 | 179684,930 |
| 179988.340 | 39876,261 | 39920,969 | 39876,261 | |
| 36.000 | | | | |
| 229340.550 | 230431,590 | 229340.550 | 539.822 | 541.573 |
| 539.822 | 456,802 | 458.563 | 456.802 | 83.020 |
| 83.010 | 83,020 | 5.502 | 5.524 | 5.502 |
| 424.845 | 425,485 | 424.845 | 179530.610 | 179225,980 |
| 179530.610 | 39792,484 | 39837,314 | 39792,484 | |
| 37.000 | | | | |
| 228864.180 | 230444,000 | 228864.180 | 539.616 | 541.618 |
| 539.616 | 456,592 | 458.593 | 456.592 | 83.023 |
| 83.025 | 83,023 | 5.500 | 5.524 | 5.500 |
| 424.124 | 425,473 | 424.124 | 179072,530 | 178767,000 |
| 179072.530 | 39708,856 | 39753,645 | 39708,856 | |
| 38.000 | | | | |
| 227890.120 | 230456,400 | 227890.120 | 538.309 | 541.663 |
| 538.309 | 456,135 | 458.624 | 456.135 | 82.174 |
| 83.039 | 82,174 | 5.551 | 5.523 | 5.551 |
| 423.344 | 425,461 | 423.344 | 178615,270 | 178308,000 |
| 178615.270 | 39625,249 | 39669,961 | 39625,249 | |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 5 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 39.000 | | | | |
| 230466.440 | 230468.810 | 230466.440 | 536.295 | 541.708 |
| 536.295 | 453.601 | 458.654 | 453.601 | 82.694 |
| 83.054 | 82.694 | 5.485 | 5.522 | 5.485 |
| 429.738 | 425.448 | 429.738 | 178158.090 | 177848.960 |
| 178158.090 | 39541.675 | 39586.264 | 39541.675 | |
| 40.000 | | | | |
| 229870.740 | 230481.210 | 229870.740 | 541.343 | 541.753 |
| 541.343 | 458.314 | 458.685 | 458.314 | 83.029 |
| 83.068 | 83.029 | 5.520 | 5.522 | 5.520 |
| 424.631 | 425.436 | 424.631 | 177701.530 | 177389.880 |
| 177701.530 | 39458.025 | 39502.551 | 39458.025 | |
| 41.000 | | | | |
| 229084.370 | 230493.750 | 229084.370 | 540.194 | 541.798 |
| 540.194 | 457.287 | 458.715 | 457.287 | 82.907 |
| 83.083 | 82.907 | 5.516 | 5.521 | 5.516 |
| 424.078 | 425.424 | 424.078 | 177244.140 | 176930.790 |
| 177244.140 | 39374.449 | 39418.823 | 39374.449 | |
| 42.000 | | | | |
| 228991.330 | 230506.280 | 228991.330 | 540.869 | 541.843 |
| 540.869 | 457.856 | 458.745 | 457.856 | 83.014 |
| 83.098 | 83.014 | 5.515 | 5.521 | 5.515 |
| 423.376 | 425.412 | 423.376 | 176786.610 | 176471.660 |
| 176786.610 | 39290.718 | 39335.082 | 39290.718 | |
| 43.000 | | | | |
| 229931.230 | 230518.810 | 229931.230 | 541.392 | 541.887 |
| 541.392 | 458.346 | 458.775 | 458.346 | 83.046 |
| 83.111 | 83.046 | 5.519 | 5.520 | 5.519 |
| 424.703 | 425.400 | 424.703 | 176329.190 | 176012.490 |
| 176329.190 | 39207.160 | 39251.326 | 39207.160 | |
| 44.000 | | | | |
| 228844.030 | 230531.330 | 228844.030 | 541.461 | 541.930 |
| 541.461 | 458.442 | 458.806 | 458.442 | 83.019 |
| 83.124 | 83.019 | 5.522 | 5.520 | 5.522 |
| 422.642 | 425.389 | 422.642 | 175871.460 | 175553.310 |
| 175871.460 | 39123.529 | 39167.557 | 39123.529 | |
| 45.000 | | | | |
| 229947.960 | 230543.670 | 229947.960 | 540.652 | 541.976 |
| 540.652 | 457.584 | 458.838 | 457.584 | 83.068 |
| 83.138 | 83.068 | 5.509 | 5.519 | 5.509 |
| 425.316 | 425.376 | 425.316 | 175414.580 | 175094.080 |
| 175414.580 | 39039.791 | 39083.774 | 39039.791 | |
| 46.000 | | | | |
| 230900.530 | 230556.180 | 230900.530 | 541.222 | 542.023 |
| 541.222 | 458.190 | 458.872 | 458.190 | 83.032 |
| 83.151 | 83.032 | 5.518 | 5.519 | 5.518 |
| 426.628 | 425.363 | 426.628 | 174956.340 | 174634.830 |
| 174956.340 | 38956.268 | 38999.978 | 38956.268 | |
| 47.000 | | | | |
| 227915.910 | 230568.690 | 227915.910 | 539.149 | 542.069 |
| 539.149 | 456.195 | 458.905 | 456.195 | 82.954 |
| 83.164 | 82.954 | 5.499 | 5.518 | 5.499 |
| 422.733 | 425.349 | 422.733 | 174499.740 | 174175.550 |
| 174499.740 | 38872.627 | 38916.169 | 38872.627 | |
| 48.000 | | | | |
| 228539.130 | 230581.200 | 228539.130 | 540.156 | 542.116 |
| 540.156 | 457.156 | 458.938 | 457.156 | 82.999 |
| 83.178 | 82.999 | 5.508 | 5.518 | 5.508 |
| 423.099 | 425.336 | 423.099 | 174043.450 | 173716.220 |
| 174043.450 | 38789.179 | 38832.346 | 38789.179 | |

TABLE AP 2-2 (Sheet 6 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 49.000 | | | | |
| 230015.860 | 230593.710 | 230015.860 | 542.340 | 542.162 |
| 542.340 | 459.118 | 458.971 | 459.118 | 83.222 |
| 83.191 | 83.222 | 5.517 | 5.517 | 5.517 |
| 424.118 | 425.322 | 424.118 | 173585.790 | 173256.870 |
| 173585.790 | 38705.295 | 38748.510 | 38705.295 | |
| 50.000 | | | | |
| 227908.600 | 230606.220 | 227908.600 | 535.846 | 542.209 |
| 535.846 | 452.719 | 459.004 | 452.719 | 83.127 |
| 83.204 | 83.127 | 5.446 | 5.517 | 5.446 |
| 425.325 | 425.309 | 425.325 | 173128.120 | 172797.490 |
| 173128.120 | 38621.490 | 38654.661 | 38621.490 | |
| 51.000 | | | | |
| 228459.430 | 230618.770 | 228459.430 | 540.427 | 542.255 |
| 540.427 | 457.369 | 459.038 | 457.369 | 83.058 |
| 83.218 | 83.058 | 5.507 | 5.516 | 5.507 |
| 422.739 | 425.296 | 422.739 | 172670.890 | 172338.060 |
| 172670.890 | 38537.745 | 38580.798 | 38537.745 | |
| 52.000 | | | | |
| 228248.770 | 230631.310 | 228248.770 | 540.718 | 542.302 |
| 540.718 | 457.622 | 459.071 | 457.622 | 83.095 |
| 83.231 | 83.095 | 5.507 | 5.516 | 5.507 |
| 422.122 | 425.282 | 422.122 | 172213.710 | 171878.610 |
| 172213.710 | 38453.897 | 38496.923 | 38453.897 | |
| 53.000 | | | | |
| 228226.890 | 230643.850 | 228226.890 | 541.421 | 542.348 |
| 541.421 | 458.314 | 459.104 | 458.314 | 83.107 |
| 83.244 | 83.107 | 5.515 | 5.515 | 5.515 |
| 421.533 | 425.269 | 421.533 | 171755.210 | 171419.120 |
| 171755.210 | 38370.100 | 38413.034 | 38370.100 | |
| 54.000 | | | | |
| 229870.930 | 230656.390 | 229870.930 | 540.777 | 542.395 |
| 540.777 | 457.712 | 459.137 | 457.712 | 83.065 |
| 83.258 | 83.065 | 5.510 | 5.515 | 5.510 |
| 425.075 | 425.256 | 425.075 | 171297.130 | 170959.600 |
| 171297.130 | 38286.314 | 38329.131 | 38286.314 | |
| 55.000 | | | | |
| 229013.580 | 230668.940 | 229013.580 | 540.124 | 542.439 |
| 540.124 | 456.954 | 459.170 | 456.954 | 83.169 |
| 83.269 | 83.169 | 5.494 | 5.514 | 5.494 |
| 424.002 | 425.244 | 424.002 | 170838.990 | 170500.050 |
| 170838.990 | 38202.627 | 38245.216 | 38202.627 | |
| 56.000 | | | | |
| 230400.460 | 230681.480 | 230400.460 | 539.775 | 542.481 |
| 539.775 | 456.498 | 459.203 | 456.498 | 83.277 |
| 83.278 | 83.277 | 5.482 | 5.514 | 5.482 |
| 426.845 | 425.234 | 426.845 | 170382.460 | 170040.460 |
| 170382.460 | 38118.812 | 38161.291 | 38118.812 | |
| 57.000 | | | | |
| 230662.550 | 230694.030 | 230662.550 | 540.034 | 542.524 |
| 540.034 | 456.903 | 459.236 | 456.903 | 83.132 |
| 83.288 | 83.132 | 5.496 | 5.514 | 5.496 |
| 427.126 | 425.224 | 427.126 | 169924.780 | 169580.840 |
| 169924.780 | 38035.081 | 38077.356 | 38035.081 | |
| 58.000 | | | | |
| 230174.320 | 230706.560 | 230174.320 | 538.027 | 542.567 |
| 538.027 | 454.828 | 459.269 | 454.828 | 83.199 |
| 83.297 | 83.199 | 5.467 | 5.514 | 5.467 |
| 427.812 | 425.213 | 427.812 | 169466.610 | 169121.190 |
| 169466.610 | 37951.226 | 37993.412 | 37951.226 | |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 7 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 59.000 | | | | |
| 229755.160 | 230719.220 | 229755.160 | 541.742 | 542.610 |
| 541.742 | 458.583 | 459.303 | 458.583 | 83.159 |
| 83.307 | 83.159 | 5.514 | 5.513 | 5.514 |
| 424.104 | 425.203 | 424.104 | 169008.430 | 168661.500 |
| 169008.430 | 37867.402 | 37909.459 | 37867.402 | |
| 60.000 | | | | |
| 229771.170 | 230731.900 | 229771.170 | 540.770 | 542.652 |
| 540.770 | 457.516 | 459.336 | 457.516 | 83.253 |
| 83.316 | 83.253 | 5.495 | 5.513 | 5.495 |
| 424.897 | 425.193 | 424.897 | 168550.690 | 168201.780 |
| 168550.690 | 37783.708 | 37825.496 | 37783.708 | |
| 61.000 | | | | |
| 230136.950 | 230744.950 | 230136.950 | 541.191 | 542.696 |
| 541.191 | 458.377 | 459.370 | 458.327 | 82.864 |
| 83.326 | 82.864 | 5.531 | 5.513 | 5.531 |
| 425.241 | 425.183 | 425.241 | 168091.840 | 167742.030 |
| 168091.840 | 37699.816 | 37741.523 | 37699.816 | |
| 62.000 | | | | |
| 230427.120 | 230758.000 | 230427.120 | 541.951 | 542.740 |
| 541.951 | 458.610 | 459.403 | 458.610 | 83.340 |
| 83.336 | 83.340 | 5.503 | 5.513 | 5.503 |
| 425.181 | 425.173 | 425.181 | 167633.060 | 167282.250 |
| 167633.060 | 37615.905 | 37657.541 | 37615.905 | |
| 63.000 | | | | |
| 230343.460 | 230771.060 | 230343.460 | 541.233 | 542.783 |
| 541.233 | 458.079 | 459.437 | 458.029 | 83.204 |
| 83.346 | 83.204 | 5.505 | 5.512 | 5.505 |
| 425.591 | 425.163 | 425.591 | 167174.770 | 166822.430 |
| 167174.770 | 37532.149 | 37573.548 | 37532.149 | |
| 64.000 | | | | |
| 230860.610 | 230784.110 | 230860.610 | 541.851 | 542.827 |
| 541.851 | 458.743 | 459.470 | 458.743 | 83.109 |
| 83.356 | 83.109 | 5.520 | 5.512 | 5.520 |
| 426.059 | 425.153 | 426.059 | 166716.230 | 166362.570 |
| 166716.230 | 37448.394 | 37489.546 | 37448.394 | |
| 65.000 | | | | |
| 230120.410 | 230797.160 | 230120.410 | 541.722 | 542.870 |
| 541.722 | 458.466 | 459.504 | 458.466 | 83.256 |
| 83.366 | 83.256 | 5.507 | 5.512 | 5.507 |
| 424.794 | 425.143 | 424.794 | 166257.640 | 165902.690 |
| 166257.640 | 37364.480 | 37405.533 | 37364.480 | |
| 66.000 | | | | |
| 230035.210 | 230810.210 | 230035.210 | 542.312 | 542.914 |
| 542.312 | 458.493 | 459.537 | 458.493 | 83.818 |
| 83.376 | 83.818 | 5.470 | 5.512 | 5.470 |
| 424.175 | 425.132 | 424.175 | 165798.760 | 165442.760 |
| 165798.760 | 37280.574 | 37321.511 | 37280.574 | |
| 67.000 | | | | |
| 229420.840 | 230823.260 | 229420.840 | 540.638 | 542.957 |
| 540.638 | 457.519 | 459.571 | 457.519 | 83.119 |
| 83.386 | 83.119 | 5.504 | 5.511 | 5.504 |
| 424.352 | 425.122 | 424.352 | 165340.080 | 164982.810 |
| 165340.080 | 37196.650 | 37237.478 | 37196.650 | |
| 68.000 | | | | |
| 230607.990 | 230836.300 | 230607.990 | 541.558 | 543.001 |
| 541.558 | 458.327 | 459.605 | 458.327 | 83.231 |
| 83.396 | 83.231 | 5.507 | 5.511 | 5.507 |
| 425.823 | 425.112 | 425.823 | 164881.930 | 164522.830 |
| 164881.930 | 37112.724 | 37153.435 | 37112.724 | |

TABLE AP 2-2 (Sheet 8 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 69.000 | | | | |
| 229788.820 | 230849.360 | 229788.820 | 541.787 | 543.044 |
| 541.787 | 458.654 | 459.638 | 458.654 | 83.133 |
| 83.406 | 83.133 | 5.517 | 5.511 | 5.517 |
| 424.131 | 425.102 | 424.131 | 164424.130 | 164062.810 |
| 164424.130 | 37028.827 | 37069.383 | 37028.827 | |
| 70.000 | | | | |
| 228529.100 | 230862.400 | 228529.100 | 541.452 | 543.088 |
| 541.452 | 458.176 | 459.672 | 458.176 | 83.276 |
| 83.416 | 83.276 | 5.502 | 5.511 | 5.502 |
| 422.067 | 425.092 | 422.067 | 163966.110 | 163602.750 |
| 163966.110 | 36944.897 | 36985.320 | 36944.897 | |
| 71.000 | | | | |
| 228745.200 | 230875.710 | 228745.200 | 541.946 | 543.132 |
| 541.946 | 458.541 | 459.705 | 458.541 | 83.405 |
| 83.426 | 83.405 | 5.498 | 5.510 | 5.498 |
| 422.081 | 425.082 | 422.081 | 163507.300 | 163142.660 |
| 163507.300 | 36860.890 | 36901.248 | 36860.890 | |
| 72.000 | | | | |
| 230533.330 | 230889.010 | 230533.330 | 541.654 | 543.176 |
| 541.654 | 458.372 | 459.739 | 458.372 | 83.282 |
| 83.437 | 83.282 | 5.504 | 5.510 | 5.504 |
| 425.610 | 425.073 | 425.610 | 163048.320 | 162682.540 |
| 163048.320 | 36777.061 | 36817.165 | 36777.061 | |
| 73.000 | | | | |
| 230169.270 | 230902.370 | 230169.270 | 541.743 | 543.220 |
| 541.743 | 458.272 | 459.773 | 458.272 | 83.471 |
| 83.447 | 83.471 | 5.490 | 5.510 | 5.490 |
| 424.868 | 425.063 | 424.868 | 162589.010 | 162222.390 |
| 162589.010 | 36693.118 | 36733.072 | 36693.118 | |
| 74.000 | | | | |
| 230610.040 | 230915.790 | 230610.040 | 542.640 | 543.264 |
| 542.640 | 459.477 | 459.807 | 459.477 | 83.164 |
| 83.457 | 83.164 | 5.525 | 5.509 | 5.525 |
| 424.978 | 425.053 | 424.978 | 162129.700 | 161762.190 |
| 162129.700 | 36609.115 | 36648.969 | 36609.115 | |
| 75.000 | | | | |
| 230218.430 | 230929.220 | 230218.430 | 535.552 | 543.308 |
| 535.552 | 452.239 | 459.841 | 452.239 | 83.312 |
| 83.467 | 83.312 | 5.428 | 5.509 | 5.428 |
| 429.872 | 425.043 | 429.872 | 161671.090 | 161301.970 |
| 161671.090 | 36525.264 | 36564.855 | 36525.264 | |
| 76.000 | | | | |
| 230539.680 | 230942.640 | 230539.680 | 540.378 | 543.352 |
| 540.378 | 457.086 | 459.875 | 457.086 | 83.292 |
| 83.478 | 83.292 | 5.488 | 5.509 | 5.488 |
| 426.627 | 425.033 | 426.627 | 161213.490 | 160841.710 |
| 161213.490 | 36441.394 | 36480.730 | 36441.394 | |
| 77.000 | | | | |
| 229890.860 | 230956.070 | 229890.860 | 543.562 | 543.397 |
| 543.562 | 460.521 | 459.909 | 460.521 | 83.040 |
| 83.488 | 83.040 | 5.546 | 5.509 | 5.546 |
| 422.934 | 425.023 | 422.934 | 160755.050 | 160381.420 |
| 160755.050 | 36357.468 | 36396.596 | 36357.468 | |
| 78.000 | | | | |
| 230567.460 | 230969.500 | 230567.460 | 542.043 | 543.441 |
| 542.043 | 458.699 | 459.943 | 458.699 | 83.343 |
| 83.498 | 83.343 | 5.504 | 5.508 | 5.504 |
| 425.368 | 425.013 | 425.368 | 160296.160 | 159921.090 |
| 160296.160 | 36273.497 | 36312.451 | 36273.497 | |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 9 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | | |
|------------|------------|------------|------------|------------|--|
| 79.000 | | | | | |
| 230302.340 | 230982,920 | 230302,340 | 537.825 | 543.485 | |
| 537.825 | 454,362 | 459,977 | 454,362 | 83.462 | |
| 83.509 | 83,462 | 5,444 | 5,508 | 5,444 | |
| 428,211 | 425,003 | 428,211 | 159838,230 | 159460,740 | |
| 159838,230 | 36189,286 | 36228,297 | 36189,286 | | |
| 80.000 | | | | | |
| 229752,640 | 230996,350 | 229752,640 | 540.109 | 543.529 | |
| 540.109 | 456,636 | 460,011 | 456,636 | 83.472 | |
| 83.519 | 83,472 | 5,471 | 5,508 | 5,471 | |
| 425,382 | 424,993 | 425,382 | 159381,170 | 159000,340 | |
| 159381,170 | 36105,160 | 36144,131 | 36105,160 | | |
| 81.000 | | | | | |
| 228272,080 | 231009,070 | 228272,080 | 540,228 | 543,572 | |
| 540,228 | 456,898 | 460,044 | 456,898 | 83,329 | |
| 83,528 | 83,329 | 5,483 | 5,508 | 5,483 | |
| 422,548 | 424,984 | 422,548 | 158924,360 | 158539,910 | |
| 158924,360 | 36021,145 | 36059,956 | 36021,145 | | |
| 82.000 | | | | | |
| 229711,300 | 231021,780 | 229711,300 | 538,570 | 543,613 | |
| 538,570 | 455,344 | 460,077 | 455,344 | 83,227 | |
| 83,536 | 83,227 | 5,471 | 5,508 | 5,471 | |
| 426,521 | 424,974 | 426,521 | 158467,800 | 158079,460 | |
| 158467,800 | 35937,250 | 35975,774 | 35937,250 | | |
| 83.000 | | | | | |
| 229566,360 | 231034,500 | 229566,360 | 541,132 | 543,655 | |
| 541,132 | 457,801 | 460,111 | 457,801 | 83,331 | |
| 83,544 | 83,331 | 5,494 | 5,507 | 5,494 | |
| 424,233 | 424,965 | 424,233 | 158011,210 | 157618,960 | |
| 158011,210 | 35853,203 | 35891,582 | 35853,203 | | |
| 84.000 | | | | | |
| 228614,610 | 231047,220 | 228614,610 | 539,332 | 543,697 | |
| 539,332 | 456,092 | 460,144 | 456,092 | 83,241 | |
| 83,552 | 83,241 | 5,479 | 5,507 | 5,479 | |
| 423,885 | 424,956 | 423,885 | 157555,520 | 157158,430 | |
| 157555,520 | 35769,384 | 35807,382 | 35769,384 | | |
| 85.000 | | | | | |
| 227995,020 | 230230,820 | 227995,020 | 540,756 | 542,737 | |
| 540,756 | 457,456 | 459,223 | 457,456 | 83,300 | |
| 83,514 | 83,300 | 5,492 | 5,499 | 5,492 | |
| 421,623 | 424,203 | 421,623 | 157099,140 | 156698,350 | |
| 157099,140 | 35685,400 | 35723,197 | 35685,400 | | |
| 86.000 | | | | | |
| 228194,630 | 230202,660 | 228194,630 | 537,581 | 542,675 | |
| 537,581 | 454,241 | 459,157 | 454,241 | 83,339 | |
| 83,518 | 83,339 | 5,451 | 5,498 | 5,451 | |
| 424,485 | 424,200 | 424,485 | 156642,260 | 156238,760 | |
| 156642,260 | 35601,372 | 35639,030 | 35601,372 | | |
| 87.000 | | | | | |
| 229910,870 | 230174,790 | 229910,870 | 541,629 | 542,612 | |
| 541,629 | 458,168 | 459,091 | 458,168 | 83,461 | |
| 83,521 | 83,461 | 5,490 | 5,497 | 5,490 | |
| 424,480 | 424,197 | 424,480 | 156185,810 | 155779,240 | |
| 156185,810 | 35517,320 | 35554,859 | 35517,320 | | |
| 88.000 | | | | | |
| 229545,660 | 230146,930 | 229545,660 | 541,204 | 542,550 | |
| 541,204 | 458,073 | 459,026 | 458,073 | 83,131 | |
| 83,524 | 83,131 | 5,510 | 5,496 | 5,510 | |
| 424,139 | 424,195 | 424,139 | 155728,380 | 155319,790 | |
| 155728,380 | 35433,270 | 35470,685 | 35433,270 | | |

TABLE AP 2-2 (Sheet 10 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 89.000 | | | | |
| 228345.500 | 230119,150 | 228345.500 | 540.851 | 542.488 |
| 540.851 | 457,045 | 458.961 | 457,045 | 83.806 |
| 83.528 | 83,806 | 5.454 | 5.495 | 5.454 |
| 422.197 | 424,192 | 422.197 | 155269.700 | 154860.390 |
| 155269.700 | 35349,072 | 35386.506 | 35349.072 | |
| 90.000 | | | | |
| 230000.590 | 230091,390 | 230000.590 | 542.629 | 542.427 |
| 542.629 | 458,881 | 458.896 | 458,881 | 83.747 |
| 83.531 | 83,747 | 5.479 | 5.494 | 5.479 |
| 423.864 | 424,189 | 423.864 | 154811.990 | 154401.070 |
| 154811.990 | 35264,798 | 35302.327 | 35264.798 | |
| 91.000 | | | | |
| 229765.130 | 230063,880 | 229765.130 | 541.149 | 542.365 |
| 541.149 | 457,445 | 458.831 | 457,445 | 83.704 |
| 83.535 | 83,704 | 5.465 | 5.493 | 5.465 |
| 424.587 | 424,186 | 424.587 | 154354.310 | 153941.810 |
| 154354.310 | 35180,520 | 35218.143 | 35180.520 | |
| 92.000 | | | | |
| 230103.000 | 230036,380 | 230103.000 | 542.578 | 542.304 |
| 542.578 | 458,543 | 458.766 | 458,543 | 84.035 |
| 83.538 | 84,035 | 5.457 | 5.492 | 5.457 |
| 424.092 | 424,184 | 424.092 | 153896.760 | 153482.620 |
| 153896.760 | 35096,166 | 35133.954 | 35096.166 | |
| 93.000 | | | | |
| 230564.280 | 230008,870 | 230564.280 | 542.876 | 542.242 |
| 542.876 | 459,240 | 458.700 | 459,240 | 83.636 |
| 83.542 | 83,636 | 5.491 | 5.491 | 5.491 |
| 424.709 | 424,181 | 424.709 | 153437.850 | 153023.480 |
| 153437.850 | 35011,724 | 35049.763 | 35011.724 | |
| 94.000 | | | | |
| 230377.560 | 229981,360 | 230377.560 | 541.947 | 542.181 |
| 541.947 | 458,353 | 458.635 | 458,353 | 83.594 |
| 83.545 | 83,594 | 5.483 | 5.490 | 5.483 |
| 425.093 | 424,178 | 425.093 | 152979.430 | 152564.420 |
| 152979.430 | 34927,529 | 34955.568 | 34927.529 | |
| 95.000 | | | | |
| 230100.440 | 229953,860 | 230100.440 | 539.769 | 542.120 |
| 539.769 | 456,172 | 458.570 | 456,172 | 83.596 |
| 83.549 | 83,595 | 5.457 | 5.489 | 5.457 |
| 426.294 | 424,176 | 426.294 | 152521.690 | 152105.420 |
| 152521.690 | 34843,241 | 34881,368 | 34843.241 | |
| 96.000 | | | | |
| 229861.200 | 229926,360 | 229861.200 | 541.471 | 542.058 |
| 541.471 | 457,875 | 458.505 | 457,875 | 83.596 |
| 83.553 | 83,596 | 5.477 | 5.488 | 5.477 |
| 424.513 | 424,173 | 424.513 | 152064.570 | 151646.480 |
| 152064.570 | 34758,937 | 34797.166 | 34758.937 | |
| 97.000 | | | | |
| 229878.870 | 230736,800 | 229878.870 | 540.979 | 543.020 |
| 540.979 | 456,296 | 459.417 | 456,296 | 84.683 |
| 83.603 | 84,683 | 5.388 | 5.495 | 5.388 |
| 424.931 | 424,914 | 424.931 | 151605.930 | 151187.120 |
| 151605.930 | 34674,578 | 34712.935 | 34674.578 | |
| 98.000 | | | | |
| 229969.290 | 230759,020 | 229969.290 | 542.972 | 543.086 |
| 542.972 | 459,255 | 459.473 | 459,255 | 83.717 |
| 83.613 | 83,717 | 5.486 | 5.495 | 5.486 |
| 423.538 | 424,903 | 423.538 | 151148.190 | 150727.280 |
| 151148.190 | 34590,130 | 34628.676 | 34590.130 | |

TABLE AP 2-2 (Sheet 11 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 99.000 | | | | |
| 230445.820 | 230780.930 | 230445.820 | 542.498 | 543.151 |
| 542.498 | 458.443 | 459.528 | 458.443 | 84.054 |
| 83.623 | 84.054 | 5.454 | 5.495 | 5.454 |
| 424.787 | 424.893 | 424.787 | 150689.590 | 150267.380 |
| 150689.590 | 34505.757 | 34544.406 | 34505.757 | |
| 100.000 | | | | |
| 230227.850 | 230802.850 | 230227.850 | 542.845 | 543.216 |
| 542.845 | 459.382 | 459.584 | 459.382 | 83.462 |
| 83.632 | 83.462 | 5.504 | 5.495 | 5.504 |
| 424.114 | 424.882 | 424.114 | 150230.680 | 149807.420 |
| 150230.680 | 34421.390 | 34460.127 | 34421.390 | |
| 101.000 | | | | |
| 229560.390 | 230824.810 | 229560.390 | 539.840 | 543.281 |
| 539.840 | 455.633 | 459.639 | 455.633 | 84.207 |
| 83.642 | 84.207 | 5.411 | 5.495 | 5.411 |
| 425.238 | 424.872 | 425.238 | 149771.500 | 149347.410 |
| 149771.500 | 34337.010 | 34375.838 | 34337.010 | |
| 102.000 | | | | |
| 229443.360 | 230846.770 | 229443.360 | 540.582 | 543.346 |
| 540.582 | 456.971 | 459.694 | 456.971 | 83.611 |
| 83.652 | 83.611 | 5.465 | 5.495 | 5.465 |
| 424.438 | 424.861 | 424.438 | 149315.010 | 148887.340 |
| 149315.010 | 34252.493 | 34291.540 | 34252.493 | |
| 103.000 | | | | |
| 229721.750 | 230868.730 | 229721.750 | 540.245 | 543.411 |
| 540.245 | 456.722 | 459.750 | 456.722 | 83.524 |
| 83.661 | 83.524 | 5.468 | 5.495 | 5.468 |
| 425.217 | 424.851 | 425.217 | 148857.680 | 148427.230 |
| 148857.680 | 34168.216 | 34207.233 | 34168.216 | |
| 104.000 | | | | |
| 229725.840 | 230890.680 | 229725.840 | 540.697 | 543.475 |
| 540.697 | 457.197 | 459.805 | 457.197 | 83.500 |
| 83.670 | 83.500 | 5.475 | 5.495 | 5.475 |
| 424.870 | 424.842 | 424.870 | 148400.560 | 147967.050 |
| 148400.560 | 34084.029 | 34122.916 | 34084.029 | |
| 105.000 | | | | |
| 227658.710 | 230912.680 | 227658.710 | 538.913 | 543.538 |
| 538.913 | 455.269 | 459.861 | 455.269 | 83.644 |
| 83.678 | 83.644 | 5.443 | 5.495 | 5.443 |
| 422.441 | 424.832 | 422.441 | 147945.200 | 147506.810 |
| 147945.200 | 33999.909 | 34038.591 | 33999.909 | |
| 106.000 | | | | |
| 227655.540 | 230934.720 | 227655.540 | 537.888 | 543.602 |
| 537.888 | 454.194 | 459.916 | 454.194 | 83.694 |
| 83.686 | 83.694 | 5.427 | 5.495 | 5.427 |
| 423.239 | 424.823 | 423.239 | 147490.410 | 147046.520 |
| 147490.410 | 33915.590 | 33954.258 | 33915.590 | |
| 107.000 | | | | |
| 228999.270 | 230956.770 | 228999.270 | 536.888 | 543.665 |
| 536.888 | 453.310 | 459.972 | 453.310 | 83.577 |
| 83.693 | 83.577 | 5.424 | 5.495 | 5.424 |
| 426.531 | 424.814 | 426.531 | 147034.880 | 146586.180 |
| 147034.880 | 33831.276 | 33869.916 | 33831.276 | |
| 108.000 | | | | |
| 229302.060 | 230978.820 | 229302.060 | 537.575 | 543.729 |
| 537.575 | 454.050 | 460.027 | 454.050 | 83.526 |
| 83.701 | 83.526 | 5.436 | 5.495 | 5.436 |
| 426.549 | 424.805 | 426.549 | 146578.570 | 146125.780 |
| 146578.570 | 33746.902 | 33785.567 | 33746.902 | |

TABLE AP 2-2 (Sheet 12 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 109.000 | | | | |
| 227642.890 | 231000.860 | 227642.890 | 537.260 | 543.792 |
| 537.260 | 453.460 | 450.083 | 453.460 | 83.800 |
| 83.709 | 83.800 | 5.411 | 5.495 | 5.411 |
| 423.711 | 424.796 | 423.711 | 146123.130 | 145665.330 |
| 146123.130 | 33662.480 | 33701.210 | 33662.480 | |
| 110.000 | | | | |
| 227715.970 | 231022.910 | 227715.970 | 534.685 | 543.855 |
| 534.685 | 451.146 | 450.138 | 451.146 | 83.540 |
| 83.717 | 83.540 | 5.400 | 5.496 | 5.400 |
| 425.888 | 424.787 | 425.888 | 145668.650 | 145204.820 |
| 145668.650 | 33578.227 | 33616.846 | 33578.227 | |
| 111.000 | | | | |
| 227953.990 | 230201.690 | 227953.990 | 536.868 | 542.882 |
| 536.868 | 453.341 | 459.205 | 453.341 | 83.527 |
| 83.677 | 83.527 | 5.427 | 5.488 | 5.427 |
| 424.600 | 424.037 | 424.600 | 145213.210 | 144744.750 |
| 145213.210 | 33493.925 | 33532.497 | 33493.925 | |
| 112.000 | | | | |
| 228260.980 | 230168.700 | 228260.980 | 539.965 | 542.804 |
| 539.965 | 456.343 | 459.126 | 456.343 | 83.623 |
| 83.678 | 83.623 | 5.457 | 5.487 | 5.457 |
| 422.733 | 424.036 | 422.733 | 144758.090 | 144285.180 |
| 144758.090 | 33409.588 | 33448.167 | 33409.588 | |
| 113.000 | | | | |
| 228271.160 | 230136.000 | 228271.160 | 541.710 | 542.728 |
| 541.710 | 457.677 | 459.048 | 457.677 | 84.033 |
| 83.680 | 84.033 | 5.446 | 5.485 | 5.446 |
| 421.390 | 424.036 | 421.390 | 144300.520 | 143825.690 |
| 144300.520 | 33325.204 | 33363.836 | 33325.204 | |
| 114.000 | | | | |
| 229202.110 | 230103.310 | 229202.110 | 540.016 | 542.651 |
| 540.016 | 456.873 | 458.971 | 456.873 | 83.143 |
| 83.681 | 83.143 | 5.495 | 5.485 | 5.495 |
| 424.436 | 424.035 | 424.436 | 143843.360 | 143356.280 |
| 143843.360 | 33240.917 | 33279.505 | 33240.917 | |
| 115.000 | | | | |
| 228601.440 | 230070.610 | 228601.440 | 540.502 | 542.575 |
| 540.502 | 457.247 | 458.893 | 457.247 | 83.254 |
| 83.682 | 83.254 | 5.492 | 5.484 | 5.492 |
| 422.943 | 424.035 | 422.943 | 143386.120 | 142906.950 |
| 143386.120 | 33156.676 | 33195.173 | 33156.676 | |
| 116.000 | | | | |
| 228314.180 | 230037.910 | 228314.180 | 541.022 | 542.498 |
| 541.022 | 457.360 | 458.815 | 457.360 | 83.662 |
| 83.683 | 83.662 | 5.467 | 5.483 | 5.467 |
| 422.005 | 424.034 | 422.005 | 142927.940 | 142447.700 |
| 142927.940 | 33072.206 | 33110.838 | 33072.206 | |
| 117.000 | | | | |
| 228351.320 | 230005.210 | 228351.320 | 542.410 | 542.422 |
| 542.410 | 458.659 | 458.737 | 458.659 | 83.751 |
| 83.685 | 83.751 | 5.476 | 5.482 | 5.476 |
| 420.994 | 424.034 | 420.994 | 142471.480 | 141988.520 |
| 142471.480 | 32987.695 | 33026.502 | 32987.695 | |
| 118.000 | | | | |
| 227679.130 | 229972.510 | 227679.130 | 541.450 | 542.345 |
| 541.450 | 457.495 | 458.659 | 457.495 | 83.955 |
| 83.686 | 83.955 | 5.449 | 5.481 | 5.449 |
| 420.499 | 424.034 | 420.499 | 142013.270 | 141529.430 |
| 142013.270 | 32903.141 | 32942.167 | 32903.141 | |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 13 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 119.000 | | | | |
| 227373.030 | 229939.820 | 227373.030 | 540.422 | 542.269 |
| 540.422 | 456.423 | 458.582 | 456.423 | 83.999 |
| 83.687 | 83.999 | 5.434 | 5.483 | 5.434 |
| 420.732 | 424.033 | 420.732 | 141555.250 | 141070.410 |
| 141555.250 | 32818.514 | 32857.829 | 32818.514 | |
| 120.000 | | | | |
| 225784.640 | 229907.130 | 225784.640 | 542.465 | 542.192 |
| 542.465 | 458.615 | 458.504 | 458.615 | 83.851 |
| 83.688 | 83.851 | 5.469 | 5.479 | 5.469 |
| 416.219 | 424.033 | 416.219 | 141097.330 | 140611.470 |
| 141097.330 | 32733.975 | 32773.489 | 32733.975 | |
| 121.000 | | | | |
| 225617.820 | 230709.490 | 225617.820 | 540.939 | 543.132 |
| 540.939 | 457.087 | 459.395 | 457.087 | 83.852 |
| 83.736 | 83.852 | 5.451 | 5.485 | 5.451 |
| 417.086 | 424.776 | 417.086 | 140639.820 | 140152.120 |
| 140639.820 | 32649.276 | 32689.127 | 32649.276 | |
| 122.000 | | | | |
| 226006.310 | 230723.610 | 226006.310 | 541.383 | 543.175 |
| 541.383 | 457.464 | 459.431 | 457.464 | 83.919 |
| 83.744 | 83.919 | 5.451 | 5.485 | 5.451 |
| 417.461 | 424.769 | 417.461 | 140182.990 | 139692.310 |
| 140182.990 | 32564.613 | 32604.736 | 32564.613 | |
| 123.000 | | | | |
| 225790.230 | 230737.620 | 225790.230 | 542.787 | 543.218 |
| 542.787 | 458.757 | 459.467 | 458.757 | 84.030 |
| 83.751 | 84.030 | 5.459 | 5.485 | 5.459 |
| 415.983 | 424.761 | 415.983 | 139725.990 | 139232.460 |
| 139725.990 | 32479.843 | 32520.339 | 32479.843 | |
| 124.000 | | | | |
| 224612.500 | 230751.640 | 224612.500 | 539.909 | 543.260 |
| 539.909 | 455.925 | 459.503 | 455.925 | 83.983 |
| 83.758 | 83.983 | 5.429 | 5.485 | 5.429 |
| 416.019 | 424.753 | 416.019 | 139268.820 | 138772.570 |
| 139268.820 | 32395.268 | 32435.935 | 32395.268 | |
| 125.000 | | | | |
| 223565.290 | 230765.660 | 223565.290 | 542.144 | 543.303 |
| 542.144 | 458.266 | 459.539 | 458.266 | 83.877 |
| 83.765 | 83.877 | 5.464 | 5.485 | 5.464 |
| 412.373 | 424.746 | 412.373 | 138810.740 | 138312.650 |
| 138810.740 | 32310.588 | 32351.524 | 32310.588 | |
| 126.000 | | | | |
| 223723.540 | 230779.690 | 223723.540 | 539.729 | 543.346 |
| 539.729 | 455.882 | 459.575 | 455.882 | 83.847 |
| 83.772 | 83.847 | 5.437 | 5.485 | 5.437 |
| 414.511 | 424.738 | 414.511 | 138353.600 | 137852.690 |
| 138353.600 | 32226.010 | 32267.106 | 32226.010 | |
| 127.000 | | | | |
| 224609.940 | 230793.710 | 224609.940 | 541.732 | 543.389 |
| 541.732 | 457.882 | 459.610 | 457.882 | 83.850 |
| 83.779 | 83.850 | 5.461 | 5.485 | 5.461 |
| 414.614 | 424.730 | 414.614 | 137896.450 | 137392.700 |
| 137896.450 | 32141.488 | 32182.681 | 32141.488 | |
| 128.000 | | | | |
| 224760.800 | 230807.740 | 224760.800 | 541.244 | 543.432 |
| 541.244 | 457.327 | 459.646 | 457.327 | 83.917 |
| 83.786 | 83.917 | 5.450 | 5.485 | 5.450 |
| 415.267 | 424.723 | 415.267 | 137440.380 | 136932.670 |
| 137440.380 | 32056.864 | 32098.249 | 32056.864 | |

TABLE AP 2-2 (Sheet 14 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 129.000 | | | | |
| 224289.340 | 230821,760 | 224289.340 | 536.645 | 543.475 |
| 536.645 | 452,867 | 459.682 | 452.867 | 83.778 |
| 83.793 | 83,778 | 5,406 | 5,486 | 5,406 |
| 417.947 | 424,715 | 417,947 | 136984.390 | 136472.610 |
| 136984.390 | 31972,425 | 32013,810 | 31972,425 | |
| 130.000 | | | | |
| 224539.720 | 230835,790 | 224539.720 | 540.999 | 543.518 |
| 540.999 | 457,344 | 459,718 | 457,344 | 83,655 |
| 83.800 | 83,655 | 5,467 | 5,486 | 5,467 |
| 415.046 | 424,707 | 415,046 | 136529.350 | 136012.510 |
| 136529.350 | 31887,973 | 31929,363 | 31887,973 | |
| 131.000 | | | | |
| 223197.250 | 230849,820 | 223197.250 | 536,284 | 543,560 |
| 536.284 | 452,432 | 459,754 | 452,432 | 83,852 |
| 83.807 | 83,852 | 5,396 | 5,486 | 5,396 |
| 416.192 | 424,699 | 416,192 | 136075.090 | 135552,370 |
| 136075.090 | 31803,422 | 31844,910 | 31803,422 | |
| 132.000 | | | | |
| 223279.500 | 230863,850 | 223279.500 | 539,331 | 543,603 |
| 539.331 | 455,482 | 459,790 | 455,482 | 83,849 |
| 83.814 | 83,849 | 5,432 | 5,486 | 5,432 |
| 413.994 | 424,692 | 413,994 | 135617.730 | 135092,200 |
| 135617.730 | 31718,820 | 31760,450 | 31718,820 | |
| 133.000 | | | | |
| 223396.570 | 230089,320 | 223396.570 | 540,519 | 542,749 |
| 540.519 | 456,716 | 458,970 | 456,716 | 83,803 |
| 83.779 | 83,803 | 5,450 | 5,478 | 5,450 |
| 413.300 | 423,933 | 413,300 | 135163,070 | 134632,420 |
| 135163,070 | 31634,142 | 31676,003 | 31634,142 | |
| 134.000 | | | | |
| 224303,950 | 230103,060 | 224303,950 | 538,626 | 542,791 |
| 538.626 | 454,845 | 459,005 | 454,845 | 83,781 |
| 83.786 | 83,781 | 5,429 | 5,478 | 5,429 |
| 415,437 | 423,926 | 416,437 | 134706,910 | 134173,040 |
| 134706,910 | 31549,690 | 31591,570 | 31549,690 | |
| 135.000 | | | | |
| 224298,150 | 230117,090 | 224298,150 | 538,361 | 542,833 |
| 538.361 | 454,788 | 459,041 | 454,788 | 83,572 |
| 83.792 | 83,572 | 5,442 | 5,478 | 5,442 |
| 416,632 | 423,919 | 416,632 | 134251,650 | 133713,610 |
| 134251,650 | 31465,112 | 31507,131 | 31465,112 | |
| 136.000 | | | | |
| 224542,590 | 230131,130 | 224542,590 | 538,211 | 542,873 |
| 538.211 | 454,399 | 459,077 | 454,399 | 83,812 |
| 83.797 | 83,812 | 5,422 | 5,478 | 5,422 |
| 417,202 | 423,913 | 417,202 | 133796,790 | 133254,160 |
| 133796,790 | 31380,729 | 31422,686 | 31380,729 | |
| 137.000 | | | | |
| 224261,540 | 230145,160 | 224261,540 | 536,020 | 542,914 |
| 536.020 | 452,128 | 459,112 | 452,128 | 83,892 |
| 83.802 | 83,892 | 5,389 | 5,479 | 5,389 |
| 418,383 | 423,907 | 418,383 | 133344,180 | 132794,660 |
| 133344,180 | 31296,153 | 31338,236 | 31296,153 | |
| 138.000 | | | | |
| 224695,590 | 230159,200 | 224695,590 | 539,464 | 542,955 |
| 539.464 | 455,786 | 459,148 | 455,786 | 83,678 |
| 83.807 | 83,678 | 5,447 | 5,479 | 5,447 |
| 416,516 | 423,901 | 416,516 | 132889,830 | 132335,130 |
| 132889,830 | 31211,554 | 31253,782 | 31211,554 | |

Appendix 2
 Engine Performance Program (PA 4)

TABLE AP 2-2 (Sheet 15 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|------------|------------|------------|------------|
| 139.000 | | | | |
| 224456.300 | 230173.240 | 224456.300 | 539.185 | 542.996 |
| 539.185 | 455.389 | 459.184 | 455.389 | 83.796 |
| 83.812 | 83.796 | 5.435 | 5.479 | 5.435 |
| 416.288 | 423.895 | 416.288 | 132433.880 | 131875.570 |
| 132433.880 | 31126.968 | 31169.322 | 31126.968 | |
| 140.000 | | | | |
| 224415.420 | 12420.031 | 224415.420 | 539.288 | 31.097 |
| 539.288 | 455.400 | 26.399 | 455.400 | 83.887 |
| 4.697 | 83.887 | 5.429 | 5.621 | 5.429 |
| 416.133 | 399.286 | 416.133 | 131978.050 | 131574.560 |
| 131978.050 | 31042.391 | 31113.838 | 31042.391 | |
| 141.000 | | | | |
| 222946.320 | | 222946.320 | 538.543 | |
| 538.543 | 454.765 | | 454.765 | 83.778 |
| | 83.778 | 5.428 | | 5.428 |
| 413.980 | | 413.980 | 131522.280 | |
| 131522.280 | 30957.820 | | 30957.820 | |
| 142.000 | | | | |
| 224669.170 | | 224669.170 | 539.428 | |
| 539.428 | 455.651 | | 455.651 | 83.777 |
| | 83.777 | 5.439 | | 5.439 |
| 416.495 | | 416.495 | 131066.281 | |
| 131066.281 | 30873.138 | | 30873.138 | |
| 143.000 | | | | |
| 224444.580 | | 224444.580 | 540.636 | |
| 540.636 | 456.724 | | 456.724 | 83.913 |
| | 83.913 | 5.443 | | 5.443 |
| 415.149 | | 415.149 | 130609.304 | |
| 130609.304 | 30788.509 | | 30788.509 | |
| 144.000 | | | | |
| 225025.210 | | 225025.210 | 541.629 | |
| 541.629 | 457.693 | | 457.693 | 83.935 |
| | 83.935 | 5.453 | | 5.453 |
| 415.460 | | 415.460 | 130153.355 | |
| 130153.355 | 30703.886 | | 30703.886 | |
| 145.000 | | | | |
| 224353.250 | | 224353.250 | 540.451 | |
| 540.451 | 456.630 | | 456.630 | 83.821 |
| | 83.821 | 5.448 | | 5.448 |
| 415.122 | | 415.122 | 129694.726 | |
| 129694.726 | 30619.241 | | 30619.241 | |
| 146.000 | | | | |
| 224669.890 | | 224669.890 | 540.899 | |
| 540.899 | 456.845 | | 456.845 | 84.054 |
| | 84.054 | 5.435 | | 5.435 |
| 415.364 | | 415.364 | 129237.829 | |
| 129237.829 | 30534.592 | | 30534.592 | |
| 147.000 | | | | |
| 224896.860 | | 224896.860 | 541.719 | |
| 541.719 | 457.740 | | 457.740 | 83.979 |
| | 83.979 | 5.451 | | 5.451 |
| 415.154 | | 415.154 | 128779.852 | |
| 128779.852 | 30449.952 | | 30449.952 | |
| 148.000 | | | | |
| 225386.150 | | 225386.150 | 540.615 | |
| 540.615 | 456.547 | | 456.547 | 84.068 |
| | 84.068 | 5.431 | | 5.431 |
| 415.907 | | 416.907 | 128322.962 | |
| 128322.962 | 30365.326 | | 30365.326 | |

TABLE AP 2-2 (Sheet 16 of 17)
FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | | |
|------------|-----------|------------|------------|--------|--|
| 149.000 | | | | | |
| 225016.690 | | 225016.690 | 541.448 | | |
| 541.448 | 457,310 | | 457.310 | 84.137 | |
| | 84.137 | 5.435 | | 5.435 | |
| 415.584 | | 415.584 | 127866.484 | | |
| 127866.484 | 30280.495 | | 30280.495 | | |
| 150.000 | | | | | |
| 225108.600 | | 225108.600 | 540.710 | | |
| 540.710 | 456,950 | | 456.950 | 83.760 | |
| | 83,760 | 5.455 | | 5.455 | |
| 415.321 | | 416.321 | 127409.787 | | |
| 127409.787 | 30195.924 | | 30195.924 | | |
| 151.000 | | | | | |
| 225496.760 | | 225496.760 | 539.424 | | |
| 539.424 | 455,472 | | 455.472 | 83.953 | |
| | 83,953 | 5.425 | | 5.425 | |
| 418.032 | | 418.032 | 126952.808 | | |
| 126952.808 | 30111.243 | | 30111.243 | | |
| 152.000 | | | | | |
| 225220.310 | | 225220.310 | 539.454 | | |
| 539.454 | 455,437 | | 455.437 | 84.017 | |
| | 84.017 | 5.421 | | 5.421 | |
| 417.497 | | 417.497 | 126495.737 | | |
| 126495.737 | 30026.636 | | 30026.636 | | |
| 153.000 | | | | | |
| 225218.470 | | 225218.470 | 540.865 | | |
| 540.865 | 456,890 | | 456.890 | 83.975 | |
| | 83,975 | 5.441 | | 5.441 | |
| 416.404 | | 416.404 | 126038.913 | | |
| 126038.913 | 29941.934 | | 29941.934 | | |
| 154.000 | | | | | |
| 225042.770 | | 225042.770 | 542.467 | | |
| 542.467 | 458,439 | | 458.439 | 84.028 | |
| | 84.028 | 5.456 | | 5.456 | |
| 414.851 | | 414.851 | 125579.953 | | |
| 125579.953 | 29857.334 | | 29857.334 | | |
| 155.000 | | | | | |
| 225802.750 | | 225802.750 | 542.547 | | |
| 542.547 | 458,708 | | 458.708 | 83.840 | |
| | 83,840 | 5.471 | | 5.471 | |
| 416.190 | | 416.190 | 125121.784 | | |
| 125121.784 | 29772.700 | | 29772.700 | | |
| 156.000 | | | | | |
| 223911.580 | | 223911.580 | 533.813 | | |
| 533.813 | 449,709 | | 449.709 | 84.104 | |
| | 84,104 | 5.347 | | 5.347 | |
| 419.457 | | 419.457 | 124663.974 | | |
| 124663.974 | 29687.960 | | 29687.960 | | |
| 157.000 | | | | | |
| 224793.790 | | 224793.790 | 537.950 | | |
| 537.950 | 453,992 | | 453.992 | 83.958 | |
| | 83,958 | 5.407 | | 5.407 | |
| 417.871 | | 417.871 | 124209.274 | | |
| 124209.274 | 29603.530 | | 29603.530 | | |
| 158.000 | | | | | |
| 224858.590 | | 224858.590 | 536.670 | | |
| 536.670 | 453,067 | | 453,067 | 83.603 | |
| | 83,603 | 5.419 | | 5.419 | |
| 418.989 | | 418.989 | 123753.367 | | |
| 123753.367 | 29519.179 | | 29519.179 | | |

Appendix 2
 Engine Performance Program (PA49)

TABLE AP 2-2 (Sheet 17 of 17)
 FIRST BURN ENGINE PERFORMANCE PROGRAM (PA49)

| | | | | |
|------------|-----------|------------|------------|--------|
| 159.000 | | | | |
| 224660.860 | | 224660.860 | 536.215 | |
| 536.215 | 452,186 | | 452.186 | 84.029 |
| | 84,029 | 5.381 | | 5.381 |
| 418.975 | | 418.975 | 123300.418 | |
| 123300.418 | 29434,635 | | 29434.635 | |
| 160.000 | | | | |
| 224160.050 | | 224160.050 | 538.173 | |
| 538.173 | 454,179 | | 454.179 | 83.994 |
| | 83,994 | 5.407 | | 5.407 |
| 416.521 | | 416.521 | 122845.946 | |
| 122845.946 | 29349,955 | | 29349.955 | |
| 161.000 | | | | |
| 224610.880 | | 224610.880 | 538.673 | |
| 538.673 | 454,576 | | 454.576 | 84.097 |
| | 84,097 | 5.405 | | 5.405 |
| 416.971 | | 416.971 | 122390.111 | |
| 122390.111 | 29265,362 | | 29265.362 | |
| 162.000 | | | | |
| 224324.030 | | 224324.030 | 538.079 | |
| 538.079 | 454,267 | | 454.267 | 83.811 |
| | 83,811 | 5.420 | | 5.420 |
| 416.898 | | 416.898 | 121934.351 | |
| 121934.351 | 29180,820 | | 29180.820 | |
| 163.000 | | | | |
| 223175.990 | | 223175.990 | 535.810 | |
| 535.810 | 451,994 | | 451.994 | 83.816 |
| | 83,816 | 5.393 | | 5.393 |
| 416.520 | | 416.520 | 121479.160 | |
| 121479.160 | 29096,319 | | 29096.319 | |
| 164.000 | | | | |
| 224201.490 | | 224201.490 | 538.887 | |
| 538.887 | 454,861 | | 454.861 | 84.026 |
| | 84,026 | 5.413 | | 5.413 |
| 416.046 | | 416.046 | 121024.568 | |
| 121024.568 | 29011.693 | | 29011.693 | |
| 165.000 | | | | |
| 223765.750 | | 223765.750 | 538.777 | |
| 538.777 | 455,046 | | 455.046 | 83.731 |
| | 83,731 | 5.435 | | 5.435 |
| 415.322 | | 415.322 | 120568.615 | |
| 120568.615 | 28927,140 | | 28927.140 | |
| 166.000 | | | | |
| 223119.670 | | 223119.670 | 534.258 | |
| 534.258 | 450,465 | | 450.465 | 83.794 |
| | 83,794 | 5.376 | | 5.376 |
| 417.625 | | 417.625 | 120113.976 | |
| 120113.976 | 28842,513 | | 28842.513 | |
| 167.000 | | | | |
| 224565.040 | | 224565.040 | 538.407 | |
| 538.407 | 454,641 | | 454.641 | 83.767 |
| | 83,767 | 5.427 | | 5.427 |
| 417.091 | | 417.091 | 119658.943 | |
| 119658.943 | 28757,957 | | 28757.957 | |
| 168.000 | | | | |
| 223492.730 | | 223492.730 | 538.863 | |
| 538.863 | 455,095 | | 455.095 | 83.768 |
| | 83,768 | 5.433 | | 5.433 |
| 414.748 | | 414.748 | 119204.098 | |
| 119204.098 | 28673,478 | | 28673.478 | |
| 169.000 | | | | |
| 224158.990 | | 224158.990 | 535.965 | |
| 535.965 | 452,077 | | 452.077 | 83.888 |
| | 83,888 | 5.389 | | 5.389 |
| 418.234 | | 418.234 | 118750.471 | |
| 118750.471 | 28588,966 | | 28588.966 | |
| 169.766 | | | | |
| 222836.240 | | 222836.240 | 519.595 | |
| 519.595 | 435,632 | | 435.632 | 83.963 |
| | 83,963 | 5.189 | | 5.189 |
| 428.908 | | 428.908 | 118403.599 | |
| 118403.599 | 28524,238 | | 28524.238 | |

APPENDIX 3

OBSERVED TRAJECTORY (AA83)

1. OBSERVED TRAJECTORY (AA83)

This appendix presents a detailed tabulation of the AS-502 vehicle observed trajectory from guidance reference release (RO -16.845 sec) to launch vehicle/spacecraft (LV/SC) separation (RO +11,667.8 sec). The trajectory data was obtained from various radar tracking histories, explained in table AP 3-1, while the aerodynamic data is based on the final meteorological summary of appendix 5.

Table AP 3-2 presents the definition of symbols for the trajectory parameters furnished in tables AP 3-3 and AP 3-4. All trajectory parameters are consistent with Project Apollo Coordinate System Standards. Table AP 3-3 presents the observed trajectory from guidance reference release to parking orbit insertion. Vehicle radar parameters were calculated for KSC launch complex 39A, Cape Tel 4, Grand Bahama, Bermuda, and the Insertion Ship, sites one through five, respectively. Table AP 3-4 presents the observed trajectory from parking orbit insertion to LV/SC separation. Vehicle radar parameters were calculated for Bermuda, Canary Island, Carnarvon, Hawaii, and Guaymas, sites one through five, respectively. Table AP 3-5 presents the vehicle acquisition and loss times for each of these radar stations.

TABLE AP 3-1
TRACKING HISTORY

| | |
|----------------------------|--|
| -16.845 sec to 757.04 sec | Boost composite fit of final Glotrac (Sta 1) and Bermuda, 3.18, 1.16, 0.18, and 19.18 C-band radars (CMP) |
| 757.04 sec to 11,667.8 sec | Orbit fit of Redstone tracking ship, Carnarvon, White Sands, Mila, and Hawaii C-band radars |

TABLE AP 3-2 (Sheet 1 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| 1 | TIME (SEC) | ALTITUDE (FEET) | RANGE (FEET) | GAMMA SB 1 (DEG,) | GAMMA SB 2 (DEG,) |
|----|------------------------|----------------------|--------------------------|------------------------|-------------------------|
| 2 | V SB E (FT/SEC) | V SB I (FT/SEC) | A SB I (FT/SSQ) | GAMMA(1) PR (DEG,) | GAMMA(2) PR (DEG,) |
| 3 | X SB E (FEET) | X SB S (FEET) | X SB SFE (FEET) | XI (METERS) | X SB GS (FEET) |
| 4 | Y SB E (FEET) | Y SB S (FEET) | Y SB SFE (FEET) | ETA (METERS) | Y SB GS (FEET) |
| 5 | Z SB E (FEET) | Z SB S (FEET) | Z SB SFE (FEET) | ZETA (METERS) | Z SB GS (FEET) |
| 6 | D-X SB E (FT/SEC) | D-X SB S (FT/SEC) | D-X SB SFE (FT/SEC) | D-XI (M/SEC) | D-X SB GS (FT/SEC) |
| 7 | D-Y SB E (FT/SEC) | D-Y SB S (FT/SEC) | D-Y SB SFE (FT/SEC) | D-ETA (M/SEC) | D-Y SB GS (FT/SEC) |
| 8 | D-Z SB E (FT/SEC) | D-Z SB S (FT/SEC) | D-Z SB SFE (FT/SEC) | D-ZETA (M/SEC) | D-Z SB GS (FT/SEC) |
| 9 | DD-X SB E (FT/SSQ) | V SB W (FT/SEC) | ALPHA SB WIND (DEG,) | MU (DEG,) | KHU (DEG,) |
| 10 | DD-Y SB E (FT/SSQ) | E SB W (DEG,) | BETA SB WIND (DEG,) | TEMPERATURE (DEG R) | DENSITY (SL/FT3) |
| 11 | DD-Z SB E (FT/SSQ) | V SB RM (FT/SEC) | MACH NUMBER | PRESSURE (LB/FT2) | DYN PRESS Q (LB/FT2) |
| 12 | RANGE ANGLE (DEG,) | REYN/L (1/FT) | VISCOSITY (LB-S/FT2) | REL HUMID (PERCENT) | SOUND VEL (FT/SEC) |
| 13 | D* SB 1 (FEET) | D* SB 2 (FEET) | D* SB 3 (FEET) | D* SB 4 (FEET) | D* SB 5 (FEET) |
| 14 | A* SB 1 (DEG,) | A* SB 2 (DEG,) | A* SB 3 (DEG,) | A* SB 4 (DEG,) | A* SB 5 (DEG,) |
| 15 | E* SB 1 (DEG,) | E* SB 2 (DEG,) | E* SB 3 (DEG,) | E* SB 4 (DEG,) | E* SB 5 (DEG,) |

GJIDANCE REFERENCE RELEASE

| | | | | | |
|----|----------|-------------|--------------|-----------|------------|
| 1 | -16.8450 | 193.3564 | .5455 | 90.0000 | .0000 |
| 2 | .0000 | 1340.6744 | 32.140 | .0000 | 90.0000 |
| 3 | 193.6 | .0 | -3137778.700 | .000 | .000 |
| 4 | .0 | .0 | 18115556.0 | .000 | .000 |
| 5 | .0 | .0 | 9960274.6 | .000 | .000 |
| 6 | .000 | .000 | -1321.021 | -.0000 | .000 |
| 7 | .000 | 414.291 | -228.716 | .0012 | .000 |
| 8 | .000 | 1275.057 | .0000 | .0036 | .000 |
| 9 | .000 | 27.595 | -90.0000 | -80.6042 | 28.6084 |
| 10 | .000 | 147.200 | -75.1764 | 526.9597 | .0023224 |
| 11 | .000 | 27.571 | .0244 | 2115.2772 | .8827 |
| 12 | .0000 | 555417.8300 | .0000 | .8546 | 344.1884 |
| 13 | 193.4 | 54911.5 | 1036753.1 | 5186520.1 | 11129393.7 |
| 14 | .0000 | 16.6024 | 314.4925 | 259.0173 | 273.9795 |
| 15 | 89.9901 | .1262 | -1.4115 | -7.1129 | -15.4072 |

S-IC ENGINE START COMMAND

| | | | | | |
|----|---------|-------------|--------------|-----------|------------|
| 1 | -8.7700 | 193.3564 | .5455 | 90.0000 | .0000 |
| 2 | .0000 | 1340.6744 | 32.140 | .0000 | 90.0000 |
| 3 | 193.6 | -2.8 | -3148445.300 | 319.245 | -1050.189 |
| 4 | .0 | 3343.9 | 18113706.0 | .027 | -1.509 |
| 5 | .0 | 10296.6 | 9960274.4 | .081 | .300 |
| 6 | .000 | -.693 | -1320.886 | 79.0699 | -260.109 |
| 7 | .000 | 413.932 | -229.494 | .0076 | -.381 |
| 8 | .000 | 1275.174 | .0000 | .0230 | .053 |
| 9 | .000 | 27.595 | -90.0000 | -80.6042 | 28.6084 |
| 10 | .000 | 147.200 | -75.1602 | 526.9597 | .0023224 |
| 11 | .000 | 27.571 | .0244 | 2115.2772 | .8827 |
| 12 | .0000 | 555417.8200 | .0000 | .8546 | 344.1884 |
| 13 | 193.4 | 54911.5 | 1036753.1 | 5186520.1 | 11129393.6 |
| 14 | .0000 | 16.6024 | 314.4925 | 259.0173 | 273.9795 |
| 15 | 89.9901 | .1262 | -1.4115 | -7.1129 | -15.4072 |

TABLE AP 3-2 (Sheet 2 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| RANGE ZERO | | | | | |
|-----------------------|----------|-------------|--------------|-----------|------------|
| 1 | .0000 | 193.3564 | .5455 | 90.0000 | .0000 |
| 2 | .0000 | 1340.6744 | 32.140 | .0000 | 90.0000 |
| 3 | 193.6 | -12.2 | -3160028.800 | 1389.251 | -4570.086 |
| 4 | .0 | 6972.4 | 18111689.0 | .176 | -6.829 |
| 5 | .0 | 21480.4 | 9960274.1 | .535 | .490 |
| 6 | .000 | -1.446 | -1320.739 | 164.9451 | -542.604 |
| 7 | .000 | 413.541 | -230.339 | .0288 | -.841 |
| 8 | .000 | 1275.300 | .0000 | .0881 | -.035 |
| 9 | .000 | 27.596 | -90.0000 | -80.6042 | 28.6084 |
| 10 | .000 | 147.200 | -75.1425 | 526.9597 | .0023224 |
| 11 | .000 | 27.571 | .0244 | 2115.2772 | .8827 |
| 12 | .0000 | 555417.8300 | .0000 | .8546 | 344.1884 |
| 13 | 193.4 | 54911.5 | 1036753.1 | 5186520.1 | 11129393.7 |
| 14 | .0000 | 16.6024 | 314.4925 | 259.0173 | 273.9795 |
| 15 | 89.9901 | .1262 | -1.4115 | -7.1129 | -15.4072 |
| FIRST MOTION | | | | | |
| 1 | .3800 | 193.3564 | .5455 | 90.0000 | .0000 |
| 2 | .0000 | 1340.6744 | 35.420 | .0000 | 90.0000 |
| 3 | 193.6 | -12.7 | -3160530.600 | 1452.637 | -4778.601 |
| 4 | .0 | 7129.6 | 18111601.0 | .187 | -7.153 |
| 5 | .0 | 21965.0 | 9960274.1 | .569 | .476 |
| 6 | .000 | -1.478 | -1320.733 | 168.6661 | -554.845 |
| 7 | .000 | 413.524 | -230.376 | .0301 | -.862 |
| 8 | .000 | 1275.306 | .0000 | .0920 | -.042 |
| 9 | 3.281 | 27.596 | -90.0000 | -80.6042 | 28.6084 |
| 10 | .000 | 147.200 | -75.1417 | 526.9597 | .0023224 |
| 11 | .000 | 27.571 | .0244 | 2115.2772 | .8827 |
| 12 | .0000 | 555417.8300 | .0000 | .8546 | 344.1884 |
| 13 | 193.4 | 54911.5 | 1036753.1 | 5186520.1 | 11129393.7 |
| 14 | .0000 | 16.6024 | 314.4925 | 259.0173 | 273.9795 |
| 15 | 89.9901 | .1262 | -1.4115 | -7.1129 | -15.4072 |
| LIFTOFF SIGNAL - TB 1 | | | | | |
| 1 | .6900 | 193.6412 | .1954 | 87.2967 | 220.3412 |
| 2 | 1.3122 | 1340.6350 | 37.474 | .0560 | 90.0019 |
| 3 | 193.8 | -12.9 | -3160940.300 | 1505.477 | -4952.151 |
| 4 | .6 | 7258.4 | 18111531.0 | .391 | -7.423 |
| 5 | -.0 | 22360.3 | 9960273.7 | .594 | .462 |
| 6 | 1.311 | -.194 | -1320.890 | 172.1011 | -564.830 |
| 7 | .032 | 413.543 | -229.243 | .0412 | -.879 |
| 8 | -.053 | 1275.259 | .5862 | .0796 | -.048 |
| 9 | 5.335 | 27.598 | -82.3214 | -80.6042 | 28.6084 |
| 10 | -.012 | 147.183 | 103.5285 | 526.9600 | .0023224 |
| 11 | -.025 | 27.619 | .0245 | 2115.2572 | .8858 |
| 12 | .0000 | 556374.2300 | .0000 | .8545 | 344.1885 |
| 13 | 193.6 | 54911.0 | 1036752.6 | 5186520.3 | 11129393.7 |
| 14 | 160.9496 | 16.6028 | 314.4925 | 259.0173 | 273.9795 |
| 15 | 89.8336 | .1265 | -1.4114 | -7.1129 | -15.4072 |
| START YAW MANEUVER | | | | | |
| 1 | 1.9000 | 205.3166 | 1.8164 | 88.5130 | 236.7543 |
| 2 | 11.2023 | 1340.4789 | 40.923 | .4787 | 90.0055 |
| 3 | 205.3 | -3.3 | -3162540.600 | 1723.906 | -5659.176 |
| 4 | 2.4 | 7760.4 | 18111262.0 | .959 | -8.528 |
| 5 | -.2 | 23903.3 | 9960277.6 | .655 | .389 |
| 6 | 11.198 | 9.590 | -1322.172 | 186.9632 | -603.806 |
| 7 | .076 | 413.537 | -220.720 | .0601 | -.947 |
| 8 | -.280 | 1275.060 | 5.2222 | .0269 | -.073 |
| 9 | 8.783 | 27.676 | -34.1508 | -80.6042 | 28.6084 |
| 10 | .002 | 146.483 | 115.9181 | 526.9701 | .0023214 |
| 11 | -.146 | 29.807 | .0264 | 2114.4174 | 1.0312 |
| 12 | .0000 | 600190.9700 | .0000 | .8524 | 344.1896 |
| 13 | 205.2 | 54909.5 | 1036751.5 | 5186521.9 | 11129396.9 |
| 14 | 167.3974 | 16.6036 | 314.4924 | 259.0173 | 273.9795 |
| 15 | 89.3457 | .1385 | -1.4108 | -7.1127 | -15.4072 |
| START YAW MANEUVER | | | | | |
| 1 | 5.0000 | 278.5015 | 10.1728 | 87.8164 | 207.8672 |
| 2 | 39.2345 | 1340.5555 | 41.432 | 1.6761 | 90.0518 |
| 3 | 278.7 | 64.6 | -3166645.300 | 2362.321 | -7685.752 |
| 4 | 10.2 | 9049.8 | 18110614.0 | 3.496 | -11.739 |
| 5 | -3.9 | 27853.3 | 9960305.1 | -.043 | .044 |
| 6 | 39.206 | 37.332 | -1326.008 | 225.8549 | -703.662 |
| 7 | 1.041 | 414.379 | -196.172 | .3708 | -1.125 |
| 8 | -1.073 | 1274.357 | 17.6125 | -.1634 | -.152 |
| 9 | 9.291 | 28.070 | -13.6248 | -80.6042 | 28.6084 |
| 10 | .035 | 142.409 | 143.9750 | 527.0345 | .0023154 |
| 11 | -.372 | 48.541 | .0430 | 2109.0526 | 2.7279 |
| 12 | .0000 | 974824.8800 | .0000 | .8390 | 344.1968 |
| 13 | 278.7 | 54901.3 | 1036748.2 | 5186534.7 | 11129419.4 |
| 14 | 182.9297 | 16.6052 | 314.4921 | 259.0172 | 273.9795 |
| 15 | 87.7468 | .2151 | -1.4068 | -7.1119 | -15.4068 |

TABLE AP 3-2 (Sheet 3 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| STOP YAW MANEUVER | | | | | |
|--------------------------------|----------|--------------|--------------|-----------|------------|
| 1 | 9.8000 | 579.7837 | 46.3304 | 87.7315 | 207.3903 |
| 2 | 85.8435 | 1341.8853 | 42.304 | 3.6653 | 90.1187 |
| 3 | 579.9 | 355.9 | -3173034.600 | 3593.673 | -11434.400 |
| 4 | 46.0 | 11069.1 | 18109783.0 | 14.718 | -17.827 |
| 5 | -13.7 | 33965.9 | 9960416.6 | -2.013 | -1.049 |
| 6 | 85.776 | 83.492 | -1332.301 | 287.0503 | -858.274 |
| 7 | 2.386 | 415.545 | -155.420 | .8145 | -1.414 |
| 8 | -2.419 | 1273.188 | 38.4227 | -.4714 | -.311 |
| 9 | 10.164 | 39.013 | -12.1743 | -80.6042 | 28.6083 |
| 10 | .066 | 133.930 | 155.4622 | 527.2987 | .0022911 |
| 11 | -.374 | 94.623 | .0838 | 2087.2172 | 10.2566 |
| 12 | .0001 | 1879530.3000 | .0000 | .7839 | 344.2246 |
| 13 | 581.8 | 54869.0 | 1036729.1 | 5186582.6 | 11129506.7 |
| 14 | 178.6588 | 16.6179 | 314.4906 | 259.0168 | 273.9793 |
| 15 | 85.2678 | .5300 | -1.3901 | -7.1087 | -15.4053 |
| | | | | | |
| 1 | 10.0000 | 597.7240 | 48.2867 | 87.6995 | 206.1970 |
| 2 | 87.8661 | 1342.0236 | 42.350 | 3.7513 | 90.1248 |
| 3 | 597.8 | 373.3 | -3173301.800 | 3651.504 | -11606.699 |
| 4 | 47.9 | 11153.7 | 18109753.0 | 15.333 | -18.111 |
| 5 | -14.2 | 34220.6 | 9960423.5 | -2.095 | -1.112 |
| 6 | 87.795 | 85.494 | -1332.624 | 289.6240 | -864.716 |
| 7 | 2.529 | 415.681 | -153.625 | .8595 | -1.426 |
| 8 | -2.459 | 1273.157 | 39.2598 | -.4786 | -.319 |
| 9 | 10.210 | 39.128 | -12.0179 | -80.6042 | 28.6083 |
| 10 | .067 | 133.712 | 155.7761 | 527.3145 | .0022897 |
| 11 | -.339 | 96.545 | .0855 | 2085.9277 | 10.6709 |
| 12 | .0001 | 1916469.9000 | .0000 | .7807 | 344.2262 |
| 13 | 599.7 | 54867.5 | 1036728.2 | 5186583.3 | 11129511.9 |
| 14 | 178.5024 | 16.6186 | 314.4906 | 259.0168 | 273.9793 |
| 15 | 85.2300 | .5485 | -1.3891 | -7.1085 | -15.4052 |
| | | | | | |
| START PITCH AND ROLL MANEUVERS | | | | | |
| 1 | 11.0100 | 688.4146 | 61.2536 | 87.9138 | 207.3361 |
| 2 | 98.2897 | 1342.6667 | 42.581 | 4.1957 | 90.1241 |
| 3 | 688.3 | 461.4 | -3174652.100 | 3949.566 | -12496.491 |
| 4 | 61.0 | 11584.1 | 18109603.0 | 19.405 | -19.582 |
| 5 | -16.6 | 35506.6 | 9960455.4 | -2.549 | -1.454 |
| 6 | 98.225 | 95.836 | -1334.115 | 302.6923 | -897.248 |
| 7 | 2.515 | 415.632 | -144.684 | .8637 | -1.489 |
| 8 | -2.545 | 1273.114 | 44.2415 | -.4795 | -.358 |
| 9 | 10.442 | 39.476 | -11.1010 | -80.6042 | 28.6083 |
| 10 | .069 | 133.000 | 158.0676 | 527.3940 | .0022824 |
| 11 | -.172 | 106.210 | .0940 | 2079.4148 | 12.8734 |
| 12 | .0002 | 2101395.4000 | .0000 | .7641 | 344.2339 |
| 13 | 691.1 | 54856.4 | 1036720.1 | 5186599.2 | 11129537.5 |
| 14 | 177.2592 | 16.6243 | 314.4901 | 259.0166 | 273.9792 |
| 15 | 84.7518 | .6434 | -1.3841 | -7.1075 | -15.4048 |
| | | | | | |
| 1 | 15.0000 | 1165.8328 | 33.5763 | 88.9147 | 191.9210 |
| 2 | 141.8243 | 1347.6661 | 43.568 | 6.0400 | 90.0953 |
| 3 | 1165.8 | 928.7 | -3179969.200 | 5261.341 | -16332.903 |
| 4 | 23.6 | 13194.8 | 18109080.0 | 8.478 | -26.025 |
| 5 | -27.6 | 40585.8 | 9960711.9 | -4.514 | -3.223 |
| 6 | 141.799 | 139.068 | -1341.742 | 355.0406 | -1025.764 |
| 7 | 2.328 | 415.311 | -107.845 | .8433 | -1.743 |
| 8 | -1.340 | 1274.512 | 65.5887 | .0002 | -.534 |
| 9 | 11.425 | 39.770 | -6.5898 | -80.6042 | 28.6084 |
| 10 | -.270 | 137.787 | 163.8387 | 525.9172 | .0022508 |
| 11 | .679 | 147.639 | .1309 | 2044.8427 | 24.5303 |
| 12 | .0001 | 2886850.5000 | .0000 | .7906 | 343.7510 |
| 13 | 1166.3 | 54889.6 | 1036770.3 | 5186668.6 | 11129677.1 |
| 14 | 211.4033 | 16.5927 | 314.4906 | 259.0171 | 273.9794 |
| 15 | 88.2111 | 1.1413 | -1.3577 | -7.1022 | -15.4024 |
| | | | | | |
| 1 | 20.0000 | 2015.2902 | 33.5427 | 88.2522 | 65.4979 |
| 2 | 201.3768 | 1361.3462 | 44.844 | 8.5024 | 89.8675 |
| 3 | 2015.6 | 1763.8 | -3186704.500 | 7201.856 | -21864.318 |
| 4 | 28.7 | 15264.4 | 18108656.0 | 10.837 | -35.563 |
| 5 | -25.9 | 46967.5 | 9961114.9 | -1.526 | -6.534 |
| 6 | 201.283 | 198.108 | -1356.425 | 422.1200 | -1186.800 |
| 7 | -.695 | 412.130 | -60.417 | -.0253 | -2.075 |
| 8 | 6.102 | 1282.251 | 98.6146 | 2.4395 | -.799 |
| 9 | 12.640 | 39.203 | -3.7112 | -80.6042 | 28.6083 |
| 10 | -.576 | 142.574 | -10.3686 | 521.9185 | .0022004 |
| 11 | 2.429 | 205.333 | .1827 | 1984.1742 | 46.3865 |
| 12 | .0001 | 3948445.4000 | .0000 | .9012 | 342.4658 |
| 13 | 2015.8 | 54912.2 | 1036787.4 | 5186772.4 | 11129901.1 |
| 14 | 203.9888 | 16.5973 | 314.4905 | 259.0170 | 273.9794 |
| 15 | 88.9010 | 2.0278 | -1.3108 | -7.0929 | -15.3982 |

TABLE AP 3-2 (Sheet 4 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|--------------------|----------|--------------|--------------|-----------|------------|
| 1 | 25.0000 | 3187,3901 | 40,3526 | 84,9441 | 62,8328 |
| 2 | 269.1644 | 1388,1521 | 46,3999 | 11,1352 | 89,5126 |
| 3 | 3187.6 | 2918,8 | -3193338,300 | 9485,276 | -28200,878 |
| 4 | 18.8 | 17318,3 | 18108483,0 | 8,905 | -46,801 |
| 5 | 36.2 | 53411,3 | 9961701,0 | 20,809 | -11,291 |
| 6 | 268.117 | 264,465 | -1381,293 | 491,4248 | -1347,821 |
| 7 | -3.779 | 408,892 | -9,744 | -,9059 | -2,423 |
| 8 | 23.418 | 1299,936 | 137,8883 | 7,9255 | -1,112 |
| 9 | 14.038 | 37,850 | -1,8328 | -80,6040 | 28,6084 |
| 10 | -,517 | 148,864 | -7,7885 | 516,7385 | ,0021324 |
| 11 | 4.596 | 271,951 | ,2433 | 1902,7431 | 78,8535 |
| 12 | ,0001 | 5107285,2000 | ,0000 | ,9589 | 340,6704 |
| 13 | 3187.7 | 55012,6 | 1036798,5 | 5186856,4 | 11130153,7 |
| 14 | 99,3865 | 16,6447 | 314,4938 | 259,0171 | 273,9794 |
| 15 | 89,2659 | 3,2461 | -1,2460 | -7,0800 | -15,3923 |
| | | | | | |
| 1 | 30.0000 | 4710,3303 | 217,8133 | 81,2853 | 65,1723 |
| 2 | 345.1702 | 1429,9006 | 47,896 | 13,8018 | 89,0542 |
| 3 | 4710.6 | 4422,2 | -3200525,200 | 12120,279 | -35342,494 |
| 4 | -,5.0 | 19357,4 | 18108570,0 | 3,019 | -59,819 |
| 5 | 213.0 | 59971,7 | 9962498,0 | 79,239 | -17,740 |
| 6 | 341.185 | 337,007 | -1417,534 | 562,6082 | -1508,821 |
| 7 | -6.218 | 406,297 | 43,058 | -1,5859 | -2,787 |
| 8 | 51,931 | 1328,896 | 182,6462 | 16,8636 | -1,476 |
| 9 | 15,316 | 25,982 | -1,2561 | -80,6035 | 28,6086 |
| 10 | -,447 | 144,931 | -4,1078 | 521,6689 | ,0020084 |
| 11 | 6,570 | 346,785 | ,3095 | 1801,5315 | 120,7636 |
| 12 | ,0006 | 6088788,5000 | ,0000 | ,522 | 341,5679 |
| 13 | 4715.2 | 55243,7 | 1036778,5 | 5186870,3 | 11130390,5 |
| 14 | 70,6323 | 16,7819 | 314,5030 | 259,0173 | 273,9796 |
| 15 | 87,4094 | 4,8157 | -1,1618 | -7,0631 | -15,3845 |
| | | | | | |
| STOP ROLL MANEUVER | | | | | |
| 1 | 30.2000 | 4778,9596 | 227,9530 | 81,1398 | 65,2415 |
| 2 | 348,3831 | 1431,8664 | 47,962 | 13,9077 | 89,0336 |
| 3 | 4779.1 | 4489,9 | -3200808,300 | 12233,084 | -35644,902 |
| 4 | -,6.3 | 19438,6 | 18108579,0 | 2,694 | -60,378 |
| 5 | 223.0 | 60237,1 | 9962534,5 | 82,494 | -18,037 |
| 6 | 344,225 | 340,025 | -1419,204 | 565,4910 | -1515,260 |
| 7 | -,6.315 | 406,194 | 45,204 | -1,6131 | -2,802 |
| 8 | 53,290 | 1330,275 | 184,5522 | 17,2886 | -1,492 |
| 9 | 15,372 | 24,640 | -1,2014 | -80,6035 | 28,6086 |
| 10 | -,442 | 144,605 | -3,8538 | 522,1051 | ,0020022 |
| 11 | 6,654 | 349,895 | ,3121 | 1797,1188 | 122,5591 |
| 12 | ,0006 | 6120411,8000 | ,0000 | ,2255 | 341,6785 |
| 13 | 4784.2 | 55256,2 | 1036776,8 | 5186869,0 | 11130399,1 |
| 14 | 70,4025 | 16,7898 | 314,5035 | 259,0173 | 273,9796 |
| 15 | 87,3272 | 4,8860 | -1,1580 | -7,0623 | -15,3842 |
| | | | | | |
| 1 | 35.0000 | 6614,3062 | 564,9877 | 77,8481 | 67,2242 |
| 2 | 430,4680 | 1485,8959 | 49,474 | 16,4479 | 88,5418 |
| 3 | 6614.8 | 6304,1 | -3207718,100 | 15116,000 | -43289,044 |
| 4 | -,40.5 | 21384,1 | 18108927,0 | -,6,063 | -74,695 |
| 5 | 556.4 | 66701,2 | 9963532,4 | 189,778 | -26,135 |
| 6 | 420,820 | 416,056 | -1464,292 | 635,7673 | -1669,794 |
| 7 | -7,546 | 404,807 | 98,862 | -1,9245 | -3,166 |
| 8 | 90,312 | 1367,814 | 232,2989 | 28,8521 | -1,891 |
| 9 | 16,571 | 14,069 | -1,3436 | -80,6026 | 28,6090 |
| 10 | -,173 | 114,648 | -1,2638 | 517,0748 | ,0018879 |
| 11 | 8,779 | 432,681 | ,3873 | 1682,6462 | 176,7212 |
| 12 | ,0015 | 7190529,6000 | ,0000 | ,5993 | 340,4737 |
| 13 | 6638.1 | 55665,1 | 1036703,2 | 5186767,0 | 11130569,3 |
| 14 | 67,8341 | 17,0532 | 314,5206 | 259,0176 | 273,9799 |
| 15 | 85,1789 | 6,7486 | -1,0564 | -7,0417 | -15,3746 |
| | | | | | |
| 1 | 40.0000 | 8934,6454 | 1133,4366 | 74,3954 | 68,7740 |
| 2 | 526,5972 | 1558,9647 | 51,174 | 18,9802 | 87,9508 |
| 3 | 8935.0 | 8598,9 | -3215176,100 | 18482,858 | -52040,383 |
| 4 | -,79.2 | 23406,8 | 18109570,0 | -,15,819 | -91,506 |
| 5 | 1121.4 | 73655,3 | 9964828,6 | 369,450 | -36,733 |
| 6 | 507,180 | 501,749 | -1524,109 | 710,9410 | -1830,735 |
| 7 | -7,977 | 404,200 | 156,799 | -1,9893 | -3,561 |
| 8 | 141,455 | 1419,592 | 287,8842 | 44,7765 | -2,358 |
| 9 | 17,778 | 10,607 | ,5060 | -80,6009 | 28,6096 |
| 10 | -,083 | 189,191 | -1,0281 | 512,3436 | ,0017578 |
| 11 | 11,404 | 525,230 | ,4732 | 1546,8794 | 242,4642 |
| 12 | ,0031 | 8185550,6000 | ,0000 | ,1421 | 338,3121 |
| 13 | 9005.3 | 56344,7 | 1036542,5 | 5186496,6 | 11130646,3 |
| 14 | 67,9571 | 17,5063 | 314,5491 | 259,0179 | 273,9803 |
| 15 | 82,8283 | 9,0478 | -,9278 | -7,0155 | -15,3623 |

TABLE AP 3-2 (Sheet 5 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|--------|-----------|---------------|--------------|-----------|------------|
| 1 | 45.0000 | 11702.4139 | 1993.2403 | 70.9241 | 69.7341 |
| 2 | 634.2338 | 1630.2335 | 53.099 | 21.2915 | 87.2606 |
| 3 | 11702.7 | 11337.6 | -3222968.700 | 22230.267 | -61596.331 |
| 4 | -120.3 | 25426.0 | 18110305.0 | -25.980 | -110.330 |
| 5 | 1978.4 | 80904.8 | 9966420.6 | 639.894 | -49.801 |
| 6 | 599.405 | 593.202 | -1598.245 | 787.8588 | -1991.637 |
| 7 | -8.209 | 403.765 | 215.264 | -1.9969 | -3.971 |
| 8 | 207.181 | 1486.054 | 350.0678 | 65.1930 | -2.879 |
| 9 | 18.964 | 2.757 | .1304 | -80.5984 | 28.6104 |
| 10 | .000 | 308.594 | -1.6401 | 500.2997 | .0016247 |
| 11 | 14.560 | 633.798 | .5776 | 1397.1695 | 326.3275 |
| 12 | .0055 | 9301096.5000 | .0000 | .3568 | 334.4356 |
| 13 | 11869.2 | 57376.8 | 1036266.3 | 5185994.2 | 11130562.4 |
| 14 | 68.5186 | 18.1930 | 314.5919 | 259.0182 | 273.9808 |
| 15 | 80.3871 | 11.6914 | -.7742 | -6.9840 | -15.3474 |
| | | | | | |
| 1 | 50.0000 | 14946.4124 | 3219.3185 | 67.5514 | 70.4582 |
| 2 | 754.7344 | 1760.1701 | 55.126 | 23.3369 | 86.5107 |
| 3 | 14946.4 | 14548.1 | -3231170.200 | 26366.653 | -71956.673 |
| 4 | -160.3 | 27445.4 | 18111735.0 | -33.493 | -131.243 |
| 5 | 3202.4 | 88525.2 | 9968339.0 | 1024.253 | -63.618 |
| 6 | 697.498 | 690.397 | -1687.525 | 866.5124 | -2152.492 |
| 7 | -7.782 | 403.952 | 274.198 | -1.8102 | -4.397 |
| 8 | 288.201 | 1567.921 | 418.6602 | 90.3221 | -3.457 |
| 9 | 20.066 | 5.414 | .0595 | -80.5948 | 28.6116 |
| 10 | .061 | 333.230 | -1.5506 | 486.4273 | .0014789 |
| 11 | 17.856 | 754.506 | .6976 | 1235.8408 | 420.9454 |
| 12 | .0088 | 10304155.5000 | .0000 | .3911 | 329.6817 |
| 13 | 15286.4 | 58867.3 | 1035841.1 | 5185189.7 | 11130253.8 |
| 14 | 69.1341 | 19.1624 | 314.6524 | 259.0184 | 273.9815 |
| 15 | 77.8921 | 14.6303 | -.5938 | -6.9467 | -15.3296 |
| | | | | | |
| 1 | 55.0000 | 18696.0310 | 4893.0071 | 64.2185 | 70.7453 |
| 2 | 889.4163 | 1889.8537 | 57.257 | 25.0614 | 85.6508 |
| 3 | 18695.8 | 18259.5 | -3239859.200 | 30900.826 | -83121.159 |
| 4 | -200.4 | 29463.2 | 18113256.0 | -44.779 | -154.322 |
| 5 | 4874.7 | 96598.5 | 9970621.2 | 1547.570 | -84.474 |
| 6 | 800.793 | 792.641 | -1793.347 | 946.6885 | -2313.293 |
| 7 | -8.524 | 402.917 | 331.524 | -1.9912 | -4.838 |
| 8 | 386.935 | 1667.611 | 495.5256 | 120.9023 | -4.095 |
| 9 | 20.989 | 17.558 | 1.0126 | -80.5899 | 28.6131 |
| 10 | .125 | 242.788 | -.8963 | 473.6992 | .0013131 |
| 11 | 21.505 | 881.976 | .8265 | 1068.0469 | 510.7034 |
| 12 | .0134 | 10921820.4000 | .0000 | .3567 | 325.2606 |
| 13 | 19321.7 | 60938.9 | 1035236.3 | 5184007.1 | 11129650.0 |
| 14 | 69.6443 | 20.4536 | 314.7349 | 259.0184 | 273.9823 |
| 15 | 75.3742 | 17.7870 | -.3848 | -6.9033 | -15.3088 |
| | | | | | |
| 1 | 60.0000 | 22972.4240 | 7106.0755 | 60.9198 | 70.9732 |
| 2 | 1038.5323 | 2039.7182 | 59.167 | 26.4068 | 84.7516 |
| 3 | 22971.5 | 22491.5 | -3249121.500 | 35838.674 | -95089.498 |
| 4 | -244.0 | 31476.0 | 18115059.0 | -54.939 | -179.644 |
| 5 | 7087.3 | 105217.2 | 9973304.9 | 2238.133 | -106.678 |
| 6 | 907.444 | 898.057 | -1917.379 | 1027.8127 | -2474.032 |
| 7 | -9.144 | 401.936 | 385.633 | -2.1512 | -5.294 |
| 8 | 504.986 | 1786.727 | 579.1352 | 157.4227 | -4.797 |
| 9 | 21.624 | 19.389 | .9322 | -80.5834 | 28.6151 |
| 10 | .192 | 260.916 | -1.1758 | 458.0027 | .0011449 |
| 11 | 24.870 | 1029.383 | .9813 | 899.9074 | 606.5891 |
| 12 | .0195 | 11418278.7000 | .0000 | .1597 | 319.7367 |
| 13 | 24041.0 | 63724.5 | 1034419.7 | 5182359.4 | 11128669.5 |
| 14 | 70.0279 | 22.0958 | 314.8439 | 259.0184 | 273.9832 |
| 15 | 72.8439 | 21.0492 | -.1457 | -6.8533 | -15.2845 |
| | | | | | |
| MACH 1 | | | | | |
| 1 | 60.5050 | 23434.6810 | 7363.8911 | 60.6146 | 71.0001 |
| 2 | 1054.4861 | 2055.7883 | 59.361 | 26.5327 | 84.6642 |
| 3 | 23433.6 | 22948.8 | -3250093.200 | 36360.122 | -96342.983 |
| 4 | -248.1 | 31679.5 | 18115256.0 | -55.859 | -182.330 |
| 5 | 7345.2 | 106122.3 | 9973599.5 | 2318.517 | -109.120 |
| 6 | 918.633 | 909.111 | -1930.685 | 1036.1291 | -2490.263 |
| 7 | -9.133 | 401.907 | 391.244 | -2.1458 | -5.341 |
| 8 | 517.659 | 1799.515 | 587.9219 | 161.3433 | -4.872 |
| 9 | 21.683 | 15.079 | .7181 | -80.5827 | 28.6153 |
| 10 | .199 | 250.875 | -.9769 | 456.1771 | .0011280 |
| 11 | 25.204 | 1047.161 | 1.0003 | 883.0795 | 618.4738 |
| 12 | .0202 | 11481140.6000 | .0000 | .1471 | 319.0924 |
| 13 | 24558.9 | 64050.8 | 1034323.4 | 5182163.1 | 11128545.6 |
| 14 | 70.0656 | 22.2826 | 314.8566 | 259.0184 | 273.9834 |
| 15 | 72.5872 | 21.3798 | -.1199 | -6.8478 | -15.2819 |

TABLE AP 3-2 (Sheet 6 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|-----------|---------------|--------------|-----------|-------------|
| 1 | 65.0000 | 27789.0820 | 9948.7718 | 57.8853 | 71.3179 |
| 2 | 1200.6319 | 2206.0397 | 61.503 | 27.4327 | 83.9221 |
| 3 | 27786.8 | 27256.4 | -3259044.100 | 41183.882 | -107861.359 |
| 4 | -286.8 | 33487.6 | 18117126.0 | -64.751 | -207.285 |
| 5 | 9931.2 | 114472.7 | 9976417.5 | 3123.951 | -132.559 |
| 6 | 1016.615 | 1005.800 | -2056.891 | 1109.6247 | -2634.701 |
| 7 | -7.767 | 402.877 | 437.651 | -1.7207 | -5.765 |
| 8 | 638.710 | 1921.632 | 666.5374 | 198.7763 | -5.567 |
| 9 | 22.451 | 20.600 | .6795 | -80.5750 | 28.6176 |
| 10 | .259 | 288.193 | -1.3443 | 437.7597 | .0009803 |
| 11 | 28.504 | 1192.032 | 1.1624 | 736.3311 | 696.4651 |
| 12 | .0273 | 11742336.2000 | .0000 | .0976 | 312.5639 |
| 13 | 29509.5 | 67347.4 | 1033355.1 | 5180159.6 | 11127228.7 |
| 14 | 70.3462 | 24.0992 | 314.9839 | 259.0183 | 273.9844 |
| 15 | 70.3251 | 24.2855 | .1244 | -6.7964 | -15.2567 |

| | | | | | |
|----|-----------|---------------|--------------|-----------|-------------|
| 1 | 70.0000 | 33162.6500 | 13503.2101 | 55.0582 | 71.5725 |
| 2 | 1380.1774 | 2391.9372 | 64.207 | 28.2098 | 83.1046 |
| 3 | 33158.6 | 32570.1 | -3269708.000 | 46941.166 | -121436.375 |
| 4 | -321.5 | 35504.9 | 18119448.0 | -72.109 | -237.320 |
| 5 | 13489.5 | 124448.9 | 9979983.7 | 4230.622 | -162.470 |
| 6 | 1130.870 | 1118.403 | -2214.399 | 1192.8938 | -2795.291 |
| 7 | -6.177 | 403.944 | 488.106 | -1.2471 | -6.251 |
| 8 | 791.191 | 2075.420 | 761.2841 | 245.9080 | -6.410 |
| 9 | 23.526 | 30.936 | 1.0307 | -80.5646 | 28.6207 |
| 10 | .319 | 267.000 | -.8875 | 413.9691 | .0008192 |
| 11 | 32.186 | 1363.338 | 1.3672 | 581.8676 | 761.3281 |
| 12 | .0370 | 11748450.4000 | .0000 | .1500 | 303.9439 |
| 13 | 35798.7 | 71919.3 | 1032010.3 | 5177329.4 | 11125253.0 |
| 14 | 70.6344 | 26.4448 | 315.1590 | 259.0179 | 273.9858 |
| 15 | 67.8568 | 27.3712 | .4270 | -6.7324 | -15.2251 |

| | | | | | |
|----|-----------|---------------|--------------|-----------|-------------|
| 1 | 75.0000 | 39123.7740 | 17868.5680 | 52.3809 | 71.7822 |
| 2 | 1579.1306 | 2599.3143 | 67.530 | 28.7428 | 82.3125 |
| 3 | 39116.3 | 38460.9 | -3281209.400 | 53119.026 | -135814.130 |
| 4 | -348.0 | 37527.5 | 18122017.0 | -77.088 | -269.824 |
| 5 | 17862.2 | 135246.3 | 9984044.5 | 5588.964 | -196.789 |
| 6 | 1249.985 | 1235.601 | -2392.282 | 1277.5372 | -2955.794 |
| 7 | -4.108 | 405.382 | 536.082 | -.6560 | -6.753 |
| 8 | 964.973 | 2250.643 | 863.7366 | 299.5966 | -7.331 |
| 9 | 24.138 | 69.029 | 2.0340 | -80.5516 | 28.6245 |
| 10 | .425 | 254.999 | -.4890 | 388.4236 | .0006615 |
| 11 | 37.505 | 1537.994 | 1.5923 | 440.8581 | 782.4078 |
| 12 | .0490 | 11285035.2000 | .0000 | .1870 | 294.4093 |
| 13 | 43003.1 | 77564.2 | 1030355.4 | 5173775.9 | 11122655.4 |
| 14 | 70.8838 | 29.0947 | 315.3744 | 259.0172 | 273.9875 |
| 15 | 65.4524 | 30.2001 | .7643 | -6.6506 | -15.1895 |

MAXIMUM DYNAMIC PRESSURE

| | | | | | |
|----|-----------|---------------|--------------|-----------|-------------|
| 1 | 75.2430 | 39428.8810 | 18103.3950 | 52.2490 | 71.7888 |
| 2 | 1589.3845 | 2610.0664 | 67.733 | 28.7605 | 82.2730 |
| 3 | 39421.5 | 38762.6 | -3281791.700 | 53430.198 | -136533.330 |
| 4 | -348.9 | 37626.1 | 18122149.0 | -77.209 | -271.468 |
| 5 | 18097.5 | 135794.0 | 9984255.2 | 5662.019 | -198.576 |
| 6 | 1255.853 | 1241.368 | -2401.589 | 1281.6717 | -2963.592 |
| 7 | -4.042 | 405.414 | 538.235 | -.6387 | -6.778 |
| 8 | 974.145 | 2259.888 | 868.9793 | 302.4289 | -7.378 |
| 9 | 24.163 | 67.664 | 1.9777 | -80.5510 | 28.6247 |
| 10 | .431 | 251.000 | -.3052 | 387.1465 | .0006540 |
| 11 | 37.830 | 1548.836 | 1.6061 | 434.4215 | 784.4783 |
| 12 | .0496 | 11266792.9000 | .0000 | .1762 | 293.9245 |
| 13 | 43378.3 | 77868.1 | 1030266.3 | 5173582.9 | 11122511.8 |
| 14 | 70.8954 | 29.2305 | 315.3861 | 259.0171 | 273.9876 |
| 15 | 65.3371 | 30.3293 | .7816 | -6.6569 | -15.1877 |

| | | | | | |
|----|-----------|--------------|--------------|-----------|-------------|
| 1 | 80.0000 | 45689.7640 | 23172.0630 | 49.6128 | 71.9483 |
| 2 | 1801.9943 | 2834.4722 | 71.187 | 28.9387 | 81.5229 |
| 3 | 45677.4 | 44944.6 | -3293669.100 | 59722.129 | -150994.160 |
| 4 | -363.8 | 39557.3 | 18124811.0 | -79.084 | -304.674 |
| 5 | 23177.8 | 146994.1 | 9988641.0 | 7238.474 | -235.926 |
| 6 | 1371.258 | 1354.613 | -2598.285 | 1362.7039 | -3116.200 |
| 7 | -1.744 | 406.957 | 576.289 | -.0184 | -7.270 |
| 8 | 1169.116 | 2456.348 | 975.2125 | 362.6025 | -8.338 |
| 9 | 24.211 | 83.143 | 2.0593 | -80.5360 | 28.6290 |
| 10 | .552 | 259.000 | -.5206 | 375.5370 | .0004957 |
| 11 | 43.662 | 1749.653 | 1.8422 | 319.3946 | 758.7882 |
| 12 | .0635 | 9897887.5000 | .0000 | .0000 | 289.4806 |
| 13 | 51222.6 | 84408.4 | 1028349.4 | 5169376.6 | 11119318.9 |
| 14 | 71.1008 | 32.0006 | 315.6369 | 259.0162 | 273.9894 |
| 15 | 63.0927 | 32.6747 | 1.1379 | -6.5808 | -15.1496 |

TABLE AP 3-2 (Sheet 7 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|-----------|--------------|--------------|-----------|-------------|
| 1 | 85.0000 | 52860,3350 | 29568,3020 | 46,7673 | 72,0932 |
| 2 | 2048,3097 | 3096,6103 | 75,545 | 28,7859 | 80,7643 |
| 3 | 52839,7 | 52017,2 | -3307229,700 | 66749,118 | -166975,950 |
| 4 | -367,1 | 41595,2 | 18127775,0 | -77,825 | -342,545 |
| 5 | 29592,7 | 159849,3 | 9993813,1 | 9227,085 | -280,327 |
| 6 | 1490,374 | 1471,077 | -2833,208 | 1447,0617 | -3276,501 |
| 7 | 1,234 | 408,953 | 604,616 | ,7520 | -7,801 |
| 8 | 1405,118 | 2694,010 | 1093,7866 | 435,3770 | -9,438 |
| 9 | 23,509 | 63,018 | 1,0545 | -80,5170 | 28,6345 |
| 10 | ,711 | 288,603 | -1,1070 | 371,2888 | ,0003505 |
| 11 | 51,225 | 2014,345 | 2,1331 | 223,2801 | 711,1321 |
| 12 | ,0810 | 8135418,3000 | ,0000 | ,0000 | 287,8376 |
| 13 | 60563,0 | 92577,2 | 1025943,9 | 5163979,5 | 11115092,9 |
| 14 | 71,2894 | 35,0994 | 315,9547 | 259,0148 | 273,9916 |
| 15 | 60,7473 | 34,7149 | 1,5486 | -6,4926 | -15,1052 |
| | | | | | |
| 1 | 90.0000 | 60619,3150 | 37224,3290 | 43,8563 | 72,1840 |
| 2 | 2319,7543 | 3386,5947 | 79,508 | 28,3049 | 80,0284 |
| 3 | 60586,7 | 59660,2 | -3322045,200 | 74194,172 | -183758,970 |
| 4 | -351,7 | 43646,3 | 18130845,0 | -71,724 | -382,911 |
| 5 | 37275,9 | 173981,4 | 9999593,7 | 11606,659 | -330,478 |
| 6 | 1604,274 | 1581,878 | -3098,524 | 1529,6585 | -3436,687 |
| 7 | 3,807 | 410,312 | 617,156 | 1,3329 | -8,348 |
| 8 | 1675,575 | 2966,198 | 1219,5480 | 518,7064 | -10,640 |
| 9 | 22,300 | 7,263 | ,0305 | -80,4943 | 28,6409 |
| 10 | -,152 | 328,377 | -,1288 | 368,0797 | ,0002387 |
| 11 | 58,063 | 2318,523 | 2,4658 | 150,7507 | 641,6328 |
| 12 | ,1020 | 6424564,5000 | ,0000 | ,0000 | 286,5904 |
| 13 | 71136,1 | 102187,1 | 1023086,5 | 5157418,3 | 11109813,6 |
| 14 | 71,4594 | 38,3118 | 316,3371 | 259,0129 | 273,9942 |
| 15 | 58,3969 | 36,2732 | 1,9967 | -6,3958 | -15,0560 |
| | | | | | |
| 1 | 95.0000 | 68943,2320 | 46308,2870 | 41,0051 | 72,1323 |
| 2 | 2619,4485 | 3705,2339 | 83,617 | 27,6062 | 79,2694 |
| 3 | 68892,2 | 67845,0 | -3338259,600 | 82048,390 | -201342,610 |
| 4 | -335,8 | 45691,2 | 18133935,0 | -66,678 | -426,049 |
| 5 | 46398,0 | 189561,1 | 10006031,7 | 14429,383 | -386,911 |
| 6 | 1714,318 | 1688,345 | -3393,061 | 1610,8964 | -3596,748 |
| 7 | 2,273 | 407,308 | 613,565 | ,5885 | -8,910 |
| 8 | 1980,561 | 3272,973 | 1356,2595 | 612,6116 | -11,953 |
| 9 | 21,618 | 6,807 | ,0869 | -80,4674 | 28,6485 |
| 10 | -,407 | 279,640 | -,1434 | 381,6109 | ,0001521 |
| 11 | 64,146 | 2614,911 | 2,7313 | 99,6052 | 520,1317 |
| 12 | ,1269 | 4478616,0000 | ,0000 | ,0000 | 291,8135 |
| 13 | 83060,2 | 113357,2 | 1019754,2 | 5149524,1 | 11103313,3 |
| 14 | 71,5852 | 41,5312 | 316,7942 | 259,0107 | 273,9972 |
| 15 | 56,0395 | 37,3358 | 2,4818 | -6,2904 | -15,0020 |
| | | | | | |
| 1 | 100.0000 | 77816,9420 | 56982,5110 | 38,3475 | 72,1117 |
| 2 | 2946,6365 | 4050,6436 | 87,701 | 26,7974 | 78,5950 |
| 3 | 77739,5 | 76552,5 | -3356017,700 | 90305,770 | -219726,230 |
| 4 | -326,9 | 47721,1 | 18136974,0 | -65,311 | -472,033 |
| 5 | 57124,3 | 206754,1 | 10013169,9 | 17745,934 | -450,214 |
| 6 | 1821,890 | 1791,839 | -3714,985 | 1691,1878 | -3756,678 |
| 7 | 1,219 | 404,523 | 598,115 | -,0848 | -9,486 |
| 8 | 2315,898 | 3610,179 | 1499,6210 | 715,8298 | -13,390 |
| 9 | 21,800 | 12,292 | -,1476 | -80,4357 | 28,6575 |
| 10 | -,131 | 70,669 | -,1646 | 393,5225 | ,0000967 |
| 11 | 69,250 | 2956,291 | 3,0407 | 65,2616 | 422,3897 |
| 12 | ,1561 | 3135067,0000 | ,0000 | ,0000 | 296,3350 |
| 13 | 96471,3 | 126203,7 | 1015928,2 | 5140135,4 | 11095431,6 |
| 14 | 71,6721 | 44,6600 | 317,3362 | 259,0082 | 274,0009 |
| 15 | 53,6905 | 37,9320 | 3,0044 | -6,1762 | -14,9430 |
| | | | | | |
| 1 | 105.0000 | 87248,1410 | 69380,7240 | 36,0306 | 72,1209 |
| 2 | 3301,8072 | 4421,6111 | 92,487 | 26,0225 | 78,0130 |
| 3 | 87133,0 | 85784,5 | -3375446,200 | 98966,632 | -238909,160 |
| 4 | -321,4 | 49738,2 | 18139922,0 | -66,955 | -520,938 |
| 5 | 69591,9 | 225698,1 | 10021045,1 | 21598,502 | -521,032 |
| 6 | 1933,330 | 1898,701 | -4060,886 | 1772,4629 | -3916,467 |
| 7 | 1,016 | 402,342 | 577,967 | -,5692 | -10,078 |
| 8 | 2676,596 | 3972,871 | 1651,0040 | 826,8575 | -14,961 |
| 9 | 22,808 | 24,937 | -,1565 | -80,3989 | 28,6680 |
| 10 | ,005 | 124,574 | -,3412 | 409,3605 | ,0000601 |
| 11 | 74,493 | 3314,143 | 3,3422 | 42,1834 | 329,8386 |
| 12 | ,1901 | 2113288,4000 | ,0000 | ,0000 | 302,2425 |
| 13 | 111513,6 | 140836,2 | 1011407,8 | 5129120,9 | 11086040,9 |
| 14 | 71,7353 | 47,6168 | 317,9722 | 259,0054 | 274,0051 |
| 15 | 51,3858 | 38,1282 | 3,5662 | -6,0528 | -14,8787 |

TABLE AP 3-2 (Sheet 8 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|-----------|--------------|--------------|------------|-------------|
| 1 | 110.0000 | 97262.8410 | 83629.3350 | 34.0016 | 72.1379 |
| 2 | 3686.7237 | 4820.2279 | 97.760 | 25.2878 | 77.5007 |
| 3 | 97095.5 | 95561.4 | -3396668.400 | 108036.980 | -258890.650 |
| 4 | -316.4 | 51744.4 | 18142757.0 | -71.028 | -572.834 |
| 5 | 83931.5 | 246524.4 | 10029700.8 | 26027.262 | -600.076 |
| 6 | 2049.457 | 2009.704 | -4432.376 | 1854.9547 | -4076.106 |
| 7 | .991 | 400.070 | 552.917 | -1.0771 | -10.683 |
| 8 | 3064.581 | 4362.985 | 1811.8855 | 946.2887 | -16.682 |
| 9 | 23.422 | 6.331 | -.0350 | 80.3567 | 28.6800 |
| 10 | .062 | 123.153 | -.1570 | 417.6503 | .0000376 |
| 11 | 80.523 | 3690.024 | 3.6841 | 26.9544 | 256.0911 |
| 12 | .2292 | 1449472.2000 | .0000 | .0000 | 305.2889 |
| 13 | 128343.7 | 157376.8 | 1006813.2 | 5116361.0 | 11075025.9 |
| 14 | 71.7839 | 50.3463 | 318.7114 | 259.0021 | 274.0101 |
| 15 | 49.1589 | 38.0026 | 4.1701 | -5.9196 | -14.8088 |
| | | | | | |
| 1 | 115.0000 | 107880.3270 | 99868.6500 | 32.1481 | 72.1668 |
| 2 | 4102.4476 | 5248.5687 | 103.432 | 24.5409 | 77.0512 |
| 3 | 107641.6 | 105894.6 | -3419818.900 | 117520.085 | -279669.960 |
| 4 | -310.5 | 53739.5 | 18145444.0 | -77.544 | -627.796 |
| 5 | 100287.8 | 269378.3 | 10039182.3 | 31076.825 | -688.124 |
| 6 | 2166.372 | 2120.882 | -4832.553 | 1937.4514 | -4235.586 |
| 7 | 1.474 | 397.990 | 318.439 | -1.5220 | -11.304 |
| 8 | 3483.807 | 4784.448 | 1981.1953 | 1075.3248 | -18.566 |
| 9 | 23.245 | 9.770 | .0278 | 80.3085 | 28.6937 |
| 10 | -.025 | 185.402 | -.1256 | 426.1803 | .0000230 |
| 11 | 87.416 | 4099.180 | 4.0514 | 16.7919 | 192.9371 |
| 12 | .2737 | 966846.1300 | .0000 | .0000 | 308.3922 |
| 13 | 147120.5 | 175958.7 | 1001578.5 | 5101720.1 | 11062255.5 |
| 14 | 71.8226 | 52.8218 | 319.5645 | 258.9983 | 274.0157 |
| 15 | 47.0254 | 37.6238 | 4.8186 | -5.7758 | -14.7330 |
| | | | | | |
| 1 | 120.0000 | 119104.0680 | 118262.2450 | 30.4100 | 72.1765 |
| 2 | 4551.6505 | 5709.6002 | 109.452 | 23.7617 | 76.6341 |
| 3 | 118768.9 | 116778.7 | -3445049.900 | 127414.000 | -301246.230 |
| 4 | -304.7 | 55720.7 | 18147925.0 | -87.343 | -685.893 |
| 5 | 118829.9 | 294429.5 | 10049535.0 | 36799.083 | -786.031 |
| 6 | 2281.775 | 2229.870 | -5264.048 | 2019.2294 | -4394.899 |
| 7 | .537 | 394.127 | 470.439 | -2.5062 | -11.938 |
| 8 | 3938.404 | 5241.363 | 2160.5629 | 1215.2210 | -20.628 |
| 9 | 23.050 | 38.405 | .2236 | 80.2539 | 28.7092 |
| 10 | -.234 | 228.350 | -.1976 | 436.3288 | .0000144 |
| 11 | 94.553 | 4521.379 | 4.4164 | 10.7998 | 147.4524 |
| 12 | .3241 | 657173.8700 | .0000 | .0000 | 312.0442 |
| 13 | 168007.9 | 196727.8 | 995951.5 | 5085037.6 | 11047571.2 |
| 14 | 71.8530 | 55.0380 | 320.5444 | 258.9941 | 274.0221 |
| 15 | 44.9852 | 37.0453 | 5.5131 | -5.6211 | -14.6509 |
| | | | | | |
| 1 | 125.0000 | 130935.1030 | 138980.6200 | 28.7982 | 72.1897 |
| 2 | 5037.7882 | 6206.6806 | 115.970 | 22.9789 | 76.2609 |
| 3 | 130472.1 | 128204.8 | -3472518.800 | 137715.780 | -323618.640 |
| 4 | -305.0 | 57680.3 | 18150136.0 | -102.758 | -747.197 |
| 5 | 139734.4 | 321854.8 | 10060809.4 | 43248.267 | -894.727 |
| 6 | 2397.496 | 2338.428 | -5729.718 | 2100.8226 | -4554.034 |
| 7 | -.659 | 389.610 | 410.157 | -3.6856 | -12.586 |
| 8 | 4430.725 | 5736.101 | 2350.5321 | 1366.7049 | -22.885 |
| 9 | 23.223 | 29.425 | .0510 | 80.1924 | 28.7266 |
| 10 | -.234 | 324.624 | -.6828 | 452.0599 | .0000086 |
| 11 | 101.909 | 5030.119 | 4.8271 | 6.6520 | 108.4957 |
| 12 | .3808 | 422357.9200 | .0000 | .0000 | 317.6220 |
| 13 | 191177.1 | 219841.0 | 990008.7 | 5066146.0 | 11030808.4 |
| 14 | 71.8749 | 57.0020 | 321.6651 | 258.9893 | 274.0294 |
| 15 | 43.0366 | 36.3132 | 6.2551 | -5.4548 | -14.5624 |
| | | | | | |
| 1 | 130.0000 | 143387.7300 | 162220.0900 | 27.3141 | 72.2067 |
| 2 | 5563.7190 | 6742.6161 | 123.889 | 22.2103 | 75.9279 |
| 3 | 142756.2 | 140173.9 | -3502410.700 | 148425.470 | -346786.270 |
| 4 | -312.0 | 59615.4 | 18152012.0 | -124.626 | -811.774 |
| 5 | 163204.6 | 351858.2 | 10073063.7 | 50486.863 | -1015.232 |
| 6 | 2514.653 | 2447.611 | -6231.753 | 2182.5488 | -4712.983 |
| 7 | -2.130 | 384.385 | 337.791 | -5.0764 | -13.247 |
| 8 | 4963.012 | 6270.912 | 2552.2619 | 1530.4679 | -25.354 |
| 9 | 23.847 | 37.866 | .1405 | 80.1234 | 28.7461 |
| 10 | -.286 | 291.263 | -.6673 | 475.4911 | .0000050 |
| 11 | 110.491 | 5537.812 | 5.1816 | 4.0678 | 76.4530 |
| 12 | .4445 | 259617.9600 | .0000 | .0000 | 325.7532 |
| 13 | 216829.7 | 245486.3 | 983848.5 | 5046853.5 | 11011779.3 |
| 14 | 71.8904 | 58.7322 | 322.9431 | 258.9840 | 274.0376 |
| 15 | 41.1763 | 35.4668 | 7.0463 | -5.2763 | -14.4669 |

TABLE AP 3-2 (Sheet 9 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|---|-----------|-------------|--------------|------------|-------------|
| 1 | 135.0000 | 156486.4100 | 188176.1600 | 25.9615 | 72.2285 |
| 2 | 6134.9688 | 7322.8765 | 132.843 | 21.4757 | 75.6312 |
| 3 | 155635.8 | 152696.6 | -3534912.200 | 159545.940 | -370748.150 |
| 4 | -326.7 | 61523.0 | 18153498.0 | -153.865 | -879.693 |
| 5 | 189444.3 | 384643.9 | 10086360.9 | 38577.470 | -1148.656 |
| 6 | 2636.025 | 2560.106 | -6774.694 | 2265.2248 | -4871.735 |
| 7 | -3.850 | 378.438 | 254.260 | -6.6833 | -13.922 |
| 8 | 5539.783 | 6850.341 | 2768.2858 | 1707.9016 | -28.056 |
| 9 | 24.735 | 103.605 | .4291 | -80.0463 | 28.7679 |
| 10 | -.505 | 252.947 | -.4862 | 493.6024 | .0000029 |
| 11 | 119.989 | 6042.016 | 5.5487 | 2.4745 | 53.3308 |
| 12 | .5156 | 161149.4100 | .0000 | .0000 | 331.9015 |
| 13 | 245176.9 | 273862.5 | 977612.8 | 5020971.3 | 10990300.0 |
| 14 | 71.9011 | 60.2498 | 324.3957 | 258.9781 | 274.0468 |
| 15 | 39.4044 | 34.5410 | 7.8885 | -5.0845 | -14.3640 |
| | | | | | |
| 1 | 140.0000 | 170269.2100 | 217080.1700 | 24.7261 | 72.2471 |
| 2 | 6757.2790 | 7953.2786 | 143.430 | 20.7762 | 75.3602 |
| 3 | 169136.1 | 165792.9 | -3570244.100 | 171083.080 | -395503.270 |
| 4 | -352.7 | 63396.7 | 18154536.0 | -192.383 | -951.019 |
| 5 | 218694.3 | 420453.8 | 10100781.0 | 67594.104 | -1296.211 |
| 6 | 2762.683 | 2676.876 | -7363.497 | 2349.1409 | -5030.279 |
| 7 | -6.734 | 370.794 | 158.259 | -8.8036 | -14.610 |
| 8 | 6166.714 | 7480.074 | 3001.4201 | 1900.7444 | -31.010 |
| 9 | 25.823 | .000 | .0000 | -79.9604 | 28.7922 |
| 10 | -.658 | .000 | -.5443 | 481.5559 | .0000017 |
| 11 | 131.088 | 6757.279 | 6.2827 | 1.4191 | 39.2093 |
| 12 | .5948 | 108025.5330 | .0000 | .0000 | 327.8248 |
| 13 | 276467.5 | 305209.5 | 971488.5 | 4994276.6 | 10966155.2 |
| 14 | 71.9075 | 61.5780 | 326.0432 | 258.9716 | 274.0572 |
| 15 | 37.7180 | 33.5628 | 8.7835 | -4.8783 | -14.2532 |
| | | | | | |
| STOP PITCH MANEUVER | | | | | |
| 1 | 140.9000 | 172825.7600 | 222614.3600 | 24.5134 | 72.2506 |
| 2 | 6875.4384 | 8072.8221 | 145.442 | 20.6526 | 75.3142 |
| 3 | 171633.9 | 168212.7 | -3576922.100 | 173204.430 | -400043.350 |
| 4 | -358.7 | 63730.0 | 18154671.0 | -200.412 | -964.224 |
| 5 | 224298.2 | 427239.9 | 10103502.3 | 69321.349 | -1324.371 |
| 6 | 2786.012 | 2698.305 | -7475.074 | 2364.3639 | -5058.795 |
| 7 | -7.347 | 369.261 | 139.383 | -9.2328 | -14.735 |
| 8 | 6285.677 | 7599.557 | 3045.3758 | 1937.3336 | -31.570 |
| 9 | 26.150 | .000 | .0000 | -79.9440 | 28.7968 |
| 10 | -.674 | .000 | -.5574 | 478.5488 | .0000016 |
| 11 | 133.135 | 6875.438 | 6.4126 | 1.2821 | 36.9038 |
| 12 | .6100 | 100423.9860 | .0000 | .0000 | 326.7993 |
| 13 | 282432.3 | 311186.6 | 970415.8 | 4989155.2 | 10961508.9 |
| 14 | 71.9083 | 61.7987 | 326.3621 | 258.9704 | 274.0593 |
| 15 | 37.4233 | 33.3830 | 8.9502 | -4.8395 | -14.2323 |
| | | | | | |
| S-IC CENTER ENGINE CUTOFF SIGNAL - TB 2 | | | | | |
| 1 | 144.7200 | 183944.8100 | 247301.1100 | 23.6529 | 72.2686 |
| 2 | 7395.2501 | 8598.2129 | 153.857 | 20.1445 | 75.1313 |
| 3 | 182473.2 | 178700.9 | -3606414.900 | 182361.800 | -419599.000 |
| 4 | -392.0 | 65127.6 | 18155044.0 | -239.340 | -1021.534 |
| 5 | 249309.2 | 457274.3 | 10115904.6 | 77029.426 | -1449.633 |
| 6 | 2886.750 | 2790.586 | -7965.155 | 2429.3571 | -5179.746 |
| 7 | -10.008 | 362.484 | 54.765 | -11.1350 | -15.271 |
| 8 | 6808.546 | 8124.686 | 3237.6818 | 2098.1488 | -34.050 |
| 9 | 27.115 | .000 | .0000 | -79.8706 | 28.8175 |
| 10 | -.674 | .000 | -.6101 | 464.7552 | .0000010 |
| 11 | 141.839 | 7395.250 | 6.9991 | .8252 | 28.2972 |
| 12 | .6776 | 73278.9500 | .0000 | .0000 | 322.0529 |
| 13 | 308952.5 | 337766.4 | 966028.1 | 4966274.4 | 10940701.1 |
| 14 | 71.9098 | 62.6780 | 327.7974 | 258.9649 | 274.0482 |
| 15 | 36.2009 | 32.6097 | 9.6774 | -4.6691 | -14.1406 |
| | | | | | |
| 1 | 145.0000 | 184776.5100 | 249186.2100 | 23.5935 | 72.2699 |
| 2 | 7430.6367 | 8633.9922 | 138.940 | 20.1077 | 75.1198 |
| 3 | 183282.4 | 179483.0 | -3608649.200 | 183042.630 | -421050.580 |
| 4 | -394.8 | 65229.0 | 18155058.0 | -242.469 | -1025.815 |
| 5 | 251219.9 | 459553.6 | 10116412.6 | 77618.244 | -1459.213 |
| 6 | 2892.858 | 2796.085 | -7998.605 | 2433.7336 | -5188.606 |
| 7 | -10.227 | 361.965 | 48.227 | -11.2811 | -15.310 |
| 8 | 5844.387 | 8160.682 | 3250.5133 | 2109.1779 | -34.239 |
| 9 | 23.086 | .000 | .0000 | -79.8650 | 28.8191 |
| 10 | -.670 | .000 | -.6143 | 463.5667 | .0000010 |
| 11 | 127.362 | 7430.637 | 7.0416 | .7984 | 27.7121 |
| 12 | .6828 | 71568.6040 | .0000 | .0000 | 321.6409 |
| 13 | 310972.6 | 339791.1 | 965719.9 | 4964525.0 | 10939107.4 |
| 14 | 71.9099 | 62.7389 | 327.9078 | 258.9644 | 274.0489 |
| 15 | 36.1133 | 32.5526 | 9.7318 | -4.6562 | -14.1937 |

TABLE AP 3-2 (Sheet 10 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| S-IC OUTBOARD ENGINE CUTOFF SIGNAL - TB 3 | | | | | |
|---|-----------|-------------|--------------|------------|-------------|
| 1 | 148.4000 | 195026.7700 | 272840.4900 | 22.9120 | 72.2915 |
| 2 | 7822.7281 | 9030.7097 | 128.078 | 19.6573 | 75.0048 |
| 3 | 193234.5 | 189093.6 | -3636511.600 | 191404.710 | -438874.660 |
| 4 | -433.3 | 66449.8 | 18155085.0 | -283.582 | -1078.690 |
| 5 | 275206.1 | 488018.3 | 10127716.5 | 85009.643 | -1579.605 |
| 6 | 2951.395 | 2847.425 | -8370.658 | 2482.1580 | -5296.138 |
| 7 | -12.375 | 356.263 | -33.443 | -12.8720 | -15.794 |
| 8 | 7244.597 | 8562.650 | 3388.9078 | 2232.4187 | -36.604 |
| 9 | 16.485 | .000 | .0000 | 79.7946 | 28.8389 |
| 10 | .131 | .000 | -.6552 | 447.9166 | .0000007 |
| 11 | 118.319 | 7822.728 | 7.5416 | .5278 | 21.0136 |
| 12 | .7476 | 52922.4180 | .0000 | .0000 | 316.1625 |
| 13 | 336270.9 | 365149.1 | 962179.1 | 4942551.6 | 10919053.6 |
| 14 | 71.9097 | 63.4398 | 329.3031 | 258.9592 | 274.0776 |
| 15 | 35.0743 | 31.8613 | 10.4033 | -4.4962 | -14.0476 |
| S-IC/S-II SEPARATION COMMAND | | | | | |
| 1 | 149.0800 | 197117.0300 | 277721.2800 | 22.7375 | 72.2982 |
| 2 | 7862.6768 | 9071.9847 | 4.923 | 19.5302 | 74.9961 |
| 3 | 195259.7 | 191047.6 | -3642229.700 | 193100.230 | -442483.350 |
| 4 | -442.2 | 66691.4 | 18155069.0 | -292.539 | -1089.463 |
| 5 | 280157.9 | 493866.7 | 10130037.1 | 86535.586 | -1604.662 |
| 6 | 2942.580 | 2837.479 | -8411.599 | 2485.6775 | -5317.631 |
| 7 | -12.500 | 355.538 | -56.761 | -13.0634 | -15.891 |
| 8 | 7291.279 | 8609.485 | 3397.4563 | 2246.8433 | -37.094 |
| 9 | -32.518 | .000 | .0000 | 79.7801 | 28.8429 |
| 10 | .162 | .000 | -.6601 | 444.5499 | .0000006 |
| 11 | -5.321 | 7862.677 | 7.6088 | .4843 | 19.6247 |
| 12 | .7610 | 49539.8070 | .0000 | .0000 | 314.9714 |
| 13 | 341489.3 | 370379.3 | 961528.1 | 4938015.1 | 10914908.2 |
| 14 | 71.9095 | 63.5712 | 329.5932 | 258.9581 | 274.0794 |
| 15 | 34.8750 | 31.7260 | 10.5401 | -4.4633 | -14.0299 |
| S-II ENGINE START COMMAND | | | | | |
| 1 | 149.7700 | 199245.7100 | 282678.9200 | 22.6245 | 72.3024 |
| 2 | 7858.9073 | 9069.1714 | 4.249 | 19.4309 | 74.9993 |
| 3 | 197321.5 | 193036.6 | -3648038.500 | 194827.140 | -446160.020 |
| 4 | -451.0 | 66936.6 | 18155056.0 | -301.571 | -1100.462 |
| 5 | 285188.8 | 499807.5 | 10132396.1 | 88086.039 | -1630.430 |
| 6 | 2925.063 | 2819.260 | -8411.362 | 2486.7705 | -5339.436 |
| 7 | -12.878 | 354.780 | -73.761 | -13.2642 | -15.990 |
| 8 | 7294.261 | 8612.536 | 3390.1930 | 2247.9267 | -37.597 |
| 9 | -32.518 | .000 | .0000 | 79.7654 | 28.8471 |
| 10 | .191 | .000 | -.6690 | 441.0795 | .0000006 |
| 11 | -4.559 | 7858.907 | 7.6350 | .4433 | 18.0870 |
| 12 | .7746 | 45971.3430 | .0000 | .0000 | 313.7391 |
| 13 | 346797.6 | 375698.6 | 960897.3 | 4933408.5 | 10910698.8 |
| 14 | 71.9093 | 63.7006 | 329.8885 | 258.9570 | 274.0813 |
| 15 | 34.6792 | 31.5929 | 10.6792 | -4.4298 | -14.0119 |
| S-II ENGINE START COMMAND | | | | | |
| 1 | 150.0000 | 199917.4900 | 284327.2700 | 22.5763 | 72.3059 |
| 2 | 7858.3658 | 9069.0350 | 3.263 | 19.3890 | 75.0018 |
| 3 | 197970.5 | 193661.4 | -3649964.700 | 195392.130 | -447388.950 |
| 4 | -453.7 | 67018.4 | 18155020.0 | -304.575 | -1104.143 |
| 5 | 286861.2 | 501782.9 | 10133162.9 | 88601.401 | -1639.097 |
| 6 | 2918.154 | 2812.104 | -8412.298 | 2486.8046 | -5346.704 |
| 7 | -12.727 | 354.793 | -80.622 | -13.2501 | -16.023 |
| 8 | 7296.446 | 8614.732 | 3387.3516 | 2248.6474 | -37.766 |
| 9 | -32.518 | .000 | .0000 | 79.7605 | 28.8485 |
| 10 | .199 | .000 | -.6680 | 439.9762 | .0000006 |
| 11 | -3.441 | 7858.366 | 7.6440 | .4311 | 17.6305 |
| 12 | .7791 | 44905.0210 | .0000 | .0000 | 313.3462 |
| 13 | 348542.4 | 377448.6 | 960685.8 | 4931871.5 | 10909289.4 |
| 14 | 71.9093 | 63.7427 | 329.9869 | 258.9566 | 274.0819 |
| 15 | 34.6105 | 31.5448 | 10.7233 | -4.4191 | -14.0061 |
| S-II ENGINE START COMMAND | | | | | |
| 1 | 155.0000 | 214661.4400 | 320267.8600 | 21.6921 | 72.3704 |
| 2 | 7851.4340 | 9069.4775 | 24.259 | 18.6202 | 75.0472 |
| 3 | 212189.3 | 207337.6 | -3691978.700 | 207829.350 | -474517.220 |
| 4 | -513.0 | 68789.8 | 18154278.0 | -371.038 | -1186.063 |
| 5 | 323354.5 | 544868.2 | 10149919.8 | 99851.078 | -1837.399 |
| 6 | 2790.137 | 2678.762 | -8430.934 | 2494.2793 | -5504.569 |
| 7 | -11.173 | 353.428 | -209.727 | -13.4454 | -16.747 |
| 8 | 7338.939 | 8657.642 | 3336.2851 | 2262.8968 | -41.606 |
| 9 | -21.346 | .000 | .0000 | 79.6535 | 28.8784 |
| 10 | .389 | .000 | -.6705 | 415.3297 | .0000003 |
| 11 | 21.613 | 7851.434 | 7.8607 | .2289 | 9.9015 |
| 12 | .8776 | 26460.0290 | .0000 | .0000 | 304.4392 |
| 13 | 386759.2 | 415755.9 | 956908.7 | 4898382.9 | 10878576.6 |
| 14 | 71.9090 | 64.5658 | 332.1499 | 258.9485 | 274.0952 |
| 15 | 33.2733 | 30.5992 | 11.6855 | -4.1825 | -13.8790 |

TABLE AP 3-2 (Sheet 11 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| ACTIVATE PJ SYSTEM | | | | | |
|--------------------|-----------|-------------|--------------|------------|-------------|
| 1 | 155.2600 | 215414.9600 | 322145.7800 | 21.6450 | 72.3739 |
| 2 | 7854.1657 | 9072.5863 | 24.476 | 18.5803 | 75.0488 |
| 3 | 212913.7 | 208033.0 | -3694170.300 | 208477.850 | -475949.450 |
| 4 | -515.9 | 68881.7 | 18154223.0 | -374.532 | -1190.422 |
| 5 | 325262.5 | 547119.0 | 10150786.6 | 100439.377 | -1848.243 |
| 6 | 2784.415 | 2672.732 | -8434.673 | 2494.9414 | -5512.771 |
| 7 | -11.081 | 353.353 | -216.552 | -13.4569 | -16.785 |
| 8 | 7344.033 | 8662.764 | 3334.8507 | 2264.5216 | -41.814 |
| 9 | -21.233 | .000 | .0000 | -79.6479 | 28.8800 |
| 10 | .398 | .000 | -.6704 | 414.0672 | .0000003 |
| 11 | 21.800 | 7854.166 | 7.8755 | .2214 | 9.6131 |
| 12 | .8827 | 25745.0250 | .0000 | .0000 | 303.9759 |
| 13 | 388752.0 | 417753.3 | 956749.9 | 4896631.0 | 10876966.7 |
| 14 | 71.9091 | 64.6043 | 332.2638 | 258.9481 | 274.0959 |
| 15 | 33.2083 | 30.5521 | 11.7345 | -4.1702 | -13.8724 |
| | | | | | |
| 1 | 160.0000 | 228941.8500 | 356633.5100 | 20.7954 | 72.4409 |
| 2 | 7918.3198 | 9143.4148 | 25.855 | 17.8650 | 75.0767 |
| 3 | 225874.0 | 220450.3 | -3734338.400 | 220335.190 | -502434.250 |
| 4 | -563.4 | 70554.2 | 18152899.0 | -438.560 | -1271.631 |
| 5 | 360319.8 | 588428.3 | 10166541.6 | 111251.564 | -2055.686 |
| 6 | 2684.801 | 2567.313 | -8514.905 | 2508.3584 | -5662.209 |
| 7 | -8.995 | 352.278 | -340.745 | -13.5717 | -17.483 |
| 8 | 7449.265 | 8768.515 | 3313.9601 | 2297.9574 | -45.761 |
| 9 | -20.665 | .000 | .0000 | -79.5452 | 28.9087 |
| 10 | .514 | .000 | -.6632 | 391.7893 | .0000002 |
| 11 | 23.040 | 7918.320 | 8.1625 | .1197 | 5.5819 |
| 12 | .9772 | 15525.1972 | .0000 | .0000 | 295.6815 |
| 13 | 425264.3 | 454349.2 | 954508.2 | 4864419.8 | 10847310.7 |
| 14 | 71.9103 | 65.2470 | 334.3706 | 258.9401 | 274.1087 |
| 15 | 32.0824 | 29.7218 | 12.6081 | -3.9478 | -13.7531 |
| | | | | | |
| 1 | 165.0000 | 242778.3100 | 393521.2100 | 19.9227 | 72.5133 |
| 2 | 7993.3818 | 9225.0962 | 26.270 | 17.1316 | 75.1070 |
| 3 | 239040.7 | 233013.8 | -3777134.800 | 232913.760 | -531138.950 |
| 4 | -602.3 | 72313.0 | 18150867.0 | -506.625 | -1360.908 |
| 5 | 397853.7 | 632559.7 | 10183060.2 | 122832.754 | -2295.543 |
| 6 | 2582.086 | 2458.325 | -8604.009 | 2523.1209 | -5819.631 |
| 7 | -6.618 | 351.213 | -471.198 | -13.6685 | -18.230 |
| 8 | 7564.849 | 8884.577 | 3294.1496 | 2334.6965 | -50.234 |
| 9 | -20.407 | .000 | .0000 | -79.4353 | 28.9392 |
| 10 | .541 | .000 | -.6537 | 370.1301 | .0000001 |
| 11 | 23.363 | 7993.382 | 8.4777 | .0615 | 3.0957 |
| 12 | 1.0783 | 8948.4771 | .0000 | .0000 | 287.3879 |
| 13 | 464142.6 | 493314.8 | 953518.7 | 4829886.1 | 10815402.1 |
| 14 | 71.9132 | 65.8219 | 336.6501 | 258.9313 | 274.1224 |
| 15 | 30.9985 | 28.8949 | 13.4871 | -3.7147 | -13.6281 |
| | | | | | |
| 1 | 170.0000 | 256182.5900 | 430946.6900 | 19.0731 | 72.5872 |
| 2 | 8072.7998 | 9310.7342 | 26.533 | 16.4177 | 75.1391 |
| 3 | 251697.0 | 245035.5 | -3820381.900 | 245566.890 | -560630.220 |
| 4 | -628.9 | 74066.8 | 18148183.0 | -575.086 | -1453.949 |
| 5 | 435970.9 | 677276.6 | 10199482.3 | 134599.470 | -2558.566 |
| 6 | 2480.440 | 2350.277 | -8694.894 | 2538.1056 | -5976.841 |
| 7 | -4.065 | 350.224 | -601.352 | -13.7388 | -18.989 |
| 8 | 7682.285 | 9002.407 | 3275.2067 | 2372.0724 | -55.029 |
| 9 | -20.279 | .000 | .0000 | -79.3237 | 28.9700 |
| 10 | .560 | .000 | -.6426 | 350.0627 | .0000001 |
| 11 | 23.574 | 8072.800 | 8.8040 | .0311 | 1.6889 |
| 12 | 1.1809 | 5070.2129 | .0000 | .0000 | 279.4843 |
| 13 | 503410.7 | 532669.1 | 953990.6 | 4794765.9 | 10782837.4 |
| 14 | 71.9173 | 66.3139 | 338.9837 | 258.9220 | 274.1363 |
| 15 | 29.9989 | 28.1094 | 14.3181 | -3.4829 | -13.5041 |
| | | | | | |
| 1 | 175.0000 | 269161.5700 | 468919.2300 | 18.2475 | 72.6612 |
| 2 | 8156.0165 | 9399.7751 | 26.880 | 15.7238 | 75.1718 |
| 3 | 263847.5 | 256518.8 | -3864087.100 | 258295.390 | -590907.000 |
| 4 | -643.1 | 75815.0 | 18144849.0 | -644.101 | -1550.814 |
| 5 | 474679.6 | 722586.8 | 10215812.2 | 146554.540 | -2846.372 |
| 6 | 2379.766 | 2243.079 | -8787.045 | 2553.2863 | -6133.844 |
| 7 | -1.546 | 349.101 | -731.227 | -13.8462 | -19.759 |
| 8 | 7801.110 | 9121.541 | 3257.1352 | 2409.9449 | -60.148 |
| 9 | -20.113 | .000 | .0000 | -79.2104 | 29.0012 |
| 10 | .576 | .000 | -.6327 | 330.4033 | .0000000 |
| 11 | 23.860 | 8156.016 | 9.1557 | .0155 | .9100 |
| 12 | 1.2849 | 2843.2903 | .0000 | .0000 | 271.5183 |
| 13 | 543080.6 | 572423.9 | 955972.6 | 4759048.7 | 10749609.0 |
| 14 | 71.9223 | 66.7400 | 341.3653 | 258.9123 | 274.1504 |
| 15 | 29.0672 | 27.3587 | 15.0963 | -3.2523 | -13.3810 |

TABLE AP 3-2 (Sheet 12 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| S-II SECOND PLANE SEPARATION | | | | | |
|------------------------------|-----------|-------------|--------------|------------|-------------|
| 1 | 179.0600 | 279393.2600 | 500159.2100 | 17.5931 | 72.7216 |
| 2 | 8226.0568 | 9474.2774 | 27.177 | 15.1735 | 75.1990 |
| 3 | 273344.0 | 265449.5 | -3899915.600 | 268686.820 | -616068.940 |
| 4 | -645.0 | 77230.6 | 18141664.0 | -700.461 | -1632.320 |
| 5 | 506549.1 | 759817.6 | 10229005.7 | 156401.790 | -3099.428 |
| 6 | 2298.405 | 2156.330 | -8862.601 | 2565.6580 | -6261.183 |
| 7 | .505 | 348.123 | -836.694 | -13.9511 | -20.393 |
| 8 | 7898.440 | 9219.057 | 3242.8693 | 2441.0081 | -64.546 |
| 9 | -19.935 | .000 | .0000 | -79.1171 | 29.0268 |
| 10 | .588 | .000 | -.6253 | 325.3700 | .0000000 |
| 11 | 24.090 | 8226.057 | 9.3056 | .0088 | .5308 |
| 12 | 1.3705 | 1666.6738 | .0000 | .0000 | 269.4412 |
| 13 | 575594.8 | 605005.9 | 958723.0 | 4729602.8 | 10722135.8 |
| 14 | 71.9270 | 67.0463 | 343.3294 | 258.9041 | 274.1621 |
| 15 | 28.3522 | 26.7712 | 15.6865 | -3.0658 | -13.2817 |
| | | | | | |
| 1 | 180.0000 | 281723.3300 | 507444.7800 | 17.4440 | 72.7361 |
| 2 | 8242.7338 | 9491.9546 | 27.245 | 15.0481 | 75.2057 |
| 3 | 275495.8 | 267467.1 | -3908254.900 | 271099.910 | -621968.320 |
| 4 | -644.3 | 77557.7 | 18140866.0 | -713.571 | -1651.559 |
| 5 | 513984.4 | 768494.3 | 10232052.5 | 158699.780 | -3160.594 |
| 6 | 2279.704 | 2136.368 | -8880.343 | 2568.5543 | -6290.647 |
| 7 | 1.041 | 347.948 | -861.058 | -13.9593 | -20.541 |
| 8 | 7921.213 | 9241.866 | 3239.6453 | 2448.2802 | -65.595 |
| 9 | -19.893 | .000 | .0000 | -79.0953 | 29.0327 |
| 10 | .592 | .000 | -.6228 | 325.3700 | .0000000 |
| 11 | 24.141 | 8242.734 | 9.3244 | .0077 | .4677 |
| 12 | 1.3905 | 1465.6588 | .0000 | .0000 | 269.4412 |
| 13 | 583162.3 | 612589.1 | 959508.1 | 4722728.0 | 10715711.6 |
| 14 | 71.9281 | 67.1128 | 343.7876 | 258.9022 | 274.1648 |
| 15 | 28.1913 | 26.6377 | 15.8175 | -3.0227 | -13.2587 |
| | | | | | |
| LAUNCH ESCAPE TOWER JETTISON | | | | | |
| 1 | 184.7700 | 293324.1600 | 544721.9200 | 16.7017 | 72.8084 |
| 2 | 8329.2633 | 9583.3515 | 27.823 | 14.4237 | 75.2393 |
| 3 | 286144.2 | 277416.5 | -3950828.600 | 283387.060 | -652331.100 |
| 4 | -633.4 | 79214.7 | 18136461.0 | -780.455 | -1751.338 |
| 5 | 552044.1 | 812853.8 | 10247466.3 | 170466.110 | -3486.496 |
| 6 | 2185.441 | 2035.640 | -8970.947 | 2583.3920 | -6440.055 |
| 7 | 3.602 | 346.846 | -984.474 | -14.0647 | -21.297 |
| 8 | 8037.441 | 9358.232 | 3223.9040 | 2485.4270 | -71.102 |
| 9 | -19.691 | .000 | .0000 | -78.9839 | 29.0631 |
| 10 | .609 | .000 | -.6129 | 325.3700 | .0000000 |
| 11 | 24.660 | 8329.263 | 9.4223 | .0040 | .2494 |
| 12 | 1.4926 | 773.3412 | .0000 | .0000 | 269.4412 |
| 13 | 621797.0 | 651301.9 | 964365.5 | 4687506.5 | 10682742.9 |
| 14 | 71.9342 | 67.4275 | 346.1292 | 258.8921 | 274.1787 |
| 15 | 27.3993 | 25.9738 | 16.4490 | -2.8047 | -13.1428 |
| | | | | | |
| 1 | 185.0000 | 293874.4600 | 546532.7100 | 16.6666 | 72.8119 |
| 2 | 8333.5284 | 9587.8429 | 27.854 | 14.3941 | 75.2409 |
| 3 | 286646.4 | 277884.2 | -3952892.600 | 283981.350 | -653813.150 |
| 4 | -632.7 | 79294.3 | 18136235.0 | -783.722 | -1756.241 |
| 5 | 553893.6 | 815007.1 | 10248207.9 | 171038.020 | -3502.881 |
| 6 | 2180.937 | 2030.822 | -8975.356 | 2584.1179 | -6447.255 |
| 7 | 3.729 | 346.794 | -990.402 | -14.0694 | -21.334 |
| 8 | 8043.084 | 9363.880 | 3223.1726 | 2487.2316 | -71.375 |
| 9 | -19.683 | .000 | .0000 | -78.9785 | 29.0645 |
| 10 | .610 | .000 | -.6124 | 325.3700 | .0000000 |
| 11 | 24.689 | 8333.528 | 9.4271 | .0039 | .2421 |
| 12 | 1.4976 | 750.3313 | .0000 | .0000 | 269.4412 |
| 13 | 623670.2 | 653178.8 | 964637.0 | 4685793.8 | 10681137.6 |
| 14 | 71.9345 | 67.4418 | 346.2427 | 258.8916 | 274.1794 |
| 15 | 27.3621 | 25.9424 | 16.4781 | -2.7942 | -13.1373 |
| | | | | | |
| 1 | 190.0000 | 305626.4600 | 586195.3000 | 15.9153 | 72.8889 |
| 2 | 8428.5274 | 9687.5868 | 28.234 | 13.7617 | 75.2775 |
| 3 | 297306.6 | 287776.6 | -3998011.300 | 296941.380 | -686440.560 |
| 4 | -657.1 | 81025.4 | 18130957.0 | -854.343 | -1864.918 |
| 5 | 594418.2 | 862135.9 | 10264283.6 | 183573.110 | -3874.903 |
| 6 | 2083.471 | 1926.439 | -9072.303 | 2599.9781 | -6603.674 |
| 7 | 6.532 | 345.652 | -1119.330 | -14.1722 | -22.139 |
| 8 | 8166.957 | 9487.819 | 3207.7683 | 2526.8723 | -77.490 |
| 9 | -19.460 | .000 | .0000 | -78.8599 | 29.0967 |
| 10 | .621 | .000 | -.6013 | 342.0947 | .0000000 |
| 11 | 24.983 | 8428.527 | -.2942 | .0020 | .1237 |
| 12 | 1.6063 | 362.6910 | .0000 | .0000 | 276.4104 |
| 13 | 664623.6 | 694212.2 | 971393.9 | 4648234.0 | 10645877.1 |
| 14 | 71.9414 | 67.7346 | 348.7224 | 258.8805 | 274.1943 |
| 15 | 26.5725 | 25.2696 | 17.0749 | -2.5664 | -13.0165 |

TABLE AP 3-2 (Sheet 13 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| INITIATE ITERATIVE GUIDANCE MODE | | | | | |
|----------------------------------|-----------|-------------|--------------|------------|-------------|
| 1 | 190.9000 | 307700.1100 | 593396.3900 | 15.7820 | 72.9032 |
| 2 | 8445.7297 | 9705.6142 | 28.320 | 13.6494 | 75.2846 |
| 3 | 299173.7 | 289501.7 | -4006184.400 | 299282.570 | -692396.510 |
| 4 | -600.9 | 81336.4 | 18129938.0 | -867.089 | -1884.908 |
| 5 | 601778.7 | 870685.2 | 10267169.0 | 185850.580 | -3945.154 |
| 6 | 2065.864 | 1907.576 | -9089.674 | 2602.8045 | -6631.809 |
| 7 | 7.092 | 345.492 | -1142.553 | -14.1764 | -22.285 |
| 8 | 8189.170 | 9510.035 | 3204.8965 | 2533.9900 | -78.626 |
| 9 | -19.408 | .000 | .0000 | -78.8383 | 29.1025 |
| 10 | .625 | .000 | -.5987 | 345.4408 | .0000000 |
| 11 | 25.050 | 8445.730 | 9.2671 | .0018 | .1102 |
| 12 | 1.6260 | 319.6929 | .0000 | .0000 | 277.7854 |
| 13 | 672043.7 | 701646.5 | 972785.3 | 4641405.9 | 10639456.4 |
| 14 | 71.9427 | 67.7839 | 349.1706 | 258.8784 | 274.1970 |
| 15 | 26.4342 | 25.1507 | 17.1754 | -2.5254 | -12.9948 |
| | | | | | |
| 1 | 195.0000 | 316988.2400 | 626439.6500 | 15.1941 | 72.9682 |
| 2 | 8526.2802 | 9789.7407 | 28.416 | 13.1542 | 75.3168 |
| 3 | 307481.4 | 297148.6 | -4043616.700 | 309981.040 | -719849.590 |
| 4 | -566.9 | 82751.1 | 18125036.0 | -925.368 | -1977.645 |
| 5 | 635564.3 | 909886.3 | 10280283.4 | 196307.220 | -4278.347 |
| 6 | 1987.549 | 1823.479 | -9169.967 | 2616.2163 | -6759.908 |
| 7 | 9.598 | 344.681 | -1247.106 | -14.2196 | -22.954 |
| 8 | 8291.382 | 9612.240 | 3193.0343 | 2566.7631 | -83.944 |
| 9 | -18.633 | .000 | .0000 | -78.7394 | 29.1292 |
| 10 | .709 | .000 | -.5876 | 360.4137 | .0000000 |
| 11 | 24.801 | 8526.280 | 9.1552 | .0011 | .0667 |
| 12 | 1.7166 | 184.7042 | .0000 | .0000 | 283.8624 |
| 13 | 706036.1 | 735702.7 | 979807.3 | 4610041.4 | 10609924.6 |
| 14 | 71.9488 | 67.9970 | 351.2172 | 258.8689 | 274.2094 |
| 15 | 25.8173 | 24.6170 | 17.6058 | -2.3392 | -12.8963 |
| | | | | | |
| 1 | 200.0000 | 327979.2700 | 667265.6200 | 14.5506 | 73.0532 |
| 2 | 8625.3491 | 9892.6757 | 28.868 | 12.6126 | 75.3625 |
| 3 | 317186.9 | 306016.0 | -4089711.000 | 323104.870 | -754039.330 |
| 4 | -509.6 | 84473.6 | 18118485.0 | -996.120 | -2094.480 |
| 5 | 677330.7 | 958256.9 | 10296212.3 | 209240.480 | -4714.919 |
| 6 | 1899.915 | 1728.720 | -9267.059 | 2634.8994 | -6915.963 |
| 7 | 13.464 | 344.468 | -1366.781 | -14.0324 | -23.782 |
| 8 | 8413.488 | 9734.368 | 3180.9717 | 2606.0595 | -90.742 |
| 9 | -16.227 | .000 | .0000 | -78.6172 | 29.1620 |
| 10 | .813 | .000 | -.5636 | 378.0990 | .0000000 |
| 11 | 24.087 | 8625.349 | 9.0378 | .0007 | .0379 |
| 12 | 1.8284 | 99.5275 | .0000 | .0000 | 290.8896 |
| 13 | 747920.1 | 777662.3 | 989900.8 | 4571218.3 | 10573284.9 |
| 14 | 71.9568 | 68.2337 | 353.7174 | 258.8566 | 274.2247 |
| 15 | 25.0932 | 23.9836 | 18.0697 | -2.1123 | -12.7768 |
| | | | | | |
| 1 | 205.0000 | 338663.3600 | 708653.4700 | 13.9887 | 73.1405 |
| 2 | 8724.6942 | 9995.3645 | 29.225 | 12.1405 | 75.4116 |
| 3 | 326484.4 | 314439.5 | -4136286.800 | 336331.070 | -789008.930 |
| 4 | -431.9 | 86196.1 | 18111366.0 | -1065.588 | -2215.480 |
| 5 | 719697.9 | 1007228.7 | 10312092.0 | 222367.600 | -5186.345 |
| 6 | 1821.377 | 1642.986 | -9362.770 | 2656.2800 | -7071.843 |
| 7 | 17.626 | 344.524 | -1477.586 | -13.7597 | -24.620 |
| 8 | 8532.442 | 9853.387 | 3172.1620 | 2644.5141 | -97.886 |
| 9 | -14.782 | .000 | .0000 | -78.4931 | 29.1950 |
| 10 | .843 | .000 | -.5361 | 405.7513 | .0000000 |
| 11 | 23.637 | 8724.694 | 8.8089 | .0004 | .0220 |
| 12 | 1.9418 | 53.6884 | .0000 | .0000 | 301.8855 |
| 13 | 790289.4 | 820103.3 | 1001701.4 | 4531794.6 | 10535994.5 |
| 14 | 71.9655 | 68.4486 | 356.2115 | 258.8438 | 274.2402 |
| 15 | 24.4010 | 23.3720 | 18.4691 | -1.8849 | -12.6575 |
| | | | | | |
| 1 | 210.0000 | 349076.0800 | 750593.2400 | 13.4716 | 73.2282 |
| 2 | 8825.5972 | 10099.2905 | 29.375 | 11.7062 | 75.4620 |
| 3 | 335406.4 | 322451.4 | -4183340.200 | 349669.260 | -824757.480 |
| 4 | -333.3 | 87918.8 | 18103708.0 | -1133.726 | -2340.699 |
| 5 | 762656.0 | 1056791.5 | 10327934.6 | 235686.060 | -5694.368 |
| 6 | 1747.146 | 1561.458 | -9458.637 | 2678.8902 | -7227.552 |
| 7 | 21.814 | 344.543 | -1584.611 | -13.4948 | -25.470 |
| 8 | 8650.906 | 9971.902 | 3165.2605 | 2682.9220 | -105.381 |
| 9 | -14.774 | .000 | .0000 | -78.3673 | 29.2284 |
| 10 | .862 | .000 | -.5093 | 432.6000 | .0000000 |
| 11 | 23.784 | 8825.597 | 8.6145 | .0003 | .0135 |
| 12 | 2.0568 | 30.7264 | .0000 | .0000 | 312.2698 |
| 13 | 833151.6 | 863033.5 | 1015222.4 | 4491785.9 | 10498071.8 |
| 14 | 71.9749 | 68.6447 | 358.6891 | 258.8303 | 274.2560 |
| 15 | 23.7393 | 22.7823 | 18.8054 | -1.6566 | -12.5382 |

TABLE AP 3-2 (Sheet 14 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | INITIATE STEERING | MISALIGNMENT | CORRECTION | | |
|----|-------------------|--------------|--------------|------------|-------------|
| 1 | 210.6000 | 350308.1400 | 755663.0700 | 13.4106 | 73.2388 |
| 2 | 8837.7830 | 10111.8274 | 29.419 | 11.6549 | 75.4682 |
| 3 | 336452.2 | 323385.5 | -4189018.600 | 351277.460 | -829099.600 |
| 4 | -320.1 | 88125.4 | 18102754.0 | -1141.822 | -2356.012 |
| 5 | 767850.6 | 1062778.8 | 10329833.3 | 237297.130 | -5757.873 |
| 6 | 1738.240 | 1551.668 | -9470.143 | 2681.5980 | -7246.226 |
| 7 | 22.325 | 344.549 | -1597.458 | -13.4619 | -25.572 |
| 8 | 8665.127 | 9986.125 | 3164.4270 | 2687.5385 | -106.304 |
| 9 | -14.791 | .000 | .0000 | -78.3521 | 29.2324 |
| 10 | .866 | .000 | -.5061 | 435.7631 | .0000000 |
| 11 | 23.844 | 8837.783 | 8.5932 | .0002 | .0127 |
| 12 | 2.0707 | 28.8341 | .0000 | .0000 | 313.4757 |
| 13 | 838328.4 | 868218.3 | 1016960.6 | 4486945.7 | 10493478.5 |
| 14 | 71.9760 | 68.6671 | 358.9848 | 258.8286 | 274.2579 |
| 15 | 23.6618 | 22.7129 | 18.8415 | -1.6292 | -12.5239 |
| | | | | | |
| 1 | 215.0000 | 359225.8500 | 793089.8300 | 12.9667 | 73.3161 |
| 2 | 8928.9039 | 10205.4648 | 29.700 | 11.2814 | 75.5130 |
| 3 | 343956.8 | 330054.8 | -4230874.800 | 363120.110 | -861284.160 |
| 4 | -213.8 | 89641.3 | 18095515.0 | -1200.607 | -2470.195 |
| 5 | 806208.9 | 1106949.5 | 10343743.3 | 249197.560 | -6240.750 |
| 6 | 1672.603 | 1479.488 | -9555.646 | 2701.3145 | -7383.092 |
| 7 | 26.011 | 344.474 | -1692.473 | -13.2536 | -26.331 |
| 8 | 8770.807 | 10091.778 | 3158.5909 | 2721.8527 | -113.230 |
| 9 | -14.971 | .000 | .0000 | -78.2397 | 29.2620 |
| 10 | .907 | .000 | -.4838 | 458.5764 | .0000000 |
| 11 | 24.254 | 8928.904 | 8.4501 | .0002 | .0086 |
| 12 | 2.1732 | 18.4925 | .0000 | .0000 | 322.0694 |
| 13 | 876515.3 | 906461.6 | 1030462.8 | 4451188.3 | 10459513.7 |
| 14 | 71.9847 | 68.8245 | 1.1410 | 258.8161 | 274.2719 |
| 15 | 23.1048 | 22.2123 | 19.0794 | -1.4272 | -12.4191 |
| | | | | | |
| 1 | 220.0000 | 369113.0800 | 836156.0400 | 12.4698 | 73.4076 |
| 2 | 9035.8116 | 10315.1265 | 30.078 | 10.8628 | 75.5674 |
| 3 | 352132.7 | 337246.2 | -4278901.100 | 376682.300 | -898588.140 |
| 4 | -71.9 | 91364.6 | 18086778.0 | -1265.906 | -2604.024 |
| 5 | 850368.7 | 1157714.0 | 10359518.4 | 262906.170 | -6827.271 |
| 6 | 1597.305 | 1396.613 | -9655.110 | 2723.4124 | -7538.468 |
| 7 | 30.729 | 344.813 | -1801.779 | -12.8844 | -27.203 |
| 8 | 8893.456 | 10214.325 | 3151.8709 | 2761.7063 | -121.437 |
| 9 | -15.158 | .000 | .0000 | -78.1103 | 29.2959 |
| 10 | .945 | .000 | -.4531 | 505.1200 | .0000000 |
| 11 | 24.770 | 9035.812 | 8.1278 | .0001 | .0055 |
| 12 | 2.2912 | 10.8110 | .0000 | .0000 | 338.8509 |
| 13 | 920393.6 | 950400.9 | 1047414.1 | 4409988.7 | 10420307.7 |
| 14 | 71.9951 | 68.9901 | 3.5592 | 258.8011 | 274.2881 |
| 15 | 22.4942 | 21.6598 | 19.2922 | -1.1965 | -12.2999 |
| | | | | | |
| 1 | 225.0000 | 378737.3300 | 879804.4000 | 11.9797 | 73.4995 |
| 2 | 9145.6135 | 10427.5592 | 30.406 | 10.4491 | 75.6224 |
| 3 | 359929.6 | 344020.4 | -4327428.800 | 390354.000 | -936668.570 |
| 4 | 93.8 | 93089.5 | 18077490.0 | -1329.404 | -2742.243 |
| 5 | 895147.0 | 1209096.2 | 10375260.1 | 276815.850 | -7455.728 |
| 6 | 1520.856 | 1312.443 | -9756.184 | 2745.0662 | -7693.680 |
| 7 | 35.487 | 345.080 | -1912.852 | -12.5337 | -28.086 |
| 8 | 9018.203 | 10338.879 | 3145.1359 | 2802.2822 | -130.006 |
| 9 | -15.347 | .000 | .0000 | -77.9790 | 29.3301 |
| 10 | .980 | .000 | -.4235 | 554.1485 | .0000000 |
| 11 | 25.221 | 9145.614 | 7.8342 | .0001 | .0037 |
| 12 | 2.4108 | 6.6732 | .0000 | .0000 | 355.8215 |
| 13 | 964799.1 | 994864.5 | 1066063.4 | 4368173.9 | 10380440.7 |
| 14 | 72.0059 | 69.1433 | 5.9361 | 258.7854 | 274.3045 |
| 15 | 21.9046 | 21.1229 | 19.4454 | -.9645 | -12.1807 |
| | | | | | |
| 1 | 230.0000 | 388098.1500 | 924047.2500 | 11.4989 | 73.5926 |
| 2 | 9258.6457 | 10543.0961 | 30.700 | 10.0424 | 75.6789 |
| 3 | 367341.8 | 350371.0 | -4376466.500 | 404133.000 | -975524.670 |
| 4 | 283.3 | 94815.5 | 18067642.0 | -1391.205 | -2884.907 |
| 5 | 940555.0 | 1261106.9 | 10390968.6 | 290930.440 | -8127.939 |
| 6 | 1443.663 | 1227.377 | -9859.223 | 2766.3986 | -7848.734 |
| 7 | 40.413 | 345.403 | -2025.379 | -12.1625 | -28.981 |
| 8 | 9145.312 | 10465.712 | 3138.5437 | 2843.6640 | -138.939 |
| 9 | -15.471 | .000 | .0000 | -77.8459 | 29.3646 |
| 10 | 1.011 | .000 | -.3934 | 601.3302 | .0000000 |
| 11 | 25.590 | 9258.646 | 7.5946 | .0001 | .0026 |
| 12 | 2.5321 | 4.3641 | .0000 | .0000 | 371.5846 |
| 13 | 1009744.4 | 1039865.1 | 1086393.9 | 4325731.2 | 10339899.7 |
| 14 | 72.0172 | 69.2857 | 8.2651 | 258.7688 | 274.3212 |
| 15 | 21.3336 | 20.5998 | 19.5414 | -.7909 | -12.0615 |

TABLE AP 3-2 (Sheet 15 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|-----------|-------------|--------------|------------|--------------|
| 1 | 235.0000 | 397196.5200 | 968896.0700 | 11.0288 | 73.6876 |
| 2 | 9374.4175 | 10661.2496 | 30.981 | 9.6442 | 75.7375 |
| 3 | 374366.8 | 356294.6 | -4426023.400 | 418018.030 | -1015155.640 |
| 4 | 498.2 | 96543.6 | 18057229.0 | -1450.997 | -3032.073 |
| 5 | 986603.3 | 1313756.3 | 10406643.9 | 305253.600 | -8845.741 |
| 6 | 1365.839 | 1141.536 | -9963.826 | 2787.4467 | -8003.631 |
| 7 | 45.625 | 345.900 | -2139.054 | -11.7347 | -29.887 |
| 8 | 9274.271 | 10594.315 | 3131.9144 | 2885.6976 | -148.243 |
| 9 | -15.576 | .000 | .0000 | -77.7108 | 29.3993 |
| 10 | 1.028 | .000 | -.3614 | 665.5474 | .0000000 |
| 11 | 25.929 | 9374.418 | 7.2929 | .0001 | .0019 |
| 12 | 2.6550 | 2.8536 | .0000 | .0000 | 391.7951 |
| 13 | 1055242.5 | 1085415.7 | 1108385.3 | 4282648.9 | 10298673.2 |
| 14 | 72.0288 | 69.4184 | 10.5402 | 258.7514 | 274.3380 |
| 15 | 20.7792 | 20.0891 | 19.5830 | -.4958 | -11.9422 |
| | | | | | |
| 1 | 240.0000 | 406034.5200 | 1014361.4000 | 10.5712 | 73.7828 |
| 2 | 9493.2235 | 10782.3013 | 31.344 | 9.2559 | 75.7965 |
| 3 | 381001.4 | 361787.3 | -4476107.500 | 432007.670 | -1055560.700 |
| 4 | 739.3 | 98274.2 | 18046246.0 | -1508.664 | -3183.798 |
| 5 | 1033301.3 | 1367053.5 | 10422286.8 | 319788.670 | -9610.991 |
| 6 | 1287.676 | 1055.204 | -10070.165 | 2808.2984 | -8158.374 |
| 7 | 50.821 | 346.270 | -2253.832 | -11.3425 | -30.805 |
| 8 | 9405.350 | 10724.956 | 3125.7097 | 2928.4665 | -157.919 |
| 9 | -15.648 | .000 | .0000 | -77.5737 | 29.4343 |
| 10 | 1.049 | .000 | -.3313 | 756.5958 | .0000000 |
| 11 | 26.340 | 9493.224 | 6.9138 | .0000 | .0014 |
| 12 | 2.7796 | 1.8560 | .0000 | .0000 | 418.5159 |
| 13 | 1101305.6 | 1131529.0 | 1132014.2 | 4238916.7 | 10256750.9 |
| 14 | 72.0409 | 69.5427 | 12.7565 | 258.7331 | 274.3552 |
| 15 | 20.2400 | 19.5899 | 19.5733 | -.2589 | -11.8229 |
| | | | | | |
| 1 | 245.0000 | 414615.4600 | 1060454.8000 | 10.1275 | 73.8785 |
| 2 | 9614.9353 | 10906.1264 | 31.721 | 8.8786 | 75.8565 |
| 3 | 387244.9 | 366847.7 | -4526727.300 | 446101.250 | -1096739.200 |
| 4 | 1006.5 | 100006.3 | 18034685.0 | -1564.420 | -3340.137 |
| 5 | 1080659.7 | 1421008.7 | 10437899.8 | 334539.320 | -10425.566 |
| 6 | 1209.371 | 968.579 | -10178.177 | 2829.0150 | -8312.966 |
| 7 | 56.077 | 346.588 | -2369.470 | -10.9625 | -31.733 |
| 8 | 9538.410 | 10857.502 | 3119.9251 | 2971.9309 | -167.973 |
| 9 | -15.703 | .000 | .0000 | -77.4346 | 29.4696 |
| 10 | 1.068 | .000 | -.3021 | 844.3369 | .0000000 |
| 11 | 26.753 | 9614.935 | 6.6166 | .0000 | .0010 |
| 12 | 2.9059 | 1.2884 | .0000 | .0000 | 442.9185 |
| 13 | 1147948.1 | 1178219.3 | 1157257.9 | 4194523.5 | 10214122.4 |
| 14 | 72.0533 | 69.6592 | 14.9100 | 258.7138 | 274.3725 |
| 15 | 19.7147 | 19.1012 | 19.5160 | -.0200 | -11.7034 |
| | | | | | |
| 1 | 250.0000 | 422943.4700 | 1107186.6000 | 9.6966 | 73.9750 |
| 2 | 9739.2669 | 11032.4490 | 32.090 | 8.5117 | 75.9177 |
| 3 | 393096.0 | 371473.8 | -4577890.900 | 460297.940 | -1138690.100 |
| 4 | 1300.3 | 101740.0 | 18022545.0 | -1618.286 | -3501.148 |
| 5 | 1128687.9 | 1475630.9 | 10453484.5 | 349508.900 | -11291.365 |
| 6 | 1130.732 | 881.470 | -10287.626 | 2849.5384 | -8467.410 |
| 7 | 61.432 | 346.892 | -2486.044 | -10.5833 | -32.673 |
| 8 | 9673.210 | 10991.708 | 3114.3698 | 3016.0177 | -178.409 |
| 9 | -15.748 | .000 | .0000 | -77.2935 | 29.5052 |
| 10 | 1.091 | .000 | -.2733 | 928.8692 | .0000000 |
| 11 | 27.148 | 9739.267 | 6.3787 | .0000 | .0008 |
| 12 | 3.0339 | .9400 | .0000 | .0000 | 465.3811 |
| 13 | 1195183.0 | 1225499.7 | 1184090.2 | 4149459.8 | 10170777.6 |
| 14 | 72.0659 | 69.7689 | 16.9975 | 258.6934 | 274.3902 |
| 15 | 19.2020 | 18.6224 | 19.4148 | .2211 | -11.5838 |
| | | | | | |
| 1 | 255.0000 | 431023.2400 | 1154567.5000 | 9.2805 | 74.0714 |
| 2 | 9866.5925 | 11161.6379 | 32.475 | 8.1968 | 75.9792 |
| 3 | 398554.1 | 375664.0 | -4629606.200 | 474597.070 | -1181413.000 |
| 4 | 1620.4 | 103474.6 | 18009819.0 | -1670.455 | -3666.888 |
| 5 | 1177395.6 | 1530929.4 | 10469043.4 | 364700.810 | -12210.308 |
| 6 | 1052.121 | 794.231 | -10398.830 | 2869.9779 | -8621.708 |
| 7 | 66.722 | 347.016 | -2603.425 | -10.2556 | -33.625 |
| 8 | 9810.109 | 11127.936 | 3109.4519 | 3060.8387 | -189.232 |
| 9 | -15.790 | .000 | .0000 | -77.1503 | 29.5410 |
| 10 | 1.111 | .000 | -.2468 | 1010.2899 | .0000000 |
| 11 | 27.557 | 9866.592 | 6.1856 | .0000 | .0007 |
| 12 | 3.1638 | .7135 | .0000 | .0000 | 486.1820 |
| 13 | 1243023.8 | 1273383.9 | 1212484.8 | 4103715.6 | 10126707.1 |
| 14 | 72.0788 | 69.8724 | 19.0168 | 258.6721 | 274.4080 |
| 15 | 18.7012 | 18.1928 | 19.2734 | .4645 | -11.4640 |

TABLE AP 3-2 (Sheet 16 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 260.0000 | 438858.0400 | 1202608.6000 | 8.8769 | 74.1706 |
| 2 | 9996.7246 | 11293.5342 | 32.927 | 7.8118 | 76.0437 |
| 3 | 403618.0 | 379416.6 | -4681882.200 | 488997.810 | -1224907.000 |
| 4 | 1968.1 | 105210.6 | 17996504.0 | -1720.715 | -3837.412 |
| 5 | 1226792.9 | 1586914.1 | 10484577.3 | 380118.640 | -13184.336 |
| 6 | 973.127 | 706.448 | -10511.802 | 2890.2081 | -8775.862 |
| 7 | 72.440 | 347.451 | -2721.737 | -9.8297 | -34.587 |
| 8 | 9948.984 | 11266.062 | 3104.5290 | 3106.3572 | -200.445 |
| 9 | -15.849 | .000 | .0000 | -77.0050 | 29.5772 |
| 10 | 1.131 | .000 | -.2171 | 1088.6943 | .0000000 |
| 11 | 28.042 | 9996.725 | 6.0273 | .0000 | .0006 |
| 12 | 3.2954 | .5592 | .0000 | .0000 | 505.5372 |
| 13 | 1291484.5 | 1321886.0 | 1242414.3 | 4057280.5 | 10081900.4 |
| 14 | 72.0918 | 69.9702 | 20.9663 | 258.6495 | 274.4262 |
| 15 | 18.2113 | 17.6918 | 19.0957 | .7106 | -11.3439 |
| | | | | | |
| 1 | 265.0000 | 446452.2900 | 1251322.9000 | 8.4853 | 74.2700 |
| 2 | 10130.2879 | 11428.7543 | 33.309 | 7.4766 | 76.1086 |
| 3 | 408286.6 | 382729.4 | -4734728.900 | 503499.360 | -1269171.400 |
| 4 | 2344.6 | 106948.7 | 17982595.0 | -1768.869 | -4012.779 |
| 5 | 1276891.4 | 1643595.9 | 10500088.3 | 395766.370 | -14215.415 |
| 6 | 893.720 | 618.081 | -10626.956 | 2910.2170 | -8929.875 |
| 7 | 78.155 | 347.756 | -2841.389 | -9.4396 | -35.561 |
| 8 | 10090.485 | 11406.730 | 3100.1233 | 3152.7710 | -212.052 |
| 9 | -15.930 | .000 | .0000 | -76.8575 | 29.6136 |
| 10 | 1.151 | .000 | -.1891 | 1164.1745 | .0000000 |
| 11 | 28.457 | 10130.288 | 5.8969 | .0000 | .0005 |
| 12 | 3.4289 | .4501 | .0000 | .0000 | 523.6150 |
| 13 | 1340580.1 | 1371020.8 | 1273851.6 | 4010143.4 | 10036346.0 |
| 14 | 72.1051 | 70.0630 | 22.8456 | 258.6258 | 274.4447 |
| 15 | 17.7317 | 17.2389 | 18.8854 | .9595 | -11.2235 |
| | | | | | |
| 1 | 270.0000 | 453808.9600 | 1300720.1000 | 8.1060 | 74.3700 |
| 2 | 10266.0671 | 11566.0891 | 33.772 | 7.1512 | 76.1747 |
| 3 | 412556.6 | 385598.5 | -4788153.200 | 518100.240 | -1314205.500 |
| 4 | 2749.7 | 108688.0 | 17968084.0 | -1815.140 | -4193.044 |
| 5 | 1327700.2 | 1700983.7 | 10515577.2 | 411647.280 | -15305.530 |
| 6 | 813.848 | 529.094 | -10743.210 | 2929.9947 | -9083.750 |
| 7 | 83.907 | 347.983 | -2962.022 | -9.0702 | -36.547 |
| 8 | 10233.413 | 11548.741 | 3095.8516 | 3199.7158 | -224.060 |
| 9 | -16.030 | .000 | .0000 | -76.7078 | 29.6503 |
| 10 | 1.169 | .000 | -.1624 | 1236.8020 | .0000000 |
| 11 | 28.964 | 10266.067 | 5.7887 | .0000 | .0004 |
| 12 | 3.5643 | .3704 | .0000 | .0000 | 540.5505 |
| 13 | 1390323.1 | 1420801.2 | 1306769.5 | 3962294.6 | 9990033.7 |
| 14 | 72.1186 | 70.1511 | 24.6544 | 258.6008 | 274.4634 |
| 15 | 17.2616 | 16.7936 | 18.6458 | 1.2115 | -11.1029 |
| | | | | | |
| 1 | 275.0000 | 460931.0800 | 1350812.5000 | 7.7383 | 74.4703 |
| 2 | 10405.3465 | 11706.8276 | 34.169 | 6.8352 | 76.2414 |
| 3 | 416426.1 | 388021.1 | -4842164.200 | 532799.450 | -1360008.600 |
| 4 | 3183.3 | 110427.9 | 17952967.0 | -1859.738 | -4378.264 |
| 5 | 1379230.4 | 1759088.0 | 10531046.2 | 427765.180 | -16456.693 |
| 6 | 733.476 | 439.429 | -10861.731 | 2949.5239 | -9237.487 |
| 7 | 89.668 | 348.089 | -3084.106 | -8.7342 | -37.543 |
| 8 | 10379.075 | 11693.399 | 3092.0740 | 3247.5907 | -236.472 |
| 9 | -16.134 | .000 | .0000 | -76.5559 | 29.6873 |
| 10 | 1.194 | .000 | -.1372 | 1306.6623 | .0000000 |
| 11 | 29.396 | 10405.346 | 5.6995 | .0000 | .0004 |
| 12 | 3.7015 | .3108 | .0000 | .0000 | 556.4565 |
| 13 | 1440727.9 | 1471241.6 | 1341142.3 | 3913723.5 | 9942953.0 |
| 14 | 72.1322 | 70.2350 | 26.3933 | 258.5745 | 274.4825 |
| 15 | 16.8004 | 16.3556 | 18.3805 | 1.4669 | -10.9818 |
| | | | | | |
| 1 | 280.0000 | 467823.0200 | 1401614.7000 | 7.3829 | 74.5725 |
| 2 | 10547.8099 | 11850.6639 | 34.602 | 6.5291 | 76.3101 |
| 3 | 419892.8 | 389993.9 | -4896773.600 | 547595.750 | -1406580.100 |
| 4 | 3646.6 | 112168.9 | 17937236.0 | -1902.469 | -4568.498 |
| 5 | 1431495.4 | 1817922.1 | 10546497.0 | 444124.710 | -17670.937 |
| 6 | 652.689 | 349.170 | -10982.345 | 2968.8311 | -9391.089 |
| 7 | 95.682 | 348.318 | -3207.375 | -8.3570 | -38.552 |
| 8 | 10527.162 | 11840.398 | 3088.3445 | 3296.3038 | -249.293 |
| 9 | -16.242 | .000 | .0000 | -76.4017 | 29.7245 |
| 10 | 1.215 | .000 | -.1110 | 1373.8335 | .0000000 |
| 11 | 29.864 | 10547.810 | 5.6262 | .0000 | .0003 |
| 12 | 3.8407 | .2651 | .0000 | .0000 | 571.4257 |
| 13 | 1491811.7 | 1522359.0 | 1376946.5 | 3864416.5 | 9895089.5 |
| 14 | 72.1459 | 70.3150 | 28.0634 | 258.5668 | 274.5019 |
| 15 | 16.3476 | 15.9244 | 18.0925 | 1.7260 | -10.8604 |

TABLE AP 3-2 (Sheet 17 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 285.0000 | 474487,2200 | 1453137,9000 | 7.0377 | 74,6756 |
| 2 | 10692.8015 | 11996,9477 | 35,068 | 6,2313 | 76,3802 |
| 3 | 422953.0 | 391512,5 | -4951989,400 | 562487,590 | -1453919,300 |
| 4 | 4140.2 | 113911,0 | 17920886,0 | -1943,328 | -4763,801 |
| 5 | 1484505.2 | 1877495,1 | 10561929,6 | 460729,380 | -18950,321 |
| 6 | 571.078 | 257,919 | -11104,369 | 2987,7951 | -9544,559 |
| 7 | 101.811 | 348,534 | -3332,035 | -7,9803 | -39,571 |
| 8 | 10677.055 | 11989,111 | 3085,0151 | 3345,6659 | -262,529 |
| 9 | -16.358 | .000 | .0000 | -76,2452 | 29,7621 |
| 10 | 1.237 | .000 | -.0852 | 1438,3845 | .0000000 |
| 11 | 30.366 | 10692,802 | 5.5661 | .0000 | .0003 |
| 12 | 3.9819 | .2294 | .0000 | .0000 | 585,5366 |
| 13 | 1543587.4 | 1574166,6 | 1414157,3 | 3814364,2 | 9846432,9 |
| 14 | 72.1597 | 70,3915 | 29,6661 | 258,5176 | 274,5216 |
| 15 | 15.9028 | 15,4997 | 17,7848 | 1,9890 | -10,7385 |
| | | | | | |
| 1 | 290.0000 | 480926,9300 | 1505394,8000 | 6,7040 | 74,7793 |
| 2 | 10841.3900 | 12146,7449 | 35,494 | 5,9428 | 76,4512 |
| 3 | 425604.2 | 392573,4 | -5007820,700 | 577473,720 | -1502025,500 |
| 4 | 4664.5 | 115653,9 | 17903908,0 | -1982,395 | -4964,230 |
| 5 | 1538271.2 | 1937818,4 | 10577346,2 | 477583,170 | -20296,928 |
| 6 | 488.924 | 165,935 | -11228,781 | 3006,4956 | -9697,896 |
| 7 | 107.975 | 348,648 | -3458,228 | -7,6311 | -40,602 |
| 8 | 10829.822 | 12140,608 | 3081,9750 | 3396,0039 | -276,183 |
| 9 | -16.471 | .000 | .0000 | -76,0863 | 29,7999 |
| 10 | 1.264 | .000 | -.0608 | 1500,3914 | .0000000 |
| 11 | 30.820 | 10841,390 | 5,5179 | .0000 | .0003 |
| 12 | 4.1251 | .2010 | .0000 | .0000 | 598,8569 |
| 13 | 1596069.9 | 1626679,4 | 1452752,7 | 3763555,1 | 9796971,2 |
| 14 | 72.1737 | 70,4646 | 31,2029 | 258,4867 | 274,5416 |
| 15 | 15.4655 | 15,0812 | 17,4601 | 2,2562 | -10,6161 |
| | | | | | |
| 1 | 295.0000 | 487146,5900 | 1558400,1000 | 6,3819 | 74,8851 |
| 2 | 10992.8113 | 12299,3034 | 35,934 | 5,6639 | 76,5245 |
| 3 | 427843.3 | 393172,5 | -5064279,600 | 592552,700 | -1550898,000 |
| 4 | 5220.7 | 117398,0 | 17886297,0 | -2019,497 | -5169,844 |
| 5 | 1592807.3 | 1998905,0 | 10592747,8 | 494690,780 | -21712,864 |
| 6 | 406.215 | 73,213 | -11355,002 | 3024,9318 | -9851,104 |
| 7 | 114.443 | 348,934 | -3585,616 | -7,2263 | -41,645 |
| 8 | 10984.707 | 12294,136 | 3078,9903 | 3447,0906 | -290,262 |
| 9 | -16.587 | .000 | .0000 | -75,9250 | 29,8381 |
| 10 | 1.296 | .000 | -.0348 | 1559,9284 | .0000000 |
| 11 | 31.285 | 10992,811 | 5,4798 | .0000 | .0002 |
| 12 | 4.2704 | .1782 | .0000 | .0000 | 611,4467 |
| 13 | 1649276.2 | 1679914,3 | 1492713,5 | 3711976,5 | 9746690,6 |
| 14 | 72.1877 | 70,5348 | 32,6759 | 258,4542 | 274,5620 |
| 15 | 15.0352 | 14,6686 | 17,1207 | 2,5282 | -10,4931 |
| | | | | | |
| 1 | 300.0000 | 493149,4400 | 1612166,2000 | 6,0706 | 74,9915 |
| 2 | 11147.5965 | 12455,1523 | 36,354 | 5,3937 | 76,5987 |
| 3 | 429667.1 | 393306,0 | -5121374,700 | 607723,120 | -1600536,300 |
| 4 | 5809.1 | 119143,1 | 17868044,0 | -2054,686 | -5380,699 |
| 5 | 1648124.2 | 2060765,4 | 10608135,0 | 512056,040 | -23200,266 |
| 6 | 322.781 | -20,425 | -11483,396 | 3043,0496 | -10004,184 |
| 7 | 120.945 | 349,112 | -3714,634 | -6,8508 | -42,699 |
| 8 | 11142.266 | 12450,243 | 3076,3559 | 3499,0941 | -304,770 |
| 9 | -16.700 | .000 | .0000 | -75,7612 | 29,8765 |
| 10 | 1.320 | .000 | -.0103 | 1614,6772 | .0000000 |
| 11 | 31.723 | 11147,597 | 5,4552 | .0000 | .0002 |
| 12 | 4.4177 | .1599 | .0000 | .0000 | 622,8521 |
| 13 | 1703220.7 | 1733885,8 | 1534020,3 | 3659618,0 | 9695579,6 |
| 14 | 72.2019 | 70,6022 | 34,0871 | 258,4199 | 274,5827 |
| 15 | 14.6117 | 14,2617 | 16,7691 | 2,8051 | -10,3696 |
| | | | | | |
| 1 | 305.0000 | 498939,6600 | 1666706,4000 | 5,7715 | 75,0990 |
| 2 | 11305.2817 | 12613,8306 | 36,848 | 5,1336 | 76,6744 |
| 3 | 431072.7 | 392969,6 | -5179116,100 | 622983,540 | -1650939,700 |
| 4 | 6430.2 | 120889,0 | 17849144,0 | -2088,035 | -5596,852 |
| 5 | 1704234.3 | 2123411,6 | 10623510,2 | 529683,200 | -24761,294 |
| 6 | 238.906 | -114,692 | -11613,626 | 3060,9372 | -10157,137 |
| 7 | 127.571 | 349,278 | -3844,855 | -6,4755 | -43,764 |
| 8 | 11302.037 | 12608,473 | 3074,0071 | 3551,8772 | -319,713 |
| 9 | -16.819 | .000 | .0000 | -75,5949 | 29,9152 |
| 10 | 1.345 | .000 | .0000 | 1656,1229 | .0000000 |
| 11 | 32.238 | 11305,282 | 5,4580 | .0000 | .0002 |
| 12 | 4.5672 | .1465 | .0000 | .0000 | 631,3347 |
| 13 | 1757919.0 | 1788609,4 | 1576656,2 | 3606468,5 | 9643625,5 |
| 14 | 72.2161 | 70,6670 | 35,4388 | 258,3836 | 274,6038 |
| 15 | 14.1947 | 13,8601 | 16,4072 | 3,0875 | -10,2454 |

TABLE AP 3-2 (Sheet 18 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 310.0000 | 504521.9200 | 1722034.9000 | 5.4835 | 75.2085 |
| 2 | 11466.2816 | 12775.7628 | 37.393 | 4.8828 | 76.7524 |
| 3 | 432057.1 | 392159.6 | -5237514.700 | 638332.580 | -1702107.500 |
| 4 | 7085.4 | 122636.2 | 17829588.0 | -2119.335 | -5818.362 |
| 5 | 1761150.1 | 2186855.6 | 10638873.9 | 547576.700 | -26398.133 |
| 6 | 154.394 | -209.796 | -11746.116 | 3078.5311 | -10309.964 |
| 7 | 134.489 | 349.591 | -3976.529 | -6.0519 | -44.841 |
| 8 | 11464.453 | 12769.257 | 3071.8266 | 3605.5727 | -335.096 |
| 9 | -16.944 | .000 | .0000 | -75.4261 | 29.9542 |
| 10 | 1.373 | .000 | .0000 | 1695.9360 | .0000000 |
| 11 | 32.805 | 11466.281 | 5.4659 | .0000 | .0002 |
| 12 | 4.7188 | .1350 | .0000 | .0000 | 639.4059 |
| 13 | 1813387.2 | 1844101.5 | 1620606.2 | 3552516.7 | 9590815.8 |
| 14 | 72.2304 | 70.7294 | 36.7333 | 258.3453 | 274.6253 |
| 15 | 13.7838 | 13.4639 | 16.0368 | 3.3757 | -10.1205 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 315.0000 | 509900.6700 | 1778165.9000 | 5.2976 | 75.3182 |
| 2 | 11630.8260 | 12941.1718 | 37.854 | 4.6421 | 76.8309 |
| 3 | 432617.9 | 390872.5 | -5296581.400 | 653769.050 | -1754039.100 |
| 4 | 7774.9 | 124384.4 | 17809370.0 | -2148.689 | -6045.285 |
| 5 | 1818885.1 | 2251110.3 | 10654228.0 | 565741.050 | -28112.999 |
| 6 | 69.425 | -305.562 | -11880.981 | 3095.8854 | -10462.667 |
| 7 | 141.354 | 349.704 | -4109.716 | -5.6858 | -45.930 |
| 8 | 11629.760 | 12932.838 | 3070.2557 | 3660.2568 | -350.925 |
| 9 | -17.070 | .000 | .0000 | -75.2546 | 29.9934 |
| 10 | 1.400 | .000 | .0000 | 1734.1684 | .0000000 |
| 11 | 33.278 | 11630.826 | 5.4785 | .0000 | .0002 |
| 12 | 4.8726 | .1252 | .0000 | .0000 | 647.0880 |
| 13 | 1869642.1 | 1900378.7 | 1665857.7 | 3497751.1 | 9537137.0 |
| 14 | 72.2448 | 70.7896 | 37.9730 | 258.3047 | 274.6472 |
| 15 | 13.3790 | 13.0728 | 15.6597 | 3.6704 | -9.9949 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 320.0000 | 515081.2200 | 1835114.1000 | 4.9420 | 75.4284 |
| 2 | 11798.2247 | 13109.3751 | 38.289 | 4.4099 | 76.9104 |
| 3 | 432751.7 | 389103.9 | -5356326.900 | 669291.370 | -1806733.900 |
| 4 | 8498.7 | 126132.8 | 17788482.0 | -2176.330 | -6277.679 |
| 5 | 1877452.4 | 2316188.6 | 10669574.9 | 584180.880 | -29908.135 |
| 6 | -16.347 | -402.327 | -12017.569 | 3112.8975 | -10615.246 |
| 7 | 148.215 | 349.666 | -4244.479 | -5.3618 | -47.030 |
| 8 | 11797.282 | 13098.535 | 3068.9053 | 3715.7233 | -367.204 |
| 9 | -17.218 | .000 | .0000 | -75.0805 | 30.0329 |
| 10 | 1.428 | .000 | .0000 | 1770.8681 | .0000000 |
| 11 | 33.727 | 11798.225 | 5.4952 | .0000 | .0002 |
| 12 | 5.0287 | .1167 | .0000 | .0000 | 654.4020 |
| 13 | 1926700.2 | 1957457.7 | 1712399.9 | 3442160.0 | 9482575.6 |
| 14 | 72.2593 | 70.8477 | 39.1601 | 258.2618 | 274.6696 |
| 15 | 12.9798 | 12.6865 | 15.2773 | 3.9720 | -9.8685 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 325.0000 | 520067.1200 | 1892891.1000 | 4.6867 | 75.5406 |
| 2 | 11968.2851 | 13280.1907 | 38.780 | 4.1863 | 76.9922 |
| 3 | 432454.3 | 380848.7 | -5416759.000 | 684897.810 | -1860191.400 |
| 4 | 9257.4 | 127881.2 | 17766917.0 | -2202.263 | -6515.602 |
| 5 | 1936862.0 | 2382099.7 | 10684914.7 | 602899.750 | -31785.809 |
| 6 | -102.931 | -500.101 | -12155.813 | 3129.5650 | -10767.702 |
| 7 | 155.341 | 349.750 | -4380.660 | -4.9974 | -48.141 |
| 8 | 11966.834 | 13266.163 | 3067.4952 | 3771.9177 | -383.941 |
| 9 | -17.384 | .000 | .0000 | -74.9037 | 30.0728 |
| 10 | 1.456 | .000 | .0000 | 1806.0730 | .0000000 |
| 11 | 34.237 | 11968.285 | 5.5158 | .0000 | .0002 |
| 12 | 5.1870 | .1093 | .0000 | .0000 | 661.3644 |
| 13 | 1984574.7 | 2015351.7 | 1760220.3 | 3385735.5 | 9427121.4 |
| 14 | 72.2738 | 70.9039 | 40.2970 | 258.2163 | 274.6923 |
| 15 | 12.5862 | 12.3051 | 14.8910 | 4.2811 | -9.7412 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 330.0000 | 524863.6500 | 1951510.6000 | 4.4417 | 75.6542 |
| 2 | 12141.8202 | 13434.4316 | 39.332 | 3.9713 | 77.0757 |
| 3 | 431722.6 | 384102.8 | -5477888.500 | 700586.940 | -1914410.700 |
| 4 | 10052.3 | 129630.2 | 17744667.0 | -2226.327 | -6759.111 |
| 5 | 1997126.6 | 2448856.0 | 10700248.5 | 621902.050 | -33748.323 |
| 6 | -190.334 | -598.909 | -12296.415 | 3145.8799 | -10920.037 |
| 7 | 162.632 | 349.844 | -4518.581 | -4.6265 | -49.264 |
| 8 | 12139.239 | 13436.543 | 3066.3279 | 3829.0920 | -401.141 |
| 9 | -17.556 | .000 | .0000 | -74.7242 | 30.1128 |
| 10 | 1.482 | .000 | .0000 | 1839.8353 | .0000000 |
| 11 | 34.807 | 12141.820 | 5.5402 | .0000 | .0002 |
| 12 | 5.3476 | .1029 | .0000 | .0000 | 667.9937 |
| 13 | 2043281.7 | 2074076.8 | 1809309.6 | 3328467.5 | 9370761.4 |
| 14 | 72.2883 | 70.9582 | 41.3859 | 258.1682 | 274.7159 |
| 15 | 12.1979 | 11.9283 | 14.5018 | 4.5983 | -9.6129 |

TABLE AP 3-2 (Sheet 19 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 335.0000 | 529474.1000 | 2010988.5000 | 4.2068 | 75.7690 |
| 2 | 12318.8189 | 13632.0877 | 39.864 | 3.7648 | 77.1607 |
| 3 | 430551.7 | 380860.0 | -5539726.800 | 716356.670 | -1969391.600 |
| 4 | 10883.9 | 131379.6 | 17721722.0 | -2248.538 | -7008.265 |
| 5 | 2058260.4 | 2516471.0 | 10715576.9 | 641192.680 | -35798.004 |
| 6 | -278.584 | -698.781 | -12439.348 | 3161.8335 | -11072.251 |
| 7 | 170.044 | 349.899 | -4658.283 | -4.2640 | -50.399 |
| 8 | 12314.495 | 13609.670 | 3065.4290 | 3887.2466 | -418.809 |
| 9 | -17.736 | .000 | .0000 | 74.5419 | 30.1532 |
| 10 | 1.509 | .000 | .0000 | 1860.7384 | .0000000 |
| 11 | 35.353 | 12318.819 | 5.5855 | .0000 | .0002 |
| 12 | 5.5106 | .0982 | .0000 | .0000 | 672.2388 |
| 13 | 2102838.3 | 2133650.2 | 1859661.8 | 3270343.8 | 9313480.7 |
| 14 | 72.3029 | 71.0108 | 42.4292 | 258.1170 | 274.7392 |
| 15 | 11.8147 | 11.5560 | 14.1108 | 4.9243 | -9.4837 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 340.0000 | 533903.4900 | 2071341.1000 | 3.9820 | 75.8857 |
| 2 | 12499.7475 | 13813.6321 | 40.443 | 3.5668 | 77.2478 |
| 3 | 428936.8 | 377114.6 | -5602286.000 | 732205.090 | -2025133.100 |
| 4 | 11793.2 | 133129.3 | 17698075.0 | -2268.908 | -7263.120 |
| 5 | 2120278.3 | 2584959.2 | 10730901.1 | 660776.760 | -37937.211 |
| 6 | -367.730 | -799.784 | -12585.085 | 3177.4057 | -11224.343 |
| 7 | 177.720 | 350.050 | -4799.918 | -3.8685 | -51.545 |
| 8 | 12493.073 | 13786.017 | 3064.7817 | 3946.5272 | -436.952 |
| 9 | -17.887 | .000 | .0000 | 74.3567 | 30.1938 |
| 10 | 1.536 | .000 | .0000 | 1880.5936 | .0000000 |
| 11 | 35.935 | 12499.748 | 5.6338 | .0000 | .0002 |
| 12 | 5.6760 | .0941 | .0000 | .0000 | 676.2624 |
| 13 | 2163262.5 | 2194089.8 | 1911272.1 | 3211353.0 | 9255264.3 |
| 14 | 72.3175 | 71.0619 | 43.4290 | 258.0628 | 274.7633 |
| 15 | 11.4365 | 11.1881 | 13.7188 | 5.2599 | -9.3535 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 345.0000 | 538157.9900 | 2132585.1000 | 3.7682 | 76.0028 |
| 2 | 12683.8154 | 13998.2677 | 41.034 | 3.3782 | 77.3358 |
| 3 | 426875.0 | 372862.4 | -5665579.200 | 748130.720 | -2081634.800 |
| 4 | 12660.7 | 134879.4 | 17673715.0 | -2287.420 | -7523.736 |
| 5 | 2183195.5 | 2654335.4 | 10746223.3 | 680659.500 | -40168.333 |
| 6 | -457.525 | -901.652 | -12732.849 | 3192.6771 | -11376.315 |
| 7 | 185.351 | 349.999 | -4943.136 | -3.5313 | -52.703 |
| 8 | 12674.206 | 13964.815 | 3064.5537 | 4006.7013 | -455.576 |
| 9 | -18.059 | .000 | .0000 | 74.1686 | 30.2347 |
| 10 | 1.564 | .000 | .0000 | 1899.6093 | .0000000 |
| 11 | 36.531 | 12683.815 | 5.6845 | .0000 | .0002 |
| 12 | 5.8438 | .0904 | .0000 | .0000 | 680.1046 |
| 13 | 2224573.0 | 2255414.4 | 1964138.6 | 3151483.8 | 9196096.9 |
| 14 | 72.3322 | 71.1115 | 44.3874 | 258.0051 | 274.7880 |
| 15 | 11.0631 | 10.8244 | 13.3266 | 5.6059 | -9.2221 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 350.0000 | 542242.0400 | 2194736.5000 | 3.5632 | 76.1217 |
| 2 | 12871.6788 | 14186.6623 | 41.652 | 3.1970 | 77.4257 |
| 3 | 424361.2 | 368097.3 | -5729618.000 | 764131.550 | -2138896.000 |
| 4 | 13607.1 | 136629.5 | 17648634.0 | -2304.163 | -7790.170 |
| 5 | 2247026.6 | 2724613.5 | 10761544.6 | 700845.900 | -42493.790 |
| 6 | -548.497 | -1004.935 | -12883.230 | 3207.4809 | -11528.167 |
| 7 | 193.196 | 349.988 | -5088.512 | -3.1782 | -53.872 |
| 8 | 12858.536 | 14146.697 | 3064.4514 | 4067.9640 | -474.687 |
| 9 | -18.236 | .000 | .0000 | 73.9776 | 30.2759 |
| 10 | 1.592 | .000 | .0000 | 1917.8136 | .0000000 |
| 11 | 37.152 | 12871.679 | 5.7377 | .0000 | .0002 |
| 12 | 6.0141 | .0871 | .0000 | .0000 | 683.7728 |
| 13 | 2286787.3 | 2317641.5 | 2018259.2 | 3090723.5 | 9135963.8 |
| 14 | 72.3469 | 71.1596 | 45.3064 | 257.9437 | 274.8132 |
| 15 | 10.6944 | 10.4649 | 12.9349 | 5.9633 | -9.0895 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 355.0000 | 546161.8500 | 2257812.5000 | 3.3693 | 76.2415 |
| 2 | 13063.4218 | 14378.8964 | 42.375 | 3.0255 | 77.5170 |
| 3 | 421390.8 | 362813.4 | -5794415.300 | 780205.590 | -2196916.200 |
| 4 | 14592.8 | 138379.1 | 17622820.0 | -2319.261 | -8062.479 |
| 5 | 2311787.5 | 2795808.8 | 10776866.7 | 721341.360 | -44916.034 |
| 6 | -640.131 | -1109.123 | -13036.356 | 3221.9721 | -11679.898 |
| 7 | 201.097 | 349.860 | -5235.705 | -2.8571 | -55.053 |
| 8 | 13046.179 | 14331.788 | 3064.8840 | 4130.3551 | -494.292 |
| 9 | -18.410 | .000 | .0000 | 73.7835 | 30.3173 |
| 10 | 1.620 | .000 | .0000 | 1935.2368 | .0000000 |
| 11 | 37.874 | 13063.422 | 5.7935 | .0000 | .0002 |
| 12 | 6.1870 | .0841 | .0000 | .0000 | 687.2749 |
| 13 | 2349924.3 | 2380790.3 | 2073634.7 | 3029067.4 | 9074848.7 |
| 14 | 72.3616 | 71.2064 | 46.1881 | 257.8782 | 274.8389 |
| 15 | 10.3302 | 10.1094 | 12.5443 | 6.3931 | -8.9557 |

TABLE AP 3-2 (Sheet 20 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 360.0000 | 549923,6100 | 2321831,5000 | 3,1853 | 76,3610 |
| 2 | 13258,9996 | 14574,9259 | 42,980 | 2,8624 | 77,6092 |
| 3 | 417960.1 | 357005,9 | -5859984,800 | 796351,160 | -2258694,800 |
| 4 | 15617,8 | 140127,5 | 17596266,0 | -2332,916 | -8340,723 |
| 5 | 2377494,9 | 2867937,7 | 10792192,4 | 742151,630 | -47437,546 |
| 6 | -732,712 | -1214,503 | -13192,088 | 3236,0634 | -11831,508 |
| 7 | 208,938 | 349,495 | -5384,995 | -2,6049 | -56,246 |
| 8 | 13237,090 | 14520,032 | 3065,7998 | 4193,8598 | -514,396 |
| 9 | -18,613 | ,000 | ,0000 | -73,5863 | 30,3590 |
| 10 | 1,647 | ,000 | ,0000 | 1951,9150 | ,0000000 |
| 11 | 38,478 | 13259,000 | 5,8518 | ,0000 | ,0002 |
| 12 | 6,3624 | ,0815 | ,0000 | ,0000 | 690,6187 |
| 13 | 2414004,1 | 2444880,7 | 2130267,8 | 2966498,5 | 9012735,7 |
| 14 | 72,3763 | 71,2520 | 47,0342 | 257,8085 | 274,8652 |
| 15 | 9,9704 | 9,7578 | 12,1552 | 6,7165 | -8,8205 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 365.0000 | 553533,5000 | 2386810,5000 | 3,0111 | 76,4843 |
| 2 | 13458,1672 | 14774,5153 | 43,617 | 2,7079 | 77,7036 |
| 3 | 414064,0 | 350668,3 | -5926339,300 | 812566,130 | -2315231,100 |
| 4 | 16682,6 | 141874,2 | 17568961,0 | -2345,244 | -8624,959 |
| 5 | 2444164,5 | 2941015,1 | 10807522,8 | 763282,020 | -50060,846 |
| 6 | -826,251 | -1321,085 | -13350,327 | 3249,7511 | -11982,998 |
| 7 | 217,032 | 349,206 | -5536,193 | -2,3258 | -57,450 |
| 8 | 13431,026 | 14711,191 | 3066,8665 | 4258,4072 | -535,008 |
| 9 | -18,835 | ,000 | ,0000 | -73,3860 | 30,4009 |
| 10 | 1,675 | ,000 | ,0000 | 1967,8788 | ,0000000 |
| 11 | 39,113 | 13458,167 | 5,9123 | ,0000 | ,0002 |
| 12 | 6,5405 | ,0791 | ,0000 | ,0000 | 693,8126 |
| 13 | 2479045,5 | 2509931,4 | 2188161,2 | 2903009,6 | 8949608,7 |
| 14 | 72,3910 | 71,2963 | 47,8466 | 257,7339 | 274,8921 |
| 15 | 9,6149 | 9,4101 | 11,7682 | 7,1147 | -8,6838 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 370.0000 | 556996,5800 | 2452768,5000 | 2,8448 | 76,6083 |
| 2 | 13661,7890 | 14978,5319 | 44,369 | 2,5600 | 77,8000 |
| 3 | 409696,5 | 343793,5 | -5993492,900 | 828848,130 | -2375524,600 |
| 4 | 17788,7 | 143619,8 | 17540893,0 | -2356,086 | -8915,245 |
| 5 | 2511813,4 | 3015057,7 | 10822859,0 | 784738,420 | -52788,482 |
| 6 | -921,283 | -1429,428 | -13511,716 | 3262,8651 | -12134,366 |
| 7 | 225,333 | 348,930 | -5690,061 | -2,0395 | -58,666 |
| 8 | 13628,828 | 14906,088 | 3068,0938 | 4324,2506 | -556,132 |
| 9 | -19,058 | ,000 | ,0000 | -73,1825 | 30,4431 |
| 10 | 1,702 | ,000 | ,0000 | 1983,1568 | ,0000000 |
| 11 | 39,862 | 13661,789 | 5,9755 | ,0000 | ,0002 |
| 12 | 6,7213 | ,0770 | ,0000 | ,0000 | 696,8627 |
| 13 | 2545068,6 | 2575962,7 | 2247319,3 | 2838590,6 | 8885450,5 |
| 14 | 72,4057 | 71,3395 | 48,6269 | 257,6542 | 274,9196 |
| 15 | 9,2636 | 9,0662 | 11,3835 | 7,5291 | -8,5456 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 375.0000 | 560318,4700 | 2519725,2000 | 2,6885 | 76,7336 |
| 2 | 13869,3754 | 15186,4830 | 45,159 | 2,4209 | 77,8979 |
| 3 | 404851,4 | 336373,7 | -6061460,400 | 845194,630 | -2436574,500 |
| 4 | 18936,2 | 145363,4 | 17512050,0 | -2365,669 | -9211,640 |
| 5 | 2580460,0 | 3090083,1 | 10838202,4 | 806526,970 | -55623,037 |
| 6 | -1017,257 | -1538,975 | -13675,884 | 3275,5749 | -12285,612 |
| 7 | 233,694 | 348,526 | -5846,036 | -1,7885 | -59,894 |
| 8 | 13830,045 | 15104,284 | 3069,7463 | 4391,2581 | -577,777 |
| 9 | -19,327 | ,000 | ,0000 | -72,9757 | 30,4855 |
| 10 | 1,729 | ,000 | ,0000 | 1993,8248 | ,0000000 |
| 11 | 40,653 | 13869,375 | 6,0469 | ,0000 | ,0002 |
| 12 | 6,9047 | ,0753 | ,0000 | ,0000 | 699,0990 |
| 13 | 2612094,3 | 2642995,6 | 2307748,9 | 2773231,2 | 8820242,2 |
| 14 | 72,4204 | 71,3817 | 49,3768 | 257,5687 | 274,9478 |
| 15 | 8,9163 | 8,7259 | 11,0015 | 7,9614 | -8,4059 |

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 380.0000 | 563505,9700 | 2587700,8000 | 2,5403 | 76,8608 |
| 2 | 14081,5195 | 15398,9685 | 45,887 | 2,2888 | 77,9980 |
| 3 | 399523,2 | 328402,5 | -6130257,000 | 861603,430 | -2498380,500 |
| 4 | 20126,3 | 147105,4 | 17482422,0 | -2373,882 | -9514,200 |
| 5 | 2650122,8 | 3166109,2 | 10853554,5 | 828653,920 | -58567,131 |
| 6 | -1114,710 | -1650,280 | -13843,315 | 3287,7114 | -12436,735 |
| 7 | 242,306 | 348,171 | -6004,699 | -1,5192 | -61,133 |
| 8 | 14035,238 | 15306,326 | 3071,5600 | 4459,5985 | -599,948 |
| 9 | -19,600 | ,000 | ,0000 | -72,7655 | 30,5282 |
| 10 | 1,760 | ,000 | ,0000 | 2002,9429 | ,0000000 |
| 11 | 41,375 | 14081,520 | 6,1223 | ,0000 | ,0002 |
| 12 | 7,0910 | ,0738 | ,0000 | ,0000 | 701,0510 |
| 13 | 2680144,4 | 2711051,9 | 2369457,9 | 2706922,8 | 8753965,6 |
| 14 | 72,4350 | 71,4228 | 50,0977 | 257,4770 | 274,9766 |
| 15 | 8,5729 | 8,3892 | 10,6223 | 8,4133 | -8,2644 |

TABLE AP 3-2 (Sheet 21 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|--------------|
| 1 | 385.0000 | 566563.8200 | 2656715.7000 | 2.4008 | 76.9900 |
| 2 | 14297.8948 | 15615.6631 | 46.650 | 2.1643 | 78.1003 |
| 3 | 393704.0 | 319870.2 | -6199897.800 | 878071.440 | -2560941.700 |
| 4 | 21359.9 | 148845.5 | 17451993.0 | -2380.736 | -9822.986 |
| 5 | 2720820.2 | 3243154.0 | 10868915.8 | 851125.550 | -61623.417 |
| 6 | -1213.499 | -1763.198 | -14013.742 | 3299.3182 | -12587.733 |
| 7 | 251.160 | 347.857 | -6163.828 | -1.2336 | -62.383 |
| 8 | 14244.091 | 15511.902 | 3073.5249 | 4529.1788 | -622.654 |
| 9 | -19.872 | .000 | .0000 | -72.5520 | 30.5711 |
| 10 | 1.791 | .000 | .0000 | 2011.6688 | .0000000 |
| 11 | 42.126 | 14297.895 | 6.1999 | .0000 | .0002 |
| 12 | 7.2801 | .0725 | .0000 | .0000 | 702.9184 |
| 13 | 2749240.1 | 2780152.5 | 2432454.7 | 2639657.3 | 8686601.2 |
| 14 | 72.4497 | 71.4630 | 50.7912 | 257.3784 | 275.0062 |
| 15 | 8.2333 | 8.0560 | 10.2463 | 8.8869 | -8.1210 |
| | | | | | |
| 1 | 390.0000 | 569499.4400 | 2726790.8000 | 2.2705 | 77.1208 |
| 2 | 14518.8561 | 15836.9212 | 47.477 | 2.0480 | 78.2046 |
| 3 | 387387.7 | 310769.4 | -6270398.400 | 894596.210 | -2624257.600 |
| 4 | 22638.0 | 150583.7 | 17420752.0 | -2386.287 | -10138.053 |
| 5 | 2792571.6 | 3321235.9 | 10884288.0 | 873948.340 | -64794.583 |
| 6 | -1313.526 | -1877.645 | -14187.489 | 3310.4211 | -12738.606 |
| 7 | 260.195 | 347.516 | -6329.493 | -.9527 | -63.646 |
| 8 | 14456.975 | 15721.380 | 3075.8395 | 4600.1137 | -645.902 |
| 9 | -20.151 | .000 | .0000 | -72.3349 | 30.6143 |
| 10 | 1.822 | .000 | .0000 | 2020.0258 | .0000000 |
| 11 | 42.939 | 14518.856 | 6.2797 | .0000 | .0002 |
| 12 | 7.4722 | .0714 | .0000 | .0000 | 704.7066 |
| 13 | 2819403.6 | 2850320.2 | 2496749.6 | 2571428.0 | 8618130.4 |
| 14 | 72.4644 | 71.5022 | 51.4586 | 257.2721 | 275.0365 |
| 15 | 7.8975 | 7.7261 | 9.8735 | 9.3844 | -7.9758 |
| | | | | | |
| 1 | 395.0000 | 572318.7500 | 2797948.7000 | 2.1483 | 77.2529 |
| 2 | 14744.3847 | 16062.7246 | 48.264 | 1.9387 | 78.3104 |
| 3 | 380567.0 | 301091.4 | -6341776.000 | 911174.900 | -2688327.600 |
| 4 | 23961.3 | 152319.7 | 17388684.0 | -2390.560 | -10459.462 |
| 5 | 2865397.9 | 3400375.5 | 10899672.5 | 897129.310 | -68083.356 |
| 6 | -1415.137 | -1993.968 | -14364.396 | 3320.9132 | -12889.353 |
| 7 | 269.270 | 347.002 | -6496.034 | -.7212 | -64.920 |
| 8 | 14673.846 | 15934.706 | 3078.4441 | 4672.3884 | -669.698 |
| 9 | -20.443 | .000 | .0000 | -72.1143 | 30.6577 |
| 10 | 1.852 | .000 | .0000 | 2028.0356 | .0000000 |
| 11 | 43.705 | 14744.385 | 6.3618 | .0000 | .0002 |
| 12 | 7.6672 | .0703 | .0000 | .0000 | 706.4198 |
| 13 | 2890659.0 | 2921578.7 | 2562355.1 | 2502228.9 | 8548531.4 |
| 14 | 72.4790 | 71.5406 | 52.1012 | 257.1572 | 275.0676 |
| 15 | 7.5652 | 7.3996 | 9.5041 | 9.9085 | -7.8286 |
| | | | | | |
| 1 | 400.0000 | 575030.2700 | 2870209.3000 | 2.0352 | 77.3876 |
| 2 | 14974.2730 | 16292.8726 | 49.188 | 1.8375 | 78.4190 |
| 3 | 373235.6 | 290828.5 | -6414045.700 | 927804.870 | -2753150.900 |
| 4 | 25331.1 | 154053.7 | 17355780.0 | -2393.480 | -10787.268 |
| 5 | 2939317.2 | 3480590.0 | 10915070.0 | 920674.640 | -71492.501 |
| 6 | -1518.029 | -2111.868 | -14544.682 | 3330.8855 | -13039.970 |
| 7 | 278.724 | 346.655 | -6665.005 | -.4349 | -66.205 |
| 8 | 14894.521 | 16151.705 | 3081.1499 | 4745.9526 | -694.051 |
| 9 | -20.729 | .000 | .0000 | -71.8900 | 30.7013 |
| 10 | 1.876 | .000 | .0000 | 2035.7213 | .0000000 |
| 11 | 44.605 | 14974.273 | 6.4460 | .0000 | .0002 |
| 12 | 7.8652 | .0694 | .0000 | .0000 | 708.0637 |
| 13 | 2963027.4 | 2993949.2 | 2629282.0 | 2432059.0 | 8477786.6 |
| 14 | 72.4937 | 71.5782 | 52.7203 | 257.0328 | 275.0995 |
| 15 | 7.2364 | 7.0763 | 9.1383 | 10.4621 | -7.6791 |
| | | | | | |
| 1 | 405.0000 | 577641.4600 | 2943596.7000 | 1.9311 | 77.5235 |
| 2 | 15209.1968 | 16528.0360 | 50.020 | 1.7443 | 78.5292 |
| 3 | 365385.9 | 279971.4 | -6487225.400 | 944483.290 | -2818727.000 |
| 4 | 26748.3 | 155785.7 | 17322022.0 | -2395.077 | -11121.531 |
| 5 | 3014352.0 | 3561901.2 | 10930482.6 | 944591.790 | -75024.815 |
| 6 | -1622.334 | -2231.495 | -14728.196 | 3340.2917 | -13190.458 |
| 7 | 288.219 | 346.123 | -6836.881 | -.2018 | -67.502 |
| 8 | 15119.677 | 16373.045 | 3084.3619 | 4821.0118 | -718.968 |
| 9 | -21.027 | .000 | .0000 | -71.6621 | 30.7451 |
| 10 | 1.898 | .000 | .0000 | 2043.1061 | .0000000 |
| 11 | 45.406 | 15209.197 | 6.5325 | .0000 | .0002 |
| 12 | 8.0663 | .0686 | .0000 | .0000 | 709.6426 |
| 13 | 3036534.2 | 3067457.1 | 2697545.3 | 2360915.6 | 8405873.7 |
| 14 | 72.5083 | 71.6150 | 53.3169 | 256.8978 | 275.1322 |
| 15 | 6.9111 | 6.7561 | 8.7760 | 11.0486 | -7.5275 |

TABLE AP 3-2 (Sheet 22 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|-----------------------|------------|-------------|--------------|-------------|--------------|
| 1 | 410.0000 | 580160.5800 | 3018133.6000 | 1.8350 | 77.6608 |
| 2 | 15448.9744 | 16768.0350 | 50.964 | 1.6583 | 78.6411 |
| 3 | 357011.6 | 268512.3 | -6561332.600 | 961207.390 | -2885055.300 |
| 4 | 28213.2 | 157514.5 | 17287398.0 | -2395.622 | -11462.309 |
| 5 | 3090523.5 | 3644329.8 | 10945912.3 | 968887.870 | -78683.140 |
| 6 | -1728.324 | -2353.123 | -14915.304 | 3349.0476 | -13340.612 |
| 7 | 297.767 | 345.416 | -7011.827 | -.0186 | -68.811 |
| 8 | 15349.105 | 16598.510 | 3087.8808 | 4897.5023 | -744.457 |
| 9 | -21.355 | .000 | .0000 | -71.4303 | 30.7891 |
| 10 | 1.925 | .000 | .0000 | 2050.2176 | .0000000 |
| 11 | 46.320 | 15448.974 | 6.6213 | .0000 | .0002 |
| 12 | 8.2706 | .0678 | .0000 | .0000 | 711.1631 |
| 13 | 3111203.6 | 3142126.8 | 2767160.4 | 2288801.5 | 8332772.3 |
| 14 | 72.5230 | 71.6510 | 53.8922 | 256.7508 | 275.1659 |
| 15 | 6.5892 | 6.4391 | 8.4174 | 11.6720 | -7.3733 |
| S-II NO. 2 ENGINE OUT | | | | | |
| 1 | 412.9000 | 581574.2900 | 3061898.9000 | 1.7827 | 77.7394 |
| 2 | 15587.4585 | 16906.6320 | 39.849 | 1.6113 | 78.7054 |
| 3 | 351902.7 | 261578.2 | -6604741.900 | 970924.600 | -2923870.000 |
| 4 | 29084.7 | 158515.4 | 17266908.0 | -2395.586 | -11662.968 |
| 5 | 3135228.8 | 3692654.8 | 10954865.5 | 983155.000 | -80863.840 |
| 6 | -1790.341 | -2424.278 | -15022.703 | 3353.9210 | -13427.956 |
| 7 | 302.827 | 344.465 | -7113.759 | -.0753 | -69.575 |
| 8 | 15481.338 | 16728.374 | 3089.8347 | 4941.6716 | -759.505 |
| 9 | -21.511 | .000 | .0000 | -71.2941 | 30.8148 |
| 10 | 1.934 | .000 | .0000 | 2054.2018 | .0000000 |
| 11 | 35.048 | 15587.458 | 6.6727 | .0000 | .0002 |
| 12 | 8.3905 | .0674 | .0000 | .0000 | 712.0149 |
| 13 | 3155050.0 | 3185972.9 | 2808158.5 | 2246532.0 | 8289820.0 |
| 14 | 72.5314 | 71.6716 | 54.2165 | 256.6594 | 275.1858 |
| 15 | 6.4039 | 6.2565 | 8.2110 | 12.0520 | -7.2829 |
| S-II NO. 3 ENGINE OUT | | | | | |
| 1 | 414.2000 | 582199.3600 | 3081636.0000 | 1.7562 | 77.7725 |
| 2 | 15636.9917 | 16956.2090 | 34.775 | 1.5874 | 78.7331 |
| 3 | 349555.9 | 258404.8 | -6624294.900 | 975285.740 | -2941351.600 |
| 4 | 29479.3 | 158962.5 | 17257630.0 | -2395.836 | -11753.639 |
| 5 | 3155385.4 | 3714431.8 | 10958879.9 | 989589.700 | -81855.615 |
| 6 | -1817.833 | -2455.550 | -15059.154 | 3356.2914 | -13467.005 |
| 7 | 304.226 | 343.348 | -7155.294 | -.3111 | -69.919 |
| 8 | 15527.989 | 16773.952 | 3088.1587 | 4957.6392 | -766.315 |
| 9 | -21.318 | .000 | .0000 | -71.2326 | 30.8263 |
| 10 | 1.937 | .000 | .0000 | 2055.9625 | .0000000 |
| 11 | 29.827 | 15636.992 | 6.6904 | .0000 | .0002 |
| 12 | 8.4446 | .0672 | .0000 | .0000 | 712.3911 |
| 13 | 3174825.2 | 3205748.0 | 2826677.3 | 2227489.3 | 8270443.3 |
| 14 | 72.5352 | 71.6807 | 54.3596 | 256.6169 | 275.1949 |
| 15 | 6.3212 | 6.1751 | 8.1190 | 12.2271 | -7.2420 |
| S-II NO. 4 ENGINE OUT | | | | | |
| 1 | 415.0000 | 582580.4500 | 3093813.3000 | 1.7390 | 77.7926 |
| 2 | 15663.3072 | 16982.5500 | 32.762 | 1.5717 | 78.7501 |
| 3 | 348093.8 | 256431.5 | -6636351.400 | 977971.050 | -2952135.000 |
| 4 | 29723.1 | 159236.9 | 17251894.0 | -2396.148 | -11809.659 |
| 5 | 3167820.1 | 3727862.9 | 10961349.6 | 993559.980 | -82470.355 |
| 6 | -1834.635 | -2474.572 | -15077.744 | 3357.8167 | -13491.031 |
| 7 | 304.900 | 342.534 | -7179.418 | -.4946 | -70.131 |
| 8 | 15552.503 | 16797.804 | 3086.2010 | 4966.1928 | -770.525 |
| 9 | -20.521 | .000 | .0000 | -71.1947 | 30.8334 |
| 10 | 1.938 | .000 | .0000 | 2057.0353 | .0000000 |
| 11 | 27.575 | 15663.307 | 6.6995 | .0000 | .0002 |
| 12 | 8.4780 | .0670 | .0000 | .0000 | 712.6204 |
| 13 | 3187026.2 | 3217948.8 | 2838111.7 | 2215746.6 | 8258486.4 |
| 14 | 72.5375 | 71.6862 | 54.4469 | 256.5903 | 275.2005 |
| 15 | 6.2705 | 6.1251 | 8.0625 | 12.3362 | -7.2168 |
| S-II NO. 5 ENGINE OUT | | | | | |
| 1 | 420.0000 | 584914.4200 | 3170303.9000 | 1.6853 | 77.9229 |
| 2 | 15799.5532 | 17118.9420 | 31.631 | 1.5236 | 78.8625 |
| 3 | 338684.7 | 243789.7 | -6711977.700 | 994792.510 | -3019965.400 |
| 4 | 31258.8 | 160938.6 | 17215659.0 | -2400.942 | -12163.638 |
| 5 | 3245903.5 | 3812163.1 | 10976743.4 | 1018506.020 | -86389.376 |
| 6 | -1922.592 | -2575.785 | -15173.095 | 3372.7121 | -13641.114 |
| 7 | 309.719 | 338.543 | -7306.399 | -1.3051 | -71.463 |
| 8 | 15679.082 | 16920.666 | 3074.4013 | 5011.7655 | -797.180 |
| 9 | -14.662 | .000 | .0000 | -70.9564 | 30.8776 |
| 10 | 1.937 | .000 | .0000 | 2063.5993 | .0000000 |
| 11 | 24.233 | 15799.553 | 6.7445 | .0000 | .0002 |
| 12 | 8.6876 | .0660 | .0000 | .0000 | 714.0233 |
| 13 | 3263674.8 | 3294596.2 | 2910088.4 | 2142106.6 | 8183349.1 |
| 14 | 72.5517 | 71.7204 | 54.9795 | 256.4158 | 275.2360 |
| 15 | 5.9565 | 5.8156 | 7.7130 | 13.0434 | -7.0584 |

TABLE AP 3-2 (Sheet 23 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 425.0000 | 587250.6700 | 3247426.4000 | 1.6913 | 78.0694 |
| 2 | 15928.8821 | 17248.4490 | 31.970 | 1.5304 | 78.9904 |
| 3 | 328890.6 | 230696.4 | -6788077.200 | 1011705.030 | -3088545.900 |
| 4 | 32826.9 | 162629.2 | 17178846.0 | -2407.112 | -12524.304 |
| 5 | 3324601.9 | 3897061.1 | 10992092.6 | 1043675.350 | -90443.147 |
| 6 | -1994.885 | -2661.344 | -15267.840 | 3392.3362 | -13791.057 |
| 7 | 318.619 | 338.758 | -7416.634 | -.8301 | -72.806 |
| 8 | 15800.259 | 17038.530 | 3065.2294 | 5055.9950 | -824.426 |
| 9 | -14.667 | .000 | .0000 | -70.7159 | 30.9217 |
| 10 | 1.926 | .000 | .0000 | 2070.1560 | .0000000 |
| 11 | 24.526 | 15928.882 | 6.7864 | .0000 | .0002 |
| 12 | 8.8989 | .0649 | .0000 | .0000 | 715.4245 |
| 13 | 3340991.4 | 3371910.8 | 2982930.9 | 2068116.0 | 8107560.2 |
| 14 | 72.5656 | 71.7535 | 55.4900 | 256.2256 | 275.2723 |
| 15 | 5.6494 | 5.5126 | 7.3714 | 13.7993 | -6.8978 |
| | | | | | |
| 1 | 430.0000 | 589607.0900 | 3325180.9000 | 1.6761 | 78.2318 |
| 2 | 16064.9492 | 17384.7720 | 32.371 | 1.5177 | 79.1329 |
| 3 | 318722.9 | 217162.7 | -6864662.700 | 1028711.680 | -3157875.700 |
| 4 | 34453.0 | 164333.8 | 17141473.0 | -2406.917 | -12891.714 |
| 5 | 3403916.4 | 3982558.5 | 11007381.7 | 1069069.400 | -94634.631 |
| 6 | -2075.312 | -2755.332 | -15367.629 | 3409.3479 | -13940.856 |
| 7 | 331.822 | 343.034 | -7534.157 | .8858 | -74.160 |
| 8 | 15926.882 | 17161.608 | 3050.0468 | 5101.9950 | -852.266 |
| 9 | -17.252 | .000 | .0000 | -70.4731 | 30.9656 |
| 10 | 1.896 | .000 | .0000 | 2076.7580 | .0000000 |
| 11 | 25.931 | 16064.949 | 6.8309 | .0000 | .0002 |
| 12 | 9.1120 | .0639 | .0000 | .0000 | 716.8352 |
| 13 | 3418979.0 | 3449895.3 | 3056623.4 | 1993820.8 | 8031122.1 |
| 14 | 72.5798 | 71.7861 | 55.9801 | 256.0168 | 275.3093 |
| 15 | 5.3490 | 5.2161 | 7.0376 | 14.6100 | -6.7347 |
| | | | | | |
| 1 | 435.0000 | 591941.1000 | 3403607.4000 | 1.6316 | 78.3835 |
| 2 | 16207.8458 | 17527.8860 | 32.794 | 1.4780 | 79.2656 |
| 3 | 308125.2 | 203130.5 | -6941752.800 | 1045794.590 | -3227954.100 |
| 4 | 36139.7 | 166053.7 | 17103480.0 | -2400.005 | -13265.924 |
| 5 | 3483878.8 | 4068684.9 | 11022590.1 | 1094697.900 | -98966.812 |
| 6 | -2166.410 | -2860.216 | -15468.912 | 3422.9934 | -14090.510 |
| 7 | 341.924 | 343.941 | -7663.932 | 1.5786 | -75.526 |
| 8 | 16058.768 | 17289.526 | 3033.7712 | 5149.6525 | -880.705 |
| 9 | -19.023 | .000 | .0000 | -70.2280 | 31.0093 |
| 10 | 1.854 | .000 | .0000 | 2083.2845 | .0000000 |
| 11 | 26.855 | 16207.846 | 6.8782 | .0000 | .0002 |
| 12 | 9.3269 | .0630 | .0000 | .0000 | 718.2297 |
| 13 | 3497664.6 | 3528576.8 | 3131180.0 | 1919212.9 | 7953983.7 |
| 14 | 72.5943 | 71.8183 | 56.4514 | 255.7866 | 275.3470 |
| 15 | 5.0540 | 4.9249 | 6.7104 | 15.4815 | -6.5694 |
| | | | | | |
| 1 | 440.0000 | 594218.0400 | 3482735.4000 | 1.5642 | 78.5238 |
| 2 | 16356.1524 | 17676.3630 | 33.213 | 1.4169 | 79.3878 |
| 3 | 297050.7 | 188552.1 | -7019350.100 | 1062939.000 | -3298780.500 |
| 4 | 37866.1 | 167766.7 | 17064813.0 | -2393.115 | -13646.992 |
| 5 | 3564510.9 | 4155460.1 | 11037718.7 | 1120568.100 | -103442.691 |
| 6 | -2266.523 | -2974.309 | -15570.645 | 3433.7870 | -14240.015 |
| 7 | 348.591 | 341.171 | -7804.220 | 1.1543 | -76.903 |
| 8 | 16194.600 | 17420.992 | 3017.1187 | 5198.5750 | -909.747 |
| 9 | -20.789 | .000 | .0000 | -69.9805 | 31.0528 |
| 10 | 1.806 | .000 | .0000 | 2089.6395 | .0000000 |
| 11 | 27.648 | 16356.152 | 6.9281 | .0000 | .0002 |
| 12 | 9.5438 | .0621 | .0000 | .0000 | 719.5875 |
| 13 | 3577067.3 | 3607974.6 | 3206615.3 | 1844301.9 | 7876108.5 |
| 14 | 72.6086 | 71.8498 | 56.9045 | 255.5325 | 275.3855 |
| 15 | 4.7635 | 4.6379 | 6.3885 | 16.4207 | -6.4020 |
| | | | | | |
| 1 | 445.0000 | 596402.8300 | 3562594.4000 | 1.4771 | 78.6715 |
| 2 | 16510.3450 | 17830.7550 | 33.623 | 1.3376 | 79.5169 |
| 3 | 285452.6 | 173379.5 | -7097463.600 | 1080130.000 | -3370354.100 |
| 4 | 39629.1 | 169468.5 | 17025421.0 | -2387.528 | -14034.975 |
| 5 | 3645834.1 | 4242903.7 | 11052753.6 | 1146686.700 | -108065.297 |
| 6 | -2375.070 | -3097.091 | -15675.329 | 3441.8856 | -14389.367 |
| 7 | 357.149 | 340.045 | -7952.600 | 1.2343 | -78.292 |
| 8 | 16334.717 | 17556.431 | 2996.0116 | 5248.8940 | -939.396 |
| 9 | -22.165 | .000 | .0000 | -69.7305 | 31.0962 |
| 10 | 1.760 | .000 | .0000 | 2095.7283 | .0000000 |
| 11 | 28.248 | 16510.345 | 6.9808 | .0000 | .0002 |
| 12 | 9.7626 | .0613 | .0000 | .0000 | 720.8882 |
| 13 | 3657206.5 | 3688108.3 | 3282939.5 | 1769107.4 | 7797458.8 |
| 14 | 72.6227 | 71.8804 | 57.3406 | 255.2507 | 275.4251 |
| 15 | 4.4766 | 4.3544 | 6.0711 | 17.4361 | -6.2327 |

TABLE AP 3-2 (Sheet 24 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 450.0000 | 598475.8700 | 3643205.1000 | 1.3828 | 78.8256 |
| 2 | 16667.5400 | 17988.1650 | 33.997 | 1.2516 | 79.6522 |
| 3 | 273298.8 | 157579.6 | -7176103.900 | 1097357.300 | -3442674.000 |
| 4 | 41440.2 | 171169.5 | 16985276.0 | -2380.038 | -14429.930 |
| 5 | 3727862.2 | 4331028.3 | 11067673.3 | 1173058.500 | -112837.677 |
| 6 | -2488.268 | -3224.716 | -15781.298 | 3448.4617 | -14538.567 |
| 7 | 367.284 | 340.318 | -8105.111 | 1.7443 | -79.692 |
| 8 | 16476.666 | 17693.488 | 2971.8566 | 5299.8927 | -969.657 |
| 9 | -23.060 | .000 | .0000 | -69.4778 | 31.1394 |
| 10 | 1.727 | .000 | .0000 | 2101.4949 | .0000000 |
| 11 | 28.676 | 16667.540 | 7.0352 | .0000 | .0002 |
| 12 | 9.9835 | .0606 | .0000 | .0000 | 722.1202 |
| 13 | 3738096.6 | 3768992.3 | 3360155.4 | 1693673.4 | 7718008.3 |
| 14 | 72.6368 | 71.9105 | 57.7608 | 254.9361 | 275.4655 |
| 15 | 4.1927 | 4.0737 | 5.7576 | 18.5377 | -6.0615 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 455.0000 | 600427.9200 | 3724582.7000 | 1.2852 | 78.9746 |
| 2 | 16827.8980 | 18148.6990 | 34.432 | 1.1623 | 79.7830 |
| 3 | 260568.5 | 141130.6 | -7255275.000 | 1114614.000 | -3515739.400 |
| 4 | 43298.6 | 172868.1 | 16944356.0 | -2371.160 | -14831.914 |
| 5 | 3810605.3 | 4419842.8 | 11082471.5 | 1199687.300 | -117762.905 |
| 6 | -2605.162 | -3356.206 | -15887.691 | 3453.8121 | -14687.611 |
| 7 | 375.664 | 338.657 | -8262.322 | 1.6683 | -81.104 |
| 8 | 16620.775 | 17832.457 | 2947.9838 | 5351.6622 | -1000.536 |
| 9 | -23.683 | .000 | .0000 | -69.2225 | 31.1825 |
| 10 | 1.700 | .000 | .0000 | 2106.9144 | .0000000 |
| 11 | 29.103 | 16827.898 | 7.0915 | .0000 | .0002 |
| 12 | 10.2066 | .0599 | .0000 | .0000 | 723.2778 |
| 13 | 3819749.1 | 3850638.0 | 3438267.5 | 1618067.2 | 7637739.7 |
| 14 | 72.6509 | 71.9401 | 58.1660 | 254.5829 | 275.5069 |
| 15 | 3.9115 | 3.7955 | 5.4476 | 19.7380 | -5.8883 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 460.0000 | 602253.3500 | 3806742.8000 | 1.1890 | 79.1191 |
| 2 | 16991.2420 | 18312.1840 | 34.845 | 1.0742 | 79.9097 |
| 3 | 247246.0 | 124016.1 | -7334978.500 | 1131894.900 | -3589549.800 |
| 4 | 45193.5 | 174552.5 | 16902640.0 | -2364.456 | -15240.984 |
| 5 | 3894074.0 | 4509356.5 | 11097152.4 | 1226576.600 | -122844.082 |
| 6 | -2724.464 | -3490.278 | -15994.767 | 3458.3274 | -14836.497 |
| 7 | 382.387 | 335.171 | -8423.086 | 1.0394 | -82.526 |
| 8 | 16767.033 | 17973.363 | 2924.9242 | 5404.2117 | -1032.037 |
| 9 | -24.046 | .000 | .0000 | -68.9645 | 31.2254 |
| 10 | 1.679 | .000 | .0000 | 2111.9765 | .0000000 |
| 11 | 29.465 | 16991.242 | 7.1497 | .0000 | .0002 |
| 12 | 10.4317 | .0594 | .0000 | .0000 | 724.3590 |
| 13 | 3902176.8 | 3933058.6 | 3517284.5 | 1542373.8 | 7556637.9 |
| 14 | 72.6648 | 71.9689 | 58.5567 | 254.1843 | 275.5495 |
| 15 | 3.6328 | 3.5196 | 5.1408 | 21.0520 | -5.7132 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 465.0000 | 603955.4600 | 3889699.6000 | 1.0971 | 79.2692 |
| 2 | 17157.3740 | 18478.4600 | 35.268 | .9900 | 80.0419 |
| 3 | 233322.3 | 106225.9 | -7415221.800 | 1149196.600 | -3664104.200 |
| 4 | 47124.8 | 176221.9 | 16860114.0 | -2360.130 | -15657.196 |
| 5 | 3978278.9 | 4599579.5 | 11111714.8 | 1253730.600 | -128084.329 |
| 6 | -2845.313 | -3626.098 | -16103.721 | 3462.2515 | -14985.224 |
| 7 | 390.429 | 332.842 | -8585.477 | .7666 | -83.961 |
| 8 | 16915.296 | 18116.130 | 2900.5670 | 5457.5201 | -1064.166 |
| 9 | -24.278 | .000 | .0000 | -68.7037 | 31.2682 |
| 10 | 1.662 | .000 | .0000 | 2116.6908 | .0000000 |
| 11 | 29.816 | 17157.374 | 7.2096 | .0000 | .0002 |
| 12 | 10.6591 | .0590 | .0000 | .0000 | 725.3660 |
| 13 | 3985393.7 | 4016267.8 | 3597213.8 | 1466705.7 | 7474689.7 |
| 14 | 72.6786 | 71.9971 | 58.9338 | 253.7311 | 275.5933 |
| 15 | 3.3563 | 3.2459 | 4.8371 | 22.4978 | -5.5361 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 470.0000 | 605540.9100 | 3973464.4000 | 1.0122 | 79.4242 |
| 2 | 17325.5970 | 18646.8270 | 35.720 | .9122 | 80.1789 |
| 3 | 218791.7 | 87753.7 | -7496013.600 | 1166517.000 | -3739401.800 |
| 4 | 49100.0 | 177882.9 | 16816775.0 | -2356.167 | -16080.608 |
| 5 | 4063228.7 | 4690519.4 | 11126152.3 | 1281152.600 | -133486.800 |
| 6 | -2966.819 | -3762.760 | -16214.132 | 3465.8896 | -15133.789 |
| 7 | 399.582 | 331.478 | -8748.624 | .7915 | -85.406 |
| 8 | 17065.012 | 18260.229 | 2875.3618 | 5511.4274 | -1096.928 |
| 9 | -24.344 | .000 | .0000 | -68.4402 | 31.3107 |
| 10 | 1.643 | .000 | .0000 | 2121.0743 | .0000000 |
| 11 | 30.178 | 17325.597 | 7.2709 | .0000 | .0002 |
| 12 | 10.8886 | .0586 | .0000 | .0000 | 726.3023 |
| 13 | 4069411.2 | 4100277.0 | 3678059.2 | 1391210.3 | 7391885.1 |
| 14 | 72.6922 | 72.0248 | 59.2980 | 253.2112 | 275.6382 |
| 15 | 3.0820 | 2.9743 | 4.5364 | 24.0973 | -5.3567 |

TABLE AP 3-2 (Sheet 25 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 475.0000 | 607018.7800 | 4058049.0000 | .9355 | 79.5776 |
| 2 | 17496.0410 | 18817.3910 | 36.124 | .8419 | 80.3146 |
| 3 | 203652.5 | 68596.5 | -7577360.300 | 1183854.900 | -3815441.800 |
| 4 | 51119.5 | 179535.2 | 16772615.9 | -2352.649 | -16511.274 |
| 5 | 4148931.9 | 4782184.4 | 11140465.4 | 1308846.000 | -139054.670 |
| 6 | -3088.646 | -3899.919 | -16325.513 | 3469.3158 | -15282.189 |
| 7 | 407.903 | 329.135 | -8913.069 | .5213 | -86.862 |
| 8 | 17216.426 | 18405.885 | 2851.1578 | 5566.0032 | -1130.327 |
| 9 | -24.355 | .000 | .0000 | -68.1738 | 31.3531 |
| 10 | 1.623 | .000 | .0000 | 2125.1559 | .0000000 |
| 11 | 30.484 | 17496.041 | 7.3336 | .0000 | .0002 |
| 12 | 11.1204 | .0583 | .0000 | .0000 | 727.1740 |
| 13 | 4154241.5 | 4185098.6 | 3759827.8 | 1316073.4 | 7308215.9 |
| 14 | 72.7058 | 72.0519 | 59.6501 | 252.6091 | 275.6844 |
| 15 | 2.8099 | 2.7048 | 4.2387 | 25.8772 | -5.1751 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 480.0000 | 608400.4000 | 4143461.4000 | .8681 | 79.7291 |
| 2 | 17668.3630 | 18989.8100 | 36.622 | .7801 | 80.4487 |
| 3 | 187904.3 | 48753.3 | -7659265.100 | 1201209.600 | -3892223.400 |
| 4 | 53177.1 | 181172.1 | 16727632.0 | -2351.623 | -16949.251 |
| 5 | 4235395.3 | 4874580.4 | 11154661.5 | 1336813.600 | -144791.150 |
| 6 | -3210.410 | -4037.183 | -16437.637 | 3472.6597 | -15430.423 |
| 7 | 415.235 | 325.663 | -9078.452 | -.0897 | -88.330 |
| 8 | 17369.282 | 18552.844 | 2828.2014 | 5621.1730 | -1164.371 |
| 9 | -24.308 | .000 | .0000 | -67.9046 | 31.3953 |
| 10 | 1.605 | .000 | .0000 | 2128.9676 | .0000000 |
| 11 | 30.878 | 17668.364 | 7.3975 | .0000 | .0002 |
| 12 | 11.3545 | .0581 | .0000 | .0000 | 727.9882 |
| 13 | 4239894.8 | 4270742.7 | 3842525.9 | 1241533.5 | 7223677.1 |
| 14 | 72.7193 | 72.0785 | 59.9904 | 251.9044 | 275.7320 |
| 15 | 2.5401 | 2.4373 | 3.9441 | 27.8695 | -4.9910 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 485.0000 | 609699.8800 | 4229713.3000 | .8112 | 79.8859 |
| 2 | 17842.9190 | 19164.4640 | 36.742 | .7281 | 80.5879 |
| 3 | 171548.4 | 28224.2 | -7741736.200 | 1218581.200 | -3969745.700 |
| 4 | 55274.4 | 182794.2 | 16681821.2 | -2352.843 | -17394.593 |
| 5 | 4322628.3 | 4967716.3 | 11168742.2 | 1365059.200 | -150699.470 |
| 6 | -3331.783 | -4174.259 | -16551.790 | 3476.0085 | -15578.487 |
| 7 | 423.797 | 323.275 | -9243.781 | -.3668 | -89.809 |
| 8 | 17523.965 | 18701.545 | 2804.9009 | 5677.0711 | -1199.063 |
| 9 | -24.223 | .000 | .0000 | -67.6324 | 31.4372 |
| 10 | 1.588 | .000 | .0000 | 2132.5485 | .0000000 |
| 11 | 30.888 | 17842.919 | 7.4628 | .0000 | .0002 |
| 12 | 11.5909 | .0579 | .0000 | .0000 | 728.7531 |
| 13 | 4326384.0 | 4357222.2 | 3926161.6 | 1167892.4 | 7138261.5 |
| 14 | 72.7325 | 72.1045 | 60.3196 | 251.0692 | 275.7810 |
| 15 | 2.2725 | 2.1720 | 3.6525 | 30.1130 | -4.8041 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 490.0000 | 610930.1000 | 4316807.3000 | .7631 | 80.0442 |
| 2 | 18016.1040 | 19337.7410 | 36.227 | .6841 | 80.7290 |
| 3 | 154587.1 | 7011.2 | -7824775.700 | 1235969.800 | -4048008.000 |
| 4 | 57415.4 | 184405.0 | 16635186.1 | -2355.236 | -17847.355 |
| 5 | 4410632.1 | 5061592.8 | 11182705.8 | 1393583.700 | -156782.870 |
| 6 | -3452.535 | -4310.800 | -16664.325 | 3479.4680 | -15726.377 |
| 7 | 432.384 | 320.833 | -9408.101 | -.6574 | -91.298 |
| 8 | 17676.908 | 18848.405 | 2781.4036 | 5732.6078 | -1234.409 |
| 9 | -24.116 | .000 | .0000 | -67.3574 | 31.4790 |
| 10 | 1.578 | .000 | .0000 | 2135.9356 | .0000000 |
| 11 | 30.257 | 18016.104 | 7.5277 | .0000 | .0002 |
| 12 | 11.8295 | .0578 | .0000 | .0000 | 729.4766 |
| 13 | 4413713.6 | 4444541.6 | 4010734.0 | 1095544.8 | 7051969.5 |
| 14 | 72.7457 | 72.1301 | 60.6383 | 250.0641 | 275.8314 |
| 15 | 2.0072 | 1.9089 | 3.3640 | 32.6539 | -4.6144 |

S-II EMR SHIFT (GUIDANCE SENSED)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 493.7000 | 611801.9300 | 4381791.4000 | .7313 | 80.1597 |
| 2 | 18141.7470 | 19463.4380 | 35.347 | .6551 | 80.8321 |
| 3 | 141647.7 | -9125.5 | -7886581.600 | 1248848.600 | -4106397.700 |
| 4 | 59025.5 | 185587.2 | 16600148.5 | -2358.514 | -18187.208 |
| 5 | 4476241.8 | 5131528.6 | 11192963.3 | 1416869.300 | -161399.250 |
| 6 | -3541.732 | -4411.670 | -16744.635 | 3482.0452 | -15835.702 |
| 7 | 437.828 | 318.091 | -9529.031 | -1.1548 | -92.407 |
| 8 | 17787.282 | 18954.194 | 2764.0929 | 5772.9537 | -1260.990 |
| 9 | -24.032 | .000 | .0000 | -67.1920 | 31.5097 |
| 10 | 1.571 | .000 | .0000 | 2138.3344 | .0000000 |
| 11 | 29.287 | 18141.747 | 7.5749 | .0000 | .0002 |
| 12 | 12.0076 | .0577 | .0000 | .0000 | 729.9888 |
| 13 | 4478871.2 | 4509691.4 | 4073911.9 | 1043137.4 | 6987559.2 |
| 14 | 72.7554 | 72.1487 | 60.8675 | 249.1791 | 275.8697 |
| 15 | 1.8123 | 1.7156 | 3.1526 | 34.7570 | -4.4721 |

TABLE AP 3-2 (Sheet 26 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 495.0000 | 612101.1000 | 4404729.6000 | .7206 | 80.2901 |
| 2 | 18184.9860 | 19506.6940 | 35.019 | .6454 | 80.8682 |
| 3 | 137023.1 | -14883.6 | -7908366.900 | 1253375.900 | -4127009.200 |
| 4 | 59595.8 | 186000.0 | 16587732.1 | -2360.157 | -18307.593 |
| 5 | 4499390.1 | 5156192.8 | 11196552.1 | 1422383.300 | -163044.660 |
| 6 | -3573.011 | -4447.036 | -16771.918 | 3482.9563 | -15874.091 |
| 7 | 439.605 | 316.995 | -9571.206 | -1.3596 | -92.799 |
| 8 | 17825.096 | 18990.380 | 2757.8907 | 5786.8564 | -1270.415 |
| 9 | -23.991 | .000 | .0000 | -67.0794 | 31.5204 |
| 10 | 1.568 | .000 | .0000 | 2139.1569 | .0000000 |
| 11 | 28.926 | 18184.986 | 7.5911 | .0000 | .0002 |
| 12 | 12.0705 | .0576 | .0000 | .0000 | 730.1645 |
| 13 | 4501870.4 | 4532687.7 | 4096227.6 | 1025004.7 | 6964819.0 |
| 14 | 72.7588 | 72.1551 | 60.9467 | 248.8335 | 275.8834 |
| 15 | 1.7442 | 1.6480 | 3.0787 | 35.5460 | -4.4217 |
| | | | | | |
| 1 | 500.0000 | 613220.5900 | 4493453.0000 | .6852 | 80.3573 |
| 2 | 18347.8690 | 19669.6420 | 34.088 | .6131 | 81.0092 |
| 3 | 118859.2 | -37456.9 | -7992480.500 | 1270800.100 | -4206748.600 |
| 4 | 61811.0 | 187574.6 | 16539469.5 | -2369.042 | -18775.360 |
| 5 | 4588872.5 | 5251485.9 | 11210278.9 | 1451449.400 | -169488.140 |
| 6 | -3692.313 | -4582.030 | -16873.802 | 3486.7887 | -16021.625 |
| 7 | 446.676 | 313.024 | -9731.314 | -2.1196 | -94.310 |
| 8 | 17966.958 | 19125.948 | 2733.3477 | 5839.3548 | -1307.086 |
| 9 | -23.740 | .000 | .0000 | -66.7987 | 31.5616 |
| 10 | 1.559 | .000 | .0000 | 2142.2324 | .0000000 |
| 11 | 27.858 | 18347.869 | 7.6523 | .0000 | .0002 |
| 12 | 12.3136 | .0575 | .0000 | .0000 | 730.8215 |
| 13 | 4590827.5 | 4621634.0 | 4182613.0 | 956935.0 | 6876839.0 |
| 14 | 72.7716 | 72.1796 | 61.2453 | 247.2950 | 275.9371 |
| 15 | 1.4836 | 1.3894 | 2.7965 | 38.8498 | -4.2258 |
| | | | | | |
| 1 | 505.0000 | 614299.6800 | 4582952.2000 | .6594 | 80.5196 |
| 2 | 18506.7300 | 19828.5770 | 33.765 | .5898 | 81.1552 |
| 3 | 100102.3 | -60701.6 | -8077094.200 | 1288244.400 | -4287225.200 |
| 4 | 64064.5 | 189132.2 | 16490414.3 | -2380.759 | -19250.707 |
| 5 | 4679052.2 | 5347444.6 | 11223878.7 | 1480774.800 | -176116.650 |
| 6 | -3809.870 | -4715.281 | -16972.475 | 3491.0858 | -16168.975 |
| 7 | 454.806 | 310.095 | -9888.195 | -2.5485 | -95.831 |
| 8 | 18104.616 | 19257.271 | 2707.6157 | 5890.7630 | -1344.426 |
| 9 | -23.255 | .000 | .0000 | -66.5153 | 31.6025 |
| 10 | 1.549 | .000 | .0000 | 2145.1946 | .0000000 |
| 11 | 27.369 | 18506.730 | 7.7118 | .0000 | .0002 |
| 12 | 12.5589 | .0574 | .0000 | .0000 | 731.4540 |
| 13 | 4680561.1 | 4711356.0 | 4269862.4 | 892176.3 | 6788057.8 |
| 14 | 72.7844 | 72.2037 | 61.5344 | 245.3212 | 275.9925 |
| 15 | 1.2255 | 1.1332 | 2.5176 | 42.6301 | -4.0267 |
| | | | | | |
| 1 | 510.0000 | 615357.1600 | 4673215.9000 | .6486 | 80.6832 |
| 2 | 18664.1410 | 19986.0540 | 33.725 | .5805 | 81.3027 |
| 3 | 80764.3 | -84606.0 | -8162198.500 | 1305711.900 | -4368438.000 |
| 4 | 66358.7 | 190675.0 | 16440581.5 | -2394.655 | -19733.691 |
| 5 | 4769916.3 | 5444056.2 | 11237352.3 | 1510356.700 | -182933.530 |
| 6 | -3924.389 | -4845.577 | -17070.395 | 3496.2266 | -16316.137 |
| 7 | 462.875 | 307.052 | -10042.176 | -3.0090 | -97.364 |
| 8 | 18241.027 | 19387.329 | 2683.0517 | 5941.9917 | -1382.440 |
| 9 | -22.590 | .000 | .0000 | -66.2292 | 31.6430 |
| 10 | 1.539 | .000 | .0000 | 2148.0952 | .0000000 |
| 11 | 27.134 | 18664.141 | 7.7708 | .0000 | .0002 |
| 12 | 12.8063 | .0573 | .0000 | .0000 | 732.0738 |
| 13 | 4771061.4 | 4801844.4 | 4357962.3 | 831786.7 | 6698493.2 |
| 14 | 72.7970 | 72.2272 | 61.8144 | 242.7058 | 276.0496 |
| 15 | .9699 | .8795 | 2.2421 | 46.9477 | -3.8241 |
| | | | | | |
| 1 | 515.0000 | 616417.8700 | 4764236.0000 | .6557 | 80.8461 |
| 2 | 18820.0840 | 20142.0530 | 33.782 | .5879 | 81.4499 |
| 3 | 60861.1 | -109154.8 | -8247790.600 | 1323207.300 | -4450386.200 |
| 4 | 68691.7 | 192201.1 | 16389985.1 | -2411.347 | -20224.362 |
| 5 | 4861460.0 | 5541315.5 | 11250706.9 | 1540194.300 | -189942.180 |
| 6 | -4034.822 | -4971.871 | -17167.761 | 3502.5287 | -16463.107 |
| 7 | 470.269 | 303.288 | -10192.683 | -3.6860 | -98.906 |
| 8 | 18376.469 | 19516.426 | 2660.7450 | 5993.1339 | -1421.133 |
| 9 | -21.319 | .000 | .0000 | -65.9404 | 31.6831 |
| 10 | 1.529 | .000 | .0000 | 2151.0024 | .0000000 |
| 11 | 26.880 | 18820.084 | 7.8291 | .0000 | .0002 |
| 12 | 13.0557 | .0571 | .0000 | .0000 | 732.6947 |
| 13 | 4862326.1 | 4893096.8 | 4446907.6 | 777085.6 | 6608158.3 |
| 14 | 72.8094 | 72.2504 | 62.0857 | 239.0964 | 276.1085 |
| 15 | .7172 | .6285 | 1.9701 | 51.8391 | -3.6176 |

TABLE AP 3-2 (Sheet 27 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 520.0000 | 617521.6100 | 4856000.0000 | .7311 | 81.0108 |
| 2 | 18971.2870 | 20293.3070 | 34.330 | .6310 | 81.5990 |
| 3 | 40425.1 | -134315.8 | -8333867.200 | 1340739.900 | -4533068.800 |
| 4 | 71061.8 | 193708.4 | 16338654.6 | -2431.381 | -20722.771 |
| 5 | 4953675.1 | 5639214.7 | 11263957.8 | 1570286.500 | -197146.010 |
| 6 | -4133.737 | -5086.687 | -17264.733 | 3512.2690 | -16609.880 |
| 7 | 477.677 | 299.603 | -10332.506 | -4.3358 | -100.459 |
| 8 | 18509.289 | 19643.172 | 2643.2298 | 6043.7676 | -1460.508 |
| 9 | -19.265 | .000 | .0000 | -65.6490 | 31.7229 |
| 10 | 1.529 | .000 | .0000 | 2154.0253 | .0000000 |
| 11 | 26.903 | 18971.287 | 7.8851 | .0000 | .0002 |
| 12 | 13.3072 | .0570 | .0000 | .0000 | 733.3402 |
| 13 | 4954349.6 | 4985107.8 | 4536689.8 | 729688.4 | 6517077.7 |
| 14 | 72.8218 | 72.2731 | 62.3486 | 233.8519 | 276.1694 |
| 15 | .4675 | .3805 | 1.7020 | 57.2719 | -3.4069 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 525.0000 | 618732.6500 | 4948491.6000 | .7578 | 81.1774 |
| 2 | 19124.0470 | 20446.1200 | 34.488 | .6448 | 81.7501 |
| 3 | 19512.6 | -160033.1 | -8420434.500 | 1358326.400 | -4616484.600 |
| 4 | 73469.2 | 195197.5 | 16286639.1 | -2454.591 | -21228.968 |
| 5 | 5046557.3 | 5737751.1 | 11277130.2 | 1600633.500 | -204548.420 |
| 6 | -4230.945 | -5199.974 | -17363.525 | 3522.4137 | -16756.450 |
| 7 | 485.327 | 296.047 | -10471.476 | -4.9435 | -102.022 |
| 8 | 18643.839 | 19771.609 | 2626.7992 | 6095.1261 | -1500.570 |
| 9 | -19.207 | .000 | .0000 | -65.3551 | 31.7623 |
| 10 | 1.536 | .000 | .0000 | 2157.3377 | .0000000 |
| 11 | 26.945 | 19124.047 | 7.9409 | .0000 | .0002 |
| 12 | 13.5607 | .0568 | .0000 | .0000 | 734.0477 |
| 13 | 5047129.7 | 5077874.9 | 4627303.8 | 691470.7 | 6425283.1 |
| 14 | 72.8340 | 72.2953 | 62.6034 | 225.7324 | 276.2324 |
| 15 | .2215 | .1361 | 1.4385 | 63.0524 | -3.1911 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 530.0000 | 620058.3500 | 5041723.3000 | .8234 | 81.3448 |
| 2 | 19278.4910 | 20600.6200 | 34.801 | .7471 | 81.9021 |
| 3 | -1881.4 | -186312.8 | -8507500.700 | 1375964.700 | -4700632.900 |
| 4 | 75914.9 | 196668.5 | 16233930.7 | -2480.912 | -21743.007 |
| 5 | 5140117.3 | 5836934.5 | 11290223.9 | 1631239.300 | -212152.860 |
| 6 | -4327.243 | -5312.525 | -17463.830 | 3532.7187 | -16902.810 |
| 7 | 492.851 | 292.240 | -10610.416 | -5.6243 | -103.595 |
| 8 | 18780.104 | 19901.690 | 2611.3749 | 6147.1961 | -1541.322 |
| 9 | -19.164 | .000 | .0000 | -65.0585 | 31.8012 |
| 10 | 1.543 | .000 | .0000 | 2160.9604 | .0000000 |
| 11 | 27.150 | 19278.491 | 7.9966 | .0000 | .0002 |
| 12 | 13.8162 | .0565 | .0000 | .0000 | 734.8216 |
| 13 | 5140678.0 | 5171409.8 | 4718757.9 | 664339.3 | 6332766.3 |
| 14 | 72.8461 | 72.3172 | 62.8506 | 212.3157 | 276.2975 |
| 15 | -.0210 | -.1049 | 1.1792 | 68.6232 | -2.9701 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 535.0000 | 621509.9200 | 5135695.4000 | .8960 | 81.5139 |
| 2 | 19432.6050 | 20754.7930 | 34.996 | .8158 | 82.0559 |
| 3 | -23756.1 | -213154.9 | -8595067.300 | 1393654.600 | -4785512.400 |
| 4 | 78398.0 | 198120.1 | 16180528.4 | -2510.773 | -22264.934 |
| 5 | 5234357.6 | 5936767.1 | 11303241.0 | 1662105.600 | -219962.810 |
| 6 | -4422.812 | -5424.457 | -17563.809 | 3543.1471 | -17048.956 |
| 7 | 500.452 | 288.425 | -10748.683 | -6.3047 | -105.178 |
| 8 | 18915.983 | 20031.314 | 2596.1309 | 6199.3383 | -1582.768 |
| 9 | -19.112 | .000 | .0000 | -64.7593 | 31.8397 |
| 10 | 1.547 | .000 | .0000 | 2164.9234 | .0000000 |
| 11 | 27.231 | 19432.605 | 8.0513 | .0000 | .0002 |
| 12 | 14.0737 | .0561 | .0000 | .0000 | 735.6683 |
| 13 | 5234998.3 | 5265716.5 | 4811052.6 | 650026.7 | 6239528.1 |
| 14 | 72.8580 | 72.3386 | 63.0905 | 190.0445 | 276.3648 |
| 15 | -.2600 | -.3425 | .9241 | 72.6880 | -2.7435 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 540.0000 | 623100.8800 | 5230411.3000 | .9735 | 81.6855 |
| 2 | 19588.0450 | 20910.3000 | 35.354 | .8893 | 82.2122 |
| 3 | -46109.5 | -240557.7 | -8683135.900 | 1411396.000 | -4871122.100 |
| 4 | 80920.4 | 199553.4 | 16126433.0 | -2543.751 | -22794.799 |
| 5 | 5329279.8 | 6037250.2 | 11316180.8 | 1693233.800 | -227981.720 |
| 6 | -4518.603 | -5536.772 | -17664.751 | 3553.3911 | -17194.880 |
| 7 | 508.464 | 284.898 | -10887.474 | -6.8946 | -106.770 |
| 8 | 19052.958 | 20161.936 | 2580.7340 | 6251.9974 | -1624.912 |
| 9 | -19.062 | .000 | .0000 | -64.4573 | 31.8777 |
| 10 | 1.544 | .000 | .0000 | 2169.2609 | .0000000 |
| 11 | 27.480 | 19588.045 | 8.1055 | .0000 | .0002 |
| 12 | 14.3333 | .0557 | .0000 | .0000 | 736.5948 |
| 13 | 5330093.4 | 5360797.6 | 4904187.8 | 649729.2 | 6145572.1 |
| 14 | 72.8698 | 72.3597 | 63.3233 | 160.3966 | 276.4346 |
| 15 | -.4957 | -.5768 | .6732 | 73.2700 | -2.5109 |

TABLE AP 3-2 (Sheet 28 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 545.0000 | 624843.3300 | 5325876.0000 | 1.0579 | 81.8573 |
| 2 | 19744.7370 | 21067.0590 | 35.731 | .9693 | 82.3688 |
| 3 | -68941.2 | -268521.9 | -8771711.600 | 1429188.500 | -4957460.800 |
| 4 | 83481.9 | 200968.1 | 16071642.6 | -2580.037 | -23332.649 |
| 5 | 5424890.4 | 6138389.6 | 11329045.9 | 1724626.900 | -236213.100 |
| 6 | -4614.006 | -5648.857 | -17766.537 | 3563.6356 | -17340.575 |
| 7 | 516.094 | 280.867 | -11026.605 | -7.6350 | -108.372 |
| 8 | 19191.124 | 20293.658 | 2566.1657 | 6305.2052 | -1667.756 |
| 9 | -19.011 | .000 | .0000 | -64.1531 | 31.9153 |
| 10 | 1.519 | .000 | .0000 | 2172.5021 | .0000000 |
| 11 | 27.747 | 19744.737 | 8.1618 | .0000 | .0002 |
| 12 | 14.5949 | .0553 | .0000 | .0000 | 737.3613 |
| 13 | 5425970.6 | 5456660.3 | 4998167.9 | 663809.8 | 6050896.6 |
| 14 | 72.8816 | 72.3804 | 63.5495 | 135.3205 | 276.5069 |
| 15 | -.7280 | -.8079 | .4263 | 69.9505 | -2.2720 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 550.0000 | 626752.3500 | 5422093.6000 | 1.1494 | 82.0302 |
| 2 | 19902.7750 | 21225.1690 | 36.095 | 1.0560 | 82.5267 |
| 3 | -92248.2 | -297045.3 | -8860799.000 | 1447032.500 | -5044527.400 |
| 4 | 86081.4 | 202361.9 | 16016156.4 | -2620.146 | -23878.530 |
| 5 | 5521194.9 | 6240190.5 | 11341839.7 | 1756287.400 | -244660.460 |
| 6 | -4708.897 | -5760.597 | -17869.439 | 3573.9133 | -17486.034 |
| 7 | 523.672 | 276.663 | -11165.887 | -8.4253 | -109.983 |
| 8 | 19330.611 | 20426.621 | 2552.2438 | 6359.0056 | -1711.305 |
| 9 | -18.962 | .000 | .0000 | -63.8460 | 31.9523 |
| 10 | 1.538 | .000 | .0000 | 2175.7636 | .0000000 |
| 11 | 28.000 | 19902.775 | 8.2183 | .0000 | .0002 |
| 12 | 14.8586 | .0548 | .0000 | .0000 | 738.1537 |
| 13 | 5522636.2 | 5553311.5 | 5092997.0 | 691729.3 | 5955503.1 |
| 14 | 72.8932 | 72.4007 | 63.7692 | 119.7242 | 276.5819 |
| 15 | -.9571 | -1.0357 | .1834 | 64.5576 | -2.0263 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 555.0000 | 628841.3000 | 5519068.2000 | 1.2471 | 82.2052 |
| 2 | 20061.9250 | 21384.3960 | 36.464 | 1.1487 | 82.6868 |
| 3 | -116029.2 | -326127.3 | -8950402.900 | 1464927.700 | -5132320.700 |
| 4 | 88719.1 | 203734.9 | 15959973.2 | -2664.191 | -24432.492 |
| 5 | 5618199.3 | 6342658.5 | 11354564.7 | 1788218.100 | -253327.330 |
| 6 | -4803.545 | -5872.255 | -17973.261 | 3584.1419 | -17631.251 |
| 7 | 531.522 | 272.610 | -11305.326 | -9.1668 | -111.603 |
| 8 | 19471.114 | 20560.515 | 2538.4878 | 6413.3058 | -1755.561 |
| 9 | -18.919 | .000 | .0000 | -63.5362 | 31.9889 |
| 10 | 1.595 | .000 | .0000 | 2179.3260 | .0000000 |
| 11 | 28.259 | 20061.925 | 8.2743 | .0000 | .0002 |
| 12 | 15.1243 | .0542 | .0000 | .0000 | 739.0197 |
| 13 | 5620097.4 | 5650757.8 | 5188679.7 | 732229.8 | 5859391.5 |
| 14 | 72.9046 | 72.4207 | 63.9827 | 110.4053 | 276.6598 |
| 15 | -1.1830 | -1.2605 | -.0557 | 58.6637 | -1.7732 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 560.0000 | 631124.2800 | 5616806.0000 | 1.3516 | 82.3824 |
| 2 | 20222.5580 | 21545.1140 | 36.776 | 1.2478 | 82.8491 |
| 3 | -140282.8 | -353767.3 | -9040529.200 | 1482874.000 | -5220839.500 |
| 4 | 91397.1 | 205088.3 | 15903092.3 | -2711.712 | -24994.574 |
| 5 | 5715909.7 | 6445799.3 | 11367221.0 | 1820421.900 | -262217.260 |
| 6 | -4897.803 | -5983.701 | -18078.423 | 3594.3583 | -17776.217 |
| 7 | 539.662 | 268.720 | -11444.939 | -9.8558 | -113.232 |
| 8 | 19613.060 | 20695.774 | 2525.0668 | 6468.2388 | -1800.527 |
| 9 | -18.875 | .000 | .0000 | -63.2237 | 32.0249 |
| 10 | 1.606 | .000 | .0000 | 2183.2111 | .0000000 |
| 11 | 28.438 | 20222.558 | 8.3299 | .0000 | .0002 |
| 12 | 15.3922 | .0535 | .0000 | .0000 | 739.9652 |
| 13 | 5718361.2 | 5749006.6 | 5285220.4 | 783671.6 | 5762562.3 |
| 14 | 72.9160 | 72.4404 | 64.1903 | 104.5031 | 276.7407 |
| 15 | -1.4057 | -1.4821 | -.2910 | 53.0051 | -1.5124 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 565.0000 | 633616.1100 | 5715309.8000 | 1.4620 | 82.5608 |
| 2 | 20384.0140 | 21706.6580 | 36.940 | 1.3525 | 83.0127 |
| 3 | -165006.9 | -385964.2 | -9131183.000 | 1500871.300 | -5310082.500 |
| 4 | 94115.6 | 206421.8 | 15845512.7 | -2762.830 | -25564.826 |
| 5 | 5814332.2 | 6549616.4 | 11379811.6 | 1852901.500 | -271333.800 |
| 6 | -4991.790 | -6095.029 | -18184.149 | 3604.5326 | -17920.923 |
| 7 | 547.765 | 264.678 | -11584.712 | -10.5888 | -114.870 |
| 8 | 19755.758 | 20831.697 | 2912.0111 | 6523.5915 | -1846.208 |
| 9 | -18.829 | .000 | .0000 | -62.9086 | 32.0604 |
| 10 | 1.611 | .000 | .0000 | 2187.4416 | .0000000 |
| 11 | 28.505 | 20384.014 | 8.3847 | .0000 | .0002 |
| 12 | 15.6622 | .0527 | .0000 | .0000 | 740.9957 |
| 13 | 5817434.3 | 5848064.3 | 5382623.4 | 844349.8 | 5665017.5 |
| 14 | 72.9273 | 72.4598 | 64.3923 | 100.5092 | 276.8249 |
| 15 | -1.6254 | -1.7007 | -.5226 | 47.8628 | -1.2433 |

TABLE AP 3-2 (Sheet 29 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 570.0000 | 636329.8400 | 5814580.2000 | 1.5773 | 82.7404 |
| 2 | 20545.0280 | 21867.7680 | 36.924 | 1.4619 | 83.1777 |
| 3 | -190199.7 | -416716.9 | -9222364.900 | 1518919.400 | -5400048.300 |
| 4 | 96874.4 | 207734.6 | 15787234.9 | -2817.767 | -26143.288 |
| 5 | 5913467.8 | 6654116.5 | 11392337.5 | 1885658.300 | -280680.540 |
| 6 | -5085.541 | -6206.225 | -18289.243 | 3614.6656 | -18065.364 |
| 7 | 555.778 | 260.456 | -11724.246 | -11.3737 | -116.516 |
| 8 | 19897.904 | 20966.980 | 2498.9935 | 6578.9672 | -1892.604 |
| 9 | -18.797 | .000 | .0000 | -62.5907 | 32.0953 |
| 10 | 1.617 | .000 | .0000 | 2192.0374 | .0000000 |
| 11 | 28.371 | 20545.029 | 8.4382 | .0000 | .0002 |
| 12 | 15.9342 | .0519 | .0000 | .0000 | 742.1165 |
| 13 | 5917318.7 | 5947933.0 | 5480888.6 | 912693.0 | 5566763.2 |
| 14 | 72.9385 | 72.4788 | 64.5889 | 97.6534 | 276.9125 |
| 15 | -1.8420 | -1.9163 | -.7506 | 43.3093 | -.9653 |

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 575.0000 | 639275.5500 | 5914610.7000 | 1.6964 | 82.9217 |
| 2 | 20705.6420 | 22028.4810 | 36.942 | 1.5751 | 83.3445 |
| 3 | -215861.9 | -448026.3 | -9314069.500 | 1537017.800 | -5490735.600 |
| 4 | 99673.4 | 209026.2 | 15728259.8 | -2876.630 | -26730.002 |
| 5 | 6013311.7 | 6759288.5 | 11404797.3 | 1918691.600 | -290261.050 |
| 6 | -5179.364 | -6317.598 | -18393.671 | 3624.6607 | -18209.530 |
| 7 | 563.856 | 256.209 | -11863.731 | -12.1638 | -118.171 |
| 8 | 20039.457 | 21101.573 | 2485.7257 | 6634.3523 | -1939.720 |
| 9 | -18.772 | .000 | .0000 | -62.2701 | 32.1296 |
| 10 | 1.494 | .000 | .0000 | 2197.0113 | .0000000 |
| 11 | 28.273 | 20705.642 | 8.4903 | .0000 | .0002 |
| 12 | 16.2083 | .0509 | .0001 | .0000 | 743.3307 |
| 13 | 6018010.3 | 6048608.8 | 5580010.4 | 987358.0 | 5467810.7 |
| 14 | 72.9495 | 72.4976 | 64.7802 | 95.5203 | 277.0037 |
| 15 | -2.0556 | -2.1290 | -.9750 | 39.3243 | -.6778 |

S-II ENGINE CUTOFF SIGNAL - TB 4

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 576.2800 | 640066.8500 | 5940340.5000 | 1.7222 | 82.9684 |
| 2 | 20742.9620 | 22065.8320 | 36.939 | 1.5796 | 83.3876 |
| 3 | -222507.9 | -456132.0 | -9337629.000 | 1541658.700 | -5514067.400 |
| 4 | 100396.5 | 209353.5 | 15713049.5 | -2892.315 | -26881.533 |
| 5 | 6038984.6 | 6786319.8 | 11407975.6 | 1927192.500 | -292751.680 |
| 6 | -5204.335 | -6346.928 | -18416.405 | 3626.9550 | -18246.391 |
| 7 | 565.839 | 255.096 | -11898.852 | -12.3735 | -118.596 |
| 8 | 20071.502 | 21131.787 | 2480.8074 | 6647.2734 | -1951.898 |
| 9 | -18.758 | .000 | .0000 | -62.1876 | 32.1383 |
| 10 | 1.478 | .000 | .0000 | 2198.3454 | .0000000 |
| 11 | 28.238 | 20742.962 | 8.5018 | .0000 | .0002 |
| 12 | 16.2789 | .0507 | .0001 | .0000 | 743.6568 |
| 13 | 6043916.1 | 6074510.6 | 5605522.0 | 1007349.6 | 5442367.8 |
| 14 | 72.9524 | 72.5024 | 64.8284 | 95.0590 | 277.0277 |
| 15 | -2.1098 | -2.1830 | -1.0319 | 38.3890 | -.6026 |

S-II/S-IVB SEPARATION COMMAND

| | | | | | |
|----|------------|-------------|--------------|-------------|--------------|
| 1 | 577.0800 | 640569.5300 | 5956445.2000 | 1.7196 | 82.9986 |
| 2 | 20752.7320 | 22075.6370 | 8.890 | 1.5973 | 83.4157 |
| 3 | -226677.0 | -461216.4 | -9352369.600 | 1544560.900 | -5528673.800 |
| 4 | 100849.8 | 209557.4 | 15703520.5 | -2902.234 | -26976.516 |
| 5 | 6055052.4 | 6803235.3 | 11409959.5 | 1932514.300 | -294316.250 |
| 6 | -5223.150 | -6367.935 | -18416.654 | 3627.5726 | -18269.420 |
| 7 | 567.019 | 254.614 | -11918.423 | -12.4395 | -118.862 |
| 8 | 20076.680 | 21135.715 | 2472.2173 | 6650.7974 | -1959.533 |
| 9 | -25.793 | .000 | .0000 | -62.1360 | 32.1437 |
| 10 | 1.469 | .000 | .0000 | 2199.1924 | .0000000 |
| 11 | .976 | 20752.732 | 8.5035 | .0000 | .0002 |
| 12 | 16.3230 | .0505 | .0001 | .0000 | 743.8639 |
| 13 | 6060132.9 | 6090724.8 | 5621494.0 | 1020009.9 | 5426444.3 |
| 14 | 72.9541 | 72.5053 | 64.8583 | 94.7854 | 277.0428 |
| 15 | -2.1436 | -2.2166 | -1.0673 | 37.8211 | -.5553 |

S-IVB ENGINE START SIGNAL

| | | | | | |
|----|-----------|-------------|--------------|------------|--------------|
| 1 | 577.2680 | 128392.3510 | 1195064.3000 | .3429 | 16.6319 |
| 2 | 4157.8241 | 4422.8712 | .331 | .3185 | 16.7153 |
| 3 | -49853.2 | -92939.5 | -1875289.200 | 309756.100 | -1109199.700 |
| 4 | 20253.0 | 42006.0 | 3145173.2 | -582.485 | -5414.714 |
| 5 | 1214816.6 | 1364803.1 | 2286178.8 | 387738.050 | -59130.894 |
| 6 | -1048.659 | -1278.207 | -3688.765 | 726.7854 | -3662.674 |
| 7 | 113.723 | 50.978 | -2389.722 | -2.4941 | -23.842 |
| 8 | 4021.801 | 4233.838 | 494.0017 | 1332.5180 | -393.394 |
| 9 | -5.274 | .000 | .0000 | -12.4434 | 6.4405 |
| 10 | .293 | .000 | .0000 | .0401 | .0000000 |
| 11 | -1.253 | .000 | .0000 | .0000 | .0000 |
| 12 | 3.2749 | .0000 | .0000 | .0000 | .0000 |
| 13 | 1215850.3 | 1221979.1 | 1127943.9 | 205703.0 | 1085500.9 |
| 14 | 14.6164 | 14.5267 | 12.9974 | 18.9621 | 55.5067 |
| 15 | -.4330 | -.4476 | -.2175 | 7.5186 | -.1062 |

TABLE AP 3-2 (Sheet 30 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| S-11/5-IVB SEPARATION COMPLETE | | | | | |
|--|------------|-------------|--------------|-------------|--------------|
| 1 | 578.1060 | 641225.2400 | 5977133.3000 | 1.7005 | 83.0382 |
| 2 | 20753.7540 | 22076.7170 | 1.018 | 1.5794 | 83.4530 |
| 3 | -232041.3 | -467758.1 | -9371299.600 | 1548285.000 | -5547433.000 |
| 4 | 101433.2 | 209818.4 | 15691271.3 | -2914.998 | -27098.642 |
| 5 | 6075691.7 | 6824960.6 | 11412502.5 | 1939351.800 | -296331.760 |
| 6 | -5249.941 | -6397.080 | -18405.135 | 3627.6878 | -18298.943 |
| 7 | 568.501 | 254.194 | -11941.439 | -12.4634 | -119.203 |
| 8 | 20070.706 | 21128.044 | 2456.5316 | 6651.4524 | -1969.352 |
| 9 | -26.319 | .000 | .0000 | -62.0697 | 32.1506 |
| 10 | 1.456 | .000 | .0000 | .2000 | .0000000 |
| 11 | -6.920 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.3797 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6080967.0 | 6111555.5 | 5642015.6 | 1036431.7 | 5405991.8 |
| 14 | 72.9564 | 72.5091 | 64.8965 | 94.4496 | 277.0623 |
| 15 | -2.1869 | -2.2597 | -1.1126 | 37.1106 | -.4942 |
| | | | | | |
| 1 | 580.0000 | 642371.8900 | 6015240.6000 | 1.6618 | 83.1115 |
| 2 | 20753.4740 | 22076.5430 | 1.101 | 1.5433 | 83.5219 |
| 3 | -242035.0 | -479928.0 | -9406122.900 | 1555155.100 | -5582143.100 |
| 4 | 102512.7 | 210299.6 | 15668614.7 | -2938.502 | -27325.010 |
| 5 | 6113679.3 | 6864947.6 | 11417120.8 | 1951945.900 | -300078.950 |
| 6 | -5299.915 | -6451.301 | -18381.555 | 3627.7633 | -18353.412 |
| 7 | 571.283 | 253.514 | -11983.478 | -12.4785 | -119.834 |
| 8 | 20057.198 | 21111.377 | 2426.6154 | 6651.9213 | -1987.558 |
| 9 | -26.301 | .000 | .0000 | -61.9474 | 32.1632 |
| 10 | 1.447 | .000 | .0000 | .2000 | .0000000 |
| 11 | -6.880 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.4841 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6119326.9 | 6149909.3 | 5679806.3 | 1067067.7 | 5368304.3 |
| 14 | 72.9606 | 72.5161 | 64.9662 | 93.8737 | 277.0987 |
| 15 | -2.2668 | -2.3393 | -1.1964 | 35.8524 | -.3816 |
| | | | | | |
| GUIDANCE INITIATION-START ARTIFICIAL TAU | | | | | |
| 1 | 582.5000 | 643860.7100 | 6065566.5000 | 1.6263 | 83.2070 |
| 2 | 20765.0860 | 22088.2790 | 13.435 | 1.5102 | 83.6116 |
| 3 | -255363.6 | -496142.6 | -9452049.500 | 1564225.600 | -5628116.400 |
| 4 | 103945.4 | 210931.9 | 15638582.4 | -2969.835 | -27625.638 |
| 5 | 6163814.1 | 6917712.8 | 11423142.4 | 1968580.800 | -305078.040 |
| 6 | -5363.529 | -6520.983 | -18362.314 | 3628.4193 | -18425.246 |
| 7 | 574.821 | 252.232 | -12041.454 | -12.6149 | -120.668 |
| 8 | 20052.206 | 21102.258 | 2391.8471 | 6656.5148 | -2011.748 |
| 9 | -24.847 | .000 | .0000 | -61.7859 | 32.1797 |
| 10 | 1.440 | .000 | .0000 | .2000 | .0000000 |
| 11 | 5.318 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.6220 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6169977.1 | 6200551.4 | 5729716.6 | 1108289.6 | 5318529.4 |
| 14 | 72.9661 | 72.5253 | 65.0570 | 93.1877 | 277.1473 |
| 15 | -2.3720 | -2.4441 | -1.3067 | 34.2890 | -.2318 |
| | | | | | |
| 1 | 585.0000 | 645330.0300 | 6115948.9000 | 1.6117 | 83.2996 |
| 2 | 20801.0410 | 22124.3340 | 18.791 | 1.4969 | 83.6979 |
| 3 | -268849.6 | -512530.9 | -9497959.000 | 1573297.800 | -5674269.200 |
| 4 | 105386.3 | 211559.7 | 15608394.1 | -3001.910 | -27928.354 |
| 5 | 6213970.8 | 6970489.5 | 11429088.0 | 1985237.800 | -310137.850 |
| 6 | -5426.253 | -6590.690 | -18365.736 | 3629.0454 | -18497.008 |
| 7 | 577.950 | 250.005 | -12107.606 | -13.0385 | -121.505 |
| 8 | 20072.495 | 21118.393 | 2364.7056 | 6668.8609 | -2036.118 |
| 9 | -25.252 | .000 | .0000 | -61.6242 | 32.1960 |
| 10 | 1.443 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.679 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.7601 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6220676.6 | 6251242.8 | 5779689.0 | 1150346.4 | 5268695.5 |
| 14 | 72.9715 | 72.5343 | 65.1464 | 92.5734 | 277.1969 |
| 15 | -2.4770 | -2.5486 | -1.4166 | 32.8278 | -.0806 |
| | | | | | |
| S-IVB PU ACTIVATE ON | | | | | |
| 1 | 585.3000 | 645505.6400 | 6122000.5000 | 1.6095 | 83.3107 |
| 2 | 20805.9780 | 22129.2820 | 19.014 | 1.4948 | 83.7083 |
| 3 | -270478.5 | -514509.3 | -9503468.600 | 1574386.500 | -5679819.500 |
| 4 | 105559.8 | 211634.6 | 15604760.2 | -3005.824 | -27964.819 |
| 5 | 6219992.9 | 6976825.3 | 11429796.7 | 1987238.700 | -310749.110 |
| 6 | -5434.122 | -6599.417 | -18366.568 | 3629.0387 | -18505.614 |
| 7 | 578.330 | 249.727 | -12116.024 | -13.0929 | -121.605 |
| 8 | 20075.472 | 21120.855 | 2361.4279 | 6670.5065 | -2039.055 |
| 9 | -25.327 | .000 | .0000 | -61.6048 | 32.1979 |
| 10 | 1.443 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.900 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.7767 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6226765.7 | 6257330.8 | 5785691.7 | 1153447.1 | 5262710.0 |
| 14 | 72.9722 | 72.5354 | 65.1571 | 92.5060 | 277.2029 |
| 15 | -2.4896 | -2.5612 | -1.4297 | 32.6589 | -.0623 |

TABLE AP 3-2 (Sheet 31 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| S-IVB PU VALVE REACHES HARDOVER POSITION | | | | | |
|--|------------|-------------|--------------|-------------|--------------|
| 1 | 589.0000 | 647654.6200 | 6196759.9000 | 1.5847 | 83.4513 |
| 2 | 20872.4830 | 22195.9440 | 20.515 | 1.4721 | 83.8393 |
| 3 | -290765.1 | -539127.4 | -9571449.100 | 1587812.700 | -5748486.700 |
| 4 | 107709.7 | 212553.5 | 15559732.3 | -3055.132 | -28417.056 |
| 5 | 6294348.0 | 7059036.6 | 11438458.1 | 2011959.600 | -318360.900 |
| 6 | -5532.098 | -6708.203 | -18381.978 | 3628.1785 | -18611.676 |
| 7 | 584.438 | 247.562 | -12221.974 | -13.3740 | -122.847 |
| 8 | 20117.527 | 21156.529 | 2320.8243 | 6692.4842 | -2075.486 |
| 9 | -26.477 | .000 | .0000 | -61.3647 | 32.2216 |
| 10 | 2.437 | .000 | .0000 | .2000 | .0000000 |
| 11 | 12.326 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.9816 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6301980.8 | 6332533.6 | 5859854.7 | 1219251.2 | 5188764.9 |
| 14 | 72.9803 | 72.5487 | 65.2868 | 91.7136 | 277.2783 |
| 15 | -2.6445 | -2.7154 | -1.5917 | 30.6803 | .1650 |
| 1 | 590.0000 | 648231.3600 | 6217005.1000 | 1.5788 | 83.4916 |
| 2 | 20891.5770 | 22215.0850 | 20.688 | 1.4568 | 83.8768 |
| 3 | -296310.4 | -545850.3 | -9589833.000 | 1591440.700 | -5767112.700 |
| 4 | 108295.1 | 212800.9 | 15547494.7 | -3068.495 | -28540.072 |
| 5 | 6314471.7 | 7076198.5 | 11440773.0 | 2018655.200 | -320441.340 |
| 6 | -5558.687 | -6737.767 | -18387.382 | 3627.8962 | -18640.313 |
| 7 | 586.924 | 247.782 | -12250.754 | -13.2046 | -123.184 |
| 8 | 20129.941 | 21167.219 | 2309.3852 | 6698.7642 | -2085.401 |
| 9 | -26.799 | .000 | .0000 | -61.2996 | 32.2279 |
| 10 | 2.449 | .000 | .0000 | .2000 | .0000000 |
| 11 | 12.472 | .000 | .0000 | .0000 | .0000 |
| 12 | 17.0371 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6322347.5 | 6352897.1 | 5879941.4 | 1236765.1 | 5168739.4 |
| 14 | 72.9825 | 72.5523 | 65.3214 | 91.5190 | 277.2990 |
| 15 | -2.6863 | -2.7570 | -1.6354 | 30.1770 | .2271 |
| 1 | 595.0000 | 651081.1700 | 6318514.0000 | 1.5359 | 83.6937 |
| 2 | 20990.2480 | 22313.9940 | 21.175 | 1.4273 | 84.0652 |
| 3 | -324447.2 | -579919.9 | -9681836.500 | 1609573.100 | -5860671.900 |
| 4 | 111261.9 | 214043.3 | 15485865.2 | -3132.172 | -29160.203 |
| 5 | 6415281.2 | 7182172.2 | 11452169.7 | 2052229.000 | -330993.060 |
| 6 | -5698.040 | -6892.065 | -18414.179 | 3624.4562 | -18783.326 |
| 7 | 599.477 | 248.861 | -12400.321 | -12.3614 | -124.870 |
| 8 | 20193.154 | 21221.496 | 2249.3277 | 6730.5499 | -2135.406 |
| 9 | -28.723 | .000 | .0000 | -60.9733 | 32.2591 |
| 10 | 2.492 | .000 | .0000 | .2000 | .0000000 |
| 11 | 12.712 | .000 | .0000 | .0000 | .0000 |
| 12 | 17.3153 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6424443.6 | 6454976.2 | 5980661.1 | 1325889.5 | 5068336.1 |
| 14 | 72.9935 | 72.5702 | 65.4918 | 90.6479 | 277.4052 |
| 15 | -2.8948 | -2.9647 | -1.8531 | 27.8390 | .5422 |
| 1 | 600.0000 | 653849.3000 | 6420496.9000 | 1.4753 | 83.8972 |
| 2 | 21091.5740 | 22415.5630 | 21.391 | 1.3713 | 84.2551 |
| 3 | -353302.5 | -614782.9 | -9773968.800 | 1627681.600 | -5954945.500 |
| 4 | 114291.1 | 215290.4 | 15423468.4 | -3191.834 | -29788.789 |
| 5 | 6516406.3 | 7288415.7 | 11463256.0 | 2085961.800 | -341796.620 |
| 6 | -5845.705 | -7054.712 | -18439.063 | 3618.3807 | -18926.040 |
| 7 | 612.283 | 250.028 | -12557.241 | -11.4893 | -126.565 |
| 8 | 20256.045 | 21275.010 | 2184.9922 | 6762.3238 | -2186.138 |
| 9 | -30.400 | .000 | .0000 | -60.6453 | 32.2894 |
| 10 | 2.525 | .000 | .0000 | .2000 | .0000000 |
| 11 | 12.545 | .000 | .0000 | .0000 | .0000 |
| 12 | 17.5947 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6526977.3 | 6557492.5 | 6081858.2 | 1417314.2 | 4967460.3 |
| 14 | 73.0047 | 72.5881 | 65.6579 | 89.9169 | 277.5156 |
| 15 | -3.1029 | -3.1721 | -2.0702 | 25.7633 | .8649 |
| 1 | 605.0000 | 656500.3000 | 6522967.4000 | 1.3945 | 84.1006 |
| 2 | 21195.0510 | 22519.2820 | 21.603 | 1.2962 | 84.4450 |
| 3 | -382919.4 | -650482.3 | -9866218.300 | 1645752.200 | -6049931.800 |
| 4 | 117383.7 | 216542.3 | 15360268.4 | -3247.464 | -30425.867 |
| 5 | 6617843.3 | 7394923.2 | 11474009.2 | 2119852.900 | -352855.660 |
| 6 | -6002.575 | -7226.559 | -18460.799 | 3609.4095 | -19068.453 |
| 7 | 624.744 | 250.692 | -12721.583 | -10.7578 | -128.268 |
| 8 | 20317.701 | 21326.793 | 2116.2020 | 6793.7919 | -2237.597 |
| 9 | -32.215 | .000 | .0000 | -60.3155 | 32.3188 |
| 10 | 2.553 | .000 | .0000 | .2000 | .0000000 |
| 11 | 12.194 | .000 | .0000 | .0000 | .0000 |
| 12 | 17.8756 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6629951.2 | 6660448.5 | 6183333.9 | 1510716.0 | 4866095.3 |
| 14 | 73.0161 | 72.6060 | 65.8198 | 89.2953 | 277.6306 |
| 15 | -3.3110 | -3.3795 | -2.2869 | 23.9080 | 1.1953 |

TABLE AP 3-2 (Sheet 32 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 610.0000 | 658997.1800 | 6625933.1000 | 1.2955 | 84.3058 |
| 2 | 21299.8750 | 22624.3440 | 21.812 | 1.2039 | 84.6367 |
| 3 | -413341.9 | -687062.1 | -9958567.800 | 1663771.300 | -6145629.500 |
| 4 | 120539.3 | 217797.8 | 15296230.2 | -3299.384 | -31071.480 |
| 5 | 6719583.6 | 7501683.3 | 11484406.1 | 2153900.000 | -364173.810 |
| 6 | -6167.832 | -7406.762 | -18479.090 | 3597.7982 | -19210.563 |
| 7 | 637.512 | 251.531 | -12892.324 | -9.9908 | -129.978 |
| 8 | 20377.342 | 21376.099 | 2042.5928 | 6824.7272 | -2289.785 |
| 9 | -33.970 | .000 | .0000 | -59.9838 | 32.3474 |
| 10 | 2.581 | .000 | .0000 | .2000 | .0000000 |
| 11 | 11.691 | .000 | .0000 | .0000 | .0000 |
| 12 | 18.1577 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6733363.5 | 6763842.3 | 6285684.9 | 1605836.7 | 4764227.6 |
| 14 | 73.0276 | 72.6239 | 65.9778 | 88.7607 | 277.7506 |
| 15 | -3.5194 | -3.5871 | -2.5038 | 22.2384 | 1.5336 |
| | | | | | |
| 1 | 615.0000 | 661303.7800 | 6729401.2000 | 1.1767 | 84.5123 |
| 2 | 21405.3420 | 22730.0420 | 21.996 | 1.0929 | 84.8299 |
| 3 | -444612.5 | -724564.8 | -10050997.600 | 1681725.500 | -6242036.900 |
| 4 | 123759.1 | 219057.6 | 15231322.5 | -3347.369 | -31725.666 |
| 5 | 6821614.7 | 7608681.2 | 11494422.6 | 2188099.700 | -375754.740 |
| 6 | -6341.873 | -7595.677 | -18492.875 | 3583.4384 | -19352.365 |
| 7 | 650.430 | 252.401 | -13069.500 | -9.2015 | -131.697 |
| 8 | 20433.949 | 21421.878 | 1963.8292 | 6854.8112 | -2342.706 |
| 9 | -35.747 | .000 | .0000 | -59.6503 | 32.3751 |
| 10 | 2.615 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.978 | .000 | .0000 | .0000 | .0000 |
| 12 | 18.4413 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6837208.6 | 6867668.6 | 6388304.8 | 1702468.7 | 4661847.7 |
| 14 | 73.0393 | 72.6417 | 66.1320 | 88.2966 | 277.8758 |
| 15 | -3.7285 | -3.7955 | -2.7210 | 20.7257 | 1.8798 |
| | | | | | |
| 1 | 620.0000 | 663381.2400 | 6833374.9000 | 1.0391 | 84.7207 |
| 2 | 21510.6230 | 22835.5430 | 22.180 | .9542 | 85.0251 |
| 3 | -476774.8 | -763033.1 | -10143484.000 | 1699601.200 | -6339152.600 |
| 4 | 127044.2 | 220322.2 | 15165513.8 | -3391.268 | -32388.467 |
| 5 | 6923920.1 | 7715898.2 | 11504031.7 | 2222447.300 | -387602.100 |
| 6 | -6524.195 | -7792.762 | -18501.489 | 3566.4938 | -19493.857 |
| 7 | 663.654 | 253.486 | -13252.299 | -8.3445 | -133.424 |
| 8 | 20486.614 | 21463.241 | 1879.7763 | 6883.7725 | -2396.361 |
| 9 | -37.390 | .000 | .0000 | -59.3149 | 32.4019 |
| 10 | 2.653 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.152 | .000 | .0000 | .0000 | .0000 |
| 12 | 18.7263 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6941478.3 | 6971919.0 | 6491384.1 | 1800442.9 | 4558948.0 |
| 14 | 73.0511 | 72.6596 | 66.2827 | 87.8902 | 278.0067 |
| 15 | -3.9385 | -4.0048 | -2.9390 | 19.3463 | 2.2340 |
| | | | | | |
| 1 | 625.0000 | 665191.1900 | 6937852.6000 | .8817 | 84.9306 |
| 2 | 21615.5350 | 22940.6570 | 22.341 | .8167 | 85.2217 |
| 3 | -509870.3 | -802508.2 | -10235999.400 | 1717385.400 | -6436975.000 |
| 4 | 130395.8 | 221592.3 | 15098776.4 | -3430.844 | -33059.923 |
| 5 | 7026477.9 | 7823309.9 | 11513207.3 | 2256936.700 | -399719.580 |
| 6 | -6715.093 | -7998.286 | -18504.364 | 3546.8821 | -19635.039 |
| 7 | 676.989 | 254.598 | -13440.872 | -7.4767 | -135.160 |
| 8 | 20534.863 | 21499.684 | 1790.3254 | 6911.4596 | -2450.755 |
| 9 | -38.936 | .000 | .0000 | -58.9777 | 32.4278 |
| 10 | 2.695 | .000 | .0000 | .2000 | .0000000 |
| 11 | 9.182 | .000 | .0000 | .0000 | .0000 |
| 12 | 19.0126 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7046159.3 | 7076580.1 | 6594908.3 | 1899616.9 | 4455525.9 |
| 14 | 73.0631 | 72.6774 | 66.4298 | 87.5317 | 278.1438 |
| 15 | -4.1496 | -4.2153 | -3.1581 | 18.0805 | 2.5964 |
| | | | | | |
| 1 | 630.0000 | 666695.6000 | 7042832.1000 | .7063 | 85.1422 |
| 2 | 21719.1990 | 23044.5000 | 22.485 | .6522 | 85.4203 |
| 3 | -543939.3 | -843029.4 | -10328513.400 | 1735065.800 | -6535502.400 |
| 4 | 133814.7 | 222868.6 | 15031084.6 | -3465.910 | -33740.077 |
| 5 | 7129263.8 | 7930889.4 | 11521922.1 | 2291560.500 | -412110.890 |
| 6 | -6913.700 | -8211.345 | -18500.949 | 3524.8785 | -19775.908 |
| 7 | 690.580 | 255.912 | -13634.114 | -6.5448 | -136.903 |
| 8 | 20577.839 | 21530.382 | 1695.5395 | 6937.6212 | -2505.889 |
| 9 | -40.503 | .000 | .0000 | -58.6387 | 32.4528 |
| 10 | 2.738 | .000 | .0000 | .2000 | .0000000 |
| 11 | 7.985 | .000 | .0000 | .0000 | .0000 |
| 12 | 19.3003 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7151236.0 | 7181636.4 | 6698861.2 | 1999871.7 | 4351581.1 |
| 14 | 73.0752 | 72.6953 | 66.5737 | 87.2135 | 278.2874 |
| 15 | -4.3623 | -4.4272 | -3.3785 | 16.9122 | 2.9670 |

TABLE AP 3-2 (Sheet 33 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 635.0000 | 667856.0500 | 7148306.4000 | .5124 | 85.3561 |
| 2 | 21821.0210 | 23146.4740 | 22.679 | .4701 | 85.6212 |
| 3 | -579021.0 | -884635.1 | -10420992.500 | 1752630.000 | -6634733.500 |
| 4 | 137302.4 | 224152.1 | 14962415.5 | -3496.101 | -34428.971 |
| 5 | 7232249.4 | 8038605.8 | 11530148.8 | 2326310.800 | -424779.710 |
| 6 | -7119.996 | -8431.882 | -18490.549 | 3500.5002 | -19916.463 |
| 7 | 704.568 | 257.588 | -13831.652 | -5.4999 | -138.656 |
| 8 | 20614.709 | 21554.496 | 1595.0845 | 6962.0028 | -2561.767 |
| 9 | -42.007 | .000 | .0000 | -58.2979 | 32.4768 |
| 10 | 2.775 | .000 | .0000 | .2000 | .0000000 |
| 11 | 6.685 | .000 | .0000 | .0000 | .0000 |
| 12 | 19.5893 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7256689.7 | 7287069.3 | 6803223.3 | 2101104.7 | 4247116.2 |
| 14 | 73.0875 | 72.7133 | 66.7144 | 86.9296 | 278.4382 |
| 15 | -4.5766 | -4.6409 | -3.6004 | 15.8275 | 3.3460 |
| | | | | | |
| 1 | 640.0000 | 668634.4100 | 7254266.8000 | .3005 | 85.5713 |
| 2 | 21920.5040 | 23246.0690 | 22.828 | .2711 | 85.8235 |
| 3 | -615152.4 | -927361.0 | -10513401.500 | 1770066.700 | -6734666.500 |
| 4 | 140860.1 | 225444.0 | 14892748.9 | -3521.036 | -35126.648 |
| 5 | 7335403.3 | 8146425.8 | 11537860.2 | 2361178.300 | -437729.810 |
| 6 | -7333.557 | -8659.435 | -18472.552 | 3473.8873 | -20056.704 |
| 7 | 718.561 | 259.257 | -14033.052 | -4.4543 | -140.416 |
| 8 | 20644.881 | 21571.434 | 1489.3283 | 6984.4250 | -2618.392 |
| 9 | -43.367 | .000 | .0000 | -57.9553 | 32.4998 |
| 10 | 2.810 | .000 | .0000 | .2000 | .0000000 |
| 11 | 5.231 | .000 | .0000 | .0000 | .0000 |
| 12 | 19.8797 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7362499.1 | 7392857.0 | 6907972.2 | 2203226.2 | 4142137.2 |
| 14 | 73.1000 | 72.7312 | 66.8520 | 86.6749 | 278.5966 |
| 15 | -4.7928 | -4.8564 | -3.8241 | 14.8152 | 3.7334 |
| | | | | | |
| 1 | 645.0000 | 668994.3100 | 7360699.8000 | .0722 | 85.7879 |
| 2 | 22016.9160 | 23342.5530 | 23.071 | .0564 | 86.0273 |
| 3 | -652367.7 | -971240.1 | -10605698.800 | 1787365.500 | -6835300.000 |
| 4 | 144488.0 | 226744.6 | 14822068.5 | -3540.652 | -35833.151 |
| 5 | 7438688.0 | 8254309.4 | 11545029.4 | 2396152.200 | -450964.900 |
| 6 | -7553.568 | -8893.154 | -18446.492 | 3445.2996 | -20196.631 |
| 7 | 732.611 | 260.999 | -14237.335 | -3.3839 | -142.186 |
| 8 | 20667.645 | 21580.514 | 1378.4275 | 7004.6806 | -2675.769 |
| 9 | -44.601 | .000 | .0000 | -57.6110 | 32.5218 |
| 10 | 2.840 | .000 | .0000 | .2000 | .0000000 |
| 11 | 3.834 | .000 | .0000 | .0000 | .0000 |
| 12 | 20.1714 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7468636.8 | 7498972.6 | 7013080.3 | 2306153.0 | 4036656.4 |
| 14 | 73.1127 | 72.7492 | 66.9866 | 86.4454 | 278.7634 |
| 15 | -5.0110 | -5.0741 | -4.0498 | 13.8657 | 4.1294 |
| | | | | | |
| 1 | 650.0000 | 668906.2500 | 7467595.6000 | -.1618 | 86.0056 |
| 2 | 22113.5090 | 23439.1670 | 23.333 | -.1637 | 86.2323 |
| 3 | -690694.8 | -1016299.1 | -10697851.800 | 1804517.600 | -6936632.300 |
| 4 | 148186.0 | 228053.8 | 14750361.0 | -3554.940 | -36548.525 |
| 5 | 7542074.2 | 8362224.8 | 11551635.3 | 2431223.700 | -464488.750 |
| 6 | -7777.155 | -9130.334 | -18416.794 | 3415.5412 | -20336.244 |
| 7 | 746.714 | 262.748 | -14443.555 | -2.3087 | -143.965 |
| 8 | 20687.329 | 21586.168 | 1264.9345 | 7024.1224 | -2733.900 |
| 9 | -44.504 | .000 | .0000 | -57.2650 | 32.5429 |
| 10 | 2.863 | .000 | .0000 | .2000 | .0000000 |
| 11 | 4.220 | .000 | .0000 | .0000 | .0000 |
| 12 | 20.4644 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7575084.0 | 7605397.0 | 7118528.4 | 2409821.2 | 3930681.8 |
| 14 | 73.1255 | 72.7673 | 67.1184 | 86.2378 | 278.9392 |
| 15 | -5.2315 | -5.2939 | -4.2776 | 12.9709 | 4.5342 |
| | | | | | |
| 1 | 655.0000 | 668380.1300 | 7574969.9000 | -.3798 | 86.2247 |
| 2 | 22214.4760 | 23540.1090 | 23.464 | -.3689 | 86.4386 |
| 3 | -730133.3 | -1062537.8 | -10789865.100 | 1821522.600 | -7038662.000 |
| 4 | 151955.7 | 229372.4 | 14677623.6 | -3563.620 | -37272.815 |
| 5 | 7645567.2 | 8470176.8 | 11557678.3 | 2466395.600 | -478305.160 |
| 6 | -7998.041 | -9364.982 | -18390.878 | 3386.4988 | -20475.543 |
| 7 | 761.168 | 264.721 | -14648.617 | -1.1623 | -145.753 |
| 8 | 20710.744 | 21595.459 | 1153.4531 | 7044.9041 | -2792.790 |
| 9 | -43.935 | .000 | .0000 | -56.9173 | 32.5629 |
| 10 | 2.860 | .000 | .0000 | .2000 | .0000000 |
| 11 | 4.979 | .000 | .0000 | .0000 | .0000 |
| 12 | 20.7586 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7681854.0 | 7712143.6 | 7224328.7 | 2514207.9 | 3824210.0 |
| 14 | 73.1385 | 72.7854 | 67.2475 | 86.0494 | 279.1248 |
| 15 | -5.4540 | -5.5158 | -4.5074 | 12.1248 | 4.9489 |

TABLE AP 3-2 (Sheet 34 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 660.0000 | 667442.3600 | 7682843.7000 | -.5824 | 86.4440 |
| 2 | 22319.3570 | 23644.9230 | 23.632 | -.5596 | 86.6452 |
| 3 | -770670.2 | -1109944.1 | -10881756.700 | 1838383.800 | -7141387.200 |
| 4 | 155797.3 | 230700.4 | 14603866.9 | -3566.747 | -38006.068 |
| 5 | 7749185.9 | 8578183.5 | 11563169.2 | 2501674.400 | -492417.920 |
| 6 | -8216.272 | -9597.128 | -18368.235 | 3358.1035 | -20614.528 |
| 7 | 775.526 | 266.477 | -14852.608 | -.0793 | -147.550 |
| 8 | 20737.530 | 21608.021 | 1044.2385 | 7066.9150 | -2852.442 |
| 9 | -43.359 | .000 | .0000 | -.56,5678 | 32.5818 |
| 10 | 2.840 | .000 | .0000 | .2000 | .0000000 |
| 11 | 5.738 | .000 | .0000 | .0000 | .0000 |
| 12 | 21.0542 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7788971.9 | 7819237.4 | 7330505.5 | 2619308.4 | 3717235.8 |
| 14 | 73.1517 | 72.8036 | 67.3740 | 85.8776 | 279.3213 |
| 15 | -5.6783 | -5.7396 | -4.7390 | 11.3223 | 5.3748 |
| | | | | | |
| 1 | 665.0000 | 666120.7700 | 7791236.0000 | -.7685 | 86.6635 |
| 2 | 22428.3140 | 23753.7750 | 23.872 | -.7349 | 86.8521 |
| 3 | -812290.8 | -1158504.1 | -10973544.000 | 1855105.000 | -7246806.700 |
| 4 | 159710.5 | 232036.6 | 14529091.4 | -3564.585 | -38748.331 |
| 5 | 7852947.5 | 8686261.8 | 11568120.3 | 2537066.600 | -506830.860 |
| 6 | -8431.693 | -9826.636 | -18349.220 | 3330.4165 | -20753.200 |
| 7 | 789.768 | 267.989 | -15055.536 | .9321 | -149.357 |
| 8 | 20768.055 | 21624.230 | 937.4804 | 7090.2710 | -2912.861 |
| 9 | -42.809 | .000 | .0000 | -.56,2165 | 32.5997 |
| 10 | 2.807 | .000 | .0000 | .2000 | .0000000 |
| 11 | 6.513 | .000 | .0000 | .0000 | .0000 |
| 12 | 21.3513 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7896461.6 | 7926702.5 | 7437081.9 | 2725120.0 | 3609757.1 |
| 14 | 73.1650 | 72.8218 | 67.4980 | 85.7206 | 279.5299 |
| 15 | -5.9043 | -5.9650 | -4.9720 | 10.5591 | 5.8134 |
| | | | | | |
| 1 | 670.0000 | 664443.9300 | 7900169.9000 | -.9380 | 86.8828 |
| 2 | 22541.5880 | 23866.9120 | 24.105 | -.8946 | 87.0587 |
| 3 | -854982.1 | -1208205.7 | -11065246.000 | 1871689.300 | -7348918.700 |
| 4 | 163694.4 | 233379.5 | 14453303.1 | -3557.661 | -39499.651 |
| 5 | 7956872.1 | 8794431.5 | 11572543.8 | 2572579.200 | -521547.820 |
| 6 | -8644.350 | -10053.571 | -18334.095 | 3303.4179 | -20891.556 |
| 7 | 803.713 | 269.064 | -15257.652 | 1.8134 | -151.173 |
| 8 | 20802.702 | 21644.466 | 833.4118 | 7115.0894 | -2974.050 |
| 9 | -42.180 | .000 | .0000 | -.55,8633 | 32.6166 |
| 10 | 2.751 | .000 | .0000 | .2000 | .0000000 |
| 11 | 7.294 | .000 | .0000 | .0000 | .0000 |
| 12 | 21.6498 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8004348.9 | 8034564.5 | 7544083.3 | 2831645.8 | 3501771.8 |
| 14 | 73.1785 | 72.8401 | 67.6196 | 85.5765 | 279.7517 |
| 15 | -6.1317 | -6.1918 | -5.2064 | 9.8317 | 6.2666 |
| | | | | | |
| 1 | 675.0000 | 662441.5500 | 8009665.8000 | -1.0892 | 87.1019 |
| 2 | 22658.5580 | 23983.7200 | 24.298 | -1.0371 | 87.2652 |
| 3 | -898728.0 | -1259033.8 | -11156881.600 | 1888140.900 | -7453721.800 |
| 4 | 167747.0 | 234726.4 | 14376507.8 | -3546.710 | -40260.077 |
| 5 | 8060979.6 | 8902711.5 | 11576454.6 | 2608219.400 | -536572.660 |
| 6 | -8853.507 | -10277.191 | -18322.803 | 3277.3329 | -21029.595 |
| 7 | 817.363 | 269.717 | -15458.250 | 2.5690 | -152.999 |
| 8 | 20841.248 | 21668.537 | 732.3230 | 7141.3128 | -3036.013 |
| 9 | -41.422 | .000 | .0000 | -.55,5081 | 32.6324 |
| 10 | 2.683 | .000 | .0000 | .2000 | .0000000 |
| 11 | 8.077 | .000 | .0000 | .0000 | .0000 |
| 12 | 21.9499 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8112659.2 | 8142848.9 | 7651534.5 | 2938890.5 | 3393281.6 |
| 14 | 73.1921 | 72.8583 | 67.7389 | 85.4439 | 279.9883 |
| 15 | -6.3603 | -6.4198 | -5.4418 | 9.1369 | 6.7362 |
| | | | | | |
| 1 | 680.0000 | 660147.6700 | 8119742.1000 | -1.2210 | 87.3208 |
| 2 | 22779.0570 | 24104.0350 | 24.505 | -1.1613 | 87.4716 |
| 3 | -943510.4 | -1310971.1 | -11248470.700 | 1904464.400 | -7559214.100 |
| 4 | 171867.2 | 236075.7 | 14298713.7 | -3532.254 | -41029.658 |
| 5 | 8165289.9 | 9011122.0 | 11579867.9 | 2643994.300 | -551909.250 |
| 6 | -9058.693 | -10497.038 | -18315.586 | 3252.3007 | -21167.316 |
| 7 | 830.719 | 269.950 | -15656.990 | 3.1998 | -154.835 |
| 8 | 20883.855 | 21696.633 | 634.4827 | 7169.0001 | -3098.755 |
| 9 | -40.597 | .000 | .0000 | -.55,1509 | 32.6471 |
| 10 | 2.614 | .000 | .0000 | .2000 | .0000000 |
| 11 | 8.860 | .000 | .0000 | .0000 | .0000 |
| 12 | 22.2516 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8221417.5 | 8251580.8 | 7759459.8 | 3046860.3 | 3284291.8 |
| 14 | 73.2057 | 72.8766 | 67.8560 | 85.3216 | 280.2415 |
| 15 | -6.5899 | -6.6489 | -5.6781 | 8.4721 | 7.2246 |

TABLE AP 3-2 (Sheet 35 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 685.0000 | 657599,5500 | 8230417,1000 | -1,3321 | 87,5397 |
| 2 | 22902,4390 | 24227,2200 | 24,636 | -1,2661 | 87,6781 |
| 3 | -989307,3 | -1363996,7 | -11340033,600 | 1920665,900 | -7665394,400 |
| 4 | 176053,8 | 237425,4 | 14219932,3 | -3514,862 | -41808,445 |
| 5 | 8269822,7 | 9119682,4 | 11582800,1 | 2679911,100 | -567561,510 |
| 6 | -9259,254 | -10712,453 | -18312,359 | 3228,5214 | -21304,715 |
| 7 | 843,835 | 269,831 | -15853,204 | 3,7262 | -156,681 |
| 8 | 20930,262 | 21728,525 | 540,0887 | 7198,0827 | -3162,278 |
| 9 | -39,544 | ,000 | ,0000 | -54,7917 | 32,6607 |
| 10 | 2,552 | ,000 | ,0000 | ,2000 | ,0000000 |
| 11 | 9,642 | ,000 | ,0000 | ,0000 | ,0000 |
| 12 | 22,5549 | ,0000 | ,0000 | ,0000 | ,0000 |
| 13 | 8330647,5 | 8360783,8 | 7867882,6 | 3155562,4 | 3174814,1 |
| 14 | 73,2195 | 72,8948 | 67,9709 | 85,2084 | 280,5132 |
| 15 | -6,8203 | -6,8787 | -5,9150 | 7,8349 | 7,7346 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 690.0000 | 654837,1600 | 8341704,8000 | -1,4203 | 87,7581 |
| 2 | 23028,2950 | 24352,8700 | 24,816 | -1,3493 | 87,8842 |
| 3 | -1036093,3 | -1418086,2 | -11431590,800 | 1936752,300 | -7772260,800 |
| 4 | 180304,6 | 238772,9 | 14140177,5 | -3495,323 | -42596,486 |
| 5 | 8374597,2 | 9228412,0 | 11585270,8 | 2715977,000 | -583533,350 |
| 6 | -9454,191 | -10922,447 | -18313,368 | 3206,2954 | -21441,790 |
| 7 | 856,458 | 269,115 | -16046,199 | 4,0737 | -158,537 |
| 8 | 20980,637 | 21764,423 | 449,8758 | 7228,6260 | -3226,588 |
| 9 | -38,446 | ,000 | ,0000 | -54,4303 | 32,6733 |
| 10 | 2,480 | ,000 | ,0000 | ,2000 | ,0000000 |
| 11 | 10,424 | ,000 | ,0000 | ,0000 | ,0000 |
| 12 | 22,8599 | ,0000 | ,0000 | ,0000 | ,0000 |
| 13 | 8440371,6 | 8470480,4 | 7976824,7 | 3265003,8 | 3064866,3 |
| 14 | 73,2333 | 72,9131 | 68,0837 | 85,1033 | 280,8056 |
| 15 | -7,0511 | -7,1090 | -6,1522 | 7,2235 | 8,2694 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 695.0000 | 651905,5900 | 8453619,6000 | -1,4856 | 87,9765 |
| 2 | 23156,7910 | 24481,1590 | 25,010 | -1,4109 | 88,0903 |
| 3 | -1083840,1 | -1473212,4 | -11523163,800 | 1952731,500 | -7879811,700 |
| 4 | 184617,8 | 240115,8 | 14059465,5 | -3474,344 | -43393,833 |
| 5 | 8479633,9 | 9337331,5 | 11587300,4 | 2752199,300 | -599828,710 |
| 6 | -9643,572 | -11127,109 | -18318,980 | 3185,5944 | -21578,535 |
| 7 | 868,813 | 268,018 | -16236,068 | 4,3080 | -160,403 |
| 8 | 21035,295 | 21804,652 | 363,7091 | 7260,7300 | -3291,687 |
| 9 | -37,214 | ,000 | ,0000 | -54,0668 | 32,6847 |
| 10 | 2,405 | ,000 | ,0000 | ,2000 | ,0000000 |
| 11 | 11,206 | ,000 | ,0000 | ,0000 | ,0000 |
| 12 | 23,1666 | ,0000 | ,0000 | ,0000 | ,0000 |
| 13 | 8550612,9 | 8580693,6 | 8086308,5 | 3375192,7 | 2954471,7 |
| 14 | 73,2472 | 72,9313 | 68,1944 | 85,0056 | 281,1216 |
| 15 | -7,2822 | -7,3395 | -6,3895 | 6,6361 | 8,8325 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 700.0000 | 648851,1500 | 8566172,3000 | -1,5240 | 88,1943 |
| 2 | 23286,0290 | 24610,1950 | 25,097 | -1,4470 | 88,2958 |
| 3 | -1132515,1 | -1529343,5 | -11614774,900 | 1968612,400 | -7988045,500 |
| 4 | 188991,1 | 241451,4 | 13977816,7 | -3452,734 | -44200,537 |
| 5 | 8584952,4 | 9446461,0 | 11588912,0 | 2788585,400 | -616451,560 |
| 6 | -9825,097 | -11324,106 | -18328,761 | 3167,1280 | -21714,946 |
| 7 | 880,579 | 266,271 | -16420,667 | 4,3475 | -162,280 |
| 8 | 21093,392 | 21848,466 | 282,7275 | 7294,1684 | -3357,579 |
| 9 | -35,529 | ,000 | ,0000 | -53,7011 | 32,6951 |
| 10 | 2,324 | ,000 | ,0000 | ,2000 | ,0000000 |
| 11 | 11,984 | ,000 | ,0000 | ,0000 | ,0000 |
| 12 | 23,4750 | ,0000 | ,0000 | ,0000 | ,0000 |
| 13 | 8661392,0 | 8691444,2 | 8196354,6 | 3486136,2 | 2843662,7 |
| 14 | 73,2610 | 72,9494 | 68,3032 | 84,9145 | 281,4642 |
| 15 | -7,5132 | -7,5701 | -6,6265 | 6,0715 | 9,4285 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 705.0000 | 645730,8500 | 8679368,7000 | -1,5327 | 88,4121 |
| 2 | 23415,7640 | 24739,7370 | 25,181 | -1,4551 | 88,5014 |
| 3 | -1182076,1 | -1586438,7 | -11706447,500 | 1984407,000 | -8096960,600 |
| 4 | 193422,6 | 242777,5 | 13895259,2 | -3431,174 | -45016,646 |
| 5 | 8690571,5 | 9555820,2 | 11590132,3 | 2825142,700 | -633405,840 |
| 6 | -9997,591 | -11512,291 | -18343,467 | 3151,2441 | -21851,020 |
| 7 | 892,020 | 264,142 | -16599,062 | 4,2735 | -164,166 |
| 8 | 21155,388 | 21896,393 | 207,4004 | 7329,1030 | -3424,267 |
| 9 | -33,554 | ,000 | ,0000 | -53,3333 | 32,7043 |
| 10 | 2,235 | ,000 | ,0000 | ,2000 | ,0000000 |
| 11 | 12,715 | ,000 | ,0000 | ,0000 | ,0000 |
| 12 | 23,7852 | ,0000 | ,0000 | ,0000 | ,0000 |
| 13 | 8772727,3 | 8802750,9 | 8306980,4 | 3597839,3 | 2732485,2 |
| 14 | 73,2749 | 72,9674 | 68,4101 | 84,8295 | 281,8372 |
| 15 | -7,7438 | -7,8002 | -6,8630 | 5,5286 | 10,0624 |

TABLE AP 3-2 (Sheet 36 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|---|------------|-------------|---------------|-------------|--------------|
| 1 | 710.0000 | 642607.9700 | 8793209.1000 | -1.5099 | 88.6299 |
| 2 | 23545.0230 | 24868.8220 | 25.379 | -1.4333 | 88.7071 |
| 3 | -1232474.4 | -1644450.2 | -11798205.700 | 2000129.600 | -8206555.200 |
| 4 | 197910.7 | 244092.3 | 13811828.0 | -3410.164 | -45842.212 |
| 5 | 8796509.5 | 9665428.6 | 11590990.6 | 2861878.000 | -650695.550 |
| 6 | -10159.868 | -11690.472 | -18363.051 | 3138.3044 | -21986.747 |
| 7 | 903.120 | 261.641 | -16770.141 | 4.0891 | -166.062 |
| 8 | 21220.970 | 21948.184 | 138.2226 | 7365.4587 | -3491.753 |
| 9 | -31.441 | .000 | .0000 | -52.9633 | 32.7123 |
| 10 | 2.130 | .000 | .0000 | .2000 | .0000000 |
| 11 | 13.421 | .000 | .0000 | .0000 | .0000 |
| 12 | 24.0972 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8884634.9 | 8914629.0 | 8418201.2 | 3710304.8 | 2620998.3 |
| 14 | 73.2888 | 72.9854 | 68.5151 | 84.7498 | 282.2448 |
| 15 | -7.9738 | -8.0297 | -7.0985 | 5.0064 | 10.7404 |
| INTRODUCTION OF CHI TILDE GUIDANCE MODE | | | | | |
| 1 | 712.5330 | 641045.4500 | 8851127.3000 | -1.4865 | 88.7401 |
| 2 | 23610.1740 | 24933.8910 | 25.525 | -1.4111 | 88.8112 |
| 3 | -1258308.9 | -1674171.8 | -11844730.500 | 2008071.800 | -8262334.200 |
| 4 | 200205.2 | 244753.2 | 13769240.5 | -3399.995 | -46264.067 |
| 5 | 8850304.7 | 9721057.3 | 11591297.7 | 2880558.400 | -659583.770 |
| 6 | -10238.114 | -11776.853 | -18374.760 | 3132.8925 | -22055.372 |
| 7 | 908.547 | 260.169 | -16853.962 | 3.9344 | -167.027 |
| 8 | 21255.490 | 21975.829 | 105.9904 | 7384.3985 | -3526.247 |
| 9 | -30.387 | .000 | .0000 | -52.7750 | 32.7160 |
| 10 | 2.050 | .000 | .0000 | .2000 | .0000000 |
| 11 | 13.747 | .000 | .0000 | .0000 | .0000 |
| 12 | 24.2559 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8941549.9 | 8971529.0 | 8474777.1 | 3767570.9 | 2564423.9 |
| 14 | 73.2958 | 72.9944 | 68.5675 | 84.7114 | 282.4662 |
| 15 | -8.0899 | -8.1456 | -7.2173 | 4.7495 | 11.1031 |
| 1 | 715.0000 | 639547.0400 | 8907694.0000 | -1.4561 | 88.8470 |
| 2 | 23673.2130 | 24996.8560 | 25.701 | -1.3822 | 88.9122 |
| 3 | -1283658.0 | -1703326.9 | -11890073.400 | 2015795.000 | -8316827.500 |
| 4 | 202452.6 | 245392.8 | 13727560.2 | -3390.623 | -46677.285 |
| 5 | 8902784.1 | 9775305.4 | 11591519.6 | 2898798.700 | -668324.720 |
| 6 | -10311.717 | -11858.421 | -18387.119 | 3128.3759 | -22122.122 |
| 7 | 913.554 | 258.456 | -16933.724 | 3.6994 | -167.968 |
| 8 | 21289.784 | 22003.498 | 75.4704 | 7403.1323 | -3560.040 |
| 9 | -29.214 | .000 | .0000 | -52.5911 | 32.7193 |
| 10 | 1.940 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.078 | .000 | .0000 | .0000 | .0000 |
| 12 | 24.4109 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8997128.8 | 9027093.2 | 8530031.0 | 3823533.7 | 2509274.6 |
| 14 | 73.3026 | 73.0032 | 68.6182 | 84.6751 | 282.6924 |
| 15 | -8.2026 | -8.2581 | -7.3327 | 4.5041 | 11.4699 |
| 1 | 720.0000 | 636612.8600 | 9022814.6000 | -1.3713 | 89.0625 |
| 2 | 23799.0760 | 25122.5850 | 26.012 | -1.3016 | 89.1158 |
| 3 | -1335573.5 | -1763016.4 | -11982071.100 | 2031418.600 | -8427775.700 |
| 4 | 207044.6 | 246675.3 | 13642494.7 | -3373.636 | -47521.914 |
| 5 | 9009408.7 | 9885465.7 | 11591751.1 | 2935910.400 | -686297.300 |
| 6 | -10452.439 | -12015.400 | -18414.888 | 3121.6813 | -22257.137 |
| 7 | 922.933 | 254.231 | -17089.058 | 2.9958 | -169.885 |
| 8 | 21360.962 | 22061.503 | 19.5690 | 7441.8707 | -3629.130 |
| 9 | -27.069 | .000 | .0000 | -52.2168 | 32.7250 |
| 10 | 1.871 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.514 | .000 | .0000 | .0000 | .0000 |
| 12 | 24.7264 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9110217.6 | 9140152.1 | 8642477.6 | 3937521.7 | 2397403.3 |
| 14 | 73.3164 | 73.0209 | 68.7195 | 84.6049 | 283.1862 |
| 15 | -8.4300 | -8.4851 | -7.5652 | 4.0213 | 12.2593 |
| 1 | 725.0000 | 633871.5300 | 9138559.1000 | -1.2562 | 89.2791 |
| 2 | 23922.0340 | 25245.4330 | 26.311 | -1.1924 | 89.3204 |
| 3 | -1388164.8 | -1823463.4 | -12074216.900 | 2047016.900 | -8539398.200 |
| 4 | 211682.6 | 247935.9 | 13556674.1 | -3360.426 | -48376.147 |
| 5 | 9116394.7 | 9995922.0 | 11591718.8 | 2973218.300 | -704617.360 |
| 6 | -10581.948 | -12161.319 | -18446.358 | 3118.2453 | -22391.783 |
| 7 | 932.282 | 250.009 | -17235.515 | 2.2958 | -171.810 |
| 8 | 21434.013 | 22121.750 | -30.4303 | 7481.5373 | -3699.023 |
| 9 | -24.741 | .000 | .0000 | -51.8404 | 32.7296 |
| 10 | 1.873 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.763 | .000 | .0000 | .0000 | .0000 |
| 12 | 25.0436 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9223907.0 | 9253811.5 | 8755546.0 | 4052261.3 | 2285493.6 |
| 14 | 73.3301 | 73.0385 | 68.8189 | 84.5388 | 283.7339 |
| 15 | -8.6557 | -8.7104 | -7.7958 | 3.5571 | 13.1189 |

TABLE AP 3-2 (Sheet 37 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 730.0000 | 631388.0900 | 9254910.9000 | -1.1119 | 89,4970 |
| 2 | 24040.9720 | 25364.2860 | 26.570 | -1,0553 | 89,5264 |
| 3 | -1441374.6 | -1884611.2 | -12166527.700 | 2062606.400 | -8651693,000 |
| 4 | 216367.7 | 249175.8 | 13470145.0 | -3350,543 | -49240,033 |
| 5 | 9223748.4 | 10106683.1 | 11591450.7 | 3010726.100 | -723288,880 |
| 6 | -10699.933 | -12295.828 | -18480,808 | 3118.1712 | -22526,049 |
| 7 | 941.764 | 245.986 | -17372.427 | 1,6595 | -173,746 |
| 8 | 21507.972 | 22183,308 | -74,7770 | 7521,8488 | -3769,720 |
| 9 | -22.350 | .000 | .0000 | -51.4621 | 32,7331 |
| 10 | 1.879 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.773 | .000 | .0000 | .0000 | .0000 |
| 12 | 25.3625 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9338195.8 | 9368070.2 | 8869234.5 | 4167738.7 | 2173678,1 |
| 14 | 73.3437 | 73,0559 | 68,9166 | 84,4764 | 284,3447 |
| 15 | -8.8792 | -8,9335 | -8.0239 | 3.1112 | 14,0605 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 735.0000 | 629225.5300 | 9371846.5000 | -.9399 | 89,7159 |
| 2 | 24154.1860 | 25477.4340 | 26,820 | -.8919 | 89,7333 |
| 3 | -1495144.7 | -1946402.3 | -12259015,100 | 2078204,300 | -8764658,000 |
| 4 | 221100.0 | 250395.7 | 13382956.8 | -3343,840 | -50113,618 |
| 5 | 9331470.9 | 10217752.0 | 11590974.9 | 3048436,300 | -742315,900 |
| 6 | -10806.099 | -12418.557 | -18516,741 | 3121,5692 | -22659,926 |
| 7 | 951.115 | 241,948 | -17499,062 | 1,0211 | -175,690 |
| 8 | 21581.203 | 22244,564 | -113,5521 | 7562,3133 | -3841,221 |
| 9 | -19.961 | .000 | .0000 | -51.0818 | 32,7353 |
| 10 | 1.887 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.571 | .000 | .0000 | .0000 | .0000 |
| 12 | 25.6829 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9453078.1 | 9482921.9 | 8983535.8 | 4283935.4 | 2062117,3 |
| 14 | 73.3572 | 73,0732 | 69,0126 | 84,4176 | 285,0301 |
| 15 | -9.1004 | -9,1543 | -8.2494 | 2,6830 | 15,0986 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 740.0000 | 627445.3600 | 9489332.2000 | -.7416 | 89,9361 |
| 2 | 24260.6710 | 25583,8740 | 27,089 | -.7035 | 89,9415 |
| 3 | -1549415.4 | -2008776.7 | -12351685,000 | 2093828,100 | -8878291,600 |
| 4 | 225879.0 | 251595.8 | 13295162.6 | -3340,193 | -50996,947 |
| 5 | 9439556.0 | 10329125.2 | 11590318.8 | 3086348,600 | -761702,430 |
| 6 | -10900.282 | -12529,300 | -18553,416 | 3128,4986 | -22793,403 |
| 7 | 960.503 | 238,096 | -17614,874 | .4425 | -177,643 |
| 8 | 21652.747 | 22304,588 | -147,0779 | 7602,6469 | -3913,525 |
| 9 | -17.627 | .000 | .0000 | -50,6997 | 32,7362 |
| 10 | 1.894 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.200 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.0049 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9568538.1 | 9598351.3 | 9098433,6 | 4400823,4 | 1951010,7 |
| 14 | 73.3707 | 73,0903 | 69,1068 | 84,3620 | 285,8044 |
| 15 | -9.3188 | -9,3724 | -8,4719 | 2,2720 | 16,2501 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 745.0000 | 626103.7100 | 9607331.8000 | -.5186 | 90,1576 |
| 2 | 24359.8580 | 25683,0330 | 27,252 | -.4914 | 90,1509 |
| 3 | -1604128.4 | -2071676.0 | -12444538,000 | 2109495,000 | -8992591,400 |
| 4 | 230704.7 | 252776.6 | 13206815.4 | -3339,415 | -51890,067 |
| 5 | 9547992.9 | 10440793.5 | 11589507.6 | 3124461,700 | -781452,500 |
| 6 | -10982.668 | -12628,209 | -18590,216 | 3138,9091 | -22926,468 |
| 7 | 969.899 | 234,422 | -17719,799 | -.0791 | -179,606 |
| 8 | 21721.948 | 22362,728 | -175,5979 | 7642,6508 | -3986,631 |
| 9 | -15.375 | .000 | .0000 | -50,3159 | 32,7360 |
| 10 | 1.901 | .000 | .0000 | .2000 | .0000000 |
| 11 | 13.551 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.3283 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9684555.5 | 9714338.1 | 9213906.4 | 4518370.2 | 1840598,4 |
| 14 | 73.3841 | 73,1073 | 69,1994 | 84,3095 | 286,6855 |
| 15 | -9.5343 | -9,5875 | -8,6912 | 1,8778 | 17,5354 |

CHI FREEZE

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 746.1000 | 625872,2100 | 9633356,6000 | -.4667 | 90,2064 |
| 2 | 24380.5100 | 25703,6800 | 27,266 | -.4421 | 90,1971 |
| 3 | -1616219.1 | -2085578.7 | -12464989,700 | 2112949,000 | -9017826,100 |
| 4 | 231772.7 | 253034.1 | 13187310,1 | -3339,545 | -52087,869 |
| 5 | 9571894.6 | 10465398.7 | 11589310,2 | 3132873,300 | -785846,640 |
| 6 | -10999.301 | -12648,461 | -18598,080 | 3141,6419 | -22955,685 |
| 7 | 971.955 | 233,632 | -17741,414 | -.1881 | -180,039 |
| 8 | 21736.604 | 22375,010 | -181,3027 | 7651,3291 | -4002,822 |
| 9 | -14.881 | .000 | .0000 | -50,2313 | 32,7358 |
| 10 | 1.903 | .000 | .0000 | .2000 | .0000000 |
| 11 | 13.358 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.3996 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9710151.5 | 9739927,4 | 9239385,0 | 4544315,3 | 1816428,8 |
| 14 | 73.3870 | 73,1110 | 69,2195 | 84,2783 | 286,8958 |
| 15 | -9.5813 | -9,6344 | -8,7389 | 1,7932 | 17,8385 |

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TABLE AP 3-2 (Sheet 38 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

S-IVB GUIDANCE CUTOFF SIGNAL

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 747.0400 | 625694.4300 | 9655614.6000 | -4227 | 90,2484 |
| 2 | 24398.1380 | 25721.3040 | 27.313 | -4003 | 90,2368 |
| 3 | -1626565.2 | -2097476.6 | -12482474.400 | 2115903.300 | -9039416.600 |
| 4 | 232687.3 | 253253.5 | 13170623.5 | -3339.733 | -52257.282 |
| 5 | 9592333.2 | 10486436.3 | 11589137.0 | 3140069.100 | -789615.860 |
| 6 | -11013.670 | -12665.920 | -18604.695 | 3143.9257 | -22980.637 |
| 7 | 973.771 | 233.014 | -17759.959 | -2635 | -180.409 |
| 8 | 21749.021 | 22385.391 | -186.3308 | 7658.7195 | -4016.688 |
| 9 | -14.461 | .000 | .0000 | -50.1589 | 32.7355 |
| 10 | 1.881 | .000 | .0000 | .2000 | .0000000 |
| 11 | 13.226 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.4606 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9732045.5 | 9761815.6 | 9261179.1 | 4566510.7 | 1795814.8 |
| 14 | 73.3895 | 73.1141 | 69.2367 | 84.2889 | 287.0807 |
| 15 | -9.6213 | -9.6744 | -8.7796 | 1.7216 | 18.1038 |

REDUNDANT S-IVB CUTOFF SIGNAL - TB 5

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 747.3800 | 625632.9800 | 9663669.5000 | -4137 | 90.2638 |
| 2 | 24401.9200 | 25725.0840 | 17.886 | -3916 | 90.2514 |
| 3 | -1630311.5 | -2101784.7 | -12488799.200 | 2116972.200 | -9047231.600 |
| 4 | 233018.5 | 253332.7 | 13164582.8 | -3339.836 | -52318.647 |
| 5 | 9599727.8 | 10494047.4 | 11589072.9 | 3142673.400 | -790982.480 |
| 6 | -11020.309 | -12673.505 | -18603.536 | 3144.3635 | -22989.659 |
| 7 | 974.392 | 232.831 | -17766.610 | -2784 | -180.543 |
| 8 | 21749.875 | 22385.444 | -189.7958 | 7660.2663 | -4021.711 |
| 9 | -15.664 | .000 | .0000 | -50.1327 | 32.7354 |
| 10 | 1.836 | .000 | .0000 | .2000 | .0000000 |
| 11 | 2.893 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.4827 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9739968.6 | 9769736.2 | 9269066.0 | 4574543.6 | 1788368.2 |
| 14 | 73.3904 | 73.1153 | 69.2429 | 84.2855 | 287.1488 |
| 15 | -9.6357 | -9.6888 | -8.7943 | 1.6958 | 18.2011 |

S-IVB PU ACTIVATE OFF

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 748.1500 | 625497.8300 | 9681908.5000 | -4089 | 90.2994 |
| 2 | 24402.3430 | 25725.5000 | 3.294 | -3871 | 90.2852 |
| 3 | -1638803.6 | -2111550.3 | -12503116.600 | 2119393.500 | -9064941.300 |
| 4 | 233769.3 | 253511.9 | 13150897.8 | -3340.019 | -52457.777 |
| 5 | 9616470.1 | 10511278.2 | 11588921.2 | 3148571.200 | -794083.470 |
| 6 | -11037.651 | -12692.511 | -18591.212 | 3144.7953 | -23010.081 |
| 7 | 975.719 | 232.584 | -17779.979 | -2614 | -180.846 |
| 8 | 21741.495 | 22375.153 | -201.4811 | 7660.6009 | -4033.098 |
| 9 | -21.679 | .000 | .0000 | -50.0734 | 32.7352 |
| 10 | 1.735 | .000 | .0000 | .2000 | .0000000 |
| 11 | -10.695 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.5326 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9757910.5 | 9787673.9 | 9286927.1 | 4592736.1 | 1771528.5 |
| 14 | 73.3925 | 73.1179 | 69.2568 | 84.2779 | 287.3054 |
| 15 | -9.6684 | -9.7214 | -8.8275 | 1.6377 | 18.4243 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 750.0000 | 625181.7100 | 9725742.7000 | -4045 | 90.3848 |
| 2 | 24404.1900 | 25727.3260 | .051 | -3826 | 90.3662 |
| 3 | -1659262.5 | -2135074.7 | -12537485.500 | 2125212.100 | -9107555.500 |
| 4 | 235577.2 | 253941.4 | 13117970.8 | -3340.536 | -52793.019 |
| 5 | 9656678.2 | 10552654.3 | 11588522.8 | 3162745.500 | -801570.100 |
| 6 | -11082.284 | -12741.100 | -18560.380 | 3144.9290 | -23059.109 |
| 7 | 978.784 | 231.840 | -17814.443 | -2653 | -181.577 |
| 8 | 21720.715 | 22349.633 | -231.0492 | 7661.1853 | -4060.536 |
| 9 | -24.408 | .000 | .0000 | -49.9308 | 32.7344 |
| 10 | 1.642 | .000 | .0000 | .2000 | .0000000 |
| 11 | -12.244 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.6528 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9801024.3 | 9830776.2 | 9329848.2 | 4636461.4 | 1731200.4 |
| 14 | 73.3974 | 73.1241 | 69.2903 | 84.2599 | 287.6958 |
| 15 | -9.7468 | -9.7997 | -8.9072 | 1.4991 | 18.9761 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 755.0000 | 624320.4200 | 9844211.5000 | -4006 | 90.6158 |
| 2 | 24405.1400 | 25728.2220 | .053 | -3782 | 90.5852 |
| 3 | -1714980.5 | -2199112.5 | -12630056.400 | 2140936.300 | -9223181.800 |
| 4 | 240491.5 | 255095.7 | 13028662.7 | -3341.856 | -53705.847 |
| 5 | 9765123.4 | 10664211.5 | 11587158.3 | 3201050.200 | -822059.200 |
| 6 | -11203.970 | -12873.165 | -18471.679 | 3144.9722 | -23191.316 |
| 7 | 986.960 | 229.861 | -17906.442 | -2652 | -183.556 |
| 8 | 21658.897 | 22274.880 | -312.9122 | 7661.1698 | -4135.238 |
| 9 | -24.339 | .000 | .0000 | -49.5455 | 32.7316 |
| 10 | 1.634 | .000 | .0000 | .2000 | .0000000 |
| 11 | -12.422 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.9774 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9917490.7 | 9947211.7 | 9445807.1 | 4754649.4 | 1623275.4 |
| 14 | 73.4107 | 73.1409 | 69.3793 | 84.2133 | 288.8615 |
| 15 | -9.9579 | -10.0105 | -9.1217 | 1.1318 | 20.5835 |

TABLE AP 3-2 (Sheet 39 of 39)
SATURN OBSERVED TRAJECTORY - BOOST PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 755.5000 | 624235.3100 | 9856059.1000 | -.4002 | 90.6389 |
| 2 | 24405.2450 | 25728.3230 | .060 | -.3778 | 90.6071 |
| 3 | -1720985.5 | -2205552.5 | -12639289.500 | 2142508.700 | -9234780.600 |
| 4 | 240985.2 | 255210.6 | 13019706.6 | -3341.989 | -53797.674 |
| 5 | 9775951.1 | 10675347.0 | 11586999.7 | 3204880.700 | -824128.700 |
| 6 | -11216.133 | -12886.361 | -18462.776 | 3144.9725 | -23204.513 |
| 7 | 987.776 | 229.663 | -17915.621 | -.2652 | -183.754 |
| 8 | 21652.682 | 22267.366 | -321.1035 | 7661.1698 | -4142.751 |
| 9 | -24.324 | .000 | .0000 | -49.5070 | 32.7312 |
| 10 | 1.633 | .000 | .0000 | .2000 | .000000 |
| 11 | -12.436 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.0099 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9929134.0 | 9958851.9 | 9457400.7 | 4766470.0 | 1612577.1 |
| 14 | 73.4120 | 73.1425 | 69.3881 | 84.2089 | 288.9879 |
| 15 | -9.9790 | -10.0315 | -9.1430 | 1.0756 | 20.7543 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 756.0000 | 624149.8000 | 9867906.3000 | -.3998 | 90.6620 |
| 2 | 24405.3510 | 25728.4230 | .060 | -.3774 | 90.6290 |
| 3 | -1726196.8 | -2211999.1 | -12648517.900 | 2144081.200 | -9246386.200 |
| 4 | 241479.3 | 255325.4 | 13010745.9 | -3342.122 | -53889.600 |
| 5 | 9786775.9 | 10686478.8 | 11586836.6 | 3208711.200 | -826201.950 |
| 6 | -11228.294 | -12899.554 | -18453.865 | 3144.9724 | -23217.705 |
| 7 | 988.592 | 229.465 | -17924.795 | -.2652 | -183.953 |
| 8 | 21646.461 | 22259.844 | -329.2953 | 7661.1698 | -4150.273 |
| 9 | -24.317 | .000 | .0000 | -49.4685 | 32.7309 |
| 10 | 1.633 | .000 | .0000 | .2000 | .000000 |
| 11 | -12.450 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.0423 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9940776.9 | 9970491.6 | 9468994.2 | 4778291.4 | 1601897.0 |
| 14 | 73.4134 | 73.1442 | 69.3969 | 84.2044 | 289.1163 |
| 15 | -10.0000 | -10.0525 | -9.1644 | 1.0596 | 20.9272 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 756.5000 | 624064.8100 | 9879754.3000 | -.3995 | 90.6851 |
| 2 | 24405.4570 | 25728.5230 | .060 | -.3770 | 90.6510 |
| 3 | -1731814.0 | -2218452.1 | -12657742.100 | 2145653.700 | -9257998.400 |
| 4 | 241973.8 | 255440.1 | 13001780.7 | -3342.255 | -53981.627 |
| 5 | 9797597.5 | 10697606.7 | 11586669.7 | 3212541.800 | -828278.970 |
| 6 | -11240.451 | -12912.742 | -18444.948 | 3144.9724 | -23230.893 |
| 7 | 989.408 | 229.266 | -17933.962 | -.2652 | -184.151 |
| 8 | 21640.233 | 22252.315 | -337.4870 | 7661.1698 | -4157.803 |
| 9 | -24.311 | .000 | .0000 | -49.4300 | 32.7305 |
| 10 | 1.632 | .000 | .0000 | .2000 | .000000 |
| 11 | -12.464 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.0748 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9952419.0 | 9982130.6 | 9480587.0 | 4790113.0 | 1591235.8 |
| 14 | 73.4147 | 73.1459 | 69.4057 | 84.1999 | 289.2467 |
| 15 | -10.0210 | -10.0735 | -9.1857 | 1.0236 | 21.1020 |

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 757.0000 | 623979.7100 | 9891602.5000 | -.3991 | 90.7082 |
| 2 | 24405.5620 | 25728.6230 | .060 | -.3766 | 90.6729 |
| 3 | -1737437.3 | -2224911.9 | -12666961.700 | 2147226.100 | -9269617.100 |
| 4 | 242468.7 | 255554.6 | 12992810.9 | -3342.387 | -54073.752 |
| 5 | 9808416.0 | 10708731.0 | 11586498.6 | 3216372.400 | -830359.760 |
| 6 | -11252.604 | -12925.925 | -18436.024 | 3144.9723 | -23244.077 |
| 7 | 990.223 | 229.067 | -17943.123 | -.2652 | -184.350 |
| 8 | 21633.997 | 22244.778 | -345.6786 | 7661.1698 | -4165.341 |
| 9 | -24.304 | .000 | .0000 | -49.3914 | 32.7301 |
| 10 | 1.631 | .000 | .0000 | .2000 | .000000 |
| 11 | -12.478 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.1073 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9964060.3 | 9993769.0 | 9492179.4 | 4801934.7 | 1580593.9 |
| 14 | 73.4160 | 73.1475 | 69.4145 | 84.1955 | 289.3792 |
| 15 | -10.0420 | -10.0945 | -9.2071 | .9877 | 21.2789 |

PARKING ORBIT INSERTION

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 757.0400 | 623978.9700 | 9892549.1000 | -.3991 | 90.7100 |
| 2 | 24405.5710 | 25728.6310 | .059 | -.3766 | 90.6746 |
| 3 | -1737881.6 | -2225423.2 | -12667700.600 | 2147353.700 | -9270547.000 |
| 4 | 242504.2 | 255559.8 | 12992095.6 | -3343.630 | -54081.126 |
| 5 | 9809283.6 | 10709623.2 | 11586491.6 | 3216679.600 | -830526.380 |
| 6 | -11253.576 | -12926.980 | -18435.310 | 3144.9723 | -23245.131 |
| 7 | 990.289 | 229.052 | -17943.855 | -.2651 | -184.366 |
| 8 | 21633.498 | 22244.174 | -346.3343 | 7661.1698 | -4165.944 |
| 9 | -24.304 | .000 | .0000 | -49.3884 | 32.7301 |
| 10 | 1.631 | .000 | .0000 | .2000 | .000000 |
| 11 | -12.480 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.1099 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9964992.8 | 9994701.0 | 9493108.2 | 4802881.1 | 1579747.9 |
| 14 | 73.4161 | 73.1476 | 69.4151 | 84.1951 | 289.3900 |
| 15 | -10.0437 | -10.0961 | -9.2087 | .9849 | 21.2933 |

TABLE AP 3-3 (Sheet 1 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| 1 | TIME (SEC) | ALTITUDE (FEET) | RANGE (FEET) | GAMMA SB 1 (DEG.) | GAMMA SB 2 (DEG.) |
|----|------------------------|----------------------|--------------------------|-------------------------|-------------------------|
| 2 | V SB E (FT/SEC) | V SB I (FT/SEC) | A SB I (FT/SSQ) | GAMMA(1) PR (DEG.) | GAMMA(2) PR (DEG.) |
| 3 | X SB E (FEET) | X SB S (FEET) | X SB SFE (FEET) | XI (METERS) | X SB GS (FEET) |
| 4 | Y SB E (FEET) | Y SB S (FEET) | Y SB SFE (FEET) | ETA (METERS) | Y SB GS (FEET) |
| 5 | Z SB E (FEET) | Z SB S (FEET) | Z SB SFE (FEET) | ZETA (METERS) | Z SB GS (FEET) |
| 6 | D-X SB E (FT/SEC) | D-X SB S (FT/SEC) | D-X SB SFE (FT/SEC) | D-XI (M/SEC) | D-X SB GS (FT/SEC) |
| 7 | D-Y SB E (FT/SEC) | D-Y SB S (FT/SEC) | D-Y SB SFE (FT/SEC) | D-ETA (M/SEC) | D-Y SB GS (FT/SEC) |
| 8 | D-Z SB E (FT/SEC) | D-Z SB S (FT/SEC) | D-Z SB SFE (FT/SEC) | D-ZETA (M/SEC) | D-Z SB GS (FT/SEC) |
| 9 | DD-X SB E (FT/SSQ) | V SB W (FT/SEC) | ALPHA SB WIND (DEG.) | MU (DEG.) | RHO (DEG.) |
| 10 | DD-Y SB E (FT/SSQ) | E SB W (DEG.) | BETA SB WIND (DEG.) | TEMPERATURE (DEG R) | DENSITY (SL/FT3) |
| 11 | DD-Z SB E (FT/SSQ) | V SB RM (FT/SEC) | MACH NUMBER | PRESSURE (LB/FT2) | DYN PRESS Q (LB/FT2) |
| 12 | RANGE ANGLE (DEG.) | REYN/L (1/FT) | VISCOSITY (LB-S/FT2) | REL HUMID (PERCENT) | SOUND VEL (FT/SEC) |
| 13 | D* SB 1 (FEET) | D* SB 2 (FEET) | D* SB 3 (FEET) | D* SB 4 (FEET) | D* SB 5 (FEET) |
| 14 | A* SB 1 (DEG.) | A* SB 2 (DEG.) | A* SB 3 (DEG.) | A* SB 4 (DEG.) | A* SB 5 (DEG.) |
| 15 | E* SB 1 (DEG.) | E* SB 2 (DEG.) | E* SB 3 (DEG.) | E* SB 4 (DEG.) | E* SB 5 (DEG.) |

PARKING ORBIT INSERTION

| | | | | | |
|----|------------|-------------|---------------|-------------|--------------|
| 1 | 757.0400 | 623978.6700 | 9892549.1000 | -.3991 | 90.7100 |
| 2 | 24405.5710 | 25728.6310 | .059 | -.3766 | 90.6746 |
| 3 | -1737881.6 | -2225423.2 | -12667700.600 | 2147353.700 | -9270547.000 |
| 4 | 242504.2 | 255559.8 | 12992095.6 | -3343.630 | -54081.126 |
| 5 | 9809283.6 | 10709623.2 | 11586491.6 | 3216679.600 | -830526.380 |
| 6 | -11253.576 | -12926.980 | -18435.310 | 3144.9723 | -23245.131 |
| 7 | 990.289 | 229.052 | -17943.855 | -.2651 | -184.366 |
| 8 | 21633.498 | 22244.174 | -346.3343 | 7661.1698 | -4165.944 |
| 9 | -24.304 | .000 | .0000 | -.49.3884 | 32.7301 |
| 10 | 1.631 | .000 | .0000 | .2000 | .0000000 |
| 11 | -12.480 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.1099 | .0000 | .0000 | .0000 | .0000 |
| 13 | 4802881.1 | 10836326.8 | 41991656.0 | 31041832.0 | 18781310.0 |
| 14 | 84.1951 | 288.0704 | 300.8273 | 52.3082 | 68.6873 |
| 15 | .9849 | -11.5570 | -81.5904 | -46.1384 | -24.5026 |
| 1 | 760.0000 | 623461.0800 | 9962698.9000 | -.3768 | 90.8467 |
| 2 | 24406.2230 | 25729.2490 | .000 | -.3741 | 90.8043 |
| 3 | -1771316.7 | -2263820.5 | -12722184.500 | .000 | .000 |
| 4 | 245443.1 | 256236.2 | 12938883.3 | .000 | .000 |
| 5 | 9873264.0 | 10775398.9 | 11585384.3 | .000 | .000 |
| 6 | -11325.459 | -13004.941 | -18382.365 | .0000 | .000 |
| 7 | 995.100 | 227.865 | -17997.977 | .0000 | .000 |
| 8 | 21596.469 | 22199.414 | -394.8159 | .0000 | .000 |
| 9 | -24.262 | .000 | .0000 | -.49.1603 | 32.7275 |
| 10 | 1.627 | .000 | .0000 | .2000 | .0000000 |
| 11 | -12.561 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.3021 | .0000 | .0000 | .0000 | .0000 |
| 13 | 4872876.6 | 10767415.9 | 41981643.0 | 31084058.0 | 18843640.0 |
| 14 | 84.1696 | 288.0700 | 300.5626 | 52.2157 | 68.6398 |
| 15 | .7744 | -11.4418 | -81.5009 | -46.2255 | -24.6051 |

TABLE AP 3-3 (Sheet 2 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| ALIGN AXIS WITH LOCAL HORIZONTAL | | | | | |
|----------------------------------|------------|-------------|---------------|------------|------------|
| 1 | 764.0000 | 622777.4300 | 10057495.5000 | -.3939 | 91.0314 |
| 2 | 24407.0780 | 25730.0590 | .000 | -.3707 | 90.9795 |
| 3 | -1816823.6 | -2316061.6 | -12795563.300 | .000 | .000 |
| 4 | 249436.7 | 257144.6 | 12866732.3 | .000 | .000 |
| 5 | 9959548.3 | 10864073.6 | 11583666.5 | .000 | .000 |
| 6 | -11422.400 | -13110.041 | -18310.435 | .0000 | .000 |
| 7 | 1001.589 | 226.264 | -18070.753 | .0000 | .000 |
| 8 | 21546.021 | 22138.466 | -460.3375 | .0000 | .000 |
| 9 | -24.206 | .000 | .0000 | -48.8520 | 32.7232 |
| 10 | 1.621 | .000 | .0000 | .2000 | .0000000 |
| 11 | -12.671 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.5619 | .0000 | .0000 | .0000 | .0000 |
| 13 | 4967475.6 | 10674255.0 | 41967943.0 | 31141029.0 | 18927809.0 |
| 14 | 84.1365 | 288.0694 | 300.2129 | 52.0907 | 68.5761 |
| 15 | .4951 | -11.2857 | -81.3796 | -46.3432 | -24.7436 |
| 1 | 770.0000 | 621786.0600 | 10199689.3000 | -.3894 | 91.3085 |
| 2 | 24408.3030 | 25731.2190 | .000 | -.3657 | 91.2423 |
| 3 | -1885782.1 | -2395182.5 | -12905096.600 | .000 | .000 |
| 4 | 255475.2 | 258494.9 | 12757985.1 | .000 | .000 |
| 5 | 10088595.9 | 10996628.9 | 11580612.5 | .000 | .000 |
| 6 | -11567.387 | -13267.147 | -18201.719 | .0000 | .000 |
| 7 | 1011.295 | 223.866 | -18179.138 | .0000 | .000 |
| 8 | 21469.469 | 22046.052 | -558.6313 | .0000 | .000 |
| 9 | -24.123 | .000 | .0000 | -48.3898 | 32.7152 |
| 10 | 1.613 | .000 | .0000 | .2000 | .0000000 |
| 11 | -12.839 | .000 | .0000 | .0000 | .0000 |
| 12 | 27.9516 | .0000 | .0000 | .0000 | .0000 |
| 13 | 5109395.0 | 10534433.3 | 41947032.0 | 31226289.0 | 19053931.0 |
| 14 | 84.0898 | 288.0681 | 299.7059 | 51.9032 | 68.4815 |
| 15 | .0872 | -11.0506 | -81.1972 | -46.5197 | -24.9511 |
| 1 | 780.0000 | 620143.0800 | 10436717.1000 | -.3819 | 91.7700 |
| 2 | 24410.3670 | 25733.1700 | .000 | -.3573 | 91.6800 |
| 3 | -2002659.7 | -2529157.3 | -13086189.000 | .000 | .000 |
| 4 | 265668.5 | 260713.4 | 12575288.0 | .000 | .000 |
| 5 | 10302644.4 | 11216309.5 | 11574202.8 | .000 | .000 |
| 6 | -11807.874 | -13527.516 | -18018.510 | .0000 | .000 |
| 7 | 1027.359 | 219.840 | -18357.766 | .0000 | .000 |
| 8 | 21339.744 | 21889.588 | -722.3873 | .0000 | .000 |
| 9 | -23.976 | .000 | .0000 | -47.6194 | 32.6977 |
| 10 | 1.600 | .000 | .0000 | .2000 | .0000000 |
| 11 | -13.108 | .000 | .0000 | .0000 | .0000 |
| 12 | 28.6011 | .0000 | .0000 | .0000 | .0000 |
| 13 | 5345978.2 | 10301118.5 | 41911125.0 | 31367815.0 | 19263774.0 |
| 14 | 84.0192 | 288.0650 | 298.9031 | 51.5906 | 68.3264 |
| 15 | -.5676 | -10.6560 | -80.8918 | -46.8139 | -25.2965 |
| 1 | 790.0000 | 618532.8100 | 10673783.0000 | -.3742 | 92.2311 |
| 2 | 24412.4020 | 25735.0910 | .000 | -.3487 | 92.1174 |
| 3 | -2121934.7 | -2665726.6 | -13265436.700 | .000 | .000 |
| 4 | 276021.9 | 262891.6 | 12390817.6 | .000 | .000 |
| 5 | 10515381.7 | 11434410.2 | 11566156.0 | .000 | .000 |
| 6 | -12046.902 | -13786.025 | -17832.740 | .0000 | .000 |
| 7 | 1043.284 | 215.785 | -18533.840 | .0000 | .000 |
| 8 | 21207.288 | 21730.023 | -886.0703 | .0000 | .000 |
| 9 | -23.830 | .000 | .0000 | -46.8493 | 32.6750 |
| 10 | 1.585 | .000 | .0000 | .2000 | .0000000 |
| 11 | -13.383 | .000 | .0000 | .0000 | .0000 |
| 12 | 29.2508 | .0000 | .0000 | .0000 | .0000 |
| 13 | 5582592.5 | 10067480.7 | 41873921.0 | 31508631.0 | 19473158.0 |
| 14 | 83.9566 | 288.0607 | 298.1491 | 51.2779 | 68.1743 |
| 15 | -1.1942 | -10.2581 | -80.5850 | -47.1080 | -25.6414 |
| 1 | 800.0000 | 616954.9700 | 10910885.5000 | -.3665 | 92.6918 |
| 2 | 24414.3980 | 25736.9680 | .000 | -.3401 | 92.5544 |
| 3 | -2243592.8 | -2804871.6 | -13442813.800 | .000 | .000 |
| 4 | 286533.7 | 265029.0 | 12204599.2 | .000 | .000 |
| 5 | 10726780.9 | 11650899.6 | 11556472.8 | .000 | .000 |
| 6 | -12284.456 | -14042.649 | -17644.412 | .0000 | .000 |
| 7 | 1059.063 | 211.699 | -18707.339 | .0000 | .000 |
| 8 | 21072.099 | 21567.355 | -1049.6655 | .0000 | .000 |
| 9 | -23.680 | .000 | .0000 | -46.0795 | 32.6470 |
| 10 | 1.570 | .000 | .0000 | .2000 | .0000000 |
| 11 | -13.655 | .000 | .0000 | .0000 | .0000 |
| 12 | 29.9005 | .0000 | .0000 | .0000 | .0000 |
| 13 | 5819208.3 | 9833528.4 | 41835424.0 | 31648726.0 | 19682071.0 |
| 14 | 83.9009 | 288.0550 | 297.4396 | 50.9649 | 68.0253 |
| 15 | -1.7959 | -9.8564 | -80.2768 | -47.4021 | -25.9859 |

TABLE AP 3-3 (Sheet 3 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | ROLL 180 DEG. TO | POSITION III DOWN | | | |
|----|------------------|-------------------|---------------|------------|------------|
| 1 | 837.0000 | 611404.1900 | 11788473.3000 | -.3374 | 94.3898 |
| 2 | 24421.4250 | 25743.5460 | .000 | -.3078 | 94.1648 |
| 3 | -2714196.4 | -3341783.7 | -14082423.900 | .000 | .000 |
| 4 | 326780.6 | 272578.5 | 11500826.2 | .000 | .000 |
| 5 | 11496872.2 | 12437391.7 | 11506435.7 | .000 | .000 |
| 6 | -13150.043 | -14975.130 | -16925.796 | .0000 | .000 |
| 7 | 1116.080 | 196.314 | -19326.474 | .0000 | .000 |
| 8 | 20548.400 | 20938.892 | -1653.8069 | .0000 | .000 |
| 9 | -23.101 | .000 | .0000 | -43.2359 | 32.4980 |
| 10 | 1.511 | .000 | .0000 | .2000 | .0000000 |
| 11 | -14.649 | .000 | .0000 | .0000 | .0000 |
| 12 | 32.3053 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6694293.5 | 8965328.7 | 41681745.0 | 32160682.0 | 20450778.0 |
| 14 | 83.7430 | 288.0206 | 295.1401 | 49.8041 | 67.4981 |
| 15 | -3.8501 | -8.3328 | -79.1263 | -48.4895 | -27.2566 |
| | | | | | |
| 1 | 900.0000 | 603021.8000 | 13283767.7000 | -.2865 | 97.2449 |
| 2 | 24432.0780 | 25753.3760 | .000 | -.2516 | 96.8721 |
| 3 | -3587796.1 | -4333607.1 | -15108233.100 | .000 | .000 |
| 4 | 400017.6 | 284098.5 | 10252107.8 | .000 | .000 |
| 5 | 12761259.1 | 13720495.8 | 11369979.2 | .000 | .000 |
| 6 | -14571.861 | -16496.883 | -15626.438 | .0000 | .000 |
| 7 | 1207.676 | 169.217 | -20295.136 | .0000 | .000 |
| 8 | 19573.677 | 19775.254 | -2675.5133 | .0000 | .000 |
| 9 | -22.016 | .000 | .0000 | -38.4211 | 32.0811 |
| 10 | 1.394 | .000 | .0000 | .2000 | .0000000 |
| 11 | -16.282 | .000 | .0000 | .0000 | .0000 |
| 12 | 36.4027 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8180716.6 | 7478871.2 | 41379502.0 | 33008306.0 | 21742989.0 |
| 14 | 83.5932 | 287.8978 | 292.0992 | 47.8098 | 66.6780 |
| 15 | -6.9219 | -5.5570 | -77.1404 | -50.3379 | -29.4080 |
| | | | | | |
| 1 | 1000.0000 | 592592.4400 | 15659448.2000 | -.2018 | 101.6250 |
| 2 | 24445.4520 | 25765.3190 | .000 | -.1600 | 101.0223 |
| 3 | -3151909.7 | -6096615.5 | -16560374.600 | .000 | .000 |
| 4 | 527403.5 | 298787.3 | 8154863.8 | .000 | .000 |
| 5 | 14633093.9 | 15596529.4 | 11022462.1 | .000 | .000 |
| 6 | -16677.690 | -18722.247 | -13384.179 | .0000 | .000 |
| 7 | 1336.339 | 124.181 | -21598.945 | .0000 | .000 |
| 8 | 17822.710 | 17700.672 | -4266.2743 | .0000 | .000 |
| 9 | -20.053 | .000 | .0000 | -30.8960 | 31.0086 |
| 10 | 1.172 | .000 | .0000 | .2000 | .0000000 |
| 11 | -18.700 | .000 | .0000 | .0000 | .0000 |
| 12 | 42.9118 | .0000 | .0000 | .0000 | .0000 |
| 13 | 10523423.4 | 5105030.4 | 40795567.0 | 34287329.0 | 23745739.0 |
| 14 | 83.5248 | 287.3862 | 288.6578 | 44.5611 | 65.5376 |
| 15 | -11.1925 | -.2421 | -73.9445 | -53.2594 | -32.7969 |
| | | | | | |
| 1 | 1500.0000 | 598329.9500 | 27547593.0000 | .2624 | 118.3482 |
| 2 | 24441.0770 | 25753.8740 | .000 | .3017 | 116.7832 |
| 3 | ***** | ***** | -20016649.000 | .000 | .000 |
| 4 | 1281570.3 | 300810.6 | -3421068.0 | .000 | .000 |
| 5 | 20799581.0 | 21253956.0 | 7112256.4 | .000 | .000 |
| 6 | -23594.674 | -25398.822 | -35.753 | .0000 | .000 |
| 7 | 1543.178 | -117.483 | -23329.880 | .0000 | .000 |
| 8 | 6186.775 | 4260.067 | -10907.6817 | .0000 | .000 |
| 9 | -6.849 | .000 | .0000 | 2.9314 | 19.4207 |
| 10 | -.460 | .000 | .0000 | .2000 | .0000000 |
| 11 | -26.529 | .000 | .0000 | .0000 | .0000 |
| 12 | 75.4695 | .0000 | .0000 | .0000 | .0000 |
| 13 | 21624275.0 | 6982014.7 | 36036228.0 | 39254182.0 | 32601438.0 |
| 14 | 84.1322 | 112.0271 | 280.0498 | 23.5458 | 61.3559 |
| 15 | -29.2268 | -4.5877 | -57.6531 | -67.2156 | -49.4494 |
| | | | | | |
| 1 | 2000.0000 | 701475.1700 | 39360115.0000 | .6855 | 124.5522 |
| 2 | 24316.3410 | 25629.9520 | .000 | .6574 | 122.5532 |
| 3 | ***** | ***** | -16609958.400 | .000 | .000 |
| 4 | 1915789.4 | 186796.0 | -13830215.3 | .000 | .000 |
| 5 | 20518120.0 | 19629490.0 | 753034.2 | .000 | .000 |
| 6 | -23197.716 | -23364.499 | 13226.440 | .0000 | .000 |
| 7 | 837.459 | -326.577 | -17096.820 | .0000 | .000 |
| 8 | -7242.175 | -10530.340 | -13771.5119 | .0000 | .000 |
| 9 | 8.310 | .000 | .0000 | 30.9258 | 2.0096 |
| 10 | -2.318 | .000 | .0000 | .2300 | .0000000 |
| 11 | -25.698 | .000 | .0000 | .0000 | .0000 |
| 12 | 107.8115 | .0000 | .0000 | .0000 | .0000 |
| 13 | 31022324.0 | 18414602.0 | 28552914.0 | 41446120.0 | 38952855.0 |
| 14 | 85.1525 | 111.5665 | 274.7240 | 335.5732 | 57.1190 |
| 15 | -45.9000 | -23.6830 | -41.1007 | -76.5947 | -65.7961 |

TABLE AP 3-3 (Sheet 4 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|------------|------------|
| 1 | 2499.9999 | 873092.4700 | 50987577.0000 | .8895 | 120.7420 |
| 2 | 24106.8680 | 25434.1790 | .000 | .7966 | 118.9803 |
| 3 | ***** | ***** | -7578343.800 | .000 | .000 |
| 4 | 1985794.3 | -8598.5 | -19572355.0 | .000 | .000 |
| 5 | 13980097.0 | 11366403.5 | -5870080.7 | .000 | .000 |
| 6 | -15822.910 | -13543.314 | 21821.482 | .0000 | .000 |
| 7 | -653.219 | -433.948 | -5257.032 | .0000 | .000 |
| 8 | -18175.530 | -21524.123 | -11961.7766 | .0000 | .000 |
| 9 | 20.305 | .000 | .0000 | 57.8878 | -15.7209 |
| 10 | -3.457 | .000 | .0000 | .2000 | .0000000 |
| 11 | -16.946 | .000 | .0000 | .0000 | .0000 |
| 12 | 139.6771 | .0000 | .0000 | .0000 | .0000 |
| 13 | 37977200.0 | 28367085.0 | 19020072.0 | 40620968.0 | 42283033.0 |
| 14 | 86.2966 | 111.4730 | 268.6314 | 273.9261 | 42.5285 |
| 15 | -62.1690 | -40.3367 | -24.0434 | -71.5983 | -81.6605 |

| | | | | | |
|----|------------|--------------|---------------|------------|------------|
| 1 | 2999.9999 | 1052374.6000 | 62318141.0000 | .7674 | 107.0060 |
| 2 | 23888.2010 | 25234.4250 | .000 | .6836 | 106.0751 |
| 3 | ***** | ***** | 3975312.000 | .000 | .000 |
| 4 | 1220261.0 | -224415.9 | -18844523.0 | .000 | .000 |
| 5 | 3300511.2 | -663980.5 | -10554796.3 | .000 | .000 |
| 6 | -3993.508 | 485.886 | 23085.871 | .0000 | .000 |
| 7 | -2391.611 | -406.402 | 8030.221 | .0000 | .000 |
| 8 | -23430.285 | -25226.475 | -6271.7125 | .0000 | .000 |
| 9 | 25.784 | .000 | .0000 | 88.8766 | -28.8793 |
| 10 | -3.248 | .000 | .0000 | .2000 | .0000000 |
| 11 | -3.667 | .000 | .0000 | .0000 | .0000 |
| 12 | 170.7619 | .0000 | .0000 | .0000 | .0000 |
| 13 | 42006233.0 | 36088300.0 | 8425264.5 | 36859424.0 | 42386843.0 |
| 14 | 87.5247 | 110.6922 | 254.3300 | 248.4591 | 263.3013 |
| 15 | -78.1970 | -56.4700 | -4.1981 | -58.4790 | -81.1733 |

| | | | | | |
|--------------------------------------|------------|--------------|---------------|------------|------------|
| INITIATE 20 DEG. PITCH DOWN MANEUVER | | | | | |
| 1 | 3207.0000 | 1112786.0000 | 63975197.0000 | .6274 | 98.7675 |
| 2 | 23814.8820 | 25167.0930 | .000 | .5701 | 98.2946 |
| 3 | ***** | ***** | 8596742.000 | .000 | .000 |
| 4 | 658892.0 | -303731.5 | -16665265.4 | .000 | .000 |
| 5 | -1586272.5 | -5817201.1 | -11541636.6 | .000 | .000 |
| 6 | 1374.554 | 6431.479 | 21357.777 | .0000 | .000 |
| 7 | -3014.281 | -356.481 | 12916.669 | .0000 | .000 |
| 8 | -23583.327 | -24328.823 | -3222.9958 | .0000 | .000 |
| 9 | 25.869 | .000 | .0000 | -256.6135 | -31.7759 |
| 10 | -2.728 | .000 | .0000 | .2000 | .0000000 |
| 11 | 2.175 | .000 | .0000 | .0000 | .0000 |
| 12 | 175.3154 | .0000 | .0000 | .0000 | .0000 |
| 13 | 42756376.0 | 38501793.0 | 4400437.8 | 34514894.0 | 41492061.0 |
| 14 | 88.1095 | 109.8691 | 230.6567 | 242.2608 | 254.7966 |
| 15 | -84.7828 | -63.0621 | 8.8753 | -52.4584 | -74.7748 |

| | | | | | |
|----|------------|--------------|---------------|------------|------------|
| 1 | 3499.9999 | 1173830.6000 | 57598702.0000 | .3671 | 85.9746 |
| 2 | 23741.3840 | 25098.0060 | .000 | .3582 | 86.1935 |
| 3 | ***** | ***** | 14257391.200 | .000 | .000 |
| 4 | -326790.7 | -393959.2 | -12019878.5 | .000 | .000 |
| 5 | -8287743.9 | ***** | -11821538.5 | .000 | .000 |
| 6 | 8721.210 | 14088.375 | 16925.913 | .0000 | .000 |
| 7 | -3658.923 | -253.791 | 18484.387 | .0000 | .000 |
| 8 | -21776.273 | -20769.287 | 1323.2124 | .0000 | .000 |
| 9 | 23.883 | .000 | .0000 | -235.2573 | -32.5379 |
| 10 | -1.603 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.032 | .000 | .0000 | .0000 | .0000 |
| 12 | 157.8446 | .0000 | .0000 | .0000 | .0000 |
| 13 | 42882030.0 | 41058585.0 | 4753517.1 | 30500933.0 | 39324675.0 |
| 14 | 268.4939 | 107.3683 | 130.7297 | 234.9920 | 250.5405 |
| 15 | -85.9272 | -72.3174 | 8.0531 | -43.7011 | -65.5249 |

| | | | | | |
|----|------------|--------------|---------------|------------|------------|
| 1 | 3999.9999 | 1197492.2000 | 46448741.0000 | -.1391 | 66.9826 |
| 2 | 23714.7960 | 25067.1600 | .000 | -.0800 | 68.2893 |
| 3 | ***** | ***** | 20006458.000 | .000 | .000 |
| 4 | -2252885.7 | -464718.2 | -1364008.4 | .000 | .000 |
| 5 | ***** | ***** | -9314803.3 | .000 | .000 |
| 6 | 18815.763 | 23088.376 | 5451.407 | .0000 | .000 |
| 7 | -3822.157 | -20.967 | 22971.133 | .0000 | .000 |
| 8 | -13919.400 | -9761.611 | 8424.4771 | .0000 | .000 |
| 9 | 15.575 | .000 | .0000 | -201.1131 | -25.0562 |
| 10 | 1.063 | .000 | .0000 | .2000 | .0000000 |
| 11 | 20.635 | .000 | .0000 | .0000 | .0000 |
| 12 | 127.2657 | .0000 | .0000 | .0000 | .0000 |
| 13 | 40592793.0 | 42969743.0 | 15037995.7 | 22120684.0 | 33360155.0 |
| 14 | 269.8809 | 60.2034 | 100.1713 | 222.9836 | 247.9901 |
| 15 | -70.1049 | -87.0348 | -16.0936 | -28.3485 | -49.5839 |

TABLE AP 3-3 (Sheet 5 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|--------------|---------------|------------|------------|
| 1 | 4499.9998 | 1122267.9000 | 35259209.0000 | -.5590 | 56.8462 |
| 2 | 23808.1870 | 25148.2920 | .000 | -.4966 | 58.8186 |
| 3 | ***** | ***** | 19408590.000 | .000 | .000 |
| 4 | -3908562.3 | -412588.7 | 9723053.6 | .000 | .000 |
| 5 | ***** | ***** | -3845627.5 | .000 | .000 |
| 6 | 23577.484 | 24761.441 | -7796.286 | .0000 | .000 |
| 7 | -2559.315 | 225.641 | 20157.293 | .0000 | .000 |
| 8 | -2093.302 | 4388.253 | 12858.3865 | .0000 | .000 |
| 9 | 2.985 | .000 | .0000 | -172.6923 | -10.1102 |
| 10 | 3.940 | .000 | .0000 | .2000 | .0000000 |
| 11 | 25.560 | .000 | .0000 | .0000 | .0000 |
| 12 | 96.5834 | .0000 | .0000 | .0000 | .0000 |
| 13 | 35307229.0 | 41701251.0 | 24962380.0 | 12783642.6 | 24918193.0 |
| 14 | 271.1402 | 305.2155 | 92.6413 | 203.0824 | 247.0307 |
| 15 | -54.2167 | -75.6442 | -33.3749 | -12.5428 | -33.3626 |

| | | | | | |
|----|------------|-------------|---------------|-----------|------------|
| 1 | 4999.9999 | 979440.1700 | 23947041.0000 | -.7716 | 56.1765 |
| 2 | 23982.8460 | 25313.7210 | .000 | -.7561 | 58.1729 |
| 3 | ***** | -6129758.8 | 12599142.600 | .000 | .000 |
| 4 | -4597091.3 | -249046.9 | 17689133.0 | .000 | .000 |
| 5 | ***** | ***** | 2853188.1 | .000 | .000 |
| 6 | 21592.586 | 18454.626 | -18716.876 | .0000 | .000 |
| 7 | -24.559 | 412.780 | 10791.676 | .0000 | .000 |
| 8 | 10437.265 | 17321.689 | 13191.0118 | .0000 | .000 |
| 9 | -10.826 | .000 | .0000 | -146.8514 | 7.5313 |
| 10 | 5.964 | .000 | .0000 | .2000 | .0000000 |
| 11 | 23.317 | .000 | .0000 | .0000 | .0000 |
| 12 | 65.5952 | .0000 | .0000 | .0000 | .0000 |
| 13 | 27367474.0 | 37318431.0 | 33201142.0 | 7154115.4 | 14576975.1 |
| 14 | 272.3847 | 299.5338 | 87.2320 | 137.6444 | 246.2081 |
| 15 | -38.1048 | -59.8140 | -49.7574 | -1.8271 | -16.2517 |

| | | | | | |
|------------------------------------|------------|-------------|---------------|------------|-----------|
| INITIATE 20 DEG. PITCH UP MANEUVER | | | | | |
| 1 | 5426.9999 | 839000.8900 | 14161433.1000 | -.7665 | 63.2555 |
| 2 | 24154.6030 | 25482.9080 | .000 | -.7801 | 64.7525 |
| 3 | -3955019.0 | -352685.5 | 3412410.800 | .000 | .000 |
| 4 | -4043269.9 | -55189.6 | 19976784.0 | .000 | .000 |
| 5 | ***** | -7102234.4 | 7910880.9 | .000 | .000 |
| 6 | 14744.912 | 8010.317 | -23437.319 | .0000 | .000 |
| 7 | 2638.341 | 477.906 | -331.957 | .0000 | .000 |
| 8 | 18949.183 | 24186.464 | 9998.0262 | .0000 | .000 |
| 9 | -20.723 | .000 | .0000 | -122.8690 | 21.4485 |
| 10 | 6.236 | .000 | .0000 | .2000 | .0000000 |
| 11 | 15.762 | .000 | .0000 | .0000 | .0000 |
| 12 | 38.7982 | .0000 | .0000 | .0000 | .0000 |
| 13 | 18879424.0 | 31312163.0 | 38381516.0 | 12546722.7 | 4827975.7 |
| 14 | 273.4378 | 297.0014 | 81.8469 | 84.0503 | 242.2577 |
| 15 | -23.9197 | -46.0811 | -63.5613 | -13.3970 | 3.5442 |

| | | | | | |
|----|------------|-------------|---------------|------------|-----------|
| 1 | 5499.9998 | 815650.0700 | 12479482.7000 | -.7494 | 65.2238 |
| 2 | 24183.2510 | 25511.3910 | .000 | -.7640 | 66.5945 |
| 3 | -2935062.4 | 156358.2 | 1691105.100 | .000 | .000 |
| 4 | -3834155.0 | -20270.7 | 19879644.0 | .000 | .000 |
| 5 | ***** | -5312829.4 | 8610870.8 | .000 | .000 |
| 6 | 13183.024 | 5926.449 | -23692.887 | .0000 | .000 |
| 7 | 3089.328 | 478.227 | -2326.191 | .0000 | .000 |
| 8 | 20037.305 | 24808.861 | 9168.8079 | .0000 | .000 |
| 9 | -22.046 | .000 | .0000 | -118.3427 | 23.4795 |
| 10 | 6.111 | .000 | .0000 | .2000 | .0000000 |
| 11 | 14.031 | .000 | .0000 | .0000 | .0000 |
| 12 | 34.1916 | .0000 | .0000 | .0000 | .0000 |
| 13 | 17303640.0 | 30098578.0 | 39068463.0 | 13916164.8 | 3152601.8 |
| 14 | 273.6174 | 296.5619 | 80.6433 | 79.7493 | 238.7257 |
| 15 | -21.4127 | -43.7123 | -65.9098 | -15.8324 | 10.8568 |

| | | | | | |
|----------------------------------|------------|-------------|--------------|------------|-----------|
| ROLL 180 DEG. TO POSITION 1 DOWN | | | | | |
| 1 | 5786.9999 | 730672.7900 | 5885424.5000 | -.6397 | 75.0757 |
| 2 | 24287.8940 | 25615.2470 | .000 | -.6457 | 75.8674 |
| 3 | -119583.1 | 640213.8 | -5075752.600 | .000 | .000 |
| 4 | -2706771.0 | 113759.1 | 18106715.0 | .000 | .000 |
| 5 | -5366912.6 | 1972419.7 | 10706888.9 | .000 | .000 |
| 6 | 6255.940 | -2603.832 | -23014.203 | .0000 | .000 |
| 7 | 4719.152 | 447.211 | -9923.854 | .0000 | .000 |
| 8 | 22989.010 | 25478.639 | 5291.9315 | .0000 | .000 |
| 9 | -25.824 | .000 | .0000 | -99.0203 | 29.8165 |
| 10 | 5.112 | .000 | .0000 | .2000 | .0000000 |
| 11 | 6.332 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.1274 | .0000 | .0000 | .0000 | .0000 |
| 13 | 10843418.2 | 24867170.0 | 41157872.0 | 19507249.0 | 3932113.9 |
| 14 | 274.3288 | 294.5472 | 73.5673 | 68.3809 | 76.9706 |
| 15 | -10.9703 | -34.3228 | -75.0725 | -25.3372 | 5.4589 |

TABLE AP 3-3 (Sheet 6 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|-------------|--------------|------------|-----------|
| 1 | 5999.9998 | 678085.6800 | 1589152.2000 | -.5182 | 84.1796 |
| 2 | 24353.1380 | 25679.1790 | .000 | -.5076 | 84.4826 |
| 3 | 615767.4 | -586157.9 | -9766748.200 | .000 | .000 |
| 4 | -1594290.4 | 203582.3 | 15445970.9 | .000 | .000 |
| 5 | -373613.9 | 7280700.7 | 11484645.0 | .000 | .000 |
| 6 | 608.871 | -8858.420 | -20798.848 | .0000 | .000 |
| 7 | 5682.437 | 391.786 | -14931.515 | .0000 | .000 |
| 8 | 23673.076 | 24099.693 | 1969.2867 | .0000 | .000 |
| 9 | -26.945 | .000 | .0000 | -83.2638 | 32.3159 |
| 10 | 3.866 | .000 | .0000 | .2000 | .0000000 |
| 11 | .047 | .000 | .0000 | .0000 | .0000 |
| 12 | 4.3549 | .0000 | .0000 | .0000 | .0000 |
| 13 | 5854625.9 | 20575415.0 | 42050724.0 | 23598647.0 | 8899712.3 |
| 14 | 274.8924 | 292.4666 | 60.6104 | 62.9497 | 72.8522 |
| 15 | -1.2647 | -27.2454 | -81.6245 | -32.3126 | -7.7649 |

| | | | | | |
|----|------------|-------------|---------------|------------|------------|
| 1 | 6499.9998 | 607464.8700 | 11179370.3000 | -.1229 | 106.2817 |
| 2 | 24441.8960 | 25761.3720 | .000 | -.0743 | 105.4266 |
| 3 | -2390703.5 | -8229034.7 | -17901172.000 | .000 | .000 |
| 4 | 1570632.5 | 349035.4 | 5775657.6 | .000 | .000 |
| 5 | 10851753.8 | 17396253.0 | 10447674.2 | .000 | .000 |
| 6 | -12339.009 | -20831.180 | -10765.554 | .0000 | .000 |
| 7 | 6626.548 | 172.225 | -22620.127 | .0000 | .000 |
| 8 | 20031.077 | 15155.216 | -6006.7462 | .0000 | .000 |
| 9 | -23.411 | .000 | .0000 | -45.5400 | 29.2098 |
| 10 | -.317 | .000 | .0000 | .2000 | .0000000 |
| 11 | -14.233 | .000 | .0000 | .0000 | .0000 |
| 12 | 30.6336 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6197484.9 | 9682427.6 | 41850578.0 | 32174326.0 | 20108275.0 |
| 14 | 95.7423 | 280.3682 | 286.8537 | 53.6705 | 71.8847 |
| 15 | -2.7820 | -9.6454 | -80.4253 | -48.5267 | -26.7096 |

| | | | | | |
|----|------------|-------------|---------------|------------|------------|
| 1 | 6999.9998 | 631574.7900 | 22962655.0000 | .3512 | 120.6737 |
| 2 | 24413.6130 | 25726.6380 | .000 | .3804 | 118.9537 |
| 3 | ***** | ***** | -19903105.000 | .000 | .000 |
| 4 | 4645956.8 | 364866.8 | -5871253.2 | .000 | .000 |
| 5 | 18618052.0 | 21555194.0 | 5821585.3 | .000 | .000 |
| 6 | -21528.681 | -25707.045 | 2983.241 | .0000 | .000 |
| 7 | 5283.512 | -112.013 | -22589.371 | .0000 | .000 |
| 8 | 10228.632 | 997.635 | -11944.8979 | .0000 | .000 |
| 9 | -12.343 | .000 | .0000 | -13.3112 | 15.7700 |
| 10 | -4.979 | .000 | .0000 | .2000 | .0000000 |
| 11 | -23.842 | .000 | .0000 | .0000 | .0000 |
| 12 | 62.9047 | .0000 | .0000 | .0000 | .0000 |
| 13 | 17696852.0 | 4520067.3 | 38451173.0 | 38485030.0 | 29785693.0 |
| 14 | 96.8747 | 169.4617 | 269.8851 | 43.8950 | 72.5832 |
| 15 | -22.7369 | 1.9076 | -64.4788 | -64.4785 | -43.6100 |

| | | | | | |
|----|------------|-------------|---------------|------------|------------|
| 1 | 7499.9998 | 751259.5200 | 34681354.0000 | .7469 | 124.5536 |
| 2 | 24267.0620 | 25583.6220 | .000 | .7310 | 122.5467 |
| 3 | ***** | ***** | -15110884.800 | .000 | .000 |
| 4 | 6505706.2 | 242200.0 | -15521178.4 | .000 | .000 |
| 5 | 20591719.0 | 18361852.0 | -801406.6 | .000 | .000 |
| 6 | -24067.032 | -21817.232 | 15586.722 | .0000 | .000 |
| 7 | 1879.059 | -365.579 | -14903.228 | .0000 | .000 |
| 8 | -2477.381 | -13356.515 | -13764.7961 | .0000 | .000 |
| 9 | 2.377 | .000 | .0000 | 13.9314 | -2.1314 |
| 10 | -8.273 | .000 | .0000 | .2000 | .0000000 |
| 11 | -25.565 | .000 | .0000 | .0000 | .0000 |
| 12 | 94.9959 | .0000 | .0000 | .0000 | .0000 |
| 13 | 27803787.0 | 14965511.4 | 32141519.0 | 41895223.0 | 37127007.0 |
| 14 | 97.7962 | 131.4430 | 263.7712 | 18.0405 | 73.9543 |
| 15 | -39.5724 | -17.9057 | -48.0794 | -79.2729 | -60.0383 |

| | | | | | |
|----|------------|-------------|---------------|------------|------------|
| 1 | 7999.9998 | 929304.4700 | 46212361.0000 | .8890 | 118.5218 |
| 2 | 24048.8030 | 25381.2500 | .000 | .7906 | 116.9006 |
| 3 | ***** | ***** | -5232556.000 | .000 | .000 |
| 4 | 6354126.6 | 18742.4 | -19965557.0 | .000 | .000 |
| 5 | 16341238.5 | 8997782.8 | -7163018.0 | .000 | .000 |
| 6 | -19382.943 | -10749.839 | 22763.651 | .0000 | .000 |
| 7 | -2537.208 | -503.904 | -2417.677 | .0000 | .000 |
| 8 | -14007.463 | -22986.842 | -10962.6138 | .0000 | .000 |
| 9 | 15.756 | .000 | .0000 | 41.3888 | -19.2532 |
| 10 | -8.891 | .000 | .0000 | .2000 | .0000000 |
| 11 | -19.408 | .000 | .0000 | .0000 | .0000 |
| 12 | 126.6031 | .0000 | .0000 | .0000 | .0000 |
| 13 | 35717060.0 | 25226875.0 | 23478694.0 | 42123898.0 | 41582836.0 |
| 14 | 98.4193 | 123.6429 | 258.7472 | 275.1480 | 76.6919 |
| 15 | -55.8461 | -34.5067 | -31.3482 | -79.8191 | -76.1965 |

TABLE AP 3-3 (Sheet 7 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|--------------|---------------|------------|------------|
| 1 | 8499.9995 | 1100962.6000 | 57489303.0000 | .7012 | 102.6971 |
| 2 | 23839.1080 | 25189.6990 | .000 | .6303 | 102.0076 |
| 3 | ***** | ***** | 6379410.800 | .000 | .000 |
| 4 | 4041833.4 | -235034.1 | -17855818.0 | .000 | .000 |
| 5 | 7348294.3 | -3328662.8 | -11173602.5 | .000 | .000 |
| 6 | -9183.542 | 3559.828 | 22386.786 | .0000 | .000 |
| 7 | -6518.061 | -483.971 | 10567.947 | .0000 | .000 |
| 8 | -21011.437 | -24932.195 | -4655.2434 | .0000 | .000 |
| 9 | 23.975 | .000 | .0000 | 73.6456 | -30.6709 |
| 10 | -6.576 | .000 | .0000 | .2000 | .0000000 |
| 11 | -8.036 | .000 | .0000 | .0000 | .0000 |
| 12 | 157.5372 | .0000 | .0000 | .0000 | .0000 |
| 13 | 40880736.0 | 33595917.0 | 13225736.8 | 39198770.0 | 42883296.0 |
| 14 | 98.1281 | 117.6879 | 251.5164 | 248.3501 | 236.7117 |
| 15 | -71.8396 | -50.4081 | -13.3238 | -65.3332 | -87.6920 |
| | | | | | |
| 1 | 8999.9995 | 1203972.8000 | 62201654.0000 | .2639 | 81.1973 |
| 2 | 23714.5880 | 25072.4420 | .000 | .2732 | 81.6782 |
| 3 | ***** | ***** | 15953681.000 | .000 | .000 |
| 4 | 133387.4 | -439893.4 | -10004377.5 | .000 | .000 |
| 5 | -3620720.1 | ***** | -11587117.9 | .000 | .000 |
| 6 | 3437.039 | 16480.882 | 14878.594 | .0000 | .000 |
| 7 | -8731.814 | -313.460 | 19952.111 | .0000 | .000 |
| 8 | -21778.978 | -18892.054 | 3027.8894 | .0000 | .000 |
| 9 | 25.322 | .000 | .0000 | -250.1950 | -31.7687 |
| 10 | -1.990 | .000 | .0000 | .2000 | .0000000 |
| 11 | 4.935 | .000 | .0000 | .0000 | .0000 |
| 12 | 170.4552 | .0000 | .0000 | .0000 | .0000 |
| 13 | 42979468.0 | 39431660.0 | 3116065.8 | 33388128.0 | 41007818.0 |
| 14 | 80.5505 | 108.4467 | 205.8169 | 240.5772 | 254.1828 |
| 15 | -87.5419 | -65.7724 | 18.8286 | -49.6476 | -71.9331 |
| | | | | | |
| 1 | 9499.9996 | 1206025.2000 | 51304784.0000 | -.2379 | 63.8992 |
| 2 | 23713.9330 | 25064.9090 | .000 | -.1722 | 65.4023 |
| 3 | ***** | ***** | 20473481.000 | .000 | .000 |
| 4 | -4250597.7 | -531602.7 | 1022794.3 | .000 | .000 |
| 5 | ***** | ***** | -8316541.8 | .000 | .000 |
| 6 | 14995.033 | 24092.579 | 2712.074 | .0000 | .000 |
| 7 | -8333.187 | -42.534 | 22953.909 | .0000 | .000 |
| 8 | -16372.464 | -6913.432 | 9696.0000 | .0000 | .000 |
| 9 | 19.848 | .000 | .0000 | -217.3322 | -22.2111 |
| 10 | 3.635 | .000 | .0000 | .2000 | .0000000 |
| 11 | 16.150 | .000 | .0000 | .0000 | .0000 |
| 12 | 140.5623 | .0000 | .0000 | .0000 | .0000 |
| 13 | 41906337.0 | 42349751.0 | 9988521.0 | 25138607.0 | 36133546.0 |
| 14 | 286.4699 | 78.3863 | 90.2671 | 235.7672 | 256.9838 |
| 15 | -76.4601 | -79.4540 | -6.5655 | -33.5551 | -56.0847 |
| | | | | | |
| 1 | 9999.9996 | 1113626.7000 | 40140937.0000 | -.6218 | 55.8967 |
| 2 | 23827.6370 | 25166.2570 | .000 | -.5676 | 57.9361 |
| 3 | ***** | ***** | 18506502.000 | .000 | .000 |
| 4 | -7736877.9 | -478631.8 | 11722640.8 | .000 | .000 |
| 5 | ***** | ***** | -2405335.6 | .000 | .000 |
| 6 | 22364.022 | 24072.813 | -10388.269 | .0000 | .000 |
| 7 | -5185.270 | 250.793 | 18664.359 | .0000 | .000 |
| 8 | -6381.204 | 7333.300 | 13306.6183 | .0000 | .000 |
| 9 | 8.888 | .000 | .0000 | -189.9295 | -6.3069 |
| 10 | 8.725 | .000 | .0000 | .2000 | .0000000 |
| 11 | 22.879 | .000 | .0000 | .0000 | .0000 |
| 12 | 109.9522 | .0000 | .0000 | .0000 | .0000 |
| 13 | 37736699.0 | 42161775.0 | 20491476.0 | 15065039.1 | 28602988.0 |
| 14 | 285.0244 | 345.0143 | 81.0440 | 229.8705 | 259.4961 |
| 15 | -60.6135 | -78.5623 | -25.7150 | -16.5741 | -40.0778 |
| | | | | | |
| 1 | 10499.9995 | 962428.6300 | 28811545.0000 | -.7876 | 57.2866 |
| 2 | 24011.9870 | 25342.9320 | .000 | -.7824 | 59.2003 |
| 3 | ***** | -4314962.2 | 10612594.800 | .000 | .000 |
| 4 | -9088589.6 | -291898.6 | 18657161.0 | .000 | .000 |
| 5 | ***** | ***** | 4272876.4 | .000 | .000 |
| 6 | 23388.527 | 16258.108 | -20339.658 | .0000 | .000 |
| 7 | 18.669 | 477.956 | 8266.488 | .0000 | .000 |
| 8 | 5436.177 | 19434.755 | 12658.1079 | .0000 | .000 |
| 9 | -4.996 | .000 | .0000 | -164.0026 | 11.3283 |
| 10 | 11.584 | .000 | .0000 | .2000 | .0000000 |
| 11 | 23.232 | .000 | .0000 | .0000 | .0000 |
| 12 | 78.9227 | .0000 | .0000 | .0000 | .0000 |
| 13 | 30729453.0 | 38874444.0 | 29692899.0 | 4397226.6 | 18924504.0 |
| 14 | 284.6552 | 317.6847 | 76.6804 | 201.8102 | 262.7640 |
| 15 | -44.5699 | -64.5553 | -42.5971 | 6.7463 | -23.5852 |

TABLE AP 3-3 (Sheet 8 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|-----------------------------------|------------|-------------|---------------|--------------|------------|
| 1 | 10999.9996 | 799627.6300 | 17293760.0000 | -.7234 | 68.5677 |
| 2 | 24211.5940 | 25540.5700 | .000 | -.7366 | 69.7353 |
| 3 | -6201162.6 | 627966.2 | -738249.410 | .000 | .000 |
| 4 | -7620285.7 | -24716.0 | 19488323.0 | .000 | .000 |
| 5 | ***** | -2724287.6 | 9542582.9 | .000 | .000 |
| 6 | 17502.636 | 2898.573 | -23782.564 | .0000 | .000 |
| 7 | 5793.483 | 562.178 | -5084.840 | .0000 | .000 |
| 8 | 15693.775 | 25369.333 | 7800.9534 | .0000 | .000 |
| 9 | -18.053 | .000 | .0000 | -134.2905 | 26.2194 |
| 10 | 10.845 | .000 | .0000 | .2000 | .0000000 |
| 11 | 16.714 | .000 | .0000 | .0000 | .0000 |
| 12 | 47.3847 | .0000 | .0000 | .0000 | .0000 |
| 13 | 21349999.0 | 32725943.0 | 36787409.0 | 8714237.5 | 7825836.4 |
| 14 | 283.8095 | 306.9398 | 73.0032 | 74.9184 | 270.7819 |
| 15 | -28.1324 | -49.1555 | -59.0689 | -6.6065 | -4.7460 |
| BEGIN RESTART PREPARATIONS - TB 6 | | | | | |
| 1 | 11287.7297 | 718846.1700 | 10595768.7000 | -.5917 | 79.5944 |
| 2 | 24312.4390 | 25640.2370 | .000 | -.5893 | 80.1405 |
| 3 | -1995040.3 | 225833.8 | -7409690.100 | .000 | .000 |
| 4 | -5330984.6 | 133694.9 | 16949172.0 | .000 | .000 |
| 5 | -8922270.6 | 4591683.7 | 11202351.5 | .000 | .000 |
| 6 | 11470.803 | -5683.526 | -22144.695 | .0000 | .000 |
| 7 | 8621.234 | 528.629 | -12407.253 | .0000 | .000 |
| 8 | 19626.250 | 24996.797 | 3618.6116 | .0000 | .000 |
| 9 | -23.529 | .000 | .0000 | -114.0487 | 31.3646 |
| 10 | 8.597 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.368 | .000 | .0000 | .0000 | .0000 |
| 12 | 29.0360 | .0000 | .0000 | .0000 | .0000 |
| 13 | 15140237.2 | 28085721.0 | 39667685.0 | 15094996.7 | 1804852.6 |
| 14 | 282.3921 | 301.5600 | 70.4131 | 67.2139 | 320.3424 |
| 15 | -18.2476 | -40.1333 | -68.5021 | -18.2016 | 21.2161 |
| 1 | 11299.9997 | 715783.6500 | 10309579.7000 | -.5846 | 80.1230 |
| 2 | 24316.3110 | 25644.0290 | .007 | -.5812 | 80.6408 |
| 3 | -1856069.3 | 153883.9 | -7680612.900 | 47578.274 | -2212.818 |
| 4 | -5424557.9 | 140164.1 | 16795149.0 | -1386305.100 | -17.111 |
| 5 | -8680683.6 | 4897904.2 | 11245566.6 | -2905078.600 | -490.667 |
| 6 | 11180.967 | -6044.070 | -22015.986 | -1732.3495 | -360.509 |
| 7 | 8725.963 | 525.833 | -12695.369 | 34.8548 | -2.807 |
| 8 | 19751.620 | 24916.039 | 3426.4009 | 7230.4187 | -80.854 |
| 9 | -23.713 | .000 | .0000 | -113.1383 | 31.5042 |
| 10 | 8.473 | .000 | .0000 | .2000 | .0000000 |
| 11 | 10.067 | .000 | .0000 | .0000 | .0000 |
| 12 | 28.2518 | .0000 | .0000 | .0000 | .0000 |
| 13 | 14865620.3 | 27872883.0 | 39768948.0 | 15364102.3 | 1685143.6 |
| 14 | 282.2969 | 301.3187 | 70.2789 | 67.0287 | 329.8412 |
| 15 | -17.8117 | -39.7472 | -68.9040 | -18.6531 | 23.0557 |
| 1 | 11324.9996 | 709658.5300 | 9726480.0000 | -.5698 | 81.2110 |
| 2 | 24324.0710 | 25651.6160 | .008 | -.5644 | 81.6708 |
| 3 | -1583993.9 | -6366.7 | -8227577.800 | 4269.253 | -20373.468 |
| 4 | -5203787.6 | 153235.4 | 16470472.7 | -1385433.600 | -162.081 |
| 5 | -8183811.7 | 5518590.7 | 11326293.6 | -2726317.400 | -4729.084 |
| 6 | 10583.559 | -6775.155 | -21739.328 | -1732.3723 | -1091.519 |
| 7 | 8934.587 | 519.798 | -13274.488 | 34.8618 | -8.866 |
| 8 | 19995.546 | 24735.249 | 3032.3347 | 7230.4799 | -261.845 |
| 9 | -24.076 | .000 | .0000 | -111.2742 | 31.7663 |
| 10 | 8.215 | .000 | .0000 | .2000 | .0000000 |
| 11 | 9.446 | .000 | .0000 | .0000 | .0000 |
| 12 | 26.6541 | .0000 | .0000 | .0000 | .0000 |
| 13 | 14304028.9 | 27435829.0 | 39969640.0 | 15910842.1 | 1586722.0 |
| 14 | 282.0896 | 300.8217 | 69.9957 | 66.6711 | 332.9187 |
| 15 | -16.9181 | -38.9604 | -69.7226 | -19.5672 | 24.6297 |
| 1 | 11349.9996 | 703690.0200 | 9143459.5000 | -.5546 | 82.3127 |
| 2 | 24331.6520 | 25659.0120 | .008 | -.5471 | 82.7142 |
| 3 | -1326965.0 | -184830.0 | -8767385.300 | -39040.357 | -56744.783 |
| 4 | -4977883.3 | 166150.2 | 16131455.0 | -1384562.000 | -464.146 |
| 5 | -7681036.5 | 6134485.9 | 11397131.4 | -2543554.600 | -13763.757 |
| 6 | 9977.319 | -7500.968 | -21443.512 | -1732.3966 | -1817.252 |
| 7 | 9136.643 | 513.312 | -13842.544 | 34.8689 | -19.374 |
| 8 | 20223.852 | 24532.773 | 2635.2857 | 7230.5443 | -464.532 |
| 9 | -24.420 | .000 | .0000 | -109.3985 | 31.9980 |
| 10 | 7.948 | .000 | .0000 | .2000 | .0000000 |
| 11 | 8.817 | .000 | .0000 | .0000 | .0000 |
| 12 | 25.0566 | .0000 | .0000 | .0000 | .0000 |
| 13 | 13739792.9 | 26994324.0 | 40162737.0 | 16455335.9 | 1704795.3 |
| 14 | 281.8624 | 300.3168 | 69.6981 | 66.3178 | 15.5779 |
| 15 | -16.0164 | -38.1732 | -70.5411 | -20.4741 | 22.2599 |

TABLE AP 3-3 (Sheet 9 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|--------------|-------------|
| 1 | 11374.9996 | 697884.3100 | 8560615.3000 | -.5389 | 83,4266 |
| 2 | 24339.0510 | 25666.2110 | .009 | -.5292 | 83,7694 |
| 3 | -1085197.6 | -381365.7 | -9299559.100 | -82350.592 | -111186,604 |
| 4 | -4747012.0 | 178897.3 | 15778380.2 | -1383690.200 | -934,519 |
| 5 | -7172750.9 | 6745049.7 | 11458009.2 | -2362790.100 | -28135,330 |
| 6 | 9362.720 | -8220.850 | -21128.771 | -1732.4223 | -2537,050 |
| 7 | 9331.919 | 506.380 | -14399.011 | 34,8760 | -22,329 |
| 8 | 20436.344 | 24308.756 | 2235,6054 | 7230,6120 | -688,771 |
| 9 | -24.745 | .000 | .0000 | -107,5123 | 32,1988 |
| 10 | 7.673 | .000 | .0000 | .2000 | .0000000 |
| 11 | 8.181 | .000 | .0000 | .0000 | .0000 |
| 12 | 23.4595 | .0000 | .0000 | .0000 | .0000 |
| 13 | 13173064.7 | 26548509.0 | 40348193.0 | 16997408.0 | 2001492,5 |
| 14 | 281.6126 | 299.8030 | 69,3840 | 66,0263 | 32,5515 |
| 15 | -15.1056 | -37,3858 | -71,3594 | -21,3743 | 17,8499 |
| | | | | | |
| 1 | 11399.9996 | 692245.5900 | 7978074.6000 | -.5227 | 84,5511 |
| 2 | 24346.2580 | 25673.2060 | .009 | -.5108 | 84,8350 |
| 3 | -858894.6 | -595817.6 | -9823629.500 | -125661.489 | -183542,340 |
| 4 | -4511345.6 | 191465.6 | 15411544.6 | -1382818.100 | -1584,301 |
| 5 | -6659352.6 | 7349745.6 | 11508866.3 | -2182023.900 | -48380,551 |
| 6 | 8740.245 | -8934.146 | -20795.358 | -1732.4495 | -3250,256 |
| 7 | 9520.206 | 499.007 | -14943.372 | 34,8830 | -29,726 |
| 8 | 20632.839 | 24063.365 | 1833,6491 | 7230,6831 | -934,395 |
| 9 | -25.050 | .000 | .0000 | -105,6170 | 32,3683 |
| 10 | 7.389 | .000 | .0000 | .2000 | .0000000 |
| 11 | 7.538 | .000 | .0000 | .0000 | .0000 |
| 12 | 21.8632 | .0000 | .0000 | .0000 | .0000 |
| 13 | 12604006.1 | 26098525.0 | 40525962.0 | 17536891.0 | 2411719,6 |
| 14 | 281.3371 | 299,2795 | 69,0511 | 65,7347 | 43,9001 |
| 15 | -14.1845 | -36,5981 | -72,1775 | -22,2687 | 13,5349 |
| | | | | | |
| 1 | 11424.9995 | 686780.1700 | 7395999.4000 | -.5061 | 85,6845 |
| 2 | 24353.2680 | 25679.9910 | .010 | -.4920 | 85,9093 |
| 3 | -648246.9 | -828012.7 | -10339132.800 | -168973.090 | -273639,050 |
| 4 | -4271061.6 | 203844.0 | 15031256.8 | -1381946.000 | -2424,476 |
| 5 | -6141243.6 | 7948041.4 | 11549649.7 | -2001255.900 | -75031,756 |
| 6 | 8110.383 | -9640,204 | -20443,542 | -1732,4784 | -3956,220 |
| 7 | 9701.302 | 491,196 | -15475,118 | 34,8901 | -37,560 |
| 8 | 20813.172 | 23796.788 | 1429,7753 | 7230,7577 | -1201,217 |
| 9 | -25.336 | .000 | .0000 | -103,7139 | 32,5062 |
| 10 | 7.097 | .000 | .0000 | .2000 | .0000000 |
| 11 | 6.888 | .000 | .0000 | .0000 | .0000 |
| 12 | 20.2681 | .0000 | .0000 | .0000 | .0000 |
| 13 | 12032788.7 | 25644522.0 | 40696001.0 | 18073624.0 | 2887347,9 |
| 14 | 281.0320 | 298,7454 | 68,6965 | 65,4610 | 51,4942 |
| 15 | -13.2517 | -35,8102 | -72,9953 | -23,1578 | 9,9437 |
| | | | | | |
| 1 | 11449.9995 | 681492.0300 | 6814605.4000 | -.4890 | 86,8251 |
| 2 | 24360.0760 | 25686.5580 | .011 | -.4726 | 86,9906 |
| 3 | -453432.9 | -1077762.1 | -10845612.900 | -212285.430 | -381287,580 |
| 4 | -4026342.1 | 216021.8 | 14637838.9 | -1381073.700 | -3465,894 |
| 5 | -5618830.0 | 8539410.1 | 11580316.4 | -1820486.000 | -108616,349 |
| 6 | 7473.633 | -10338.378 | -20073.612 | -1732.5088 | -4654,294 |
| 7 | 9875.009 | 482,954 | -15993.752 | 34,8972 | -45,825 |
| 8 | 20977.185 | 23509.232 | 1024,3455 | 7230,8359 | -1489,029 |
| 9 | -25.601 | .000 | .0000 | -101,8043 | 32,6120 |
| 10 | 6.798 | .000 | .0000 | .2000 | .0000000 |
| 11 | 6.232 | .000 | .0000 | .0000 | .0000 |
| 12 | 18.6749 | .0000 | .0000 | .0000 | .0000 |
| 13 | 11459596.5 | 25186656.0 | 40858269.0 | 18607450.0 | 3400845,5 |
| 14 | 280.6931 | 298,1996 | 68,3167 | 65,2036 | 56,7796 |
| 15 | -12.3053 | -35,0221 | -73,8127 | -24,0420 | 7,0265 |
| | | | | | |
| 1 | 11474.9996 | 676387.2100 | 6234184.6000 | -.4714 | 87,9712 |
| 2 | 24366.6740 | 25692.9030 | .011 | -.4527 | 88,0773 |
| 3 | -274618.5 | -1344860.6 | -11342620.400 | -255598.550 | -506282,660 |
| 4 | -3777374.3 | 227988.2 | 14231624.9 | -1380201.100 | -4719,267 |
| 5 | -5092521.5 | 9123330.1 | 11600831.9 | -1639714.100 | -149656,290 |
| 6 | 6830.501 | -11028.027 | -19685,875 | -1732,5407 | -5343,838 |
| 7 | 10041.137 | 474,287 | -16498,788 | 34,9042 | -54,515 |
| 8 | 21124.740 | 23200,926 | 617,7236 | 7230,9180 | -1797,604 |
| 9 | -25.846 | .000 | .0000 | -99,8897 | 32,6856 |
| 10 | 6.491 | .000 | .0000 | .2000 | .0000000 |
| 11 | 5.571 | .000 | .0000 | .0000 | .0000 |
| 12 | 17.0844 | .0000 | .0000 | .0000 | .0000 |
| 13 | 10884629.5 | 24725087.0 | 41012726.0 | 19138224.0 | 3937175,8 |
| 14 | 280.3146 | 297,6411 | 67,9076 | 64,9612 | 60,6232 |
| 15 | -11.3434 | -34,2339 | -74,6298 | -24,9217 | 4,6148 |

TABLE AP 3-3 (Sheet 10 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| MANEUVER TO OBTAIN RESTART ATTITUDE | | | | | |
|-------------------------------------|------------|-------------|---------------|--------------|--------------|
| 1 | 11487.3998 | 673924.6000 | 5946773.9000 | -.4625 | 88.5611 |
| 2 | 24369.8670 | 25699.9650 | .012 | -.4427 | 88.6177 |
| 3 | -191909.3 | -1483712.1 | -11585488.000 | -277082.400 | -574649.080 |
| 4 | -3652367.7 | 233841.9 | 14025498.8 | -1379768.300 | -5422.851 |
| 5 | -4830151.8 | 9410034.7 | 11607233.3 | -1550049.300 | -172937.890 |
| 6 | 6509.295 | -11366.737 | -19487.048 | -1732.5573 | -5682.494 |
| 7 | 10120.667 | 469.832 | -16744.097 | 34.9077 | -58.982 |
| 8 | 21191.782 | 23040.382 | 415.7075 | 7230.9601 | -1958.286 |
| 9 | -25.960 | .000 | .0000 | -.98.9386 | 32.7101 |
| 10 | 6.336 | .000 | .0000 | .2000 | .0000000 |
| 11 | 5.242 | .000 | .0000 | .0000 | .0000 |
| 12 | 16.2967 | .0000 | .0000 | .0000 | .0000 |
| 13 | 10598850.8 | 24494825.0 | 41086426.0 | 19400312.0 | 4208900.4 |
| 14 | 280.1102 | 297.3591 | 67.6923 | 64.8461 | 62.1600 |
| 15 | -10.8597 | -33.8429 | -75.0349 | -25.3566 | 3.5604 |
| 1 | 11499.9996 | 671470.2408 | 5655145.1000 | -.4534 | 89.1209 |
| 2 | 24373.0570 | 25699.0190 | .012 | -.4324 | 89.1676 |
| 3 | -111956.7 | -1629087.1 | -11829714.200 | -298912.480 | -648403.070 |
| 4 | -3524350.0 | 239732.7 | 13812960.4 | -1379328.400 | -6195.152 |
| 5 | -4562731.3 | 9699285.6 | 11611171.2 | -1458940.100 | -198667.560 |
| 6 | 6181.502 | -11708.516 | -19280.656 | -1732.5744 | -6024.216 |
| 7 | 10199.499 | 465.201 | -16989.753 | 34.9113 | -63.625 |
| 8 | 21255.708 | 22872.119 | 210.2760 | 7231.0039 | -2126.693 |
| 9 | -26.070 | .000 | .0000 | -.97.9716 | 32.7268 |
| 10 | 6.177 | .000 | .0000 | .2000 | .0000000 |
| 11 | 4.906 | .000 | .0000 | .0000 | .0000 |
| 12 | 15.4976 | .0000 | .0000 | .0000 | .0000 |
| 13 | 10308107.4 | 24259985.0 | 41159333.0 | 19665797.0 | 4487877.9 |
| 14 | 279.8899 | 297.0688 | 67.4642 | 64.7325 | 63.5305 |
| 15 | -10.3632 | -33.4456 | -75.4465 | -25.7975 | 2.5658 |
| 1 | 11524.9996 | 666746.7300 | 5078075.5000 | -.4349 | 90.2725 |
| 2 | 24379.2180 | 25704.9000 | .013 | -.4117 | 90.2597 |
| 3 | 34412.1 | -1930204.8 | -12306461.800 | -342227.290 | -807411.850 |
| 4 | -3267465.6 | 251244.8 | 13382203.0 | -1378455.600 | -7903.945 |
| 5 | -4029875.2 | 10266767.4 | 11611317.8 | -1278163.900 | -256159.660 |
| 6 | 5527.156 | -12379.217 | -18858.297 | -1732.6098 | -6694.802 |
| 7 | 10349.918 | 455.702 | -17466.182 | 34.9183 | -73.147 |
| 8 | 21369.980 | 22523.083 | -197.6293 | 7231.0939 | -2476.025 |
| 9 | -26.274 | .000 | .0000 | -.96.0514 | 32.7354 |
| 10 | 5.856 | .000 | .0000 | .2000 | .0000000 |
| 11 | 4.236 | .000 | .0000 | .0000 | .0000 |
| 12 | 13.9161 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9730275.3 | 23791525.0 | 41298055.0 | 20190031.0 | 5047942.9 |
| 14 | 279.4107 | 296.4815 | 66.9802 | 64.5163 | 65.8036 |
| 15 | -9.3616 | -32.6572 | -76.2626 | -26.6695 | .7777 |
| 1 | 11549.9996 | 662220.3800 | 4503857.3000 | -.4159 | 91.4242 |
| 2 | 24385.1520 | 25710.5410 | .013 | -.3905 | 91.3519 |
| 3 | 164360.9 | -2247961.2 | -12772438.800 | -385543.000 | -983056.370 |
| 4 | -3006921.8 | 262514.4 | 12939721.9 | -1377582.600 | -9855.869 |
| 5 | -3494372.3 | 10825273.4 | 11601265.4 | -1097385.400 | -322635.140 |
| 6 | 4867.988 | -13039.512 | -18419.159 | -1732.6470 | -7354.974 |
| 7 | 10492.219 | 445.798 | -17927.625 | 34.9254 | -83.074 |
| 8 | 21467.455 | 22154.105 | -605.6226 | 7231.1881 | -2845.312 |
| 9 | -26.456 | .000 | .0000 | -.94.1306 | 32.7113 |
| 10 | 5.528 | .000 | .0000 | .2000 | .0000000 |
| 11 | 3.562 | .000 | .0000 | .0000 | .0000 |
| 12 | 12.3425 | .0000 | .0000 | .0000 | .0000 |
| 13 | 9151411.9 | 23319890.0 | 41428857.0 | 20710789.0 | 5614241.7 |
| 14 | 278.8665 | 295.8778 | 66.4477 | 64.3116 | 67.6307 |
| 15 | -8.3346 | -31.8687 | -77.0781 | -27.5382 | -.8197 |
| 1 | 11574.9995 | 657897.1300 | 3933878.2000 | -.3966 | 92.5740 |
| 2 | 24390.8510 | 25715.9340 | .014 | -.3689 | 92.4424 |
| 3 | 277775.8 | -2582088.6 | -13227230.800 | -428859.650 | -1175068.700 |
| 4 | -2742923.6 | 273531.4 | 12485897.4 | -1376709.300 | -12060.962 |
| 5 | -2956643.2 | 11374309.1 | 11581016.0 | -916604.390 | -398589.040 |
| 6 | 4204.532 | -13688.787 | -17963.618 | -1732.6859 | -8004.122 |
| 7 | 10626.240 | 435.495 | -18373.647 | 34.9325 | -93.399 |
| 8 | 21548.052 | 21765.495 | -1013.3335 | 7231.2868 | -3234.245 |
| 9 | -26.617 | .000 | .0000 | -.92.2109 | 32.6547 |
| 10 | 5.193 | .000 | .0000 | .2000 | .0000000 |
| 11 | 2.885 | .000 | .0000 | .0000 | .0000 |
| 12 | 10.7805 | .0000 | .0000 | .0000 | .0000 |
| 13 | 8571839.7 | 22845274.0 | 41551705.0 | 21227936.0 | 6184717.6 |
| 14 | 278.2440 | 295.2565 | 65.8569 | 64.1176 | 69.1339 |
| 15 | -7.2772 | -31.0803 | -77.8927 | -28.4038 | -2.2747 |

TABLE AP 3-3 (Sheet 11 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----------------------------|------------|-------------|---------------|--------------|--------------|
| 1 | 11599.9995 | 653781.1500 | 3370442.1000 | -.3767 | 93.7202 |
| 2 | 24396.3110 | 25721.0770 | .015 | -.3469 | 93.5293 |
| 3 | 374556.2 | -2932303.7 | -13670432.300 | -472177.310 | -1383163.600 |
| 4 | -2475680.1 | 284286.0 | 12021119.9 | -1375835.900 | -14529.071 |
| 5 | -2417110.9 | 11913387.5 | 11550581.6 | -735820.930 | -484508.400 |
| 6 | 3537.326 | -14326.441 | -17492.068 | -1732.7268 | -8641.642 |
| 7 | 10751.820 | 424.804 | -18803.826 | 34.9395 | -104.114 |
| 8 | 21611.702 | 21357.585 | -1420.3905 | 7231.3899 | -3642.494 |
| 9 | -26.756 | .000 | .0000 | -.90.2936 | 32.5655 |
| 10 | 4.852 | .000 | .0000 | .2000 | .0000000 |
| 11 | 2.206 | .000 | .0000 | .0000 | .0000 |
| 12 | 9.2364 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7991942.0 | 22367879.0 | 41666571.0 | 21741343.0 | 6757955.7 |
| 14 | 277.5260 | 294.6160 | 65.1951 | 63.9333 | 70.3949 |
| 15 | -6.1829 | -30.2919 | -78.7065 | -29.2665 | -3.6214 |
| | | | | | |
| 1 | 11604.9996 | 652983.4200 | 3258852.7000 | -.3727 | 93.9488 |
| 2 | 24397.3730 | 25722.0750 | .015 | -.3425 | 93.7462 |
| 3 | 391908.3 | -3004251.3 | -13757646.700 | -480840.970 | -1426689.100 |
| 4 | -2421860.7 | 286404.5 | 11926885.2 | -1375661.200 | -15055.107 |
| 5 | -2309025.3 | 12019965.9 | 11543274.2 | -699663.930 | -502930.400 |
| 6 | 3403.482 | -14452.525 | -17395.873 | -1732.7351 | -8767.698 |
| 7 | 10775.909 | 422.620 | -18887.924 | 34.9409 | -106.303 |
| 8 | 21622.394 | 21273.717 | -1501.6908 | 7231.4110 | -3726.431 |
| 9 | -26.781 | .000 | .0000 | -.89.9105 | 32.5437 |
| 10 | 4.783 | .000 | .0000 | .2000 | .0000000 |
| 11 | 2.070 | .000 | .0000 | .0000 | .0000 |
| 12 | 8.9306 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7875962.6 | 22272085.0 | 41688583.0 | 21843563.0 | 6872840.1 |
| 14 | 277.3691 | 294.4854 | 65.0528 | 63.8976 | 70.6234 |
| 15 | -5.9589 | -30.1342 | -78.8691 | -29.4387 | -3.8800 |
| | | | | | |
| 1 | 11609.9995 | 652194.2400 | 3147723.3000 | -.3687 | 94.1772 |
| 2 | 24398.4260 | 25723.0620 | .015 | -.3380 | 93.9627 |
| 3 | 408590.8 | -3076828.1 | -13844378.700 | -489504.670 | -1470841.700 |
| 4 | -2367921.6 | 288512.1 | 11832231.9 | -1375486.500 | -15592.126 |
| 5 | -2200888.0 | 12126123.3 | 11535560.5 | -663506.810 | -521773.960 |
| 6 | 3269.515 | -14578.115 | -17299.058 | -1732.7436 | -8893.261 |
| 7 | 10799.654 | 420.420 | -18971.369 | 34.9423 | -108.507 |
| 8 | 21632.405 | 21189.094 | -1582.9471 | 7231.4324 | -3811.124 |
| 9 | -26.806 | .000 | .0000 | -.89.5277 | 32.5207 |
| 10 | 4.714 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.934 | .000 | .0000 | .0000 | .0000 |
| 12 | 8.6261 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7759992.7 | 22176190.0 | 41710274.0 | 21945629.0 | 6987786.9 |
| 14 | 277.2072 | 294.3541 | 64.9069 | 63.8522 | 70.8450 |
| 15 | -5.7330 | -29.9766 | -79.0316 | -29.6108 | -4.1354 |
| | | | | | |
| S-IVB ENGINE START COMMAND | | | | | |
| 1 | 11614.6897 | 651462.2900 | 3043955.0000 | -.3649 | 94.3912 |
| 2 | 24399.4030 | 25723.9770 | .015 | -.3338 | 94.1657 |
| 3 | 423628.9 | -3145469.9 | -13925285.800 | -497630.650 | -1512823.300 |
| 4 | -2317223.3 | 290478.9 | 11743075.1 | -1375322.600 | -16105.863 |
| 5 | -2099418.6 | 12225305.1 | 11527956.3 | -629593.790 | -539834.450 |
| 6 | 3143.753 | -14695.458 | -17207.689 | -1732.7516 | -9010.578 |
| 7 | 10821.611 | 418.344 | -19049.037 | 34.9437 | -110.588 |
| 8 | 21641.175 | 21109.039 | -1659.1173 | 7231.4525 | -3891.245 |
| 9 | -26.828 | .000 | .0000 | -.89.1687 | 32.4979 |
| 10 | 4.649 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.806 | .000 | .0000 | .0000 | .0000 |
| 12 | 8.3417 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7651233.4 | 22086157.0 | 41730328.0 | 22041216.0 | 7095650.4 |
| 14 | 277.0508 | 294.2300 | 64.7666 | 63.8293 | 71.0467 |
| 15 | -5.5194 | -29.8287 | -79.1840 | -29.7722 | -4.3722 |
| | | | | | |
| 1 | 11614.9996 | 651413.3900 | 3037105.4000 | -.3646 | 94.4054 |
| 2 | 24399.4690 | 25724.0380 | .015 | -.3336 | 94.1791 |
| 3 | 424603.3 | -3150031.6 | -13930624.900 | -498168.410 | -1515620.900 |
| 4 | -2313864.7 | 290608.7 | 11737162.8 | -1375311.800 | -16140.205 |
| 5 | -2092702.5 | 12231855.7 | 11527440.5 | -627349.600 | -541042.890 |
| 6 | 3135.427 | -14703.208 | -17201.624 | -1732.7522 | -9018.326 |
| 7 | 10823.053 | 418.206 | -19054.157 | 34.9437 | -110.727 |
| 8 | 21641.735 | 21103.719 | -1664.1563 | 7231.4540 | -3896.570 |
| 9 | -26.829 | .000 | .0000 | -.89.1450 | 32.4964 |
| 10 | 4.645 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.798 | .000 | .0000 | .0000 | .0000 |
| 12 | 8.3229 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7644036.9 | 22080196.0 | 41731644.0 | 22047538.0 | 7102790.0 |
| 14 | 277.0403 | 294.2218 | 64.7571 | 63.8272 | 71.0598 |
| 15 | -5.5052 | -29.8189 | -79.1941 | -29.7828 | -4.3878 |

TABLE AP 3-3 (Sheet 12 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11619.9996 | 650641.2400 | 2927058.3000 | -.3606 | 94.6333 |
| 2 | 24400.5020 | 25725.0040 | .016 | -.3291 | 94.3952 |
| 3 | 439944.9 | -3223859.4 | -14016382.400 | -506832.180 | -1561024.100 |
| 4 | -2259691.7 | 292694.2 | 11641681.5 | -1375137.000 | -16699.417 |
| 5 | -1984471.8 | 12337159.4 | 11518914.7 | -591192.280 | -560740.930 |
| 6 | 3001.225 | -14827.798 | -17103.577 | -1732.7607 | -9142.888 |
| 7 | 10846.105 | 415.976 | -19136.285 | 34.9452 | -112.961 |
| 8 | 21650.384 | 21017.594 | -1745.3157 | 7231.4757 | -3982.766 |
| 9 | -26.852 | .000 | .0000 | -88.7623 | 32.4707 |
| 10 | 4.576 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.662 | .000 | .0000 | .0000 | .0000 |
| 12 | 8.0214 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7528099.4 | 21984105.0 | 41752695.0 | 22149289.0 | 7217842.9 |
| 14 | 276.8679 | 294.0887 | 64.6034 | 63.7925 | 71.2683 |
| 15 | -5.2753 | -29.6612 | -79.3566 | -29.9547 | -4.6372 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11624.9996 | 649877.8200 | 2817650.4000 | -.3565 | 94.8609 |
| 2 | 24401.5240 | 25725.9610 | .016 | -.3246 | 94.6111 |
| 3 | 454615.3 | -3298308.8 | -14101648.200 | -515496.010 | -1607048.900 |
| 4 | -2205404.2 | 294768.4 | 11545791.2 | -1374962.300 | -17269.839 |
| 5 | -1876199.7 | 12442030.5 | 11509983.2 | -555034.840 | -580871.810 |
| 6 | 2866.912 | -14951.881 | -17004.920 | -1732.7695 | -9266.942 |
| 7 | 10868.808 | 413.731 | -19217.751 | 34.9466 | -115.210 |
| 8 | 21658.352 | 20930.722 | -1826.4222 | 7231.4977 | -4069.710 |
| 9 | -26.873 | .000 | .0000 | -88.3802 | 32.4438 |
| 10 | 4.506 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.525 | .000 | .0000 | .0000 | .0000 |
| 12 | 7.7215 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7412185.4 | 21887919.0 | 41773422.0 | 22250880.0 | 7332940.3 |
| 14 | 276.6900 | 293.9547 | 64.4455 | 63.7582 | 71.4708 |
| 15 | -5.0433 | -29.5036 | -79.5190 | -30.1266 | -4.8839 |

GUIDANCE INITIATION-START ARTIFICIAL TAU

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11627.7297 | 649464.8100 | 2758209.0000 | -.3542 | 94.9851 |
| 2 | 24402.0780 | 25726.4790 | .016 | -.3221 | 94.7288 |
| 3 | 462342.1 | -3339221.2 | -14147996.300 | -520226.650 | -1632440.800 |
| 4 | -2175714.5 | 295896.3 | 11493261.6 | -1374867.000 | -17586.059 |
| 5 | -1817064.6 | 12499108.2 | 11504935.2 | -535292.090 | -592047.710 |
| 6 | 2793.529 | -15019.417 | -16950.794 | -1732.7742 | -9334.462 |
| 7 | 10881.057 | 412.499 | -19261.952 | 34.9473 | -116.445 |
| 8 | 21662.415 | 20882.975 | -1870.6846 | 7231.5098 | -4117.497 |
| 9 | -26.885 | .000 | .0000 | -88.1716 | 32.4286 |
| 10 | 4.468 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.451 | .000 | .0000 | .0000 | .0000 |
| 12 | 7.5586 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7348905.6 | 21835358.0 | 41784604.0 | 22306284.0 | 7395802.5 |
| 14 | 276.5903 | 293.8812 | 64.3575 | 63.7395 | 71.5789 |
| 15 | -4.9156 | -29.4175 | -79.6076 | -30.2203 | -5.0175 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11629.9996 | 649123.5000 | 2708960.4000 | -.3524 | 95.0882 |
| 2 | 24402.5370 | 25726.9060 | .016 | -.3200 | 94.8266 |
| 3 | 468613.9 | -3373377.4 | -14186419.200 | -524159.880 | -1653692.600 |
| 4 | -2151004.2 | 296831.5 | 11449495.3 | -1374787.600 | -17851.546 |
| 5 | -1767889.5 | 12546465.4 | 11500646.3 | -518877.300 | -601439.270 |
| 6 | 2732.492 | -15075.452 | -16905.656 | -1732.7783 | -9390.484 |
| 7 | 10891.162 | 411.471 | -19298.550 | 34.9480 | -117.475 |
| 8 | 21665.638 | 20843.108 | -1907.4728 | 7231.5198 | -4157.397 |
| 9 | -26.894 | .000 | .0000 | -87.9982 | 32.4156 |
| 10 | 4.436 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.389 | .000 | .0000 | .0000 | .0000 |
| 12 | 7.4237 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7296299.7 | 21791638.0 | 41793828.0 | 22352313.0 | 7448076.5 |
| 14 | 276.5061 | 293.8198 | 64.2833 | 63.7242 | 71.6676 |
| 15 | -4.8090 | -29.3460 | -79.6813 | -30.2983 | -5.1280 |

TIME BASE 7

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11630.3197 | 649075.3400 | 2702029.3000 | -.3521 | 95.1028 |
| 2 | 24402.6010 | 25726.9660 | .016 | -.3198 | 94.8404 |
| 3 | 469487.1 | -3378203.8 | -14191828.500 | -524714.480 | -1656699.600 |
| 4 | -2147517.9 | 296953.1 | 11443317.1 | -1374776.400 | -17889.169 |
| 5 | -1760954.9 | 12553135.6 | 11500034.8 | -516562.720 | -602770.810 |
| 6 | 2723.884 | -15083.345 | -16899.281 | -1732.7788 | -9398.375 |
| 7 | 10892.581 | 411.326 | -19303.700 | 34.9481 | -117.620 |
| 8 | 21666.081 | 20837.474 | -1912.6591 | 7231.5212 | -4163.035 |
| 9 | -26.896 | .000 | .0000 | -87.9737 | 32.4138 |
| 10 | 4.431 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.380 | .000 | .0000 | .0000 | .0000 |
| 12 | 7.4047 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7288882.5 | 21785471.0 | 41795123.0 | 22358800.0 | 7455448.1 |
| 14 | 276.4941 | 293.8111 | 64.2728 | 63.7220 | 71.6800 |
| 15 | -4.7939 | -29.3359 | -79.6917 | -30.3093 | -5.1435 |

TABLE AP 3-3 (Sheet 13 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11634.9995 | 648377.1600 | 2601079.6000 | -.3483 | 95.3153 |
| 2 | 24403.5390 | 25727.8410 | .016 | -.3155 | 95.0419 |
| 3 | 481940.1 | -3449062.5 | -14270692.000 | -532823.790 | -1700952.900 |
| 4 | -2096493.2 | 298883.1 | 11352797.0 | -1374612.900 | -18444.610 |
| 5 | -1659544.5 | 12650460.2 | 11490904.4 | -482719.640 | -622447.020 |
| 6 | 2597.970 | -15198.506 | -16805.788 | -1732.7870 | -9513.509 |
| 7 | 10913.166 | 409.197 | -19378.681 | 34.9494 | -119.754 |
| 8 | 21672.242 | 20754.753 | -1988.4645 | 7231.5422 | -4245.825 |
| 9 | -26.914 | .000 | .0000 | -87.6163 | 32.3861 |
| 10 | 4.366 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.253 | .000 | .0000 | .0000 | .0000 |
| 12 | 7.1280 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7180448.0 | 21695265.0 | 41813914.0 | 22453585.0 | 7563246.8 |
| 14 | 276.3160 | 293.6840 | 64.1165 | 63.6905 | 71.8588 |
| 15 | -4.5724 | -29.1883 | -79.8436 | -30.4699 | -5.3695 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11639.9996 | 647639.7300 | 2494114.4000 | -.3441 | 95.5420 |
| 2 | 24404.5320 | 25728.7640 | .016 | -.3110 | 95.2569 |
| 3 | 494593.4 | -3525361.6 | -14354464.400 | -541487.750 | -1748826.900 |
| 4 | -2041873.1 | 300923.4 | 11255700.0 | -1374438.100 | -19049.109 |
| 5 | -1551168.2 | 12754011.6 | 11480757.6 | -446561.870 | -643898.760 |
| 6 | 2463.351 | -15321.040 | -16705.321 | -1732.7960 | -9636.013 |
| 7 | 10934.817 | 406.908 | -19458.140 | 34.9508 | -122.048 |
| 8 | 21678.165 | 20665.661 | -2069.3944 | 7231.5647 | -4334.991 |
| 9 | -26.933 | .000 | .0000 | -87.2347 | 32.3554 |
| 10 | 4.295 | .000 | .0000 | .2000 | .0000000 |
| 11 | 1.116 | .000 | .0000 | .0000 | .0000 |
| 12 | 6.8349 | .0000 | .0000 | .0000 | .0000 |
| 13 | 7064635.8 | 21598803.0 | 41833676.0 | 22554694.0 | 7678446.2 |
| 14 | 276.1195 | 293.5473 | 63.9449 | 63.6571 | 72.0448 |
| 15 | -4.3333 | -29.0307 | -80.0058 | -30.6414 | -5.6087 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11644.9995 | 646911.8700 | 2388189.3000 | -.3400 | 95.7684 |
| 2 | 24405.4670 | 25729.6320 | .000 | -.3064 | 95.4715 |
| 3 | 506573.4 | -3602272.0 | -14437732.500 | -550151.740 | -1797312.100 |
| 4 | -1987145.6 | 302952.2 | 11158207.2 | -1374263.400 | -19665.112 |
| 5 | -1442764.0 | 12857115.6 | 11470206.4 | -410404.010 | -665798.160 |
| 6 | 2328.621 | -15443.030 | -16604.217 | -1732.7996 | -9757.992 |
| 7 | 10956.095 | 404.601 | -19536.896 | 34.9514 | -124.356 |
| 8 | 21683.365 | 20575.789 | -2150.2610 | 7231.5738 | -4424.892 |
| 9 | -26.957 | .000 | .0000 | -86.8534 | 32.3233 |
| 10 | 4.217 | .000 | .0000 | .2000 | .0000000 |
| 11 | .966 | .000 | .0000 | .0000 | .0000 |
| 12 | 6.5446 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6948869.1 | 21502253.0 | 41853116.0 | 22655642.0 | 7793669.7 |
| 14 | 275.9162 | 293.4096 | 63.7682 | 63.6241 | 72.2258 |
| 15 | -4.0916 | -28.8731 | -80.1679 | -30.8128 | -5.8455 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11649.9996 | 646191.8800 | 2283451.0000 | -.3359 | 95.9944 |
| 2 | 24406.3610 | 25730.4560 | .001 | -.3019 | 95.6858 |
| 3 | 517879.5 | -3679790.9 | -14520493.900 | -558815.750 | -1846405.900 |
| 4 | -1932312.8 | 304969.4 | 11060322.5 | -1374088.600 | -20292.696 |
| 5 | -1334335.7 | 12959768.2 | 11459250.9 | -374246.140 | -688148.910 |
| 6 | 2193.791 | -15564.477 | -16502.495 | -1732.7996 | -9879.439 |
| 7 | 10977.005 | 402.278 | -19614.955 | 34.9514 | -126.680 |
| 8 | 21687.856 | 20485.157 | -2231.0606 | 7231.5738 | -4515.525 |
| 9 | -26.975 | .000 | .0000 | -86.4723 | 32.2900 |
| 10 | 4.146 | .000 | .0000 | .2000 | .0000000 |
| 11 | .830 | .000 | .0000 | .0000 | .0000 |
| 12 | 6.2576 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6833154.6 | 21405616.0 | 41872235.0 | 22756425.0 | 7908913.0 |
| 14 | 275.7057 | 293.2709 | 63.5863 | 63.5914 | 72.4021 |
| 15 | -3.8473 | -28.7155 | -80.3299 | -30.9842 | -6.0801 |

MANEUVER TO ATTAIN SEPARATION ATTITUDE

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11650.0998 | 646177.5500 | 2281367.4000 | -.3358 | 95.9989 |
| 2 | 24406.3790 | 25730.4730 | .001 | -.3018 | 95.6901 |
| 3 | 518098.9 | -3681349.0 | -14522145.500 | -558989.100 | -1847394.900 |
| 4 | -1931214.0 | 305009.7 | 11058359.0 | -1374085.100 | -20305.379 |
| 5 | -1332164.8 | 12961818.6 | 11459027.5 | -373522.270 | -688600.990 |
| 6 | 2191.091 | -15566.903 | -16500.452 | -1732.7996 | -9881.865 |
| 7 | 10977.420 | 402.231 | -19616.511 | 34.9514 | -126.726 |
| 8 | 21687.939 | 20483.334 | -2232.6774 | 7231.5737 | -4517.347 |
| 9 | -26.975 | .000 | .0000 | -86.4646 | 32.2893 |
| 10 | 4.145 | .000 | .0000 | .2000 | .0000000 |
| 11 | .827 | .000 | .0000 | .0000 | .0000 |
| 12 | 6.2519 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6830838.5 | 21403680.0 | 41872614.0 | 22758441.0 | 7911220.3 |
| 14 | 275.7014 | 293.2682 | 63.5826 | 63.5907 | 72.4056 |
| 15 | -3.8424 | -28.7123 | -80.3332 | -30.9876 | -6.0847 |

TABLE AP 3-3 (Sheet 14 of 14)
SATURN OBSERVED TRAJECTORY - ORBITAL PHASE (AA83)

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11654.9996 | 645480.6900 | 2180071.8000 | -.3317 | 96.2201 |
| 2 | 24407.2440 | 25731.2710 | .001 | -.2974 | 95.8998 |
| 3 | 528511.2 | -3757915.8 | -14602744.700 | -567479.740 | -1896105.600 |
| 4 | -1877376.1 | 306974.9 | 10962049.2 | -1373913.900 | -20931.932 |
| 5 | -1225886.6 | 13061965.9 | 11447891.7 | -338088.270 | -710954.640 |
| 6 | 2058.876 | -15685.390 | -16400.182 | -1732.7996 | -10000.352 |
| 7 | 10997.559 | 399.940 | -19692.332 | 34.9513 | -129.017 |
| 8 | 21691.664 | 20393.796 | -2311.7896 | 7231.5738 | -4606.887 |
| 9 | -26.991 | .000 | .0000 | -86.0914 | 32.2554 |
| 10 | 4.075 | .000 | .0000 | .2000 | .0000000 |
| 11 | .693 | .000 | .0000 | .0000 | .0000 |
| 12 | 5.9743 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6717498.8 | 21308896.0 | 41891029.0 | 22857042.0 | 8024171.5 |
| 14 | 275.4877 | 293.1313 | 63.3988 | 63.5590 | 72.5737 |
| 15 | -3.6001 | -28.5579 | -80.4919 | -31.1554 | -6.3125 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11659.9996 | 644778.6500 | 2078236.3000 | -.3276 | 96.4454 |
| 2 | 24408.1160 | 25732.0730 | .001 | -.2928 | 96.1134 |
| 3 | 538468.1 | -3836643.9 | -14684482.700 | -576143.740 | -1946408.500 |
| 4 | -1822337.7 | 308968.8 | 10863391.0 | -1373739.100 | -21582.893 |
| 5 | -1117420.2 | 13163705.0 | 11436128.9 | -301930.410 | -734218.990 |
| 6 | 1923.881 | -15805.763 | -16297.284 | -1732.7996 | -10120.725 |
| 7 | 11017.758 | 397.588 | -19769.025 | 34.9513 | -131.370 |
| 8 | 21694.788 | 20301.709 | -2392.4450 | 7231.5738 | -4698.973 |
| 9 | -27.007 | .000 | .0000 | -85.7109 | 32.2195 |
| 10 | 4.004 | .000 | .0000 | .2000 | .0000000 |
| 11 | .557 | .000 | .0000 | .0000 | .0000 |
| 12 | 5.6952 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6601909.0 | 21212094.0 | 41909502.0 | 22957495.0 | 8139441.4 |
| 14 | 275.2618 | 292.9907 | 63.2054 | 63.5269 | 72.7410 |
| 15 | -3.3500 | -28.4003 | -80.6538 | -31.3266 | -6.5430 |

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11664.9996 | 644085.2800 | 1978247.5000 | -.3234 | 96.6703 |
| 2 | 24408.9770 | 25732.8640 | .001 | -.2883 | 96.3266 |
| 3 | 547749.8 | -3915972.6 | -14765704.600 | -584807.750 | -1997311.900 |
| 4 | -1767199.2 | 310950.8 | 10764350.9 | -1373564.300 | -22245.652 |
| 5 | -1008939.9 | 13264981.8 | 11423963.3 | -265772.530 | -757945.580 |
| 6 | 1788.809 | -15925.592 | -16193.803 | -1732.7996 | -10240.555 |
| 7 | 11037.599 | 395.221 | -19845.030 | 34.9513 | -133.736 |
| 8 | 21697.229 | 20208.900 | -2473.0238 | 7231.5738 | -4791.782 |
| 9 | -27.022 | .000 | .0000 | -85.3307 | 32.1823 |
| 10 | 3.932 | .000 | .0000 | .2000 | .0000000 |
| 11 | .420 | .000 | .0000 | .0000 | .0000 |
| 12 | 5.4212 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6486392.4 | 21115211.0 | 41927651.0 | 23057780.0 | 8254718.7 |
| 14 | 275.0275 | 292.8491 | 63.0059 | 63.4951 | 72.9041 |
| 15 | -3.0967 | -28.2427 | -80.8156 | -31.4976 | -6.7715 |

INITIATE SPACECRAFT SEPARATION SEQUENCE

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11666.0997 | 643934.0000 | 1956513.9000 | -.3225 | 96.7198 |
| 2 | 24409.1650 | 25733.0370 | .001 | -.2873 | 96.3734 |
| 3 | 549701.4 | -3933506.7 | -14783505.500 | -586713.980 | -2008592.000 |
| 4 | -1755054.4 | 311385.3 | 10742509.1 | -1373525.900 | -22393.063 |
| 5 | -985070.6 | 13287202.3 | 11421232.5 | -257817.090 | -763228.280 |
| 6 | 1759.081 | -15951.884 | -16170.957 | -1732.7996 | -10266.846 |
| 7 | 11041.916 | 394.698 | -19861.661 | 34.9513 | -134.259 |
| 8 | 21697.674 | 20188.384 | -2490.7421 | 7231.5737 | -4812.298 |
| 9 | -27.025 | .000 | .0000 | -85.2471 | 32.1740 |
| 10 | 3.917 | .000 | .0000 | .2000 | .0000000 |
| 11 | .390 | .000 | .0000 | .0000 | .0000 |
| 12 | 5.3616 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6460987.2 | 21093885.0 | 41931599.0 | 23079822.0 | 8280082.6 |
| 14 | 274.9748 | 292.8178 | 62.9612 | 63.4882 | 72.9394 |
| 15 | -3.0406 | -28.2080 | -80.8512 | -31.5352 | -6.8215 |

S-IVB/CSM SEPARATION

| | | | | | |
|----|------------|-------------|---------------|--------------|--------------|
| 1 | 11667.7998 | 643700.9100 | 1923137.6000 | -.3211 | 96.7961 |
| 2 | 24409.4550 | 25733.3030 | .001 | -.2857 | 96.4458 |
| 3 | 552652.6 | -3960657.9 | -14810962.500 | -589659.580 | -2026079.100 |
| 4 | -1736278.5 | 312055.5 | 10708722.9 | -1373466.500 | -22621.977 |
| 5 | -948186.1 | 13321493.6 | 11416974.5 | -245524.120 | -771435.720 |
| 6 | 1713.138 | -15992.458 | -16135.600 | -1732.7996 | -10307.419 |
| 7 | 11048.553 | 393.889 | -19887.292 | 34.9513 | -135.068 |
| 8 | 21698.298 | 20156.613 | -2518.1134 | 7231.5738 | -4844.069 |
| 9 | -27.029 | .000 | .0000 | -85.1179 | 32.1609 |
| 10 | 3.892 | .000 | .0000 | .2000 | .0000000 |
| 11 | .343 | .000 | .0000 | .0000 | .0000 |
| 12 | 5.2702 | .0000 | .0000 | .0000 | .0000 |
| 13 | 6421738.3 | 21060923.0 | 41937673.0 | 23113866.0 | 8319275.8 |
| 14 | 274.8925 | 292.7694 | 62.8914 | 63.4775 | 72.9936 |
| 15 | -2.9535 | -28.1544 | -80.9062 | -31.5934 | -6.8986 |

TABLE AP 3-4 (Sheet 1 of 3)
LIST OF SYMBOLS (PROGRAM AA83)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|--------------------------|-----------------|---|
| ALTITUDE | h | Height of vehicle above the Fischer Ellipsoid of 1960 (ft) |
| ALPHA SB WIND | α_w | Wind angle-of-attack in pitch plane (deg) |
| BETA SB WIND | β_w | Wind angle-of-attack in yaw plane (deg) |
| A SB I | A_I | Total inertial acceleration (ft/sec ²) |
| A * SB i (i=1 thru 5) | $A*_i$ | Radar azimuth angle measured in the plane tangent to the earth's surface at radar station i, positive clockwise from north to the perpendicular projection of the slant range vector onto the tangent plane |
| DD-X SB E | \ddot{X}_e | Component of acceleration vector of vehicle in earth-fixed right-handed cartesian coordinate system (same orientation as X_E, Y_E, Z_E) (ft/sec ²) (PACSS No. 10) |
| DD-Y SB E | \ddot{Y}_e | |
| DD-Z SB E | \ddot{Z}_e | |
| DENSITY | ρ_a | Ambient air density (slugs/ft ³) |
| D * SB i (i=1 thru 5) | $D*_i$ | Slant range distance from radar station i to vehicle (ft) |
| D-X SB GS | \dot{X}_{gs} | Components of gravitational velocity vector, in space-fixed coordinate system (same orientation as X_S, Y_S, Z_S) (ft/sec) (PACSS No. 13) |
| D-Y SB GS | \dot{Y}_{gs} | |
| D-Z SB GS | \dot{Z}_{gs} | |
| D-XI | $\dot{\xi}$ | Components of inertial platform velocity vector, in space-fixed coordinate system (same orientation as XI, ETA, ZETA) (ft/sec) (PACSS No. 12) |
| D-ETA | $\dot{\eta}$ | |
| D-ZETA | $\dot{\zeta}$ | |
| D-X SB S | \dot{X}_s | Components of velocity vector of vehicle, in space-fixed coordinate system (same orientation as X_S, Y_S, Z_S) (ft/sec) (PACSS No. 13) |
| D-Y SB S | \dot{Y}_s | |
| D-Z SB S | \dot{Z}_s | |
| D-X SB SFE | \dot{X}_{SFE} | Components of velocity vector in space-fixed ephemeris coordinate system (same orientation as $X_{SFE}, Y_{SFE}, Z_{SFE}$) (ft/sec) (PACSS No. 4) |
| D-Y SB SFE | \dot{Y}_{SFE} | |
| D-Z SB SFE | \dot{Z}_{SFE} | |
| D-X SB E | \dot{X}_e | Components of velocity vector of vehicle, in earth-fixed right-handed cartesian coordinate system (same orientation as X_E, Y_E, Z_E) (ft/sec) (PACSS No. 10) |
| D-Y SB E | \dot{Y}_e | |
| D-Z SB E | \dot{Z}_e | |
| E * SB i (i=1 thru 5) | $E*_i$ | Radar elevation angle measured positive up from plane tangent to the earth's surface at radar station i to the radar slant range vector (ft) |
| GAMMA SB 1 | γ_1 | Elevation angle of earth-fixed velocity vector from local horizontal measured positive above the plane (deg) |
| GAMMA SB 2 | γ_2 | Azimuth angle of earth-fixed velocity vector positive East of local North (deg) |

TABLE AP 3-4 (Sheet 2 of 3)
LIST OF SYMBOLS (PROGRAM AA83)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|-----------------|---------------|---|
| GAMMA (1I) PR. | γ_{1I} | Angle between space-fixed velocity vector and plane normal to vector from geocentric center of earth, positive above plane (deg) |
| GAMMA (2I) PR. | γ_{2I} | Angle measured positive clockwise from north to projection of space-fixed velocity vector in plane normal to radius vector (deg) |
| MACH NUMBER | MACH | Mach number (dimensionless) |
| MU | μ | Longitude of vehicle (deg) |
| PRESSURE | P_a | Ambient air pressure (lbf/ft ²) |
| DYN. PRESS. Q | Q | Dynamic pressure (lbf/ft ²) |
| RANGE | S | Surface range referenced to spherical earth of instantaneous average radius (ft) |
| RANGE ANGLE | η | Angle measured from center of earth between launch site and subvehicle point (deg) |
| RE YN/L | RE/L | Reynolds number per unit length (dimensionless) |
| RHO | ρ | Latitude of vehicle (deg) |
| REL HUMID | | Relative Humidity (percent) |
| SOUND VEL | V_s | Local velocity of sound (ft/sec) |
| TEMPERATURE | TEMP | Ambient air temperature (deg R) |
| TIME | t | Time from Range Zero (sec) |
| VISCOSITY | γ | Viscosity (lb-sec/ft ²) |
| V SB E | V_e | Magnitude of earth-fixed velocity vector of vehicle (ft/sec) |
| V SB I | V_I | Magnitude of space-fixed velocity vector of vehicle (ft/sec) |
| V SB RM | V_{rm} | Magnitude of relative velocity vector of vehicle (ft/sec) |
| E SB W | ϵ_W | Wind direction azimuth, positive clockwise from North; direction is 0 deg when wind is coming from North (deg) |
| V SB W | V_W | Magnitude of wind velocity vector (ft/sec) |
| X SB GS | X_{gs} | Components of gravitational position vector, in space-fixed coordinate system (same orientation as X_S, Y_S, Z_S) (ft) (PACSS No. 13) |
| Y SB GS | Y_{gs} | |
| Z SB GS | Z_{gs} | |
| XI | ξ | Components of inertial platform displacement vector, in space-fixed coordinate system (same orientation as X_E, Y_E, Z_E at instant of launch (ft) (PACSS No. 12) |
| ETA | η | |
| ZETA | ζ | |
| X SB S | X_s | Component of position vector of vehicle, in space-fixed coordinate system (same orientation as X_E, Y_E, Z_E at instant of launcy (ft) (PACSS No. 13) |
| Y SB S | Y_s | |
| Z SB S | Z_s | |

TABLE AP 3-4 (Sheet 3 of 3)
LIST OF SYMBOLS (PROGRAM AA83)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|----------------------------------|-------------------------------------|--|
| X SB SFE Y SB SFE Z SB SFE | X_{SFE} Y_{SFE} Z_{SFE} | Components of position vector in space-fixed ephemeris coordinate system. Z_{SFE} is north along earth's rotational axis, X_{SFE} is through vernal equinox, Y_{SFE} completes a right-handed system, X_{SFE} - Y_{SFE} plane is in equatorial plane (ft) (PACSS No. 4) |
| X SB E Y SB E Z SB E | X_e Y_e Z_e | Components of position vector of vehicle, in earth-fixed right-handed cartesian coordinate system. Z_e is directed along firing direction, X_e is normal to horizontal plane and origin is on ellipsoid at launch site. Y_e completes the right-handed cartesian coordinate system (ft) (PACSS No. 10) |

TABLE AP 3-5
RADAR STATION VEHICLE ACQUISITION AND LOSS TIMES

| Station | Acquisition Time | | Loss Time | | Tracking Time Above 5° | |
|---|-------------------------------|----------------|-----------|--------|------------------------|--------|
| | Predicted | Actual | Predicted | Actual | Predicted | Actual |
| <u>Boost Phase of Flight</u> | | | | | | |
| Pad 39A | 0 | 0 | 432 | 435 | 432 | 435 |
| Cape Tel 4 | 30 | 30 | 432 | 435 | 402 | 405 |
| Grand Bahama | 116 | 115 | 459 | 460 | 343 | 345 |
| Bermuda | 335 | 335 | 688 | 710 | 353 | 375 |
| Insertion Ship | 645 | 655 | 945 | 950 | 300 | 295 |
| <u>Orbital Phase of Flight - First Orbit</u> | | | | | | |
| Canary Island | 1,044 | 1,075 | 1,344 | 1,360 | 300 | 285 |
| Carnarvon | 3,205 | 3,270 | 3,396 | 3,535 | 191 | 265 |
| Hawaii | No Acquisition on First Orbit | | | | | |
| Guaymas | 5,352 | 5,450 | 5,648 | 5,790 | 306 | 340 |
| Bermuda | 5,967 | 6,070 | 6,277 | 6,390 | 310 | 320 |
| <u>Orbital Phase of Flight - Second Orbit</u> | | | | | | |
| Canary Island | 6,705 | 6,820 | 6,824 | 6,890 | 119 | 70 |
| Carnarvon | 8,792 | 8,860 | 9,040 | 9,290 | 248 | 430 |
| Hawaii | 10,323 | 10,470 | 10,538 | 10,800 | 215 | 330 |
| Guaymas | 10,953 | 11,060 | 11,249 | 11,470 | 296 | 410 |
| Bermuda | 11,552 | No Acquisition | 11,918 | - | 366 | - |

APPENDIX 4

FLIGHT SIMULATED DATA (AD77)

1. FLIGHT SIMULATED DATA (AD77)

Presented in this appendix is a detailed five-degrees-of-freedom trajectory simulation constrained to the observed trajectory and employing adjusted engine analysis propulsion histories. Adjustments were determined by a differential correction technique. This technique correlated perturbations in thrust, weight flow, and pitch and yaw thrust vector misalignment with the resulting differences in altitude, earth-fixed velocity, earth-fixed velocity azimuth angle, and longitudinal acceleration, between the observed and simulated trajectories. A complete discussion of the trajectory simulation is presented in section 8.

Figures AP 4-1 and AP 4-2 illustrate the major coordinate systems. Tables AP 4-1 and AP 4-2 present the trajectory parameter definitions while table AP 4-3 furnishes the detailed reconstructed trajectory from S-II/S-IVB physical separation to guidance commanded engine cutoff. The ignition and cutoff weights are based on the composite best estimate ignition and cutoff weights as discussed in section 9.

TABLE AP 4-1 (Sheet 1 of 7)
LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|-------------------------------|--------------------------|---|
| A*SB i | $A*_i$ | Azimuth angle measured in the plane tangent to the earth's surface at radar station i; positive clockwise from north to the perpendicular projection of the vector drawn between the vehicle and the radar in the tangent plane (deg) |
| A SB XM A SB YM A SB ZM | a_{xm}, a_{ym}, a_{zm} | Vehicle accelerations in the vehicle coordinate system (ft/sec ²) |
| CHORD FORCE | C | Aerodynamic chord force (lbf) |
| D*SB i | $D*_i$ | Slant range distance between the vehicle and radar station i (ft) |
| ECCENTRICITY | e | Eccentricity of a conic section (dimensionless) |
| E*SB i | $E*_i$ | Elevation angle measured positively up from a plane tangent to the earth's surface at the radar site. Angle between the plane and the vector drawn between the missile and radar station i (ft) |

TABLE AP 4-1 (Sheet 2 of 7)
 LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|-------------------------------|-----------------------------|--|
| F SB AX F SB AY F SB AZ | $F_{A_x}, F_{A_y}, F_{A_z}$ | Aerodynamic forces in the vehicle coordinate system (lbf) |
| AVG F SB L | \bar{F}_L | Average Longitudinal thrust (lbf) |
| F SB T | F_T | Total effective engine thrust (lbf) |
| F SB TX F SB TY F SB TZ | $F_{T_x}, F_{T_y}, F_{T_z}$ | Propulsive forces in the vehicle system (lbf) |
| F SB X F SB Y F SB Z | F_x, F_y, F_z | Total forces in the vehicle coordinate system (lbf) |
| G (RHO) | g_ρ | Component of gravity due to the attractive force of the earth measured along r_c positive down (ft/sec ²) |
| G (PSI) | g_ψ | Component of gravity due to attractive force of the earth measured along the perpendicular to r_c positive down (ft/sec ²) |
| ALTITUDE | h | Vehicle altitude. Distance between the spheroid's surface and vehicle measured along the normal to the earth's surface positive up (ft) |
| I SB SP | I_{sp} | Specific impulse (sec) |
| AVG I SB SP | \bar{I}_{sp} | Average specific impulse (sec) |
| I SB XX I SB YY I SB ZZ | I_{xx}, I_{yy}, I_{zz} | Principal vehicle moments of inertia (slug-ft ²) |
| MACH NO. | M | Vehicle mach number |
| M SB X M SB Y M SB Z | M_x, M_y, M_z | Total moments about the axis of the vehicle coordinate system (ft-lbf) |

TABLE AP 4-1 (Sheet 3 of 7)
LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|-------------------------------|-----------------------------|--|
| M SB AX M SB AY M SB AZ | $M_{A_x}, M_{A_y}, M_{A_z}$ | Aerodynamic moments in the vehicle coordinate system (ft-lbf) |
| NORMAL FORCE | N | Aerodynamic normal force (lbf) |
| P SB M | P_M | Total vehicle roll rate; positive roll clockwise looking forward along the X_m axis (deg/sec) |
| PRESSURE | P_a | Atmospheric pressure at the vehicle (lbf/ft ²) |
| Q | q | Vehicle dynamic pressure (lbf/ft ²) |
| Q SB M | Q_M | Total vehicle pitch rate, positive nose up (deg/sec) |
| R (AP) | r_a | Radius of apogee (nautical miles) |
| R (PER) | r_{PER} | Radius of perigee (nautical miles) |
| R SB C | r_c | Instantaneous distance between the center of the earth and the vehicle (ft) |
| R SB F | r_f | Geocentric missile distance at terminal altitude (ft) |
| R SB L | r_L | Earth radius at the launcher (ft) |
| S (BAR*) | \bar{S}^* | Product of the average earth radius and the central angle traversed during glide (nautical miles) |
| S SB F | S_F | Downrange distance at terminal altitude (nautical miles) |
| R SB M | R_M | Total vehicle yaw rate; positive yaw-nose left (deg/sec) |
| RANGE | s | Spherical earth ground range (ft). Based on the spherical earth range angle and the average earth radius |
| SAF (i) | SAF_i | Space attenuation factor measured from radar station i |
| TIME | t | Current simulation time, measured from vehicle liftoff (sec) |
| T (1) | T_1 | First stage time to go (sec) |
| T (3) | T_3 | Second stage time to go (sec) |

TABLE AP 4-1 (Sheet 4 of 7)
LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|--|--------------------------|--|
| DELTA-T (3) | ΔT_3 | Correction to T_3 (sec) |
| D-T (CO) | Δt_{CO} | Time-to-go until Engine Cutoff Command (sec) |
| TEMPERATURE | T_T | The temperature specified at a certain altitude (deg R) |
| V SB E | V_e | Magnitude of the vehicle's earth fixed velocity (ft/sec) |
| V (F) | V_f | Magnitude of inertial velocity at terminal altitude (ft/sec) |
| V SB I | V_I | Magnitude of the vehicle's inertial velocity (ft/sec) |
| V SB RM | V_{RM} | Magnitude of the vehicle's velocity relative to the earth's atmosphere (ft/sec) |
| V SB W | V_W | Wind velocity relative to the earth (ft/sec) |
| WEIGHT | W | Total vehicle weight (lbm) |
| WEIGHT FLOW | \dot{W} | Time rate of change of total vehicle weight (lbm/sec) |
| AVG D-W | \bar{W} | Average time rate of change of total vehicle weight (lbm/sec) |
| X, Y, Z D-X, D-Y, D-Z DD-X, DD-Y, DD-Z | X, Y, Z | Components of vehicle position, velocity, and accelerations. A subscript on these quantities indicates the coordinate system in which these quantities are measured. (ft, ft/sec, ft/sec ² , respectively) |
| X SB CG Y SB CG Z SB CG | X_{CG}, Y_{CG}, Z_{CG} | Components of vehicle center of gravity, with X_{CG} measured positive forward from the vehicle reference plane, Y_{CG} measured positive right from the missile centerline, and Z_{CG} measured positive down from the vehicle centerline (in.) |
| X SB CP X SB CP X SB CP | X_{CP}, Y_{CP}, Z_{CP} | Components of vehicle of pressure with X_{CP} measured positive forward from the vehicle reference plane. Y_{CP} measured positive right from the missile centerline, and Z_{CP} measured positive down from the vehicle centerline (in.) |
| X (V) Y (V) Z (V) | X^V, Y^V, Z^V | Positive coordinates in the terminal radius coordinate system. Origin is at the earth's center, Y^V along the desired terminal radius, X^V in the orbit plane in the direction of orbital motion, Z^V forming a right handed coordinate system (m) |

TABLE AP 4-1 (Sheet 5 of 7)
LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|-------------------------------|-----------------|---|
| D-X (V) D-Y (V) D-Z (V) | X^V, Y^V, Z^V | Velocity coordinates in terminal radius coordinate system (ms) |
| ALPHA* | α' | Total angle of attack. Angle between the centerline of the vehicle and the vehicle air velocity vector (deg) |
| ALPHA | α | Pitch angle of attack. Angle between the projection of the vehicle's air velocity vector onto the pitch plane and the centerline of the vehicle (deg) |
| BETA | β | Yaw angle of attack. Angle between the projection of the vehicle's air velocity vector onto the yaw plane and the centerline of the vehicle (deg) |
| BETA | β_f | True anomaly at terminal altitude (deg) |
| GAMMA (1) | γ_1 | Elevation flight path angle. Angle between the earth fixed vehicle velocity and the local tangent plane positive for an ascending vehicle (deg) |
| GAMMA (2) | γ_2 | Azimuthal flight path angle. Angle between the local north clockwise to the projection of the earth fixed vehicle velocity on the local tangent plane (deg) |
| GAMMA (1I) | γ_{1I} | Inertial elevation flight path angle. Same as γ_1 except measured to inertial vehicle velocity (deg) |
| GAMMA (2I) | γ_{2I} | Inertial azimuthal flight path angle. Same as γ_2 except measured to inertial vehicle velocity (deg) |
| GAMMA (1I) PR | γ_{1I}' | Inertial elevation flight path angle. Angle between the inertial velocity vector and the X_{LI}, Z_{LI} plane. Angle is positive for an ascending vehicle (deg) |
| GAMMA (2I) PR | γ_{2I}' | Inertial azimuthal flight path angle measured in the X_{LI}, Z_{LI} plane. Angle between Z_{LI} , clockwise to the projection of the inertial velocity vector (deg) |
| GAMMA SB 1F | γ_{1f} | Inertial flight path elevation angle at the terminal altitude (deg) |

TABLE AP 4-1 (Sheet 6 of 7)
LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|---|---|--|
| GAMMA SB 2F | γ_{2f} | Inertial flight path azimuth angle, at the terminal altitude (deg) |
| DELTA (A) DELTA (B) | δ_A, δ_B | Engine "A" actuator and "B" actuator gimbal angles, respectively (deg) |
| SMCP | δ_{MCP} | Pitch thrust misalignment correction (radians) |
| SMCY | δ_{MCY} | Yaw thrust misalignment correction (radians) |
| E SB W | ϵ_W | Tabular wind azimuth angle, positive clockwise from north, as a function of altitude (at $\epsilon_W = 0$ zero wind is coming from the north) (deg) |
| EPS (THETA) | $\epsilon_\theta, \epsilon_\psi, \epsilon_\phi$ | Autopilot error signal rates (deg/sec) |
| RANGE ANGLE | η' | Spherical earth range angle. The angle is measured between lines connecting the following three points: the vehicle, the center of the earth, and the launcher with the earth's center as the vertex (radians) |
| D-THETA (M) QRP D-PSI (M) QRP D-PHI (M) QRP | θ_M, ψ_M, ϕ_M | Vehicle attitude pitch, yaw and roll Euler angle rates (deg/sec) |
| THETA SB C | θ_C | Commanded vehicle pitch Euler angle (deg) |
| THETA (M) QRP | θ_M | Vehicle pitch attitude Euler angle (deg) |
| THETA (P) THETA (Y) THETA (R) | $\theta_P, \theta_Y, \theta_R$ | For the three-gimbal stable platform, pitch, yaw and roll angles, respectively (deg) |
| MU | μ | Instantaneous vehicle longitude where Greenwich, England, is longitude zero. West of Greenwich is positive (deg) |
| MU SB F | μ_f | Longitude of r_f (deg) |
| XI ETA ZETA | ξ, η, ζ | Vehicle position obtained by integrating $\dot{\xi}, \dot{\eta}, \dot{\zeta}$. The $\xi\eta\zeta$ system coincides with the "P" system at $t = 0$, and is falling with an acceleration equal to gravity at the vehicle position. Position and velocity in this system correspond to the position and velocity the vehicle would have if gravity were zero. (m) |

TABLE AP 4-1 (Sheet 7 of 7)
LIST OF SYMBOLS (PROGRAM AD77)

| PRINTOUT SYMBOL | COMMON SYMBOL | DEFINITION |
|-------------------------|--------------------------------------|--|
| D-XI D-ETA D-ZETA | $\dot{\xi}, \dot{\eta}, \dot{\zeta}$ | Vehicle velocity obtained by integrating $\ddot{\xi}, \ddot{\eta}, \ddot{\zeta}$ (ms) |
| RHO | ρ | Instantaneous geodetic latitude, positive in the northern hemisphere (deg) |
| RHO PRIME | ρ' | Instantaneous geocentric latitude, positive in the northern hemisphere (deg) |
| RHO SB F | ρ_f | Longitude of r_f (deg) |
| TAU-P (i) | τ_{pi} | Radar polarization look angle for the ith radar station: angle between the projection of the vehicle centerline on a plane perpendicular to the radar line of sight and the line of intersection of the plane containing the radar line of sight, perpendicular to the earth's surface, and the plane perpendicular to the radar line of sight, measured positive counterclockwise from this line of intersection as viewed looking along the radar line of sight toward the vehicle (deg) |
| TAU (1G) | τ_{1G} | Ratio of \dot{W}/\dot{W} during first stage operation (sec) |
| TAU (3G) | τ_{3G} | Ratio of \dot{W}/\dot{W} during third stage operation (sec) |
| TAU SB F | τ_f | Time since/to perigee at terminal altitude (sec) |
| PHI SB C | ϕ_C | Commanded vehicle roll Euler angle (deg) |
| PHI (M) QRP | ϕ_M | Vehicle attitude roll Euler angle (deg) |
| PHI (T) | ϕ_T | Estimate of terminal range angle measured in the orbit plane from the descending node to the terminal radius vector, positive in the flight direction (radians) |
| PSI SB C | ψ_C | Commanded vehicle yaw Euler angle (deg) |
| PSI (M) QRP | ψ_M | Vehicle attitude yaw Euler angle (deg) |
| CHI SB P | χ_P | Guidance-commanded body attitude angle in the vehicle pitch plane (deg) |
| CHI SB R | χ_R | Guidance-commanded body attitude angle in the vehicle roll plane (deg) |
| CHI SB Y | χ_Y | Guidance-commanded body attitude angle in the vehicle yaw plane (deg) |

TABLE AP 4-2
 COORDINATE SUBSCRIPT DEFINITIONS

| | |
|--------|---|
| ee | Coordinate system on the surface of the spheroid representing the earth with origin at launch point latitude and longitude. X_{ee} perpendicular to the surface of the spheroid, positive up; Z_{ee} positive in the flight azimuth direction; and Y_{ee} crossrange forming a right-handed system. |
| LL | Instantaneous coordinate system located on the earth's surface under the vehicle with the X_{LL} , Z_{LL} plane tangent to the earth's surface. Positive directional are X_{LL} west, Y_{LL} up, and Z_{LL} north. (English) |
| L_I | Instantaneous inertial coordinate system coincidental with the L system. Velocities in this system are inertial. (English) |
| L'_I | Instantaneous inertial coordinate system located on the earth's surface under the vehicle where Z'_L points north, X'_L points west and Y'_L is along a line connecting the earth center and the vehicle. Velocities in this system are inertial. (English) |
| m | Vehicle coordinate system with origin at the vehicle center of gravity. The "m" system is related to the "s" system by the vehicle Euler angles θ_m , ψ_m , ϕ_m . X_m parallel to a radius from the vehicle centerline to position I, positive toward position I. If all Euler angles are zero, then X_m is up, Y_m crossrange positive right, Z_m positive in the flight azimuth direction. |
| P' | Inertial coordinate system with its origin at the center of the earth and with its X_p , axis along the line parallel to the local gravity vector at launch through the earth's center, positive up. The X_p , axis is parallel to the plane defined by the X_s and Y_x axis at launch and Z_p' forms a right-handed coordinate system. (Metric) |
| s | Coordinates initially coincident with the e system, but remaining fixed in space. (English) |
| SFE | Space Fixed Ephemeris System. The origin of the system is at the center of the earth, Z_{SFE} is positive north, X_{SFE} passes through the vernal equinox and Y_{SFE} completes the right handed system with the X_{SFE} - Y_{SFE} plane coincident with the equatorial plane. The directions of the axes remain fixed in space and the origin moves with the center of the earth. The reference equinox and equator are the true vernal equinox and equator for the epoch of midnight of the day of the launch. |

TABLE 4-3 (Sheet 1 of 19)
FLIGHT SIMULATED DATA (AD77)

| 1 | TIME | WEIGHT | F SB T | ALTITUDE | RANGE |
|----|--------------|--------------|--------------|--------------|--------------|
| 2 | V SB I | V SB E | R SB C | R SUB PF | RANGE ANGI F |
| 3 | X SB E | X SB P (M) | X SB S | XI | |
| 4 | Y SB E | Y SB P (M) | Y SB S | ETA | |
| 5 | Z SB E | Z SB P (M) | Z SB S | ZETA | |
| 6 | D-X SB E | D-X SB P (M) | D-X SB S | D-XI | A SB XM |
| 7 | D-Y SB E | D-Y SB P (M) | D-Y SB S | D-ETA | A SB YM |
| 8 | D-Z SB E | D-Z SB P (M) | D-Z SB S | D-ZETA | A SB ZM |
| 9 | F SB X | F SB TX | F SB AX | M SB X | M SB AX |
| 10 | F SB Y | F SB TY | F SB AY | M SB Y | M SB AY |
| 11 | F SB Z | F SB TZ | F SB AZ | M SB Z | M SB AZ |
| 12 | THETA(M) QRP | DTHETA(M)QRP | F AUX SB X | I SB XX | EPS(THETA) |
| 13 | PSI(M) QRP | D-PSI(M)QRP | F AUX SB Y | I SB YY | EPS(PSI) |
| 14 | PHI(M) QRP | D-PHI(M)QRP | F AUX SB Z | I SB ZZ | EPS(PHI) |
| 15 | CHI SB P | D-CHI SB P | THETA SB C | P SB M | X SB CG |
| 16 | CHI SB Y | D-CHI SB Y | PSI SB C | Q SB M | Y SB CG |
| 17 | CHI SB R | D-CHI SB R | PHI SB C | R SB M | Z SB CG |
| 18 | GAMMA SB 1 | GAMMA SB 1I | GAMMA(1I)PR. | DELTA(A) | D-DELTA(A) |
| 19 | GAMMA SB 2 | GAMMA SB 2I | GAMMA(2I)PR. | DELTA(B) | D-DELTA(B) |
| 20 | I SB SP | AVG I SB SP | WEIGHT FLOW | AVG D-W | AVG F SB L |
| 21 | Q | MACH No. | PRESSURE | TEMPERATURE | X SB CP |
| 22 | ALPHA* | ALPHA | BETA | CHORD FORCE | V SB RM |
| 23 | MU | RHO | RHO PRIME | G(RHO) | G(PSI) |
| 24 | T(2) | TAU(2) | PHI(T) | D-W(LOXB0) | DELTA-D-X(V) |
| 25 | T(3) | TAU(3) | SMCP | D-W(LH2B0) | DELTA-D-Y(V) |
| 26 | DELTA-T(CO) | DELTA-T(3) | SMCY | D-W(LH2PR) | DELTA-D-Z(V) |
| 27 | V(T) | CHI(P)-TILDE | K(1) | W(LOX)RES | WDOTSUB0 |
| 28 | Y(V,T) | CHI(Y)-TILDE | K(3) | W(LH2)RES | WDOTSUBF |
| 29 | R(PER) | V(PER) | ECCENTRICITY | BETA | |
| 30 | R(AP) | V(AP) | INCLINATION | PERIOD | E/M |
| 31 | P | THETA(T) | E SUB T | THETA SUB N | C3 SUB T |
| 32 | | | I SUB T | THETA SUB NG | C SUB 3G |
| 33 | AVG FL HMR | AVG ISP HMR | AVG WDT HMR | DELTA SB R4 | |

S-II/S-IVB PHYSICAL SEPARATION

| | | | | | |
|----|------------|------------|------------|-----------|-----------|
| 1 | 577,0800 | 354175,0 | ,0 | 640568,4 | 5956443,0 |
| 2 | 22075,6370 | 20752,7320 | 21546569,0 | ,0 | 16,3230 |
| 3 | -226677,3 | ,0 | -461024,9 | ,0 | |
| 4 | 100849,6 | ,0 | 209558,1 | ,0 | |
| 5 | 6055052,2 | ,0 | 6803241,1 | ,0 | |
| 6 | -5223,1499 | ,0000 | -6367,9395 | ,0000 | -,0000 |
| 7 | 567,0190 | ,0000 | 254,6095 | ,0000 | ,0000 |
| 8 | 20076,6800 | ,0000 | 21135,7120 | ,0000 | ,0000 |
| 9 | ,2 | ,0 | -,2 | ,000 | -,000 |
| 10 | ,0 | -,0 | -,0 | ,005 | ,005 |
| 11 | ,0 | ,0 | -,0 | ,017 | ,017 |
| 12 | -81,7590 | ,0000 | ,0 | 140640,0 | -7,9002 |
| 13 | -,7790 | ,0000 | ,0 | 9331642,1 | -,0369 |
| 14 | -,2310 | -,0000 | ,0 | 9332777,3 | ,0000 |
| 15 | -89,6600 | ,0000 | -89,6600 | ,5500 | 473,82 |
| 16 | -,8000 | ,0000 | -,8000 | ,0000 | -1,15 |
| 17 | ,0000 | ,0000 | ,0000 | ,0000 | ,34 |
| 18 | 1,7196 | 1,6165 | 1,5973 | ,0000 | ,0000 |
| 19 | 82,9987 | 83,4205 | 83,4158 | ,0000 | ,0000 |
| 20 | -,0000 | ,0000 | -30,4638 | ,0000 | ,0 |
| 21 | ,0002 | 8,5037 | ,0000 | 2478,3809 | ,00 |
| 22 | 24,9212 | 24,9077 | ,9365 | -,180 | 20752,732 |
| 23 | 62,1360 | 32,1437 | 31,9757 | -30,3279 | -,0417 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | ,0 | ,0000 |
| 28 | ,0 | ,0000 | ,00000 | ,0 | ,0000 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | ,0000 | ,0000 | ,0000 | ,0000 | |

TABLE 4-3 (Sheet 2 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|------------|------------|------------|-----------|-----------|
| 1 | 580,0000 | 354085,1 | .0 | 642354,7 | 6015208,1 |
| 2 | 22074,8860 | 20751,8150 | 21548333,0 | .0 | 16,4840 |
| 3 | -242041,7 | .0 | -479741,7 | .0 | |
| 4 | 102511,6 | .0 | 210300,1 | .0 | |
| 5 | 6113644,4 | .0 | 6864918,3 | .0 | |
| 6 | -5300,3491 | .0000 | -6451,6730 | .0000 | .7814 |
| 7 | 571,3511 | .0000 | 253,6125 | .0000 | -.0000 |
| 8 | 20055,3660 | .0000 | 21109,5290 | .0000 | .0000 |
| 9 | 8599,8 | .0 | -.2 | .000 | -.000 |
| 10 | -.0 | -.0 | -.0 | .005 | .005 |
| 11 | .0 | .0 | -.0 | .017 | .017 |
| 12 | -81,7590 | .0000 | 8600,0 | 140640,0 | -7,9003 |
| 13 | -.7790 | .0000 | .0 | 9331642,1 | -.0210 |
| 14 | -.0002 | .0011 | .0 | 9332777,3 | .0000 |
| 15 | -89,6600 | .0000 | -89,6600 | .0004 | 473,82 |
| 16 | -.8000 | .0000 | -.8000 | .0000 | -1,15 |
| 17 | .0000 | .0000 | .0000 | .0000 | .34 |
| 18 | 1,6593 | 1,5598 | 1,5409 | -.6610 | .0002 |
| 19 | 83,1118 | 83,5268 | 83,5223 | -6,2622 | -.0000 |
| 20 | 273,1998 | .0000 | -31,4788 | .0000 | .0 |
| 21 | .0002 | 8,4949 | .0000 | 2483,2812 | .00 |
| 22 | 25,1525 | 25,1358 | 1,0488 | -.178 | 20751,815 |
| 23 | 61,9475 | 32,1632 | 31,9952 | -30,3229 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | .0 | -.0000 |
| 28 | .0 | .0000 | .00000 | -.9 | -1,0163 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 7497,4357 | 243,2506 | -30,8101 | .0000 | |

| | | | | | |
|----|------------|------------|------------|------------|-----------|
| 1 | 585,0000 | 352620,9 | 193975,2 | 645304,2 | 6115892,2 |
| 2 | 22121,7690 | 20798,4720 | 21551247,0 | .0 | 16,7600 |
| 3 | -268858,0 | .0 | -512345,4 | .0 | |
| 4 | 105387,1 | .0 | 211562,6 | .0 | |
| 5 | 6213909,5 | .0 | 6970433,8 | .0 | |
| 6 | -5426,4507 | .0000 | -6590,7960 | .0000 | 17,6561 |
| 7 | 578,4181 | .0000 | 250,5271 | .0000 | -.2083 |
| 8 | 20069,7670 | .0000 | 21115,6670 | .0000 | 1,2092 |
| 9 | 193507,1 | 193507,3 | -.2 | 1206,656 | -.000 |
| 10 | -2283,0 | -2285,0 | -.0 | 407515,270 | .005 |
| 11 | 13252,6 | 13269,1 | -.0 | 52604,690 | .017 |
| 12 | -91,9764 | -2,1767 | .0 | 139962,3 | 2,1102 |
| 13 | -2,1232 | -.2720 | .0 | 9328606,0 | 1,4532 |
| 14 | .0002 | .0329 | .0 | 9329346,6 | .0000 |
| 15 | -89,8656 | .0000 | -89,8656 | .0802 | 473,97 |
| 16 | -.6700 | .0000 | -.6700 | -2,1752 | -1,15 |
| 17 | .0000 | .0000 | .0000 | -.2720 | .34 |
| 18 | 1,6091 | 1,5128 | 1,4944 | .6766 | .1580 |
| 19 | 83,3011 | 83,7038 | 83,6994 | 3,9227 | 1,3231 |
| 20 | 432,4584 | 432,5298 | -447,4587 | -443,5166 | 191834,8 |
| 21 | .0002 | 8,5002 | .0000 | 2491,3721 | .00 |
| 22 | 15,4381 | 15,2706 | 2,3795 | -.174 | 20798,473 |
| 23 | 61,6243 | 32,1959 | 32,0279 | -30,3146 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -1113,9 | -368,3971 |
| 28 | .0 | .0000 | .00000 | -304,7 | -79,5934 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 81316,4360 | 319,5458 | -200,2992 | .0000 | |

TABLE 4-3 (Sheet 3 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|-------------|-----------|
| 1 | 590,0000 | 350102,9 | 225753,9 | 648194,0 | 6216938,9 |
| 2 | 22212,8530 | 20889,3520 | 21554101,0 | ,0 | 17,0369 |
| 3 | -296326,0 | ,0 | -545671,4 | ,0 | |
| 4 | 108293,6 | ,0 | 212801,7 | ,0 | |
| 5 | 6314397,5 | ,0 | 7076129,4 | ,0 | |
| 6 | -5558,1291 | ,0000 | -6737,1215 | ,0000 | 20,7427 |
| 7 | 586,0523 | ,0000 | 246,9605 | ,0000 | ,3168 |
| 8 | 20127,8110 | ,0000 | 21165,0910 | ,0000 | -,2411 |
| 9 | 225712,3 | 225712,4 | -,2 | -152,669 | -,000 |
| 10 | 3447,1 | 3453,2 | -,0 | -88363,659 | ,005 |
| 11 | -2623,0 | -2605,9 | -,0 | -129420,523 | ,017 |
| 12 | -92,2047 | -1,9074 | ,0 | 139404,6 | -2,4312 |
| 13 | 1,9037 | ,6792 | ,0 | 9316692,9 | ,5970 |
| 14 | -,0001 | ,0188 | ,0 | 9316989,1 | ,0000 |
| 15 | -94,6376 | ,0000 | -94,6376 | -,0632 | 474,77 |
| 16 | 2,5007 | ,0000 | 2,5007 | -1,9064 | -1,16 |
| 17 | ,0000 | ,0000 | ,0000 | ,6792 | ,34 |
| 18 | 1,5785 | 1,4844 | 1,4665 | -,8765 | -,3286 |
| 19 | 83,4893 | 83,8790 | 83,8747 | -,6615 | 1,4106 |
| 20 | 426,7224 | 429,1794 | -528,9444 | -491,9752 | 211077,8 |
| 21 | ,0002 | 8,5238 | ,0000 | 2499,2995 | ,00 |
| 22 | 15,4403 | 15,3604 | -1,6462 | -,172 | 20889,353 |
| 23 | 61,2998 | 32,2279 | 32,0597 | -30,3065 | -,0417 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -3224,1 | -446,1972 |
| 28 | ,0 | ,0000 | ,00000 | -715,5 | -83,3757 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 134097,1400 | 362,2911 | -319,4296 | ,0000 | |

| | | | | | |
|----|-------------|------------|------------|------------|-----------|
| 1 | 595,0000 | 347309,0 | 228457,9 | 651040,3 | 6318433,9 |
| 2 | 22311,6110 | 20987,8690 | 21556914,0 | ,0 | 17,3150 |
| 3 | -324461,9 | ,0 | -579739,6 | ,0 | |
| 4 | 111257,9 | ,0 | 214041,9 | ,0 | |
| 5 | 6415192,9 | ,0 | 7182089,1 | ,0 | |
| 6 | -5697,8838 | ,0000 | -6891,8124 | ,0000 | 21,1632 |
| 7 | 598,9100 | ,0000 | 248,3466 | ,0000 | -,1272 |
| 8 | 20190,7420 | ,0000 | 21219,0780 | ,0000 | -,1159 |
| 9 | 228450,2 | 228450,4 | -,2 | -160,435 | -,000 |
| 10 | -1373,4 | -1371,8 | -,0 | -45739,026 | ,005 |
| 11 | -1251,0 | -1245,5 | -,0 | 20810,869 | ,016 |
| 12 | -98,0721 | -,6040 | ,0 | 139398,7 | -1,4165 |
| 13 | 1,4321 | ,1811 | ,0 | 9303320,0 | 1,2158 |
| 14 | ,0000 | ,0035 | ,0 | 9303613,1 | ,0000 |
| 15 | -99,4895 | ,0000 | -99,4895 | -,0151 | 475,71 |
| 16 | 2,6479 | ,0000 | 2,6479 | -,6039 | -1,17 |
| 17 | ,0000 | ,0000 | ,0000 | ,1811 | ,35 |
| 18 | 1,5343 | 1,4432 | 1,4258 | ,3440 | -,2606 |
| 19 | 83,6922 | 84,0681 | 84,0639 | -,3124 | -,4191 |
| 20 | 426,7652 | 427,6601 | -535,3069 | -510,2004 | 18120,7 |
| 21 | ,0002 | 8,5506 | ,0000 | 2507,1073 | ,00 |
| 22 | 9,8948 | 9,8287 | -1,1653 | -,169 | 20987,869 |
| 23 | 60,9736 | 32,2590 | 32,0908 | -30,2985 | -,0417 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -5474,3 | -452,4282 |
| 28 | ,0 | ,0000 | ,00000 | -1132,4 | -83,5150 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 160255,2500 | 380,1944 | -379,6016 | ,0000 | |

TABLE 4-3 (Sheet 4 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|-----------|-----------|
| 1 | 600.0000 | 344623.3 | 229553.3 | 653806.6 | 6420404.4 |
| 2 | 22413.4160 | 21089.4320 | 21559647.0 | .0 | 17.5945 |
| 3 | -353314.6 | .0 | -614599.3 | .0 | |
| 4 | 114284.4 | .0 | 215286.6 | .0 | |
| 5 | 6516304.9 | .0 | 7288319.8 | .0 | |
| 6 | -5845.1074 | .0000 | -7054.0311 | .0000 | 21.4307 |
| 7 | 611.7306 | .0000 | 249.5266 | .0000 | -.1005 |
| 8 | 20254.0030 | .0000 | 21272.9790 | .0000 | .0793 |
| 9 | 229549.0 | 229549.2 | -.2 | 52.648 | -.000 |
| 10 | -1076.9 | -1077.5 | -.0 | 19997.887 | .005 |
| 11 | 849.0 | 857.2 | -.0 | 11344.104 | .016 |
| 12 | -103.2668 | -.8964 | .0 | 139392.7 | -1.0997 |
| 13 | 1.5616 | -.0635 | .0 | 9289817.1 | 1.0628 |
| 14 | .0000 | -.0026 | .0 | 9290107.0 | .0000 |
| 15 | -104.3672 | .0000 | -104.3672 | -.0245 | 476.66 |
| 16 | 2.6245 | .0000 | 2.6245 | -.8961 | -1.17 |
| 17 | .0000 | .0000 | .0000 | -.0635 | .35 |
| 18 | 1.4751 | 1.3879 | 1.3711 | .2689 | .0642 |
| 19 | 83.8958 | 84.2578 | 84.2538 | .2140 | -.1209 |
| 20 | 427.2368 | 427.3160 | -537.2879 | -518.5116 | 221512.1 |
| 21 | .0002 | 8.5790 | .0000 | 2514.6960 | .00 |
| 22 | 5.1500 | 4.9891 | -1.2838 | -.167 | 21089.432 |
| 23 | 60.6456 | 32.2893 | 32.1210 | -30.2908 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -7745.7 | -454.3684 |
| 28 | .0 | .0000 | .00000 | -1549.9 | -83.5580 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 175401.2100 | 390.3903 | -414.2535 | .0000 | |

| | | | | | |
|----|-------------|------------|------------|-----------|-----------|
| 1 | 605.0000 | 341937.7 | 229739.2 | 656457.9 | 6522862.0 |
| 2 | 22517.1740 | 21192.9490 | 21562265.0 | .0 | 17.8753 |
| 3 | -382926.9 | .0 | -650293.9 | .0 | |
| 4 | 117374.6 | .0 | 216536.3 | .0 | |
| 5 | 6617729.9 | .0 | 7394815.1 | .0 | |
| 6 | -6001.3489 | .0000 | -7225.2592 | .0000 | 21.6168 |
| 7 | 624.4405 | .0000 | 250.4434 | .0000 | -.0593 |
| 8 | 20315.8800 | .0000 | 21325.0110 | .0000 | .0368 |
| 9 | 229737.8 | 229738.0 | -.2 | 21.075 | -.000 |
| 10 | -630.4 | -630.6 | -.0 | 5605.938 | .005 |
| 11 | 391.2 | 400.6 | -.0 | -2804.516 | .016 |
| 12 | -107.9998 | -1.0232 | .0 | 139386.8 | -1.2380 |
| 13 | 1.6142 | -.0264 | .0 | 9275408.5 | .9868 |
| 14 | -.0000 | -.0006 | .0 | 9275695.1 | .0000 |
| 15 | -109.2386 | .0000 | -109.2386 | -.0288 | 477.67 |
| 16 | 2.6010 | .0000 | 2.6010 | -1.0228 | -1.18 |
| 17 | .0000 | .0000 | .0000 | -.0264 | .35 |
| 18 | 1.3960 | 1.3139 | 1.2976 | .1573 | .0306 |
| 19 | 84.0998 | 84.4481 | 84.4443 | .0999 | .0584 |
| 20 | 427.7394 | 427.2438 | -537.0979 | -522.9034 | 223363.0 |
| 21 | .0002 | 8.6087 | .0000 | 2521.9691 | .00 |
| 22 | 1.4674 | .6322 | -1.3244 | -.165 | 21192.950 |
| 23 | 60.3158 | 32.3187 | 32.1504 | -30.2834 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -10018.2 | -454.7052 |
| 28 | .0 | .0000 | .00000 | -1966.2 | -83.0310 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 185130.5400 | 396.9932 | -436.4098 | .0000 | |

TABLE 4-3 (Sheet 5 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|-----------|-----------|
| 1 | 610,0000 | 339242,3 | 229394,2 | 658956,9 | 6625815,2 |
| 2 | 22622,1210 | 21297,6570 | 21564732,0 | .0 | 18,1574 |
| 3 | -413343,0 | .0 | -686866,8 | .0 | |
| 4 | 120528,8 | .0 | 217790,8 | .0 | |
| 5 | 6719458,8 | .0 | 7501564,1 | .0 | |
| 6 | -6166,4300 | .0000 | -7405,2845 | .0000 | 21,7558 |
| 7 | 637,2677 | .0000 | 251,3449 | .0000 | -.0687 |
| 8 | 20375,4560 | .0000 | 21374,2600 | .0000 | .0126 |
| 9 | 229392,8 | 229393,0 | -.2 | -7,208 | -.000 |
| 10 | -724,2 | -724,1 | -.0 | -2555,678 | .005 |
| 11 | 132,8 | 141,8 | -.0 | 77,328 | .016 |
| 12 | -112,8302 | -.9833 | .0 | 139380,8 | -1,2751 |
| 13 | 1,5805 | .0161 | .0 | 9260773,5 | 1,0333 |
| 14 | -.0000 | .0004 | .0 | 9261056,9 | .0000 |
| 15 | -114,1062 | .0000 | -114,1062 | -.0271 | 478,69 |
| 16 | 2,6139 | .0000 | 2,6139 | -.9829 | -1,19 |
| 17 | .0000 | .0000 | .0000 | .0161 | .35 |
| 18 | 1,2973 | 1,2213 | 1,2056 | .1809 | -.0094 |
| 19 | 84,3051 | 84,6397 | 84,6362 | .0354 | .0150 |
| 20 | 425,3067 | 426,9289 | -539,3590 | -525,9924 | 224521,5 |
| 21 | .0002 | 8,6395 | .0000 | 2528,8241 | .00 |
| 22 | 4,0088 | -3,8013 | -1,2770 | -.164 | 21297,657 |
| 23 | 59,9841 | 32,3473 | 32,1790 | -30,2764 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -12300,3 | -456,5840 |
| 28 | .0 | .0000 | .00000 | -2381,9 | -83,1392 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 191898,4700 | 401,3624 | -452,0958 | .0000 | |
| | | | | | |
| 1 | 615,0000 | 336545,2 | 230056,6 | 661266,7 | 6729271,0 |
| 2 | 22727,7000 | 21403,0030 | 21567012,0 | .0 | 18,4410 |
| 3 | -444605,6 | .0 | -724361,0 | .0 | |
| 4 | 123747,7 | .0 | 219050,0 | .0 | |
| 5 | 6821478,8 | .0 | 7608551,2 | .0 | |
| 6 | -6340,1151 | .0000 | -7593,8433 | .0000 | 21,9935 |
| 7 | 650,3131 | .0000 | 252,3486 | .0000 | -.0710 |
| 8 | 20432,0490 | .0000 | 21420,0440 | .0000 | .0189 |
| 9 | 230055,1 | 230055,3 | -.2 | -1,301 | -.000 |
| 10 | -742,5 | -742,5 | -.0 | -552,534 | .005 |
| 11 | 197,9 | 206,9 | -.0 | 483,651 | .016 |
| 12 | -117,7163 | -.9668 | .0 | 139374,8 | -1,2552 |
| 13 | 1,6248 | .0084 | .0 | 9245221,5 | 1,0341 |
| 14 | -.0000 | .0001 | .0 | 9245501,6 | .0000 |
| 15 | -118,9724 | .0000 | -118,9724 | -.0274 | 479,77 |
| 16 | 2,6589 | .0000 | 2,6589 | -.9664 | -1,20 |
| 17 | .0000 | .0000 | .0000 | .0084 | .36 |
| 18 | 1,1793 | 1,1106 | 1,0954 | .1849 | .0003 |
| 19 | 84,5120 | 84,8329 | 84,8297 | .0515 | -.0072 |
| 20 | 426,2314 | 426,7094 | -539,7427 | -528,1444 | 225328,2 |
| 21 | .0002 | 8,6714 | .0000 | 2535,1606 | .00 |
| 22 | 8,3693 | -8,2697 | -1,3054 | -.162 | 21403,004 |
| 23 | 59,6507 | 32,3750 | 32,2066 | -30,2699 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -14585,5 | -457,4189 |
| 28 | .0 | .0000 | .00000 | -2797,0 | -82,9652 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 196888,7500 | 404,5690 | -463,6681 | .0000 | |

TABLE 4-3 (Sheet 6 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|-----------|------------|
| 1 | 620.0000 | 333849.4 | 229734.0 | 663349.2 | 6833231.7 |
| 2 | 22833,4960 | 21508,5800 | 21569064.0 | .0 | 18,7259 |
| 3 | -476758.3 | .0 | -762819.2 | .0 | .0 |
| 4 | 127032.2 | .0 | 220314.4 | .0 | .0 |
| 5 | 6923772.9 | .0 | 7715757.3 | .0 | .0 |
| 6 | -6522,3512 | .0000 | -7790,8549 | .0000 | 22,1400 |
| 7 | 663,5566 | .0000 | 253,4476 | .0000 | -,0724 |
| 8 | 20485,0590 | .0000 | 21461.7560 | .0000 | .0219 |
| 9 | 229732.5 | 229732.7 | -,2 | 1,440 | -,0000 |
| 10 | -751.1 | -751,0 | -,0 | 369,071 | .005 |
| 11 | 227.7 | 236.7 | -,0 | 682,519 | .016 |
| 12 | -122,5847 | -,9718 | .0 | 139368.8 | -1,2509 |
| 13 | 1,6723 | .0102 | .0 | 9229440.4 | 1,0429 |
| 14 | -,0000 | .0000 | .0 | 9229717.0 | .0000 |
| 15 | -123,8365 | .0000 | -123,8365 | -,0284 | 480,87 |
| 16 | 2,7153 | .0000 | 2,7153 | -,9714 | -1,21 |
| 17 | .0000 | .0000 | .0000 | .0102 | .36 |
| 18 | 1,0421 | .9816 | .9670 | .1873 | .0062 |
| 19 | 84,7205 | 85,0277 | 85,0248 | .0590 | -,0017 |
| 20 | 426,9690 | 426,7011 | -538,0547 | -529,6642 | 225977.1 |
| 21 | .0001 | 8,7044 | .0000 | 2540,8731 | .00 |
| 22 | 12,7653 | -12,6998 | -1,3347 | -,161 | 21508,580 |
| 23 | 59,3154 | 32,4018 | 32,2333 | -30,2641 | -,0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -16870.1 | -455,6697 |
| 28 | .0 | .0000 | .00000 | -3211.4 | -83,0245 |
| 29 | | | | | |
| 30 | | | | | |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 200766,3200 | 407,1526 | -472,5003 | .0000 | |
| 1 | 625,0000 | 331154.1 | 228488.9 | 665165.9 | 6937697.1 |
| 2 | 22938,5900 | 21613,4710 | 21570852.0 | .0 | 19,0122 |
| 3 | -509842.7 | .0 | -802282.8 | .0 | .0 |
| 4 | 130383.5 | .0 | 221584.6 | .0 | .0 |
| 5 | 7026320.8 | .0 | 7823159.5 | .0 | .0 |
| 6 | -6712,7835 | .0000 | -7995,9194 | .0000 | 22,1992 |
| 7 | 677,0091 | .0000 | 254,6803 | .0000 | -,0701 |
| 8 | 20533,4450 | .0000 | 21498,3580 | .0000 | .0211 |
| 9 | 228487.5 | 228487.6 | -,2 | 1,259 | -,0000 |
| 10 | -722.0 | -721,9 | -,0 | 41,200 | .005 |
| 11 | 217.2 | 226.2 | -,0 | -222,783 | .016 |
| 12 | -127,4470 | -,9738 | .0 | 139362.7 | -1,2553 |
| 13 | 1,7570 | .0152 | .0 | 9212726.0 | 1,0403 |
| 14 | -,0000 | .0001 | .0 | 9212999.5 | .0000 |
| 15 | -128,7034 | .0000 | -128,7034 | -,0299 | 482,03 |
| 16 | 2,7974 | .0000 | 2,7974 | -,9734 | -1,22 |
| 17 | .0000 | .0000 | .0000 | .0152 | .36 |
| 18 | .8859 | .8347 | .8207 | .1810 | .0018 |
| 19 | 84,9306 | 85,2242 | 85,2218 | .0567 | -,0007 |
| 20 | 427,1790 | 426,6889 | -534,8756 | -530,8056 | 226461.2 |
| 21 | .0001 | 8,7382 | .0000 | 2545,8568 | .00 |
| 22 | 17,1544 | -17,1038 | -1,3981 | -,160 | 21613,472 |
| 23 | 58,9782 | 32,4277 | 32,2592 | -30,2590 | -,0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -19154.0 | -453,2255 |
| 28 | .0 | .0000 | .00000 | -3626.0 | -82,2858 |
| 29 | 2396,5336 | 33976,6700 | .19419 | 176,59071 | |
| 30 | 3551,6269 | 22926,4600 | 32,57331 | 67,80278 | 263042100. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 203825,2000 | 409,1899 | -479,4737 | .0000 | |

TABLE 4-3 (Sheet 7 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|-----------|------------|
| 1 | 630,0000 | 328456.8 | 229912.7 | 666678.0 | 7042664.1 |
| 2 | 23042.2350 | 21716.9340 | 21572337.0 | .0 | 19,2998 |
| 3 | -543899.2 | .0 | -842791.0 | .0 | |
| 4 | 133802.5 | .0 | 222861.4 | .0 | |
| 5 | 7129097.5 | .0 | 7930730.2 | .0 | |
| 6 | -6911.0244 | .0000 | -8208,6101 | .0000 | 22,5210 |
| 7 | 690,6837 | .0000 | 256,0847 | .0000 | -.0710 |
| 8 | 20576.3440 | .0000 | 21528,9980 | .0000 | .0219 |
| 9 | 229911.3 | 229911.4 | -.2 | 1,813 | -.000 |
| 10 | -724.6 | -724.5 | -.0 | 156,341 | .005 |
| 11 | 223.1 | 232.2 | -.0 | -393,394 | .016 |
| 12 | -132,3248 | -.9757 | .0 | 139356.7 | -1,2552 |
| 13 | 1,8341 | .0139 | .0 | 9195778.4 | 1,0369 |
| 14 | -.0000 | .0001 | .0 | 9196048.8 | .0000 |
| 15 | -133,5811 | .0000 | -133,5811 | -.0312 | 483,20 |
| 16 | 2,8710 | .0000 | 2,8710 | -.9752 | -1,23 |
| 17 | .0000 | .0000 | .0000 | .0139 | .36 |
| 18 | .7113 | .6704 | .6569 | .1805 | -.0010 |
| 19 | 85,1424 | 85,4225 | 85,4205 | .0579 | .0001 |
| 20 | 425,5544 | 426,5601 | -540,2634 | -531,7434 | 226794.7 |
| 21 | .0001 | 8,7729 | .0000 | 2550,0048 | .00 |
| 22 | 21,5437 | -21,5034 | -1,4502 | -.160 | 21716.935 |
| 23 | 58,6392 | 32,4527 | 32,2841 | -30,2548 | -.0417 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -21439.1 | -457,8701 |
| 28 | .0 | .0000 | .00000 | -4041.5 | -83,0354 |
| 29 | 2434,0937 | 33607,0810 | .18667 | 177,13544 | |
| 30 | 3551,3752 | 23034,1150 | 32,57246 | 68,44170 | 265425320. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 206263,8300 | 410,7364 | -485,1629 | .0000 | |
| | | | | | |
| 1 | 635,0000 | 325757.7 | 230616.1 | 667848.2 | 7148125.1 |
| 2 | 23144,2240 | 21818,7730 | 21573481.0 | .0 | 19,5888 |
| 3 | -578965.9 | .0 | -884381.5 | .0 | |
| 4 | 137290.6 | .0 | 224145.7 | .0 | |
| 5 | 7232073.9 | .0 | 8038438.3 | .0 | |
| 6 | -7116,9960 | .0000 | -8428,8260 | .0000 | 22,7771 |
| 7 | 704,5542 | .0000 | 257,6457 | .0000 | -.0737 |
| 8 | 20613,3650 | .0000 | 21553,2730 | .0000 | .0234 |
| 9 | 230614.6 | 230614.7 | -.2 | 2,544 | -.000 |
| 10 | -746.4 | -746.3 | -.0 | 533,118 | .005 |
| 11 | 236.5 | 245.6 | -.0 | 123,924 | .016 |
| 12 | -137,2009 | -.9733 | .0 | 139350.7 | -1,2479 |
| 13 | 1,8940 | .0136 | .0 | 9178110.2 | 1,0410 |
| 14 | -.0000 | .0001 | .0 | 9178377.5 | .0000 |
| 15 | -138,4499 | .0000 | -138,4499 | -.0322 | 484,42 |
| 16 | 2,9350 | .0000 | 2,9350 | -.9728 | -1,24 |
| 17 | .0000 | .0000 | .0000 | .0136 | .37 |
| 18 | .5182 | .4885 | .4756 | .1854 | -.0012 |
| 19 | 85,3560 | 85,6225 | 85,6211 | .0610 | .0023 |
| 20 | 426,9959 | 426,4995 | -540,0865 | -532,5319 | 227100.8 |
| 21 | .0001 | 8,8085 | .0000 | 2553,2149 | .00 |
| 22 | 25,9132 | -25,8813 | -1,4809 | -.160 | 21818,773 |
| 23 | 58,2984 | 32,4767 | 32,3080 | -30,2515 | -.0418 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -23726.0 | -457,4901 |
| 28 | .0 | .0000 | .00000 | -4456.9 | -83,2383 |
| 29 | 2471,5497 | 33247,0690 | .17925 | 177,82123 | |
| 30 | 3551,1059 | 23139,7730 | 32,57156 | 69,08051 | 267780950. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 208313,4500 | 412,0531 | -489,8965 | .0000 | |

TABLE 4-3 (Sheet 8 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|-----------|------------|
| 1 | 640,0000 | 323055,9 | 230967,6 | 668638,4 | 7254073,1 |
| 2 | 23243,9530 | 21918,3870 | 21574246,0 | .0 | 19,8792 |
| 3 | -615081,1 | .0 | -927090,9 | .0 | |
| 4 | 140848,4 | .0 | 225438,1 | .0 | |
| 5 | 7335219,6 | .0 | 8146250,6 | .0 | |
| 6 | -7330,2633 | .0000 | -8656,0959 | .0000 | 23,0026 |
| 7 | 718,5901 | .0000 | 259,3561 | .0000 | -.0728 |
| 8 | 20643,8020 | .0000 | 21570,4920 | .0000 | .0220 |
| 9 | 230966,2 | 230966,4 | -.2 | 1,371 | -.0000 |
| 10 | -730,9 | -730,8 | -.0 | -24,681 | .0005 |
| 11 | 220,5 | 229,6 | -.0 | -518,990 | .0017 |
| 12 | -142,0530 | -.9719 | .0 | 139344,5 | -1,2504 |
| 13 | 1,9564 | .0102 | .0 | 9159786,3 | 1,0303 |
| 14 | -.0000 | .0001 | .0 | 9160050,1 | .0000 |
| 15 | -143,3046 | .0000 | -143,3046 | -.0332 | 485,68 |
| 16 | 2,9867 | .0000 | 2,9867 | -.9714 | -1,25 |
| 17 | .0000 | .0000 | .0000 | .0102 | .37 |
| 18 | .3072 | .2897 | .2774 | .1813 | -.0054 |
| 19 | 85,5712 | 85,8243 | 85,8234 | .0570 | .0014 |
| 20 | 427,5099 | 426,4778 | -540,2597 | -533,2292 | 227388,6 |
| 21 | .0001 | 8,8450 | .0000 | 2555,3825 | .00 |
| 22 | 30,2412 | -30,2157 | -1,5092 | -.160 | 21918,388 |
| 23 | 57,9559 | 32,4997 | 32,3310 | -30,2493 | -.0418 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -26015,3 | -458,4185 |
| 28 | .0 | .0000 | .00000 | -4872,7 | -82,4833 |
| 29 | 2508,5861 | 32899,2760 | .17201 | 178,66424 | |
| 30 | 3550,8717 | 23242,3690 | 32,57062 | 69,71467 | 270094450, |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 210068,7200 | 413,1851 | -493,9196 | .0000 | |

| | | | | | |
|----|-------------|------------|------------|-----------|------------|
| 1 | 645,0000 | 320352,4 | 230328,1 | 669011,3 | 7360495,6 |
| 2 | 23340,7020 | 22015,0640 | 21574594,0 | .0 | 20,1708 |
| 3 | -652279,9 | .0 | -970953,2 | .0 | |
| 4 | 144476,6 | .0 | 226739,4 | .0 | |
| 5 | 7438499,3 | .0 | 8254129,8 | .0 | |
| 6 | -7550,2957 | .0000 | -8889,8491 | .0000 | 23,1320 |
| 7 | 732,7197 | .0000 | 261,1716 | .0000 | -.0763 |
| 8 | 20666,8620 | .0000 | 21579,8700 | .0000 | .1400 |
| 9 | 230322,4 | 230322,6 | -.2 | 123,365 | -.0000 |
| 10 | -759,6 | -759,6 | -.0 | 37798,817 | .005 |
| 11 | 1393,7 | 1402,2 | -.0 | 361,839 | .017 |
| 12 | -146,9006 | -.8958 | .0 | 139338,3 | -.2249 |
| 13 | 1,9746 | .0056 | .0 | 9140583,2 | 1,0347 |
| 14 | -.0000 | -.0026 | .0 | 9140843,6 | .0000 |
| 15 | -147,1257 | .0000 | -147,1257 | -.0309 | 486,99 |
| 16 | 3,0093 | .0000 | 3,0093 | -.8952 | -1,26 |
| 17 | .0000 | .0000 | .0000 | .0056 | .37 |
| 18 | .0790 | .0745 | .0628 | .1890 | -.0016 |
| 19 | 85,7880 | 86,0276 | 86,0274 | .3488 | .5799 |
| 20 | 426,5204 | 426,4606 | -540,0036 | -533,8398 | 227641,4 |
| 21 | .0001 | 8,8822 | .0000 | 2556,4056 | .00 |
| 22 | 34,5454 | -34,5263 | -1,4873 | -.161 | 22015,064 |
| 23 | 57,6116 | 32,5218 | 32,3530 | -30,2483 | -.0418 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -28306,1 | -457,3911 |
| 28 | .0 | .0000 | .00000 | -5288,6 | -83,2543 |
| 29 | 2544,8146 | 32566,7920 | .16503 | 179,68402 | |
| 30 | 3550,7392 | 23340,6180 | 32,56966 | 70,33853 | 272348310, |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 211575,8100 | 414,1509 | -497,3732 | .0000 | |

TABLE 4-3 (Sheet 9 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|------------|------------|------------|
| 1 | 650.0000 | 317648.4 | 230512.4 | 668933.3 | 7467379.5 |
| 2 | 23436.2380 | 22110.5760 | 21574493.0 | .0 | 20.4638 |
| 3 | -690592.1 | .0 | -1015997.0 | .0 | |
| 4 | 148175.6 | .0 | 228049.9 | .0 | |
| 5 | 7541877.3 | .0 | 8362037.8 | .0 | |
| 6 | -7774.1000 | .0000 | -9127.1979 | .0000 | 23.3480 |
| 7 | 746.9239 | .0000 | 263.0484 | .0000 | -.0772 |
| 8 | 20685.3350 | .0000 | 21584.3080 | .0000 | -.0590 |
| 9 | 230510.3 | 230510.4 | -.2 | -85.870 | -.000 |
| 10 | -762.6 | -762.6 | -.0 | -26065.341 | .005 |
| 11 | -582.7 | -587.1 | -.0 | 329.481 | .017 |
| 12 | -145.7964 | .4680 | .0 | 139332.1 | .3313 |
| 13 | 1.9979 | .0010 | .0 | 9121197.8 | 1.0340 |
| 14 | .0000 | .0030 | .0 | 9121454.9 | .0000 |
| 15 | -145.4648 | .0000 | -145.4648 | .0163 | 488.32 |
| 16 | 3.0319 | .0000 | 3.0319 | .4677 | -1.27 |
| 17 | .0000 | .0000 | .0000 | .0010 | .38 |
| 18 | -.1568 | -.1479 | -.1590 | .1896 | .0042 |
| 19 | 86.0060 | 86.2323 | 86.2327 | -.1459 | .0521 |
| 20 | 425.3234 | 426.3976 | -541.9650 | -534.3661 | 227833.3 |
| 21 | .0002 | 8.9211 | .0000 | 2556.1916 | .00 |
| 22 | 32.8976 | -32.8762 | -1.5017 | -.163 | 22110.577 |
| 23 | 57.2657 | 32.5428 | 32.3739 | -30.2485 | -.0418 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -30597.2 | -459.4042 |
| 28 | .0 | .0000 | .00000 | -5704.8 | -83.2049 |
| 29 | 2580.7679 | 32244.2810 | .15820 | -179.15475 | |
| 30 | 3550.7846 | 23435.6680 | 32.56871 | 70.96255 | 274583070. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 212854.9300 | 414.9398 | -500.3592 | .0000 | |

| | | | | | |
|----|-------------|------------|------------|------------|------------|
| 1 | 655.0000 | 314944.7 | 230584.2 | 668414.6 | 7574737.7 |
| 2 | 23536.7130 | 22211.0750 | 21573952.0 | .0 | 20.7580 |
| 3 | -730016.8 | .0 | -1062221.4 | .0 | |
| 4 | 151946.1 | .0 | 229370.0 | .0 | |
| 5 | 7645358.9 | .0 | 8469979.0 | .0 | |
| 6 | -7995.4735 | .0000 | -9362.3039 | .0000 | 23.5558 |
| 7 | 761.3360 | .0000 | 264.9904 | .0000 | -.0717 |
| 8 | 20708.0810 | .0000 | 21592.9140 | .0000 | .0151 |
| 9 | 230583.0 | 230583.1 | -.2 | -6.914 | -.000 |
| 10 | -701.4 | -701.7 | -.0 | -2466.599 | .005 |
| 11 | 148.0 | 142.9 | -.0 | -1774.791 | .018 |
| 12 | -143.5850 | .5329 | .0 | 139325.9 | .4765 |
| 13 | 1.9857 | -.0275 | .0 | 9100800.8 | .9918 |
| 14 | -.0000 | .0002 | .0 | 9101054.5 | .0000 |
| 15 | -143.1080 | .0000 | -143.1080 | .0185 | 489.71 |
| 16 | 2.9774 | .0000 | 2.9774 | .5326 | -1.28 |
| 17 | .0000 | .0000 | .0000 | -.0275 | .38 |
| 18 | -.3768 | -.3555 | -.3660 | .1744 | .0121 |
| 19 | 86.2250 | 86.4379 | 86.4390 | .0355 | -.0820 |
| 20 | 425.8439 | 426.3984 | -541.4733 | -534.8134 | 228025.7 |
| 21 | .0002 | 8.9642 | .0000 | 2554.7686 | .00 |
| 22 | 30.1575 | -30.1327 | -1.4862 | -.165 | 22211.075 |
| 23 | 56.9181 | 32.5628 | 32.3939 | -30.2500 | -.0418 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -32887.9 | -458.5636 |
| 28 | .0 | .0000 | .00000 | -6121.0 | -83.5532 |
| 29 | 2618.7894 | 31911.0370 | .15110 | -177.94244 | |
| 30 | 3551.0304 | 23533.5310 | 32.56782 | 71.62790 | 276943180. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 213994.6300 | 415.6776 | -502.9565 | .0000 | |

TABLE 4-3 (Sheet 10 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|-------------------------|------------|------------|------------|
| 1 | 660,0000 | 312247.6 | 230247.3 | 667481.8 | 7682594.8 |
| 2 | 23641.4040 | 22 ² 15.8340 | 21572999.0 | .0 | 21,0536 |
| 3 | -770541.6 | .0 | -1109615.2 | .0 | |
| 4 | 155788.8 | .0 | 230699.4 | .0 | |
| 5 | 7748963.6 | .0 | 8577972.4 | .0 | |
| 6 | -8214.0937 | .0000 | -9594.8262 | .0000 | 23.7246 |
| 7 | 775,7016 | .0000 | 266,7573 | .0000 | -,0761 |
| 8 | 20734,5940 | .0000 | 21605,1880 | .0000 | .0345 |
| 9 | 230245.7 | 230245.8 | -.2 | 11,938 | -,000 |
| 10 | -739.0 | -739.1 | -.0 | 3584,048 | .005 |
| 11 | 334.6 | 330,1 | -.0 | -631,723 | .018 |
| 12 | -141,2840 | .4677 | .0 | 139319.7 | .4926 |
| 13 | 1,8762 | -.0159 | .0 | 9080151.0 | 1,0038 |
| 14 | -,0000 | -.0003 | .0 | 9080401,1 | .0000 |
| 15 | -140,7909 | .0000 | -140,7909 | .0153 | 491,12 |
| 16 | 2,8800 | .0000 | 2,8800 | .4675 | -1,29 |
| 17 | .0000 | .0000 | .0000 | -.0159 | .38 |
| 18 | -,5806 | -.5480 | -,5579 | .1839 | -,0043 |
| 19 | 86,4444 | 86,6440 | 86,6456 | .0821 | -,0101 |
| 20 | 427,1514 | 426,4124 | -539,0263 | -535,1156 | 228163,2 |
| 21 | .0002 | 9,0110 | .0000 | 2552,2098 | .00 |
| 22 | 27,3385 | -27,3134 | -1,3736 | -,168 | 22315,834 |
| 23 | 56,5686 | 32,5817 | 32,4128 | -30,2527 | -,0418 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -35171,3 | -456,5822 |
| 28 | .0 | .0000 | .00000 | -6537,9 | -83,0847 |
| 29 | 2658,7164 | 31569,3770 | .14376 | -176,67340 | |
| 30 | 3551,4703 | 23633,5970 | 32,56705 | 72,33201 | 279413040. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | .00000 | .00000 | .00000 | .0 |
| 33 | 214969,2800 | 416,3384 | -505,1601 | .0000 | |
| | | | | | |
| 1 | 665,0000 | 309552,4 | 230222,3 | 666162,5 | 7790968,9 |
| 2 | 23749,8020 | 22 ⁴ 24,3370 | 21571659,0 | .0 | 21,3506 |
| 3 | -812152,5 | .0 | -1158164,7 | .0 | |
| 4 | 159703,1 | .0 | 232037,3 | .0 | |
| 5 | 7852709,2 | .0 | 8686035,1 | .0 | |
| 6 | -8429,7728 | .0000 | -9824,5668 | .0000 | 23,9285 |
| 7 | 790,0027 | .0000 | 268,3406 | .0000 | -,0763 |
| 8 | 20764,5300 | .0000 | 21620,8010 | .0000 | .0337 |
| 9 | 230220,7 | 230220,9 | -.2 | 11,020 | -,000 |
| 10 | -734,4 | -734,9 | -.0 | 3220,776 | .005 |
| 11 | 324,0 | 319,5 | -,0 | -891,623 | .019 |
| 12 | -138,8979 | .4784 | .0 | 139313,5 | .5296 |
| 13 | 1,7319 | -,0495 | .0 | 9058453,1 | .9724 |
| 14 | -,0000 | -,0000 | .0 | 9058699,8 | .0000 |
| 15 | -138,3680 | .0000 | -138,3680 | .0145 | 492,60 |
| 16 | 2,7044 | .0000 | 2,7044 | .4782 | -1,30 |
| 17 | .0000 | .0000 | .0000 | -,0495 | .38 |
| 18 | -,7681 | -,7252 | -,7345 | .1829 | .0106 |
| 19 | 86,6641 | 86,8505 | 86,8526 | .0795 | .0332 |
| 20 | 427,2389 | 426,3598 | -538,8574 | -535,3575 | 228239,0 |
| 21 | .0002 | 9,0612 | .0000 | 2548,5908 | .00 |
| 22 | 24,4479 | -24,4239 | -1,2261 | -,171 | 22424,337 |
| 23 | 56,2174 | 32,5996 | 32,4306 | -30,2564 | -,0419 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -37453,2 | -456,0272 |
| 28 | .0 | .0000 | .00000 | -6954,3 | -83,4706 |
| 29 | 2700,4580 | 31 ² 20,8900 | .13621 | -175,33444 | |
| 30 | 3552,1006 | 23735,4490 | 32,56638 | 73,07354 | 281981880. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | .00000 | .00000 | .00000 | .0 |
| 33 | 215791,4200 | 416,8639 | -507,0913 | .0000 | |

TABLE 4-3 (Sheet 11 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 670.0000 | 306849.3 | 230921.0 | 664485.3 | 7899881.9 |
| 2 | 23862.4360 | 22537.1080 | 21569964.0 | .0 | 21,6490 |
| 3 | -854834.6 | .0 | -1207856.5 | .0 | |
| 4 | 163688.3 | .0 | 233382.1 | .0 | |
| 5 | 7956614.6 | .0 | 8794185.7 | .0 | |
| 6 | -8642.6155 | .0000 | -10051.6593 | .0000 | 24,2126 |
| 7 | 804.0271 | .0000 | 269.5089 | .0000 | -.0790 |
| 8 | 20798.5570 | .0000 | 21640.4120 | .0000 | .0200 |
| 9 | 230919.5 | 230919.7 | -.2 | -4.078 | -.000 |
| 10 | -753.7 | -754.1 | -.0 | -1196.560 | .006 |
| 11 | 190.8 | 186.0 | -.0 | -449.995 | .019 |
| 12 | -136.3261 | .5045 | .0 | 139307.2 | .5285 |
| 13 | 1.5147 | -.0407 | .0 | 9036493.4 | .9800 |
| 14 | -.0000 | .0003 | .0 | 9036736.6 | .0000 |
| 15 | -135.7973 | .0000 | -135.7973 | .0133 | 494.09 |
| 16 | 2.4947 | .0000 | 2.4947 | .5043 | -1.31 |
| 17 | .0000 | .0000 | .0000 | -.0407 | .39 |
| 18 | -.9387 | -.8866 | -.8953 | .1871 | -.0014 |
| 19 | 86.8836 | 87.0568 | 87.0595 | .0461 | .0140 |
| 20 | 426.0424 | 426.3086 | -542.0109 | -535.6626 | 228342.3 |
| 21 | .0002 | 9.1150 | .0000 | 2543.9899 | .00 |
| 22 | 21.3835 | -21.3639 | -1.0065 | -.175 | 22537.108 |
| 23 | 55.8642 | 32.6165 | 32.4474 | -30.2611 | -.0419 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -39741.4 | -459.0556 |
| 28 | .0 | .0000 | .00000 | -7372.4 | -83.5994 |
| 29 | 2744.3365 | 30863.7470 | .12840 | -173.90544 | |
| 30 | 3552.9222 | 23839.6730 | 32.56586 | 73.85856 | 284663520. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 216558.6400 | 417.3283 | -508.8990 | .0000 | |
| 1 | 675.0000 | 304146.3 | 231060.2 | 662480.2 | 8009355.5 |
| 2 | 23979.1510 | 22653.9860 | 21567941.0 | .0 | 21,9491 |
| 3 | -898573.3 | .0 | -1258676.2 | .0 | |
| 4 | 167742.8 | .0 | 234731.7 | .0 | |
| 5 | 8060700.6 | .0 | 8902444.8 | .0 | |
| 6 | -8852.1804 | .0000 | -10275.6743 | .0000 | 24.4425 |
| 7 | 817.7769 | .0000 | 270.2649 | .0000 | -.0815 |
| 8 | 20836.8230 | .0000 | 21664.1920 | .0000 | .0180 |
| 9 | 231058.7 | 231058.8 | -.2 | -6.972 | -.000 |
| 10 | -770.8 | -771.2 | -.0 | -1917.511 | .006 |
| 11 | 170.3 | 165.1 | -.0 | -16.631 | .020 |
| 12 | -133.6590 | .5402 | .0 | 139300.9 | .5447 |
| 13 | 1.3067 | -.0400 | .0 | 9013444.3 | .9842 |
| 14 | -.0000 | .0003 | .0 | 9013683.9 | .0000 |
| 15 | -133.1140 | .0000 | -133.1140 | .0123 | 495.65 |
| 16 | 2.2909 | .0000 | 2.2909 | .5401 | -1.32 |
| 17 | .0000 | .0000 | .0000 | -.0400 | .39 |
| 18 | -1.0913 | -1.0310 | -1.0391 | .1912 | -.0011 |
| 19 | 87.1029 | 87.2631 | 87.2662 | .0409 | -.0032 |
| 20 | 426.9799 | 426.3268 | -541.1469 | -535.9343 | 228468.8 |
| 21 | .0002 | 9.1722 | .0000 | 2538.4896 | .00 |
| 22 | 18.2407 | -18.2256 | -.7962 | -.180 | 22653.986 |
| 23 | 55.5091 | 32.6323 | 32.4631 | -30.2667 | -.0419 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -42029.5 | -458.2013 |
| 28 | .0 | .0000 | .00000 | -7790.7 | -83.5887 |
| 29 | 2790.4196 | 30498.3530 | .12035 | -172.37225 | |
| 30 | 3553.9307 | 23946.2190 | 32.56548 | 74.68859 | 287455660. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 217279.5500 | 417.8048 | -510.5219 | .0000 | |

TABLE 4-3 (Sheet 12 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 680,0000 | 301441,9 | 230149,7 | 660181,6 | 8119409,2 |
| 2 | 24099,2870 | 22774,3050 | 21565626,0 | ,0 | 22,2507 |
| 3 | -943349,9 | ,0 | -1310606,9 | ,0 | |
| 4 | 171865,5 | ,0 | 236084,0 | ,0 | |
| 5 | 8164988,1 | ,0 | 9010833,0 | ,0 | |
| 6 | -9057,7884 | ,0000 | -10495,9255 | ,0000 | 24,5646 |
| 7 | 831,2246 | ,0000 | 270,5953 | ,0000 | -,0807 |
| 8 | 20879,0450 | ,0000 | 21691,8870 | ,0000 | ,0304 |
| 9 | 230148,1 | 230148,3 | -,2 | 6,160 | -,000 |
| 10 | -756,3 | -756,8 | -,0 | 1866,392 | ,006 |
| 11 | 284,9 | 279,7 | -,0 | -506,902 | ,021 |
| 12 | -130,9859 | ,5444 | ,0 | 139294,6 | ,6236 |
| 13 | 1,0953 | -,0477 | ,0 | 8990122,6 | ,9744 |
| 14 | -,0000 | ,0001 | ,0 | 8990358,9 | ,0000 |
| 15 | -130,3621 | ,0000 | -130,3621 | ,0104 | 497,23 |
| 16 | 2,0698 | ,0000 | 2,0698 | ,5443 | -1,33 |
| 17 | ,0000 | ,0000 | ,0000 | -,0477 | ,39 |
| 18 | -1,2246 | -1,1573 | -1,1647 | ,1884 | ,0014 |
| 19 | 87,3220 | 87,4694 | 87,4728 | ,0696 | ,0245 |
| 20 | 426,3399 | 426,3202 | -539,8235 | -536,1910 | 228575,4 |
| 21 | ,0002 | 9,2324 | ,0000 | 2532,1838 | ,00 |
| 22 | 15,1099 | -15,0997 | -,5824 | -,185 | 22774,306 |
| 23 | 55,1520 | 32,6470 | 32,4778 | -30,2732 | -,0419 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -44318,5 | -456,9242 |
| 28 | ,0 | ,0000 | ,00000 | -8209,2 | -83,5409 |
| 29 | 2838,5673 | 30126,7410 | ,11207 | -170,71464 | |
| 30 | 3555,1225 | 24054,5250 | 32,56521 | 75,56155 | 290343840, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 217923,9200 | 418,2133 | -511,9991 | ,0000 | |
| 1 | 685,0000 | 298749,2 | 228120,3 | 657625,1 | 8230060,1 |
| 2 | 24221,8380 | 22897,0560 | 21563055,0 | ,0 | 22,5539 |
| 3 | -989143,1 | ,0 | -1363627,5 | ,0 | |
| 4 | 176054,3 | ,0 | 237436,8 | ,0 | |
| 5 | 8269495,1 | ,0 | 9119368,0 | ,0 | |
| 6 | -9258,5198 | ,0000 | -10711,4749 | ,0000 | 24,5675 |
| 7 | 844,2682 | ,0000 | 270,4227 | ,0000 | -,0826 |
| 8 | 20924,6790 | ,0000 | 21722,9980 | ,0000 | ,0119 |
| 9 | 228118,9 | 228119,0 | -,2 | -13,726 | -,000 |
| 10 | -766,6 | -767,0 | -,0 | -3887,210 | ,006 |
| 11 | 110,6 | 104,6 | -,0 | -56,354 | ,021 |
| 12 | -127,8853 | ,6212 | ,0 | 139288,3 | ,6347 |
| 13 | ,8561 | -,0464 | ,0 | 8972470,1 | ,9786 |
| 14 | -,0000 | ,0005 | ,0 | 8972702,8 | ,0000 |
| 15 | -127,2505 | ,0000 | -127,2505 | ,0093 | 498,87 |
| 16 | 1,8347 | ,0000 | 1,8347 | ,6211 | -1,34 |
| 17 | ,0000 | ,0000 | ,0000 | -,0464 | ,40 |
| 18 | -1,3371 | -1,2639 | -1,2708 | ,1926 | -,0009 |
| 19 | 87,5408 | 87,6754 | 87,6792 | ,0263 | ,0049 |
| 20 | 423,0755 | 426,2616 | -539,1923 | -536,3075 | 228594,2 |
| 21 | ,0002 | 9,2950 | ,0000 | 2525,1708 | ,00 |
| 22 | 11,5706 | -11,5658 | -,3414 | -,191 | 22897,056 |
| 23 | 54,7928 | 32,6606 | 32,4913 | -30,2804 | -,0420 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -46596,7 | -455,9923 |
| 28 | ,0 | ,0000 | ,00000 | -8627,0 | -83,8408 |
| 29 | 2888,4863 | 29751,9250 | ,10365 | -168,91541 | |
| 30 | 3556,4847 | 24163,7570 | 32,56506 | 76,47244 | 293304960, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 218435,9200 | 418,5346 | -513,2314 | ,0000 | |

TABLE 4-3 (Sheet 13 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 690,0000 | 296060,2 | 228570,8 | 654852,5 | 8341319,9 |
| 2 | 24346,9580 | 23022,3830 | 21560268,0 | ,0 | 22,8588 |
| 3 | -1035926,2 | ,0 | -1417712,9 | ,0 | |
| 4 | 180307,4 | ,0 | 238787,4 | ,0 | |
| 5 | 8374240,5 | ,0 | 9228068,5 | ,0 | |
| 6 | -9453,8908 | ,0000 | -10921,8656 | ,0000 | 24,8395 |
| 7 | 856,9070 | ,0000 | 269,7388 | ,0000 | -,0843 |
| 8 | 20974,2650 | ,0000 | 21758,0910 | ,0000 | ,0369 |
| 9 | 228569,0 | 228569,2 | -,2 | 11,669 | -,000 |
| 10 | -775,7 | -776,2 | -,0 | 3687,736 | ,007 |
| 11 | 339,5 | 333,3 | -,0 | 84,285 | ,022 |
| 12 | -124,7945 | ,6387 | ,0 | 139282,0 | ,7744 |
| 13 | ,6157 | -,0484 | ,0 | 8956234,8 | ,9789 |
| 14 | -,0000 | ,0002 | ,0 | 8956464,0 | ,0000 |
| 15 | -124,0199 | ,0000 | -124,0199 | ,0069 | 500,52 |
| 16 | 1,5946 | ,0000 | 1,5946 | ,6386 | -1,35 |
| 17 | ,0000 | ,0000 | ,0000 | -,0484 | ,40 |
| 18 | -1,4272 | -1,3495 | -1,3558 | ,1946 | ,0003 |
| 19 | 87,7593 | 87,8813 | 87,8853 | ,0835 | ,0551 |
| 20 | 423,0588 | 426,1876 | -540,2776 | -536,3780 | 228584,9 |
| 21 | ,0002 | 9,3600 | ,0000 | 2517,5652 | ,00 |
| 22 | 8,0632 | -8,0626 | -,0987 | -,198 | 23022,383 |
| 23 | 54,4315 | 32,6731 | 32,5038 | -30,2882 | -,0420 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -48870,8 | -457,0403 |
| 28 | ,0 | ,0000 | ,00000 | -9045,1 | -83,8794 |
| 29 | 2940,3664 | 29373,1590 | ,09505 | -166,94075 | |
| 30 | 3558,0094 | 24274,2050 | 32,56502 | 77,42492 | 296343610, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 218877,7400 | 418,8075 | -514,3212 | ,0000 | |
| | | | | | |
| 1 | 695,0000 | 293358,8 | 228105,0 | 651905,5 | 8453205,2 |
| 2 | 24474,7310 | 23150,3660 | 21557308,0 | ,0 | 23,1654 |
| 3 | -1083672,6 | ,0 | -1472837,2 | ,0 | |
| 4 | 184622,7 | ,0 | 240133,3 | ,0 | |
| 5 | 8479244,0 | ,0 | 9336955,1 | ,0 | |
| 6 | -9643,4933 | ,0000 | -11126,7138 | ,0000 | 25,0172 |
| 7 | 869,1326 | ,0000 | 268,5289 | ,0000 | -,0852 |
| 8 | 21028,2440 | ,0000 | 21797,6290 | ,0000 | ,0104 |
| 9 | 228103,5 | 228103,7 | -,2 | -16,227 | -,000 |
| 10 | -776,9 | -777,4 | -,0 | -4508,680 | ,007 |
| 11 | 95,1 | 87,8 | -,0 | 63,121 | ,023 |
| 12 | -121,0634 | ,7429 | ,0 | 139275,6 | ,7807 |
| 13 | ,3748 | -,0485 | ,0 | 8932468,7 | ,9799 |
| 14 | -,0000 | ,0004 | ,0 | 8932694,3 | ,0000 |
| 15 | -120,2826 | ,0000 | -120,2826 | ,0049 | 502,26 |
| 16 | 1,3546 | ,0000 | 1,3546 | ,7428 | -1,37 |
| 17 | ,0000 | ,0000 | ,0000 | -,0485 | ,40 |
| 18 | -1,4938 | -1,4130 | -1,4186 | ,1953 | ,0007 |
| 19 | 87,9773 | 88,0869 | 88,0911 | ,0221 | ,0110 |
| 20 | 423,5906 | 426,0628 | -538,5003 | -536,5536 | 228592,8 |
| 21 | ,0002 | 9,4272 | ,0000 | 2509,4808 | ,00 |
| 22 | 3,9440 | -3,9413 | ,1447 | -,205 | 23150,366 |
| 23 | 54,0681 | 32,6846 | 32,5152 | -30,2965 | -,0420 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -51156,8 | -455,7776 |
| 28 | ,0 | ,0000 | ,00000 | -9463,8 | -83,3626 |
| 29 | 2994,3750 | 28989,9840 | ,08625 | -164,73880 | |
| 30 | 3559,6939 | 24386,0540 | 32,56506 | 78,42238 | 299462810, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | ,0000 | |

TABLE 4-3 (Sheet 14 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 700,0000 | 290657,4 | 225699,8 | 648834,0 | 8565726,5 |
| 2 | 24603,4700 | 23279,3100 | 21554225,0 | ,0 | 23,4738 |
| 3 | -1132348,6 | ,0 | -1528967,8 | ,0 | |
| 4 | 188997,9 | ,0 | 241471,8 | ,0 | |
| 5 | 8584526,9 | ,0 | 9446049,0 | ,0 | |
| 6 | -9825,6466 | ,0000 | -11324,3063 | ,0000 | 24,9834 |
| 7 | 880,8893 | ,0000 | 266,7823 | ,0000 | -,0850 |
| 8 | 21085,7060 | ,0000 | 21840,7810 | ,0000 | ,0589 |
| 9 | 225697,7 | 225697,9 | -,2 | 33,905 | -,000 |
| 10 | -768,2 | -768,6 | -,0 | 10241,244 | ,007 |
| 11 | 532,3 | 522,8 | -,0 | -67,639 | ,024 |
| 12 | -117,1087 | ,9672 | ,0 | 139269,3 | 1,0889 |
| 13 | ,1349 | -,0481 | ,0 | 8906820,0 | ,9802 |
| 14 | -,0000 | ,0003 | ,0 | 8907042,1 | ,0000 |
| 15 | -116,0198 | ,0000 | -116,0198 | ,0023 | 504,02 |
| 16 | 1,1150 | ,0000 | 1,1150 | ,9672 | -1,38 |
| 17 | ,0000 | ,0000 | ,0000 | -,0481 | ,41 |
| 18 | -1,5344 | -1,4518 | -1,4568 | ,1951 | ,0001 |
| 19 | 88,1951 | 88,2923 | 88,2966 | ,1327 | -,0775 |
| 20 | 418,7010 | 425,8093 | -539,0431 | -536,7142 | 228524,8 |
| 21 | ,0002 | 9,4957 | ,0000 | 2501,0552 | ,00 |
| 22 | ,5427 | ,3792 | ,3883 | -,212 | 23279,311 |
| 23 | 53,7025 | 32,6949 | 32,5255 | -30,3051 | -,0421 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -53441,7 | -455,4691 |
| 28 | ,0 | ,0000 | ,00000 | -9883,4 | -84,2146 |
| 29 | 3049,9119 | 28607,2380 | ,07738 | -162,27561 | |
| 30 | 3561,4987 | 24497,9890 | 32,56517 | 79,45381 | 302622100, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | ,0000 | |
| 1 | 705,0000 | 287956,2 | 225062,3 | 645692,3 | 8,78889,3 |
| 2 | 24732,9390 | 23408,9730 | 21551073,0 | ,0 | 23,7839 |
| 3 | -1181913,7 | ,0 | -1586065,1 | ,0 | |
| 4 | 193430,7 | ,0 | 242800,2 | ,0 | |
| 5 | 8690107,2 | ,0 | 955369,4 | ,0 | |
| 6 | -9998,7635 | ,0000 | -11513,0900 | ,0000 | 25,1465 |
| 7 | 892,1663 | ,0000 | 264,4935 | ,0000 | -,0862 |
| 8 | 21147,3120 | ,0000 | 21888,2870 | ,0000 | ,0576 |
| 9 | 225060,2 | 225060,4 | -,2 | 32,120 | -,000 |
| 10 | -771,6 | -772,2 | -,0 | 9695,006 | ,008 |
| 11 | 515,1 | 505,8 | -,0 | 9,766 | ,026 |
| 12 | -112,4316 | ,9423 | ,0 | 139262,9 | 1,1237 |
| 13 | -,1171 | -,0533 | ,0 | 8879990,0 | ,9765 |
| 14 | -,0000 | ,0005 | ,0 | 8880208,7 | ,0000 |
| 15 | -111,3078 | ,0000 | -111,3078 | -,0019 | 505,87 |
| 16 | ,8594 | ,0000 | ,8594 | ,9423 | -1,39 |
| 17 | ,0000 | ,0000 | ,0000 | -,0533 | ,41 |
| 18 | -1,5450 | -1,4623 | -1,4667 | ,1966 | ,0019 |
| 19 | 88,4124 | 88,4975 | 88,5018 | ,1288 | ,0308 |
| 20 | 418,0851 | 425,5148 | -538,3123 | -536,8597 | 228428,2 |
| 21 | ,0002 | 9,5650 | ,0000 | 2492,4368 | ,00 |
| 22 | 5,4325 | 5,3944 | ,6462 | -,220 | 23408,973 |
| 23 | 53,3348 | 32,7041 | 32,5346 | -30,3140 | -,0421 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -55726,7 | -454,9918 |
| 28 | ,0 | ,0000 | ,00000 | -10302,9 | -83,9602 |
| 29 | 3107,0288 | 28224,8650 | ,06841 | -159,49522 | |
| 30 | 3563,3598 | 24610,3320 | 32,56533 | 80,51934 | 305815990, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | ,0000 | |

TABLE 4-3 (Sheet 15 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 710,0000 | 285264,7 | 225371,5 | 642542,7 | 8792698,2 |
| 2 | 24862,2090 | 23538,4210 | 21547914,0 | .0 | 24,0958 |
| 3 | -1232319,9 | .0 | -1644082,6 | .0 | |
| 4 | 197918,6 | .0 | 244115,7 | .0 | |
| 5 | 8796004,9 | .0 | 9664937,3 | .0 | |
| 6 | -10161,9565 | .0000 | -11692,1644 | .0000 | 25,4187 |
| 7 | 902,8906 | .0000 | 261,6128 | .0000 | -,0879 |
| 8 | 21212,6550 | .0000 | 21939,7890 | .0000 | .0260 |
| 9 | 225369,8 | 225370,0 | -,2 | -1,137 | -,000 |
| 10 | -779,3 | -779,8 | -,0 | 33,041 | .008 |
| 11 | 230,8 | 221,3 | -,0 | 122,100 | .027 |
| 12 | -107,5118 | .9539 | .0 | 139256,5 | 1,0748 |
| 13 | -,3773 | -,0515 | .0 | 8852864,7 | .9805 |
| 14 | -,0000 | .0004 | .0 | 8853080,1 | .0000 |
| 15 | -106,4370 | .0000 | -106,4370 | -,0063 | 507,73 |
| 16 | .6031 | .0000 | .6031 | .9538 | -1,40 |
| 17 | .0000 | .0000 | .0000 | -,0515 | .42 |
| 18 | -1,5246 | -1,4434 | -1,4473 | .1983 | .0016 |
| 19 | 88,6292 | 88,7023 | 88,7066 | .0563 | .0294 |
| 20 | 418,1021 | 425,2689 | -539,0311 | -536,9171 | 228320,7 |
| 21 | .0002 | 9,6346 | .0000 | 2483,7967 | .00 |
| 22 | 10,6611 | 10,6235 | .9155 | -,228 | 23538,422 |
| 23 | 52,9649 | 32,7122 | 32,5427 | -30,3229 | -,0421 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -58002,3 | -455,3979 |
| 28 | .0 | .0000 | .00000 | -10722,0 | -84,2737 |
| 29 | 3165,4061 | 2745,2930 | .05941 | -156,28639 | |
| 30 | 3565,2490 | 24722,4420 | 32,56554 | 81,61303 | 309021670, |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | .0000 | |

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 715,0000 | 282576,2 | 226035,8 | 639450,9 | 8907150,7 |
| 2 | 24990,6350 | 23667,0060 | 21544815,0 | .0 | 24,4095 |
| 3 | -1283515,8 | .0 | -1702969,7 | .0 | |
| 4 | 202458,7 | .0 | 245415,3 | .0 | |
| 5 | 8902238,1 | .0 | 9774772,2 | .0 | |
| 6 | -10314,6744 | .0000 | -11860,9720 | .0000 | 25,7362 |
| 7 | 913,0540 | .0000 | 258,1473 | .0000 | -,0732 |
| 8 | 21281,4710 | .0000 | 21995,0590 | .0000 | .0217 |
| 9 | 226034,6 | 226034,9 | -,2 | -1,059 | -,000 |
| 10 | -642,8 | -643,4 | -,0 | -1360,486 | .008 |
| 11 | 190,8 | 181,1 | -,0 | -4704,293 | .028 |
| 12 | -102,6328 | .9730 | .0 | 139234,3 | 1,0700 |
| 13 | -,6307 | -,0633 | .0 | 8833488,7 | .8800 |
| 14 | -,0000 | .0004 | .0 | 8833707,3 | .0000 |
| 15 | -101,5628 | .0000 | -101,5628 | -,0107 | 509,02 |
| 16 | .2493 | .0000 | .2493 | .9729 | -1,41 |
| 17 | .0000 | .0000 | .0000 | -,0633 | .42 |
| 18 | -1,4728 | -1,3948 | -1,3980 | .1631 | -,0546 |
| 19 | 88,8456 | 88,9068 | 88,9109 | .0459 | .0008 |
| 20 | 420,4019 | 425,0794 | -537,6638 | -536,9468 | 228231,9 |
| 21 | .0002 | 9,7039 | .0000 | 2475,3153 | .00 |
| 22 | 15,8229 | 15,7830 | 1,1813 | -,237 | 23667,006 |
| 23 | 52,5928 | 32,7191 | 32,5496 | -30,3316 | -,0421 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -60274,9 | -454,3655 |
| 28 | .0 | .0000 | .00000 | -11141,1 | -83,9373 |
| 29 | 3224,7982 | 27470,2790 | .05041 | -152,45055 | |
| 30 | 3567,1703 | 24833,7190 | 32,56577 | 82,73076 | 312222970, |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | .0000 | |

TABLE 4-3 (Sheet 16 of 19)
 FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 720,0000 | 279881,2 | 226155,4 | 636480,8 | 9022242,6 |
| 2 | 25116,9190 | 23793,4270 | 21541839,0 | ,0 | 24,7249 |
| 3 | -1335448,3 | ,0 | -1762674,2 | ,0 | |
| 4 | 207047,5 | ,0 | 246695,6 | ,0 | |
| 5 | 9008822,0 | ,0 | 9884890,8 | ,0 | |
| 6 | -10456,4624 | ,0000 | -12019,0112 | ,0000 | 25,9977 |
| 7 | 922,2463 | ,0000 | 253,7221 | ,0000 | -,0985 |
| 8 | 21352,7280 | ,0000 | 22053,0880 | ,0000 | ,0272 |
| 9 | 226153,5 | 226153,7 | -,2 | -3,060 | -,000 |
| 10 | -856,9 | -856,3 | -,0 | 201,915 | ,009 |
| 11 | 236,7 | 227,0 | -,0 | 2577,931 | ,029 |
| 12 | -97,7838 | ,9747 | ,0 | 139219,2 | 1,0835 |
| 13 | -,9950 | ,0602 | ,0 | 8833422,7 | 1,0679 |
| 14 | -,0000 | -,0004 | ,0 | 8833655,9 | ,0000 |
| 15 | -96,7002 | ,0000 | -96,7002 | -,0169 | 509,02 |
| 16 | ,0729 | ,0000 | ,0729 | ,9746 | -1,41 |
| 17 | ,0000 | ,0000 | ,0000 | ,0602 | ,42 |
| 18 | -1,3903 | -1,3170 | -1,3196 | ,2169 | -,0971 |
| 19 | 89,0606 | 89,1102 | 89,1141 | ,0575 | ,0005 |
| 20 | 418,0278 | 424,8627 | -541,0016 | -537,0223 | 228147,6 |
| 21 | ,0002 | 9,7718 | ,0000 | 2467,1677 | ,00 |
| 22 | 20,9342 | 20,8856 | 1,5606 | -,245 | 23793,427 |
| 23 | 52,2186 | 32,7249 | 32,5553 | -30,3399 | -,0422 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -62553,7 | -457,3263 |
| 28 | ,0 | ,0000 | ,00000 | -11560,5 | -84,3182 |
| 29 | 3284,5379 | 27104,0690 | ,04153 | -147,64405 | |
| 30 | 3569,1899 | 24942,4520 | 32,56602 | 83,86173 | 315386940, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | ,0000 | |
| 1 | 725,0000 | 277179,2 | 227186,5 | 633699,1 | 9137961,3 |
| 2 | 25240,2470 | 23916,8670 | 21539052,0 | ,0 | 25,0420 |
| 3 | -1388061,5 | ,0 | -1823141,2 | ,0 | |
| 4 | 211681,6 | ,0 | 247953,0 | ,0 | |
| 5 | 9115767,3 | ,0 | 9995305,5 | ,0 | |
| 6 | -10587,0019 | ,0000 | -12165,9502 | ,0000 | 26,370A |
| 7 | 931,3126 | ,0000 | 249,2050 | ,0000 | -,1013 |
| 8 | 21425,7930 | ,0000 | 22113,2920 | ,0000 | ,0266 |
| 9 | 227184,5 | 227184,7 | -,3 | -4,562 | -,000 |
| 10 | -872,5 | -872,3 | -,0 | -106,194 | ,009 |
| 11 | 228,8 | 219,0 | -,0 | 2990,177 | ,030 |
| 12 | -92,8984 | ,9767 | ,0 | 139204,2 | 1,0830 |
| 13 | -,9474 | ,0198 | ,0 | 8833356,6 | 1,0750 |
| 14 | ,0000 | -,0001 | ,0 | 8833604,4 | ,0000 |
| 15 | -91,8154 | ,0000 | -91,8154 | -,0161 | 509,02 |
| 16 | ,1276 | ,0000 | ,1276 | ,9766 | -1,41 |
| 17 | ,0000 | ,0000 | ,0000 | ,0198 | ,42 |
| 18 | -1,2774 | -1,2104 | -1,2125 | ,2200 | -,0126 |
| 19 | 89,2764 | 89,3144 | 89,3180 | ,0552 | ,0004 |
| 20 | 419,9900 | 424,6528 | -540,9289 | -537,1422 | 228085,6 |
| 21 | ,0002 | 9,8377 | ,0000 | 2459,5369 | ,00 |
| 22 | 26,0271 | 25,9931 | 1,5337 | -,254 | 23916,867 |
| 23 | 51,8424 | 32,7295 | 32,5599 | -30,3478 | -,0422 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -64839,4 | -457,3771 |
| 28 | ,0 | ,0000 | ,00000 | -11980,1 | -84,1946 |
| 29 | 3344,0144 | 26750,3600 | ,03290 | -141,18031 | |
| 30 | 3571,5128 | 25046,4150 | 32,56623 | 84,99854 | 318492200, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | ,0000 | |

TABLE 4-3 (Sheet 17 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|------------|------------|
| 1 | 730.0000 | 274480.3 | 227595.2 | 631169.7 | 9254289.9 |
| 2 | 25359.5140 | 24036.2230 | 21536519.0 | .0 | 25.3608 |
| 3 | -1441298.8 | .0 | -1884314.3 | .0 | |
| 4 | 216360.7 | .0 | 249187.8 | .0 | |
| 5 | 9223080.1 | .0 | 10106024.4 | .0 | |
| 6 | -10705.9588 | .0000 | -12301.4177 | .0000 | 26.6781 |
| 7 | 940.3760 | .0000 | 244.7518 | .0000 | -.0950 |
| 8 | 21499.7250 | .0000 | 22174.7660 | .0000 | .0286 |
| 9 | 227593.4 | 227593.7 | -.3 | -.580 | -.0000 |
| 10 | -810.8 | -810.8 | -.0 | 406.748 | .009 |
| 11 | 244.2 | 234.6 | -.0 | 839.030 | .031 |
| 12 | -88.0507 | .9649 | .0 | 139189.2 | 1.0736 |
| 13 | -.8695 | .0075 | .0 | 8833290.5 | 1.0587 |
| 14 | .0000 | -.0000 | .0 | 8833553.0 | .0000 |
| 15 | -86.9771 | .0000 | -86.9771 | -.0146 | 509.03 |
| 16 | .1892 | .0000 | .1892 | .9648 | -1.41 |
| 17 | .0000 | .0000 | .0000 | .0075 | .42 |
| 18 | -1.1352 | -1.0760 | -1.0774 | .2041 | .0059 |
| 19 | 89.4933 | 89.5198 | 89.5230 | .0591 | .0029 |
| 20 | 422.5327 | 424.4939 | -538.6415 | -537.2324 | 228038.6 |
| 21 | .0002 | 9.9008 | .0000 | 2452.5984 | .00 |
| 22 | 31.0579 | 31.0345 | 1.4832 | -.261 | 24036.224 |
| 23 | 51.4641 | 32.7329 | 32.5633 | -30.3549 | -.0422 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -67121.6 | -455.3852 |
| 28 | .0 | .0000 | .00000 | -12400.0 | -.83.8964 |
| 29 | 3402.0954 | 26416.0570 | .02474 | -131.60183 | |
| 30 | 3574.6730 | 25140.7470 | 32.56638 | 86.13011 | 321509700. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 219076.5100 | 418.9128 | -514.8240 | .0000 | |
| 1 | 735.0000 | 271781.0 | 226731.4 | 628957.1 | 9371204.4 |
| 2 | 25473.4910 | 24150.2680 | 21534304.0 | .0 | 25.6812 |
| 3 | -1495101.6 | .0 | -1946135.8 | .0 | |
| 4 | 221085.2 | .0 | 250400.6 | .0 | |
| 5 | 9330762.6 | .0 | 10217052.0 | .0 | |
| 6 | -10813.2307 | .0000 | -12425.2580 | .0000 | 26.8408 |
| 7 | 949.4336 | .0000 | 240.3965 | .0000 | -.0937 |
| 8 | 21573.3190 | .0000 | 22236.3210 | .0000 | .0266 |
| 9 | 226729.6 | 226729.9 | -.3 | -2.205 | -.000 |
| 10 | -791.8 | -791.5 | -.0 | -224.634 | .009 |
| 11 | 224.8 | 215.1 | -.0 | 290.341 | .032 |
| 12 | -83.1979 | .9709 | .0 | 139174.1 | 1.0860 |
| 13 | -.7895 | .0214 | .0 | 8833224.3 | 1.0674 |
| 14 | .0000 | -.0002 | .0 | 8833501.6 | .0000 |
| 15 | -82.1119 | .0000 | -82.1119 | -.0134 | 509.03 |
| 16 | .2779 | .0000 | .2779 | .9708 | -1.41 |
| 17 | .0000 | .0000 | .0000 | .0214 | .42 |
| 18 | -.9652 | -.9151 | -.9159 | .2000 | -.0015 |
| 19 | 89.7114 | 89.7264 | 89.7291 | .0544 | .0003 |
| 20 | 420.3371 | 424.3398 | -539.4002 | -537.3192 | 227992.5 |
| 21 | .0002 | 9.9601 | .0000 | 2446.5286 | .00 |
| 22 | 36.0708 | 36.0546 | 1.4390 | -.269 | 24150.269 |
| 23 | 51.0838 | 32.7352 | 32.5655 | -30.3612 | -.0422 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -69404.6 | -456.1636 |
| 28 | .0 | .0000 | .00000 | -12819.5 | -.83.8776 |
| 29 | 3456.5199 | 26115.5750 | .01758 | -115.49830 | |
| 30 | 3580.2125 | 25213.3100 | 32.56649 | 87.24290 | 324406620. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 219076.5100 | 418.9128 | -514.8240 | .0000 | |

TABLE 4-3 (Sheet 18 of 19)
FLIGHT SIMULATED DATA (AD77)

| | | | | | |
|----|-------------|------------|-------------|-----------|------------|
| 1 | 740.0000 | 269091.5 | 226073.8 | 627121.5 | 9488674.8 |
| 2 | 25580.8170 | 24257.6410 | 21532467.0 | .0 | 26,0031 |
| 3 | -1549411.3 | .0 | -2008547.0 | .0 | |
| 4 | 225855.0 | .0 | 251592.1 | .0 | |
| 5 | 9438809.6 | .0 | 10328384.8 | .0 | |
| 6 | -10908.4027 | .0000 | -12537.0014 | .0000 | 27.0304 |
| 7 | 958.5541 | .0000 | 236.2516 | .0000 | -.0935 |
| 8 | 21645.3480 | .0000 | 22296.7710 | .0000 | .0060 |
| 9 | 226072.1 | 226072.4 | -.3 | -22.566 | -.000 |
| 10 | -782.3 | -782.1 | -.0 | -6144.004 | .010 |
| 11 | 50.5 | 39.4 | -.0 | 44.866 | .032 |
| 12 | -77.8519 | 1.1119 | .0 | 139159.1 | 1,1918 |
| 13 | -.6850 | .0197 | .0 | 8833158.4 | 1,0654 |
| 14 | .0000 | -.0004 | .0 | 8833450.2 | .0000 |
| 15 | -76.6601 | .0000 | -76.6601 | -.0133 | 509.03 |
| 16 | .3805 | .0000 | .3805 | 1.1119 | -1.41 |
| 17 | .0000 | .0000 | .0000 | .0197 | .42 |
| 18 | -.7685 | -.7287 | -.7289 | .1982 | .0010 |
| 19 | 89.9309 | 89.9345 | 89.9367 | .0100 | -.0245 |
| 20 | 420.2387 | 424.2214 | -537.9619 | -537.3382 | 227937.3 |
| 21 | .0003 | 10.0147 | .0000 | 2441.4933 | .00 |
| 22 | 41.5527 | 41.5421 | 1.3865 | -.275 | 24257.642 |
| 23 | 50.7018 | 32.7362 | 32.5665 | -30.3663 | -.0423 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -71678.0 | -454,8598 |
| 28 | .0 | .0000 | .00000 | -13238.8 | -83,7413 |
| 29 | 3502.0179 | 25883.8890 | .01276 | -86.30887 | |
| 30 | 3592.5506 | 25231.6110 | 32.56653 | 88.32070 | 327146330. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 219076.5100 | 418.9128 | -514.8240 | .0000 | |
| 1 | 745.0000 | 266403.3 | 225076.5 | 625724.5 | 9606660.8 |
| 2 | 25679.7290 | 24356.5840 | 21531070.0 | .0 | 26,3264 |
| 3 | -1604163.2 | .0 | -2071483.2 | .0 | |
| 4 | 230670.6 | .0 | 252763.4 | .0 | |
| 5 | 9547209.5 | .0 | 10440013.9 | .0 | |
| 6 | -10990.5514 | .0000 | -12635.6575 | .0000 | 27.1824 |
| 7 | 967.6865 | .0000 | 232.3234 | .0000 | -.0972 |
| 8 | 21714.3860 | .0000 | 22354.7480 | .0000 | .1320 |
| 9 | 225072.2 | 225072.5 | -.3 | 100.108 | -.000 |
| 10 | -805.0 | -804.5 | -.0 | 29438.026 | .010 |
| 11 | 1093.3 | 1087.8 | -.0 | 937.093 | .033 |
| 12 | -73.4761 | .5558 | .0 | 139144.1 | 1,0977 |
| 13 | -.5318 | .0560 | .0 | 8833092.2 | 1,1020 |
| 14 | .0000 | .0003 | .0 | 8833398.7 | .0000 |
| 15 | -72.3785 | .0000 | -72.3785 | -.0052 | 509.04 |
| 16 | .5702 | .0000 | .5702 | .5558 | -1.41 |
| 17 | .0000 | .0000 | .0000 | .0560 | .42 |
| 18 | -.5450 | -.5169 | -.5165 | .2048 | -.0143 |
| 19 | 90.1518 | 90.1440 | 90.1455 | .2769 | .5059 |
| 20 | 419.1978 | 424.0785 | -536.9123 | -537.3475 | 227864.7 |
| 21 | .0003 | 10.0634 | .0000 | 2437.6610 | .00 |
| 22 | 46.0401 | 46.0334 | 1.2891 | -.281 | 24356.584 |
| 23 | 50.3181 | 32.7359 | 32.5662 | -30.3703 | -.0423 |
| 24 | .0000 | .0000 | .0000 | .0 | .00 |
| 25 | .0000 | .0000 | .00000 | .0 | .00 |
| 26 | .00000 | .0000 | .00000 | .0 | .00 |
| 27 | .0000 | .0000 | .00000 | -73949.9 | -453,7758 |
| 28 | .0 | .0000 | .00000 | -13658.3 | -83,7747 |
| 29 | 3529.8525 | 25778.4430 | .01251 | -46.62267 | |
| 30 | 3619.2901 | 25141.4220 | 32.56652 | 89.34175 | 329681480. |
| 31 | .0 | .00000 | .00000 | .00000 | .0 |
| 32 | | | .00000 | .00000 | .0 |
| 33 | 219076.5100 | 418.9128 | -514.8240 | .0000 | |

TABLE 4-3 (Sheet 19 of 19)
FLIGHT SIMULATED DATA (AD77)

S-IVB ENGINE CUTOFF SIGNAL

| | | | | | |
|----|-------------|------------|-------------|-----------|------------|
| 1 | 747,0400 | 265308,2 | 224601,7 | 625292,5 | 9654937,1 |
| 2 | 25718,6240 | 24395,4870 | 21530639,0 | ,0 | 26,4587 |
| 3 | -1626616,0 | ,0 | -2097298,9 | ,0 | |
| 4 | 232648,6 | ,0 | 253235,9 | ,0 | |
| 5 | 9591534,7 | ,0 | 10485640,9 | ,0 | |
| 6 | -11021,7562 | ,0000 | -12673,5950 | ,0000 | 27,2373 |
| 7 | 971,5366 | ,0000 | 230,8748 | ,0000 | -,0833 |
| 8 | 21742,0510 | ,0000 | 22377,9890 | ,0000 | ,0561 |
| 9 | 224599,9 | 224600,2 | -,3 | 29,288 | -,0000 |
| 10 | -687,0 | -686,7 | -,0 | 7951,317 | ,010 |
| 11 | 462,5 | 451,6 | -,0 | -3028,662 | ,033 |
| 12 | -71,6988 | 1,1373 | ,0 | 139137,9 | ,6488 |
| 13 | -,4269 | ,0383 | ,0 | 8833065,3 | 1,0469 |
| 14 | ,0000 | -,0000 | ,0 | 8833377,7 | ,0000 |
| 15 | -71,0500 | ,0000 | -71,0500 | -,0085 | 509,04 |
| 16 | ,6200 | ,0000 | ,6200 | 1,1372 | -1,41 |
| 17 | ,0000 | ,0000 | ,0000 | ,0383 | ,42 |
| 18 | -,4489 | -,4258 | -,4252 | ,1752 | -,0351 |
| 19 | 90,2425 | 90,2300 | 90,2313 | ,1152 | -2,0652 |
| 20 | 433,1752 | 424,0341 | -518,4972 | -537,3410 | 227838,2 |
| 21 | ,0003 | 10,0820 | ,0000 | 2436,4758 | ,00 |
| 22 | 47,8580 | 47,8528 | 1,2116 | -,283 | 24395,487 |
| 23 | 50,1611 | 32,7355 | 32,5658 | -30,3715 | -,0423 |
| 24 | ,0000 | ,0000 | ,0000 | ,0 | ,00 |
| 25 | ,0000 | ,0000 | ,00000 | ,0 | ,00 |
| 26 | ,00000 | ,0000 | ,00000 | ,0 | ,00 |
| 27 | ,0000 | ,0000 | ,00000 | -74875,4 | -435,1269 |
| 28 | ,0 | ,0000 | ,00000 | -13829,2 | -83,9858 |
| 29 | 3535,7771 | 25774,0500 | ,01386 | -32,78249 | |
| 30 | 3635,1953 | 25069,1600 | 32,56650 | 89,75127 | 330681050, |
| 31 | ,0 | ,00000 | ,00000 | ,00000 | ,0 |
| 32 | | | ,00000 | ,00000 | ,0 |
| 33 | 219076,5100 | 418,9128 | -514,8240 | ,0000 | |

APPENDIX 5

METEOROLOGICAL DATA (AA99)

1. METEOROLOGICAL DATA (AA99)

A summary of the meteorological data during the AS-502 vehicle launch and flight is presented in this appendix. Surface measurements at the Kennedy Space Center at the time of launch are recorded as follows:

| TIME (GMT) | AMOUNT (%) | CLOUDS (Coverage) | BASE (ft) | VISIB (nmi) | PRESS AT MSL* (m bars) | DRY BULB TEMP (deg F) | RELATIVE HUMIDITY (%) | WIND** DIRECTION (deg) | WIND SPEED (knots)** |
|------------|------------|-------------------|-----------|-------------|------------------------|-----------------------|-----------------------|------------------------|----------------------|
| 1200 | 20 | High Scattered | 3500 | 10 | 1021 | 70 | 89 | 160 | 20 |

*MSL - Mean sea level.

**Measured at launch pad light pole.

Table AP 5-1 presents definitions, units, and sign conventions for the meteorological data presented in table AP 5-2. Table AP 5-2 records the meteorological data to an altitude of 300,000 ft.

TABLE AP 5-1
 PROGRAM AA99 METEOROLOGICAL DATA

Table of Definitions

| <u>Program Symbol</u> | <u>Definition</u> |
|-----------------------|--|
| Alt | <u>Altitude</u> : Geocentric altitude (ft) |
| Density | <u>Density</u> : row 2, column B (slugs/feet ³) row 3, column E (lb/ft ³) |
| Elec/Ref | <u>Electromagnetic Index of Refraction</u> : (unitless) |
| Opt./Ref | <u>Optical Index of Refraction</u> : (unitless) |
| Pit. Shear | <u>Shear of Wind Velocity Pitch Component</u> : (1/sec) |
| Press | <u>Ambient Pressure</u> : row 1, column C (millibars) row 2, column C (lb/ft ²) |
| Rel Humd | <u>Relative Humidity</u> : (decimal) |
| Temp | <u>Ambient Temperature</u> : row 1, column B (deg Kelvin) row 4, column A (deg Centigrade) |
| Vap. Press | <u>Water Vapor Pressure</u> : (lb/ft ²) |
| Vel/Sound | <u>Velocity of Sound</u> : (ft/sec) |
| Visc. | <u>Coefficient of Viscosity</u> : (slugs/ft-sec) |
| Wd. Merid. | <u>Meridional Component of Wind Velocity</u> : Component of wind velocity vector measured along lines of longitude, positive north (ft/sec) |
| Wd. Zonal | <u>Zonal Component of Wind Velocity</u> : Component of wind velocity vector measured along lines of latitude, positive east (ft/sec) |
| Wind Dir | <u>Wind Direction</u> : Direction from which wind is blowing, measured clockwise from north (deg) |
| Wind Pitch | <u>Wind Velocity Pitch Component</u> : Component of wind velocity vector along vehicle flight path, positive downrange (ft/sec) |
| Wind Vel | <u>Magnitude of Wind Velocity</u> : (ft/sec) |
| Wind Yaw | <u>Wind Velocity Yaw Component</u> : Component of wind velocity vector perpendicular to pitch component, lying in the local tangent plane, and positive right looking downrange (ft/sec) |
| Yaw Shear | <u>Shear of Wind Velocity Yaw Component</u> : (1/sec) |

TABLE AP 5-2 (Sheet 1 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|------------|------------|-----------|------------|----------|----------|
| 1 | ALT | TEMP. | PRESS | WIND VEL | WIND DIR | REL HUMD |
| 2 | VAP. PRESS | DENSITY | PRESS | VEL/SOUND | OPT./REF | ELEC/REF |
| 3 | WIND PITCH | WIND YAW | WD. ZONAL | WD. MERID. | DENSITY | VISC. |
| 4 | TEMP. | PIT. SHEAR | YAW SHEAR | | | |

| | | | | | | |
|---|-------------|--------|----------|----------|----------|----------|
| 1 | -.0 | 292.55 | 1019.600 | 26.2467 | 160.000 | .8900 |
| 2 | 41.8874 | .0023 | 2129.475 | 1129.163 | 268.6568 | 357.9204 |
| 3 | -1.4488 | -.0001 | -.1296 | 24.6638 | .7384 | .000000 |
| 4 | 19.400***** | | | | | |

| | | | | | | |
|---|-------------|--------|----------|----------|----------|----------|
| 1 | 1000.0 | 292.49 | 984.827 | 37.7814 | 138.192 | .7663 |
| 2 | 35.9299 | .0023 | 2056.850 | 1128.572 | 260.1264 | 336.3413 |
| 3 | -.0859 | -.0350 | -.0083 | 28.1611 | .7139 | .000000 |
| 4 | 19.340***** | | | | | |

| | | | | | | |
|---|-------------|--------|----------|----------|----------|----------|
| 1 | 2000.0 | 289.89 | 950.558 | 39.0845 | 142.384 | .8995 |
| 2 | 35.8054 | .0022 | 1985.278 | 1123.658 | 253.1865 | 330.6045 |
| 3 | -.0657 | -.0306 | -.0187 | 30.9600 | .6951 | .000000 |
| 4 | 16.736***** | | | | | |

| | | | | | | |
|---|-------------|--------|----------|----------|----------|----------|
| 1 | 3000.0 | 287.40 | 917.190 | 38.4748 | 146.424 | .9566 |
| 2 | 32.4706 | .0021 | 1915.589 | 1118.600 | 246.6854 | 317.9023 |
| 3 | -.0875 | -.0301 | -.0389 | 32.0591 | .6768 | .000000 |
| 4 | 14.251***** | | | | | |

| | | | | | | |
|---|--------------------------|--------|----------|----------|----------|----------|
| 1 | 4000.0 | 287.45 | 884.811 | 32.7719 | 144.464 | .5479 |
| 2 | 18.6581 | .0021 | 1847.964 | 1117.238 | 239.5899 | 279.2183 |
| 3 | -.1018 | -.0415 | -.0563 | 26.6692 | .6545 | .000000 |
| 4 | 14.301 .002822 .00099273 | | | | | |

| | | | | | | |
|---|-------------------------|--------|----------|----------|----------|----------|
| 1 | 5000.0 | 290.32 | 853.697 | 22.6486 | 142.750 | .1825 |
| 2 | 7.4648 | .0020 | 1782.981 | 1121.529 | 230.2405 | 244.0180 |
| 3 | -.1768 | -.0380 | -.0980 | 18.0282 | .6267 | .000000 |
| 4 | 17.166 .00725 .00472447 | | | | | |

| | | | | | | |
|---|--------------------------|--------|----------|----------|----------|----------|
| 1 | 6000.0 | 288.48 | 823.695 | 13.5118 | 119.304 | .4009 |
| 2 | 14.5888 | .0019 | 1720.321 | 1118.896 | 222.5962 | 252.8979 |
| 3 | -.1240 | -.0997 | -.0420 | 6.6185 | .6075 | .000000 |
| 4 | 15.333 .000505 .00940384 | | | | | |

| | | | | | | |
|---|-------------------------------|--------|----------|----------|----------|----------|
| 1 | 7000.0 | 286.45 | 794.556 | 10.4968 | 121.312 | .4490 |
| 2 | 14.3283 | .0019 | 1659.462 | 1114.976 | 216.2132 | 246.4557 |
| 3 | -.0618 | -.1615 | -.1298 | 5.4487 | .5901 | .000000 |
| 4 | 13.298 -1365.440100 .00857511 | | | | | |

| | | | | | | |
|---|--------------------------|--------|----------|----------|----------|----------|
| 1 | 8000.0 | 285.30 | 766.305 | 7.3588 | 149.608 | .1945 |
| 2 | 5.7553 | .0018 | 1600.458 | 1111.670 | 210.4295 | 221.0687 |
| 3 | -.1536 | -.0919 | -.3567 | 6.3532 | .5725 | .000000 |
| 4 | 12.148 .001832 .00532091 | | | | | |

TABLE AP 5-2 (Sheet 2 of 14)
 METEOROLOGICAL DATA (AA99)

| FLOATING POINT OVERFLOW | | AT , OCATION 020607 | | | | | |
|-------------------------|---------|---------------------|--------------|----------|----------|----------|--|
| | A | B | C | D | E | F | |
| 1 | 9000.0 | 284.47 | 738.901 | 11.3226 | 189.000 | .1405 | |
| 2 | 3.9370 | .0018 | 1543.225 | 1109.834 | 203.7070 | 210.2587 | |
| 3 | 5.1403 | -.0948 | 1.7712 | 11.1832 | .5539 | .000000 | |
| 4 | 11.319 | .004512 | .00062113 | | | | |
| | | | | | | | |
| 1 | 10000.0 | 282.44 | 712.380 | 7.3675 | 237.520 | .2038 | |
| 2 | 4.9866 | .0017 | 1487.835 | 1106.042 | 197.6456 | 206.8950 | |
| 3 | 7.1301 | -.7189 | 6.2116 | 3.9561 | .5377 | .000000 | |
| 4 | 9.293 | .004726 | .00181869 | | | | |
| | | | | | | | |
| 1 | 11000.0 | 280.04 | 686.671 | 2.6940 | 293.336 | .2652 | |
| 2 | 5.5093 | .0017 | 1434.139 | 1101.429 | 192.0534 | 202.8340 | |
| 3 | 2.0224 | 1.7792 | 2.4732 | -1.1466 | .5226 | .000000 | |
| 4 | 6.890 | .001104 | .00260155 | | | | |
| | | | | | | | |
| 1 | 12000.0 | 277.00 | 661.568 | 3.8087 | 301.568 | .3930 | |
| 2 | 6.6075 | .16 | 1381.710 | 1095.631 | 186.887 | 200.7244 | |
| 3 | 2.4627 | 2.8951 | 3.2368 | -.3953 | .5089 | .000000 | |
| 4 | 3.850 | -103.467642 | .00346560 | | | | |
| | | | | | | | |
| 1 | 13000.0 | 274.96 | 637.240 | 7.1869 | 327.488 | .3620 | |
| 2 | 5.2656 | .0016 | 1330.901 | 1091.419 | 181.5002 | 192.2904 | |
| 3 | 1.8061 | 6.9537 | 3.8665 | -.0633 | .4939 | .000000 | |
| 4 | 1.811 | -52.078715 | .00354180 | | | | |
| | | | | | | | |
| 1 | 14000.0 | 272.51 | 613.574 | 3.4861 | 352.312 | .3428 | |
| 2 | 4.1728 | .0015 | 1281.474 | 1086.391 | 176.4581 | 184.7669 | |
| 3 | -1.5811 | 3.4299 | .4678 | -.2709 | .4800 | .000000 | |
| 4 | -.178 | -99.921349 | .00107056 | | | | |
| | | | | | | | |
| 1 | 15000.0 | 270.00 | 590.512 | 5.1365 | 333.880 | .3944 | |
| 2 | 3.9903 | .0015 | 1233.309 | 1081.387 | 171.4034 | 179.4981 | |
| 3 | .7263 | 5.0848 | 2.2620 | -.2438 | .4662 | .000000 | |
| 4 | -.027 | -497.070680 | .00085190 | | | | |
| | | | | | | | |
| 1 | 16000.0 | 267.74 | 568.199 | 1.9942 | 85.440 | .4046 | |
| 2 | 3.4505 | .0014 | 1186.707 | 1076.773 | 166.3768 | 173.2876 | |
| 3 | -.6178 | -3.0912 | -.6504 | -5.9331 | .4525 | .000000 | |
| 4 | -.020 | -80.850806 | -47.74938200 | | | | |
| | | | | | | | |
| 1 | 17000.0 | 265.76 | 546.560 | 14.2307 | 193.528 | .4308 | |
| 2 | 3.1560 | .0014 | 1141.513 | 1072.761 | 161.2530 | 167.5772 | |
| 3 | 7.4440 | -.0312 | 3.3323 | 13.8333 | .4385 | .000000 | |
| 4 | -.005 | .002489 | -26.97998300 | | | | |
| | | | | | | | |
| 1 | 18000.0 | 263.93 | 525.617 | 17.0462 | 216.456 | .4595 | |
| 2 | 2.9175 | .0013 | 1097.772 | 1069.042 | 156.1643 | 162.0243 | |
| 3 | 13.8656 | -.1003 | 10.1232 | 13.7139 | .4246 | .000000 | |
| 4 | -.013 | .003492 | -22.00061500 | | | | |

TABLE AP 5-2 (Sheet 3 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|---------|---------------|----------|----------|----------|
| 1 | 19000.0 | 262.60 | 505,295 | 19,6648 | 250,648 | .3201 |
| 2 | 1,8296 | .0013 | 1055,328 | 1066,161 | 151,0244 | 154,0577 |
| 3 | 19,6588 | -1.6955 | 18,5546 | 6,5121 | .4104 | .000000 |
| 4 | -.011 | .0019 | -100,16845300 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|----------|----------|
| 1 | 20000.0 | 260.58 | 485,672 | 11,6772 | 260,360 | .2623 |
| 2 | 1,2744 | .0013 | 1014,345 | 1061,954 | 146,3544 | 147,9847 |
| 3 | 11,5507 | 1,6860 | 11,5064 | 1,9659 | .3976 | .000000 |
| 4 | -.007 | .000714 | .00350763 | | | |

| | A | B | C | D | E | F |
|---|---------|-------------|-----------|----------|----------|----------|
| 1 | 21000.0 | 258.32 | 466,650 | 16,0283 | 272,096 | .2500 |
| 2 | 1,0093 | .0012 | 974,618 | 1057,300 | 141,8818 | 142,8836 |
| 3 | 15,0515 | 5,5078 | 16,0169 | -2.0373 | .3854 | .000000 |
| 4 | -.002 | -476,618770 | .00478764 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|----------|----------|
| 1 | 22000.0 | 256.42 | 448,228 | 20,0759 | 271,896 | .2171 |
| 2 | .7474 | .0012 | 936,143 | 1053,341 | 137,3264 | 137,6802 |
| 3 | 18,8678 | 6,8339 | 20,0561 | -1.6930 | .3730 | .000000 |
| 4 | -.007 | .000419 | .00286140 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|----------|----------|
| 1 | 23000.0 | 254.28 | 430,400 | 19,1278 | 260,584 | .1683 |
| 2 | .4831 | .0011 | 898,908 | 1048,881 | 133,0087 | 132,6853 |
| 3 | 18,9124 | 2,8582 | 18,8700 | 3,1259 | .3612 | .000000 |
| 4 | -.006 | .000877 | .00075284 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|----------|----------|----------|
| 1 | 24000.0 | 252.00 | 413,157 | 16,7265 | 256,000 | .1196 |
| 2 | .2817 | .0011 | 862,894 | 1044,141 | 128,8577 | 128,0175 |
| 3 | 16,6858 | 1,1668 | 16,2297 | 4,0465 | .3499 | .000000 |
| 4 | -.005 | .000834 | -33,36934300 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|----------|----------|
| 1 | 25000.0 | 249.54 | 396,463 | 22,0604 | 277,400 | .0804 |
| 2 | .1522 | .0011 | 828,029 | 1038,995 | 124,8895 | 123,7267 |
| 3 | 19,9220 | 9,4637 | 21,8714 | -.2183 | .3391 | .000000 |
| 4 | -.004 | .000741 | .00177095 | | | |

| | A | B | C | D | E | F |
|---|---------|----------|-----------|----------|----------|----------|
| 1 | 26000.0 | 247.15 | 380,223 | 19,7874 | 299,000 | .0630 |
| 2 | .0960 | .0010 | 794,111 | 1034,003 | 120,9370 | 119,6624 |
| 3 | 13,4950 | 14,4716 | 17,3065 | -.1103 | .3284 | .000000 |
| 4 | -.003 | -60,1737 | .00309922 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|----------|----------|----------|
| 1 | 27000.0 | 244.99 | 364,528 | 15,1394 | 302,448 | .0784 |
| 2 | .0977 | .0010 | 761,332 | 1029,470 | 116,9669 | 115,7551 |
| 3 | 9,6378 | 11,6713 | 12,7727 | -.1563 | .3176 | .000000 |
| 4 | -.002 | -18,202416 | .00293762 | | | |

| | A | B | C | D | E | F |
|---|---------|-------------|-----------|----------|----------|----------|
| 1 | 28000.0 | 242.59 | 349,396 | 20,9231 | 284,000 | .1014 |
| 2 | .1007 | .0010 | 729,728 | 1024,417 | 113,2187 | 112,0717 |
| 3 | 17,7438 | 11,0876 | 20,3016 | -.1875 | .3074 | .000000 |
| 4 | -.001 | -113,632776 | .00213921 | | | |

TABLE AP 5-2 (Sheet 4 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|---------|---------------|----------|----------|----------|
| 1 | 29000.0 | 240.17 | 334.642 | 20.9735 | 279.000 | .1136 |
| 2 | .0892 | .0009 | 698.914 | 1019.285 | 109.5325 | 108.4029 |
| 3 | 18.6875 | 9.5218 | 20.7153 | -.2348 | .2974 | .000000 |
| 4 | -.004 | .001694 | -155.88920000 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|----------|----------|----------|
| 1 | 30000.0 | 237.60 | 320.485 | 17.8058 | 262.240 | .1315 |
| 2 | .0800 | .0009 | 669.345 | 1013.821 | 106.0320 | 104.9242 |
| 3 | 17.5216 | 3.1656 | 17.6423 | 2.4038 | .2879 | .000000 |
| 4 | -.003 | .002319 | -34.02806800 | | | |

FLOATING POINT OVERFLOW AT LOCATION 020715

| | A | B | C | D | E | F |
|---|---------|---------|--------------|----------|----------|----------|
| 1 | 31000.0 | 235.24 | 306.761 | 19.9643 | 260.856 | .1400 |
| 2 | .0670 | .0009 | 640.683 | 1008.773 | 102.5101 | 101.4098 |
| 3 | 19.7247 | 3.0758 | 19.7098 | 3.1701 | .2783 | .000000 |
| 4 | -.003 | .001102 | -37.48742100 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|---------|---------|
| 1 | 32000.0 | 232.82 | 293.446 | 29.6079 | 272.144 | .1401 |
| 2 | .0521 | .0009 | 612.874 | 1003.565 | 99.0814 | 97.9795 |
| 3 | 27.7958 | 10.1973 | 29.5865 | -1.0632 | .2690 | .000000 |
| 4 | -.003 | .002544 | .00034367 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|---------|---------|
| 1 | 33000.0 | 231.23 | 280.660 | 30.1606 | 268.328 | .1500 |
| 2 | .0423 | .0008 | 586.170 | 997.968 | 95.830 | 94.7403 |
| 3 | 28.9393 | 8.4815 | 30.1438 | .8763 | .2602 | .000000 |
| 4 | -.003 | .002914 | .00096454 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|---------|---------|
| 1 | 34000.0 | 227.63 | 268.226 | 35.6354 | 259.944 | .1545 |
| 2 | .0327 | .0008 | 560.201 | 992.310 | 92.6322 | 91.5532 |
| 3 | 35.2883 | 4.9226 | 35.0824 | 6.2231 | .2515 | .000000 |
| 4 | -.002 | .005104 | .00144797 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|---------|---------|
| 1 | 35000.0 | 225.01 | 256.242 | 44.4632 | 265.280 | .1667 |
| 2 | .0262 | .0008 | 535.171 | 986.581 | 89.5240 | 88.4646 |
| 3 | 43.2734 | 10.2114 | 44.3109 | 3.6606 | .2431 | .000000 |
| 4 | -.002 | .005295 | .00082205 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|---------|---------|
| 1 | 36000.0 | 222.67 | 244.616 | 52.1026 | 265.000 | .1700 |
| 2 | .0204 | .0007 | 510.891 | 981.436 | 86.3604 | 85.3226 |
| 3 | 50.7672 | 11.7205 | 51.9044 | 4.5410 | .2345 | .000000 |
| 4 | -.002 | .006736 | .00071864 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|---------|---------|---------|---------|
| 1 | 37000.0 | 220.31 | 233.501 | 54.4312 | 258.000 | .1800 |
| 2 | .0163 | .0007 | 487.675 | 976.219 | 83.3192 | 82.3073 |
| 3 | 54.1331 | 5.6896 | 53.2418 | 11.3169 | .2262 | .000000 |
| 4 | -.001 | .006423 | ***** | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|---------|---------|
| 1 | 38000.0 | 217.95 | 222.729 | 63.9898 | 253.704 | .1800 |
| 2 | .0122 | .0007 | 465.178 | 970.991 | 80.3332 | 79.3459 |
| 3 | 63.9594 | 1.9030 | 61.4171 | 17.9547 | .2181 | .000000 |
| 4 | -.001 | .007000 | -50.20767700 | | | |

TABLE AP 5-2 (Sheet 5 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|---------|---------|
| 1 | 39000.0 | 216.00 | 212.349 | 66.4942 | 254.488 | .1855 |
| 2 | .0099 | .0007 | 443.500 | 966.621 | 77.2831 | 76.3272 |
| 3 | 66,4286 | 2.8954 | 64,0721 | 17,7739 | .2098 | .000000 |
| 4 | -.001 | .005216 | -34.28013500 | | | |

FLOATING POINT OVERFLOW AT LOCATION 020715

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|---------|---------|
| 1 | 40000.0 | 214.21 | 202.351 | 72.2887 | 251.680 | .0441 |
| 2 | .0019 | .0076 | 422.618 | 962.599 | 74.261 | 73.3129 |
| 3 | 72,2852 | -.2492 | 68,6236 | 22.7181 | .2016 | .000000 |
| 4 | -.001 | .005719 | -45.77342000 | | | |

FLOATING POINT OVERFLOW AT LOCATION 020607

| | A | B | C | D | E | F |
|---|---------|---------------|--------------|---------|--------------|---------|
| 1 | 41000.0 | 212.67 | 192.798 | 80.0981 | 251.872***** | |
| 2 | ***** | .0006 | 402.666 | 959.135 | 71.2666 | 70.3501 |
| 3 | 80,0966 | -5999616.2000 | 76.1218 | 24.9192 | .1935 | .000000 |
| 4 | -.000 | .006839 | -35.26215200 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|--------------|---------|
| 1 | 42000.0 | 210.56 | 183.569 | 82.6118 | 254.936***** | |
| 2 | ***** | .0006 | 383.392 | 954.368 | 68.5342 | 67.6535 |
| 3 | 82,5027 | 4.2298 | 79.7718 | 21.4720 | .1861 | .000000 |
| 4 | -.000 | .005904 | -17.61506900 | | | |

FLOATING POINT OVERFLOW AT LOCATION 021123

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|--------------|---------|
| 1 | 43000.0 | 209.09 | 174.743 | 82.8221 | 257.512***** | |
| 2 | ***** | .0006 | 364.958 | 951.041 | 65.6956 | 64.8520 |
| 3 | 82,4299 | 7.9513 | 80.8526 | 17.9100 | .1784 | .000000 |
| 4 | -.002 | .003728 | .00260325 | | | |

| | A | B | C | D | E | F |
|---|---------|--------------|-----------|---------|--------------|---------|
| 1 | 44000.0 | 209.21 | 166.284 | 78.1562 | 262.552***** | |
| 2 | ***** | .0005 | 347.291 | 951.319 | 62.4781 | 61.6766 |
| 3 | 76,8322 | 14.3086 | 77.4934 | 10.1342 | .1696 | .000000 |
| 4 | -.000 | -1103.657300 | .00499651 | | | |

| | A | B | C | D | E | F |
|---|---------|-----------------|---------|---------|--------------|---------|
| 1 | 45000.0 | 208.56 | 158.269 | 76.3622 | 255.360***** | |
| 2 | ***** | .0005 | 330.551 | 949.827 | 59.6528 | 58.8883 |
| 3 | 76,2286 | 4.4697 | 73.8789 | 19.3049 | .1620 | .000000 |
| 4 | -.002 | -72.872408***** | | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|--------------|---------|
| 1 | 46000.0 | 208.56 | 150.592 | 76.3223 | 260.168***** | |
| 2 | ***** | .0005 | 314.517 | 949.826 | 56.7587 | 56.0319 |
| 3 | 75,5467 | 10.8416 | 75.1994 | 13.0342 | .1541 | .000000 |
| 4 | -.002 | -14.506442 | .00190617 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|--------------|---------|--------------|---------|
| 1 | 47000.0 | 208.74 | 143.321 | 67.1827 | 267.048***** | |
| 2 | ***** | .0005 | 299.332 | 950.241 | 53.9705 | 53.2801 |
| 3 | 64,8784 | 17.4409 | 67.0925 | 3.4613 | .1466 | .000000 |
| 4 | -.002 | -23.354703 | -63.98852500 | | | |

| | A | B | C | D | E | F |
|---|---------|-----------|-----------|---------|--------------|---------|
| 1 | 48000.0 | 208.27 | 136.351 | 54.9060 | 275.000***** | |
| 2 | ***** | .0004 | 284.774 | 949.173 | 51.4607 | 50.8028 |
| 3 | 50,5413 | 21.4535 | 54.6971 | -.2220 | .1397 | .000000 |
| 4 | -.002 | +6.552878 | .00378649 | | | |

TABLE AP 5-2 (Sheet 6 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|-----------|-----------|---------|--------------|---------|
| 1 | 49000.0 | 206.91 | 129.754 | 47.5961 | 280.574***** | |
| 2 | ***** | .0004 | 270.995 | 946.063 | 49.2930 | 48.6632 |
| 3 | 41.7991 | 22.7634 | 46.7876 | -.1372 | .1339 | .000000 |
| 4 | -.002 | -7.298424 | .00389302 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|--------------|---------|
| 1 | 50000.0 | 205.59 | 123.404 | 45.9255 | 277.200***** | |
| 2 | ***** | .0004 | 257.735 | 943.051 | 47.1804 | 46.5780 |
| 3 | 41.5543 | 19.5538 | 45.5629 | -.1007 | .1281 | .000000 |
| 4 | -.002 | -13.639722 | .00152254 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|--------------|---------|
| 1 | 51000.0 | 205.28 | 117.325 | 64.0004 | 281.610***** | |
| 2 | ***** | .0004 | 245.039 | 942.321 | 44.9256 | 44.3523 |
| 3 | 55.6405 | 31.6233 | 62.6894 | -.0076 | .1220 | .000000 |
| 4 | -.002 | .000863 | .00313567 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|--------------|---------|
| 1 | 52000.0 | 206.01 | 111.585 | 70.8688 | 288.387***** | |
| 2 | ***** | .0004 | 233.050 | 944.004 | 42.5750 | 42.0322 |
| 3 | 57.0512 | 42.0423 | 67.2507 | -.0304 | .1156 | .000000 |
| 4 | -.002 | .003835 | .00595773 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|--------------|---------|
| 1 | 53000.0 | 206.13 | 106.161 | 60.7904 | 288.433***** | |
| 2 | ***** | .0003 | 221.722 | 944.272 | 40.4821 | 39.9663 |
| 3 | 49.9088 | 36.1027 | 57.6714 | -.0549 | .1099 | .000000 |
| 4 | -.002 | .002435 | .00467317 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|--------------|---------|
| 1 | 54000.0 | 205.55 | 100.974 | 53.0278 | 287.171***** | |
| 2 | ***** | .0003 | 210.888 | 942.946 | 38.6121 | 38.1204 |
| 3 | 43.3465 | 30.5454 | 50.6640 | -.0827 | .1049 | .000000 |
| 4 | -.002 | -33.074928 | .00088044 | | | |

| | A | B | C | D | E | F |
|---|---------|-----------|--------------|---------|--------------|---------|
| 1 | 55000.0 | 204.80 | 95.978 | 42.2607 | 291.568***** | |
| 2 | ***** | .0003 | 200.453 | 941.228 | 36.8353 | 36.3665 |
| 3 | 32.5752 | 26.9211 | 39.2999 | -.0837 | .1000 | .000000 |
| 4 | -.002 | -7.118618 | -25.42141200 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|--------------|---------|--------------|---------|
| 1 | 56000.0 | 203.95 | 91.238 | 36.0502 | 281.350***** | |
| 2 | ***** | .0003 | 190.555 | 939.273 | 35.1621 | 34.7149 |
| 3 | 31.4226 | 17.6694 | 35.3448 | -.1884 | .0955 | .000000 |
| 4 | -.002 | -11.872788 | -10.55246200 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|--------------|---------|--------------|---------|
| 1 | 57000.0 | 203.65 | 86.702 | 37.7056 | 278.032***** | |
| 2 | ***** | .0003 | 181.080 | 938.590 | 33.4621 | 33.0367 |
| 3 | 33.8802 | 16.5481 | 37.3356 | -.1616 | .0909 | .000000 |
| 4 | -.002 | -26.196335 | -26.76338700 | | | |

| | A | B | C | D | E | F |
|---|---------|-------------|--------------|---------|--------------|---------|
| 1 | 58000.0 | 203.42 | 82.387 | 39.3652 | 280.427***** | |
| 2 | ***** | .0003 | 172.070 | 938.055 | 31.8332 | 31.4287 |
| 3 | 34.6186 | 18.7395 | 38.7151 | -.1875 | .0864 | .000000 |
| 4 | -.002 | -392.913060 | -33.64209200 | | | |

TABLE AP 5-2 (Sheet 7 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|--------|---------|------------|---------------|---------|--------------|---------|
| 1 | 59000.0 | 204.01 | 78,318 | 30,1764 | 286,480***** | 29,7900 |
| 2***** | | .0003 | 163,570 | 939,411 | 30,1732 | .000000 |
| 3 | 24,8761 | 17,0808 | 28,9369 | -.1427 | .0819 | |
| 4 | -.002 | -33.619567 | -176,45176000 | | | |

| | A | B | C | D | E | F |
|--------|---------|-----------|--------------|---------|--------------|---------|
| 1 | 60000.0 | 204.60 | 74,520 | 14,7496 | 303,196***** | 28,2633 |
| 2***** | | .0002 | 155,639 | 940,779 | 28,6266 | .000000 |
| 3 | 9,2479 | 11,4885 | 12,3454 | -.1580 | .0777 | |
| 4 | -.002 | -4,522089 | -89,72830500 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|--------------|---------|--------------|---------|
| 1 | 61000.0 | 204.61 | 70,810 | 5,3160 | 331,810***** | 26,8552 |
| 2***** | | .0002 | 147,889 | 940,792 | 27,2003 | .000000 |
| 3 | .9393 | 5,2322 | 2,5101 | -.2345 | .0739 | |
| 4 | -.002 | -10,838432 | -22,21466500 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|--------------|---------|--------------|---------|
| 1 | 62000.0 | 205.17 | 67,333 | 2,9734 | 290,574***** | 25,4671 |
| 2***** | | .0002 | 140,628 | 942,074 | 25,7942 | .000000 |
| 3 | 2,3238 | 1,8531 | 2,7827 | -1,1921 | .0700 | |
| 4 | -.002 | -15,732132 | -24,13893000 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|--------------|---------|--------------|---------|
| 1 | 63000.0 | 205.57 | 64,006 | 8,4364 | 310,093***** | 24,1608 |
| 2***** | | .0002 | 133,678 | 943,005 | 24,4710 | .000000 |
| 3 | 4,4573 | 7,1624 | 6,4525 | -.1409 | .0665 | |
| 4 | -.002 | -39,498547 | -12,88236620 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|-----------|---------|--------------|---------|
| 1 | 64000.0 | 207.60 | 60,927 | 13,1913 | 255,926***** | 22,7746 |
| 2***** | | .0002 | 127,248 | 947,632 | 23,0668 | .000000 |
| 3 | -,3216 | 12,5604 | -,1426 | -.0292 | .0626 | |
| 4 | -.002 | -64,274601 | .00187361 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|-----------|---------|-------------|---------|
| 1 | 65000.0 | 209.05 | 57,921 | 18,7904 | 41,797***** | 21,5004 |
| 2***** | | .0002 | 120,971 | 950,946 | 21,7762 | .000000 |
| 3 | -,0782 | 9,4538 | -,0188 | -.0956 | .0591 | |
| 4 | -.002 | -19,315471 | .00210283 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|--------------|---------|-------------|---------|
| 1 | 66000.0 | 208.33 | 55,161 | 14,8273 | 55,713***** | 20,5469 |
| 2***** | | .0002 | 115,207 | 949,305 | 20,8103 | .000000 |
| 3 | -,0939 | 4,1592 | -,0273 | -.1491 | .0565 | |
| 4 | -.002 | -18,747076 | -81,00910200 | | | |

| | A | B | C | D | E | F |
|--------|---------|------------|--------------|---------|-------------|---------|
| 1 | 67000.0 | 208.81 | 52,480 | 9,6020 | 97,681***** | 19,5031 |
| 2***** | | .0002 | 109,607 | 950,401 | 19,7531 | .000000 |
| 3 | -,1399 | -,3008 | -,1130 | 1,2801 | .0536 | |
| 4 | -.002 | -51,485042 | -25,26226500 | | | |

| | A | B | C | D | E | F |
|--------|---------|---------|--------------|---------|--------------|---------|
| 1 | 68000.0 | 211.06 | 49,985 | 6,0827 | 196,189***** | 18,3780 |
| 2***** | | .0002 | 104,397 | 955,508 | 18,6134 | .000000 |
| 3 | 3,4189 | -,1920 | 1,6986 | 5,8360 | .0506 | |
| 4 | -.000 | .005703 | -24,23542500 | | | |

TABLE AP 5-2 (Sheet 8 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|---------|---------------|---------|--------------|---------|
| 1 | 69000.0 | 211.95 | 47.559 | 7.1260 | 283.882***** | 17.4124 |
| 2 | ***** | .0002 | 99.328 | 957.517 | 17.6354 | 17.4124 |
| 3 | 6,0403 | 3,7682 | 6,9091 | -.3095 | .0479 | .000000 |
| 4 | -.000 | .006443 | -328,40972000 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|--------------|---------|
| 1 | 70000.0 | 213.34 | 45.308 | 12.7508 | 322.890***** | 16.4805 |
| 2 | ***** | .0001 | 94.628 | 960.648 | 16.6915 | 16.4805 |
| 3 | 4,1737 | 12,0440 | 7,6912 | -.0925 | .0453 | .000000 |
| 4 | -.001 | .004552 | .00392507 | | | |

| | A | B | C | D | E | F |
|---|---------|-------------|-----------|---------|--------------|---------|
| 1 | 71000.0 | 215.44 | 43.234 | 14.8810 | 350.022***** | 15.5729 |
| 2 | ***** | .0001 | 90.297 | 965.366 | 15.7722 | 15.5729 |
| 3 | 7,6013 | 14,7343 | 2,5766 | -.0906 | .0428 | .000000 |
| 4 | -.001 | -170,239980 | .00627319 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|-------------|---------|
| 1 | 72000.0 | 216.28 | 41.164 | 16.0768 | 17.013***** | 14.7691 |
| 2 | ***** | .0001 | 85.973 | 967.260 | 14.9581 | 14.7691 |
| 3 | -,1219 | 13,1645 | -,2322 | -.0850 | .0406 | .000000 |
| 4 | -.001 | -26,828267 | .00369437 | | | |

| | A | B | C | D | E | F |
|---|---------|-----------|--------------|---------|-------------|---------|
| 1 | 73000.0 | 217.45 | 39.298 | 19.6890 | 55.029***** | 14.0238 |
| 2 | ***** | .0001 | 82.075 | 969.863 | 14.2033 | 14.0238 |
| 3 | -,0579 | 5,7468 | -,0790 | -.0575 | .0386 | .000000 |
| 4 | -.001 | -1,118342 | -27,96067400 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|--------------|---------|-------------|---------|
| 1 | 74000.0 | 217.82 | 37.464 | 20.7923 | 70.860***** | 13.3469 |
| 2 | ***** | .0001 | 78.244 | 970.678 | 13.5176 | 13.3469 |
| 3 | -,0426 | .4134 | -,0516 | -.1971 | .0367 | .000000 |
| 4 | -.001 | -14,127966 | -30,68734000 | | | |

| | A | B | C | D | E | F |
|---|---------|---------------|--------------|---------|-------------|---------|
| 1 | 75000.0 | 218.09 | 35.677 | 13.1156 | 71.760***** | 12.6943 |
| 2 | ***** | .0001 | 74.513 | 971.297 | 12.8567 | 12.6943 |
| 3 | -,0002 | -5504008,3000 | -,0208 | -.3071 | .0349 | .000000 |
| 4 | -.001 | -45,559435 | -28,18582600 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|-------------|---------|
| 1 | 76000.0 | 218.08 | 34.038 | 10.9602 | 74.593***** | 12.1115 |
| 2 | ***** | .0001 | 71.089 | 971.275 | 12.2663 | 12.1115 |
| 3 | -,0679 | -2,5965 | -,0799 | -,1844 | .0333 | .000000 |
| 4 | -.001 | .001563 | -43,01641400 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|---------------|---------|-------------|---------|
| 1 | 77000.0 | 218.23 | 32.455 | 6.9569 | 79.146***** | 11.5410 |
| 2 | ***** | .0001 | 67.784 | 971.590 | 11.6885 | 11.5410 |
| 3 | -,1944 | -1,5512 | -,1966 | -,6596 | .0317 | .000000 |
| 4 | -.001 | .004742 | -205,69990000 | | | |

| | A | B | C | D | E | F |
|---|---------|--------|-----------|---------|-------------|---------|
| 1 | 78000.0 | 218.55 | 30.981 | 13.4262 | 68.932***** | 11.0003 |
| 2 | ***** | .0001 | 64.705 | 972.312 | 11.1409 | 11.0003 |
| 3 | -,0979 | .7188 | -,0186 | -,2169 | .0303 | .000000 |
| 4 | -.001 | ***** | .00010674 | | | |

TABLE AP 5-2 (Sheet 9 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|-------------|---------|
| 1 | 79000.0 | 218.87 | 29,547 | 17,4430 | 61.357***** | 10,4760 |
| 2 | ***** | .0001 | 61,710 | 973,016 | 10,6099 | .000000 |
| 3 | -.0711 | 3,2214 | -.0855 | -.1488 | .0288 | |
| 4 | -.001 | -53.503897 | .00112699 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|-------------|---------|
| 1 | 80000.0 | 220.14 | 28,205 | 23,2021 | 62.000***** | 9,9424 |
| 2 | ***** | .0001 | 58,908 | 975,841 | 10,0694 | .000000 |
| 3 | -.0265 | 4,0290 | -.0450 | -.0697 | .0273 | |
| 4 | -.001 | -27.030388 | .00145008 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|-------------|---------|
| 1 | 81000.0 | 221.25 | 26,941 | 28,7124 | 65.105***** | 9,4491 |
| 2 | ***** | .0001 | 56,268 | 978,309 | 9,5698 | .000000 |
| 3 | -.0469 | 3,4466 | -.0016 | -.0324 | .0260 | |
| 4 | -.001 | -21.529219 | .00101325 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|--------------|---------|-------------|---------|
| 1 | 82000.0 | 222.03 | 25,725 | 29,5209 | 73.796***** | 8,9908 |
| 2 | ***** | .0001 | 53,728 | 980,033 | 9,1057 | .000000 |
| 3 | -.0449 | -1,3201 | -.0472 | -.1527 | .0247 | |
| 4 | -.002 | -30.342570 | -96.72653200 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|--------------|---------|-------------|---------|
| 1 | 83000.0 | 223.56 | 24,523 | 34,1811 | 74.702***** | 8,5123 |
| 2 | ***** | .0001 | 51,218 | 983,393 | 8,6210 | .000000 |
| 3 | -.0358 | -.1199 | -.0381 | -.1283 | .0234 | |
| 4 | -.002 | -30.276329 | -46.23274800 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|-------------|---------|
| 1 | 84000.0 | 225.10 | 23,424 | 24,8355 | 76.047***** | 8,0753 |
| 2 | ***** | .0001 | 48,923 | 986,769 | 8,1784 | .000000 |
| 3 | -.0115 | -.7644 | -.0168 | -.0716 | .0222 | |
| 4 | -.002 | .000770 | -28.18509000 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|-------------|---------|
| 1 | 85000.0 | 225.83 | 22,391 | 24,4271 | 98.951***** | 7,6941 |
| 2 | ***** | .0001 | 46,765 | 988,371 | 7,7923 | .000000 |
| 3 | -.0350 | -.0641 | -.0166 | 3,8038 | .0212 | |
| 4 | -.002 | .002344 | -12.57471650 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|--------------|---------|
| 1 | 86000.0 | 226.05 | 21,332 | 28,9667 | 118.390***** | 7,3229 |
| 2 | ***** | .0001 | 44,552 | 988,855 | 7,4163 | .000000 |
| 3 | -.0490 | -.0412 | -.0060 | 13,7738 | .0201 | |
| 4 | -.002 | .004600 | -16.02757800 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|--------------|---------|
| 1 | 87000.0 | 227.10 | 20,443 | 25,9934 | 127.379***** | 6,9853 |
| 2 | ***** | .0001 | 42,695 | 991,147 | 7,0744 | .000000 |
| 3 | -.0897 | -.0379 | -.0437 | 15,7806 | .0192 | |
| 4 | -.002 | .003421 | -12.28386370 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|---------|--------------|---------|
| 1 | 88000.0 | 227.89 | 19,495 | 22,6804 | 112.243***** | 6,6381 |
| 2 | ***** | .0001 | 40,715 | 992,881 | 6,7228 | .000000 |
| 3 | -.0698 | -.0906 | -.0411 | 8,5851 | .0183 | |
| 4 | -.002 | .001509 | -51.77767900 | | | |

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TABLE AP 5-2 (Sheet 10 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|-------------|----------|
| 1 | 89000.0 | 228.56 | 18.641 | 21.2314 | 93.767***** | 6.3289 |
| 2 | ***** | .0001 | 38.932 | 994.319 | 6.4097 | 6.000000 |
| 3 | -.0510 | -.1641 | -.0395 | 1.3952 | .0174 | |
| 4 | -.002 | .000233 | .00331291 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|-------------|----------|
| 1 | 90000.0 | 229.14 | 17.788 | 22.0637 | 85.971***** | 6.0239 |
| 2 | ***** | .0001 | 37.150 | 995.593 | 6.1008 | 6.000000 |
| 3 | -.0378 | -.1544 | -.0331 | -.4217 | .0166 | |
| 4 | -.002 | -42.182452 | .00502403 | | | |

| | A | B | C | D | E | F |
|---|---------|------------|-----------|---------|-------------|----------|
| 1 | 91000.0 | 229.34 | 17.031 | 19.8568 | 87.818***** | 5.7626 |
| 2 | ***** | .0001 | 35.570 | 996.035 | 5.8361 | 5.000000 |
| 3 | -.0558 | -.1437 | -.0500 | -.5104 | .0159 | |
| 4 | -.002 | -80.280591 | .00347006 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|---------|-------------|----------|
| 1 | 92000.0 | 230.65 | 16.299 | 19.6814 | 88.499***** | 5.4835 |
| 2 | ***** | .0000 | 34.040 | 998.864 | 5.5535 | 5.000000 |
| 3 | -.0576 | -.1215 | -.0513 | -2.4375 | .0151 | |
| 4 | -.003 | .000448 | .00114622 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|---------------|----------|-------------|----------|
| 1 | 93000.0 | 232.00 | 15.566 | 17.0636 | 94.831***** | 5.2066 |
| 2 | ***** | .0000 | 32.510 | 1001.778 | 5.2730 | 5.000000 |
| 3 | -.0822 | -.2033 | -.0722 | 1.4353 | .0143 | |
| 4 | -.003 | .001362 | -326.62670000 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|--------------|----------|-------------|----------|
| 1 | 94000.0 | 232.55 | 14.896 | 13.1000 | 99.766***** | 4.9705 |
| 2 | ***** | .0000 | 31.110 | 1002.971 | 5.0339 | 4.000000 |
| 3 | -.0479 | -.0574 | -.0067 | 2.2220 | .0137 | |
| 4 | -.003 | .002651 | -55.21714800 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|-------------|----------|
| 1 | 95000.0 | 232.47 | 14.287 | 10.3930 | 89.205***** | 4.7691 |
| 2 | ***** | .0000 | 29.838 | 1002.793 | 4.8299 | 4.000000 |
| 3 | -.0999 | -.1028 | -.0854 | -4.8252 | .0131 | |
| 4 | -.003 | .002742 | .00071650 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|-------------|----------|
| 1 | 96000.0 | 231.74 | 13.678 | 12.8167 | 81.532***** | 4.5803 |
| 2 | ***** | .0000 | 28.567 | 1001.216 | 4.6387 | 4.000000 |
| 3 | -.0151 | -.5811 | -.0140 | -.6950 | .0126 | |
| 4 | -.003 | .001722 | .00131483 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|-----------|----------|--------------|----------|
| 1 | 97000.0 | 231.66 | 13.067 | 6.3799 | 112.998***** | 4.3771 |
| 2 | ***** | .0000 | 27.291 | 1001.050 | 4.4329 | 4.000000 |
| 3 | -.2185 | -.2973 | -.0863 | 2.4912 | .0120 | |
| 4 | -.003 | .001986 | .00073192 | | | |

| | A | B | C | D | E | F |
|---|---------|---------|---------------|----------|--------------|----------|
| 1 | 98000.0 | 232.49 | 12.457 | 6.5131 | 142.741***** | 4.1578 |
| 2 | ***** | .0000 | 26.016 | 1002.843 | 4.2108 | 4.000000 |
| 3 | -.5663 | -.0517 | -.3273 | 5.1836 | .0114 | |
| 4 | -.003 | .002620 | -184.98340000 | | | |

TABLE AP 5-2 (Sheet 11 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|---------|---------------|----------|--------------|---------|
| 1 | 99000.0 | 233.03 | 11,918 | 4.2464 | 144.604***** | 3.9688 |
| 2 | ***** | .0000 | 24,892 | 1004.006 | 4,0194 | .000000 |
| 3 | -.7419 | -.3137 | -.4107 | 3.4615 | .0109 | |
| 4 | -.003 | .003249 | -214.26389000 | | | |

| | A | B | C | D | E | F |
|---|----------|---------|-----------|----------|--------------|---------|
| 1 | 100000.0 | 233.52 | 11,432 | 3.2748 | 151.966***** | 3.7988 |
| 2 | ***** | .0000 | 23,875 | 1005.056 | 3,8472 | .000000 |
| 3 | -1,9977 | -.0281 | -.2028 | 2.8904 | .0104 | |
| 4 | -.003 | .001685 | .00006935 | | | |

| | A | B | C | D | E | F |
|---|----------|---------|-------------|----------|--------------|---------|
| 1 | 105000.0 | 235.36 | 9,193 | 16.4042 | 181.016***** | 3.0311 |
| 2 | ***** | .0000 | 19,201 | 1009.015 | 3,0698 | .000000 |
| 3 | 5,3450 | -.0839 | .2909 | 16.4016 | .0083 | |
| 4 | -.003 | .001212 | -3.37203220 | | | |

| | A | B | C | D | E | F |
|---|----------|---------|---------------|----------|--------------|---------|
| 1 | 115000.0 | 241.11 | 6,146 | 22.9659 | 230.000***** | 1.9780 |
| 2 | ***** | .0000 | 12,836 | 1021.268 | 2,0032 | .000000 |
| 3 | 21,2936 | -.1413 | 17,5929 | 14.7622 | .0054 | |
| 4 | -.004 | .002948 | -105.83675100 | | | |

| | A | B | C | D | E | F |
|---|----------|---------|-----------|----------|--------------|---------|
| 1 | 120000.0 | 243.02 | 4,981 | 33.4197 | 248.764***** | 1.5904 |
| 2 | ***** | .0000 | 10,402 | 1025.306 | 1,6106 | .000000 |
| 3 | 33,3652 | -.7421 | 31,1489 | 12.1056 | .0044 | |
| 4 | -.001 | .003410 | .00667384 | | | |

| | A | B | C | D | E | F |
|---|----------|------------|-----------|----------|--------------|---------|
| 1 | 125000.0 | 249.29 | 4,055 | 41.3327 | 331.238***** | 1.2623 |
| 2 | ***** | .0000 | 8,469 | 1038.443 | 1,2784 | .000000 |
| 3 | 7,7180 | 40.6057 | 19,8881 | -.0318 | .0035 | |
| 4 | -.004 | -27.436673 | .00169646 | | | |

| | A | B | C | D | E | F |
|---|----------|------------|--------------|----------|--------------|---------|
| 1 | 130000.0 | 250.38 | 3,308 | 29.5276 | 331.000***** | 1.0252 |
| 2 | ***** | .0000 | 6,909 | 1040.716 | 1,0383 | .000000 |
| 3 | 5,6341 | 28.9851 | 14,3152 | -.0033 | .0028 | |
| 4 | -.005 | -34.252934 | -54.81344200 | | | |

| | A | B | C | D | E | F |
|---|----------|---------|--------------|----------|---------|---------|
| 1 | 135000.0 | 253.36 | 2,705 | 35.3543 | 275.184 | .0000 |
| 2 | .0000 | .0000 | 5,649 | 1046.881 | .8390 | .8284 |
| 3 | 32,4621 | 13.9928 | 35,1973 | -.4301 | .0023 | .000000 |
| 4 | -.006 | .005915 | -28.55761400 | | | |

| | A | B | C | D | E | F |
|---|----------|------------|-----------|----------|---------|---------|
| 1 | 140000.0 | 260.70 | 2,220 | 52.4934 | 295.312 | .0000 |
| 2 | .0000 | .0000 | 4,637 | 1061.947 | .6693 | .6609 |
| 3 | 38,1945 | 36.0078 | 47,4522 | -.0297 | .0018 | .000000 |
| 4 | -.007 | -87.971567 | .00201963 | | | |

| | A | B | C | D | E | F |
|---|----------|------------|-------------|----------|---------|---------|
| 1 | 145000.0 | 264.31 | 1,831 | 40.5249 | 246.616 | .0000 |
| 2 | .0000 | .0000 | 3,824 | 1069.273 | .5444 | .5376 |
| 3 | 39,6691 | 1.7121 | 36,3227 | 16.5820 | .0015 | .000000 |
| 4 | -.014 | -13.506067 | -7.00462940 | | | |

TABLE AP 5-2 (Sheet 12 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|---------|------------|---------------|----------|---------|---------|
| 1 | 15000.0 | 266.31 | 1.512 | 52.0997 | 233.480 | .0000 |
| 2 | .0000 | .0000 | 3.158 | 1073.298 | .4462 | .4406 |
| 3 | 49.3818 | -.0644 | 41.8451 | 31.0167 | .0012 | .000000 |
| 4 | -.009 | -30.889440 | -102.09422300 | | | |

| | A | B | C | D | E | F |
|---|----------|---------|-----------|----------|---------|---------|
| 1 | 155000.0 | 271.70 | 1.252 | 91.7848 | 243.904 | .0000 |
| 2 | .0000 | .0000 | 2.615 | 1084.110 | .3621 | .3576 |
| 3 | 90.8657 | -.0118 | 82.4259 | 40.3668 | .0010 | .000000 |
| 4 | -.072 | .008161 | .00356888 | | | |

| | A | B | C | D | E | F |
|---|----------|-----------|-----------|----------|---------|---------|
| 1 | 160000.0 | 274.75 | 1.041 | 114.5932 | 273.072 | .0000 |
| 2 | .0000 | .0000 | 2.174 | 1090.184 | .2978 | .2940 |
| 3 | 106.9306 | 41.1969 | 114.4276 | -.0760 | .0008 | .000000 |
| 4 | 1.601 | -3.971955 | .01122213 | | | |

| | A | B | C | D | E | F |
|---|------------|----------|-------------|----------|-------|---------|
| 1 | 165000.0 | 270.86 | .838 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | 1.749 | 1082.445 | .2430 | .2400 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0007 | .000000 |
| 4 | -.054 | -.834013 | -9.09914370 | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 170000.0 | 267.60 | .687 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | 1.434 | 1075.896 | .2017 | .1992 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0005 | .000000 |
| 4 | -.019 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 175000.0 | 264.33 | .563 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | 1.176 | 1069.308 | .1674 | .1653 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0005 | .000000 |
| 4 | -.014 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 180000.0 | 261.06 | .462 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .964 | 1062.678 | .1390 | .1372 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0004 | .000000 |
| 4 | -.008 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 185000.0 | 257.25 | .379 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .791 | 1054.887 | .1158 | .1143 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0003 | .000000 |
| 4 | -.005 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 190000.0 | 253.11 | .310 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .648 | 1046.371 | .0963 | .0951 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0003 | .000000 |
| 4 | -.006 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 195000.0 | 248.76 | .253 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .528 | 1037.330 | .0799 | .0789 |
| 3 | .0000***** | .0000 | .0000 | .0000 | .0002 | .000000 |
| 4 | -.004 | .000000***** | | | | |

TABLE AP 5-2 (Sheet 13 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 200000.0 | 244.25 | .206 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .430 | 1027.883 | .0662 | .0653 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0002 | .000000 |
| 4 | -.002 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 205000.0 | 239.64 | .167 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .348 | 1018.137 | .0546 | .0539 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0001 | .000000 |
| 4 | -.004 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|----------|-------|---------|
| 1 | 210000.0 | 234.98 | .134 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .281 | 1008.192 | .0449 | .0444 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0001 | .000000 |
| 4 | -.003 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 215000.0 | 230.31 | .108 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .226 | 998.136 | .0368 | .0364 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0001 | .000000 |
| 4 | -.003 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 220000.0 | 225.68 | .086 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .180 | 988.043 | .0301 | .0297 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0001 | .000000 |
| 4 | -.002 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 225000.0 | 221.10 | .069 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .144 | 977.976 | .0245 | .0241 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0001 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 230000.0 | 216.61 | .055 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .114 | 967.978 | .0198 | .0195 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0001 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 235000.0 | 212.20 | .043 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .090 | 958.077 | .0159 | .0157 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0000 | .000000 |
| 4 | -.000 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 240000.0 | 207.88 | .034 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .071 | 948.280 | .0128 | .0126 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0000 | .000000 |
| 4 | -.002 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 245000.0 | 203.65 | .026 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .055 | 938.573 | .0102 | .0101 |
| 3 | .0000***** | .0000***** | .0000 | .0000 | .0000 | .000000 |
| 4 | -.002 | .000000***** | | | | |

TABLE AP 5-2 (Sheet 14 of 14)
 METEOROLOGICAL DATA (AA99)

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 250000.0 | 199.48 | .021 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .043 | 928,917 | .0081 | .0080 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.002 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 255000.0 | 195.35 | .016 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .033 | 919,246 | .0064 | .0063 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.002 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 260000.0 | 191.21 | .012 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .025 | 909,465 | .0050 | .0049 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 265000.0 | 187.02 | .009 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .019 | 899,447 | .0039 | .0039 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 270000.0 | 182.71 | .007 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .015 | 889,029 | .0030 | .0030 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 275000.0 | 180.65 | .005 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .011 | 883,994 | .0023 | .0023 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 280000.0 | 180.65 | .004 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .008 | 883,994 | .0018 | .0017 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 285000.0 | 180.65 | .003 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .006 | 883,994 | .0013 | .0013 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 290000.0 | 180.65 | .002 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .005 | 883,994 | .0010 | .0010 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 295000.0 | 180.65 | .002 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .004 | 883,994 | .0008 | .0008 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

| | A | B | C | D | E | F |
|---|------------|--------------|-------|---------|-------|---------|
| 1 | 300000.0 | 184.89 | .001 | .0000 | .000 | .0000 |
| 2 | .0000 | .0000 | .003 | 894,501 | .0006 | .0006 |
| 3 | .0000***** | | .0000 | .0000 | .0000 | .000000 |
| 4 | -.001 | .000000***** | | | | |

APPENDIX 6

GLOSSARY AND ABBREVIATIONS

1. GLOSSARY AND ABBREVIATIONS

This appendix (table AP 6-1) lists the commonly used S-IVB-502 stage flight evaluation terms and abbreviations together with their definitions.

TABLE AP 6-1 (Sheet 1 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|------------------------------------|---|
| AACS | -- | Auxiliary attitude control system (see APS) |
| ac | -- | Alternating current |
| AEDC | -- | Arnold Engineering Development Center |
| -- | Aerodynamically induced vibration | The oscillation of a mechanical system when set into motion by the turbulent boundary layer during flight. It is dependent on the shape and velocity of the body |
| amp | -- | Ampere |
| ANT | -- | AFETR Station on Antigua Island |
| APS | -- | Auxiliary propulsion system (see AACS) |
| AS | -- | Apollo Saturn |
| ASC | -- | AFETR Station on Ascension Island |
| ASI | -- | Augmented spark igniter |
| AST | -- | All systems test |
| A_t | -- | Throat area |
| aux | -- | Auxiliary |
| -- | Average mixture ratio | The time average of the propellant mixture ratio over 1-sec time intervals between 90 percent thrust buildup and Engine Cutoff Command |
| -- | Average thrust or specific impulse | Determined between the time of 90 percent thrust and Engine Cutoff Command |
| A_w | -- | Wind azimuth (deg) |
| A_{XM} | -- | Axial acceleration (ft/sec ²) |
| BDA | -- | Bermuda |
| BGR | -- | Bridge gain ratio |
| Btu | -- | British thermal unit |
| CCS | -- | Command communication system |
| CCW | -- | Counterclockwise |
| CDDT | -- | Countdown demonstration test |
| CECO | -- | S-IC stage Center Engine Cutoff Command |
| CEI | -- | Contract end item |
| CDF | -- | Confined detonating fuse |
| C_F | -- | Thrust coefficient |
| C_f | Collapse factor | A measure of the effectiveness of pressurization defined as: $C_f = \frac{M_{\text{actual}}}{M_{\text{theoretical}}}$, where M actual: is the mass necessary to pressure the propellant tank (lbm) |

TABLE AP 6-1 (Sheet 2 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|---|--|
| C _f | (Continued) | M _{theoretical} : is the mass necessary to pressurize the propellant tank if heat and mass transfer across the ullage boundaries are neglected (lbm) |
| -- | Composite data (acoustic and vibration) | The total energy of the oscillatory phenomenon, consisting of all frequencies and amplitudes sensed by the transducers, and represents the phenomenon at the point of measurement within the limitations of the data acquisition and reduction systems |
| CPIF | -- | Cost plus incentive fee |
| cpm | -- | Cycles per minute |
| cps | -- | Cycles per second |
| CRO | -- | Carnarvon |
| CSM | -- | Command service module |
| cu in. | -- | Cubic inches |
| CVS | -- | Continuous vent system |
| CW | -- | Clockwise |
| CYI | -- | Grand Canary Island |
| DAC | -- | Douglas Aircraft Company, Inc. |
| DAC/FTC | -- | Douglas Aircraft Company, Inc./Florida Test Center |
| DAC/HB | -- | Douglas Aircraft Company, Inc./Huntington Beach |
| db | -- | Decibel |
| dbm | -- | 10 log P (milliwatts) where p = power |
| dbw | -- | 10 log P (watts) |
| dc | -- | Direct current |
| deg | -- | Degree |
| -- | Depletion Engine Cutoff Command | The time that engine cutoff was, or would be, initiated by the depletion level sensors |
| D/O | -- | Dropout |
| e | -- | Eccentricity |
| EA | -- | Electronics assembly |
| EBW | -- | Exploding bridgewire |
| ECA | -- | Electrical control assembly |
| ECC | -- | Engine Cutoff Command |
| ECF | -- | End conditions of flight |
| ECP | -- | Engineering change proposal |
| ECS | -- | Environmental control system |
| EDS | -- | Emergency detection system |
| -- | Effective burntime | The engine burntime from 90 percent thrust buildup to Engine Cutoff Command |

TABLE AP 6-1 (Sheet 3 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|---------------------------------------|---|
| EMC | -- | Electromagnetic compatibility |
| EMI | -- | Electromagnetic interference |
| EMR | Engine propellant mixture ratio | The ratio of engine LOX mass flowrate to LH2 mass flowrate includes gas generator operations |
| eng | -- | Engine |
| -- | Engine cutoff transient | Engine operation during the period from the Engine Cutoff Command until the end of thrust decay |
| ESC | -- | Engine Start Command |
| EST | -- | Eastern standard time |
| -- | Engine start transient | Engine operation during the period from the Engine Start Command until the time of 90 percent thrust (approximately a 3-sec period) |
| -- | Engine steady-state operation | Engine operation during the period from the time of 90 percent thrust until Engine Cutoff Command |
| ETD | -- | End of thrust decay |
| ETR | -- | Eastern Test Range |
| °F | -- | Degree Fahrenheit |
| F | Stage longitudinal thrust | Thrust (lbf) developed by the J-2 engine. Ullage rocket thrust is not included |
| F _a | -- | Ullage rocket thrust (lbf) |
| -- | Flow integral propellant mass history | That propellant mass history determined by combining independent engine analyses by a statistical method |
| F/B | -- | Feedback |
| FCC | -- | Flight control computer |
| FM | -- | Frequency modulation |
| fps | -- | Feet per second |
| ft | -- | Foot |
| FTC | -- | Florida Test Center |
| fwd | -- | Forward |
| g | Gravitational acceleration | The acceleration produced by the force of gravity, which varies with the altitude and elevation of the point of observation. The value 32.1739 ft/sec ² has been chosen as the standard by international agreement for sea level at 45° north latitude |
| GBI | -- | AFETR Station on Grand Bahama Island |
| GCC | -- | Guidance Cutoff Command |
| GG | -- | Gas generator |
| GH2 | -- | Gaseous hydrogen |
| GMT | -- | Greenwich mean time |
| GN2 | -- | Gaseous nitrogen |
| GOX | -- | Gaseous oxygen |

TABLE AP 6-1 (Sheet 4 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|--------------|---|
| gpm | -- | Gallons per minute |
| grms | -- | Gravity root mean square |
| GSE | -- | Ground support equipment |
| GYM | -- | Guaymas |
| h | -- | Altitude |
| h (AP) | -- | Apogee altitude |
| HAW | -- | Hawaii |
| He | -- | Helium |
| HF | -- | High frequency |
| hr | -- | Hour |
| H/W | -- | Hardwire |
| Hz | Hertz | Cycles per second |
| i | -- | Inclination |
| IAS | -- | Initiation of automatic sequence |
| IECO | -- | S-IC stage Inboard Engine Cutoff Command |
| IGM | -- | Iterative guidance mode |
| in. | -- | Inches |
| in./in. | -- | Inches per inch (strain) |
| IP&CL | -- | Instrumentation Program and Components List |
| ips | -- | Inches per second |
| IRIG | -- | Inter range instrumentation group |
| Isp | -- | Specific Impulse |
| IU | -- | Instrument unit |
| k | -- | Insulation thermal conductivity |
| kc | -- | Kilocycles |
| KSC | -- | Kennedy Space Center |
| ksi | -- | 1,000 lb/in. ² |
| L | -- | Trajectory fit parameter |
| lbf | -- | Pounds force |
| lbm | Pounds mass | 1/32.1739 slug |
| lbm/hr | -- | Pounds mass, hour |
| lbm/sec | -- | Pounds mass, second |
| lb/pf | -- | Pounds per picofarad |
| LC | -- | Launch Complex |
| L/C | -- | Loading Computer |

TABLE AP 6-1 (Sheet 5 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|--|--|
| LCC | -- | Launch control center |
| LES | -- | Launch escape system |
| LET | -- | Launch escape tower |
| -- | Level sensor residuals | Those propellant residuals above the main propellant valves determined by combining data from one or more level sensors by a statistical method and extrapolating to Engine Cutoff Command |
| LH2 | -- | Liquid hydrogen |
| LM | -- | Lunar module |
| LO | -- | Vehicle liftoff time |
| -- | Look angle | Angle between the vehicle centerline and the line of sight, measured from the rear of the vehicle (deg) |
| LOS | -- | Loss of signal |
| LOX | -- | Liquid oxygen |
| L/S | -- | Level sensor |
| LTA | -- | Lunar test article (Structural representation of LM) |
| LV | -- | Launch vehicle |
| LVDC | -- | Launch vehicle digital computer |
| M | -- | Mach number |
| \dot{M} | Stage propellant mass flowrate (lbm/sec) | Engine propellant mass flowrate (includes propellant flowrate for gas generator operation) |
| \dot{M}_f | Stage LH2 mass flowrate (lbm/sec) | Engine LH2 mass flowrate (includes LH2 flowrate for gas generator operation) |
| \dot{M}_o | Stage LOX mass flowrate (lbm/sec) | Engine LOX mass flowrate (includes LOX flowrate for gas generator operation) |
| ma | -- | Milliamperere |
| M&A | -- | Manufacturing and assembly building (STC) |
| max q | -- | Maximum dynamic pressure |
| μ in./in. | Micro inch per inch | Millionth of an inch per inch |
| MDF | -- | Mild detonating fuse |
| MFV | -- | Main fuel valve |
| MHz | -- | Millihertz |
| MILA | -- | Merritt Island Florida |
| MOI | -- | Moment of inertia |
| MOV | -- | Main oxidizer valve |
| ms | Millisecond | Thousandth of a sec |
| MSC | -- | Manned Spacecraft Center, Houston, Texas |
| MSFC | -- | Marshall Space Flight Center |
| MSL | -- | Mean sea level |

TABLE AP 6-1 (Sheet 6 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|-------------------------------|-------------------------------|---|
| MSSD | -- | Missile and Space Systems Division, Huntington Beach, California |
| mv | -- | Millivolt |
| m _{xr} | -- | Multiplexer |
| N/A | -- | Not applicable |
| NASA | -- | National Aeronautics and Space Administration |
| NC | -- | Normally closed |
| -- | Ninety percent thrust buildup | Time from Engine Start Command until the last engine chamber pressure (injector end) reaches 618 psia |
| nmi | -- | Nautical miles |
| NO | -- | Normally open |
| No. | -- | Number |
| N ₂ O ₄ | NTO | Nitrogen Tetroxide |
| NPSP | -- | Net positive suction pressure |
| NPV | -- | Nonpropulsive vent |
| OAT | -- | Overall test |
| OECCO | -- | S-IC stage Outboard Engine Cutoff Command |
| O-P | -- | Zero to peak |
| P | -- | Geodetic latitude |
| P | -- | Pitch |
| P _a | -- | Ambient pressure |
| P _c | -- | Combustion chamber pressure measured at the injector |
| PA | -- | Pressure actuated |
| PAM | -- | Pulse amplitude modulation |
| PCF | -- | Preconditions of flight |
| PCM | -- | Pulse code modulation |
| -- | Phase I | Time from liftoff to ECCL +10 sec |
| -- | Phase II | Time from liftoff to planned LV/SC separation |
| PMR | Programmed mixture ratio | A method of controlling the PU valve mixture ratio to obtain maximum efficiency of the stage. The propellant loading is provided to cause the PU system to command the PU valve against the LOX rich stop for the initial portion of flight and then decrease to a lower mixture ratio during the final portion of flight |
| P/N | -- | Part number |
| P-P | -- | Peak to peak |
| ppm | -- | Parts per million |
| -- | Propellant residuals | The sum of LOX and LH2 remaining onboard at Engine Cutoff Command. The residuals include both usable and trapped propellants |

TABLE AP 6-1 (Sheet 7 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|-----------------------------------|--|
| PS | -- | Pressurization system |
| P/S | -- | Pulse sensor |
| PSD | -- | Power spectral density |
| psia | -- | Pounds per square inch absolute |
| psid | -- | Pounds per square inch differential |
| psig | -- | Pounds per square inch gauge |
| PTCS | -- | Propellant tanking computer system |
| P/U | -- | Pickup |
| PU | -- | Propellant utilization |
| -- | PU system propellant mass history | That propellant mass history determined for flight by the PU system |
| -- | PU system residuals | Those propellant residuals above the main propellant valves determined by the PU system |
| q | -- | Dynamic pressure |
| R | -- | Rankine |
| RACS | -- | Remote analog calibration system |
| reg | -- | Regulator |
| RF | -- | Radio frequency |
| RFI | -- | Radio frequency interference |
| RMR | -- | Reference mixture ratio |
| rms | -- | Root mean square |
| R/NAA | -- | Rocketdyne, North American Aviation |
| RO | -- | An event time used as reference for S-IVB stage flight evaluation sequence of events. Defined as the first Greenwich mean time second prior to vehicle liftoff |
| rpm | -- | Revolutions per minute |
| R/S | -- | Range safety |
| RSCR | -- | Range safety command receiver |
| rss | -- | Root sum square |
| S | -- | Surface range (ft) |
| SC | -- | Spacecraft |
| scfm | -- | Standard cubic ft/min |
| scim | -- | Standard cubic in./min |
| sco | -- | Subcarrier oscillator |
| sec | -- | Seconds |
| S-IB | -- | First stage of the Saturn IB (200) series of vehicles |
| S-IC | -- | First stage of the Saturn V (500) series of vehicles |

TABLE AP 6-1 (Sheet 8 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|---|---|
| S-II | -- | Second Stage of the Saturn V (500) series of vehicles |
| S-IVB | -- | Second stage of the Saturn IB (200) series of vehicles and third stage of Saturn V (500) series of vehicles |
| SLA | -- | Spacecraft LM adapter |
| -- | Slug | English system unit of mass |
| SLV | -- | Saturn launch vehicle |
| SM | -- | Santa Monica |
| SM | -- | Service module |
| S/N | -- | Serial number |
| SPS | -- | Service propulsion system |
| SOV | -- | Shutoff valve |
| SSB | -- | Single sideband |
| SSS | -- | Stage switch selector |
| sta | -- | Station |
| -- | Statistical weighted average loaded propellants | The most accurate determination of actual propellant load at liftoff as derived from the statistically weighted average mass |
| -- | Statistical weighted average mass determination | A statistical combination of the PU system, engine system, flight simulation, and propellant level sensors at Engine Start Command and Engine Cutoff Command |
| -- | Statistical weighted average residual propellants | The most accurate determination of actual propellant residual at Engine Cutoff Command as derived from the statistically weighted average mass determination method |
| STC | -- | Sacramento Test Center |
| STD | -- | Start tank discharge |
| STDV | -- | Start tank discharge valve |
| S/V | -- | Space vehicle |
| sw | -- | Switch |
| Sw sel | -- | Switch selector |
| T | -- | Countdown time from prospective liftoff or as specifically defined in the text |
| Tel 2 | -- | Telemetry station at KSC |
| Tel 3 | -- | Cape Kennedy Telemetry Station IV |
| Tel 4 | -- | Merritt Island Telemetry Station IV |
| TEX | -- | Cropus Christi, Texas |
| tk | -- | Tank |
| T/M | -- | Telemetry |
| -- | Total depletion burntime | The engine burntime from Engine Start Command to the time that the Depletion Engine Cutoff Command would have been initiated |

TABLE AP 6-1 (Sheet 9 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|----------------------------|--|
| -- | Total propellants consumed | That amount of liquid propellants consumed from Engine Start Command to Engine Cutoff Command includes engine consumption, boiloff, and LH2 tank pressurant |
| TPEP | -- | Telemetry performance evaluation period |
| -- | Total stage burntime | The engine burntime from Engine Start Command to Engine Cutoff Command |
| -- | Total stage mass history | A compilation of all final hardware, propellant, and gas masses. The measured and computed mass of each constituent is adjusted within its accuracy band so that the total stage mass at Engine Start Command and Engine Cutoff Command agrees with the total stage mass as determined by the Statistical Weighted Average mass determination method |
| TP&E | -- | Test Planning and Evaluation |
| TVCS | -- | Thrust vector control system |
| -- | Unusable propellants | Those propellants remaining after a propellant depletion cutoff. This includes the propellant in the tank below the depletion sensor, propellant in the feed duct, and trapped propellants. It does not include sensor lag time or the propellant consumed during engine cutoff but does include sensor time delay |
| U/R | -- | Ullage rocket |
| -- | Usable residual | Propellants in excess of trapped propellants left onboard a stage after powered flight has been terminated by some specified cutoff criteria |
| USB | -- | Unified S-band |
| v | -- | Volt |
| V_E | -- | Relative velocity |
| V_I | -- | Inertial velocity |
| V_{RM} | -- | Freestream velocity |
| V_W | -- | Wind velocity (speed) |
| VAB | -- | Vehicle Assembly Building, KSC, Florida |
| vac | -- | Voltage, alternating current |
| VCO | -- | Voltage controlled oscillator |
| vdc | -- | Voltage, direct current |
| VHF | -- | Very high frequency |
| VSE | -- | Vehicle support equipment |
| VSWR | -- | Voltage standing wave ratio |
| w | -- | Watt |
| WRO | -- | DAC work release order |
| wt | -- | Weight |
| \dot{W}_T | -- | Time rate of change of total vehicle weight |
| X_E | -- | Downrange distance |
| \dot{X}_E | -- | Downrange velocity |

TABLE AP 6-1 (Sheet 10 of 10)
GLOSSARY AND ABBREVIATIONS

| <u>ABBREVIATION</u> | <u>TERMS</u> | <u>DEFINITION</u> |
|---------------------|--------------|---|
| Y | -- | Yaw |
| Y_E | -- | Vertical distance |
| \dot{Y}_E | -- | Vertical velocity |
| Z_E | -- | Crossrange distance |
| \dot{Z}_E | -- | Crossrange velocity |
| α_P | -- | Pitch angle of attack |
| α_q | -- | Product of angle of attack and dynamic pressure |
| α_Y | -- | Yaw angle of attack |
| γ_1 | -- | Earth fixed flight path elevation angle |
| Δw | -- | Delta weight |
| γ_{1I} | -- | Inertial flight path elevation angle |
| γ_{2I} | -- | Inertial flight path azimuth angle |
| μ | -- | Longitude |
| μv | -- | Microvolt |

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AF02 Materials & Methods - Research & Engineering
KBDB Project Support
KCBC System Performance
KDDH Electronics
LCCO Saturn Support Branch
KKBH TP&E - Flight Test

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