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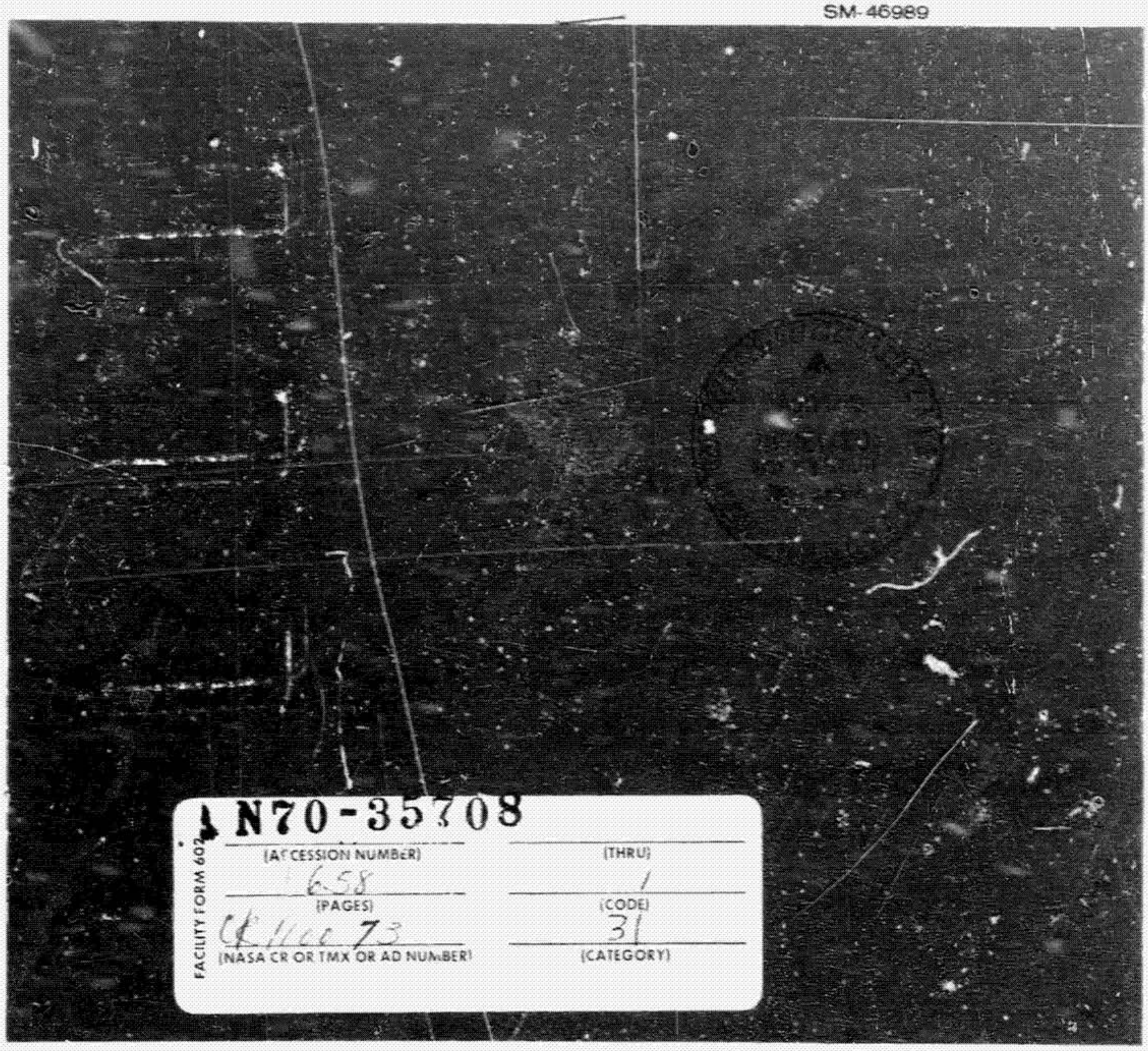

SATURN S-IVB-204 STAGE FLIGHT EVALUATION REPORT

PRIL 1968

DOUGLAS

MISSILE & SPACE SYSTEMS DIVISION

SATURN S-IVB-204 STAGE
FLIGHT EVALUATION REPORT

DOUGLAS REPORT SM-46989
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ABSTRACT

This report presents the evaluation results of the prelaunch countdown, powered flight, and orbital phase of the S-IVB-204 which was launched on 22 January 1968 as the second stage of the Saturn AS-204 vehicle.

All flight objectives were satisfied and the stage and ground support equipment functioned as anticipated.

The report is a contractual document as outlined in NASA Report MFSC-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 Douglas Aircraft Company, Missile and Space Systems Division.

DESCRIPTORS

Data Evaluation	S-IVB-204
Flight Test	Saturn AS-204 Vehicle
Saturn IB	Countdown

PREFACE

The purpose of this report is to document the evaluation of the S-IVB-204 flight stage which was launched from the Kennedy Space Center 22 January 1967.

This report, prepared in compliance with the National Aeronautics and Space Administration Contract NAS7-101 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. It was prepared by the Saturn S-IVB Test Planning and Evaluation Committee and coordinated by the Saturn S-IVB Project Office of the Douglas Aircraft Company, Missile and Space Systems Division.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

APPENDICES

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

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-204 stage.

Also described are tests conducted at Kennedy Space Center (KSC), and pertinent modifications made to the S-IVB stage and related ground support equipment.

This report is authorized by NASA Contract NAS7-101 and is the final report on the S-IVB-204 stage by the Douglas S-IVB Test Planning and Evaluation Committee of the Space Systems Center (SSC), Huntington Beach, California.

1.2 Background

The S-IVB-204 stage was assembled at SSC where a limited checkout was performed in the vehicle checkout laboratory prior to shipping the stage to Sacramento Test Center (STC).

The S-IVB-204 stage was successfully acceptance fired at STC on 18 March 1966. No confidence firings on the two APS modules were scheduled. Evaluation and analysis of the acceptance firing is presented in Douglas Report No. SM-47470, Saturn S-IVB-204 Stage Acceptance Firing Report.

The S-IVB-204 stage was shipped to KSC and was erected on Launch Complex L34. Space vehicle integrated umbilical in test was completed on 25 January 1967, two days before the fire in the space vehicle. The S-IVB-204 was transferred from Launch Complex L34 to Launch Complex L37B. The stage was successfully launched on 22 January 1968 at 2248:08.2 GMT.

Table 1-1 lists the milestones of the S-IVB-204 stage events and dates of completion from manufacturing to launch.

TABLE 1-1
MILESTONES, SATURN S-IVB-204 STAGE

EVENT	COMPLETION DATE
Tank Assembly	28 January 65
Proof Test	5 February 65
Insulation and Bonding	14 May 65
LH2 Tank Installation	25 June 65
Stage Checkout and Join J-2 Engine	7 October 65
Systems Checkout	17 December 65
Ship to Sacramento Test Center	10 January 66
Stage Installed on Test Stand	15 January 66
Prefiring Checkout	28 January 66
Integrated Systems Test	10 March 66
Simulated Static Test	14 March 66
Acceptance Firing	18 March 66
Removed from Test Stand	26 March 66
Final Post-Firing Checkout (VCL)	28 April 66
Simulated Flight Test (VCL)	2 May 66
Shipped to KSC	5 August 66
Erected on L34	31 August 66
Power on Stage	15 September 66
Full Pressure Test	28 October 66
Umbilical In OAT	28 December 66
Electrical Mate Space Vehicle	18 January 67
Integrated Umbilical In Test	25 January 67
De-erected Stage from L34	3 April 67
Re-erected Stage on L37	10 April 67
Power on State	18 April 67
Umbilical In OAT	4 August 67
Rerun Umbilical in OAT	15 December 67
Flight Readiness Test	22 December 67
APS Load and Burp Fire	15 January 68
CDDT	19 January 68
Launch	22 January 68

SECTION 2

SUMMARY

2. SUMMARY

The S-IVB-204 stage was successfully launched as the second stage of the SA-204/LM-1 launch vehicle on 22 January 1968. Liftoff occurred at 2248:08.2 hrs (GMT) from the Kennedy Space Center (KSC) Launch Complex L37B. The S-IVB-204 stage and its associated GSE performed satisfactorily during countdown, boost, and flight.

2.1 Countdown Operations

The S-IVB-204 countdown was initiated at liftoff minus 3 hr and 30 min. No hold or delays were attributed to the S-IVB stage; however, spacecraft chilldown problems and data acquisition ground station problems did cause the launch to slip approximately 4 hrs.

2.2 Cost Plus Incentive Fee

Performance of both the S-IB stage and the S-IVB stage was very close to that predicted. All preconditions of flight (PCF) were within tolerance; all actual end conditions of flight (ECF) values were within tolerance. With respect to the command signals: all received commands were recognized, and all end condition commands were given.

2.3 Trajectory

The AS-204 trajectory was close to that predicted and well within stage design trajectory conditions.

At S-IB/S-IVB separation, the S-IB had achieved a range 180 ft shorter; a velocity 13.6 ft/sec slower; an altitude 2,195 ft higher; and a burn-time of 0.06 sec longer than predicted. The conditions at S-IVB stage engine cutoff were very close to those predicted. The following tables present significant trajectory parameters for the S-IVB stage at S-IB S-IVB Separation Command and at S-IVB Engine Cutoff Command.

Trajectory Parameters at S-IB/S-IVB Separation Command

Parameter	Units	Actual	Deviation*
Range time	sec	143.50	0.06
Inertial velocity	ft/sec	7,761.4	-13.6
Altitude	ft	210,507	2,195
Range	ft	205,305	-180
Crossrange (earth-fixed)	ft	833	993
Crossrange velocity (earth-fixed)	ft/sec	8.86	6.46

Trajectory Parameters at S-IVB Stage Engine Cutoff Command

Parameter	Units	Actual	Deviation*
Range time	sec	593.34	-4.87
Inertial velocity	ft/sec	25,658.7	-2.3
Altitude	ft	536,164	758
Range	ft	5,791,547	-94,734
Crossrange (earth-fixed)	ft	287,303	-10,307
Crossrange velocity (earth-fixed)	ft/sec	1,731.1	-18.7
Inertial flight path elevation angle	deg	-.009	-.006

*Deviation is actual minus predicted

2.4 Mass Characteristics

At S-IVB-204 Engine Start Command, the mass of the remaining AS-204 vehicle was 297,035 ±638 lbm. At S-IVB-204 Engine Cutoff Command, the mass of the remaining AS-204 vehicle was 70,226 ±178 lbm. All total vehicle mass characteristics parameters were within tolerance throughout the flight although propellant loading values were higher than predicted.

2.5 Engine Analysis

The engine system performance of the S-IVB was satisfactory during the AS-204 mission. The engine operated with the propellant utilization valve in the closed position, providing higher thrust for a period of time longer than predicted. The higher thrust was offset by a reduction in burntime. A satisfactory experiment was conducted to verify the capability of the engine to dump propellants from the tanks after the conclusion of engine burn operations.

2.6 Solid Rockets

The solid rocket motors on the AS-204 launch vehicle performed satisfactorily and accomplished their intended purpose. The S-IB was separated from the S-IVB stage by the retrorockets, and the S-IVB propellants were settled prior to engine start by the ullage rockets.

2.7 Oxidizer System

The oxidizer system performed adequately throughout boost and powered flight. The LOX tank was satisfactorily prepressurized prior to liftoff. The ullage pressure was maintained within the prescribed control band after engine start. Cold helium supply and regulation were adequate. The recirculation chilldown system adequately chilled the LOX pump. LOX supply to the engine during the firing period was satisfactory, and the net positive suction pressure (NPSP) at the pump inlet was above minimum limits at all times.

The LOX tank orbital venting operations were satisfactorily accomplished. During cold helium dump, the LOX tank ullage pressure decay rate was much lower than expected and the vent valve closed indication picked up 1,134 sec after the close command, but neither of these impaired the mission.

The LOX dump through the J-2 engine was performed as planned with very little, if any, liquid remaining in the tank at the end of the programmed time. The total thrust at the termination of LOX dump substantiated the theory that essentially all of the liquid had been dumped.

2.8 Fuel System

The fuel system performed adequately throughout boost and powered flight. The LH2 tank pressurization system satisfactorily controlled the LH2 tank ullage pressure throughout powered flight. The recirculation chilldown system adequately chilled the LH2 pump. LH2 supply to the engine during the firing period was satisfactory, and the NPSP at the pump inlet was above minimum requirements at all times.

Three programmed LH2 vents occurred after J-2 engine cutoff and effectively safed the LH2 tank, thus obviating the need for LH2 dump.

2.9 Auxiliary Propulsion System

The auxiliary propulsion system (APS) operations were satisfactory. The APS modules provided roll control during S-IVB-204 powered flight and pitch and yaw control after S-IVB engine cutoff. During orbital coast the APS modules successfully compensated for induced disturbances.

2.10 Pneumatic Control and Purge System

The pneumatic control and purge system performed satisfactorily throughout the flight. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits; and all components functioned normally.

The pneumatic helium supply was more than adequate to meet the requirements of the AS-204 orbital mission. The usage was significantly lower than predicted which, with the unpredicted orbital heatup, resulted in a higher than predicted supply pressure. Passivation of the sphere was not technically accomplished during the 204 mission, but will be guaranteed on future missions by a longer sphere blowdown.

Cold helium passivation was accomplished by a backup to the normal method of passivation and the results indicate that the backup method was satisfactory.

2.11 Propellant Utilization System

The propellant utilization (PU) system successfully accomplished the requirements associated with propellant loading and management during engine burn. The best estimate propellant mass value at liftoff was 194,111 lbm LOX and 37,361 lbm LH2 as contrasted with the desired mass values of 193,273 lbm LOX and 37,440 lbm LH2.

Extrapolation of propellant residuals to depletion indicated that LOX depletion would have occurred approximately 7.46 sec after the guidance-initiated velocity cutoff with a usable LH2 residual of 144 lbm. This yields a PU efficiency of 99.94 percent.

PU valve cutback occurred at ESC +325.1 sec, which was 20.1 sec later than predicted. The extended cutback time was primarily caused by higher LH2 flowrates and a LOX overload.

2.12 S-IB/S-IVB Separation

Separation of the S-IVB stage was accomplished satisfactorily within the desired time period. First axial motion between the stages occurred 0.09 sec after Separation Command. Complete separation was accomplished 0.97 sec after Separation Command. Small S-IB and S-IVB angular velocities and lateral accelerations utilized 2.0 in. of the available 83 in. of lateral clearance. The S-IB pitch, yaw and roll rates remained below 0.5 deg/sec. The S-IVB rotational rates were small (±0.3 deg/sec), well below the maximum allowable rates.

2.13 Data Acquisition System

The performance of the data acquisition system was very good throughout the launch phase. All systems performed as designed, and no system malfunctions were observed. Ten measurements were deleted prior to liftoff but the measurement failures during the launch phase were very low. A summarization of the AS-204 launch vehicle measurements is presented below:

Measurements assigned	515
Checkout measurements	11

Prelaunch measurement	1
Measurement inoperative due to stage configuration	1
Measurement monitored by S-IB stage	5
Measurements deleted prior to liftoff	10
Total active measurements at liftoff	487
Measurement failures during launch phase	6
Measurement failures during orbital phase	2
Total measurement efficiency	98.33%

2.14 Electrical System

The electrical control system and the electrical power system performed satisfactorily. All responses to switch selector commands were satisfactory. All event measurements verified that the engine control system had responded properly to the Engine Start and Engine Cutoff Commands. A review of the event and pressure measurements verified that each control pressure switch functioned properly. The APS electrical control system performed within prescribed limitations. All batteries performed within expected limits. The chilldown inverters performed satisfactorily. Both 5 volt excitation modules performed satisfactorily. The static inverter-converter operated within design limits throughout the flight.

2.15 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.

2.16 Flight Control

The thrust vector control system responded satisfactorily to instrument unit attitude command signals and provided pitch and yaw control during S-IVB powered flight and during the first 80 sec of the LOX dump during the propellant removal test. Transient experienced during S-IB/S-IVB separation J-2 engine start, guidance mode changes, and the LOX dump were well within the capabilities of the control system. Control system data indicated the presence of low frequency, low amplitude oscillations during S-IVB powered flight. These oscillations have been experienced on previous flights and are attributed to a combination of propellant sloshing and limit cycle operation resulting from nonlinearities induced by gimbal bearing friction.

The auxiliary attitude control system (AACS) provided satisfactory roll stabilization during powered flight, and satisfactory pitch, yaw and roll control during orbit. During powered flight, unexpected high frequency and amplitude oscillations were observed on the roll rate gyro following guidance initiation which significantly effected roll control system operation. The high frequency oscillations damped to a relatively low amplitude after approximately 40 sec and roll control system operation appeared normal for the remainder of the flight. Sustained undamped oscillation could have resulted in a diverging roll attitude error and a potential loss of attitude control.

All orbital maneuvers were accomplished as planned and vehicle attitude control was verified until loss of signal at Tananarive during the seventh revolution (RO +36,078 sec). LVDC and IU data indicated an uncontrolled vehicle at acquisition of signal over Hawaii (RO +38,082 sec). This data indicates that although AACS firing commands were issued from the IU, the vehicle attitude did not respond to these commands. The available data indicates that the most probable cause is APS propellant depletion. Loss of attitude control occurred after the required time period of attitude control (4-1/2 hr) and was expected for the observed orbital conditions. Sufficient data is not available to confirm the cause of loss of attitude control.

2.17 Hydraulic System

The S-IVB hydraulic system performance was within predicted limits and the entire system operated satisfactorily throughout flight. All redlines were met prior to liftoff. There were no orbital thermal cycles and there was no loss of system fluid due to overboard venting as a result of reservoir fluid thermal expansion. System internal leakage was 0.72 gpm which is well within the 0.4 to 0.8 gpm allowable.

2.18 Stage Structure and Environment

Strain, acceleration, pressure, and temperature data indicated that adequate structural strength existed in the stage for the conditions encountered. Body bending moments and skin differential pressures were less than the maximum predicted values due to comparatively moderate wind shears and gusts. Maximum vehicle axial accelerations at S-IB IECO was identical to predicted values. Axial load values were in agreement with predicted values from liftoff to approximately 80 sec of flight. After this time the axial loads were slightly greater than predicted, apparently due to aerodynamic heating and because of a partial integration resulting from the limited number of instrumented stringers. Axial strains in the aft skirt stringers were as predicted for the strain gages mounted on the sides and tops of the stringers. Flight temperatures did not exceed maximum predicted temperatures. Propellant tank pressures did not exceed design pressures. Differential pressures on the common bulkhead were as expected. Internal common bulkhead pressure remained substantially constant at less than 1 psia as predicted.

2.19 Environmental Control Systems

The forward skirt thermoconditioning system operated satisfactorily throughout powered flight. The inlet pressure was essentially constant at 46 psia as was the outlet pressure at 28.5 psia, with the flowrate maintained at 8.3 gpm. There were no significant variations in the outlet temperature of the fluid.

The purge system provided a satisfactory ambient atmosphere of 60 deg F in the S-IVB forward skirt area prior to launch. The aft skirt thermoconditioning and purge system maintained the APS module oxidizer and fuel tank temperatures within their launch limits during the countdown.

2.20 Acoustic and Vibration Environment

Thirty vibration, six acoustical, and sixteen dynamic strain measurements were monitored. The vibration and acoustic environments were comparable to those measured on the AS-203 flight. The dynamic strain measurements showed that panel flutter did not occur and that the dynamic strain levels due to random pressure fluctuations in the boundary layer were significantly lower than those measured during the qualification test. The duration of the maximum levels were also significantly less during flight.

2.21 Aero/Thermodynamic Environment

The aero/thermodynamic instrumentation consisted of pressure transducers to measure external pressure distribution and internal compartment pressures, and temperature transducers to measure structural temperatures, select component temperatures, and propellant heating. In general, the data were within stage design limits and the measurement objectives were satisfactorily accomplished.

2.22 Propellant Dump Experiment

A propellant dump experiment was conducted on the S-IVB-204 stage approximately one and one-half hr after LM-1 separation to evaluate the feasibility of dumping propellants through the J-2 engine. Pitch and yaw control was maintained during the dump by engine gimbaling (Thrust Vector Control). In addition, programmed venting of the pneumatic control sphere and cold helium spheres was conducted to evaluate the time periods necessary to insure adequate depletion of sphere residuals in preparation for future missions.

LOX and LH2 dumps were successfully completed although the LH2 residuals had been reduced to zero prior to the actual dump experiment. Venting of the pneumatic control sphere and cold helium spheres were conducted as planned, although the vent periods were not of sufficient duration to completely empty the spheres.

SECTION 3

TEST CONFIGURATION

3. CONFIGURATION

3.1 Stage General

The general configuration of the S-IVB-204 stage is described in the Douglas Report No. SM-46977D, S-IVB-204 Stage Flight Test Plan, dated 9 August 1967 and revised 18 January 1968. Additional stage configuration information is presented in table 3-1.

3.2 Propulsion Stage and GSE Systems

Figure 3-1 is a schematic of the S-IVB-204 stage propulsion system and shows the locations of the telemetry instrumentation from which the test data were obtained. Figure 3-2 shows the location of the major propulsion components. The functional propulsion system components are listed in table 3-2; the APS components are called out on the APS schematic. The propulsion system orifice characteristics and pressure switch settings are presented in tables 3-3 and 3-4.

The propulsion GSE (figure 3-3) consisted of pneumatic consoles (Models 432, 433, and 436), a vacuum system console, a gas heat exchanger (Model 438), and umbilical kits (Models DSV-4B-353 and DSV-4B-354).

Those stage and ground support equipment modifications and deviations that were necessitated by parts shortages or other exigencies are presented in tables 3-5 and 3-6. The details of specific system modifications are discussed in appropriate sections of this report.

3.3 Structural Mechanical Systems

Configuration descriptions and schematics of the S-IVB-204 stage are contained in the publication documents as listed in table 3-1. Significant modifications and deviations that were accomplished at Florida Test Center are presented in tables 3-7 and 3-8.

3.4 Electronic and Instrumentation System

Configuration description of the electronic and instrumentation system are contained in the publication documents as listed in table 3-1. Significant modification and deviations to the electrical and instrumentation system are presented in tables 3-9 and 3-10 respectively.

TABLE 3-1
S-IVB-204 CONFIGURATION PUBLICATIONS

REPORT NO.	TITLE	RELEASE DATE
SM-46804	Saturn S-IVB-204 Stage Acceptance Firing Test Plan	January 1966
1B59668B	Saturn S-IVB-204 Stage End Item Test Plan	5 May 1966
SM-53183	Saturn S-IVB-204 Narrative End Item Report	May 1966
SM-47470	Saturn S-IVB-204 Stage Acceptance Firing Report	May 1966
SM-47184	Saturn S-IVB/IB Range Safety Report	19 November 1965 revised 28 February 1966
SM-46977D	Saturn S-IVB-204 Stage Flight Test Plan	9 August 1966 revised 5 November, 16 December, 17 January and 18 January 1966

TABLE 3-2 (Sheet 1 of 5)
STAGE HARDWARE LIST - S-IVB-204 FLIGHT

FIND NO.*	PART NO.	NAME
1	7851861-1	Disconnect, LH2 pressurization
2	1B53817-505	Valve, hand, LOX vent and relief valve and LOX sensing line purge
3	1B65673-1	Valve, check, LH2 prepressurization
4	1A57350-507	Module, control helium dump
5	1A49990-505	Sphere, control helium, 4.5 cu ft
6	1A58345-517	Module, pneumatic power control
7	7851823-503	Disconnect, ambient helium fill
8	1B51361-1	Valve, check control helium fill
9	1A48857-501	Plenum, control helium, 100 cu in.
10	1B68260-501	Disconnect, LH2 ground vent
11	1B53817-505	Valve, hand, LH2 chilldown valve, LH2 vent and relief valve, LH2 nonpropulsive vent, LH2 fill and drain valve, and LOX fill and drain valve purge
12	1B40622-507	Orifice, LH2 chilldown valve purge, 14 scfm with 3,200 psid
13	1B51361-1	Valve, check, LH2 fill and drain valve and nonpropulsive vent purge
22	1A49982-509	Module, actuation control, LH2 fill and drain valve
22A	1B67481-1	Valve, check, LH2 fill and drain valve actuation control module vent
23	1B40622-505	Orifice, LH2 fill and drain valve purge, 15 scfm with 3,200 psid
24	1B66932-501	Disconnect, LH2 fill and drain
25	1A48240-505	Valve, LH2 fill and drain
26	1B41065-1	Disconnect, common bulkhead vacuum system
27	1B66932-501	Disconnect, LOX fill and drain
28	1B51361-1	Valve, check, LOX fill and drain valve purge

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

TABLE 3-2 (Sheet 2 of 5)
STAGE HARDWARE LIST - S-IVB-204 FLIGHT

FIND NO.*	PART NO.	NAME
29	1B40622-505	Orifice, LOX fill and drain valve purge, 15 scfm with 3,200 psid
30	1A48240-505	Valve, LOX fill and drain
31	1A49982-509	Module, actuation control, LOX fill and drain valve
31A	1B67481-1	Valve, check, LOX fill and drain valve actuation control module vent
32	1B57781-505	Module, cold helium dump
33	1B40824-507	Valve, check, cold helium fill
34	1B42290-505	Module, control, LOX tank pressurization
35	7851844-501	Disconnect, cold helium fill and LOX tank prepressurization
36	1B40824-507	Valve, check, cold helium fill and LOX tank prepressurization
37	1A49991-1	Plenum, LOX tank pressurization, 250 cu in.
38	7851830-517	Switch, pressure, cold helium regulator backup, P/U 465 +20, -15 psia, D/O 350 +20, -15 psia
39	1B63046-515	Orifice, LOX tank pressurization module, heat exchanger primary
40	1B63047-515	Orifice, LOX tank pressurization heat exchanger bypass
42	1A49958-517	Disconnect, mainstage OK pressure switch checkout
42A	1A49958-519	Disconnect, thrust chamber jacket purge and chilldown
43	1B55200-505	Module, control, LH2 tank pressurization
44	1B64443-505	Orifice, LH2 pressurization overcontrol
45	1B66230-501	Orifice, LH2 pressurization, normal undercontrol
46	1B66230-501	Orifice, LH2 pressurization step
48	1B40622-501	Orifice, LH2 tank nonpropulsive vent purge, 1 scfm with 3,200 psid
49	1B59265-1	Orifice, LH2 tank nonpropulsive vent No. 1, 2.180 in. dia

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

TABLE 3-2 (Sheet 3 of 5)
STAGE HARDWARE LIST - S-IVB-204 FLIGHT

FIND NO.*	PART NO.	NAME
50	1B59265-1	Orifice, LH2 tank nonpropulsive vent No. 2, 2.180 in. dia
51	1A49988-1	Valve, directional, LH2 tank vent
52	7851860-537	Switch, pressure, LH2 flight control, P/U 34 psia max, D/O 31 psia min
53	7851860-537	Switch, pressure, LH2 prepressurization and ground fill, P/U 34 psia max, D/O 31 psia min
54	1A49591-531	Valve, relief, LH2 tank, crack 40 psia max, reseat 37 psia min
55	1A48257-505	Valve, LH2 tank vent and relief, crack 39 psia max, reseat 36 psia min
56	1A48858-1	Sphere, cold helium, 3.5 cu ft
57	1A77907-509	Probe, LH2 tank instrumentation
57A	1A48430-507	Probe, LOX mass sensor
58	1B65812-1	Diffuser, LH2 tank pressurization
59	1A48431-501	Probe, LH2 mass sensor
59A	1A69275-505	Probe, LOX instrumentation
60	1A49421-501	Pump, LH2 chilldown
61	1A48854-1	Orifice, LOX chilldown pump purge, 37 scim with 3,500 psid
61A	1B40622-511	Orifice, LOX chilldown pump purge
62	1A58347-505	Module, LOX chilldown pump purge
63	7851847-535	Switch, pressure, LOX chilldown pump purge backup, P/U 54 psia max, D/O 49 psia min
64	1A49423-507	Valve, relief, LOX chilldown pump purge (part of pump assembly)
65	1A67913-1	Valve, dump, LOX chilldown pump purge
66	1A49423-507	Pump, LOX chilldown
67	1A49964-501	Valve, check, LOX chilldown return
68	1A49965-525	Valve, LOX chilldown shutoff

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

TABLE 3-2 (Sheet 4 of 5)
STAGE HARDWARE LIST - S-IVB-204 FLIGHT

FIND NO.*	PART NO.	NAME
69	1A89104-507	Flowmeter, LOX chilldown
71	1B52985-501	Filter, LOX chilldown pump discharge
72	1A49968-509	Prevalve, LOX
73	7851847-533	Switch, pressure, LOX prepressurization, ground and flight control, P/U 40.8 max, D/O 37 min
73A	1B40622-501	Orifice, LOX sensing line purge, 200 scim with 550 psid
73B	10414087**	Valve, hand, LOX tank pressure switch shutoff
78	1A49982-509	Module, actuation control, directional valve
78A	1B67481-1	Valve, check, directional valve actuation control module vent
79	1A49982-509	Module, actuation control, LH2 tank vent and relief valve
79A	1B67481-1	Valve, check, LH2 tank vent and relief valve actuation control module vent
82	1B51361-1	Valve, check, LOX vent and relief valve purge
91	1B63206-1	Orifice, LOX tank vent and relief valve purge, 65 scfm with 3,200 psid
101	1A49590-515	Valve, relief, LOX tank, crack 45 psia max, reseat 42 psia min
104	1A48312-501	Valve, vent and relief, LOX tank, crack 44 psia max, reseat 41 psia min
107	1A49982-509	Module, actuation control, LOX tank, vent and relief valve
107A	1B67481-1	Valve, check, LOX tank vent and relief valve actuation control module vent
110	1A49968-507	Prevalve, LH2
111	1B52985-501	Filter, LH2 chilldown pump discharge
112	1B53920-503	Valve, check, LH2 chilldown pump discharge
113	1A89104-509	Flowmeter, LH2 chilldown pump discharge
114	1A49965-523	Valve, shutoff, LH2 chilldown line

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

**Ordnance number

TABLE 3-2 (Sheet 5 of 5)
STAGE HARDWARE LIST - S-IVB-204 FLIGHT

FIND NO.*	PART NO.	NAME
115	1A49982-509	Module, actuation control, chilldown valves and prevalves
115A	1B67481-1	Valve, check, chilldown valves and prevalves actuation control module vent
116	1A49964-501	Valve, check LH2 chilldown return
120	1A58347-507	Module, engine purge cont. 1, 0.00166 lbm/sec with 475 psig in and 85 psig out
121	1A67002-509	Switch, pressure, engine purge module backup, PU 130 psia max, D/O 105 psia min
122	1A49958-521	Disconnect, engine start sphere vent and relief valve drain
123	1A49958-515	Disconnect, engine control helium sphere fill
124	1A49958-523	Disconnect, engine start sphere fill
125	1A49938-517	Disconnect, LH2 pump seal drain
126	1A49958-517	Disconnect, LOX pump seal drain

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

TABLE 3-3 (Sheet 1 of 4)
SATURN S-IVB-204 STAGE AND GSE ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
	Stage			
12	LH2 chilldown valve purge	14 scfm with 3,200 psid	--	sintered
23	LH2 fill and drain valve purge	15 scim with 3,200 psid	--	sintered
29	LOX fill and drain valve purge	15 scim with 3,[illegible] psid	--	sintered
39	LOX tank pressurization module heat exchanger primary	0.196 in. dia	0.87	0.0262
40	LOX tank pressurization module heat exchanger bypass	0.166 in. dia	0.88	0.[illegible]
44	LH2 tank pressurization module overcontrol	--	--	0.107
45	LH2 tank pressurization module undercontrol	--	--	0.0730
46	LH2 tank pressurization	--	--	0 167
48	LH2 tank nonpropulsive vent purge	1 scfm with 3,200 psid	--	sintered
49	LH2 tank nonpropulsive vent No. 1	2.180 in. dia	--	--
50	LH2 tank nonpropulsive vent No. 2	2.180 in. dia	--	--
61	LOX chilldown pump purge	37 scim with 475 psid	--	sintered
61A	LOX chilldown pump purge bypass	10 scim with 475 psid	--	sintered
62	LOX chilldown pump purge module	0.00166 lbm/sec with 475 psig in and 85 psig out	--	--

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

TABLE 3-3 (Sheet 2 of 4)
SATURN S-IVB-204 STAGE AND GSE ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
73A	[illegible]k sensing line purge	200 scim with 550 psia	--	sintered
91	LOX tank vent and relief valve purge	65 scfm with 3,200 psid	--	sintered
120	Engine purge control module	0.00166 lbm/sec with 475 psig in and 85 psig out	--	--
	<u>Pneumatic Console 432</u>			
A11748	Console 432 stage 1 bleed	--	--	--
A11779	Mainstage OK pressure switch checkout, fine	0.025 in. dia	--	--
A11792	Pressure switch checkout, low pressure, coarse (used with A11793)	0.015 in. dia	--	--
A11793	Pressure switch checkout, low	0.015 in. dia	--	--
A11806	Pressure switch checkout, high pressure, fine	0.018 in. dia	--	--
A11810	Pressure switch checkout, high pressure, coarse (used with A11806)	0.018 in. dia	--	--
A11820	LH2 system checkout supply, coarse (used with A11824)	0.016 in. dia	--	--
A11824	LH2 system checkout supply, fine	0.016 in. dia	--	--
A11836	LOX system checkout supply, coarse (used with A11837)	0.016 in. dia	--	--
A11837	LOX system checkout supply, fine	0.016 in. dia	--	--

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

TABLE 3-3 (Sheet 3 of 4)
SATURN S-IVB-204 STAGE AND GSE ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
A11841	Console 432 GN2 inerting supply	0.031 in. dia	--	--
A11852	APS helium sphere fill	0.027 in. dia	--	--
A12054	Mainstage OK pressure switch checkout, coarse (used with A11779)	0.025 in. dia	--	--
A12078	Stage 2 regulator vent	--	--	--
A12119	Stage 1 regulator dome bleed	--	--	--
A12113	Stage 4 regulator vent	--	--	--
A12116	Stage 5 regulator vent	--	--	--
	Pneumatic Console 433			
A11886	2,000 psig cold purge valve supply	--	--	--
A11897	750 psig cold purge valve supply	--	--	--
A11908	Umbilical purge supply bleed	--	--	--
A11912	Umbilical purge supply	0.305 in. dia	--	--
A11937	Thrust chamber jacket purge and chilldown supply	0.072 in. dia	0.89	0.00360
A11946	Engine control helium sphere supply	0.125 in. dia	0.84	0.01033
A11954	LOX tank prepressurization supply, located in model 315 (aft umb kit)	0.114 in. dia	0.88	0.00898
A11954	Cold helium sphere pressurization supply (same orifice as above)	--	--	--

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

TABLE 3-3 (Sheet 4 of 4)
SATURN S-IVB-204 STAGE AND GSE ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
A12152	Stage 3 regulator outlet bleed	0.0022 lbm/min	--	sintered
A12153	Stage 3 regulator inlet	0.180 in. dia	--	--
	Heat Exchanger (438)			
A11971	LH2 tank prepressurization supply	0.162 in. dia	0.90	0.01855
A12106	Circuit number 1 upstream vent	0.081 in. dia	--	--
A12117	Circuit number 1 downstream vent	0.550 in. dia	--	--
A12234	GH2 regulator dome bleed	0.0003 in. dia	--	sintered

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

TABLE 3-4
PRESSURE SWITCH CHECKOUT DATA

NOMENCLATURE	SPECIFICATION	PICKUP (psia)	DROPOUT (psia)	DEAD BAND (psi)
LOX Tank Prepress P/N 7851847-533 Serial No. 104	Pickup: 40.8 psia max Dropout: 37 psia min Dead Band: 0.5 psi min	39.7	37.1	2.6
Cold He Reg Backup P/N 7851830-517 Serial No. 110	Pickup: 450-485 psia Dropout: 335-370 psia Dead Band: None	461	353	108
LOX C/D Pump Purge P/N 7851847-535 Serial No. 106	Pickup: 54 psia max Dropout: 49 psia min Dead Band: 0.5 psi min	51.6	48.7	2.9
Engine Pump Purge P/N 1A67002-509 Serial No. 104	Pickup 130 psia max Dropout: 105 psia min Dead Band: 5.0 psi min	125.4	114.7	107
LH2 Tk Fill Valve Control P/N 7851860-537 Serial No. 109	Pickup: 34 psia max Dropout: 31 psia min Dead Band: 0.5 psi min	33.4	31.1	2.3
LH2 Flight Control P/N 7851860-537 Serial No. 112	Pickup: 34 psia max Dropout: 31 psia min Dead Band: 0.5 psi min	33.5	31.6	1.9
Control He Reg Backup P/N 7851830-521 Serial No. 1022	Pickup: 600 ±15 psia Dropout: 490 ±25 psia Dead Band: None	595	491	104
Mainstage OK No. 1 P/N NA5-27302 Serial No. 25301	Pickup: 500 ±15 psig Dropout = Pickup minus 75 ±25 psig	512	437	75
Mainstage OK No. 2 P/N NA5-27302 Serial No. 25302	Pickup: 500 ±15 psig Dropout = Pickup minus 75 ±25 psig	510	430	80
Orbit Vent Initiation P/N 1A67005-507 Serial No. 100	Pickup: 35.5 ±0.75 psia Dropout: 31 psia min Dead Band: 0.5 psi min	35.1	31.4	3.7
Orbit Vent Termination P/N 1B39199-503 Serial No. 105	Pickup: 30.0 psia max Dropout: 25 ±1 psia Dead Band: 0.5 psi min	27.1	25.5	1.6

TABLE 3-5 (Sheet 1 of 5)
STAGE MODIFICATIONS - PROPULSION

WRO	ECP	DESCRIPTION
538	--	Installation of Rocketdyne ECP's.
	J2-470 R1	Replacement of the purge control valve.
	J2-511	Installation of a filter assembly at the accumulator outlet flange.
	J2-513	Retiming of the main oxidizing valve.
	J2-538	Installation of Schrader valves on spark ignitor cable.
	J2-547	Installation of four (4) temperature sensors on the engine to provide an inflight capability of monitoring exhaust system component temperature.
	J2-551	Removal of the ASI chamber pressure line braze joint which is susceptible to failure.
	J2-557	Installation of silicone elastomer insulation to provide thermal protection of the ECA.
	J2-575	Replacement of a section of the ASI LOX line assembly with a standard in-line weld sleeve.
	J2-594	Addition of start tank pressurization instrumentation to prevent a countdown hold due to a failure of a single transducer in the start tank.
	J2-590	Application of Dynatherm coating to the turbine crossover duct.
	J2-603	Checkout procedure change in conjunction with helium regulator.
	J2-605	Replacement of the fuel inlet duct vent port check valves and bleed port plugs
	J2-607	Replacement of the vent port check valves.
	J2-616	Addition of a pressure transducer to measure the thrust chamber pressure.

TABLE 3-5 (Sheet 2 of 5)
STAGE MODIFICATIONS - PROPULSION

WRO	ECP	DESCRIPTION
376A	0354	Installation of thermal gaskets and shims on the ambient helium fill module to raise its operating temperature.
399A	0493	Replacement of LH2 and LOX chilldown valves which include redesigned actuator bellows.
2765	0534	Replacement of the redesigned tank relief valve which includes a new spring guide.
2795	0565	Replacement of the redesigned fill and drain valve to assure consistent predictable closing operation.
2846	0493	Replacement of the redesigned chilldown valves to reduce leakage.
2849	0592	Deletion of the APS helium fill module.
2863	0593	Modification of the pneumatic system by removing and replacing six (6) actuation control modules.
2905	0616	Modification of the pneumatic supply system to install a 4.5 cu ft helium storage bottle and associated piping in place of the existing bottle.
2913	0633	Modification of the mount, resilient LH2 propellant duct to replace the staked uniball joint with a solid bushing and collar.
2915	0630	Modification of the LOX inlet duct to provide a positive clearance between the bellows and the shroud covering the bellows.
2930	0557	Install APS helium pressure regulator which incorporates a redesigned bellows to meet environmental and performance requirements.
2959	0663	Modification of the LH2 inlet duct to provide adequate clearance between the bellows and shroud.

TABLE 3-5 (Sheet 3 of 5)
STAGE MODIFICATIONS - PROPULSION

WRO	ECP	DESCRIPTION
2985	0597	Modification of the seal and support flanges on the flight half of the LOX and fuel fill disconnects.
3021	0699	Rework of the LOX tank ullage transducer line to provide for a low pressure purge system. This is due to cyclical pressure surges of LOX boiloff trapped in the sensing lines causing erratic ullage pressure indications.
3027 R1	0648 R2	Deletion of the relief valve from the ambient helium fill module. The stage no longer requires an onboard relief valve as the relief function exists in the GSE supply.
3049	1008	Provide a redundant means of EDS J-2 Engine cutoff.
3086	2033	Replacement of six (6) pipe assemblies attached to the pneumatic power control module and the engine pump module. New pipe assemblies shall include coils that will allow more movement of the shock mounted modules.
3156	2046	Relocate pressure transducer (D0016) in order to provide required thermal isolation.
3197 R1	2060 R2	Replacement of check valve, P/N 1B40824-503, with valve, P/N 1B40824-503-005, which has a redesigned poppet seal to reduce leakage.
3207	0936	Replacement of the LOX relief valve, P/N 1A49590-513, with relief valve, P/N 1A49590-016-017, which has been verified not to chatter at relief pressure.
326[illegible]	2117 R1	Addition of a check valve in the actuation control module vent port. This will preclude the possibility of freezing the shutoff valves.

TABLE 3-5 (Sheet 4 of 5)
STAGE MODIFICATIONS - PROPULSION

WRO	ECP	DESCRIPTION
3310	2124	Modification of the LOX chilldown pump to include an improved shaft seal spring. Existing spring failed the qualification testing.
3314 (3519)	2180 R2	Replacement of the LOX relief valve with a redesigned valve which has a larger diameter threaded shaft in the pilot poppet. This change provides greater poppet shaft strength.
3372	2175	Installation of a bypass line and orifice in the LOX chilldown pump container purge line to assure positive pressure in the LOX pump motor container in the event of solenoid failure in the chill pump purge module.
3518	2334 R2	Replacement of the fuel relief valve with a redesigned valve which has a larger diameter threaded shaft in the pilot poppet. This change provides greater poppet shaft strength.
3533	2244	Replacement of the pneumatic power control modules having new shutoff valve seats and new vent valve seats. These changes correct the low temperature operational and leakage problems.
3542	2304	Replacement of the LOX tank pressurization control module with a more qualified unit.
3553	2253 R2	Redesign of the flight half of the LH2 vent disconnect to reduce leakage. Efforts to develop a new seal (ECP 2253-R1) have been unsuccessful.
3564	2269	Rework of the chill system shutoff valve to provide a new microswitch actuator spring for the open position indication switch. This will enable the present bellows shaft to actuate the switch during critical component cycling.

TABLE 3-5 (Sheet 5 of 5)
STAGE MODIFICATIONS - PROPULSION

WRO	ECP	DESCRIPTION
3652	2308	Installation of a locking device for the cover of the vacuum seal off valve to prevent loosening of the vacuum seal off valve.
3719	2434	Replacement of the J-2 engine/stage thrust mount attach bolts with bolts that are certified to meet specification requirements.
3756	2425 J2-620 R1	Installation of an overboard dump for the J-2 engine LOX pump primary seal cavity drain to minimize hazardous conditions within the aft interstage during boost.
3863	2311 R1	Modification of the LH2 pressurization system by replacing the 26.5 to 29.5 psi pressure switch with a 31-34 psi pressure switch and resizing the sintered orifice in the pressurization control module.
3956	2621	Replacement of the LOX tank pressurization control module with units having Belleville springs installed subsequent to August 1967. Potential stress corrosion of the Belleville spring exists in older modules.

TABLE 3-6 (Sheet 1 of 3)
GROUND SUPPORT EQUIPMENT MODIFICATION

WRO	ECP	MODEL	DESCRIPTION
2402	N/A	438-1	Installation of RF filters in the power lines to bring unit within tolerance of EMI testing.
2502	N/A	353	Modifies the aft umbilical kit to add a restrictor and tube assembly to the LOX tank pressurization supply disconnect and a tube assembly to the LH2 fill line sample port.
2570	0341-2	438-1	Modifies unit by replacing the check valve in the 50 psi helium line with a new part to meet specification requirements.
2606	0459	433-1	Replaces two (2) 3/4 in. tubes to correct their end point connections.
2786	0546	436-1	Reworks the filter elements to incorporate a new element compressor screw and a filter element flow deflective washer.
2747	0393	432-1	Removes the GN2 crossover to provide for the elimination of the GN2 post purging requirement in order to prevent system contamination.
2838	0562	438-1	Replacement of one (1) 6 in. butterfly valve to incorporate new lip seal design.
3023	0606-1 -3	432 433	Removal of the pneumatic plumbing comprising the nitrogen and helium manifold vent system. Removal of the manifold system will provide individual leak check capability and thus shorten console checkout.
3047	0597	353	Modification of the ground half of LOX and LH2 disconnects by the addition of an offset split ring.
3105	0931	438-1	Modification of the pneumatic valve, P/N 7864252, to eliminate the abrupt transition between the wrenching flats and the full diameter of the shaft.
3123	5004 R2	438	Painting of all external uninsulated tubing and vacuum jacketed lines. Exposure to the sea-coast atmosphere has caused extensive pinhole corrosion in the tubing and lines. Painting of the lines will curb corrosion.

TABLE 3-6 (Sheet 2 of 3)
GROUND SUPPORT EQUIPMENT MODIFICATION

WRO	ECP	MODEL	DESCRIPTION
''31	0952	433	Addition of an orifice to the LOX umbilical purge system to keep the regulator leakage from reaching system relief setting.
3159	0458	432-1 -2	Replacement of the 50 psi purge supply pressure transducer.
3172	2050	353	Addition of a check valve in the purge vent port. This will prevent moisture from entering the valve interior and causing failure.
3195	2022	353	Replacement of bushing on the swing arm withdrawal mechanism attach bracket since the existing bushing is too long for use with the MSFC supplied bracket.
3199	2059-1 -3 -5 -7	432 433 436 438	Rework of the manually operated regulator, P/N 1B37340, to replace "O" rings, seats and lubricant in order to meet low temperature requirements.
3237	2082	438	Installation of a check valve in the outlet of the LH2 tank prepressurization supply vent valve to allow ambient vent of the GHe.
3279	2024	438	Addition of a pressure gage to the gas heat exchanger to indicate its ullage pressure.
3351	2159	438	Replacement of the 3 micron cold gas filter with unit that has passed the cold leakage requirement.
3407	2186-1 -3	432 433	Rework of the 6000 psig solenoid valve to include a new bonnet and "O" ring gland which have been qualification tested.
3655	2058	433	Modification of the LOX umbilical purge supply circuit to provide a nominal 50 psia system by replacing components with units which have a lower psig range.
-	2222	433	Installation of a continuous GN2 purge to the console J-box to curb corrosion of electrical components.

TABLE 3-6 (Sheet 3 of 3)
GROUND SUPPORT EQUIPMENT MODIFICATION

WRO	ECP	MODEL	DESCRIPTION
3766	2455	354	Revision of hydrogen vent disconnect ground half bellows.
3768	2416	303	Permanent sealing of the console to maintain a static pressure of two (2) in. of water.
3786	2459 R1	432 433 438	Sealing of the consoles to maintain a static pressure of two (2) in. of water.
3788	2458	432	Installation of a relief valve downstream of the 2,000 psi preset regulator. This will protect the system in the event the regulator fails.
3831	2510	438	Application of sealant to the GH2 system purge solenoid valve to prevent moisture from entering the valve.
3910	0955 R1	433	Replacement of the 1/4 in. check valve in the cold helium vent system with a 3/4 in. check valve.
3919	0966	303	Sealing of the console to maintain a static pressure of 2 inches of water.
3926	0967	433	Addition of a relief assembly to the console to relieve excessive pressure buildup in the console when warming purge is used.
39[illegible]7	2626	353	Addition of 3 helium control orifices, 2 pressure monitor ports, and 3 nitrogen control orifices. This will effectively distribute the He and N2 purge gas, thereby optimizing gas consumption.
		354	Addition of a metal shroud around the H2 vent disconnect. The carrier plate shall be tapped to receive the He gas supply for purging. This will provide an inert atmosphere around the hydrogen vent disconnect, preventing the formation of liquid air.

TABLE 3-7 (Sheet 1 of 3)
STAGE MODIFICATIONS - STRUCTURES

WRO	ECP	DESCRIPTION
864	X190	Replacement of Douglas furnished quick disconnects in the thermoconditioning system.
331A	0321	Installation of brackets and associated hardware for the aft interstage to support the lines of the hazardous gas detection system.
2877	0590	Substitution of mylar material (Schjeldahl-X850) for the mylar previously being used.
2936	0585	Installation of a drag-in cable door in the aft interstage for cables and hoses which previously entered the stage through the aft interstage access door and caused a safety hazard.
2966	0667	Reduction of the forward skirt vent area from 200 sq in. to 100 sq in. (Subsequently changed to 150 sq in. per ECP 0330 R2, reference WRO 3462)
2971	0671	Modification of the Safety and Arming Device to add vent holes in the device body in line with the rotor explosive leads with the rotor in the safe position.
3028	0692	Addition of external insulation on main and auxiliary tunnels.
3111	0939	Replacement of the field splice sealant along the separation plane between the aft interstage and the aft skirt to avoid separation problems.
3145	0965	Removal of all the existing Korotherm insulation and primer from all the stringer tops and sides on the aft interstage. Addition of Silicone insulation, Dow-Corning 93-044 over the entire stringer. Addition of Silicone sealer, Dow-Corning 92-009, to the forward and aft skirts. Application of the Silicone sealer will prevent flaking of the Korotherm.
3256	1012	Installation of the 40M39515-119 retrorocket firing units. The -119 firing unit is a high reliability part.

TABLE 3-7 (Sheet 2 of 3)
STAGE MODIFICATIONS - STRUCTURES

WRO	ECP	DESCRIPTION
3258	0653	Change of the stage forward and aft umbilical panel markings to agree with the markings on the hose and cable assemblies of the GSE umbilical kits.
3291	2130	Eddy current testing of all helium pressure vessels which are fabricated with titanium alloys using filler wire to verify filler wire is of the same composition as the vessel parent metal.
3327	2078 R1	Reduction of thermal emissivity by the installation of an aluminum shroud between the forward skirt cold plates and the stage structure.
3359	2164	Modification of the EBW wiring support to prevent chafing the EBW cable.
3462	0330 R2	Modification of the vent holes in the forward skirt to increase the vent area from 100 sq in. to 150 sq in. in order to prevent flutter.
3488	2212	Addition of Korotherm insulation to the forward skirt, LH2 tank, aft skirt, and the aft interstage to meet aerodynamic heating requirements.
3493	2079 R2	Installation of rain baffles in the ECS vents on the forward skirt and the aft interstage to prevent rain from entering the stage.
3494	0944	Modification of the thermoconditioning supply line supports to prevent interference with the supply line.
3585	2179	Modification of the thermoconditioning return line support in the forward skirt to accomodate the revised end fitting of the IBM furnished flex line.
3718	2487	Replacement of the retrorocket motors, P/N 1B59670-501 with P/N 1B59670-505. The -505 will reduce the possibility of motor case burnout.

TABLE 3-7 (Sheet 3 of 3)
STAGE MODIFICATIONS - STRUCTURES

WRO	ECP	DESCRIPTION
3901	2597	Reinforcement of the main and auxiliary tunnel clips by bonding fiberglass doublers across the tunnel support assemblies and onto the LH2 tank.
3913	0962 R1	Addition of caterpillar grommets to holes where the LOX tank shape charge CDF passes through the ambient helium bottle support pan and thrust structure to protect CDF from chafing.
3934	2615	Thermally isolating the actuation control module from the thrust structure.

TABLE 3-8
STAGE MODIFICATION - HYDRAULICS

WRO	ECP	DESCRIPTION
2833	0575	Rework of the auxiliary hydraulic pump assemblies to replace the pressure control spring guide.
2899	0600	Redesign of the high pressure check valve used in the vehicle engine driven pump assembly to conform to the burst pressure requirement of 9,200 psi without valve failure.
2995	0685	Redesign of the accumulator reservoir aft support clip so that it will adequately support the accumulator reservoir.
2999	0682	Replacement of compensator "O" rings to prevent excessive leakage and incorporating higher torque requirements on the compensator hold-down bolts.
3090	2037 R1	Replacement of the compensator attach bolts to the engine driven hydraulic pump to be compatible with increased torque requirements.
3198	2061	Removal of seal lock relief valve from auxiliary pump assembly and replace the "O" ring seal on the poppet seat with a new "O" ring.
3240	2073 R1	Application of protective coating to aluminum parts of hydraulic actuators.

TABLE 3-9 (Sheet 1 of 3)
STAGE MODIFICATION - ELECTRONICS

WRO	ECP	DESCRIPTION
361A	0302	Modify the PU system shaping network to obtain increased attenuation at slosh frequencies.
479A	0449	Modified the thermoconditioning panel on the forward skirt by installing four (4) mounting studs. This will allow installation and removal of the pulse sensor assembly during test.
2629	0486	Replacement of diode modules with modules X-ray inspected for silver contamination.
2713	0466	Redesign the PU static inverter-converter T/M supply to provide voltage adjustment.
2874	0605	Addition of vibration and isolation brackets for the emergency detection system (EDS) transducers and redeveloped plumbing.
2901	0622	Perform an insulation resistance test on all 10-amp relay modules.
2901 R3	2282	Replacement of the 10-amp relay modules. This change was required in order to provide modules which will operate at low temperatures.
2938	0651	Rework the chilldown inverter to eliminate voltage spike.
2960	0634	Modification of the EDS to separate the engine cutoff circuits at the connector, semi-conductor, and module level so that no single component failure shall cause an erroneous abort.
2989	0681 R2	Installation of LOX and LH2 depletion sensor electronic control units and necessary wiring to verify spare depletion sensor operation during stage loading.
3001	0686	Replacement of the LH2 depletion sensor time delay module with a 2-amp relay module.

TABLE 3-9 (Sheet 2 of 3)
STAGE MODIFICATION - ELECTRONICS

WRO	ECP	DESCRIPTION
3082	2027	Inspection of all coaxial feed-through sockets for 1/2 oz minimum pickup force and rework those which do not meet requirements.
3130	5015	Installation of metal connector covers to all unmated electrical connectors.
3179	2053	Modification of chilldown inverter assembly to suppress over-voltage conditions.
3348	2160	Replacement of all coax contacts which exist in connectors 1337872-1 and -503 that are used inside the LOX and LH2 tanks. The external connectors are inspected for recessed pins and and the pins replaced as required.
3352	2101 R1	Installation of an automatic passivation system to the S-IVB high pressure supplies, LOX and LH2 tanks.
3373	2176 R1	Rerouting of the range safety coax cable to prevent interference with the forward access kit.
3510	2235	Replacement of the 2-amp relay module with unit that satisfies thermal cycling screening tests for high and low temperature operation.
3544	2242	Replacement of the PU component oven with units which have been inspected for faulty transistors.
3545	2247	Insulation of the static inverter heat to prevent shorting of the inverter output.
3578	2279	Application of sealant around the range safety and T/M antennas and the forward skirt to prevent moisture from entering the antenna cover.
3600	2292	Installation of insulating washers to the mounting hardware of the diode modules located on the sequencer and aft power distributor assemblies. This will prevent diode from shorting.

TABLE 3-9 (Sheet 3 of 3)
STAGE MODIFICATION - ELECTRONICS

WRO	ECP	DESCRIPTION
3638	2303 R1	Changing of the engine ready bypass signal to a continuous signal to eliminate the possibility of an erroneous engine cutoff.
3661	2312	Inspection and re-identification of the motor transmission in the PU electronics assembly to insure that all units have had sufficient torque testing.
3743	2420 R1	Replacement of the APS control relay packages with reworked units.
3873	2572	Application of sealant to the LOX probe connector in the tunnel to prevent moisture from entering the connector.
3980	2652	Replacement of the PU component oven with unit which has been reworked per NASA direction.

TABLE 3-10 (Sheet 1 of 2)
STAGE MODIFICATION - INSTRUMENTATION

WRO	ECP	DESCRIPTION
480A	0505	Modify the breakpoint amplifier module circuit by installing a new signal conditioning setup procedure for use in obtaining calibration data without removing the breakpoint amplifier module from the stage.
490A	0448	Converts the D0110-426 and D0113-426 forward skirt external pressure measurements into the forward skirt internal pressure measurements D0234-411 and D0235-411.
2640	0353	Rechannelize telemetry measurement VK0132-404 to the BO multiplexer.
2848	0594	Replacement of two (2) defective vendor supplied APS chamber transducer cable assemblies with Douglas fabricated cable assemblies.
2871	0547	Replace bi-level summing network module with unit modified to reduce leakage current.
2923	0639	Relocate four (4) pressure transducers presently installed on propulsion fittings to brackets installed on the adjacent structure.
2990	0675	Relocate sixteen (16) strain gage measurements on forward skirt.
2992	0659	Remove and replace four (4) signal conditioning modules used to monitor fuel turbine manifold and crossover duct flight temperatures for ECP J2-547E.
3109	0937	Relocation of two (2) strain gages for measurements S0046 and S0047 approximately one in. from their former locations. Relocation eliminates need for replacing wire harness to defective gages.
3110	0938	Replacement of the T/M calibrator 1B52716-1 with 1B58798-1. The 1B52716-1 failed during checkout.
3208	2071	Deletion of "Internal Timer" telemetry.
3392	2181	Replacement of the APS helium regulator transducer mounting bolts to provide bolts with the proper grip length.

TABLE 3-10 (Sheet 2 of 2)
STAGE MODIFICATION - INSTRUMENTATION

WRO	ECP	DESCRIPTION
3569	2302	Replacement of eight (8) flutter measurement bridge modules with units having higher frequency response.
3797	2354	Addition of a flight measurement which will indicate when the stage is activated for propellant removal operations.

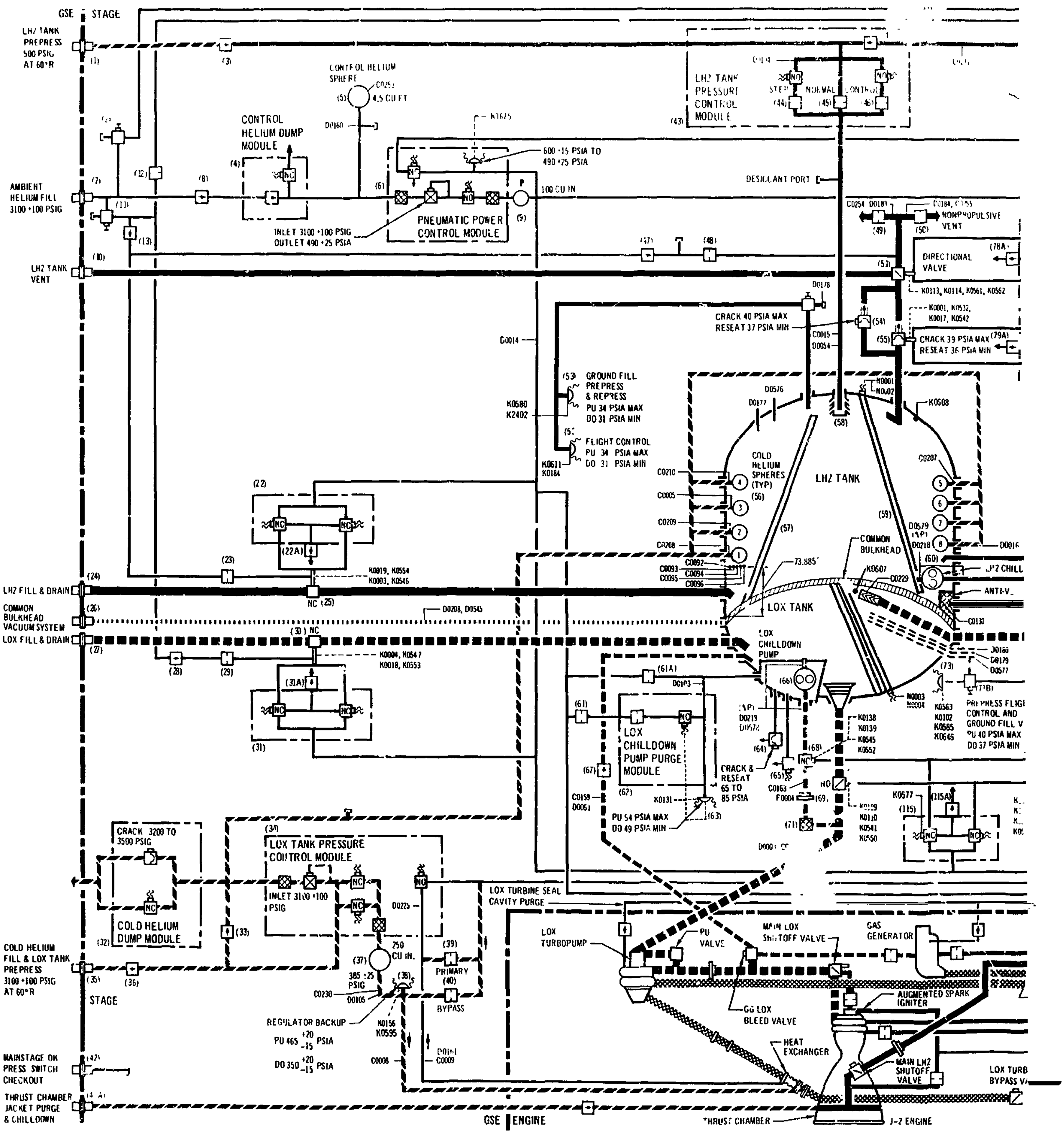
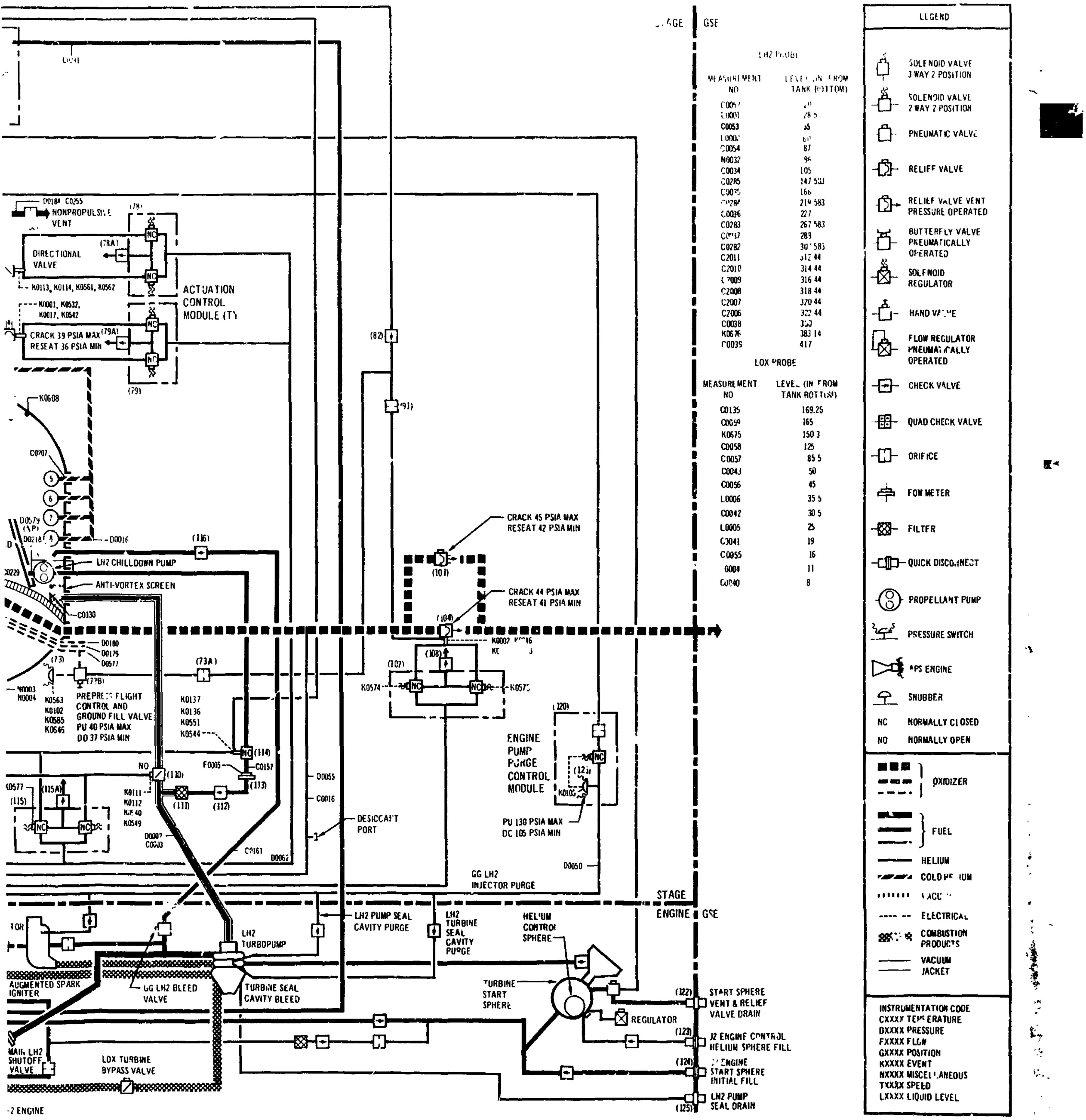


Figure 3-1. Propulsion System Configuration and Instrumentation

FOLDOUT FRAME 1



FOLDOUT FRAME 2

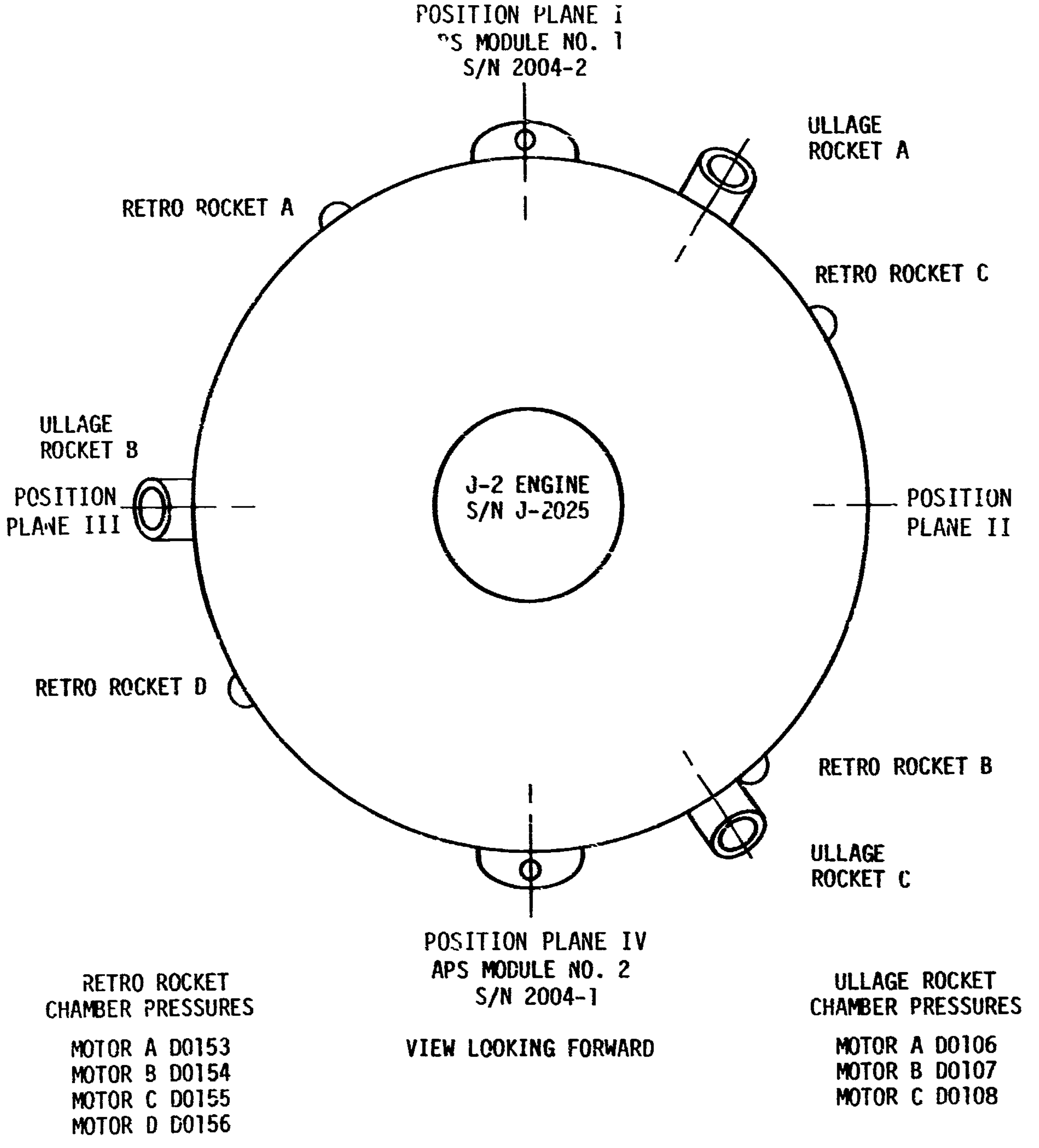


Figure 3-2. Propulsion [illegible] Components Locations

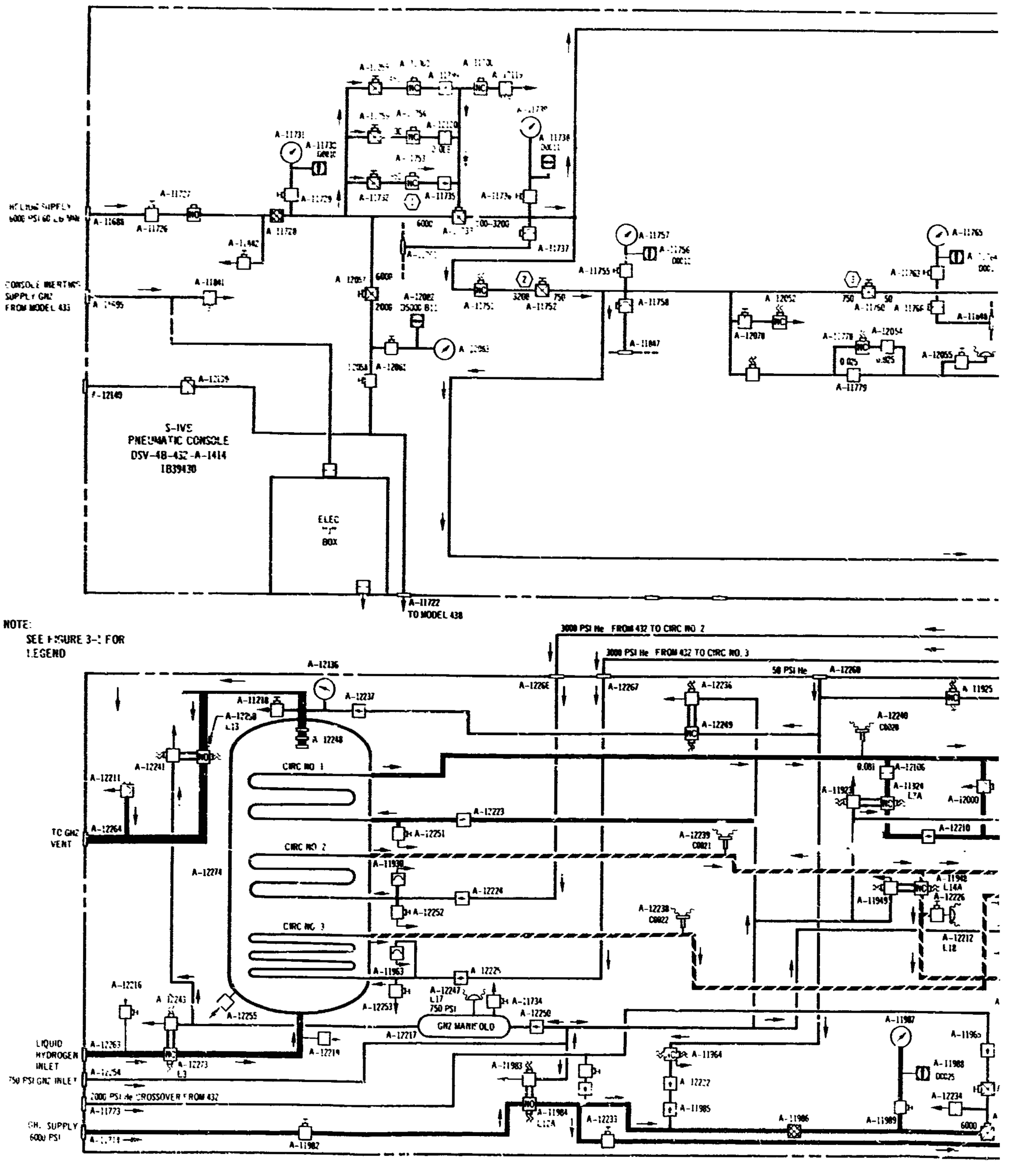
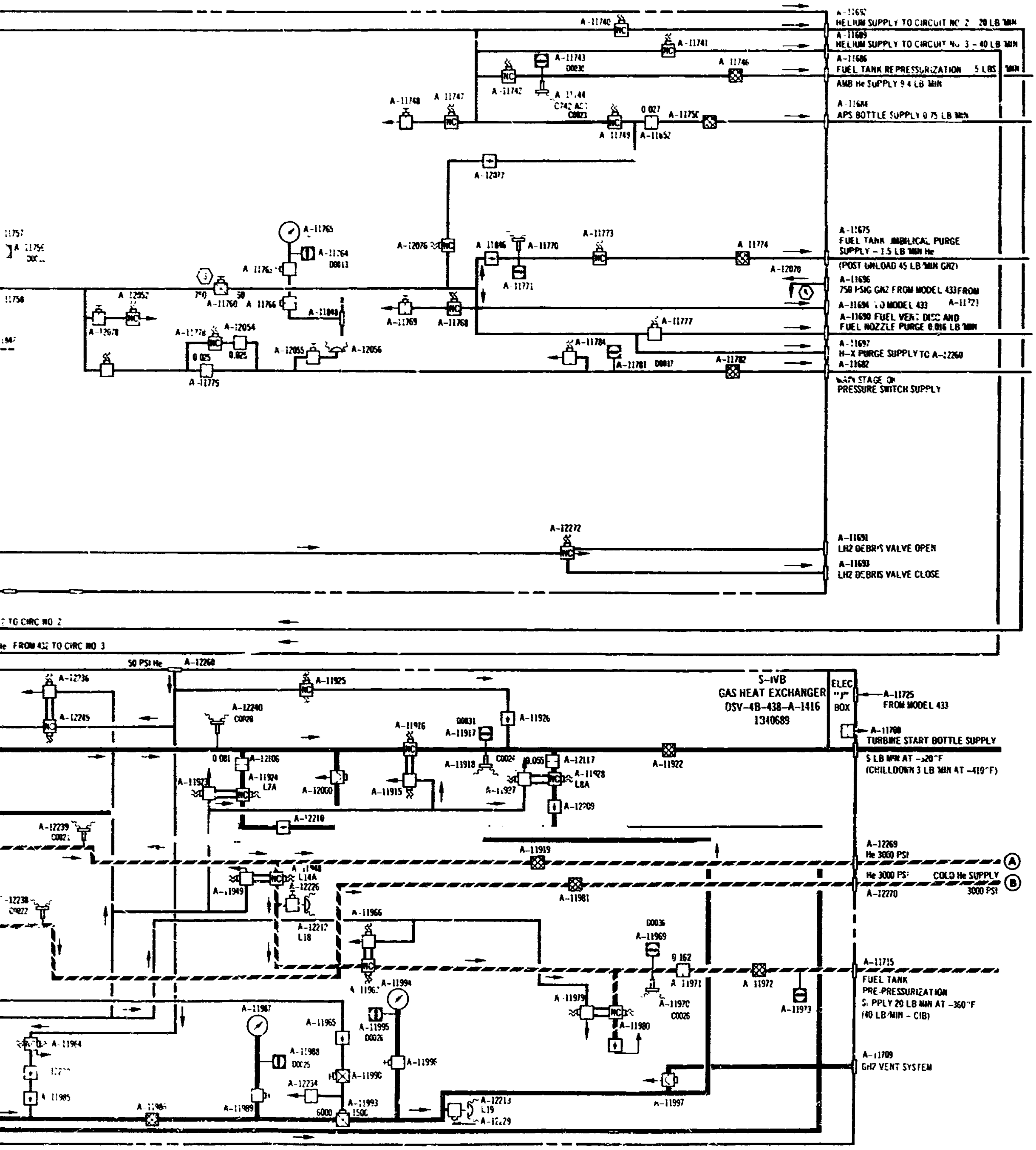


Figure 3-3. Facility Propellant and Pneumatic Loading Systems (Sheet 1 of 2)



FOLDOUT FRAME 2

SECTION 4

SEQUENCE OF EVENTS

4. SEQUENCE OF EVENTS

4.1 AS-204 Postflight Sequence

Table 4-1 presents the AS-204 predicted and actual sequence of events. Three types of items are presented in this sequence.

a. LVDC commands - These items initiate from the launch vehicle data computer (LVDC) in the instrument unit (IU) to perform vehicle system functions.

b. Incidents - These items are monitored occurrences such as the time of maximum dynamic pressure.

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

d. Ground commands - These commands originate at ground stations and are transmitted to the vehicle.

All 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.

4.1.1 Predicted and Monitored Times

The predicted times in this sequence were obtained from DAC Report No. SM-46977D, S-IVB-204 Stage Flight Test Plan, revised 18 January 1968.

Commands issued from the LVDC to the S-IB stage, S-IVB stage, and IU were monitored at the LVDC. Times for these items were obtained from MSFC. Commands issued from the LVDC to the S-IVB stage were monitored as responses at the S-IVB stage switch selector (SSS). These items were obtained from Douglas data.

Times for incidents were obtained from postflight analysis of parameters associated with each event.

The time from range zero is provided for all items. Range zero, the integer second prior to liftoff, occurred at 22:48:08 GMT.

A time from base is given for all LVDC commands (and their responses) which were preprogrammed. A time from base is not applicable (N/A) for items such as incidents and commands that were not preprogrammed. An example of commands not preprogrammed but experienced during this flight was the cycling of the IU water coolant valve (item Nos. 73, 207.1, 207.2, 221, 240.1, 240.2, 249.1, 252.1, 262, and 264.

SLA panel deployment occurred as preprogrammed at approximately 1,193 sec. However, the discrete signal for SLA panel deployment was not received by ground station equipment. Therefore, at 1,272 sec, a superfluous command sequence to deploy the SLA panels ("SLA panel deploy A" and "SLA panel deploy B") was transmitted to the vehicle.

At the end of the second revolution, over MILA, the absence of the S-IVB LOX vent closed indication was noted and a command sequence to close the vent was transmitted. The generated switch selector mode command was sent at 11,707 sec and properly received by the vehicle; however, ground verification was not received because of a ground equipment malfunction. The ground then attempted 7 more times to transmit the command sequence; each time the sequence was not executed.

Presently available information indicates that the vehicle completed the mission without the implementation of the ground initiated sequence.

4.2 Time Bases

Four sequential series of preprogrammed were issued from the LVDC. Each sequential series was initiated by the establishment of its time base in the LVDC. Listed below are the four time bases with their respective originating events:

a. Time base 1, TB1: IU umbilical disconnect

b. Time base 2, TB2: S-IB propellant level sensor actuation

c. Time base 3, TB3: S-IB outboard engine cutoff

d. Time base 4, TB4: S-IVB engine cutoff.

4.3 Data Omissions

Monitored times were not available for all events due to the reasons noted at the end of table 4-1.

4.4 Ground Sequence of Events

Table 4-2 presents the ground sequence of events from approximately range zero -20 min to liftoff. These events are related to the S-IVB-204 stage and associated ground support equipment and are derived from the digital events evaluation. No out of sequence events or other anomalies occurred.

4.5 Late Sequence Changes

The latest monitored time for the following events represent a significant change from those used in Douglas calculations.

ITEM NO.	EVENT	MONITORED TIME (FROM RANGE ZERO) USED IN DOUGLAS CALCULATIONS	LATEST MONITORED TIME (FROM RANGE ZERO) RECEIVED FROM MFSC, APRIL 2, 1968
36	Tilt Arrest	135.257	131.89
51.1	S-IB/S-IVB Physical Separation	143.59	143.89
60.1	90% J-2 Thrust Level	147.7	148.28
67	Active Guidance Initiation	159.47	159.48
89A	Time Base 4 Signal from LVDC for: S-IVB Engine C/O (Guidance C/O)	593.34	593.35
132	Start Maneuver to Separation Attitude	3,000.04	3,000.8

TABLE 4-1 (Sheet 1 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY** (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	-00:00:05.0 (-5.0)	N/A	N/A	-00:00:04.96 (-4.96)	N/A	MSFC	--
2	S-IB Engine Start	-00:00:03.1 (-3.1)	N/A	N/A	-00:00:02.97 (-2.97)	N/A	MSFC	--
3	Range Zero	00:00:00.0 (0)	N/A	N/A	00:00:00.0	N/A	MSFC	--
4	First Vertical Motion	00:00:00.0 (0)	N/A	N/A	00:00:00.20 (0.20)	N/A	MSFC	--
4.1	First Motion Switch No. 1	N/A	N/A	N/A	00:00:00.28 (0.28)	N/A	MSFC	--
4.2	First Motion Switch No. 2	N/A	N/A	N/A	00:00:00.29 (0.29)	N/A	MSFC	--
5	Time Base 1 AS-204 Liftoff; IU Umbilical Disconnect	00:00:00.2 (0.2)	TB1 +0.0	IU	00:00:00.36 (0.36)	TB1 +0.0	MSFC	--
6	Signal from LVDC for: Multiple S-IB Engine Cutoff Enable	00:00:10.2 (10.2)	TB1 +10.0	IU	00:00:10.31 (10.31)	TB1 +9.95	MSFC	--
7	Pitch Program Start	00:00:10.2 (10.2)	N/A	N/A	00:00:09.22 (9.22)	N/A	MSFC	--
8	Roll Program Start	00:00:10.2 (10.2)	N/A	N/A	00:00:09.22 (9.22)	N/A	MSFC	--
9	Signal from LVDC for: Telemeter Calibration On	00:00:20.2 (20.2)	TB1 +20.0	IU	00:00:20.31 (20.31)	TB1 +19.95	MSFC	--
10	Signal from LVDC for: Telemetry Calibration Off	00:00:25.2 (25.2)	TB1 +25.0	IU	00:00:25.33 (25.33)	TB1 +25.97	MSFC	--
11	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	00:00:27.2 (27.2)	TB1 +27.0	IU	00:00:27.31 (27.31)	TB1 +26.95	MSFC	--
12	End Roll Program	00:00:28.33 (28.33)	N/A	N/A	00:00:28.70 (28.70)	N/A	MSFC	--
13	Signal from LVDC for: LOX Tank Relief Control Valve Enable	00:00:30.0 (30.0)	TB1 +29.8	IU	00:00:30.12 (30.12)	TB1 +29.76	MSFC	--
14	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:00:32.2 (32.2)	TB1 +32.0	IU	00:00:32.31 (32.31)	TB1 +31.95	MSFC	--
15	Signal from LVDC for: Tape Recorder Record On	00:00:39.2 (39.2)	TB1 +39.0	IU	00:00:39.31 (39.31)	TB1 +38.95	MSFC	--
16	Signal from LVDC for: Flight Control Computer-Switch Point No. 1	00:00:40.2 (40.2)	TB1 +40.0	IU	00:00:40.31 (40.31)	TB1 +39.95	MSFC	--
17	Mach 1	N/A	N/A	N/A	00:00:59.76 (59.76)	N/A	MSFC	--
18	Signal from LVDC for: Launch Vehicle Engines EDS Cutoff Enable	00:01:00.2 (60.2)	TB1 +60.0	IU	00:01:00.31 (60.31)	TB1 +59.95	MSFC	--
19	Maximum Dynamic Pressure	00:01:14.0 (74.0)	N/A	N/A	00:01:11.5 (71.5)	N/A	MSFC	--

*Range Zero = 22:48:08 (GMT)

**See note 8 at end of table.

TABLE 4-1 (Sheet 2 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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: Telemetry Calibrator In-Flight Calibrate On	00:01:30.4 (90.4)	TB1 +90.2	IU	00:01:30.51 (90.51)	TB1 +90.15	MSFC	--
21	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:01:35.4 (95.4)	TB1 +95.2	IU	00:01:35.51 (95.51)	TB1 +95.15	MSFC	--
22	Signal from LVDC for: Flight Control Computer-Switch Point No. 2	00:01:40.2 (100.2)	TB1 +100.0	IU	00:01:40.33 (100.33)	TB1 +99.97	MSFC	--
23	Signal from LVDC for: Telemetry Calibration On	00:02:00.0 (120.0)	TB1 +119.8	IU	00:02:00.11 (120.11)	TB1 +119.75	MSFC	--
24	Signal from LVDC for: Flight Control Computer-Switch Point No. 3	00:02:00.2 (120.2)	TB1 +120.0	IU	00:02:00.32 (120.32)	TB1 +119.96	MSFC	--
25	Signal from LVDC for: Control Accelerometer Off	00:02:00.4 (120.4)	TB1 +120.2	IU	00:02:00.53 (120.53)	TB1 +120.17	MSFC	--
26	Signal from LVDC for: Telemeter Calibration Off	00:02:05.1 (125.1)	TB1 +124.9	IU	00:02:05.21 (125.21)	TB1 +124.85	MSFC	--
27a	Signal from LVDC for: Special TM Calibration On	00:02:05.3 (125.3)	TB1 +125.1	IU	00:02:05.41 (125.41)	TB1 +125.05	MSFC	--
27b	Signal Received in S-IVB for: Special TM Calibration On	00:02:05.3 (125.3)	TB1 +125.1	S-IVB	00:02:05.42 (125.42)	TB1 +125.05	DAC (FM)	13
28a	Signal from LVDC for: Regular Telemeter Calibration On	00:02:05.5 (125.5)	TB1 +125.3	IU	00:02:05.62 (125.62)	TB1 +125.26	MSFC	--
28b	Signal Received in S-IVB for Regular Telemeter Calibration On	00:02:05.5 (125.5)	TB1 +125.3	S-IVB	00:02:05.63 (125.63)	TB1 +125.27	DAC (FM)	13
29a	Signal from LVDC for: Regular Telemetry Calibration Off	00:02:10.5 (130.5)	TB1 +130.3	IU	00:02:10.62 (130.62)	TB1 +130.26	MSFC	--
29b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	00:02:10.5 (130.5)	TB1 +130.3	S-IVB	00:02:10.62 (130.62)	TB1 +130.26	DAC (FM)	13
30a	Signal from LVDC for: Special Telemetry Calibration Off	00:02:10.7 (130.7)	TB1 +130.5	IU	00:02:10.83 (130.83)	TB1 +130.47	MSFC	--
30b	Signal Received in S-IVB for: Special Telemetry Calibration Off	00:02:10.7 (130.7)	TB1 +130.5	S-IVB	00:02:10.83 (130.83)	TB1 +130.47	DAC (FM)	13
31	Signal from LVDC for: Excessive Rate (P,Y,R) Auto-Abort Inhibit Enable	00:02:11.7 (131.7)	TB1 +131.5	IU	00:02:11.82 (131.82)	TB1 +131.44	MSFC	--
32	Signal from LVDC for: Excessive Rate (P,Y,R) Auto-Abort Inhibit	00:02:11.9 (131.9)	TB1 +131.7	IU	00:02:12.03 (132.03)	TB1 +131.67	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 3 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
33	Signal from LVDC for: S-IB Two Engines Out Auto-Abort Inhibit Enable	00:02:12.1 (132.1)	TB1 +131.9	IU	00:02:12.21 (132.21)	TB1 +131.85	MSFC	--
34	Signal from LVDC for: S-IVB Two Engines Out Auto-Abort Inhibit	00:02:12.3 (132.3)	TB1 +132.1	IU	00:02:12.42 (132.42)	TB1 +132.06	MSFC	--
35	Signal Received in S-IB for: Propellant Level Sensors Enable	00:02:12.5 (132.5)	TB1 +132.3	S-IB	00:02:12.63 (132.63)	TB1 +132.27	MSFC	--
36	Tilt Arrest	00:02:13.4 (133.4)	N/A	N/A	00:02:11.89 (131.89)†	N/A	MSFC	--
37	Time Base 2 Signal Received in S-IB for: S-IB Propellant Level Sensor Actuation	00:02:16 (136.0)	TB2 +0.0	S-IB	00:02:15.91 (135.91)	TB2 +0.0	MSFC	--
38	Signal from LVDC for: IU Tape Recorder Record On	00:02:16.2 (136.2)	TB2 +0.2	IU	00:02:16.07 (136.07)	TB2 +0.16	MSFC	--
39a	Signal from LVDC for: Fast Record On	00:02:16.4 (136.4)	TB2 +0.4	IU	00:02:16.26 (136.26)	TB2 +0.35	MSFC	--
39b	Signal Received in S-IVB for: Fast Record On	00:02:16.4 (136.4)	TB2 +0.4	S-IVB	00:02:16.27 (136.27)	TB2 +0.36	DAC (FM)	13
40	Signal Received in S-IB for: S-IB Inboard Engines Cutoff (IECO)	00:02:19.1 (139.1)	TB2 +3.1	S-IB	00:02:18.97 (138.97)	TB2 +3.06	MSFC	--
41	Signal from LVDC for: Auto-Abort Enable Relays Reset	00:02:19.3 (139.3)	TB2 +3.3	IU	00:02:19.18 (139.18)	TB2 +3.27	MSFC	--
42a	Signal from LVDC for: Ullage Ignition Charge On	00.02:20 (140.0	TB2 +4.0	IU	00:02:19.88 (139.88)	TB2 -3.97	MSFC	--
42b	Signal Received in S-IVB for: Ullage Ignition Charge On	00:02:20 (140.0)	TB2 +4 0	S-IVB	00:02:19.88 (139.88)	TB2 +3.97	DAC (FM)	13
43a	Signal from LVDC for: Prevalves Open	00:02:20.4 (140.4)	TB2 +4.4	IU	00:02:20.26 (140.26)	TB2 +4.35	MSFC	--
43b	Signal Received in S-IVB for: Prevalves Open	00:02:20.4 (140.4)	TB2 +4.4	S-IVB	00:02:20.27 (140.27)	TB2 +4.36	DAC (FM)	13
44	Signal Received in S-IB for: LOX Depletion Cutoff Enable	00:02:20.6 (140.6)	TB2 +4.6	S-IB	00:02:20.47 (140.47)	TB2 +4.56	MSFC	--
45	Signal Received in S-IB for: Fuel Depletion Cutoff Enable	00:02:21.6 (141.6)	TB2 +5.6	S-IB	00:02:21.46 (141.46)	TB2 +5.55	MSFC	--
46	Time Base 3 Signal Received in S-IB for: S-IB Outboard Engines Cutoff (OECO)	00:02:22.1 (142.1)	TB3 +0.0	S-IB	00:02:22.25 (142.25)	TB3 +0.0	MSFC	--

*Range Zero = 22:48:08 (GMT)   †See paragraph 4.5

TABLE 4-1 (Sheet 4 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONI-TORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCU-RACY (ms)
47a	Signal from LVDC for: Engine Cutoff Signal Off	00:02:22.5 (142.5)	TB3 +0.4	IU	00:02:22.62 (142.62)	TB3 +0.37	MSFC	--
47b	Signal Received in S-IVB for: Engine Cutoff Signal Off	00:02:22.5 (142.5)	TB3 +0.4	S-IVB	00:02:22.62 (142.62)	TB3 +0.37	DAC (FM)	13
48a	Signal from LVDC for: Ullage Rockets Ignition	00:02:23.2 (143.2)	TB3 +1.1	IU	00:02:23.30 (143.30)	TB3 +1.05	MSFC	--
48b	Signal Received in S-IVB for Ullage Rockets Ignition	00:02:23.2 (143.2)	TB3 +1.1	S-IVB	00:02:23.31 (143.31)	TB3 +1.06	DAC (FM)	13
49	Signal Received in S-IB for: S-IB/S-IVB Separation	00:02:23.4 (143.4)	TB3 +1.3	S-IB	00:02:23.50 (143.50)	TB3 +1.25	MSFC	--
50	Signal from LVDC for: Flight Control Computer S-IVB Burn Mode On "B"	00:02:23.5 (143.5)	TB3 +1.4	IU	00:02:23.60 (143.60)	TB3 +1.35	MSFC	--
51	Signal from LVDC for: Flight Control Computer S-IVB Burn Mode On "A"	00:02:23.6 (143.6)	TB3 +1.5	IU	00:02:23.70 (143.70)	TB3 +1.45	MSFC	--
51.1	S-IB/S-IVB Physical Separation	N/A	N/A	N/A	00:02:23.89 (143.89)†	N/A	MSFC	--
52a	Signal from LVDC for: Engine Ready Bypass On	00:02:23.8 (143.8)	TB3 +1.7	IU	00:02:23.90 (143.90)	TB3 +1.65	MSFC	--
52b	Signal Received in S-IVB for: Engine Ready Bypass On	00:02:23.8 (143.8)	TB3 +1.7	S-IVB	00:02:23.90 (143.90)	TB3 +1.65	DAC (FM)	13
53a	Signal from LVDC for: LH2 Chilldown Pump Off	00:02:24.2 (144.2)	TB3 +2.1	IU	00:02:24.31 (144.31)	TB3 +2.06	MSFC	--
53b	Signal Received in S-IVB for: LH2 Chilldown Pump Off	00:02:24.2 (144.2)	TB3 +2.1	S-IVB	00:02:24.32 (144.32)	TB3 +2.07	DAC (FM)	13
54a	Signal from LVDC for: LOX Chilldown Pump Off	00:02:24.4 (144.4)	TB3 +2.3	IU	00:02:24.52 (144.52)	TB3 +2.27	MSFC	--
54b	Signal Received in S-IVB for: LOX Chilldown Pump Off	00:02:24.4 (144.4)	TB3 +2.3	S-IVB	00:02:24.52 (144.52)	TB3 +2.27	DAC (FM)	13
55a	Signal from LVDC for: S-IVB Engine Ignition Sequence Start	00:02:24.8 (144.8)	TB3 +2.7	IU	00:02:24.90 (144.90)	TB3 +2.65	MSFC	--
55b	Signal Received in S-IVB for: S-IVB Engine Ignition Sequence Start	00:02:24.8 (144.8)	TB3 +2.7	S-IVB	00:02:24.90 (144.90)	TB3 +2.65	DAC (FM)	13
56a	Signal from LVDC for: Engine Ignition Sequence Start Relay Reset	00:02:25.3 (145.3)	TB3 +3.2	IU	00:02:25.40 (145.40)	TB3 +3.15	MSFC	--
56b	Signal Received in S-IVB for: Engine Ignition Sequence Start Relay Reset	00:02:25.3 (145.3)	TB3 +3.2	S-IVB	00:02:25.40 (145.40)	TB3 +3.15	DAC (FM)	13

*Range Zero = 22:48:08 (GMT) †See paragraph 4.5

TABLE 4-1 (Sheet 5 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
57a	Signal from LVDC for: LOX Tank Flight Pressurization Switch Enable	00:02:25.6 (145.6)	TB3 +3.5	IU	00:02:25.70 (145.70)	TB3 +3.45	MSFC	--
57b	Signal Received in S-IVB for: LOX Tank Flight Pressurization Switch Enable	00:02:25.6 (145.6)	TB3 +3.5	S-IVB	00:02:25.71 (145.71)	TB3 +3.46	DAC (FM)	13
58a	Signal from LVDC for: Fuel Injection Temperature OK Bypass	00:02:25.8 (145.8)	TB3 +3.7	IU	00:02:25.90 (145.90)	TB3 +3.65	MSFC	--
58b	Signal Received in S-IVB for: Fuel Injection Temperature OK Bypass	00:02:25.8 (145.8)	TB3 +3.7	S-IVB	00:02:25.91 (145.91)	TB3 +3.66	DAC (FM)	13
59	Signal from LVDC for: S-IVB Engine Out Indication "A" Enable	00:02:26 (146.0)	TB3 +3.9	IU	00:02:26.11 (146.11)	TB3 +3.86	MSFC	--
60a	Signal from LVDC for: LH2 Tank Pressurization Control Switch Enable	00:02:27.4 (147.4)	TB3 +5.3	IU	00:02:27.51 (147.51)	TB3 +5.26	MSFC	--
60b	Signal Received in S-IVB for: LH2 Tank Pressurization Control Switch Enable	00:02:27.4 (147.4)	TB3 +5.3	S-IVB	00:02:27.51 (147.51)	TB3 +5.26	DAC (FM)	13
60.1	90 Percent J-2 Thrust Level	00:02:28.34 (148.34)	N/A	N/A	00:02:28.28 (148.28)†	N/A	MSFC	--
61a	Signal from LVDC for: PU System Activate	00:02:30.8 (150.8)	TB3 +8.7	IU	00:02:30.91 (150.91)	TB3 +8.66	MSFC	--
61b	Signal Received in S-IVB for: PU System Activate	00:02:30.8 (150.8)	TB3 +8.7	S-IVB	00:02:30.92 (150.92)	TB3 +8.67	DAC (FM)	13
62a	Signal from LVDC for: Emergency Playback Enable	00:02:31.8 (151.8)	TB3 +9.7	IU	00:02:31.90 (151.90)	TB3 +9.65	MSFC	--
62b	Signal Received in S-IVB for: Emergency Playback Enable	00:02:31.8 (151.8)	TB3 +9.7	S-IVB	00:02:31.91 (151.91)	TB3 +9.66	DAC (FM)	13
63a	Signal from LVDC for: Fast Record Off	00:02:31.9 (151.9)	TB3 +9.8	IU	00:02:32.00 (152.00)	TB3 +9.75	MSFC	--
63b	Signal Received in S-IVB for: Fast Record Off	00:02:31.9 (151.9)	TB3 +9.8	S-IVB	00:02:32.00 (152.00)	TB3 +9.75	DAC (FM)	13
64a	Signal from LVDC for: Charge Ullage Jettison EBW Firing Units	00:02:32.3 (152.3)	TB3 +10.2	IU	00:02:32.41 (152.41)	TB3 +10.16	MSFC	--
64b	Signal Received in S-IVB for: Charge Ullage Jettison EBW Firing Units	00:02:32.3 (152.3)	TB3 +10.2	S-IVB	00:02:32.41 (152.41)	TB3 +10.16	DAC (FM)	13
65a	Signal from LVDC for: Ullage Rockets Jettison	00:02:35.4 (155.4)	TB3 +13.3	IU	00:02:35.32 (155.32)	TB3 +13.27	MSFC	--

*Range Zero = 22:48:08 (GMT), †See paragraph 4.5

TABLE 4-I (Sheet 6 of 16)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
65b	Signal Received in S-IVB for: Ullage Rockets Jettison	00:02:35.4 (155.4)	TB3 +13.3	S-IVB	00:02:35.52 (155.52)	TB3 +13.27	DAC (FM)	13
66a	Signal from LVDC for: Fuel Injection Temperature OK Bypass Reset	00:02:35.8 (155.8)	TB3 +13.7	IU	00:02:35.90 (155.90)	TB3 +13.65	MSFC	
66b	Signal Received in S-IVB for: Fuel Injection Temperature OK Bypass Reset	00:02:35.8 (155.8)	TB3 +13.7	S-IVB	00:02:35.91 (155.91)	TB3 +13.66	DAC (FM)	13
67	Active Guidance Initiation	00:02:39.1 (159.1)	N/A	N/A	00:02:39.[illegible] (159.[illegible])	N/A	MSFC	--
68	Signal from LVDC for: Tape Recorder Record Off	00:02:41.1 (161.1)	TB3 +19.0	IU	00:02:41.20 (161.20)	TB3 +18.95	MSFC	--
69a	Signal from LVDC for: Ullage EBW Firing Units Charge Relay Reset	00:02:41.4 (161.4)	TB3 +19.3	IU	00:02:41.50 (161.50)	TB3 +19.25	MSFC	--
69b	Signal Received in S-IVB for: Ullage EBW Firing Units Charge Relay Reset	00:02:41.4 (161.4)	TB3 +19.3	S-IVB	00:02:41.51 (161.51)	TB3 +19.26	DAC (FM)	13
70a	Signal from LVDC for: Ullage Rockets Ignition and Jettison Relays Reset	00:02:41.6 (161.6)	TB3 +19.5	IU	00:02:41.70 (161.70)	TB3 +19.45	MSFC	--
70b	Signal Received in S-IVB for: Ullage Rockets Ignition and Jettison Relays Reset	00:02:41.6 (161.6)	TB3 +19.5	S-IVB	00:02:41.71 (161.71)	TB3 +19.46	DAC (FM)	13
71	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	00:02:50.9 (170.9)	TB3 +28.8	IU	00:02:51.00 (171.00)	TB3 +28.75	MSFC	--
72	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:02:55.9 (175.9)	TB3 +33.8	IU	00:02:56.02 (176.02)	TB3 +33.77	MSFC	--
73	Signal from LVDC for: Water Coolant Valve Open	00:02:59.8 (179.8)	TB3 +37.7	IU	00:02:59.90 (179.90)	TB3 +37.65	MSFC	--
73.1	Initiate Steering Misalignment Correction	N/A	N/A	N/A	00:03:13.48 (193.48)	N/A	MSFC	--
74	Signal from LVDC for: Flight Control Computer-Switch Point No. 4	00:04:45.8 (285.8)	TB3 +143.7	IU	00:04:45.91 (285.91)	TB3 +143.66	MSFC	--
75	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	00:05:49.8 (349.8)	TB3 +207.7	IU	00:05:49.90 (349.90)	TB3 +207.65	MSFC	--
76a	Signal from LVDC for: Regular TM Calibration On	00:05:50.8 (350.8)	TB3 +208.7	IU	00:05:50.92 (350.92)	TB3 +208.67	MSFC	--
76b	Signal Received in S-IVB for: Regular Telemetry Calibration On	00:05:50.8 (350.8)	TB3 +208.7	S-IVB	00:05:50.93 (350.93)	TB3 +208.68	DAC (FM)	13

*Range Zero = 22:43:08 (GMT) †See paragraph 4.9

TABLE 4-1 (Sheet 7 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
77	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:05:54.8 (354.8)	TB3 +212.7	IU	00:05:54.92 (354.92)	TB3 +212.67	MSFC	--
78a	Signal from LVDC for: Regular Telemetry Calibration Off	00:05:55.8 (355.8)	TB3 +213.7	IU	00:05:55.90 (355.90)	TB3 +213.65	MSFC	--
78b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	00:05:55.8 (355.8)	TB3 +213.7	S-IVB	00:05:55.91 (355.91)	TB3 +213.66	DAC (FM)	13
79a	Signal from LVDC for: LH2 Tank Pressurization Control Switch Disable	00:07:25.0 (445.0)	TB3 +302.9	IU	00:07:25.10 (445.10)	TB3 +302.85	MSFC	--
79b	Signal Received in S-IVB for: LH2 Tank Pressurization Control Switch Disable	00:07:25.0 (445.0)	TB3 +302.9	S-IVB	00:07:25.11 (445.11)	TB3 +302.86	DAC (FM)	13
80	Introduction of Artificial Tau Mode	00:07:54.1 (474.1)	N/A	N/A	00:08:22.83 (502.83)	TB3 +360.58	MSFC	--
81	Guidance Staging	00:07:54.1 (474.1)	N/A	N/A	00:08:22.83 (502.83)	N/A	MSFC	--
82	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	00:08:20.9 (500.9)	TB3 +358.8	IU	00:08:21.02 (501.02)	TB3 +358.77	MSFC	--
83	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:08:25.9 (505.9)	TB3 +363.8	IU	00:08:26.00 (506.00)	TB3 +363.75	MSFC	--
84a	Signal from LVDC for: Chilldown Shutoff Valves Close	00:09:27.5 (567.5)	TB3 +425.4	IU	00:09:27.60 (567.60)	TB3 +425.35	MSFC	--
84b	Signal Received in S-IVB for: Chilldown Shutoff Valves Close	00:09:27.5 (567.5)	TB3 +425.4	S-IVB	00:09:27.60 (567.60)	TB3 +425.35	DAC (FM)	13
85a	Signal from LVDC for: Emergency Playback Inhibit	00:09:42.5 (582.5)	TB3 +440.4	IU	00:09:42.60 (582.60)	TB3 +440.35	MSFC	--
85b	Signal Received in S-IVB for: Emergency Playback Inhibit	00:09:42.5 (582.5)	TB3 +440.4	S-IVB	00:09:42.60 (582.60)	TB3 +440.35	DAC (FM)	13
86	Introduction of Chi-Tilde Guidance Mode	00:09:44.4 (584.4)	N/A	N/A	00:09:38.79 (578.79)	N/A	MSFC	--
87	Freeze Body Attitude	00:09:55.1 (595.1)	N/A	N/A	00:09:51.01 (591.01)	N/A	MSFC	--
88a	Signal from LVDC for: Arm S-IVB Propellant Depletion Sensor	00:09:59.2 (599.2)	TB3 +457.1	IU	Not Issued (S-IVB Guidance Cutoff)	N/A	--	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 8 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY+ (ms)
88b	Signal Received in S-IVB for: Arm S-IVB Propellant Depletion Sensor	00:09:59.2 (599.2)	TB3 +457.1	S-IVB	Not Issued (S-IVB Guidance Cutoff)	N/A	--	--
89a	Time Base 4 Signal from LVDC for: S-IVB Engine Cutoff (Guidance Cutoff)	00:09:58.2 (598.2)	TB4 +0.0	IU	00:09:53.35 (593.35)	TB4 -0.21	MSFC	--
89b	Signal Received in S-IVB for: S-IVB Engine Cutoff (Guidance Cutoff)	00:09:58.2 (598.2)	TB4 +0.0	S-IVB	00:09:53.4 (593.34)	TB4 -0.22	DAC (FM)	13
89c	Initiate Time Base 4 (TB4)	00:09:58.2 (598.2)	TB4 +0.0	N/A	00:09:53.56 (593.56)	TB4 +0.0	MSFC	--
89d	Signal from LVDC for: Redundant S-IVB Engine Cutoff	00:09:58.2 (598.2)	TB4 +0.0	IU	00:09:53.56 (593.56)	TB4 +0.0	MSFC	--
89e	Signal Received in S-IVB for: Redundant S-IVB Engine Cutoff	00:09:58.2 (598.2)	TB4 +0.0	S-IVB	00:09:53.63 (593.63)	TB4 +0.07	DAC (FM)	13
90a	Signal from LVDC for: LOX Tank Vent Valve Open	00:09:58.4 (598.4)	TB4 +0.2	IU	00:09:53.76 (593.76)	TB4 +0.20	MSFC	--
90b	Signal Received in S-IVB for: LOX Tank Vent Valve Open	00:09:58.4 (598.4)	TB4 +0.2	S-IVB	00:09:53.76 (593.76)	TB4 +0.20	DAC (FM)	13
91a	Signal from LVDC for: LH2 Tank Vent Valve Open	00:09:58.6 (598.6)	TB4 +0.4	IU	00:09:53.93 (593.93)	TB4 +0.37	MSFC	--
91b	Signal Received in S-IVB for: LH2 Tank Vent Valve Open	00:09:58.6 (598.6)	TB4 +0.4	S-IVB	00:09:53.92 (593.92)	TB4 +0.36	DAC (FM)	13
92a	Signal from LVDC for: LOX Tank Pressurization Shutoff Valves Close	00:09:59.0 (599.0)	TB4 +0.8	IU	00:09:54.31 (594.31)	TB4 +0.75	MSFC	--
92b	Signal Received in S-IVB for: LOX Tank Pressurization Shutoff Valves Close	00:09:59.0 (599.0)	TB4 +0.8	S-IVB	00:09:54.31 (594.31)	TB4 +0.75	DAC (FM)	13
93a	Signal from LVDC for: Prevalves Close	00:09:59.2 (599.2)	TB4 +1.0	IU	00:09:54.52 (594.52)	TB4 +0.96	MSFC	--
93b	Signal Received in S-IVB for: Prevalves Close	00:09:59.2 (599.2)	TB4 +1.0	S-IVB	00:09:54.52 (594.52)	TB4 +0.96	DAC (FM)	13
94a	Signal from LVDC for: LOX Tank Flight Pressurization Switch Disable	00:09:59.4 (599.4)	TB4 +1.2	IU	00:09:54.73 (594.73)	TB4 +1.17	MSFC	--
94b	Signal Received in S-IVB for: LOX Tank Flight Pressurization Switch Disable	00:09:59.4 (599.4)	TB4 +1.2	S-IVB	00:09:54.73 (594.73)	TB4 +1.17	DAC (FM)	13
95a	Signal from LVDC for: LOX Chilldown Pump Purge Off	00:09:59.8 (599.8)	TB4 +1.6	IU	00:09:55.11 (595.11)	TB4 +1.55	MSFC	--

*Range Zero = 22:48:08 (GMT) +See paragraph 4.5

TABLE 4-1 (Sheet 9 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONI-TORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCU-RACY (ms)
95b	Signal Received in S-IVB for: LOX Chilldown Pump Purge Off	00:09:59.8 (599.8)	TB4 +1.6	S-IVB	00:09:55.11 (595.11)	TB4 +1.55	DAC (FM)	13
96a	Signal from LVDC for: Propellant Depletion Cutoff Disarm	00:10:00.0 (600.0)	TB4 +1.8	IU	00:09:55.32 (595.32)	TB4 +1.76	MSFC	--
96b	Signal Received in S-IVB for: Propellant Depletion Cutoff Disarm	00:10:00.0 (600.0)	TB4 +1.8	S-IVB	00:09:55.31 (595.31)	TB4 +1.75	DAC (FM)	13
97a	Signal from LVDC for: PU System Deactivate	00:10:01.3 (601.3)	TB4 +3.1	IU	00:09:56.62 (596.62)	TB4 +3.06	MSFC	--
97b	Signal Received in S-IVB for: PU System Deactivate	00:10:01.3 (601.3)	TB4 +3.1	S-IVB	00:09:56.62 (596.62)	TB4 +3.06	DAC (FM)	13
98a	Signal from LVDC for: PU Inverter and DC Power Off	00:10:01.5 (601.5)	TB4 +3.3	IU	00:09:56.81 (596.81)	TB4 +3.25	MSFC	--
98b	Signal Received in S-IVB for: PU Inverter and DC Power Off	00:10:01.5 (601.5)	TB4 +3.3	S-IVB	00:09:56.81 (596.81)	TB4 +3.25	DAC (FM)	13
99	Signal from LVDC for: Flight Control Computer S-IVB Burn Mode Off "B"	00:10:01.6 (601.6)	TB4 +3.4	IU	00:09:56.93 (596.93)	TB4 +3.36	MSFC	--
100	Signal from LVDC for: Flight Control Computer S-IVB Burn Mode Off "A"	00:10:01.7 (601.7)	TB4 +3.5	IU	00:09:57.02 (597.02)	TB4 +3.46	MSFC	--
101a	Signal from LVDC for: Aux Hydraulic Pump Flight Mode Off	00:10:01.9 (601.9)	TB4 +3.7	IU	00:09:57.23 (597.23)	TB4 +3.66	MSFC	--
101b	Signal Received in S-IVB for: Aux Hydraulic Pump Flight Mode Off	00:10:01.9 (601.9)	TB4 +3.7	S-IVB	00:09:57.23 (597.23)	TB4 +3.65	DAC (FM)	13
102	Signal from LVDC for: Tape Recorder Playback Reverse On	00:10:02.1 (602.1)	TB4 +3.9	IU	00:09:57.41 (597.41)	TB4 +3.85	MSFC	--
103a	Signal from LVDC for: Emergency Playback Enable	00:10:02.3 (602.3)	TB4 +4.1	IU	00:09:57.62 (597.62)	TB4 +4.06	MSFC	--
103b	Signal Received in S-IVB for: Emergency Playback Enable	00:10:02.3 (602.3)	TB4 +4.1	S-IVB	00:09:57.62 (597.62)	TB4 +4.06	DAC (FM)	13
104	Orbital Insertion	00:10:08.35 (608.35)	N/A	N/A	00:10:03.34 (603.34)	N/A	MSFC	--
104.1	Start Orbital Guidance/Navigation	N/A	N/A	N/A	00:10:10.73 (610.73)	N/A	MSFC	--
105a	Signal from LVDC for: Emergency Playback Inhibit	00:10:28.1 (628.1)	TB4 +29.9	IU	00:10:23.41 (623.41)	TB4 +29.85	MSFC	--
105b	Signal Received in S-IVB for: Emergency Playback Inhibit	00:10:28.1 (628.1)	TB4 +29.9	S-IVB	00:10:23.42 (623.42)	TB4 +29.86	DAC (FM)	13

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 10 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONI-TORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCU-RACY (ms)
106	Signal from LVDC for: Tape Recorder Playback Reverse Off	00:10:30.2 (630.2)	TB4 +32.0	IU	00:10:25.51 (625.51)	TB4 +31.95	MSFC	--
107a	Signal from LVDC for: LOX Tank Vent Valve Close	00:10:38.4 (638.4)	TB4 +40.2	IU	00:10:33.71 (633.71)	TB4 +40.35	MSFC	--
107b	Signal Received in S-IVB for: LOX Tank Vent Valve Close	00:10:38.4 (638.4)	TB4 +40.2	S-IVB	00:10:33.71 (633.71)	TB4 +40.35	DAC (FM)	13
108a	Signal from LVDC for: LOX Tank Vent Valve Boost Close On	00:10:41.4 (641.4)	TB4 +43.2	IU	00:10:36.71 (636.71)	TB4 +43.15	MSFC	--
108b	Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close On	00:10:41.4 (641.4)	TB4 +43.2	S-IVB	00:10:36.71 (636.71)	TB4 +43.15	DAC (FM)	13
109	Signal from LVDC for: Nose Cone/SLA Separation Sequence Start "A"	00:10:43.2 (643.2)	TB4 +45.0	IU	00:10:38.51 (638.51)	TB4 +44.95	MSFC	--
110	Signal from LVDC for: Nose Cone/SLA Separation Sequence Start "B"	00:10:43.4 (643.4)	TB4 +45.2	IU	00:10:38.71 (638.71)	TB4 +45.15	MSFC	--
111a	Signal from LVDC for: LOX Tank Vent Valve Boost Close Off	00:10:43.6 (643.6)	TB4 +45.4	IU	00:10:38.91 (638.91)	TB4 +45.35	MSFC	--
111b	Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close Off	00:10:43.6 (643.6)	TB4 +45.4	S-IVB	00:10:38.91 (638.91)	TB4 +45.35	DAC (FM)	13
112	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	00:10:48.5 (648.5)	TB4 +50.3	IU	00:10:43.81 (643.81)	TB4 +50.25	MSFC	--
113	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:10:53.5 (653.5)	TB4 +55.3	IU	00:10:48.81 (648.81)	TB4 +55.25	MSFC	--
114	Signal from LVDC for: Nose Cone/SLA Separation Sequence Start Reset	00:10:53.7 (653.7)	TB4 +55.5	IU	00:10:49.01 (649.01)	TB4 +55.45	MSFC	--
115a	Signal from LVDC for: Chilldown Shutoff Valves Open	00:10:58.5 (658.5)	TB4 +60.3	IU	00:10:53.81 (653.81)	TB4 +60.25	MSFC	--
115b	Signal Received in S-IVB for: Chill-down Shutoff Valves Open	00:10:58.5 (658.5)	TB4 +60.3	S-IVB	00:10:53.81 (653.81)	TB4 +60.25	DAC (FM)	13
116a	Signal from LVDC for: Prevalves Open	00:10:58.7 (658.7)	TB4 +60.5	IU	00:10:54.01 (654.01)	TB4 +60.45	MSFC	--
116b	Signal Received in S-IVB for: Pre-valves Open	00:10:58.7 (658.7)	TB4 +60.5	S-IVB	00:10:54.01 (654.01)	TB4 +60.45	DAC (FM)	13
117	Start Pitch Maneuver (To Local Horizontal)	00:11:28.2 (688.2)	N/A	N/A	00:11:23.82 (683.82)	N/A	MSFC	--
118a	Signal from LVDC for: Slow Record On	00:11:37.9 (697.9)	TB4 +99.7	IU	00:11:33.22 (693.22)	TB4 +99.66	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 11 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
118b	Signal Received in S-IVB for: Slow Record On	00:11:37.9 (697.9)	TB4 +99.7	S-IVB	00:11:33.22 (693.22)	TB4 +99.66	DAC (FM)	13
119a	Signal from LVDC for: Slow Record On	00:11:47.9 (707.9)	TB4 +109.7	IU	00:11:43.21 (703.21)	TB4 +109.65	MSFC	—
119b	Signal Received in S-IVB for: Slow Record On	00:11:47.9 (707.9)	TB4 +109.7	S-IVB	00:11:43.21 (703.21)	TB4 +109.65	DAC (FM)	13
120	Signal from LVDC for: Azusa Transponder Power Off	00:14:58.2 (898.2)	TB4 +300.0	IU	00:14:53.51 (893.51)	TB4 +299.95	MSFC	—
121	Signal from LVDC for: SLA Panel Deployment "A"	00:19:58.2 (1,198.2)	TB4 +600.0	IU	00:19:53.51 (1,193.51)	TB4 +599.95	MSFC	—
122	Signal from LVDC for: SLA Panel Deployment "B"	00:19:58.2 (1,198.4)	TB4 +600.2	IU	00:19:53.71 (1,193.71)	TB4 +600.15	MSFC	—
122.1	Signal from LVDC for: SLA Panel Deployment "A"	N/A	N/A	IU	00:21:13.12 (1,273.12)	N/A	MSFC	—
122.2	Signal from LVDC for: SLA Panel Deployment "B"	N/A	N/A	IU	00:21:13.99 (1,273.99)	N/A	MSFC	—
123a	Signal from LVDC for: LH2 Vent Valve Close	00:30:58.6 (1,858.6)	TB4 +1,260.4	IU	00:30:53.93 (1,853.93)	TB4 +1,260.37	MSFC	—
123b	Signal Received in S-IVB LH2 Vent Valve Close	00:30:58.6 (1,858.6)	TB4 +1,260.4	S-IVB	See Note 1 at end of table		DAC (FM)	—
124a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close On	00:31:01.6 (1,861.6)	TB4 +1,263.4	IU	00:30:56.93 (1,856.93)	TB4 +1,263.37	MSFC	—
124b	Signal Received by S-IVB for: LH2 Tank Vent Valve Boost Close On	00:31:01.6 (1,861.6)	TB4 +1,263.4	S-IVB	See Note 1 at end of table		DAC (FM)	—
125a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close Off	00:31:03.6 (1,863.6)	TB4 +1,265.4	IU	00:30:58.93 (1,858.93)	TB4 +1,265.37	MSFC	—
125b	Signal Received by S-IVB for: LH2 Tank Vent Valve Boost Close Off	00:31:03.6 (1,863.6)	TB4 +1,265.4	S-IVB	See Note 1 at end of table		DAC (FM)	—
126a	Signal from LVDC for: Slow Record On	00:38:17.9 (2,297.9)	TB4 +1,699.7	IU	00:38:13.21 (2,293.21)	TB4 +1,699.65	MSFC	—
126b	Signal Received in S-IVB for: Slow Record On	00:38:17.9 (2,297.9)	TB4 +1,699.7	S-IVB	00:38:13.21 (2,293.21)	TB4 +1,699.65	DAC (FM)	13
127a	Signal from LVDC for: Slow Record Off	00:38:49.9 (2,329.9)	TB4 +1,731.7	IU	00:38:45.21 (2,325.21)	TB4 +1,731.65	MSFC	—
127b	Signal Received in S-IVB for: Slow Record Off	00:38:49.9 (2,329.9)	TB4 +1,731.7	S-IVB	00:38:45.21 (2,325.21)	TB4 +1,731.65	DAC (FM)	13
128a	Signal from LVDC for: Recorder Playback On	00:38:50.1 (2,330.1)	TB4 +1,731.9	IU	00:38:45.41 (2,325.41)	TB4 +1,731.85	MSFC	—
128b	Signal Received in S-IVB for: Recorder Playback On	00:38:50.1 (2,330.1)	TB4 +1,731.9	S-IVB	00:38:45.41 (2,325.41)	TB4 +1,731.85	DAC (FM)	13

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 12 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
129a	Signal from LVDC for: Recorder Playback Off	00:42:22.1 (2,542.1)	TB4 +1,943.9	IU	00:42:17.41 (2,537.41)	TB4 +1,943.85	MSFC	—
129b	Signal Received in S-IVB for: Recorder Playback Off	00:42:22.1 (2,542.1)	TB4 +1,943.9	S-IVB	00:42:17.42 (2,537.42)	TB4 +1,943.86	DAC (FM)	13
130a	Signal from LVDC for: Slow Record On	00:42:22.3 (2,542.3)	TB4 +1,944.1	IU	00:42:17.61 (2,537.61)	TB4 +1,944.05	MSFC	—
130b	Signal Received in S-IVB for: Slow Record On	00:42:22.3 (2,542.3)	TB4 +1,944.1	S-IVB	00:42:17.62 (2,537.62)	TB4 +1,944.06	DAC (FM)	13
131a	Signal from LVDC for: Slow Record On	00:42:32.3 (2,552.3)	TB4 +1,954.1	IU	00:42:27.61 (2,547.61)	TB4 +1,954.05	MSFC	—
131b	Signal Received in S-IVB for: Slow Record On	00:42:32.3 (2,552.3)	TB4 +1,954.1	S-IVB	00:42:27.62 (2,547.62)	TB4 +1,954.06	DAC (FM)	13
132	Start Maneuver to Separation Attitude	00:49:59.8 (2,999.8)	N/A	N/A	00:50:00.80 (3,000.80)†	N/A	MSFC	—
133	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	00:53:42.9 (3,222.9)	TB4 +2,624.7	IU	00:53:38.20 (3,218.20)	TB4 +2,624.64	MSFC	—
134a	Signal from LVDC for: Special Telemetry Calibration On	00:53:43.1 (3,223.1)	TB4 +2,624.9	IU	00:53:38.40 (3,218.40)	TB4 +2,624.84	MSFC	—
134b	Signal Received in S-IVB for: Special Telemetry Calibration On	00:53:43.1 (3,223.1)	TB4 +2,624.9	S-IVB	00:53:38.42 (3,218.42)	TB4 +2,624.86	DAC (FM)	13
135a	Signal from LVDC for: Regular Telemetry Calibration On	00:53:43.3 (3,223.3)	TB4 +2,625.1	IU	00:53:38.61 (3,218.61)	TB4 +2,625.05	MSFC	—
135b	Signal Received in S-IVB for: Regular Telemetry Calibration On	00:53:43.3 (3,223.3)	TB4 +2,625.1	S-IVB	00:53:38.63 (3,218.63)	TB4 +2,625.07	DAC (FM)	13
136	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	00:53:47.9 (3,227.9)	TB4 +2,629.7	IU	00:53:43.21 (3,223.21)	TB4 +2,629.65	MSFC	—
137a	Signal from LVDC for: Regular Telemetry Calibration Off	00:53:48.3 (3,228.3)	TB4 +2,630.1	IU	00:53:43.61 (3,223.61)	TB4 +2,630.05	MSFC	—
137b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	00:53:48.3 (3,228.3)	TB4 +2,630.1	S-IVB	00:53:43.62 (3,223.62)	TB4 +2,630.06	DAC (FM)	13
138a	Signal from LVDC for: Special Telemetry Calibration Off	00:53:48.5 (3,228.5)	TB4 +2,630.3	IU	00:53:43.81 (3,223.81)	TB4 +2,630.25	MSFC	—
138b	Signal Received in S-IVB for: Special Telemetry Calibration Off	00:53:48.5 (3,228.5)	TB4 +2,630.3	S-IVB	00:53:43.83 (3,223.83)	TB4 +2,630.27	DAC (FM)	13

*Range Zero = 22:48:08 (GMT), †See paragraph 4.5

TABLE 4-1 (Sheet 13 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONI-TORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCU-RACY (ms)
139	LM Separation Sequence Initiated	00:53:54.8 (3,234.8)	N/A	N/A	00:53:55.24 (3,235.24)	N/A	MSFC	--
140a	Signal from LVDC for: Slow Record On	00:55:17.9 (3,317.9)	TB4 +2,719.7	IU	00:55:13.22 (3,313.22)	TB4 +2,719.66	MSFC	--
140b	Signal Received in S-IVB for: Slow Record On	00:55:17.9 (3,317.9)	TB4 +2,719.7	S-IVB	00:55:13.23 (3,313.23)	TB4 +2,719.67	DAC (FM)	13
141a	Signal from LVDC for: LH2 Tank Vent Valve Open	00:56:43.2 (3,403.2)	TB4 +2,805.0	IU	00:56:38.51 (3,398.51)	TB4 +2,804.95	MSFC	--
141b	Signal Received in S-IVB for: LH2 Tank Vent Valve Open	00:56:43.2 (3,403.2)	TB4 +2,805.0	S-IVB	00:56:38.53 (3,398.53)	TB4 +2,804.97	DAC (FM)	13
142	Pitch to Local Horizontal	00:56:54.8 (3,414.8)	N/A	N/A	00:56:55.80 (3,415.80)	N/A	MSFC	--
143	Signal from LVDC for: Temperature Control Sensor Bias On	01:12:00.4 (4,320.4)	TB4 +3,772.2	IU	01:11:55.71 (4,315.71)	TB4 +3,722.15	MSFC	--
144	Signal from LVDC for: Cooling System Electronic Assembly Power Off	01:13:40.4 (4,420.4)	TB4 +3,822.2	IU	01:13:35.71 (4,415.71)	TB4 +3,822.15	MSFC	--
145a	Signal from LVDC for: LH2 Tank Vent Valve Close	01:16:43.2 (4,603.2)	TB4 +4,005.0	IU	01:16:38.51 (4,598.51)	TB4 +4,004.95	MSFC	--
145b	Signal Received in S-IVB for LH2 Tank Vent Valve Close	01:16:43.2 (4,603.2)	TB4 +4,005.0	S-IVB	See Note 2 at end of table		DAC (FM)	--
146a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close On	01:16:46.2 (4,606.2)	TB4 +4,008.0	IU	01:16:41.51 (4,601.51)	TB4 +4,007.95	MSFC	--
146b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close On	01:16:46.2 (4,606.2)	TB4 +4,008.0	S-IVB	See Note 2 at end of table		DAC (FM)	--
147a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close Off	01:16:48.2 (4,608.2)	TB4 +4,010.0	IU	01:16:43.51 (4,603.51)	TB4 +4,009.95	MSFC	--
147b	Signal Received in S-IVB for LH2 Tank Vent Valve Boost Close Off	01:16:48.2 (4,608.2)	TB4 +4,010.0	S-IVB	See Note 2 at end of table		DAC (FM)	--
148	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	01:29:12.9 (5,352.9)	TB4 +4,754.7	IU	01:29:08.2 (5,348.21)	TB4 +4,754.65	MSFC	--
149a	Signal from LVDC for: Special Telemetry Calibration On	01:29:13.1 (5,353.1)	TB4 +4,754.9	IU	01:29:08.41 (5,348.41)	TB4 +4,754.85	MSFC	--
149b	Signal Received in S-IVB for: Special Telemetry Calibration On	01:29:13.1 (5,353.1)	TB4 +4,754.9	S-IVB	01:29:08.43 (5,348.43)	TB4 +4,754.87	DAC (FM)	13
150a	Signal from LVDC for: Regular Telemetry Calibration On	01:29:13.3 (5,353.3)	TB4 +4,755.1	IU	01:29:08.61 (5,348.61)	TB4 +4,755.05	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 14 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
150b	Signal Received in S-IVB for: Regular Telemetry Calibration On	01:29:13.3 (5,353.3)	TB4 +4,755.1	S-IVB	01:29:08.63 (5,348.63)	TB4 +4,755.07	DAC (FM)	13
151	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	01:29:17.9 (5,357.9)	TB4 +4,759.7	IU	01:29:13.21 (5,353.21)	TB4 +4,759.65	MSFC	--
152a	Signal from LVDC for: Regular Telemetry Calibration Off	01:29:18.3 (5,358.3)	TB4 +4,760.1	IU	01:29:13.61 (5,353.61)	TB4 +4,759.85	MSFC	--
152b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	01:29:18.3 (5,358.3)	TB4 +4,760.1	S-IVB	01:29:13.64 (5,353.64)	TB4 +4,760.08	DAC (FM)	13
153a	Signal from LVDC for: Special Telemetry Calibration Off	01:29:18.5 (5,358.5)	TB4 +760.3	IU	01:29:13.81 (5,353.81)	TB4 +4,760.05	MSFC	--
153b	Signal Received in S-IVB for: Special Telemetry Calibration Off	01:29:18.5 (5,358.5)	TB4 +4,760.3	S-IVB	01:29:13.84 (5,353.84)	TB4 +4,760.28	DAC (FM)	13
154a	Signal from LVDC for: Slow Record On	01:29:18.9 (5,358.9)	TB4 +4,760.7	IU	01:29:14.21 (5,354.21)	TB4 +4,760.25	MSFC	--
154b	Signal Received in S-IVB for: Slow Record On	01:29:18.9 (5,358.9)	TB4 +4,760.7	S-IVB	01:29:14.24 (5,354.24)	TB4 +4,760.68	DAC (FM)	13
155a	Signal from LVDC for: Slow Record Off	01:29:48.9 (5,388.9)	TB4 +4,790.7	IU	01:29:44.21 (5,384.21)	TB4 +4,790.25	MSFC	--
155b	Signal Received in S-IVB for: Slow Record Off	01:29:48.9 (5,388.9)	TB4 +4,790.7	S-IVB	See Note 3 at end of table		DAC (FM)	--
156a	Signal from LVDC for: Recorder Playback On	01:29:49.1 (5,389.1)	TB4 +4,790.9	IU	01:29:44.41 (5,384.41)	TB4 +4,790.45	MSFC	--
156b	Signal Received in S-IVB for: Recorder Playback On	01:29:49.1 (5,389.1)	TB4 +4,790.9	S-IVB	See Note 3 at end of table		DAC (FM)	--
157	Start Inertial Attitude Hold	01:31:24.8 (5,484.8)	N/A	N/A	01:31:25.80 (5,485.80)	N/A	MSFC	--
158a	Signal from LVDC for: Recorder Playback Off	01:35:44.9 (5,744.9)	TB4 +5,146.7	IU	01:35:40.21 (5,740.21)	TB4 +5,146.65	MSFC	--
158b	Signal Received in S-IVB for: Recorder Playback Off	01:35:44.9 (5,744.9)	TB4 +5,146.7	S-IVB	01:35:40.24 (5,740.24)	TB4 +5,146.68	DAC (FM)	13
159a	Signal from LVDC for: Slow Record On	01:35:45.1 (5,745.1)	TB4 +5,146.9	IU	01:35:40.41 (5,740.41)	TB4 +5,146.85	MSFC	--
159b	Signal Received in S-IVB for: Slow Record On	01:35:45.1 (5,745.1)	TB4 +5,146.9	S-IVB	01:35:40.44 (5,740.44)	TB4 +5,146.88	DAC (FM)	13
160a	Signal from LVDC for: Slow Record On	01:35:55.1 (5,755.1)	TB4 +5,156.9	IU	01:35:50.41 (5,750.41)	TB4 +5,156.85	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 15 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONITORED AT	MONITORED TIME		DATA SOURC.	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)		
160b	Signal Received in S-IVB for: Slow Record On	01:35:55.1 (5,755.1)	TB4 +5,156.9	S-IVB	01:35:50.43 (5,750.43)	TB4 +5,156.87	DAC (FM)	13
161a	Signal from LVDC for: Passivation Enable	01:36:59.4 (5,819.4)	TB4 +5,221.2	IU	01:36:54.71 (5,814.71)	TB4 +5,221.15	MSFC	--
161b	Signal Received in S-IVB for: Passivation Enable	01:36:59.4 (5,819.4)	TB4 +5,221.2	S-IVB	01:36:54.74 (5,814.74)	TB4 +5,221.18	DAC (FM)	13
162a	Signal from LVDC for: LH2 Tank Vent Valve Open	01:42:28.2 (6,148.2)	TB4 +5,550.0	IU	01:42:23.51 (6,143.51)	TB4 +5,549.95	MSFC	--
162b	Signal Received in S-IVB for: LH2 Tank Vent Valve Open	01:42:28.2 (6,148.2)	TB4 +5,550.0	S-IVB	01:42:43.42 (6,143.42)	TB4 +5,549.86	DAC (FM)	13
163	Signal from LVDC for: Telemetry Calibrate In-Flight Calibrate On	01:44:53.9 (6,293.9)	TB4 +5,695.7	IU	01:44:49.21 (6,289.21)	TB4 +5,695.65	MSFC	--
164a	Signal from LVDC for: Special Telemetry Calibration On	01:44:54.1 (6,294.1)	TB4 +5,695.9	IU	01:44:49.41 (6,289.41)	TB4 +5,695.85	MSFC	--
164b	Signal Received in S-IVB for: Special Telemetry Calibration On	01:44:54.1 (6,294.1)	TB4 +5,695.9	S-IVB	01:44:49.43 (6,289.43)	TB4 +5,695.87	DAC (FM)	13
165a	Signal from LVDC for: Regular Telemetry Calibration On	01:44:54.3 (6,294.3)	TB4 +5,696.1	IU	01:44:49.61 (6,289.61)	TB4 +5,696.05	MSFC	--
165b	Signal Received in S-IVB for: Regular Telemetry Calibration On	01:44:54.3 (6,294.3)	TB4 +5,696.1	S-IVB	01:44:49.63 (6,289.63)	TB4 +5,696.07	DAC (FM)	13
166	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	01:44:58.9 (6,298.9)	TB4 +5,700.7	IU	01:43:54.21 (6,294.21)	TB4 +5,700.65	MSFC	--
167a	Signal from LVDC for: Regular Telemetry Calibration Off	01:44:59.3 (6,299.3)	TB4 +5,701.1	IU	01:43:54.61 (6,294.61)	TB4 +5,701.05	MSFC	--
167b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	01:44:59.3 (6,299.3)	TB4 +5,701.1	S-IVB	01:44:54.63 (6,294.63)	TB4 +5,701.07	DAC (FM)	13
168a	Signal from LVDC for: Special Telemetry Calibration Off	01:44:59.5 (6,299.5)	TB4 +5,701.3	IU	01:43:54.81 (6,294.81)	TB4 +5,701.25	MSFC	--
168b	Signal Received in S-IVB for: Special Telemetry Calibration Off	01:44:59.5 (6,299.5)	TB4 +5,701.3	S-IVB	01:44:54.83 (6,294.83)	TB4 +5,701.27	DAC (FM)	13
169	Start Pitch to Retrograde Attitude	01:45:54.8 (6,354.8)	N/A	N/A	01:45:55.80 (6,355.80)	N/A	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 16 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
170a	Signal from LVDC for: Auxiliary Hydraulic Pump Coast Mode On	01:46:18.2 (6,378.2)	TB4 +5,780.0	IU	01:46:13.51 (6,373.51)	TB4 +5,779.95	MSFC	--
170b	Signal Received in S-IVB for: Auxiliary Hydraulic Pump Coast Mode On	01:46:18.2 (6,378.2)	TB4 +5,780.0	S-IVB	01:46:13.53 (6,373.53)	TB4 +5,779.97	DAC (FM)	13
171a	Signal from LVDC for: LH2 Tank Vent Valve Close	01:52:28.2 (6,748.2)	TB4 +6,150.0	IU	01:52:23.51 (6,743.51)	TB4 +6,149.95	MSFC	--
171b	Signal Received in S-IVB for: LH2 Tank Vent Valve Close	01:52:28.2 (6,748.2)	TB4 +6,150.0	S-IVB	01:52:23.54 (6,743.54)	TB4 +6,149.98	DAC (FM)	13
172a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close On	01:52:31.2 (6,751.2)	TB4 +6,153.0	IU	01:52:26.51 (6,746.51)	TB4 +6,152.95	MSFC	--
172b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close On	01:52:31.2 (6,751.2)	TB4 +6,153.0	S-IVB	01:52:26.54 (6,746.54)	TB4 +6,152.98	DAC (FM)	13
173a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close On	01:52:33.2 (6,753.2)	TB4 +6,155.0	IU	01:52:28.51 (6,748.51)	TB4 +6,154.95	MSFC	--
173b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close Off	01:52:33.2 (6,753.2)	TB4 +6,155.0	S-IVB	01:52:28.54 (6,748.54)	TB4 +6,154.98	DAC (FM)	13
174a	Signal from LVDC for: Slow Record On	02:10:39.9 (7,839.9)	TB4 +7,241.7	IU	02:10:35.22 (7,835.22)	TB4 +7,241.66	MSFC	--
174b	Signal Received in S-IVB for: Slow Record On	02:10:39.9 (7,839.9)	TB4 +7,241.7	S-IVB	02:10:35.24 (7,835.24)	TB4 +7,241.86	DAC	13
175a	Signal from LVDC for: Slow Record Off	02:11:11.9 (7,871.9)	TB4 +7,273.7	IU	02:11:07.22 (7,867.22)	TB4 +7,273.66	MSFC	--
175b	Signal Received in S-IVB for: Slow Record Off	02:11:11.9 (7,871.9)	TB4 +7,273.7	S-IVB	02:11:08.24 (7,868.24)	TB4 +7,274.68	DAC (FM)	13
176a	Signal from LVDC for: Recorder Playback On	02:11:12.1 (7,872.1)	TB4 +7,273.9	IU	02:11:07.42 (7,867.42)	TB4 +7,273.86	MSFC	--
176b	Signal Received in S-IVB for: Recorder Playback On	02:11:12.1 (7,872.1)	TB4 +7,273.9	S-IVB	02:11:08.44 (7,868.44)	TB4 +7,274.68	DAC (FM)	13
177a	Signal from LVDC for: Recorder Playback Off	02:15:40.1 (8,140.1)	TB4 +7,541.9	IU	02:15:35.41 (8,135.41)	TB4 +7,541.85	MSFC	--
177b	Signal Received in S-IVB for: Recorder Playback Off	02:15:40.1 (8,140.1)	TB4 +7,541.9	S-IVB	02:15:35.43 (8,135.43)	TB4 +7,541.87	DAC (FM)	13
178a	Signal from LVDC for: Slow Record On	02:15:40.3 (8,140.3)	TB4 +7,542.1	IU	02:15:35.61 (8,135.61)	TB4 +7,542.05	MSFC	--
178b	Signal Received in S-IVB for: Slow Record On	02:15:40.3 (8,140.3)	TB4 +7,542.1	S-IVB	02:15:35.63 (8,135.63)	TB4 +7,542.07	DAC (FM)	13
179a	Signal from LVDC for: Slow Record On	02:15:50.3 (8,150.3)	TB4 +7,552.1	IU	02:15:45.61 (8,145.61)	TB4 +7,552.05	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 17 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
179b	Signal Received in S-IVB for: Slow Record On	02:15:50.3 (8,150.3)	TB4 +7,552.1	S-IVB	02:15:45.63 (8,145.63)	TB4 +7,552.07	DAC (FM)	13
180	Start Pitch to Passivation Attitude	02:20:38.2 (8,438.2)	N/A	N/A	02:20:33.8 (8,433.8))	N/A	MSFC	--
181	Initiate Constant Roll	02:25:55.2 (8,755.2)	N/A	N/A	02:25:50.34 (8,750.8)	N/A	MSFC	--
182a	Signal from LVDC for: Auxiliary Hydraulic Pump Flight Mode On	02:26:13.0 (8,773.0)	TB4 +8,174.8	IU	02:26:08.31 (8,768.31)	TB4 +8,174.75	MSFC	--
182b	Signal Received in S-IVB for: Auxiliary Hydraulic Pump Flight Mode On	02:26:13.0 (8,773.0)	TB4 +8,174.8	S-IVB	02:26:08.34 (8,768.34)	TB4 +8,174.78	DAC (FM)	13
183	Signal from LVDC for: Flight Control Computer S-IVB Burn Mode On "A"	02:26:18.3 (8,778.3)	TB4 +8,180.1	IU	02:26:13.61 (8,773.61)	TB4 +8,180.05	MSFC	--
184	Signal from LVDC for: Flight Control Computer S-IVB Burn Mode On "B"	02:26:18.5 (8,778.5)	TB4 +8,180.3	IU	02:26:13.81 (8,773.81)	TB4 +8,180.25	MSFC	--
185a	Signal from LVDC for: Engine Mainstage Control Valve Open On	02:26:19.0 (8,779.0)	TB4 +8,180.8	IU	02:26:14.31 (8,774.31)	TB4 +8,180.75	MSFC	--
185b	Signal Received in S-IVB for: Engine Mainstage Control Valve Open On	02:26:19.0 (8,779.0)	TB4 +8,180.8	S-IVB	02:26:14.35 (8,774.35)	TB4 +8,180.79	DAC (FM)	13
186a	Signal from LVDC for: Engine He Control Valve Open On	02:26:19.2 (8,779.2)	TB4 +3,181.0	IU	02:26:14.51 (8,774.51)	TB4 +8,180.95	MSFC	--
186b	Signal Received in S-IVB for: Engine He Control Valve Open On	02:26:19.2 (8,779.2)	TB4 +8,181.0	S-IVB	02:26:14.55 (8,774.55)	TB4 +8,180.99	DAC (FM)	13
187	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	02:26:47.9 (8,807.9)	TB4 +8,209.7	IU	02:26:43.21 (8,803.21)	TB4 +8,209.65	MSFC	--
188a	Signal from LVDC for: Special Telemetry Calibration On	02:26:48.1 (8,808.1)	TB4 +8,209.9	IU	02:26:43.41 (8,803.41)	TB4 +8,209.85	MSFC	--
188b	Signal Received in S-IVB for: Special Telemetry Calibration On	02:26:48.1 (8,808.1)	TB4 +8,209.9	S-IVB	02:26:43.44 (8,803.44)	TB4 +8,209.88	DAC (FM)	13
189a	Signal from LVDC for: Regular Telemetry Calibration On	02:26:48.3 (8,808.3)	TB4 +8,210.1	IU	02:26:43.61 (8,803.61)	TB4 +8,210.05	MSFC	--
189b	Signal Received in S-IVB for: Regular Telemetry Calibration On	02:26:48.3 (8,808.3)	TB4 +8,210.1	S-IVB	02:26:43.65 (8,803.65)	TB4 +8,210.09	DAC (FM)	13

*Range Zero = 22:43:08 (GMT)

TABLE 4-1 (Sheet 18 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
190	Signal from LVDC for: Telemetry Calibrate In-Flight Calibrate Off	02:26:52.9 (8,812.9)	TB4 +8,214.7	IU	02:26:48.21 (8,808.21)	TB4 +8,214.65	MSFC	--
191a	Signal from LVDC for: Regular Telemetry Calibration Off	02:26:53.3 (8,813.3)	TB4 +8,215.1	IU	02:26:48.61 (8,808.61)	TB4 +8,215.05	MSFC	--
191b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	02:26:53.3 (8,813.3)	TB4 +8,215.1	S-IVB	02:26:48.65 (8,808.65)	TB4 +8,215.09	DAC (FM)	13
192a	Signal from LVDC for: Special Telemetry Calibration Off	02:26:53.5 (8,813.5)	TB4 +8,215.3	IU	02:26:48.81 (8,808.81)	TB4 +8,215.25	MSFC	--
192b	Signal Received in S-IVB for: Special Telemetry Calibration Off	02:26:53.5 (8,813.5)	TB4 +8,215.3	S-IVB	02:26:48.85 (8,808.85)	TB4 +8,215.29	DAC (FM)	13
193a	Signal from LVDC for: Slow Record On	02:26:55.9 (8,815.9)	TB4 +8,217.7	IU	02:26:51.21 (8,811.21)	TB4 +8,217.65	MSFC	--
193b	Signal Received in S-IVB for: Slow Record On	02:26:55.9 (8,815.9)	TB4 +8,217.7	S-IVB	02:26:51.24 (8,811.24)	TB4 +8,217.68	DAC (FM)	13
194	Signal from LVDC for: Flight Control Computer Burn Mode Off "A"	02:27:40.2 (8,860.2)	TB4 +8,262.0	IU	02:27:35.51 (8,855.51)	TB4 +8,261.95	MSFC	--
195	Signal from LVDC for: Flight Control Computer Burn Mode Off "B"	02:27:40.2 (8,860.4)	TB4 +8,262.2	IU	02:27:35.71 (8,855.71)	TB4 +8,262.15	MSFC	--
196a	Signal from LVDC for: Engine Mainstage Control Valve Open Off	02:28:19.2 (8,899.2)	TB4 +8,301.0	IU	02:28:14.51 (8,894.51)	TB4 +8,300.95	MSFC	--
196b	Signal Received in S-IVB for: Engine Mainstage Control Valve Open Off	02:28:19.2 (8,899.2)	TB4 +8,301.0	S-IVB	02:28:14.55 (8,894.55)	TB4 +8,300.99	DAC (FM)	13
197a	Signal from LVDC for: Engine He Control Valve Open Off	02:28:20.2 (8,900.2)	TB4 +8,302.0	IU	02:28:15.51 (8,895.51)	TB4 +8,301.95	MSFC	--
197b	Signal Received in S-IVB for: Engine He Control Valve Open Off	02:28:20.2 (8,900.2)	TB4 +8,302.0	S-IVB	02:28:15.55 (8,895.55)	TB4 +8,301.98	DAC (FM)	13
198a	Signal from LVDC for: Engine Ignition Phase Control Valve Open	02:28:29.0 (8,909.0)	TB4 +8,310.8	IU	02:28:24.31 (8,904.31)	TB4 +8,310.75	MSFC	--
198b	Signal Received in S-IVB for: Engine Ignition Phase Control Valve Open	02:28:29.0 (8,909.0)	TB4 +8,310.8	S-IVB	02:28:24.35 (8,904.35)	TB4 +8,310.79	DAC (FM)	13
199a	Signal from LVDC for: Engine He Control Valve Open On	02:28:29.2 (8,909.2)	TB4 +8,311.0	IU	02:28:24.51 (8,904.51)	TB4 +8,310.95	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 19 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
199b	Signal Received in S-IVB for: Engine He Control Valve Open On	02:28:29.2 (8,909.2)	TB4 +8,311.0	S-IVB	02:28:24.55 (8,904.55)	TB4 +8,310.99	DAC (FM)	13
200a	Signal from LVDC for: Engine Ignition Phase Control Valve Closed	02:31:29.2 (9,089.2)	TB4 +8,491.0	IU	02:31:24.51 (9,084.51)	TB4 +8,490.95	MSFC	--
200b	Signal Received in S-IVB for: Engine Ignition Phase Control Valve Closed	02:31:29.2 (9,089.2)	TB4 +8,491.0	S-IVB	02:31:24.55 (9,084.55)	TB4 +8,490.99	DAC (FM)	13
201a	Signal from LVDC for: Engine He Control Valve Open Off	02:31:30.2 (9,090.2)	TB4 +8,492.0	IU	02:31:25.51 (9,085.51)	TB4 +8,491.95	MSFC	--
201b	Signal Received in S-IVB for Engine He Control Valve Open Off	02:31:30.2 (9,090.2)	TB4 +8,492.0	S-IVB	02:31:25.55 (9,085.55)	TB4 +8,491.99	DAC (FM)	13
202a	Signal from LVDC for: Auxiliary Hydraulic Pump Coast Mode On	02:31:32.7 (9,092.7)	TB4 +8,494.5	IU	02:31:28.01 (9,088.01)	TB4 +8,494.45	MSFC	--
202b	Signal Received in S-IVB for: Auxiliary Hydraulic Pump Coast Mode On	02:31:32.7 (9,092.7)	TB4 +8,494.5	S-IVB	02:31:28.05 (9,088.05)	TB4 8,494.49	DAC (FM)	13
203a	Signal from LVDC for: Auxiliary Hydraulic Pump Coast Mode Off	02:31:32.9 (9,092.9)	TB4 +8,494.7	IU	02:31:28.21 (9,088.21)	TB4 +8,494.65	MSFC	--
203b	Signal Received in S-IVB for: Auxiliary Hydraulic Pump Coast Mode Off	02:31:32.9 (9,092.9)	TB4 +8,494.7	S-IVB	02:31:28.25 (9,088.25)	TB4 +8,494.69	DAC (FM)	13
204a	Signal from LVDC for: LH2 Tank Vent Valve Open	02:31:39.0 (9,099.0)	TB4 +8,500.8	IU	02:31:28.31 (9,094.31)	TB4 +8,500.75	MSFC	--
204b	Signal Received in S-IVB for: LH2 Tank Vent Valve Open	02:31:39.0 (9,099.0)	TB4 +8,500.8	S-IVB	02:31:34.35 (9,094.35)	TB4 +8,500.79	DAC (FM)	13
205a	Siganl from LVDC for: LOX Tank Vent Valve Open	02:31:39.2 (9,099.2)	TB4 +8,501.0	IU	02:31:34 51 (9,094.51)	TB4 +8,500.95	MSFC	--
205b	Signal Received in S-IVB for: LOX Tank Vent Valve Open	02:31:39.2 (9,099.2)	TB4 +8,501.0	S-IVB	02:31:34.55 (9,094.55)	TB4 +8,500.99	DAC (FM)	13
206	Terminate Constant Roll	02:32:25.2 (9,145.2)	N/A	N/A	02:32:23.74 (9,143.74)	N/A	MSFC	--
207	Pitch Nose Up to Local Horizontal	02:36:38.2 (9,398.2)	N/A	N/A	02:36:33.80 (9,393.8)	N/A	MSFC	--
207.1	Water Coolant Valve Open	N/A	N/A	IU	02:37:10.50 (9,430.50)	N/A	MSFC	--
207.2	Water Coolant Valve Close	N/A	N/A	IU	02:42:01.00 (9,731.00)	N/A	MSFC	--
208a	Signal from LVDC for: LOX Tank Pressurization Shutoff Valves Open	02:52:34.2 (10,354.2)	TB4 +9,756.0	IU	02:52:29.51 (10,349.51)	TB4 +9,755.95	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 20 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
208b	Signal Received in S-IVB for: LOX Tank Pressurization Shutoff Valves Open	02:52:34.2 (10,354.2)	TB4 +9,756.0	S-IVB	02:52:29.53 (10,349.53)	TB4 +9,755.97	DAC (FM)	13
209a	Signal from LVDC for: Slow Record On	02:52:36.9 (10,356.9)	TB4 +9,758.7	IU	02:52:32.22 (10,352.22)	TB4 +9,758.66	MSFC	--
209b	Signal Received in S-IVB for: Slow Record On	02:52:36.9 (10,356.9)	TB4 +9,758.7	S-IVB	02:52:32.24 (10,352.24)	TB4 +9,758.68	DAC (FM)	13
210a	Signal from LVDC for: Slow Record Off	02:53:08.9 (10,388.9)	TB4 +9,790.7	IU	02:53:04:21 (10,384.21)	TB4 +9,790.65	MSFC	--
210b	Signal Received in S-IVB for: Slow Record Off	02:53:08.9 (10,388.9)	TB4 +9,790.7	S-IVB	02:53:04.23 (10,384.23)	TB4 +9,790.67	DAC (FM)	13
211a	Signal from LVDC for: Recorder Playback On	02:53:09.1 (10,389.1)	TB4 +9,790.9	IU	02:53:04:41 (10,384.41)	TB4 +9,790.85	MSFC	--
211b	Signal Received in S-IVB for: Recorder Playback On	02:53:01.1 (10,389.1)	TB4 +9,790.9	S-IVB	02:53:04.43 (10,384.43)	TB4 +9,790.87	DAC (FM)	13
212a	Signal from LVDC for: Recorder Playback Off	02:57:51.1 (10,671.1)	TB4 +10,072.9	IU	02:57:46.41 (10,666.41)	TB4 +10,072.85	MSFC	--
212b	Signal Received in S-IVB for: Recorder Playback Off	02:57:51.1 (10,671.1)	TB4 +10,072.9	S-IVB	See Note 4 at end of table		DAC (FM)	--
213a	Signal from LVDC for: Slow Record On	02:57:51.3 (10,671.3)	TB4 +10,073.1	IU	02:57:46.41 (10,666.61)	TB4 +10,073.05	MSFC	--
213b	Signal Received in S-IVB for: Slow Record On	02:57:51.3 (10,671.3)	TB4 +10,073.1	S-IVB	See Note 4 at end of table		DAC (FM)	--
214a	Signal from LVDC for: Slow Record On	02:58:01.3 (10,681.3)	TB4 +10,083.1	IU	02:57:56.61 (10,676.61)	TB4 +10,083.05	MSFC	--
214b	Signal Received in S-IVB for: Slow Record On	02:58:01.3 (10,681.3)	TB4 +10,083.1	S-IVB	02:57:56.72 (10,676.72)	TB4 +10,083.16	DAC (PCM)	25
215	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	03:03:25.9 (11,005.9)	TB4 +10,407.7	IU	03:03:21.21 (11,001.21)	TB4 +10,407.65	MSFC	--
216a	Signal from LVDC for: Special Telemetry Calibration On	03:03:26.1 (11,006.1)	TB4 +10,407.9	IU	03:03:21.41 (11,001.41)	TB4 +10,407.85	MSFC	--
216b	Signal Received in S-IVB for: Special Telemetry Calibration On	03:03:26.1 (11,006.1)	TB4 +10,407.9	S-IVB	03:03:21.45 (11,001.45)	TB4 +10,407.89	DAC (FM)	13
217a	Signal from LVDC for: Regular Telemetry Calibration On	03:03:26.3 (11,006.3)	TB4 +10,408.1	IU	03:03:21.61 (11,001.61)	TB4 +10,408.05	MSFC	--
217b	Signal Received in S-IVB for: Regular Telemetry Calibration On	03:03:26.3 (11,006.3)	TB4 +10,408.1	S-IVB	03:03:21.65 (11,001.65)	TB4 +10,408.09	DAC (FM)	13
218	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	03:03:30.9 (11,010.9)	TB4 +10,412.7	IU	03:03:26.21 (11,006.21)	TB4 +10,412.65	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 21 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONI-TORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCU-RACY (ms)
219a	Signal from LVDC for: Regular Telemetry Calibration Off	03:03:31.3 (11,011.3)	TB4 +10,413.1	IU	03:03:26.61 (11,006.61)	TB4 +10,413.05	MSFC	--
219b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	03:03:31.3 (11,011.3)	TB4 +10,413.1	S-IVB	03:03:26.65 (11,006.65)	TB4 +10,413.09	DAC (FM)	13
220a	Signal from LVDC for: Special Telemetry Calibration Off	03:03:31.5 (11,011.5)	TB4 +10,413.3	IU	03:03:26.81 (11,006.81)	TB4 +10,413.25	MSFC	--
220b	Signal Received in S-IVB for: Special Telemetry Calibration Off	03:03:31.5 (11,011.5)	TB4 +10,413.3	S-IVB	03:03:26.85 (11,006.85)	TB4 +10,413.29	DAC (FM)	13
221	Water Coolant Valve Closed	N/A	N/A	IU	03:07:07.66 (11,227.66)	N/A	MSFC	--
222a	Signal from LVDC for: LOX Tank Pressurization Shutoff Valves Close	03:14:15.8 (11,655.8)	TB4 +11,057.6	IU	03:14:11.11 (11,651.11)	TB4 +11,057.55	MSFC	--
222b	Signal Received in S-IVB for: LOX Tank Pressurization Shutoff Valves Close	03:14:15.8 (11,655.8)	TB4 +11,057.6	S-IVB	03:14:11.15 (11,651.15)	TB4 +11,057.59	DAC (FM)	13
223a	Signal from LVDC for: LOX Tank Vent Valve Close	03:14:16.0 (11,656.0)	TB4 +11,057.8	IU	03:14:11.31 (11,651.31)	TB4 +11,057.75	MSFC	--
223b	Signal Received by S-IVB for: LOX Tank Vent Valve Close	03:14:16.0 (11,656.0)	TB4 +11,057.8	S-IVB	03:14:11.35 (11,651.35)	TB4 +11,057.79	DAC (FM)	13
224a	Signal from LVDC for: LH2 Tank Vent Valve Close	03:14:16.2 (11,656.2)	TB4 +11,058.0	IU	03:14:11.51 (11,651.51)	TB4 +11,057.95	MSFC	--
224b	Signal Received in S-IVB for: LH2 Tank Vent Valve Close	03:14:16.2 (11,656.2)	TB4 +11,058.0	S-IVB	03:14:11.53 (11,651.55)	TB4 +11,057.99	DAC (FM)	13
225a	Signal from LVDC for: LOX Tank Vent Valve Boost Close On	03:14:19.0 (11,659.0)	TB4 +11,060.8	IU	03:14:14.31 (11,654.31)	TB4 +11,060.75	MSFC	--
225b	Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close On	03:14:19.0 (11,659.0)	TB4 +11,060.8	S-IVB	03:14:14.34 (11,654.34)	TB4 +11,060.78	DAC (FM)	13
226a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close On	03:14:19.2 (11,659.2)	TB4 +11,061.0	IU	03:14:14.51 (11,654.51)	TB4 +11,060.95	MSFC	--
226b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close On	03:14:19.2 (11,659.2)	TB4 +11,061.0	S-IVB	03:14:14.54 (11,654.54)	TB4 +11,060.93	DAC (FM)	13
227a	Signal from LVDC for: LOX Tank Vent Valve Boost Close Off	03:14:21.0 (11,661.0)	TB4 +11,062.8	IU	03:14:16.31 (11,656.31)	TB4 +11,062.75	MSFC	--
227b	Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close Off	03:14:21.0 (11,661.0)	TB4 +11,062.8	S-IVB	03:14:16.34 (11,656.34)	TB4 +11,062.78	DAC (FM)	13

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 22 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME: TIME FROM RANGE ZERO (hr:min:sec) (sec)	PREDICTED TIME: TIME FROM BASE (sec)	SIGNAL MONITORED AT	MONITORED TIME: TIME FROM RANGE ZERO* (hr:min:sec) (sec)	MONITORED TIME: TIME FROM BASE (sec)	DATA SOURCE	ACCURACY (ms)
228a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close Off	03:14:21.2 (11,661.2)	TB4 +11,063.0	IU	03:14:16.51 (11,656.51)	TB4 +11,062.95	MSFC	--
228b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close Off	03:14:21.2 (11,661.2)	TB4 +11,063.0	S-IVB	03:14:16.54 (11,656.54)	TB4 +11,062.98	DAC (FM)	13
229	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	03:16:17.9 (11,777.9)	TB4 +11,179.7	IU	03:16:13.21 (11,773.21)	TB4 +11,179.65	MSFC	--
230a	Signal from LVDC for: Special Telemetry Calibration On	03:16:18.1 (11,778.1)	TB4 +11,179.9	IU	03:16:13.41 (11,773.41)	TB4 +11,179.85	MSFC	--
230b	Signal Received in S-IVB for: Special Telemetry Calibration On	03:16:18.1 (11,778.1)	TB4 +11,179.9	S-IVB	03:16:13.44 (11,773.44)	TB4 +11,179.88	DAC (FM)	13
231a	Signal from LVDC for: Regular Telemetry Calibration On	03:16:18.3 (11,778.3)	TB4 +11,180.1	IU	03:16:13.61 (11,773.61)	TB4 +11,180.05	MSFC	--
231b	Signal Received in S-IVB for: Regular Telemetry Calibration On	03:16:18.3 (11,778.3)	TB4 +11,180.1	S-IVB	03:16:13.64 (11,773.64)	TB4 +11,180.08	DAC (FM)	13
232	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	03:16:22.9 (11,782.9)	TB4 +11,184.7	IU	03:16:18.21 (11,778.21)	TB4 +11,184.65	MSFC	--
233a	Signal from LVDC for: Regular Telemetry Calibration Off	03:16:23.3 (11,783.3)	TB4 +11,185.1	IU	03:16:18.61 (11,778.61	TB4 +11,185.05	MSFC	--
233b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	03:16:23.3 (11,783.3)	TB4 +11,185.1	S-IVB	03:16:18.64 (11,778.64)	TB4 +11,185.09	DAC (FM)	13
234a	Signal from LVDC for: Special Calibration Off	03:16:23.5 (11,783.5)	TB4 +11,185.3	IU	03:16:18.81 (11,778.81)	TB4 +11,185.25	MSFC	--
234b	Signal Received in S-IVB for: Special Calibration Off	03:16:23.5 (11,783.5)	TB4 +11,185.3	S-IVB	03:16:18.84 (11,778.84)	TB4 +11,185.29	DAC (FM)	13
235a	Signal from LVDC for: Slow Record On	03:28:39.9 (12,519.9)	TB4 +11,921.7	IU	03:28:34.21 (12,515.21)	TB4 +11,921.65	MSFC	--
235b	Signal Received in S-IVB for: Slow Record On	03:28:39.9 (12,519.9)	TB4 +11,921.7	S-IVB	See Note 5 at end of table		DAC (FM)	--
236a	Signal from LVDC for: Slow Record Off	03:29:11.9 (12,551.9)	TB4 +11,953.7	IU	03:29:07.21 (12,547.21)	TB4 +11,963.65	MSFC	--
236b	Signal Received in S-IVB for: Slow Record Off	03:29:11.9 (12,551.9)	TB4 +11,953.7	S-IVB	See Note 5 at end of table		DAC (FM)	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 23 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM NO.	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
237a	Signal from LVDC for: Record Playback On	03:29:12.1 (12,552.1)	TB4 +11,953.9	IU	03:29:07.41 (12,547.41)	TB4 +11,953.85	MSFC	--
237b	Signal Received in S-IVB for: Record Playback On	03:29:12.1 (12,552.1)	TB4 +11,953.9	S-IVB	See Note 5 at end of table		DAC (FM)	--
238a	Signal from LVDC for: Recorder Playback Off	03:33:09.1 (12,789.1)	TB4 +12,190.9	IU	03:33:04.41 (12,784.41)	TB4 +12,190.85	MSFC	--
238b	Signal Received in S-IVB for: Recorder Playback Off	03:33:09.1 (12,789.1)	TB4 +12,190.9	S-IVB	03:33:04.46 (12,784.46)	TB4 +12,190.90	DAC (FM)	13
239a	Signal from LVDC for: Slow Record On	03:33:46.9 (12,826.9)	TB4 +12,228.7	IU	03:33:02.21 (12,822.21)	TB4 +12,228.65	MSFC	--
239b	Signal Received in S-IVB for: Slow Record On	03:33:46.9 (12,826.9)	TB4 +12,228.7	S-IVB	03:33:42.21 (12,822.26)	TB4 +12,228.70	DAC (FM)	13
240a	Signal from LVDC for: Slow Record On	03:33:56.9 (12,836.9)	TB4 +12,238.7	IU	03:33:52.22 (12,832.22)	TB4 +12,238.65	MSFC	--
240b	Signal Received in S-IVB for: Slow Record On	03:33:56.9 (12,836.9)	TB4 +12,238.7	S-IVB	03:33:52.26 (12,832.26)	TB4 +12,238.70	DAC (FM)	13
240.1	Water Coolant Valve Open	N/A	N/A	IU	03:47:12.35 (13,632.35)	N/A	MSFC	--
240.2	Water Coolant Valve Close	N/A	N/A	IU	03:52:17.00 (13,937.00)	N/A	MSFC	--
241a	Signal from LVDC for: LH2 Tank Vent Valve Open	03:57:01.2 (14,221.2)	TB4 +13,623.0	IU	03:56:56.51 (14,216.51)	TB4 +13,622.95	MSFC	--
241b	Signal Received in S-IVB for: LH2 Tank Vent Valve Open	03:57:01.2 (14,221.2)	TB4 +13,623.0	S-IVB	03:56:56.55 (14,216.55)	TB4 +13,622.99	DAC (PCM)	25
242a	Signal from LVDC for: LOX Tank Vent Valve Open	03:57:01.4 (14,221.4)	TB4 +13,623.2	IU	03:56:56.71 (14,216.71)	TB4 +13,623.15	MSFC	--
242b	Signal Received in S-IVB for: LOX Tank Vent Valve Open	03:57:01.4 (14,221.4)	TB4 +13,623.2	S-IVB	03:56:56.75 (14,216.75)	TB4 +13,623.19	DAC (PCM)	25
243	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate On	03:59:43.9 (14,383.9)	TB4 +13,785.7	IU	03:59:39.21 (14,379.21)	TB4 +13,785.65	MSFC	--
244a	Signal from LVDC for: Special Telemetry Calibration On	03:59:44.1 (14,384.1)	TB4 +13,785.9	IU	03:59:39.41 (14,379.41)	TB4 +13,785.85	MSFC	--
244b	Signal Received in S-IVB for: Special Telemetry Calibration On	03:59:44.1 (14,384.1)	TB4 +13,785.9	S-IVB	03:59:39.47 (14,379.47)	TB4 +13,785.91	DAC (FM)	13
245a	Signal from LVDC for: Regular Telemetry Calibration On	03:59:44.4 (14,384.4)	TB4 +13,786.2	IU	03:59:39.71 (14,379.71)	TB4 +13,786.15	MSFC	--
245b	Signal Received in S-IVB for: Regular Telemetry Calibration On	03:59:44.4 (14,384.4)	TB4 +13,786.2	S-IVB	03:59:39.77 (14,379.77)	TB4 +13,786.21	DAC (FM)	13

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 24 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

ITEM	EVENT	PREDICTED TIME		SIGNAL MONI-TORED AT	MONITORED TIME		DATA SOURCE	ACCU-RACY (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)		
246	Signal from LVDC for: Telemetry Calibrator In-Flight Calibrate Off	03:59:48.9 (14,388.9)	TB4 +13,790.7	IU	03:59:44.21 (14,384.21)	TB4 +13,790.65	MSFC	--
247a	Signal from LVDC for: Regular Telemetry Calibration Off	03:59:49.4 (14,389.4)	TB4 +13,791.2	IU	03:59:44.71 (14,384.71)	TB4 +13,791.15	MSFC	--
247b	Signal Received in S-IVB for: Regular Telemetry Calibration Off	03:59:49.4 (14,389.4)	TB4 +13,791.2	S-IVB	03:59:44.77 (14,384.77)	TB4 +13,791.21	DAC (PCM)	25
248a	Signal from LVDC for: Special Telemetry Calibration Off	03:59:49.6 (14,389.6)	TB4 +13,791.4	IU	03:59:44.91 (14,384.91)	TB4 +13,791.35	MSFC	--
248b	Signal Received in S-IVB for: Special Telemetry Calibration Off	03:59:49.6 (14,389.6)	TB4 +13,791.4	S-IVB	03:59:44.97 (14,384.97)	TB4 +13,791.41	DAC (PCM)	25
249a	Signal from LVDC for: Slow Record On	03:59:55.9 (14,395.9)	TB4 +13,7[illegible]	IU	03:5[illegible]:51.21 (14,391.21)	TB4 +13,797.65	MSFC	--
249b	Signal Received in S-IVB for: Slow Record On	03:59:55.9 (14,395.9)	TB4 +13,797.7	S-IVB	03:5[illegible].22 (14,[illegible].22)	TB4 +13,797.66	DAC (PCM)	25
249.1	Water Coolant Valve Open	N/A	N/A	IU	04:22:20.50 (15,740.50)	N/A	MSFC	--
250a	Signal from LVDC for: Slow Record [illegible]	04:25:04.9 (15,904.9)	TB4 +15,306.7	IU	04:25:00.21 (15,900.21)	TB4 +15,306.65	MSFC	--
250b	Signal Received [illegible]n S-IVB for: Slow Record On	04:25:04.[illegible] (15,904.9)	TB4 +15,306.7	S-IVB	04:25:00.26 (15,900.26)	TB4 +15,306.70	DAC (FM)	13
251a	Signal from LVDC for: Slow Record Off	04:25:36.9 (15,936.9)	TB4 +15,338.7	IU	04:25:32.21 (15,932.21)	TB4 +15,338.65	MSFC	--
251b	Signal Received in S-IVB for: Slow Record Off	04:25:36.9 (15,936.9)	TB4 +15,338.7	S-IVB	04:25:32.25 (15,932.25)	TB4 +15,338.69	DAC (FM)	13
252a	Signal from LVDC for: Recorder Playback On	04:25:37.1 (15,937.1)	TB4 +15,338.9	IU	04:25:32.41 (15,932.41)	TB4 +15,932.41	MSFC	--
252b	Signal Received in S-IVB for: [illegible]ecorder Playback On	04:25:37.1 (15,937.1)	TB4 +15,338.9	S-IVB	04:25:32.45 (15,932.45)	TB4 +15,338.89	DAC (FM)	13
252.1	Water Coolant Valve Close	N/A	N/A	IU	04:32:17.54 (16,347.54)	N/A	MSFC	--
253a	Signal from LVDC for: Recorder Playback Off	04:32:29.1 (16,349.1)	TB4 +15,750.9	IU	04:32:24.41 (16,344.41)	TB4 +15,750.85	MSFC	--
253b	Signal Received in S-IVB for: Recorder Playback Off	04:32:29.1 (16,349.1)	TB4 +15,750.9	S-I[illegible]B	See Note 4 at end of table		DAC (FM)	--
254a	Signal from LVDC for: Slow Record On	04:32:29.3 (16,349.3)	TB4 +15,751.1	IU	04:32:24.61 (16,344.61)	TB4 +15,751.05	MSFC	--
254b	[illegible]nal Received in [illegible]VB for: Slow Record On	04:32:29.3 (16,349.3)	TB4 +15,751.1	S-IVB	See Note 4 at end of table		DAC (FM)	--
255a	Signal from LVDC for: LH2 Tank Vent Valve Close	04:43:05.2 (16,985.2)	TB4 +16,387.0	IU	04:43:00.51 (16,980.51)	TB4 +16,386.95	MSFC	--
255b	Signal Received in S-IVB for: LH2 Tank Vent Valve Close	04:43:05.2 (16,985.2)	TB4 +16,387.0	S-IVB	04:43:00.58 (16,980.58)	TB4 +16,387.02	DAC (FM)	13

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 25 of 26)
AS-204 POSTFLIGHT 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 FASE (sec)		TIME FROM RANGE ZERO* (hr:min:sec) (sec)	TIME FROM FASE (sec)		
256a	Signal from LVDC for: LOX Tank Vent Valve Close	04:43:05.4 (16,985.4)	TB4 +16,387.2	IU	04:43:00.71 (16,980.71)	TB4 +16,387.15	MSFC	--
256b	Signal Received in S-IVB for: LOX Tank Vent Valve Close	04:43:05.4 (16,985.4)	TB4 +16,387.2	S-IVB	04:43:00.77 (16,980.77)	TB4 +16,387.21	DAC (FM)	13
257a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close On	04:43:08.2 (16,988.2)	TB4 +16,390.0	IU	04:43:03.51 (16,983.51)	TB4 +16,389.95	MSFC	--
257b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close On	04:43:08.2 (16,988.2)	TB4 +16,390.0	S-IVB	04:43:03.58 (16,983.58)	TB4 +16,390.02	DAC (FM)	13
258a	Signal from LVDC for: LOX Tank Vent Valve Boost Close On	04:43:08.4 (16,988.4)	TB4 +16,390.2	IU	04:43:03.71 (16,983.71)	TB4 +16,390.15	MSFC	--
258b	Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close On	04:43:08.4 (16,988.4)	TB4 +16,390.2	S-IVB	04:43:03.78 (16,983.78)	TB4 +16,390.22	DAC (FM)	13
259a	Signal from LVDC for: LH2 Tank Vent Valve Boost Close Off	04:43:10.2 (16,990.2)	TB4 +16,392.0	IU	04:43:05.51 (16,985.51)	TB4 +16,391.95	MSFC	--
259b	Signal Received in S-IVB for: LH2 Tank Vent Valve Boost Close Off	04:43:10.2 (16,990.2)	TB4 +16,392.0	S-IVB	04:43:05.57 (16,985.57)	TB4 +16,392.01	DAC (FM)	13
260a	Signal from LVDC for: LOX Tank Vent Valve Boost Close Off	04:43:10.4 (16,990.4)	TB4 +16,392.2	IU	04:43:05.71 (16,985.71)	TB4 +16,392.15	MSFC	--
260b	Signal Received in S-IVB for: LOX Tank Vent Valve Boost Close Off	04:43:10.4 (16,990.4)	TB4 +16,392.2	S-IVB	04:43:05.78 (16,985.78)	TB4 +16,392.22	DAC (FM)	13
261a	Signal from LVDC for: Open He Control Vent	04:43:10.6 (16,990.6)	TB4 +16,392.4	IU	04:43:05.91 (16,985.91)	TB4 +16,392.35	MSFC	--
261b	Signal Received in S-IVB for: Open He Control Vent	04:43:10.6 (16,990.6)	TB4 +16,392.4	S-IVB	04:43:05.97 (16,985.97)	TB4 +16,392.43	DAC (FM)	13
262	Water Coolant Valve Open	N/A	N/A	IU	04:47:19.01 (17,239.01	N/A	MSFC	--
263a	Signal from LVDC for: Close He Control Vent	04:48:10.6 (17,290.6)	TB4 +16,692.4	IU	04:48:05.91 (17,285.91)	TB4 +16,692.35	MSFC	--
263b	Signal Received in S-IVB for: Close He Control Vent	04:48:10.6 (17,290.6)	TB4 +16,692.4	S-IVB	See Note 6 at end of table		DAC (FM)	--
264	Water Coolant Valve Closed	N/A	N/A	IU	06:12:28.6 (22,348.6)	N/A	MSFC	--

*Range Zero = 22:48:08 (GMT)

TABLE 4-1 (Sheet 26 of 26)
AS-204 POSTFLIGHT SEQUENCE OF EVENTS

NOTES

1. These events occurred out of range of any station and were not on the airborne tape recorder. They occurred after the recorder had reached its full capacity. The times for item numbers 123b, 124b, and 125b are not available for this reason.

2. These events could not be verified because the recorder playback data received at Guaymas were not reducible. This caused the absence of times for item numbers 145b, 146b, and 147b.

3. Excessive noise on the PCM and FM links prevented verification of the times for items 155b and 156b.

4. These commands occurred out of range of the Hawaii station. They are items 212b, 213b, 253b, and 254b.

5. These events occurred prior to acquisition of signal at Ascension. These are items 235b, 236b, and 237b.

6. This event occurred out of range of ground receivers. This caused the loss of the time for item number 263b.

7. No accuracy data received from MSFC.

TABLE 4-2 (Sheet 1 of 4)
GROUND SEQUENCE OF EVENTS

TIME FROM RO min sec	EVENT
-19:57.980	Start Tank Vent Open
56.610	Start Tank Purge Valve Open
54.906	Thrust Chamber Purge Valve Open
-14:59.284	Ground Cold Helium Crossover Valve Opened
58.853	Thrust Chamber Purge Valve Closed
57.409	Thrust Chamber Childown Valve Opened
38.934	Inflight Relays Off
38.931	Telemetry Ready Off
29.804	Start Tank Purge Valve Closed
28.898	Start Tank Supply Valve Open
28.896	Start Bottle Pressurizing
05.548	Inflight Relays On
05.545	Telemetry Ready On
-12:28.253	Cold HX Ckt 1 Vent Valve Open
-10:44.907	Inflight Mode Relay Reset Off
44.831	Aux Hydraulic Pump Motor On
44.827	Hydraulics System Ready On
41.516	Ground and Coast Relay Reset
-9:58.107	LH2 Childown Pump On
48.032	LOX Childown Pump On
42.170	LH2 Prevalve Closed
42.016	LOX Prevalve Closed
42.011	Recirculation OK On
-7:50.942	Engine Control Power On
34.222	Engine Ignition Power On
34.216	Engine Systems Ready On
-6:56.936	Checkout Meas Group Off

TABLE 4-2 (Sheet 2 of 4)
GROUND SEQUENCE OF EVENTS

TIME FROM RO min sec	EVENT
-5:57.826	LOX Tank Vent Valve Opened
54.751	LH2 Tank Vent Closed
52.988	LH2 Tank Directional Vent Ground Position
47.804	LH2 Tank Vent Open
29.702	Start Bottle Vent Closed
27.777	Cold HX Ckt 1 Vent Valve Closed
14.704	EBW and Receiver Test Power Off
-4:59.374	Engine Control Helium Supply Valve Closed
59.351	Start Tank Supply Valve Closed
56.888	Engine Control Helium Bottle Valve Open
56.863	Start Tank Supply Vent Open
-3:55.123	APS Power On Mod 1
55.121	APS 2 System Ready On
55.121	APS Mod 2 Bus On
55.120	APS Mod 1 and 2 Busses On
55.118	Aux Propulsion System 2 OK On
45.845	S&A Armed
45.842	All Systems Ready On
45.839	Prop Dispersion Ordnance Ready On
40.701	S-IVB Systems Ready On
29.117	Ground Cold Helium Crossover Valve Closed
-2:43.680	Automatic Launch Sequence Start
43.322	LOX Tank Vent Closed
41.977	Launch Sequence Ready Ind Off
29.480	LOX Tank Prepress On
24.674	LOX Fill and Drain Valve Closed
23.965	*HX Fill Valve Open
17.881	HX Fill Valve Closed

*HX Fill Valve cycled periodically to Automatic Launch Sequence but only times after ALS are shown.

TABLE 4-2 (Sheet 3 of 4)
GROUND SEQUENCE OF EVENTS

TIME FROM RO min sec	EVENT
-1:59.265	HX Fill Valve Open
52.586	HX Fill Valve Closed
52.491	LH2 Tank Vent Closed
52.409	LH2 Tank Prepress Supply Valve Open
25.095	LH2 Fill and Drain Valve Closed
24.409	LH2 Umb Purge Supply Valve Open
20.422	HX Fill Valve Open
09.660	HX Fill Valve Closed
07.900	Fuel Tank Prepress OK On
07.810	Fuel Tank Prepress Supply Valve Cl
00.635	HX Fill Valve On
-0:46.456	HX Fill Valve Closed
37.675	HX Fill Valve Open
31.084	LOX Tank Vent Closed
30.373	HX Fill Valve Closed
27.727	S-IVB Power Internal On
27.724	S-IVB Power Transfer OK Ind On
27.581	Fuel Tank Directional Vent Flight Position
27.574	S-IVB Ready to Launch Ind On
13.849	HX Fill Valve Open
07.868	HX Fill Valve Closed
04.965	Receiver 1 Signal Blocked Off
04.965	Receiver 2 Signal Blocked Off
04.959	Ullage Rocket Firing Unit Enabled
02.968	Ignition Command On (S-IB)
02.908	Fuel Tank Prepress Supply Vent Open
02.891	Cold Helium Supply Vent Open
02.882	Cold Helium Supply Closed
02.880	Thrust Chamber Chilldown Valve Closed
02.591	Stage Control Helium Supply Closed

TABLE 4-2 (Sheet 4 of 4)
GROUND SEQUENCE OF EVENTS

TIME FROM RO sec	EVENT
1.838	**L.. Overfill Sensor Wet On
01.823	**LH2 Ove.fill Sensor Wet Off
01.677	C/He Ckt 3 Crossover Pressure Switch Made On
01.364	LOX Tank Vent Closed
00.995	C/He Ckt 2 Crossover Press Switch Made On
00.985	C/He Ckt 2 Crossover Press Switch Made Off
00.945	C/He Ckt 2 Crossover Press Switch Made On
00.945	C/He Ckt 2 Crossover Press Switch Made Off
00.941	C/He Ckt 2 Crossover Press Switch Made Off
RO = 2243:08.000	
+0:00.027	Commit Indication On
00.351	Liftoff Indication On
00.361	IU Umbilical Disconnect

**This sensor continued to cycle until liftoff.

SECTION 5

COUNTDOWN OPERATIONS

5. COUNTDOWN OPERATIONS

The launch day countdown was initiated at 15:00 hr GMT on 21 January 1968 and culminated in a successful liftoff at 22:48:08 hr on 22 January 1968.

The countdown was delayed approximately 4 hr by spacecraft problems, however, the S-IVB-204 stage portion of the countdown proceeded satisfactorily, and all stage systems responded correctly to commands.

The precountdown and countdown activities are reviewed and evaluated in the following paragraphs which include discussions of the prelaunch checkouts, auxiliary propulsion system (APS) preparations, propellant and cold gas loading, and terminal countdown. Significant events occurred at the following times:

Event	Time (GMT)
Liftoff	22:48:08.2
LOX loading initiated	18:08:00
LH2 loading initiated	21:04:00
Cold helium loading initiated	21:40:53
Terminal countdown initiated	22:45:24

5.1 Propulsion System Checkouts

The stage was first erected on Launch Complex 34. Propulsion system checkout was initiated on 1 September 1966 and was essentially completed by 4 October 1966. Integrated testing and stage modifications continued until 3 April 1967 when the stage was transferred to Launch Complex 37. On 10 April 1967 the propulsion system checkout procedure was again initiated and completed.

Although the stage had been transported between the two complexes and approximately 1 year had elapsed between the completion dates of the two propulsion system checkouts, the results of the two checkouts closely agreed.

5.2 Launch Vehicle Tests

Launch vehicle tests conducted when the 204 stage was on Launch Complex 34 are presented in table 5-1, and those tests conducted when the stage was on Complex 37 are presented in table 5-2.

5.3 Countdown Demonstration Test

The objectives of the countdown demonstration test (CDDT) were to perform an operation in the same sequence as the launch countdown to completely verify hardware and personnel compatibilities, to verify RF compatibility of the space vehicle and associated ground equipment, to complete a space vehicle alignment, and to perform an LH2 boiloff test.

Major Douglas activities during the CDDT began on 16 January and were completed on 21 January 1968.

Test completion was scheduled for 13:00 GMT on 19 January and test cutoff was scheduled for RO -3 sec through a planned ignition failure. During the test, however, several unscheduled holds absorbed the 6 hr built in hold and delayed countdown activities nearly 12 hr. At 01:36 GMT on 20 January during a hold at RO -20 min the test was terminated because of ground power supply problems and the lack of ground computer support after LOX and LH2 loading.

Although the final portion of the countdown was not accomplished, the test was considered acceptable. Propellant drain was concluded without incident, and post-test activities (including recycle) were initiated for the tasks required between the CDDT and start of the launch countdown. Final Douglas operations were completed at 09:38 GMT on 21 January 1968.

5.4 APS Preparations

APS preparations for launch consisted of propellant transfer system purges, propellant loading, and engine confidence firing. Module propellant loading was started on 13 January and completed on 15 January 1968. Confidence test firings were conducted on 15 January and were satisfactorily accomplished.

5.4.1 APS Propellant Loading

On 13 January the APS module oxidizer tanks were loaded without problems; however, when the tanks were pressurized the bellows extension decreased, indicating gas in the system. Module 1 and module 2 oxidizer bellows decreased 0.3 and 0.1 in., respectively. When pressure was increased to flight level, the bellows decreased an additional 0.4 in. for module 1 and 0.2 in. for module 2.

The oxidizer tanks were then drained and propellant loading was again initiated. However, many gas bubbles appeared in the sight glass of the hand valve panel, and loading was terminated.

When troubleshooting of the oxidizer servicer indicated no leaks, the servicer was loaded with fresh propellant. Loading resumed on 15 January and was successfully completed. APS loading data is presented in table 5-3. The cause of the gas bubbles is under investigation. Possibilities under consideration are inadequate recirculation or nitrogen saturation and subsequent outgassing of the propellants.

5.4.2 APS Confidence Firing

The AP ... ence firing was accomplished in accordance with NASA proc ... .04. Each firing sequence consisted of one 250-ms cl ... ulse and two 65-ms pulses with a 750-ms delay between each pu ... as follows:

a. Minus pitch - engine III_P

b. Minus roll - engines I_{IV} and III_{II}

c. Plus pitch - engine I_P

d. Plus roll - engine I_{II} and III_{IV}

The resulting data indicated that the systems were acceptable for flight.

5.5 AS-204 Launch Countdown

The AS-204 space vehicle launch countdown began at 15:00 GMT on 21 January 1968 with the count at 22 hr. The countdown was conducted in accordance with NASA procedure I-20000, revision 002; Douglas preparations were conducted in accordance with Douglas procedure 1B62219, TCP No. I-20045 S-IVB4.

The final portion of the count started at 15:30 GMT on 22 January with the count at RO -3 hr 30 min. Spacecraft chilldown problems and a digital data acquisition ground station problem caused the launch to slip approximately 4 hr, and liftoff occurred at 22:48:08.2 GMT.

5.5.1 Prelaunch Purging

The oxidizer, fuel, engine, and nonpropulsive vent systems on the S-IVB stage were purged in accordance with Douglas procedure. Except for the J-2 engine fuel propellant system and the LOX and LH2 tanks, these purges were accomplished during both the CDDT and the launch countdown.

5.5.2 Loading Operations

LOX and LH2 tank loading, thrust chamber chilldown, and helium and GH2 sphere loading were all satisfactorily accomplished. Data are presented in figures 5-1 through 5-4.

5.5.2.1 LOX Loading

S-IVB stage LOX loading was conducted in accordance with procedure I-20065 and was initiated at 16:07 GMT with LOX replenish line chilldown. Because of a spacecraft problem, LOX loading was terminated at 16:15 GMT with 2 percent LOX loaded. Loading was reinitiated at 18:08 GMT and was satisfactorily completed. Pressures, temperatures, and flowrates are presented in table 5-4.

5.5.2.2 LH2 Loading

S-IVB stage LH2 loading was initiated at 20:46 GMT with chilldown of the heat exchanger and was conducted in accordance with procedure I-20066, revision 002. Loading was not interrupted and was satisfactorily completed at 21:50 GMT. Pressures, temperatures, and flowrates are presented in table 5-4.

5.5.2.3 Helium and GH2 Loading

All S-IVB stage cold and ambient helium and gaseous hydrogen spheres were satisfactorily loaded before launch. The cold helium spheres were pressurized to 1,275 psia before LH2 loading was initiated; the pressure was increased to 3,080 psia when 92 percent LH2 had been loaded. Sphere pressurization data are presented in table 5-5.

5.5.3 Terminal Countdown

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

5.5.3.1 Engine Conditioning

J-2 engine conditioning was initiated at RO -20 min with a 50 psi helium purge to the J-2 engine start sphere and thrust chamber jacket. At RO -15 min the thrust chamber jacket purge was terminated, and chilldown was initiated with cold helium flowing through circuits 2 and 3 of the heat exchanger. At RO -14 min 30 sec, the start sphere purge was terminated and start sphere chilldown was initiated with cold GH2 flowing through circuit 1 of the heat exchanger.

Engine conditioning produced the following results:

Parameter	At Initiation of Automatic Sequence	At Liftoff
Thrust chamber jacket temperature (°R)	245	238*
Engine start sphere pressure (psia)	1,310	1,325
Engine start sphere temperature (°R)	263	272
Engine control sphere pressure (psia)	-	3,030
Engine control sphere temperature (°R)	-	280

5.5.3.2 Stage Conditioning

LH2 turbopump chilldown was initiated at RO -10 min instead of RO -5 min because of the unsatisfactory recirculation during the power transfer test of the CDDT. This time, however, the LH2 flowrate did not drop below 80 gpm while the tank was unpressurized as it did during the CDDT. The flowrate after tank pressurization was also within the expected values.

*Maximum allowable is 265 deg R.

LOX turbopump chilldown was initiated approximately RO -9 min 45 sec. The LOX flowrate was 36 to 38 gpm unpressurized and 37 to 39 gpm pressurized, well within the expected range of 30 to 50 gpm.

LOX tank prepressurization was initiated at RO -2 min 43 sec and was completed in approximately 14 sec. One LOX tank ullage pressure makeup cycle was necessary to maintain the required pressure. At liftoff the LOX tank ullage pressure was 42.5 psia.

LH2 tank prepressurization was initiated at RO -1 min 52 sec and was completed in approximately 46 sec. At liftoff the LH2 tank ullage pressure was 36.6 psia.

The stage pneumatic system functioned normally during stage conditioning.

5.6 Environmental Control

5.6.1 Aft Interstage Thermoconditioning and Purge System

The aft interstage thermoconditioning and purge system functioned properly during the countdown. The APS control temperature was set at 82 deg F, 5 deg less than the normal 87 deg F. The control temperature was changed during the CDDT when the upper redline temperature for one of the APS modules was approached; the new setting was maintained for the launch countdown. The purge flowrate was the same as for previous launches (300 lb/min).

APS propellant temperatures at launch were as follows:

Module	Oxidizer Temp (°F)	Fuel Temp (°F)
1	92.0	86.5
2	81.0	78.0

All these temperatures were within the launch redline values of 75 to 100 deg F. Several electronic components, such as those bridge modules whose temperatures were monitored by measurements C0236, C0237, and C0238, were 3 to 27 deg F below the corresponding values on AS-202 and 10 to 40 deg F below those values on AS-203. Some of these temperatures were undesirably low, while other bridge modules, similarly emplaced in the aft interstage (measurements C0233, C0234, and C0235), were in an acceptable temperature range (55 deg F plus). It is believed that the lowered temperatures of some of the electronic equipment probably resulted from the lowered aft purge temperature.

5.6.2 Common Bulkhead Vacuum Monitoring System

During the CDDT and prior to bulkhead conditioning, the common bulkhead internal pressure was approximately 2.0 psia. A gas sample was taken before the evacuation sequence and indicated 76.5 percent Argon, which was indicative of a thorough bulkhead purge. The bulkhead was evacuated, and, at the initiation of LOX loading, the internal pressure was reading 1.0 psia. During LOX and LH2 loading, the internal pressure decayed to 0.2 psia and remained essentially at this level until LOX draining. At the completion of LOX draining, the pressure was reading 1.3 psia. The internal pressure history of the common bulkhead during the CDDT was indicative of a sound bulkhead.

During the countdown proper, common bulkhead conditioning commenced at 02:00 GMT on 21 January. A gas sample was taken and the vacuum supply valves opened to allow pumping on the bulkhead until cryogenic loading. The gas sample indicated a satisfactorily inert atmosphere in the bulkhead, table 5-7. During the count, intermittent pressure variations from a minimum of 0.7 psia to a maximum of 1.4 psia were observed while the bulkhead was open to the vacuum pump. At 15:30 GMT, a second gas sample was taken which indicated an inert mixture. A pressure rise check was made by closing the vacuum supply valves for 21 min. The pressure increased from 1.4 to 1.6 psia during this period. Pressure variations during S-IB LOX loading supported the possibility that vibration of the vehicle was causing a leak at the unbilical quick-disconnect "O" ring. The bulkhead remained open to the vacuum pump until liftoff.

5.7 Redline Limits

The redline limits for launch vehicle parameters are presented in the Apollo/Saturn IB Launch Mission Rules Apollo 5 (SA-204/LM-1) Final, revised 11 January 1968; in Douglas report SM46977B, Saturn S-IVB-204 Stage Flight Test Plan, revised 17 January 1968; and in the A41 Redline Monitoring Briefs.

5.8 Countdown Problems

The fol- ing problems were encountered during the launch countdown;

a. After opening the recirculation shutoff valves during LH2 loading, the pneumatic control regulator outlet pressure (D0014) increased to approximately 600 psia which was above the redline limit. The pressure was dropped by cycling the recirculation shutoff valves. Subsequent operation was normal as the regu-ator pressure stayed in the normal operating range through the rest of the launch countdown.

b. In the final minutes of the countdown, the cold helium pressure measurement (D0016) started a slow oscillation between 2,800 psia and 3,200 psia. Since these values were within redline limits, this trend presented no problems.

5.9 Atmospheric Conditions

The atmospheric conditions on the launch day are presented in table 5-8.

TABLE 5-1
LAUNCH VEHICLE TESTS CONDUCTED ON LAUNCH COMPLEX 34

TITLE	PROCEDURE	DATE
L/V Switch Selector Functional Test	I-20003-SA4/12	9-15-66
L/V Power Transfer Test	I-20004-SA4/12	9-26-66
L/V Propellant Dispersion System Functional Test	I-20005-SA4/12	9-26-66
AS-204 LH2 Systems Simulate Test and Malfunction Test	I-20029-SA204	10-12-66
AS-204 S-IVB Stage Full Pressure Test	I-24138-SIVB4	10-28-66
LOX System Simulate and Malfunction Test	I-20008-SA204	11-9-66
L/V Flight Sequence and EBW Functional Test	I-20006-SA4/12	11-15-66
L/V Sequence Malfunction Tests	I-20007-SA4/12	10-5-66 11-17-66
L/V Systems Overall Test-Plugs In	I-20008-SA4/12	10-8-66
L/V OAT Malfunction Test	I-20050-SA204	1-5-67
L/V MCC-H Interface Test	I-20038-SA4/12	1-23-67
AS-204 Space Vehicle System Test-Plugs In	I-20014-SA204	1-25-67
AS-204 Space Vehicle Systems Plug Drop Test	I-20015-SA204	1-27-67

TABLE 5-2
LAUNCH VEHICLE TESTS CONDUCTED ON LAUNCH COMPLEX 37

TITLE	PROCEDURE	DATE
SA-204/LM-1 L/V Electrical Mate Test	I-20002-SA204L	6-13-67
SA-204/LM-1 L/V Switch Selector Functional Tests	I-20003-SA204L	6-14-67
SA-204/LM-1 Pull Test	I-20051-SA204L	7-18-67
SA-204/LM-1 L/V Sequence Malfunction Test	I-20007-SA204L	8-3-67
SA-204/LM-1 L/V Plugs-In OAT	I-20008-SA204L	8-4-67
SA-204/LM-1 LOX System Simulate Test and Malfunction Test	I-20036 Rev 002	10-26-67
SA-204/LM-1 LH2 System Simulate Test	I-20037 Rev 003	11-7-67
SA-204/LM-1 L/V MCC-H Interface Test	I-20038 Rev 002	11-30-67
SA-204/LM-1 Space Vehicle Plugs-In OAT	I-2[illegible]14 Rev 002	12-12-67
SA-204/LM-1 Space Vehicle Plugs-Out OAT	I-20015 Rev 002	12-15-67
SA-204/LM-1 L/V MCC-H Interface II Test	I-20059 Rev 002	12-20-67
SA-204/LM-1 Space Vehicle Flight Readiness Test	I-20016 Rev 001	12-22-67

TABLE 5-3
APS PROPELLANTS DATA

PROPELLANTS		INDICATED BELLOWS EXTENSION (IN)	INDICATED PROPELLANT TEMP (°F)
TANK	MODULE		
		(UNPRESSURIZED AND BEFORE FIRING)	
Oxidizer	1	9.90	87.8
Fuel	1	9.85	81.0
Oxidizer	2	9.90	85.1
Fuel	2	9.90	79.0
		(PRESSURIZED AND BEFORE FIRING)	
Oxidizer	1	9.90	87.5
Fuel	1	9.85	81.2
Oxidizer	2	9.90	85.0
Fuel	2	9.90	80.0
		(PRESSURIZED AND AFTER FIRING)	
Oxidizer	1	9.86	87.2
Fuel	1	9.78	83.0
Oxidizer	2	9.80	84.8
Fuel	2	9.80	81.5
		(PRESSURIZED AT LIFTOFF)	
Oxidizer	1	9.84	92.0
Fuel	1	9.75	86.5
Oxidizer	2	9.87	81.0
Fuel	2	9.77	[illegible].0

3

TABLE 5-4
S-IVB STAGE PROPELLANT LOADING DATA

PARAMETER	LOX	LH2
Chilldown initiated (GMT)	16:07	20:46
Slow fill		
Levels (percent)	0 to 5	0 to 5
Initiation time (GMT)	18:08*	21:04
Flowrate (gpm)	**	300
Maximum swing arm pressure (psia)	**	18.38
Maximum ullage pressure (psia)	31	17.0
Fast fill		
Levels (percent)	5 to 96	5 to 96
Initiation time (GMT)	18:37	21:15
Flowrate (gpm)	900	2,200
Swing arm pressure		
Maximum (psia)	**	35.8
Stabilized (psia)	**	33.0
Maximum ullage pressure (psia)	20.2	17.2
Final slow fill		
Level at initiation (percent)	96	96
Initiation time (GMT)	18:59	21:42
Flowrate (gpm)	135	120
Swing arm pressure (psia)	**	19.77
Maximum ullage pressure (psia)	**	16.8
Total time require (min)	55	46

*LOX loading was interrupted because of a spacecraft problem and reinitiated at 18:08 with the LOX load at 2 percent.

**Not available.

TABLE 5-5
SPHERE PRESSURIZATION DATA

SPHERE	VOLUME (FT^3)	INITIATION TIME (GMT)	PRESSURE AT LIFTOFF (PSIA)	TEMPERATURE AT LIFTOFF (DEG R)
Control helium	4.5	02:53	3,032	460
Cold helium	28.0	21:41*	2,958	40.9
APS helium				
Module 1	0.160	21:41*	3,080	550
Module 2	0.160	21:41*	3,040	540
Engine control helium	0.578	15:38	3,030	280
Engine start GH2	4.224		1,325	272

*Pressurized in two steps

TABLE 5-6 (Sheet 1 of 2)
TERMINAL COUNTDOWN SEQUENCE

FUNCTION	TIME FROM T (MIN:SEC)
LH2 chilldown pumps ON	-25:35
LOX chilldown pumps ON	-25:18
All stages to internal power simultaneously	-24:35
S-IVB back to external power	-24:03
LOX and LH2 recirculation pumps OFF	-23:53
S-IVB power transfer complete	-22:58
Start sphere vent open	-19:58
Thrust chamber purge supply closed	-14:59
Cold helium crossover valve open	-14:59
Thrust chamber chill supply open	-14:57
Start sphere supply open	-14:29
Cold heat exchanger circuit 1 vent open	-12:28
LH2 chilldown inverter power ON	-9:58
LOX chilldown pump inverter power ON	-9:48
LH2 prevalve closed	-9:42
LOX prevalve closed	-9:42
LOX tank vent valve cycled	-5:58
LH2 tank vent closed	-5:55
LH2 directional vent cycled	-5:53
LH2 tank vent open	-5:48
Start sphere vent closed	-5:30
Cold heat exchanger circuit 1 vent closed	-5:28

TABLE 5-6 (Sheet 2 of 2)
TERMINAL COUNTDOWN SEQUENCE

FUNCTION	TIME FROM T (MIN:SEC)
Start sphere supply closed	-4:59
Engine control sphere supply valve closed	-4:59
Start sphere supply vent open	-4:57
Engine control sphere supply vent valve open	-4:57
Cold helium crossover valve closed	-3:29
LOX vent closed	-2:43
LOX tank pressurized	-2:29
LOX fill and drain valve closed	-2:25
LH2 tank vent valve closed	-1:52
LH2 tank ground prepressurization supply valve open	-1:52
LH2 fill and drain valve closed	-1:25
LH2 tank ground prepressurization supply valve closed	-1:07
Power transfer complete	-0:28
LH2 directional vent to flight position	-0:28
S-IVB ready for launch	-0:28
Commit and liftoff (T)	0

TABLE 5-7
COMMON BULKHEAD GAS SAMPLE CONCENTRATIONS

GAS	FIRST SAMPLE (PERCENT)	SECOND SAMPLE (PERCENT)
Ar	60.2	24.7
He	0.01	0.14
H2	0.45	0.13
N2	28.3	59.2
02	6.46	14.1
CO2	4.58	1.73

TABLE 5-8
AS-204 LAUNCH ATMOSPHERE CONDITIONS

TIME		AMBIENT TEMPERATURE (°F)	DEW POINT (°F)	RELATIVE HUMIDITY (PERCENT)	WIND* DIRECTION (DEG FROM NORTH)	WIND* VELOCITY (KNOTS)	BARAMETRIC PRESSURE** (INCHES OF HG)
EST	GMT						
12:00	17:00	71.0	47	43.0	330	5	30.100
13:00	18:00	70.6	48	47.0	030	5	30.800
14:00	19:00	70.0	48	49.0	030	8	30.060
15:00	20:00	69.6	48	49.0	020	5	30.060
16:00	21:00	67.6	49	52.0	030	4	30.060
17:00	22:00	66.8	53	62.0	030	3	30.060
17:48†	22:48†	61.2	59	91.0	070	2	30.060
18:00	23:00	60.8	58	89.0	070	3	30.060

*Surface winds 3 miles South of Launch Complex 37

**At 16 ft above sea level

†Liftoff

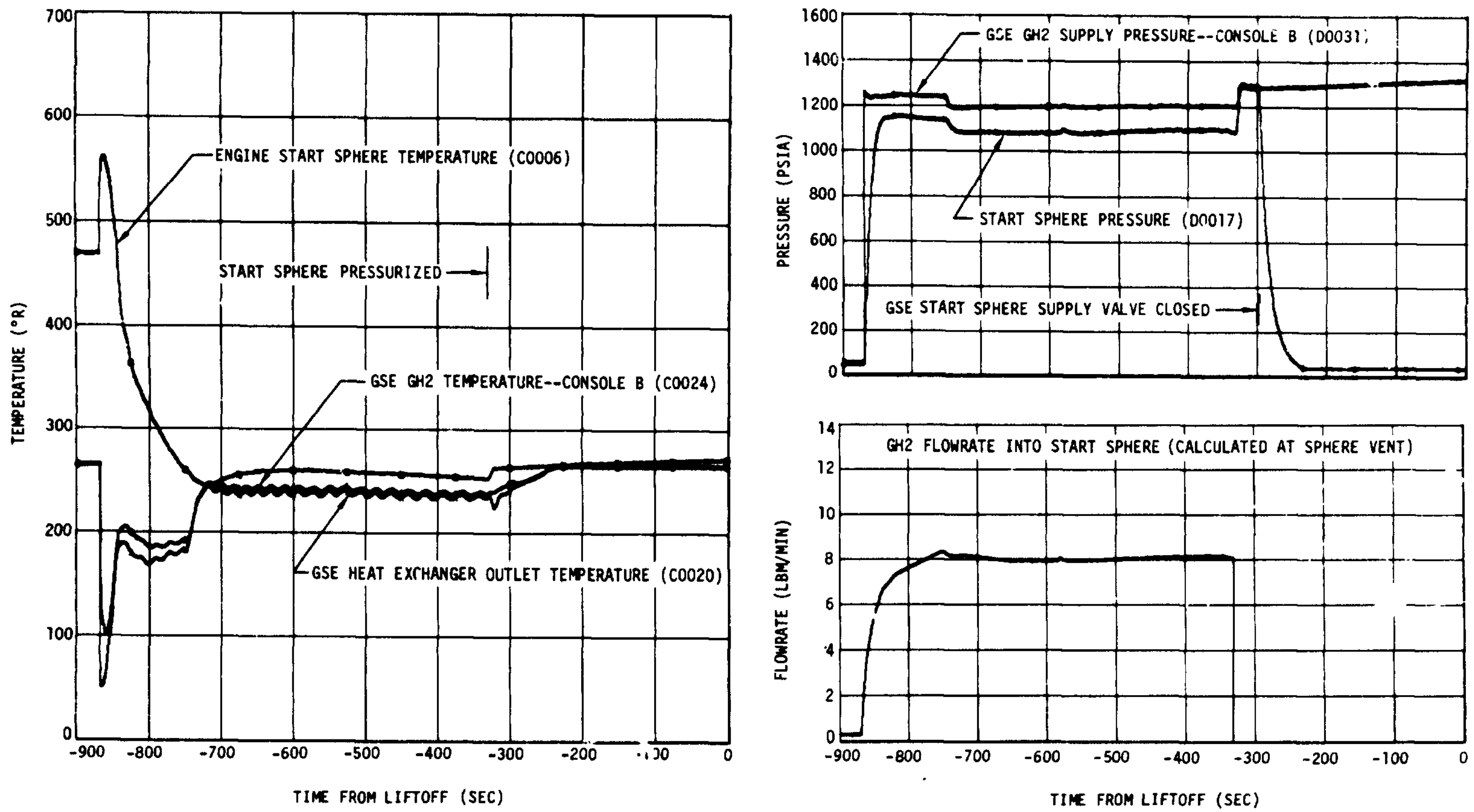


Figure 5-1. GSE Performance During Engine Start Sphere Childown and Loading

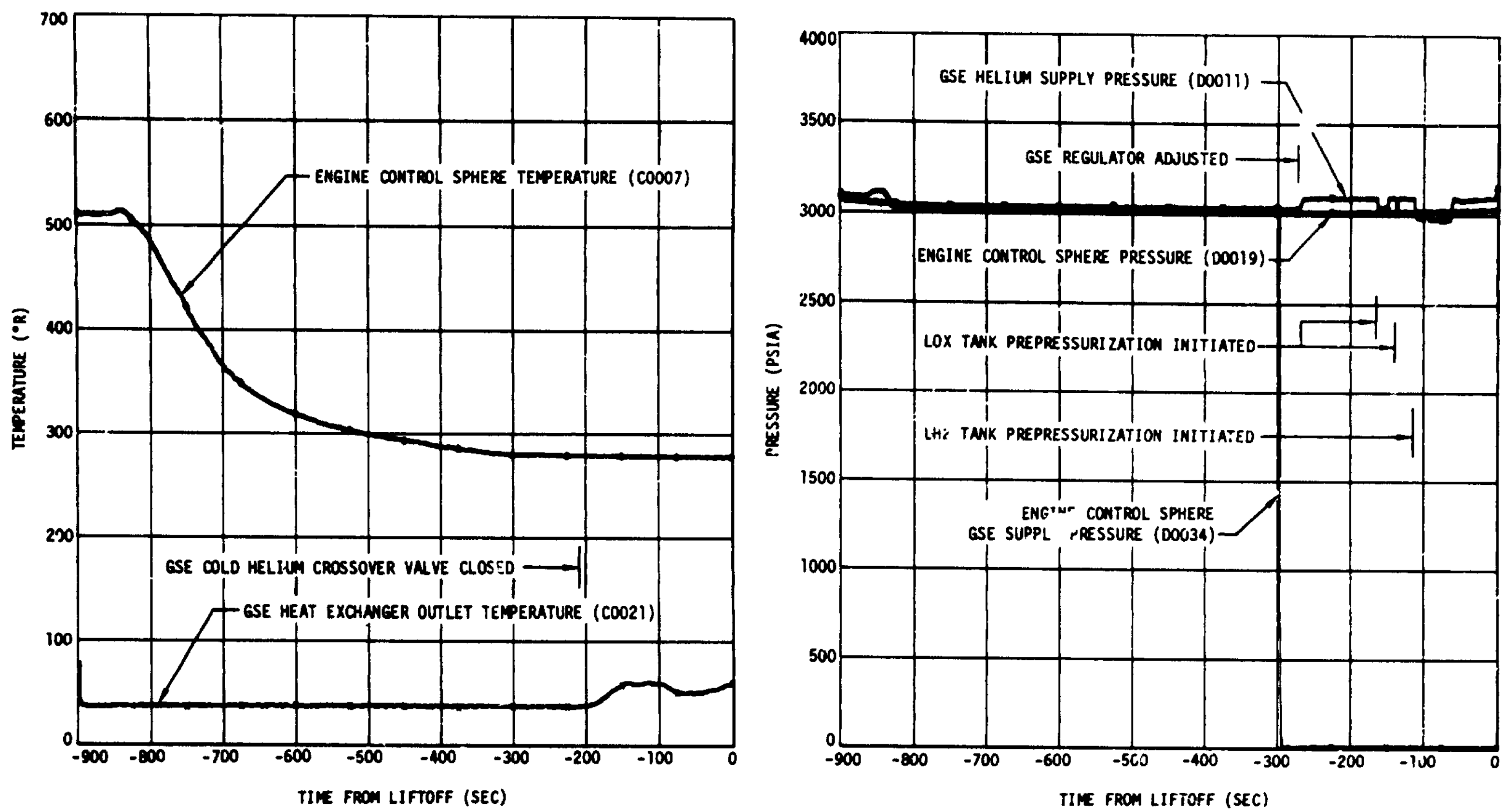
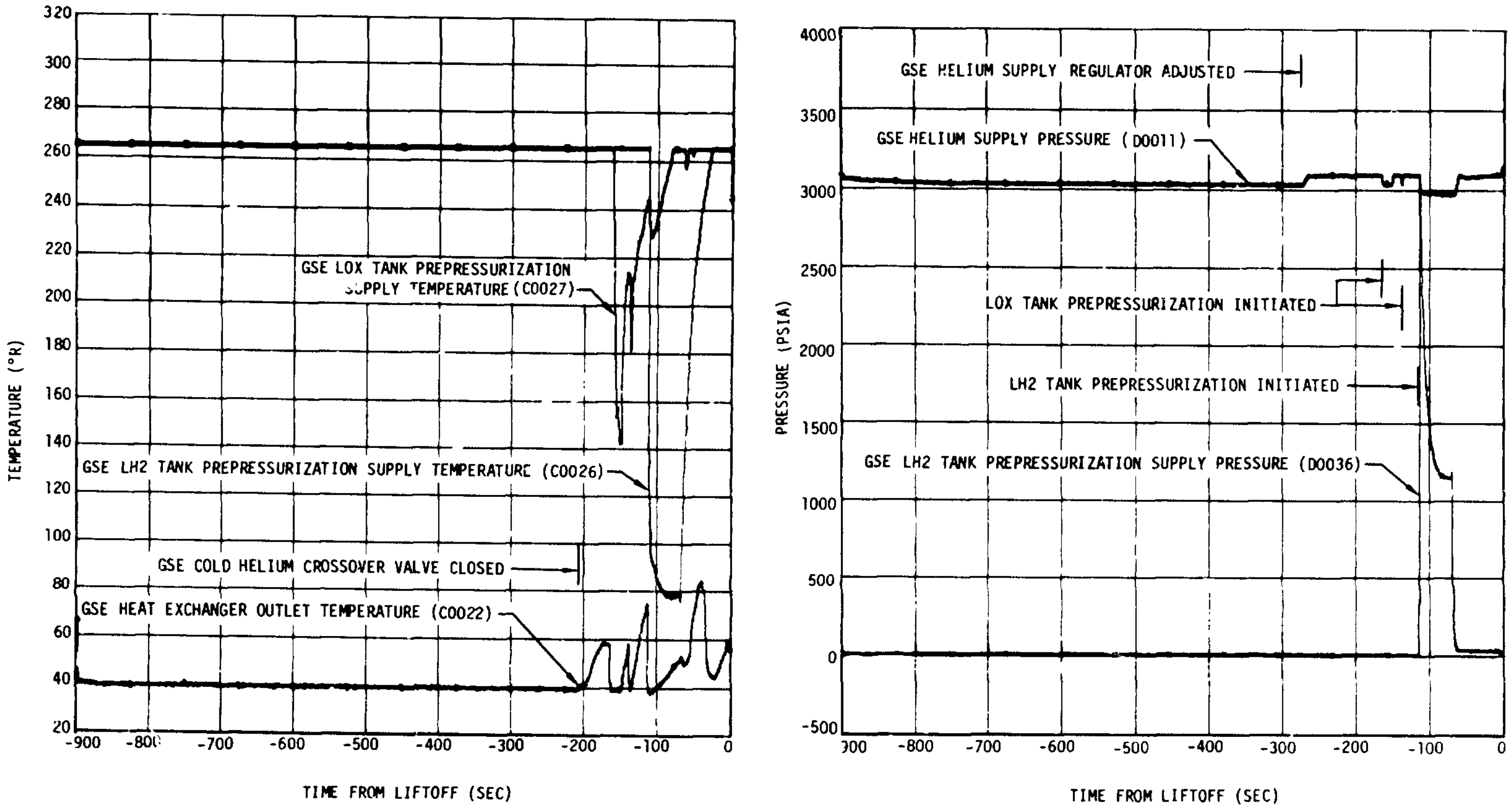


Figure 5-2. GSE Performance During Engine Control Sphere Loading



5-3. GSE Performance During LOX and LH2 Prepressurization

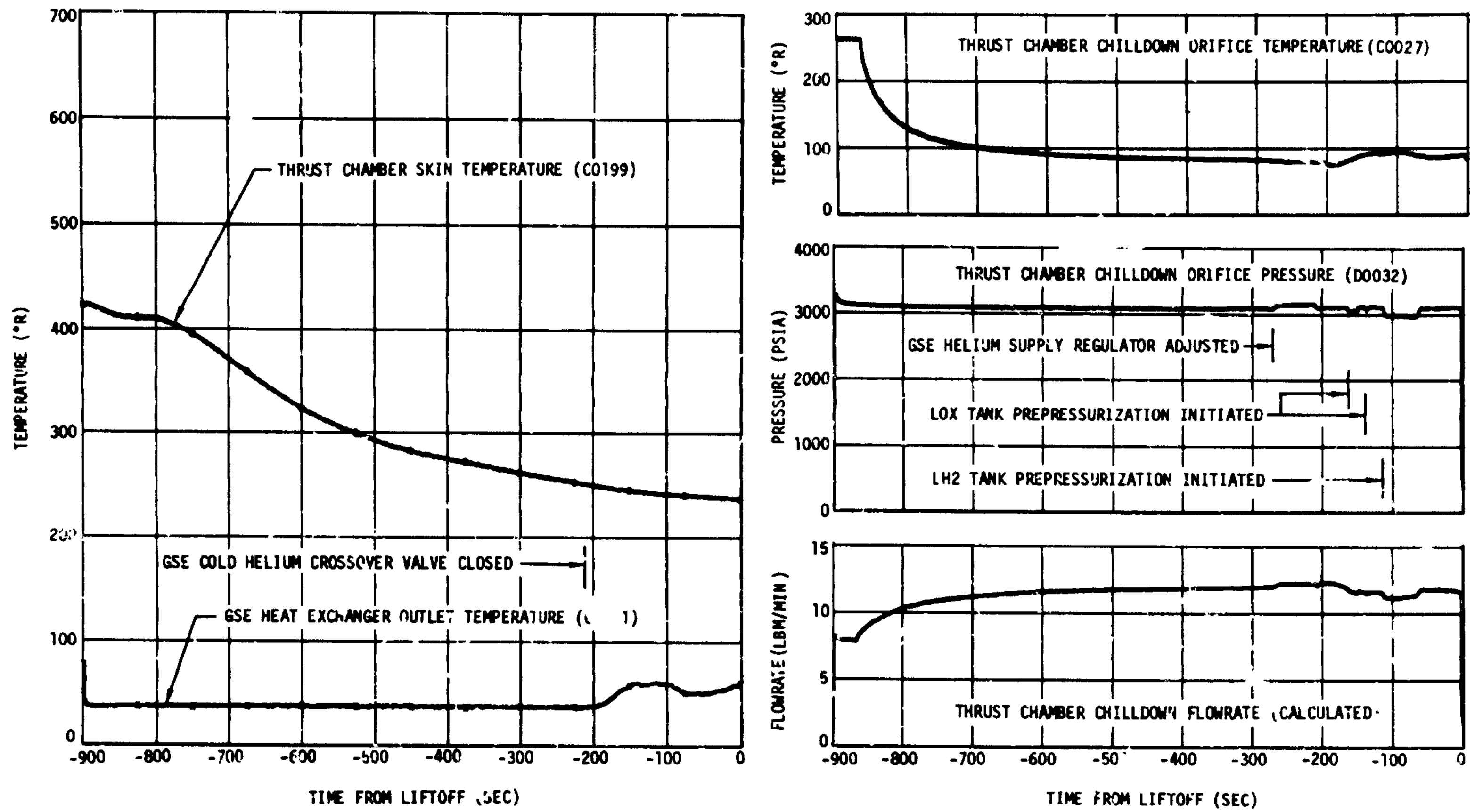


Figure 5-4. GSE Performance During Thrust Chamber Chilldown

SECTION 6

COST PLUS INCENTIVE FEE

6. COST PLUS INCENTIVE FEE

Flight Mission Accomplishment

Flight data evaluated to establish preconditions of flight (PCF) and end conditions of flight (ECF) were obtained from observed trajectory and attitude data transmitted by magnetic tape and printout to Douglas from MSFC as requested in Douglas Report No. SM-46538, Douglas S-IVB Stage Data Acquisition Requirements Document for Saturn IB Flights, P revision. Tables 6-1 and 6-2 compare actual and allowable values of PCF and ECF, respectively.

Performance of the S-IB stage provided PCF at S-IB/S-IVB Separation Command that were within allowable tolerances. Trajectory ECF at orbit insertion were within tolerance; also, maximum flight values of attitude errors and rates for both phases of S-IVB operation (i.e., burn, and orbit phase) did not exceed the respective allowable tolerances. All received command signals were recognized, and all end conditions command signals were given. It was concluded for purposes of incentive achievement, therefore, that all PCF and ECF were achieved.

The Contractor through postflight engineering analysis has for ECF purposes interpreted the maximum roll rate during powered flight as -0.50 deg per sec which is within the allowable incentive envelope of ±1.50 deg per sec. However, due to structural vibrations localized in the vicinity of the instrument unit, roll rate could be interpreted to be as great as ±1.75 deg per sec. Regardless of the method used for evaluating this parameter, the Contractor believes the possible out of tolerance roll rate was not caused by an S-IVB system or subsystem failure, nor was the phenomena in question anymore than a temporary or intermittent out of tolerance condition which should be ignored for incentive purposes as set forth in paragraph 3.3.6 (h) of Exhibit "J" to S.A. 1100 of NAS7-101 Contract.

The Contractor agreed to evaluate the achievement of attitude error limits during the orbital phase of the flight. The Contractor advises that the attitude deviations were within the ±4 deg envelope as proposed by NASA, although this was not a mutually acceptable parameter for the S-IVB-204 flight performance incentive.

Table 6-1 presents the nominal values for PCF and the allowable deviations agreed upon between Douglas and NASA, and the actual values obtained during the AS-204 mission of 22 January 1968. The actual values were all within tolerance. All received commands were recognized, and all end condition commands were given. The extent of the agreement is set forth in Douglas Letter A3-131-5.3.1.13-L-147, dated 16 January 1968, and NASA Letter I-CO-S-IVB-8-71, dated 19 January 1968.

Table 6-2 presents the nominal values for ECF and the allowable deviations agreed upon between Douglas and NASA as set forth in Douglas Letter A3-131-5.3.1.13-L-147, dated 16 January 1968, as modified by NASA Letter I-CO-S-IVB-8-71, dated 19 January 1968, and Douglas Letter A3-131-5.3.1.13-L-617, dated 9 February 1968, and the actual values obtained during the AS-204 mission of 22 January 1968. The actual values were all within tolerance. All received commands were recognized, and all end condition commands were given.

Evaluation of the telemetry performance indicated that the telemetry system operated at 98.8 percent efficiency during the telemetry performance evaluation period (TPEP) phase I (liftoff to first S-IVB engine cutoff plus 10 sec) and performed at 98.4 percent efficiency during the TPEP phase II (liftoff to issuance of the flight control computer S-IVB Burn Mode ON "A" Command which was programmed to occur at time base 4 plus 8,180.1 sec i.e., T_4 +8,180.1 sec).

The results of the telemetry performance analysis are shown in table 6-3.

TABLE 6-1
MISSION ACCOMPLISHMENT (PCF)

PARAMETER	UNITS	NOMINAL	ACTUAL	ALLOWABLE DEVIATION*	ACTUAL DEVIATION
Range	km	62.63	62.52	+10.32 -5.32	-0.11
Crossrange	km	-0.05	0.25	±5.72	+0.30
Altitude	km	63.49	64.16	+3.06 -4.16	+0.67
Velocity Vector Magnitude	m/sec	2,369.8	2,365.7	+58.1 -70.1	-4.1
Velocity Vector Direction	deg	27.16	27.39	+2.51 -3.94	+0.23
Pitch Attitude	deg	-59.46	-59.58	±3.0	-0.12
Pitch Rate	deg/sec	0.00	-0.1	±1.5	-0.1
Yaw Attitude	deg	-0.08	-0.25	±3.0	-0.17
Yaw Rate	deg/sec	0.00	-0.05	±1.5	-0.05
Roll Attitude	deg	0.00	0.75	±6.8	+0.75
Roll Rate	deg/sec	0.00	0.1	±1.5	+0.1

NOTE: PCF are evaluated at the instant of Separation Command.

*Deviations consist of allowable error plus evaluation uncertainty

TABLE 6-2
MISSION ACCOMPLISHMENT (ECF)

A. TRAJECTORY PARAMETERS (Evaluated at orbit insertion)

PARAMETER	UNITS	NOMINAL	ACTUAL	ALLOWABLE DEVIATION*	ACTUAL DEVIATION
Range	km	1,868.55	1,837.56	+83.74 -88.23	-30.99
Crossrange	km	146.12	143.27	+5.64 -5.79	-2.85
Altitude	km	163.22	163.44	±1.35	+0.22
Velocity Vector Magnitude	m/sec	7,828.6	7,828.5	+6.2 -6.1	-0.1
Velocity Vector Direction	deg	0.008	0.005	+0.077 -0.080	-0.003

B. ATTITUDE CONTROL PARAMETERS

PARAMETER	UNITS	ALLOWABLE ENVELOPE	MAXIMUM FLIGHT VALUE
S-IVB Burn Phase:			
Pitch Attitude Error	deg	±9.0	+2.4
Yaw Attitude Error	deg	±9.0	-4.2
Roll Attitude Error	deg	±9.0	+2.3
Pitch Rate	deg/sec	±3.0	-1.4
Yaw Rate	deg/sec	±3.0	+1.1
Roll Rate	deg/sec	±1.5	-0.50
Orbit (to Time Base 4 +8,180.1 sec)			
Pitch Rate	deg/sec	±1.0	+0.7
Yaw Rate	deg/sec	±1.0	+0.78
Roll Rate	deg/sec	±1.5	-0.5

NOTE: Trajectory ECF are evaluated at orbit injection (10 sec after S-IVB Engine Cutoff Command).

*Deviations consist of allowable error plus evaluation uncertainty

TABLE 6-3 (Sheet 1 of 3)
FLIGHT TELEMETRY PERFORMANCE SUMMARY

ITEM	DESCRIPTION	TOTAL
1	Total number of measurements listed in the S-IVB-204 Instrumentation Program and Components List, Douglas Drawing 1B43557, AS Change.	515
2	Measurements listed in the IP&CL which are not wholly on the S-IVB-204 Stage: Measurements transmitted by the S-IB telemetry system: C0375-402 Temp - Heat Flux Aft Interstage - 3 D0153-424 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 (LCC): D0545-407 Press - Common Bulkhead Internal - H/W	6
3	Measurements known to be inoperative at start of automatic launch sequence, or became inoperative prior to start of automatic launch sequence: 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. K0141-411 Event - R/S 1 Pulse Sensor K0142-411 Event - R/S 2 Pulse Sensor K0143-404 Event - Ullage Rkt 1 Ignition P/S 1 K0144-404 Event - Ullage Rkt 1 Ignition P/S 2 K0145-404 Event - Ullage Rkt 2 Ignition P/S 1 K0146-404 Event - Ullage Rkt 2 Ignition P/S 2 K0147-404 Event - Ullage Rkt 3 Ignition P/S 1 K0148-404 Event - Ullage Rkt 3 Ignition P/S 2 K0149-404 Event - Ullage Jettison 1 P/S K0150-404 Event - Ullage Jettison 2 P/S K0169-404 Event - EBW Pulse Sensor OFF Ind. The following measurement was listed in the IP&CL and the capability to make the measurement existed on the stage. MSFC did not require the associated rate gyro installation, therefore, the measurement is inoperative. K0152-404 Event - Rate Gyro Wheel Speed OK Ind.	22

TABLE 6-3 (Sheet 2 of 3)
FLIGHT TELEMETRY PERFORMANCE SUMMARY

ITEM	DESCRIPTION	TOTAL
	The following measurements malfunctioned prior to the start of the automatic sequence: C0040-406 Temp - Oxidizer Tank Position 1 C0041-406 Temp - Oxidizer Tank Position 2 C0042-406 Temp - Oxidizer Tank Position 3 C0043-406 Temp - Oxidizer Tank Position 4 C0055-406 Temp - LOX Tank Ullage 1% C0056-406 Temp - LOX Tank Ullage 20% C0072-408 Temp - Fuel Tank Wall Internal - 4 C0135-406 Temp - Oxidizer Tank Ullage D0121-419 Press - External Aft Interstage 1 E0082-401 Vib - LOX Turbopump Lateral	
4	Measurements from which Douglas could not obtain data due to noise from unknown sources, and measurements which were degraded or prevented from being transmitted.	0
5	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, 4.	487
6	Measurements which were failures during TPEP phase I (liftoff to first S-IVB engine cutoff plus 10 sec). Details regarding these measurement failures may be obtained in section 17 of this report. D0016-425 Press - Cold He Sphere D0062-424 Press - LH2 Circ Ret Line Tk Inlet D0122-419 Press - External Aft Interstage 4 D0124-419 Press - External Aft Interstage 2 D0158-402 Press - Interstage Internal 2 D0045-403 Press - Differential Engine "Y" Actuator	6
7	Measurements which were failures during TPEP phase II liftoff to issuance of the Flight Control Computer S-IVB Burn Mode ON "A" Command which was programmed to occur at time base 4 plus 8,180.1 sec). Details regarding these measurement failures may be obtained in section 17 of this report. All measurements which were failures during TPEP phase I are included as phase II failures because phase II encompasses phase I. These six measurements are shown in item 6 above.	8

TABLE 6-3 (Sheet 3 of 3)
FLIGHT TELEMETRY PERFORMANCE SUMMARY

ITEM	DESCRIPTION	TOTAL
	In addition to those measurements which were failures during TPEP phase I, the following two measurements were failures during phase II. C0079-409 Temp - Fuel Tank External C0080-409 Temp - Fuel Tank External 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. $\frac{487-6}{487} \times 100 = \frac{481}{487} \times 100 = 98.8$ percent 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. $\frac{487-8}{487} \times 100 = \frac{479}{487} \times 100 = 98.3$ percent	

SECTION 7

TRAJECTORY

7. TRAJECTORY

7.1 Scope

This section presents a discussion of the AS-204 trajectory. Comparisons are made between the actual observed trajectory and the preflight predicted trajectory; also, results of the Douglas simulated actual trajectory are presented. Actual observed trajectory deviations from the predicted are explained in terms of S-IVB and lower stage system performance deviations. In general, the Marshall Space Flight Center predicted trajectory is compared with the S-IB stage actual trajectory parameters, and the Douglas predicted trajectory is compared with the S-IVB actual trajectory parameters.

7.2 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 S-IB stage predicted trajectory is the same as that presented in the Chrysler Corporation Technical Note TN-AP-67-255, AS-204/LM-1 Launch Vehicle Operational Flight Trajectory (Revision 1), dated July 25, 1967. The S-IVB stage portion of the predicted trajectory is presented in Douglas Report No. SM-46977C, S-IVB-204 Stage Flight Test Plan, dated January 17, 1968. Figures are presented comparing the actual and predicted values of altitude, surface range, crossrange position, crossrange velocity, inertial velocity, axial acceleration, inertial flight path elevation angle, and inertial flight path azimuth angle for the S-IB, S-IVB, and orbital phases of the flight. Figures 7-1 through 7-20 compare the actual and predicted histories for each trajectory parameter, and figures 7-21 through 7-24 present a history of the differences between the predicted and actual trajectory parameters during S-IVB flight. Tables 7-1 through 7-6 show conditions at certain significant event times.

The actual trajectory of the AS-204 flight was very close to that predicted. During the S-IB portion of the flight, the trajectory can be characterized as slow, high, and short and to the right of the predicted path. S-IB trajectory parameters are shown in figures 7-1 through 7-13. At S-IB/S-IVB separation signal the altitude was 2,195 ft higher than its predicted value. This is shown in table 7-2. The departure from predicted crossrange position and velocity during the S-IB flight, shown in figures 7-3 and 7-4, was small compared with expected three sigma deviations. The cause of the deviations was most likely the combination of small yaw engine misalignment and higher than predicted azimuth winds at the 40,000-ft level. Table 7-1 and figure 7-8 show that the maximum dynamic pressure was (18 psf) lower than predicted and occurred 2.5 sec earlier than predicted.

The S-IVB stage trajectory is presented in figures 7-14 through 7-25. The trajectory was close to predicted throughout the S-IVB portion of the flight. Observed deviations from predicted, shown in figures 7-21 through 7-24, are caused primarily by a 20-sec late engine mixture ratio (EMR) shift and by pitch and yaw steady-state thrust vector misalignments. One example of this is the sharp increase in range over the predicted value starting at a range time of approximately 500 sec. This results from the higher-than-predicted acceleration late in S-IVB flight caused by the late EMR shift.

As shown in table 7-3, S-IVB guidance cutoff occurred 4.87 sec earlier than predicted. This early guidance cutoff was also primarily caused by the late EMR shift. The late EMR shift and the corresponding increase in impulse caused the guidance system to attach to the desired orbit at a smaller surface range, crossrange position, and crossrange velocity. The inertial velocity, inertial flight path elevation angle, and attitude were very close to their predicted values at cutoff. A summary of trajectory conditions and orbit elements at orbit insertion is presented in tables 7-4 and 7-5. From table 7-4 the trajectory at orbit insertion can be characterized as short, high, and slightly fast. These S-IVB stage end conditions of flight were well within the preflight determined three sigma tolerances (see section 6).

An orbit was achieved which had an apogee altitude of 119.7 nmi, 0.8 nmi higher than predicted, and a perigee altitude of 85.1 nmi, 0.1 nmi higher than predicted. Differences between actual and predicted values of altitude, inertial velocity, inertial flight path elevation angle, and inertial flight path azimuth angle for the time period from orbit insertion to S-IVB/LM separation are presented in figures 7-26 and 7-27. The altitude at S-IVB/LM separation was approximately 3,000 f higher than predicted, while the inertial velocity and the inertial flight path angles are close to their predicted values. The primary cause of the difference in altitude at S-IVB/LM separation was the change in apogee altitude, near which LM separation occurred, caused by a higher than predicted perigee velocity at insertion. The perigee velocity deviation was 1.6 ft/sec higher than predicted (table 7-5) due to higher than predicted S-IVB cutoff impulse.

7.3 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 match closely the observed trajectory (appendix 3, Observed Trajectory). The simulation program used a differential correction technique which determined the necessary adjustments, before and after mixture ratio shift, to thrust and weight flow from the engine analysis (section 9) 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 slant range distance from the launch site between the observed and simulated trajectories.

Differences between the observed and simulated trajectories are presented in figure 7-28. The average and maximum deviations between the actual and simulated trajectories are:

Parameter	Average Deviation	Maximum Deviation
Altitude (ft)	72.6	-237.0
Earth-fixed velocity (ft/sec)	0.91	2.6
Earth-fixed velocity azimuth angle (deg)	0.024	-0.06
Slant range distance (ft)	9.00	-36.0

To obtain a match of the observed trajectory it was necessary to adjust the levels of thrust and weight flow determined by engine analysis. Before thrust cutback the thrust and weight flow determined by engine analysis were increased by 0.15 percent and 0.13 percent, respectively, after cutback the engine analysis thrust and weight flow were decreased by 1.67 percent and 1.27 percent, respectively. The corresponding change in specific impulse over the values determined from engine analysis were a decrease of 0.42 percent at the reference mixture ratio (RMR) and no change at the high EMR.

Histories of simulated thrust and weight flow are presented in figure 7-29. The average values for these parameters are:

Parameter	Predicted	Actual
Total average thrust (lbf)	213,692	216,063
Total average weight flow (lbm/sec)	500.81	508.29
Total average specific impulse (sec)	426.83	425.15
Average thrust at high mixture ratio (lbf)	223,811	224,233
Average weight flow at high mixture ratio (lbm/sec)	525.66	527.65
Average specific impulse at high mixture ratio (sec)	425.77	424.85
Average thrust at reference mixture ratio (lbf)	184,752	184,890
Average weight flow at reference mixture ratio (lbm/sec)	429.70	432.86
Average specific impulse at reference mixture ratio (sec)	429.96	427.16

These results indicate that the thrust and weight flow were very close to predicted during high EMR operation. During RMR operation the thrust was slightly higher than predicted, but the weight flow was 0.74 percent higher than predicted, thus decreasing the specific impulse by 0.65 percent from the predicted value.

The maximum inaccuracies in the simulated propulsion parameters due to the observed trajectory and simulation uncertainties are estimated to be

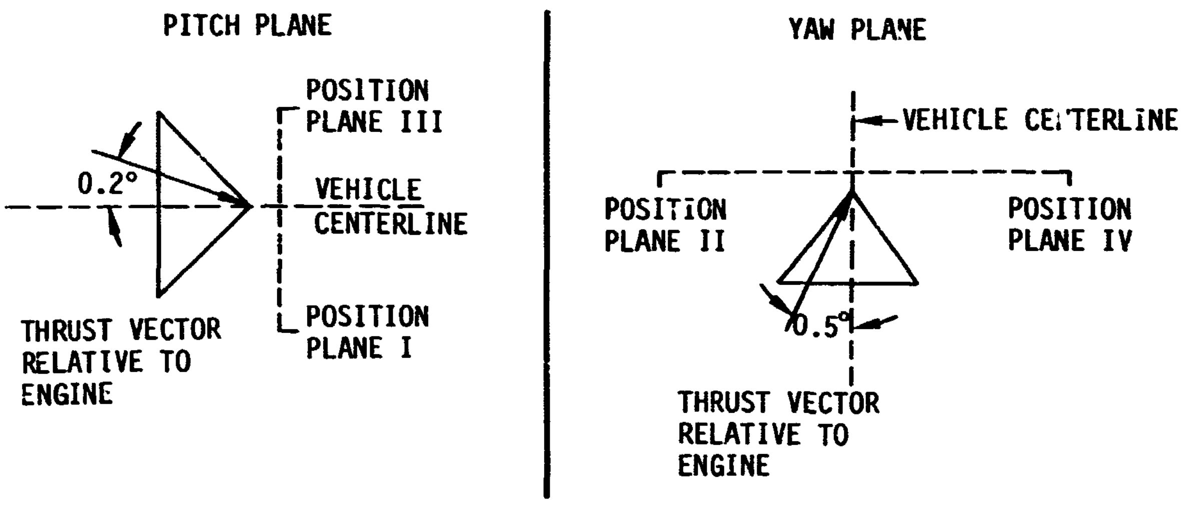
0.2 percent from thrust and weight flow and 0.3 percent for specific impulse. An additional inaccuracy is added by the uncertainty in the ignition and cutoff weight. As a result, the total inaccuracy in thrust, weight flow, and specific impulse is 0.3 percent in each.

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

Parameter	Control Analysis Value	Simulated Value
Pitch thrust misalignment (deg)	0.21	0.2
Yaw thrust misalignment (deg)	0.36	0.5

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:



The simulated S-IVB stage weights and predicted values are:

	Predicted	Simulated
Engine Start Command (lbm)	296,170	297,050
Engine Cutoff Command (lbm)	70,423	70,150

These weights were derived from the composite best estimate ignition and cutoff weight (section 8, Mass Characteristics). The weights were determined by finding the point on the trajectory reconstruction line (figure 8-5), that has the highest probability of being equal to the best estimate value for ignition and cutoff weight. Using the non-propellant weights of 65,676 lbm at ESC and 65,703 lbm at ECC presented in section 15 and the best estimate of the liquid oxygen to liquid hydrogen ratios presented there, flight simulation results indicate the following propellant consumptions.

	ESC		Total
	LOX	LH2	Propellants (lbm)
Actual	194,078	37,296	231,374
Predicted	193,273	37,440	230,713
Deviation*	805	-144	661

	ECC		Total
	LOX	LH2	Propellants (lbm)
Actual	2,987	1,460	4,447
Predicted	3,282	1,501	4,783
Deviation*	-295	-41	-336

	TOTAL CONSUMED		Total
	LOX	LH2	Propellants (lbm)
Actual	191,091	35,836	226,927
Predicted	189,991	35,939	225,930
Deviation*	1,100	-103	970

*Deviation equals actual minus predicted.

The flight simulation verifies the 4.9 sec difference between predicted and actual guidance cutoff time. Components of the short burntime are:

Contributor	Burntime Component (sec)
Slow S-IB/S-IVB separation velocity	+0.2
High S-IVB initial propellant weight	+1.6
High-stop engine operation	-0.3
Late cutback time	-4.7
Low stop engine operation	-2.1
Total	-5.3

The total of these components is in close agreement with the difference observed for the S-IVB burn.

TABLE 7-1
CONDITIONS AT MAXIMUM DYNAMIC PRESSURE

PARAMETER		UNITS	PREDICTED	ACTUAL	DEVIATION
Range time	(t)	sec	74.00	71.50	-2.50
Dynamic pressure	(q)	lbf/ft^2	682.8	664.6	-18.2
Altitude	(h)	ft	40,495	37,633	-2,862
Mach number	(M)	-	1.54	1.43	-0.11
Ambient pressure	(P_a)	lbf/ft^2	413.9	458.7	44.8
Pitch angle of attack	(α)	deg	-0.52	-2.30	-1.79
Yaw angle of attack	(β)	deg	-0.04	1.32	1.36

Deviation = Actual - predicted

TABLE 7-2
CONDITIONS AT S-IB/S-IVB SEPARATION SIGNAL

PARAMETER		UNITS	PREDICTED	ACTUAL	DEVIATION
Range time	(t)	sec	143.44	143.50	0.06
Downrange distance	(Z_E)	ft	207,346	207,186	-160
Vertical distance	(X_E)	ft	207,295	209,492	2,197
Crossrange distance	(Y_E)	ft	-160.0	833.3	993.3
Downrange velocity	($\dot{Z}_E$)	ft/sec	5,648.7	5,621.7	-27.0
Vertical velocity	($\dot{X}_E$)	ft/sec	3,498.8	3,520.9	22.1
Crossrange velocity	($\dot{Y}_E$)	ft/sec	2.40	8.86	6.46
Relative velocity	(V_E)	ft/sec	6,644.5	6,633.3	-11.2
Inertial velocity	(V_I)	ft/sec	7,775.0	7,761.4	-13.6
Inertial flight path elevation angle	(γ_{1_I}')	deg	27.161	27.394	0.233
Inertial flight path azimuth angle	(γ_{2_I}')	deg	75.644	75.709	0.065
Altitude	(h)	ft	208,312	210,507	2,195
Range	(S)	ft	205,485	205,305	-180
Dynamic pressure	(q)	lbf/ft^2	8.98	8.34	-0.64
Pitch angle of attack	(α)	deg	-0.99	-1.12	-0.13
Yaw angle of attack	(β)	deg	-0.06	-0.16	-0.10

Deviation = Actual - predicted

TABLE 7-3
CONDITIONS AT S-IVB ENGINE CUTOFF COMMAND

PARAMETER		UNITS	PREDICTED	ACTUAL	DEVIATION
Range time	(t)	sec	598.21	593.34	-4.87
Downrange distance	(Z_E)	ft	5,949,935	5,857,127	-92,806
Vertical distance	(X_E)	ft	-307,511	-280,041	27,470
Crossrange distance	(Y_E)	ft	297,610	287,303	-10,307
Downrange velocity	($\dot{Z}_E$)	ft/sec	23,311.0	23,340.0	29.0
Vertical velocity	($\dot{X}_E$)	ft/sec	-6,743.3	-6,639.2	104.1
Crossrange velocity	($\dot{Y}_E$)	ft/sec	1,749.8	1,731.1	-18.7
Relative velocity	(V_E)	ft/sec	24,329.8	24,327.6	-2.2
Inertial velocity	(V_I)	ft/sec	25,661.1	25,658.7	-2.3
Inertial flight path elevation angle	(${\gamma_1}_I$')	deg	-0.003	-0.009	-0.006
Inertial flight path azimuth angle	(${\gamma_2}_I$')	deg	85.691	85.496	-0.195
Altitude	(h)	ft	535,406	536,164	758
Range	(S)	ft	5,886,281	5,791,547	-94,734

Deviation = Actual - predicted

TABLE 7-4
CONDITIONS AT ORBIT INSERTION

PARAMETER		UNITS	PREDICTED	ACTUAL	DEVIATION
Range time	(t)	sec	608.21	603.34	-4.87
Downrange distance	(Z_E)	ft	6,184,060	6,090,385	-93,675
Vertical distance	(X_E)	ft	-376,647	-347,777	28,870
Crossrange distance	(Y_E)	ft	315,294	304,706	-10,588
Downrange velocity	($\dot{Z}_E$)	ft/sec	23,253.5	23,287.6	34.1
Vertical velocity	($\dot{X}_E$)	ft/sec	-7,010.6	-6,905.5	105.1
Crossrange velocity	($\dot{Y}_E$)	ft/sec	1,776.2	1,747.8	-28.4
Relative velocity	(V_E)	ft/sec	24,351.5	24,352.7	1.2
Inertial velocity	(V_I)	ft/sec	25,682.8	25,683.9	1.1
Inertial flight path elevation angle	(${\gamma_1}'_I$)	deg	0.009	0.005	-0.004
Inertial flight path azimuth angle	(${\gamma_2}'_I$)	deg	86.111	85.914	-0.197
Altitude	(h)	ft	535,489	536,231	742
Range	(S)	ft	6,124,868	6,028,912	-95,956

Deviation = Actual - predicted

TABLE 7-5
ORBIT ELEMENTS AT INSERTION

PARAMETER		UNITS	PREDICTED	ACTUAL	DEVIATION
Range time	(t)	sec	608.21	603.34	-4.87
Semi-major axis	(a)	nmi	3,545.9	3,545.7	-0.5
Apogee altitude*	(h_A)	nmi	118.9	119.7	0.8
Perigee altitude*	(h_P)	nmi	85.0	85.1	0.1
Apogee velocity	(V_A)	ft/sec	25,438.9	25,435.0	-3.9
Perigee velocity	(V_P)	ft/sec	25,683.3	25,684.0	0.7
Eccentricity	(e)	-	0.0048	0.0049	0.0001
Inclination	(i)	deg	31.615	31.627	0.012
Period	(P)	min	88.27	88.28	0.01
Inertial velocity	(V_I)	ft/sec	25,683.2	25,683.9	0.7
Inertial flight path elevation angle	(γ_{1_I}')	deg	0.009	0.005	-0.004
Descending Node	(θ_N)	deg	119.054	119.060	0.006
Conic energy	(C_3)	ft^2/sec^2	-652,205,935	-652,106,984	98,951

Deviation = Actual - predicted

*Measured with respect to a mean earth radius of 3,443.94 nmi.

TABLE 7-6
ORBIT ELEMENTS AT S-IVB/LM SEPARATION

PARAMETER		UNITS	PREDICTED	ACTUAL	DEVIATION
Range time	(t)	sec	3,235.00	3,235.24	0.24
Semi-major axis	(a)	nmi	3,546.3	3,546.5	0.2
Apogee altitude*	(h_A)	nmi	116.3	116.8	0.5
Perigee altitude*	(h_P)	nmi	88.5	88.4	-0.1
Apogee velocity	(V_A)	ft/sec	25,458.8	25,456.0	-2.8
Perigee velocity	(V_P)	ft/sec	25,659.5	25,661.1	1.6
Eccentricity	(e)	-	0.0039	0.0040	0.0001
Inclination	(i)	deg	31.615	31.628	0.013
Period	(P)	min	88.28	88.29	0.001
Inertial velocity	(V_I)	ft/sec	25,459.1	25,456.2	-2.9
Inertial flight path elevation angle	(γ_{1_I}')	deg	-0.016	-0.013	-0.003
Descending node	(θ_N)	deg	118.844	118.818	-0.026
Conic energy	(C_3)	ft^2/sec^2	-652,269,270	-652,089,729	199,541

Deviation = Actual - predicted

*Measured with respect to a mean earth radius of 3,443.94 nmi

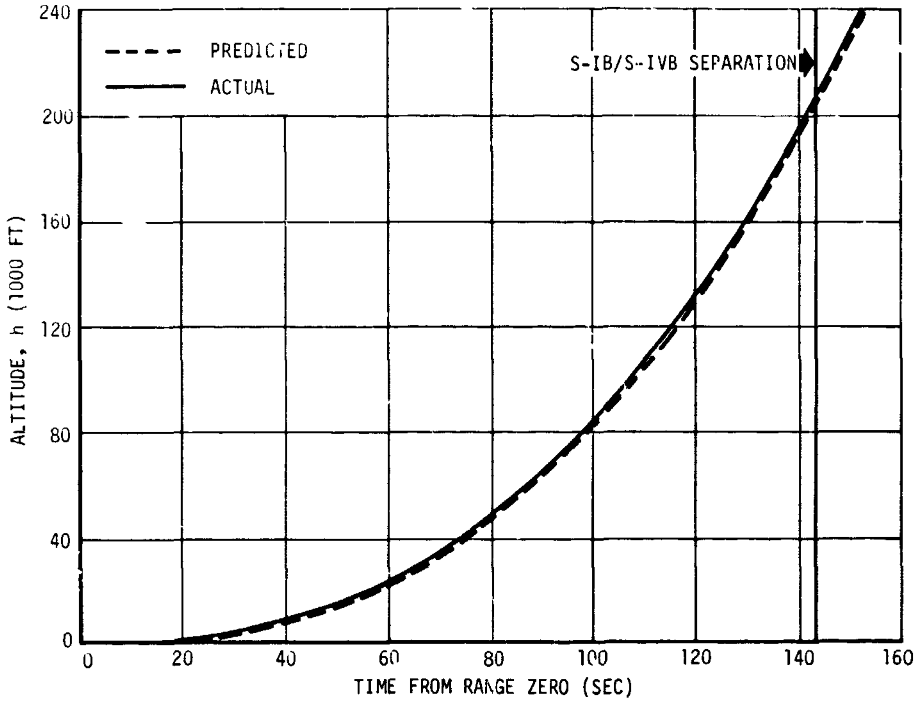


Figure 7-1. S-IB Stage Altitude History

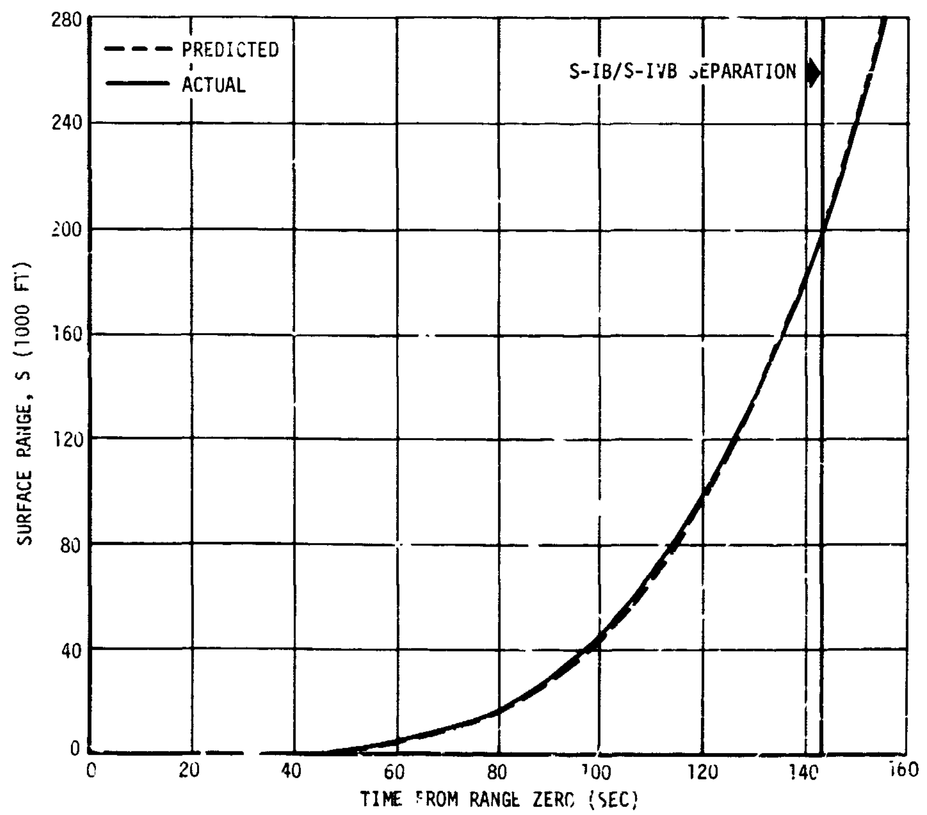


Figure 7-2. S-IB Stage Surface Range History

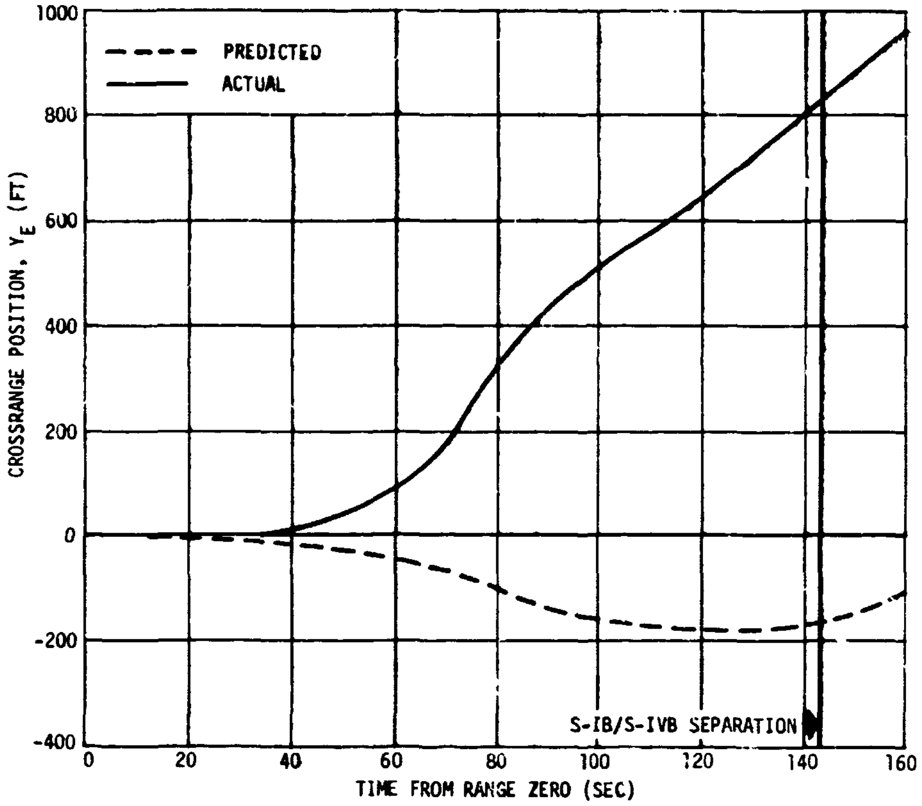


Figure 7-3. S-IB Stage Crossrange Position History

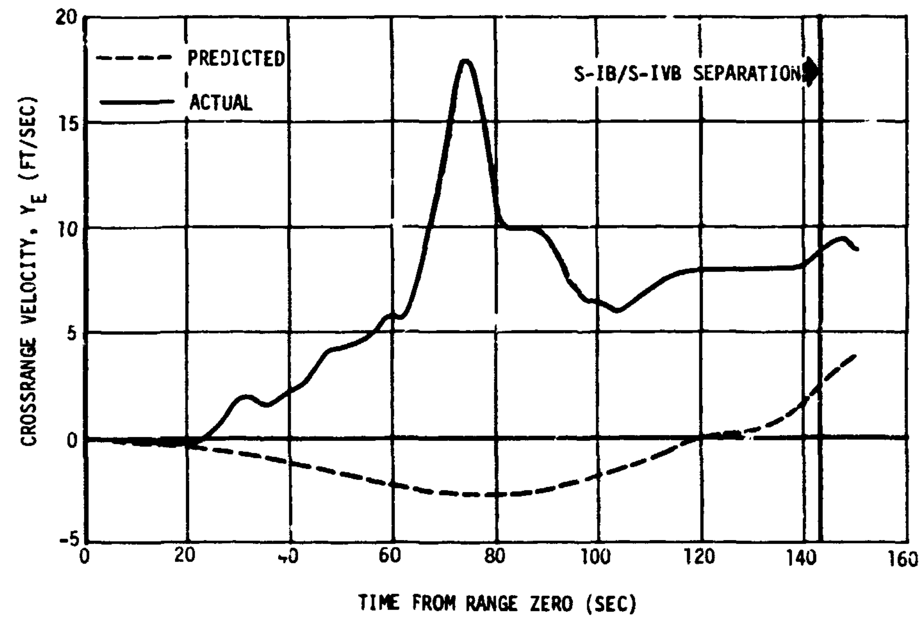


Figure 7-4. S-IB Stage Crossrange Velocity History

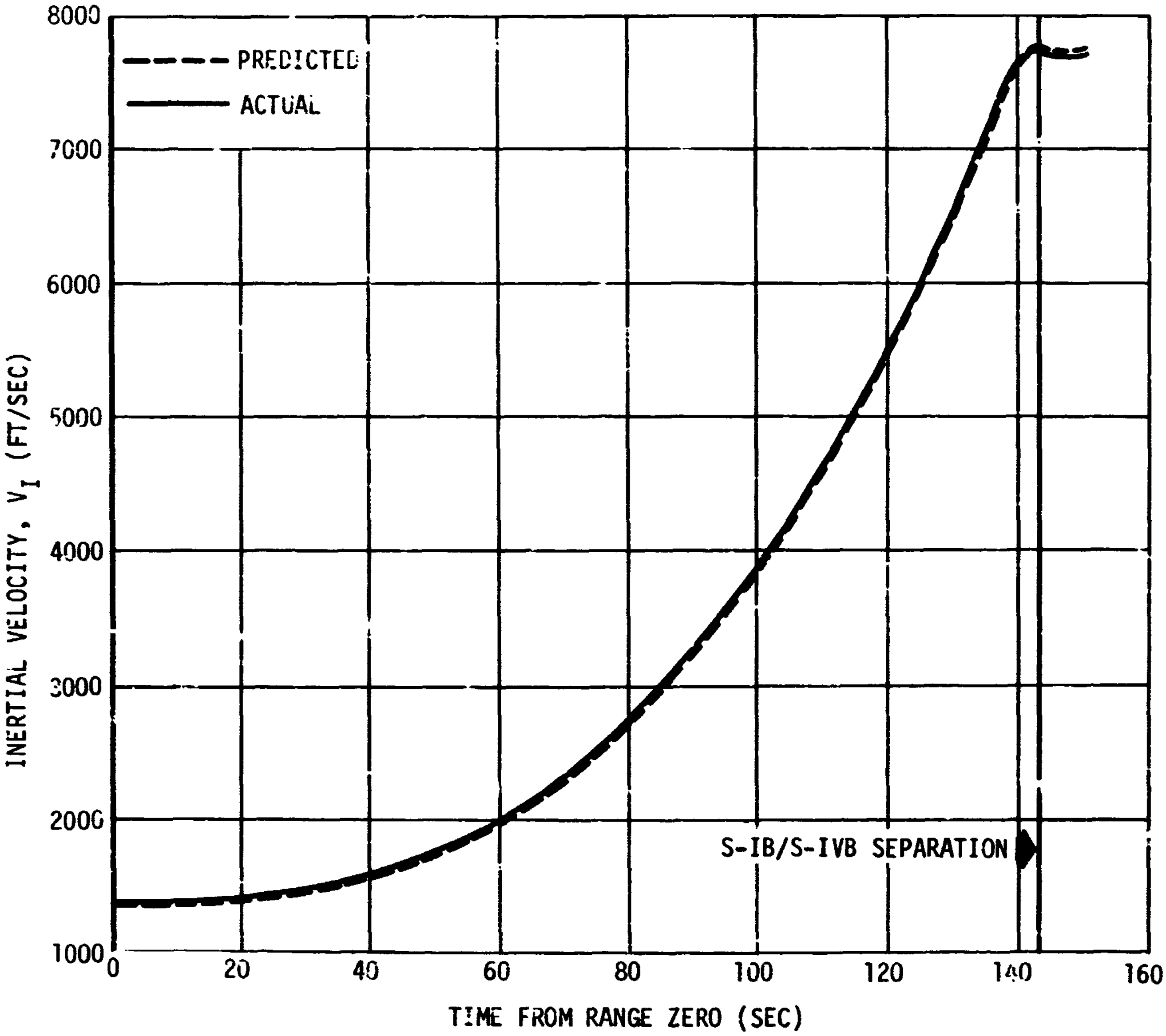


Figure 7-5. S-IB Stage Inertial Velocity History

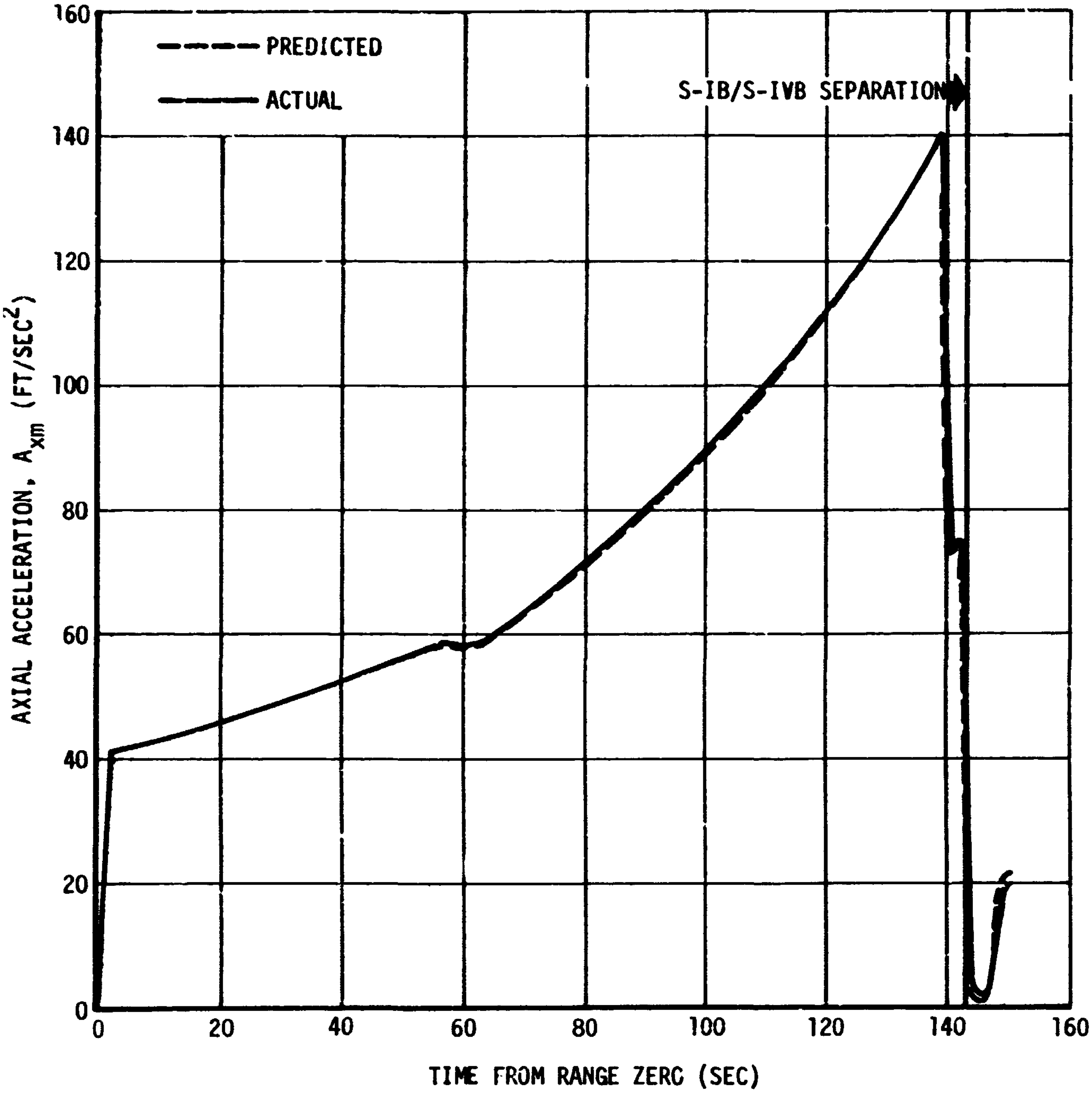


Figure 7-6. S-IB Stage Axial Acceleration History

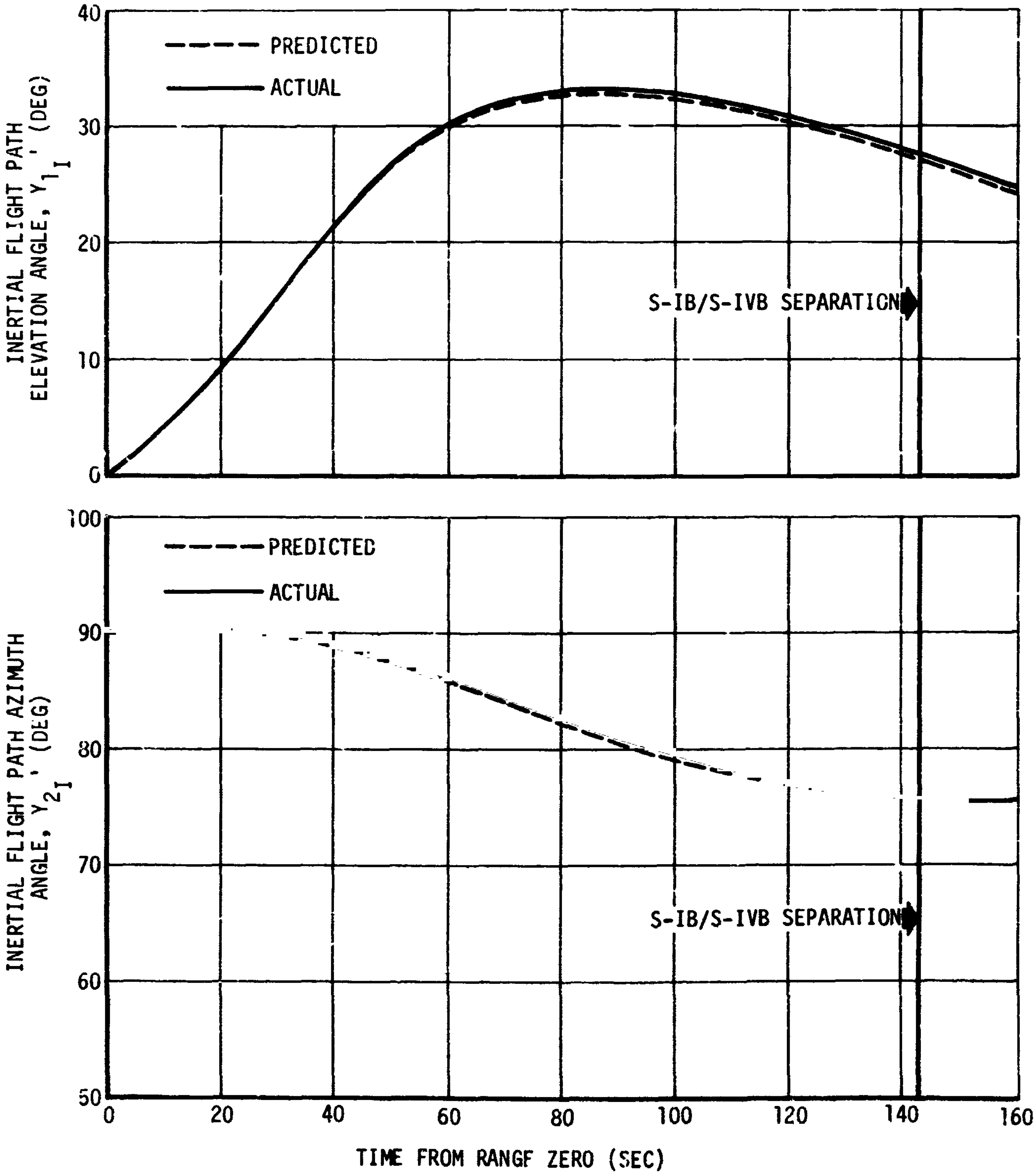


Figure 7-7. S-IB Stage Inertial Flight Path Angle History

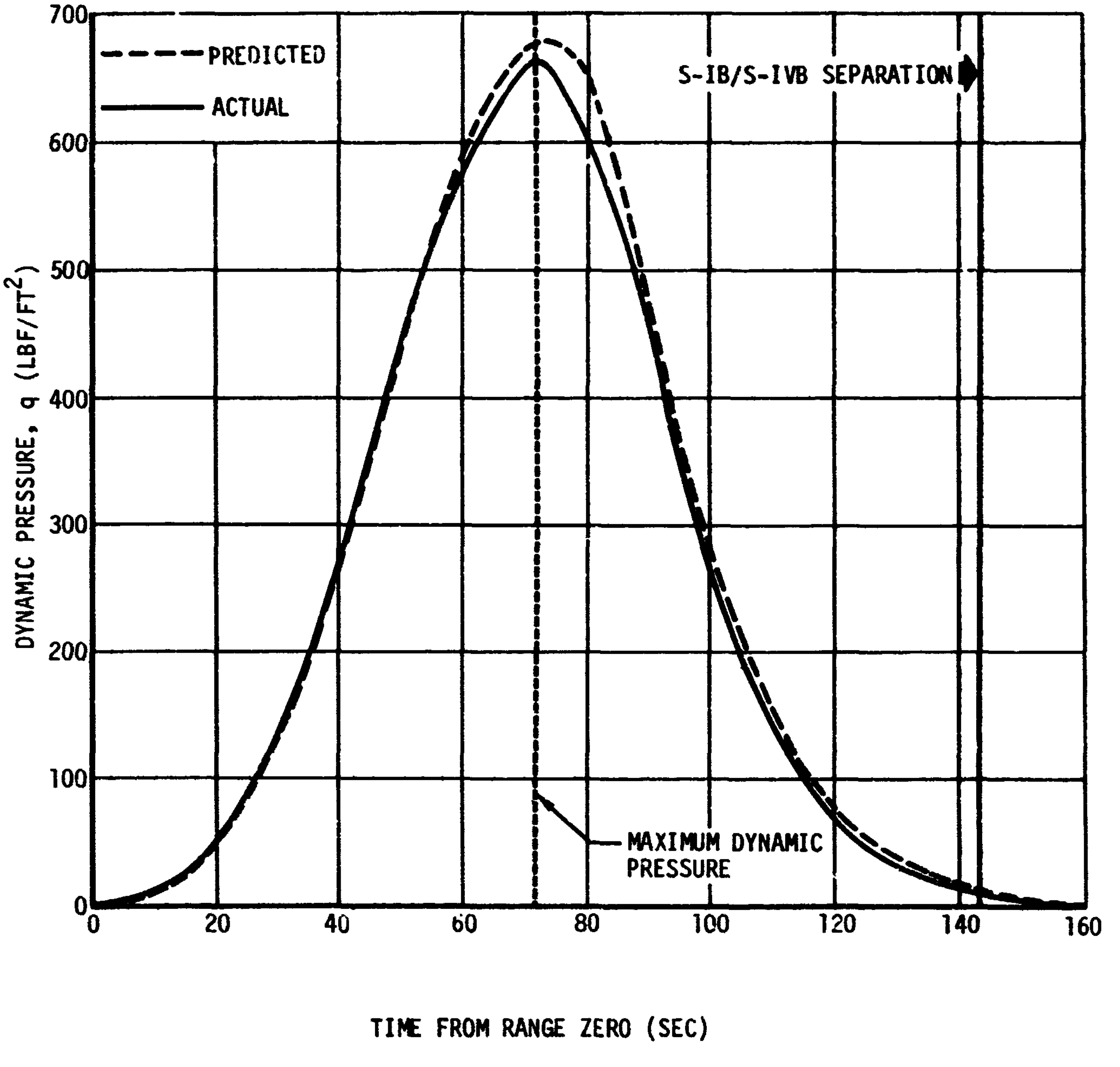


Figure 7-8. S-IB Stage Dynamic Pressure History

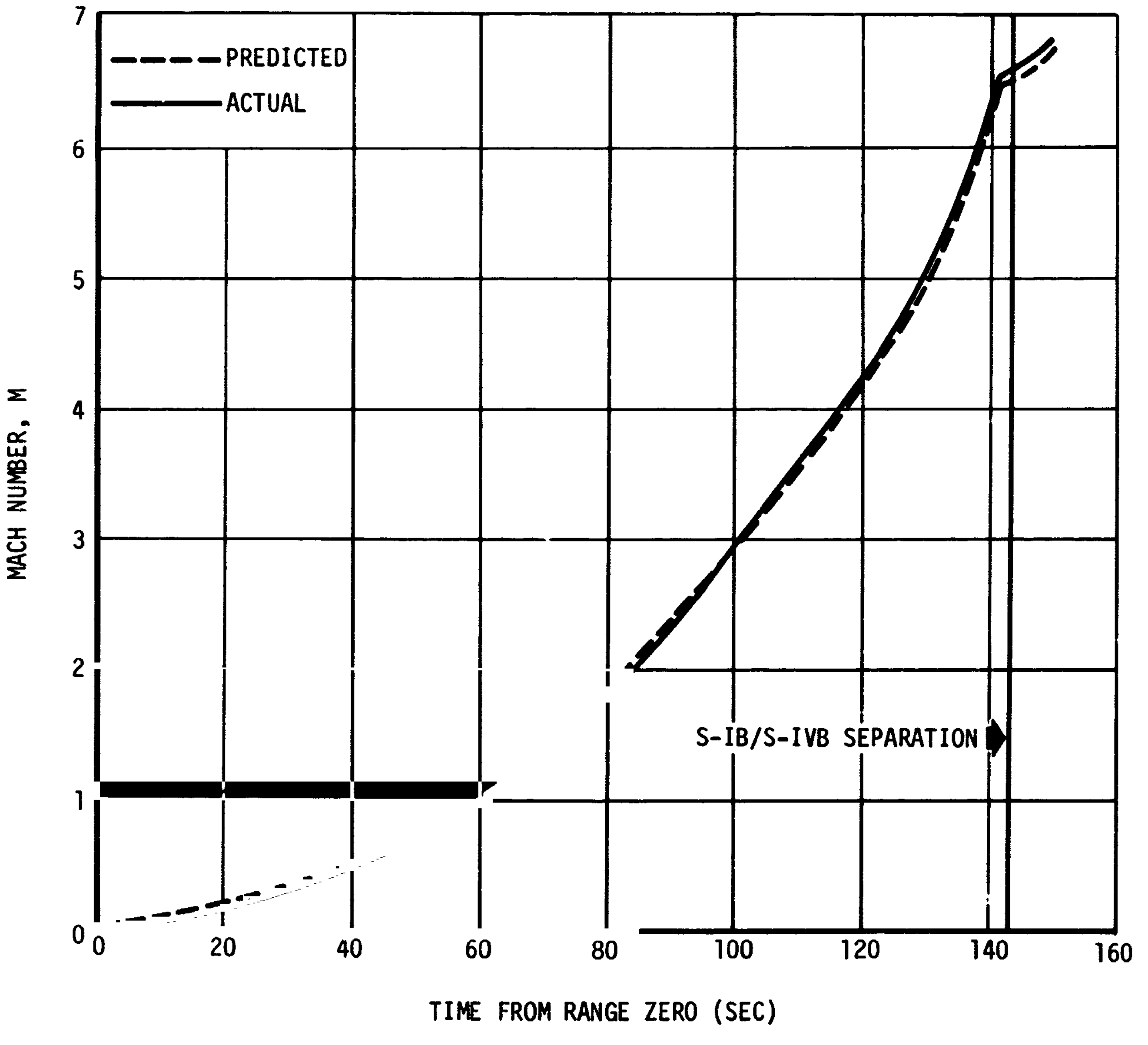


Figure 7-9. S-IB Stage Mach Number History

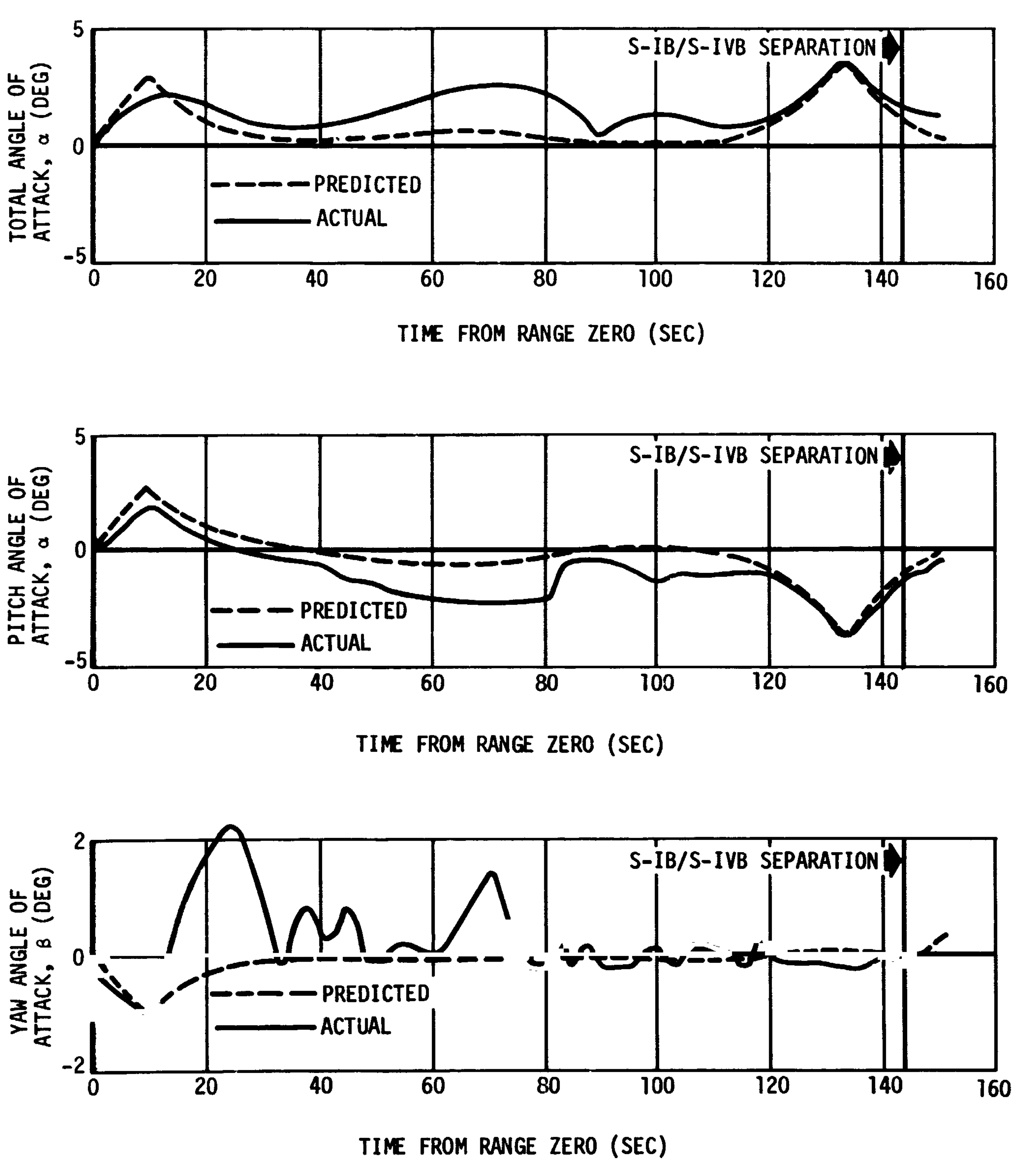


Figure 7-10. S-IB Stage Angle of Attack History

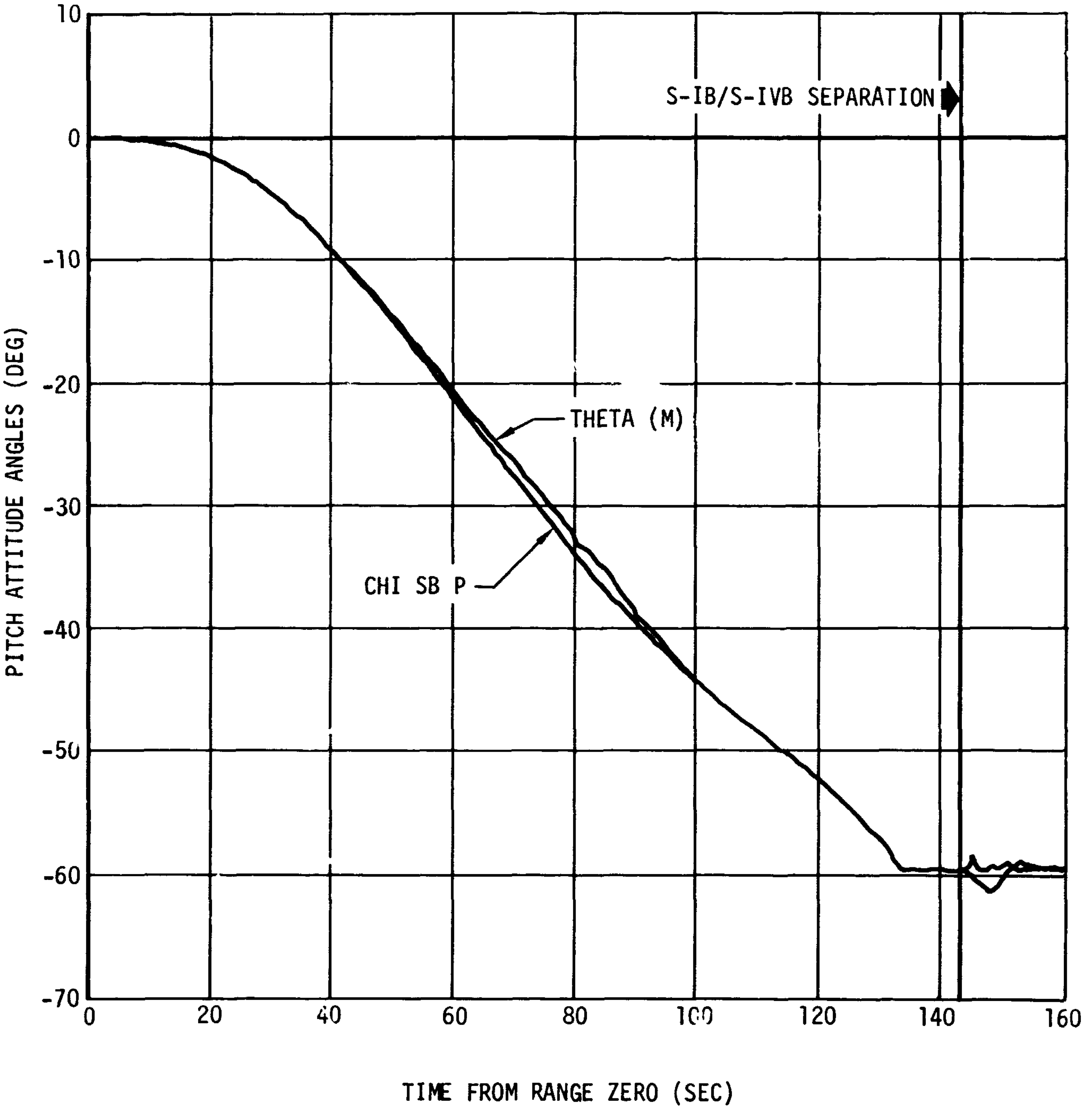


Figure 7-11. S-IB Stage Pitch Attitude Angle History

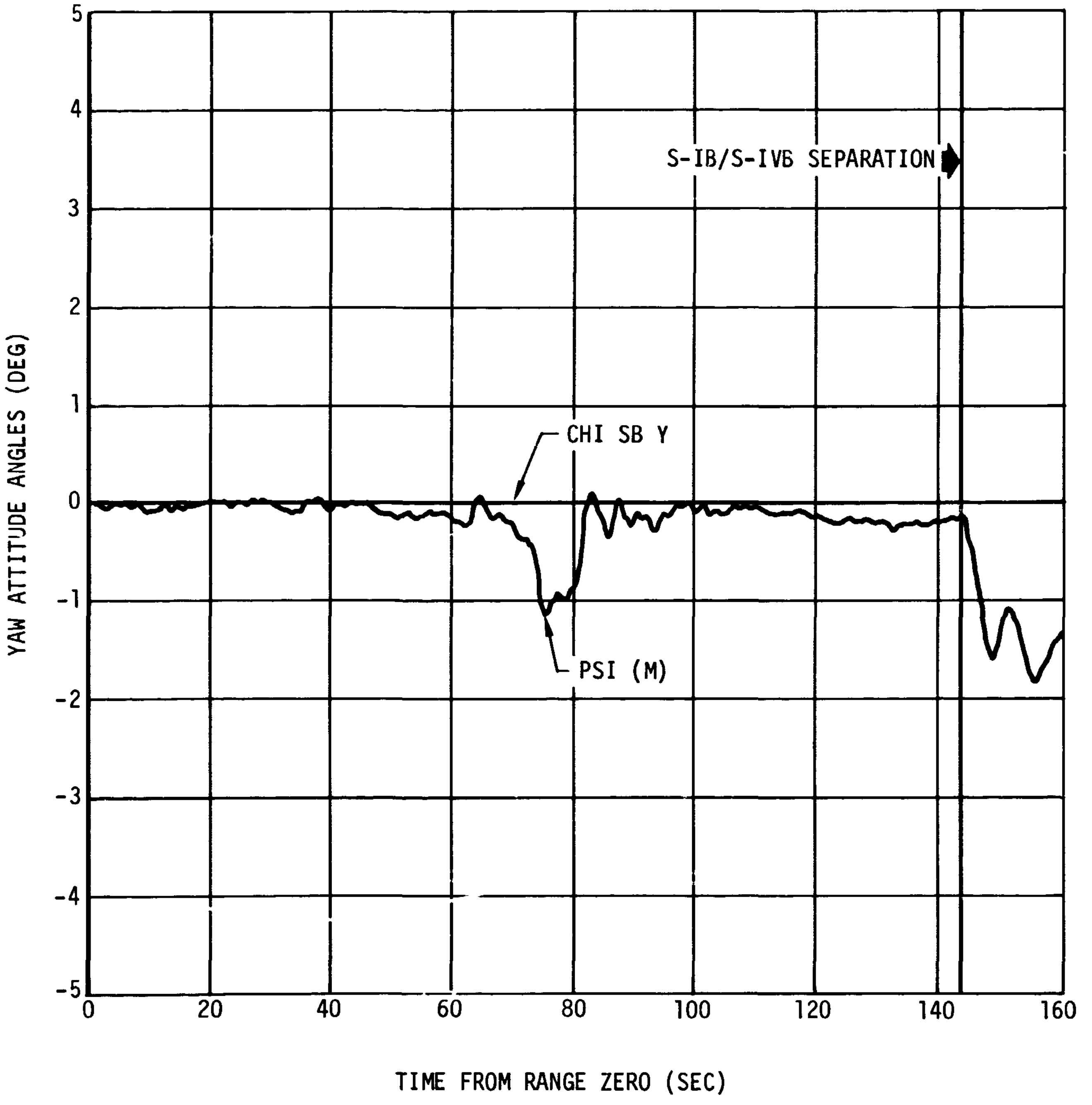


Figure 7-12. S-IB Stage Yaw Attitude Angle History

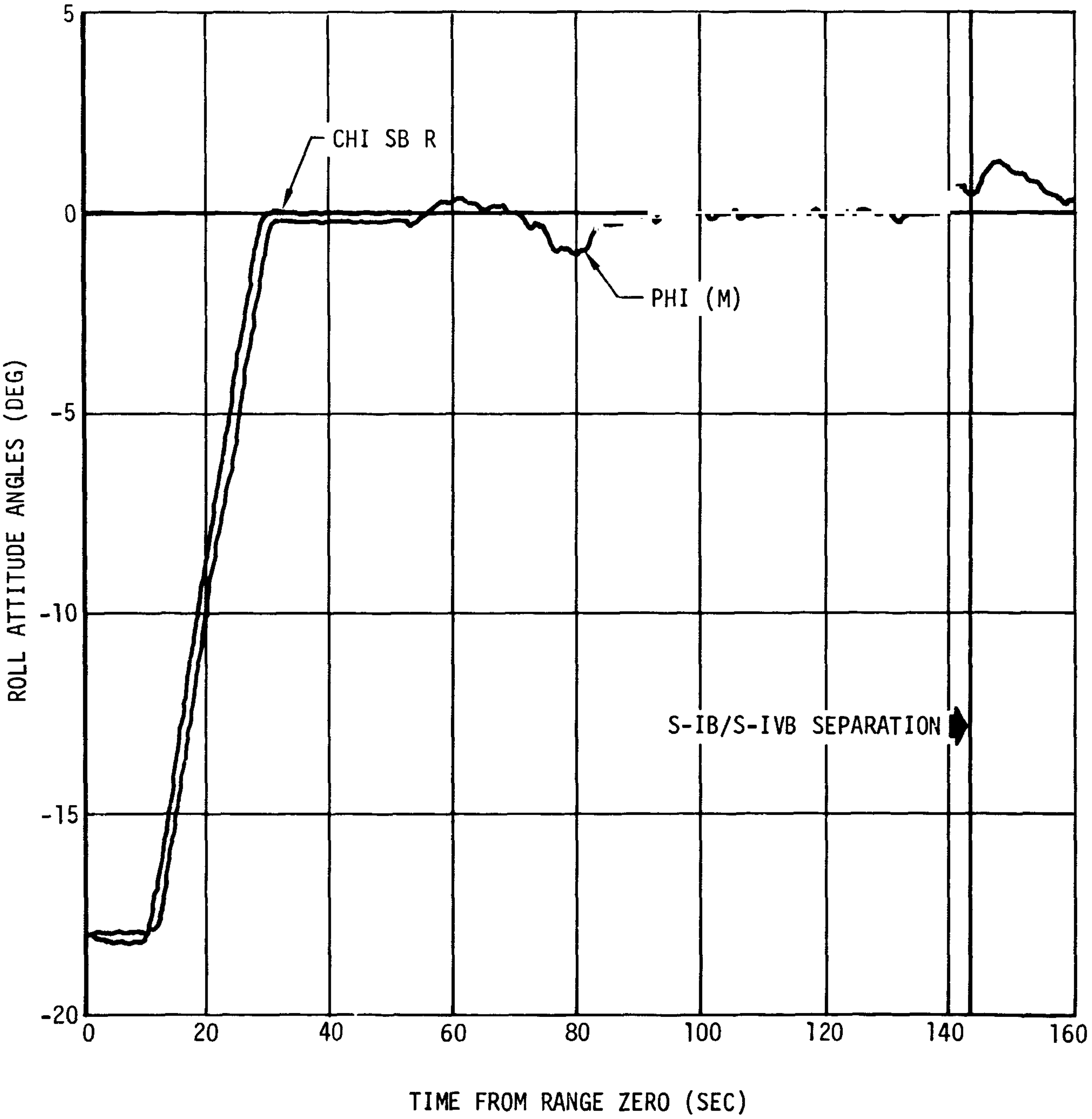


Figure 7-13. S-IB Stage Roll Attitude Angle History

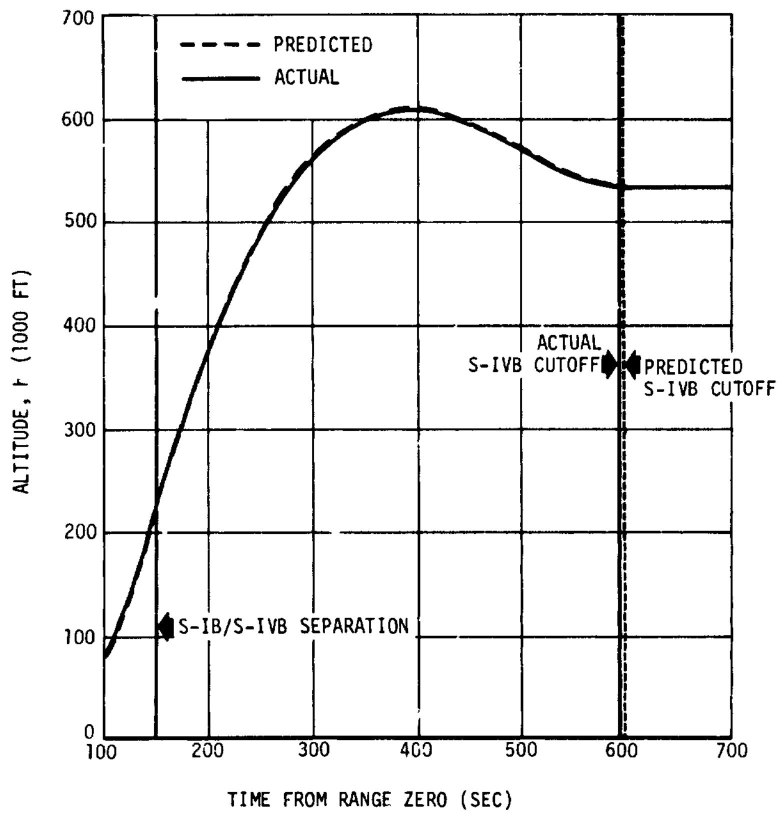


Figure 7-14. S-IVB Stage Altitude History

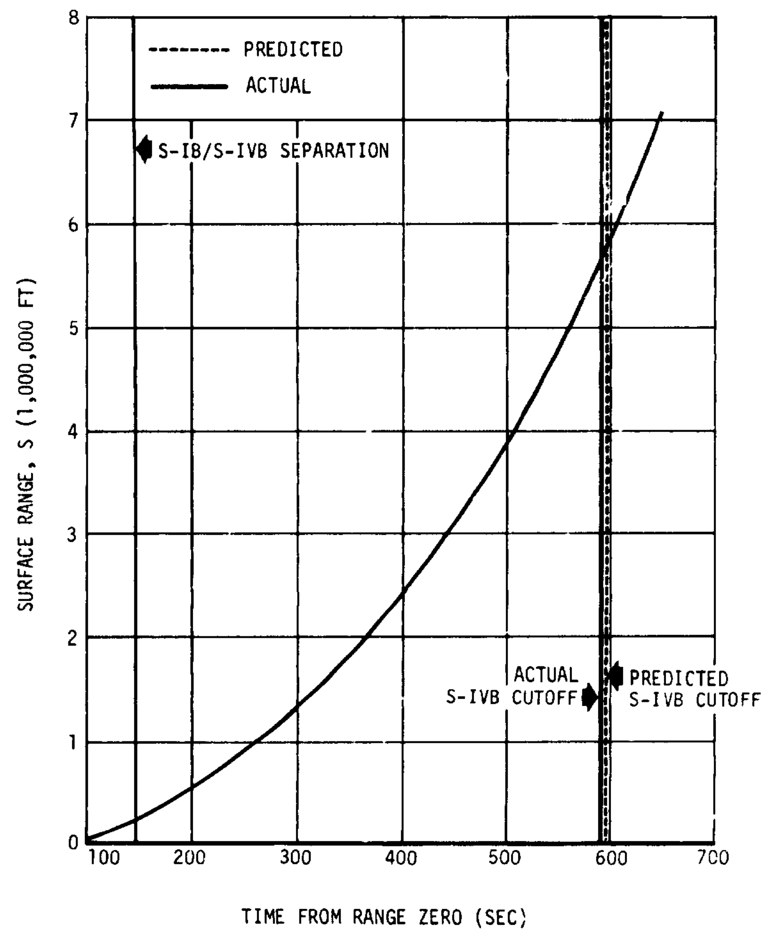


Figure 7-15. S-IVB Stage Surface Range History

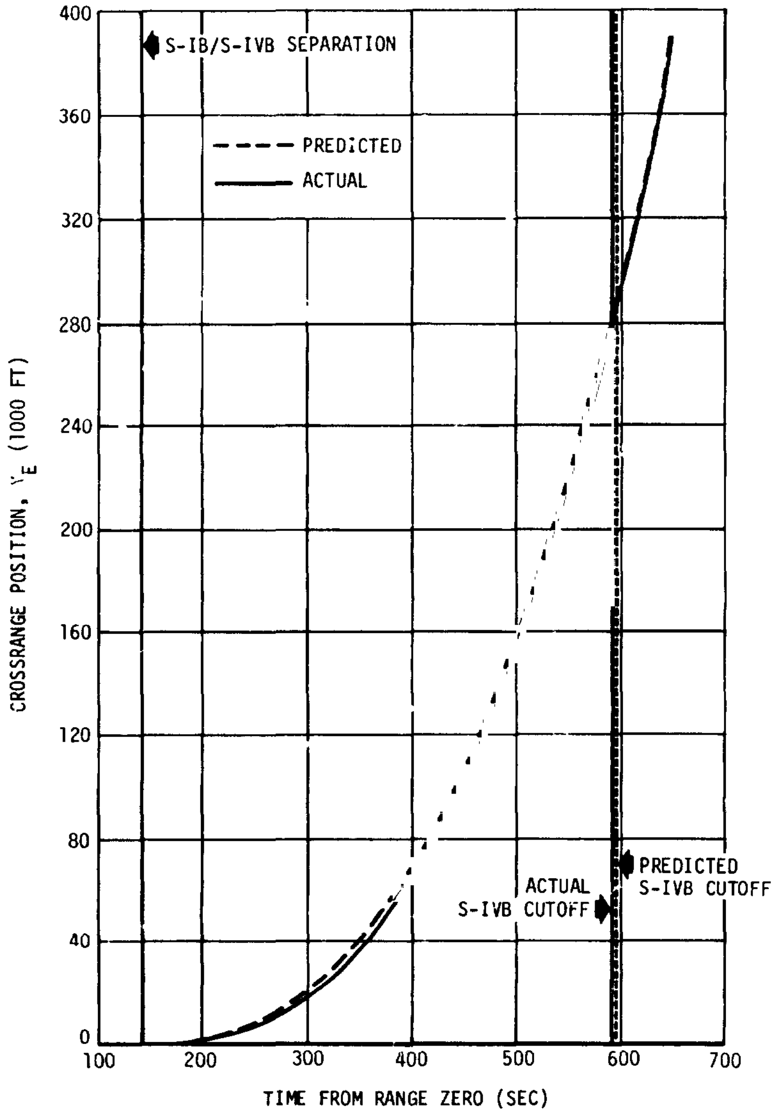


Figure 7-16. S-IVB Stage Crossrange Position History

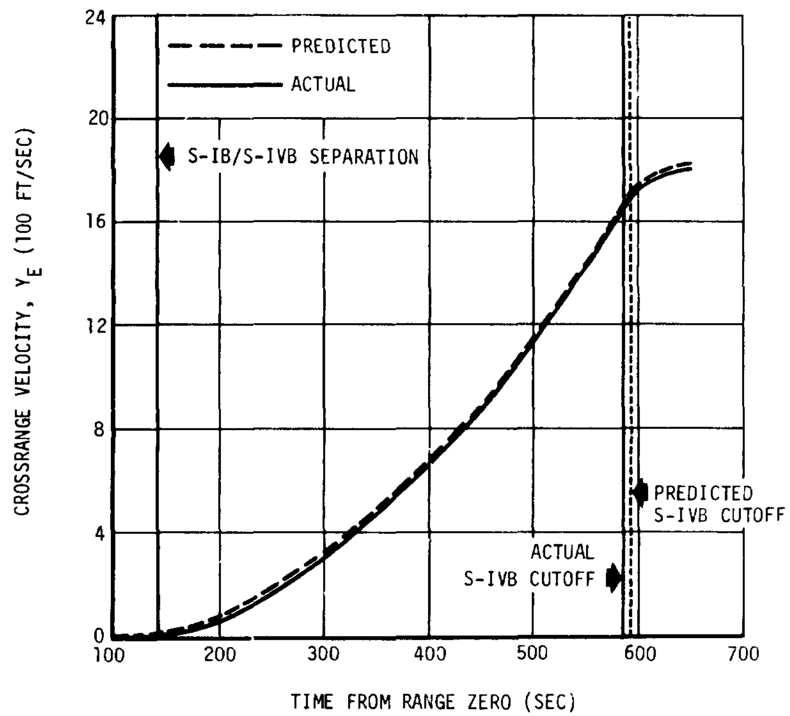


Figure 7-17. S-IVB Stage Crossrange Velocity History

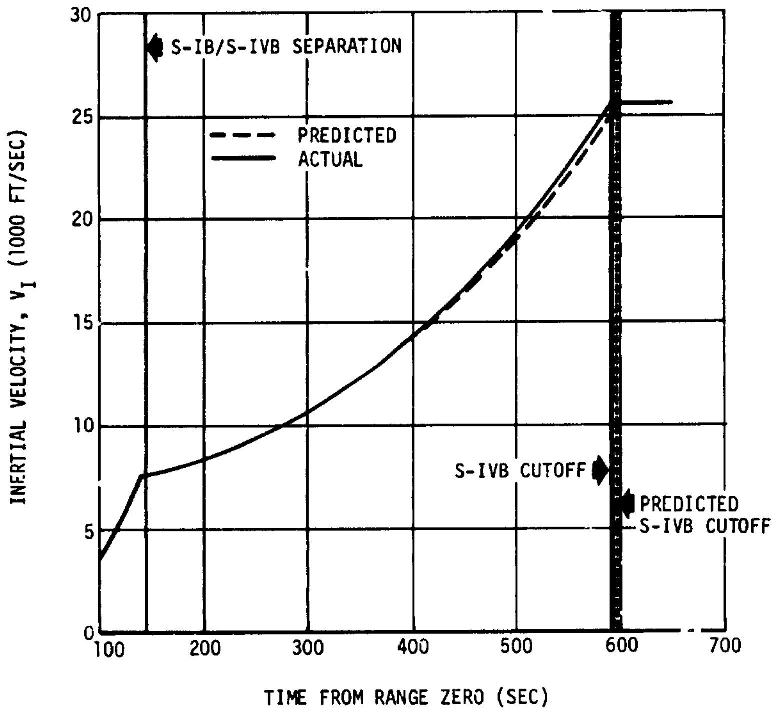


Figure 7-18. S-IVB Stage Inertial Velocity History

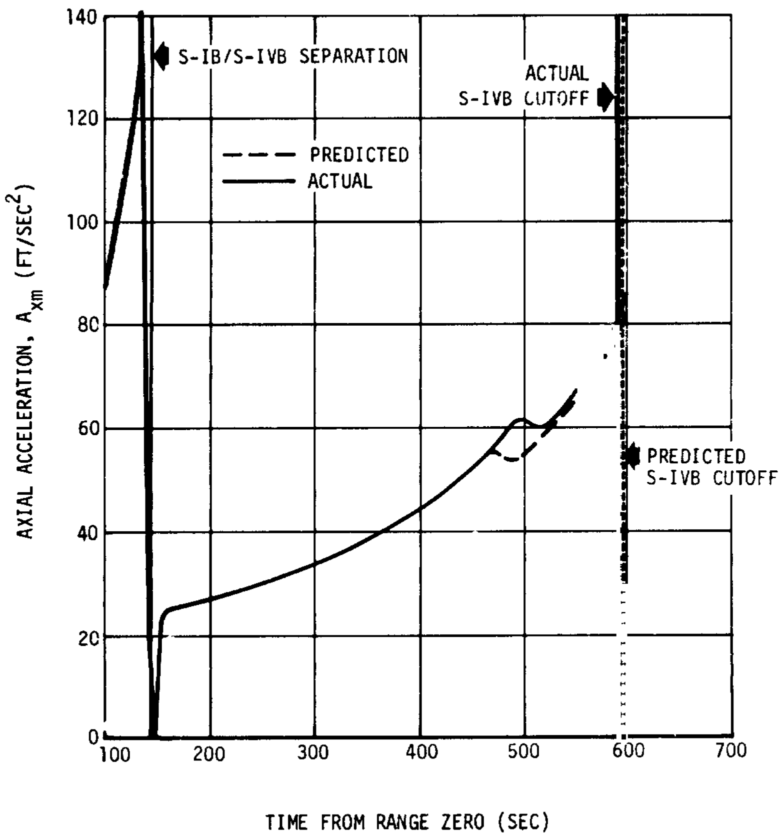


Figure 7-19. S-IVB Stage Axial Acceleration History

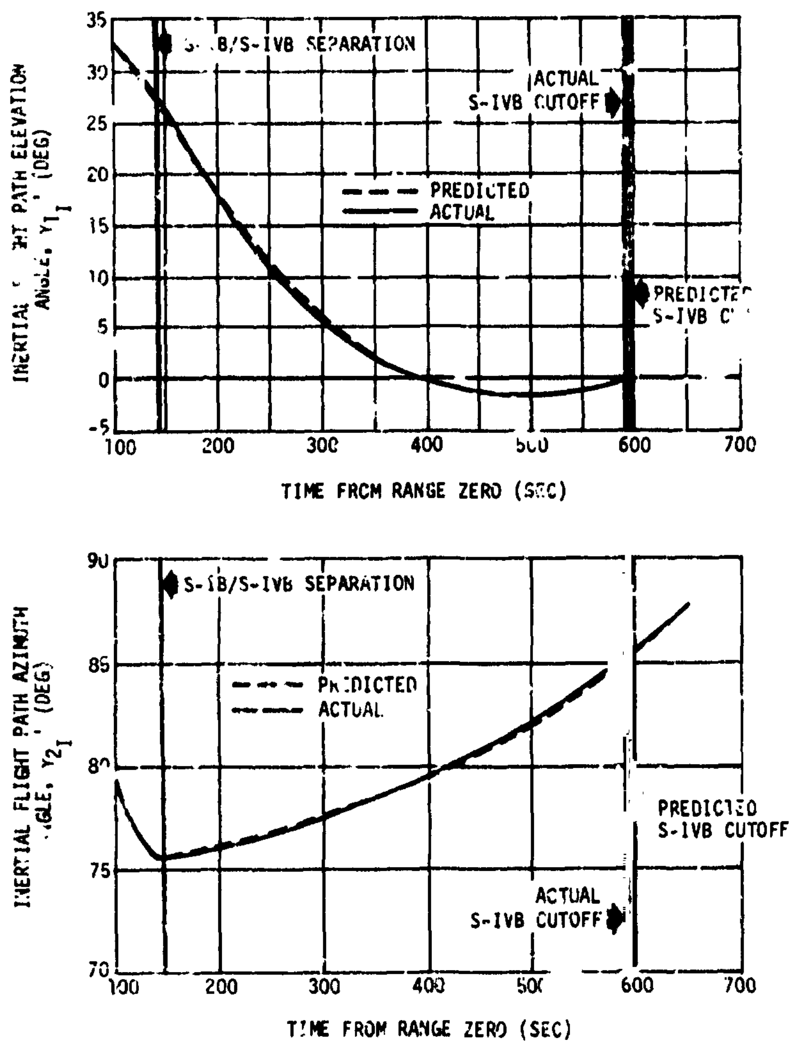


Figure 7-20. S-IVB Stage Inertial Flight Path Angle History

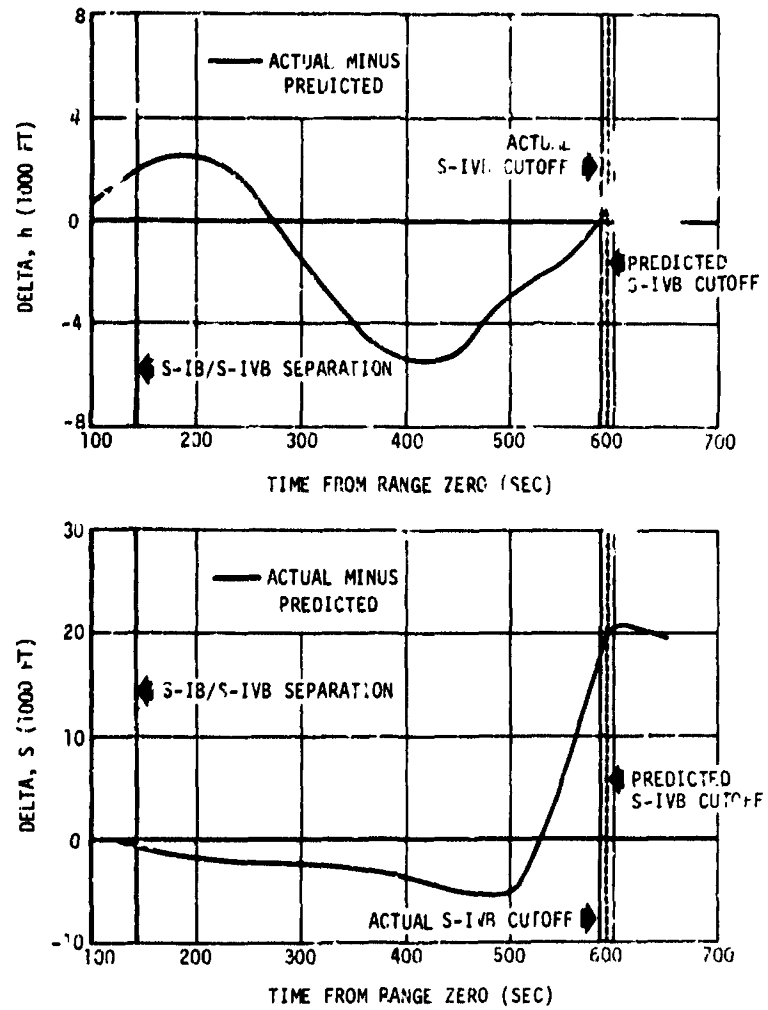


Figure 7-21. S-IVB Stage Difference Histories, Altitude and Range

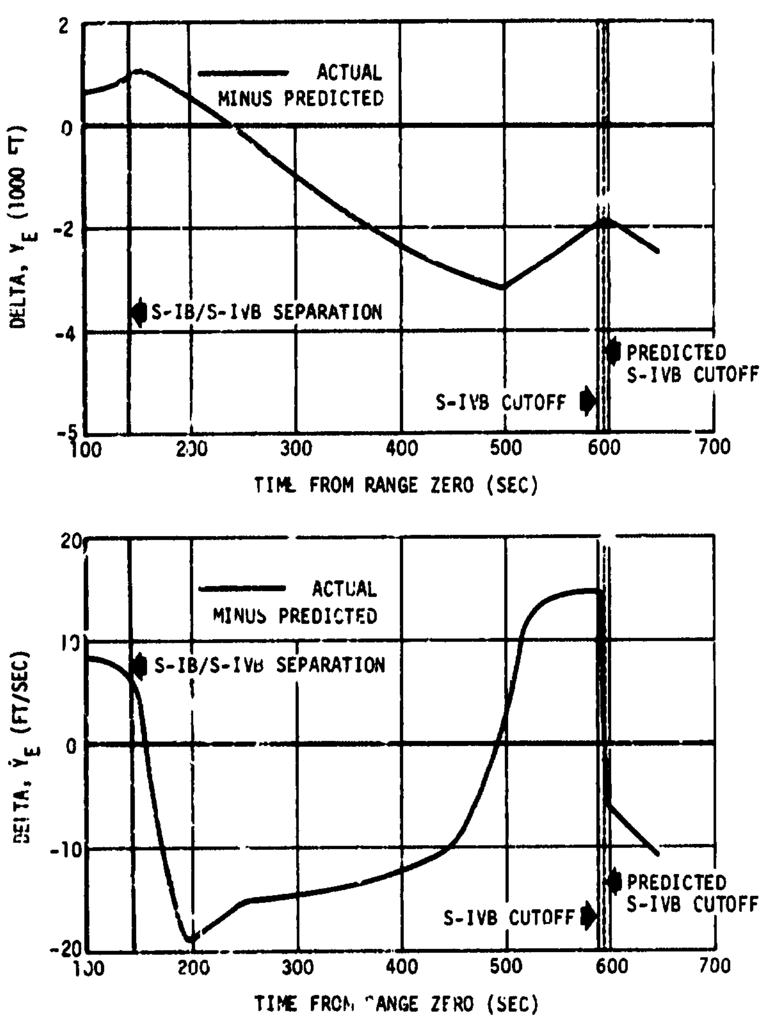


Figure 7-22. S-IVB Stage Difference Histories, Crossrange and Crossrange Velocity

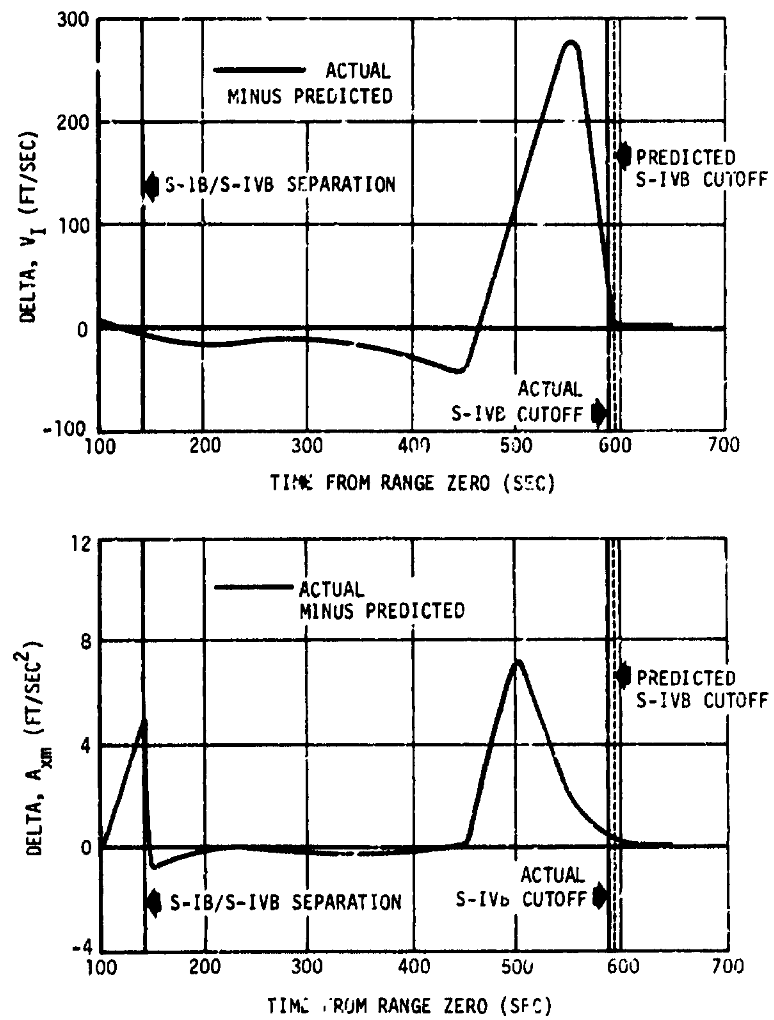


Figure 7-23. S-IVB Stage Difference Histories, Velocity and Acceleration

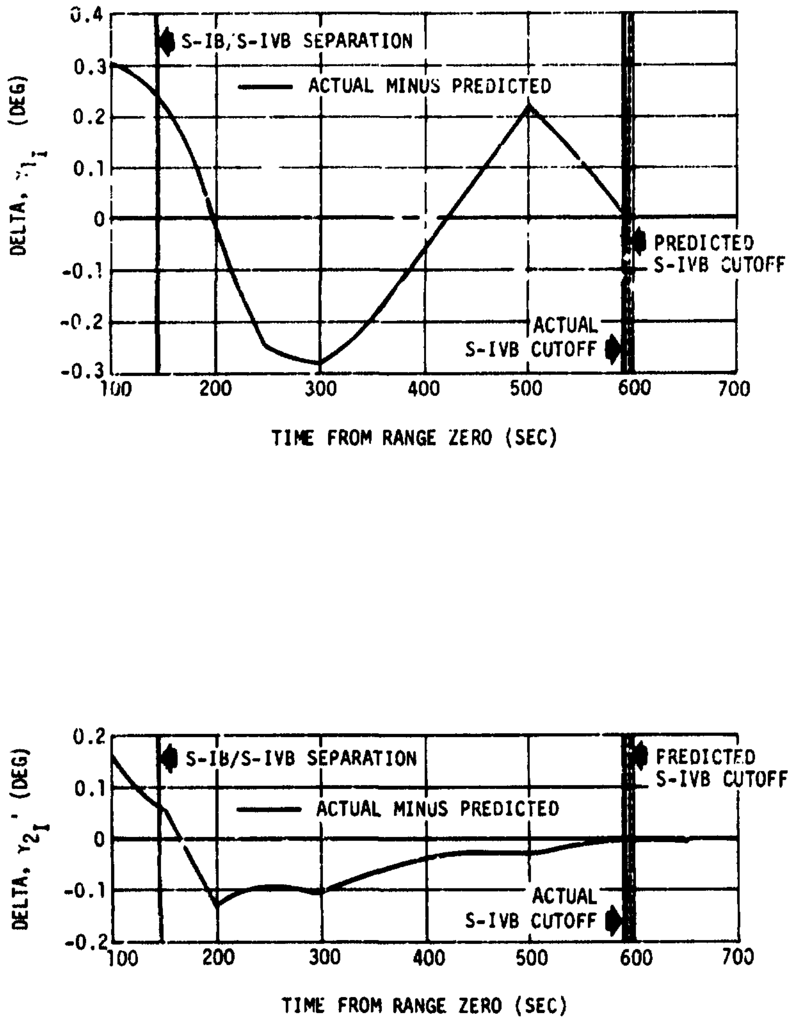


Figure 7-24. S-IVB Stage Difference Histories, Elevation and Azimuth Flight Path Angles

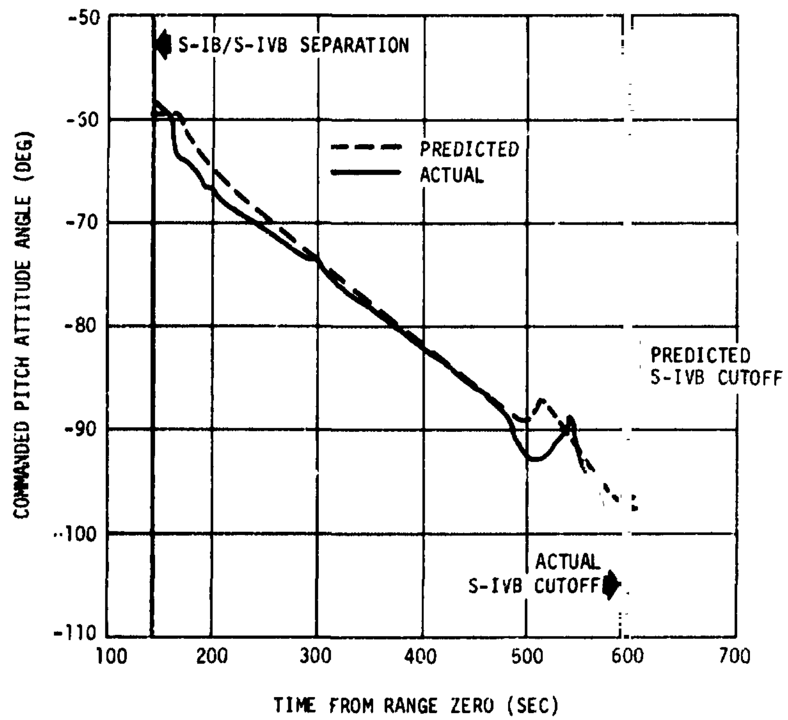


Figure 7-25. S-IVB Stage Commanded Pitch Attitude Angle History

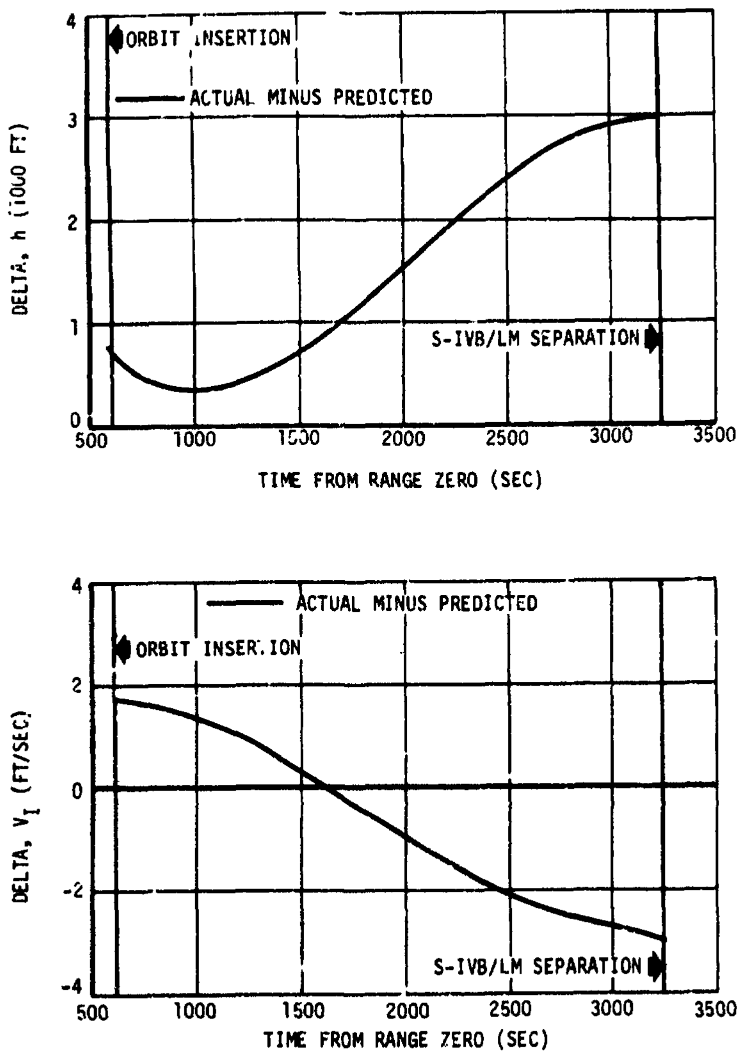


Figure 7-26. Orbit Difference Histories, Altitude and Velocity

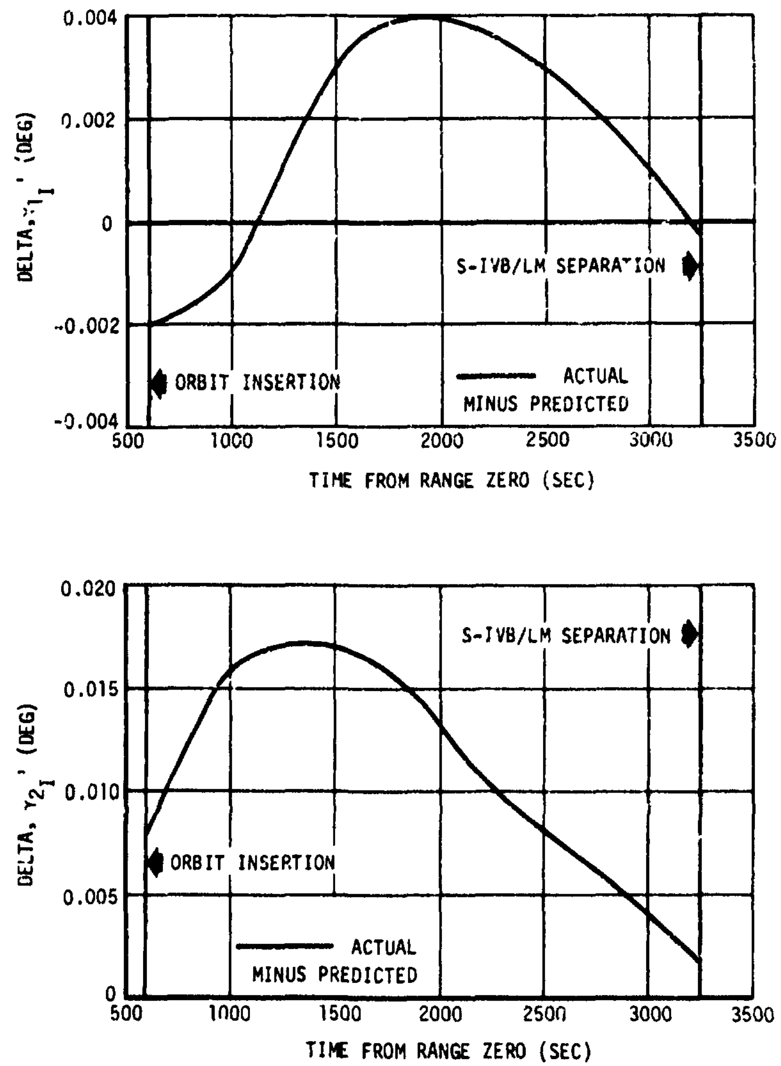


Figure 7-27. Orbit Difference Histories, Elevation and Azimuth Flight Path Angles

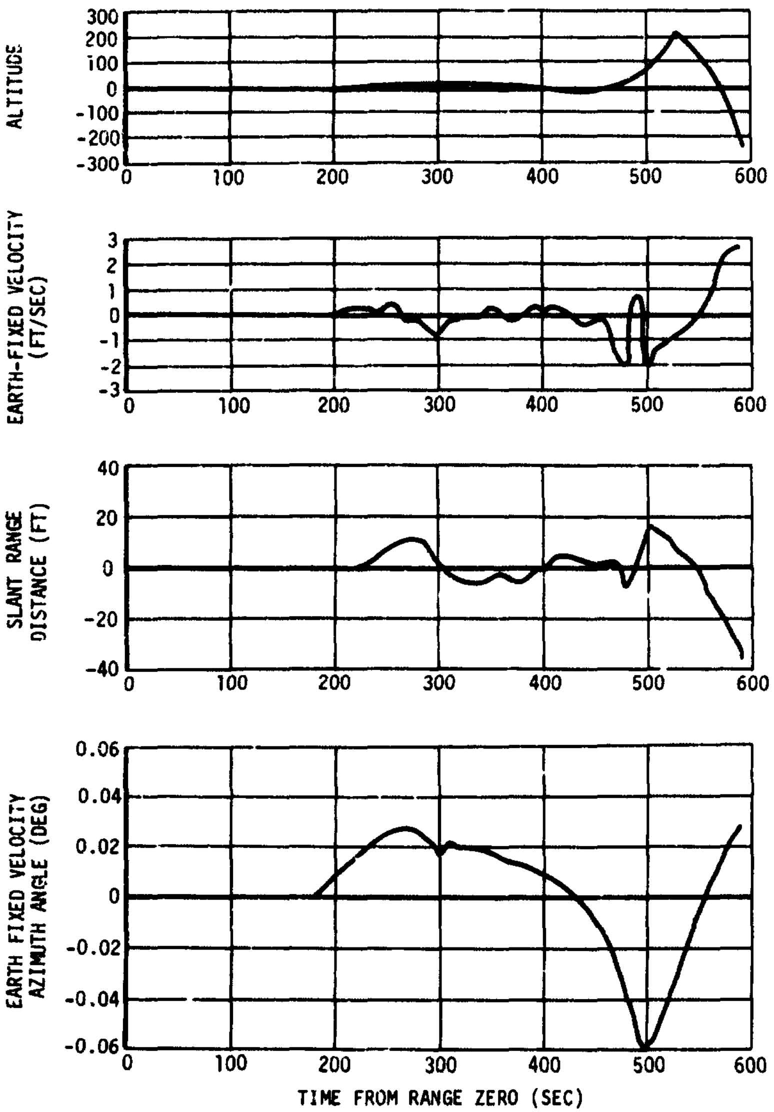


Figure 7-28. Trajectory Reconstruction Simulation Deviations

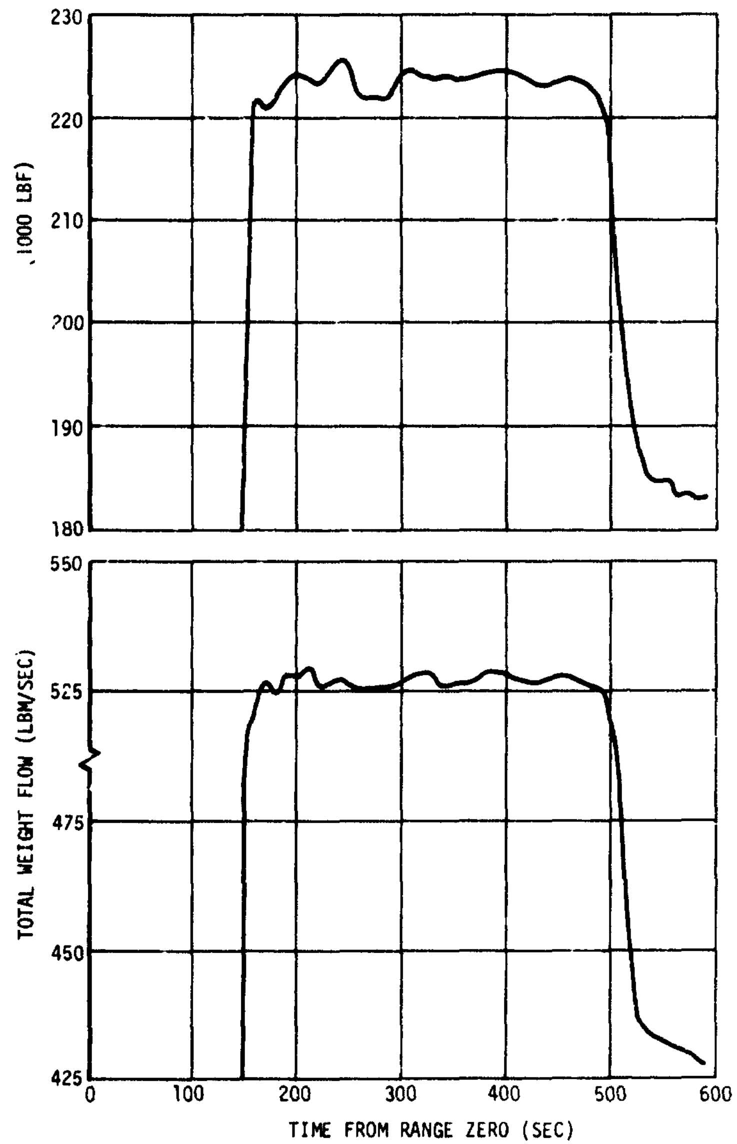


Figure 7-29. Thrust and Weight Flow

SECTION 8

MASS CHARACTERISTICS

8. MASS CHARACTERISTICS

8.1 Mass Characteristics Summary

The AS-204 second flight stage (S-IVB-204, IU, and payload) mass summary presented in table 8-1, and the mass characteristics presented in appendix 1 are "best estimate" values.

8.2 Mass Properties Dispersion Analysis

Figures 8-1 through 8-4 present a comparison of the predicted vehicle mass characteristics and three sigma dispersions versus the postflight vehicle mass characteristics for the AS-204 second flight stage during S-IVB powered flight. The predicted dispersions were determined from a statistical analysis of component mass properties uncertainties and are referenced relative to time from Engine Start Command rather than event.

With the exception of the roll moment of inertia, the postflight mass properties were within the predicted three sigma dispersion bands. Figure 8-3 shows the actual roll moment of inertia to be greater than the maximum predicted dispersion. Investigation showed the predicted roll moment of inertia values were in error due to an erroneous roll radius of gyration for the S-IVB-204 dry stage. The resulting error in the predicted roll moment of inertia was approximately -4,000 slug-ft^2 which when corrected would cause the predicted nominal and the actual values to agree in close proximity.

8.3 Second 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.

Two measurement systems provide unique values for ignition mass and three measurement systems provide unique values for cutoff mass while two systems provide a linear relationship between them. 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 volumetric (2) PU indicated (corrected) (3) level sensors (4) flow integral, and (5) trajector reconstruction. Measurement systems (1) through (4) are described in section 15 and the trajectory reconstruction is described in section 7.

Figure 8-5 is a graphical presentation of the best estimate analysis for ignition and cutoff mass. The second flight stage ignition mass was 297,035 ±638 lbm and the cutoff mass w 70,226 ±178 lbm.

8.3.1 Best Estimate Program Input

Table 8-2 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 nonpropellant mass value and dispersion are used for computation. The linear relationship values are presented as utilized for best estimate analysis.

TABLE 8-1
MASS CHARACTERISTICS (lbm)

EVENT	S-IB LIFTOFF	S-IB/S-IVB SEPARATION	S-IVB ESC	S-IVB 90 PERCENT THRUST	PU CUTBACK	START EMR SHIFT	END EMR SHIFT	S-IVB ECC	S-IVB ETD*	JETTISON NOSE CONE	DEPLOY SLA PANELS	LEM/S-IVB SEPARATION	START LOX DUMP	END LOX DUMP	END PROGRAM
Frost	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Separation Pkg	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ullage Rockets	399	389	322	222	0	0	0	0	0	0	0	0	0	0	0
Nose Cone	1,067	1,067	1,067	1,067	1,067	1,067	1,067	1,067	1,067	0	0	0	0	0	0
SLA Ring	91	91	91	91	91	91	91	91	91	0	0	0	0	0	0
Lunar Module	31,530	31,530	31,530	31,530	31,530	31,530	31,530	31,530	31,530	31,530	31,530	0	0	0	0
Adapter	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859	3,859
Instrument Unit	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605	4,605
S-IVB-204 Dry Stg	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477	23,477
LOX in Tank	193,703	193,698	193,698	192,678	49,958	39,802	19,967	2,641	2,521	2,504	2,475	2,371	2,086	0	0
LOX Ullage Gas	30	35	35	36	233	247	278	308	308	232	261	365	650	557	0
LOX Below Tank	367	367	367	397	397	397	397	397	367	367	367	367	367	0	0
LH2 in Tank	37,266	37,246	37,246	36,979	10,936	9,083	5,024	1,427	1,400	1,376	1,067	343	0	0	0
LH2 Ullage Gas	147	167	167	168	339	352	379	405	405	405	403	757	0	0	0
LH2 Below Tank	48	48	48	58	58	58	58	58	48	48	48	48	0	0	0
Cold Helium	316	316	316	315	201	193	174	157	157	157	157	157	157	157	0
APS Propellant	129	129	129	129	125	125	124	124	124	122	106	101	83	83	83
GH2 Start Tank	5	5	5	1	7	7	7	7	7	7	7	7	7	7	7
Service Items	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Env Cont Fluid	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
TOTAL MASS	297,246	297,102	297,035	295,685	126,957	114,[illegible]5	91,111	70,226	70,039	68,762	68,435	36,530	35,364	32,818	32,054
TIME FROM RANGE ZERO (sec)	0.360	143.50	144.90	148.20	470.00	492.90	544.90	593.34	594.74	638.51	1,193.52	3,232.53	8,774.35	8,894.55	20,000.00

*End of thrust decay

TABLE 8-2
BEST ESTIMATE PROGRAM INPUT VALUES

UNIQUE MEASUREMENT SYSTEMS

EVENT	UNIQUE MEASUREMENT SYSTEM	LOX (lbm)		LH2 (lbm)		NON-PROPELLANTS (lbm)		TOTAL (lbm)	
		VALUE	ERROR	VALUE	ERROR	VALUE	ERROR	VALUE	ERROR
ESC	PU Volumetric	194,117	±960	37,220	±250	65,676	± 0	297,013	±1,003
	PU Indicated (Corrected)	193,287	±1,380	37,320	±267	65,676	±150	296,283	±1,414
ECC	PU Volumetric	2,937	±490	1,513	±130	65,703	±150	70,153	±529
	Pt Level Sensor	3,205	±248	1,462	±40	65,703	±150	70,370	±293
	PU Indicated (Corrected)	3,062	±490	1,575	±130	65,703	±150	70,340	±529

LINEAR RELATIONSHIPS

EVENT	MEASUREMENT SYSTEM	SLOPE	INTERCEPT (lbm)	ERROR (lbm)
ESC to ECC	Flow Integral	1.0	226,725	±1,384
	Trajectory Reconstruction	4.23469	0	±891

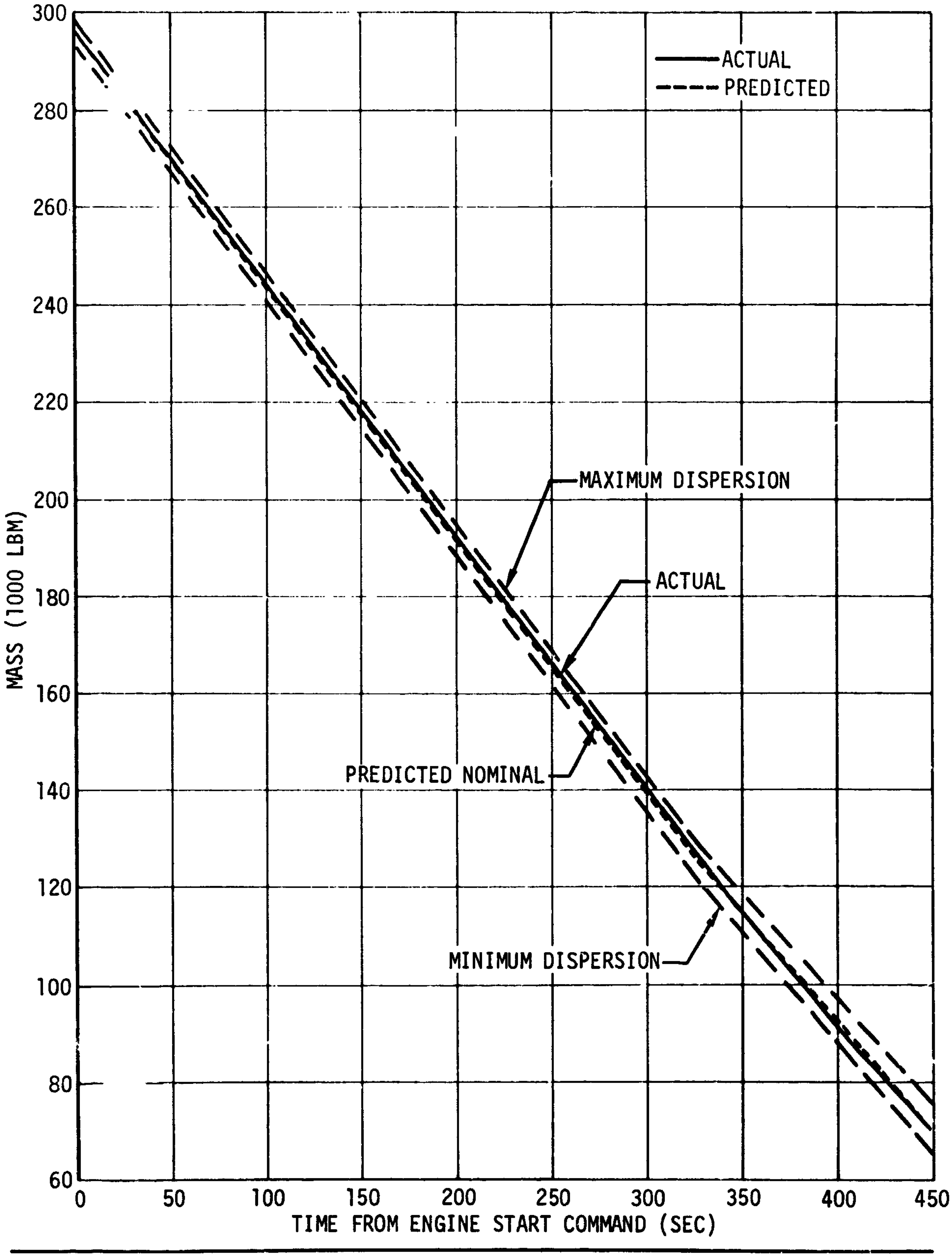


Figure 8-1. AS-204 Second Flight Stage Vehicle Mass

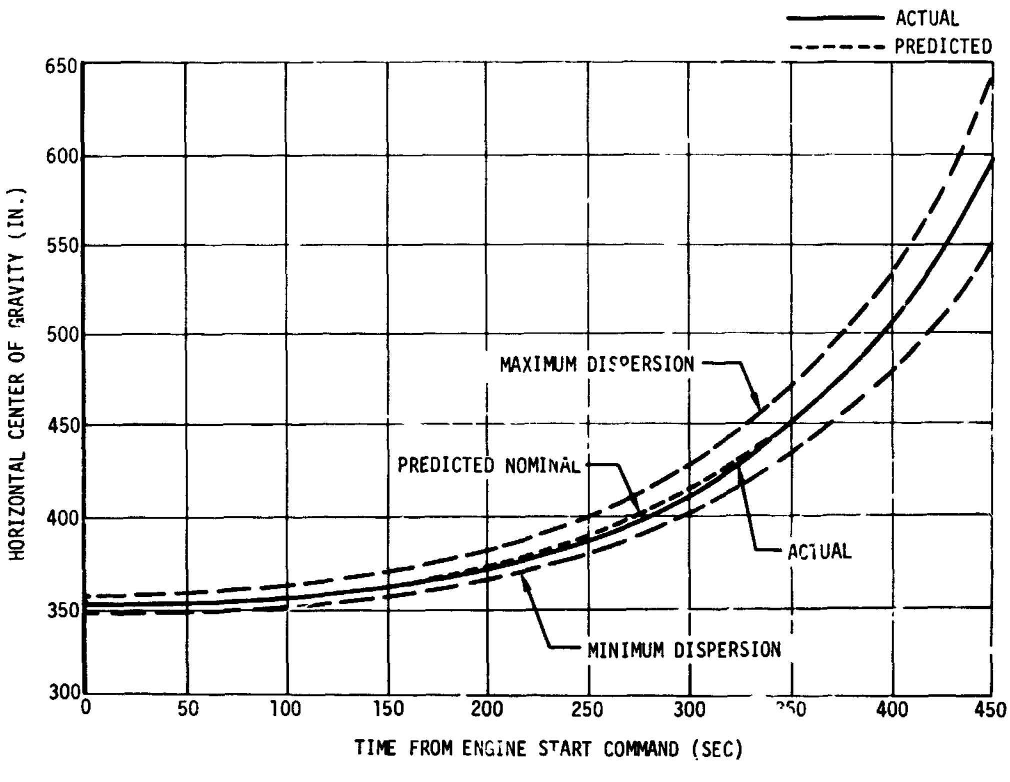


Figure 8-2. AS-204 Second Flight Stage Vehicle Horizontal Center of Gravity

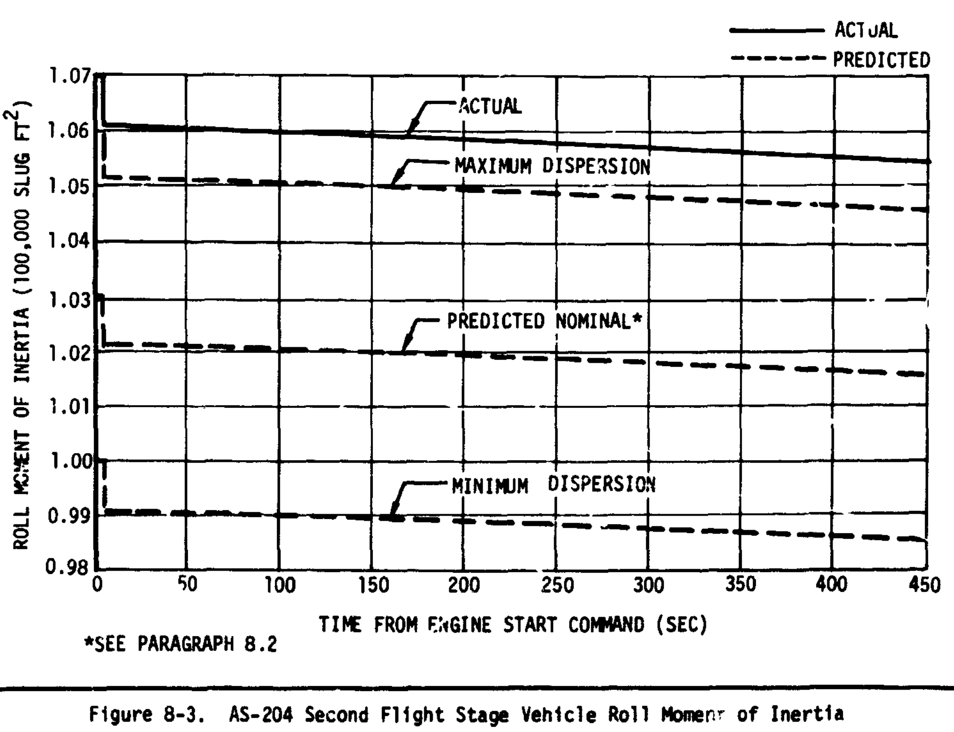


Figure 8-3. AS-204 Second Flight Stage Vehicle Roll Moment of Inertia

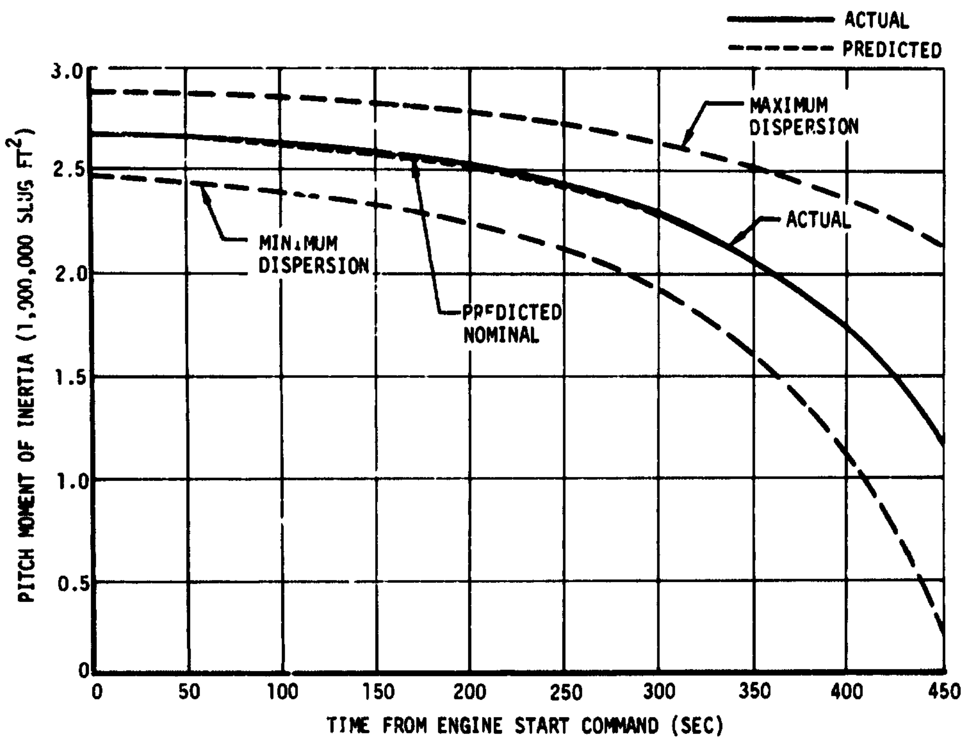


Figure 8-4. AS-204 Second Flight Stage Vehicle Pitch Moment of Inertia

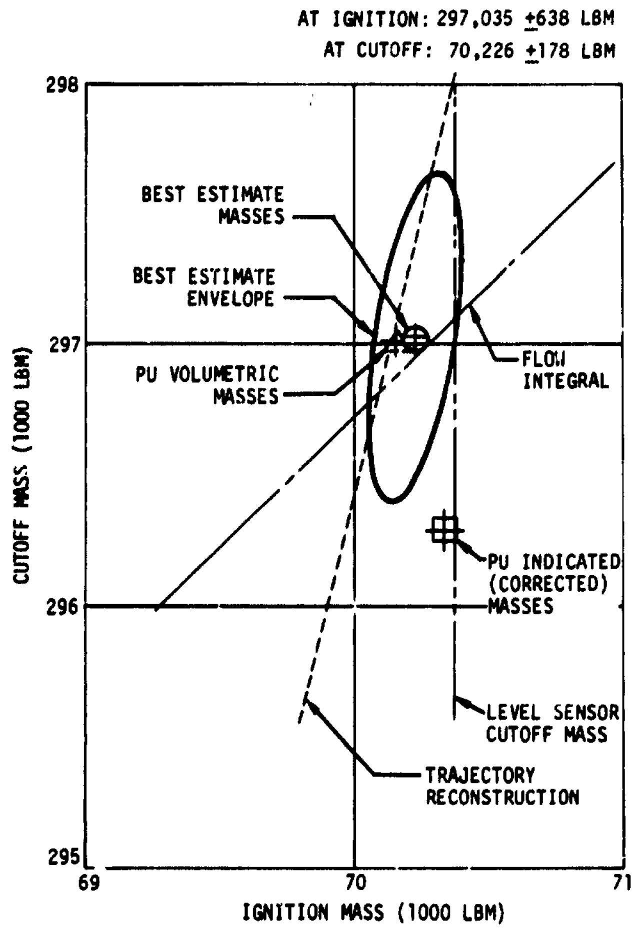


Figure 8-5. AS-204 Second Flight Stage Best Estimate Masses

SECTION 9

ENGINE SYSTEM

9. ENGINE SYSTEM

The main propulsion system of the S-IVB stage of the AS-204 launch vehicle consisted of a 225,000-lbf-thrust Rocketdyne J-2 engine, S/N J-2025, shown schematically in figure 9-1 with the associated propellant ducting and conditioning systems. 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 and were used in the flight prediction.

TAG VALUES

Thrust (F)	223,013 lbf
Engine mixture ratio (EMR)	5.552
Specific impulse (I_{sp})	424.8 sec

ENGINE CONSTANTS

LOX flowmeter	4.9178 cycles/gal.
LH2 flowmeter	1.7382 cycles/gal.
LOX boot strap orifice	0.272 sq in.
LH2 boot strap orifice	0.463 sq in.
LOX turbine bypass nozzle	1.080 sq in.

The engine was equipped with a 0.640-sec start tank discharge valve (STDV) delay timer in the engine control circuit; however, actuation of the STDV, which determines the fuel lead duration, was controlled by a stage timer (ESC +1 sec) through the fuel injection temperature bypass circuit. There were no engine modifications that affected performance, except for the addition of a poppet orifice to the main oxidizer valve (MOV) opening system which provided a more rapid start transient.

Significant engine events during the S-IVB powered flight phase of the AS-204 mission were as follows:

Event	Reference Time (sec)			
	ESC	Range Zero	Prediction	Percent Deviation
Engine Start Command (ESC)	0	144.905	147.1	-2.195
Engine Cutoff Command (ECC)	448.422	593.331	591.508	+1.823

Comparisons are made to the predicted propulsion system performance as published to Marshall Space Flight Center (MSFC) in Douglas letter A3-860-KCBO-4.23.9-L-1729, dated 28 June 1967.

9.1 Engine Chilldown and Conditioning

9.1.1 Engine Turbopump Chilldown

The engine LOX and LH2 turbopumps were adequately chilled, and the temperatures and pressures were within the required band at Engine Start Command (paragraphs 11.4 and 12.2).

9.1.2 Thrust Chamber Chilldown

Thrust chamber chilldown (figure 9-2) was adequate to prevent excessive LH2 pump back pressure, and the LH2 pump performance was satisfactory during the engine start transient with no indication of stall (figure 9-3). Further information on the chilldown operation is presented in table 9-1 and paragraph 5.5.3.1.

9.1.3 Engine Start Sphere Chilldown and Loading

Engine start sphere chilldown and loading met the requirements for engine start (figures 9-4 and 9-5). Further information is presented in section 5.

9.1.4 Engine Control Sphere Chilldown and Loading

Engine control sphere conditioning was adequate, and all objectives were accomplished. Significant control sphere performance data are presented in table 9-2 and figure 9-4.

9.2 Start Sphere Performance

9.2.1 During Engine Operation

The J-2 engine start sphere conditions at S-IVB Engine Start Command of the AS-204 flight were 1,342 psia pressure and 273.5 deg R temperature with a mass of 3.62 lbm (figures 9-4 and 9-6) as compared to predicted values of 1,300 psi pressure, 285 deg R temperature, and 3.47 lbm mass. The deviation produced a negligible effect on the start transient.

Start Tank Discharge Valve (STDV) Command occurred at ESC +1.004 sec, and the pressure decay initiated at ESC +1.195 sec. The blowdown was terminated by the STDV closure at ESC +1.720 sec. Approximately 2.84 lbm of GH2 were discharged during the 0.57 sec blowdown with terminal conditions as shown in figure 9-6. The blowdown was 0.04 sec shorter than the blowdown during the S-IVB first start of the AS-501 mission. The difference was due to rapid response of the STDV and a 0.02 sec reduction in ignition phase control timer duration. Although all individual deviations were within allowable tolerances, reasons for the deviations and the effect of a tolerance stack-up on the start transient are being investigated. As a result of the relatively short blowdown, the terminal conditions differed from the S-IVB-501 conditions as shown in figure 9-6 Although restart was not required, the start sphere was refilled with hydrogen from the fuel injection manifold and pump discharge area at ESC +2 sec when the transient pressure in those regions exceeded the residual pressure in the start sphere. Since there was no planned restart for this mission, the modifications normally made to guarantee restart reliability were not made for S-IVB-204. These modifications include replacing the 0.1 sq in. orifice with a 0.055 sq in. orifice in the refill line from the fuel pump discharge area and a vent and relief valve selected and calibrated to relieve at approximately 1,300 psia. As a result of the larger (0.1 sq in.) refill orifice, the S-IVB-204 start tank refilled faster and colder than S-IVB-501, reaching equilibrium with the fuel injection manifold pressure at ESC +4 sec (figure 9-7), as compared to ESC +10 sec during the S-IVB-501 first burn. Although the initial temperature for refill was higher because of the short blowdown, the S-IVB-204 refill temperature was approximately 8 deg colder than S-IVB-501 (figure 9-6). The topping portion of the refill cycle (characterized by increasing pressure and decreasing temperature was terminated at ESC +45 sec (compared to ESC +74.37 sec for S-IVB-501) when the start tank pressure was in equilibrium (1,185 psia) with the fuel pump discharge pressure (figure 9-7). As can be seen in figure 9-6, there was negligible difference in temperature when the topping process was terminated (the pressure difference was due to pump operating characteristics); therefore, the most noteworthy effect of the enlarged orifice is the quickness of the refill. This information has significant potential in future mission planning.

While a restart was not required, the recharge capability as defined by Rocketdyne was determined. Figure 9-8 shows that the refill was not within the calculated performance region. The effect of this deviation on a planned restart is being studied. At ESC +50 sec, the start tank pressure was within the safe start envelope (above 1,200 psia) at a relatively low temperature (figure 9-6). The pressure continued to increase as heat was absorbed from the walls and surroundings during the remainder of the burn. The effect of the longer duration can be seen by comparing the pressure at engine cutoff for S-IVB-204 and S-IVB-501.

9.2.2 <u>During Orbit</u>

The conditions in the start tank at J-2 engine cutoff during the AS-204 mission were 1,365 psia pressure, 194 deg R temperature, and 5.20 lbm mass. Heat input from the surroundings caused a temperature and corresponding pressure increase; however, as during the S-IVB-203 and S-IVB-501 missions, the measured temperature did not indicate reasonable agreement with perfect gas laws (figure 9-9). The close proximity of the uninsulated start tank temperature transducer to turbine crossover duct exposed the transducer to a high temperature (approximately 1,200 deg R) at Engine Cutoff Command. Comparisons of the start tank and crossover duct temperatures showed that the region of large start tank temperature rise rate corresponded to the region of large crossover duct temperature decay rate. As the crossover duct temperatures stabilized so did the start tank temperature. It was thus concluded that the transducer was measuring very local conditions and was not indicative of hydrogen gas bulk temperature. Perturbations in the g forces on the stage such as induced by venting or propellant dumping, were reflected in the temperature measurement as shown in figure 9-9 thereby indicating the lack of convection induced mixing in the zero g environment. Assuming the pressure measurement to be correct, a bulk temperature was calculated using perfect gas laws. The results are shown in figure 9-9. As indicated in paragraph 9.2.1, the start tank vent and relief valve was not calibrated as it would be for a restartable engine; therefore, the flowrate during relief conditions was unknown and no temperature determinations were made after the estimated time of relief. The relief setting of the valve was high (1,390 psia relief and 1,330 psia reseat at ambient room temperatures, thereby allowing the pressure to exceed the safe start envelope (1,410 psia). No data were available at the time of the relief, but extrapolation of the pressure rise rate to the indicated relief level resulted in an estimated relief at ECC +3,852 sec. The flowrate through the relief valve was sufficient to prevent any significant pressure increase in the duration of recorded data.

9.3 Control Sphere Performance

9.3.1 During Engine Operation

Just prior to J-2 Engine Start Command, the conditions in the engine helium control sphere were 3,044 psia pressure, 278 deg R temperature, and 1.98 lbm mass. At Engine Start Command, the helium control solenoid valve was energized, initiating helium flow through the engine. As predicted, the control sphere pressure decreased 400 psi during the period of high flowrate associated with the 1 sec fuel lead. However, the purge control valve closure did not occur until approximately 0.5 sec later, allowing the pressure to decrease an additional 40 psi. The purge control valve closure delay is normal, but the duration has been non-predictable Rocketdyne has recorded delays as long as 0.7 sec during static tests. The helium consumption was slightly higher than predicted because of the lower refill temperature of the start tank (paragraph 9.2.1). The pressure at Engine Cutoff Command was 1,680 psia as compared to the predicted value of 1,800 psia; and the helium mass remaining was 1.595 lbm, as compared to the predicted value of 1.655 lbm. The helium consumption was 0.465 lbm as compared to the predicted 0.33 lbm. Determination of helium mass when conditions are not static is not precise because the effects of the start tank refill, orbital heating, and helium out-flow on the control sphere temperature measurement. The 1 sec blowdown after cutoff was as predicted. Figure 9-10 shows the control sphere pressure profile and the prediction.

9.3.2 During Orbit

At the conclusion of the 1 sec post cutoff blowdown, the temperature and pressure in the control sphere were 193 deg R and 1,585 psia, respectively. The control sphere temperature transducer sensor is located in a region of high velocity and senses total temperature during rapid blowdowns; therefore, the bulk temperature must be estimated. The transducer is also afflicted with the low g heat transfer problems of the start tank temperature transducer (paragraph 9.2.2), although not as drastically. The pressure data are considered more reliable and figure 9-11 shows the pressure buildup from engine cutoff to the initiation of the propellant dump test due to heat input. The measured temperature data and data calculated using perfect gas laws are also shown. There was no indication of leakage.

9.4 J-2 Engine Performance Analysis Methods and Instrumentation

Engine performance for the powered flight portion of the S-IVB-204 mission was calculated by use of computer programs AA89 and G105-1. The average of the results of the two programs, which is considered to be the best current estimate of engine performance, was calculated by computer program PA49 . Revised tag values based on flight data were generated by computer program G-307 (Rocketdyne PAST 641) and used in AA89. The results of the PA49 program were used in determining the best estimate of stage propellant consumption. Computer program UT23A was used to investigate internal engine performance. Computer program PA53 was used to compute start and cutoff transient performance. A description of the operation and a comparison of the results of each program is presented in table 9-3. Data inputs to the computer programs with the applicable biases are shown in table 9-4.

9.5 J-2 Engine Performance

The S-IVB stage J-2 engine met all objectives during the AS-204 mission. Plots of selected data showing engine characteristics are presented in figure 9-12 through 9-17 for engine mainstage operation. The engine propellant inlet conditions are discussed in sections 10 and 11.

The engine performance level STDV +60 sec as determined by computer program G307 (PAST -641 deck) at standard attitude conditions was as follows:

Parameter	Flight	Stage* Acceptance	Engine Acceptance	Percent Deviation Actual to Pred
Thrust (lbf)	222,000	225,013	224,366	+0.46
EMR	5.536	5.552	5.56	+0.29
Specific impulse (sec)	424.6	424.8	422.8	+0.05

*Used for flight prediction.

A plot of these and other performance values is shown in figure 9-18. All values were within the three sigma run-to-run deviations. The composite values for steady state performance with a comparison to the predicted, as well as the overall, engine average performance from the 90-percent performance level (chamber pressure = 618 psia - including bias - by definition) to Engine Cutoff Command (ECC) are presented in table 9-5. The variation of the site I_{sp} with mixture ratio is shown in figure 9-19. The stage propellant and impulse summary is presented in table 9-5. Deviations in burntimes were due to the longer than predicted operation with the PU valve closed which was a result of loading errors and engine performance variations. All values were within the prediction accuracy of 1 percent.

9.5.1 Start Transient

The J-2 engine performance during the start transient was satisfactory. A summary of engine performance during the start transient is presented in the following table:

Parameter	Flight	Acceptance Test	J-2 Engine Spec Book
Time of STDV Command (sec from ESC)	1.004	0.623	1.0
Time from ESC to 90 percent performance level* (sec)	3.49	3.91	3.36
Thrust rise rate time** (sec)	2.05	2.79	1.91
Total impulse to 90 percent performance level* (lb-sec)	187,751	268,300	168,750***

*Defined as chamber pressure = 618 psia

**Time from initial thrust rise after STDV to 90 percent performance level

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

Engine thrust buildup occurred at a null PU valve position following a 1 sec fuel lead. The fuel lead, PU valve position, and main oxidizer valve operation were satisfactory and a good start was obtained. Thrust buildup to the 90 percent performance level (chamber pressure = 618 psia) was within the maximum and minimum thrust limits shown in figure 9-26

Thrust buildup during flight was faster than during the acceptance test. This was probably largely due to the shorter main oxidizer valve (MOV) first stage plateau time during flight. This resulted in more [illegible] going to the thrust chamber and less going to the gas generator during the early phases of thrust buildup during flight. Also the second stage ramp time was shorter during flight which caused the thrust buildup to be faster during the later phases of the start transient. The total impulse during start (to the 90 percent performance level) was greater than the engine log book value and much less than the acceptance test value. These total impulse values were approximately proportional to the thrust rise times and were the result of the various MOV opening times on the three tests.

The S-IVB-204 flight start transient thrust buildup was very similar to that observed during the S-IVB-501 flight first burn start transient.

9.5.2 Steady-State Operation

The J-2 engine performed satisfactorily during the steady-state portion of engine burn. Figures 9-12 through 9-1, contain plots of selected data used as input values to the engine performance computer programs. Sections 11 and 12 contain a discussion of the engine turbopump inlet conditions; figure 9-21 presents the computed performance parameters. None of the engine instrumentation showed any evidence of any engine performance shifts.

Table 9-5 compares average performance values with predicted performance values during closed PU valve and reference mixture ratio operation. All values were within the 1 percent accuracy of the prediction. Several values in the overall performance column exceeded the prediction due to the 20 sec deviation between actual and predicted cutback time (section 15). Although within the prediction accuracy, the fuel flowrate exhibited a relatively high deviation (0.7 percent) during closed PU valve operation. The deviation was due to the increased fuel pressurization flowrate which increased the fuel tank pressure. The increased pressurization flowrate was caused by an orifice change in the pressurization system prior to flight and its effect was not included in the prediction.

The actual engine performance tag value trends were very close to those predicted based on stage acceptance test (figure 9-45). The major difference was due to a variation in LOX flowrate; however, the effects on overall consumption were compensating.

Engine thrust variations during the flight are presented in table 9-6 and are compared to the predicted values and to Contract End Item (CEI) thrust variation limits. Thrust oscillations between ESC +60 sec and engine cutback, along with oscillations during the final 70 sec of burn, are presented in figure 9-22. Since the cutback time was 325 sec from Engine Start Command, the thrust limits between engine cutback +60 sec and ECC -70 sec cann' be defined. All parameters were within the specified limits for the two given time periods.

During the final 70 sec of burn, which are critical to guidance, the mean thrust slope was -87.4 lbf/sec and the maximum oscillation about this slope was ±1,400 lbf. The maximum rate of change of thrust during the period was -742 lbf/sec.

The maximum rate of change of thrust was predicted to be -175 lbf/sec, primarily a function of the PU system non-linearities and is not comparable to the actual observed rate of -742 lbf/sec which was the result of an unpredicted LOX pressurization cycle which occurred at approximately ESC +420 sec. The comparable actual rate of change of thrust exclusive of the pressurization cycle effects and PU valve c tback effects was -83 lbf/sec.

9.5.3 Cutoff Transients

The J-2 engine performance during the engine cutoff transient was satisfactory. The time lapse between engine cutoff, as received at the J-2 engine, and thrust decrease to 11,250 lbf (5 percent rated thrust was within the maximum allowable time of 800 milliseconds (ms). Engine performance during the cutoff transient is presented in the following table:

Parameter	Flight	Acceptance	J-2 Engine Log Book
Time for thrust decrease to 11,250 lbf (ms)	453	577	371
PU valve position at Engine Cutoff Command (deg)	-11.8	-23.5	0
Thrust at Engine Cutoff Command (lbf)	183,332	174,845	199,261
Actual total impulse (lb-sec)			
To 5 percent thrust	38,538	34,017	--
To zero thrust	45,470	--	--
Total impulse to 5 percent thrust adjusted to null PU valve position (lb-sec)	41,886	38,767	32,456

The thrust decrease time during flight was between the values obtained from the acceptance test and the engine log book and was considered satisfactory. The total impulse to 5 percent thrust during flight was greater than during the acceptance test, partly because of higher thrust at cutoff during flight. Also during flight the main oxidizer valve (MOV) started closing later and slower than during the acceptance test. This was most likely due to a colder MOV actuator temperature during flight. Data from flight, acceptance, and log book tests were adjusted to a common cutoff thrust which would occur with the PU valve in the null position. The difference in MOV actuator temperature could not be accounted for due to lack of instrumentation; however, if the MOV actuator temperature at cutoff on S-IVB-204 flight was approximately the same as at S-IVB-501 first burn cutoff and the S-IVB-204 log book MOV actuator temperature was approximately the same as the values reported in the S-IVB-209 and S-IVB-505N log books, the total impulse values to 5 percent thrust for the flight and log book adjusted to 460 deg R would agree within 1,000 lbf-sec. Therefore, the difference in total impulse after adjusting to a common cutoff thrust are most likely due to the difference in MOV actuator temperature which affected MOV closing times.

The cutoff impulse to zero thrust computed from actual trajectory data was 45,918 lbf-sec which was in reasonably good agreement with the 45,457 lbf-sec predicted trajectory and the 45,470 lbf-sec computed from engine thrust data. Figure 9-23 shows the thrust chamber pressure, the thrust decrease, and total impulse during the cutoff transient. Figure 9-24 compares the predicted velocity gain during the cutoff transient to the actual velocity gain as determined by trajectory analysis and engine analysis.

9.5.4 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 3, Observed Trajectory). 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 slant range distance from the launch site between the observed and simulated trajectories.

To obtain a match of the observed trajectory it was necessary to adjust the levels of thrust and weight flow from those determined by engine analysis. Before thrust cutback the thrust and weight flow determined by engine analysis were increased by 0.15 percent and 0.13 percent, respectively, after cutback the engine analysis thrust and weight flow were decreased by 1.67 percent and 1.27 percent, respectively. The corresponding change in specific impulse over the values determined from engine analysis were a decrease of 0.42 percent at the reference mixture ratio (RMR) and no change at the high EMR.

Histories of simulated thrust and weight flow are presented in figure 7-32. The average values for these parameters are presented in paragraph 7.3.

These results indicate that the thrust and weight flow were very close to predicted during high EMR operation. During RMR operation the thrust was slightly higher than predicted, but the weight flow was 0.74 percent higher than predicted, thus decreasing the specific impulse by 0.65 percent from the predicted value.

9.6 Propellant Dump Test

The propellant dump test and related orbital venting are covered in section 26.

9.7 Component Operation

9.7.1 Main LOX Valve

The main LOX valve opened and closed satisfactorily. The opening time data were as follows:

	Preflight			
	Specification	Checkout	Acceptance	Flight
First stage travel time (ms)	50 ±25	39	49	84*
First stage plateau time (ms)	365 ±75	377	446	407**
Second stage travel time (ms)	1,390 ±40	1,415	1,996	1,926
Total time (ms)	1,805 ±140	1,831	2,491	2,417

*Maximum possible value. Actual value may be slightly less

**Minimum possible value. Actual value may be slightly greater

The flight data were taken from 12 sample per sec data which was the best available, but somewhat affected the accuracy of the reported times. However, with careful interpretation of the data, reasonably good accuracy was obtained. During flight, the first stage plateau time, second stage travel time, and total opening time were less than during the acceptance test. As a result, thrust buildup was faster during flight than during the acceptance test.

The given specification times are for a dry valve at ambient temperature. During the preflight checkout when these same conditions existed, all valve opening times were within specifications, as shown in the preceding table. The opening times were longer during acceptance and flight due to a colder valve actuator temperature when LOX was in the engine.

The main LOX valve closing time during flight was 176 ms compared to 165 ms during the acceptance test. Also the valve started closing 18 ms later (relative to Engine Cutoff Command) during flight. These later and slower valve closing times were most likely due to a colder valve actuator temperature during flight. During preflight checkout (ambient temperature, the valve closing time was 120 ms which was within the specification of 120 ±15 ms.

9.7.2 Pumps and Turbines

The LH2 and LOX pumps and turbines performed satisfactorily throughout the engine firing. The pump speeds and discharge pressures and temperatures responded as expected to PU system cutback and also to engine inlet conditions. The pressure and temperature increases across the pumps were satisfactory. Temperatures and pressures for both turbines responded as expected to PU system cutback. The pressure and temperature drops across the turbines were nominal. The LH2 and LOX pump and turbine data are shown in figures 9-15 and 9-16.

9.7.3 PU Valve

The PU valve performed satisfactorily. At Engine Start Command, the PU valve was at zero deg which was within the required range of 0 ± 2 deg. The PU valve remained in the null position (zero deg) during the start transient until PU activation at ESC +6 sec. At that time the valve started closing, reaching the fully closed position (33.9 deg) at ESC +7.5 sec. The valve remained in the fully closed position (high EMR) until PU valve cutback at ESC +325.1 sec. PU valve cutback occurred slightly later than the predicted time of ESC +305 sec primarily due to the higher than predicted fuel flowrate and slightly higher than predicted initial LOX load. After cutback the valve opened to approximately -11.5 deg, where it remained until engine cutoff. After cutoff, the PU valve started closing to the null position, but did not reach null due to deactivation of the PU system. PU valve response to PU system commands is further discussed in section 11. Plots of PU valve performance are shown in figure 9-14.

9.7.4 Gas Generator

The gas generator (GG) performance was adequate. The GG chamber pressure and LH2 turbine inlet temperature indicated nominal values before and after EMR cutback. The GG flowrates and mixture ratio were nominal, and sufficient energy was delivered to the turbines to assure satisfactory operation. Plots of GG performance are shown in figure 9-25.

9.7.5 Engine Driven Hydraulic Pump

The engine driven hydraulic pump performed satisfactorily during engine burn. The average power required by the pump was 5 horsepower.

9.8 Engine Sequence

The engine start and cutoff sequences were satisfactory and were compatible with the engine logic and flight test plan. Table 9-7 shows the times of the significant flight events compared to the nominal times. Figure 9-26 shows the engine power rise as controlled by the sequence of events. Some inconsistencies are necessarily introduced into the sequencing because different sources of data must be used to obtain sequence times. Valve opening or closing can be obtained from either microswitches or potentiometer positions. In all cases, valve opening or closing times were obtained from one source or the other, but not a combination of the two, in order to eliminate as many inconsistencies as possible.

The start sequence of events for S-IVB-204 appears to be better than for any previous S-IVB stage flown. Almost all of the events occur very near the nominal times and in the correct order. The main fuel valve opening time and the GG opening time appear to be slightly longer than nominal, and as has been observed on all previous S-IVB flights, the main LOX valve opening time was longer than the nominal which was based on actual ambient condition. All other events were very near nominal.

All engine cutoff events except main fuel valve open dropout occurred very near nominal time. The main fuel valve open dropout appears to have been late. Some doubt about the validity of the main fuel valve opening and closing times exists because it was necessary to obtain the timing for the fuel valve from microswitch data instead of potentiometer position plots.

TABLE 9-1
THRUST CHAMBER CHILLDOWN

PARAMETER	S-IVB-204	S-IVB-203	S-IVB-202
Engine start requirement (deg R)	260 ±50	260 ±50	260 ±50
Thrust chamber chilldown initiated (sec from liftoff)	-900	-900	-900
Thrust chamber chilldown terminated (sec from liftoff)	0	0	0
Thrust chamber skin temperature at end of chilldown (deg R)	238	227	212
Thrust chamber temperature at engine start (deg R)	255	255	240

TABLE 9-2
ENGINE CONTROL SPHERE PERFORMANCE

PARAMETER	TEMPERATURE (deg R)			PRESSURE (psia)			MASS (lbm)		
	S-IVB-204	S-IVB-203	S-IVB-202	S-IVB-204	S-IVB-203	S-IVB-202	S-IVB-204	S-IVB-203	S-IVB-202
Engine start requirement	290 ±30			2,800 to 3,450			-	-	-
At liftoff	278	275	284	3,029	3,320	2,950	1.98	2.16	1.90
At Engine Start Command	278	278	284	3,044	3,335	2,982	1.98	2.15	1.90
ECC +1 sec	193	193	250	1,585	1,960	1,990	1.55	1.87	1.47
Total helium usage during burn	-	-	-	-	-	-	0.43	0.28	0.43

TABLE 9-3
COMPARISON OF COMPUTER PROGRAM RESULTS

PROGRAM	INPUT	METHOD	RESULTS AT ESC +60 sec
AA89	LOX and LH2 pump inlet pressures and temperature, PU valve position, and engine tag values	Influence equations relate nominal inlet conditions to nominal performance. Using actual inlet conditions, PU valve position and engine tag values, the actual performance is simulated.	F = 224,339 lbf $\dot{W}_T$ = 528.57 lbm/sec I_{sp} = 424.4 sec MR = 5.56
G105 Mode 3	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 = 224,280 lbf $\dot{W}_T$ = 527.27 lbm/sec I_{sp} = 425.4 sec MR = 5.52
PA49	AA89 and G105 outputs	Averaging	F = 224,310 lbf $\dot{W}_T$ = 527.92 lbm/sec I_{sp} = 424.9 sec MR = 5.5
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 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 = 224,384 lbf $\dot{W}_T$ = 528.54 lbm/sec I_{sp} = 424.5 sec MR = 5.53
UT23A	All measured engine data	Calculates turbopump and feed system performance using classical methods.	Does not calculate engine output performance
PA57	Thrust chamber pressure, chamber throat area	The C_T is computed from equation $C_F = f\ (P_c)$ and thrust is computed from computed from equation $F = C_F\ A_t\ P_c$. The impulse is determined from integrated thrust.	Refer to paragraphs 9.5.1 and 9.5.3.

F = Thrust, W_T = Total weight flowrate, I_{sp} = Specific impulse, MR = Engine mixture ratio

TABLE 9-4 (Sheet 1 of 2)
DATA INPUTS TO COMPUTER PROGRAMS

PARAMETER	PROGRAM	SELECTION	BIAS	REASON
Chamber pressure	G105-1	D0001 (TM/FM)	-25.43 psi	-15 psi Rocketdyne estimation of P_c purge effect
				-10.43 psi Douglas estimation of data shift
	PA53 (Start)	D0001 (TM/FM)	98.9 percent	Agree with bias of steady-state programs at ESC +60 sec
			-16.68 psi	Data zero shift at engine start
	(Cutoff)		98.3 percent	Agree with bias of steady-state programs at Engine Cutoff Command
			-14.59 psi	Post-test data zero shift
LH2 pump disch press	G105-1	D0008 (TM/PCM)	0 percent	
LH2 pump disch temp	G105-1	C0134 (TM/PCM)	0 percent	
LOX pump disch press	G105-1	D0009 (TM/PCM)	0 percent	
LOX pump disch temp	G105-1	C0133 (TM/PCM)	0 percent	
LH2 flowrate	G105-1	F0002 (TM/FM)	0 percent	

TM = telemetry
FM = frequency modulated
PCM - pulse code modulated

TABLE 9-4 (Sheet 2 of 2)
DATA INPUTS TO COMPUTER PROGRAMS

PARAMETER	PROGRAM	SELECTION	BIAS	REASON
LOX flowrate	G105-1	F0001 (TM/FM)	100.113 percent	Adjust generated flowrate to agree with actual pip count
LH2 pump inlet press	AA89	D0002 (TM/PCM)	+1.3 psi	Dynamic heat adjustment
LH2 pump inlet temp	AA89	C0003 (TM/PCM)	0 percent	
LOX pump inlet press	AA89	D0003 (TM/PCM)	+2.6 psi	Dynamic heat adjustment
LOX pump inlet temp	AA89	C0004 (TM/PCM)	0 percent	
PU valve position	AA89	G0010 (TM/PCM)	0 percent	

TM = telemetry
FM = frequency modulated
PCM = pulse code modulated

TABLE 9-5
ENGINE PERFORMANCE

PARAMETER	CLOSED PU VALVE OPERATION			REFERENCE MIXTURE RATIO OPERATION			OVERALL PERFORMANCE- 90 PERCENT THRUST TO ECC		
	ACTUAL	PREDICTED	PERCENT DEVIATION	ACTUAL	PREDICTED	PERCENT DEVIATION	ACTUAL	PREDICTED	PERCENT DEVIATION
Thrust (lbf)	223,900	223,811	+0.04	184,7[illegible]	184,752	-0.01	215,893	213,692	+1.[illegible]
Total flowrate (lbm/sec)	526.98	525.66	+0.3	430.67	429.70	+0.23	507.42	500.81	+1.3
LOX flowrate (lbm/sec)	446.10	445.34	+0.2	355.66	354.45	+0.341	427.80	421.84	+1.4
LH2 flowrate (lbm/sec)	80.87	80.32	+0.7	75.01	75.24	-0.31	79.62	78.97	+0.8
Engine mixture ratio	5.516	5.544	-0.5	4.741	4.711	+0.64	5.364	5.332	+0.6
Specific impulse (sec)	424.87	425.77	-0.2	428.92	429.96	-0.2	425.60	426.83	-0.3

PARAMETER	MAINSTAGE*			TO DEPLETION**		
	ACTUAL	PREDICTED	PERCENT DEVIATION	ACTUAL	PREDICTED	PERCENT DEVIATION
Burntime	444.938	450.068	1.14	455.912	461.389	1.19
Consumption						
LOX (lbm)	190,344	189,485	0.45	193,311	192,544	0.39
LH2 (lbm)	35,428	35,517	0.25	36,102	36,208	0.29
Impulse (lbf-sec)	96.06×10^6	96.18×10^6	0.12	97.62×10^6	97.[illegible]2 X 10^6	0

*Mainstage is time from 90 percent thrust to cutoff.

**Depletion is time from Engine Start Command to LOX load = 516 lbm.

TABLE 9-6
ENGINE THRUST VARIATIONS

TIME PERIOD / PARAMETER	LIMITS	HARDOVER OPERATION	FINAL 70 sec OF S-IVB BURN
Variation in mean thrust level hardover or thrust band centerline variation at ECC -70 sec (lbf)	Allowable	±5,000	+40,000 to -5,500
	Actual	+600	+[illegible],580
Oscillations about mean thrust level or thrust variation band (lbf)	Allowable	±2,500	±10,000
	Actual	±1,200	±1,400
	Predicted	±1,100	±625
Rate of change of thrust (lbf/sec) all frequencies	Allowable	±500	+500, -2,000
	Actual	±152	-742
	Predicted	±100	-175
Rate of change of thrust (lbf/sec) 0 -0.1 cps	Allowable	--	+500, -1,800
	Actual	--	-83
	Predicted	--	-175
Thrust acceleration (lbf/sec/sec) all frequencies	Allowable	±125	+350, -500
	Actual	+18	+349
Thrust acceleration (lbf/sec/sec) 0 -0.1 cps	Allowable	--	+125, -300
	Actual	--	-4
Thrust band slope (lbf/sec)	Allowable	--	+58, -700
	Actual	--	-87.4
	Predicted	--	-72.3
Variation of thrust band slope (lbf/sec)	Allowable	--	+30, -660
	Actual		+15.1

TABLE 9-7 (Sheet 1 of 4)
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 SPEC REF
K0021	*Engine Start Command P/U			0	0	0
		K0007	Helium Control Solenoid Enrg P/U	Within 10 ms of K0021	0	0
		K0010	Thrust Chamber Spark On P/U	Within 10 ms of K0021	003	003
		K0011	Gas Generator Spark On P/U	Within 10 ms of K0021	003	003
		K0006	Ignition Phase Control Solenoid Enrg P/U	Within 20 ms of K0021	014	014
		K0126	LOX Bleed Valve Closed P/U	Within 130 ms of K0007	095	095
		K0127	LH2 Bleed Valve Closed P/U	Within 130 ms of K0007	095	095
		K0020	ASI LOX Valve Open P/U	Within 20 ms of K0006	081	081
		K0119	Main Fuel Valve Closed D/O	60 ±30 ms from K0006	052	038
		K0118	Main Fuel Valve Open P/U	80 ±50 ms from K0119	243	191
K0021	**Engine Start Command D/O			Approx 200 ms from K0021 P/U	498	498
K0096	***Start Tank Disc Control Solenoid Enrg			1,000 ±40 ms from K0021	1,004	1,004

P/U Pickup
D/O Dropout

*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 N010 (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.

TABLE 9-7 (Sheet 2 of 4)
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 SPEC REF
		K0123	Start Tank Disc Valve Closed D/O	100 $\pm$20 ms from K0096	1,155	151
		K0122	Start Tank Disc Valve Open P/U	105 $\pm$20 ms from K0123	1,243	088
K0005	Mainstage Control Solenoid Enrg			450 $\pm$30 ms from K0096	1,437	433
		K0096	Start Tank Disc Control Solenoid Enrg D/O	450 $\pm$30 ms from K0096	1,445	441
		K0121	Main LOX Valve Closed D/O	50 $\pm$20 ms from K0005	1,467	030
		K0116	Gas Generator Valve Closed D/O	140 $\pm$10 ms from K0005	1,481	044
		K0122	Start Tank Disc Valve Open D/O	95 $\pm$20 ms from K0096	1,518	073
		K0117	Gas Generator Valve Open P/U	50 $\pm$30 ms from K0116	1,746	265
		K0124	LOX Turbine Bypass Valve Open D/O		1,597	-
			LOX Turbine Bypass Valve 80 Percent Closed	400 +150, -50 ms from K0122	1,856	338
		K0123	Start Tank Disc Valve Closed P/U	250 $\pm$40 ms from K0122	1,720	202

P/U Pickup
D/O Dropout

TABLE 9-7 (Sheet 3 of 4)
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 SPEC REF
		K0125	*LOX Turbine Bypass Valve Closed P/U		1,929	-
K0158	Mainstage Press Switch No. 1 Depress D/O				2,774	-
K0159	Mainstage Press Switch No. 2 Depress D/O				2,782	-
		K0120	Main LOX Valve Open P/U	1,955 ±160 ms from K0005	3,884	2,447
		K0010	Thrust Chamber Spark On D/O	3,300 ±200 ms from K0005 P/U	4,712	3,275
		K0011	Gas Generator Spark On D/O	3,300 ±200 ms from K0005 P/U	4,712	3,275
K0013	Engine Cutoff PU (New time reference)			0	0	0
		K0005	Mainstage Control Solenoid Enrg D/O	Within 10 ms of K0013	007	007
		K0006	Ignition Phase Control Solenoid Enrg D/O	Within 10 ms of K0013	010	010
		K0020	ASI LOX Valve Open D/O		086	-
		K0120	Main Oxidizer Valve Open D/O	50 ±15 ms from K0005	096	089
		K0117	Gas Generator Valve Open D/O	75 +25, -35 ms from K0006	096	086

P/U Pickup
D/O Dropout
*Within 5,000 ms of K0005 (Normally = 500 ms)

TABLE 9-7 (Sheet 4 of 4)
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 SPEC REF
		K0118	Main Fuel Valve Open D/O	90 $\pm$25 ms from K0006	171	161
		K0121	Main Oxidizer Valve Closed P/U	120 $\pm$15 ms from K0120	205	109
		K0116	Gas Generator Valve Closed P/U	500 ms from K0006	154	144
		K0119	Main Fuel Valve Closed P/U	225 $\pm$25 ms from K0118	421	250
K0158	*Mainstage Press Switch A Depress P/U				189	
K0159	Mainstage Press Switch B Depress P/U			*	189	
K0007	Helium Control Solenoid Enrg D/O			1,000 $\pm$110 ms from K0013	975	975
		K0125	Oxidizer Turbine Bypass Valve Closed D/O		289	-
		K0124	Oxidizer Turbine Bypass Valve Open P/U	10,000 ms from K0005	837	830
K0126	LOX Bleed Valve Closed D/O			30,000 ms from K0005	4,176	4,169
K0127	LH2 Bleed Valve Closed D/O			30,000 ms from K0005	4,176	4,169

P/U Pickup
D/O Dropout
*Signal drops out when pressure reaches 425 $\pm$25 psig.

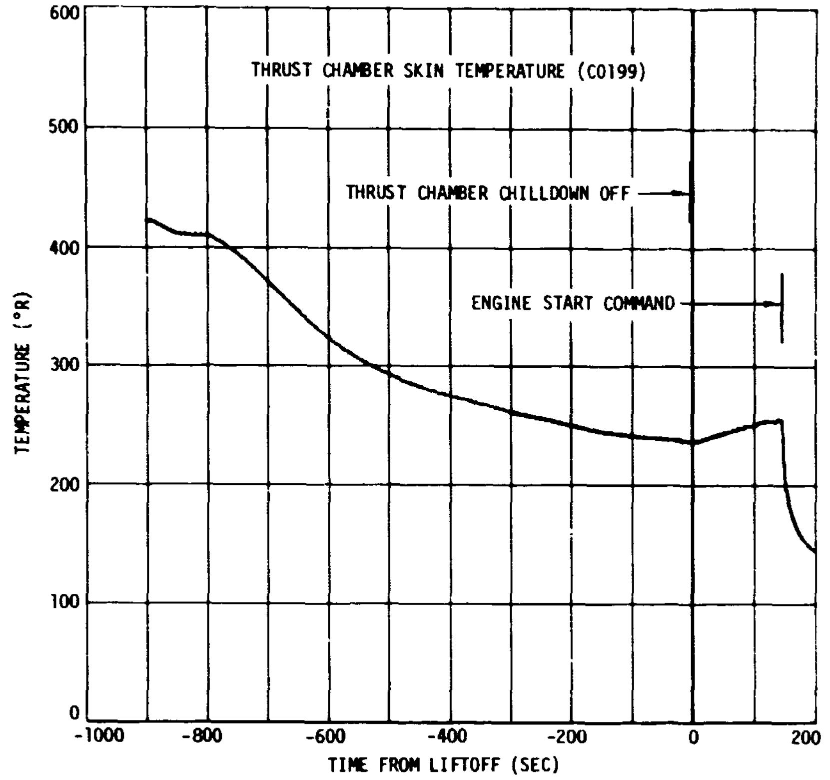


Figure 9-2. Thrust Chamber Childown

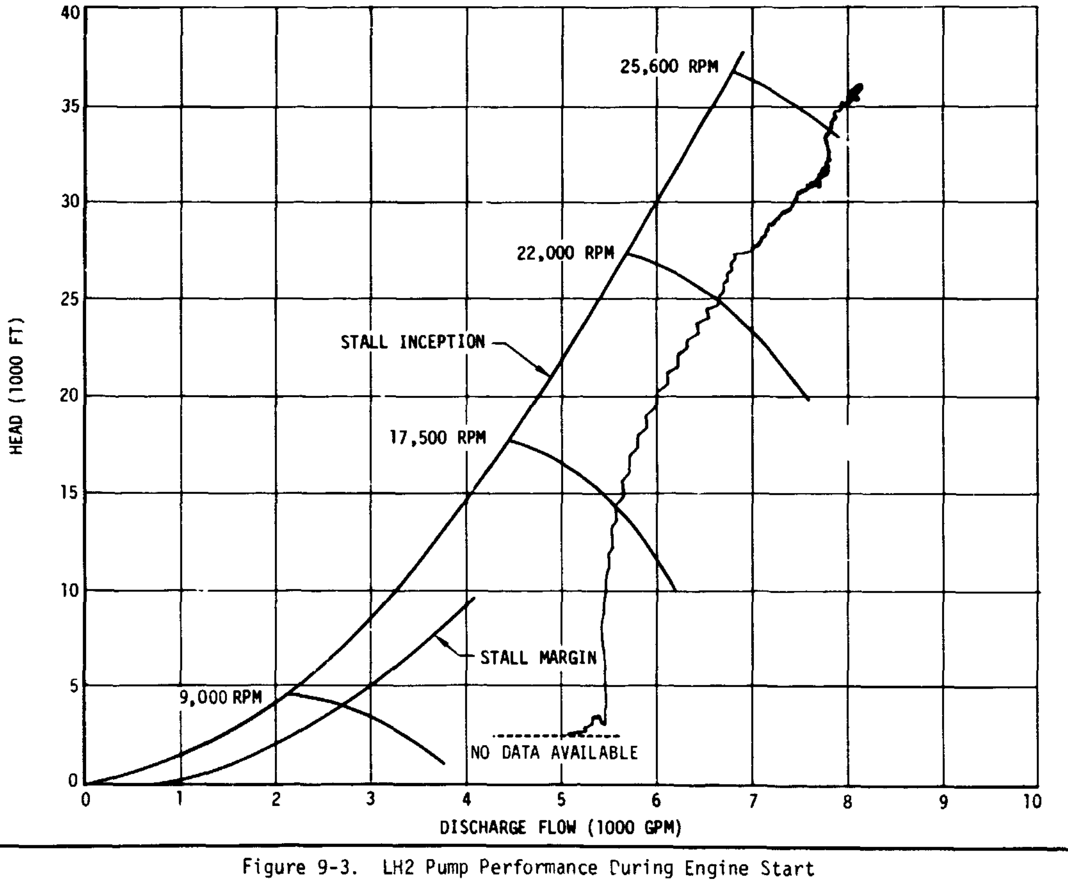


Figure 9-3. LH2 Pump Performance During Engine Start

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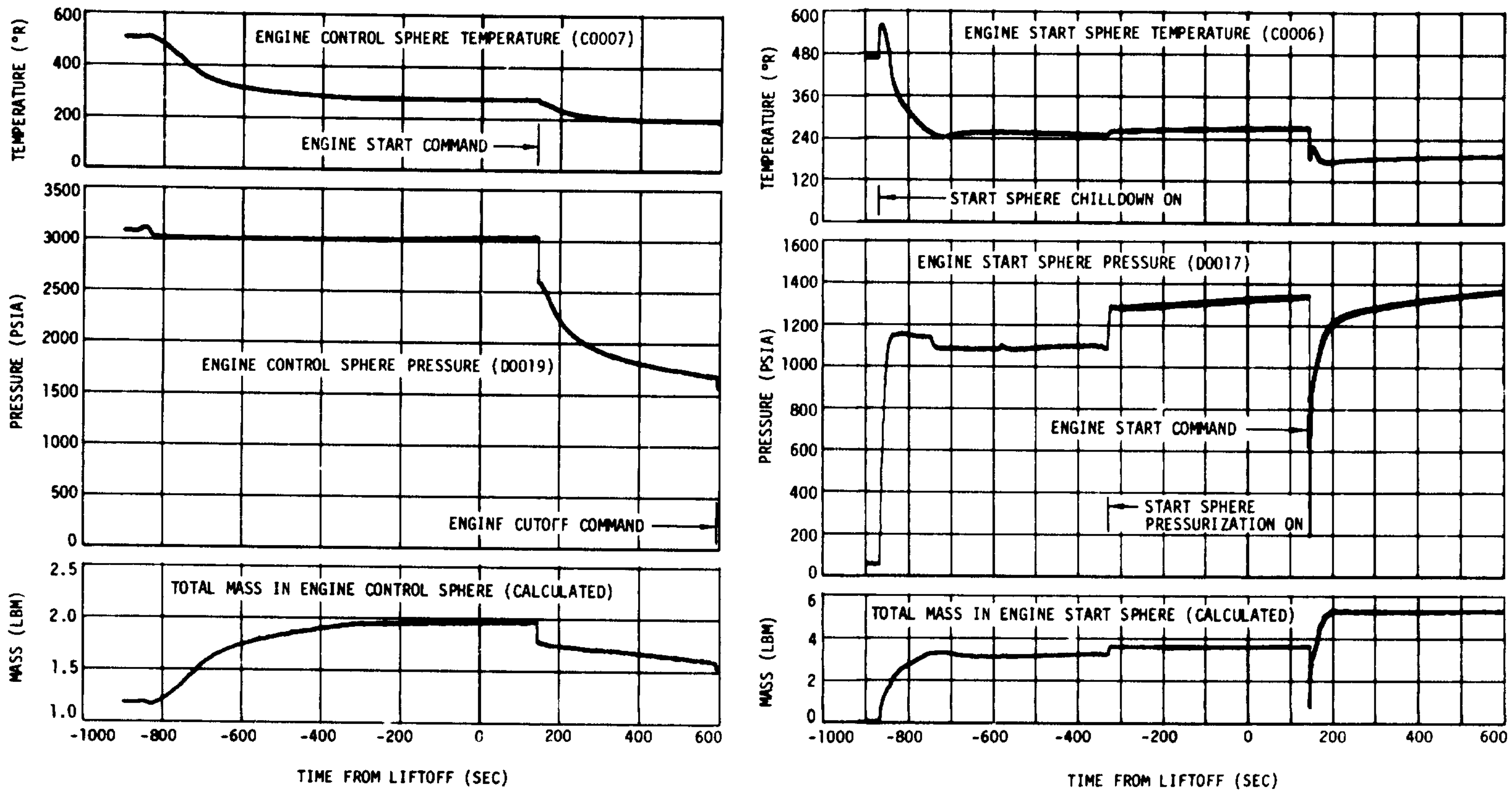


Figure 9-4. Engine Start and Control Sphere Performance

PARAMETER	TEMPERATURE (°R)			PRESSURE (PSIA)			MASS (LBM)		
	202 FLT	203 FLT	204 FLT	202 FLT	203 FLT	204 FLT	202 FLT	203 FLT	204 FLT
LIFTOFF	290	278	272	1275	1300	1323	3.26	3.48	3.62
LIFTOFF REQUIREMENT	SEE	LIFTOFF	BOX	SEE	LIFTOFF	BOX	SEE	LIFTOFF	BOX
AT ENGINE START COMMAND	286	278	274	1269	1307	1342	3.26	3.48	3.62
AFTER START SPHERE BLOWDOWN	210	210	197	160	160	200	0.75	0.54	0.78
AT ENGINE CUTOFF COMMAND	275	215	194	265	1150	1365	0.80	4.51	5.20
TOTAL GH2 USAGE DURING START	—	—	—	—	—	—	2.51	2.94	2.84

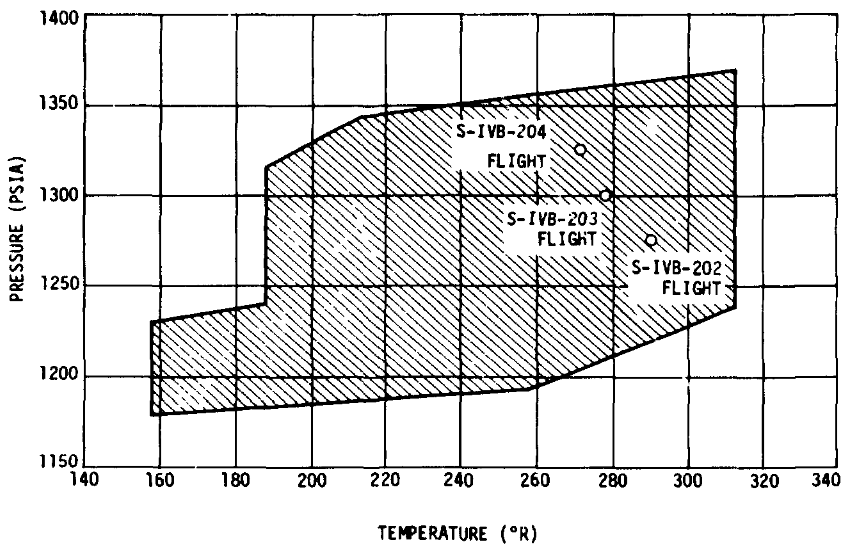


Figure 9-5. GH2 Start Sphere Critical Limits at Liftoff

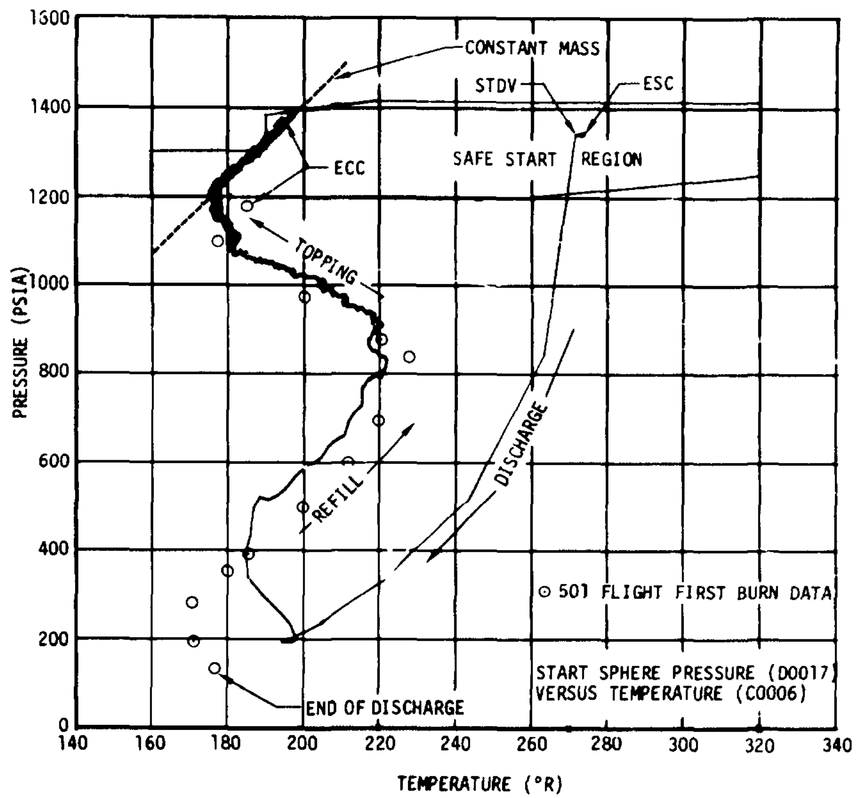


Figure 9-6. Engine Start Sphere Discharge and Refill Performance

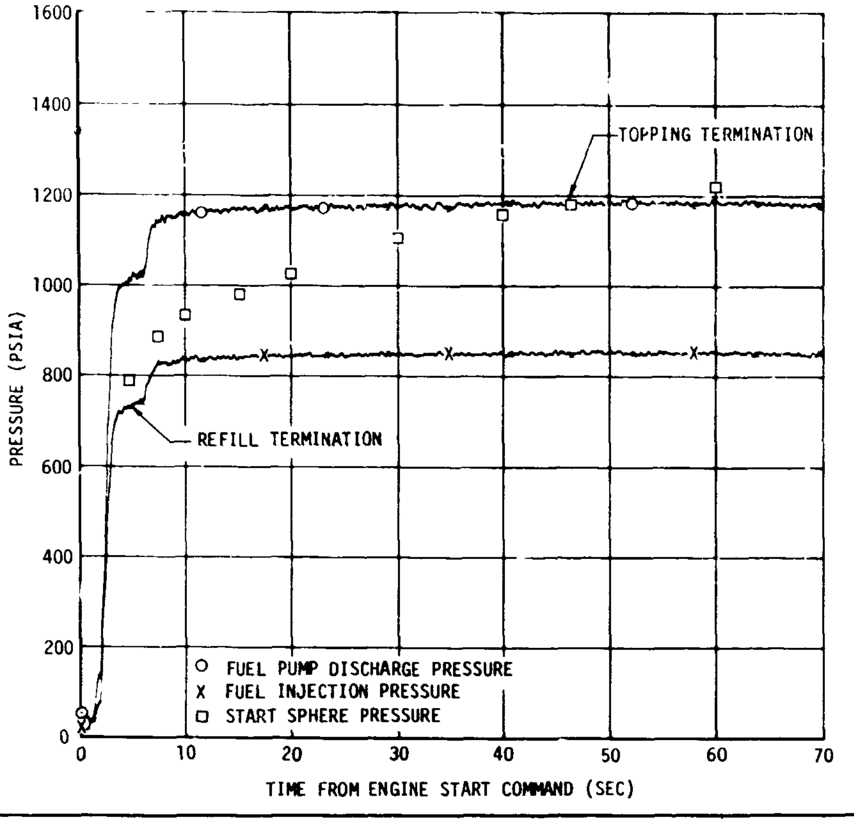


Figure 9-7. Start Sphere Refill

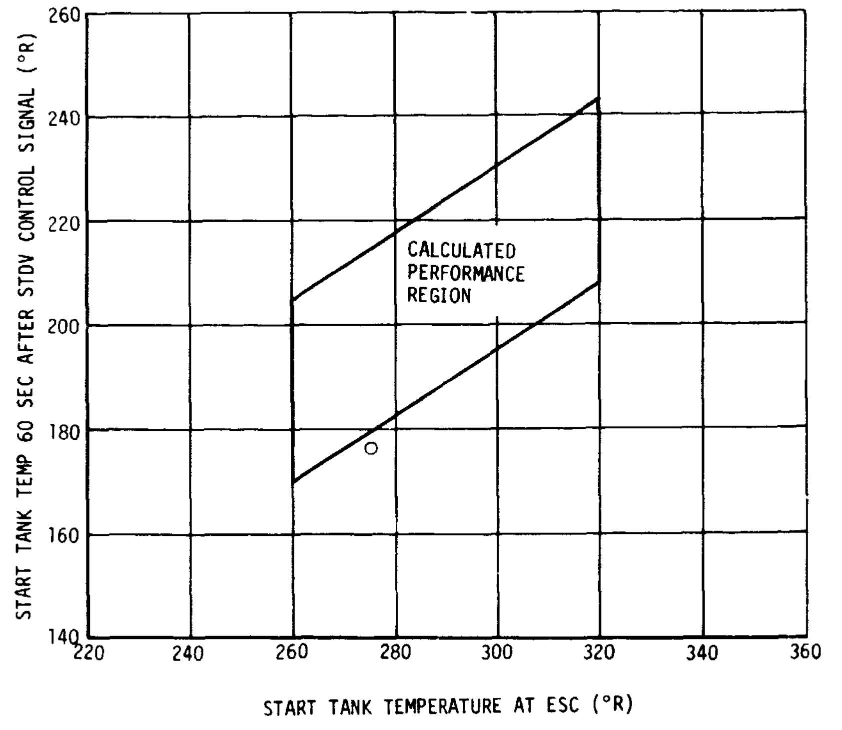


Figure 9-8. S-IVB-204 Start Tank Restart Capability

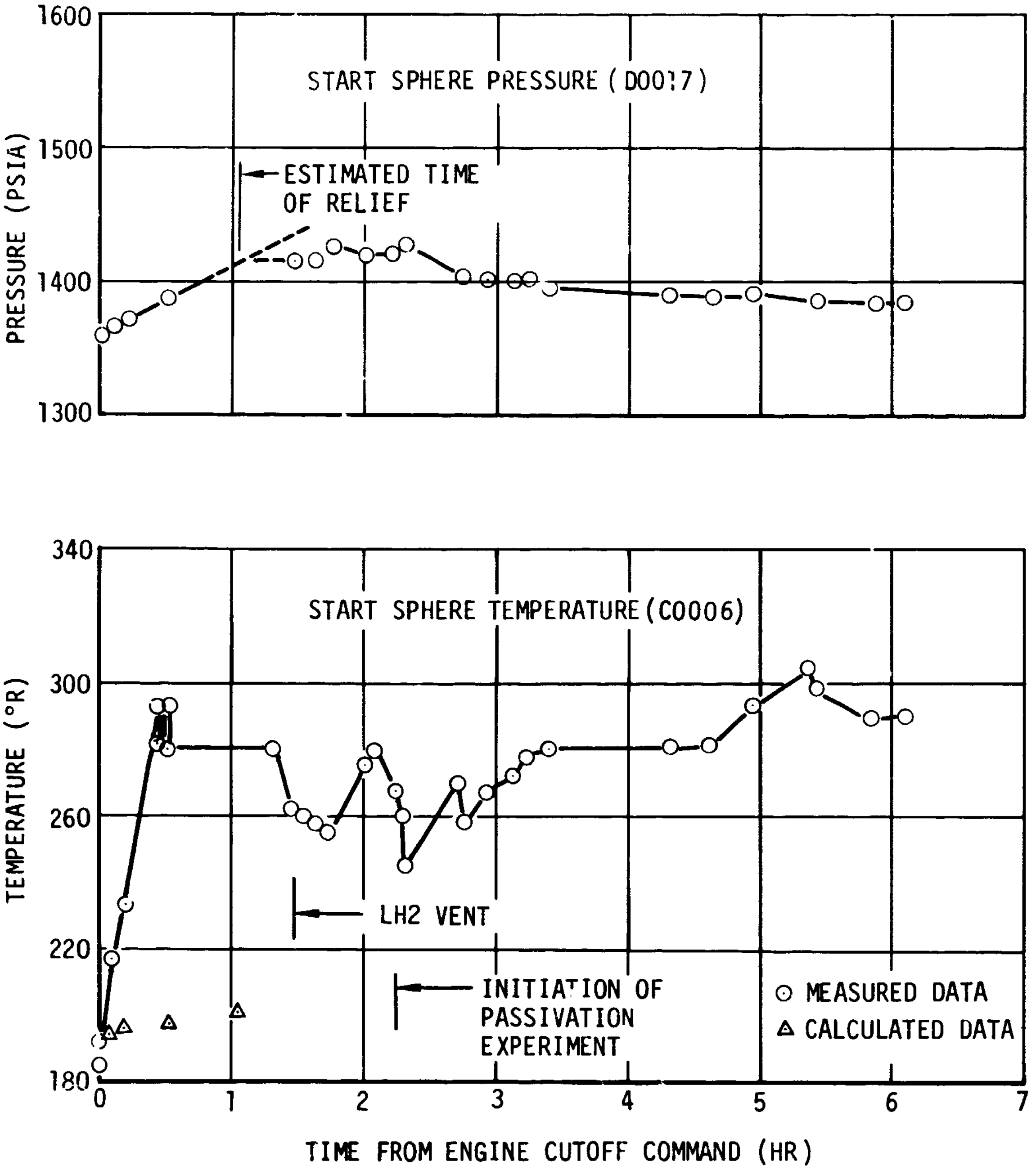


Figure 9-9. Start Sphere Orbital Conditions

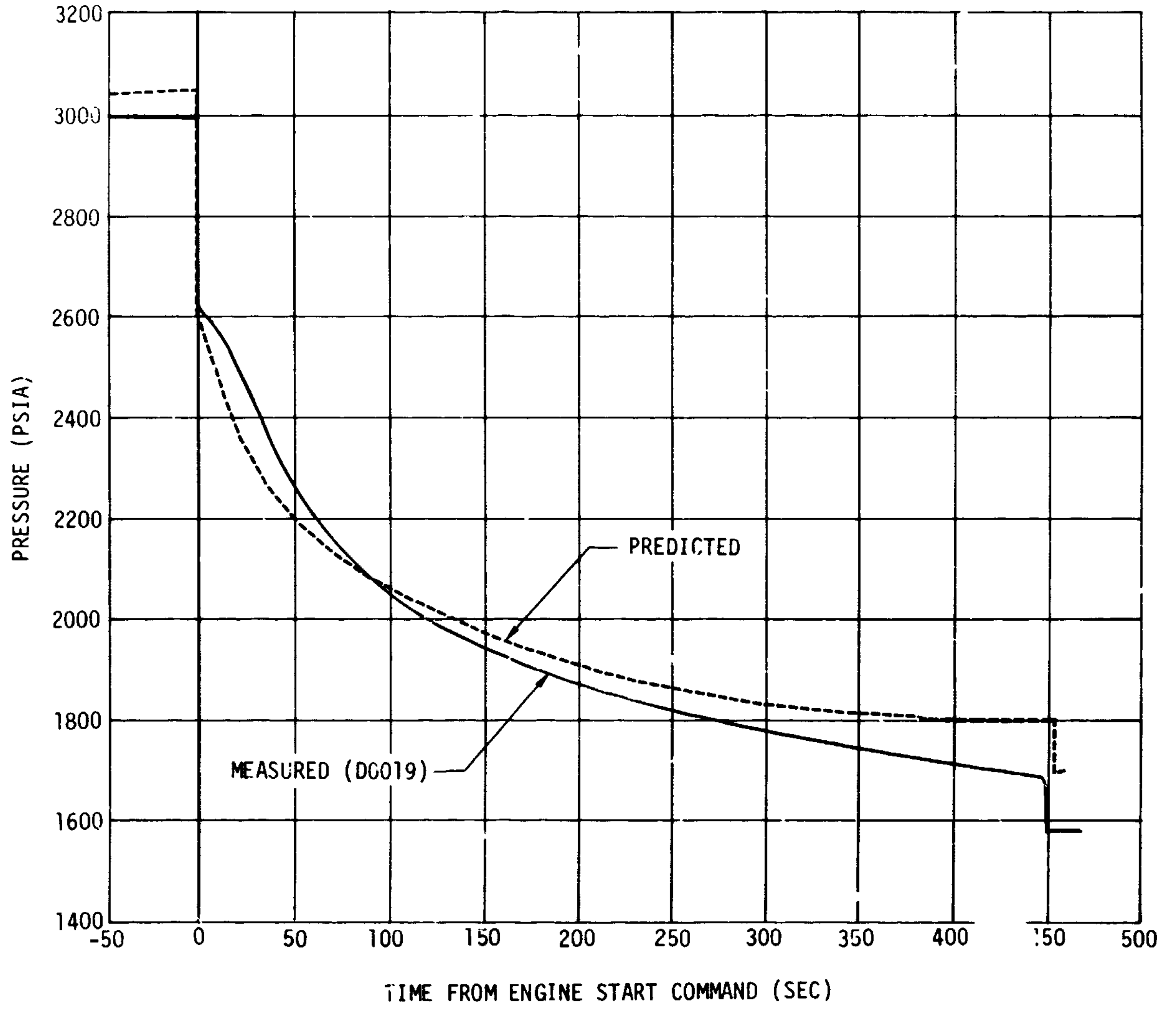


Figure 9-10. Engine Control Sphere Performance

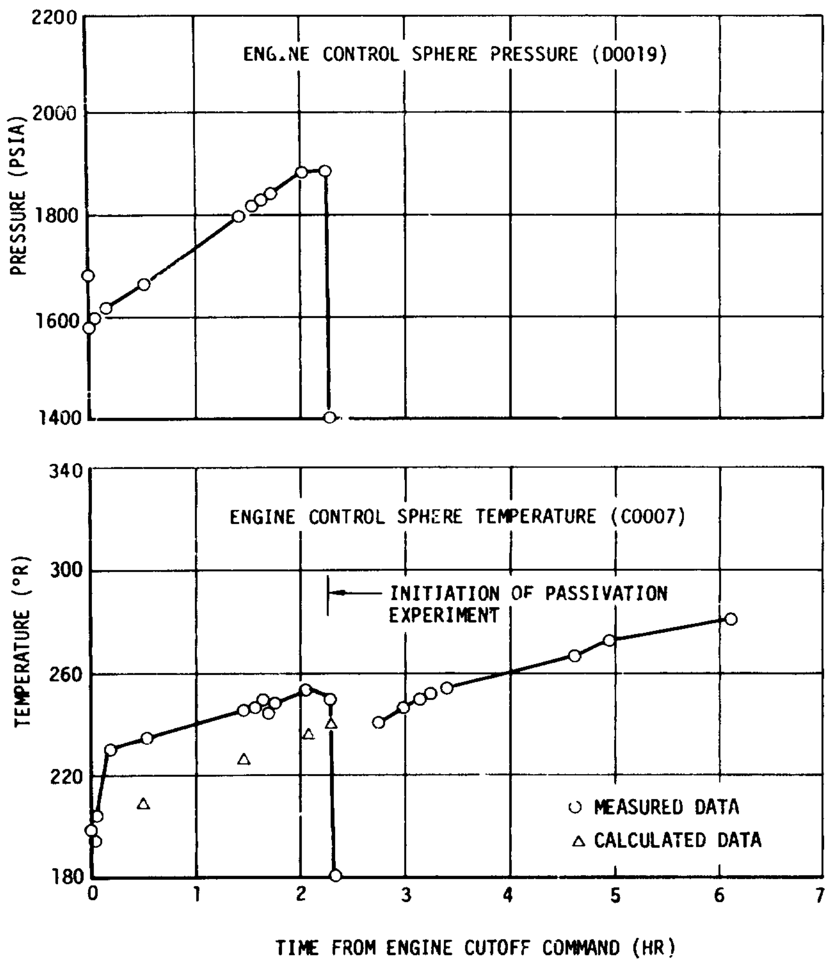


Figure 9-11. Control Sphere Orbital Conditions

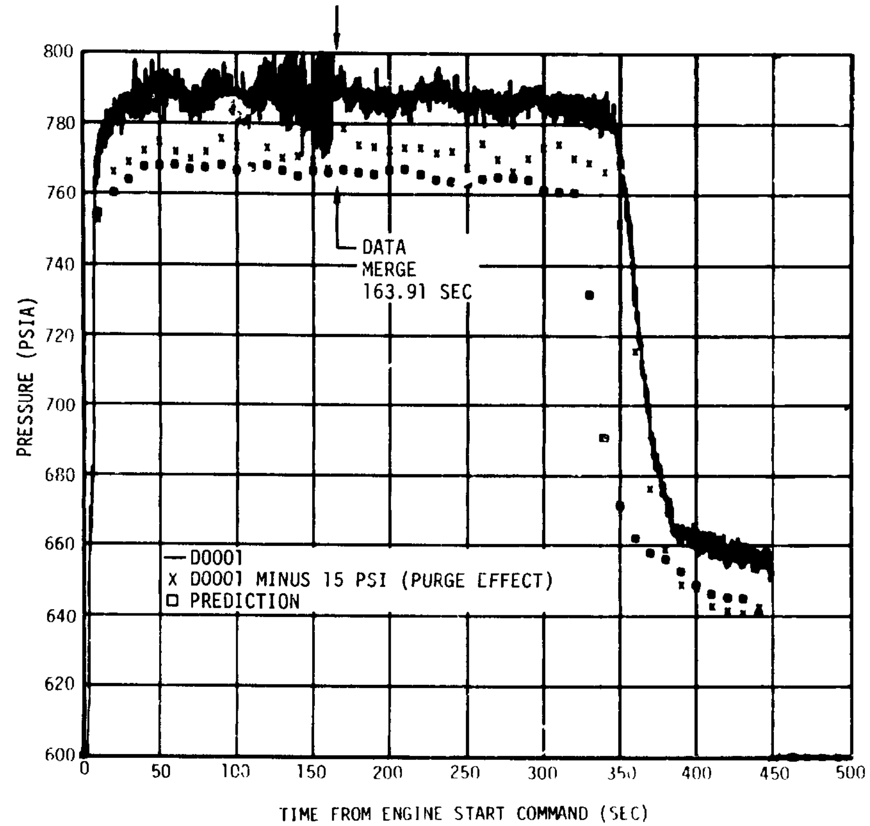


Figure 9-12. J-2 Engine Chamber Pressure

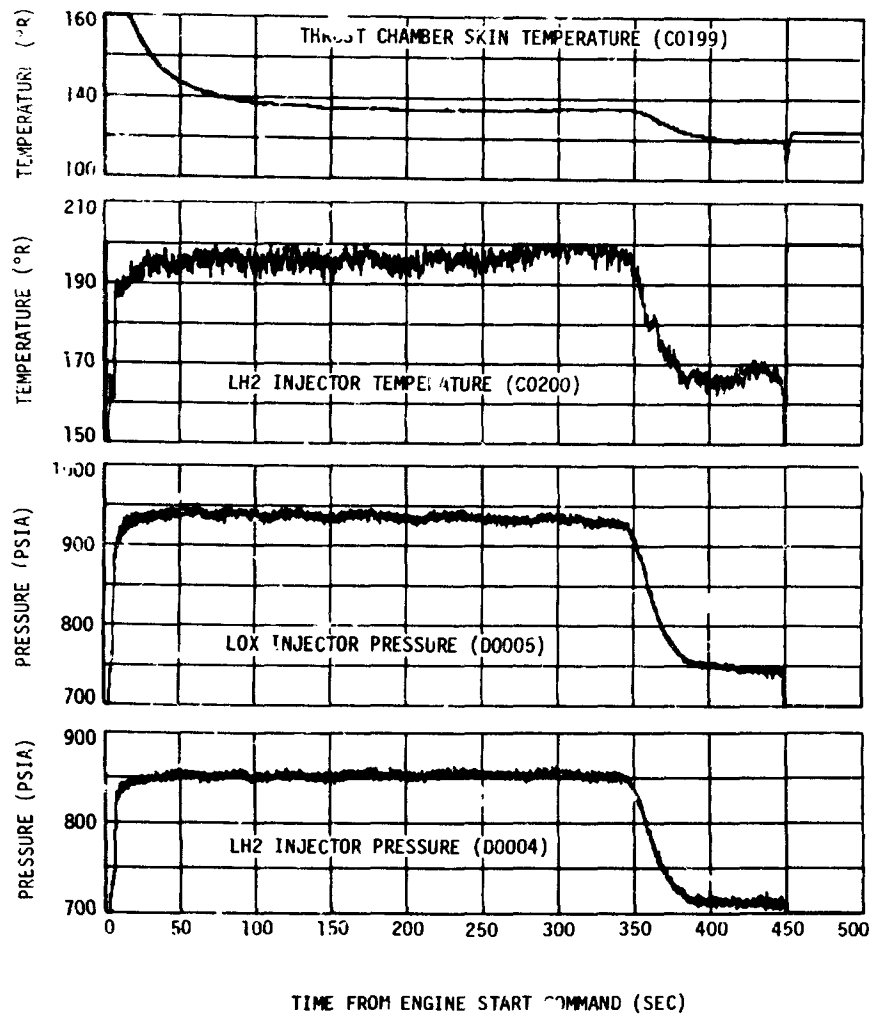


Figure 9-13. J-2 Engine Injector Supply Conditions

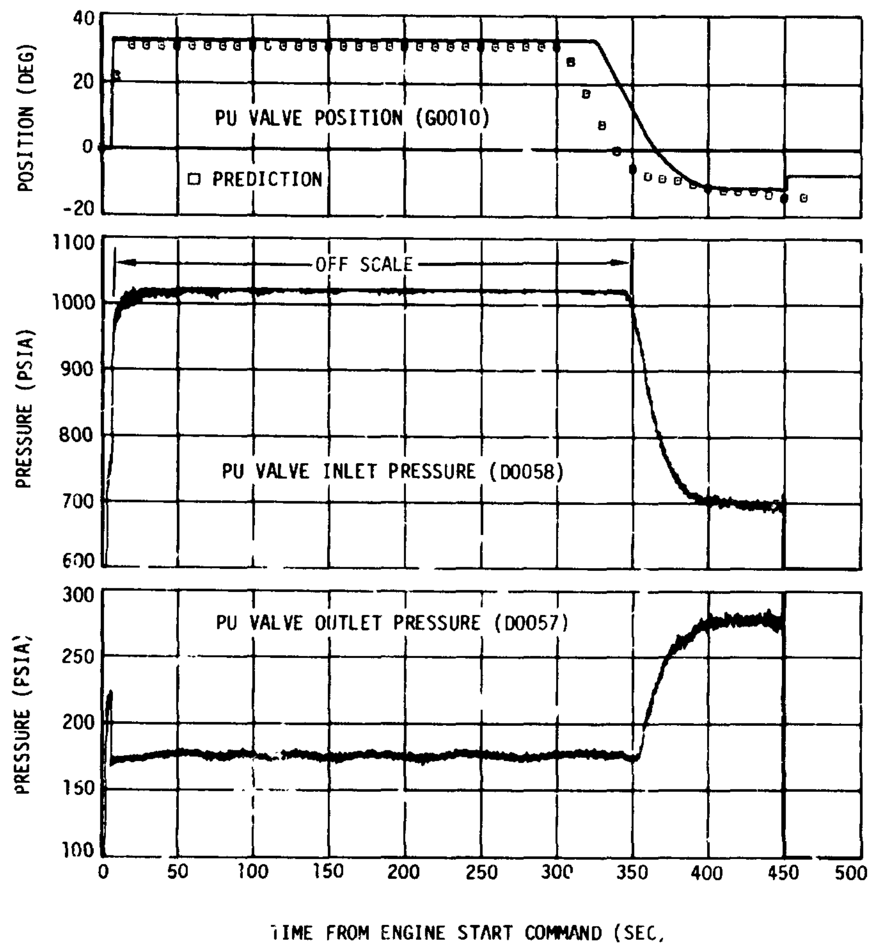


Figure 9-14. PU Valve Operation

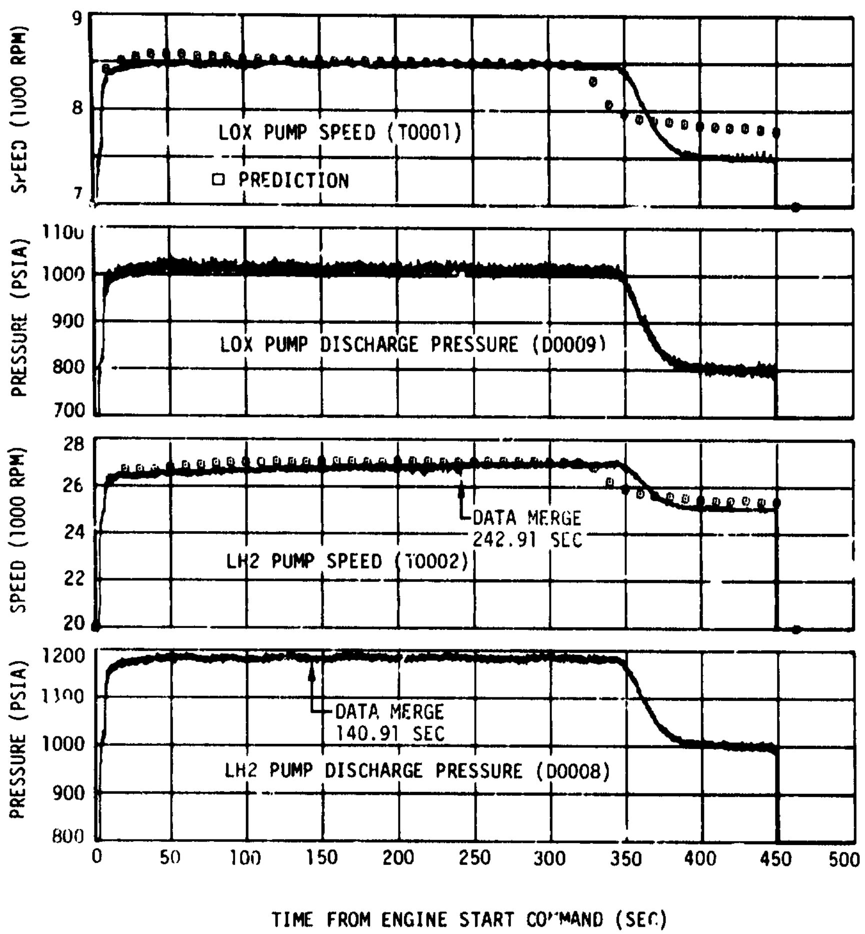


Figure 9-15. J-2 Engine Pump Operating Conditions

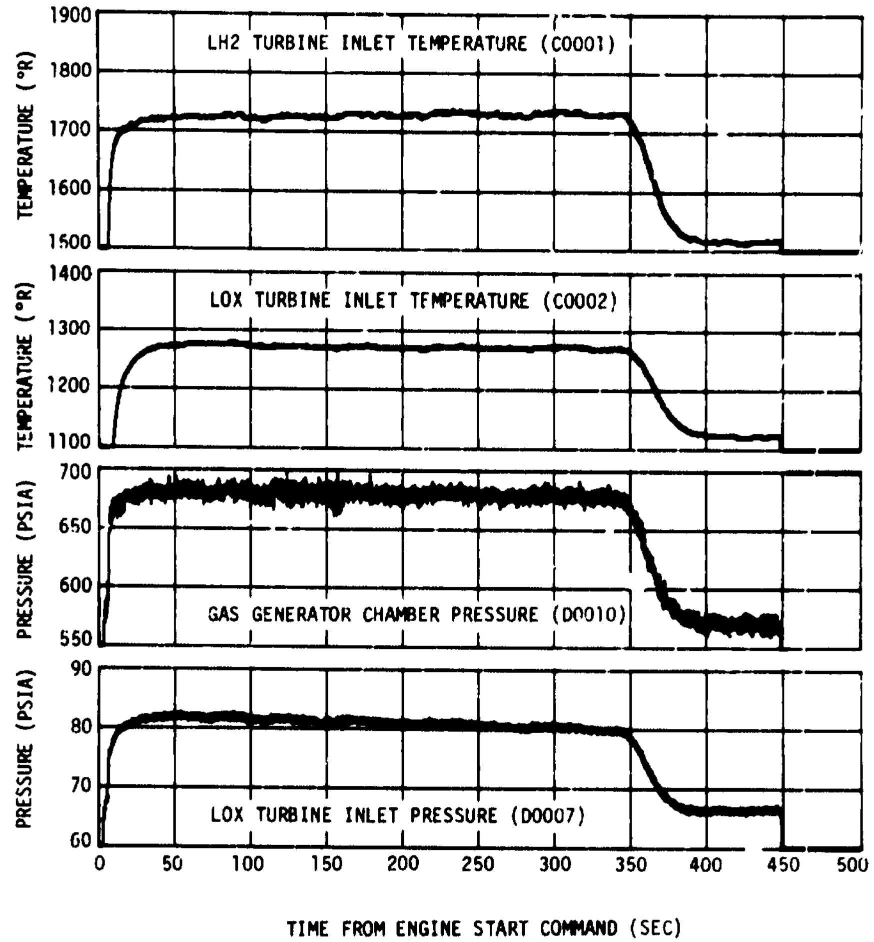


Figure 9-16. Turbine Inlet Operating Conditions

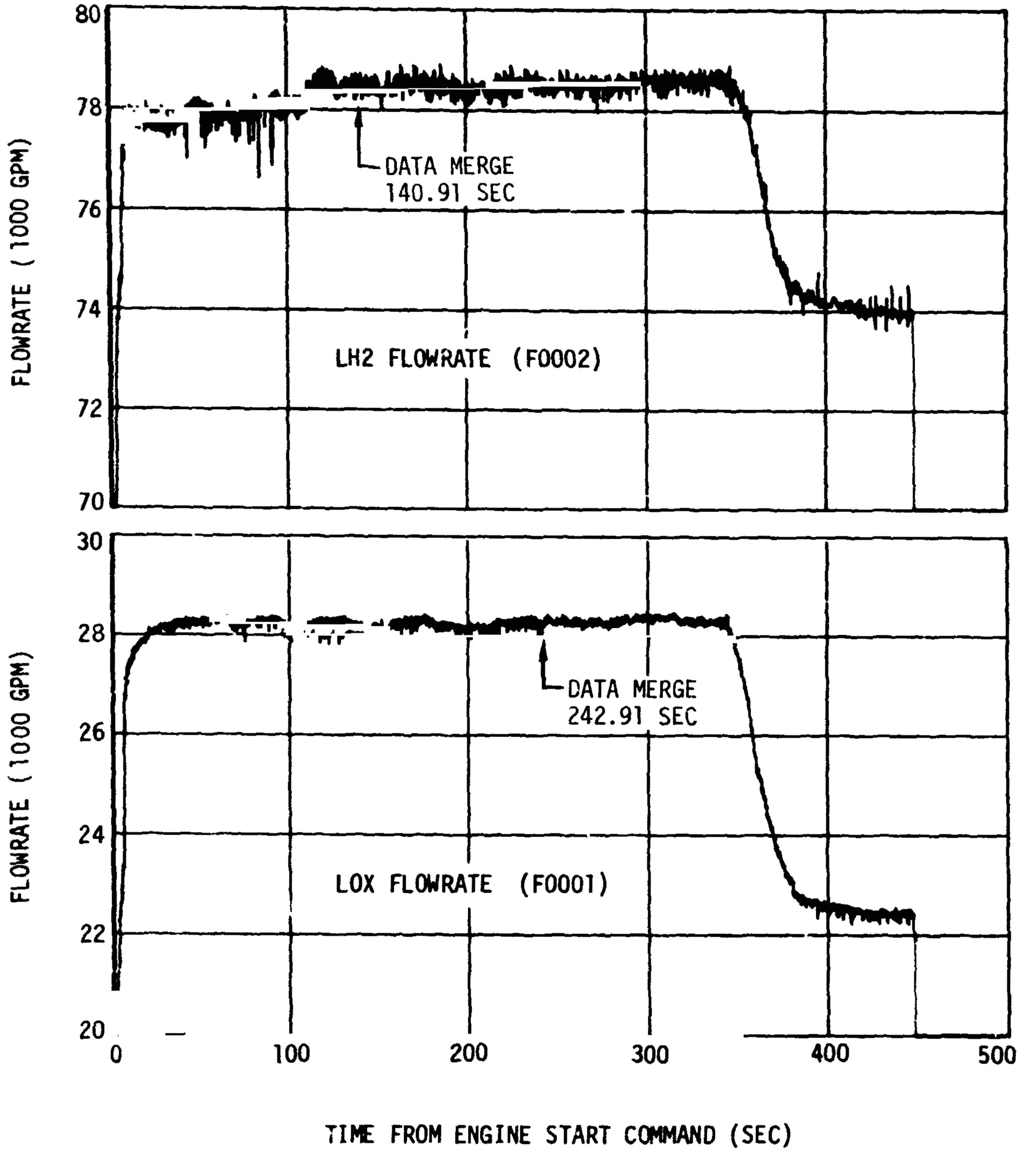


Figure 9-17. LOX and LH2 Flowrate

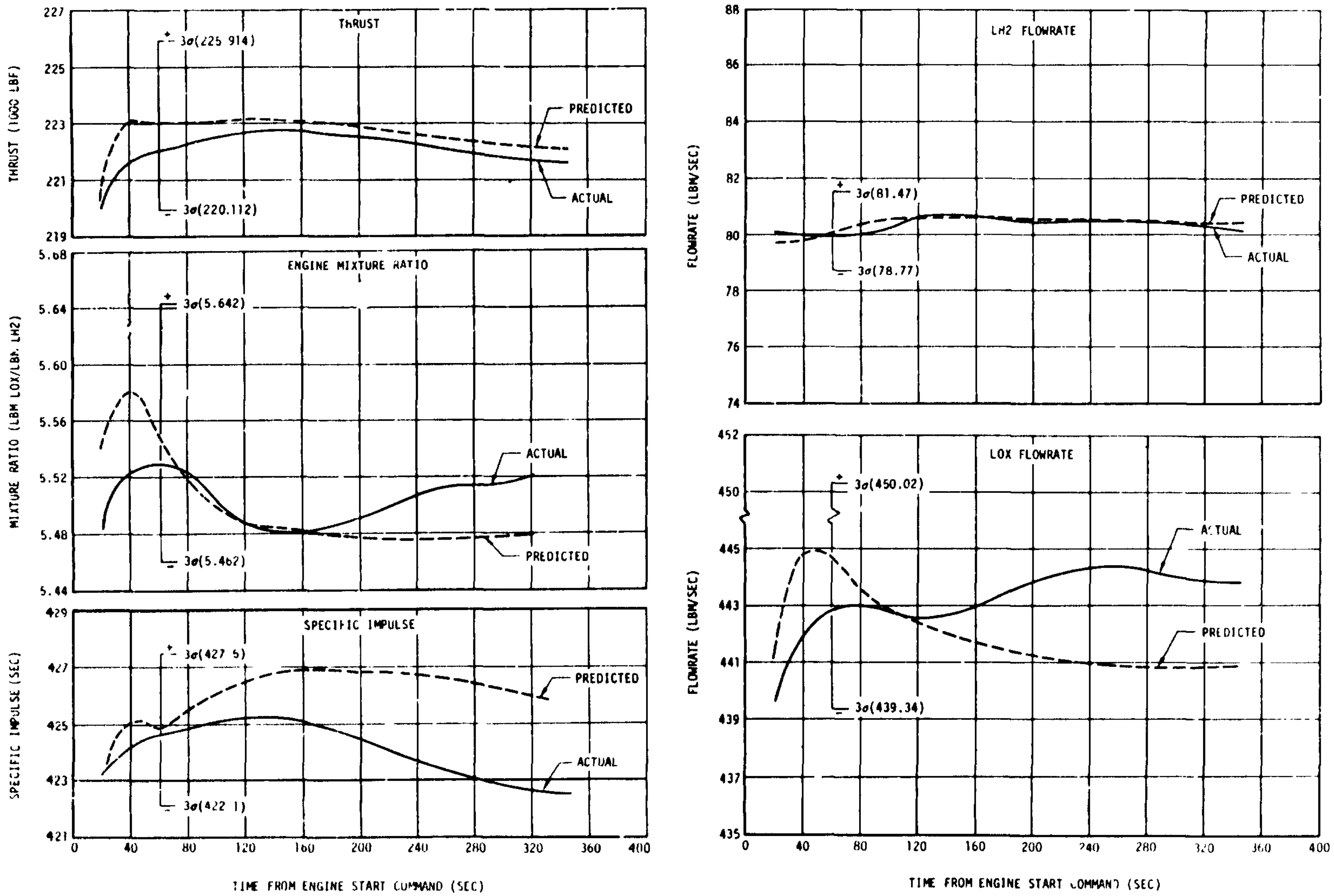


Figure 9-18. Engine Tag Values

Figure 9-18. Engine Tag Values

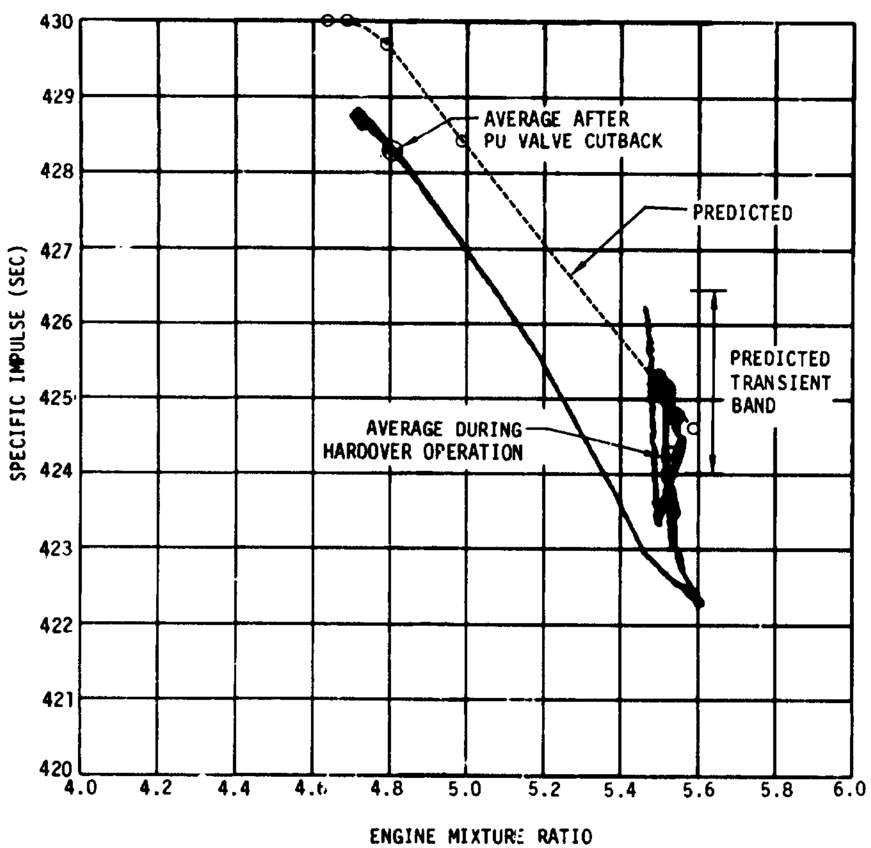


Figure 9-19. Specific Impulse Versus Engine Mixture Ratio

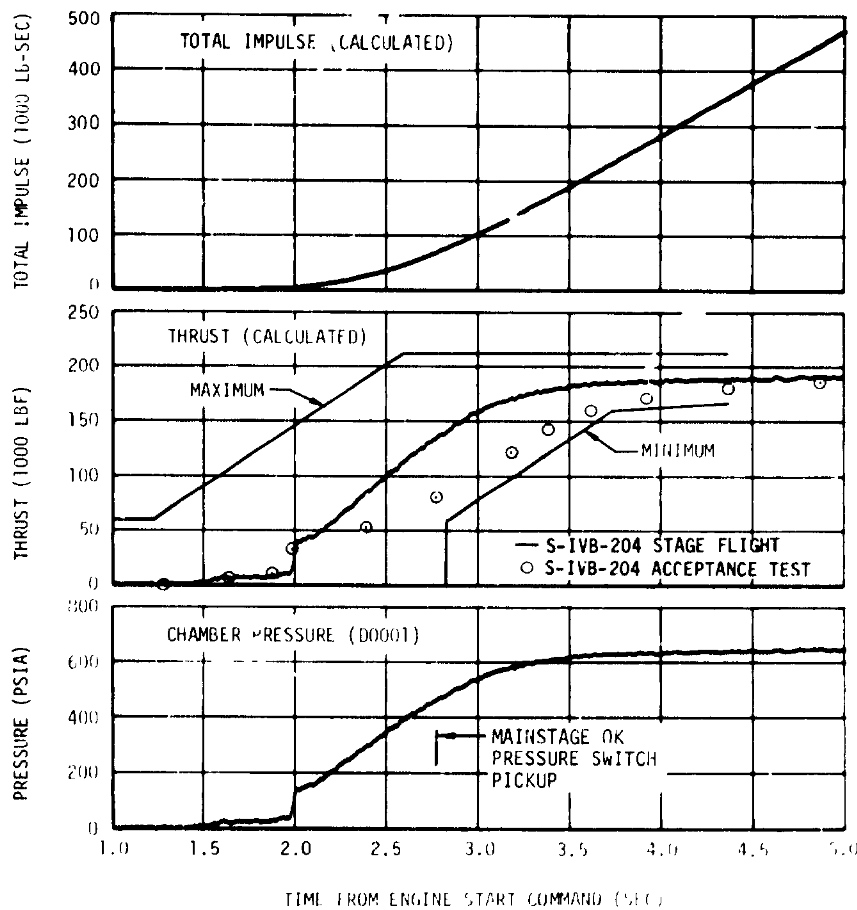


Figure 9-20. Engine Start Transient Characteristics

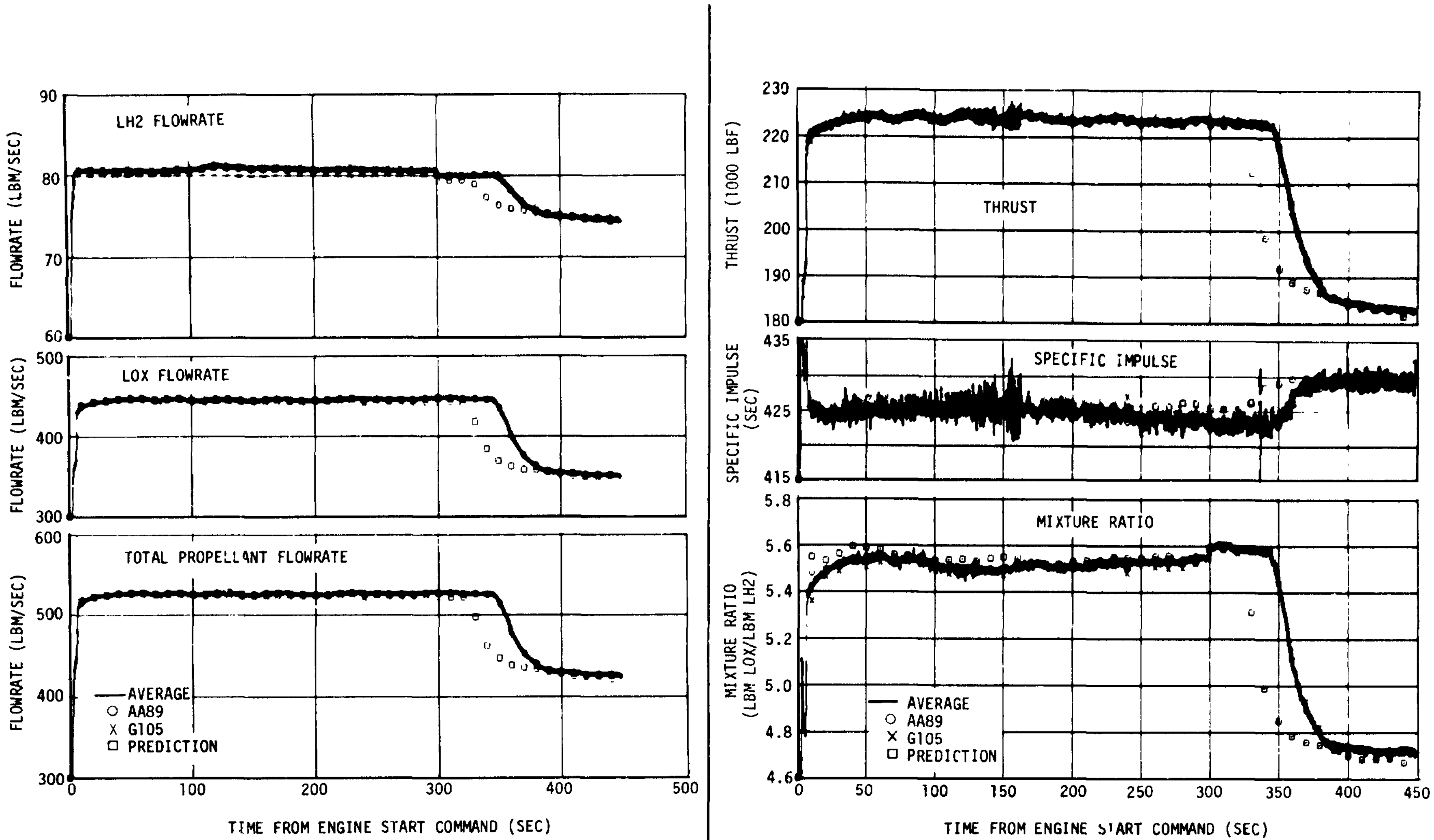


Figure 9-21. Engine Steady-State Performance (Sheet 1 of 2)

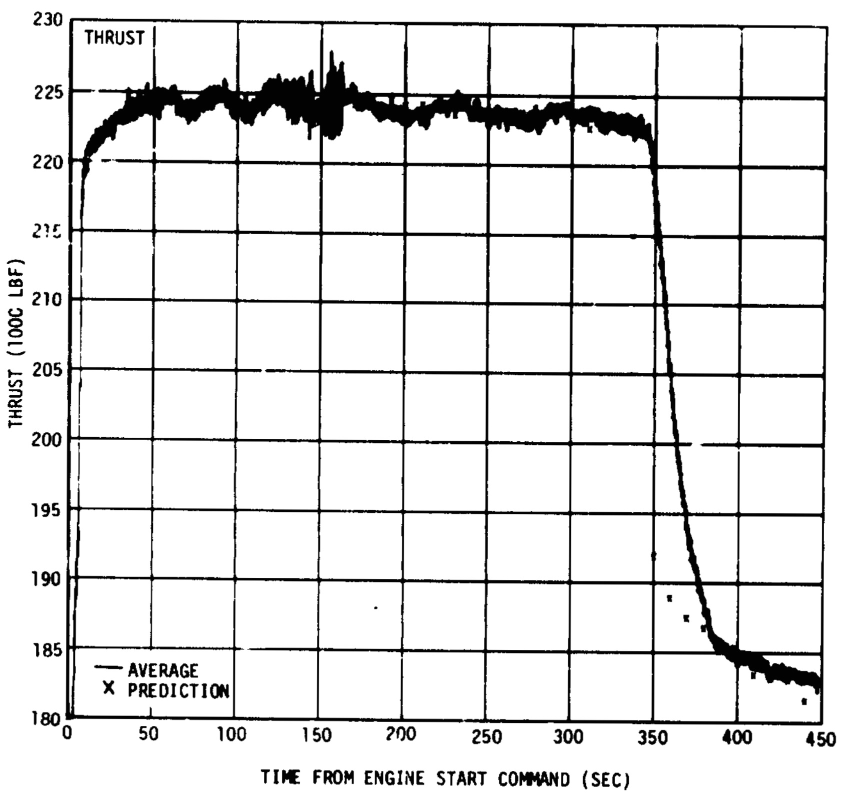


Figure 9-21. Engine Steady-State Performance (Sheet 2 of 2)

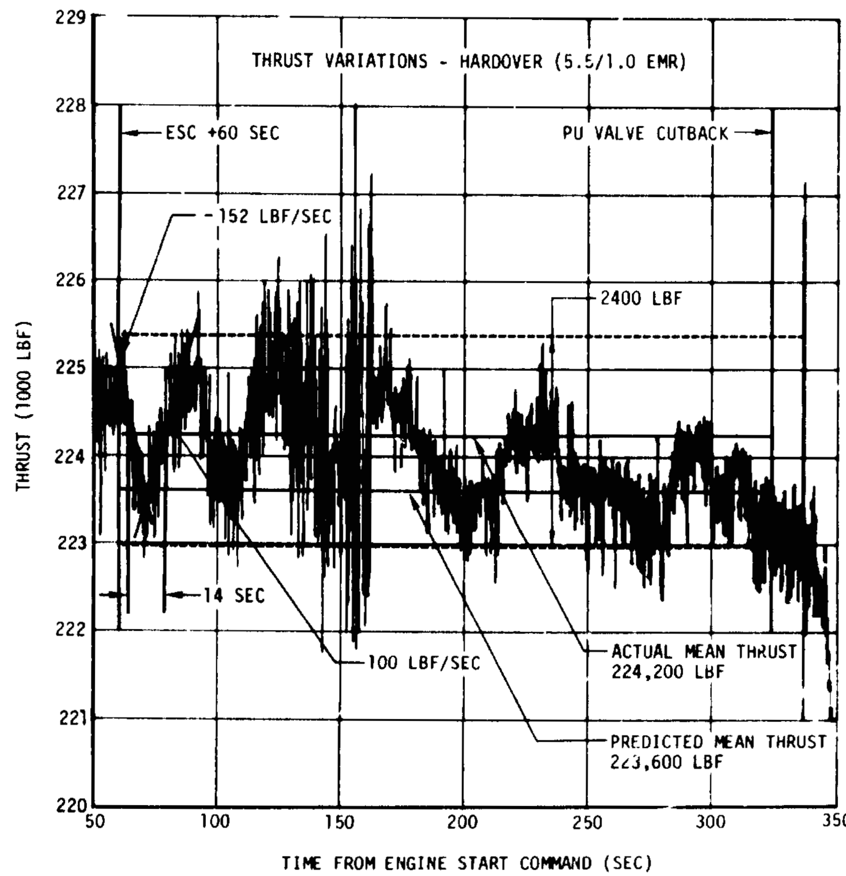


Figure 9-22. Thrust Variation (Sheet 1 of 2)

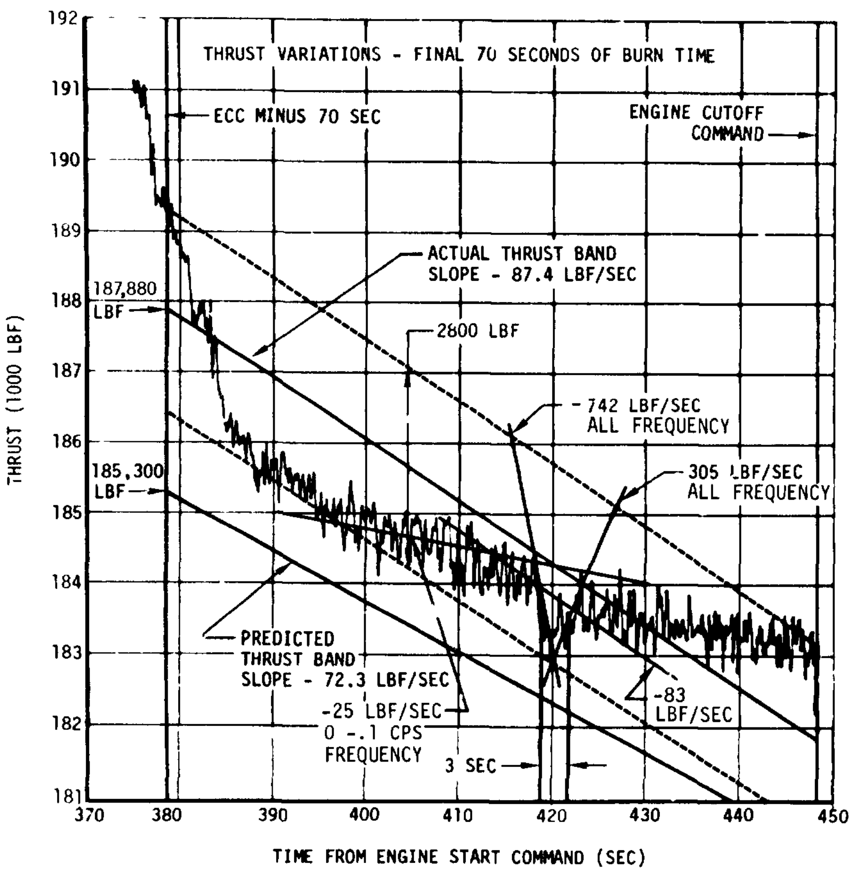


Figure 9-22. Thrust Variation (Sheet 2 of 2)

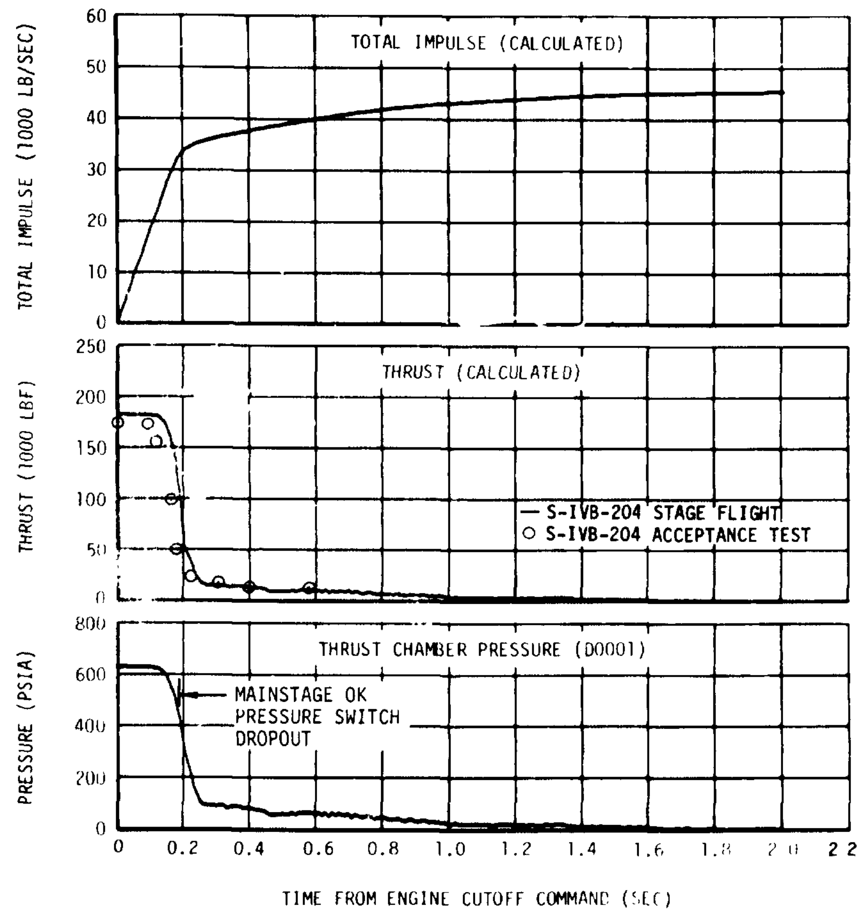


Figure 9-23. Engine Cutoff Transient Characteristics

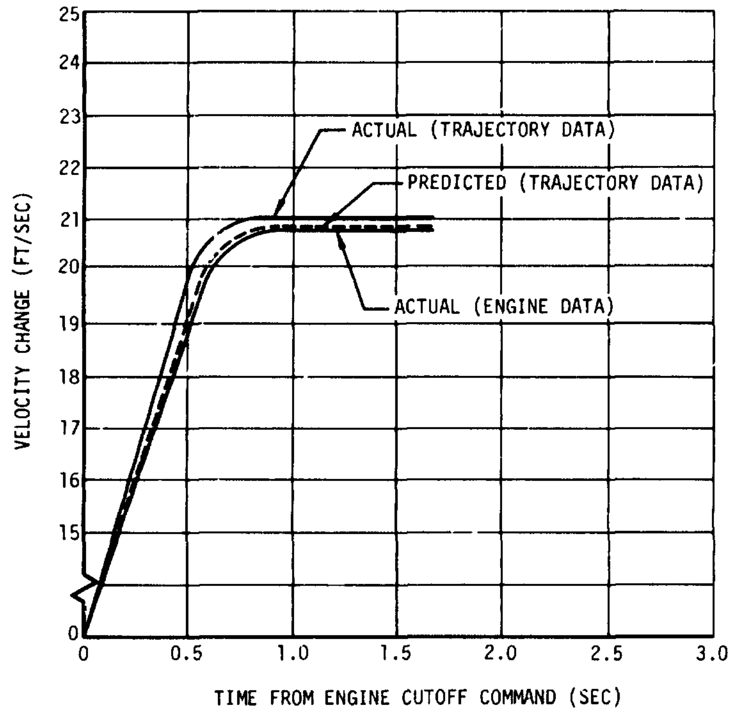


Figure 9-24. S-IVB Change in Velocity Due to Cutoff Impulse

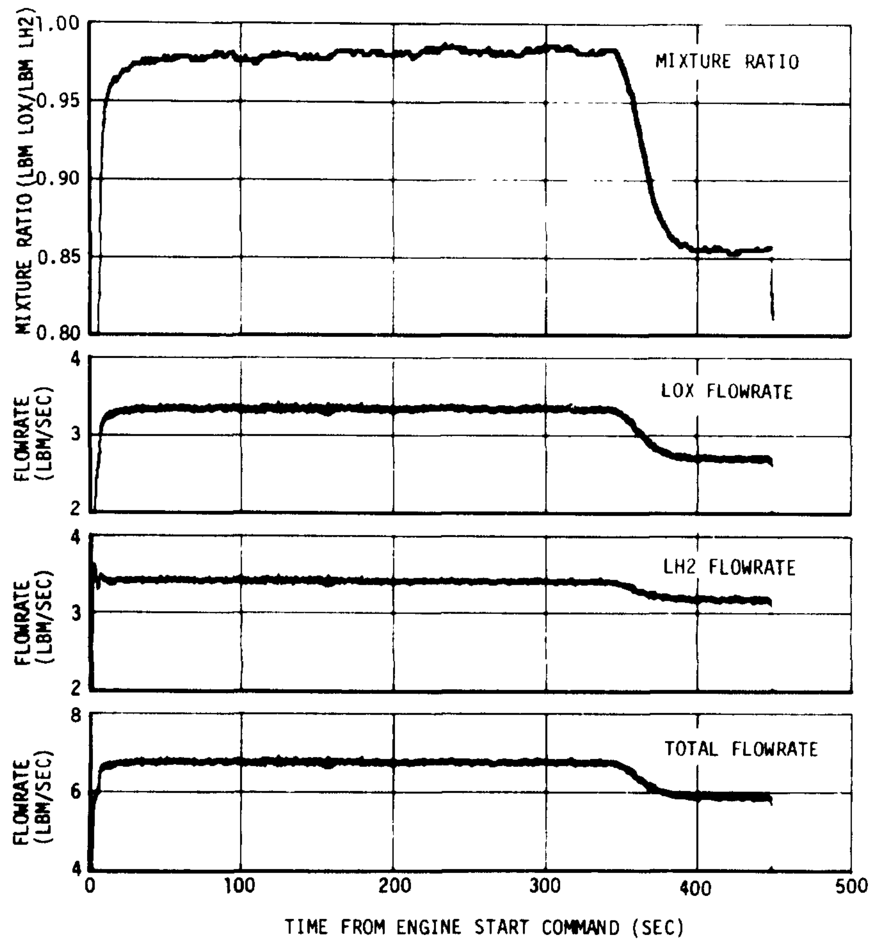


Figure 9-25. Gas Generator Performance

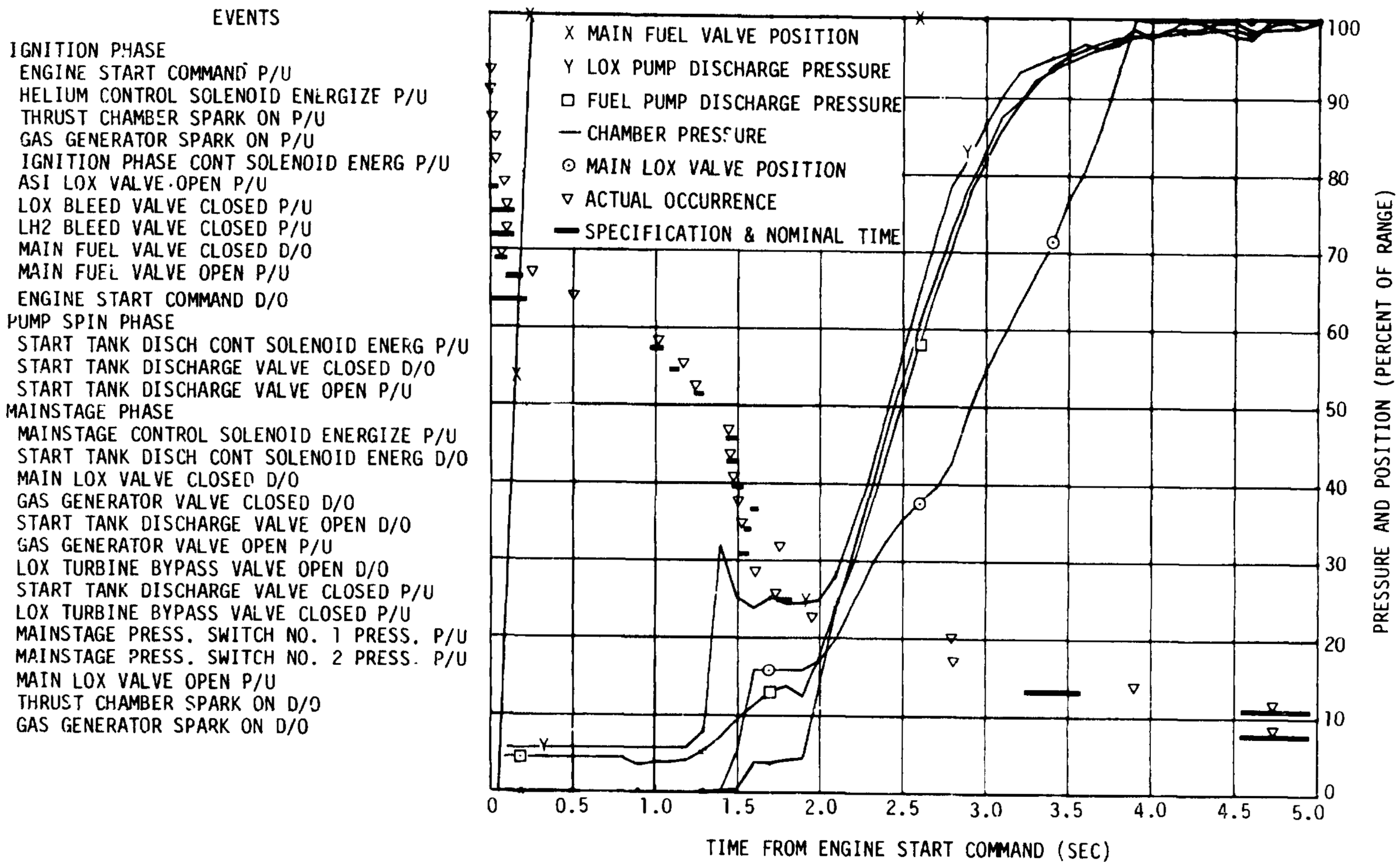


Figure 9-26. Engine Start Sequence

SECTION 10

SOLID ROCKETS

10. SOLID ROCKETS

The solid rocket motors on the AS-204 launch vehicle performed satisfactorily and accomplished their intended purpose. The S-IB was separated from the S-IVB stage by the retrorockets, and the S-IVB propellants were settled prior to engine start by the ullage rockets.

10.1 Retrorockets

The four retrorockets mounted on the S-IB stage performed satisfactorily and separated the S-IB stage from the S-IVB stage. The pressure buildup for all four retrorockets began within 0.02 sec of each other at range zero plus 143.58 sec (RO +143.58 sec). The chamber pressure profiles (figure 10-1) for the four rockets were very similar and the maximum difference in burn times was 0.04 sec. Table 10-1 presents performance parameters for the individual rocket motors. All performance parameters were close to their nominal values.

Motor B (D0154, Pos II-III) exhibited a small pressure oscillation of approximately 75 psi during the first 0.5 sec of firing. Usually the chamber pressure data shows a variation of approximately 40 psi (2 percent of maximum pressure) which is attributed to data noise since it exists before, during, and after firing. The oscillating motor B data during the first 0.5 sec of firing appeared to be valid since the oscillations were higher than the nominal noise level before and after firing. However, these low amplitude pressure oscillations (4 percent of maximum pressure) produced no detrimental effect on the motor performance.

10.2 Ullage Rockets

Ullage rocket performance was satisfactory. The Ullage Rocket Ignition Command was given at RO +143.306 sec, with the jettison command at RO +155.521 sec. These times, relative to Engine Start Command, were very close to predicted. Table 10-2 presents the individual rocket motor performance parameters as defined in the Thiokol Chemical Company Model Specification, SP-544A, dated 29 November 1965. A comparison of these data with nominal performance limits indicates that the three motors performed within design specifications. Figure 10-2 presents the thrust profiles during firing.

TABLE 10-1
RETROROCKET 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 AT 520°R
Burn Time*	sec	1.48	1.51	1.52	1.51	1.51	1.538
Average Chamber Pressure During Burn Time	psia	1,739	1,687	1,688	1,694	1,702	1,710
Chamber Pressure Integrated Over Burn Time ($\int P_c dt$)	psi-sec	2,574	2,547	2,566	2,558	2,561	2,645
Average Burn Rate During Burn Time	in./sec	1.043	1.023	1.016	1.023	1.026	1.005
Theoretical Burn Time**	sec	1.529	1.542	1.542	1.541	1.539	1.538

*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.

**Theoretical burn time = $\frac{\text{Web thickness (W)}}{\text{Burn rate (r)}}$

where W = 1.544 $\pm$0.036 in.

and $r = 0.860 \left(\frac{P_c}{1000}\right)^{0.29}$

where P_c is average chamber pressure (in psia) during burn time.

TABLE 10-2
ULLAGE ROCKET PERFORMANCE

PARAMETER	UNITS	MOTOR A (POS I-II, D0106)	MOTOR B (POS IV-I, D0107)	MOTOR C (POS II-III, D0108)	NOMINAL PERFORMANCE LIMITS	
					MAXIMUM	MINIMUM
Action Time*	sec	5.83	5.82	5.80	6.08	5.01
Burn Time**	sec	3.84	3.83	3.80	4.10	3.54
Maximum Chamber Pressure	psia	1,035	1,053	1,045	1,220	900
Maximum Ignition Chamber Pressure	psia	1,047	1,098	1,075	1,470	--
Average Action Time Chamber Pressure	psia	748	762	752	880	680
Average Burn Time Chamber Pressure	psia	1,001	1,022	1,012	1,100	890
Maximum Thrust	lbf	3,591	3,654	3,626	4,150	2,600
Maximum Ignition Thrust	lbf	3,633	3,810	3,730	5,100	--
Average Action Time Thrust	lbf	2,597	2,644	2,609	3,045	2,345
Average Burn Time Thrust	lbf	3,472	3,547	3,511	3,786	3,090
Action Time Total Impulse	lbf-sec	15,138	15,390	15,130	15,595	14,335
Burn Time Total Impulse	lbf-sec	13,333	13,585	13,341	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.

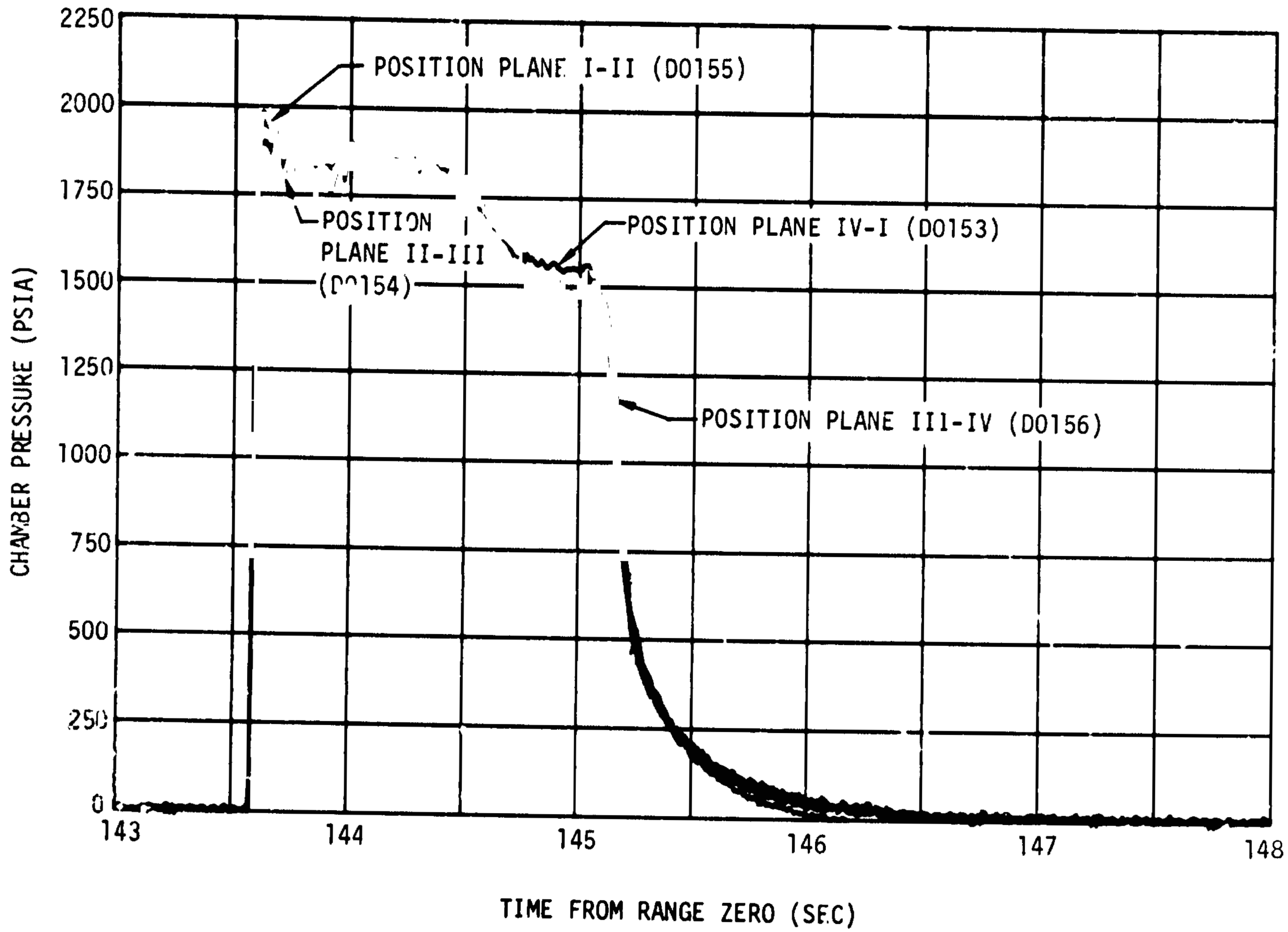


Figure 10-1. Retrorocket Performance

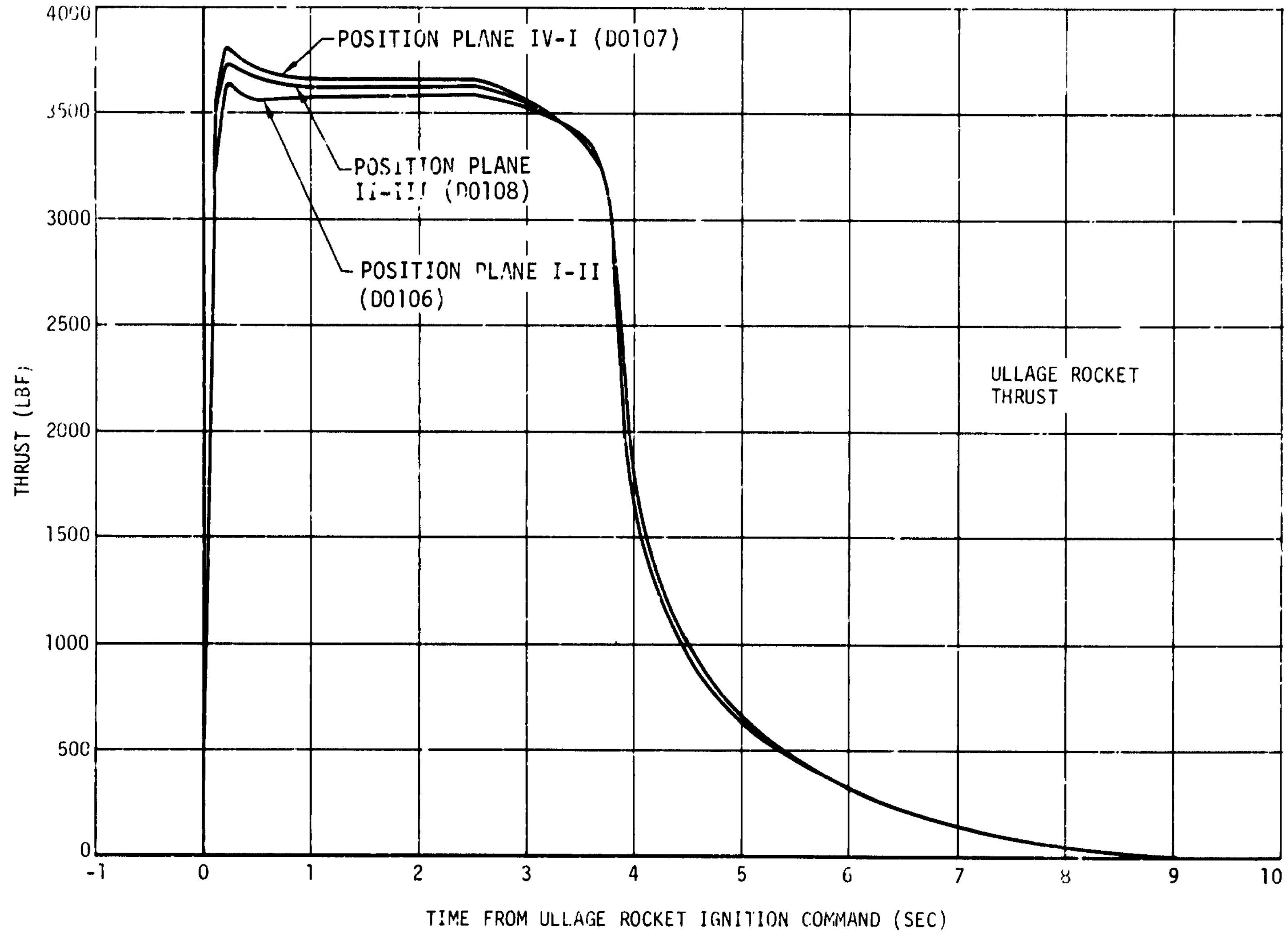


Figure 10-2. Ullage Rocket Performance

SECTION II

OXIDIZER SYSTEM

11. OXIDIZER SYSTEM

The oxidizer system performed adequately throughout boost and powered flight. The LOX tank was satisfactorily prepressurized prior to liftoff. Following engine start the ullage pressure was maintained within the prescribed control band. Cold helium supply and regulation were adequate. The recirculation chilldown system adequately chilled the LOX pump. LOX supply to the engine during the firing period was satisfactory, and the net positive suction pressure (NPSP) was above minimum limits at all times.

11.1 LOX Tank Pressurization Control and Internal Environment

The LOX tank pressurization system (figure 11-1) satisfactorily maintained pressure in the LOX tank throughout the flight. All parts of the system performed close to their design specifications.

11.1.1 Prepressurization

LO[illegible] pressurization was initiated 308 sec prior to engine start [illegible] accomplished from ground support equipment (GSE) cold helium [illegible]ly. One makeup cycle was required to maintain the LOX tank ullage pressure before the ullage temperature stabilized. After the makeup cycle, the ullage pressure gradually increased as the LOX vent valve and LOX ullage pressure sense lines were purged with ambient helium. At this time, the LOX vent and relief valve opened momentarily and the ullage pressure decreased to 42.3 psia. A second relief occurred just prior to liftoff, again a result of ground supplied purge.

The purge was terminated at liftoff; the ullage pressure then started to decrease as the result of ullage cooling. The ullage pressure continued to decrease until 9 sec prior to engine start. From this time to engine start, it increased from 38.1 to 40.0 psia as the stage decelerated and the liquid compressed the ullage. This phenomenon was also observed on the S-IVB-201 and -202 flights.

The prepressurization flowrates were calculated from temperature and pressure data obtained at the LOX vent inlet. Calculation showed that

3.5 lbm of helium were used to prepressurize and maintain the LOX tank ullage pressure prior to Engine Start Command (ESC). The cold gaseous helium leaving the GSE heat exchanger warmed to approximately 420 deg R by the time it reached the LOX vent inlet.

Significant LOX tank prepressurization data are presented in figure 11-2 and are compared to previous test data in table 11-1.

11.1.2 Pressurization

Operation of the LOX tank pressurization system was near nominal. During J-2 engine operation the LOX tank ullage pressure cycled within the control band seven times in 418 sec. Except for a period immediately after engine start, the ullage pressure was maintained within a pressure control range that agreed closely with the pressure switches. After engine start, the pressure decreased rapidly to a minimum of 34.8 psia at ESC +20 sec, although the overcontrol valve had opened when the pressure decreased below 37.4 psia. Characteristically the pressure recovered after this transient and cycled normally. The decrease was a result of the low initial pressurant mass flowrate into the LOX tank caused by temperature transients at the bypass orifice and pressure transients at the heat exchanger outlet. As soon as the temperatures and pressures stabilized, the ullage pressure recovered and cycled satisfactorily. The pressure during this transient period was sufficient to meet the minimum NPSP requirements.

The LOX tank ullage temperatures show a stratified profile generally within 20 deg R of those which occurred during the S-IVB-202 flight and S-IVB-204 acceptance test.

The LOX tank pressurization total flowrate varied as it normally does because of the variation in the bypass flowrate. This variation is normal because the bypass orifice inlet temperature changes as it follows the cold helium sphere temperature. Significant LOX tank pressurization data are presented in figure 11-3 and are compared to previous flight data in table 11-2.

LOX venting during orbital phase is covered in paragraph 26.4.1.

11.1.3 LOX Tank Pressurization Control Module

The LOX pressurization module outlet temperature and pressure (figure 11-3) displayed normal profiles through the start transient and during engine operation. The pressure was maintained within the specified 400 ±25 psia during powered flight.

11.2 Cold Helium Supply

During a portion of terminal countdown and S-IB boost, the cold helium sphere pressure transducer (D0016) behaved erratically. Before and after this period, the pressure was stable, but the level was not valid. Using other sphere pressures, a bias was obtained and applied during S-IB boost and S-IVB burn. This bias was used to obtain the helium usage and sphere conditions at significant times shown in table 11-3 and figure 11-4.

Between Engine Cutoff Command and RO +3,525 sec, the cold helium pressure and average temperature decreased to 750 psia and 42.9 deg R, respectively, indicating a mass loss of 29 lbm during this period. Apparent mass losses have occurred on previous flights, but are believed to be the result of instrumentation. The pressure and temperature subsequently increased and were 1,268 psia and 64.4 deg R at the initiation of cold helium passivation (RO +10,349 sec). These values indicate an apparent mass gain of 10 lbm between RO +3,525 and RO +10,349 sec and substantiate the theory that mass losses are the result of instrumentation.

11.3 J-2 Heat Exchanger

The J-2 heat exchanger inlet temperature began to decrease immediately after engine start as the line was being cooled. The temperature decrease was interrupted several times (figure 11-5) because of flowrate variations during undercontrol and overcontrol. The temperature reached a minimum of 45 deg R approximately 237 sec after Engine Start Command. Thereafter the temperature increased, reaching 63 deg R at engine cutoff. The heat exchanger outlet temperature increased to 968 deg R during the

60 sec warmup transient. Temperatures during the flight were 16 to 54 deg R higher than those recorded during acceptance testing. This difference is generally attributed to the absence of convective heat transfer loss. Significant J-2 heat exchanger performance data are presented in table 11-4.

Figure 11-5 compares the LOX tank inlet temperature and the theoretical gas mixture temperature. The theoretical mixture temperature is the temperature that would be obtained by complete mixing of the cold bypass gas and the hot gas from the J-2 engine heat exchanger. This comparison gives an indication of the heat transfer to or from the pressurization lines between the mixing point and the vent inlet. It also shows that the system stabilized only after an extended period of overcontrol or undercontrol operation.

11.4 LOX Childown

The LOX pump chilldown system performed adequately. At Engine Start Command the NPSP at the pump inlet was above the minimum requirement of 12.8 psi.

Recirculation chilldown was started 588 sec prior to liftoff and was terminated shortly before engine start. To remove any bubbles that might have collected under the prevalve during chilldown, it was commanded open at ESC -3.6 sec while the chilldown pump was still running. The chilldown shutoff valve was closed before engine cutoff.

After prepressurization, the ullage pressure varied with the normal makeup cycles until liftoff. During this time interval, the LOX pump inlet pressure and return line pressure followed the ullage pressure trend. After liftoff the ullage pressure decreased, while the chilldown system pressures increased rapidly as a result of the increasing vehicle acceleration. The LOX pump inlet pressure increased beyond 60 psia at 10 sec after liftoff thus exceeding the range of the transducer. Thereafter the LOX pump inlet pressure was calculated by adding the chilldown pump developed head and liquid head pressures (determined from predicted vehicle acceleration data) to the ullage pressure. As the LOX pump inlet pressure increased during boost it also diverged from the return line pressure because the pump inlet transducer was located approximately 69 in. lower than the return line pressure transducer and was subjected to a larger liquid head which increased with acceleration. At approximately 5.9 sec prior to S-IVB ESC the S-IB inboard engines were cut off causing the LOX pump inlet pressures and return line pressure to decrease (figure 11-6). These pressures decreased further at S-IB outboard engine cutoff (ESC -2.7 sec). Opening of the prevalve at approximately the same time caused a loss of chilldown pump developed heat and an additional pressure decrease.

During the chilldown process the LOX was subcooled throughout the recirculation system with 16.6 deg R of subcooling at the pump inlet at Engine Start Command.

The NPSP at the LOX pump inlet reached 42.0 psi at liftoff, after which time it increased with increasing pump inlet pressure to a maximum value of 64.6 psi at S-IB inboard engine cutoff. After this time it dropped continuously to a value of 22.6 psi at S-IVB Engine Start Command.

The chilldown system temperatures increased slightly prior to liftoff as a result of bulk heating. The chilldown system temperatures continued to increase slightly during the first few seconds of boost, then decreased during the remaining period of boost. By engine start, the heat inputs had gradually decreased to the levels presented in figure 11-7, which contains significant chilldown data. These same heating trends were observed during the S-IVB-201, -202, and -203 flights. Other comparative data are presented in table 11-5.

11.5 Engine LOX Supply

The LOX supply system (figure 11-8) delivered the necessary quantity of LOX to the engine pump inlet throughout engine operation and maintained the pressure and temperature conditions within a range that provided a LOX pump NPSP above the minimum requirements, although, in general it was 0.7 psi less than predicted. Figure 11-9 presents the data and the calculated performance; table 11-6 compares the S-IVB-204 stage data and calculated performance with that from previous tests.

The LOX pump inlet temperature and pressure were plotted in the engine LOX pump operating region (figure 11-10) and showed that the LOX pump inlet conditions were satisfactory throughout engine operation.

In figure 11-11 the LOX pump inlet temperature is plotted against the mass remaining in the tank during engine operation and compared to the S-IVB-204 acceptance test data. The data used for comparison have been biased to the LOX pump inlet temperature observed at Engine Start Command of S-IVB-204 flight to correct for instrument error, different heating duri pressurization, and other test to test variations.

TABLE 11-1
LOX TANK PREPRESSURIZATION DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Prepressurization duration (sec)	14	68	15
Number of makeup cycles	1	5	1
Prepressurization helium			
Flowrate (lbm/sec)	0.22 to 0.25	0.57 to 1.05	N/A
Mass added to LOX tank during prepressurization (lbm)	3.2	40	3.8*
Mass added to LOX tank during makeup cycles (lbm)	0.26	15	N/A
Ullage pressure			
At prepressurization initiation (psia)	15.4	15.2	16.4
At prepressurization termination (psia)	40.3	39.2	40.5
At liftoff (psia)	42.3	39.0	43.0
At Engine Start Command (psia)	40.0	38.7	41.0
Events (sec from liftoff)			
Prepressurization initiation	-163	-263	-162
Prepressurization termination	-149	-195	-147
Engine Start Command	145	145	145

N/A = Not available.

*Total mass added during prepressurization and during makeup cycle.

TABLE 11-2
LOX TANK PRESSURIZATION DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Number of secondary flow intervals	7	3	7
Pressure control band			
Minimum (psia)	37.7	37.0	37.8
Maximum (psia)	39.6	39.2	40.2
Ullage pressure			
At Engine Start Command (psia)	40.0	38.7	41.0
Minimum during start transient (psia)	34.9	37.0	34.6
At Engine Cutoff Command (psia)	39.3	37.2	38.5
Pressurant total flowrate			
During undercontrol (lbm/sec)	0.27 to 0.31	0.30 to 0.39	0.26 to 0.33
During overcontrol (lbm/sec)	0.37 to 0.42	0.40 to 0.45	0.39 to 0.45
Maximum LOX tank vent inlet temperature (deg R)	513	335	477

Section 11
Oxidizer System

TABLE 11-3
COLD HELIUM SUPPLY DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Pressure			
At liftoff (psia)	2,958	3,150	3,060
At Engine Start Command (psia)	2,927	2,690	3,050
At Engine Cutoff Command (psia)	1,179	1,380	1,200
Average temperature			
At liftoff (deg R)	40.9	39.5	39.2
At Engine Start Command (deg R)	40.4	39.0	39.0
At Engine Cutoff Command (deg R)	48.9 to 56.2	31.8 to 28.2	48.4 to 55.6
Helium mass			
At Engine Start Command (lbm)	334	340	340
At Engine Cutoff Command (lbm)	175	230	187
Usage calculated from sphere conditions (lbm)	159	110	153
Usage calculated by integration of flowrate (lbm)	149	110	153

TABLE 11-4
J-2 HEAT EXCHANGER PERFORMANCE DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Flowrate through heat exchanger			
During overcontrol (lbm/sec)	0.19	0.18	0.20
During undercontrol (lbm/sec)	0.07	0.05	0.08
Heat exchanger inlet temperature			
During overcontrol (deg R)	45 to 60	33 to 51	35 to 55
During undercontrol (deg R)	50 to 75	39 to 54	40 to 75
Minimum (deg R)	46	36	35
Heat exchanger outlet temperature			
At end of 60 sec transient (deg R)	968	840	850
During overcontrol (deg R)	981 to 1,003	880 to 900	875 to 935
During Undercontrol (deg R)	990 to 1,054	850 to 910	870 to 880
At Engine Cutoff Command (deg R)	952	933	840
Heat exchanger outlet pressure			
During overcontrol (psia)	334 to 347	332 to 344	340 to 355
During undercontrol (psia)	369 to 402	380 to 390	400 to 410
Average LOX vent inlet pressure			
During overcontrol (psia)	67	*	68
During undercontrol (psia)	48	*	48
Maximum LOX vent inlet temperature (deg R)	513	335	475

*Transducer D0055 was faulty on S-IVB-203.

TABLE 11-5 (Sheet 1 of 2)
LOX CHILLDOWN SYSTEM PERFORMANCE DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
NPSP			
At Engine Start Command (psi)	22.64	23.0	24.5
Minimum required at engine start (psi)	12.8	12.8	12.8
At opening of prevalve (psi)	43.01	N/A	N/A
LOX pump inlet conditions at Engine Start Command			
Pressure (psia)	39.9	39.0	41.0
Temperature (deg R)	165.1	164.5	165.0
Amount of subcooling (deg R)	16.6	16.7	17.3
Average flow coefficient ($sec^2/in.^2-ft^3$)	20.4	12.2	10.0
Heat absorption rate (Btu/hr)			
Section 1 (tank to pump inlet)	5,000	1,500	3,500
Section 2 (pump inlet to bleed valve)	18,000	20,000	22,000
Section 3 (bleed valve to tank inlet)	6,000	5,000	4,500
Total	29,000	26,500	30,000
Chilldown flowrate			
Unpressurized (gpm)	36.8	N/A	N/A
Pressurized (gpm)	38.5	43.4	44.3

N/A = Not available.

TABLE 11-5 (Sheet 2 of 2)
LOX CHILLDOWN SYSTEM PERFORMANCE DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Chilldown pump pressure differential			
Unpressurized (psi)	N/A	N/A	N/A
Pressurized (psi)	10.5	8	7
Events (sec from liftoff)			
Chilldown initiation	-588.032	-658	-672
Prevalve closed	-582.016	N/A	N/A
Prepressurization initiation	-163.232	-263	-110
Prevalve Open Command	140.269	N/A	N/A
Prevalve closed signal dropout	141.288	N/A	N/A
Prevalve open signal pickup	143.088	148.3	N/A
Delay between prevalve Open Command and pickup of open signal	2.819	N/A	N/A
Chilldown shutoff valve closed	568.071	144.0	145.2
Engine Start Command (K0021)	144.905	143.9	144.6

N/A = Not available.

TABLE 11-6
LOX PUMP INLET CONDITION DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Pump inlet conditions			
Static pressure at engine start (psia)	39.9	39.0	41.0
Temperature at engine start (deg R)	165.1	164.5	165.0
Temperature at engine cutoff (deg R)	166.3	166.7	165.8
NPSP			
Required at Engine Start Command (psi)	12.8	12.8	12.8
Available at Engine Start Command (psi)	22.6	23.0	24.5
Maximum during firing (psi)	27.0	28.5	26.8
Minimum during firing (psi)	21.8	25.0	21.1
At Engine Cutoff Command (psi)	24.8	25.3	23.5
LOX feed duct			
At high EMR			
Pressure drop (psi)	2.3	1.7	3.1
Flowrate (lbm/sec)	445	396	448
After EMR cutback			
Pressure drop (psi)	*	**	2.0
Flowrate (lbm/sec)	365	**	356

*Calculation inaccurate.

**No cutback.

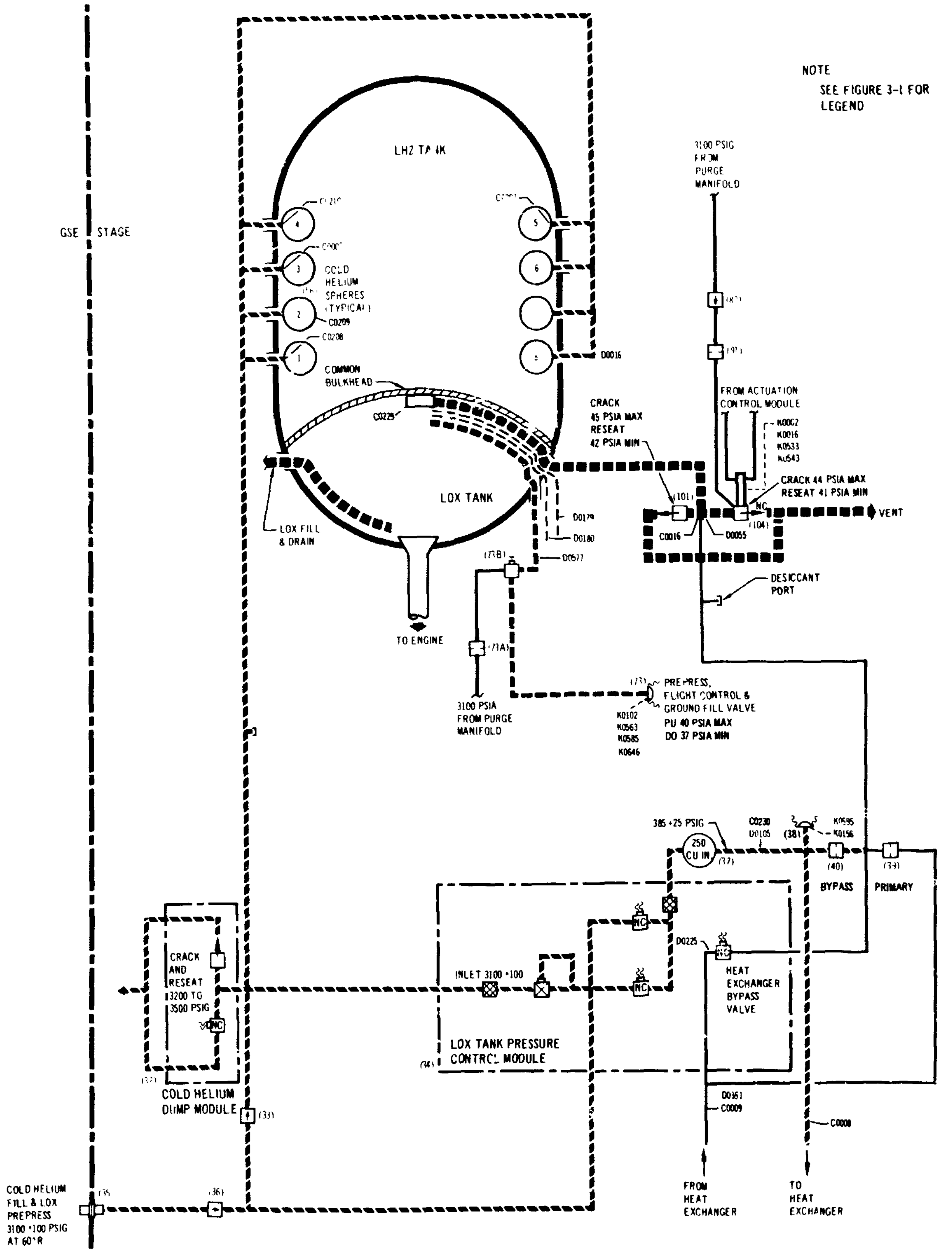


Figure 11-1. LOX Tank Pressurization System

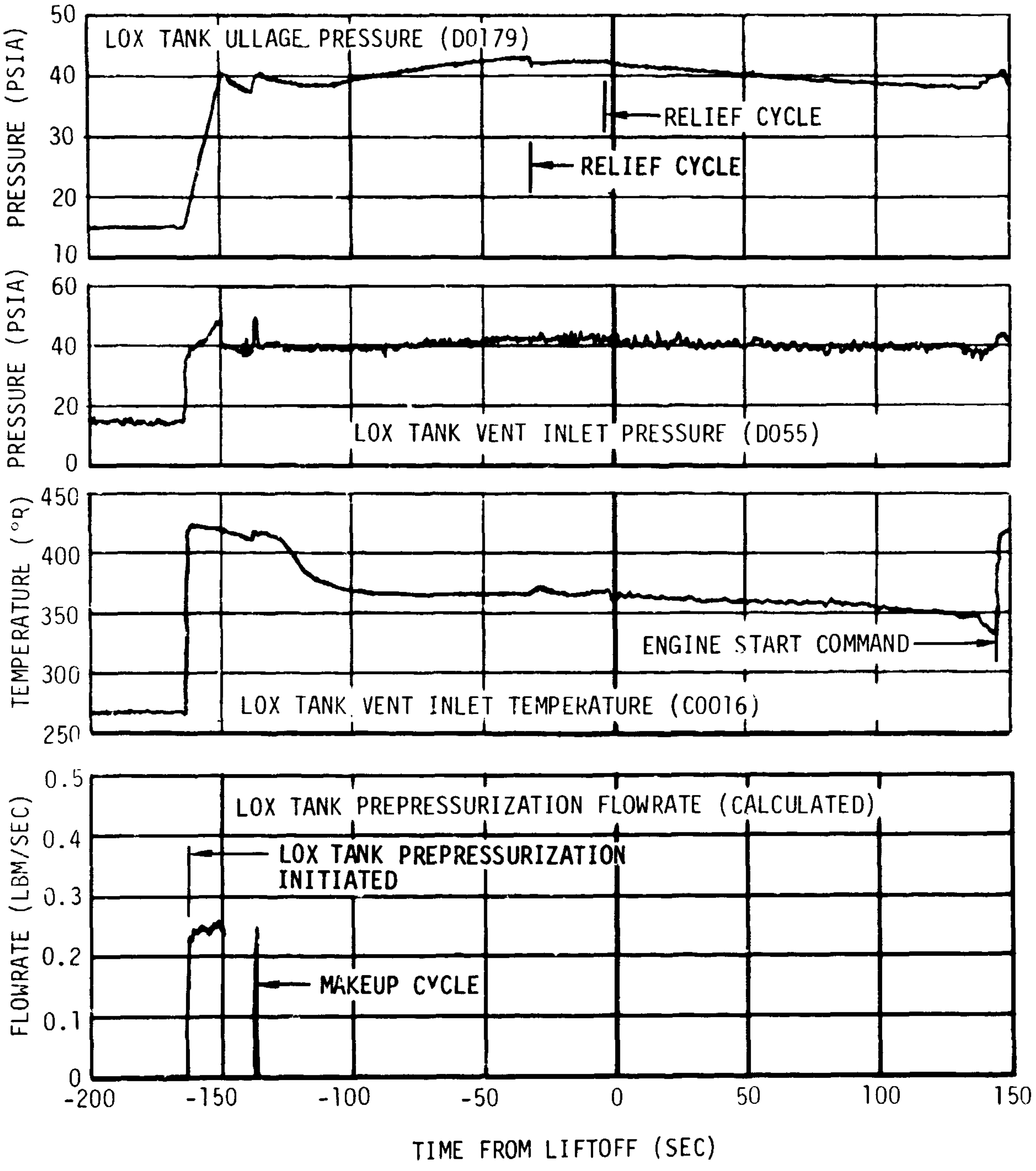


Figure 11-2. LOX Tank Conditions During Prepressurization and Boost

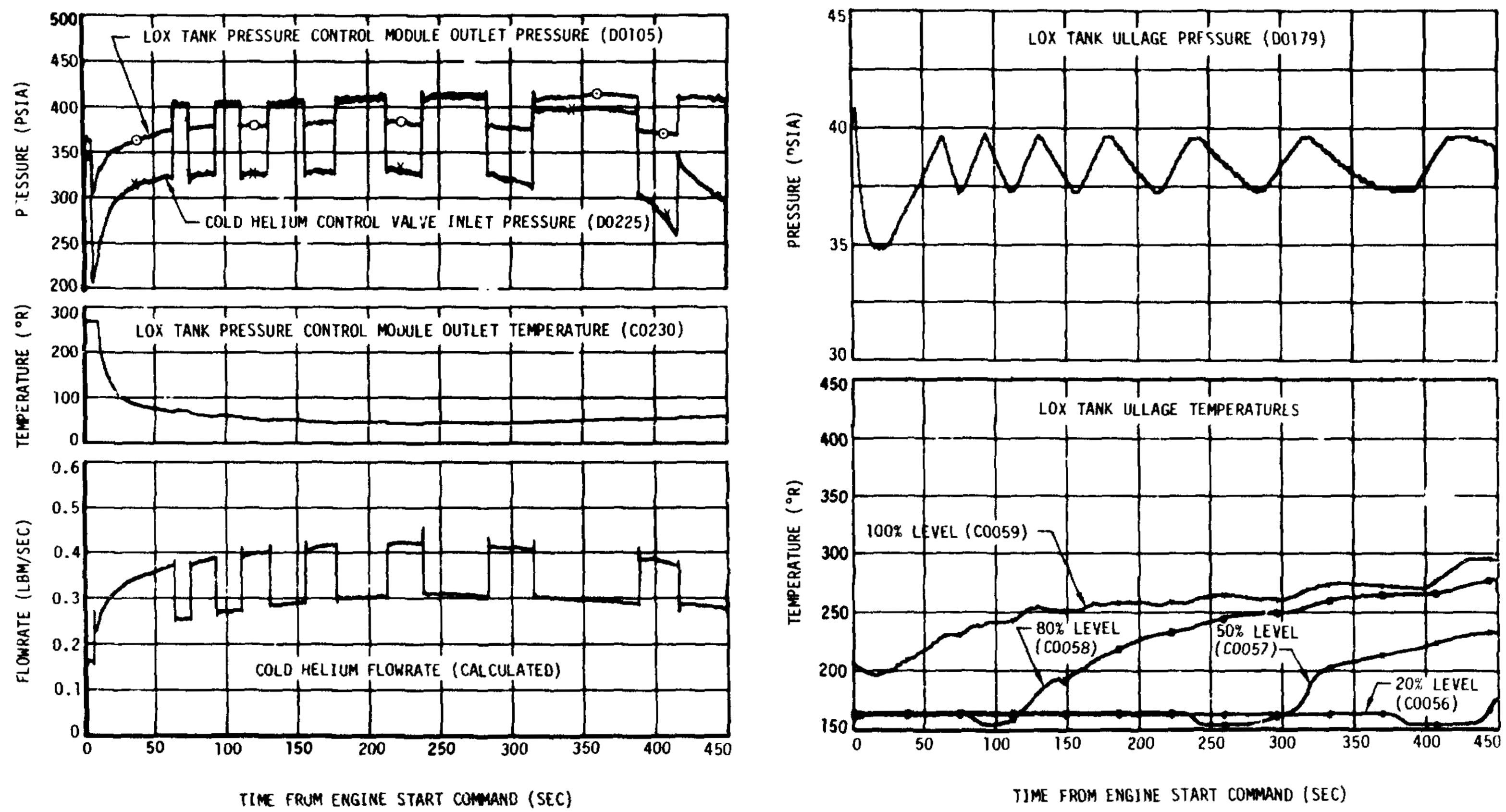


Figure 11-3. LOX Tank Pressurization System Performance

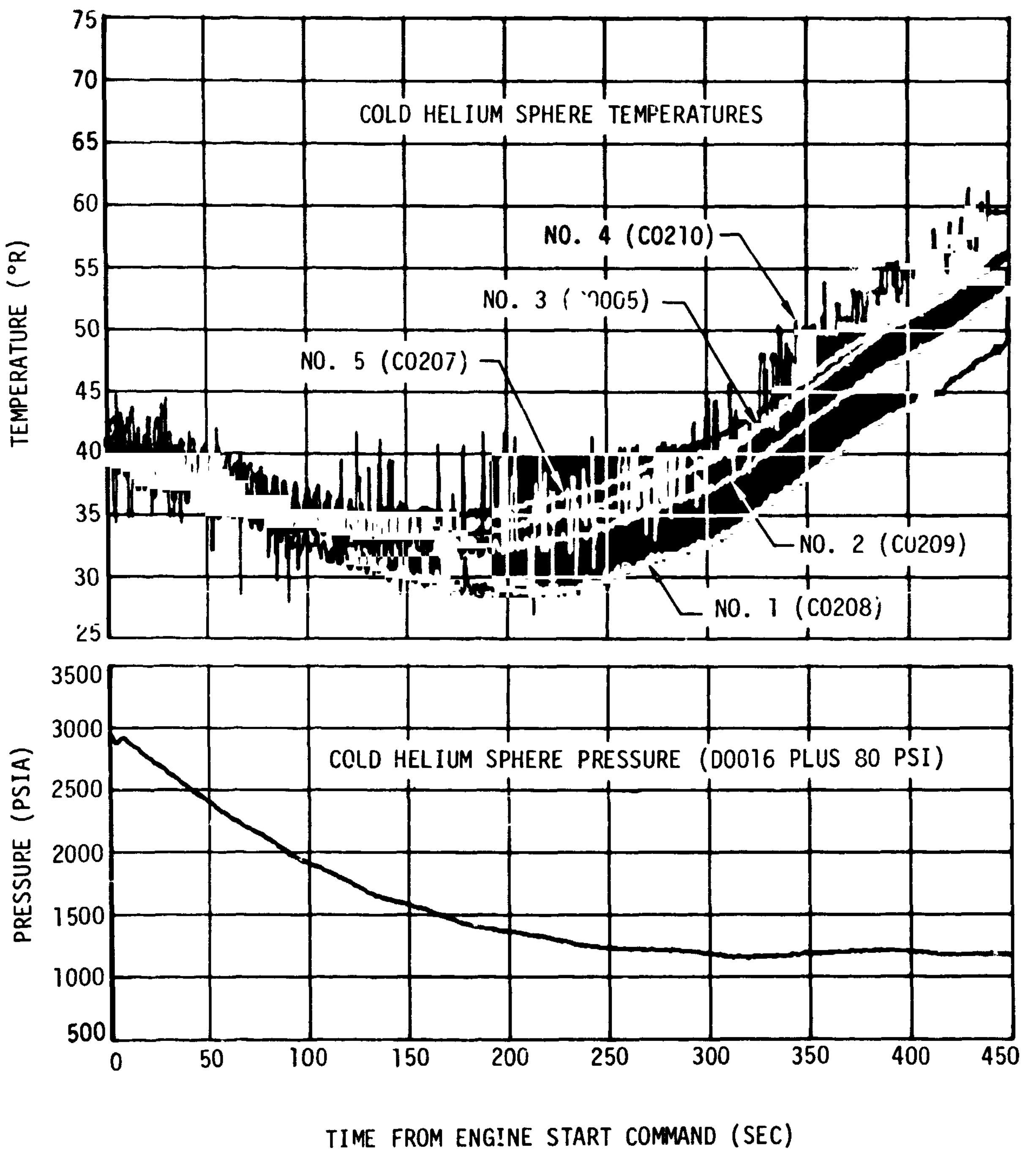


Figure 11-4. Cold Helium Supply

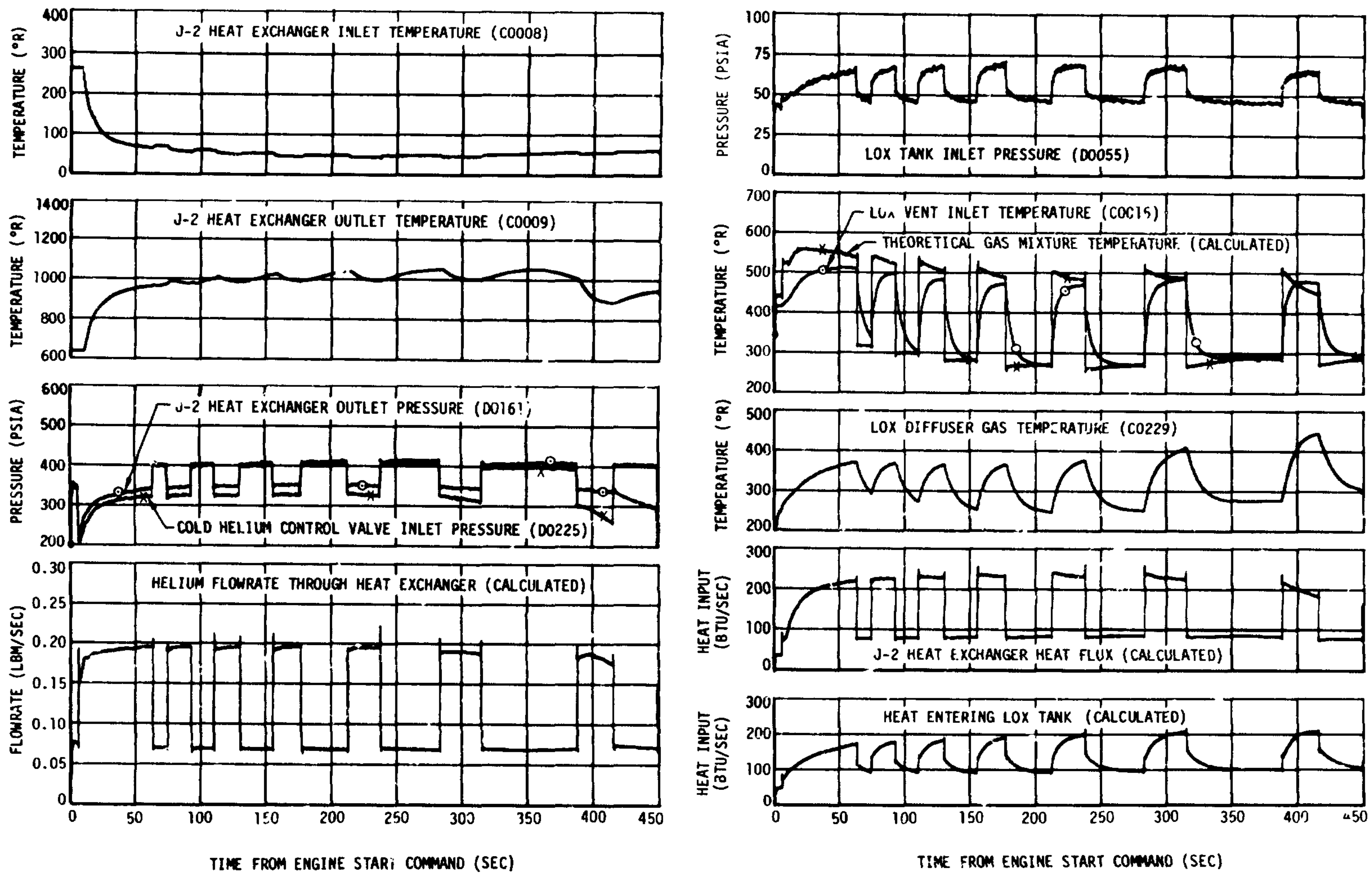


Figure 11-5. J-2 Heat Exchanger Performance

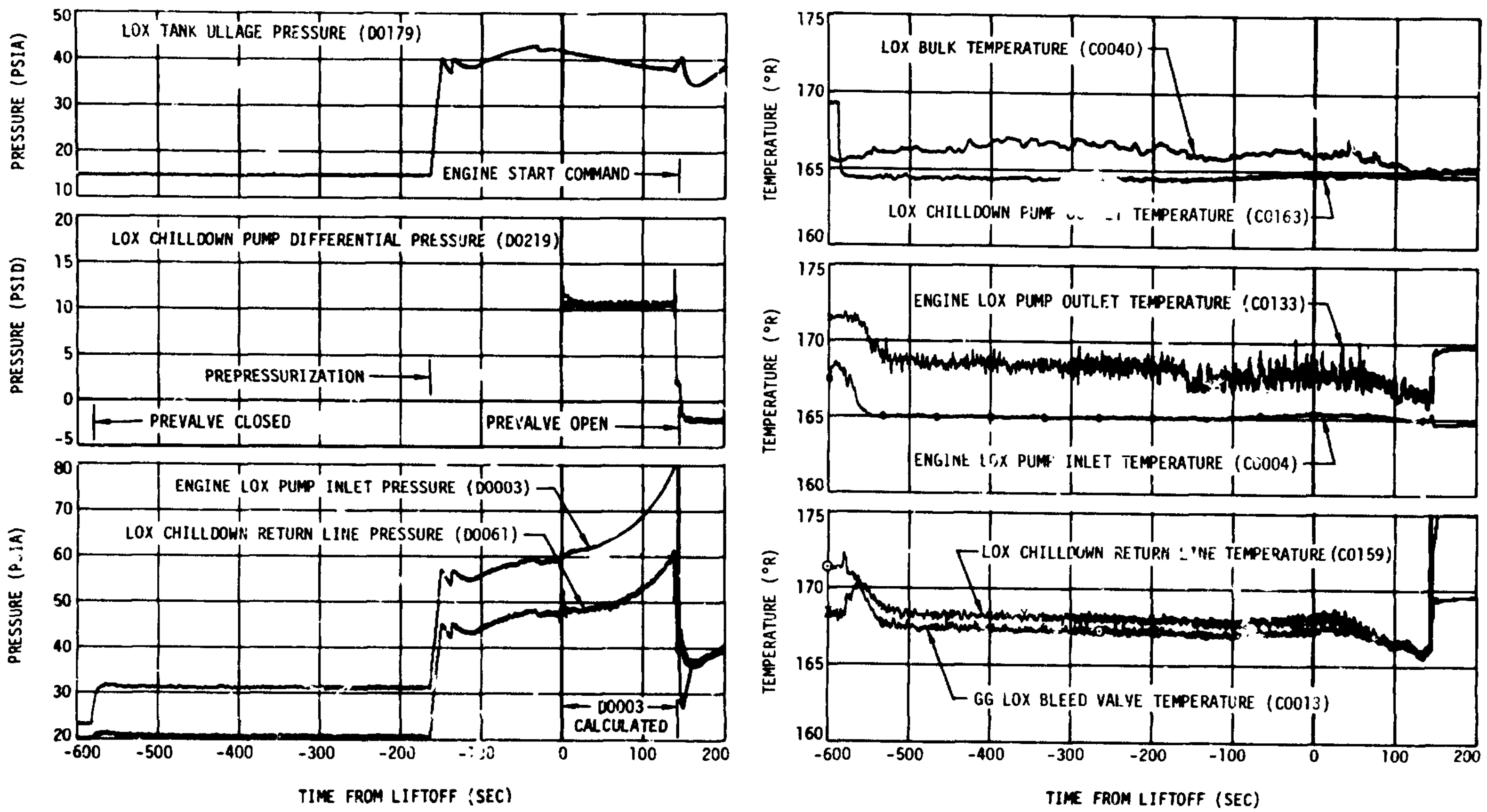


Figure 11-6. LOX Pump Chilldown System Operation

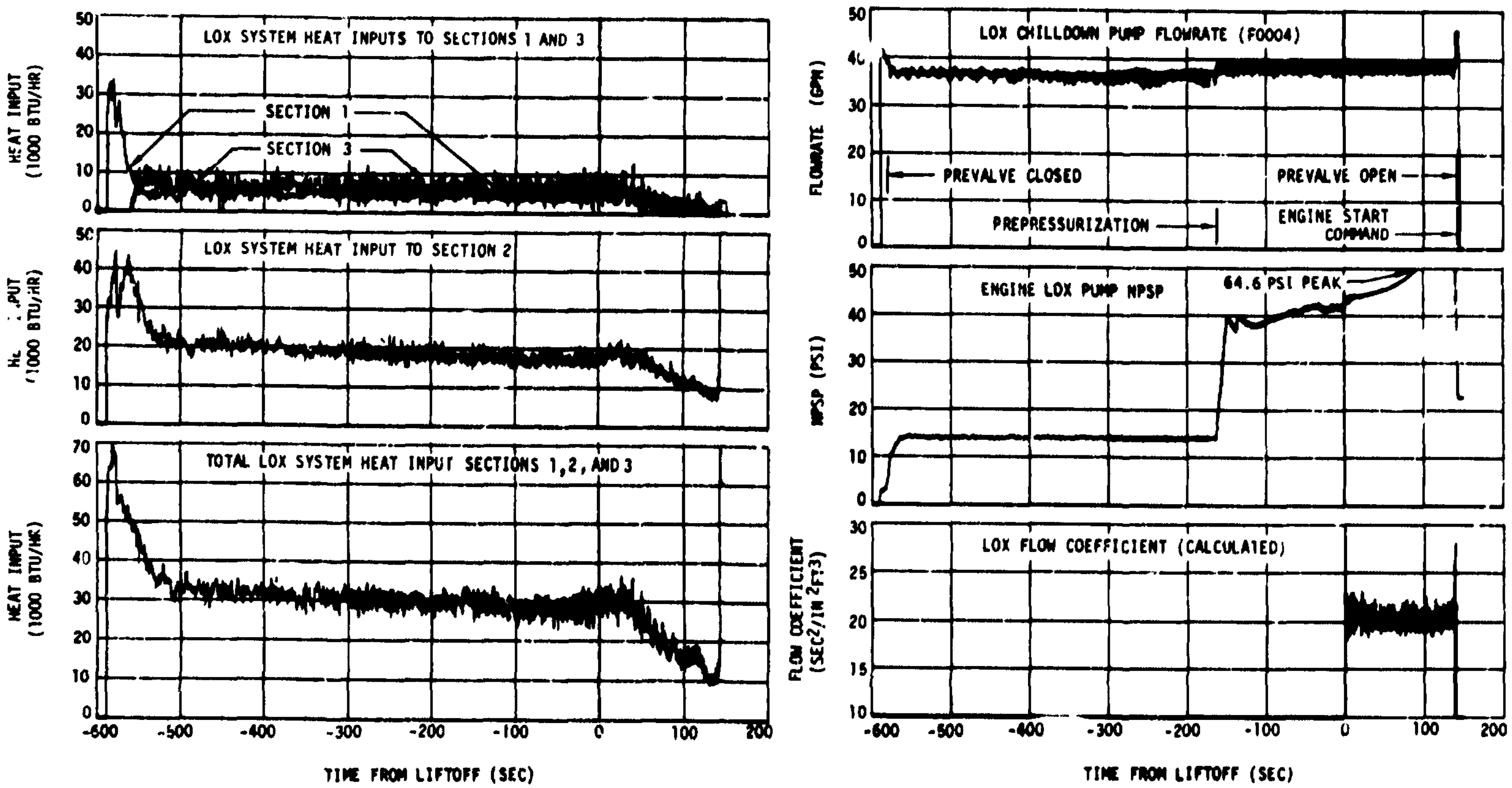


Figure 11-7. LOX Pump Chilldown Characteristics

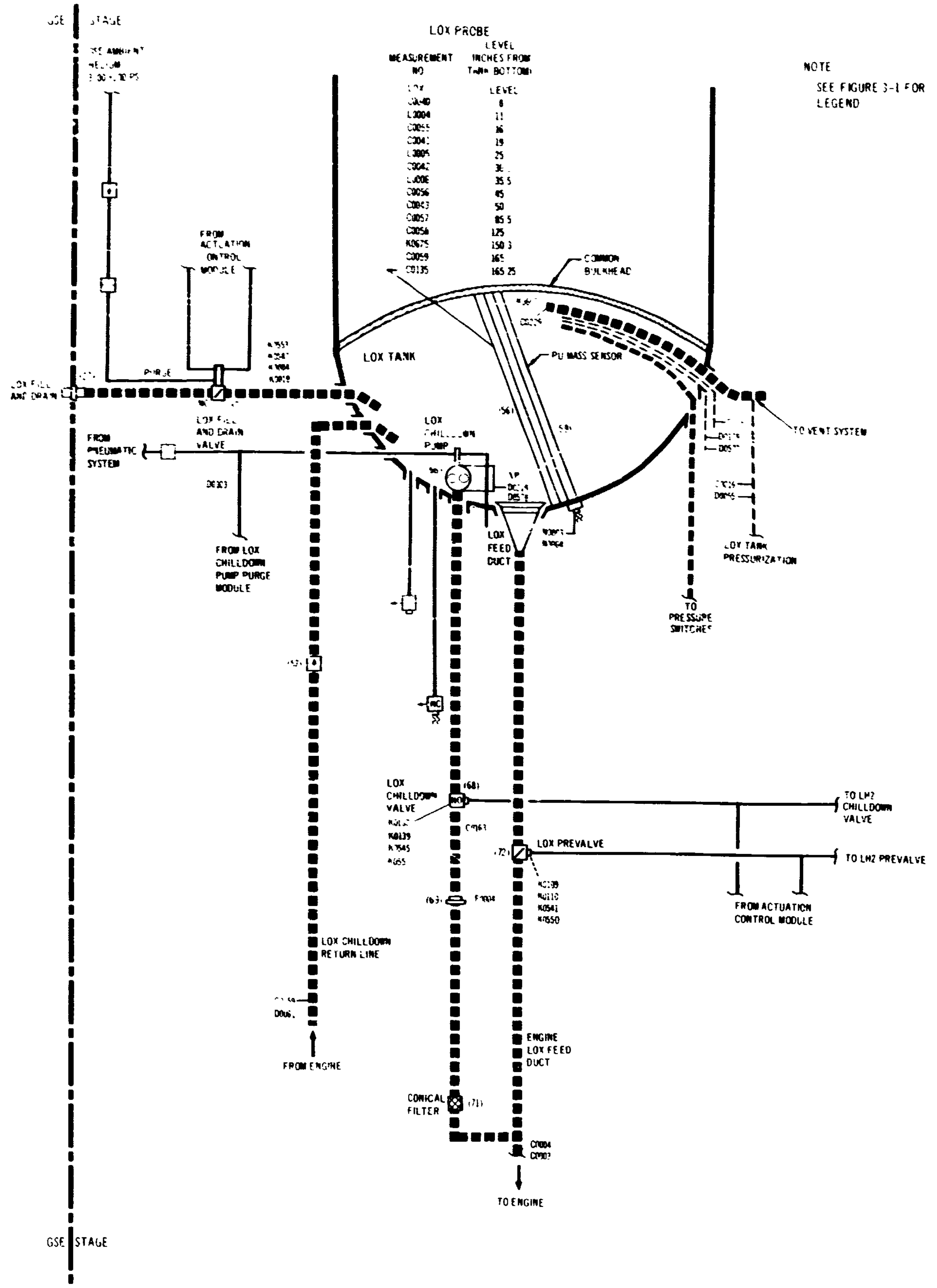


Figure 11-8. LOX Supply System

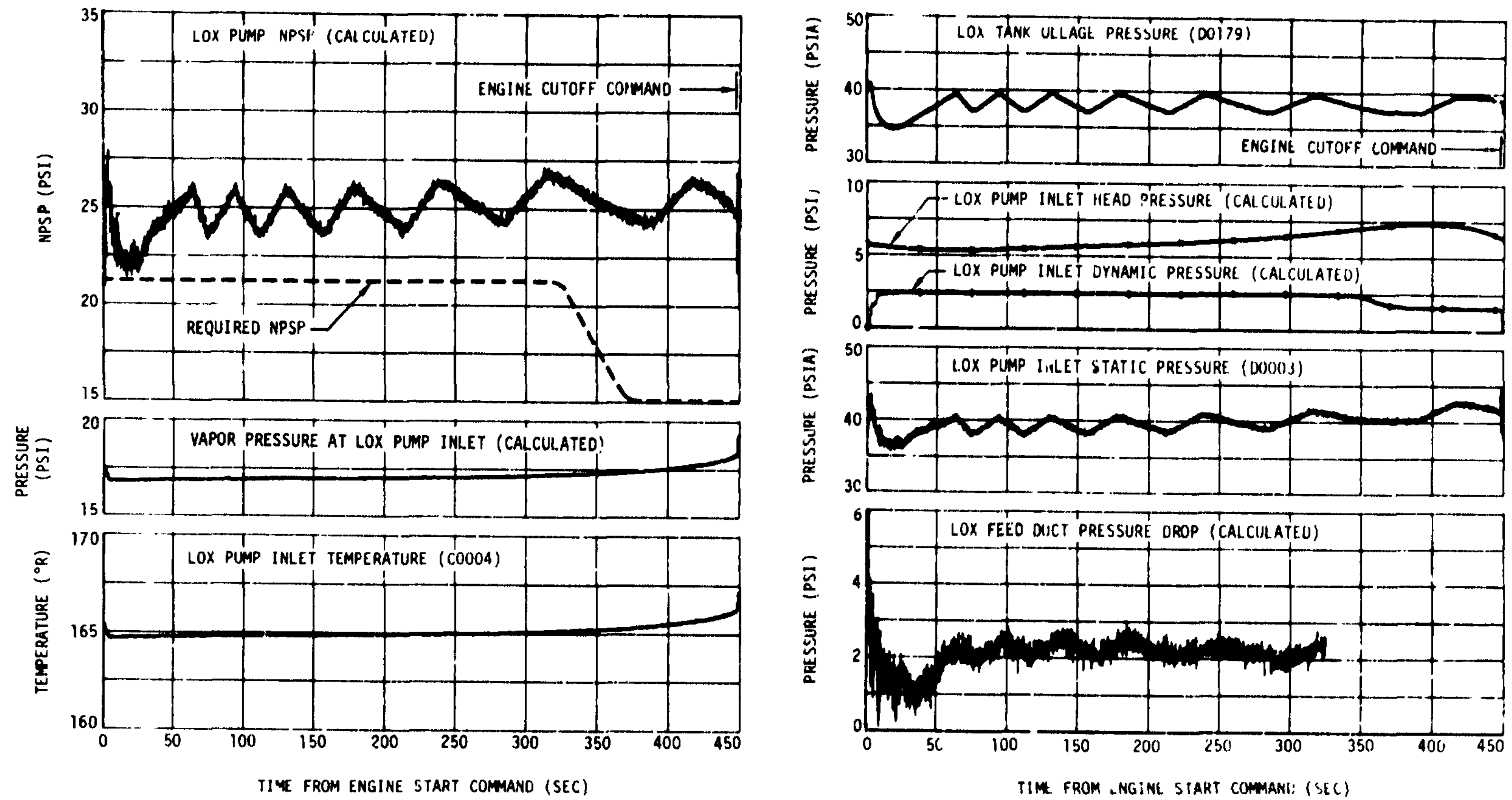


Figure 11-9. LOX Pump Inlet Conditions

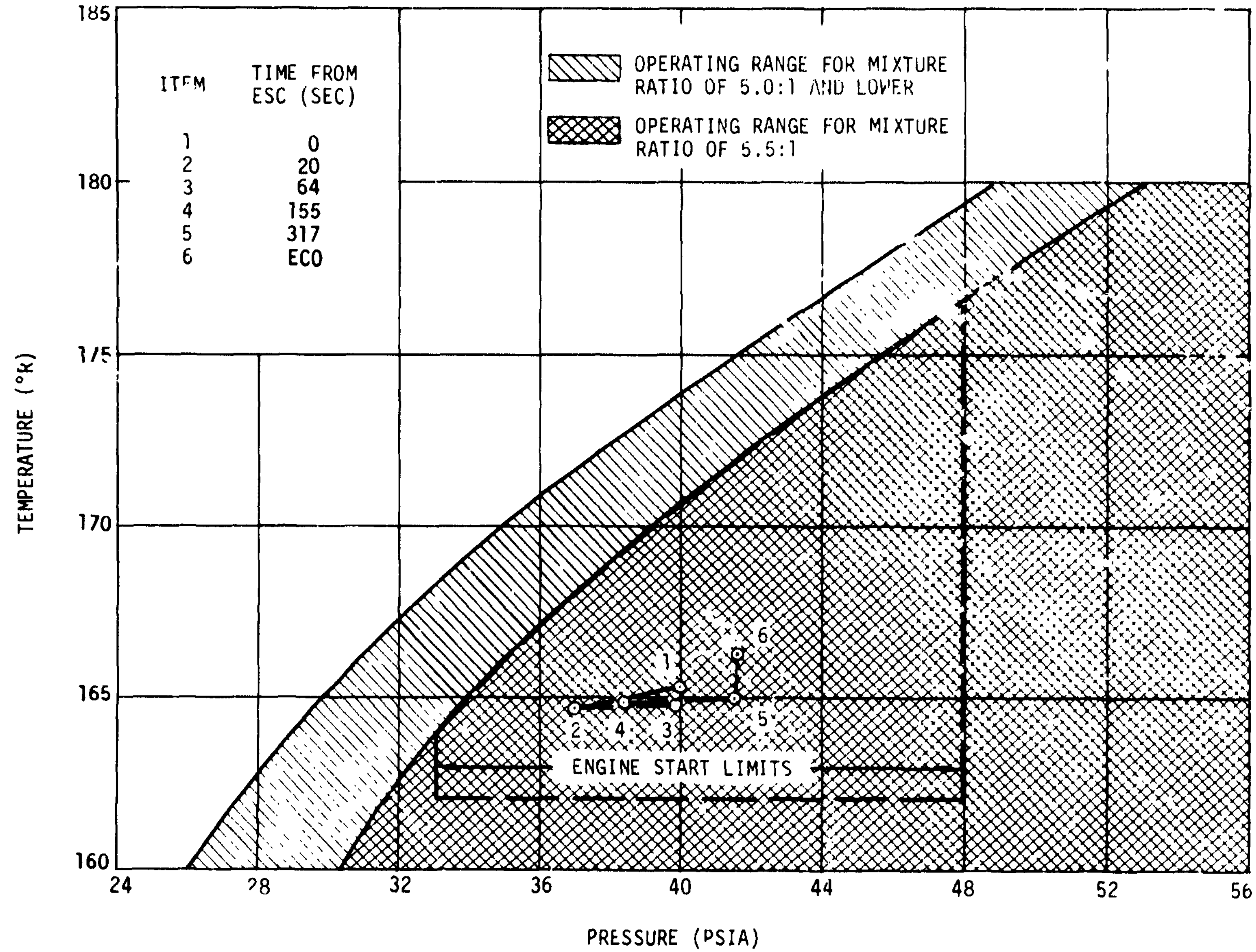


Figure 11-10. LOX Pump Inlet Conditions During Firing

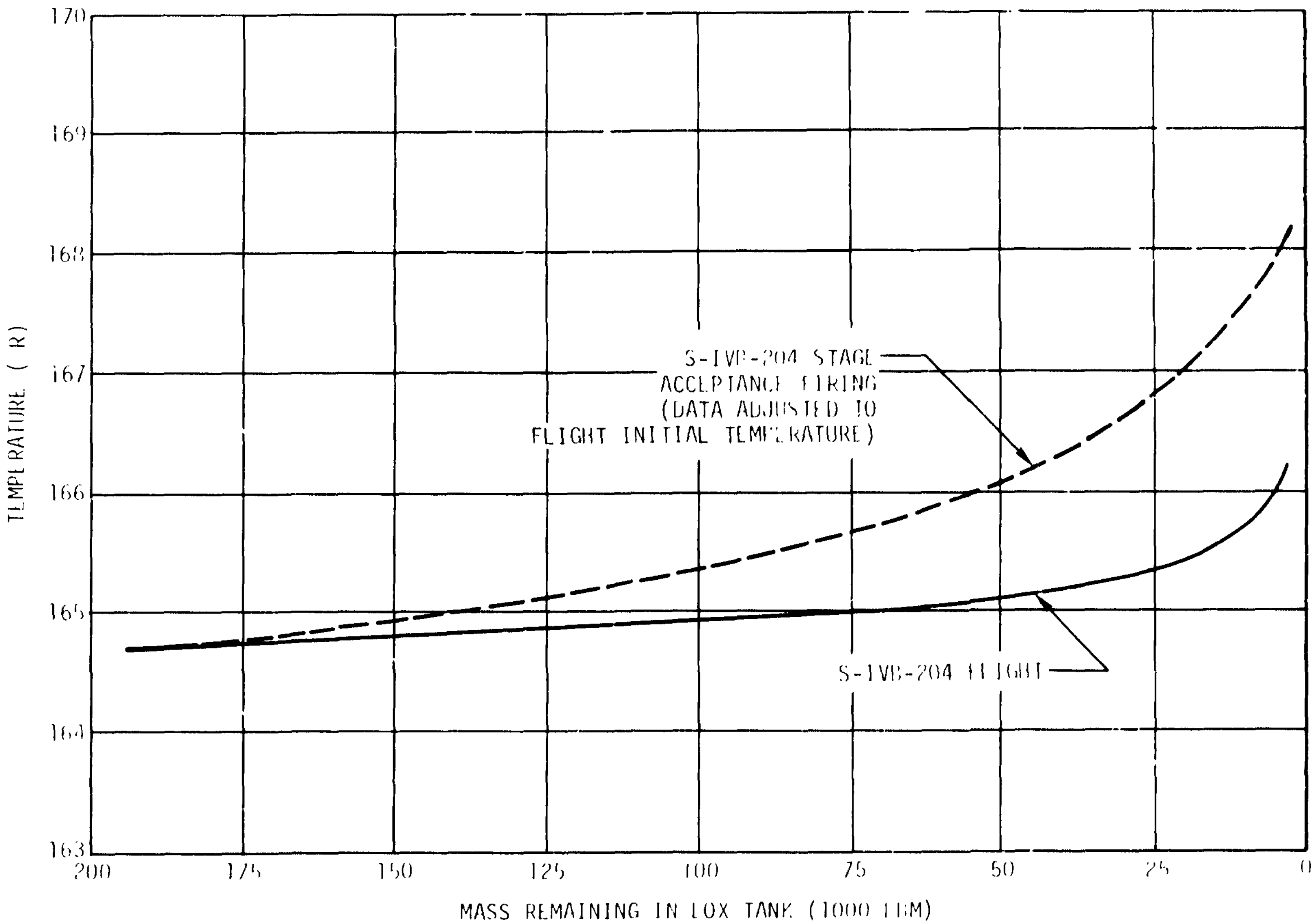


Figure 11-11. Effect of LOX Mass Level on LOX Pump Inlet Temperature

SECTION 12

FUEL SYSTEM

12. FUEL SYSTEM

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification.

12.1 Pressurization Control and Internal Environment

The LH2 tank pressurization system (figure 12-1) operated in all three phases (prepressurization, primary pressurization, and step pressurization) and satisfactorily controlled the LH2 tank ullage pressure for the duration of the powered flight phase.

12.1.1 Prepressurization

The LH2 tank was satisfactorily prepressurized with helium from GSE console model 438. Figure 12-2 presents the prepressurization data; table 12-1 compares S-IVB-204 data with that from S-IVB-202 flight. The LH2 prepressurization command was received at 113 sec prior to liftoff. The LH2 tank pressurized signal was received 46 sec later when the LH2 tank ullage pressure reached 33.7 psia. The ullage pressure continued to increase as the ullage warmed, reaching 36.4 psia at liftoff and 39.2 psia by Engine Start Command.

12.1.2 Pressurization

During engine operation, LH2 tank pressurization was satisfactorily accomplished by GH2 bleed from the J-2 engine (figures 9-1 and 12-1). Data are presented in figure 12-3 and compared to previous test data in table 12-2. Between Engine Start Command and ESC +2.7 sec, GH2 bleed from the engine flowed into the LH2 tank through the normal pressurization orifice, the control pressurization orifice, and the step pressurization orifice. This GH2 bleed, however, produced no noticeable increase in ullage pressure during this period.

When the control and step pressurization flow paths were closed, the ullage pressure began a normal decrease to a minimum of 35.4 psia at ESC +300 sec. The minimum tank pressure was 3.8 psia above the pressure required to initiate the overcontrol mode. The ullage pressure was higher than it was on the S-IVB-204 acceptance test because of two subsequent modifications: a 60 percent increase in the undercontrol orifice size and the addition of a nylon bag around the diffuser.

During S-IVB powered flight the GH2 pressurization flowrates were very near predictions. From Engine Start Command to Engine Cutoff Command, 357 lbm of GH2 were added to the ullage. The collapse factor increased from 0.82 to 0.88 during steady-state high engine mixture ratio (EMR) operation; it increased to 1.0 approximately 50 sec after EMR cutback during the step pressurization mode. This was caused by the venting of LH2 through the nonpropulsive vent (NPV) and is discussed in the following paragraph.

12.1.3 LH2 Tank Venting During Burn

LH2 tank venting occurred during the last 115 sec of powered flight (figure 12-4). The vented GH2 flowrate varied between 0.466 and 0.596 lbm/sec during the venting period; however, the data do not indicate whether the GH2 was vented through the vent and relief valve or through the relief valve. Based upon Douglas production testing, the crack pressure for the vent and relief valve and the relief valve were 38.5 psia and 39.5 psia, respectively. The LH2 tank ullage pressure was 39.2 psia when the venting began, and the calculated GH2 flowrate could have been vented by either of the two valves.

It is believed the relief was through the vent and relief valve. If the vented GH2 had passed through the vent and relief valve, the stroke of the valve main piston should have been sufficient to cause a loss of the closed valve position indication. The loss of the closed valve position indication was never received, however. Test data on the valve indicate the closed valve position microswitch may not be tripped if the tank pressure rise rate is less than 0.2 psi/sec. During flight, the pressure rise rate was 0.116 psi/sec. The indicated high relief pressure of 39.2 psia was found to be within the valve crack pressure range when the accuracy of instrumentation is considered. The quoted crack pressures have an accuracy range of ±0.6 psi while the ullage pressures have an accuracy of approximately +1.0 psia.

LH2 venting during the orbital phase is covered in paragraph 26.4.2.

12.2 LH2 Chilldown

The LH2 chilldown system performed satisfactorily. At Engine Start Command the net positive suction pressure (NPSP) at the pump inlet was well above the minimum requirement of 6.3 psi.

System temperatures and pressures and LH2 flowrate, as noted in figures 12-5 and 12-6, were used to determine pressure drops and heat inputs.

Chilldown was initiated at 598 sec prior to liftoff. During unpressurized chilldown, saturated conditions existed throughout the chilldown system. The chilldown flowrate stabilized before LH2 tank prepressurization and increased (off-scale-high) after prepressurization as vapor condensed and was replaced by liquid from the tank. The liquid entering the system was sufficiently subcooled after pressurization to absorb all the heat input to the system without vaporizing. This also explains the increase in pump inlet, bleed valve, and return line temperatures at the initiation of prepressurization. These temperature increases followed the saturation curve until the LH2 entering the tank became sufficiently subcooled to absorb the input from the tank to the respective transducer location without reaching saturation temperature.

When steady state conditions were achieved after prepressurization, subcooled LH2 at the pump inlet, bleed valve, and return line exit indicated subcooled liquid throughout the chilldown system.

After liftoff, chilldown pump outlet, engine pump inlet, bleed valve, and chilldown return line temperatures showed a decrease which continued until engine start. The pump inlet temperature was 39.4 deg R at liftoff and decreased during boost to 38.1 deg R at engine start. This decrease was greater than it was on S-IVB-201 and S-IVB-203 flights because the heat input rate from the tank to the LH2 pump inlet prior to liftoff was higher for S-IVB-204 flight.

During pressurized chilldown prior to liftoff, the NPSP was 19.4 psi. It increased during boost, as the acceleration head increased and the system temperatures decreased, to a maximum of 31.8 psi just prior to booster inboard engine cutoff. At S-IVB engine start it was 20.2 psi, which was well above the minimum requirement of 6.3 psi. Heat leakage into the fuel system is shown in figure 12-6 and is compared with the corresponding pre-liftoff data from S-IVB-201, -202, and -203 flights in table 12-3.

During boost, the bleed valve and return line temperatures also decreased due to decreasing heat inputs. Just prior to engine start, the total heat input rate to the system was approximately 27,000 Btu/hr.

12.3 Engine LH2 Supply

The engine LH2 supply system (figure 12-7) provided LH2 to the engine within specifications throughout the engine firing period. The minimum available NPSP during engine operation occurred at cutoff and was above the allowable minimum NPSP at that time. Figure 12-8 presents the data and calculated performance; table 12-4 compares the data to that of previous tests.

The LH2 pump inlet static pressure was 39.8 psia at engine start. It then followed the ullage pressure, reaching a minimum of 24.0 psia at ESC +300 sec. The pump inlet static pressure agreed closely with predicted values. The LH2 pump inlet temperature was 38.1 deg R at engine start. It decreased to 37.6 deg R after the start transient, then increased with time during engine operation to 40.1 deg R at Engine Cutoff Command. LH2 pump inlet pressure and temperature during engine operation are presented in figure 12-9 which shows that the engine LH2 pump inlet conditions were met satisfactorily throughout engine operation.

Figure 12-10 is a plot of the pump inlet temperature as a function of the propellant mass remaining within the LH2 tank and includes S-IVB-204 acceptance data for comparison. The data used for comparison have been biased to the LH2 pump inlet temperature observed at Engine Start Command of S-IVB-204 flight to correct for instrumentation error, different heating during pressurization, and other test-to-test variations. As the figure shows, the data from the two tests agree closely.

12.4 LH2 Behavior During Orbit

The LH2 began to move to the forward end of the tank after Engine Cutoff Command. The first indication of liquid at the forward bulkhead was noted at approximately ECC +120 sec, as indicated by the NPV temperatures which abruptly dropped to saturation while the ullage temperatures remained relatively high. The liquid and gas temperature probes in the LH2 tank indicated that the main liquid mass continued to migrate toward the forward dome during the next 720 sec (from RO +720 sec to RO +1,440 sec). An inverse temperature stratification of the ullage gas became apparent at approximately 3,300 sec after Engine Cutoff Command and became increasingly pronounced. The inverse temperature stratification is the result of the relocation of the liquid to the forward end of the tank and, therefore, corroborates the movement of the LH2. The initial liquid displacement was apparently induced by cutoff disturbances. The movement of the main liquid mass to the forward dome was probably due primarily to entrainment in the ullage gas moving towards the vent and secondarily to drag forces on the vehicle.

TABLE 12-1
LH2 TANK PREPRESSURIZATION DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-202 FLIGHT
Prepressurization duration (sec)	4[illegible].0	67.0
Helium mass added (lbm)	25.0	35.0
Ullage pressure		
At prepressurization initiation (psia)	16.24	15.8
At prepressurization termination (psia)	33.7	36.9
At liftoff (psia)	36.4	37.7
At Engine Start Command (psia)	39.2	41.0
Rate of increase after prepressurization (psi/min)	1.58	1.31
Events (sec from liftoff)		
Prepressurization initiation	-113.0	-110.0
Prepressurization termination	-67.0	-43.0
Engine Start Command	144.9	144.6

TABLE 12-2
LH2 TANK PRESSURIZATION DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-202 FLIGHT
Pressure switch setting		
Lower (psia)	33.5	28.5
Upper (psia)	31.6	30.5
Ullage pressure		
At Engine Start Command (psia)	39.2	41.0
At Engine Cutoff Command (psia)	38.7	41.2
GH2 pressurant flowrate		
Undercontrol (lbm/sec)	0.61	0.35
Overcontrol (lbm/sec)	*	0.57
Step before cutback (lbm/sec)	1.27	1.18
Step after cutback (lbm/sec)	1.13	1.05
Total GH2 added (lbm)	357.0	281.0
Events (sec from ESC)		
Step pressurization	300.2	300.0
Relief valve opening	333.0	**

*The overcontrol mode was not required during S-IVB-204 powered flight.

**Relief valve did not open.

TABLE 12-3 (Sheet 1 of 2)
LH2 CHILLDOWN SYSTEM PERFORMANCE DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
NPSP			
At Engine Start Command (psi)	20.18	13.5	21.8
Minimum required at engine start (psi)	6.3	6.3	6.3
At opening of prevalve (psi)	20.54	N/A	N/A
Fuel pump inlet conditions at Engine Start Command			
Pressure (psia)	39.83	36.5	41.0
Temperature (deg R)	38.08	39.0	38.2
Amount of subcooling (deg R)	5.40	3.8	5.5
Average flow coefficient ($sec^2/in.^2-ft^3$)	17.1	15.9	10.8
Fuel quality in sections* 2 and 3 (lbm gas/lbm mixture)			
Maximum during unpressurized chilldown	0.057	0.022	0.06
Heat absorption rate during unpressurized chilldown			
Section 1* (Btu/hr)	25,500	25,000	24,000
Sections 2 and 3* (Btu/hr)	31,500	16,000	40,000
Total (Btu/hr)	57,000	41,000	64,000

N/A = Not available.

*Section 1 is tank to pump inlet; section 2 is pump inlet to bleed valve; section 3 is bleed valve to tank.

TABLE 12-3 (Sheet 2 of 2)
LH2 CHILLDOWN SYSTEM PERFORMANCE DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Heat absorption rate during pressurized childown			
Section 1 (Btu/hr)	27,500	30,000	31,000
Section 2 (Btu/hr)	27,500	3,000	6,000
Section 3 (Btu/hr)	5,000	24,000	17,000
Total (Btu/hr)	60,000	57,000	54,000
Chilldown flowrate			
Unpressurized (gpm)	86	111	89
Pressurized (gpm)	145	148	147.5
Chilldown pump pressure differential			
Unpressurized (psi)	N/A	N/A	6.7
Pressurized (psi)	7.8	7.5	5.5
Events (sec from liftoff)			
Chilldown initiation	-598.107	-650	-869
Prevalve closed	-582.170	-652	-591
Prepressurization initiation	-112.409	-112	-110
Prevalve Open Command	140.269	N/A	N/A
Prevalve closed signal dropout	141.288	N/A	N/A
Prevalve open signal pickup	143.088	142.6	143
Delay between prevalve Open Command and pickup of open signal	2.819	N/A	N/A
Chilldown shutoff valve closed	568.071	144	145.2
Engine Start Command (K0021)	144.905	143.9	144.6

N/A = Not available.

TABLE 12-4
LH2 PUMP INLET CONDITION DATA

PARAMETER	S-IVB-204 FLIGHT	S-IVB-203 FLIGHT	S-IVB-202 FLIGHT
Pump inlet conditions			
Static pressure at engine start (psia)	39.8	36.5	41.0
Temperature at engine start (deg R)	38.1	39.0	38.2
Temperature at engine cutoff (deg R)	40.1	38.8	40.1
NPSP			
Required at engine start (psi)	6.3	6.3	6.3
Available at Engine Start Command (psi)	20.2	13.5	21.8
Maximum during flight (psi)	22.0	25.0	22.0
Minimum during flight (psi)	14.5	10.0	7.3
At Engine Cutoff Command (psi)	14.5	10.0	15.0
LH2 feed duct			
At high EMR			
Pressure drop (psi)	0.8	*	1.7
Flowrate (lbm/sec)	76	80	79
After EMR cutback**			
Pressure drop (psi)	0.7	-	1.[illegible]
Flowrate (lbm/sec)	72	-	72

*Not calculated.

**On S-IVB-203 flight, there was no EMR cutback.

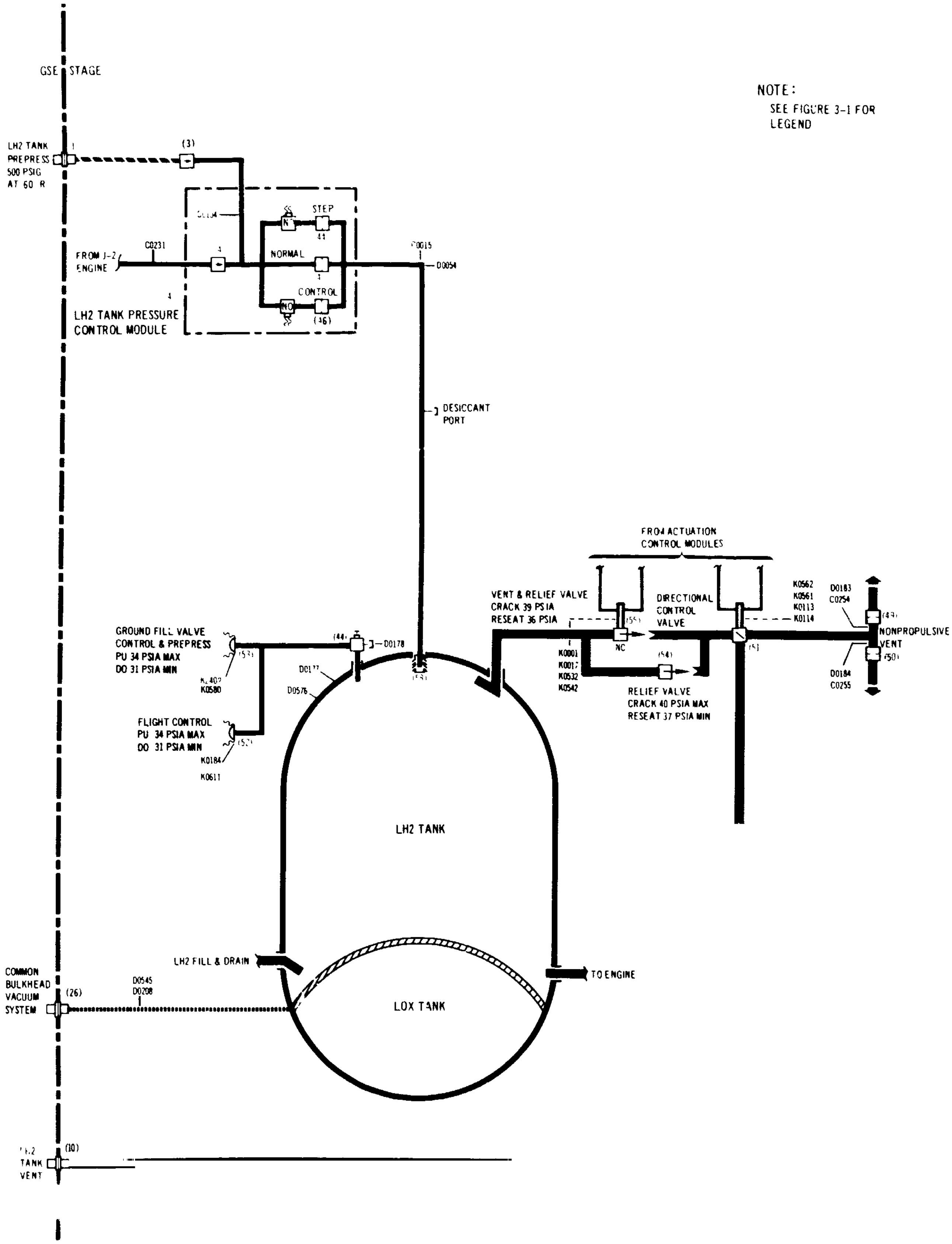


Figure 12-1. LH2 Tank Pressurization System

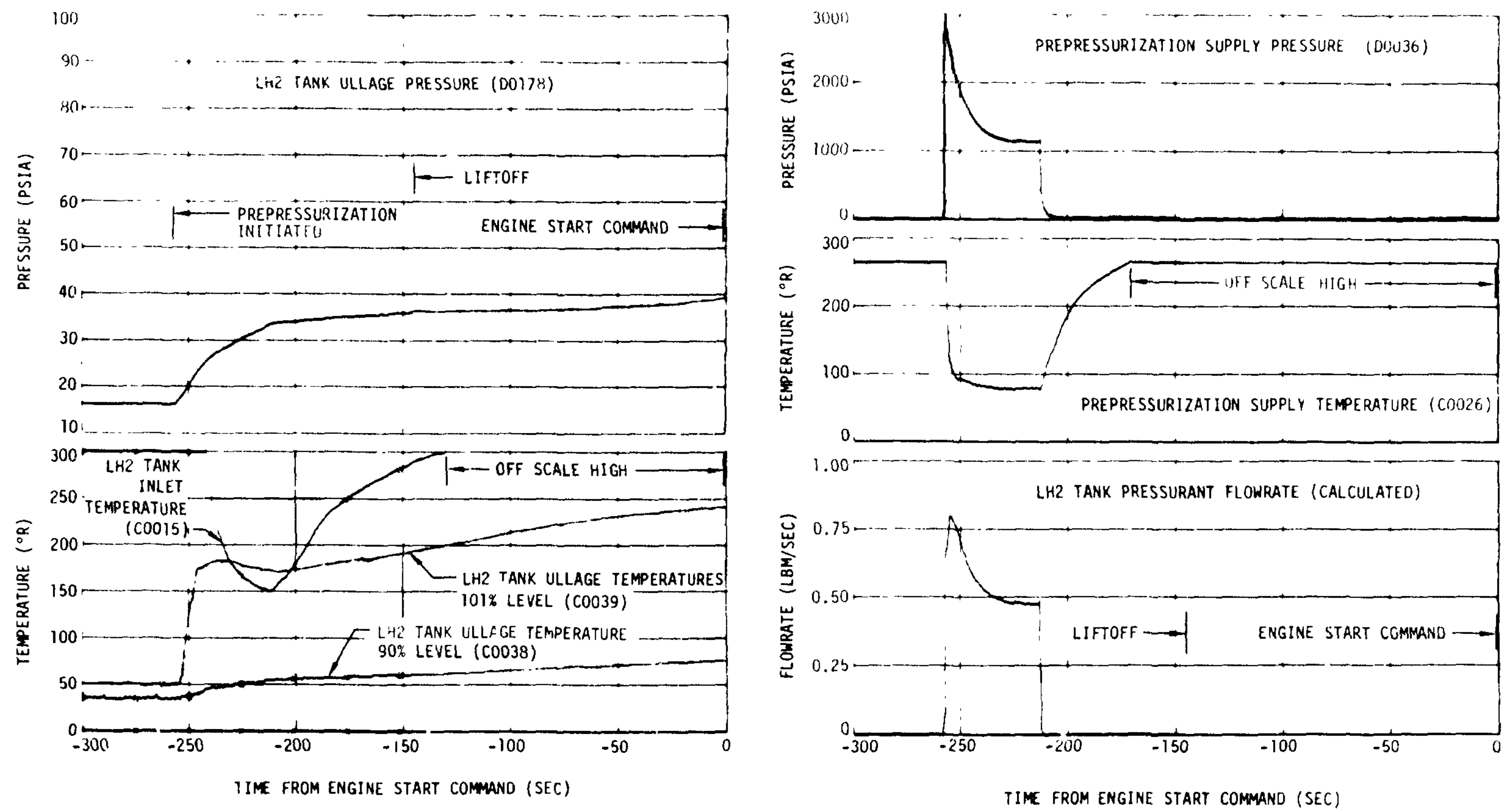


Figure 12-2. LH2 Tank Prepressurization System Performance

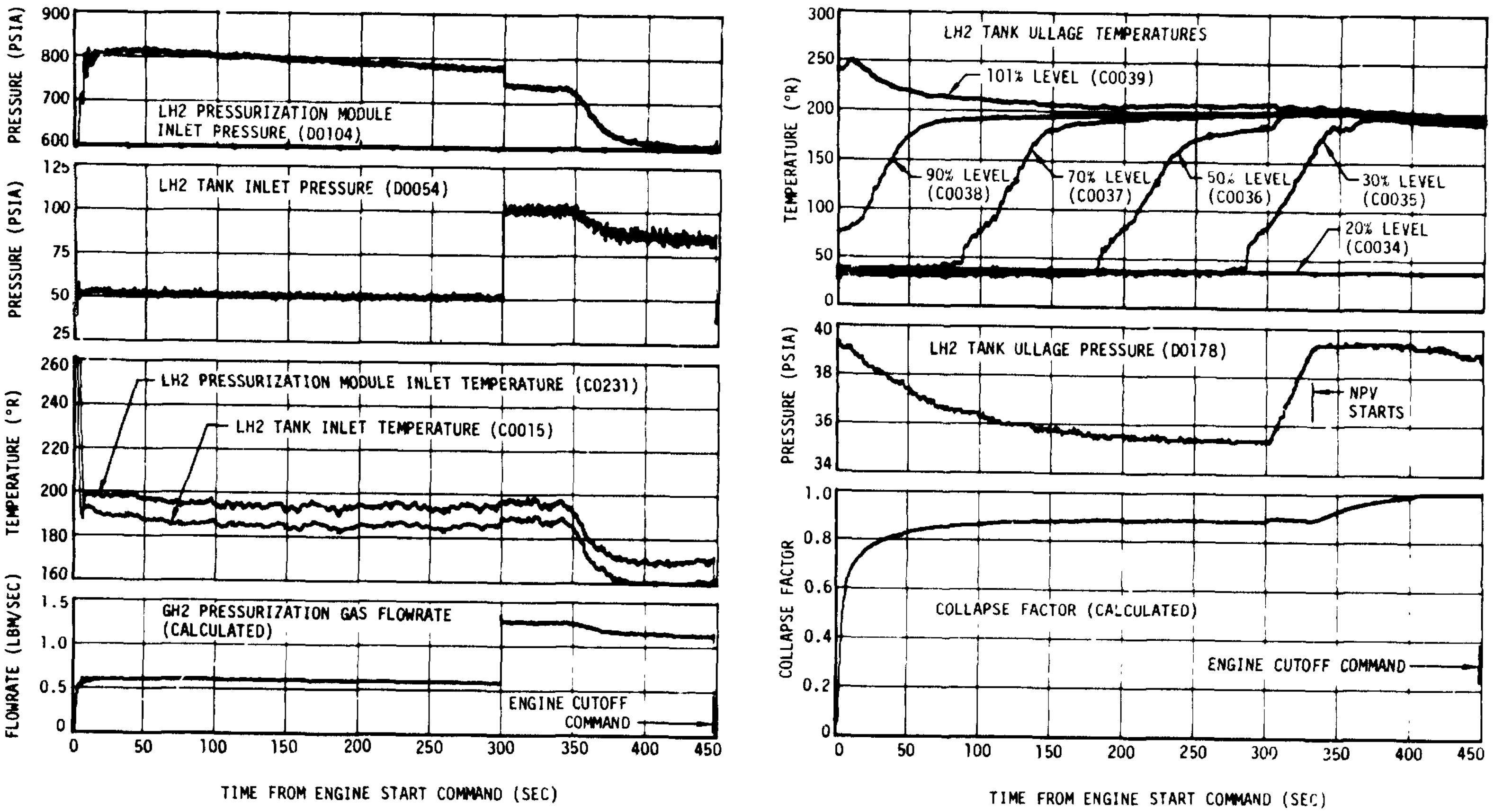


Figure 12-3. LH2 Tank Pressurization System Performance

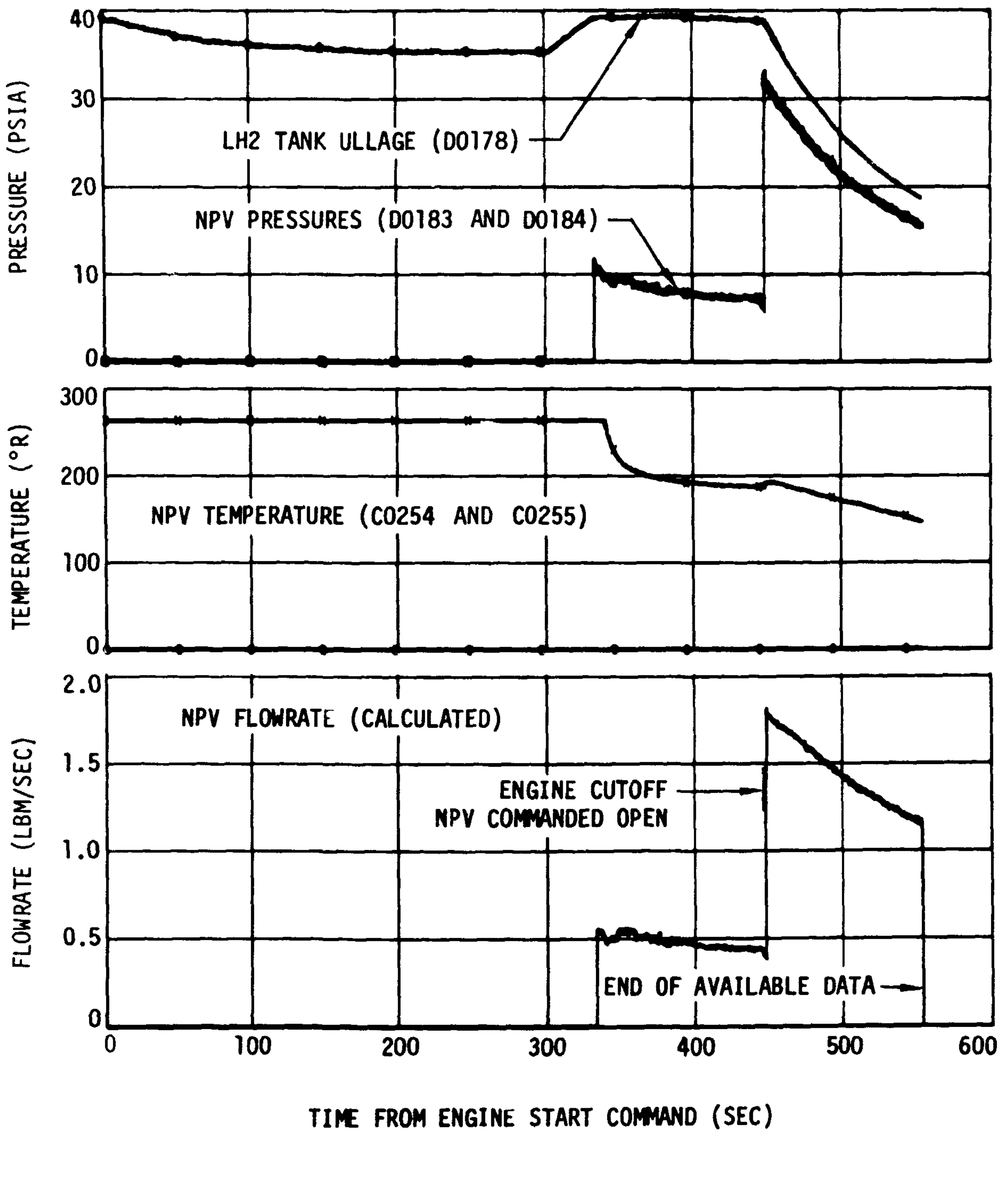


Figure 12-4. LH2 Tank Venting During Engine Operation

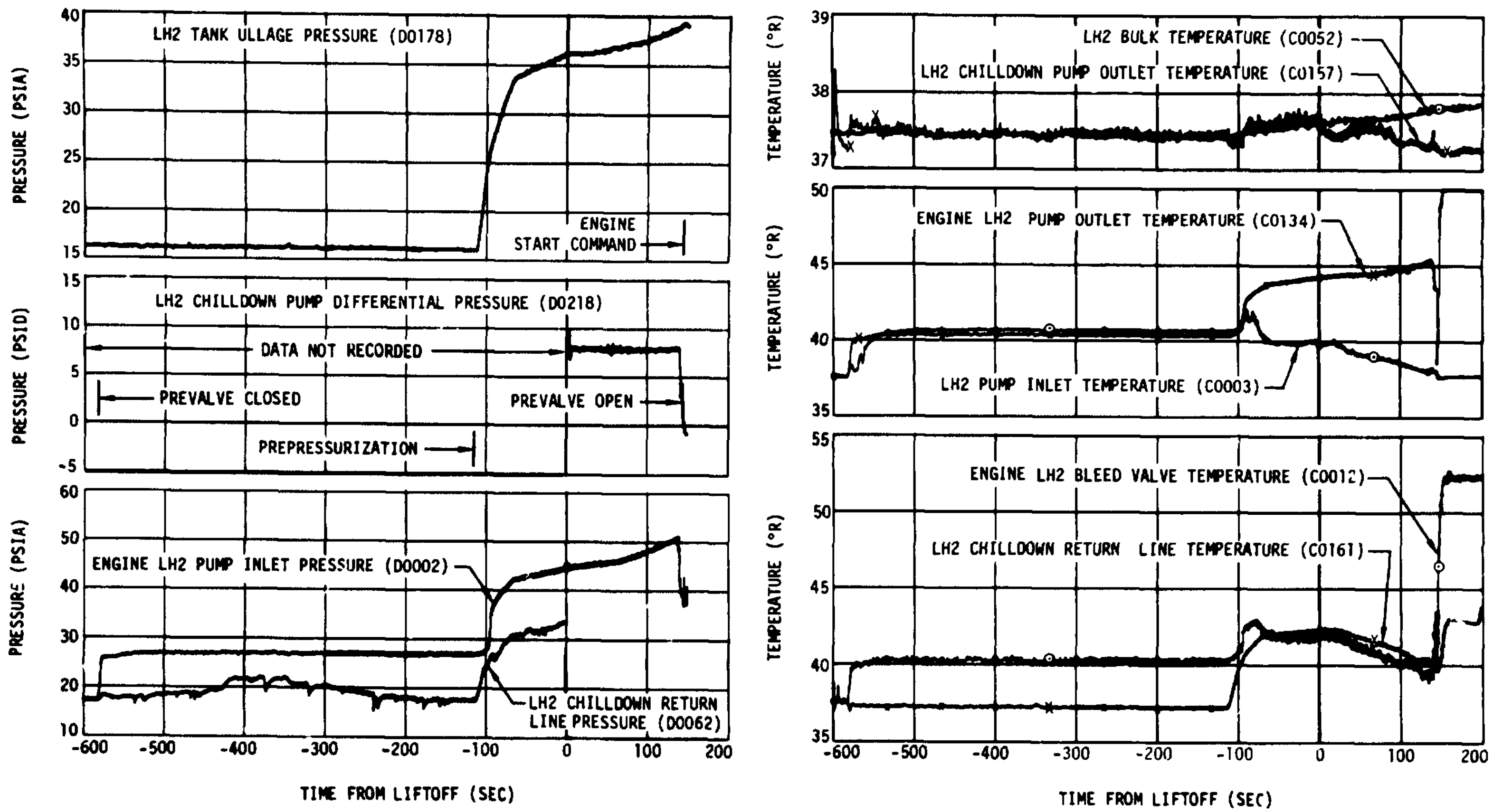


Figure 12-5. LH2 Pump Chilldown Operation

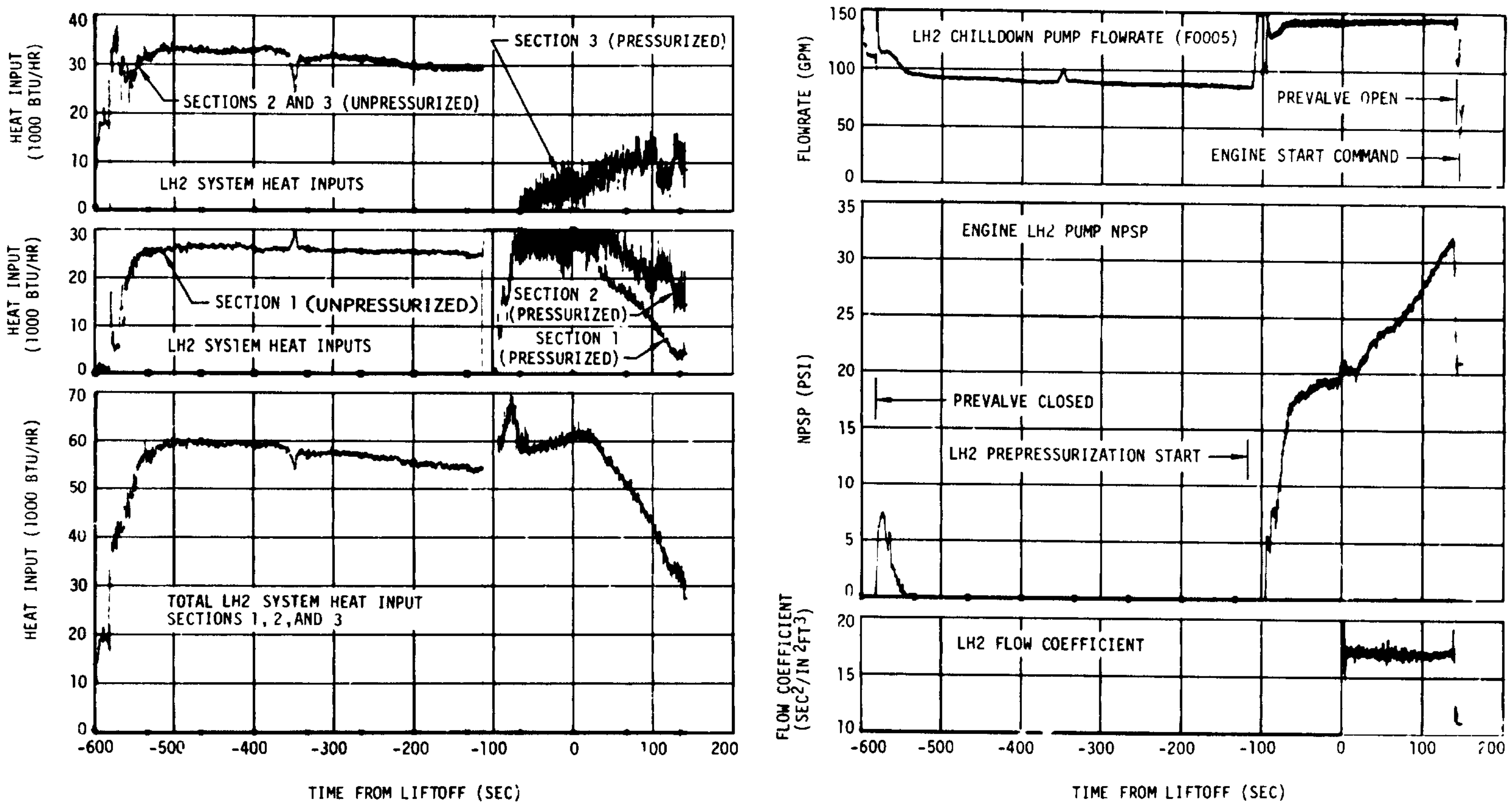
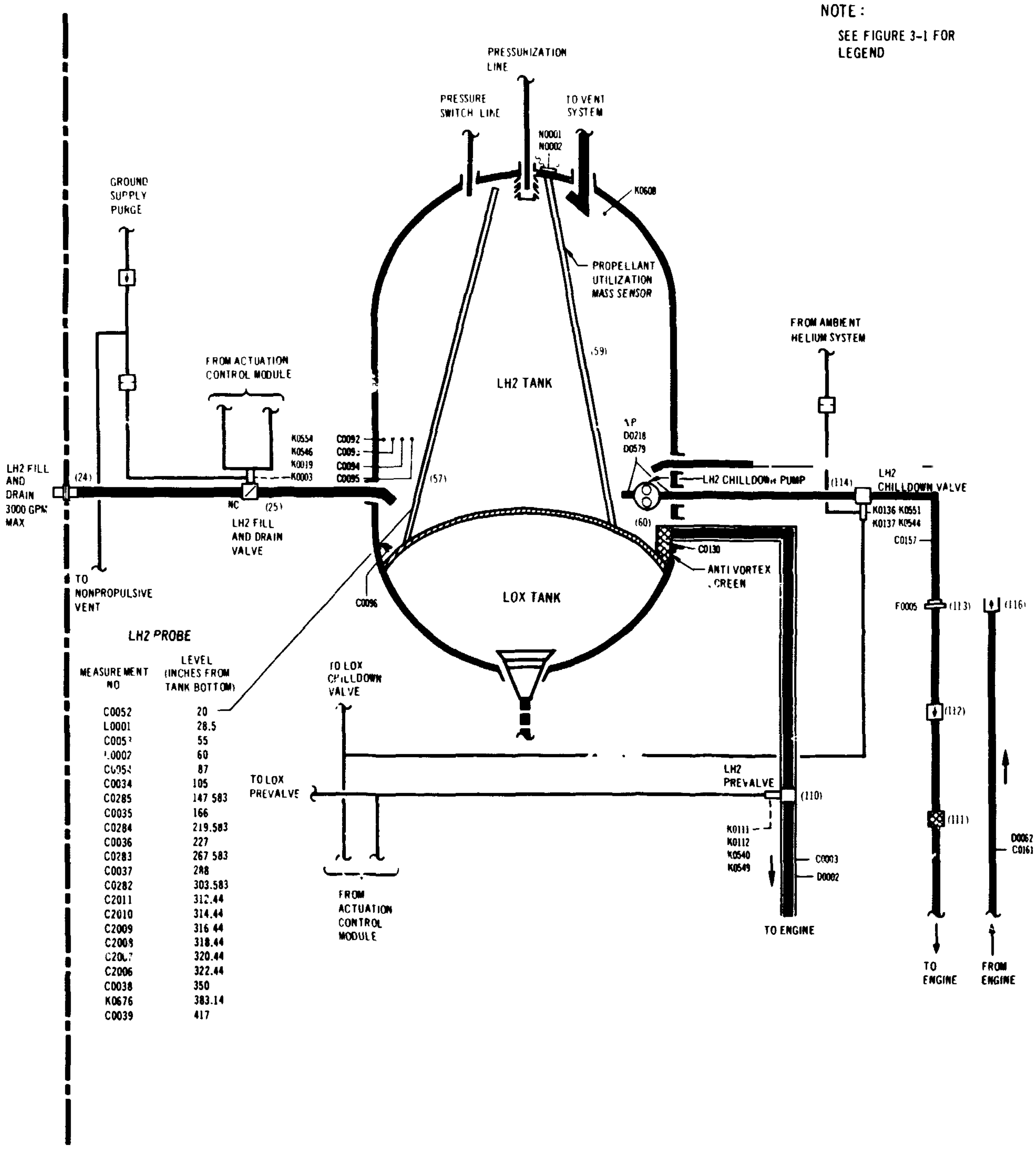


Figure 12-6. LH2 Pump Chilldown Characteristics



LH2 PROBE

MEASUREMENT NO	LEVEL (INCHES FROM TANK BOTTOM)
C0052	20
L0001	28.5
C0053	55
L0002	60
C0054	87
C0034	105
C0285	147 583
C0035	166
C0284	219.583
C0036	227
C0283	267 583
C0037	288
C0282	303.583
C2011	312.44
C2010	314.44
C2009	316 44
C2008	318.44
C2007	320.44
C2006	322.44
C0038	350
K0676	383.14
C0039	417

Figure 12-7. LH2 Supply System

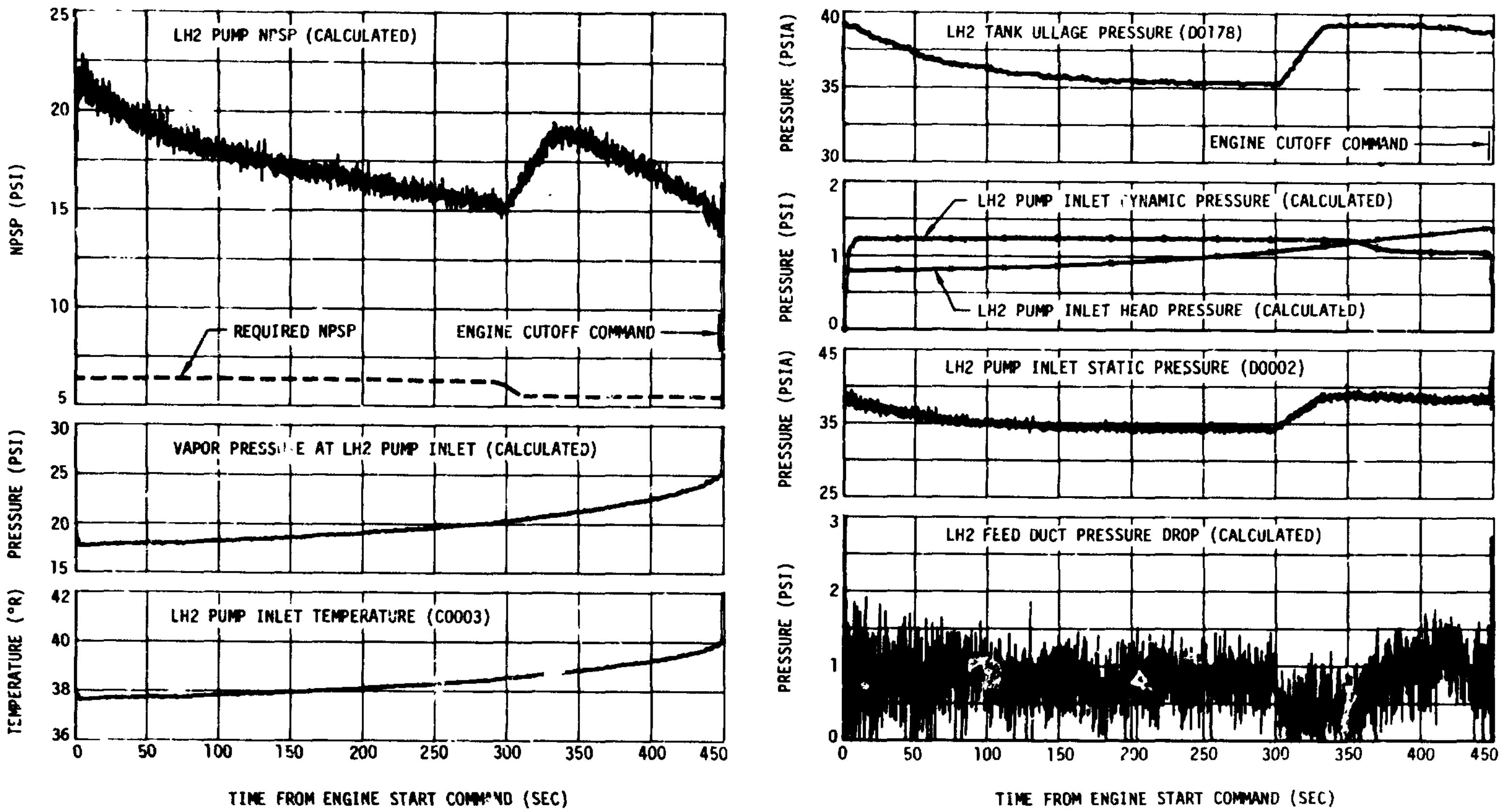


Figure 12-3. LH2 Pump Inlet Conditions

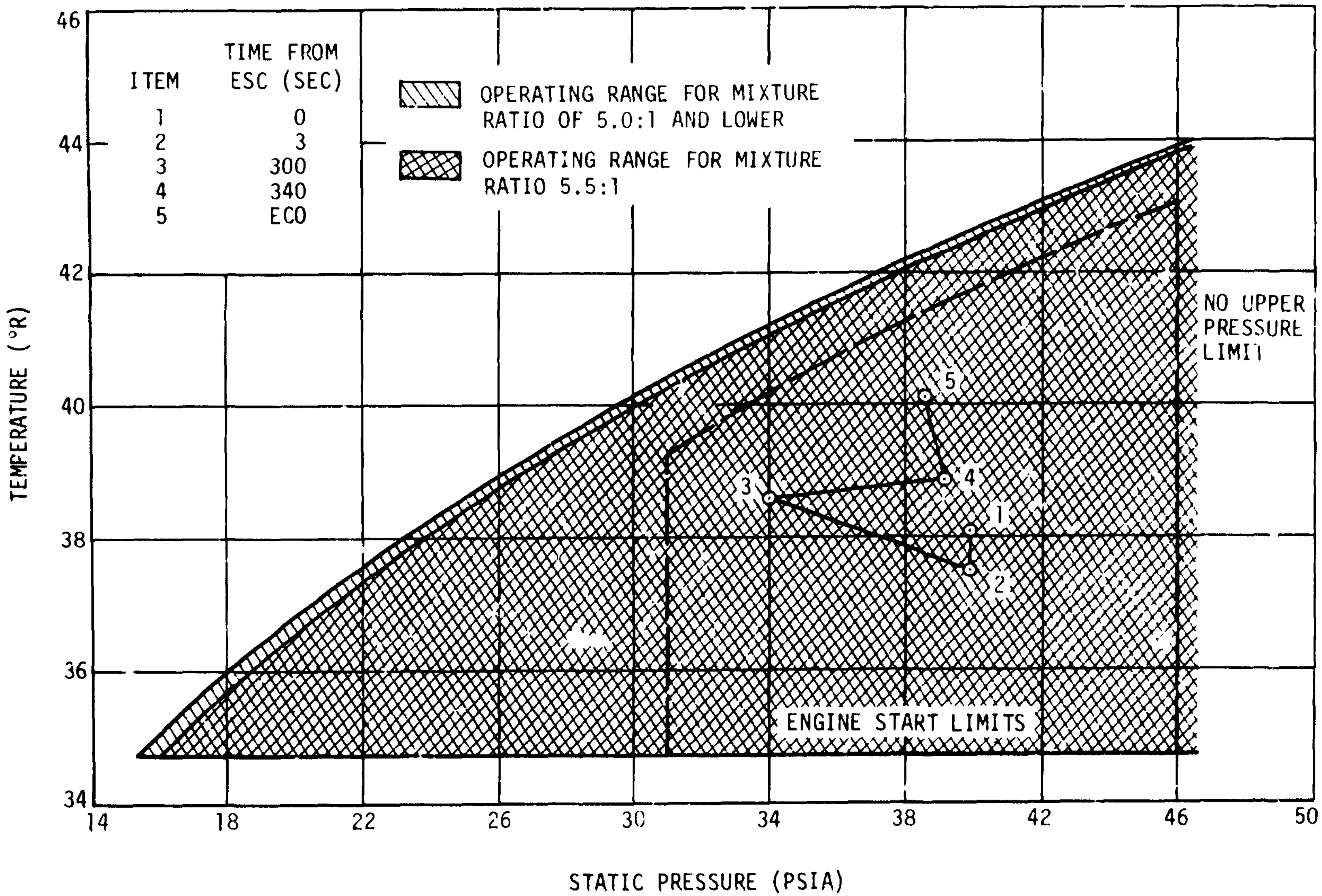


Figure 12-9. LH2 Pump Inlet Conditions During Firing

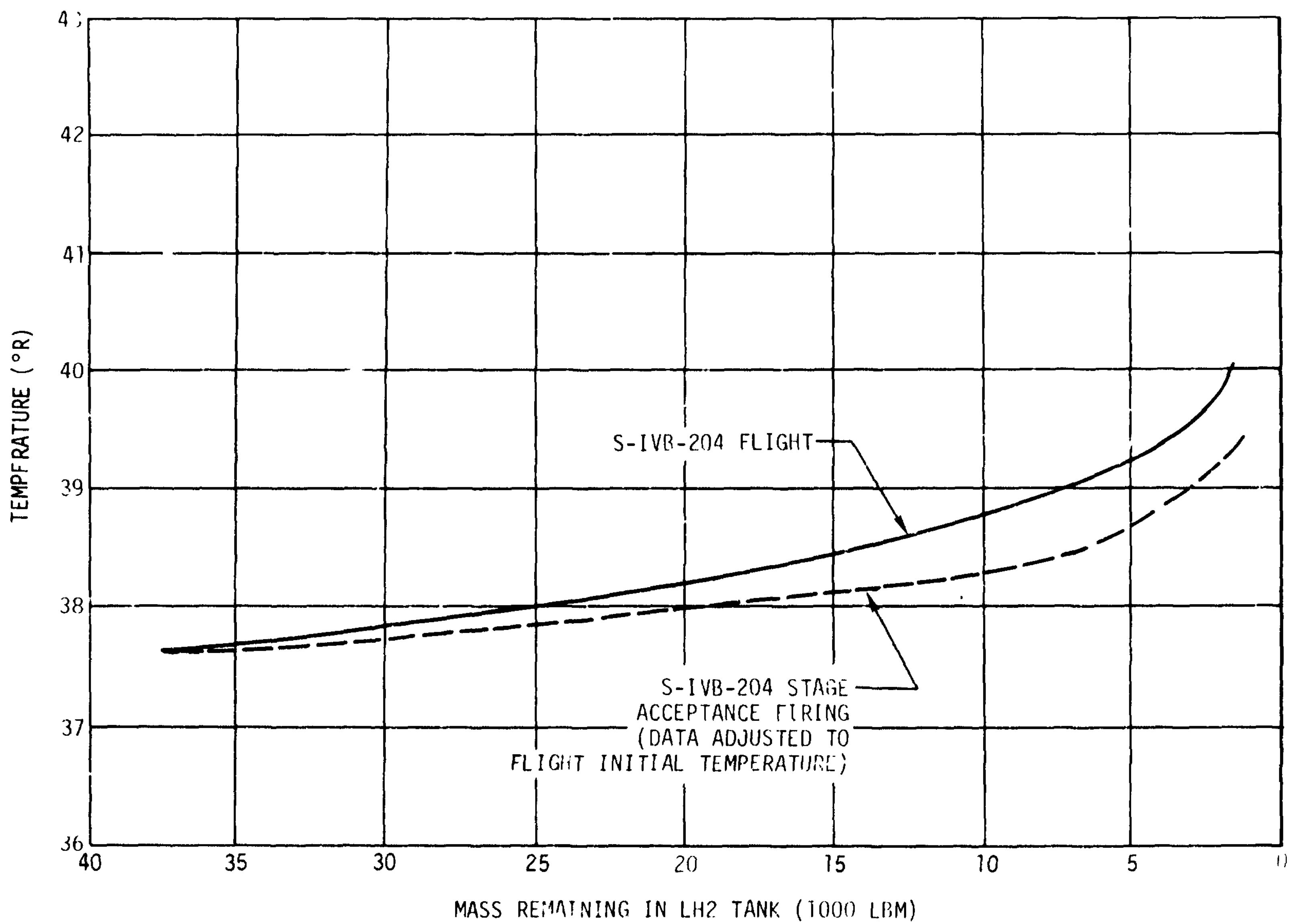


Figure 12-10. Effect of LH2 Mass Level on LH2 Pump Inlet Temperature

SECTION 13

AUXILIARY PROPULSION SYSTEM

13. AUXILIARY PROPULSION SYSTEM

The auxiliary propulsion system (APS) data during orbital flight indicate that the two APS modules operated normally. The individual engines performed as expected, and the data agreed with the engine manufacturer's test data obtained at simulated altitude conditions. The pulsing sequences of the six engines indicate that the modules were functioning as required to perform the attitude corrections desired.

Approximately 1 sec after S-IB outboard engine cutoff, the APS was activated to provide roll control during the S-IVB-204 powered flight. Roll control required 79 pulses each from engines 1-3 and 2-3 to correct for a positive roll disturbance.

During S-IVB powered flight, APS module No. 1 consumed 2.7 lbm of propellant and provided 600 lbf-sec of impulse which resulted in a specific impulse of 222 sec. During the same period, APS module No. 2 consumed 3.0 lbm of propellant and provided 591 lbf-sec of impulse, which resulted in a specific impulse of 197 sec.

At S-IVB engine cutoff, the APS pitch and yaw control were activated to maintain the vehicle in the desired attitude. After this time, the two APS modules functioned to compensate for induced disturbances and to maneuver the vehicle. Figure 13-1 shows the APS and associated instrumentation.

13.1 APS Module No. 1

The module No. 1 oxidizer system, fuel system, and helium pressurization system operated normally; and no difficulties were encountered. Figure 13-2 and table 13-1 present the bellows extension, oxidizer and fuel quantities and temperatures, and the helium pressurization data for the flight. The agreement between the two methods of calculating helium usage substantiates the accuracy of the bellows extensions as well as the helium sphere conditions.

The overall mixture ratio for module No. 1 was 1.60 to 1 (oxidizer to fuel), which agrees well with the expected nominal of 1.65 to 1. After achieving altitude reference pressure, the regulator outlet pressure was nominal, varying from 197 to 199 psia. The desired range is 196 ±3 psia.

13.2 APS Module No. 2

The module No. 2 oxidizer system, fuel system, and helium pressurization system also operated normally and without difficulties. Figure 13-2 and table 13-1 presents the bellows extension, oxidizer and fuel quantities and temperatures, and the helium pressurization data from the flight. Although the fuel quantity potentiometer data were noisy, the data level was easily distinguished. As in the case of module No. 1, the helium usage was determined by two methods which agreed very well, thus substantiating the accuracy of the bellows extensions and the helium sphere conditions recorded.

The overall mixture ratio of module No. 2 during flight was 1.55 to 1, which agrees well with the expected nominal of 1.65 to 1. After achieving altitude reference pressure, the regulator outlet pressure for this module varied from 194 to 196 psia which was within the 196 ±3 psia requirement.

13.3 Engine Performance

Since the minimum impulse bit duration of the APS engines is 0.065 sec, data used in the evaluation of engine performance must be recorded continuously. The only APS engine data from the S-IVB-204 flight meeting this requirement were the engine chamber pressures. By integrating the chamber pressure (P_c) and multiplying by the thrust coefficient (C_f) and the throat area (A_t), the total impulse for each pulse of an engine was determined.

The specific impulse of the APS modules was calculated by dividing the total impulse of a module during a period of continuous data by the propellant consumption of that module during the same period (table 13-2).

Since no data were obtained during portions of the mission, the total impulse supplied by the APS during these periods was calculated utilizing the propellant consumption and an average specific impulse of 213 sec. Figure 13-3 shows the accumulative total impulse of each module as a function of mission time. The values shown in this figure include both the impulse calculated from available data and that approximated by the aforementioned method. Module No. 1 supplied 8,230 lb-sec, and module No. 2 supplied 7,650 lb-sec.

The first pulses on engines 1-3 and 2-3 indicated steady-state chamber pressures of 100 to 104 psia. These levels were attained with propellant supply pressures of approximately 205 to 210 psia which are a result of system lockup with the regulators referenced to sea level pressure. After the supply pressure had stabilized to altitude conditions (regulator referenced to altitude pressure) of approximately 190 psia, the steady-state chamber pressures were in the 93 to 95 psia range, as expected. No degradation in chamber pressures was noted throughout the powered flight or orbital coast phase. Figure 13-4 shows typical chamber pressure traces at various times during the flight. These traces are of minimum pulses, approximately 55 ms in duration (10 percent chamber pressure to 10 percent chamber pressure). Figure 13-5 shows the thrust level of the engines throughout the mission and the impulse of the engines as a function of pulse width.

TABLE 13-1
APS DATA

PARAMETER	MODULE 1		MODULE 2	
	INITIALLY	AT 22,680 SEC	INITIALLY	AT 22,680 SEC
Oxidizer				
Bellows extension (in.)	9.85	4.18	9.85	4.54
Temperature (deg R)	552	535	540	526
Mass (lbm)	39.2	16.8	39.5	18.4
Usage (lbm)	--	22.3 (57%)	--	21.1 (53%)
Fuel				
Bellows extension (in.)	9.78	4.05	9.78	4.22
Temperature	546	542	539	537
Mass (lbm)	23.8	9.9	23.9	10.3
Usage (lbm)	--	13.9 (58%)	--	13.6 (57%)
Helium				
Pressure (psia)	2,990	2,200	2,980	2,210
Temperature (deg R)	551	535	540	527
Mass (lbm)	0.293	0.228	0.297	0.232
Usage (lbm)	--	0.065	--	0.065
Usage calculated by change in volume (lbm)	--	0.066	--	0.063

TABLE 13-2
APS MODULE SPECIFIC IMPULSE

SPECIFIC IMPULSE	UNITS	MODULE NO. 1	MODULE NO. 2
First orbit (Guaymas through Canary Islands)	sec	223	216
Second orbit (Guaymas through Redstone)	sec	204	175
Third orbit (Guaymas through Bermuda)	sec	193	230
Average* specific impulse	sec	227	220

*Based on overall propellant consumption and total impulse.

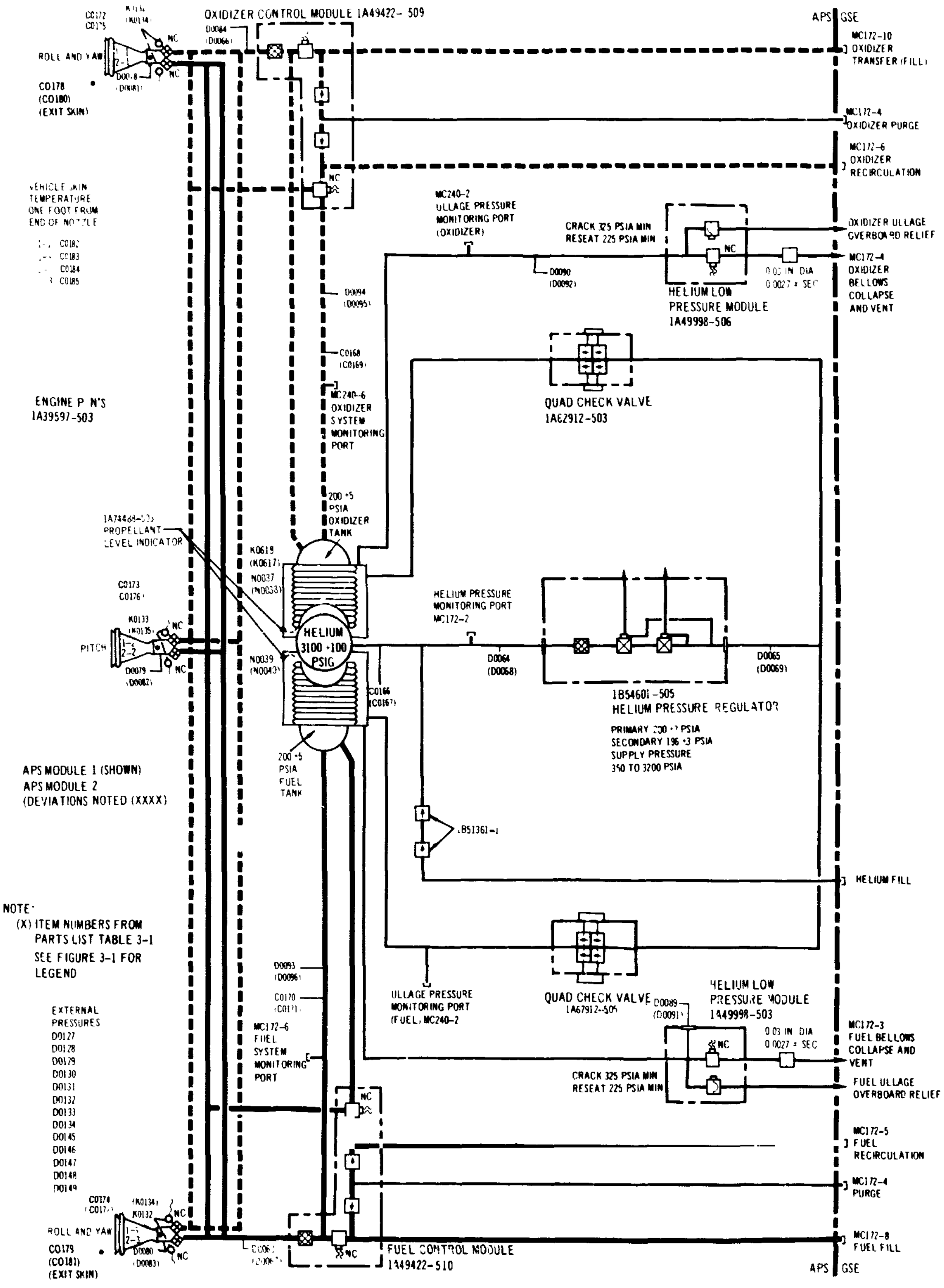


Figure 13-1. Auxiliary Propulsion System and Instrumentation

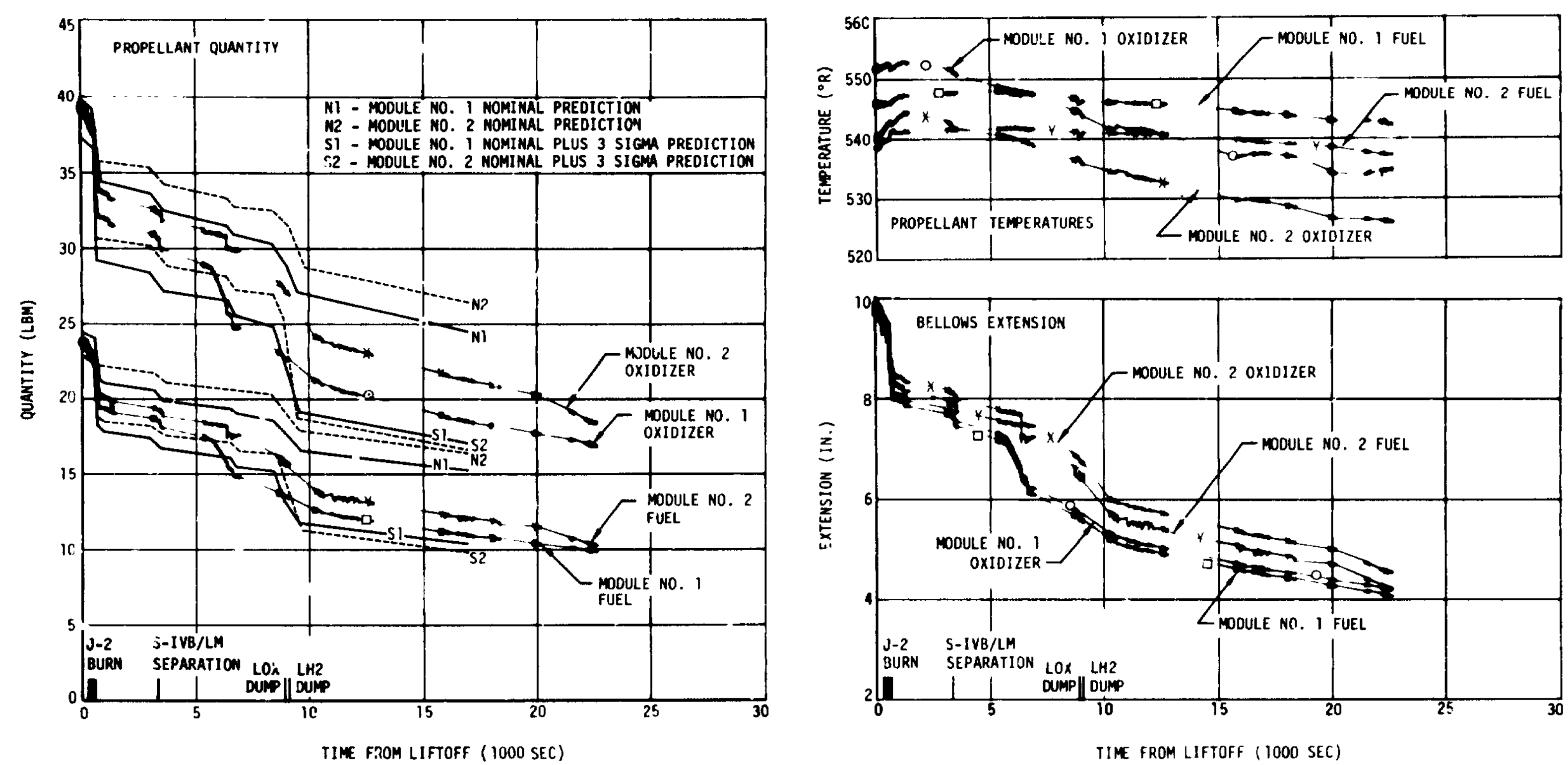


Figure 13-2. APS Propellant Conditions

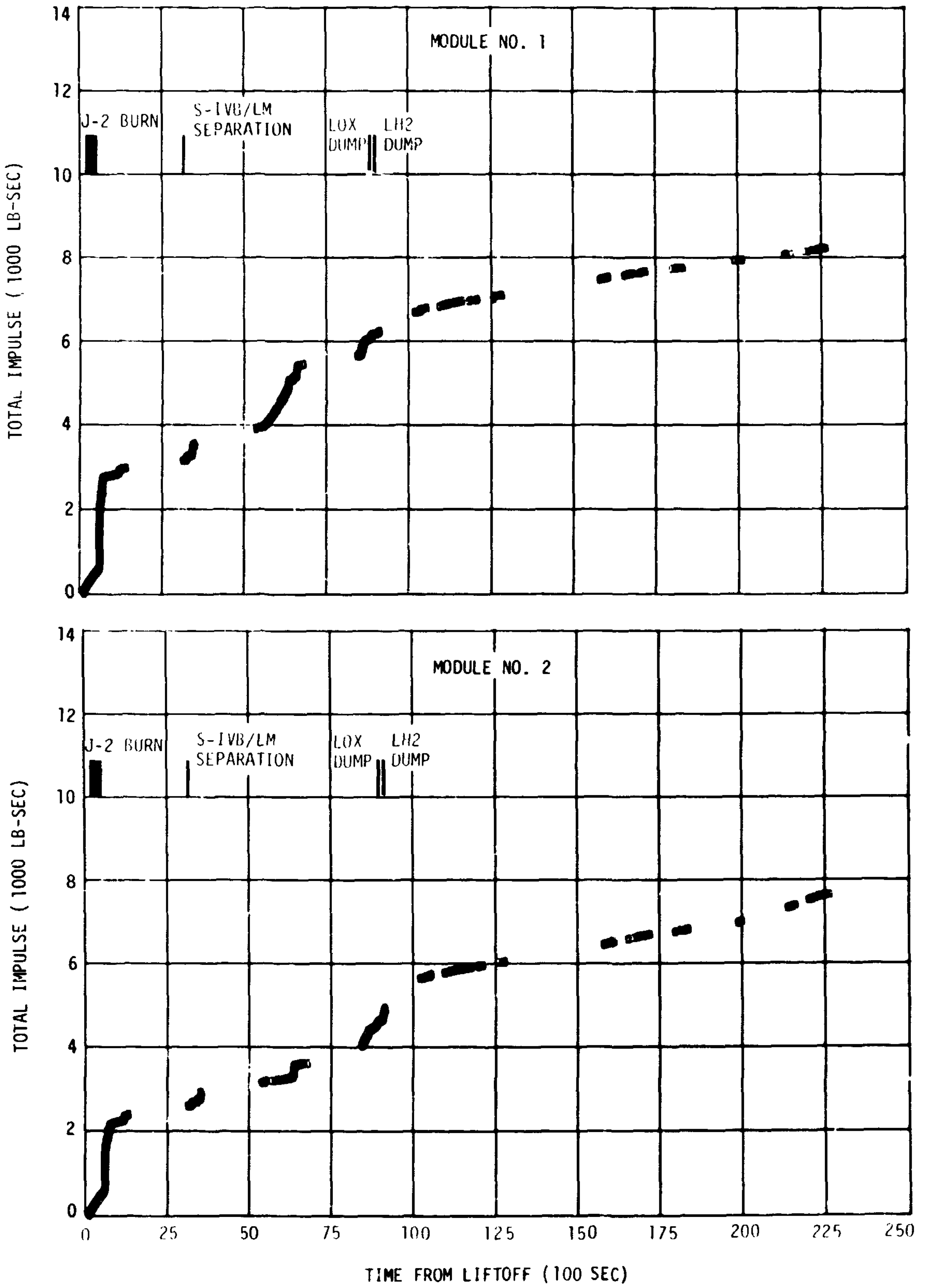


Figure 13-3. APS Total Impulse

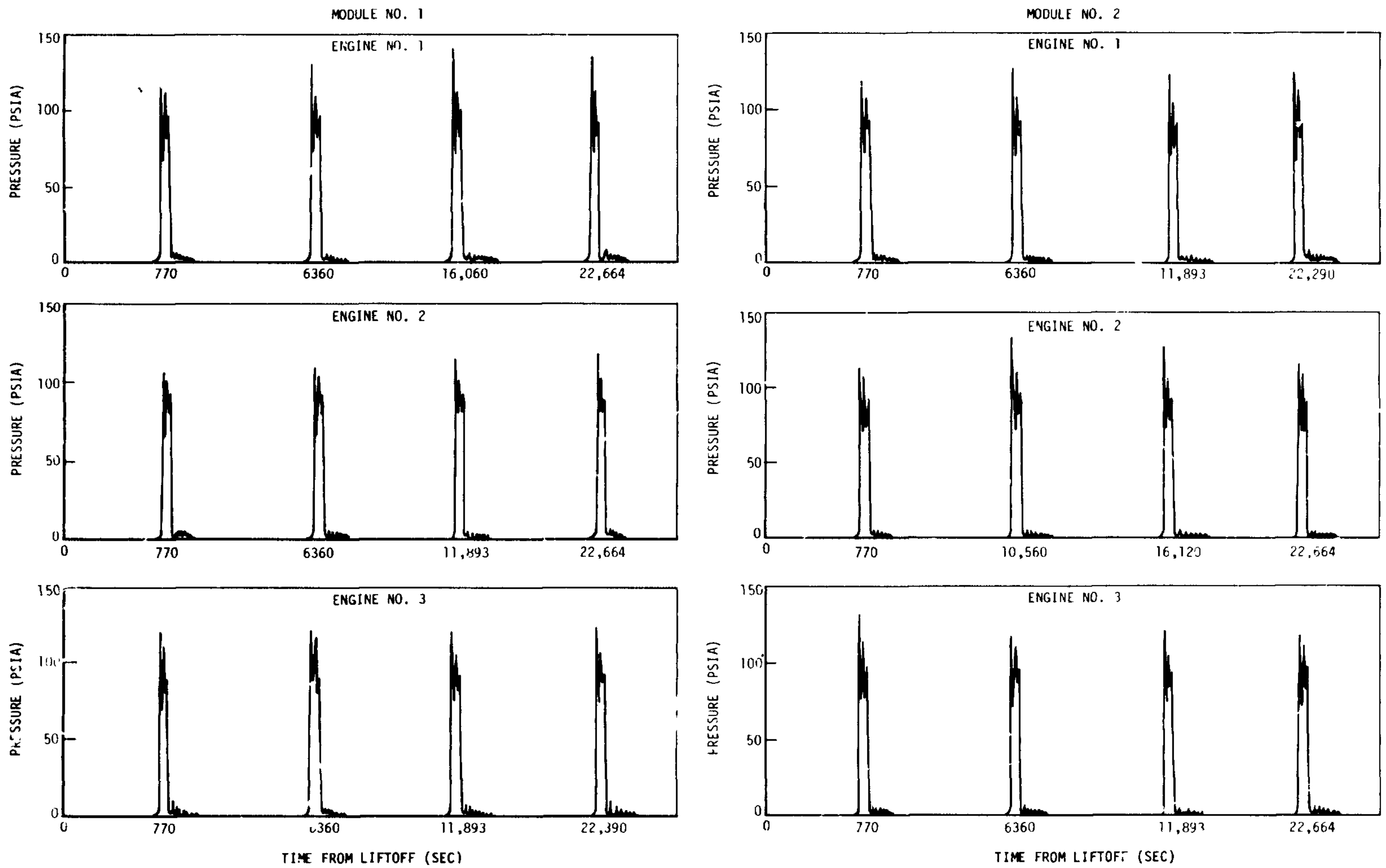


Figure 13-4 Typical Chamber Pressure Tracers (0.055 SEC PULSES)

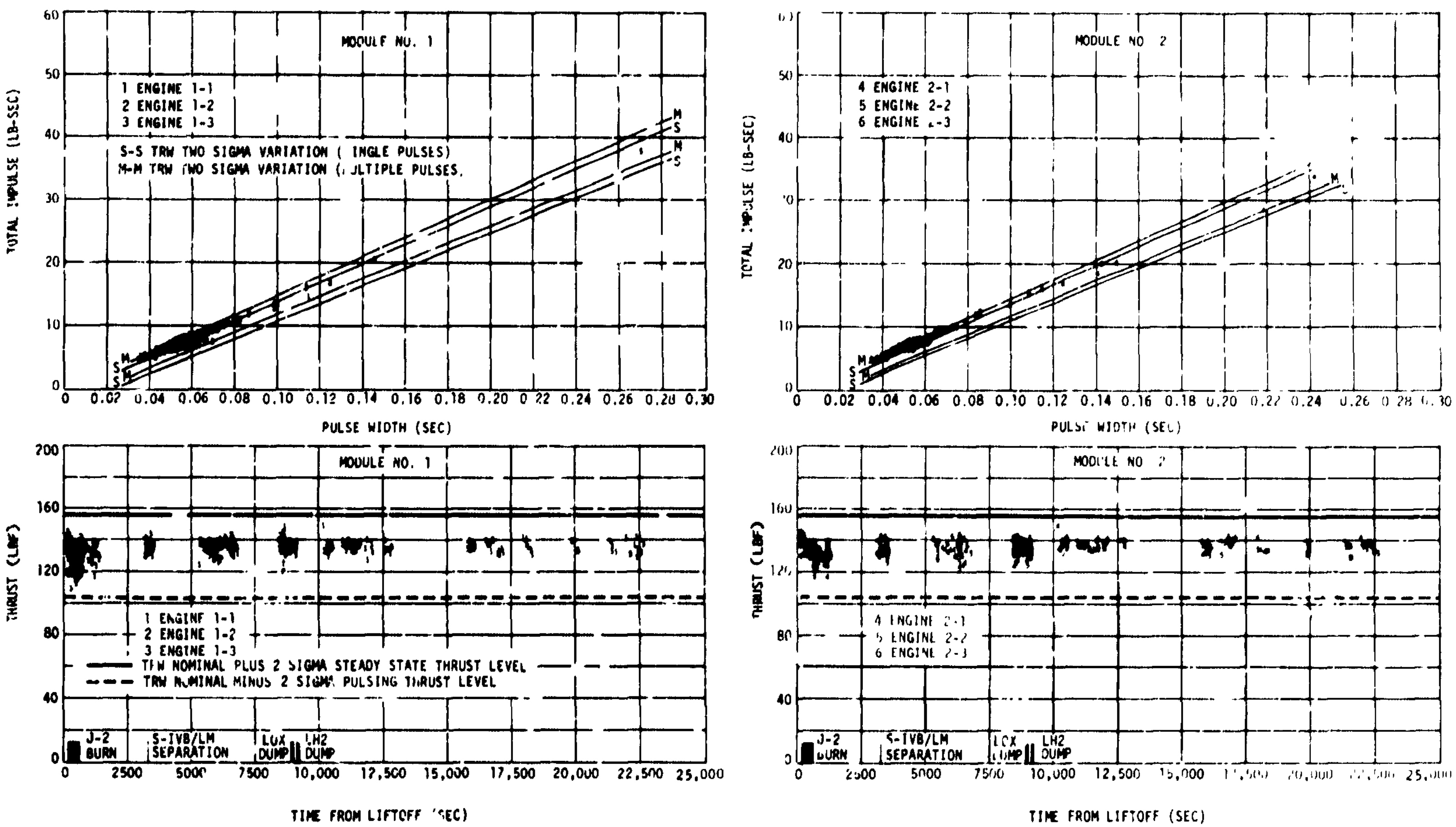


Figure 13-5. APS Engine Performance

SECTION 14

PNEUMATIC CONTROL AND PURGE SYSTEM

14. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 14-1) performed satisfactorily throughout the flight. The helium supply to the system was adequate for both pneumatic valve control and purging; the regulated pressure was maintained within acceptable limits; and all components functioned normally. Only two problems were observed:

a. A high regulator outlet pressure during the countdown demonstration test (CDDT) was corrected by replacing the regulator.

b. Orbital heating caused the supply pressure to reach 3,310 psia after three orbits. This problem is discussed in paragraph 14.2.

14.1 Ambient Helium Supply

Ambient helium sphere conditions at significant times and helium consumption during boost and burn are shown in table 14-1.

14.2 Pneumatic Control

The pneumatic control system performed satisfactorily (figure 14-2), and was more than adequate to meet the requirements of the AS-204 mission. The pneumatic control helium regulator outlet pressure was high (approximately 580 psia) during the CDDT, and the regulator was replaced. During the launch countdown LH2 loading operation, the outlet pressure of the new regulator increased to approximately 600 psia after the childown shutoff valves were opened. The valves were cycled to decrease the regulator outlet pressure, and the regulator subsequently operated satisfactorily at a pressure of 530 to 565 psia. During periods of high pneumatic usage, the regulator discharge pressure dropped to as low as 409 psia. These momentary drops have occurred during all previous tests and are considered normal.

The stage pneumatic helium usage was significantly lower than predicted. This, plus the unpredicted orbital heatup, resulted in a higher than predicted supply pressure. Most of the anticipated usage was for vent valve actuations. A comparison based on the observed heatup and the absence of vent valve leakage during actuation agrees closely with S-IVB-204 data (figure 26-6). During the period between Engine Cutoff Command (RO +593 sec) and sphere blowdown initiation (RO +10,349 sec), the supply temperature increased from 461 to 523 deg R and the pressure increased from 3,050 to 3,310 psia. These changes indicate a mass loss of 0.43 lbm during this 9,756 sec period.

14.3 Ambient Helium Purges

All stage and GSE purges were satisfactorily accomplished throughout the countdown. The sizes and flowrates of the purge orifices are listed in table 3-2.

The LOX chilldown motor container purge pressure was maintained within the design range throughout boost and burn. The engine pump purge pressure (D0050) was normal

TABLE 14-1
PNEUMATIC CONTROL AND PURGE SYSTEM DATA

PARAMETER	S-IVB-202 FLIGHT	S-IVB-203 FLIGHT	S-IVB-204 FLIGHT
Sphere volume (cu ft)	0.524	4.5	4.5
Sphere pressure			
At liftoff (psia)	[illegible]05	3,113	3,032
At Engine Start Command (psia)		3,089	3,011
At Engine Cutoff Command (psia)		3,087	3,040
Sphere temperature			
At liftoff (deg R)	460	492	459
At Engine Start Command (deg R)	448	490	456
At Engine Cutoff Command (deg R)	451	490	461
Helium mass			
At liftoff (lbm)	1.11	9.56	9.90
At Engine Start Command (lbm)	1.030	9.49	9.90
At Engine Cutoff Command (lbm)	1.024	9.47	9.90
Usage during engine operation (lbm)	0.006	0.02	0.00
Regulator outlet pressure			
Maintained pressure band (psia)	494 to 538	535 to 540	530 to 565
Minimum system pressure during start and cutoff transient (psia)	397	410	409
Average LOX chilldown motor container purge pressure (psia)	51	52	63

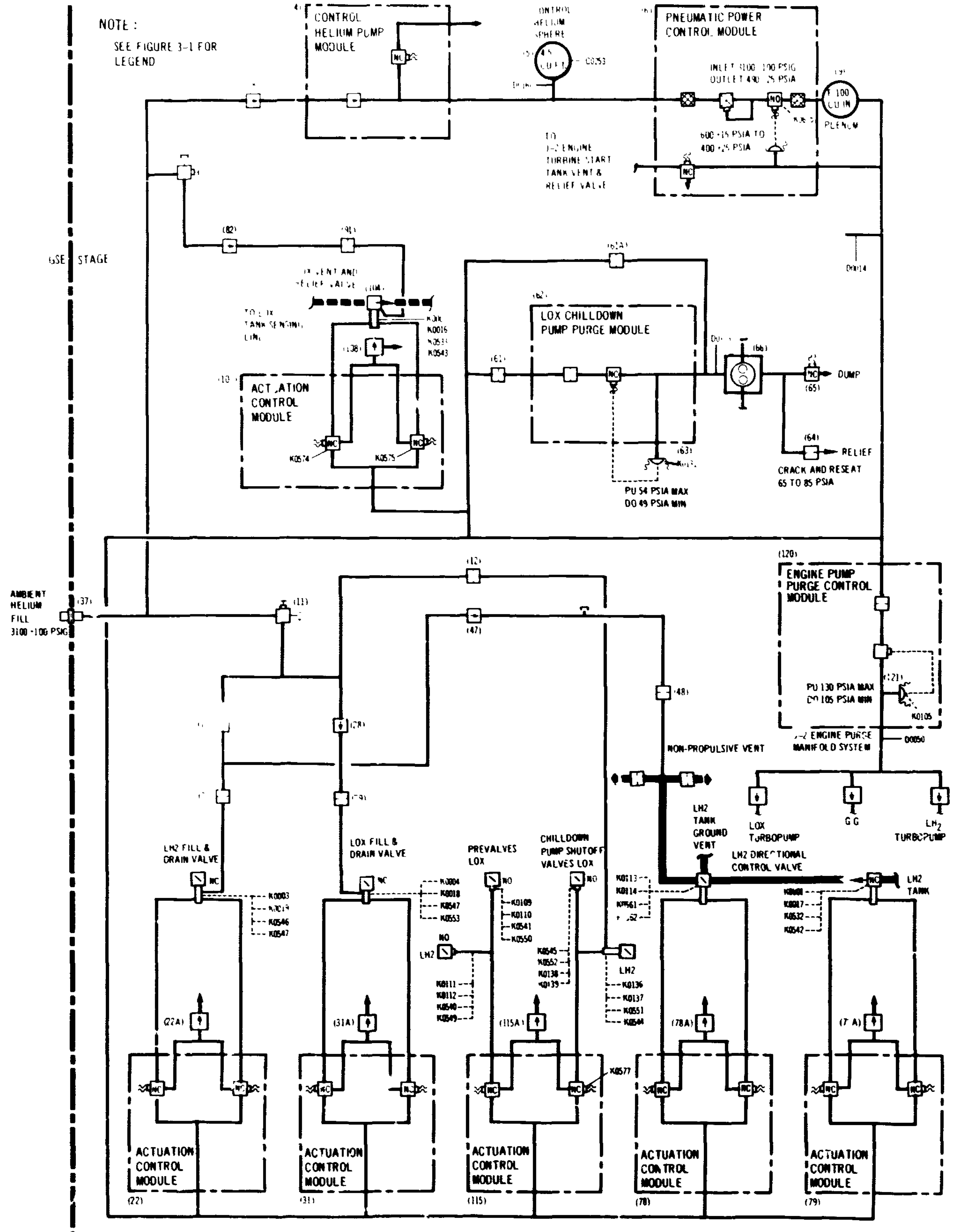


Figure 14-1. Pneumatic Control and Purge System

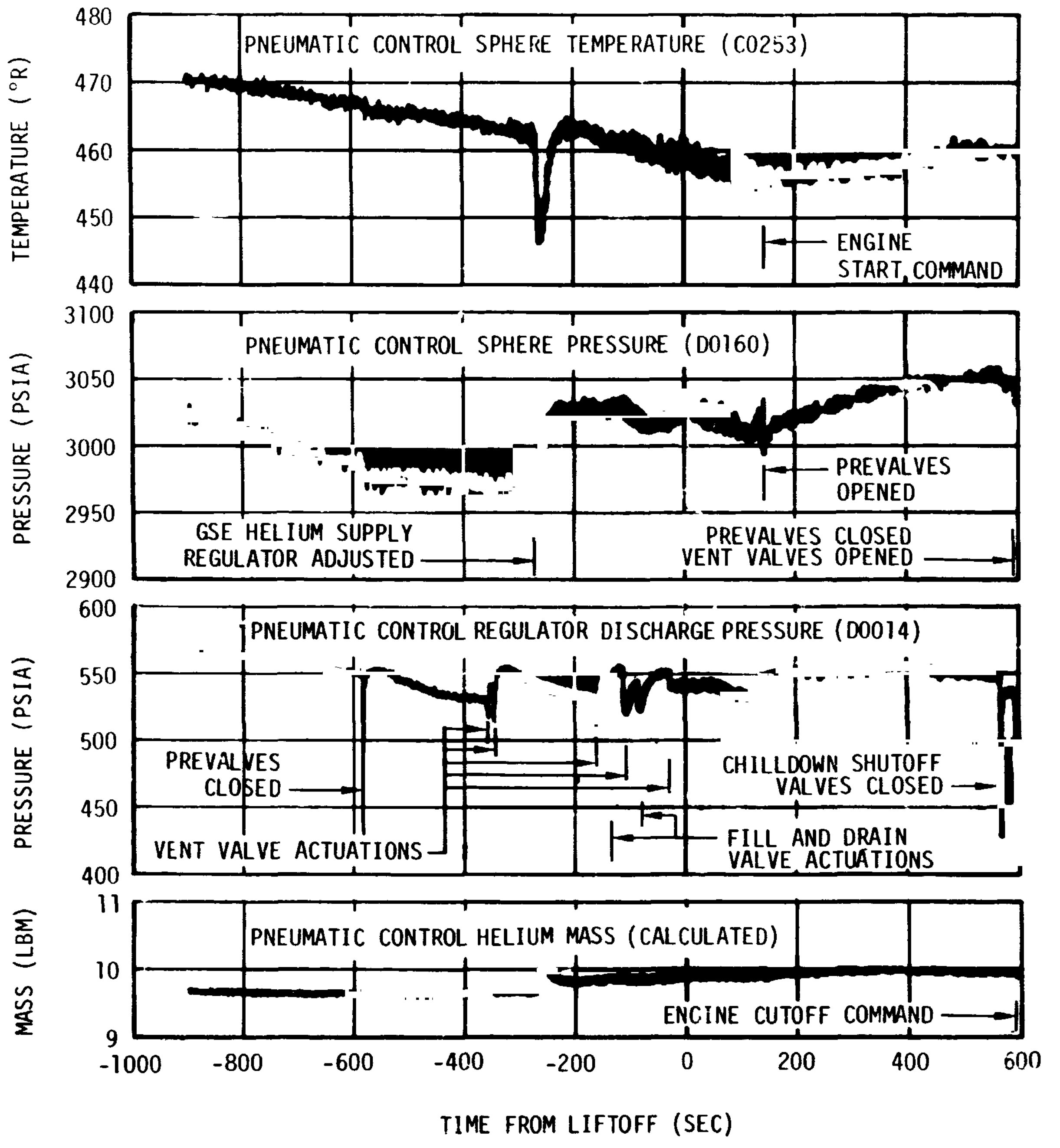


Figure 14-2. Pneumatic Control and Purge System Performance

SECTION 15

PROPELLANT UTILIZATION SYSTEM

15. PROPELLANT UTILIZATION SYSTEM

The propellant utilization (PU) system successfully met the loading accuracy requirement of the stage and satisfactorily accomplished propellant management during burn. The best estimate propellant mass values at liftoff were 194,111 lbm LOX and 37,361 lbm LH2 as compared with the desired mass values of 193,273 lbm LOX and 37,440 lbm LH2. These values are well within the required ±1.12 percent stage loading accuracy.

After velocity cutoff the usable propellant residuals were extrapolated to depletion. This extrapolation indicates that a LOX depletion would have occurred 7.46 sec after velocity cutoff with an LH2 residual of 144 lbm. This yields a propellant utilization efficiency of 99.94 percent.

The PU valve was positioned at null during engine start and remained there until the PU system was activated at ESC +6.0 sec. Following PU activate the valve moved to the LOX rich stop until PU valve cutback, at ESC +325.1 sec, which occurred 20.1 sec later than the predicted cutback time of ESC +305 sec. The extended operation at the LOX rich stop (high EMR) was primarily caused by a higher than predicted LH2 flowrate and a slight LOX overload caused by a calibration deviation.

Although sloshing was observed on the mass signals and PU summing point error signal, the redesigned forward shaping network successfully attenuated the effects of the slosh on the signal fed to the PU valve servo.

15.1 PU Mass Sensor Calibration

The preflight propellant mass at the full point calibration was determined from the S-IVB-204 acceptance firing full load by the flow integral analysis method. The capacitance value corresponding to the full load masses were measured data during acceptance firing.

The propellant masses at the lower calibration point were computed from unique tank volume and predicted propellant density data. The corresponding capacitance was determined by adding the mean deviation between vendor air capacitance and measured empty capacitance on all stages that have been acceptance fired, to the S-IVB-204 stage vendor air capacitance.

The following table presents a summary of the PU mass sensor calibration data used in support of the predicted flight load.

SENSOR	FULL LOAD POINT		BOTTOM OF INNER ELEMENT	
	MASS (lbm)	CAPACITANCE (pf)	MASS (lbm)	CAPACITANCE (pf)
LOX	193,273	412.48	1,270	282.23
LH2	37,440	1,153.02	206	972.27

15.2 Propellant Mass History

Propellant masses were obtained from four mass measurement systems at significant flight events and are presented in table 15-1. Table 15-1 also presents the predicted propellant masses and the best estimate propellant masses which were determined from the best estimate stage mass analysis as described in section 8. The best estimate propellant masses are derived from the total best estimate stage mass by subtracting the nonpropellant masses (dry stage, ullage gases, etc.) from the total best estimate stage mass at ignition and cutoff. The remaining propellant mass is then divided into LOX and LH2 according to the average propellant mixture ratio as determined by the PU volumetric and flow integral methods at the specific flight event time.

The four propellant mass measurement systems represented are (1) flight flow integral, (2) PU indicated (corrected), (3) PU volumetric, and (4) trajectory reconstruction. A description of these measurement systems is as follows:

a. 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 mass during engine burn. Flow integral mass values were based on the analysis of engine flowmeter data, thrust chamber pressure, engine influence equation, and engine tag values. The initial full load mass, using the flow integral method, is determined by adding to the total mass consumed, the statistical weighted average propellant residuals at engine cutoff, the fuel pressurant added to the ullage, and the propellant lost to boiloff.

b. The PU indicated (corrected) system 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 dynamic effects.

c. The propellant masses as determined by the PU volumetric masses are derived from raw PU probe output data which is reduced according to preflight volumetric calibration slopes and adjusted for flight dynamics effects and volumetric tank-to-sensor mismatch.

d. The trajectory reconstruction method determines vehicle mass changes from observed trajectory data. A detailed description of this method is presented in section 7.

From table 15-1, the flight flow integral, the PU volumetric and the trajectory reconstruction propellant masses and consumption agree favorably with the best estimate values. The PU indicated (corrected) mass is 752 lbm less at ESC and 114 lbm more at ECC than the best estimate value; the total consumption is 866 lbm less than best estimate consumption.

The predicted total propellant mass is 646 lbm less than the best estimate at ESC and is 260 lbm more than the best estimate at ECC. The predicted total propellant mass consumption is 906 lbm less than the best estimate.

15.2.1 Propellant Loading

Propellant loading was accomplished automatically by the loading computer. Table 15-2 presents a tabulation of the LOX, LH2 and total propellant mass at liftoff. The desired and best estimate values are shown in addition o the mass values determined by the various measurement systems. The deviation of each value from the best estimate is also shown.

The loading computer values at liftoff were 100.00 percent for LOX and 100.06 percent for LH2 which were well within the 0.5 percent loading computer accuracy.

The postflight best estimate total liftoff mass was 759 lbm greater than desired, the LOX mass was 838 lbm g eater than desired, and LH2 mass was 79 lbm less than desired.

Both LOX and LH2 were well within the guaranteed loading accuracy of ±1.12 percent.

15.2.2 Propellant Residuals

The propellant residuals were computed at Engine Cutoff Command by means of the point level sensors and the PU mass sensors. Two level sensors in each tank were activated during the engine burn and were used for residual computations (level sensors Nos. L0006 and L0005 in the LOX tank, N0032 and L0002 in the LH2 tank).

The point level sensor residuals were generated using the engine consumption data to extrapolate from each level sensor activation to Engine Cutoff Command. An average level sensor residual was computed from two level sensors for each propellant tank. The final propellant residual masses at engine cutoff are the weighted average of the level sensor and PU mass sensor residuals. These values are considered the most accurate determination of propellant residuals. Table 15-3 summarizes the propellant residual data determined by the PU mass sensor and the point level sensors.

Total masses at ECC were 3,141 lbm LOX and 1,466 lbm LH2. These total masses include unusable masses of 516 lbm LOX and 760 lbm LH2. The usable masses at ECC were 2,625 lbm LOX and 706 lbm LH2. By extrapolating to depletion cutoff at propellant flowrates of 352 lbm/sec LOX and 75.6 lbm/sec LH2, LOX depletion cutoff would occur 7.46 sec after ECC with a PU residual of 144 lbm LH2. This residual is well within the maximum allowable residual of 575 lbm.

15.2.3 PU Efficiency

Utilizing the extrapolated flowrate and residual of section 15.2.2 PU efficiency is determined to be 99.94 percent. This value is within the 99.50 percent specification value.

15.2.4 Total PU Volumetric Method Mass Sensor Flight Corrections

Figures 15-1 and 15-2 present the total correction to the indicated propellant mass, as determined by the PU volumetric method, for the LOX and LH2 mass sensors. The total correction is the sum of the PU inflight dynamics correction, volumetric tank-to-sensor mismatch, and the difference in preflight flow integral and volumetric calibration slopes. The total LOX correction agrees closely with the predicted. The deviation between the predicted and postflight LH2 sensor correction is caused primarily by the dispersion of the inflight dynamics correction prediction.

15.2.4.1 Inflight Dynamics Effects

The effect of inflight dynamics on PU mass indication is shown in figures 15-3 through 15-6.

The center of gravity (CG) offset correction is caused by tilting of the propellant level during boost and S-IVB burn. Figures 15-3 and 15-4 show the predicted CG offset versus the postflight correction for the LOX and LH2 mass sensors, respectively. Good agreement between the predicted and postflight data was obtained for both mass sensors.

The tank deflection PU mass correction is caused by tank skin temperature variations and differential tank pressure differences from those experienced during acceptance firing. Figures 15-5 and 15-6 present a comparison of the predicted and actual flight evaluation corrections for the LOX and LH2 mass sensors. The predicted LOX data shows good agreement with the postflight evaluation. The slightly lower actual correction for the higher LOX mass values is attributed to a lower ullage pressure than predicted. The actual LH2 sensor correction is substantially less than predicted due to a considerably colder skin temperature than predicted prior to liftoff. Consequently, the skin temperature did not rise to the expected value during boost. The actual mass correction deviation from predicted is -65 lbm at S-IVB stage Engine Start Command.

15.2.4.2 Propellant Tank-to-Sensor Mismatch

The 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-204 stage volumetric tank-to-sensor mismatch nonlinearity is presented in figures 15-7 and 15-8 for LOX and LH2, respectively.

15.2.5 PU Nonlinearity Analysis

Figures 15-9 and 15-10 present a comparison of the LOX and LH2 mass sensor sensor nonlinearities as determined by the PU volumetric and flow integral methods. The volumetric nonlinearities were obtained by normalizing the volumetric total flight corrections to the flight full propellant load and residual propellant masses. The predicted flow integral nonlinearity was obtained from smoothed acceptance firing data. The flow integral actual data are smoothed nonlinearities from the flight flow integral analysis.

The small deviation between the predicted and actual volumetric nonlinearities is caused by the PU mass sensor flight dynamics effect. The deviation between the predicted and actual flow integral nonlinearities is caused primarily by the difference between acceptance firing and flight analysis.

The LOX data exhibits generally good trend agreement between the volumetric and flow integ .l data while the LH2 data differ considerably and are currently being investigated.

15.3 PU System Response

The PU valve was positioned at null during engine start and remained there until PU activate at ESC +6.0 sec. The PU valve was commanded to the LOX rich stop at activation due to the planned LOX overload and remained there until PU valve cutback at ESC +325.1 sec.

The PU valve reached the LOX rich stop at ESC +7.8 sec as compared to the predicted time of ESC +10.5 sec. This deviation between the predicted and actual valve position slope following PU activation was due to a difference between the method used to activate the PU system in the simulation model and the actual implementation of PU activation in flight. This difference was removed in the reconstruction by activating the PU system 2.5 sec earlier in the simulation model. The difference between the actual valve positions on the LOX rich stop was due to an error in the prediction, however this produces no flowrate deviations at this position.

The LOX weight error was reduced by high engine mixture ratio operation and produced PU valve cutback 20.1 sec later than the predicted cutback time of ESC +305 sec (figure 15-11).

After the PU valve cutback transient, the average PU valve level was 1 deg higher than predicted. The following table summarizes the dispersions between the reconstructed and predicted PU valve position histories.

DEVIATION DESCRIPTION	CUTBACK TIME DEVIATION (sec)	VALVE POSITION SHIFT (deg)
1. Loading deviation	-3.5	0
2. Updated J-2 engine influence coefficients and auxiliary drive	+5.0	+0.5
3. Engine tag values	0	-1.0
4. PU system nonlinearities	-3.2	0
5. Calibration (best estimate)	+12.7	+1.5
6. Propellant environment deviations	+11.5	+0.2
7. Simulation deviation	-2.5	0
TOTAL	+20.0	+1.2

Considering the above factors, the predicted cutback time would increase by 20.0 sec and the mean level of valve position after the cutback transient would increase 1.2 deg. This gives a close comparison between the actual valve response and the postfiring reconstruction (figure 15-11).

The above dispersions are discussed in the following sections.

15.3.1 Loading Deviation

Loading deviations are the difference between the PU system indicated loads at liftoff and the desired loads at liftoff. The loading deviations were -20 lbm LOX (-0.01 percent) and +43 lbm LH2 (+0.11 percent). The combined effect of these loading deviations decreased cutback time by 3.5 sec. The mean level of the valve position after cutback is not affected by these loading deviations. The accompanying table gives the propellant loads used for this analysis.

PROPELLANT LOADING	LOX (lbm)	LH2 (lbm)
Desired full load	193,273	37,440
Indicated full load (PU fine mass reading)	193,253	37,483
Indicated residual (PU fine mass reading)	3,264	1,616
PU consumed mass	189,989	35,867
Actual full load at ESC (best estimate)	194,065	37,294
Actual residual (statistical average)	3,141	1,466
Consumed mass	190,924	35,828

15.3.2 Updated J-2 Engine Influence Coefficients and Auxiliary Drive

The J-2 engine influence coefficients and the auxiliary drive horsepower were updated subsequent to the flight prediction. The effect on the actual flight was to alter propellant flowrates such that cutback occurred 5.0 sec later and the mean level of the valve position after the cutback transient was 0.5 deg higher.

15.3.3 Engine Tag Values

Revised variable engine tag values resulted in propellant flowrates that varied from predicted propellant flowrates. The combined flowrates had no effect on PU valve cutback. The new tag values shifted the mean value of the valve position after the cutback transient down 1.0 deg.

15.3.4 PU System Nonlinearities

The predicted and actual flow integral mismatch nonlinearities are compared in figures 15-12 and 15-13. The actual mismatch was obtained by normalizing curves of PU coarse indicated mass versus G0105 flow integral mass. The calibration line was also the actual calibration as calculated from the actual and indicated initial loads and residuals.

The predicted LOX mismatch nonlinearities were revised due to a change in the nonlinearity from the probe calibration point (187,633 lbm) to the full load point. The revised nonlinearity agrees very well with the actual mismatch below 100,000 lbm. The LH2 mismatch nonlinearity deviates from the predicted nonlinearity up to ESC +400 sec (5,000 lbm). From ESC +400 sec to ECC, the LH2 nonlinearity is very close to predicted and caused little change in the shape of the PU valve position.

The combined effect of the actual flow integral mismatch nonlinearities was to reduce cutback time by 3.2 sec. There was no valve position level change after the cutback transient because of the close agreement between the predicted and actual nonlinearities after the ESC +400 sec.

15.3.5 Mass/Capacitance Calibration Deviations

Calibration deviations as determined by the best estimate method at Engine Start Command were +0.42 percent LOX and -0.50 percent LH2 thus causing the initial LOX mass to be overloaded 792 lbm and the initial LH2 mass to be underloaded 146 lbm. Calibration deviations at Engine Cutoff Command were -0.06 percent LOX and -0.40 percent LH2. The slope deviations between ESC and ECC were +0.48 percent LOX and -0.10 percent LH2. Those slope deviations caused the desired bridge gain ratio (BGR) of 4.8:1.0 to actually be 4.81:1.0. This change had little effect on the desired reference mixture ratio (RMR) of 4.7:1.0.

The LOX equivalent calibration error between the mass/capacitance end points was +0.58 percent. This LOX equivalent calibration error would cause a 12.7 sec increase in cutback time and a +1.5 deg shift in valve position.

15.3.6 Propellant Environment Deviations

The effect of the differences between the predicted and actual pump inlet conditions, pressurization, and boiloff rates for the S-IVB-204 flight was to increase cutback by 11.5 sec and shift the mean level of valve position after the cutback transient +0.2 deg. Reference section 9 for details of increased engine performance.

15.3.7 Simulation Deviation

This deviation is due to the faster travel of the PU valve after PU activate at ESC +6.0 sec. The faster travel of the PU valve was caused by a difference between the method used to activate the PU system in the simulation model and the actual implementation of PU activation in flight. This difference was removed in the reconstruction by activating the PU system 2.5 sec earlier in the simulation model.

15.3.8 Sloshing

The redesigned forward shaping network (slosh filter) successfully removed the effects of propellant sloshing on the PU valve. Propellant sloshing within a 0.2 to 1.0 Hz range was present on the mass signals and the PU summing point error signal. However, the added filter attenuation removed the slosh effects on the signal fed to the PU valve servo.

15.3.9 PU Error Signal

The telemetry summing point error signal had a bias of -0.3 volts. This bias was also present on the acceptance test data. The biased error signal was used as an input to the PU electronics mathematical model to generate a PU valve response that matched the actual PU valve response. The agreement between the actual and generated response verifies PU valve response to the summing point error signal.

15.3.10 PU Thrust Variation Response

CEI thrust variation limits for cutback and the final 70 sec of engine burn are presented in table 9-6. A comparison of the variation in actual PU valve cutback time to the CEI limits shows the achieved +20.1 sec variation was well within the allowable +56 or -50 sec.

Figure 9-22 shows the thrust history during the final 70 sec of burn. The thrust values are compared with the CEI thrust variation limits in table 9-6. Late cutback caused part of the thrust cutback transient to occur during the last 70 sec. There were no thrust variations caused by the total PU sensor nonlinearities. Had the flight gone to depletion cutoff, there would have been a 1,500 lbf thrust tailoff and a 1 deg valve tailoff.

15.3.11 Conclusions

The S-IVB-204 PU system performed satisfactorily for loading and throughout flight. As a result of this evaluation two minor changes will be made in the predictions for future flights. The PU simulation model will be revised to provide a more accurate representation of PU valve response following activation. Again as on the S-IVB-501 flight, colder LH2 tank skin temperatures were observed prelaunch thus modifying the tank deflection nonlinearities from that experienced during the acceptance firing.

TABLE 15-1
PROPELLANT MASS HISTORY TABLE

EVENT		PREDICTED MASS (lbm)	FLIGHT FLOW INTEGRAL MASS (lbm)	PU INDICATED CORRECTED MASS (lbm)	PU VOLUMETRIC MASS (lbm)	TRAJECTORY RECONSTRUCTION MASS (lbm)	BEST ESTIMATE MASS (lbm)
Liftoff RO +0.36 sec	LOX	193,273	194,000	193,333	194,163		194,111
	LH2	37,440	37,367	37,392	37,282		37,361
	Total	230,713	231,367	230,725	231,445		231,472
S-IVB Engine Start Command RO +144.90 sec	LOX	193,273	194,000	193,287	194,117		194,065
	LH2	37,440	37,367	37,320	37,220		37,294
	Total	230,713	231,367	230,607	231,337	231,374	231,359
PU Valve Cutback Time RO +470.00	LOX	58,725	50,370	50,204	50,944		
	LH2	12,908	11,076	11,268	11,041		
	Total	71,633	61,446	61,472	61,985	-	
Engine Cutoff Command RO +593.34 sec	LOX	3,282	3,141	3,062	2,937		3,038
	LH2	1,501	1,466	1,575	1,513		1,485
	Total	4,783	4,607	4,637	4,450	4,447	4,523
Propellant Consumed	LOX	189,991	190,846	190,225	191,226		191,027
	LH2	35,939	35,900	35,745	35,769		35,809
	Total	225,930	226,746	225,970	226,995	226,927	226,836

TABLE 15-2
PROPELLANT LOADING SUMMARY

PROPELLANT LOAD	LOX (lbm)	LH2 (lbm)	TOTAL (lbm)
Desired	193,273	37,440	230,713
PU Loading Computer (Uncorrected)	193,273	37,464	230,737
PU Indicated Corrected	193,333	37,392	230,725
Flight Flow Integral	194,000	37,367	231,367
Volumetric	194,163	37,282	231,445
Trajectory			231,374
Best Estimate	194,111	37,361	231,472
DEVIATION FROM BEST ESTIMATE			
Desired	-838 (0.43%)	+79 (0.21%)	-759 (0.33%)
PU Loading Computer (Uncorrected)	-838 (0.43%)	+103 (0.28%)	-735 (0.32%)
PU Indicated Corrected	-778 (0.40%)	+31 (0.08%)	-747 (0.32%)
Flight Flow Integral	-111 (0.06%)	+6 (0.02%)	-105 (0.05%)
Volumetric	+52 (0.03%)	-79 (0.21%)	-27 (0.01%)
Trajectory			-98 (0.04%)

TABLE 15-3
PROPELLANT RESIDUALS SUMMARY

LEVEL SENSOR NO. (ACTIVATION TIME FROM LIFTOFF) (sec)	LOX TANK			LH2 TANK		
	PU MASS SENSOR (lbm)	LEVEL SENSOR (lbm)	LEVEL SENSOR RESIDUAL (EXTRAPOLATED TO ECC) (lbm)	PU MASS SENSOR (lbm)	LEVEL SENSOR (lbm)	LEVEL SENSOR RESIDUAL (EXTRAPOLATED TO ECC) (lbm)
L0006 (548.7)	19,095	19,045	3,277			
L0005 (574.6)	9,692	9,776	3,172			
N0032 (530.9)					6,138	1,388
L0002 (584.0)					2,186	1,479
Residuals at ECC	2,937 (±490)		3,205* (±277)	1,513 (±130)		1,462* (±42)
Best Estimate** Residuals		3,141 ±248		1,466 ±40		

*Statistical average of level sensor residuals.

**Statistical average of level sensor and PU mass sensor residuals.

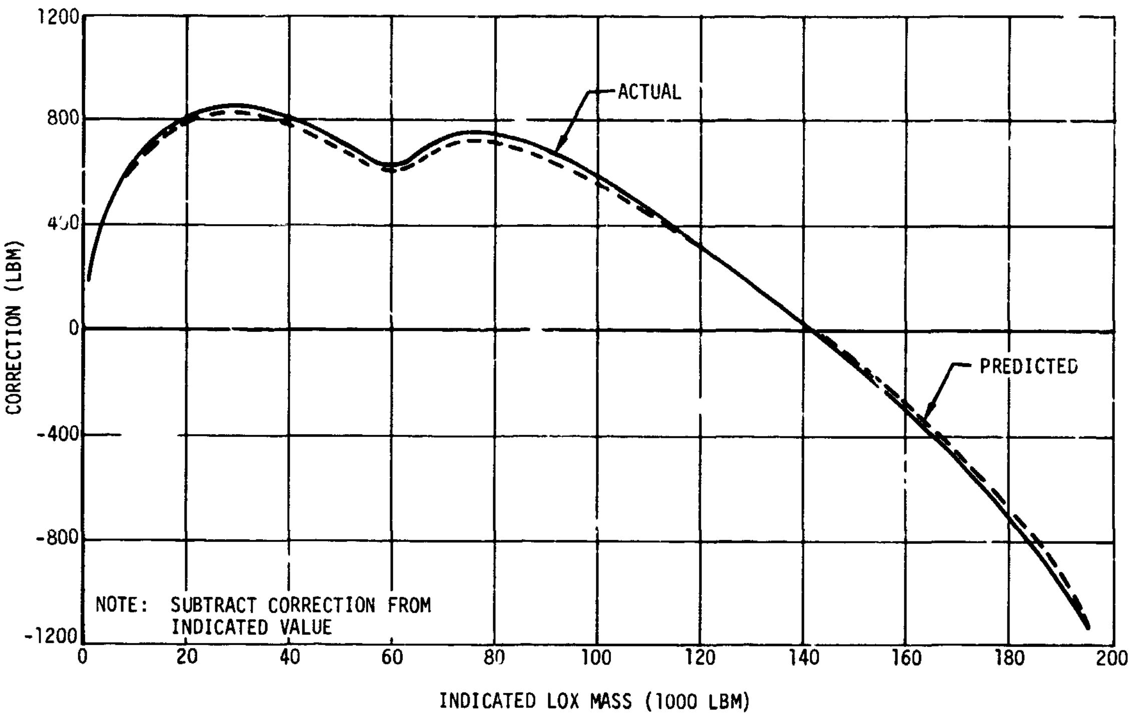


Figure 15-1. Total Flight LOX Sensor Correction as Determined by the Volumetric Method

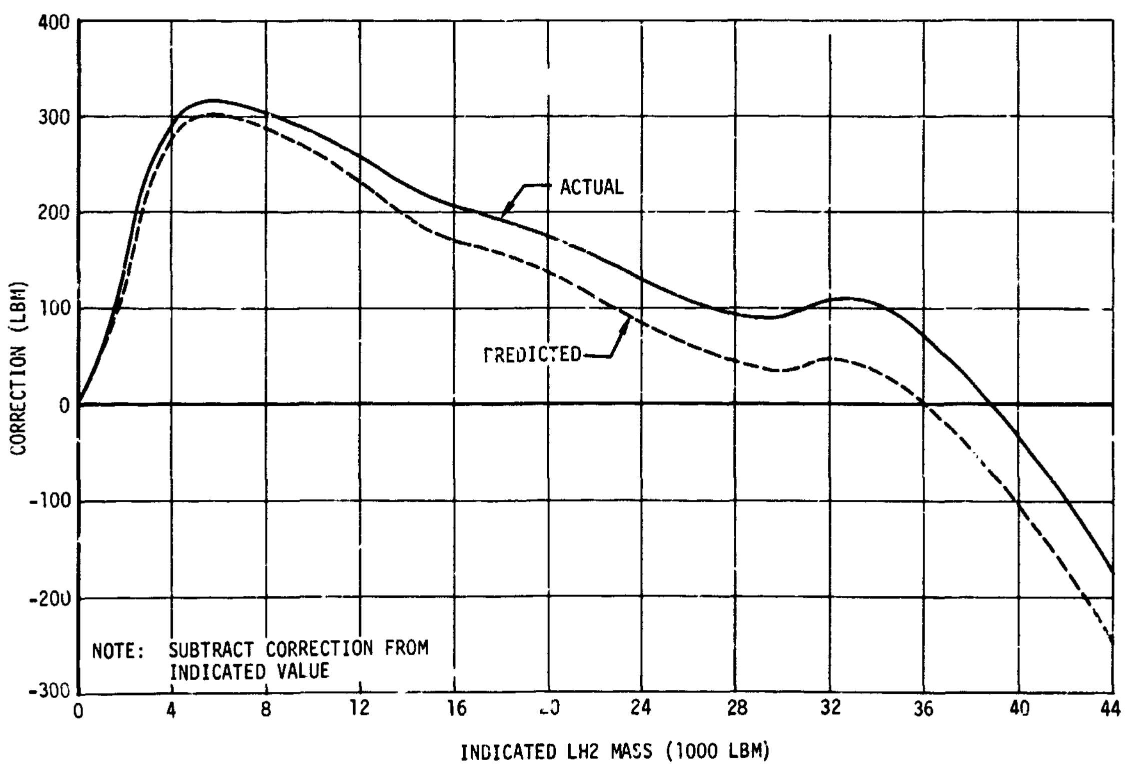


Figure 15-2. Total Flight LH2 Sensor Correction as Determined by the Volumetric Method

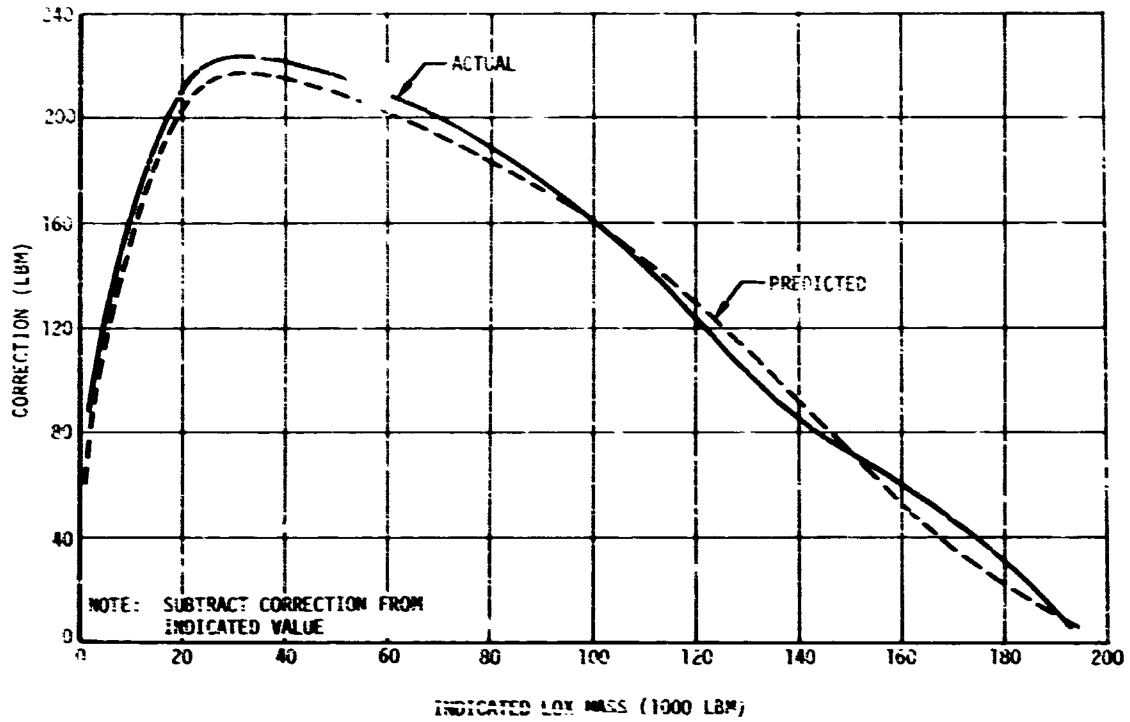


Figure 15-3. LOX PU Mass Sensor Correction Due to C.G. Offset

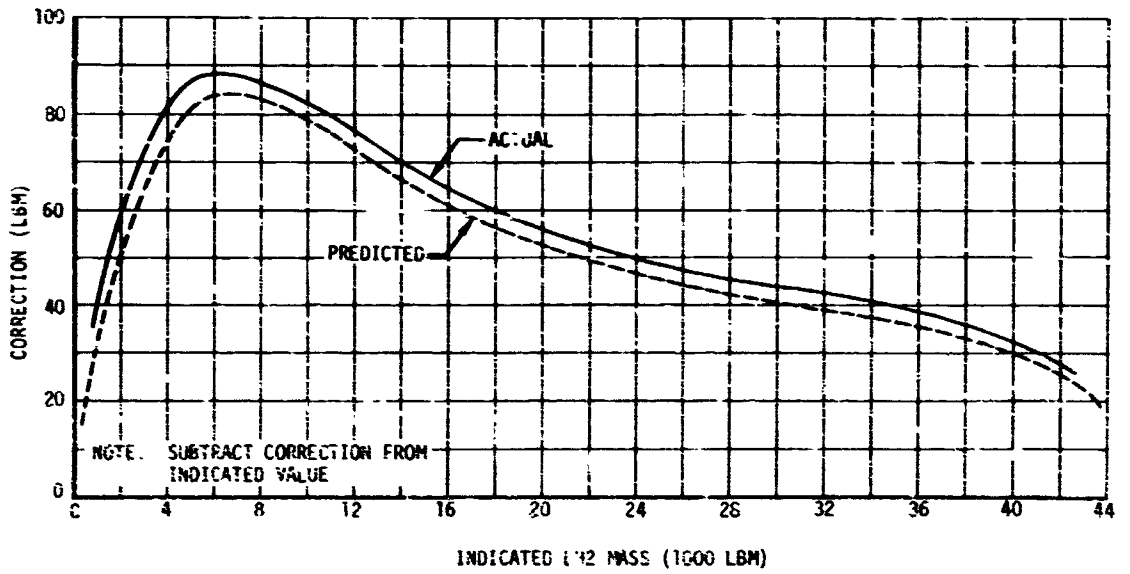


Figure 15-4. LH2 Correction Due to C G. Offset

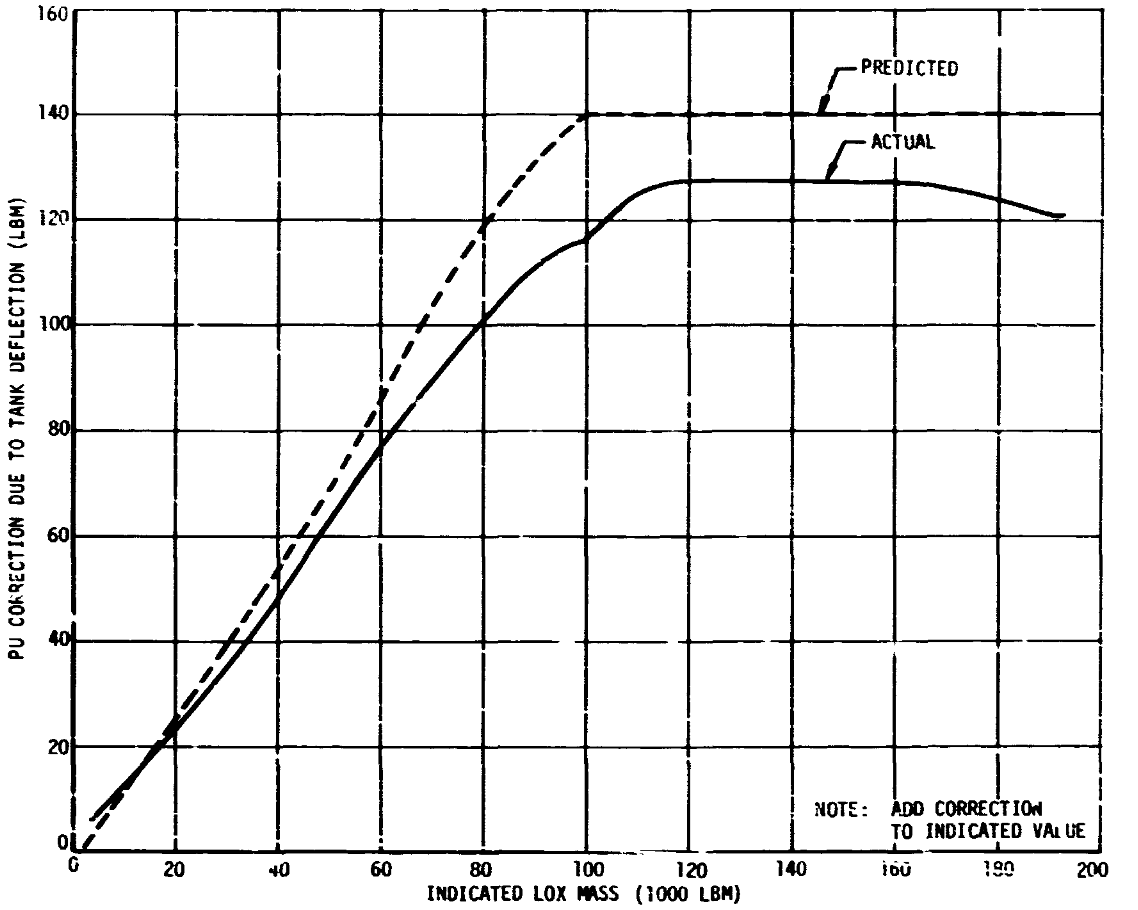


Figure 15-5. Flight Indicated PU Correction Due to LOX Tank Deflection

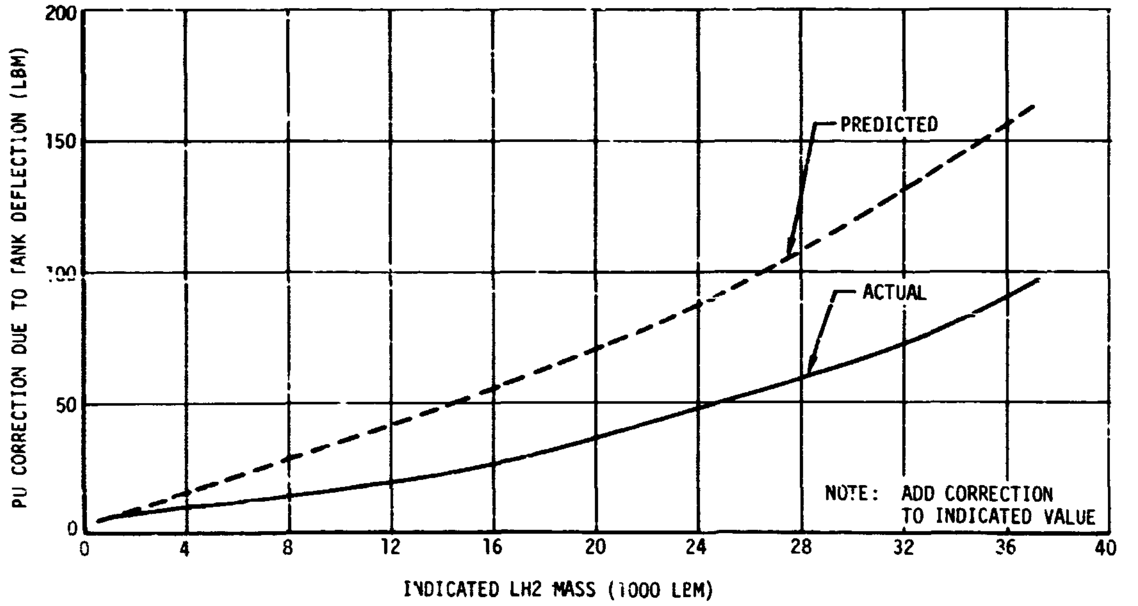


Figure 15-6. Flight Indicated PU Correction Due to LH2 Tank Deflection

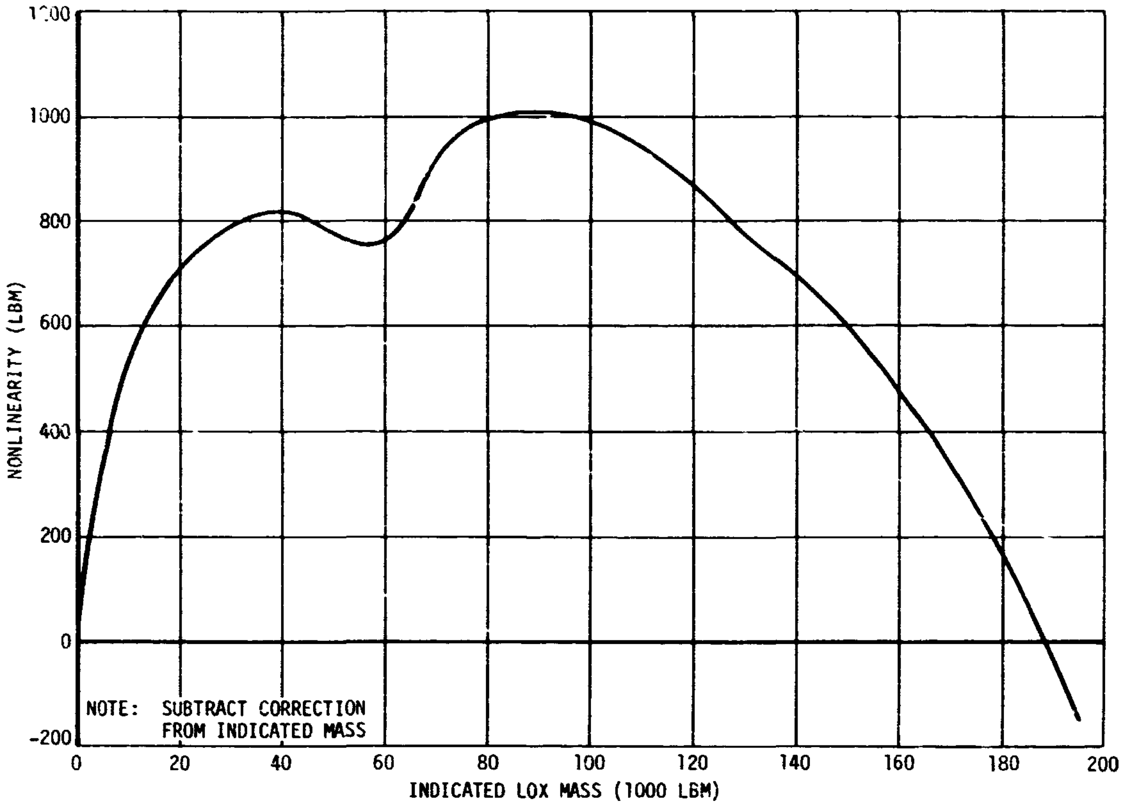


Figure 15-7. LOX Tank-to-Sensor Mismatch as Determined by the Volumetric Method

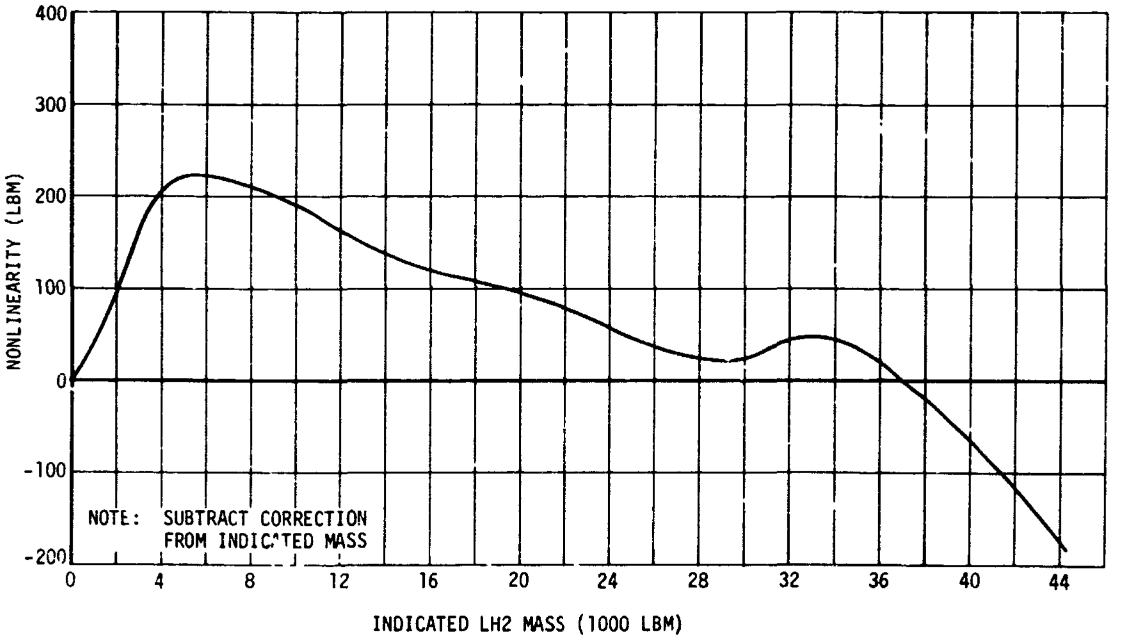


Figure 15-8. LH2 Tank-to-Sensor Mismatch as Determined by the Volumetric Method

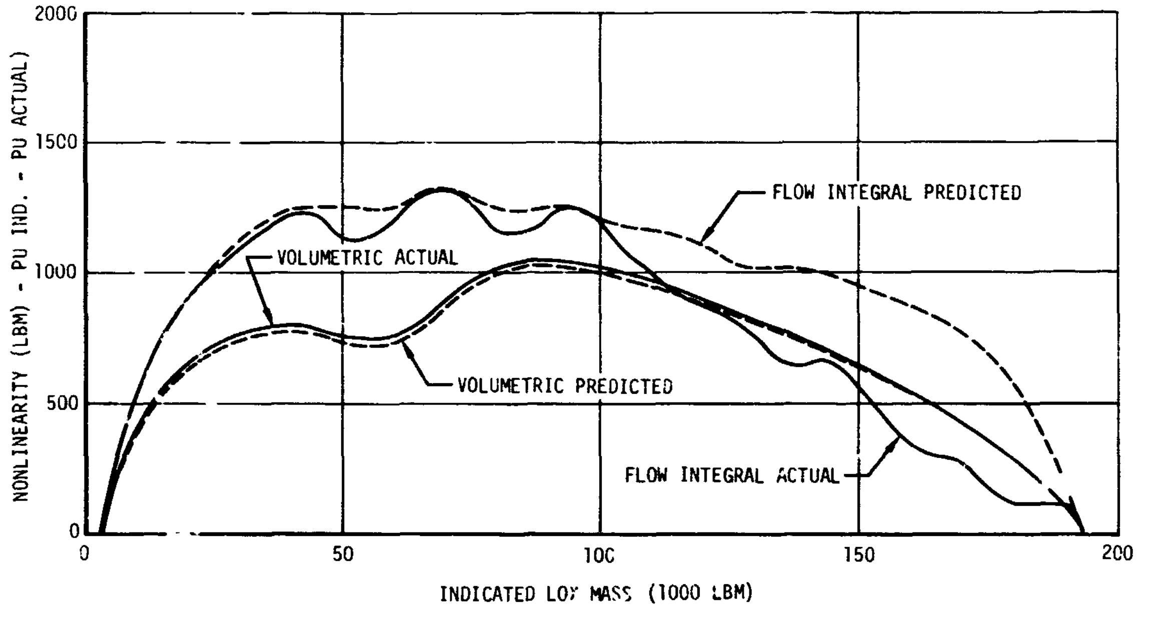


Figure 15-9. Total LOX Sensor Flight Nonlinearity

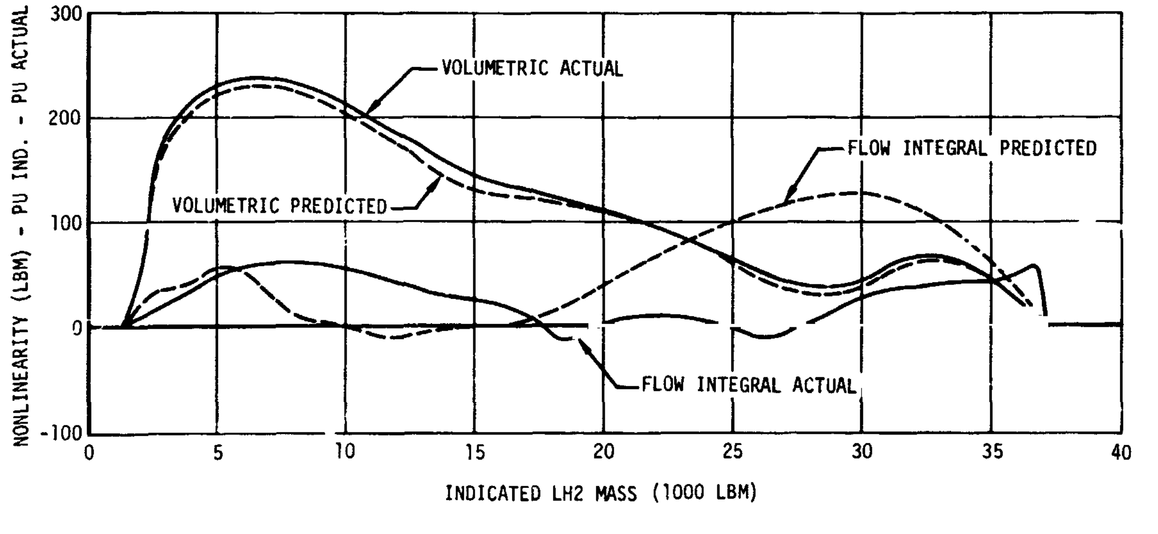


Figure 15-10. Total LH2 Sensor Flight Nonlinearity

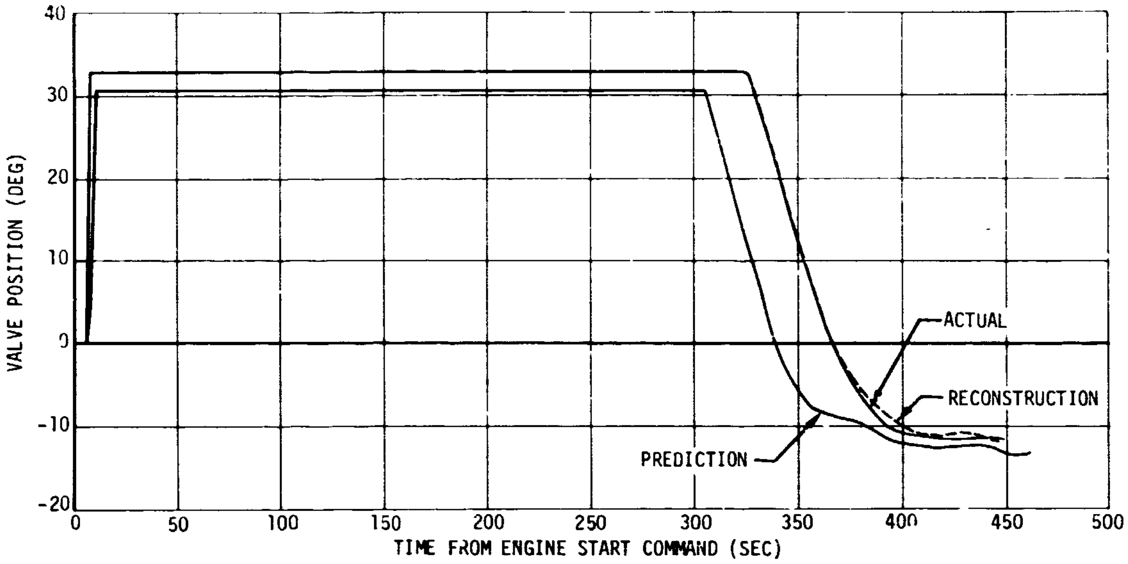


Figure 15-11. Flight PU Valve Position History

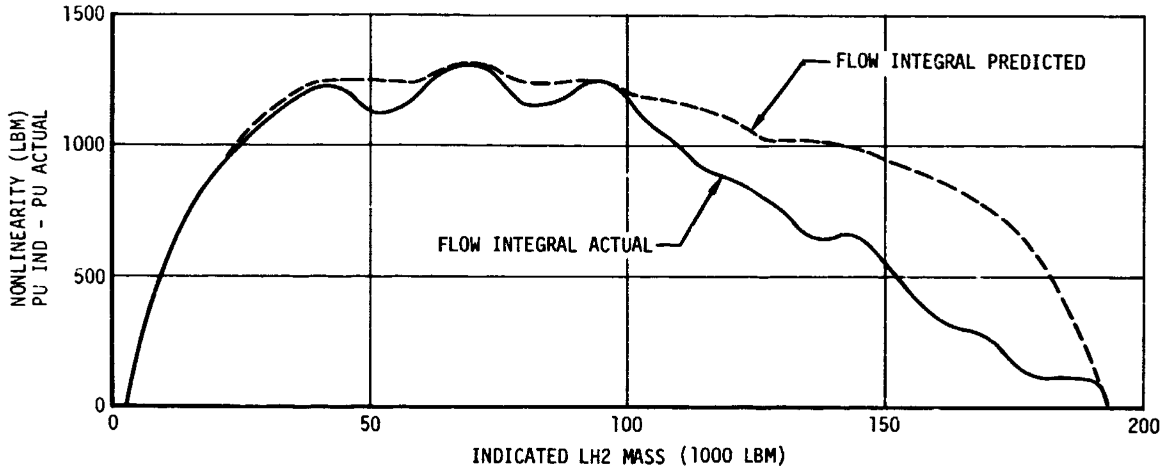


Figure 15-12. PU System LOX Mismatch Nonlinearity

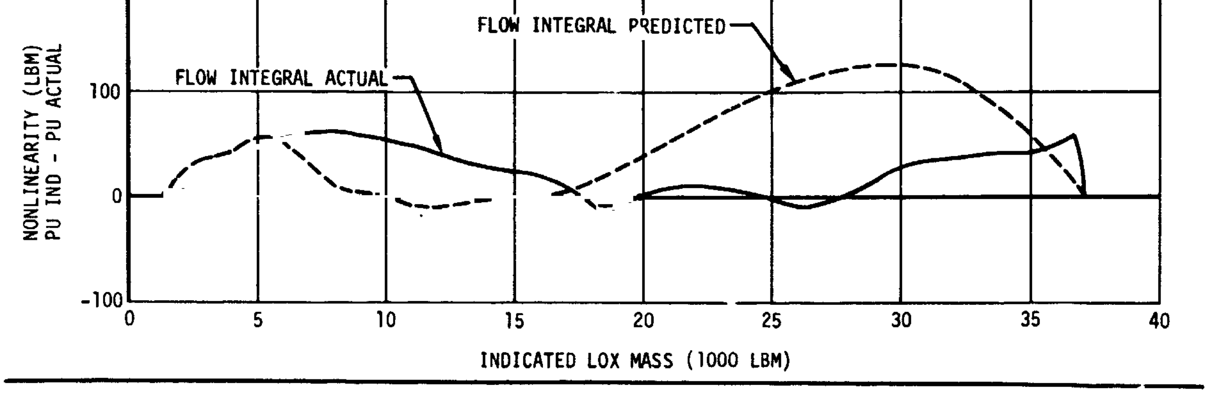


Figure 15-13. PU System LH2 Mismatch Nonlinearity

SECTION 16

S-IB/S-IVB STAGE SEPARATION DYNAMICS

16. S-IB/S-IVB SEPARATION DYNAMICS

Separation of the S-IVB stage from the S-IB stage was accomplished satisfactorily within the desired time period. First axial motion between the stages occurred 0.09 sec after the separation command. Complete separation was accomplished 0.97 sec after the separation command. Small S-IB and S-IVB angular velocities and lateral accelerations utilized 2.0 in. of the available 83 in. of lateral clearance. The S-IB pitch, yaw, and roll rates remained below 0.3 deg per sec during separation. The maximum S-IVB rotational rates were slightly larger than the S-IB (±0.5 deg/sec). All were well below the maximum allowable rates.

16.1 Separation Distance

Complete separation of the S-IVB stage from the S-IB stage occurs when the S-IVB stage engine nozzle bell clears the S-IB stage separation plane. The axial distance required for complete separation is 217 in., and the lateral clearance available is 83 in. (when the S-IVB engine is in a null position). Times of events significant to the S-IB/S-IVB separation are listed in table 16-1. From extensometer and acceleration data the time of first axial motion and the axial separation history were reconstructed. Figure 16-1 contains the predicted separation history and the separation histories reconstructed from extensometer and acceleration data. Figure 16-2 presents the relative velocity between the stages.

16.2 Stage Accelerations and Angular Velocities

The actual longitudinal accelerations of the S-IB and S-IVB stages are shown in figure 16-3. The reconstructed acceleration histories were obtained from S-IB and S-IVB accelerometer data. A time bias 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.

The S-IB and S-IVB angular velocities during separation are shown in figure 16-4. Prior to the first motion between the stages, the pitch, yaw, and roll rates were approximately zero. The S-IB angular velocities remained small during the separation interval, never exceeding 0.3 deg per sec. The S-IVB roll angular velocity did not exceed a level of

+0.5 deg per sec during separation. S-IVB pitch and yaw angular velocities reached the levels of -0.3 deg per sec at the time of separation completion. These values for the S-IB and S-IVB stage angular velocities, at Separation Command, were less than the design maximum rates of one deg per sec.

The S-IVB stage lateral accelerations during separation are shown in figure 16-5. These acceleration histories were obtained from the telemetered accelerometer data. The pitch lateral acceleration during separation varied from 0.25 to -0.1 ft/sec^2. The yaw lateral acceleration varied during separation between 0.30 to -0.10 ft/sec^2. The S-IB lateral accelerations remained essentially zero during the separation interval.

16.3 Clearance Distance

The lateral clearance used during separation was 2.0 in. Preflight studies indicate that the probability of exceeding this lateral displacement is 0.72 as shown in figure 16-6. This indicates that less than the average usage occurred on this flight. The path of the S-IB interstage lip during separation is shown two-dimensionally in figure 16-7. During separation, a point of the S-IVB engine bell between positions III and IV utilized 2.0 in. of the available 83 in. of lateral clearance.

TABLE 16-1
SEQUENCE OF EVENTS DURING S-IB/S-IVB SEPARATION

EVENT	MEASURED TIME FROM RANGE ZERO (sec)	MEASURED TIME FROM SEPARATION COMMAND (sec)	PREDICTED TIME FROM SEPARATION COMMAND (sec)
S-IB Stage OECO	142.25	-1.25	-1.3
S-IVB Ullage Rocket Ignition	143.30	-0.20	-0.2
S-IB/S-IVB Separation Command	143.50	-	-
Ullage Rocket Thrust - 75 Percent	143.40	-0.10	-
Retrorocket Thrust - 10 Percent	143.588	0.088	-
First Axial Motion	143.59	0.09	0.12
Retrorocket Thrust - 90 Percent	143.595	0.095	-
S-IB/S-IVB Separation Complete	144.47	0.97	1.01
S-IVB Engine Start Command	144.90	1.40	1.4
J-2 Engine Thrust - 90 Percent			4.9

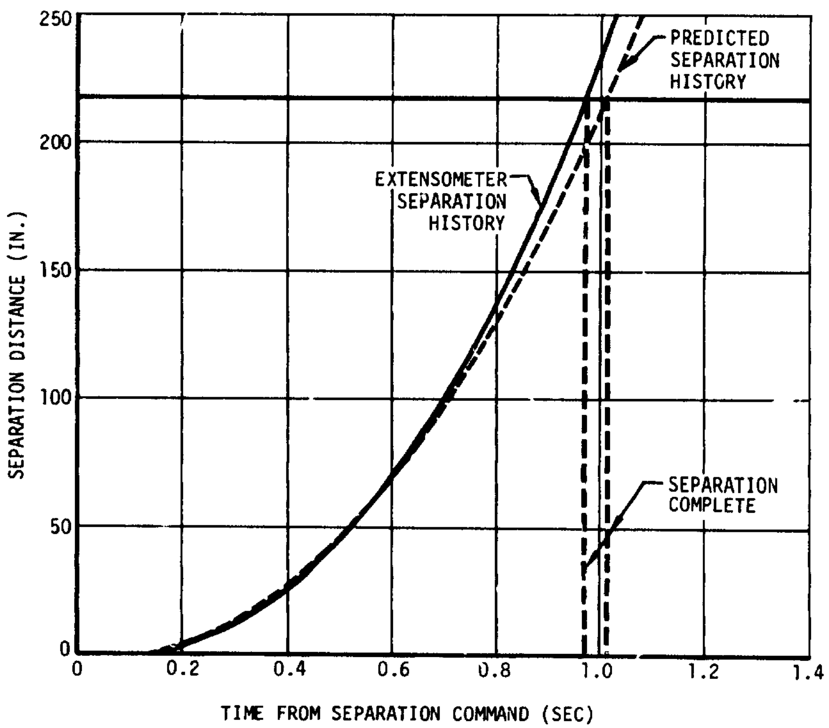


Figure 16-1. Axial Separation History

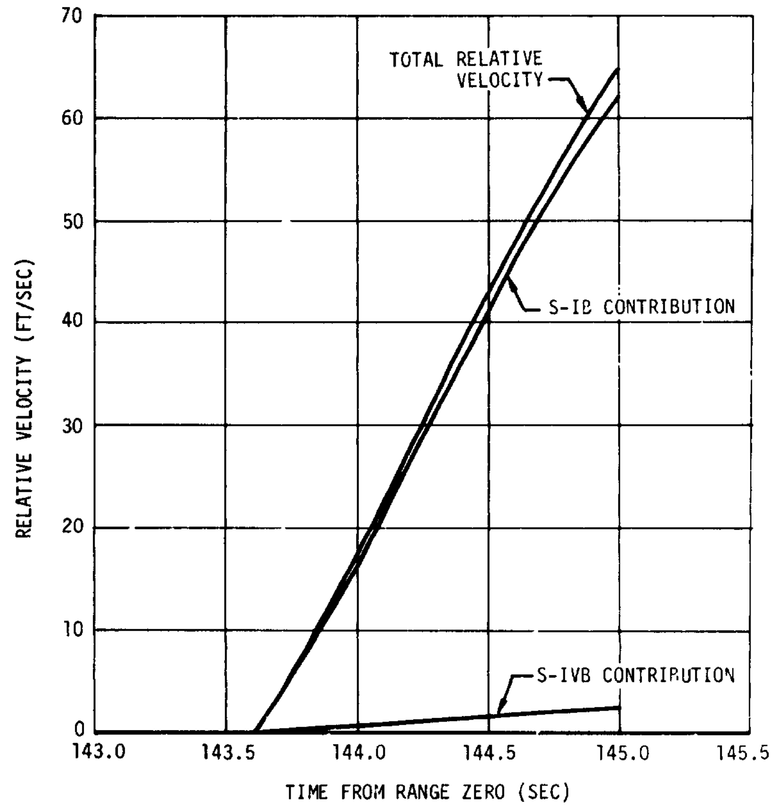


Figure 16-2. Relative Velocity History

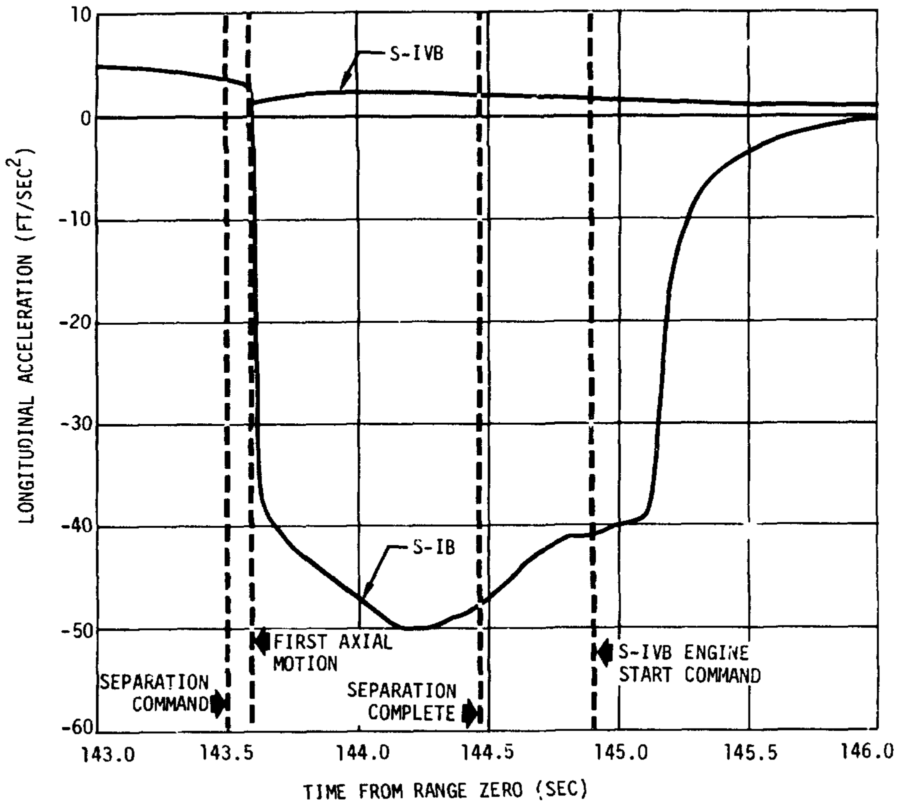


Figure 16-3. Longitudinal Acceleration

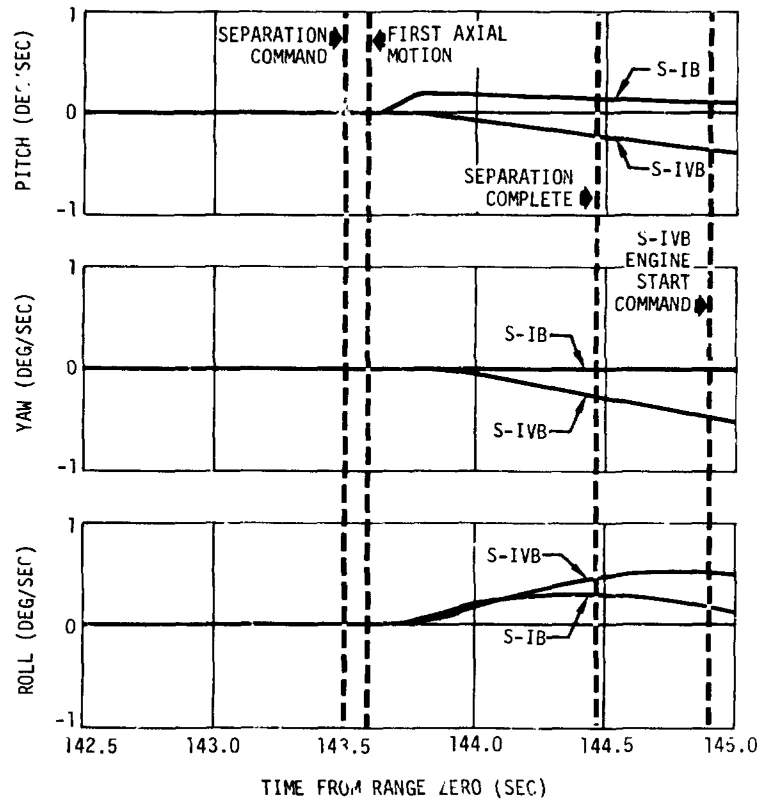


Figure 16-4. Angular Velocities

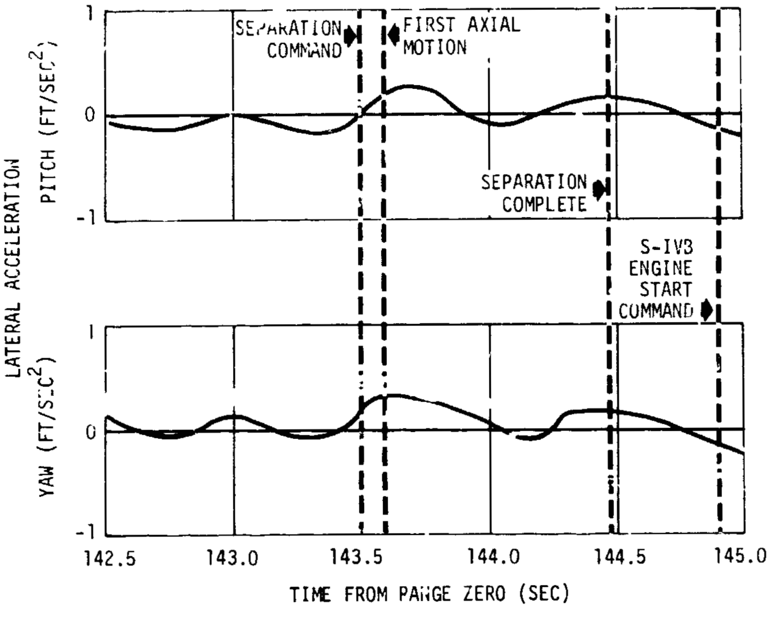


Figure 16-5. S-IVB Lateral Accelerations

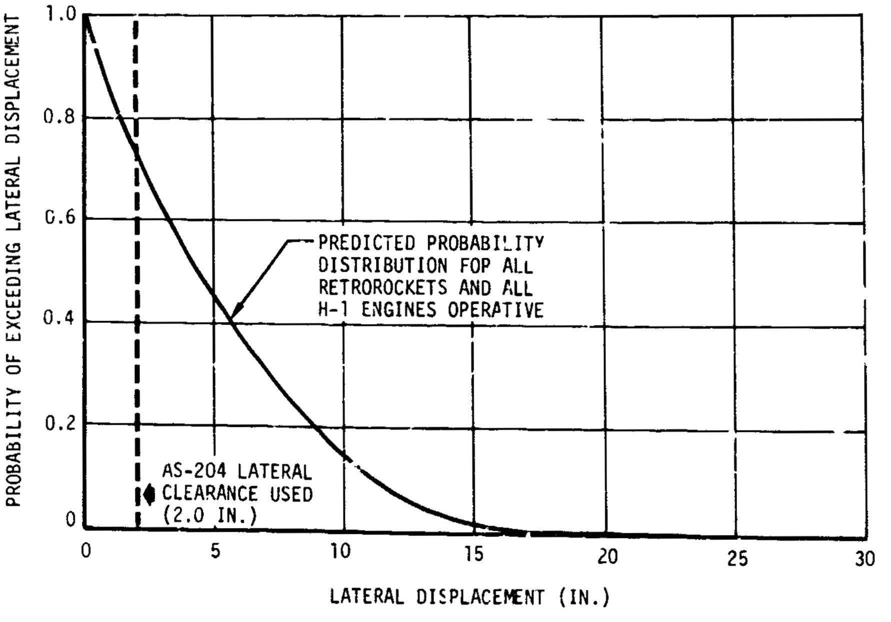


Figure 16-6. AS-204 S-IB/S-IVB Separation Probability of Lateral Displacement Exceeding a Specified Value

NOTE: DURING SEPARATION A POINT ON THE S-IVB ENGINE BELL BETWEEN POSITIONS III AND IV UTILIZED 2.0 IN. OF THE AVAILABLE 83 IN. OF LATERAL CLEARANCE.

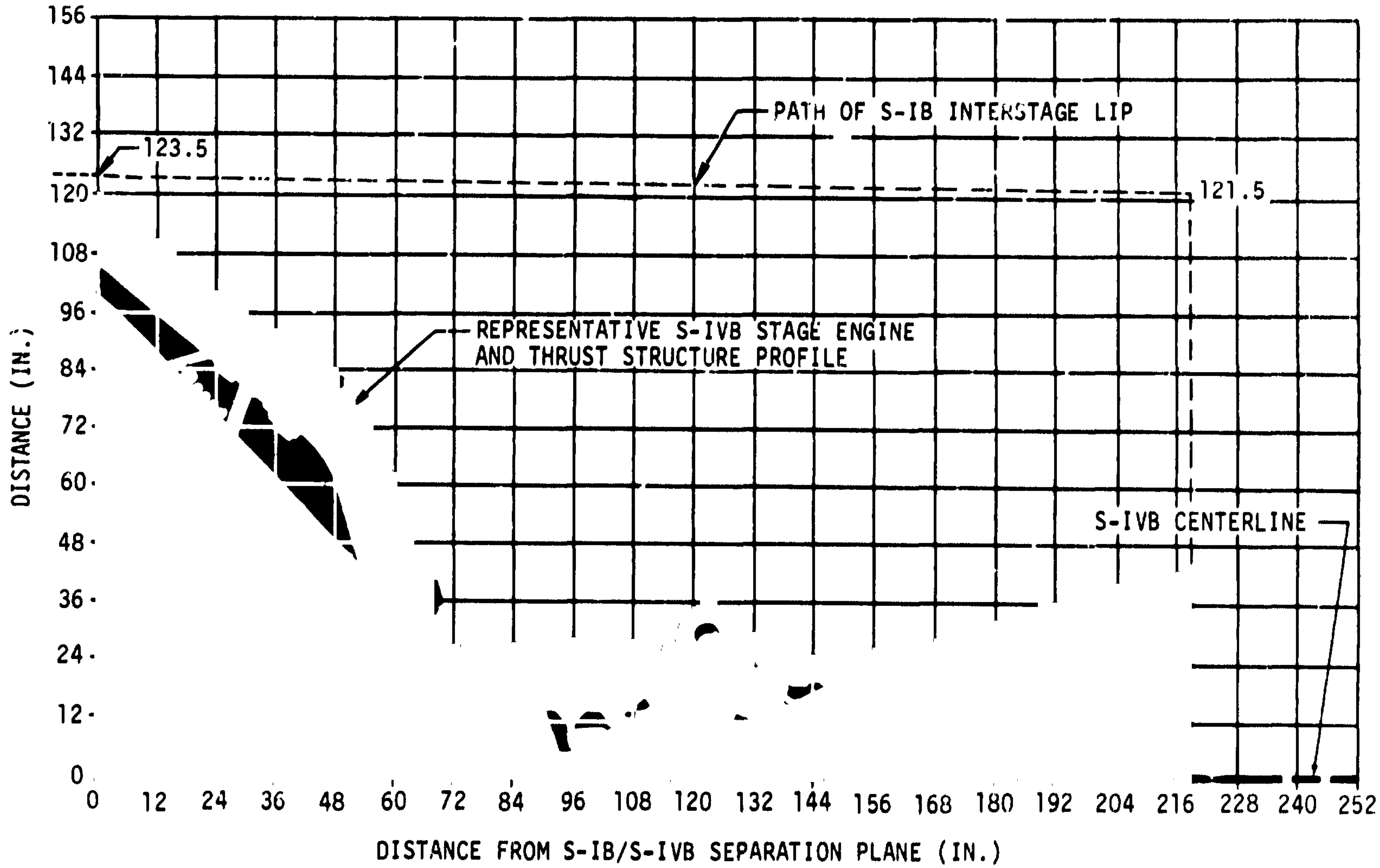


Figure 16-7. AS-204 S-IB/S-IVB Separation Distance

SECTION 17

DATA ACQUISITION SYSTEM

17. DATA ACQUISITION SYSTEM

17.1 Launch Phase

17.1.1 Data Acquisition System Objective

The objective of the Data Acquisition System (DAS) was to gather information describing stage environments and the performance of stage systems. The measurements collected are specified in the Ins ntation Program and Components List (IP&CL) (Douglas Aircraft Drawing -557 "AS" change). The information acquired from the measurements was converted into telemetry format and transmitted to ground stations located throughout the flight path.

The evaluation of the DAS performed in this section shall be from ground hold through the termination of S-IVB engine burn plus 10 sec (RO +603 sec) and shall be referred to as the launch phase.

17.1.2 Summary of Performance

The performance of the DAS was very good throughout the launch phase. All systems performed as designed, and no system malfunctions were observed. Ten measurements were deleted prior to liftoff but the measurement failures during the launch phase were very low. A summarization of the AS-204 launch vehicle measurements is presented below:

Measurements assigned	515
Checkout measurements	11
Prelaunch measurement	1
Measurement inoperative due to stage configuration	1
Measurement monitored by S-IB stage	5
Measurements deleted prior to liftoff	10
Total active measurements at liftoff	487
Measurement failures during launch phase	6
Launch phase measurement efficiency (phase I)	98.8%

A detailed presentation of the measurements status is presented in table 17-1.

17.1.3 Instrumentation System Performance

The performance of the instrumentation system was very good throughout the launch phase. There were six measurements classified as launch phase failures. There were two measurements which were partial successes. Ten measurements were considered as malfunctions prior to the start of the automatic countdown sequence and therefore deleted from CPIF consideration in the instrumentation system performance.

Item 6 of table 17-1 lists the measurements deleted prior to the automatic countdown sequence. Evaluation of the data for the launch phase at A3 indicate that the following deleted measurements performed satisfactorily and presented usable information: C0040-406, C0056-406, and D0121-419. Measurement failures are presented in detail in table 17-2. Measurements considered as partial success are delineated in table 17-3; and measurements which were not failures but considered as measurement anomalies are covered in table 17-4.

17.1.4 Telemetry System Performance

17.1.4.1 Pulse Code Modulation System

The performance of the pulse code modulation (PCM) system during the launch phase was excellent. All multiplexers were properly synchronized and their outputs properly interlaced as attested by the reduced data. All data was recovered on the ground and presented for evaluation without problems.

PCM was utilized as the prime data source in the evaluation of the DAS.

17.1.4.2 Pulse Amplitude Modulation System

The performance of the pulse amplitude modulation (PAM) system was excellent throughout the launch phase. There were no system component malfunctions and synchronization was excellent. The PAM evaluation was based upon data stripouts of selective measurement channels requested for the verification of PCM data that were considered questionable. The PAM to PCM data comparison was during the period of remote analog calibration system (RACS) and it indicates the levels to be within the design limits. The analog data noise levels are within the normal operating characteristics of the PAM systems.

17.1.4.3 Frequency Modulation System

The performance of the frequency modulation (FM) system was very good during the launch phase. The voltage controlled oscillators (VCO) that make up the FM systems performed within the requirements set forth in the flight test plan with the exception of CF3-6 which showed a VCO frequency shift of approximately plus 5.2 percent. Linearity of the channel was not affected and there was no interference with adjacent channels. VCO center and bandedge frequencies are presented in table 17-5.

All measurements assigned to the FM systems were acceptable to the using technologies.

17.1.4.4 Single Sideband System

The single sideband (SS) system performed very well during the launch phase and all data was successfully reduced. The SS translator calibrated as specified and all calibration signals were clean and easily distinguishable for the launch phase evaluation.

Measurement E0082-401, Vib-LOX Turbo Pump-Lateral, was deleted from the active measurements list prior to liftoff and it is delineated in table 17-2. Measurement E0084-401, Vib-LH2 Turbo-Lateral, was invalid from RO +298 sec and is covered in table 17-3. Measurements B0009-427, Acous-Sta 1212, Pos II, Oct 7 - Ext, B0010-427, Acous-Sta 1212 Pos II Oct 8 - Ext, B0012-427, Acous-Pos II (50 - 3,000 cps) - Ext, showed momentary decrease in data amplitude at liftoff and near RO +50 sec. The measurements are acceptable but the anomaly is discussed in table 17-4.

The vibration multiplexer (model 245) sampling rate and period were as specified with no discrepancies observed.

The SS translator 1,700 Hz calibration signal frequency was 1,690 Hz measured at RO +129 sec.

17.1.4.5 Tape Recorder Assembly

The tape recorder performance during the launch phase was very good. The tape recorder recorded all analog data on fast record and played it back on command. PCM data on slow record is evaluated as part of the orbital phase.

Fast record was initiated at RO +136 sec and 26 sec of data was recorded. Fast record playback was commanded at RO +597 sec.

Measurement K0153-411, Event - Ready to Record indication, was not active prior to the Fast Record Command because the recording tape was advanced before liftoff to reduce the analog data recording time. This was necessary since the fast record circuit configuration and the programming of the flight sequence would fast record data in excess of the playback time and the significant S-IB/S-IVB separation data would be lost.

Reduction of the 120 kc frequency indicate wow to be 15.9 Hz at 0.195 in./sec peak-to-peak. Flutter frequency was 5,317 Hz at 0.523 in./sec peak-to-peak amplitude.

17.1.4.6 Calibration Assembly

The telemetry calibrator assembly performed all inflight calibrations as commanded by the sequencer. Calibration steps observed were at the correct levels and the calibration sequencers were in proper synchronization.

17.1.5 Radio Frequency System

The performance of the radio frequency (RF) system was very good throughout the launch phase. The RF system output power from all transmitters except one met the minimum design requirements. FM/FM transmitter No. 3 was slightly low prior to launch and this was documented by failure and rejection report (FARR) A259718. The report was dispositioned as acceptable prior to liftoff.

The data from No. 3 link which were reduced from CIF data tapes were observed to be noisy from RO +300 sec through +550 sec. However, data reduced from BDA data tapes do not reflect the same noise over the comparable period and the problem is attributed to ground acquisition of the flight data.

RF blackout due to flame attenuation was observed during S-IB/S-IVB separation at RO +143.5 sec for two sec.

The performance values for the RF systems are presented in table 17-6.

17.1.6 Signal Strength

RF signal strength from three stations has been reviewed in order to demonstrate the acquisition of satisfactory data during the launch phase.

Figure 17-1 summarizes all data received for S-IVB PCM/FM 1 right hand circular polarized (CP1-RHCP) (232.9 MHz). Data from the other RF links follow similar patterns but at higher levels.

Comparison of the actual data with the predicted signal strength levels at TEL-4 shows the actual level to be well above that predicted.

The signal strength received by GBI was not included in the coverage prediction because of overlapping coverage; however, the data was reviewed and demonstrates satisfactory performance of the stage RF system. A 10 sec drop in power is attributed to ground equipment problems as is supported by the continuation of TEL-4 data and the nature of the discontinuity.

Signal strength in figure 17-1 received at BDA is questionable because reviewed data plots included resolvable data where signal strengths were indicated lower than -120 dbm. It is not expected that the BDA receiving station could provide such sensitive reception. Some decommutated data from BDA was reviewed to confirm the adequacy of the received signal strength. This review revealed a one sec data dropout at RO +330 sec for RF link CF3. This dropout is not attributed to the stage antenna system because of continued coverage at RO +330 sec for all other RF links. The decommutated data, in general, continued to be clear until approximately RO +780 sec at which time data stopped. This review concluded that the RF signal strength received at BDA was adequate.

17.1.7 Electromagnetic Compatibility

The data acquisition system did not interfere with other stage systems in the areas of electromagnetic compatibility. The reference channel levels, M0069-404 and M0071-411, were within the ±8 bit counts limit when evaluated between RO -60 sec to S-IVB cutoff +30 sec. No chilldown inverter noise which exceeded 2 percent was encountered on the measurements during chilldown inverter operation.

17.2 Orbital Phase

17.2.1 Summary of Performance

The data acquisition system performance was very good. All components performed well with the exception of the PCM transmitter which underwent a power drop at RO +1,100 sec; however, no loss of PCM data was observed. Measurement failures for orbital phase is presented in table 17-1. A summarization of the SA-204 launch vehicle measurements is presented below:

Total active measurements at liftoff	487
Measurement failures during launch phase	6
Measurement failures during orbital phase	2
Total measurement efficiency	98.33%

17.2.2 Instrumentation System Performance

The performance of the instrumentation system was excellent. There were six measurement failures during the launch phase and two during the orbital phase. The two orbital phase failure measurements utilized patch-type fiber glass temperature transducers (P/N 1A68589-503) which are susceptible to debonding. Both measurements were off-scale high during the orbital phase.

Comparable external skin temperatures were approximately 330 deg R whereas the off-scale high temperatures indicated in excess of 640 deg R. Measurement C0080 came back on scale and indicated an acceptable temperature level at RO +1,010 sec. However, the sudden off-scale to on-scale temperature change in approximately 2 sec confirms an open circuited sensor. C0079 was also open circuited, although the time of failure cannot be confirmed.

The fiber glass patch-type temperature transducers have been reworked on vehicle 502 and replaced with the new ceramic patch transducers at Kennedy Space Center.

17.2.3 Telemetry System Performance

Telemetry system performance was as follows:

a. PCM System. Although there was a reduction in PCM/FM transmitter output power, good PCM data were obtained. No synchronization problems in data reduction and no multiplexer synchronization problems were observed.

b. PAM System. Performance of the PAM system was good. No component malfunctions were observed and synchronization was good. A1 and A2 multiplexer PAM data were shown merged with the PCM data plots at RO +5,400 sec. Reduced BO multiplexer data of excellent quality were observed.

c. FM System. The FM systems performed very well. Measurements assigned to the FM system presented good data.

d. Single Sideband System. The single sideband system measurements were not required for evaluation during the orbital phase period. However, based upon pilot tone and service channel verification at RO +6,000 sec, the single sideband system was considered operational.

e. Tape Recorder. Tape recorder performance in handling PCM data was very good. Analog data recordings are discussed in section 17. PCM data played back from the airborne tape recorder were merged with ground recorded realtime PCM data. Merged PCM playback data were observed in evaluated data plots at the following times:

RO +9,120 sec to RO +10,380 sec
RO +10,670 sec to RO +10,930 sec
RO +13,820 sec to RO +15,930 sec

PCM playback data times beyond the orbital phase period are called out since no orbital period recorded PCM data were reduced.

Very little PCM playback data were expected from Tananarive for the first revolution. The airborne recorder recording tape was at the end stop at the end of fast record. The tape was advanced prior to liftoff to allow approximately 30 sec of analog data to be recorded. This was necessary to recover the analog data of the stage separation period within the short playback time of 25.8 sec. With 25.8 sec of playback time from the tape end stop, only 206 sec of PCM data could be recorded between Bermuda and Tananarive. The short recorder playback data from Tananarive were not displayed on the data plots because realtime data were available. The PCM playback data from Tananarive during the second revolution were not recoverable. The pulse train did not return to zero and the baseline contained low frequency noise. This problem was attributed to poor recording quality resulting in a poor signal-to-noise ratio. PCM data from the airborne tape recorder, recorded at Guaymas during the first revolution, were extremely noisy and have not been reduced. This was caused by ground station recording difficulties during the first orbit. However, the acquisition and reduction of playback PCM data shown merged in data plots at the times mentioned above confirm proper operation of the airborne tape recorder.

17.2.4 RF System Performance

The overall performance of the RF system during the orbital phase was very good.

At RO +1,100 sec the PCM transmitter output power dropped from 26.8 watts to 13.6 watts. At RO +1,200 sec, the output power increased to 19 watts. At the end of the orbital phase evaluation period, the power was 12.4 watts. A malfunction in the dc to dc converter in the power amplifier is suspected. Although the malfunction reduced the power amplifier output below the minimum requirement of 25 watts, the orbital phase data did not show significant degradation. Good PCM data were reduced from the PCM/FM data link when observed at RO +22,680 sec, which is beyond the dump experiment period.

FM/FM transmitter No. 3 output power, which was failure and rejection report (FARR) tagged at 24.8 watts and dispositioned as acceptable before launch, maintained good output power level. The output power stayed at 24.8 watts throughout the orbital phase.

The other three transmitters - FM/FM transmitter No. 1, FM/FM transmitter No. 2 and the SS/FM transmitter, maintained excellent output power throughout the orbital phase.

The power levels for the RF system during the orbital phase are presented in table 17-7.

17.2.5 Signal Strength

RF signal strength levels from revolutions 1 and 2 over Carnarvon, Canary Island, and Corpus Christi, Texas, were above predicted levels. The data reviewed were for CP1-RHCP (232.9 MHz). Data from the other RF links follow similar patterns but at higher levels.

17.2.6 Electromagnetic Compatibility

The data acquisition system did not interfere with other stage systems in the areas of electromagnetic compatibility.

TABLE 17-1 (Sheet 1 of 2)
MEASUREMENT STATUS

1.	Total number measurements listed in IP&CL (Dwg 1B43557, "AS" chg)	515
2.	Measurements for checkout only	11

K0141-411	Event - R/S 1 Pulse Sensor
K0142-411	Event - R/S 2 Pulse Sensor
K0143-403	Event - Ull Rkt 1 Ign P/S 1
K0144-404	Event - Ull Rkt 1 Ign P/S 2
K0145-404	Event - Ull Rkt 2 Ign P/S 1
K0146-404	Event - Ull Rkt 2 Ign P/S 2
K0147-404	Event - Ull Rkt 3 Ign P/S 1
K0148-404	Event - Ull Rkt 3 Ign P/S 2
K0149-404	Event - Ullage Jettison 1 P/S
K0150-404	Event - Ullage Jettison 2 P/S
K0169-404	Event - EBW Pulse Sensor Off Ind

3.	Measurement used for prelaunch only	1

D0545-407	Press - Common Bulkhead Int-H/W

4.	Inactive measurement	1

K0152-404	Event - Rt Gyro Whl Speed OK Ind

5.	Measurements monitored by S-IB	5

C0375-402	Temp - Heat Flux Aft Interstage 3
D0153-423	Press - Chamb Retro Rkt Pos IV-I
D0154-421	Press - Chamb Retro Rkt Pos II-III
D0155-420	Press - Chamb Retro Rkt Pos I-II
D015[illegible]-422	Press - Chamb Retro Rkt Pos III-IV

6.	Measurements deleted prior to liftoff	10

C0040-406	Temp - LOX Tk Pos 1
C0041-406	Temp - LOX Tk Pos 2

TABLE 17-1 (Sheet 2 of 2)
MEASUREMENT STATUS

C0042-406	Temp - LOX Tk Pos 3
C0043-406	Temp - LOX Tk Pos 4
C0055-406	Temp - LOX Tk Ullage Gas 1 Percent
C0056-406	Temp - LOX Tk Ullage Gas 20 Percent
C0072-408	Temp - Fuel Tk Wall External 4
C0133-406	Temp - LOX Tk Ullage
D0121-419	Press - External Att Interstage 1
E0082-403	Vib - LOX Turbo Pump - Lateral

7. Measurements active for flight evaluation 487

8. Launch phase measurement failures 6

D0016-425	Press - Cold Helium Sphere
D0045-403	Press - Engine Actuator Yaw Diff
D0062-424	Press - LH2 Circ Ret Line Tk Inlet
D0122-419	Press - Ext Aft Interstage 2
D0124-419	Press - Ext Aft Interstage 4
D0158-402	Press - Interstage Internal [illegible]

9. Orbital phase measurement failures 2

C0079-409	Temp - Fuel Tank External 5
C0080-409	Temp - Fuel Tank External 6

TABLE 17-2 (Sheet 1 of 4)
MEASUREMENT FAILURES

MEAS. NO.	TITLE	COMMENTS
C0041-406 C0042-406 C0043-406 C0055-406 C0135-406	Temp - Oxid Tank Pos 2 Temp - Oxid Tank Pos 3 Temp - Oxid Tank Pos 4 Temp - LOX Tk Ullage Gas 1 Percent Temp - Oxid Tank Ullage	These temperature measurements were deleted from the active measurement list prior to liftoff. Measurement C0041-406 indicated off-scale-low throughout the launch phase. Measurement C0042-406 indicated off-scale-high until RO +570 sec when it went off-scale-low. At RO +615 sec the measurement went off-scale high and remained off-scale-high. Measurement C0043-406 indicated off-scale-low throughout the launch phase. Measurement C0055-406 was off-scale-high until RO -150 sec and behaved in an erratic manner through the launch phase. Measurement C0135-406 remained off-scale-high before indicating an erroneous on-scale temperature of 315 deg R at RO +45 sec. The measurement went off-scale-high again at RO +140 sec. All of the measurements are probe type temperature transducers, P/N 1A67862, located in the LOX tank. A study is presently being conducted at A3 on the failure of these measurements. A failure analysis will be released when completed.
D0016-425	Press - Cold Helium Sphere	The measurement is considered a failure and Propulsion finds it unreliable and not usable for calculations. During the automatic countdown, the pressure showed an unusual increase from 2,900 psia to 3,100 psia at RO -450 sec and it reacted in an erratic manner through liftoff. A steady pressure at approximately 3,000 psia is expected until there is a blowdown of the cold helium system. The anomalous behavior of the measurement is considered an unlikely failure mode of the transducer and the apparent failure is under continued investigation at A3.

TABLE 17-2 (Sheet 2 of 4)
MEASUREMENT FAILURES

MEAS. NO.	TITLE	COMMENTS
D0045-403	Press - Engine Actuator Yaw Diff	High speed stripout of the measurement covering the launch phase indicates the pressure variation is not compatible with the yaw position changes. The data indicates that the potentiometer-type transducer wiper arm or differential diaphram was not responding to pressure changes and the measurement is a phase I failure.
D0062-424	Press - LH2 Circ Ret Line Tk Inlet	The measurement indicated a sudden drop in pressure at liftoff. The pressure showed some recovery at RO +5 sec before going off-scale-low again at RO +50 sec. The measurement makes a recovery at RO +160 sec and trend data is indicated from RO +200 sec. The measurement utilized a strain gage pressure transducer, P/N 1B40242, qualified down to a temperature of 140 deg R. Review of the transducer installation drawing reveals that the transducer can be subjected to cold soaking in LH2. The identical problem occurred on AS-203 where the same strain gage transducer was used. On AS-202, a potentiometer-type pressure transducer was used and the problem did not occur. ECP 1002 was initiated to correct the problem by installing the transducers with extended sense lines for AS-501, AS-502, and AS-503. The correction was not made on AS-204. With the transducer installed on a sense line on AS-501, the problem did not occur.
D0122-419	Press - External - Aft Intstg 2	The measurement indicated 11.5 psia prior to liftoff where 14.7 psia was expected. A check of raw data before liftoff at sea level and at zero pressure (2250:28.127 GMT) showed bit counts of 693 bits and 0 bits, respectively. The zero pressure point is negatively over-biased and represents a non-recoverable data point which is required in the proper calibration adjustment of the measurement. High RACS

TABLE 17-2 (Sheet 3 of 4)
MEASUREMENT FAILURES

MEAS. NO.	TITLE	COMMENTS
D0122-419	(Continued)	was 516 bit counts (50 percent) and low RACS was 0 bit counts (-2.5 percent). The measurement is a launch phase failure due to a negative overbias of the transducer.
D0124-419	Press - External Aft Interstg 4	The using technology could not utilize the data after the recalibration of the measurement. Investigation into the rejection of the measurement indicates that the transducer was subjected to a low temperature environment exceeding its specification limits. The measurement is considered a phase I failure. The specification temperature limit of the transducer on the low end is 490 deg R. The temperature in the vicinity of the transducer was approximately 300 deg R. The engine bell chilldown which occurs 15 min prior to liftoff, and continues to liftoff, cooled the transducer beyond the specification limit. Since the transducer is recalibrated utilizing the barometric pressure at sea level prior to liftoff and the zero pressure of outer space, when the transducer warmed up during the boost phase, the resultant was a non-linear recalibration of the transducer. The low temperature condition is being investigated at A3.
D0158-402	Press - Interstg - Internal 2	The measurement zero pressure calibration point exceeded 0 bit counts and, therefore, a two-point calibration adjustment cannot be made. Data is considered trend only and it is a phase I failure. RACS levels prior to launch reveal the following: high RACS - 801 bit counts, low RACS - 185 bit counts. Low RACS show a 3.5 percent underbias at the 20 percent calibration level and the failure is due to a shift in the low side calibration of the pressure transducer (P/N 1B497442) which makes valid data unretrievable.

TABLE 17-2 (Sheet 4 of 4)
MEASUREMENT FAILURES

MEAS. NO.	TITLE	COMMENTS
E0082-401	Vib - LOX Turbo Pump - Lateral	The measurement was deleted from the active measurements list prior to liftoff. The COAX connector at the transducer was damaged during checkout and the cable was coiled and stowed.

TABLE 17-3
MEASUREMENTS PARTIALLY SUCCESSFUL

MEAS. NO.	TITLE	COMMENTS
D0121-419	Press - External - Aft Interstage 1	The measurement was deleted from the active measurements list prior to liftoff. The launch phase data showed 4 percent peak-to-peak noise on the measurement. Although the noise level exceeds the 2 percent error limit allowed for the measurement, it is usable data and the measurement is a partial success.
E0084-401	Vib - LH2 Turbo Pump - Lateral	The measurement is considered a partial success. The data becomes increasingly noisy from RO +298 sec. Because of the gradual degradation of the data, a loose connector aggravated by the high engine vibration is suspected.

TABLE 17-4 (Sheet 1 of 3)
MEASUREMENT ANOMALIES

MEASUREMENT NO.	TITLE	COMMENTS
B0009-427 B0010-427 B0012-427	Acous - Sta 1212, Pos II, Oct 7 - Ext. Acous - Sta 1212, Pos II, Oct 8 - Ext. Acous - Pos II (50 - 3,000 cps) - Ext.	The measurements reflected a momentary decrease in data amplitude during the following times when the data amplitude was expected to be at a steady level: RO -1 sec, +1 sec, +48 sec, and +52 sec. B0009-427 and B0010-427 displayed a slight drop in data level on PAM. B0012-427 showed the data level going to zero. Except for the momentary anomalies, the data is valid throughout the launch phase. It is believed that the data at these times are valid and may be due to localized acoustic environment.
C0040-406 C0056-406	Temp - Oxid Tank Pos 1 Temp - LOX Tank Ullage 20%	These measurements were deleted from the active measurement list prior to liftoff. C0040-406 was deleted as off scale high following prelaunch LOX loading and C0056-406 was deleted as off scale low during launch countdown. However, evaluation of data at A3 indicates the measurements were valid during the launch phase. High and low RACS levels were 80 percent and 0 percent respectively, and both measurements were at 166 deg R prior to launch.
C0072-408	Temp - Fuel Tk Wall Internal 4	The measurement was deleted from the active measurements list prior to liftoff. During launch countdown, the measurement was active but the indicated temperature was lower than expected at 34 deg R. A verification of high and low RACS calibration showed 80 percent and 0 percent levels respectively when it should have been 98 percent and 18 percent. The higher calibration levels are required to accommodate the change in the temperature transducer from P/N 1A68589-503 to P/N 1A68589-521. The CAT-1 calibration curve was corrected to reflect the RACS calibration error.

TABLE 17-4 (Sheet 2 of 3)
MEASUREMENT ANOMALIES

MEASUREMENT NO.	TITLE	COMMENTS
C2013-401	Temp - Fuel Turbine Manf Ext. Wall	The temperature was suspected of being too low at 150 deg R prior to liftoff. A check of the RACS level showed proper signal conditioning setup at 80 percent and 0 percent. C2013-401, C2014-401, C2015-401 and C2016-401 utilize the same temperature probe (118FS) and they are related measurements. Therefore, the ambient temperatures were expected to be reading approximately the same before propellant loading. When the four temperature measurements were verified at 18:34 hrs (GMT), prior to LOX loading, they all read approximately 568 deg R within ± 5 deg R. Since the temperature error suspected was 200 deg R, the ambient check verified the calibration used with the measurement was valid. The same temperature condition occurred during CDDT. The problem was investigated and the results indicate that condensation of purge nitrogen gas occurred, dripping onto areas in close proximity to the measurement. The measurement is considered valid.
D0159-402	Press - Interstage Internal 3	Measurement was commented as being off scale high during data qualification. The calibration curve for this pressure transducer was readjusted using calibration points at sea level from barometric pressure readings and the zero pressure of space. With the readjusted calibration curve, the measurement is successful.
N0040-415	Misc - Qty - Fuel Tk Mod 2 (APS)	The measurement became noisy beginning at S-IVB operation at RO +144 sec and throughout the launch phase. The noise is attributed to sticky potentiometer operation which has been observed on previous stages. Although the measurement is slightly

TABLE 17-4 (Sheet 3 of 3)
MEASUREMENT ANOMALIES

MEASUREMENT NO.	TITLE	COMMENTS
N0040-415 (Cont'd)		degraded, the quantity information is useable and the measurement was successful.
N0056-411	Misc - R/S Revr 2 H/L Sig Strength	The H/L signal strength is a normally noisy measurement. However, the noise characteristic changes at +110 sec displaying periodic noise spikes approximately 9 sec apart. A level shift from 1.5 vdc to 3.5 vdc is indicated at approximately RO +420 sec. Historical data from previous flight stages reveal data characteristic changes at approximately RO +110 sec. The observed phenomena does not characterize loss of signal at the receiver. Loss of the range safety system would be normally indicated by increased H/L high level signal strength accompanied by the loss of low level signal strength (N0062-411). The measurement is a success and it indicates the actual performance of the range safety receiver.
T0001-401	Speed - Oxidizer Pump	Analog stripout of the data pulses from the Flow Rate and Turbo Speed (FRATS) module indicated erroneous oxidizer turbine speed at twice the expected value. Examination of the RACS output verified that the pulse rate output was twice the calibration frequency and that there was a failure in the FRATS module countdown circuit. Toggle type flip-flops are used in a divide-by-two countdown and a loss of flip-flop is suspected. A failure analysis is presently being conducted by the responsible technology at A3. The CAT-1 calibration curve was corrected to reflect the countdown error and the measurement is a success.

TABLE 17-5 (Sheet 1 of 3)
FM VCO FREQUENCY

SYSTEM 1

IRIG CHANNEL	NOMINAL		PREFLIGHT		INFLIGHT	
	f_c	f_{be}	f_c	f_{be}	f_c	f_{be}
6	1,700	1,828 1,572	1,699	1,828 1,570	1,699	1,827 1,570
7	2,300	2,473 2,127	2,301	2,475 2,127	2,301	2,475 2,127
8	3,000	3,225 2,775	3,000	3,226 2,772	3,000	3,226 2,772
9	3,900	4,193 3,607	3,900	4,195 3,608	3,900	4,195 3,606
10	5,400	5,805 4,995	5,402	5,804 4,993	5,399	5,804 4,993
11	7,350	7,901 6,799	7,342	7,898 6,794	7,342	7,898 6,794
12	10,500	11,288 9,712	10,492	11,284 9,722	10,492	11,283 9,720
13	14,500	15,588 13,412	14,488	15,576 13,405	14,488	15,575 13,405
14	22,000	23,650 20,350	21,983	23,641 20,331	21,978	23,575 20,228
15	30,000	32,250 27,750	30,002	32,245 27,748	20,004	32,249 27,748

f_c = center frequency

f_{be} = bandedge frequencies

TABLE 17-5 (Sheet 2 of 3)
FM VCO FREQUENCY

SYSTEM 2

IRIG CHANNEL	NOMINAL		PREFLIGHT		INFLIGHT	
	f_c	f_{be}	f_c	f_{be}	f_c	f_{be}
3	730	785 675	730	785 675	730	785 674
6	1,700	1,828 1,572	1,700	1,828 1,572	1,700	1,828 1,571
7	2,300	2,473 2,127	2,301	2,477 2,127	2,303	2,477 2,127
8	3,000	3,225 2,775	3,000	3,224 2,774	3,000	3,224 2,774
9	3,900	4,193 3,607	3,904	4,197 3,604	N/A	N/A N/A
10	5,400	5,805 4,995	5,398	5,804 4,992	5,398	5,805 4,994
11	7,350	7,901 6,799	7,344	7,895 6,794	7,345	7,895 6,794
12	10,500	11,288 9,712	10,488	11,298 9,702	10,490	11,281 9,696
13	14,500	15,588 13,412	14,488	15,585 13,395	14,492	15,583 13,398
14	22,000	23,650 20,350	21,993	23,652 20,335	21,990	23,657 20,333
15	30,000	32,250 27,750	29,983	32,233 27,715	29,983	32,232 27,715

N/A = Data Not Available

f_c = center frequency
f_{be} = bandedge frequencies

TABLE 17-5 (Sheet 3 of 3)
FM VCO FREQUENCY

SYSTEM 3

IRIG CHANNEL	NOMINAL		PREFLIGHT		INFLIGHT	
	f_c	f_{be}	f_c	f_{be}	f_c	f_{be}
6	1,700	1,828 1,572	1,706	1,835 1,578	N/A	N/A N/A
7	2,300	2,473 2,127	N/A	N/A N/A	N/A	N/A N/A
8	3,000	3,225 2,775	N/A	N/A N/A	N/A	N/A N/A
9	3,900	4,193 3,607	3,906	4,202 3,603	N/A	N/A N/A
10	5,400	5,805 4,995	5,400	5,807 4,995	5,397	5,803 4,992
11	7,350	7,901 6,799	7,344	7,903 6,791	7,344	7,900 6,789
12	10,500	11,288 9,712	10,490	11,279 9,702	10,490	11,278 9,699
13	14,500	15,588 13,412	14,500	15,596 13,413	14,500	15,592 13,413
14	22,000	23,650 20,350	21,695	23,643 20,325	21,970	23,645 20,335
15	30,000	32,250 27,750	30,015	32,275 27,750	30,015	32,275 27,750

N/A = Data Not Available

f_c = center frequency
f_{be} = bandedge frequencies

TABLE 17-6
RF SYSTEM PERFORMANCE-LAUNCH PHASE

MEASUREMENT	TITLE	LAUNCH PHASE POWER (watts)
[illegible]-411	FM/FM Xmtr #1 Output Pwr	3[illegible]
X0016-411	FM/FM Xmtr #2 Output Pwr	28.4
X0017-411	FM/FM Xmtr #3 Output Pwr	24.9*
X0018-411	PCM/FM Xmtr Output Pwr	26.8
X0019-411	SS/FM Xmtr Output Pwr	26.8
X0011-411	T/M 1 Antenna Fwd RF Pwr	18.6
X0007-411	T/M 1 Antenna Rfl RF Pwr	0.8
X0012-411	T/M 2 Antenna Fwd RF Pwr	16.0
X0008-411	T/M 2 Antenna Rfl RF Pwr	0.6
X0033-411	T/M 3 Antenna Fwd RF Pwr	22.6
X0034-411	T/M 3 Antenna Rfl RF Pwr	0.4
X0035-411	T/M 4 Antenna Fwd RF Pwr	20.8
X0036-411	T/M 4 Antenna Rfl RF Pwr	0.2

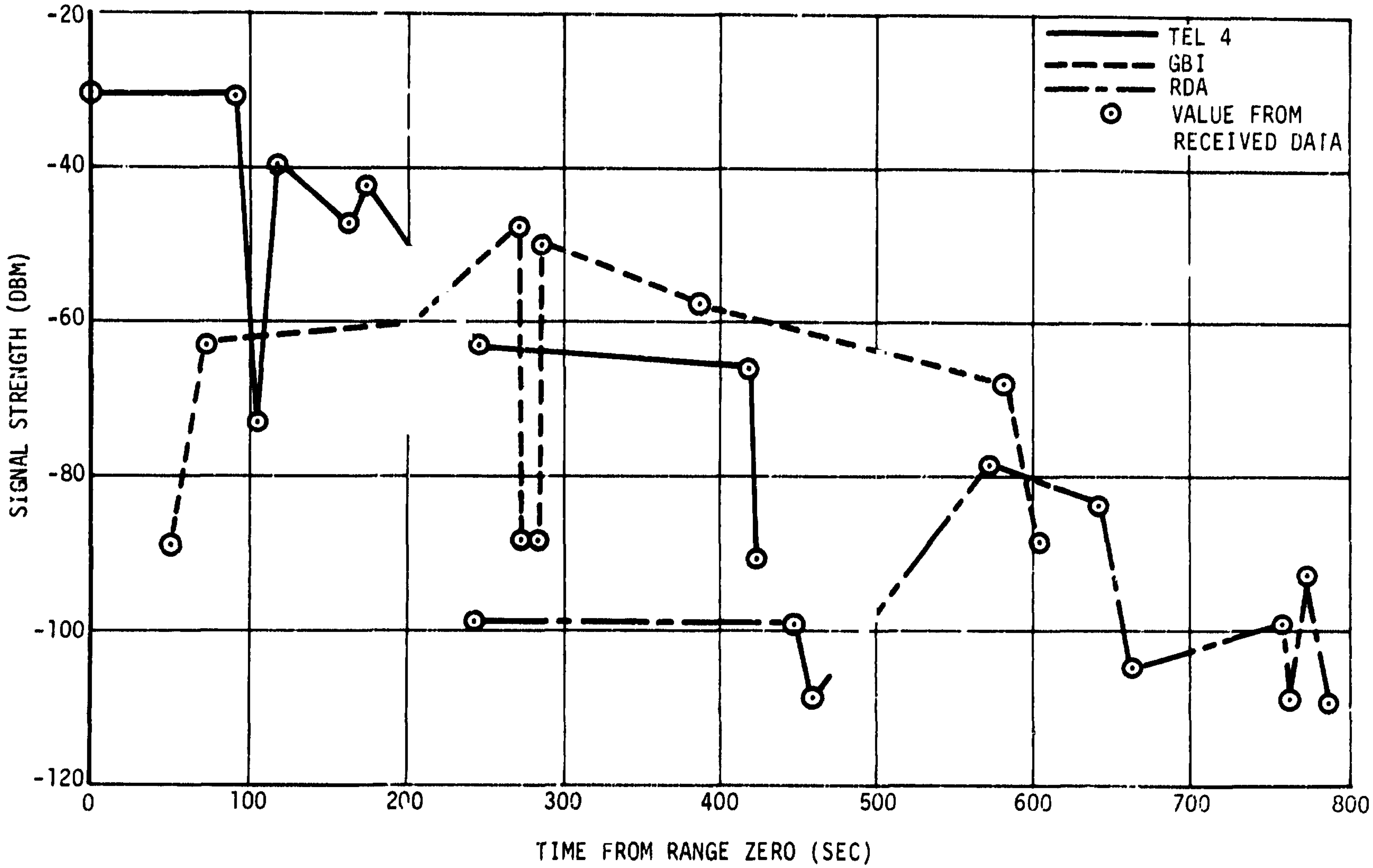
*The output power was below the minimum power requirement of 25 watts and FARR tag A259718 was written. The FARR tag was dispositioned as acceptable before launch.

ANTENNA NO.	INSERTION LOSS (db)	LAUNCH PHASE VSWR	S-IB/S-IVB FLAME ATT VSWR
T/M Antenna No. 1	5.1	1.53:1	3.21:1
T/M Antenna No. 2	5.4	1.47:1	2.42:1
T/M Antenna No. 3	5.6	1.31:1	1.63:1
T/M Antenna No. 4	5.9	1.22:1	2.86:1

TABLE 17-7
RF SYSTEM PERFORMANCE - ORBITAL PHASE

	R0 +3,400 sec	R0 +8,774 sec
FM/FM Xmtr No. 1 Output Pwr (N0015-411)	36.4 w	38.0 w
FM/FM Xmtr No. 2 Output Pwr (N0016-411)	30.0 w	31.4 w
FM/FM Xmtr No. 3 Output Pwr (N0017-411)	24.8 w*	24.8 w*
PCM/FM Xmtr Output Pwr (N0018-411)	16.4 w	12.4 w
SS/FM Xmtr Output Pwr (N0019-411)	26.7 w	27.4 w
T/M 1 Antenna Fwd RF Pwr (N0011-411)	18.4 w	18.4 w
T/M 1 Antenna Refl Pwr (N0007-411)	0.5 w	0.6 w
T/M 2 Antenna Fwd RF Pwr (N0012-411	16.4 w	17.4 w
T/M 2 Antenna Refl Pwr (N0008-411)	0.4 w	0.4 w
T/M 3 Antenna Fwd RF Pwr (N0033-411)	22.0 w	21.6 w
T/M 3 Antenna Refl Pwr (N0034-411)	0.6 w	0.6 w
T/M 4 Antenna Fwd RF Pwr (N0035-411)	17.8 w	17.2 w
T/M 4 Antenna Refl Pwr (N0036-411)	0.3 w	0.3 w
VSWR		
T/M Antenna No. 1	1.39:1	1.43:1
T/M Antenna No. 2	1.37:1	1.35:1
T/M Antenna No. 3	1.38:1	1.40:1
T/M Antenna No. 4	1.29:1	1.31:1
INSERTION LOSS		
T/M Antenna No. 1	5.2 db	5.3 db
T/M Antenna No. 2	5.6 db	5.6 db
T/M Antenna No. 3	5.2 db	5.3 db
T/M Antenna No. 4	6.0 db	6.1 db

*The output power was below the minimum requirement of 25 watts and FARR tag A259718 was written. The FARR tag was dispositioned as acceptable before launch at Kennedy Space Center.



CP1 - RIGHT HAND CIRCULAR POLARIZED TELEMETRY SIGNAL STRENGTH MEASURED AT THE NOTED STATIONS

Figure 17-1. Signal Strength - Launch Phase

SECTION 18

ELECTRICAL SYSTEM

18. ELECTRICAL SYSTEM

18.1 Launch Phase

The electrical control system and the electrical power system performed satisfactorily throughout the launch phase of flight.

18.1.1 Electrical Control System

The operational integrity of the stage electrical control system is verified in section 4.0 of this evaluation. All responses to switch selector commands were satisfactory.

18.1.1.1 J-2 Engine Control System

All J-2 engine event measurements verified that the engine control system had responded properly to the engine start and cutoff commands. Engine start was initiated at RO +144.905 sec with engine velocity cutoff initiated at RO +593.344 sec. The telemetry event measurements which descr[illegible] performance occurred in the proper sequential order and with[illegible]cified incremental times.

18[illegible]2 Control Pressure Switches

A review of the event and pressure measurements verified that each control pressure switch functioned properly during the launch phase. Listed below are those measurements and a description of their performance.

The engine pump purge regulator backup pressure switch is used to maintain the engine pump purge regulator pressure between 105 to 130 psia when enabled by the engine pump purge control valve command. The following measurements indicate that the command was not exercised during flight and the pressure switch remained de-energized.

K0105-404 Event - Pump Purge Reg Bkup De-en

D0050-403 Press - Eng Pump Purge Regulator

The LH2 tank flight control pressure switch regulated the LH2 bypass control valve when the LH2 tank pressurization control switch enable command was on. The fuel tank was pressurized to approximately 36 psia at liftoff and increased to 39 psia for engine start. The command was given during mainstage and the pressure switch remained energized as the ullage pressure was beyond the 31 to 34 psia operating limits of the pressure switch.

K0184-404 Event - Fuel Tk Flt Cont Press Sw

D0177-410 Press - Fuel Tank Ullage EDS 1

D0178-410 Press - Fuel Tank Ullage EDS 2

The LH2 tank ground fill valve and repress pressure switch was used to control pressurization prior to liftoff and was not operational during flight.

The LOX prepress and flight control pressure switch controlled the heat exchanger bypass valve and the cold helium supply shutoff valves during LOX tank flight pressure system commands. The LOX tank was pressurized to approximately 42 psia at liftoff and decreased to 40 psia at engine start. The following measurements verified that the pressure switch maintained a 37 to 40.8 psia pressure in the LOX tank during J-2 engine operation.

K0102-404 Event - LOX Repress Flight Sw-En

D0179-424 Press - Oxid Tank Ullage EDS 1

D0180-424 Press - Oxid Tank Ullage EDS 2

The LOX chilldown pump helium purge control regulator backup pressure switch is used to regulate the LOX pump purge control valve during the LOX chilldown pump purge control valve on command. The pressure switch remained energized during the launch phase as the regulator backup pressure was beyond the operating limits of the pressure switch.

K0131-403 Event - LOX Chilldown Purge Sw De-en

D0103-403 Press - He Press to LOX Mot Cntr

The control helium regulator backup pressure switch regulates the control helium shutoff valve to maintain a 490 $\pm$25 to 600 $\pm$15 psia pressure. The regulator discharge pressure remained within the operating limits of the pressure switch throughout the launch phase of flight.

D0014-403 Press - Control He Reg Discharge

The cold helium regulator backup pressure switch opens the cold helium supply shutoff valves when the cold helium backup pressure exceeds 465 +10 -15 psia. The following measurements indicate that the pressure switch was de-energized as the actuation pressure was not attained.

K0156-404 Event - LOX Tk Reg Bkup Press - En

D0225-403 Press - Cold Helium Cont Vlv Inl

The LOX and LH2 orbital coast vent low pressure switches and the LH2 orbital coast vent high pressure switch were installed but were not made operational for flight. No data is available to evaluate their performance.

18.1.1.3 APS Electrical Control System

A review of the APS feed valve and chamber pressure data verified that the APS electrical control system performed within design limits during the launch phase.

D0078-414 Press - Att Control Chamber 1-1

D0079-414 Press - Att Control Chamber 1-2

D0080-414 Press - Att Control Chamber 1-3

D0081-415 Press - Att Control Chamber 2-1

D0082-415 Press - Att Control Chamber 2-2

D0083-415 Press - Att Control Chamber 2-3

K0132-404 Event - APS Eng 1-1/1-3 Fd Vlv - Op

K0134-404 Event - APS Eng 2-1/2-3 Fd Vlv - Op

K0135-404 Event - APS Eng 2-2 Fd Vlv - Op

18.1.1.4 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

18.1.1.5 Vent Valves

The following measurements indicate that the LOX and LH2 vent valves responded to their respective commands during the launch phase and operated properly.

K0001-410 Event - Fue 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

18.1.1.6 Fill and Drain Valves

The LOX and LH2 fill and drain valves were commanded close through the umbilical prior to liftoff and remained closed throughout flight.

K0003-427 Event - Fuel Fill Valve - Closed

K0004-427 Event - Oxid Fill Valve - Closed

18.1.2 Electrical Power System

The electrical power system performed satisfactorily throughout the launch phase of flight.

18.1.2.1 Flight Batteries

All batteries performed within the expected limits as verified from the load profiles and temperature data shown in figures 18-1 through 18-4.

18.1.2.2 Chilldown Inverter

The chilldown inverters performed satisfactorily and were turned off just prior to engine start. At liftoff, the LOX inverter temperature was 520 deg R and the LH2 inverter temperature was 515 deg R. The temperatures remained fairly constant until turnoff.

Meas. No.	Measurement Nomenclature	Acceptable Range	Actual Value
M0026-404	Volt - Phase A-B Fuel Chldwn Inv	56 ±4 vrms	56.5 vrms
M0027-404	Volt - Phase A-B LOX Chldwn Inv	56 ±4 vrms	57.0 vrms
M0028-404	Freq - Fuel Chilldown Inverter	400 ±10 Hz	401.4 Hz
M0029-404	Freq - Oxid Chilldown Inverter	400 ±10 Hz	400.0 Hz
M0040-404	Volt - Phase A-C LOX Chldwn Inv.	56 ±4 vrms	57.0 vrms
M0041-404	Volt - Phase A-C Fuel Chldwn Inv	56 ±4 vrms	57.0 vrms
M0044-404	Volt - Phase A1-B1, LOX Chldwn Inv	56 ±4 vrms	56.0 vrms
M0045-404	Volt - Phase A1-C1, LOX Chldwn Inv	56 ±4 vrms	56.0 vrms
M0046-404	Volt - Phase A1-B1, LH2 Chldwn Inv	56 ±4 vrms	56.5 vrms
M0047-404	Volt - Phase A1-C1, LH2 Chldwn Inv	56 ±4 vrms	57.0 vrms

18.1.2.3 5 Volt Excitation Modules

All three 5 vdc excitation modules performed satisfactorily during the launch phase. Actual output values are listed below:

Meas. No.	Measurement Nomenclature	Acceptable Range	Actual Value
M0024-411	Volt - 5 Volt Excitation Mod Fwd	5.00 ±0.025 vdc	5.02 vdc
M0068-411	Volt - 5 Volt Excitation Mod Fwd 2	5.00 ±0.025 vdc	5.02 vdc
M0025-404	Volt - 5 Volt Excitation Mod Aft	5.00 ±0.025 vdc	5.01 vdc
M0042-411	Freq - 5 Volt Excitation Mod Aft	2,000 ±200 Hz	1,980 Hz
M0043-411	Freq - 5 Volt Excitation Mod Fwd	2,000 ±200 Hz	1,980 Hz

18.1.2.4 Static Inverter-Converter

The static inverter-converter operated within design limits throughout the flight. The inverter temperature was 534 deg R at activation and 536 deg R at inverter power turnoff.

Meas. No.	Measurement Nomenclature	Acceptable Range	Actual Value
M0001-411	Volt - Static Inv-Conv	115.00 ±3.45 vrms	114.50 vrms
M0004-411	Volt - Static Inv-Conv 5 Volts DC	4.9 ±0.2 vdc	5.07 vdc
M0012-411	Freq - Static Inv-Conv	400 ±6 Hz	401 Hz
M0023-411	Volt - Static Inv-Conv 21 Volts DC	21.0 +1.5, -1.0 vdc	21.50 vdc

18.2 Orbital Phase

18.2.1 Electrical Control System

The stage electrical control system responded to all fifty-three switch selector orbital commands. System performance was as follows:

a. Control Pressure Switches. No commands were given to enable the control functions of the pressure switches. The pressure switch positions reflected their respective environmental pressures.

b. Auxiliary Propulsion System. The APS electrical control system responded to stage commands to provide pitch, yaw, and roll control.

c. Chilldown Shutoff Valves. The chilldown shutoff valve open command was exercised early in the orbital phase. The LOX and LH2 chilldown shutoff valves responded to this command and operated properly.

d. Vent Valves. The LOX and LH2 vent valve commands were exercised throughout the orbital phase. The valves responded to each command and operated properly.

18.2.2 Electrical Power System

Components in the electrical power system functioned as follows:

a. Flight Batteries. All battery currents, voltages, and temperatures were within the expected design limits. Battery current and voltage profiles are shown in figures 18-5 through 18-8.

b. Volt Excitation Modules. The 5-VDC excitation modules operated satisfactorily. The outputs are listed below.

Meas. No.	Measurement Nomenclature	Acceptance Range	Actual Value
M0024-411	Volt - 5 Volt Excitation Mod Fwd	5.000 ±0.025 VDC	5.025 VDC
M0068-411	Volt - 5 Volt Excitation Mod Fwd 2	5.000 ±0.025 VDC	5.025 VDC
M0025-404	Volt - 5 Volt Excitation Mod Aft	5.000 ±0.025 VDC	5.010 VDC
M0042-404	Freq - 5 Volt Excitation Mod Aft	2000 ±200 Hz	2000 Hz
M0043-411	Freq - 5 Volt Excitation Mod Fwd	2000 ±200 Hz	2000 Hz

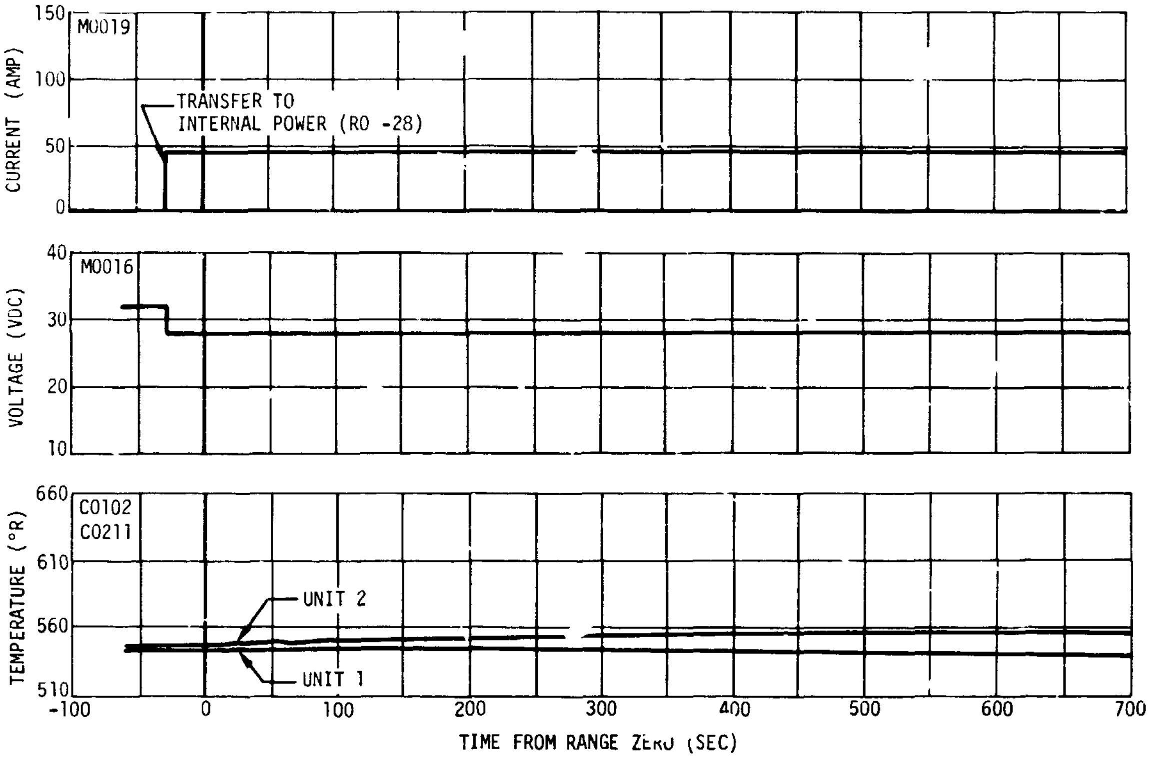


Figure 18-1. Forward Battery No. 1 (Launch Phase)

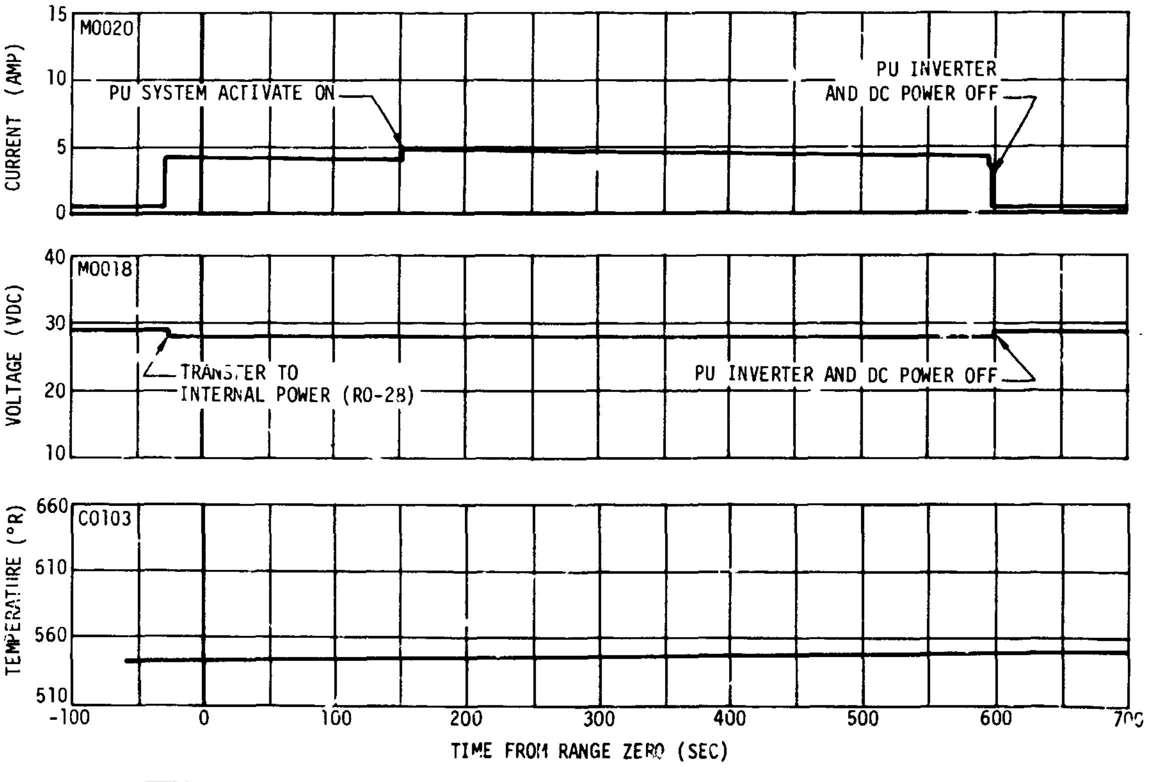


Figure 18-2. Forward Battery No. 2 (Launch Phase)

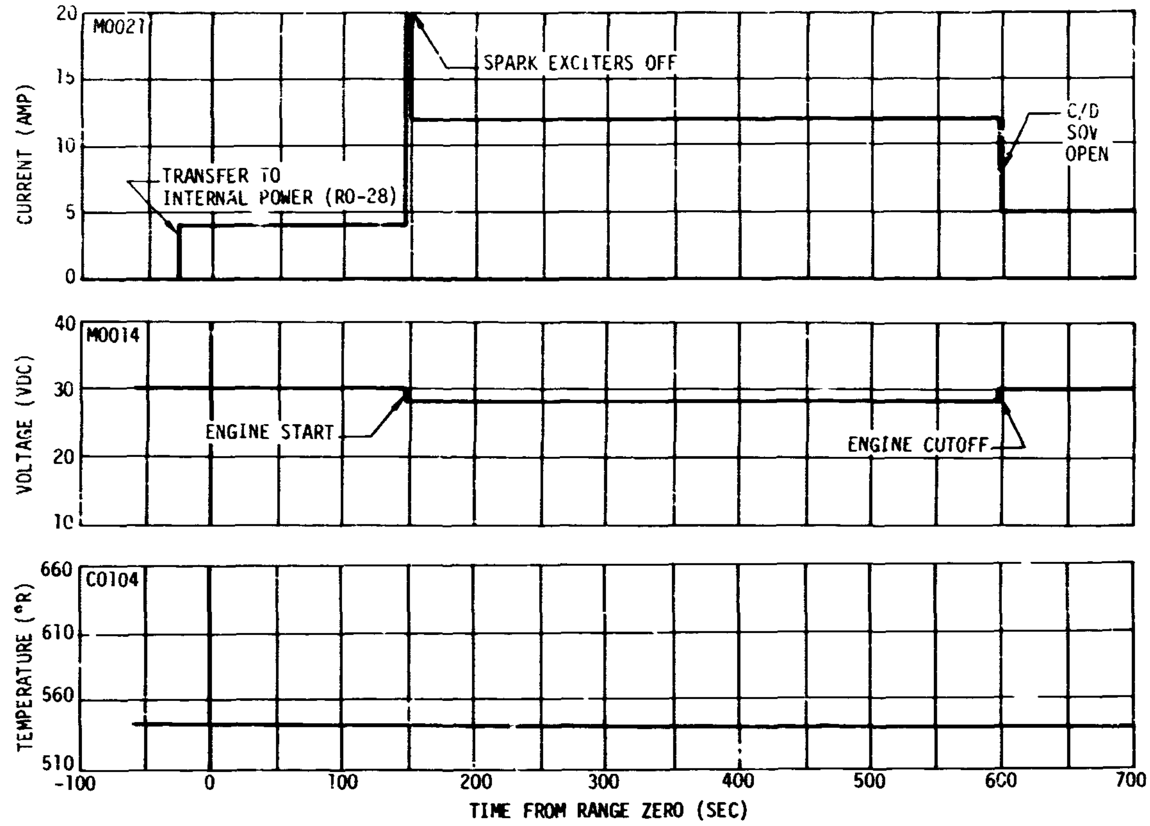


Figure 18-3. Aft Battery No. 1 (Launch Phase)

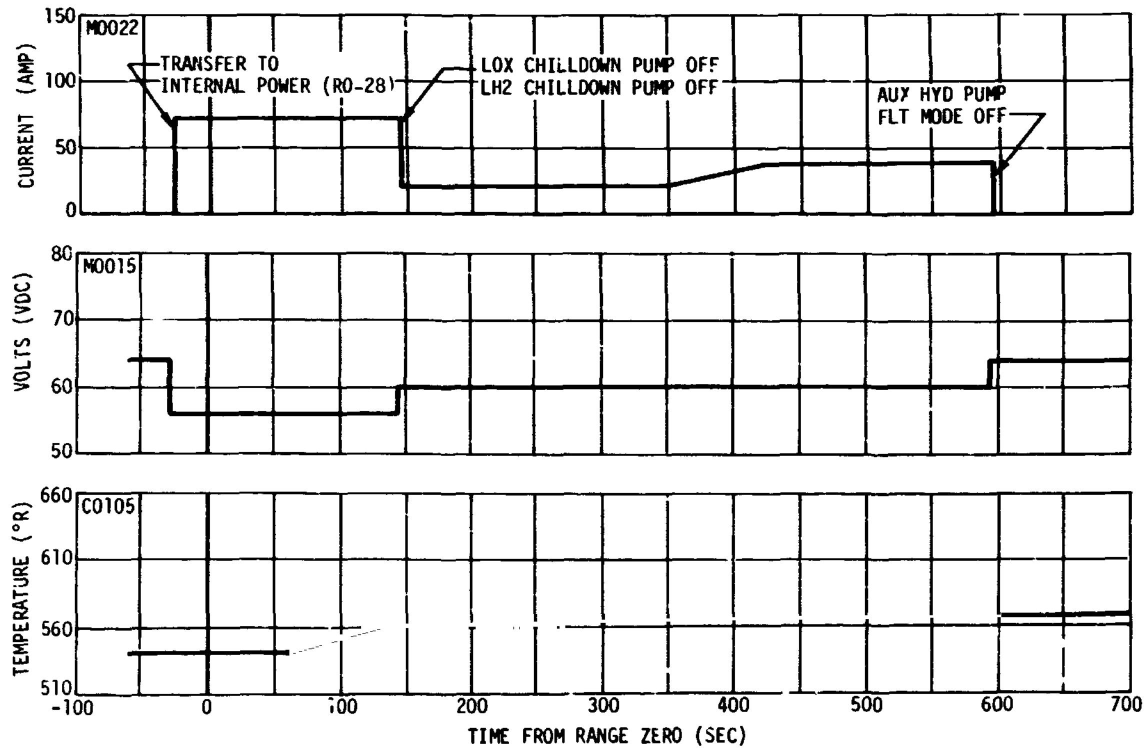


Figure 18-4. Aft Battery No. 2 (Launch Phase)

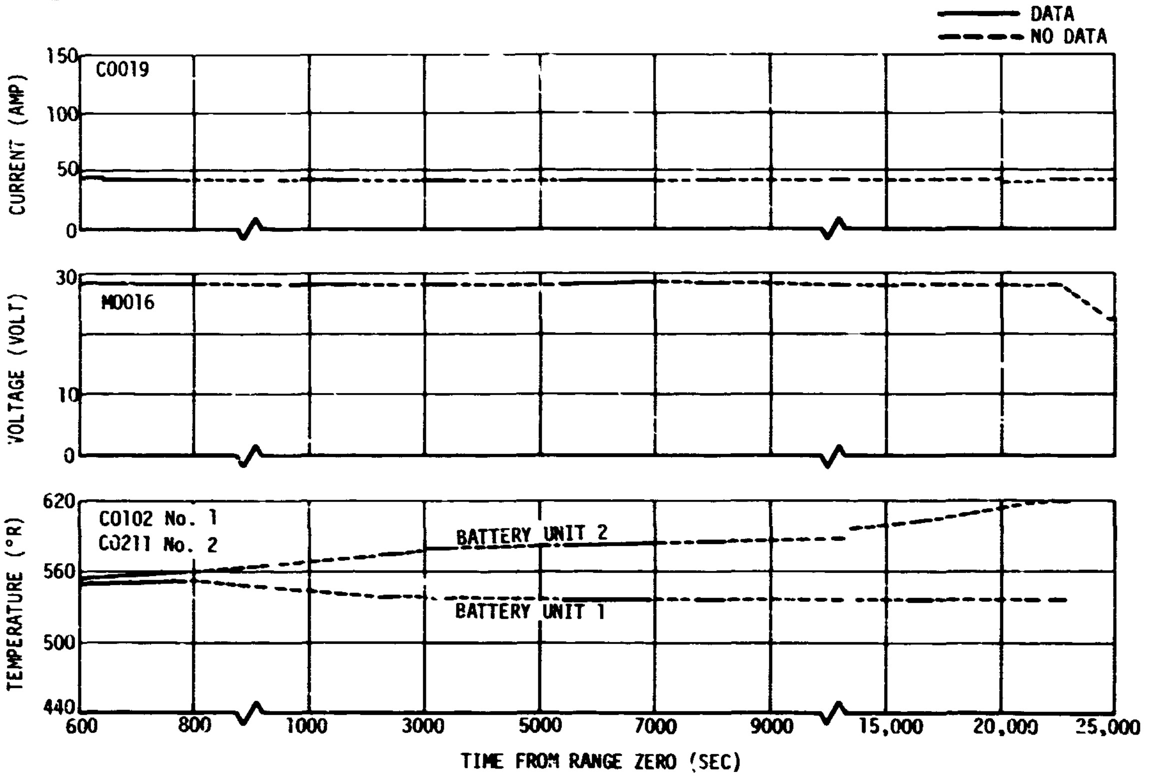


Figure 18-5. Forward Battery No. 1 (Orbital Phase)

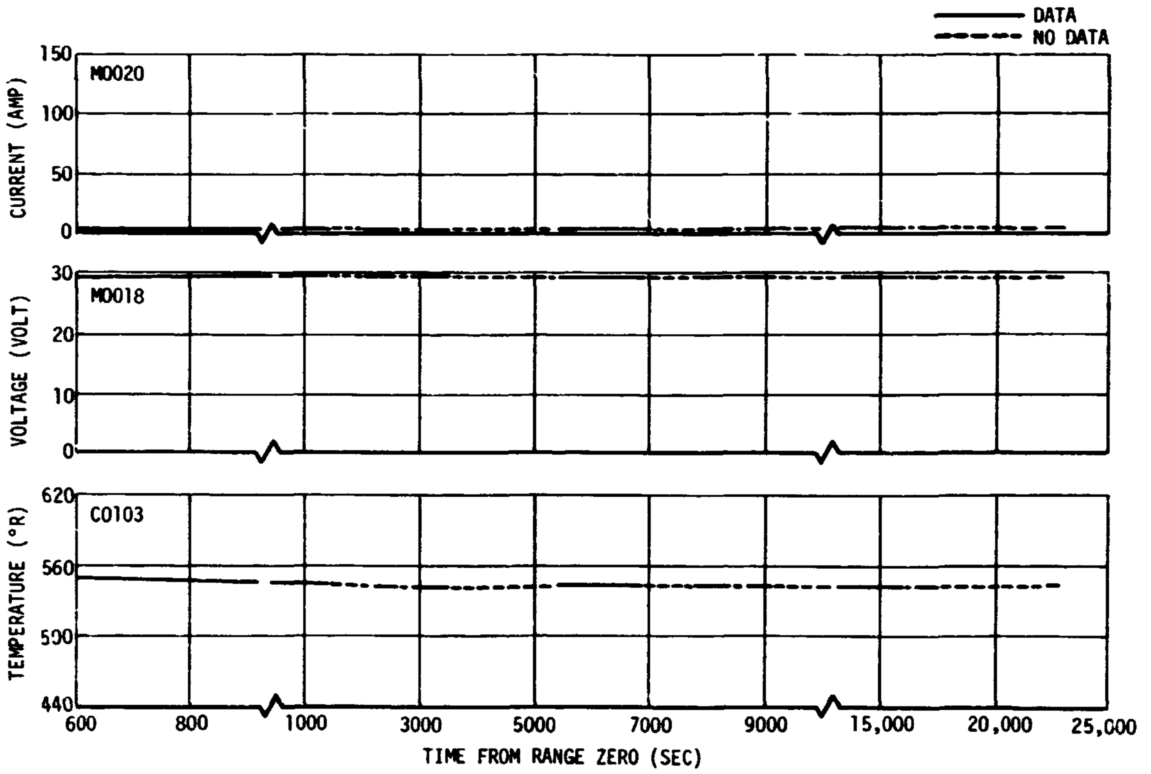


Figure 18-6. Forward Battery No. 2 (Orbital Phase)

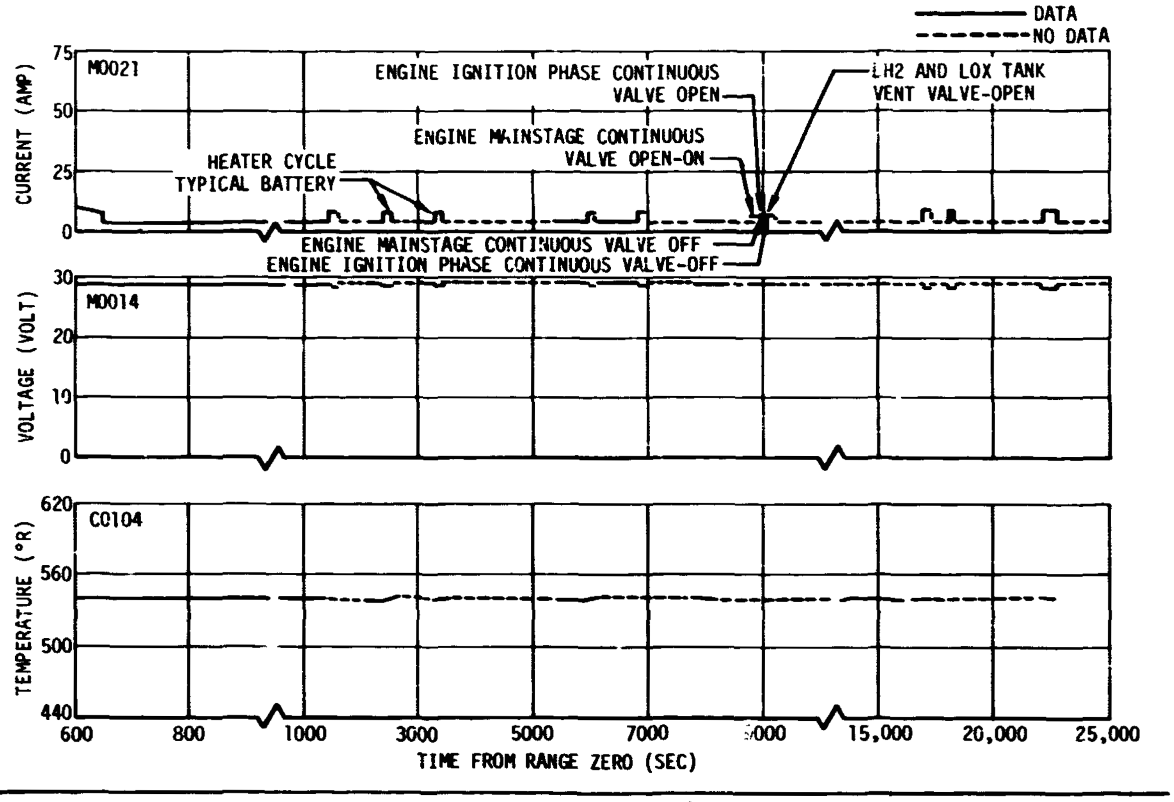


Figure 18-7. Aft Battery No. 1 (Orbital Phase)

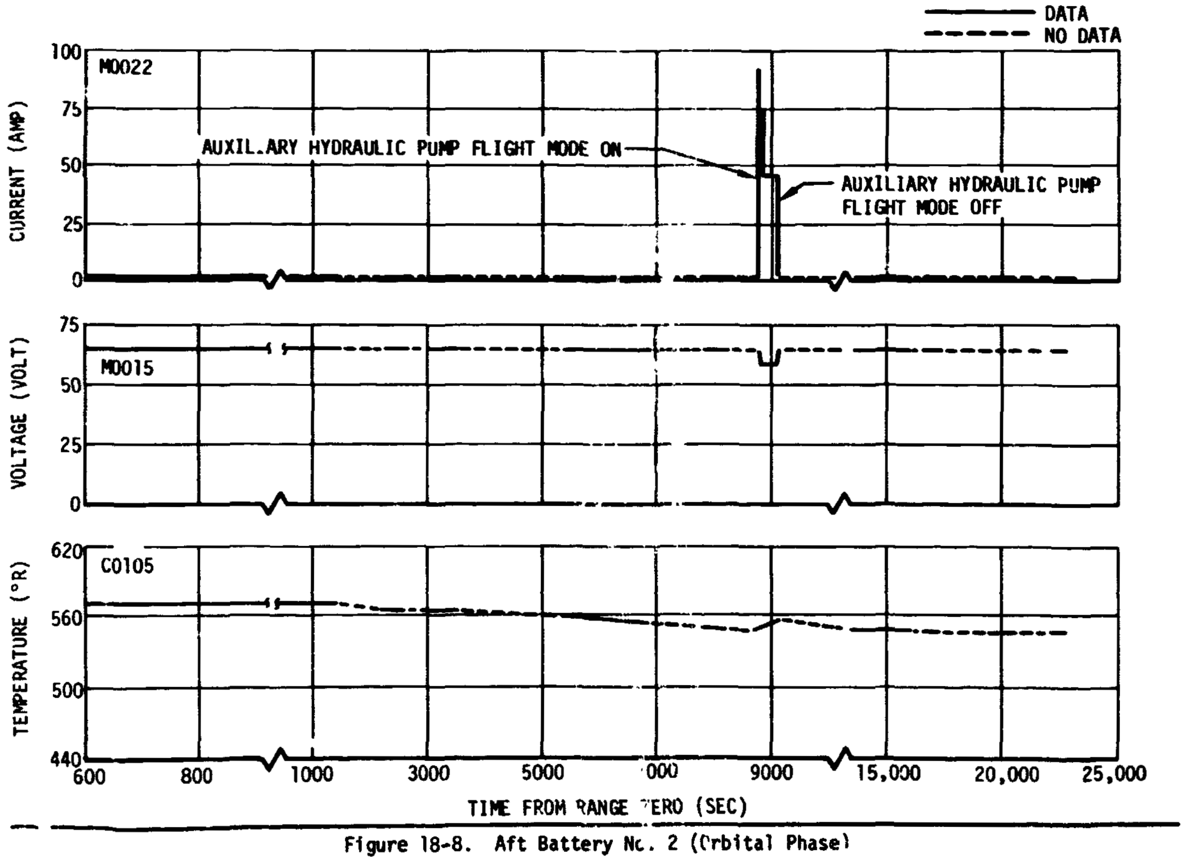


Figure 18-8. Aft Battery No. 2 (Orbital Phase)

SECTION 19

RANGE SAFETY SYSTEM

19. RANGE SAFETY SYSTEM

The range safety system was not required for propellant dispersion during flight. All indications showed that it operated properly and would have satisfactorily terminated an erratic flight.

19.1 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. Performance was satisfactory throughout range safety operation.

19.2 Firing Units Monitors

The following measurements indicate that the firing units were not charged throughout flight.

M0030-411 Volt - F/U 1 EBW Range Safety

M0031-411 Volt - F/U 2 EBW Range Safety

19.3 Receivers Signal Strength

An RF carrier was received by the stage until the range safety system was safed at approximately 630 sec after liftoff. Range safety receiver No. 1 low level signal strength was 3.56 vdc and range safety receiver No. 2 low level signal strength was 4.00 vdc. The high level signal strength measurement for range safety receiver No. 2 exhibited rapid variations after RO +120 sec and a shift in level at RO +420 sec. The rapid variations are attributed to vehicular roll attitude changes causing a traverse of antenna null pattern. The level shift is due to downrange acquisition and look angle from the ground station. During this time, the range safety system operated properly as shown by its response to the safe command.

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 20

FLIGHT CONTROL

20. FLIGHT CONTROL

The thrust vector control (TVC) system responded satisfactorily to instrument unit (IU) attitude command signals providing pitch and yaw control during S-IVB powered flight and during the first 80 sec of LOX dump during the propellant removal test. Transients experienced during S-IB/S-IVB separation, attitude error and rate gain change, guidance mode changes, and during the first 80 sec of LOX dump were well within the capabilities of the control system. Low frequency and amplitude oscillations (approximately 0.35 cps and 0.12 deg peak-to-peak of actuator deflection) were observed during powered flight. Similar low frequency oscillations have been experienced by the control system on previous flights and are attributed to a combination of propellant sloshing and limit cycle operation resulting from nonlinearities induced by gimbal bearing friction. Stability studies have indicated that these oscillations would be expected during S-IVB burn for the AS-204 mission.

The auxiliary attitude control system (AACS) provided satisfactory roll stabilization during powered flight, and satisfactory pitch, yaw, and roll control during earth orbit. During powered flight, high frequency and magnitude oscillations (between 17 and 22 cps and 3.3 deg/sec peak-to-peak maximum) were observed on the roll rate gyro. These oscillations were predominant during a 40 sec interval following guidance initiation and appeared to affect roll control system operation by allowing the roll attitude error to increase significantly beyond the normal system deadband for the observed flight conditions. The high frequency rate signals damped to a relatively low amplitude following the noted 40 sec time interval and roll control system operation appeared normal for the remainder of the flight. Sustained undamped oscillations of a higher amplitude could have resulted in a diverging roll attitude error and potential loss of attitude control.

All orbital maneuvers were accomplished as planned, and vehicle attitude control was verified until loss of signal at Tananarive during the seventh revolution (RO +36,078 sec). Launch vehicle digital computer (LVDC) data and IU attitude control data indicated an uncontrolled

S-IVB/IU at acquisition of signal at Hawaii during the seventh revolution (RO +38,082 sec). The required duration of attitude control for the AS-204 mission was 4.5 hr. The cause of loss of attitude control between Tananarive and Hawaii has not been determined; however, flight data indicates that depletion of AACS propellants may have occurred.

Limited LH2 and LOX sloshing was observed on the PU sensor fine mass data during powered flight. The slosh frequencies and amplitudes were comparable to that experienced during previous flights and appeared normal during both S-IB and S-IVB burn phases. Propellant sloshing did not have an appreciable effect on attitude control system operation during powered flight.

20.1 Attitude Control (Powered Flight)

The TVC system and the AACS responded satisfactorily to IU guidance commands and provided satisfactory attitude control during powered flight.

20.1.1 Thrust Vector Control System Performance (Powered Flight)

Pitch and yaw guidance commands and corresponding vehicle attitudes (platform gimbal angles) during S-IVB powered flight are shown in figures 20-1 and 20-2 respectively. The actual vehicle attitude correlates well with the commanded attitude indicating normal control system operation. TVC system transients were experienced at S-IB/S-IVB separation, introduction of the thrust misalignment correction term into the guidance equations, attitude error and rate gain change, initiation and termination of the Artificial Tau Guidance Mode, Chi Tilde Guidance Mode, Chi Freeze, and J-2 cutoff. These control system transients were expected and appeared normal during each of these intervals.

Attitude errors generated in the LVDC, angular rates obtained from control rate gyros, and actuator positions during powered flight are presented in figures 20-3, 20-4 and 20-5 respectively. These data indicate normal TVC system operation. Maximum values of control system parameters during powered flight are summarized in table 20-1. The most severe transients experienced during powered flight were at S-IB/S-IVB separation and at initiation of the Iterative Guidance Mode (IGM). These disturbances were well within the capabilities of the control system. Another significant control system transient occurred following attitude error and rate gain change (approximately RO +286 sec). This transient was larger than that experienced during previous flights and is attributed primarily to the magnitude of the AS-204 gain change.

Low frequency and amplitude oscillations (approximately 0.12 deg peak-to-peak maximum actuator deflection at 0.35 cps) were observed in the pitch axis during S-IVB powered flight. These oscillations were readily discernable on the pitch actuator position, servo amplifier command current, differential pressure, and pitch rate gyro measurements until approximately 145 sec after Engine Start Command. At this time, the attitude error and rate gain change reduced the actuator position amplitude from 0.12 deg peak-to-peak to approximately 0.06 deg peak-to-peak.

Nonlinear analog simulations were employed to determine the effects of gimbal bearing friction and initial slosh conditions on the thrust vector control system. The following cases were considered for comparison with the control system response during flight.

a. An initial slosh condition and a nominal value of gimbal bearing friction. (Gimbal bearing friction is known to induce control system limit cycling.)

b. A nominal value of gimbal bearing friction and zero initial slosh conditions.

c. An initial slosh condition and zero gimbal bearing friction.

The results of case (a) indicated the presence of low frequency and amplitude oscillations on the actuator position similar to those experienced during flight. The results of case (b) indicated the absence of any oscillations on the actuator position. Case (c) resulted in an actuator response identical to that experienced during flight; therefore, the results of the nonlinear analog simulations indicate that the low frequency oscillations occurring early during S-IVB-204 powered flight can be attributed primarily to propellant sloshing. The results of case (c) are presented in figure 20-6, and 20-7. As in flight, the low frequency and amplitude oscillations were reduced at attitude error and rate gain change. Similar actuator oscillations were also experienced during the S-IVB-201 powered flight. The oscillations on AS-201 were attributed to sloshing early in powered flight and control system limit cycle operation due to gimbal bearing friction late in the burn period.

The attitude control system response was simulated during powered flight to determine the nature of the experienced transients and to verify satisfactory control system operation. The initial conditions, thrust vector misalignment and steady state roll torque used in the simulation is presented in table 20-2. A comparison of actual and simulated pitch attitude errors, angular rates, and actuator positions is shown in figure 20-8. Corresponding information in the yaw plane is presented in figure 20-9. The effective thrust vector misalignment was 0.21 deg in pitch and -0.36 deg in yaw. The results indicate that TVC system response to guidance commands was satisfactory.

20.1.2 <u>Auxiliary Attitude Control System Performance (Powered Flight)</u>

The AACS provided satisfactory roll control during S-IVB powered flight. High frequency oscillations (between 17 and 22 cps and 3.3 deg/sec peak-to-peak maximum) were observed on the pitch, yaw and roll rate gyros during S-IVB powered flight. The oscillations were most significant on the pitch and roll rate gyros during a 40 sec interval following S-IVB guidance initiation as shown in figure 20-4. During this interval, the roll attitude error increased from approximately 0.0 deg to 2.3 [illegible]. A roll attitude error of this magnitude would normally be indicat[illegible] of a relatively large roll disturbance accompanied by high frequency [illegible] continuous AACS operation, depending on the vehicle angular rate. Flight data indicated a relatively low and unexpected AACS roll engine duty cycle during this interval. The S-IVB AACS responded satisfactorily to IU spatial amplifier commands; however, the high frequency rate signal appeared to circumvent expected spatial amplifier operation. Investigation has indicated that the high frequency signal effectively increases the roll control deadband and allows the attitude error to increase beyond the design deadband of ±1 deg. The high frequency roll rate experienced on AS-204 damped to a relatively small amplitude approximately 40 sec after guidance initiation, after which time the spatial amplifier functioned as expected to reduce the roll attitude error to within the desired deadband. A sustained high frequency signal from the roll rate gyro during powered flight could result in a diverging roll attitude error and potential loss of roll control. The origin of the noted high frequency signals and the effect on the control system are being investigated further. Similar high frequency signals have been observed during previous flights, particularly AS-201, and AS-203. The magnitudes of oscillations experienced during these flights were not of sufficient magnitude to affect operation of the roll control system. Similar to AS-204, the high frequency signals experienced on AS-201 and AS-203 were predominantly on the pitch and roll rate gyros.

Attitude control engines I_{II} and III_{IV} were the only engines required to fire for roll attitude correction during powered flight. The roll attitude error and attitude control engine firings are presented in figure 20-3. The roll angular rate is shown in figure 20-4. The frequency of engine firings was higher than that experienced during previous flights. This is attributed to a higher steady state roll torque (approximately 27 ft-lbf in a clockwise direction), resulting from J-2 engine exhaust gas swirl. The highest steady state roll torque experienced previously was 20 ft-lbf (AS-202). Propellant requirements and impulse usage for roll control during powered flight were approximately 2.7 lbf and 600 lbf-sec for each module, respectively. The 2.7 lbf represents approximately 4.3 percent of the total propellants available for attitude control. This quantity is higher than the mean predicted usage but within the expected range of propellant usage for roll control during powered flight.

Roll control system simulations were conducted in conjunction with TVC system simulations during powered flight. A comparison of actual and simulated roll attitude errors and angular rates during powered flight are presented in figure 20-10. As indicated, operation of the roll control system was significantly affected by the high frequency oscillations resulting in an unexpected roll attitude error excursion.

The steady state roll attitude error during powered flight was approximately 0.5 deg as opposed to the expected nominal 1.0 deg. This is attributed to a rate bias of approximately 0.1 deg/sec.

20.2 Attitude Control — Orbit

The auxiliary attitude control system provided satisfactory pitch, yaw and roll control during orbit.

All orbital maneuvers and inertial attitude holds were accomplished as planned and attitude control was verified until loss of signal at Tananarive during the seventh revolution (RO +36,078 sec).

Following the first 80 sec of LOX dump during the propellant removal test, attitude control was successfully transferred from the TVC system to the AACS as planned.

20.2.1 S-IVB J-2 Engine Cutoff

An inertial attitude hold was initiated just prior to S-IVB J-2 engine cutoff and maintained until approximately 90 sec after cutoff. The inertial attitude hold was initiated for nose cone separation. Relatively large pitch and yaw disturbances and subsequent high AACS engine duty cycles were experienced following initiation of the LOX vent at TB4 +0.2 sec. These disturbances were expected since the LOX vent nozzle was aligned to pass through the vehicle center of gravity following LEM separation. The duration of the LOX vent was 40 sec. The AACS impulse usage during the time interval (RO +593 to RO +636 sec) was 621, 1,107, 1,118, and 7 lbf-sec from engines I_P, I_{II}, III_{II}, and III_{IV}, respectively. The engine firing history is included in figure 20-11 and the impulse usage is included in table 20-3.

Approximately 124 lbf-sec of the 621 lbf-sec pitch impulse usage was required to stop an initial pitch rate of 0.2 deg/sec. The remaining impulse usage (497 lbf-sec) that was required to control the average disturbing moment of 366 ft-lbf (nose down) was attributed primarily to the LOX vent. Similar to the pitch control requirements, approximately 124 lbf-sec of impulse usage was required to stop an initial yaw rate of 0.2 deg/sec. The remaining yaw impulse usage of 2,164 lbf-sec produced an average yaw moment of 1,605 ft-lbf (nose left) which can be attributed to venting disturbances. Approximately 45 sec after S-IVB cutoff, nose-cone separation occurred. Relatively small disturbances were experienced during this interval.

Nose cone separation disturbance and the maneuver to local horizontal following S-IVB cutoff were simulated to determine characteristics of disturbing forces and verify satisfactory control system performance. The simulation indicated that maximum pitch, yaw and roll disturbing moments during the nose cone separation were 20 ft-lbf (nose down), 220 ft-lbf (nose left), and 125 ft-lbf (counter clockwise), respectively. These disturbances were adequately controlled by the attitude control system. The commanded, actual and simulated platform gimbal angles during the rated time interval are presented in figure 20-12. The simulated pitch and yaw attitude gimbal angle compare favorably with the actual gimbal angles, indicating normal AACS performance. The actual and simulated roll gimbal angles do not indicate good correlation due to the difficulty in simulating yaw/roll interaction.

20.2.2 Spacecraft LEM Adapter Panel Deployment

The spacecraft LEM adapter (SLA) panels were deployed at approximately RO +1,194 sec to enable LEM separation which occurred at approximately RO +3,235 sec. Positive and negative yaw and roll disturbances were experienced following the SLA panel deployment. AACS impulse requirements during this interval were as follows:

<u>Yaw</u>

102 lbf-sec to correct for positive disturbance

72 lbf-sec to correct for negative disturbance

Roll

90 lbf-sec to correct for positive disturbance

85 lbf-sec to correct for negative disturbance

20.2.3 LEM Separation

Guidance commands were frozen at RO +3,000 sec to minimize disturbances during LEM separation which occurred approximately RO +3,235 sec. Disturbances during LEM separation were relatively small. Approximately 180 sec after LEM separation, a maneuver was initiated to align the vehicle with the local horizontal and establish an orbital pitch rate. Commanded and actual vehicle attitudes during this interval are presented in figure 20-13. Attitude errors and angular rates for this time period are shown in figures 20-14, and 20-15, respectively. These data indicate satisfactory control system performance during LEM separation and the maneuver to the local horizontal. The AACS firing history and impulse usage during this interval are included in figure 20-11 and table 20-3 respectively.

20.2.4 Chi Freeze and Maneuver to Retrograde Attitude

Guidance commands were frozen at RO +5,485 sec placing the vehicle in an inertial hold. A retrograde maneuver was initiated at RO +6,355 sec at which time the vehicle had attained a nose up attitude of 60 deg with respect to the local horizontal. Aerodynamic momemts increased significantly as the vehicle angle of attack increased during the time period after which the guidance commands were frozen. This was evidenced by increased attitude control system engine firings in the pitch plane (engine I_p). Impulse usage from engine I_p during the time interval in which the guidance commands were frozen was approximately 860 lbf-sec. This represents an average control moment of approximately 16.7 ft-lbf required to correct for aerodynamic and gravity gradient disturbances during this time interval. Attitude errors and angular rates during the maneuver to retrograde attitude are shown in figures 20-16 and 20-17 respectively.

20.2.5 Propellant Dump Test

The propellant dump test is covered in paragraph 26.6.

20.2.6 Propellant Requirements for Attitude Control

Propellant requirements for attitude control during powered flight were higher than the mean predicted usage but within the expected usage range. Orbital propellant requirements for attitude control were higher than predicted during the first two LH2 vents and during the chi freeze period prior to the pitch maneuver to retrograde attitude. The actual and predicted propellant usage for attitude control are presented in figure 20-18 for module I and module II.

The high propellant usage can be attributed primarily to the following:

a. A high steady state roll torque during powered flight resulted in high usage (the roll torque was higher than the mean predicted but less than the predicted three sigma).

b. Higher than expected vented flowrates and subsequent disturbance during the first two LH2 vents resulting in a high rate of usage during the time of these vents.

c. Aerodynamic effects were not included in the APS propellant consumption prediction. At large angles of attack, the aerodynamic moments produced by the open SLA panels are significant. Thus, during the retrograde maneuver large aerodynamic moments resulted. Figure 20-18 includes the revised aerodynamic effects on the predicted propellant consumption.

Platform gimbal angles obtained from the LVDC and vehicle attitude errors and angular rates obtained from the IU indicate the S-IVB/IU lost attitude control between Tananarive and Hawaii of the seventh revolution. Platform gimbal angles (compressed data) during a portion of this time interval are shown in figure 20-19. Loss of signal of IU data at Tananarive (RO +36,078 sec) indicated normal attitude control operation. Attitude errors and angular rates during this interval are shown in figures 20-20 and 20-21. Acquisition of signal of IU data at Hawaii

(RO +38,082 sec) indicated an uncontrolled S-IVB/IU. Attitude errors and angular rates for this time period are shown in figures 20-22 and 20-23. Spatial amplifier command signals to the attitude control engines during the seventh revolutions over Tananarive and Hawaii are shown in figure 20-24. Attitude control parameters shown in figures 20-22 and 20-23, indicate that the attitude control system was not responding to command signals over Hawaii.

Investigation indicates that the most probable cause of loss of attitude control is depletion of attitude control propellants. A linear extrapolation of AACS propellant usage from approximately 27,000 sec to depletion indicates that propellants in module I and module II would be depleted at approximately 45,000 and 41,000 sec, respectively. Increased aerodynamic disturbances attributed to the decaying orbit would contribute to an earlier depletion. In addition, guidance commands were frozen approximately 33,450 sec which terminated the orbital pitch rate and increased AACS control requirements due to increased aerodynamic disturbances. As a result, it is reasonable that AACS propellants would have depleted earlier than the time obtained using a linear extrapolation. Predictions based on flight data indicate that S-IVB and IU battery power necessary to operate the attitude control system would be adequate beyond the time of attitude control loss. Although sufficient data is not available to confirm depletion of AACS propellants, flight data indicate that propellant depletion was probable.

The AACS impulse usage is summarized in table 20-3. The AACS engine firing history during realtime data coverage is presented in figure 20-11.

20.2.7 Propellant Sloshing

S-IVB PU system fine mass data indicated tha presence of LOX and LH2 sloshing during S-IVB powered flight. Propellant sloshing was similar to that experienced during previous flights and did not have an appreciable effect on the attitude control system.

Predicted and actual LH2 and LOX slosh frequencies during powered flight are shown in figure 20-25. LH2 sloshing occurred primarily near the predicted LH2 first mode natural frequency as experienced during previous flights. The observed LOX sloshing frequency was very near the predicted LOX second mode natural frequency.

LH2 slosh amplitudes are shown in figure 20-26. The LH2 slosh amplitude observed at the PU sensor was comparable to that experienced during previous flights. The maximum LH2 slosh amplitude observed at the PU sensor was 4 in. zero-to-peak. The maximum slosh amplitude at the tank wall was 19 in. zero-to-peak. The LOX slosh amplitude observed on the LOX PU sensor is shown in figure 20-27. The maximum LOX slosh amplitude was 0.65 in.

TABLE 20-1
MAXIMUM VALUES OF CRITICAL FLIGHT CONTROL PARAMETERS

PARAMETER	S-IVB/S-IB SEPARATION	GUIDANCE INITIATION	ATTITUDE ERROR AND RATE GAIN CHANGE	ARTIFICIAL TAU GUIDANCE	CHI TILDE GUIDANCE	CHI FREEZE AND J-2 ENGINE CUTOFF
Pitch Attitude Error (deg)	-1.7	+2.4	+0.8	-0.9	-0.8	-1.1
Yaw Attitude Error (deg)	-1.8	-3.4	-4.2	-3.9	-3.9	-4.0
Roll Attitude Error (deg)	+1.3	+2.3	+0.6	+0.5	+0.44	+0.3
Pitch Angular Rate (deg/sec)	+0.7	-1.4	-0.3	-0.7	+0.4	+0.5
Yaw Angular Rate (deg/sec)	-0.6	+1.1	-0.6	+0.25	-0.35	+0.6
Roll Angular Rate (deg/sec)	-0.4	+0.2	-0.3	+0.2	-0.3	-0.5
Pitch Actuator Position (deg)	-0.63	+0.7	+0.36	+0.25	+0.32	+0.14
Yaw Actuator Position (deg)	-0.75	-0.95	-0.81	-0.85	-0.79	-0.82

TABLE 20-2
SIMULATED FLIGHT CONDITIONS

PARAMETER	UNITS	VALUE
Initial Pitch Attitude Error (Positive Nose Up)	deg	-0.1
Initial Yaw Attitude Error (Positive Nose Right)	deg	-0.15
Initial Pitch Rate (Positive Nose Up)	deg/sec	0.10
Initial Yaw Rate (Positive Nose Right)	deg/sec	0.19
Initial Pitch Actuator Position (Positive Steers Nose Down)	deg	0.0
Initial Yaw Actuator Position (Positive Steers Nose Left)	deg	0.0
Pitch Effective Thrust Vector Misalignment (Positive Steers Nose Down)	deg	+0.21
Yaw Effective Thrust Vector (Misalignment (Positive Steers Nose Left)	deg	-0.36
Initial Pitch Angle of Attack (Positive Nose Up)	deg	-0.992
Initial Yaw Angle of Attack (Positive Nose Right)	deg	+0.056
Steady State Roll Torque (Positive CW Looking Forward)	ft-lbf	27.0

TABLE 20-3 (Sheet 1 of 2)
APS IMPULSE SUMMARY

EVENT	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 Jett RO +144 to RO +210	LBF-S	171.7	168.8	0	0	171.7	0	0	168.8
	N-S	763.8	750.8	0	0	763.8	0	0	750.8
Limit Cycle Operations for Remaining Burntime; RO +210 to RO +594	LBF-S	428.8	422.1	0	0	428.8	0	0	422.1
	N-S	1,907.4	1,877.6	0	0	1,907.4	0	0	1,877.6
INITIAL RECOVERY FOLLOWING J-2 CUTOFF: RO +595 to RO +635 (Includes LOX & LH2 Venting)	LBF-S	1,721.0	1,188.3	0	620.6	1,100.4	1,188.3	0	0
	N-S	7,655.4	5,285.8	0	2,760.6	4,894.8	5,285.8	0	0
ALIGNMENT TO LOCAL HORIZONTAL FOLLOWING J-2 CUTOFF: RO +683 to RO +780 (Includes LH2 Venting)	LBF-S	379.7	341.4	122.3	173.1	94.4	119.1	139.7	82.5
	N-S	1,689.0	1,518.6	499.5	770.0	419.9	529.8	621.4	367.0
SLA PANEL DEPLOYMENT: RO +1,194 to RO +1,200 (Includes LH2 Venting)	LBF-S	72.8	102.0	27.7	0	45.2	57.0	0	45.0
	N-S	323.8	453.7	123.2	0	201.0	253.5	0	200.2
LEM SEPARATION: RO +3,231 to RO +3,250	LBF-S	65.3	55.6	0	0	65.3	55.6	0	0
	N-S	290.5	247.3	0	0	290.5	247.3	0	0
ALIGNMENT TO LOCAL HORIZONTAL FOLLOWING LEM SEPARATION: RO +3,415 to RO +3,540 (Includes LH2 Venting)	LBF-S	260.5	210.9	22.7	201.3	36.7	70.0	133.5	7.4
	N-S	1,158.8	938.1	101.0	895.4	163.2	311.4	593.8	32.9

*See figure 20-28 for engine locations

TABLE 20-3 (Sheet 2 of 2)
APS IMPULSE SUMMARY

EVENT	UNITS	MODULE 1	MODULE 2	APS ENGINE*					
				I_{IV}	I_P	I_{II}	III_{II}	III_P	III_{IV}
INERTIAL HOLD: RO +5,480 to RO +6,356 (LH2 Venting RO to 6,133 through RO +6,356)	LBF-S	950.6	117.7	52.0	860.4	38.2	66.1	22.5	29.2
	N-S	4,228.5	523.6	231.3	3,827.2	169.9	294.0	100.1	129.9
MANEUVER TO RETROGRADE: RO +6,356 ro RO +6,645 (Includes LH2 Venting)	LBF-S	536.4	343.2	97.8	329.7	109.1	113.1	130.7	99.3
	N-S	2,386.0	1,526.6	435.0	1,466.6	485.3	503.1	581.4	441.7
LOX REMOVAL DURING TVC ONLY: RO +8,774 to RO +8,856	LBF-S	14.9	14.6	7.6	0	7.3	7.5	0	7.1
	N-S	66.3	64.9	33.8	0	32.5	33.4	0	31.6
RECOVERY FROM LOX REMOVAL: RO +8,856 to RO +8,904	LBF-S	98.7	62.7	24.2	37.4	37.1	34.1	0	28.6
	N-S	439.0	278.9	107.6	166.4	165.0	151.7	0	127.2
LH2 REMOVAL: RO +8,904 to RO +9,085	LBF-S	36.5	118.5	14.4	0	22.2	15.2	88.9	14.3
	N-S	162.4	527.1	64.0	0	98.8	67.6	395.4	63.6
INITIATE PITCH TO RETROGRADE FOLLOWING LH2 REMOVAL:	LBF-S	51.1	242.7	36.7	0	14.3	139.5	103.2	0
RO +9,105 to RO +9,180 (Includes LOX and LH2 Venting)	N-S	227.3	1,079.6	163.2	0	63.6	620.5	459.0	0

*See figure 20-28 for engine locations

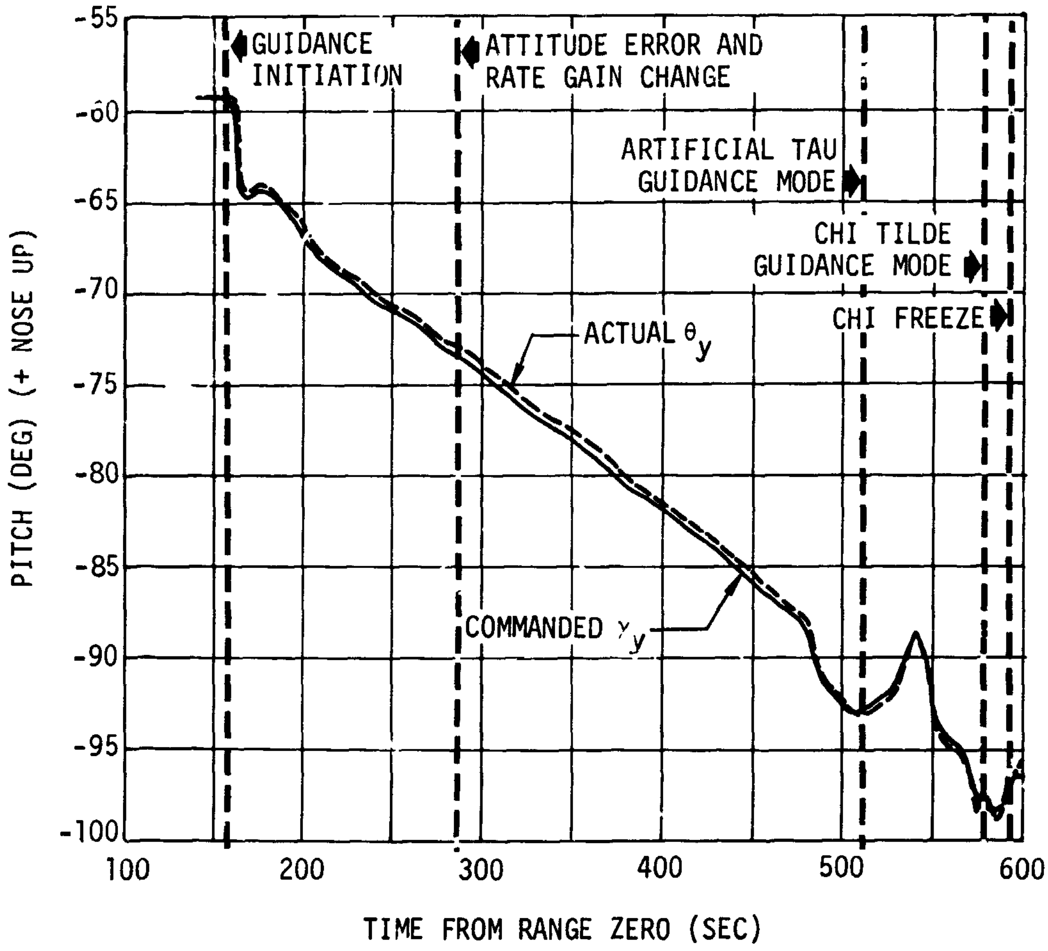


Figure 20-1. Pitch Commanded and Actual Vehicle Attitude During S-IVB Powered Flight

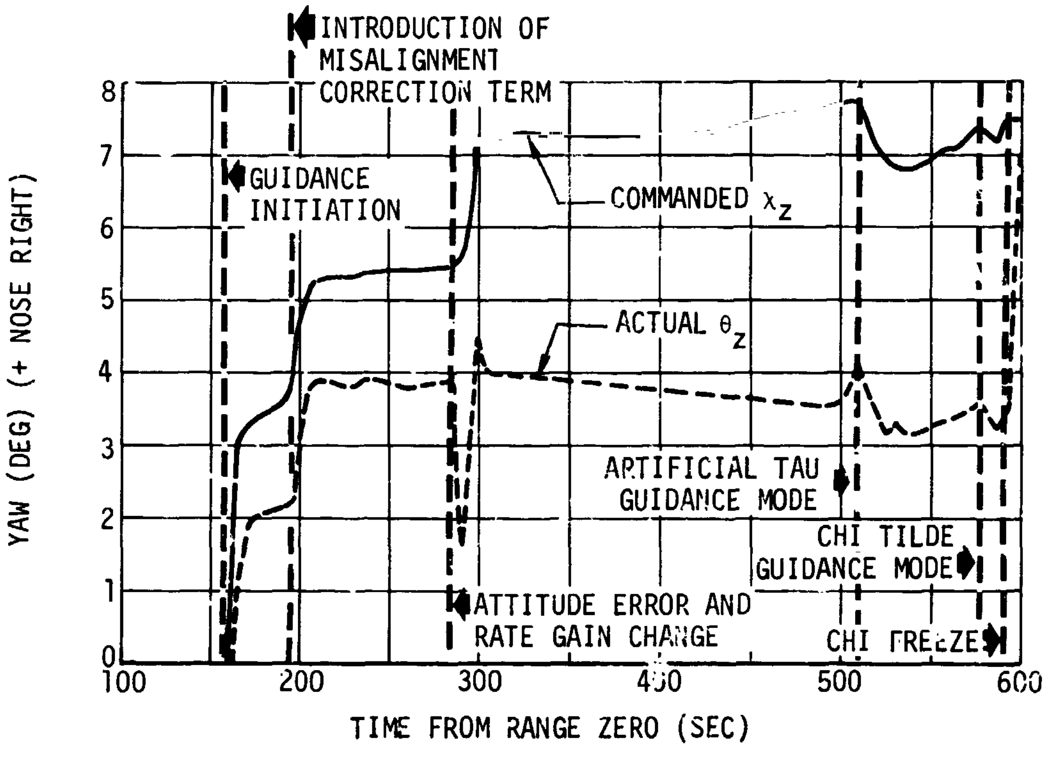


Figure 20-2. Yaw Commanded and Actual Vehicle Attitude During S-IVB Powered Flight

1. S-IB/S-IVB SEPARATION
2. GUIDANCE INITIATION
3. INTRODUCTION OF MISALIGNMENT CORRECTION TERM
4. ATTITUDE ERROR AND RATE GAIN CHANGE
5. PREDICTED ARTIFICIAL TAU GUIDANCE MODE
6. ARTIFICIAL TAU GUIDANCE MODE
7. END OF ARTIFICIAL TAU GUIDANCE
8. CHI TILDE GUIDANCE MODE
9, 10. CHI FREEZE AND J-2 ENGINE CUTOFF

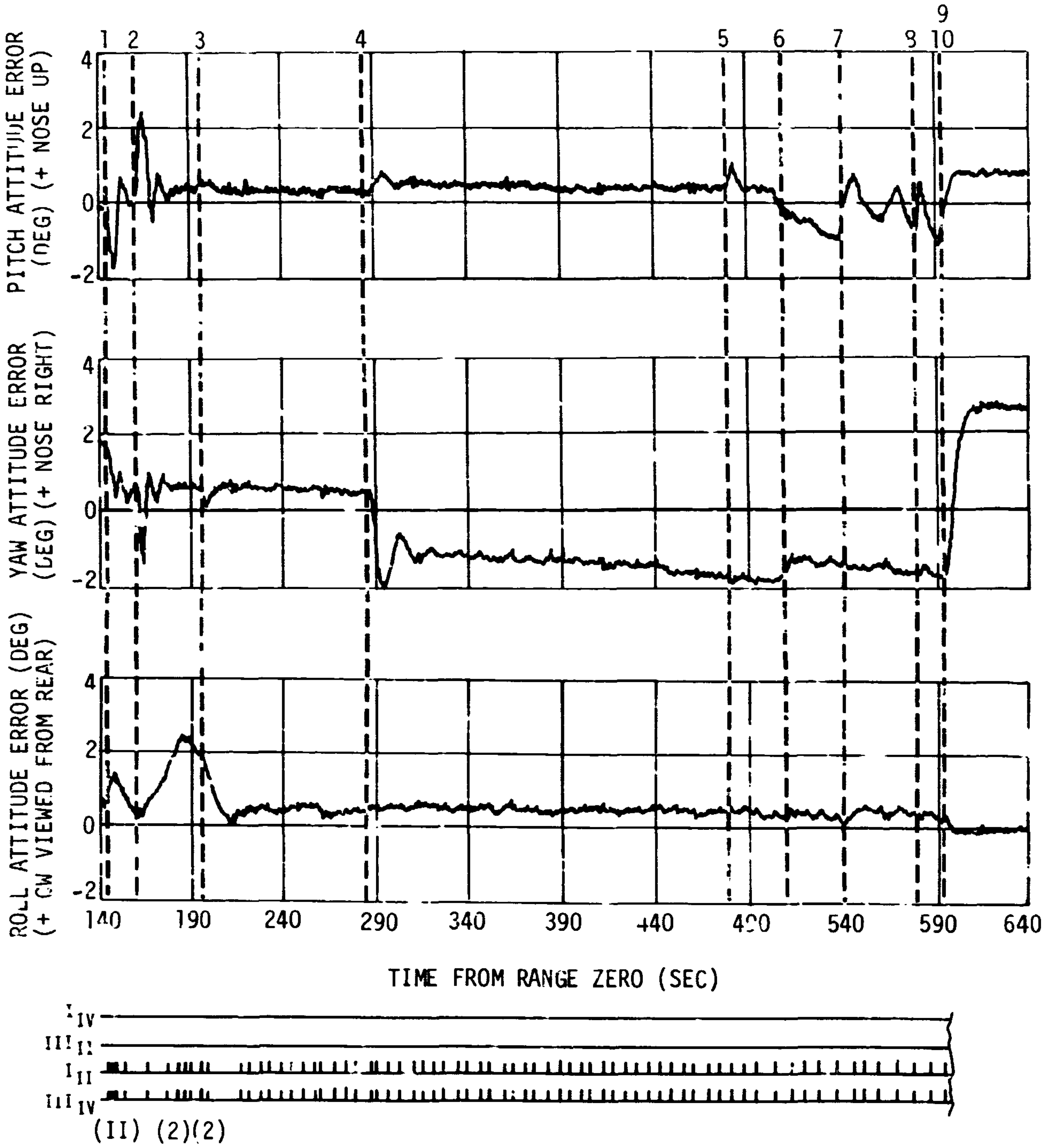


Figure 20-3. Attitude Errors and AACS Firings During S-IVB Powered Flight

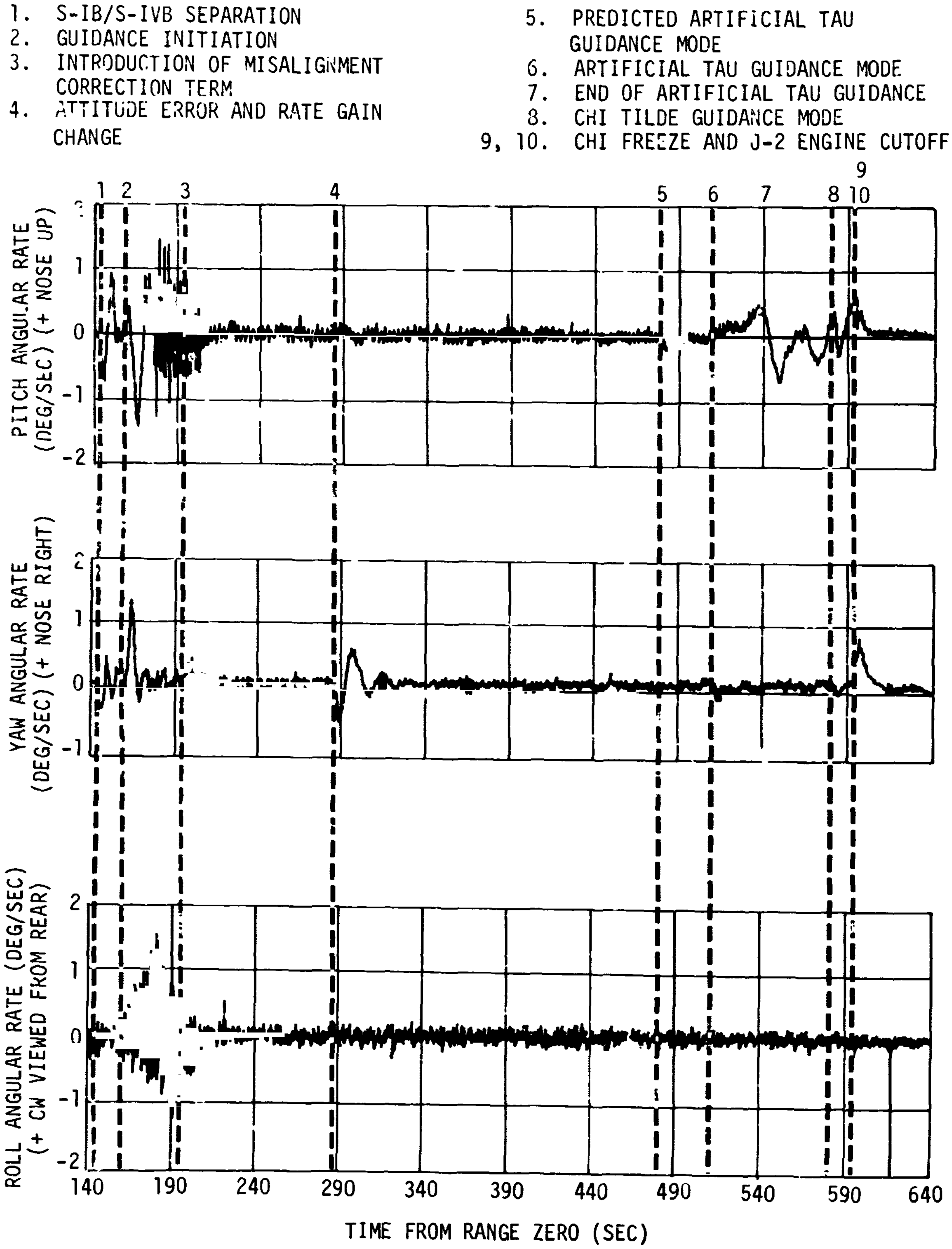


Figure 20-4. Angular Rates During S-IVB Powered Flight

1. S-IB/S-IVB SEPARATION
2. GUIDANCE INITIATION
3. INTRODUCTION OF MISALIGNMENT CORRECTION TERM
4. ATTITUDE ERROR AND RATE GAIN CHANGE
5. PREDICTED ARTIFICIAL TAU GUIDANCE MODE
6. ARTIFICIAL TAU GUIDANCE MODE
7. END OF ARTIFICIAL TAU GUIDANCE
8. CHI TILDE GUIDANCE MODE
9, 10. CHI FREEZE AND J-2 ENGINE CUTOFF

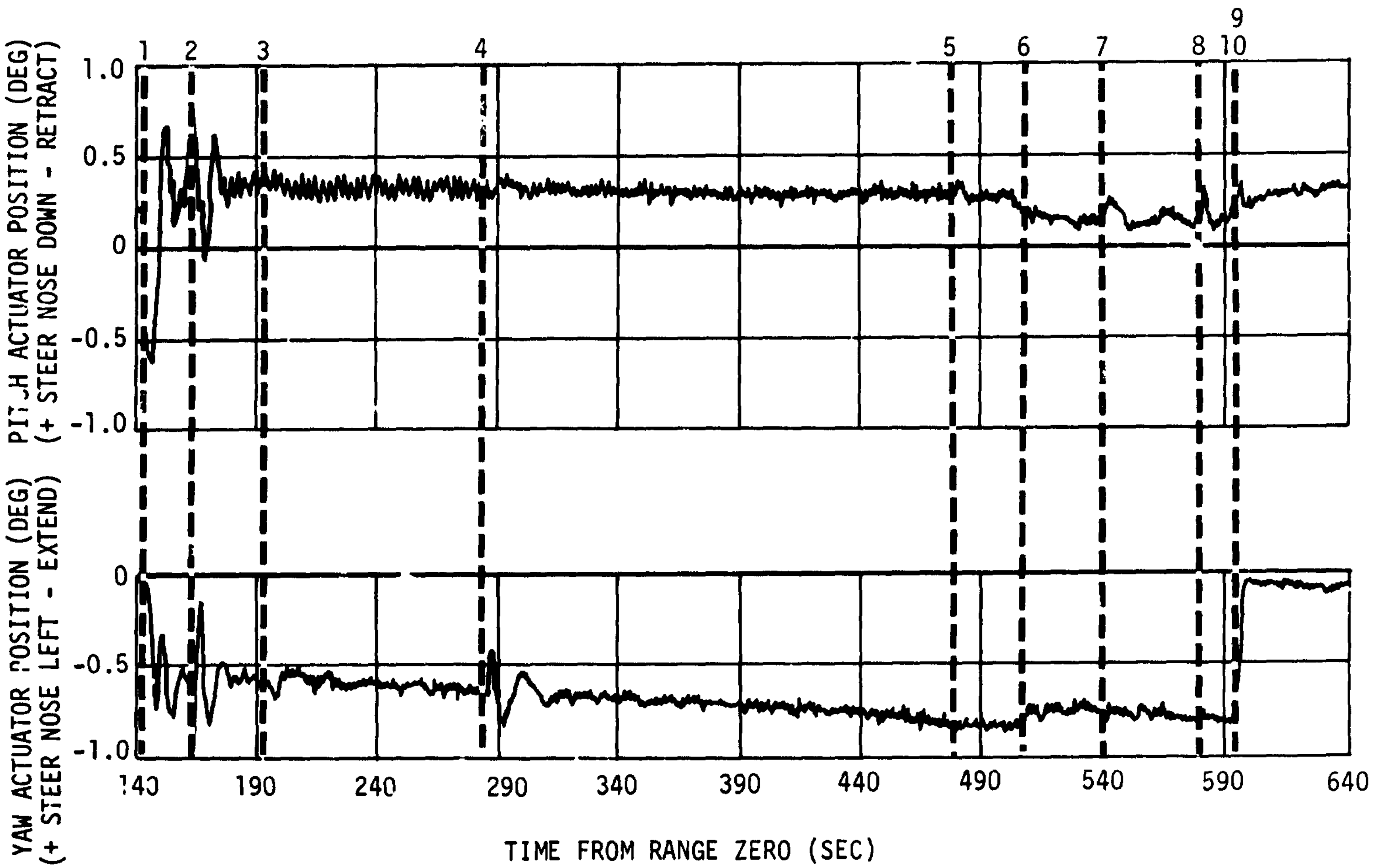


Figure 20-5. Pitch and Yaw Actuator Position During S-IVB Powered Flight

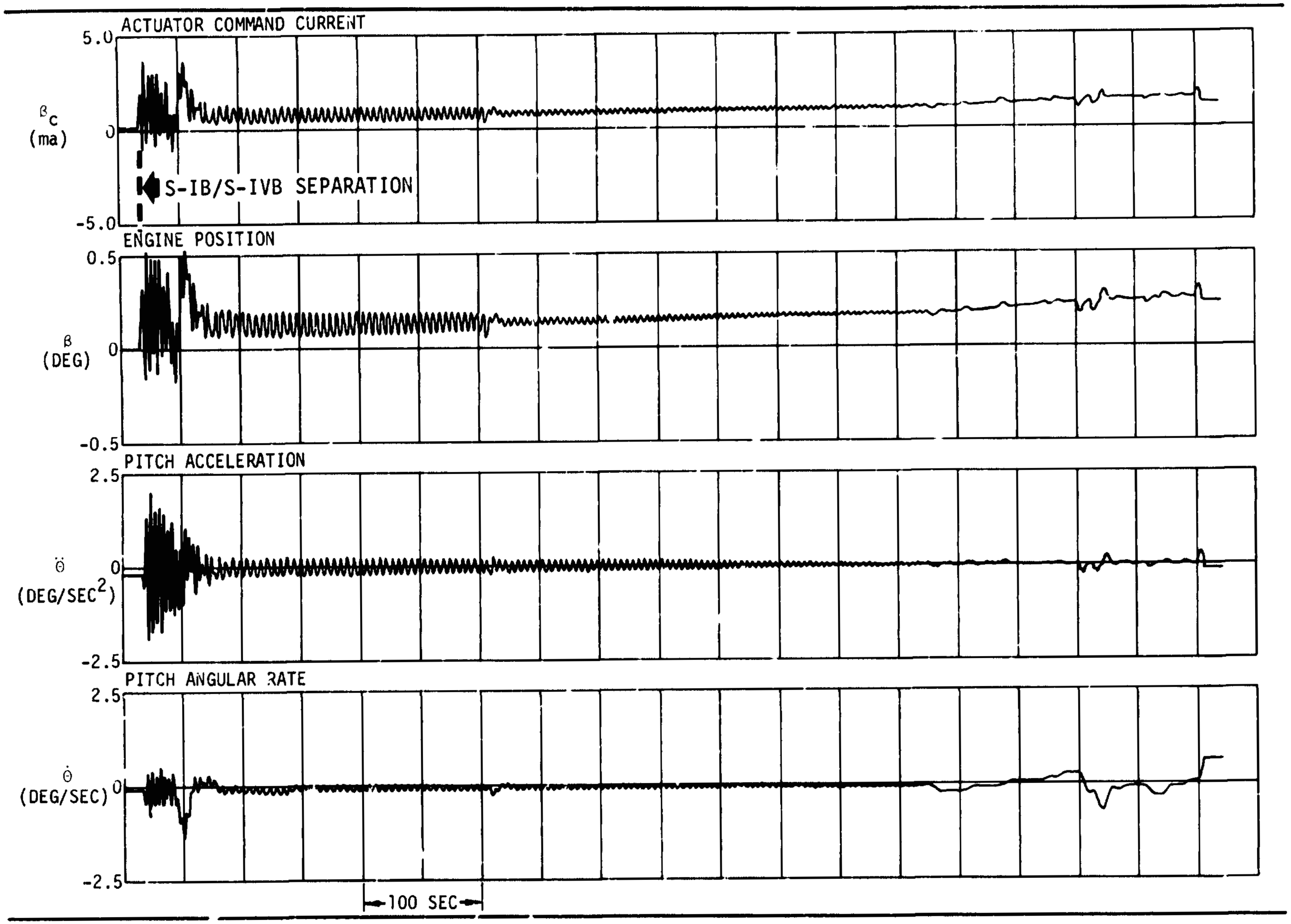


Figure 20-6. Nonlinear Control System Response During S-IVB Powered Flight (β_c, β, $\ddot{\theta}$, and $\dot{\theta}$)

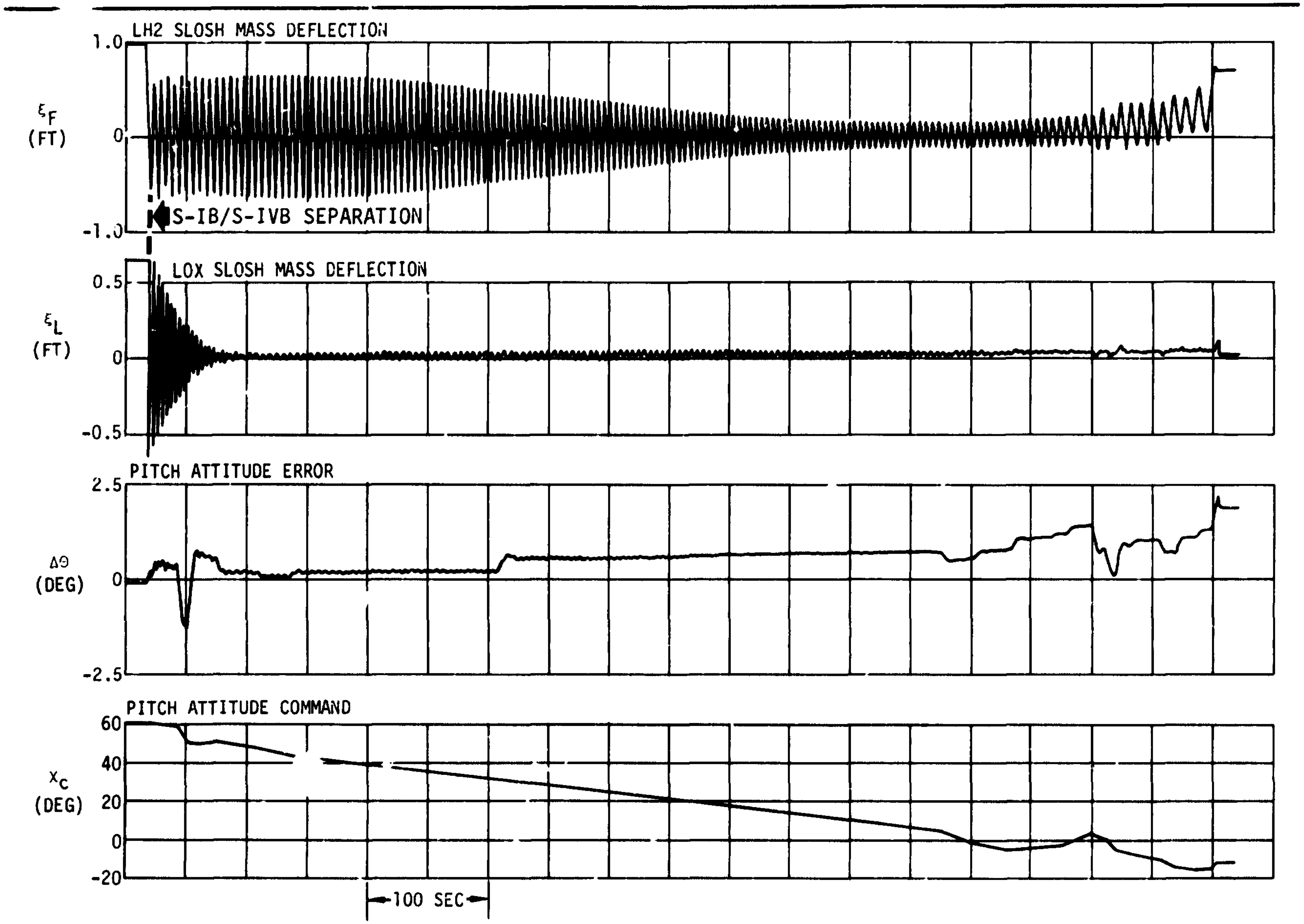


Figure 20-7. Nonlinear Control System Response During S-IVB Powered Flight (ξ_F, ξ_L, $\Delta\Theta$, and χ_c)

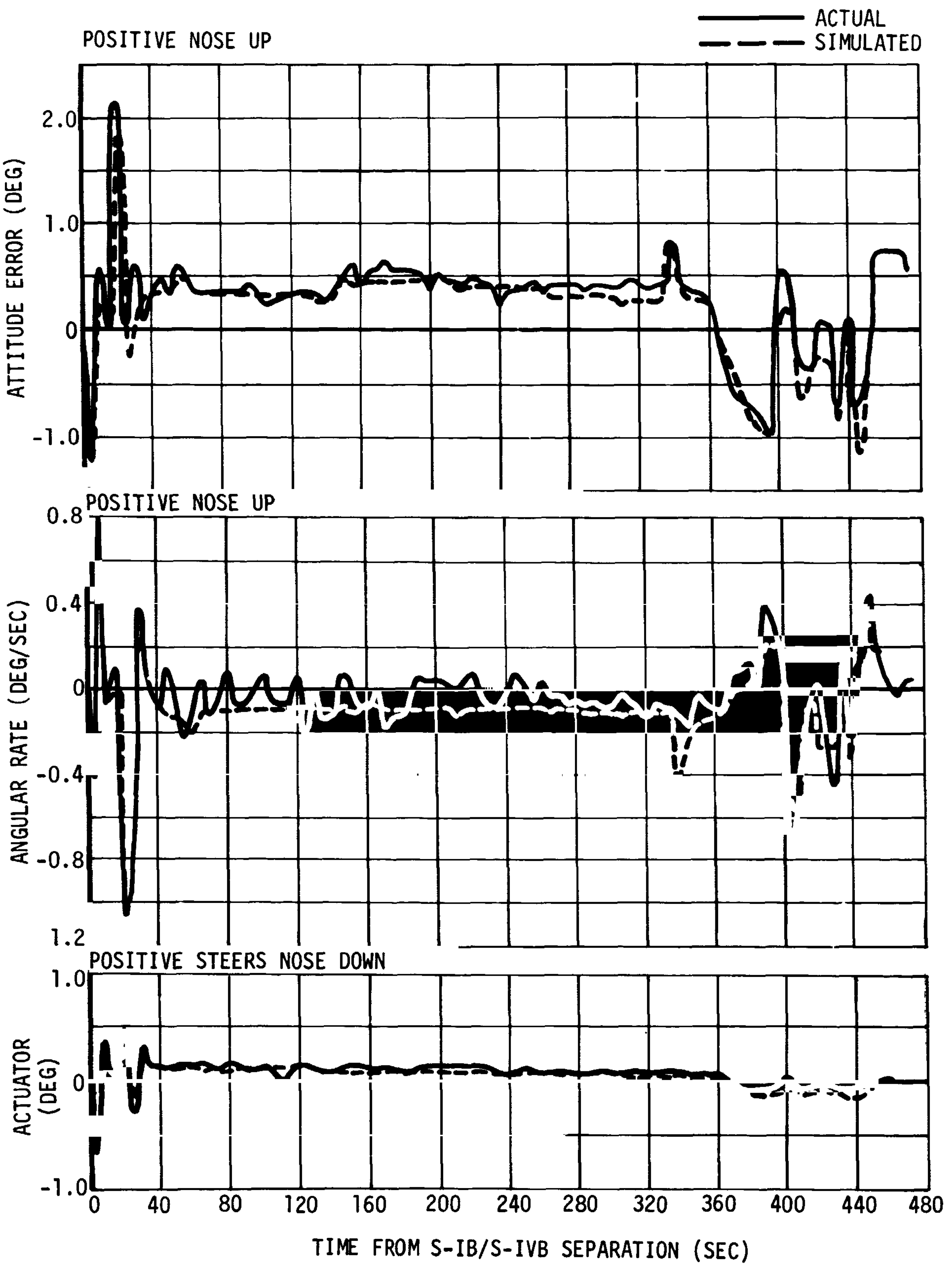


Figure 20-8. Pitch Attitude Error, Angular Rate, and Actuator Position during S-IVB Powered Flight

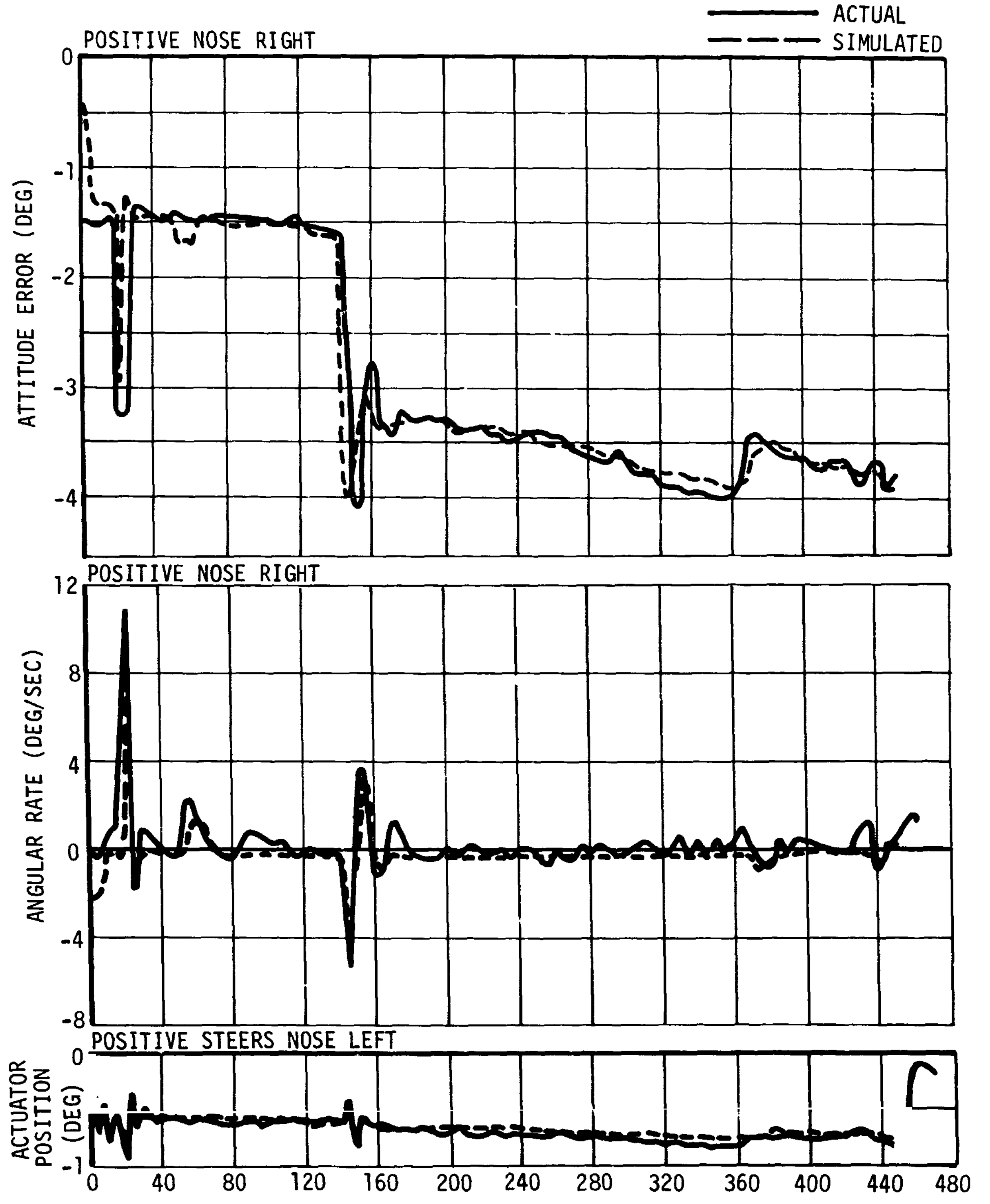


Figure 20-9. Yaw Attitude Error, Angular Rate, and Actuator Position During S-IVB Powered Flight

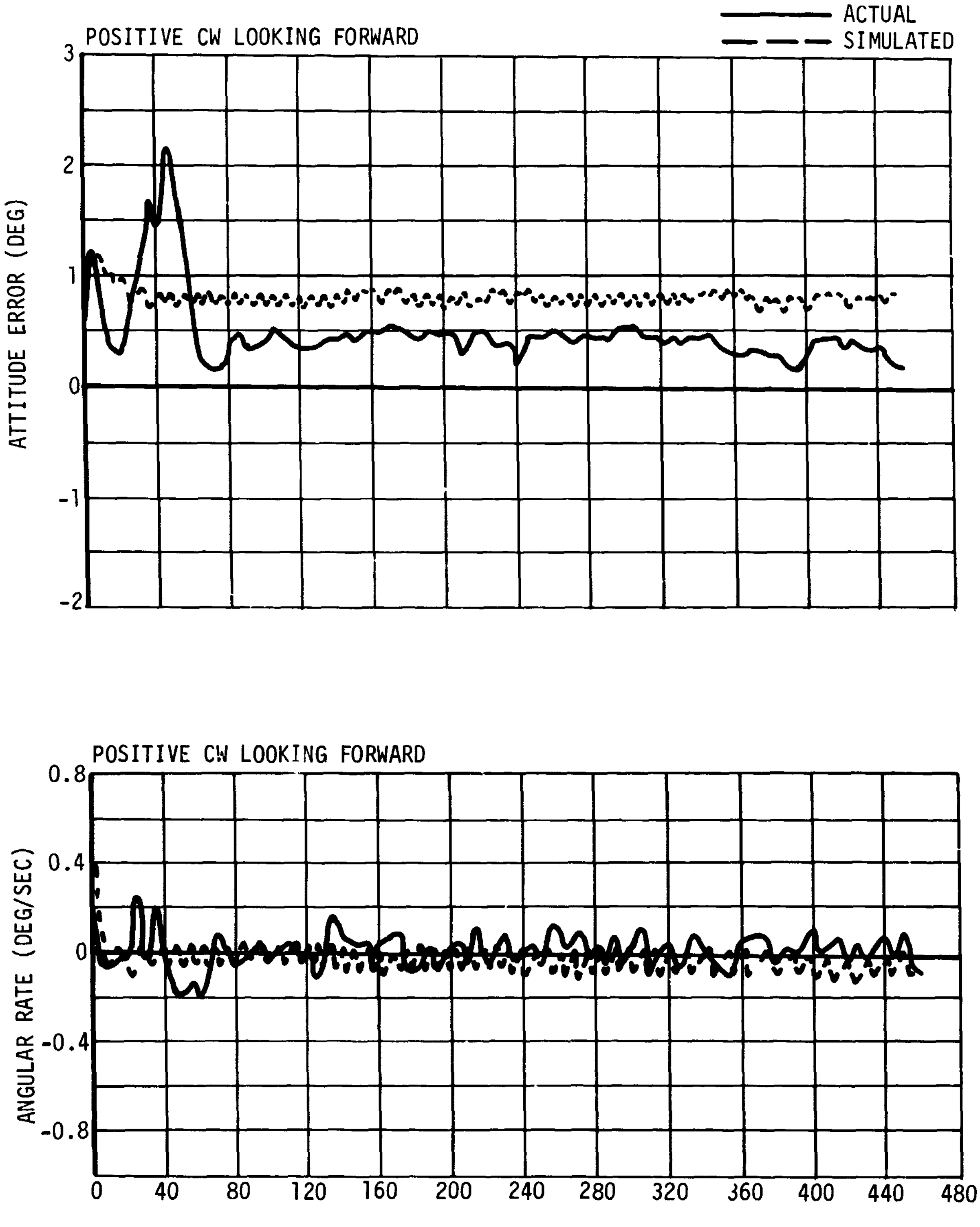


Figure 20-10. Roll Attitude Error and Angular Rate During Powered Flight

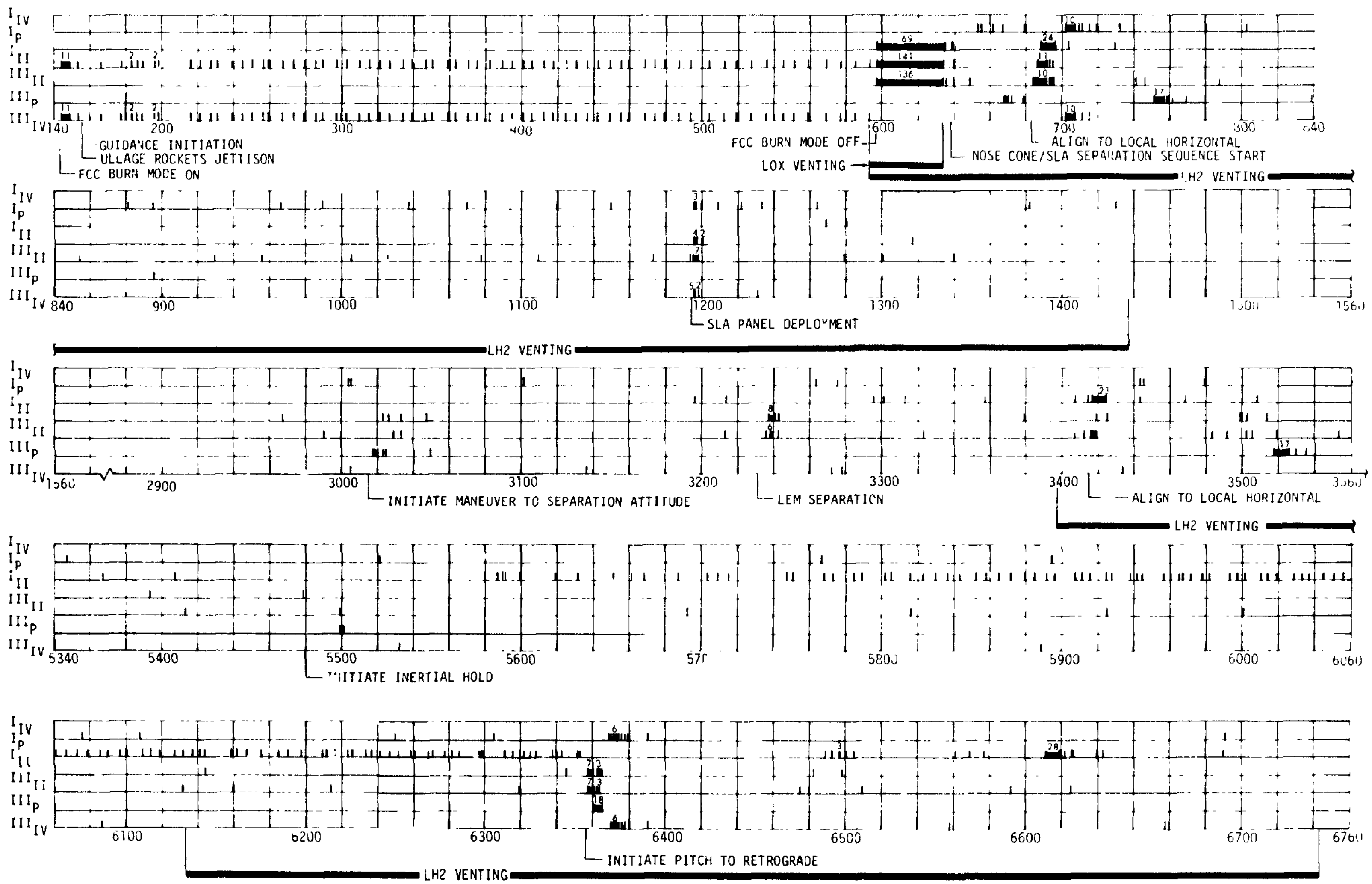


Figure 20-11. Auxiliary Attitude Control System Firing History (Sheet 1 of 2)

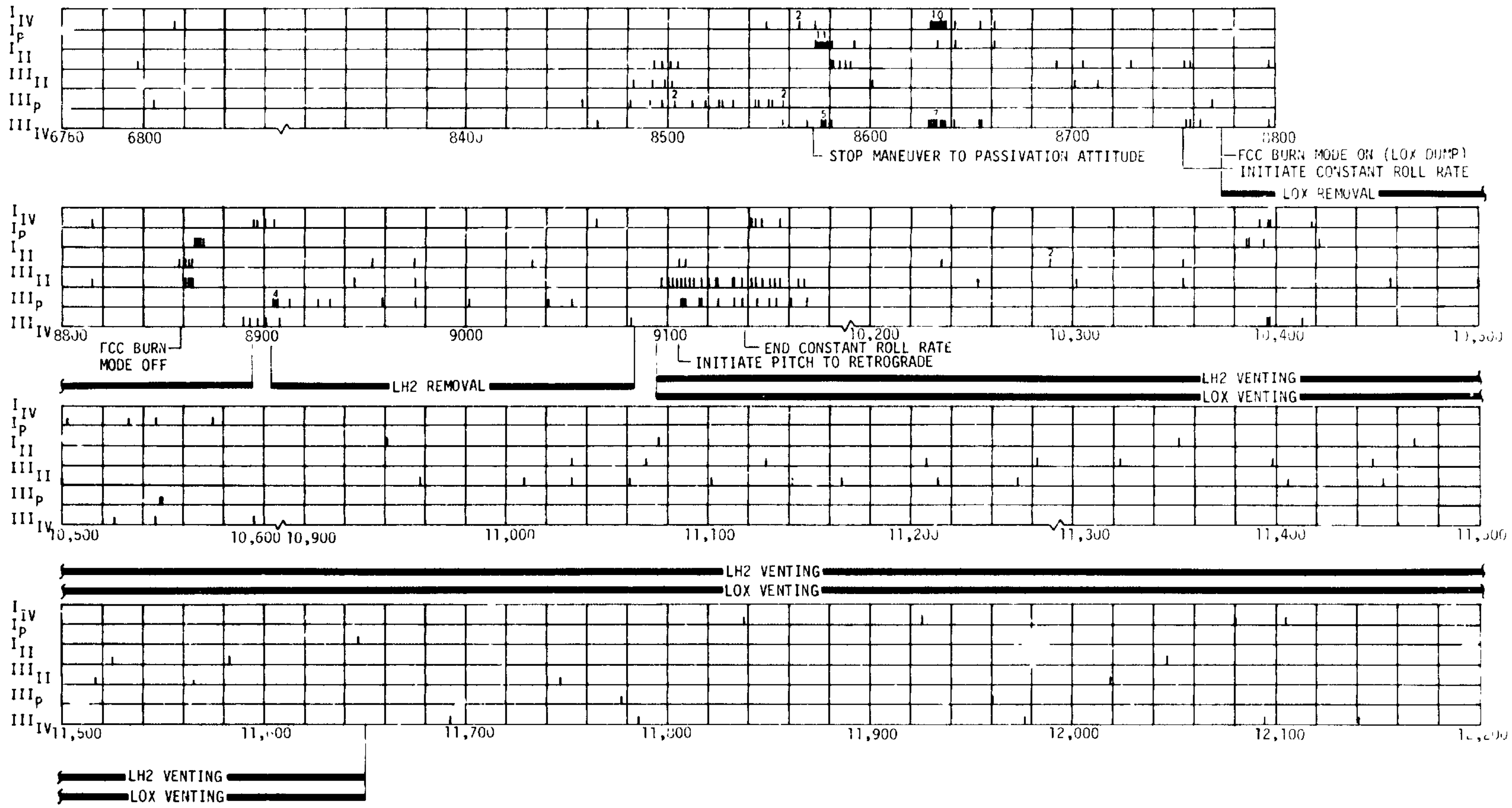


Figure 20-11. Auxiliary Attitude Control System Firing History (Sheet 2 of 2)

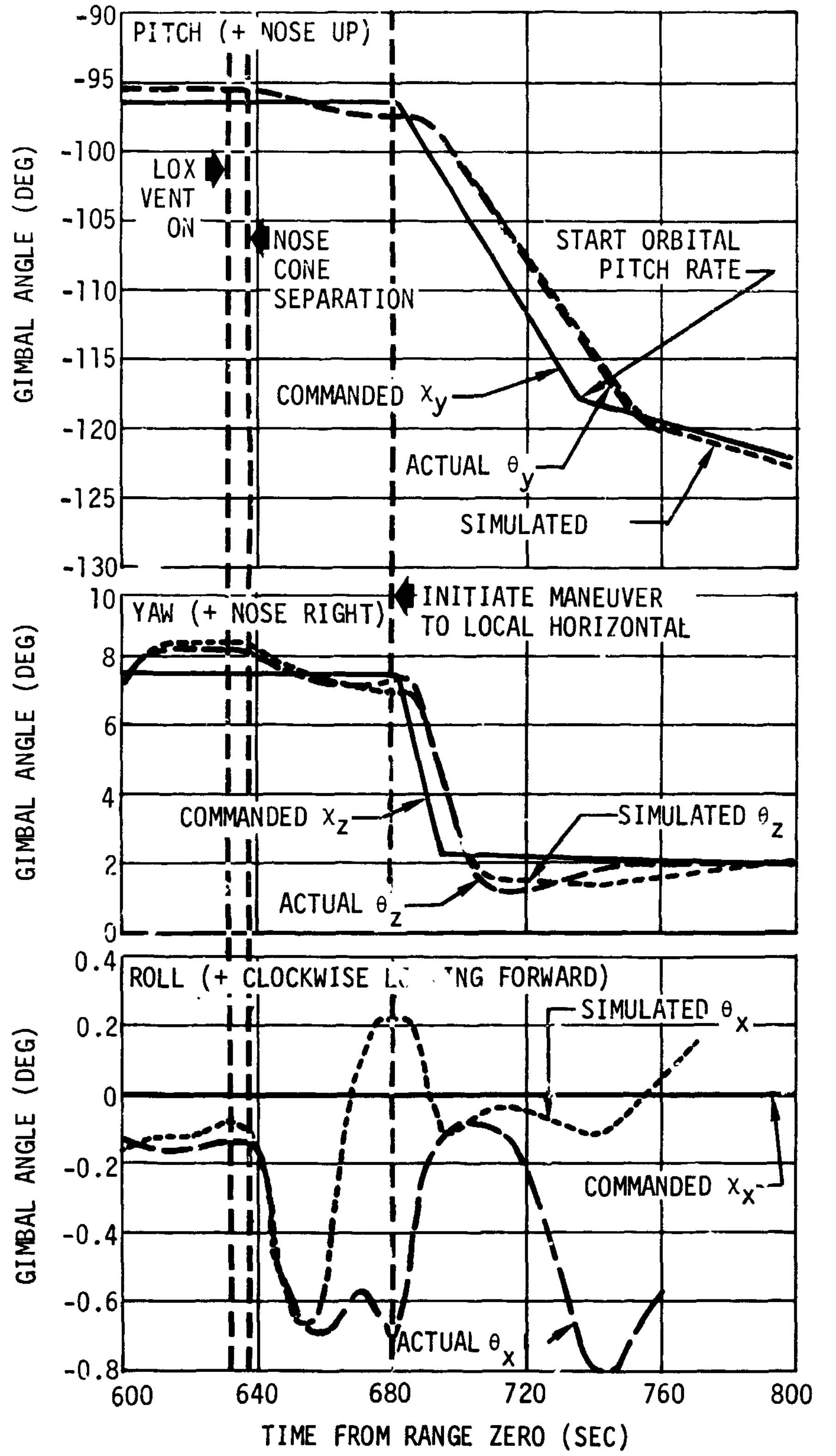


Figure 20-12. Commanded and Actual Vehicle Attitude Following S-IVB Cutoff

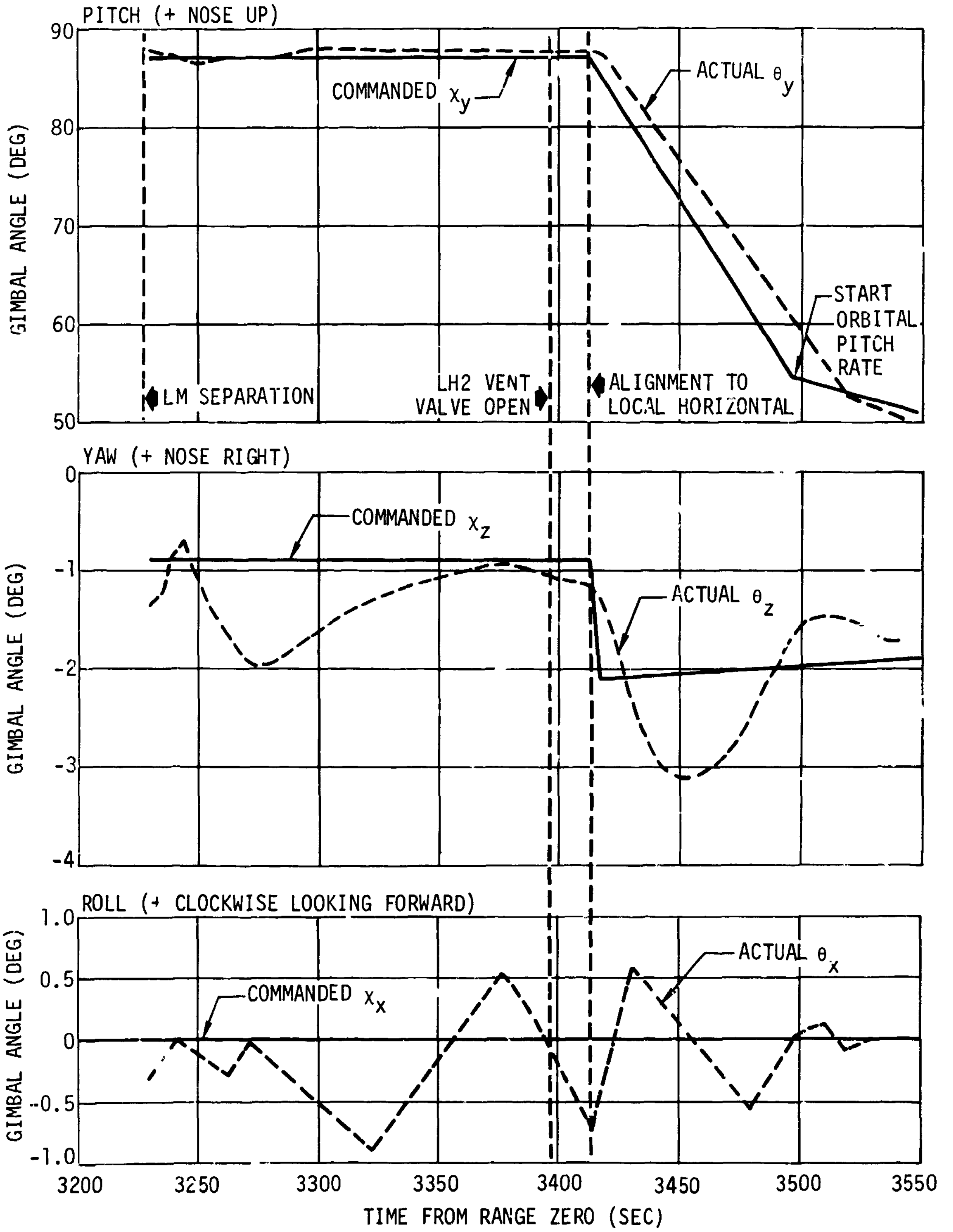


Figure 20-13. Commanded and Actual Vehicle Attitude During LM Separation and Maneuver to Local Horizontal

1. LM SEPARATION COMMAND
2. INITIATE LH2 TANK VENT
3. ALIGNMENT TO LOCAL HORIZONTAL

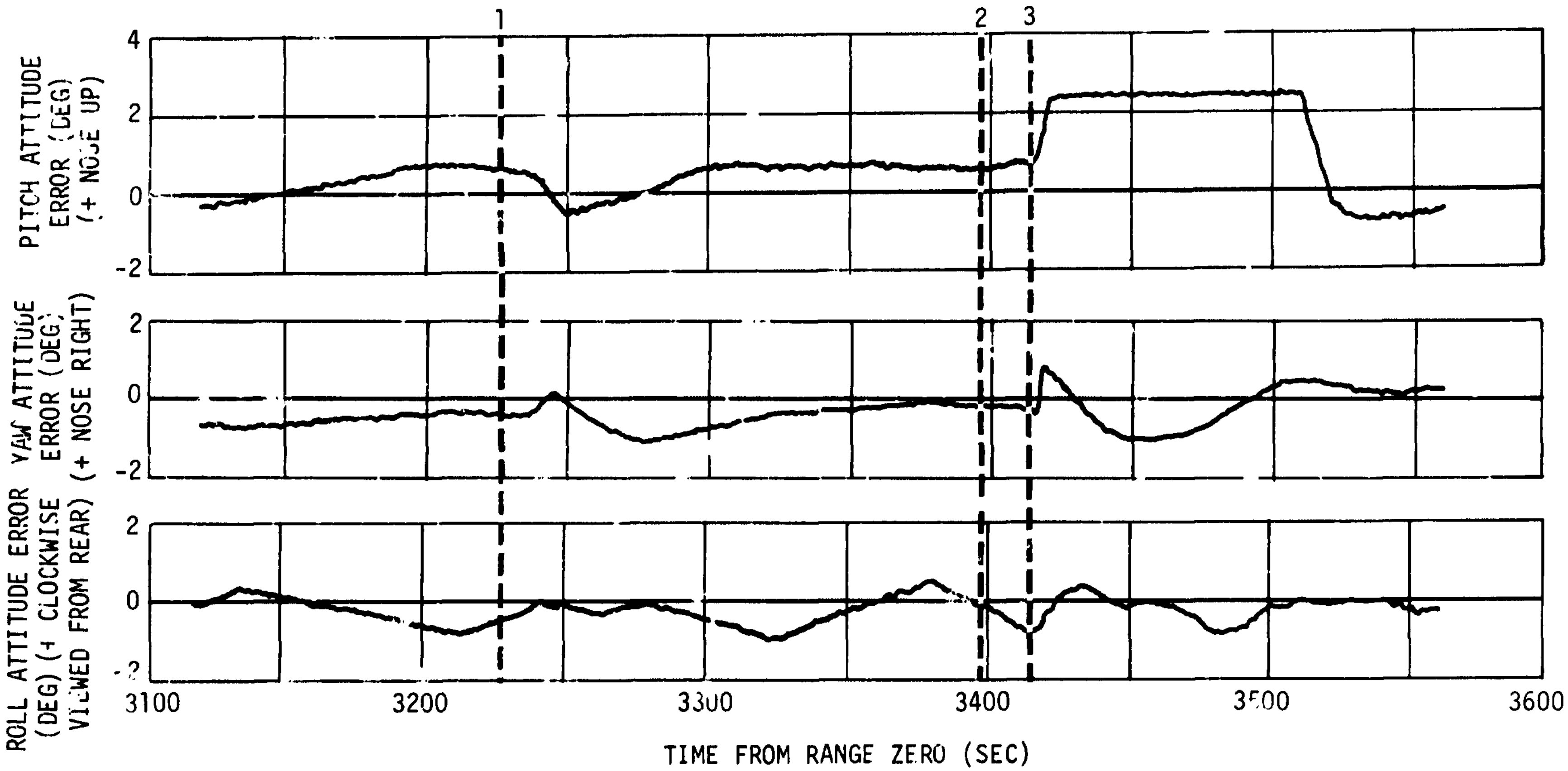


Figure 20-14. Attitude Errors During LM Separation and Maneuver to Local Horizontal

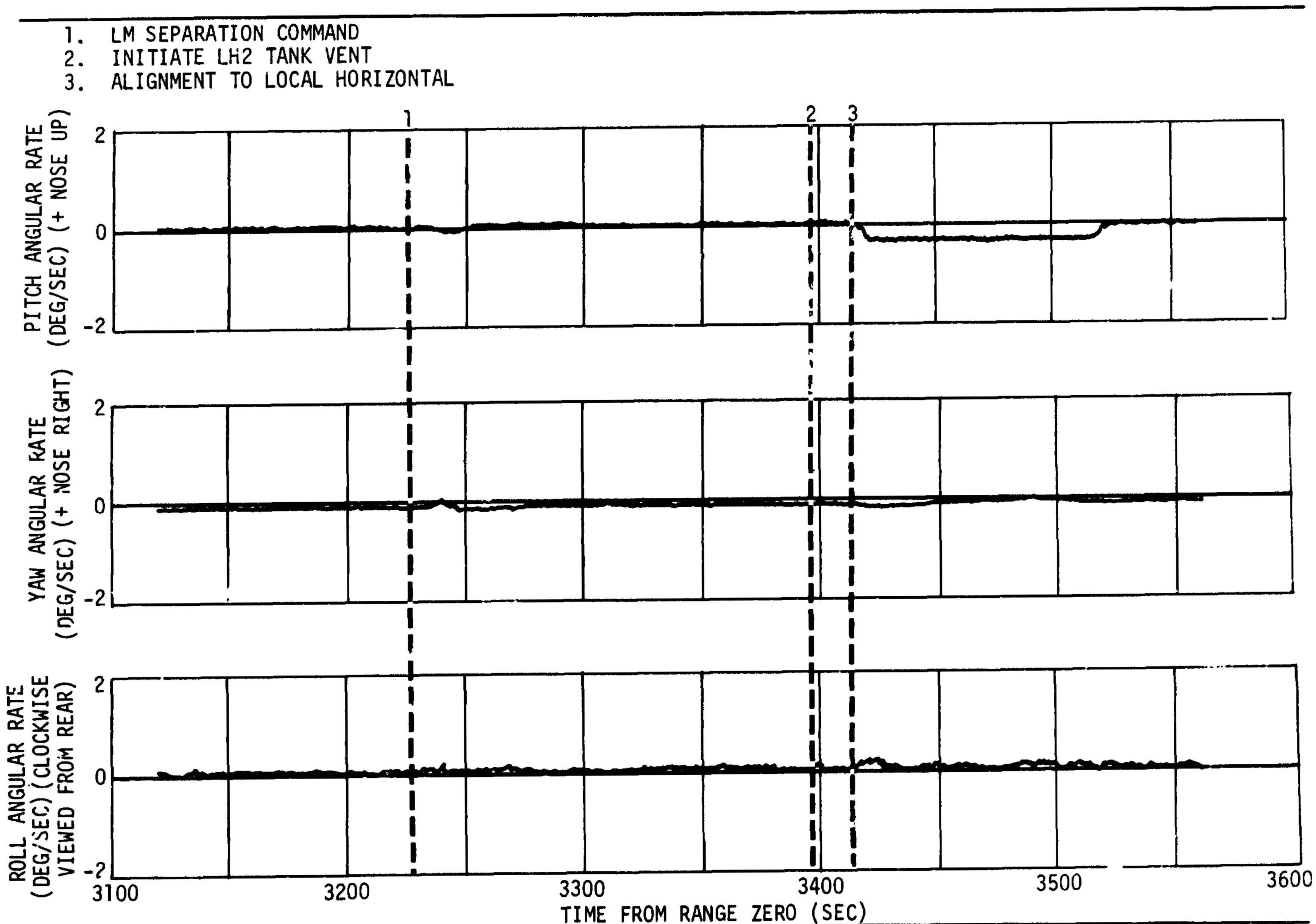


Figure 20-15. Angular Rates During LM Separation and Maneuver to Local Horizontal

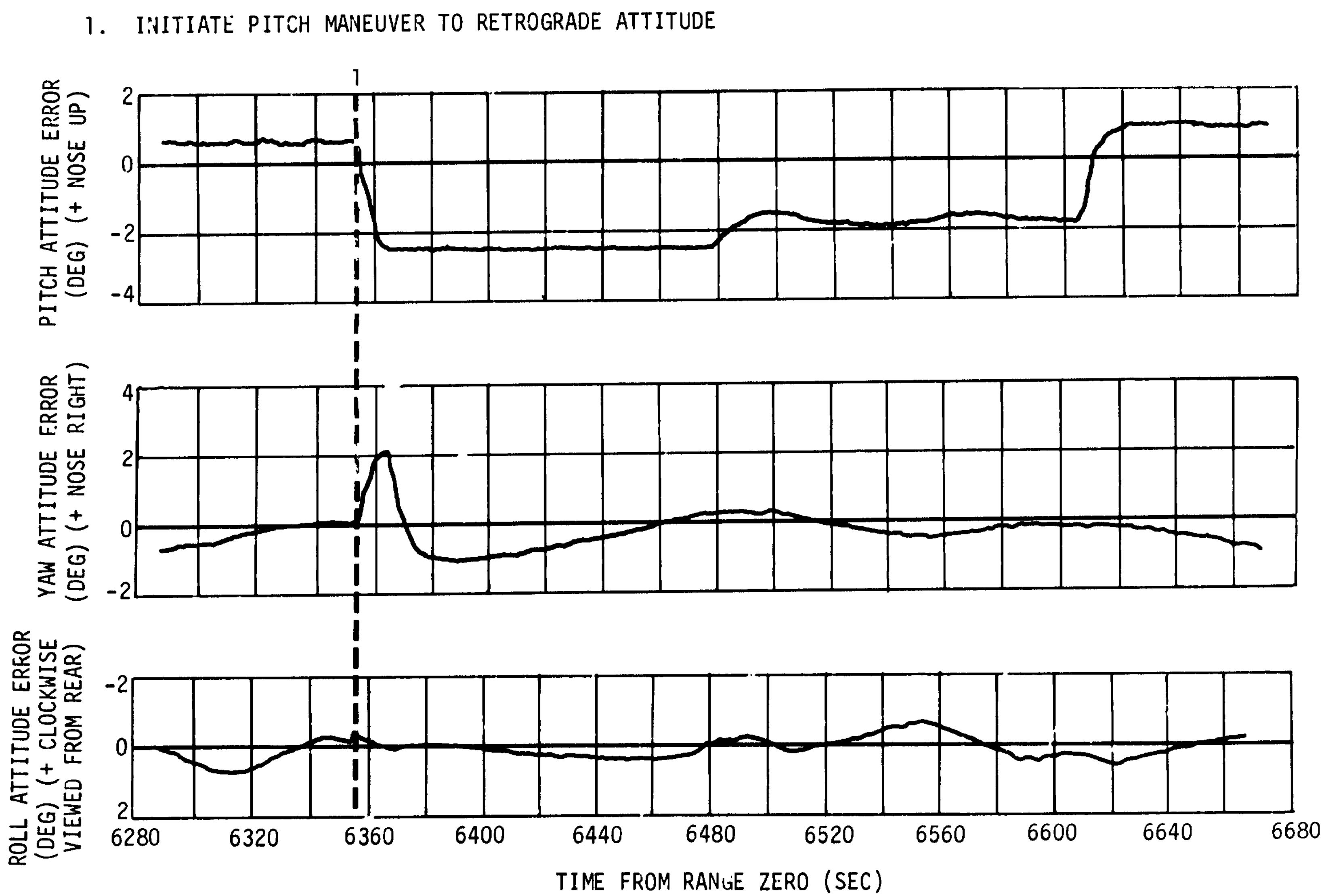


Figure 20-16. Attitude Errors During Maneuver to Retrograde Attitude

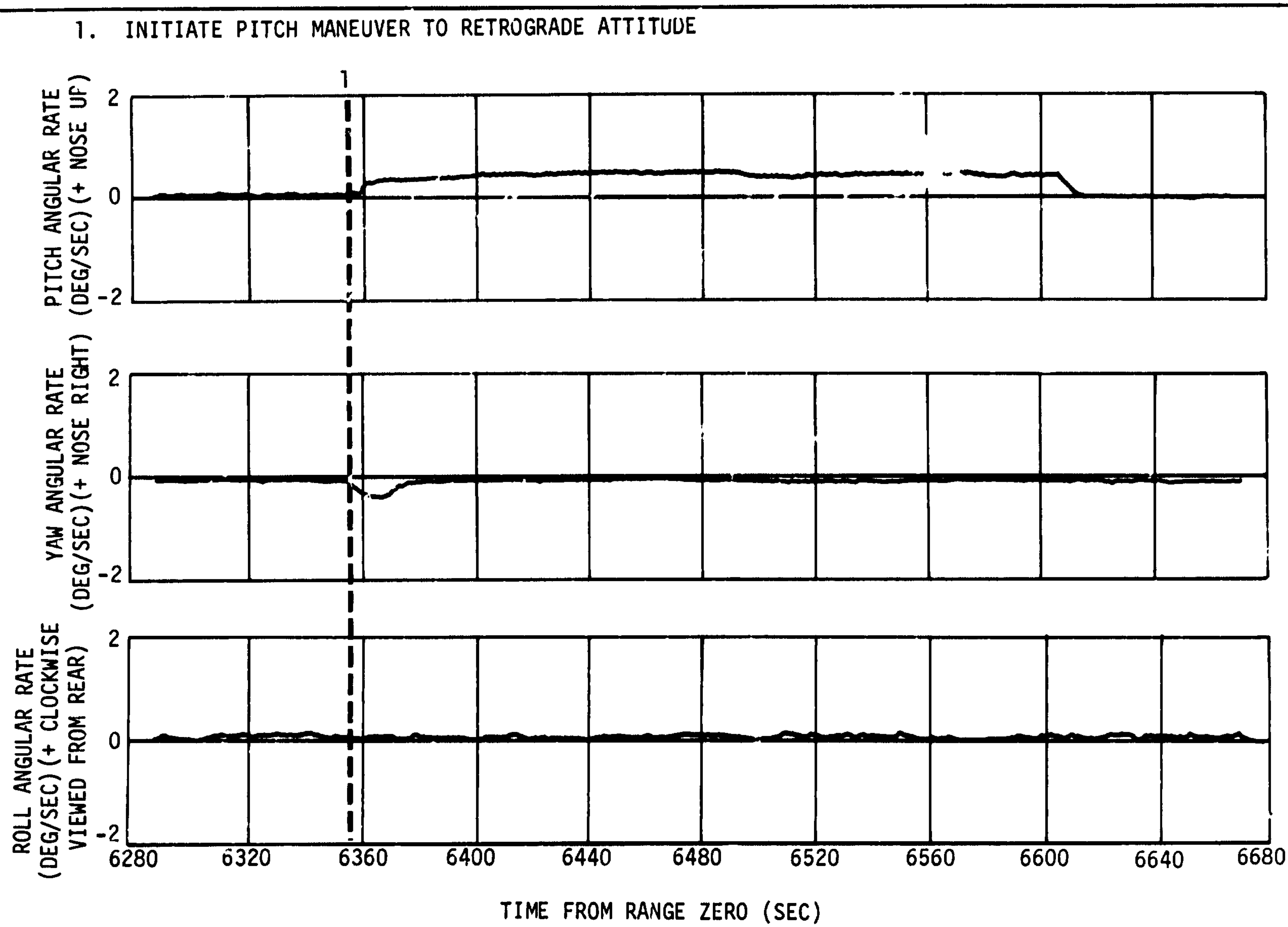


Figure 20-17. Angular Rates During Maneuver to Retrograde Attitude

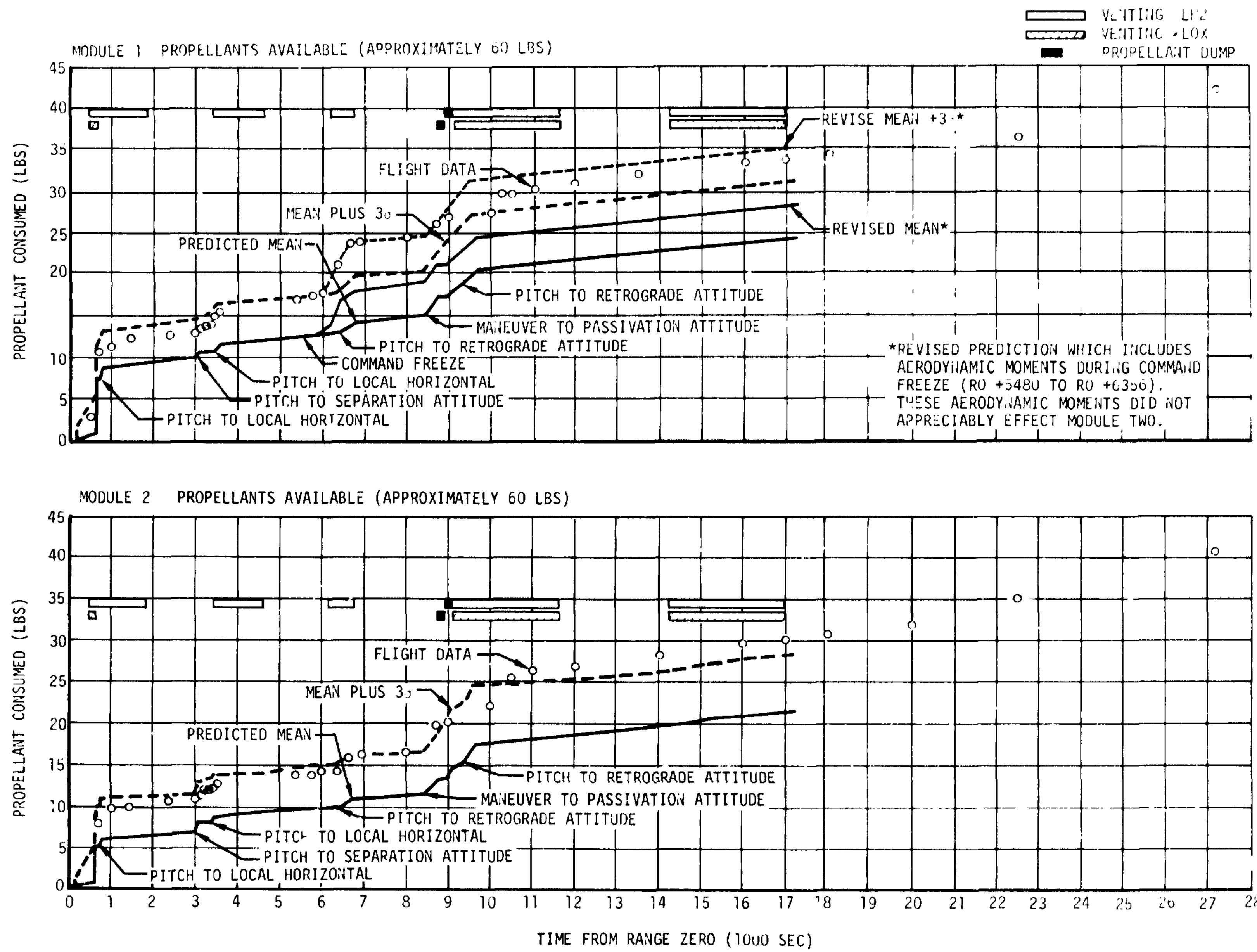


Figure 20-18. APS Propellant Usage

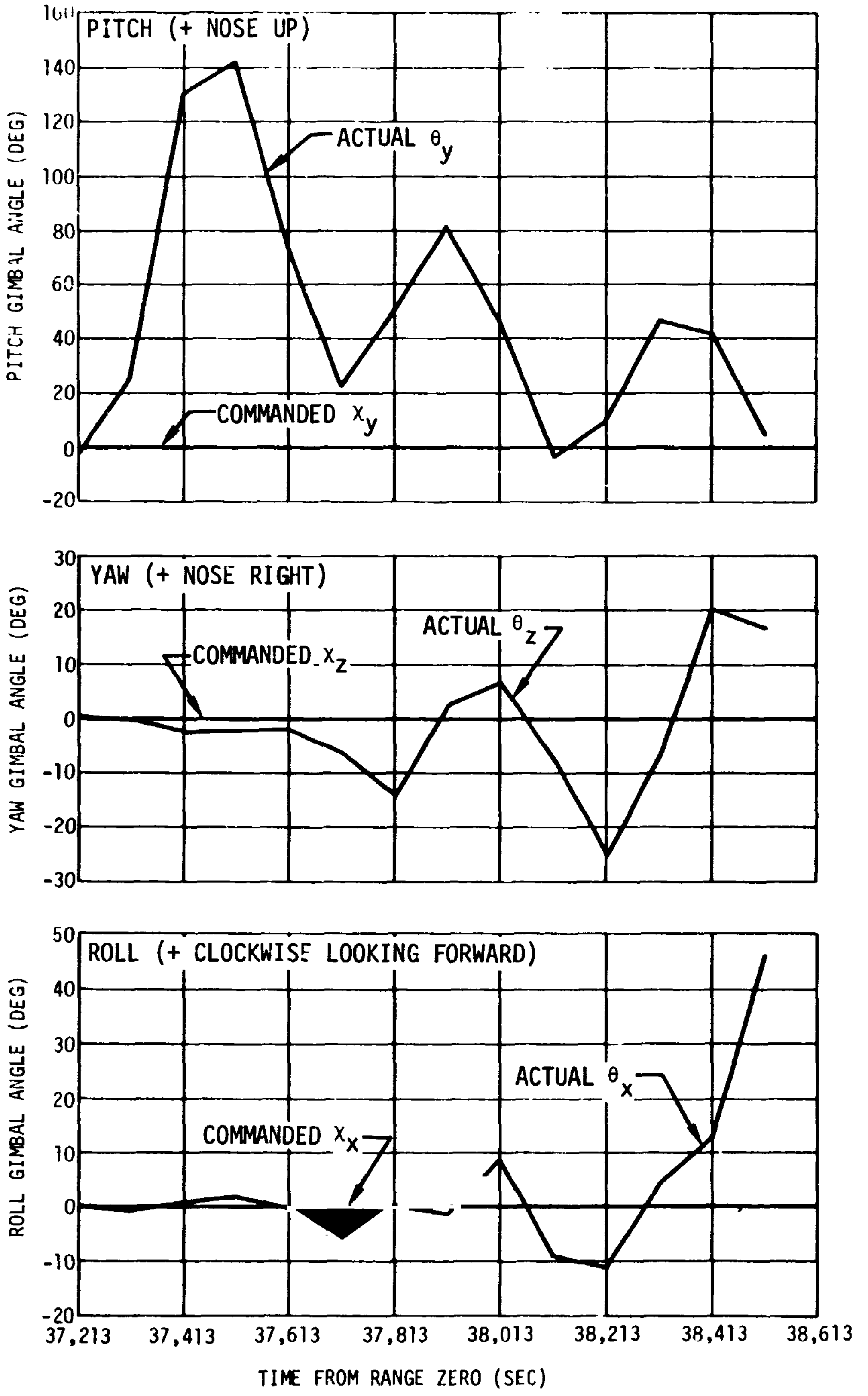


Figure 20-19. ST-124 Stable Platform Gimbal Angle Data (Compressed Data)

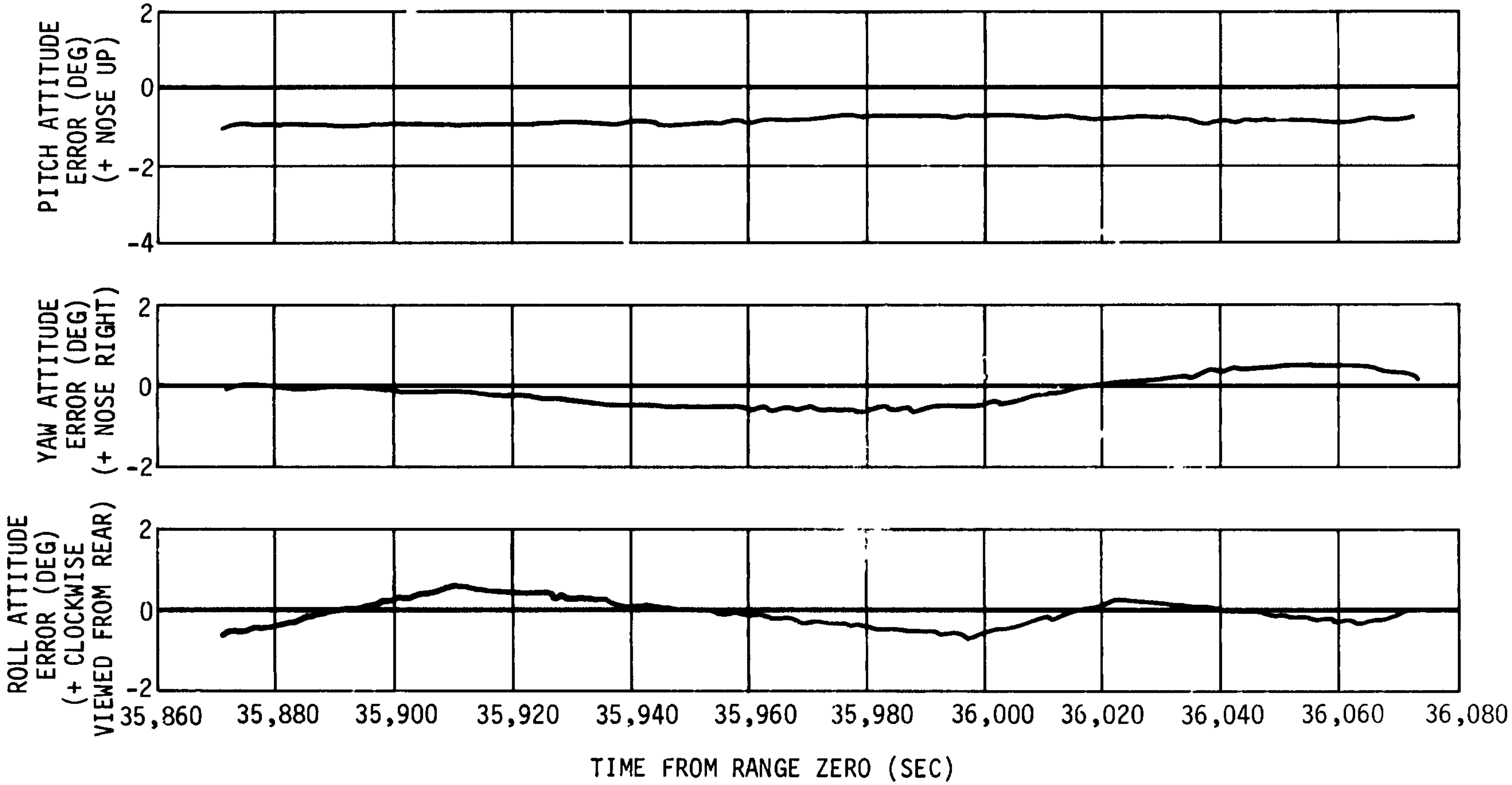


Figure 20-20. Attitude Errors During Seventh Revolution Over Tananarive (Normal Control)

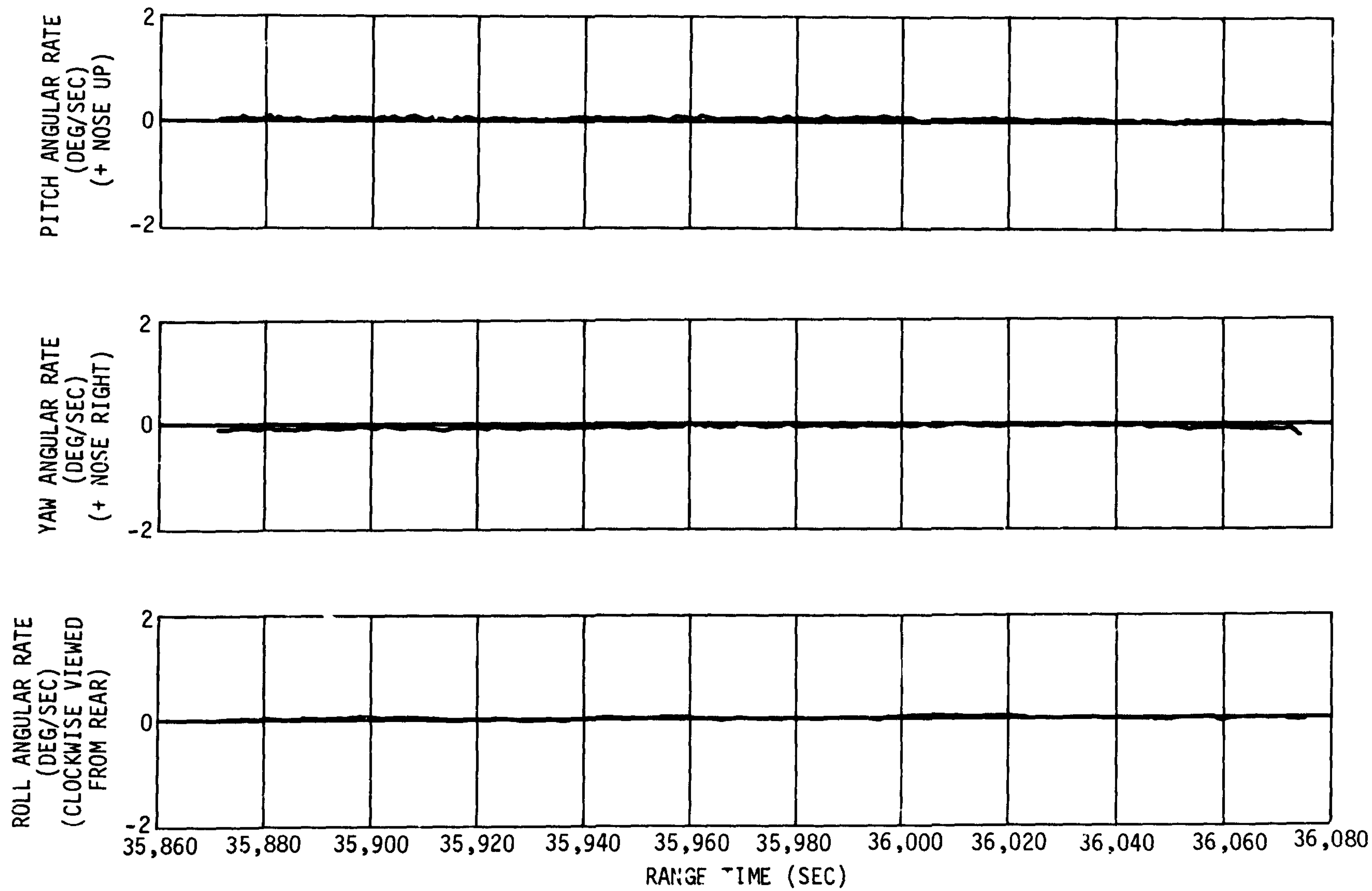


Figure 20-21. Angular Rates During Seventh Revolution Over Tananarive (Normal Control)

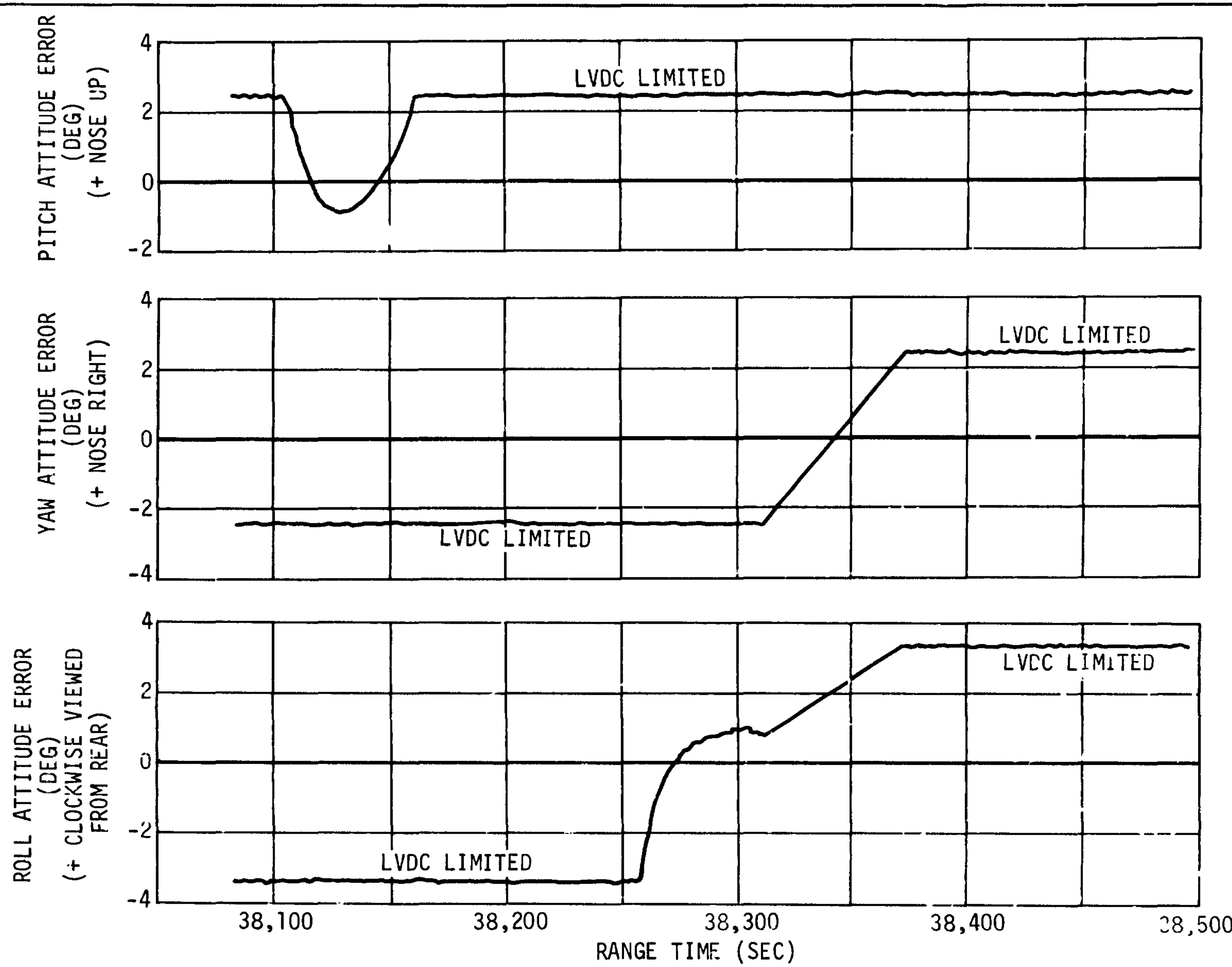


Figure 20-22. Attitude Errors During Seventh Revolution Over Hawaii (Uncontrolled)

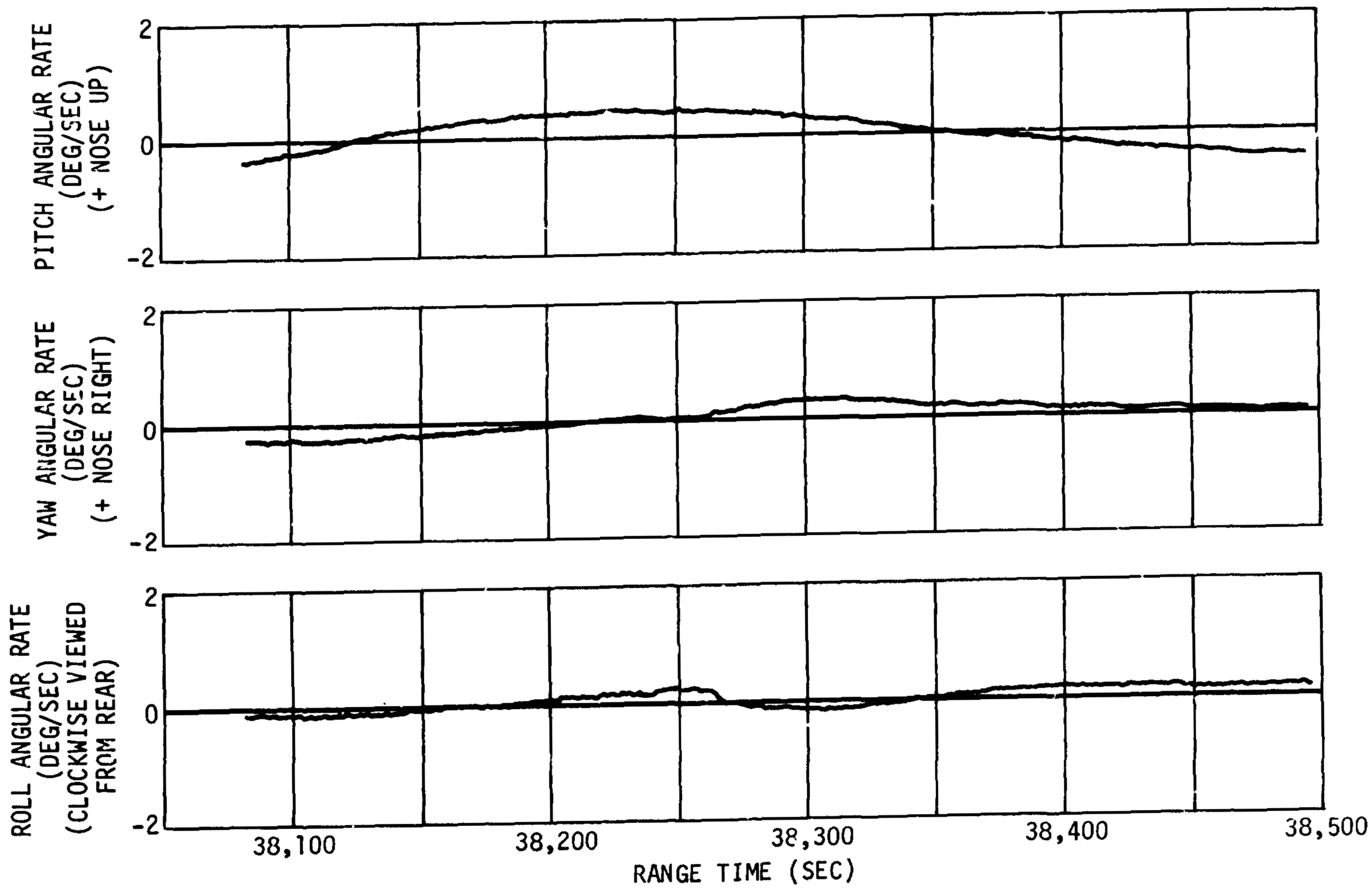


Figure 20-23. Angular Rates During Seventh Revolution Over Hawaii (Uncontrolled)

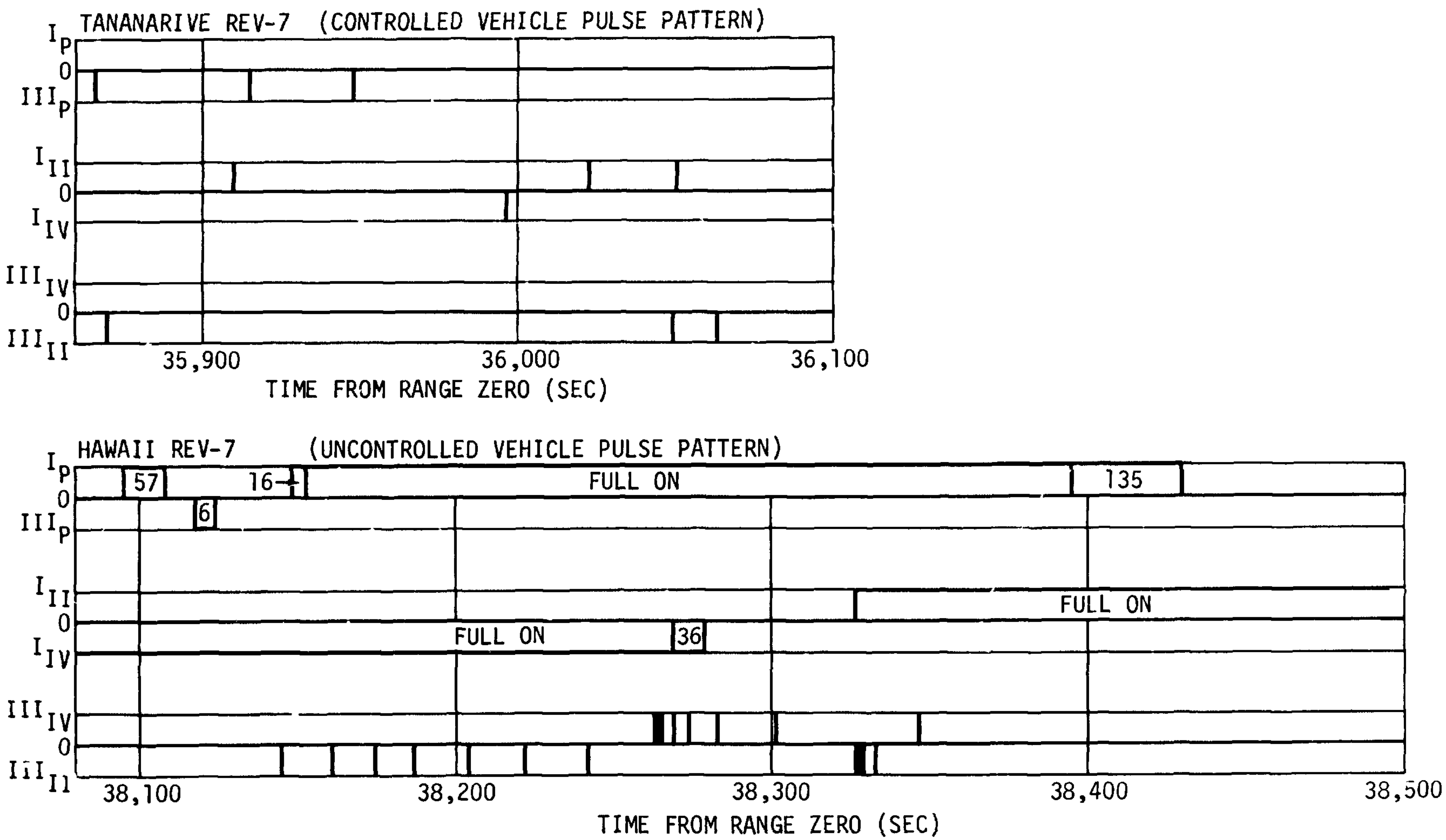


Figure 20-24. IU Spatial Amplifier Command Signals During Seventh Revolution

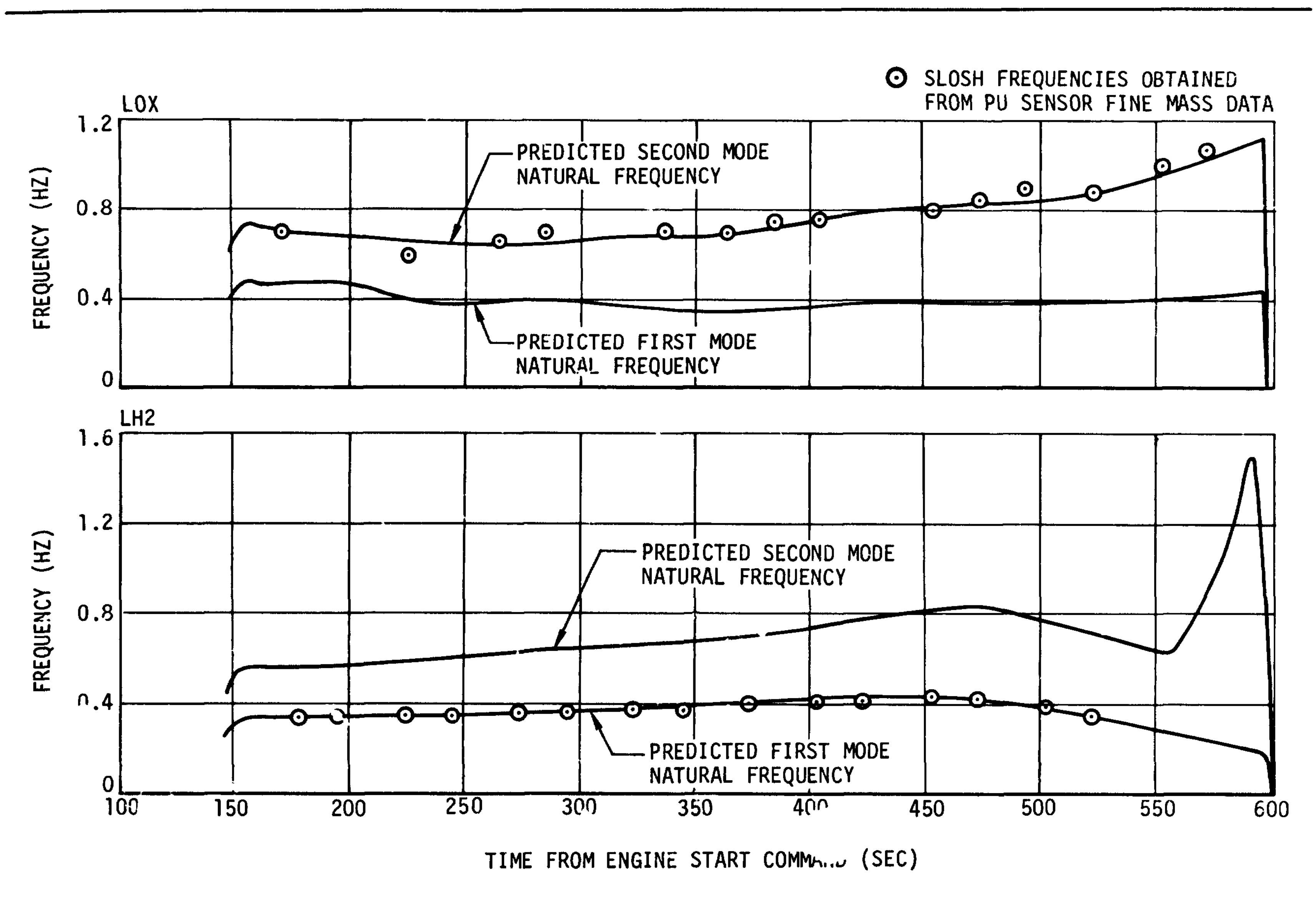
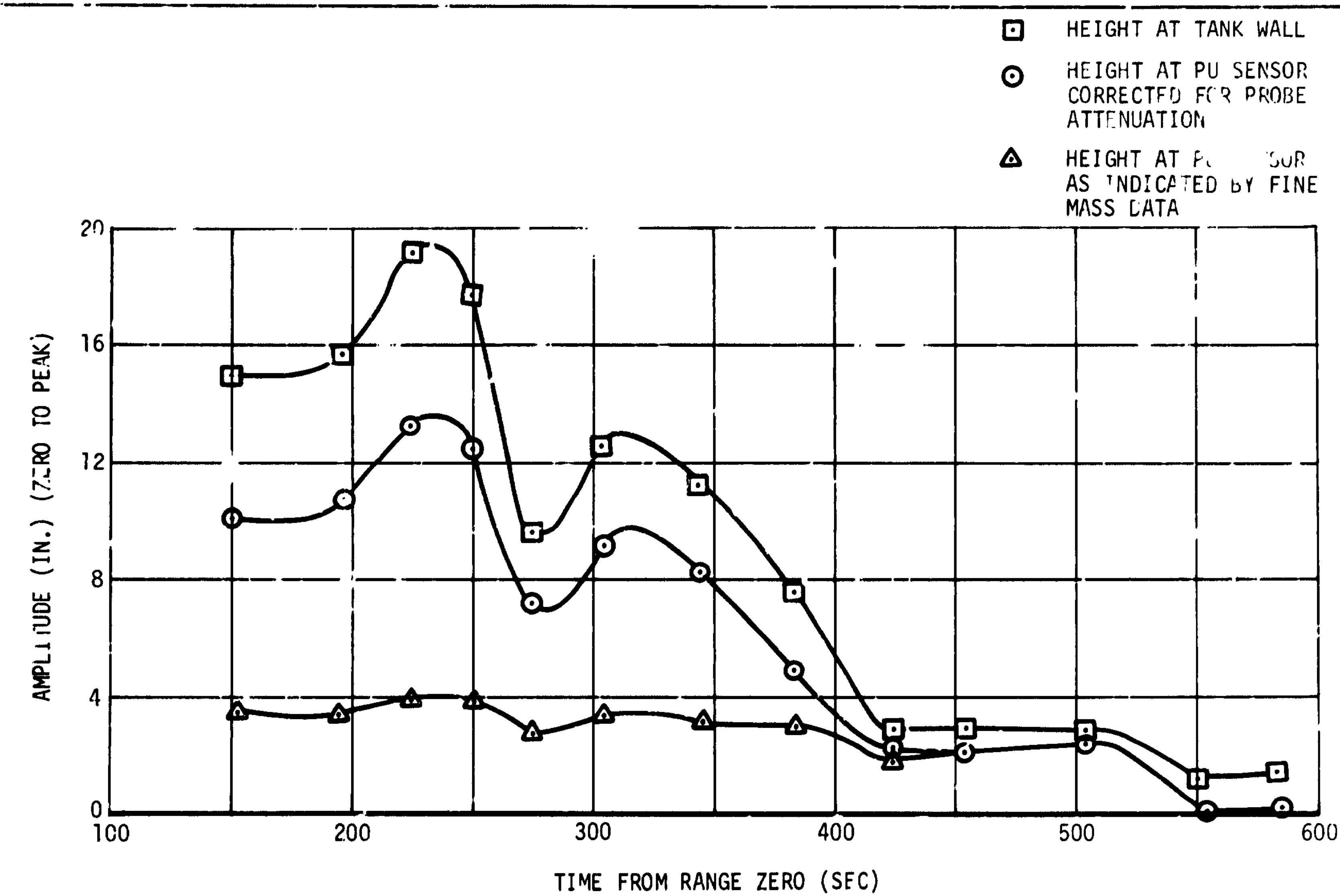


Figure 20-25. Predicted and Actual LOX and LH2 Slosh Frequencies During S-IVB Burn



NOTE: THE DIRECTION OF LH2 SLOSH EXCITATION WAS PREDOMINATELY IN THE PITCH PLANE

Figure 20-26. LH2 Slosh Amplitudes During S-IVB Burn

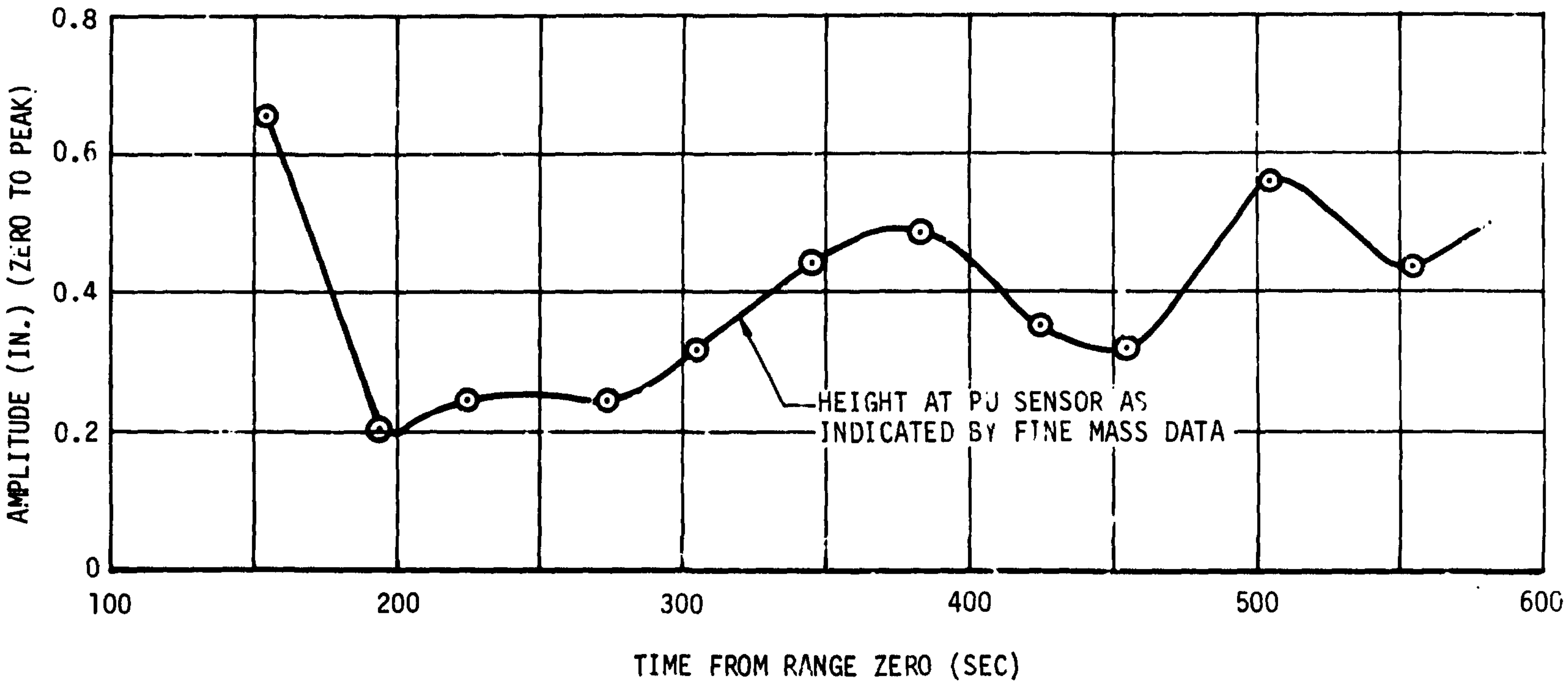


Figure 20-27. LOX Slosh Amplitudes During S-IVB Burn

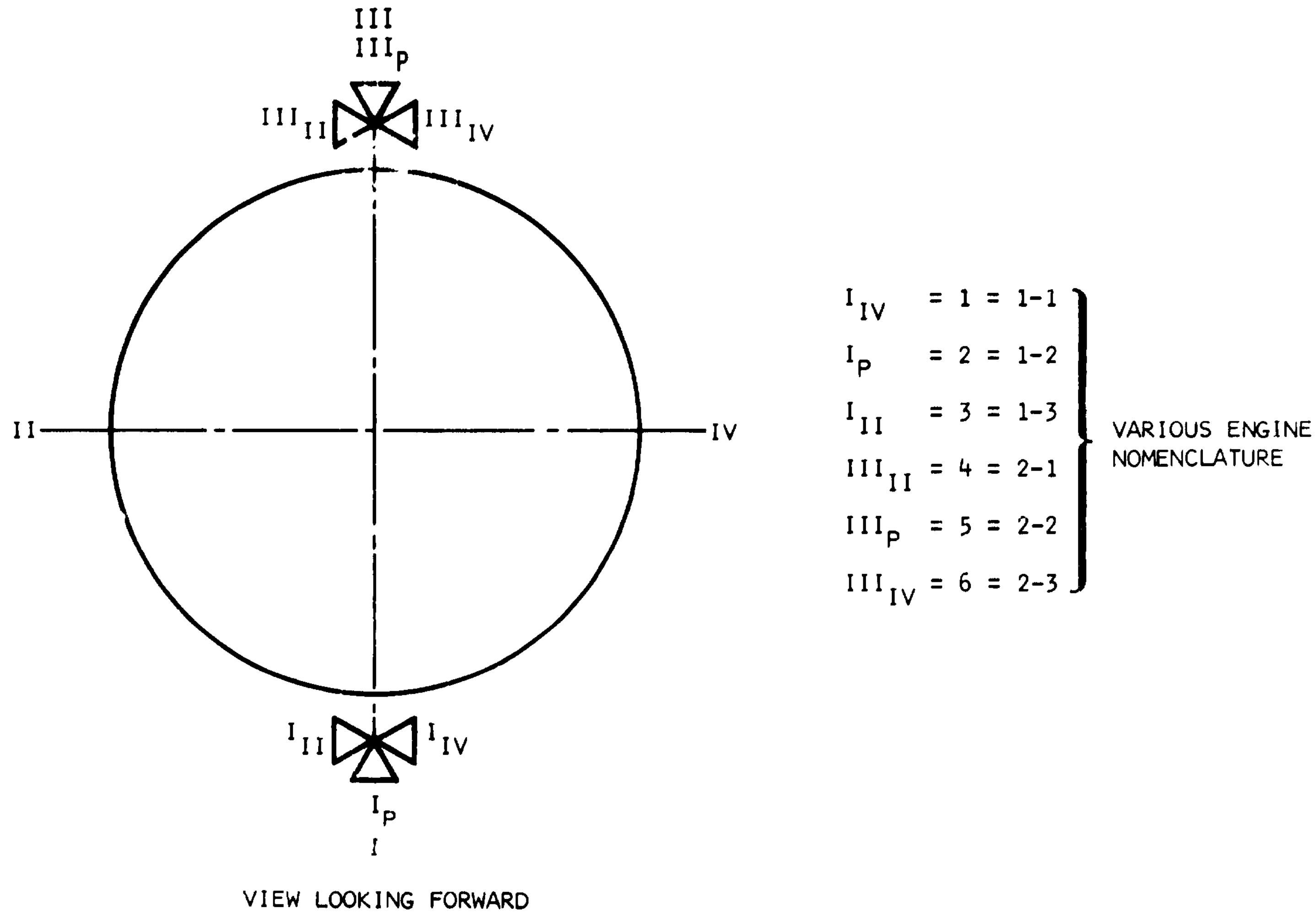


Figure 20-28. Locations of Attitude Control Engines

SECTION 21

HYDRAULIC SYSTEM

21. HYDRAULIC SYSTEM

21.1 Hydraulic System Operation

The S-IVB hydraulic system performance was within predicted values and the entire system operated satisfactorily throughout flight. All redline limits were met prior to liftoff. There were no orbital thermal cycles and no loss of system fluid due to overboard venting as a result of reservoir fluid thermal expansion. System internal leakage was 0.72 gpm which is within the 0.4 to 0.8 gpm allowable range.

Pitch actuator transient loads during engine start were negligible as were the loads throughout the flight. Proper operation of the pitch actuator dynamic pressure feedback mechanism is indicated by the actuator differential pressure traces. The hydraulic servoactuators responded properly to incoming instrument unit signals. Good correlation was observed between the S-IVB actuator position data and the instrumer. ι actuator command data throughout the powered flight.

A summ. em pressure measurements obtained during various phases of f. presented in table 21-1. System temperatures, reservoir oil l and actuator positions are shown in figure 21-1 through 21-4.

21.2 Prelaunch

During countdown the auxiliary hydraulic pump was switched to the coast thermal mode at 3.5 hr prior to liftoff, just prior to propellant loading. Thermal cycling occurred approximately ten times during this period for a total pump operating time of approximately 2.1 hr. Actuation temperatures at the pump inlet (C0050) were 20 to 30 deg F for pump on and 75 to 80 deg F for pump off. The accumulator was precharged to 2,425 psia at 79 deg F. Reservoir oil level (auxiliary pump off) was 87 percent at 65 deg F.

The auxiliary hydraulic pump was turned on the flight mode at approximately RO -11 min. After stabilization, the following measurements were recorded:

System pressure (D0041)	3,610 psia
Reservoir pressure (D0042)	170 psia

Reservoir oil level (L0007)	27 percent
Pump inlet temperature (C0050)	45 deg F
Reservoir oil temperature (C0051)	56 deg F

21.3 Boost and Powered Flight

During boost the pump inlet oil temperature rose steadily as auxiliary pump operation warmed the oil. Accumulator gas and actuator cylinder temperature remained low during boost but started to rise as soon as the engine driven pump started. The main pump discharge pressure setting was approximately 15 to 25 psi higher than the auxiliary pump. Reservoir fluid level rose to 30 percent at the end of engine burn due to the increased fluid temperature. The reversion to 93 percent static level occurred after the Flight Mode Off Command. Pump power extracted during accessory power pad operation was approximately 4.9 hp.

Engine deflections were nominal throughout the powered flight and during the passivation experiment. Prior to the event Flight Control Computer S-IVB Burn Mode On, the pitch and yaw actuator positions (G0001 and G0002) were offset +0.2 and 0.0 deg respectively. During the powered flight, offsets of +0.3 and -0.6 deg in the pitch and yaw planes were observed. At engine cutoff the actuators returned to their original offset positions held prior to engine start. The actuator positions were offset from null during powered flight due to the displacement of the vehicle's center of gravity off the vehicle's vertical axis, due to J-2 engine installation tolerances, thrust misalignment, and uncompensated gimbal clearances and thrust structure compression effects.

The maximum deflection of the pitch actuator was -0.64 deg occurring at time RO +147.3 sec. This was a displacement of 0.94 deg from its offset position. At time RO +162.5 sec the yaw actuator deflected to a maximum displacement of -0.96 deg which is an excursion of 0.36 deg from its offset position. The pitch actuator loads during this activity caused the differential pressure (D0044) to rise to -900 psi. This produced an actuator torque of 126,000 in-lb which is 26 percent of the torque available. The yaw actuator differential pressure measurement (D0045) is suspected as not working commencing at S-IVB engine start. A 0.35 cps frequency with an amplitude of approximately 0.12 deg peak-to-peak was observed superimposed on the pitch actuator control signal from 150 to 290 sec after liftoff. The pitch actuator differential pressure responded to this excitation until RO +430 sec.

Refer to figures 21-1 through 21-4 for history of the above mentioned parameters during boost and powered flight.

21.4 Temperatures During Orbital Coast

After S-IVB engine cutoff the main pump inlet oil temperature continued to rise due to the transfer of heat from the LOX turbine housing to the pump manifold. Inlet temperature peaked at 185 deg F at RO +3,500 sec during orbital coast.

21.5 Propellant Dump Test

The propellant dump test data is covered in paragraph 26.5.

TABLE 21-1
HYDRAULIC SYSTEM PRESSURES

SYSTEM PRESSURES (psia)	BOOST		POWERED FLIGHT		ORBITAL COAST		PASSIVATION	
	MEASURED VALUE	PREDICTED LIMITS	MEASURED VALUE	PREDICTED LIMITS	MEASURED VALUE	PREDICTED LIMITS	MEASURED VALUE	PREDICTED LIMITS
Pump Output	3,625	3,650 3,500	3,640	3,650 3,500	-	- -	3,620	3,650 3,500
Accumulator Gas	3,625	3,650 3,500	3,650	3,650 3,500	2,450*	2,400 2,300	3,620	3,650 3,500
Reservoir Oil	172	185 165	185	185 165	70	90 65	170	186 165
Auxiliary Pump Air Tank	375	450 250	390	450 250	425	450 250	430	450 250
Auxiliary Pump Motor Air	28	35 25	29	35 25	21	30 20	14	25 15

*Corrected to 68 deg F

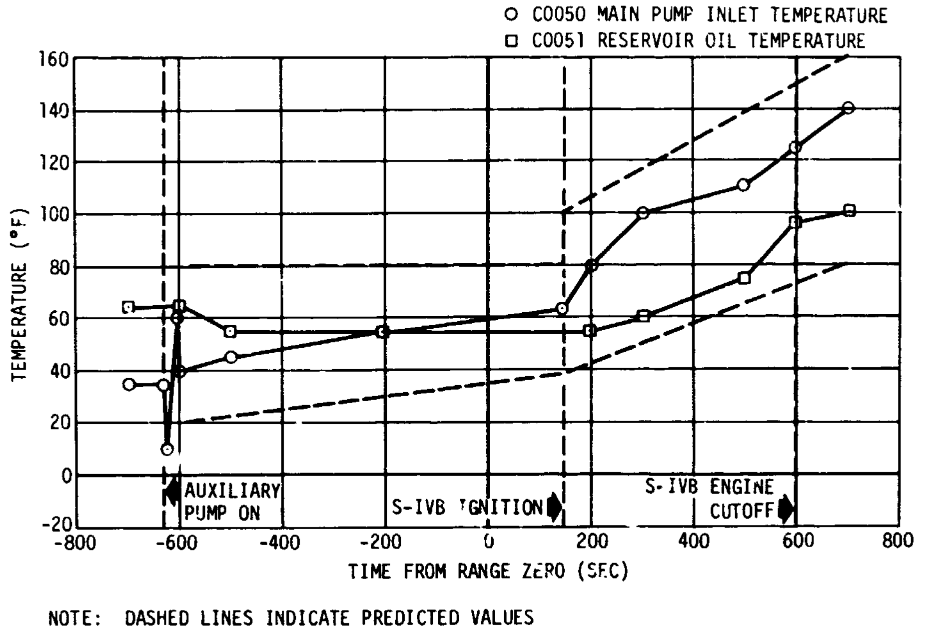


Figure 21-1. Pump Inlet and Reservoir Oil Temperatures During Boost and Powered Flight

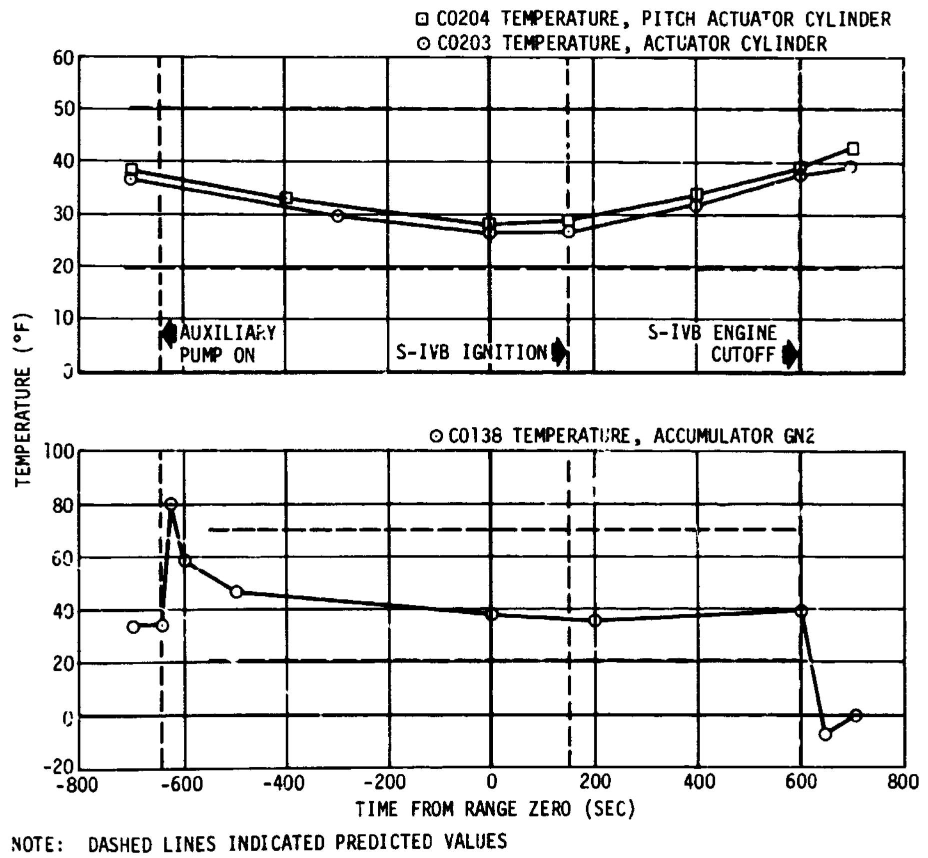


Figure 21-2. Actuator and Accumulator Gas Temperatures During Boost and Powered Flight

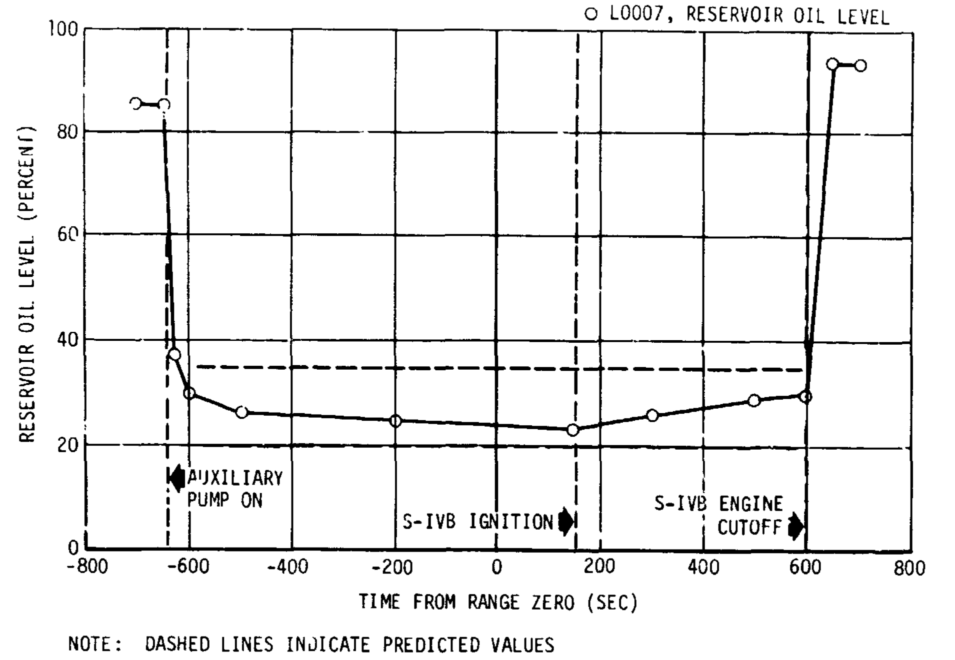


Figure 21-3. Hydraulic Reservoir Oil Level During Boost and Powered Flight

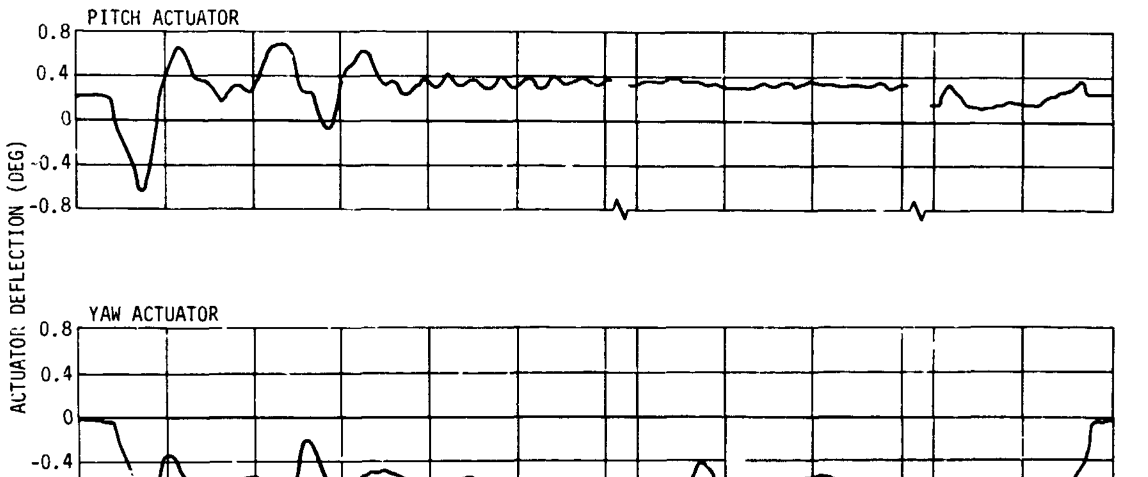


Figure 21-4. Hydraulic Actuator Positions During Powered Flight

SECTION 22

STAGE STRUCTURE AND ENVIRONMENT

22. STAGE STRUCTURE AND ENVIRONMENT

22.1 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 stage from S-IB stage. The three ullage rockets and four retrorockets all fired, thus accomplishing a normal separation sequence.

Approximately 12 sec following separation, the three ullage rockets and their fairings were jettisoned. The jettison indication was a drop to zero of the voltages that monitor ullage rocket chamber pressure. These voltages are measured by strain gage type pressure transducers which have a built in offset of 0.3 volts. When pressure is zero, the voltage is 0.3 volts. When the fairing is jettisoned, the circuit opens and the voltage drops to zero.

The safety and arming device, an element of the range safety system, was cycled electrically from ARMED to SAFE position several times during ter . al countdown and functioned as required.

22.2 Flight Load Conditions and Structural Integrity

An evaluation of strain, acceleration, pressure, and temperature data from the S-IVB stage for the AS-204 trajectory indicated adequate structural strength existed in the stage for the conditions encountered.

Body bending moments were less than the maximum predicted values due to comparatively moderate wind shears and gusts. The maximum vehicle axial acceleration at S-IB stage inboard engines cutoff (IECO) was identical to the predicted axial acceleration, which verified the computer preflight axial loads for the S-IVB stage. Axial loads computed from flight strain gage data are in agreement with preflight computed axial loads from lift-off to approximately 80 sec of flight time. 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.

Measured axial strains in the aft skirt stringers were generally as predicted for both stringer side mounted and top mounted strain gages. The measured strains revealed incremental internal strains from structural expansions and contractions resulting from aerodynamic heating between approximately 60 and 120 sec of flight time. These thermally induced strains were evaluated and extracted analytically from total measured strains in order to more accurately compute corresponding flight body bending moments and axial loads. Preflight and postflight detailed analyses including thermal effects, indicated that positive margins of safety existed in the stringers.

Recorded skin pressure differentials at the forward and aft skirts revealed a higher than design crushing pressure adjacent to the aft end of the forward skirt. This crushing pressure was localized near the skirt flange and extended annularly around the skirt. Analysis has shown the frames and stringers at the aft end of the forward skirt are stabilized locally by the adjacent pressurized LH2 tankage, and that instability did not occur.

Recorded maximum temperatures of the S-IVB stage structure subjected to aerodynamic heating indicated that flight temperatures did not exceed maximum design trajectory temperatures.

The LH2 tank 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 one psia as predicted.

22.2.1 Body Strains

Sixteen axial strain gages were installed on external hat stringers of the S-IVB stage. The gages were located at vehicle sta 1261 of the aft skirt. Eight measurement locations at the station were approximately equally spaced around the circumference. Two strain gages were installed at each measurement location. One gage was mounted to the side of the stringer near the neutral axis, and the other gage was mounted to the top of the stringer. The dual 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 gage data were temperature compensated.

The recorded data from the strain gages appeared to be valid throughout S-IB stage powered flight where critical body bending and axial loads occur. After approximately 70 sec of flight time the strain traces generally indicated strain changes attributable in part to differential structural expansion or contraction from aerodynamic heating. The strain data allowed the evaluation of margins of safety including actual flight thermal effects from the AS-204 trajectory.

The strain histories for the 16 gages on the aft skirt are presented in figures 22-1 through 22-4. At range zero (RO) -10 sec, all measured strains have been adjusted to the computed correct strain corresponding to the one 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 tankage ullage pressurizations. The adjustment to each measured strain at one g loading just prior to liftoff was applied uniformly to the corresponding strain trace throughout flight, so that measured strain increments during flight were not affected. The increments of strain on the S-IVB stage due to bending moments from ground winds were computed and found to be relatively small. Ground wind induced strains have been neglected in the adjustments to strain traces.

The maximum and minimum strain envelopes in figures 22-1 through 22-5 show the analytically predicted limits of strain based on the AS-204 vehicle programmed trajectory. Flight test measurements, adjusted to the initial one g condition, are shown superimposed in the figures to indicate the degree of correlation between predicted and measured strains. The maximum and minimum strain envelopes include the effects of maximum analytical aerodynamic gusts and wind shears. The envelopes also include the tolerance 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 derived from the structural qualification test results of the S-IVB/IB-SD396 aft skirt.

The stringer side mounted gages on the aft skirt provided strain histories substantially as predicted. The side gage strain traces ideally would converge approximately to a common value at IECO, since at this flight time airloads should be nearly non-existent and body bending negligible. The non-convergence of the measured strains after 70 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 72 sec of flight time. Gage No. 38 (figure 22-1) was not used in subsequent evaluations of body bending, since this gage indicated excessive response to temperature effects throughout S-IB stage powered flight. Gage No. 38 was mounted on stringer No. 3, and this stringer was initially cooled due to the proximity of the LH2 chilldown return duct. Stringer No. 3, after liftoff, was aerodynamically heated at an accelerated rate due to being adjacent to an auxiliary propulsive unit protuberance. Gage No. 38 reflected this unique thermal environment of stringer No. 3.

An abnormality in the strain readings during flight is indicated in figure 22-2 by the trace of side mounted gage No. 52. This gage responded excessively at engine ignition but returned to normal values at approximately 40 sec. This temporary, excessive lateral bending strain in stringer No. 103, on which gage No. 52 was mounted, has been speculatively related to ice deposits, or structural irregularities. The anomaly is of analytical significance, but did not affect structural integrity since indicated strain levels are relatively low.

The stringer top mounted gages on the aft skirt, figures 22-3 and 22-4, also provided strain data substantially as predicted. The top gages were displaced from the stringer neutral axis and were responsive to local stringer bending. Gage No. 43, figure 22-3, indicated excessive strain increases after approximately 70 sec. This gage was mounted on stringer No. 30 which was adjacent to the main tunnel and therefore subject to excessive aerodynamic heating. It is concluded the high strains from gage No. 43 at IECO were thermally induced and resulted from differential structural expansions and contractions. Detailed stress analyses including thermal effects, both preflight and postflight, indicated positive margins of safety. Conversely, the lower than average strains from gage No. 49, figure 22-4, are attributed to less than average aerodynamic heating of the stringer on which the gage was mounted.

Figure 22-5 illustrates the effect of aerodynamic heating on stringer strains. The strain data from gages No. 38 and No. 44 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-IB stage separation (RO +141 sec). However, the actual measured strain traces, after correction to the one g condition, did not decrease to zero strains at RO +141 sec and the residual strains were assumed to be measurements of thermally induced strains. Residual compressive strains at RO +141 sec were subtracted from measured strains at IECO (RO +139 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 IECO (RO +139 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 structural temperature rise which began at approximately RO +60 sec and stabilized at higher temperatures near 120 sec of flight time. 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 are reacted internally by the structure, and hence these increments of strain were included in detailed stringer stress analyses.

22.2.2 Stringer Strains

The local stringer bending moments and axial loads for the aft skirt at strain measurement sta 1261 are shown in table 22-1. The table compares the stringer maximum flight loads derived from strain gage data to corresponding stringer local design loads. At the maximum αq condition, the flight loads are less than the design loads. For the IECO condition, comparison of the flight loads to the critical design αq loads indicates positive margins of safety, since the elevated temperature at the IECO condition reduces the allowable compressive yield stress by only 3 percent.

It was computed that strains at the neutral axes were within approximately 5 percent of the strains at the strain gage locations for side mounted gages.

22.2.3 Axial Loads

The strain data measured at sta 1261 during flight were used for computing the flight axial load history presented in figure 22-6. The measured strain data was 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 sta 1261 were computed. This axial load history is shown compared to preflight computed axial loads. The divergence of the flight measured plot above 80 sec of flight time 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 22-2. The maximum acceleration of 4.33g occurred at S-IB stage IECO. This was the value predicted, and was greater than the design limit axial load factor of 4.17g at IECO as expected. Detailed stress analysis, including the effects of S-IVB-204 stage flight measured temperatures, indicated positive margins of safety for the 4.33g axial load condition.

22.2.4 Body Bending Moments

The strain data measured during flight was also used in computing the body bending moment history, as shown in figure 22-7. 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 sta 1261 from flight loads were computed. In figure 22-7, the flight moment histories are shown compared to preflight computed design limit moments, and to maximum predicted values for the AS-204 trajectory at the maximum αq condition. The curve shows the S-IVB-204 stage was subjected to relatively small aerodynamic loading as compared to maximum design values. The maximum bending moments at sta 1261 based on flight test results, are summarized as follows for four Saturn IB vehicles.

VEHICLE	TIME OF MEASURED MAX MOMENT (sec from RO)	MAX MEASURED BODY MOMENT AT STA 1261 (in.-lb)	DESIGN MAX MOMENT AT STA 1261 (in.-lb)
AS-201	80	20,060,000	54,600,000
AS-202	80	6,700,000	54,600,000
SA-203	70	6,500,000	54,600,000
AS-204	72	13,700,000	54,600,000

The largest body bending at sta 1261 occurred in vehicle AS-201, and the corresponding design maximum bending moment was 54,600,000 in.-lb, assuming the worst expected flight conditions. The relatively low flight measured bending moments reflect that the launchings were conducted under faborable high altitude wind shear conditions.

22.2.5 Pressures-Skirts and Interstage

For the S-IVB-204 stage, the flight measured maximum differential pressures of the forward and aft skirts and interstage are presented in table 22-3. Bursting and crushing pressures are presented separately. Corresponding values of predicted and design pressures are given.

For the forward skirt, the maximum measured bursting pressures were greater than predicted but less than the limit design value. However, the maximum measured crushing pressure was -0.42 psid, which exceeded the limit design pressure of -0.34 psid. This measured crushing pressure was a localized condition at the aft end of the forward skirt. The crushing pressure was induced by the outwardly extending aft flange of the skirt. The pressure peaked approximately at the flange and diminished to a negligible quantity at approximately 10 in. forward of the flange. The crushing pressure distribution extended annularly around the forward skirt, however, the frames and stringers at the aft end of the forward skirt were stabilized locally by the adjacent pressurized LH2 tankage, and instability did not occur. Hence, due to the local nature of the negative pressure differential, it was determined that positive margins of safety existed for the forward skirt structure.

The aft skirt and interstage flight measured differential bursting pressures were as predicted. The measured crushing pressures were less than predicted. however, the peak crushing pressures occurred earlier in flight than expected.

22.2.6 Temperatures - Structural

A summary of maximum measured skin temperatures for the major structural assemblies subject to aerodynamic heating is given in table 22-4. No temperatures were measured for the stringers. Maximum skin temperatures for the thermal design trajectory are also shown. The flight measured temperatures did not exceed design trajectory values. This comparison supports other evidence that structural integrity was maintained.

22.2.7 LH2 and LOX Tank Ullage Pressures

The maximum LH2 ullage pressures recorded w e 36 psia prelaunch and 39 psia postlaunch during S-IVB stage burn. These values compare with the design limit ullage pressure of 39 psia for the LH2 tank.

The design limit ullage pressure for the LOX tank is 44 psia, whereas the maximum ullage pressure recorded during prelaunch was 43 psia, and the maximum postlaunch recorded pressure was 40 psia during S-IVB stage burn.

22.2.8 Common Bulkhead Pressure Environment

The common bulkhead internal vacuum pressure measured during prelaunch and through powered flight and orbital coast ranged from 0.1 psia to 0.8 psia. This favorably corresponds to expected values of less than 1.0 psia.

The ullage differential pressures on the common bulkhead during prelaunch powered flight, and significant orbital coast are shown in figures 22-8 and 22-9. 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. These limit curves have been calculated to include the liquid hydrogen head effects.

The maximum negative differential pressure occurred during the first venting period following S-IVB engine cutoff. The LOX ullage pressure declined more rapidly than the LH2 ullage pressure over a 35 sec time span causing a negative pressure across the common bulkhead. The negative differential pressure reached a maximum of -14.0 psid before the LOX vent was closed at 635 sec after liftoff. This negative pressure compares satisfactorily with the limit negative differential capability of -23.2 psid at this period of operation.

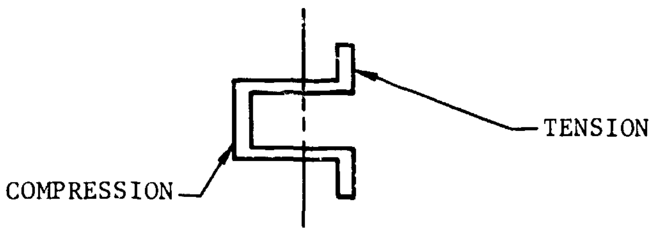
The largest positive differential pressure prior to orbital coast occurred during initial pressurization of the LOX tank while the hydrogen tank was vented and stabilized at a saturation pressure condition. The pres. re obtained was +24.2 psid, and this was expected since sequencing permits pressurization to the LOX tank vent and relief valve setting of 44 psia while the hydrogen tank is unpressurized. The measured positive differential pressure was below the bulkhead limit structural capability as shown in figure 22-8.

The significant ullage differential pressures during orbital coa. were as shown in figure 22-9. LH2 pressure decr. sed to zero at 6,700 sec and remained at substantially zero pressure for the duration of orbital coast. The LOX liquid dumping began at 8,780 sec followed by partial gaseous valving at 8,840 sec. The valve closed at 8,900 sec. Subsequent venting reduced the common bulkhead differential pressure to +2 psid and then to substantially 0 psid, to complete the LOX dumping. The maximum measured differential pressure was +27.0 psid, which was below the limit structural capability of the common bulkhead.

22.3 Forward Skirt Panel Transient Strains

Sixteen dynamic strain measurements of forward skirt skin panels were made to evaluate the effect of dynamic loads on structural integrity as discussed in section 24.4 A supplementary load analysis was conducted to determine panel stresses on the forward skirt at various times between 72 and 92 sec in connection with dynamic strain transients. The bending moments were determined from data obtained from stringer mounted strain gages on the aft skirt. The aft skirt transient bending moments after RO +72 sec were smaller than at maximum αq condition and are not shown on figure 22-7. The data showed, however, that there were bending moment fluctuations and a neutral axis rotation during the time interval. The stress calculations indicated that the forward skirt panels which showed dynamic strain transients usually were on the compression side of the vehicle at the corresponding time.

TABLE 22-1
LOCAL STRINGER BENDING MOMENT AND AXIAL LOAD
AFT SKIRT STA 1261



+ MOMENT AS SHOWN

AXIAL LOAD
- COMPRESSION
+ TENSION

CONDITION	MAXIMUM FLIGHT LOAD (CALCULATED FROM TOP AND SIDE STRAIN GAGES)		LOAD USED IN DESIGN ANALYSIS (LIMIT)	
	MOMENT (in.-lbf)	AXIAL LOAD (lbf)	MOMENT (in.-lbf)	AXIAL LOAD (lbf)
MAX αq	-1,000	-6,946	-8,340	-12,500
IECO	-1,850	-10,360	*	-10,350

*The stringer design moment at IECO was not evaluated since it was known by quantitative analysis to be less than that at max αq design condition.

TABLE 22-2
AXIAL LOAD FACTORS DURING POWERED FLIGHT

CONDITION	MAXIMUM MEASURED LOAD FACTOR (g)	FLIGHT TIME OF MEASURED LOAD FACTOR (sec)	PREDICTED LOAD FACTOR (g)	FLIGHT TIME OF PREDICTED LOAD FACTOR (sec)
S-IB Liftoff	1.29	0.2	1.25	0.2
S-IB IECO	4.33	139	4.33*	140
S-IB OECO	2.05	142	2.18	145
S-IVB Ignition	0.73	152	0.75	160
S-IVB ECO	2.59	593	3.2	625

*S-IB IECO (AS-204 design load factor is 4.17 g at RO +139 sec).

TABLE 22-3
MAXIMUM DIFFERENTIAL PRESSURES OF FORWARD AND
AFT SKIRTS AND INTERSTAGE

(A) Bursting Pressures (psid) vs Time (sec) from Range Zero

STRUCTURE	PREDICTED		FLIGHT MEASURED		DESIGN LIMIT	
	Δp	TIME	Δp	TIME	Δp	TIME
Fwd Skirt	2.22	61	2.45	57	4.0	65
Aft Skirt	1.2	71	1.2	71	2.5	72
Interstage	1.2	71	1.2	71	2.5	72

(B) Crushing Pressures (psid) vs Time (sec) from Range Zero

STRUCTURE	PREDICTED		FLIGHT MEASURED		DESIGN LIMIT	
	Δp	TIME	Δp	TIME	Δp	TIME
Fwd Skirt	-0.25	57	-0.42	64	-0.34	65
Aft Skirt	-0.03	42	-0.05	30	-0.2	65
Interstage	-0.03	42	-0.05	30	-0.2	65

TABLE 22-4
MAXIMUM SKIN 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 (sec)	
Forward Skirt	180	120	350	140	No
Aft Skirt	145	130	Not Applicable***	-	Yes
Interstage	Temperatures were assumed to be similar to aft skirt temperatures				

*Measured temperatures are adjusted for measurement lag due to mass of temperature sensors.

**At location of temperature sensor.

***Upper design limit was 330 deg F in insulated areas.

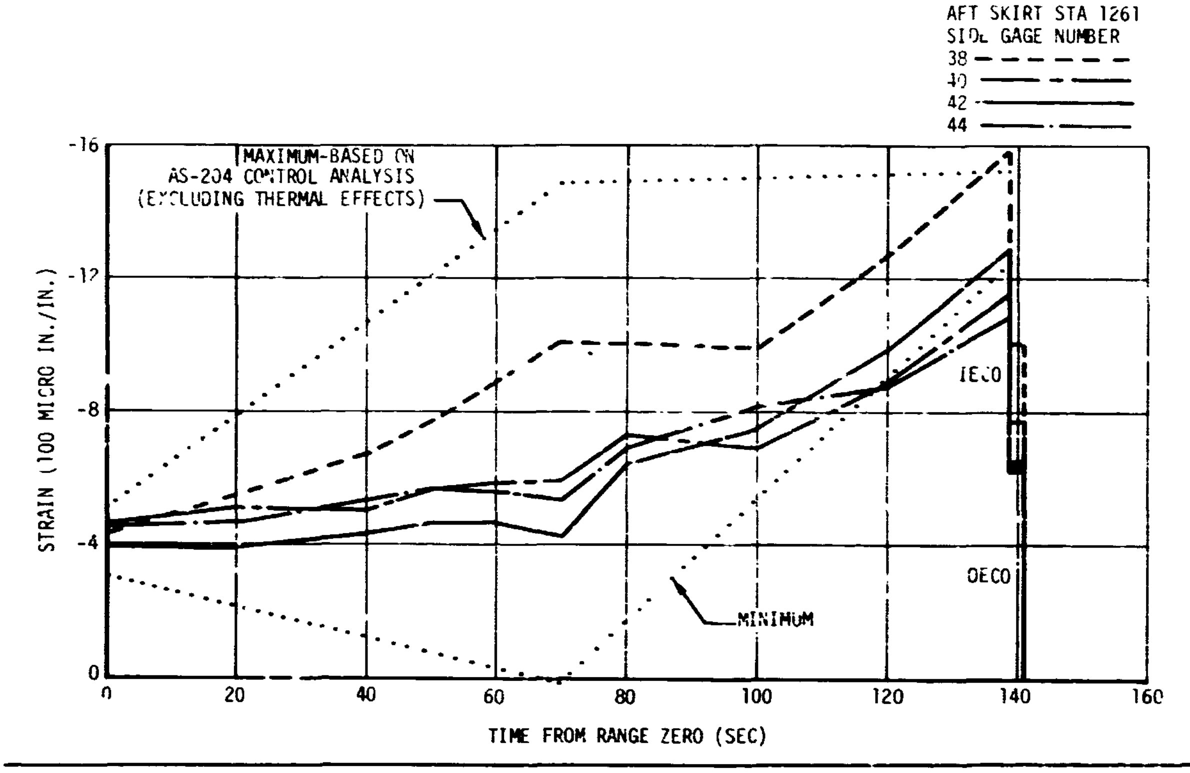


Figure 22-1. Axial Strain Versus Flight Time-Side Gage Nos. 38, 40, 42, and 44

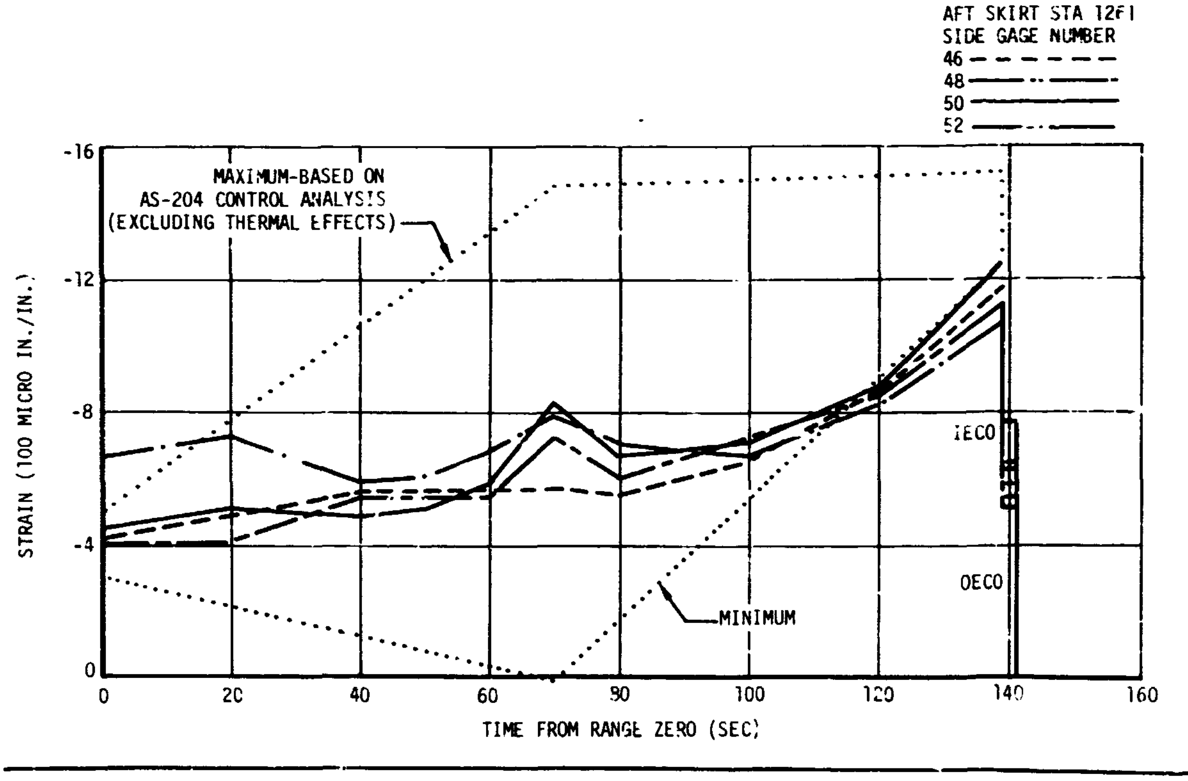


Figure 22-2. Axial Strain Versus Flight Time-Side Gage Nos. 46, 48, 50, and 52

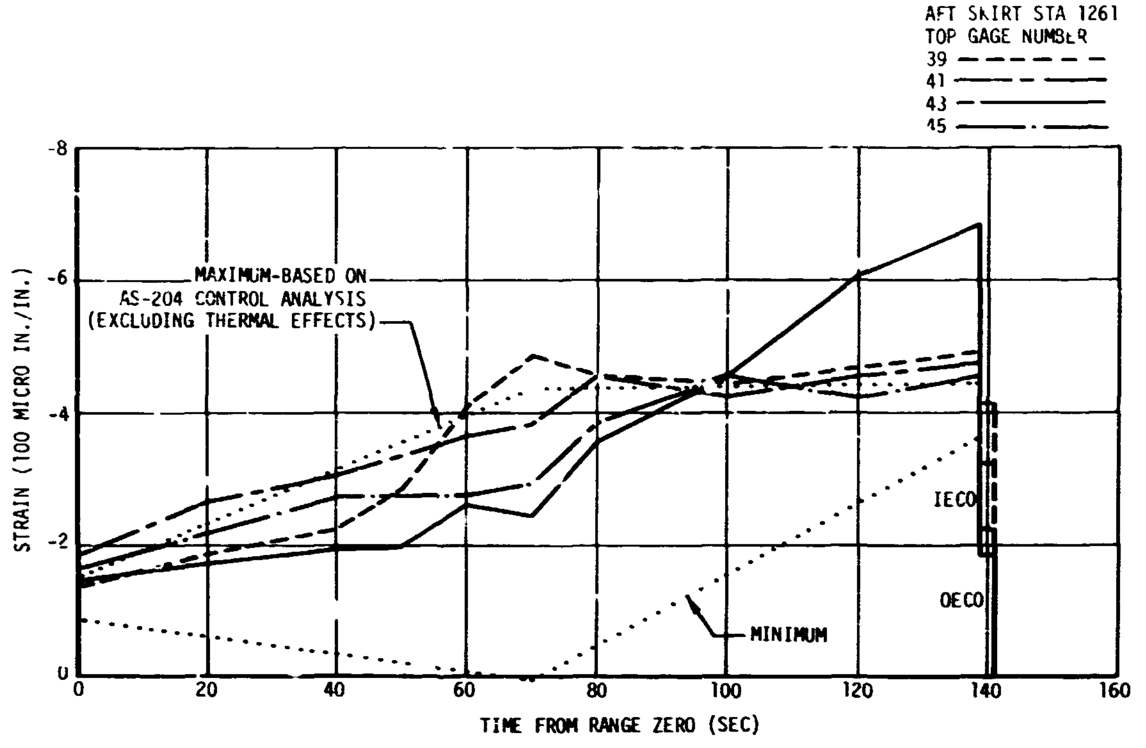


Figure 22-3. Axial Strain Versus Flight Time-Top Gage Nos. 39, 41, 43, and 45

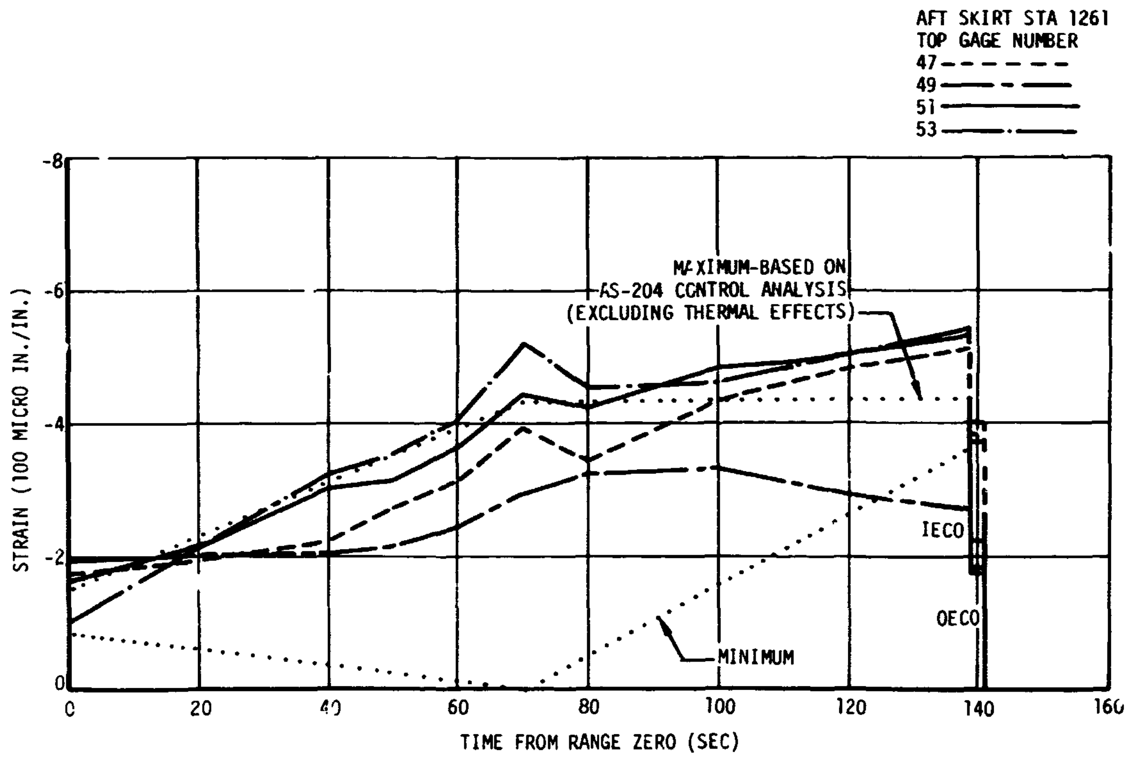


Figure 22-4. Axial Strain Versus Flight Time-Top Gage Nos. 47, 49, 51, and 53

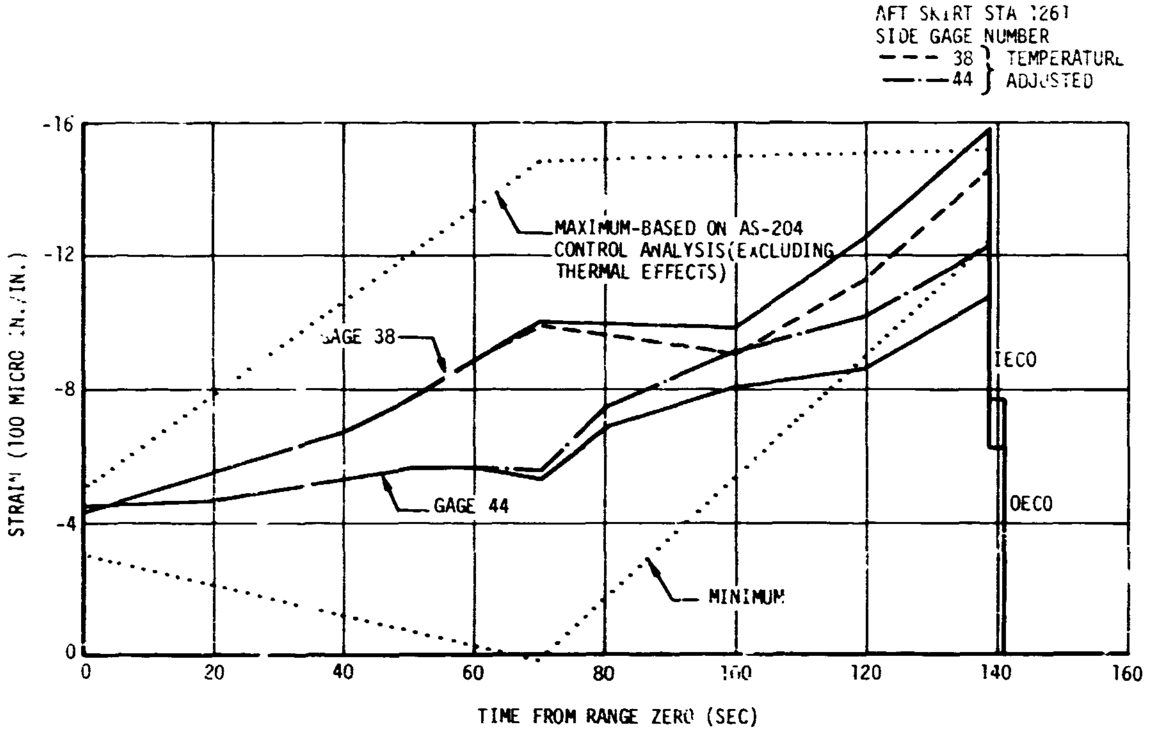


Figure 22-5. Axial Strain Versus Flight Time (Temperature Adjusted)

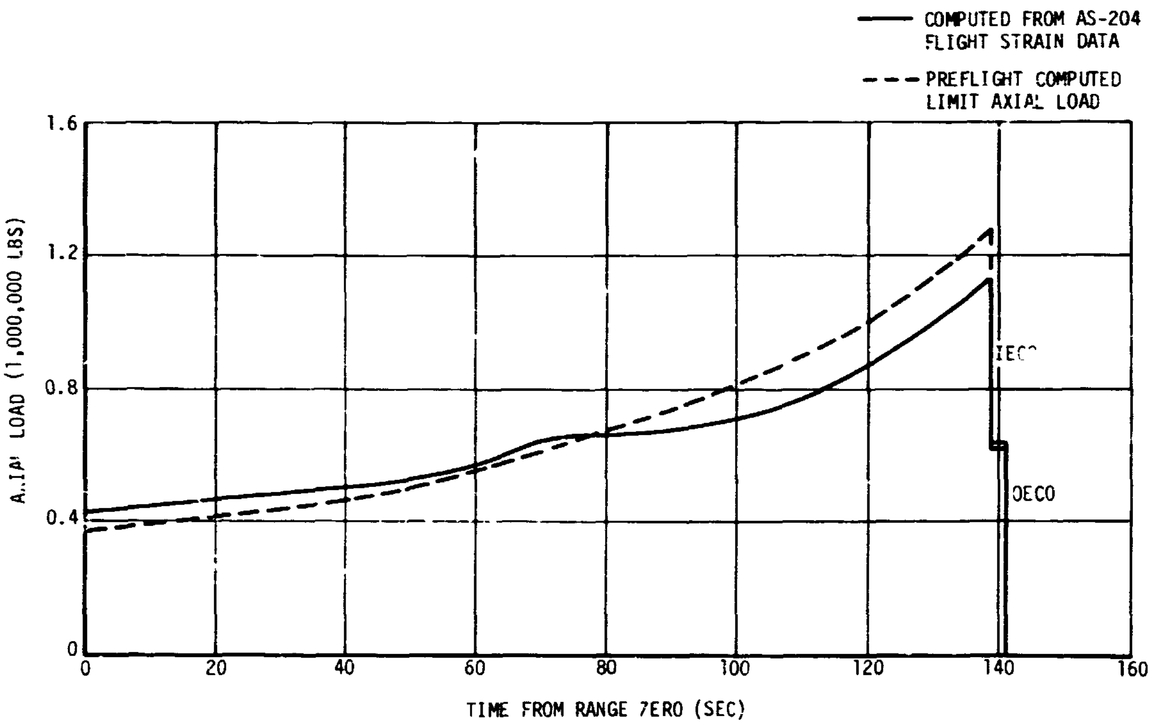


Figure 22-6. AS-204 Flight Axial Load VS Time-Aft Skirt Station 1261

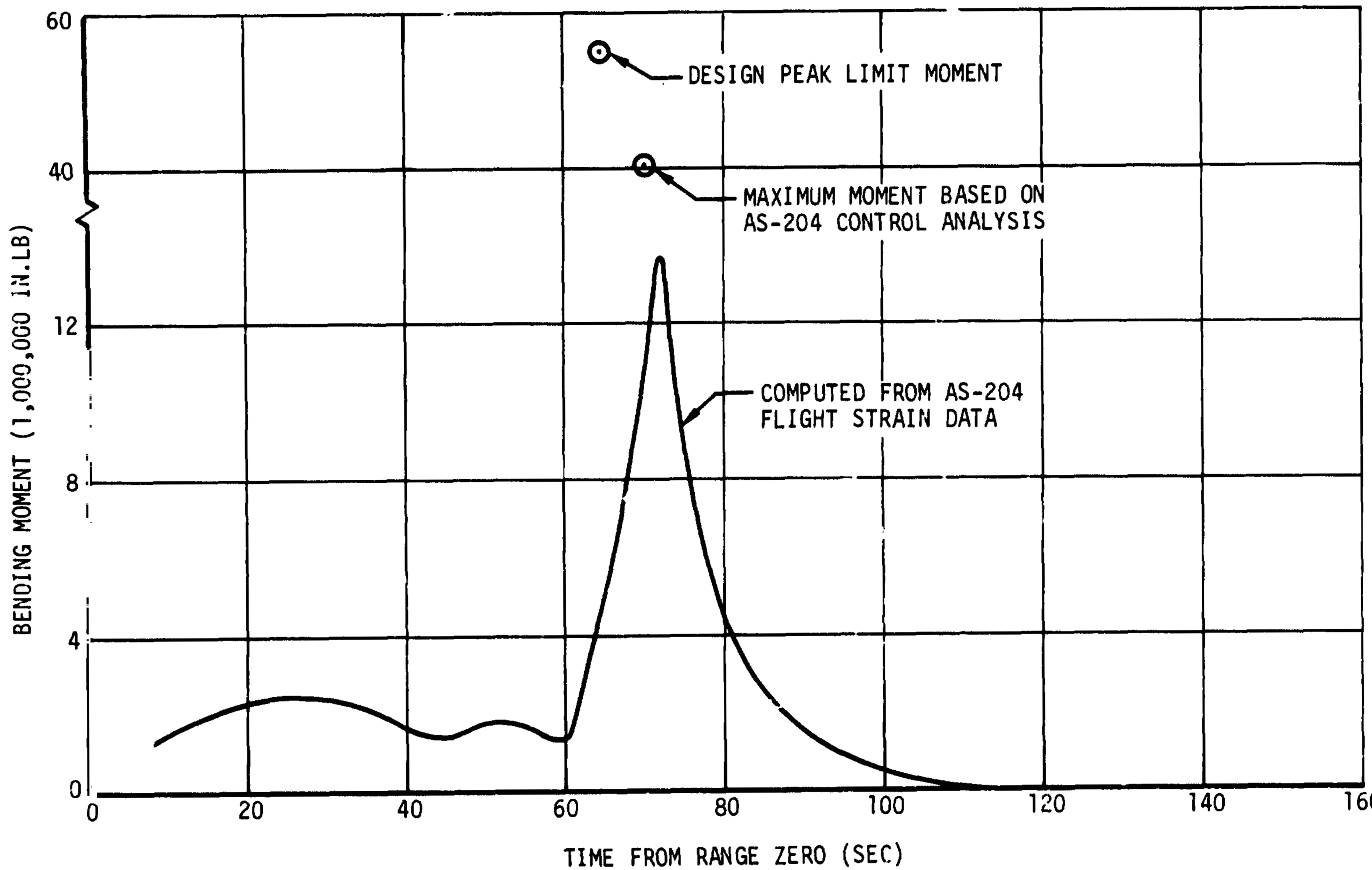


Figure 22-7. AS-204 Flight Stage Bending Moment Vs Time-Aft Skirt Station 1261

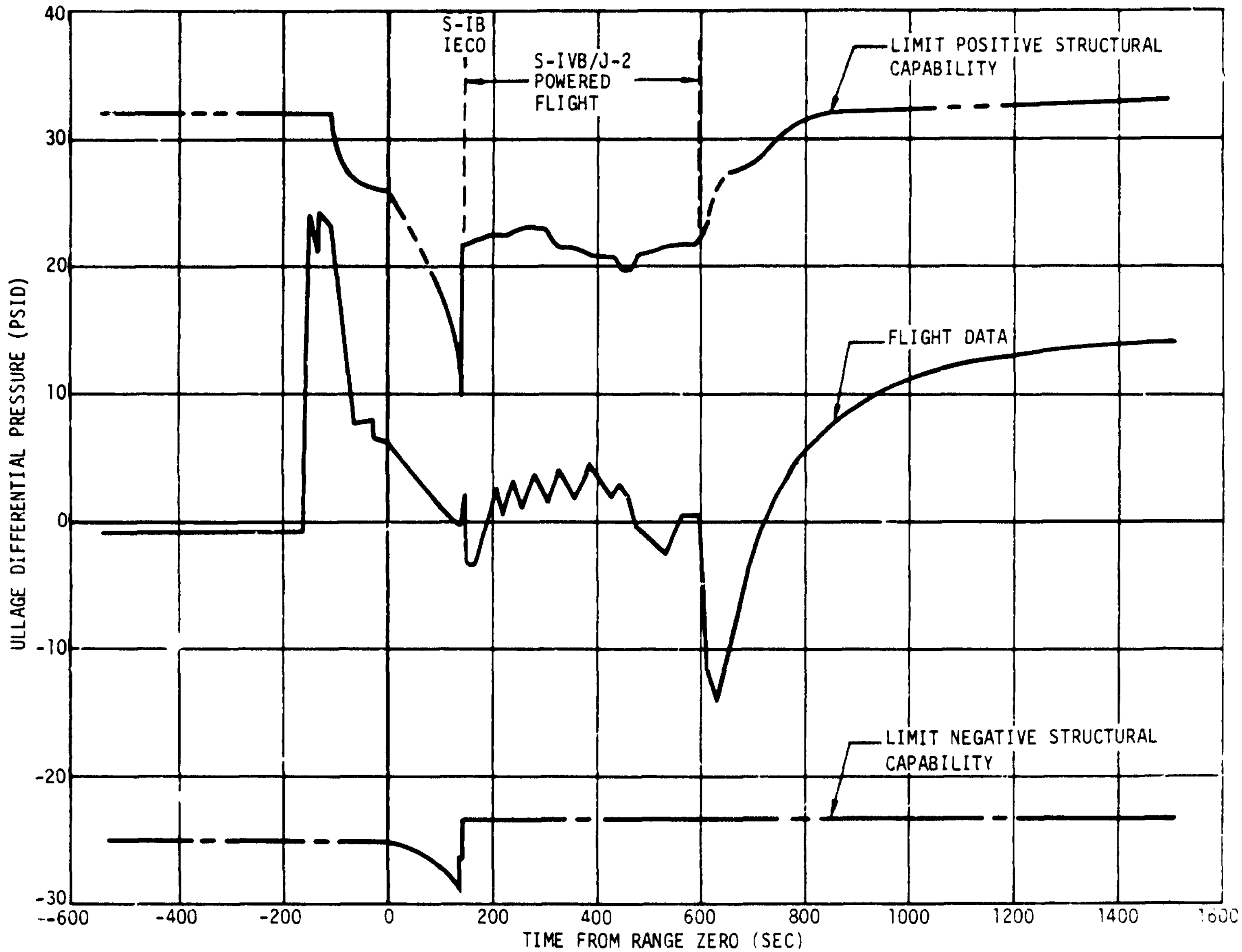


Figure 22-8. Ullage Differential Pressure Versus Flight Time Through S-IVB Cutoff

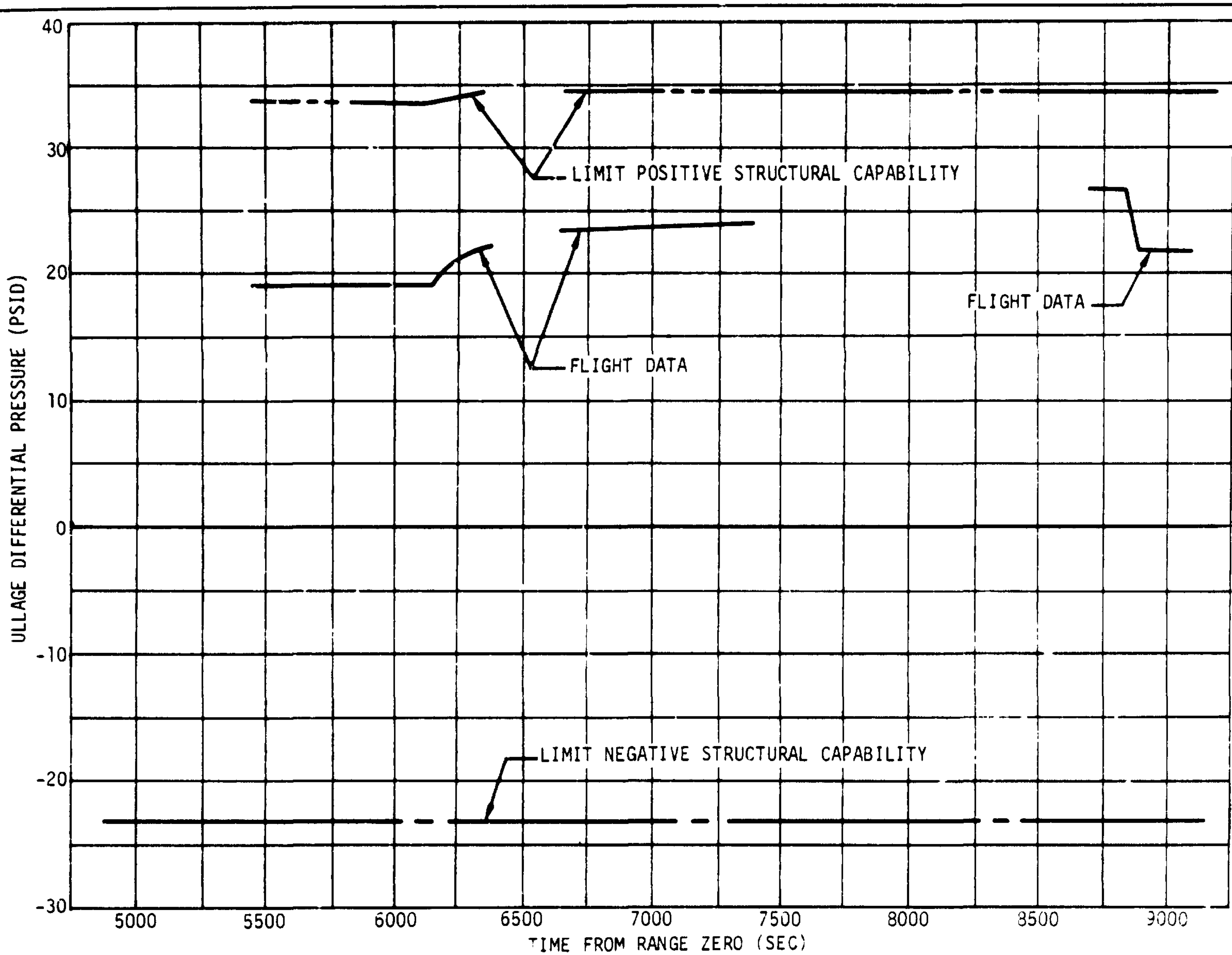


Figure 22-9. Ullage Differential Pressure Versus Orbital Flight Time

SECTION 23

ENVIRONMENTAL CONTROL SYSTEMS

23. ENVIRONMENTAL CONTROL SYSTEMS

23.1 Forward Skirt Thermoconditioning System

The thermoconditioning system operated normally during flight. All parameters were within their design limits.

The S-IVB heat transfer fluid exit temperature (measurement C0026-601) decreased from 59 deg F at liftoff to 57.6 deg F after RO +106 sec, and then increased to 61.2 deg F at RO +560 sec. There was no apparent long term trend or major disturbance in the exit temperature, except that at approximately RO +5,760 sec the exit temperature dropped linearly with time, roughly 20 deg F over an 85 sec period. This temperature decay followed a similar linear decay in the methanol/water control temperature (measurement C0015-601).

The S-IVB exit coolant pressure was 29.5 psia at liftoff and increased to 30.5 psia during the first 135 sec of flight. At RO +150 sec, there was a drop to 28 psia followed by a gradual increase to 29.5 psia by RO +560 sec. From that point on until RO +17,300 sec, the exit pressure stayed in the 28 to 29 psia range. Between RO +17,300 and RO +38,000 sec, the exit pressure decreased to approximately 13 psia.

The S-IVB coolant flowrate at liftoff was 8.2 gpm, increased to 8.5 gpm in 40 sec, decreased to 8.3 by RO +60 sec, and remained at this value through RO +850 sec. From this point onwards until RO +5,460 sec the flowrate stayed inside the 8.3 ±0.2 gpm range. At RO +5,460 sec, the flowrate decreased linearly with time to 3.4 gpm to approximately RO +5,470 sec and then instantaneously rose to 8.3 gpm. It stayed at 8.3 gpm until RO +5,760 sec and then increased in a linear fashion to approximately 8.9 gpm at RO +5,845 sec. At this time the flowrate abruptly decreased to 8.3 gpm, gradually increased to approximately 8.5 gpm by RO +6,400 sec and remained constant at that value until at least RO +17,275 sec. Between RO +17,275 sec and RO +38,090 sec, the flow decreased to 6.0 gpm, and remained constant until approximately RO +38,315 sec where it instantaneously decreased to 3.0 gpm and thereupon linearly increased back to 6.0 gpm at RO +38,370 sec where it then remained constant until data runout.

23.2 Common Bulkhead Vacuum Monitoring System

A satisfactory internal bulkhead pressure was maintained throughout the flight. At liftoff the pressure (D0208-407) was 0.80 psia. During the first, second, and third orbit, the internal pressure was, respectively, 0.27, 0.46, and 0.67 psia.

SECTION 24

ACOUSTIC, VIBRATION AND DYNAMIC STRAIN MEASUREMENTS

24. ACOUSTIC, VIBRATION AND DYNAMIC STRAIN MEASUREMENTS

Thirty vibration and six acoustical measurements were monitored on the S-IVB stage. The measurements were similar to those on the AS-203 flight. One vibration measurement was inoperative prior to launch and another provided no valid data after RO +298 sec.

In general, the acoustic and vibration environments were comparable to those measured on the AS-203 flight.

Ten vibration measurements were deleted from the original measurement program to provide telemetry channels for the addition of 16 dynamic strain measurements on forward skirt skin panels. The strain gage locations duplicated those used during the forward skirt panel flutter qualification test.

All sixteen measurements showed that panel flutter did not occur and that the dynamic strain levels due to random pressure fluctuations in the boundary layer were significantly lower than those measured during the qualification test. The duration of the maximum levels during flight was also significantly less.

24.1 Data Acquisition and Reduction

A list and locations of the acoustic and vibration measurements monitored during the flight, including composite levels during specific flight periods, is presented in table 24-1 and figure 24 1 respectively. For comparison purposes, the maximum level from similar measurements made during the AS-203 flight are also presented in the table. The dynamic strain measurements are presented in table 24-2 and the measurement locations in figure 24-33.

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 vibration (5 to 440 cps) and dynamic strain (5 to 660 cps) 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/FM set was better than normal and, therefore, 40 cps information was recoverable on this flight.

A time sharing arrangement was utilized to obtain a greater number of measurements than the number of allocated telemetry channels. This method of acquisition provided data for 3 sec out of 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 estimated levels 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 24-1 and 24-2. Because there was no convenient way to correct the time history plots, the levels shown may differ from the values shown in the tables. The levels below 40 cps in the power spectral density (PSD) plots from the SSB/FM 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 24-2 through 24-49).

24.2 Vibration Environment

The primary sources of vibration excitation on the S-IVB stage were the H-1 engine exhaust noise at launch, unsteady aerodynamic flow conditions during transonic flight, boundary layer turbulence during max q, J-2 engine combustion chamber processes during S-IVB powered flight, and staging transients at separation and S-IVB engine ignition and cutoff. Twenty-nine vibration pickups were located on the S-IVB stage to determine the response amplitudes of the stage structure and components to these excitation sources.

The measurements were grouped into engine, thrust structure, aft LOX dome, aft interstage and skirt, LH2 tank cylinder, and forward skirt measurements.

24.2.1 Engine Measurements

The engine measurements were monitored on the combustion chamber dome and on the flange above the LH2 and LOX turbopump housings. The measurement system at the LOX turbopump was found to be inoperative prior to launch and therefore deleted from the measurement program. The LH2 turbopump measurement did not provide valid data after RO +298 sec due to an instrumentation malfunction. The data were usable prior to this time. The vibration amplitudes on the engine were approximately 15 percent lower than those measured on the AS-203 flight. Composite time history and spectrum levels are shown in figures 24-2 and 24-3.

24.2.2 Thrust Structure Measurements

The measurements on the thrust structure were located on the stringer at the base of the auxiliary hydraulic pump and on the LH2 and LOX feedlines at the support bracket mounted on the gimbal block. These locations provided the vibration input data from the thrust structure to the components. The data are shown in figures 24-4 through 24-8 The PSD plots showed that at liftoff most of the energy was concentrated at about 100 cps and during S-IVB powered flight the spectrum consisted of many peaks at higher discrete frequencies. The vibration levels were comparable to those measured on the AS-203 flight.

24.2.3 Aft LOX Dome Measurements

The measurements on the LOX dome were located on the LH2 and LOX feedlines, at the juncture of the dome, and on the LOX tank vent valve. The data are shown in figures 24-9 through 24-13. The data from the LH2 feedline measurements indicated that the transducer systems were not installed in the same manner as the AS-203 flight measurements, i.e., the measurements in the thrust and radial directions are interchanged.

The AS-203 flight measurements were suspected of being crosswired when the data showed the liftoff levels in the thrust direction were higher than those in the radial direction; however, there was no confirming information at that time. The AS-204 flight data showed the expected conditions at liftoff. The radial direction levels are higher than the thrust direction (figures 2'-9 and 24-10).

The vibration amplitudes at these locations were comparable to th measured on the AS-203 flight. The higher amplitudes on the LOX ve valve after S-IVB engine cutoff (figure 24-13) are due to gas flow in the vent tube during venting.

24.2.4 Aft Interstage and Skirt Measurements

The attach points of the retrorocket between position plane II and III and APS module No. 1 were each monitored with three measurements. The data from these measurements are shown in figures 24-14 through 24-19. The maximum amplitudes are expected to exist during launch; however, due to the time sharing arrangement, three of these measurements did not provide data during this time interval. The liftoff levels for these measurements are estimated to be 10 times the level of the PSD plots at RO +6.9 sec. Figures 24-14 through 24-16 show no data after separation for the retrorocket measurements because the transducer wirings are severed at this time. The vibration amplitudes at both components were comparable to those on the AS-203 flight.

24.2.5 LH2 Tank Cylinder Measurements

Four measurements were located on the LH2 tank cylinder. Three at sta 1436, 45 deg apart, can be classified as the vibration response of an unloaded tank structure and one at the cold helium sphere as the vibration input to a 100 lbm component. The data are shown in figures 24-20 through 24-23. The data shows the vibration characteristics for mass loading.

The amplitudes for the unloaded tank structure were comparable at launch and approximately 40 percent lower during transonic flight (near mach 1) than those measured on the AS-203 flight. Due to the capability of providing low frequency data, these measurements were used to evaluate the 17 cps oscillation noted on the rate gyro. The three measurements showed significant oscillations during the time interval of RO +164 sec to RO +204 sec. The maximum amplitude noted was approximately 1 g zero-to-peak. Similar oscillations were not observed in the AS-203 flight vibration data.

24.2.6 Forward Skirt Measurements

The seven measurements on the forward skirt included two at the LH2 vent valve assembly, two at the base of a telemetry antenna, and three on the field splice near position plane II. The data from these measurements are shown in figures 24-24 through 24-30. The composite time histories showed the same characteristics for measurements on the forward skirt as those on past flights. The maximum levels occurred at liftoff and during the transonic period of flight (near mach 1). The vibration amplitudes during S-IVB powered flight were negligible.

The LH2 vent valve measurements indicated an increase in level during the later portion of S-IVB powered flight. The increase in level was attributed to venting.

24.3 Acoustic Environment

The acoustic environment was produced by the H-1 Engine exhaust noise at launch, unsteady flow conditions during the transonic period of flight (near mach 1), and by boundary layer turbulence during high dynamic pressures. Two microphones were located on the aft skirt at sta 1212 near position plane II to measure the internal and external environment. Each transducer system had a dual output capability with the data signal below 3,000 cps transmitted by SSB/FM and the data level for the seventh (2,400 to 4,800 cps) and eighth (4,800 to 9,600 cps) octave bands transmitted via PAM/FM.

RMS composite time history and one-third octave band plots for specific flight periods are shown in figures 24-31 and 24-32. The sound pressure levels were slightly higher at liftoff and the fluctuating pressures were lower inflight than those measured on the AS-203 flight. The lower inflight levels may be due to the lower dynamic pressures experienced on the AS-204 flight.

The external measurement exhibited the same unexpected characteristics in the data as those on the AS-203 flight. The overall sound pressure level during launch appears reasonable, although the spectrum was not of the expected shape. Several data signal dropouts were observed during launch and S-IB powered flight. As on the AS-203 flight, the fluctuating pressures maintained a high level long after max q. The aforementioned similarities between the two flights, although highly peculiar, may be attributed to a local phenomenon. Therefore, use of the data from this measurement should be tempered with the knowledge that the measured data were peculiar to a small localized area.

24.4 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 of the forward skirt, at sta 1576, oriented in the thrust axis, located midway between stringers and 4 in. forward of the panel trailing edge. The installation duplicated that used in the panel flutter qualification test performed in the Arnold Engineering Development Center transonic wind tunnel on a full scale segment of the S-IVB forward skirt. A transducer location sketch and a comparison of RMS composite time histories of the measurements are shown in figures 24 - 33. PSD plots and samples of the instantaneous wave forms for selected flight periods and RMS composite time histories are shown in figures 24 - 34 through 24 - 49. The composite dynamic strain levels at liftoff, transonic, and supersonic periods of flight are presented in table 24-2.

The time history of the composite dynamic strain levels from most measurements followed the same trend as the vibration levels measured on the forward skirt with maximum levels occurring at liftoff and the next highest levels occurring during transonic flight. A similar trend has also been observed in the acoustic data from previous flights. During the time interval of RO +71 sec, to RO +92 sec, however, seven measurements showed short duration transients which correlate in time of occurrence with vehicle bending moments induced by angle of attack variations due to changes in wind direction and speed.

The strain response spectra and wave forms were compared with those derived from the wind tunnel test data to determine whether the dynamic strain transients that occurred during supersonic flight could be attributed to panel flutter. The dominant response modes (320 to 600 Hz) indicated by the flight data were observed in the wind tunnel data when the panels were responding to the random fluctuating pressures in the boundary layer during periods when panel flutter was not occurring. The wave form of the flight data, which is similar to the wind tunnel data during periods when panel flutter was not occurring, was that of narrow band random vibration. This wave form is typical of panel response to acoustic nosie or pressure fluctuations due to random turbulence in the boundary layer.

When panel flutter was induced in the wind tunnel the panel response was characterized by a single dominant mode (below 250 Hz) with a periodic wave form, almost sinusoidal, and with peak strain levels more than three times higher than those measured during flight. This single mode high level type of panel response is consistent with the generally accepted description of panel flutter. Since this response did not occur during flight it is concluded that panel flutter did not occur.

The closest approximation of a periodic signal during flight occurred on measurement S0092 at RO +85 sec; however, the peak dynamic strain level was only about 20 percent of the maximum values measured in the wind tunnel. The PSD plot in figure 24-40 shows two dominant response modes at frequencies of approximately 400 Hz and 600 Hz which are much higher in frequency than the flutter mode observed in the wind tunnel.

The dynamic strain transients during supersonic flight can be explained as follows. The wind tunnel test showed that with mach number, differential pressure, and dynamic pressure held constant, the dynamic strain levels due to fluctuating pressures in the boundary layer increased as the compression loads applied to the panel were increased. The maximum dynamic strain levels occurred when the panel compression load was equal to or greater than the static buckling load. The compression loads on the forward skirt panels were estimated from bending moments based on static strain measurements on the S-IVB aft skirt, paragraph 22.3. The compression loads on the panels that exhibited the maximum dynamic strain transients were estimated to be near static buckling. The effects of differential pressure were included in the estimation of the static buckling load.

Since panel flutter was induced in the wind tunnel when critical buckling loads were applied during approximately the same dynamic pressure and mach number range that existed during flight between RO +71 and RO +92 sec, it is concluded that the absence of panel flutter during flight was due to the thicker boundary layer and/or the higher static differential pressure.

In summary, it is concluded that panel flutter did not occur and that the fatigue life of the forward skirt panels, as demonstrated in the wind tunnel qualification test, was not impaired by the pressure fluctuations in the boundary layer during supersonic flight.

TABLE 24-1 (Sheet 1 of 4)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

MEASUREMENT NUMBER	MEASUREMENT	DIRECTION	FREQUENCY RANGES (cps)	S-IB POWERED FLIGHT LEVELS		S-IVB POWERED FLIGHT LEVELS		AS-203 FLIGHT MAX LEVEL
				LIFTOFF	MAXIMUM INFLIGHT	AFTER S-IVB IGNITION	PRIOR TO S-IVB CUTOFF	
				ACCELERATION (grms)				
	<u>VIBRATION</u>							
E0029-409	LH2 Tank Station 1436 Position III - IV	Radial	5 to 440	7.3	5.5	0.2	0.3	9.0
E0030-409	LH2 Tank Station 1436 Position III	Radial	5 to 440	8.6	5.4	0.3	0.3	I
E0031-409	LH2 Tank Station 1436 Position II - III	Radial	5 to 440	9.4	6.3	0.3	0.4	10.2
E0032-427	APS Mod 1 Aft Attach Point	Thrust	40 to 3,000	7*	5.9	0.5	0.7	5.0
E0033-427	APS Mod 1 Aft Attach Point	Radial	40 to 3,000	6*	4.7	0.4	0.6	5*
E0034-427	APS Mod 1 Fwd Attach Point	Radial	40 to 3,000	7.6	5.1	0.6	0.7	5.4
E0036-411	Telemetry Antenna	Tangential	40 to 3,000	5*	3.9	0.3	0.4	5*
E0037-411	Telemetry Antenna	Radial	40 to 3,000	11.3	7.8	0.3	0.6	9.4
E0038-411	Field Splice Position II	Thrust	40 to 3,000	4*	1.6	0.3	0.3	4*

* - Estimated Level
I - Data Invalid

TABLE 24-1 (Sheet 2 of 4)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

MEASUREMENT NUMBER	MEASUREMENT	DIRECTION	FREQUENCY RANGES (cps)	S-IB POWERED FLIGHT LEVELS		S-IVB POWERED FLIGHT LEVELS		AS-203 FLIGHT MAX LEVEL
				LIFTOFF	MAXIMUM INFLIGHT	AFTER S-IVB IGNITION	PRIOR TO S-IVB CUTOFF	
				ACCELERATION (grms)				
	VIBRATION							
E0039-411	Field Splice Position II	Tangential	40 to 3,000	6.2	3.0	0.3	0.3	4.5
E0040-411	Field Splice Position II	Radial	40 to 3,000	6.1	2.6	0.2	0.3	6.5
E0044-402	Retrorocket Center Attach Point	Thrust	40 to 3,000	3.3	1.7	NM	NM	2.8
E0045-402	Retrorocket Fwd Attach Point	Radial	40 to 3,000	6*	3.2	NM	NM	5*
E0046-402	Retrorocket Fwd Attach Point	Tangential	40 to 3,000	3.3	2.2	NM	NM	D
E0048-403	Auxiliary Hydraulic Pump	Thrust	40 to 3,000	2.8	1.2	3.3	3.8	3.4
E0049-401	Combustion Chamber Dome	Thrust	40 to 3,000	3.1	2.4	7.4	7.6	8.9
E0053-404	LH2 Feedline at LH2 Tank	Thrust	40 to 3,000	2.8	1.9	2.3	2.8	3.2
E0054-404	LH2 Feedline at LH2 Tank	Radial	40 to 3,000	4.9	2.0	2.2	2.1	4.4
E0055-403	LH2 Feedline at Gimbal Point	Thrust	40 to 3,000	1.6	0.7	3.4	2.8	3.6

* - Estimated Level
D - Measurement Deleted
NM - Measurement Not Monitored

TABLE 24-1 (Sheet 3 of 4)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

MEASUREMENT NUMBER	MEASUREMENT	DIRECTION	FREQUENCY RANGES (cps)	S-IB POWERED FLIGHT LEVELS		S-IVB POWERED FLIGHT LEVELS		AS-203 FLIGHT MAX LEVEL
				LIFTOFF	MAXIMUM INFLIGHT	AFTER S-IVB IGNITION	PRIOR TO S-IVB CUTOFF	
				ACCELERATION (grms)				
	VIBRATION							
E0056-403	LH2 Feedline at Gimbal Point	Radial	40 to 3,000	1.1	0.4	3.3	3.6	3.5
E0057-424	LOX Feedline at LOX Tank	Thrust	40 to 3,000	2.5	1.2	1.4	1.7	2.1
E0058-424	LOX Feedline at LOX Tank	Radial	40 to 3,000	1.1	0.5	0.6	0.9	0.8
E0059-403	LOX Feedline at Gimbal Point	Thrust	40 to 3,000	2.6	0.8	7.0	6.7	5.2
E0060-403	LOX Feedline at Gimbal Point	Radial	40 to 3,000	1.1	0.4	2.3	2.5	2.5
E0069-410	LH2 Vent Valve	Thrust	40 to 3,000	2.8	1.3	0.2	0.7	5.7
E0070-410	LH2 Vent Valve	Radial	40 to 3,000	6.2	4.8	0.2	1.4	5.6
E0072-424	LOX Vent Valve	Parallel to Tank	40 to 3,000	1.2	0.9	0.6	0.7	1.2
E0074-405	Cold Helium Sphere	Radial	40 to 3,000	5*	3.2	1.9	0.9	4*
E0082-401	LOX Turbopump	Radial	40 to 3,000	D	D	D	D	60.0
E0084-401	LH2 Turbopump	Radial	40 to 3,000	0.8	0.5	14.8	I	17.6

* - Estimated Level
D - Measurement Deleted
I - Data Invalid

TABLE 24-1 (Sheet 4 of 4)
COMPOSITE VIBRATION AND ACOUSTIC LEVELS

MEASUREMENT NUMBER	MEASUREMENT	DIRECTION	FREQUENCY RANGES (cps)	S-IB POWERED FLIGHT LEVELS		S-IVB POWERED FLIGHT LEVELS		AS-203 FLIGHT MAX LEVEL
				LIFTOFF	MAXIMUM INFLIGHT	AFTER S-IVB IGNITION	PRIOR TO S-IVB CUTOFF	
				SOUND PRESSURE LEVEL (db)				
	ACOUSTICS							
B0007-404	Aft Skirt Position II	Internal	2,400 to 4,800	115C	110C	NF	NF	111
B0008-404	Aft Skirt Position II	Internal	4,800 to 9,600	104C	102C	NF	NF	111
B0009-427	Aft Skirt Position II	External	2,400 to 4,800	142	139	NF	NF	140
B0010-427	Aft Skirt Position II	External	4,800 to 9,600	136	136	NF	NF	136
B0011-404	Aft Skirt Position II	Internal	40 to 3,000	145.3	127.7	NF	NF	144
B0012-427	Aft Skirt Position II	External	40 to 3,000	154.2	148.5	NF	NF	152.6

NF - System Noise Floor

C - Data Corrected for System Noise

TABLE 24-2
COMPOSITE DYNAMIC STRAIN LEVELS

MEASUREMENT NO.	MEASUREMENT	DIRECTION	FREQUENCY RANGE (cps)	S-IB POWERED FLIGHT LEVELS STRAIN (μ in./in. rms)		
				LIFTOFF	TRANSONIC	SUPERSONIC
S0086-426	Forward Skirt Panel 13	Thrust	40 TO 800	42.6 K		18
S0087-426	Forward Skirt Panel 17	Thrust	40 TO 800	71.2 K		20
S0088-426	Forward Skirt Penal 26	Thrust	40 TO 800	72.4 K		24
S0089-426	Forward Skirt Panel 33	Thrust	40 TO 800	60*K	22.9	11
S0090-426	Forward Skirt Panel 40	Thrust	5 TO 800	192.8	73.5	117
S0091-426	Forward Skirt Panel 46	Thrust	40 TO 800	152.8		
S0092-426	Forward Skirt Panel 55	Thrust	40 TO 800	137.2		108
S0093-426	Forward Skirt Panel 61	Thrust	40 TO 800	133.3		33
S0094-426	Forward Skirt Panel 69	Thrust	5 TO 800	93.9	74.0	36
S0095-426	Forward Skirt Panel 76	Thrust	40 TO 800	70*K	77.6	
S0096-426	Forward Skirt Panel 80	Thrust	40 TO 800	60.5 K		
S0097-426	Forward Skirt Panel 87	Thrust	40 TO 800	102.5		
S0098-426	Forward Skirt Panel 94	Thrust	5 TO 800	93.4	61.2	81
S0099-426	Forward Skirt Panel 101	Thrust	40 TO 800	148.6		29
S0100-426	Forward Skirt Panel 108	Thrust	40 TO 800	113*	50.0	127
S0101-426	Forward Skirt Panel 7	Thrust	40 TO 800	118.7		77

*Estimated level.

K = Panel either partially or completely coated with 0.010 in. thickness of Korotherm for thermal protection near protuberances.

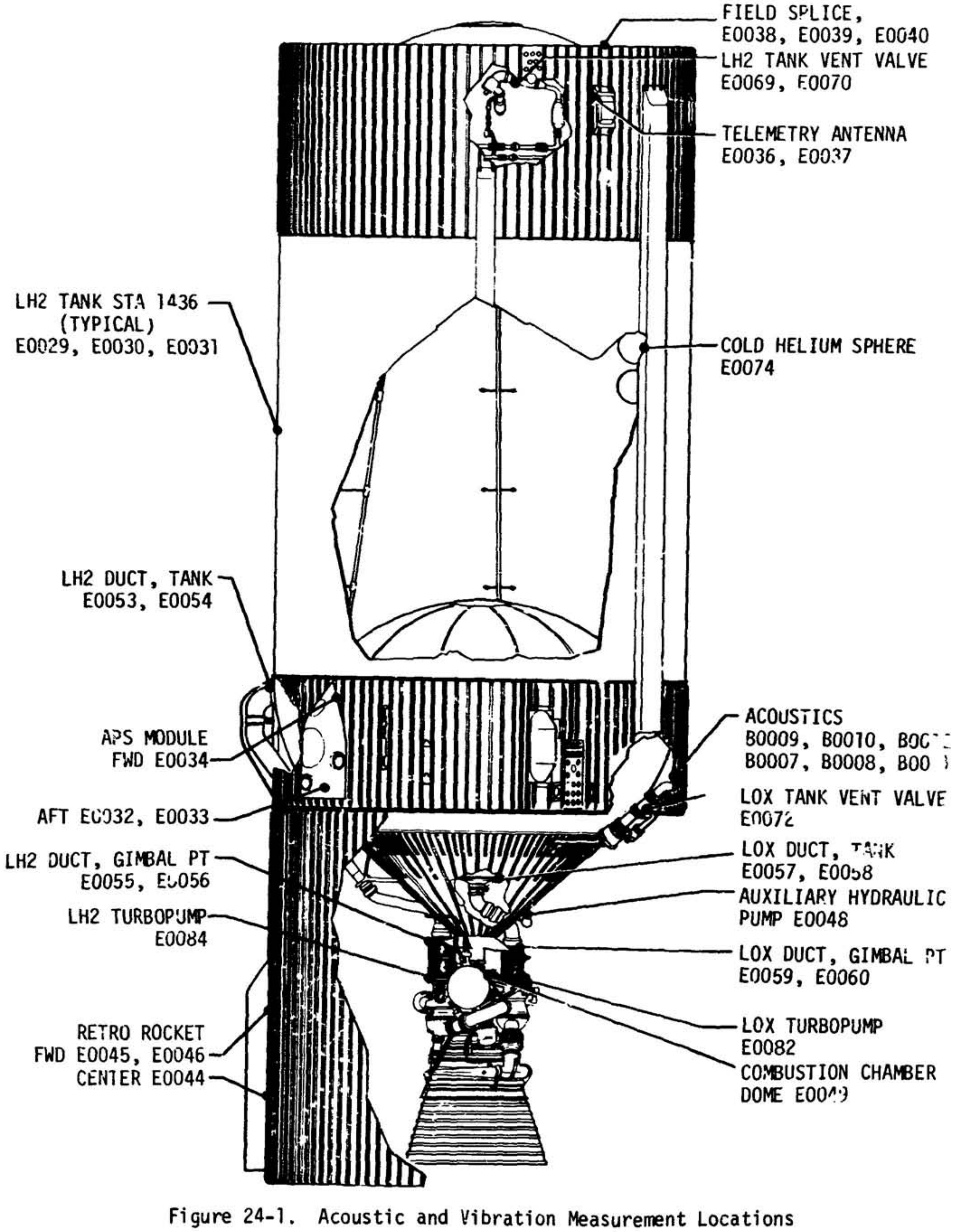


Figure 24-1. Acoustic and Vibration Measurement Locations

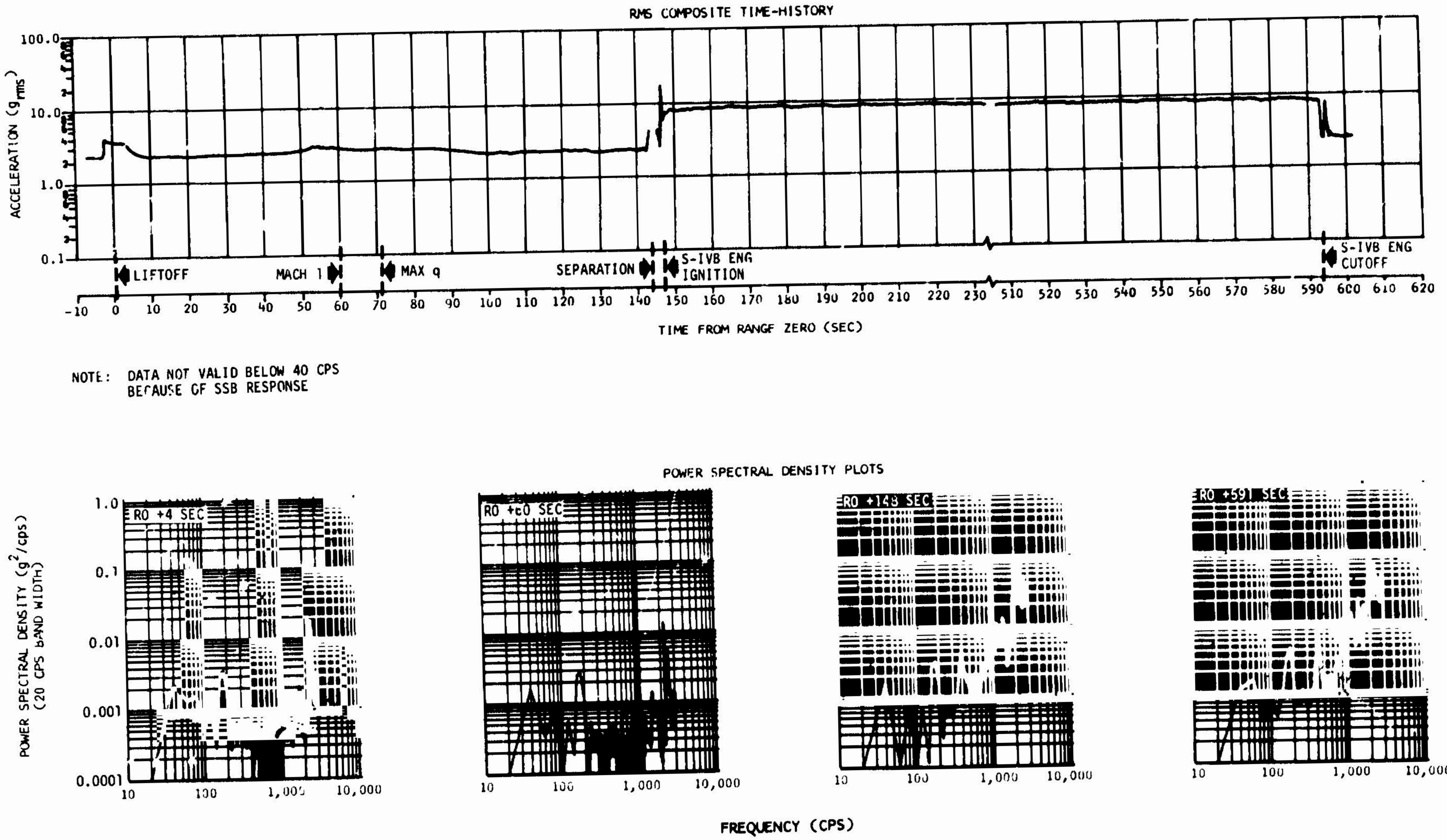


Figure 24-2. Vibration Measured on Combustion Chamber Dome, Thrust Direction (E0049-401)

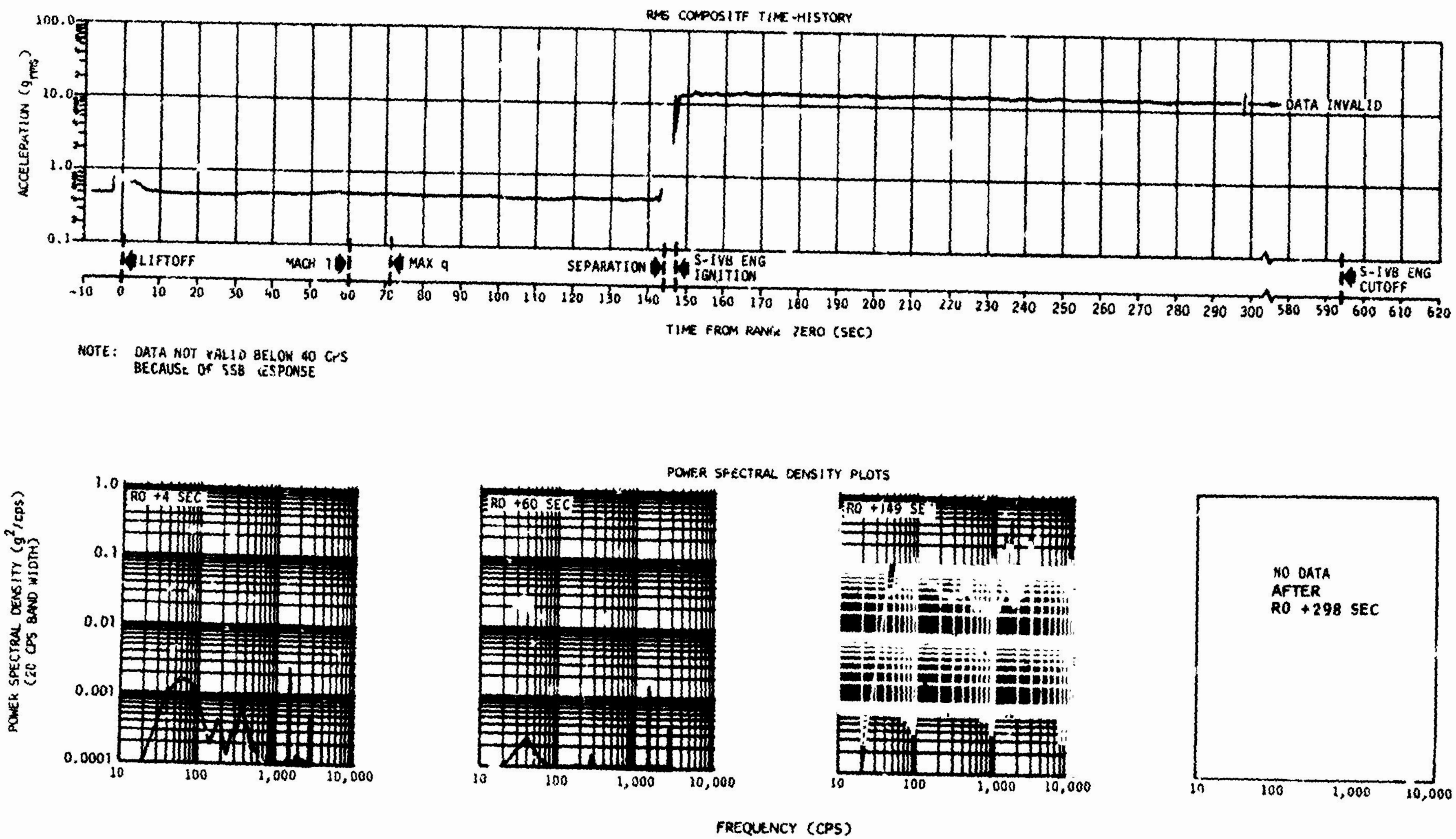


Figure 24-3. Vibration Measured at LH2 Turbopump, Radial Direction (E0084-401)

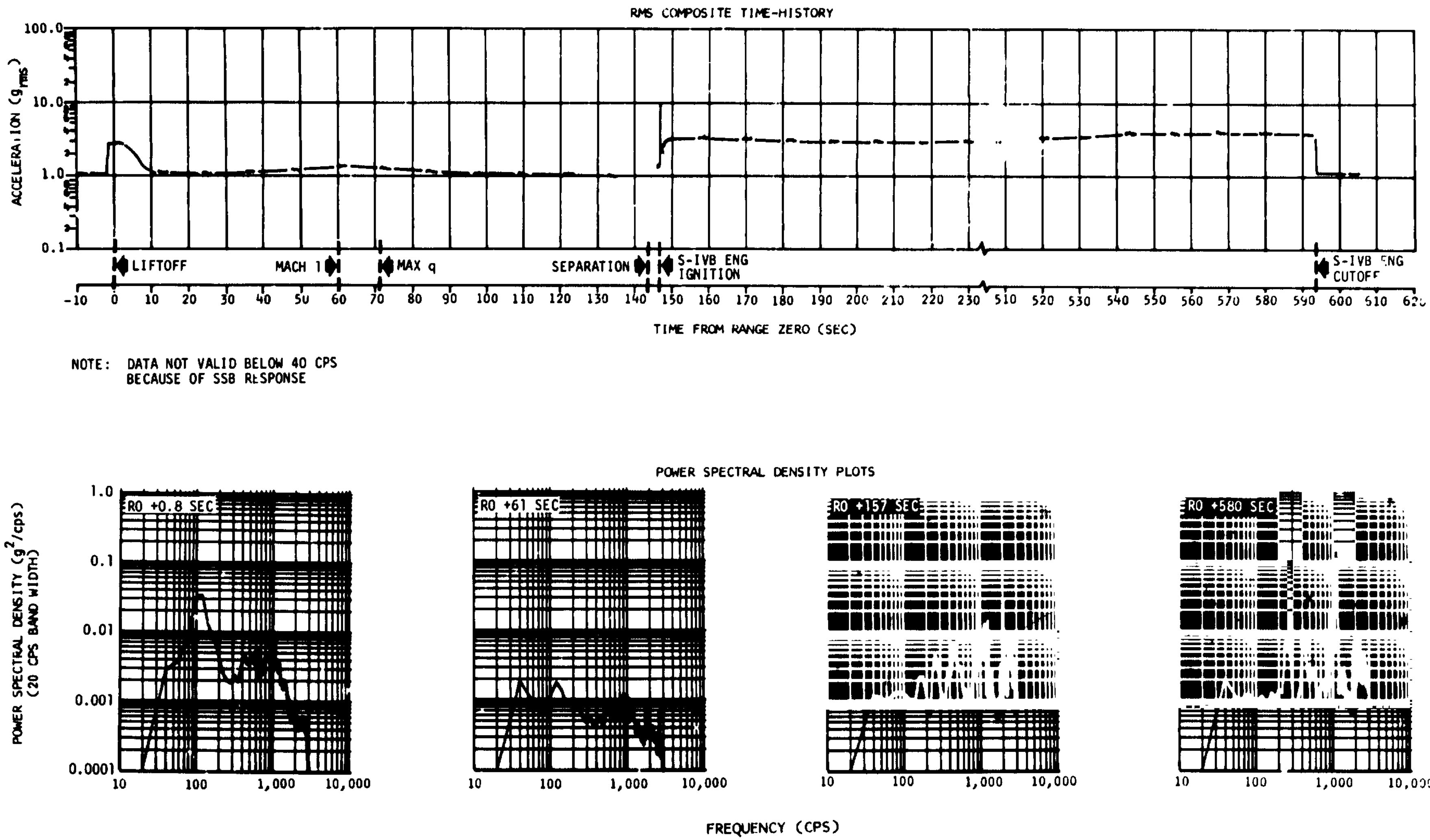


Figure 24-4. Vibration Measured at Input to Auxiliary Hydraulic Pump, Thrust Direction (E0048-403)

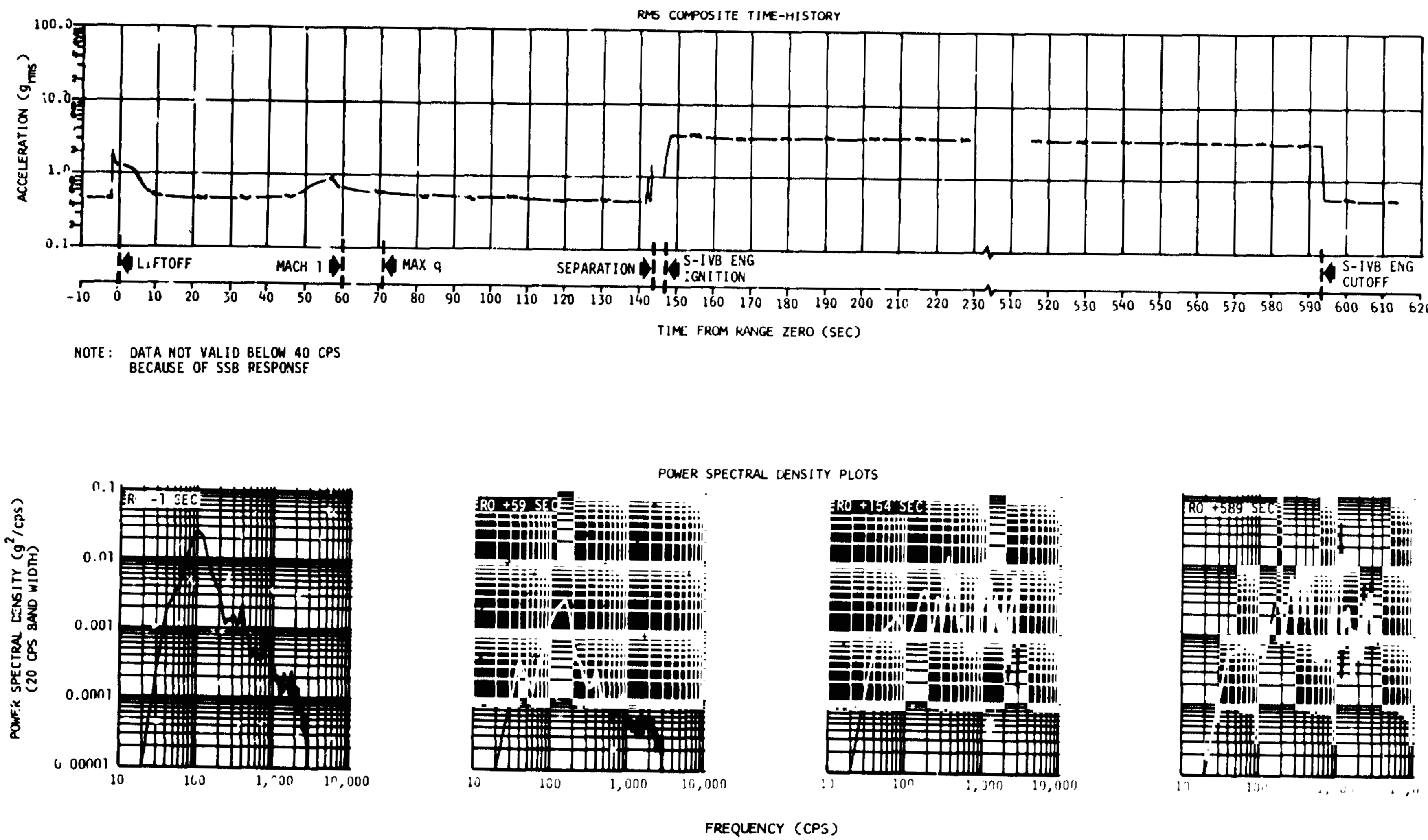


Figure 24-5. Vibration Measured on LH2 Feedline at Gimbal Point, Thrust Direction (E0055-403)

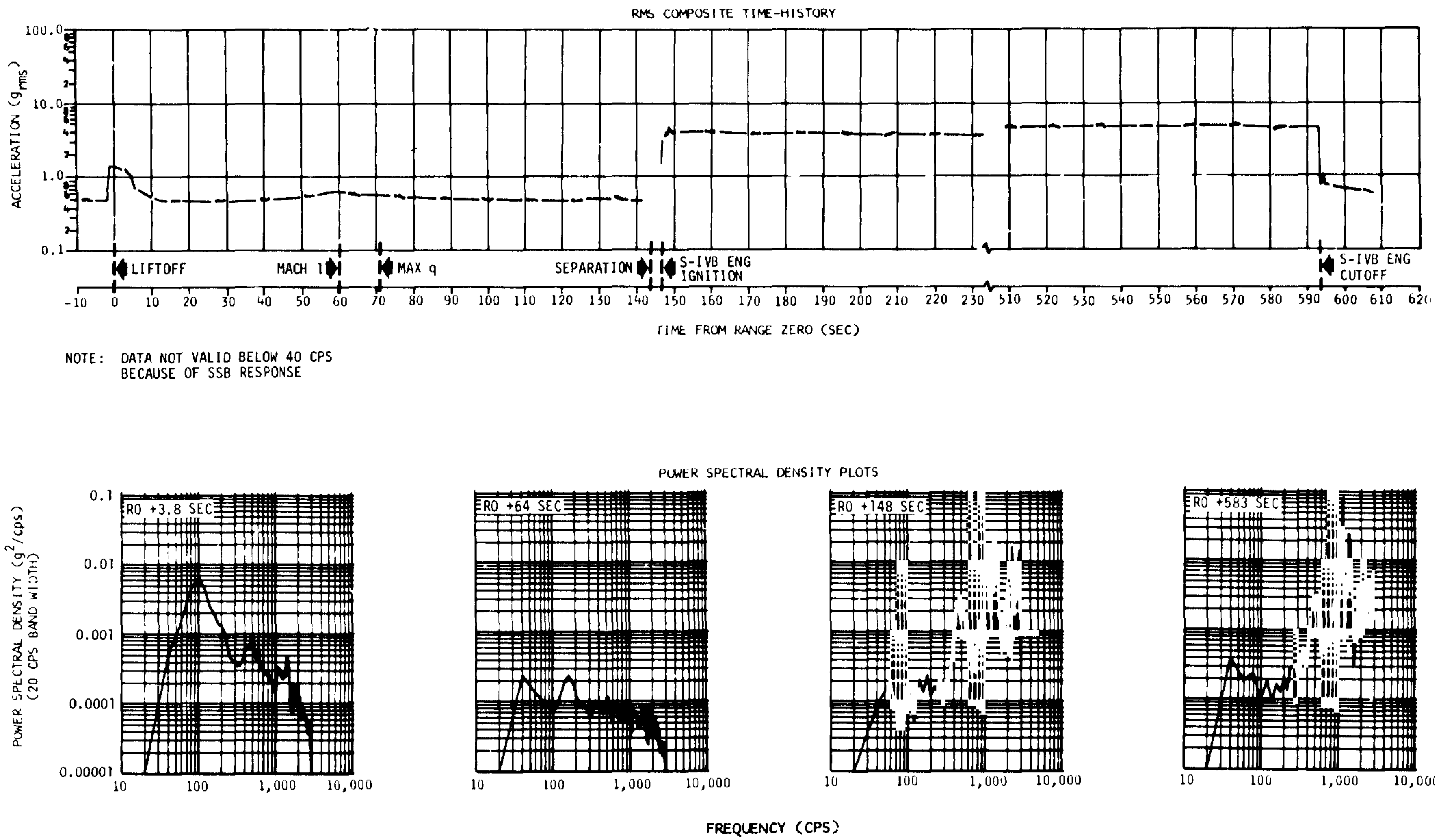


Figure 24-6. Vibration Measured on LH2 Feedline at Gimbal Point, Radial Direction (E0056-403)

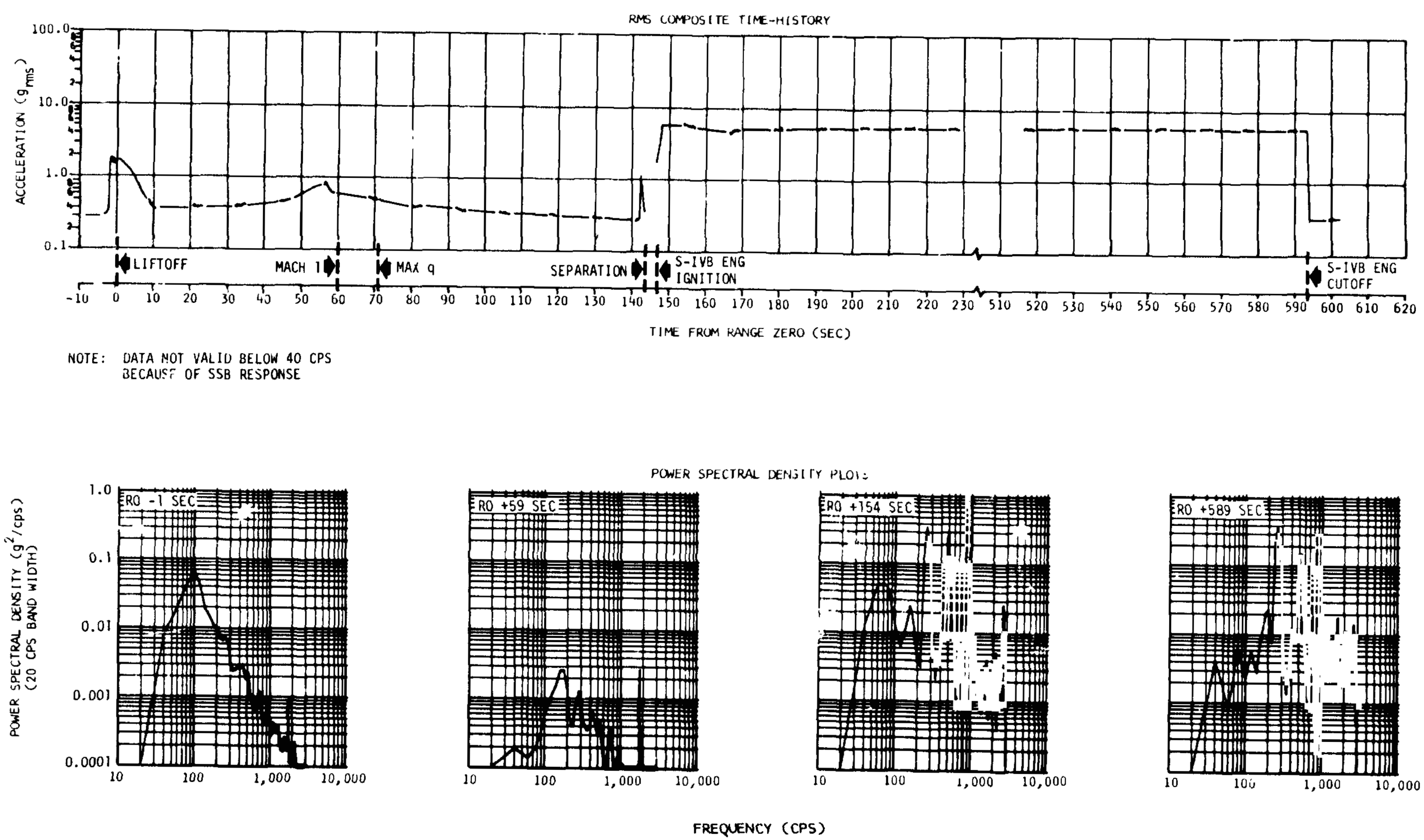


Figure 24-7. Vibration Measured on LOX Feedline at Gimbal Point, Thrust Direction (E0059-403)

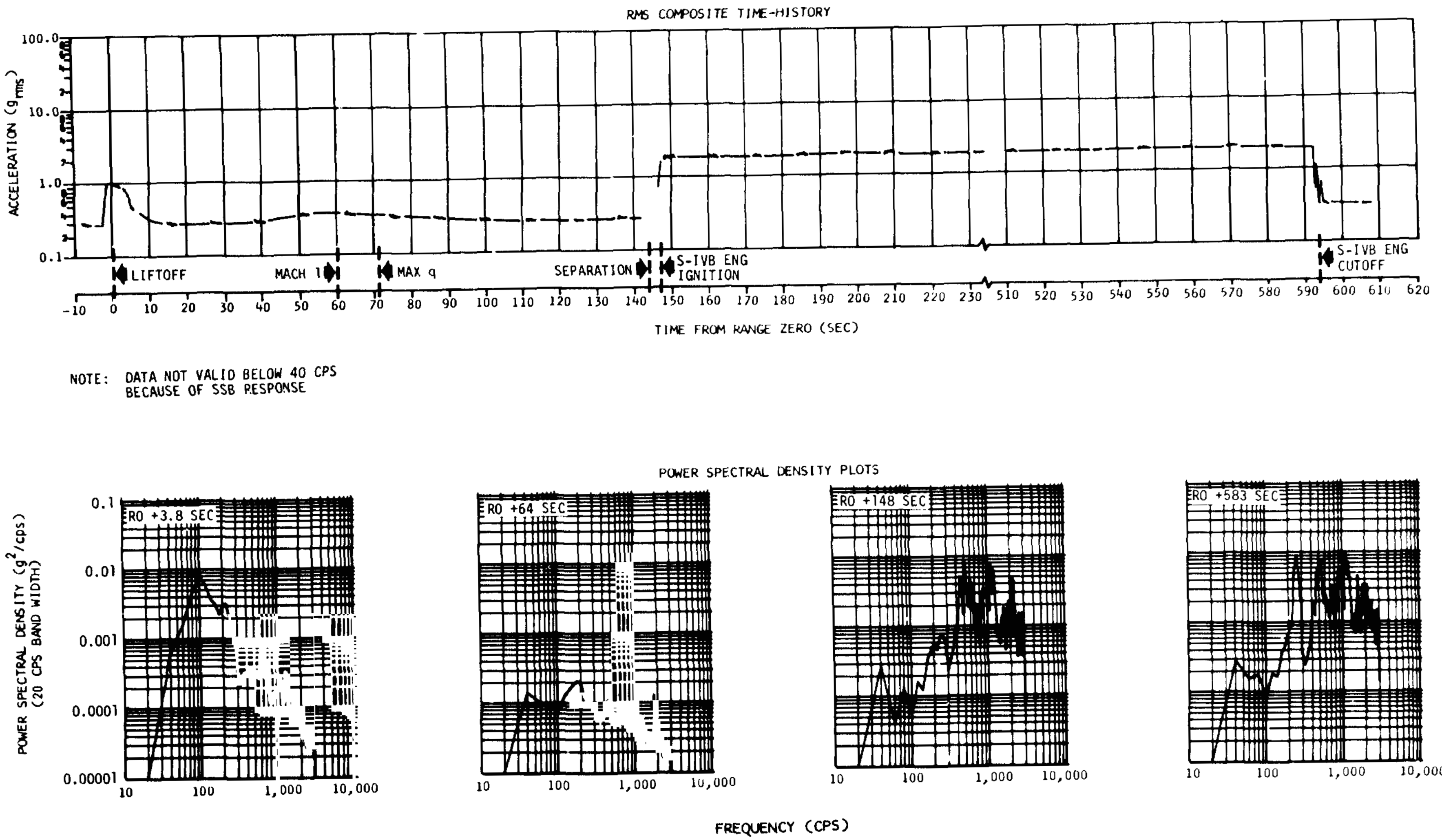


Figure 24-8. Vibration Measured on LOX Feedline a. .imbal Point, Radial Direction (E0060-403)

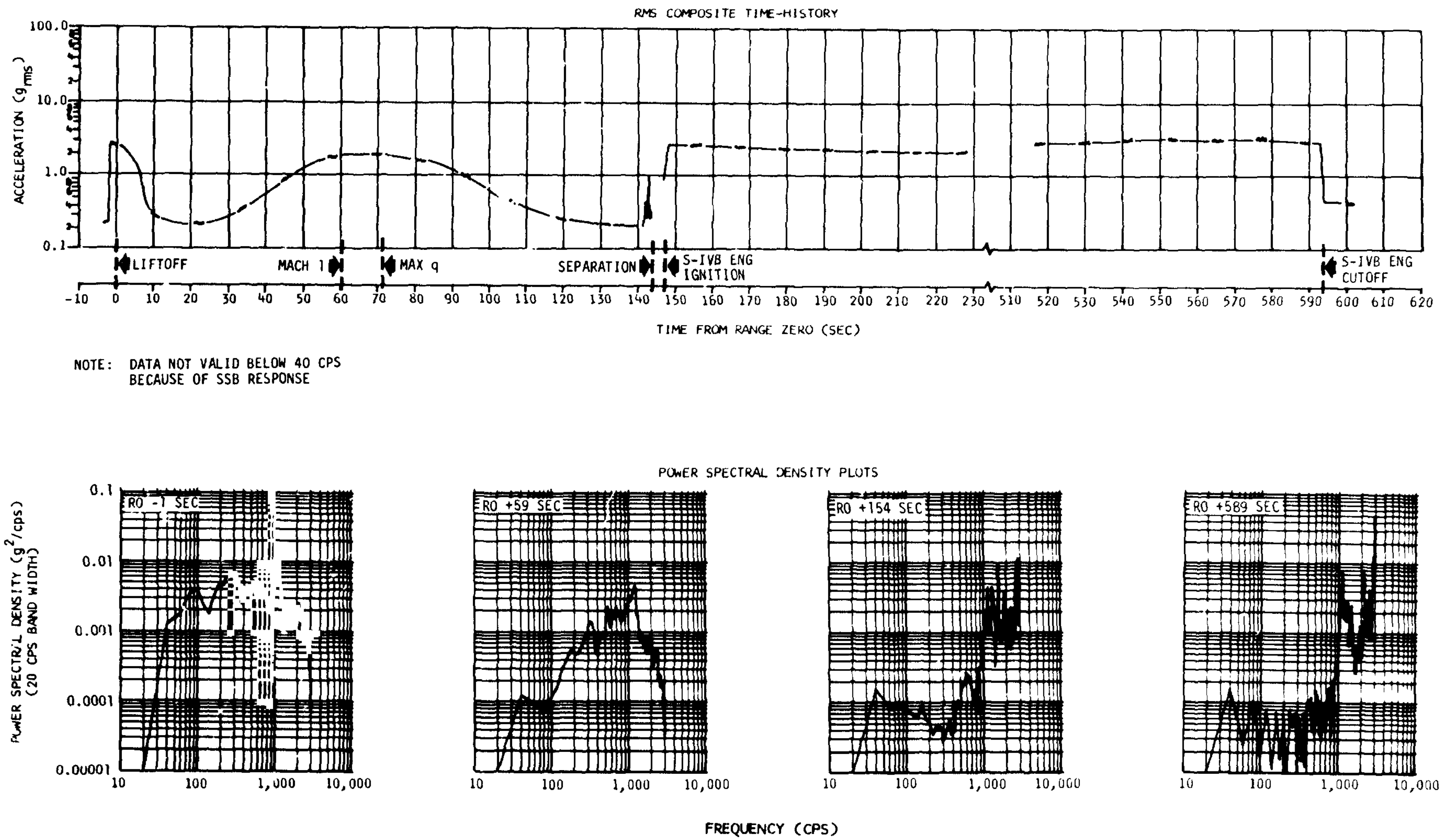


Figure 24-9. Vibration Measured on LH2 Feedline at LH2 Tank, Thrust Direction (E0053-404)

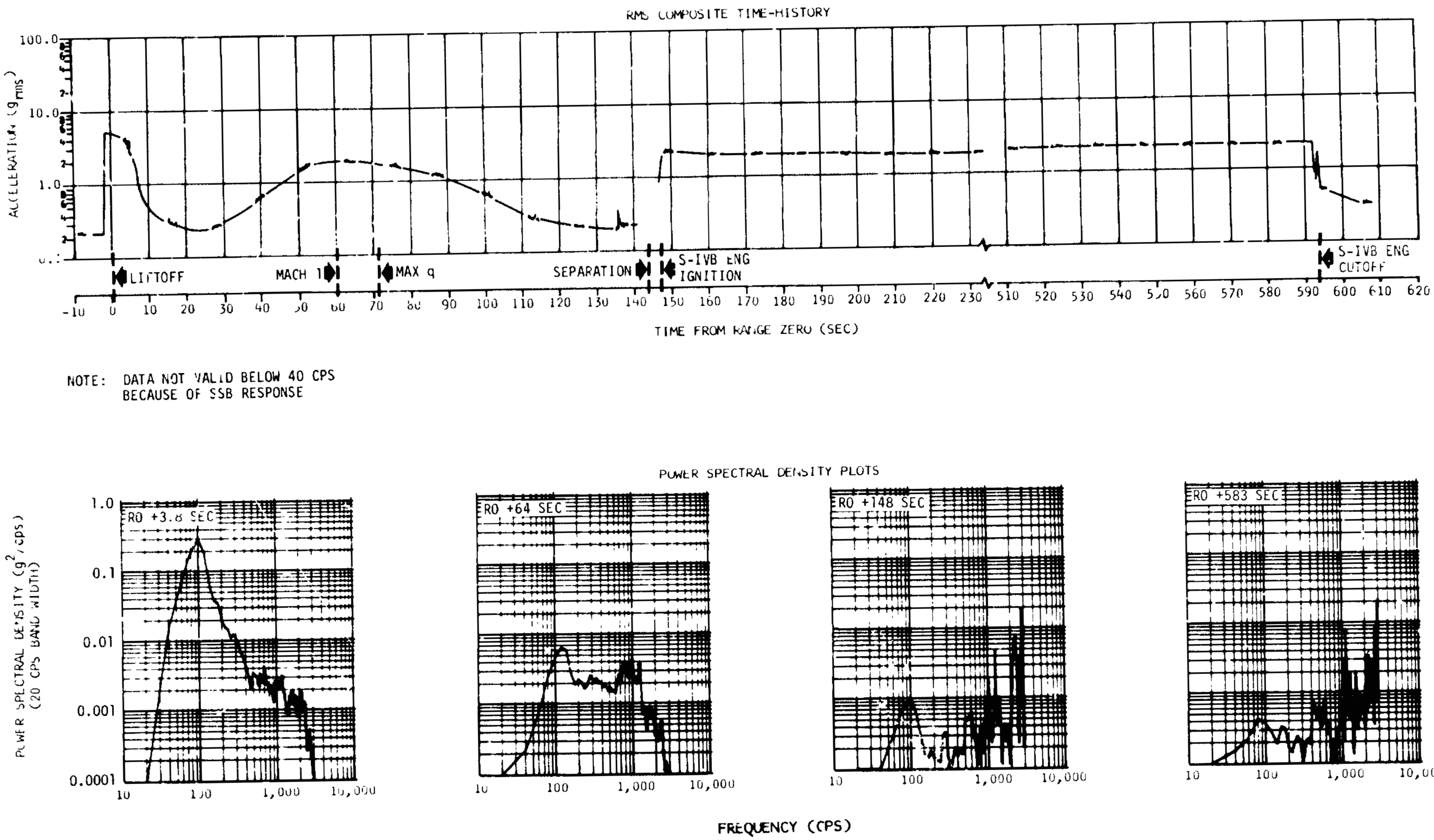


Figure 24-10. Vibration Measured on LH2 Feedline at LH2 Tank, Radial Direction (E0054-404)

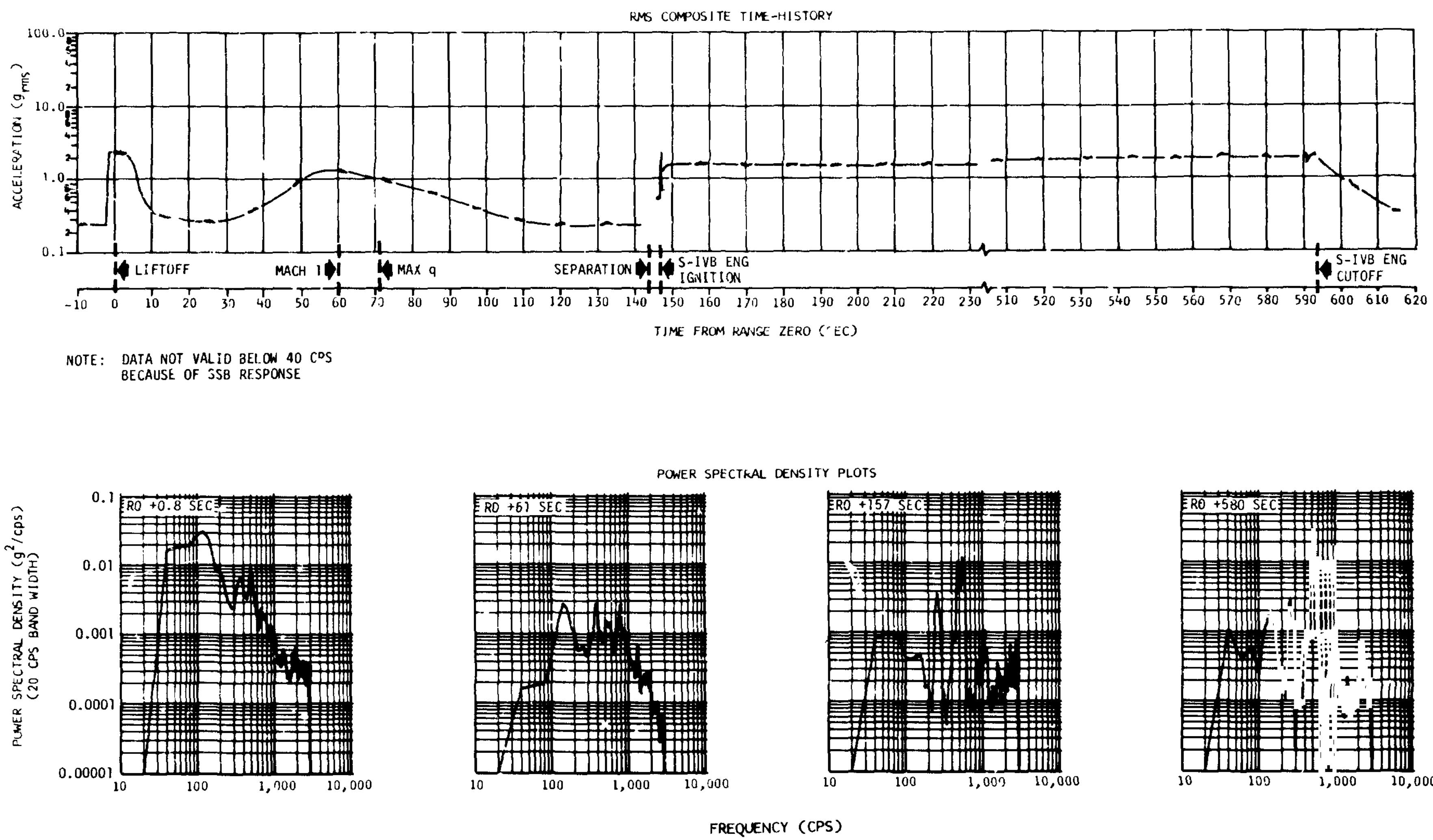


Figure 24-11. Vibration Measured on LOX Feedline at LOX Sump, Thrust Direction (E0057-424)

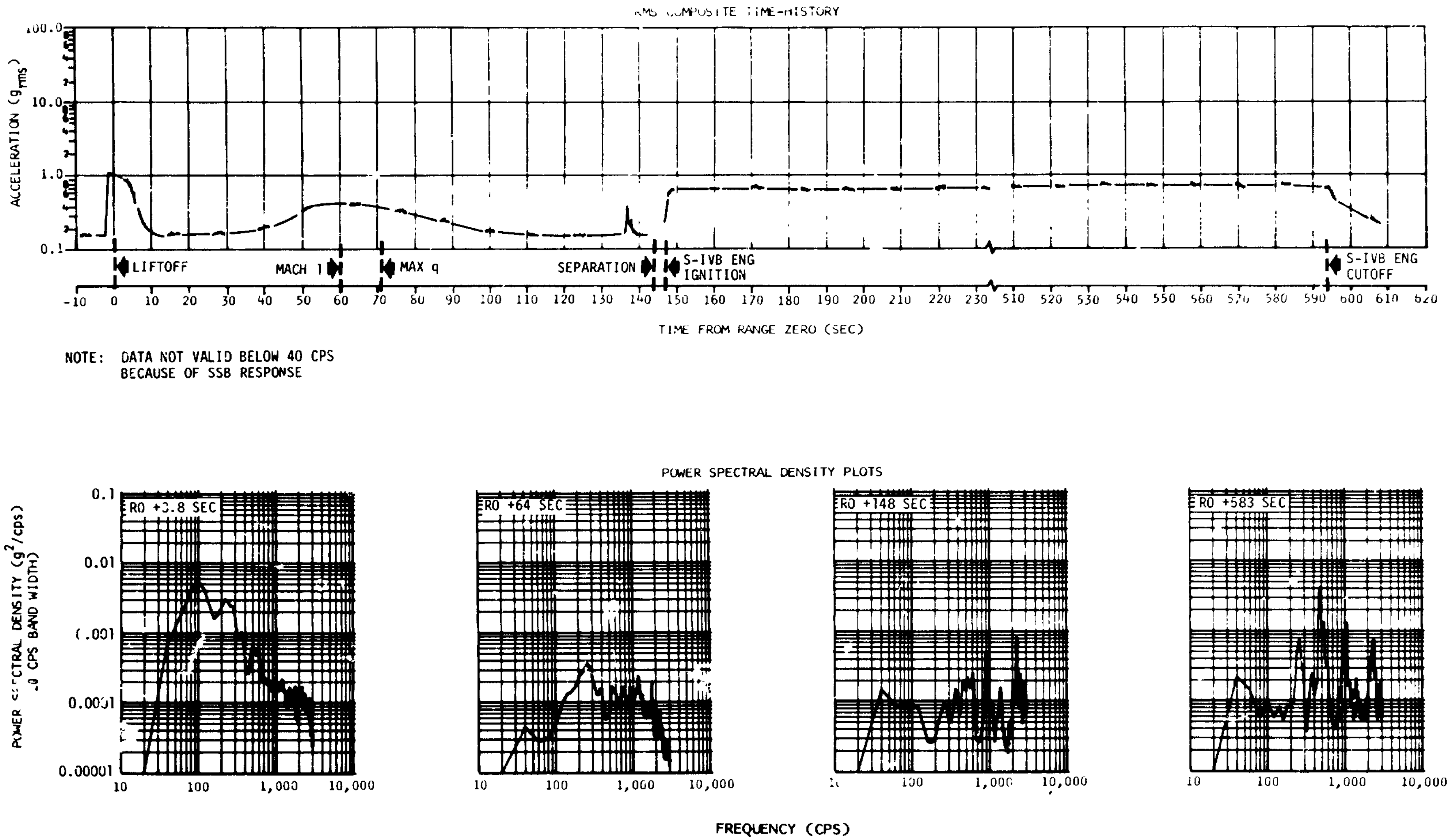


Figure 24-12. Vibration Measured on LOX Feedline at LOX Sump, Radial Direction (E0058-424)

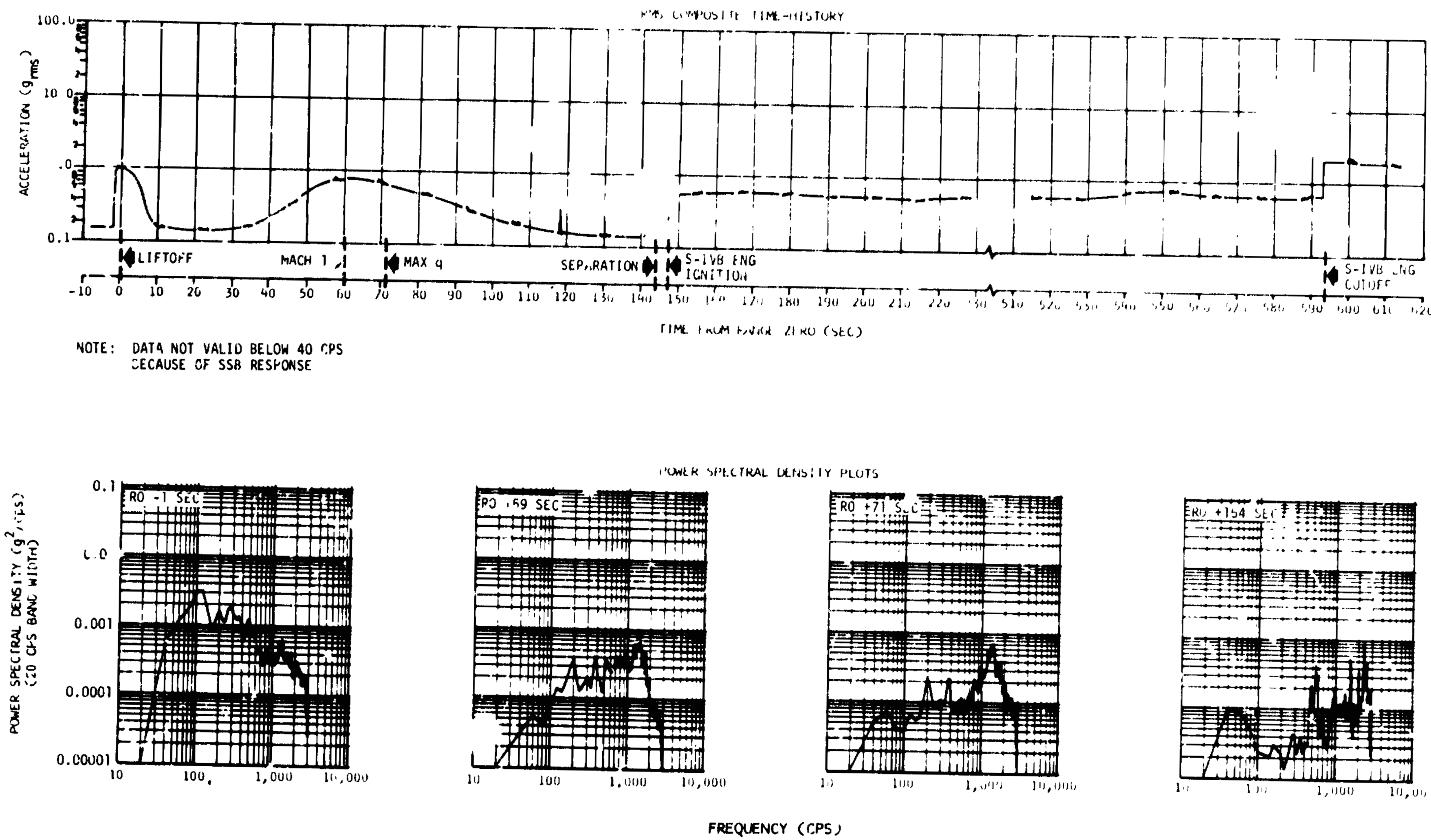


Figure 24-13. Vibration Measured on LOX Vent Valve, Parallel to Tank (E0072-424)

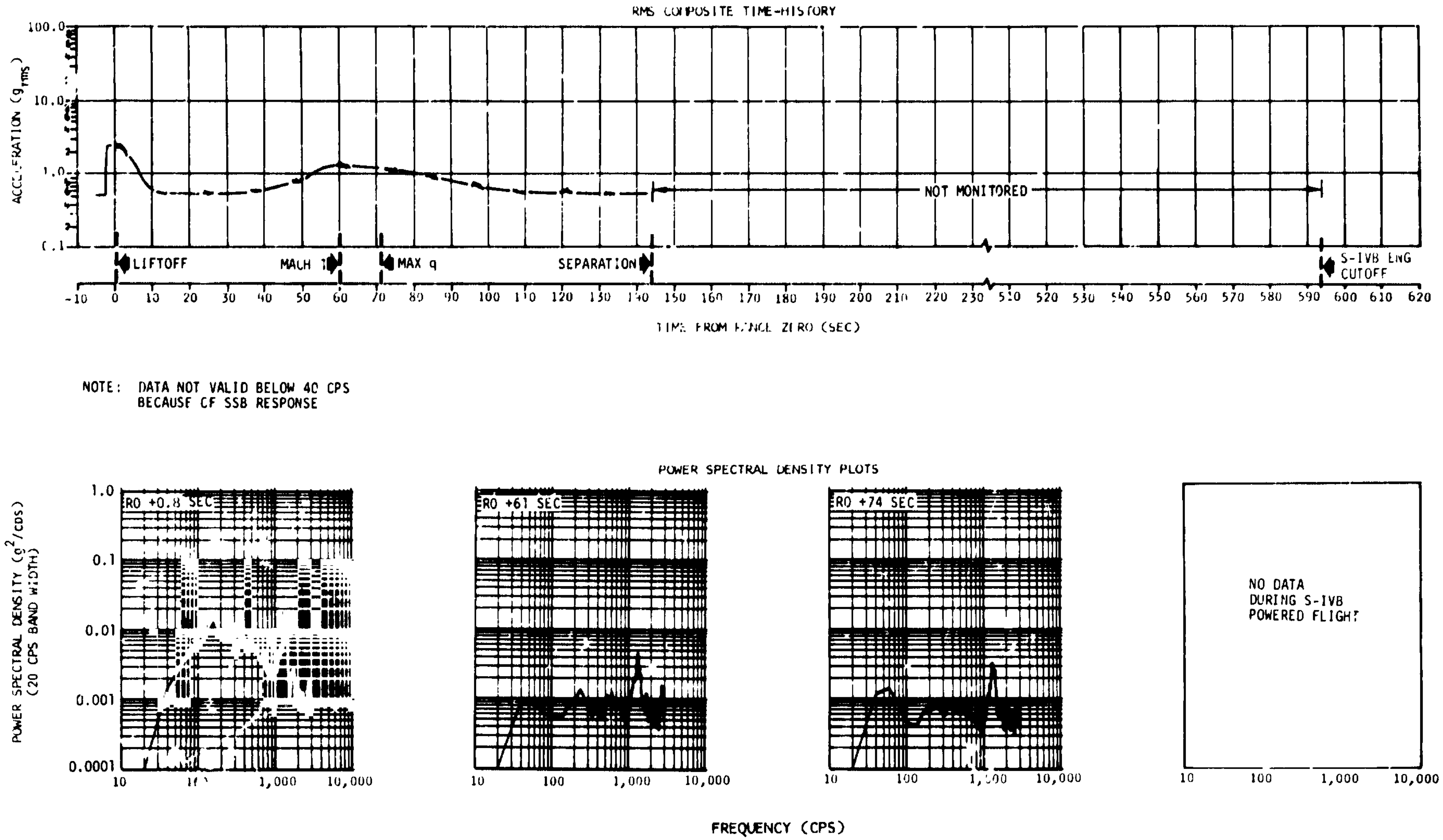


Figure 24-14. Vibration Measured at Center Attach Point of Retrorocket, Thrust Direction (E0044-402)

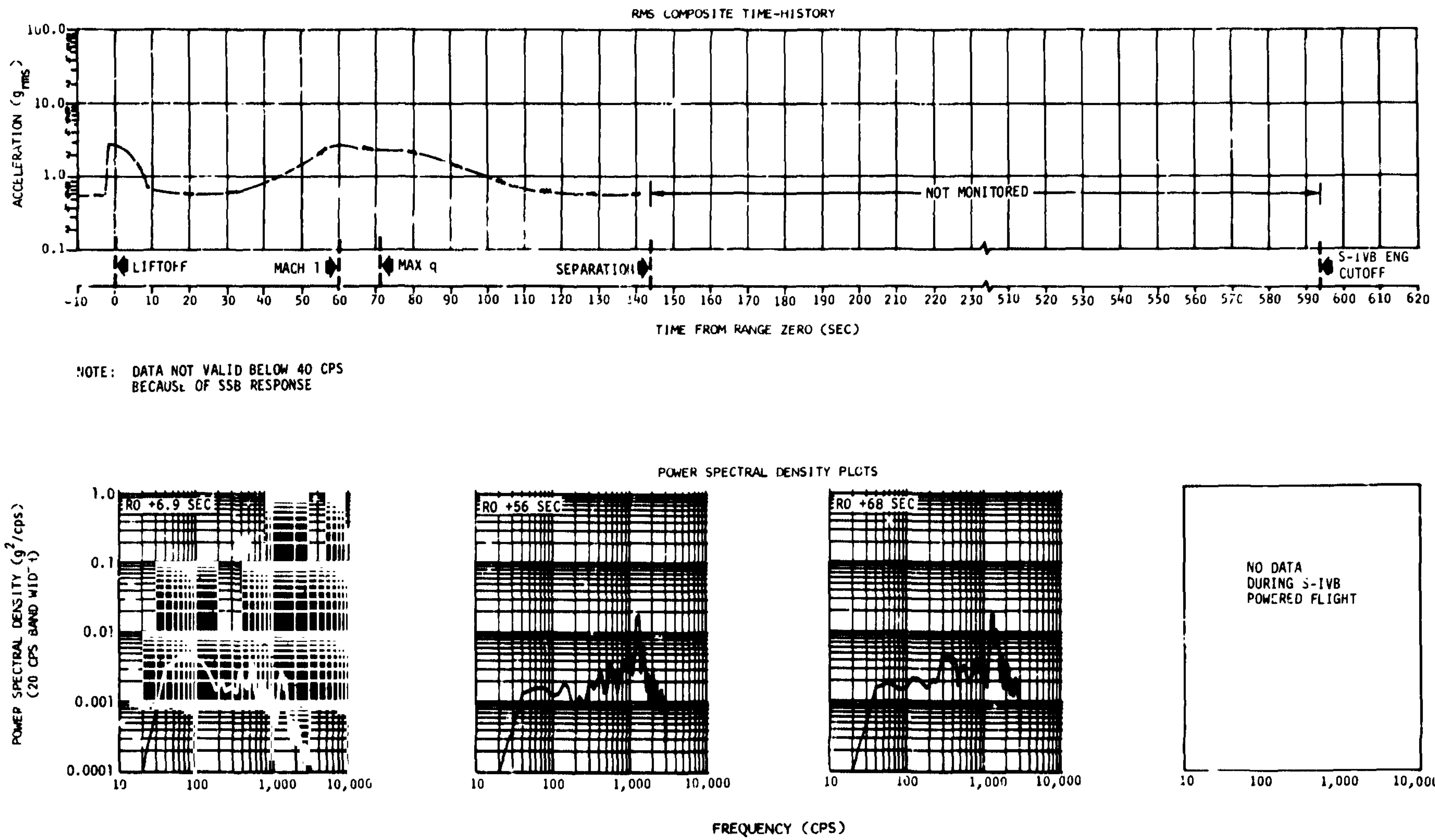


Figure 24-15. Vibration Measured at Forward Attach Point of Retrorocket, Radial Direction (E0045-402)

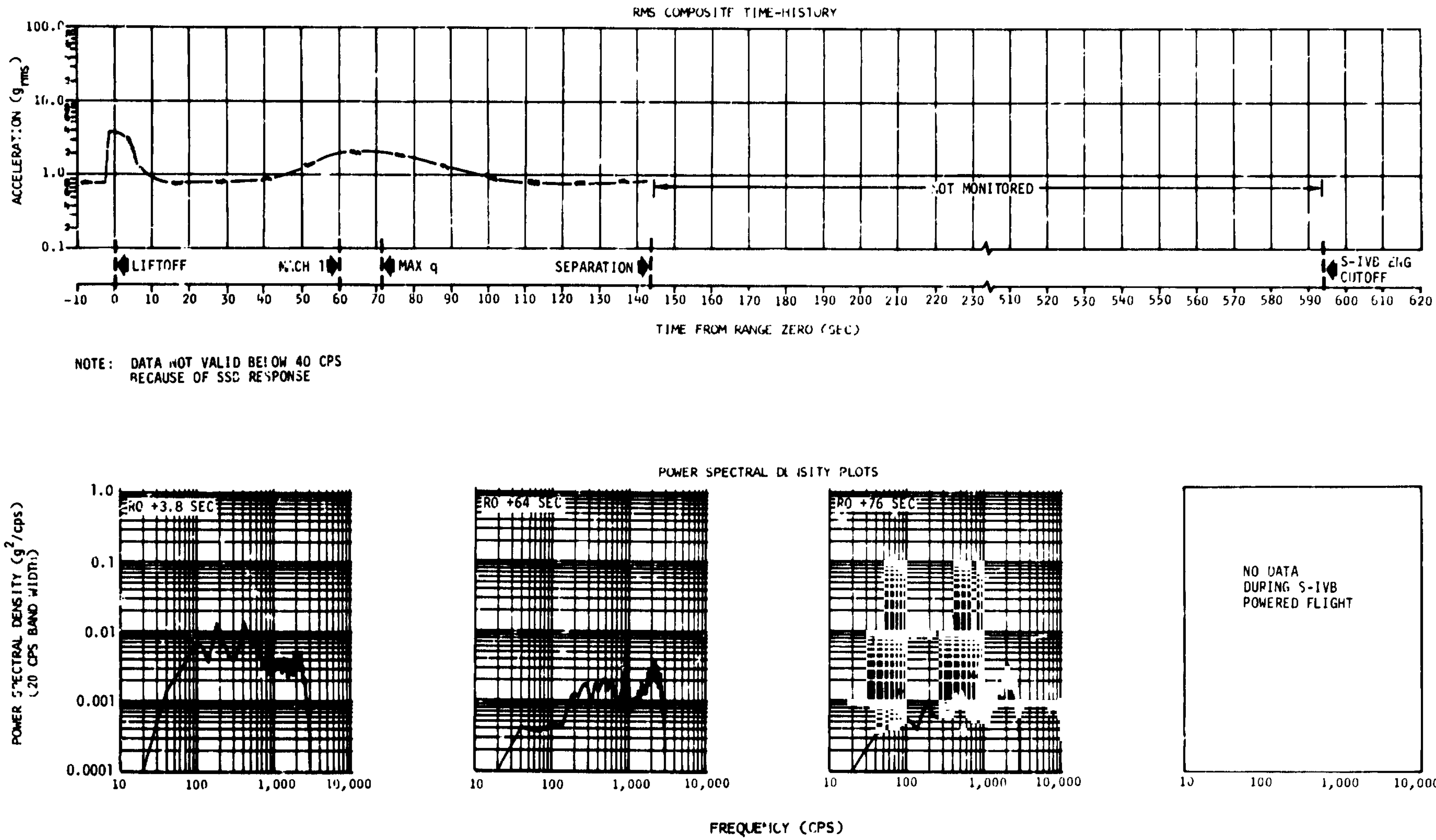


Figure 24-16. Vibration Measured at Forward Attach Point of Retrorocket, Tangential Direction (E0046-402)

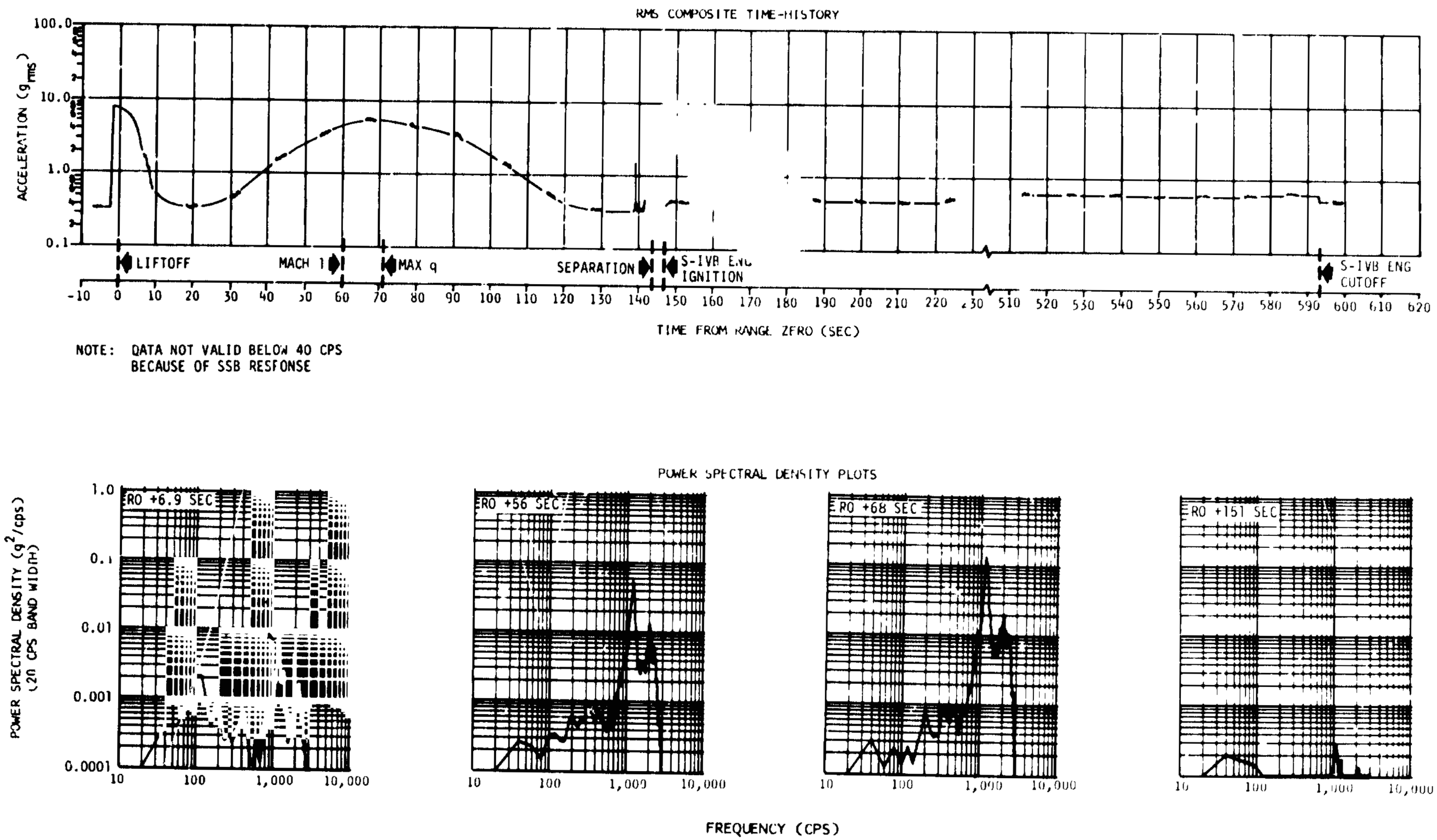


Figure 24-17. Vibration Measured at Aft Attach Point of APS Module 1, Thrust Direction (E0032-427)

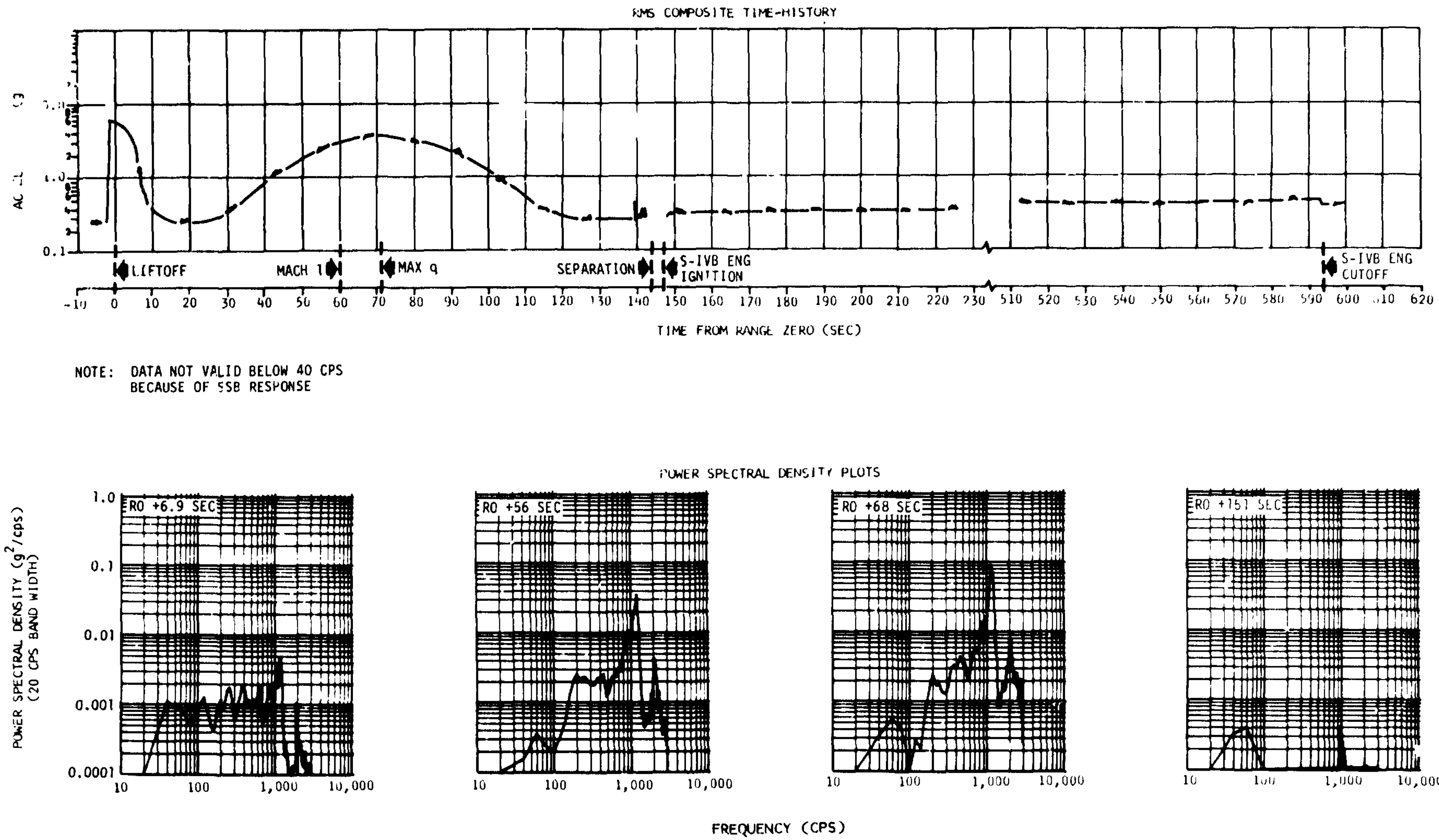


Figure 24-18. Vibration Measured at Aft Attach Point of APS Module 1, Radial Direction (E0033-427)

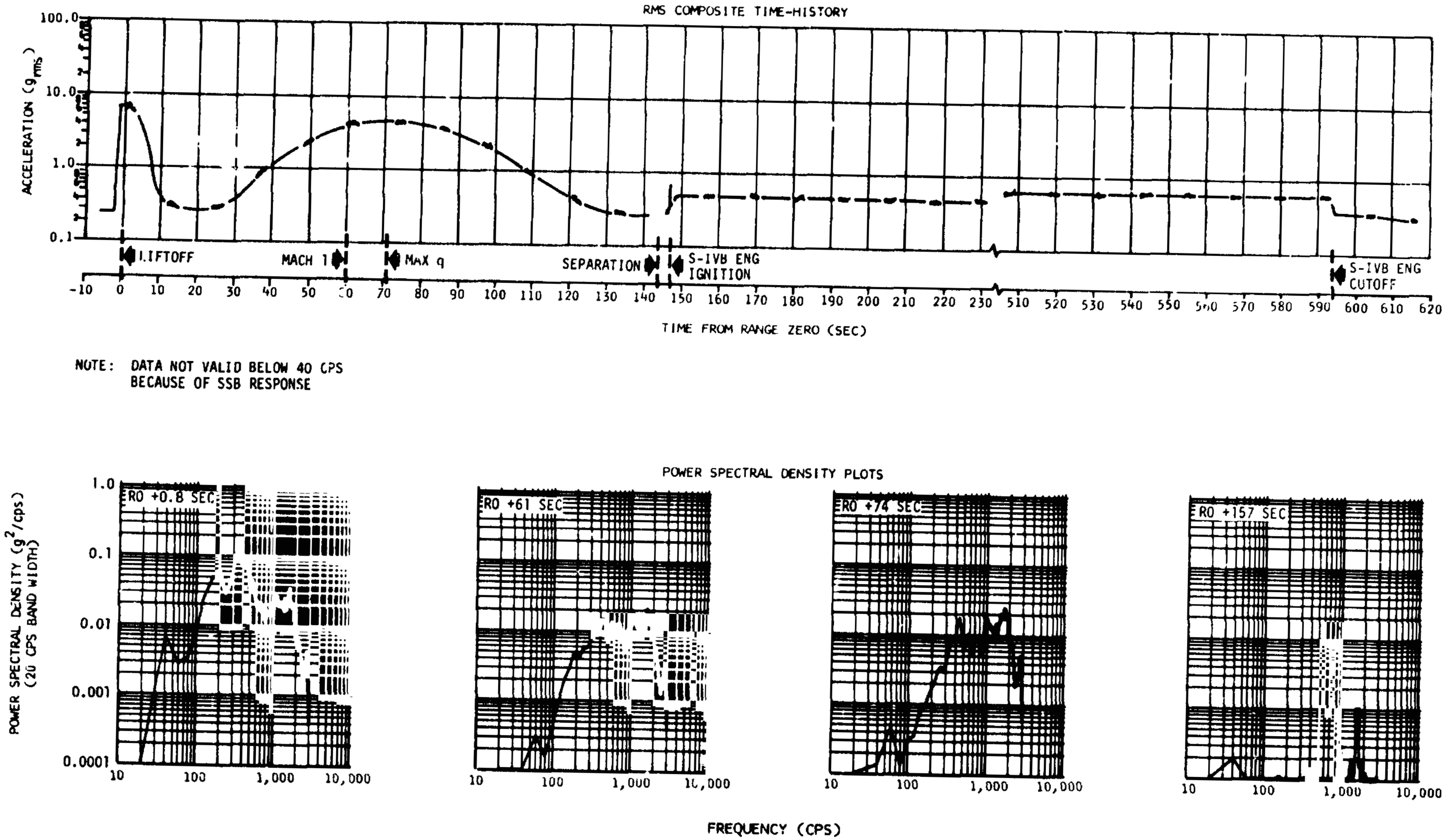


Figure 24-19. Vibration Measured at Forward Attach Point of APS Module 1, Radial Direction (E0034-427)

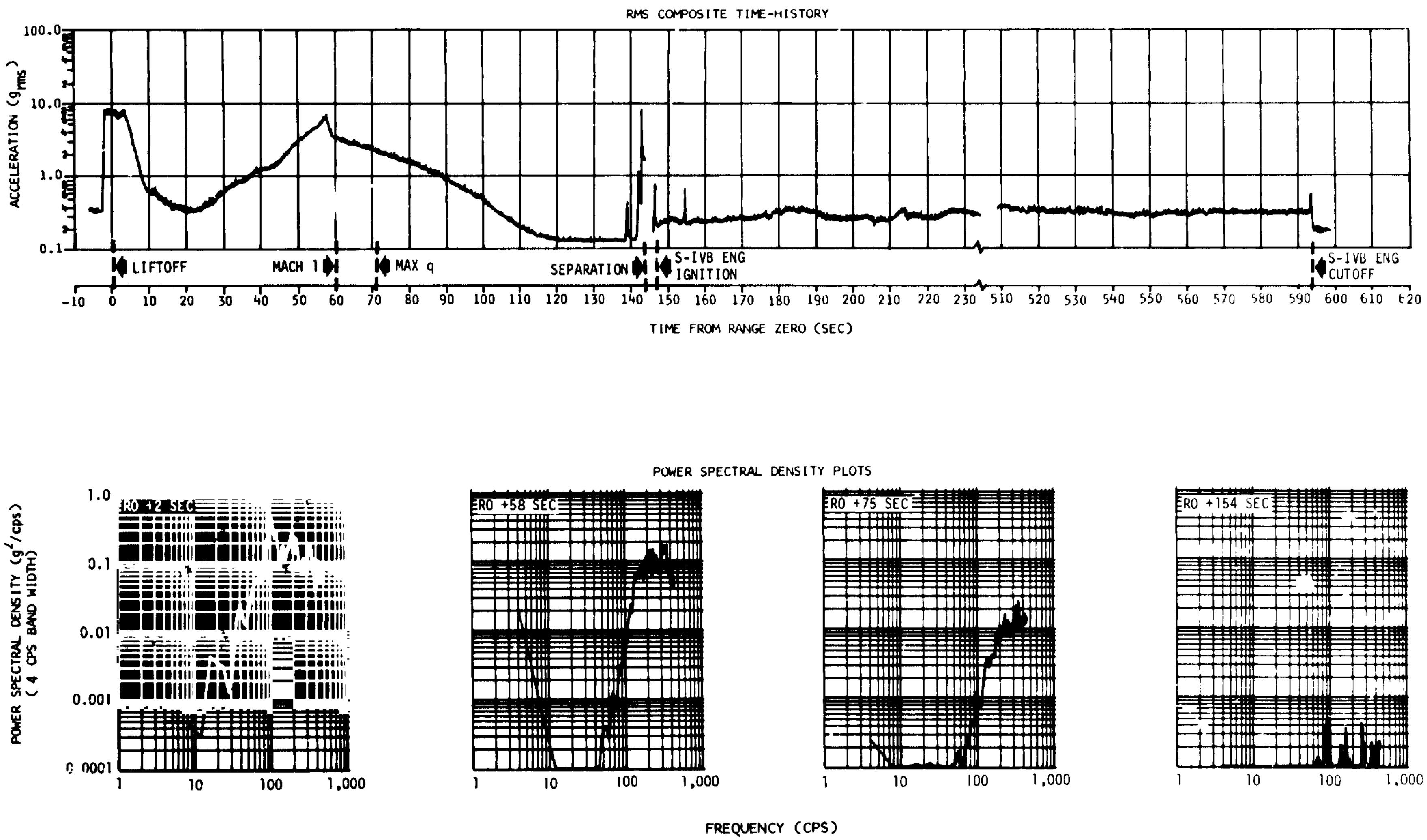


Figure 24-20. Vibration Measured on LH2 Tank Cylinder Between Positions III and IV, Radial Direction (E0029-409)

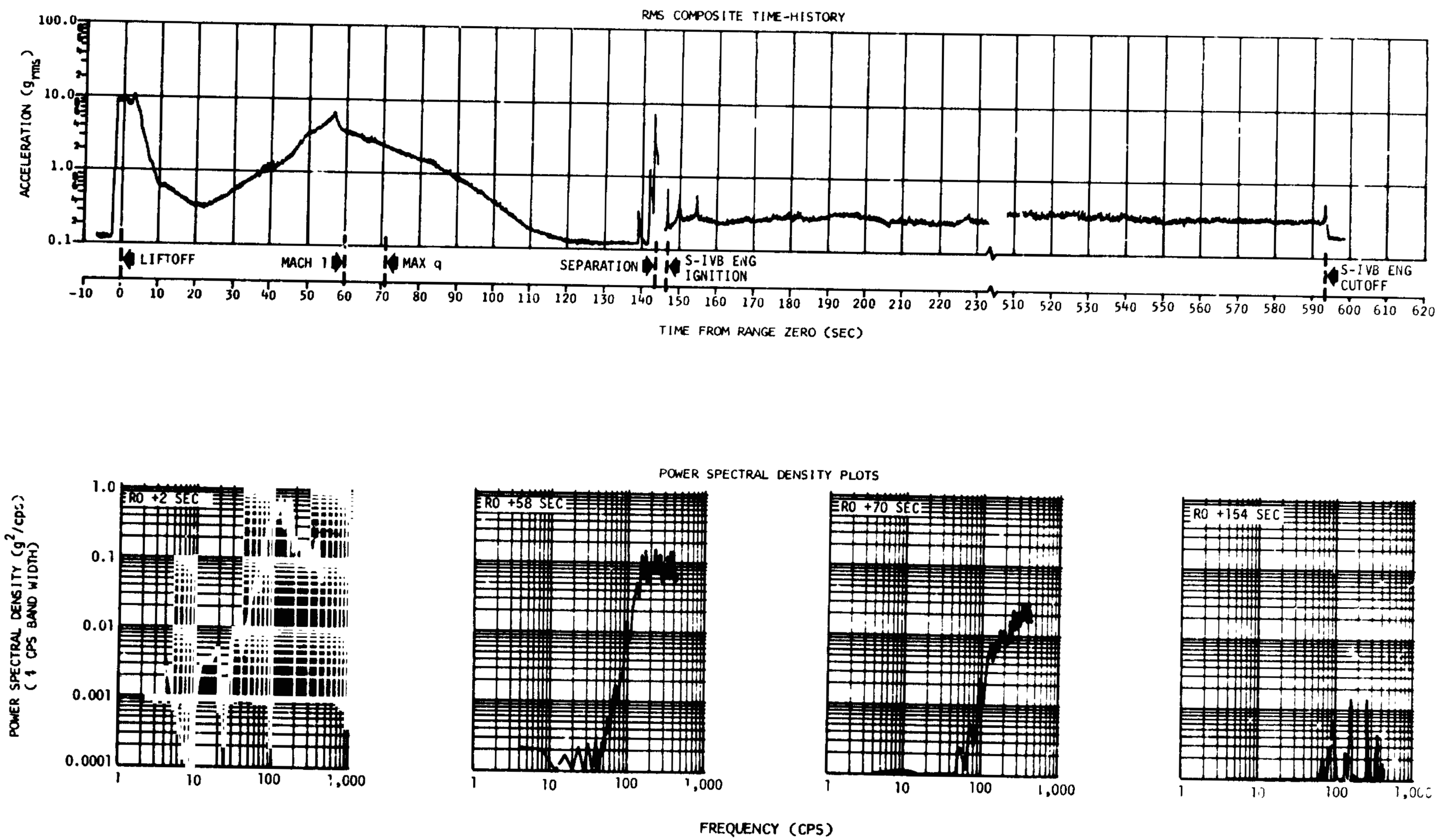


Figure 24-21. Vibration Measured on LH2 Tank Cylinder Position III, Radial Direction (E0030-409)

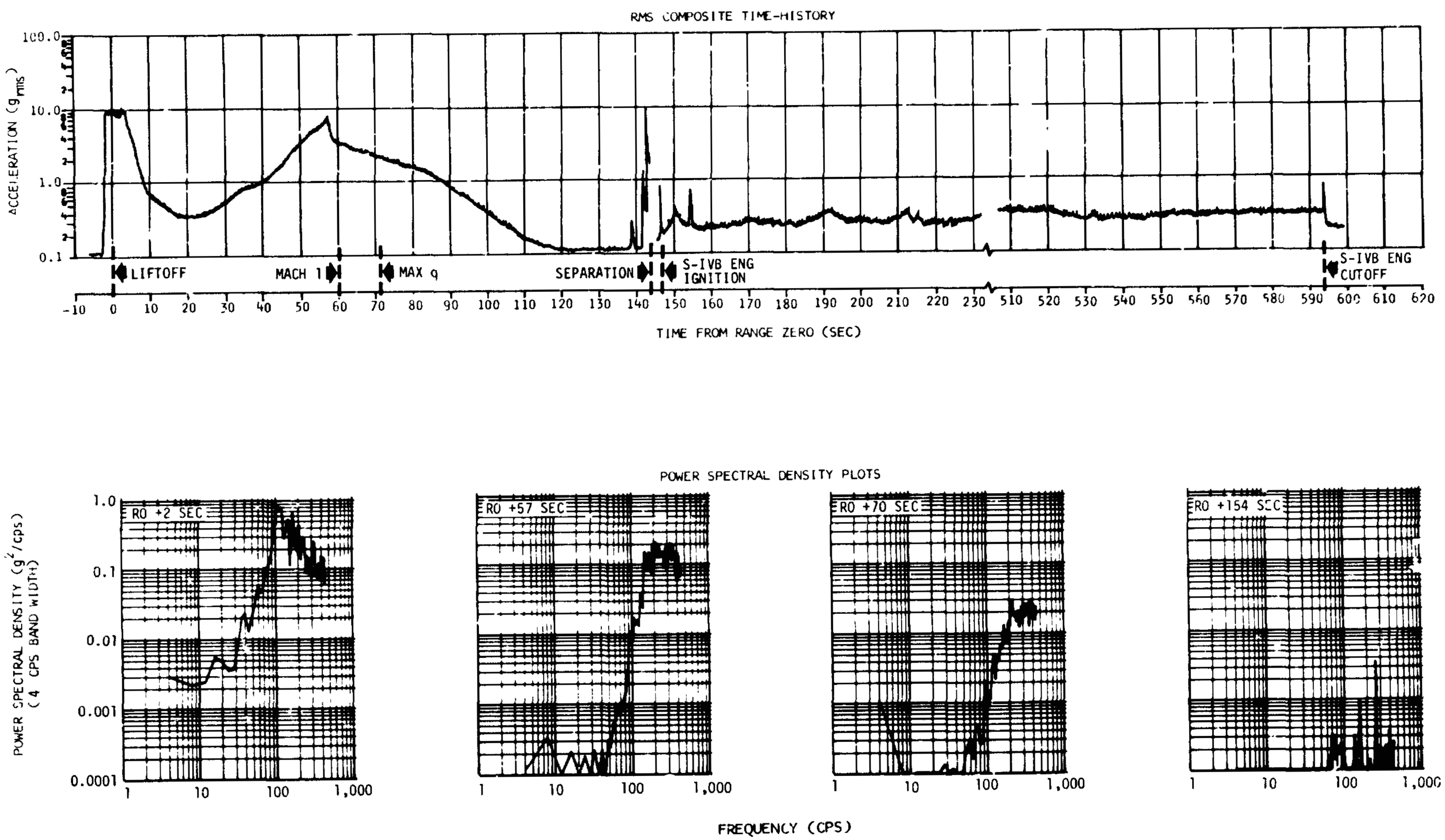


Figure 24-22. Vibration Measured on LH2 Tank Cylinder Between Positions II and III, Radial Direction (E0031-409)

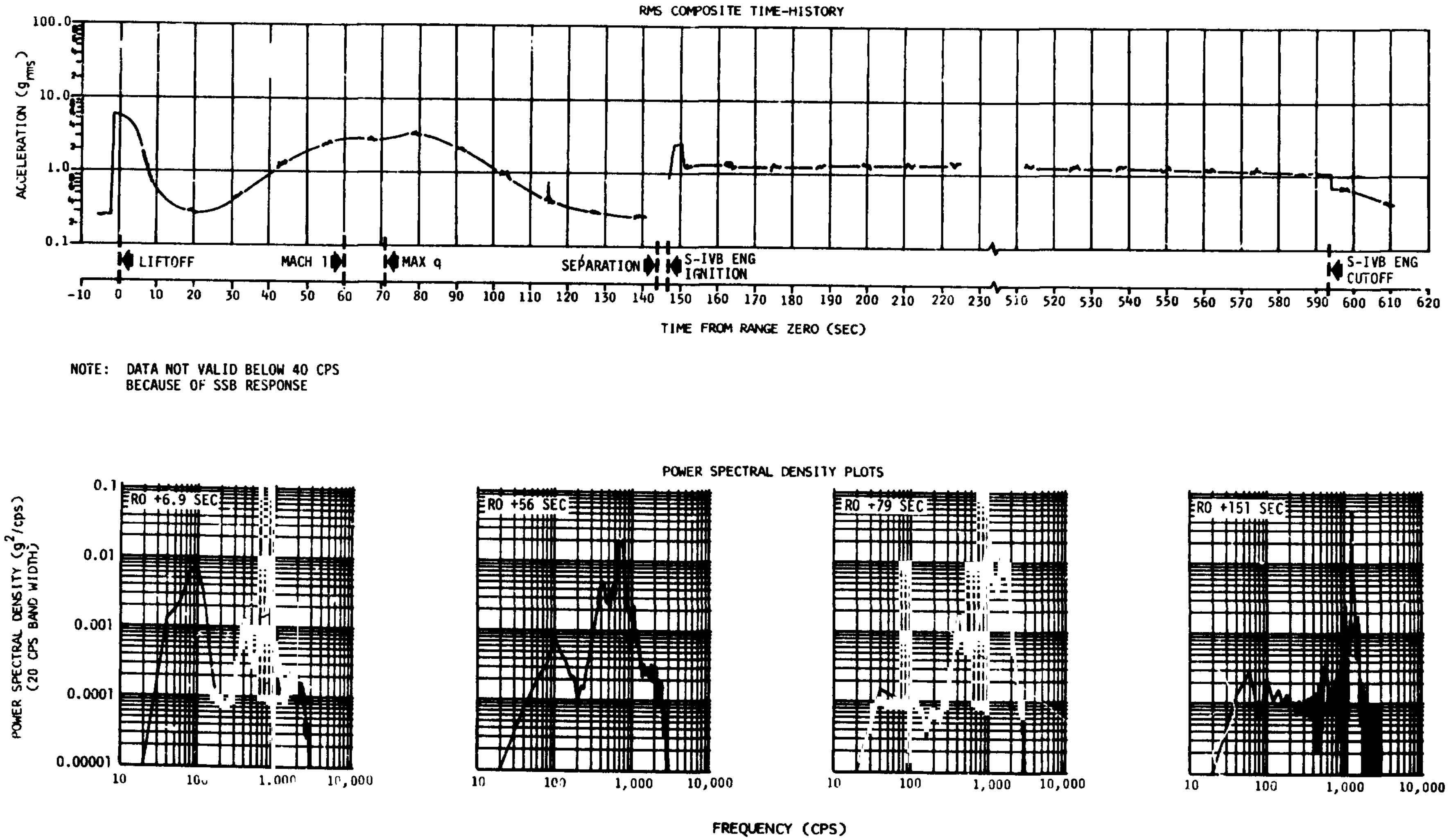


Figure 24-23. Vibration Measured at Input to Cold Helium Sphere, Radial Direction (E0074-405)

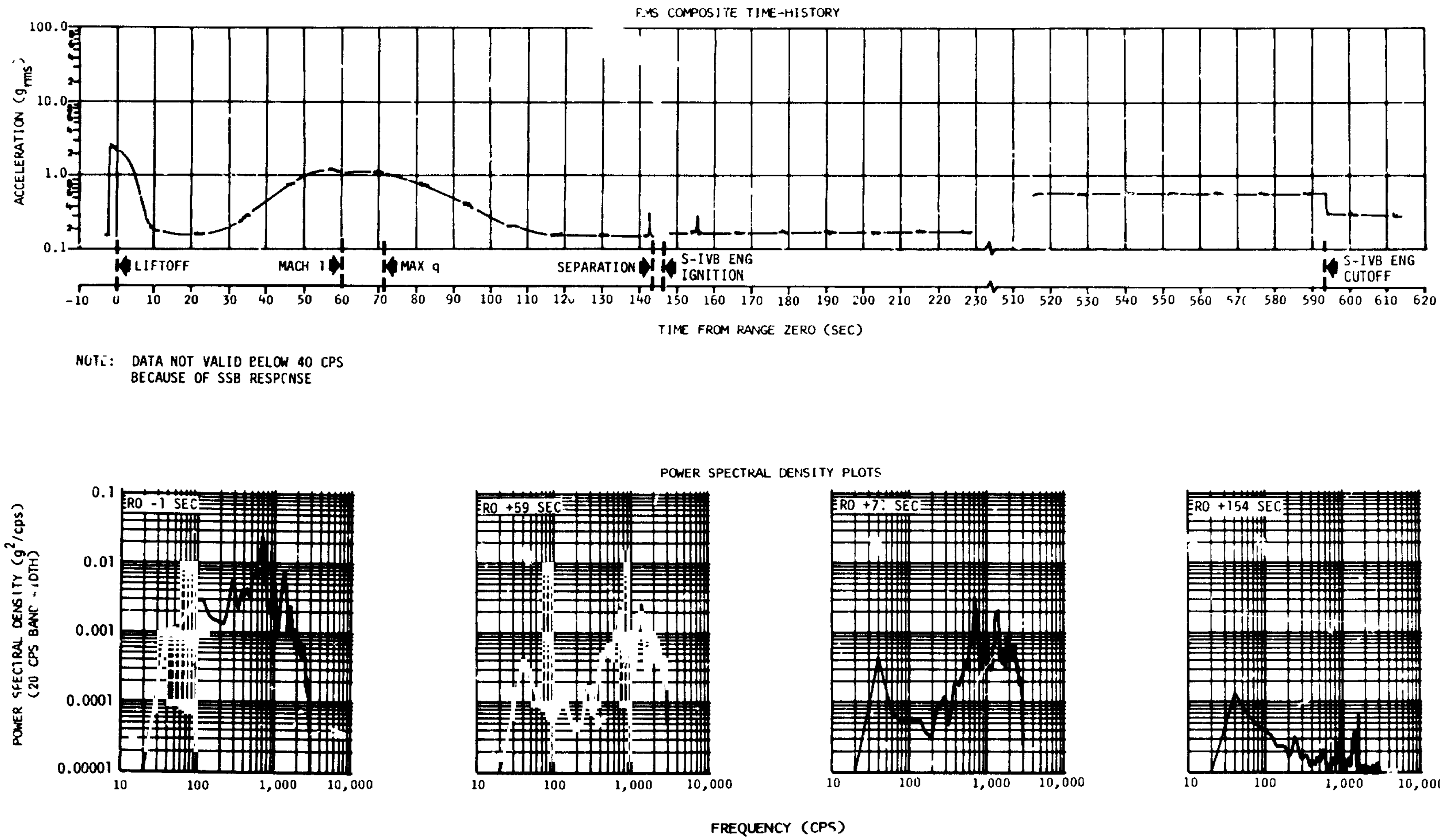


Figure 24-24. Vibration Measured at Input to LH2 Vent Valve Assembly, Thrust Direction (E0069-410)

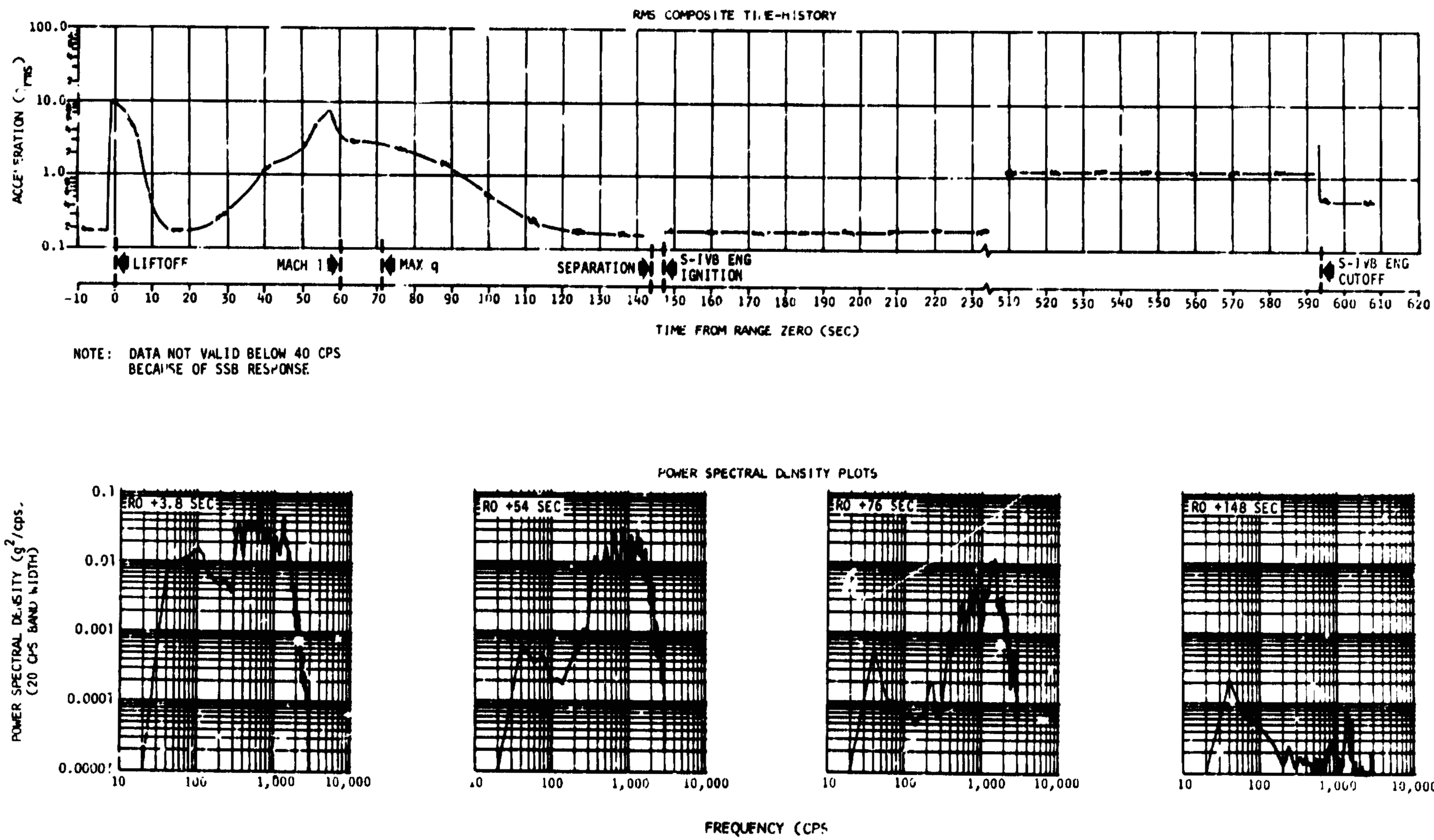


Figure 24-25. Vibration Measured at Input to LH2 Vent Valve Assembly, Radial Direction (E0070-410)

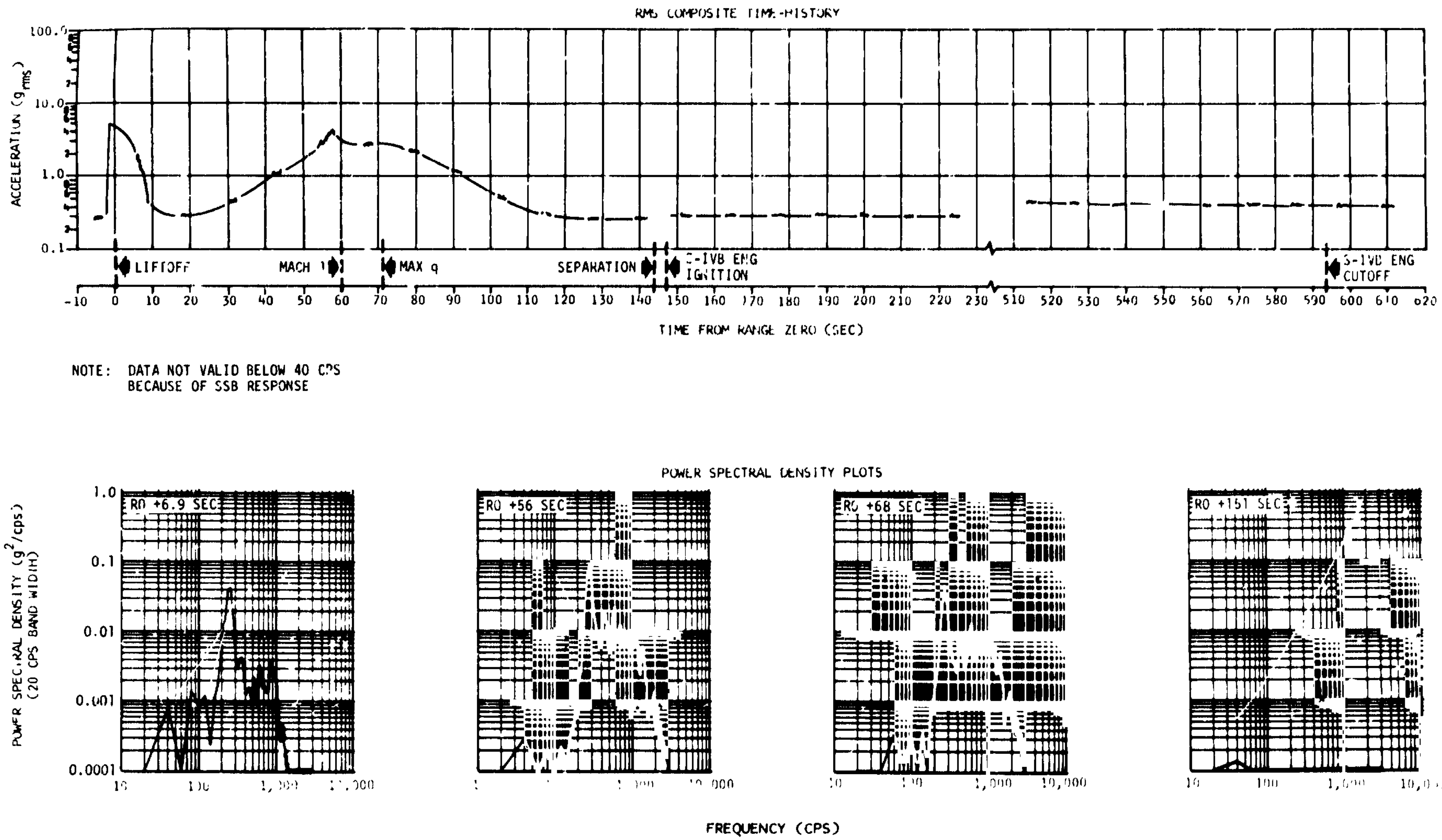


Figure 24-26. Vibration Measured at Input to Telemetry Antenna, Tangential Direction (E0036-411)

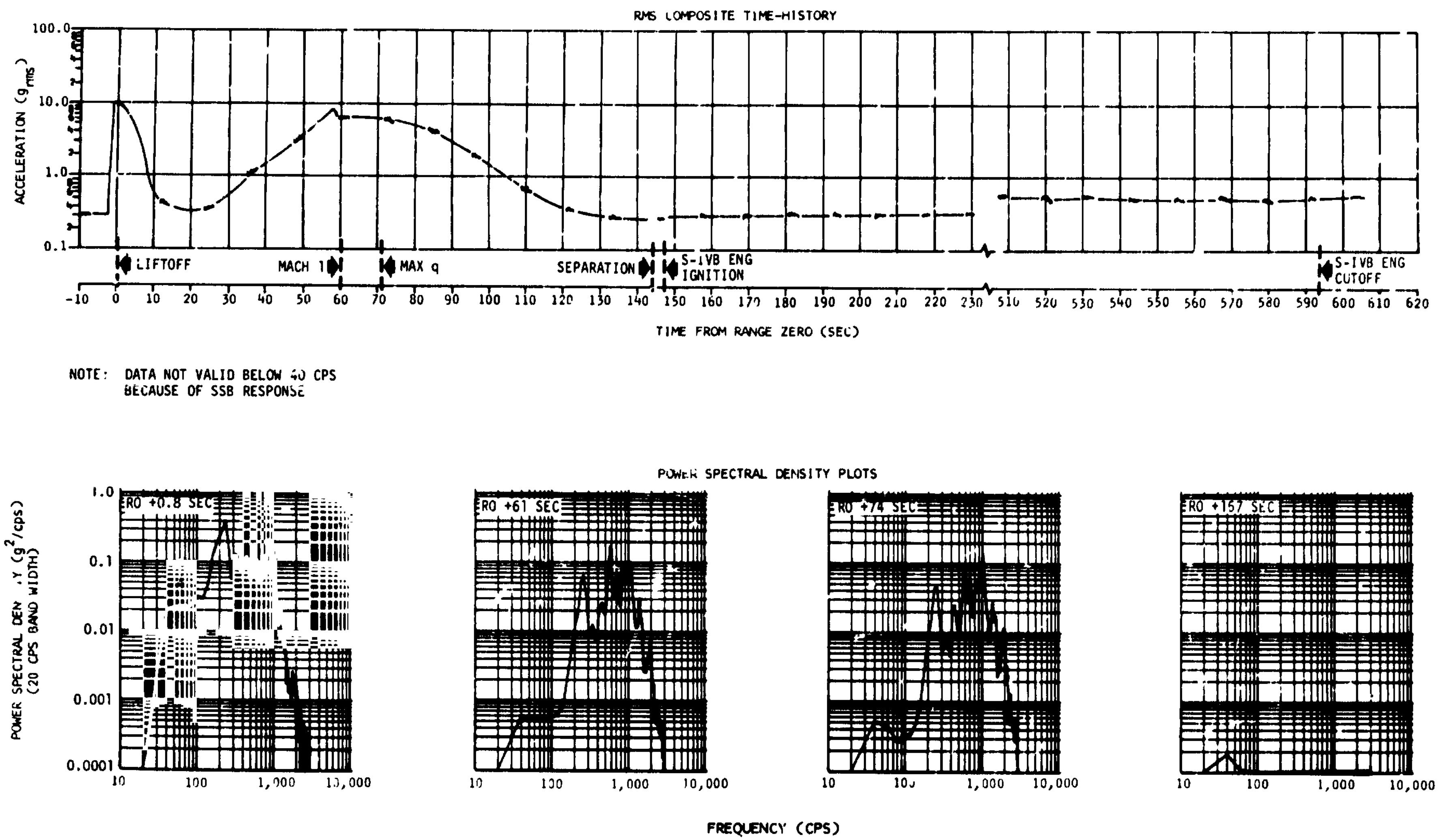


Figure 24-27. Vibration Measured at Input to Telemetry Antenna, Radial Direction (E0037-411)

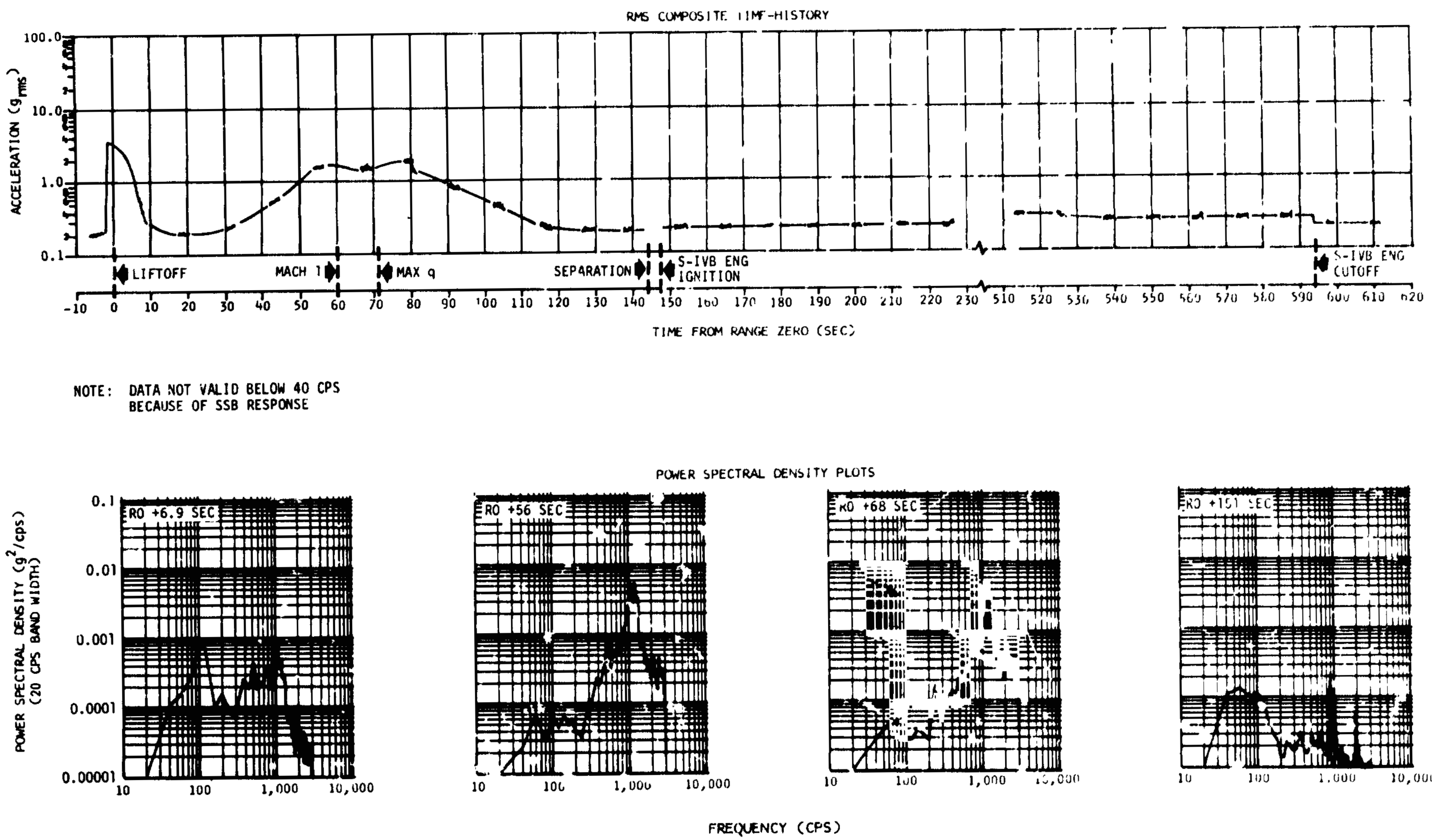


Figure 24-28. Vibration Measured on Field Splice Position II, Thrust Direction (E038-411)

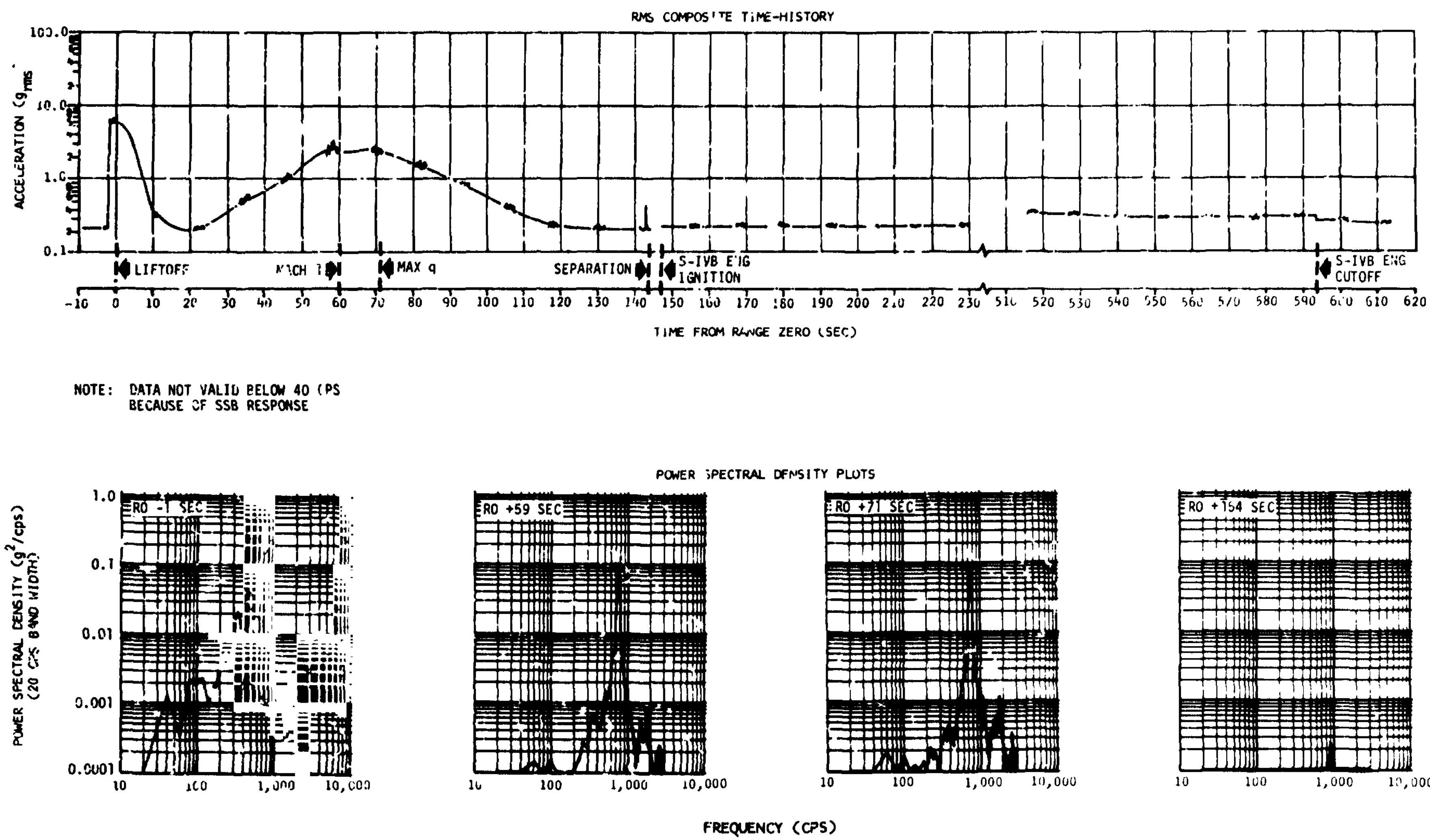


Figure 24-29. Vibration Measured on Field Splice Position II, Tangential Direction (E0039-411)

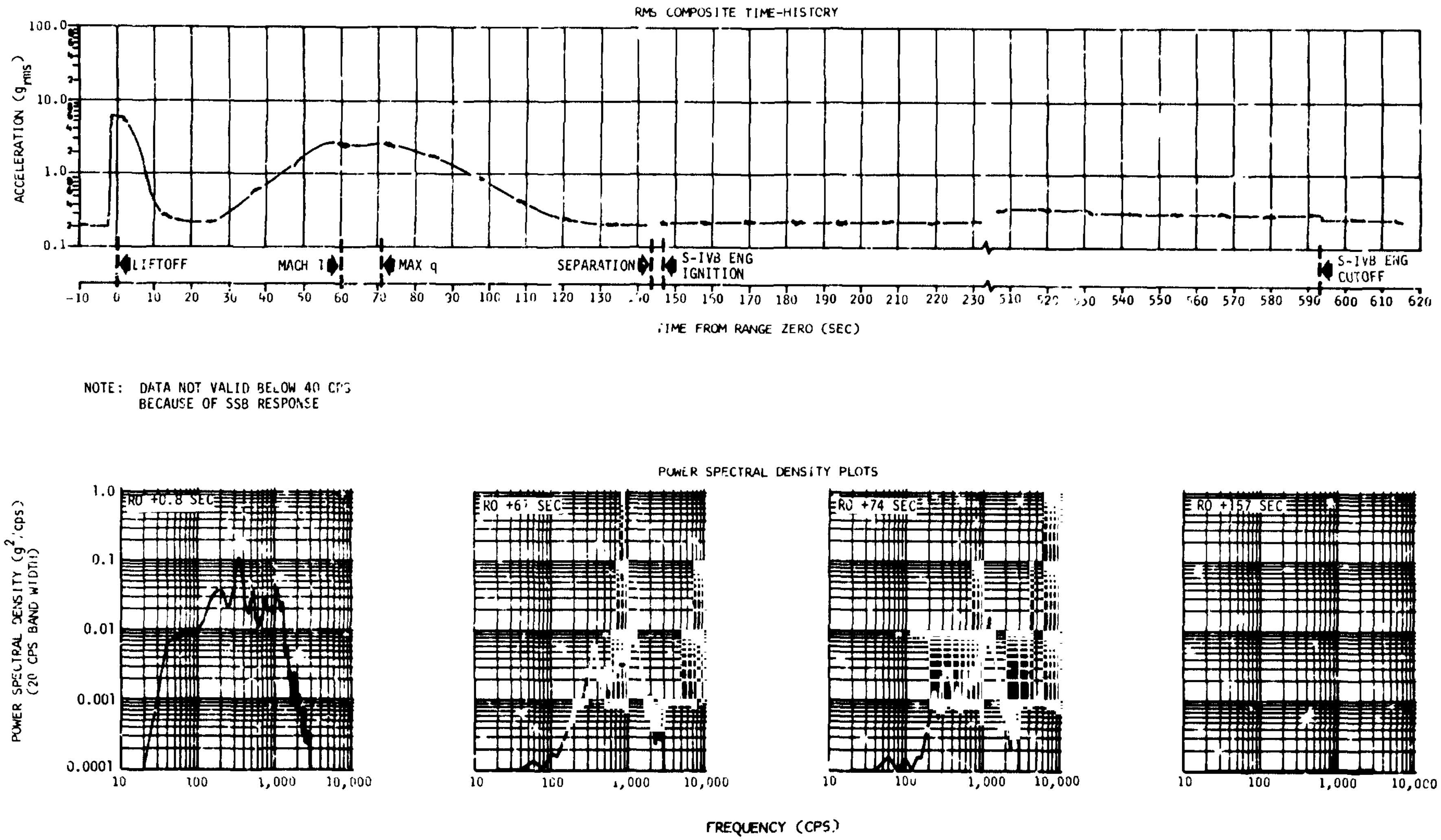


Figure 24-30. Vibration Measured on Field Splice Position II, Radial Direction (E0040-411)

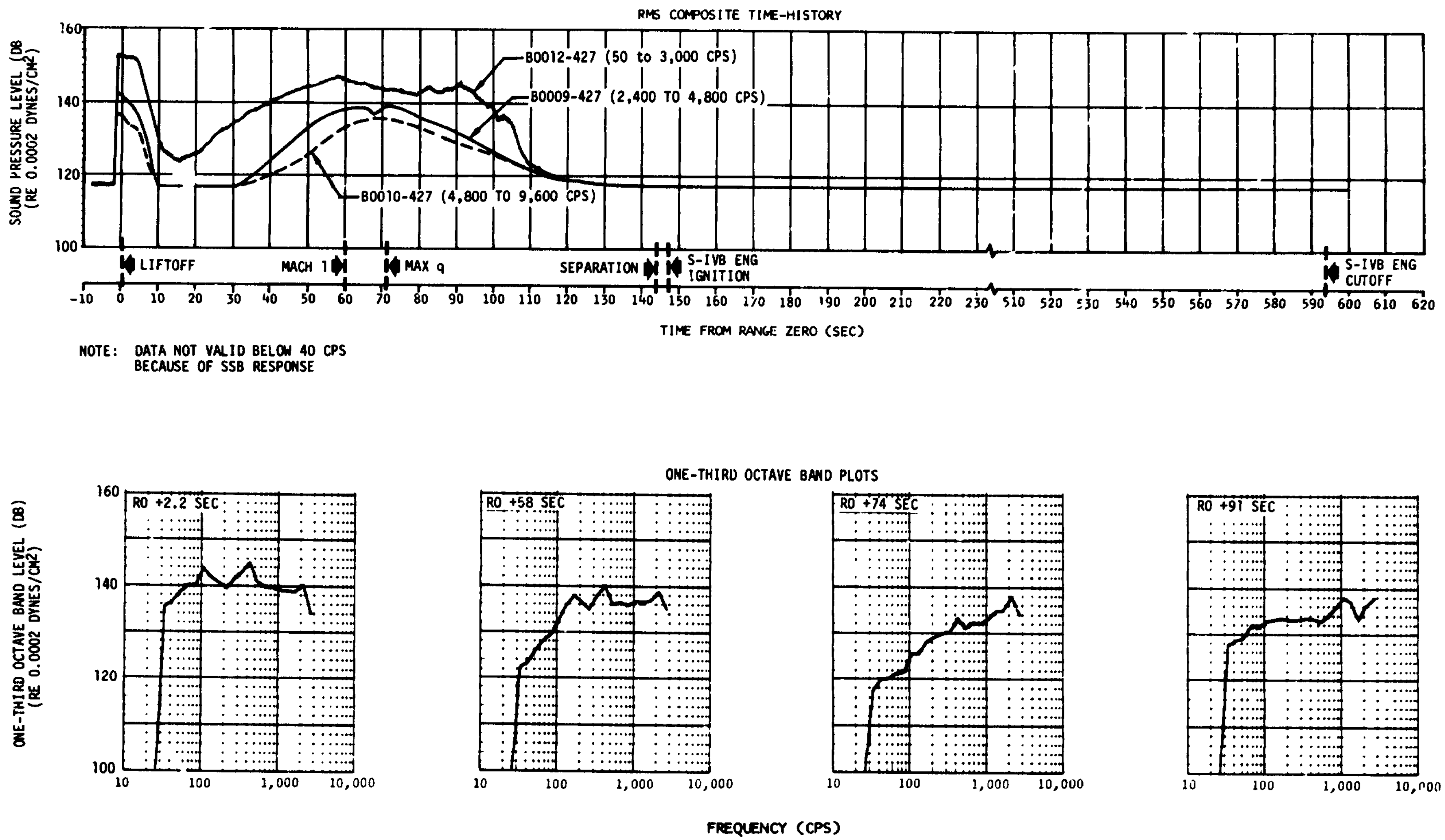


Figure 24-31. External Sound Pressure Levels Measured on Aft Skirt

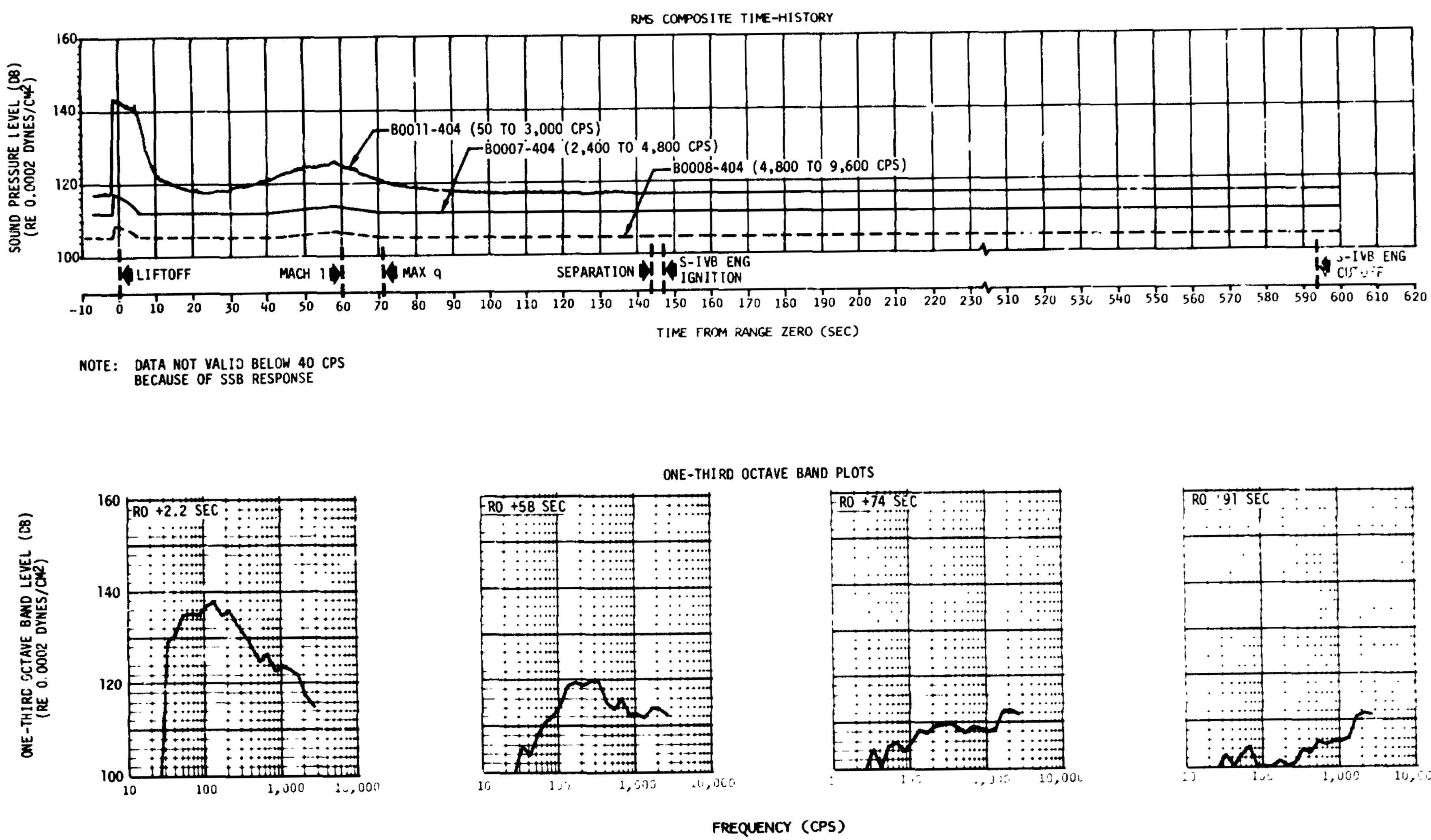


Figure 24-32. Internal Sound Pressure Levels Measured in Aft Skirt

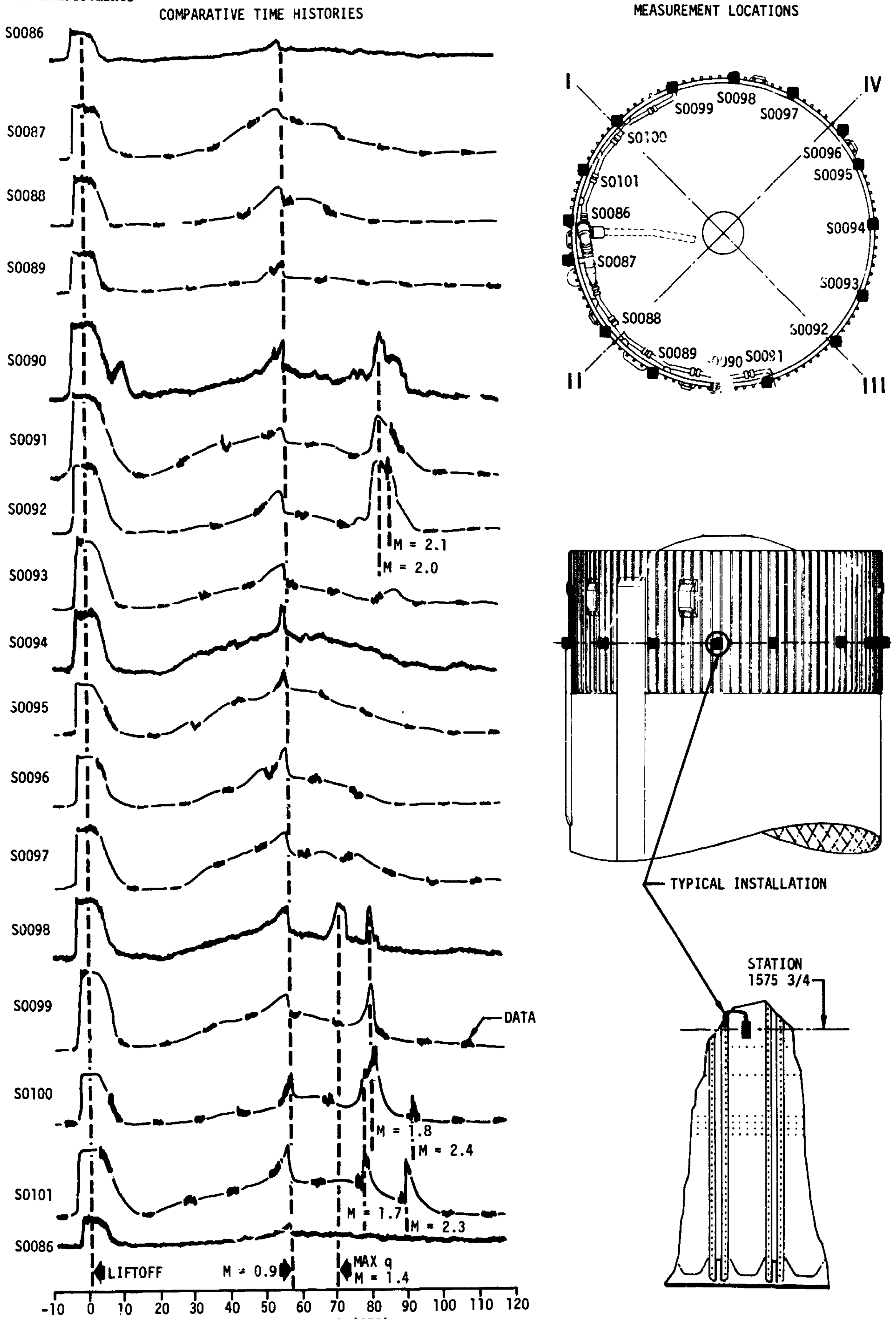


Figure 24-33. S-IVB Forward Skirt Dynamic Strains

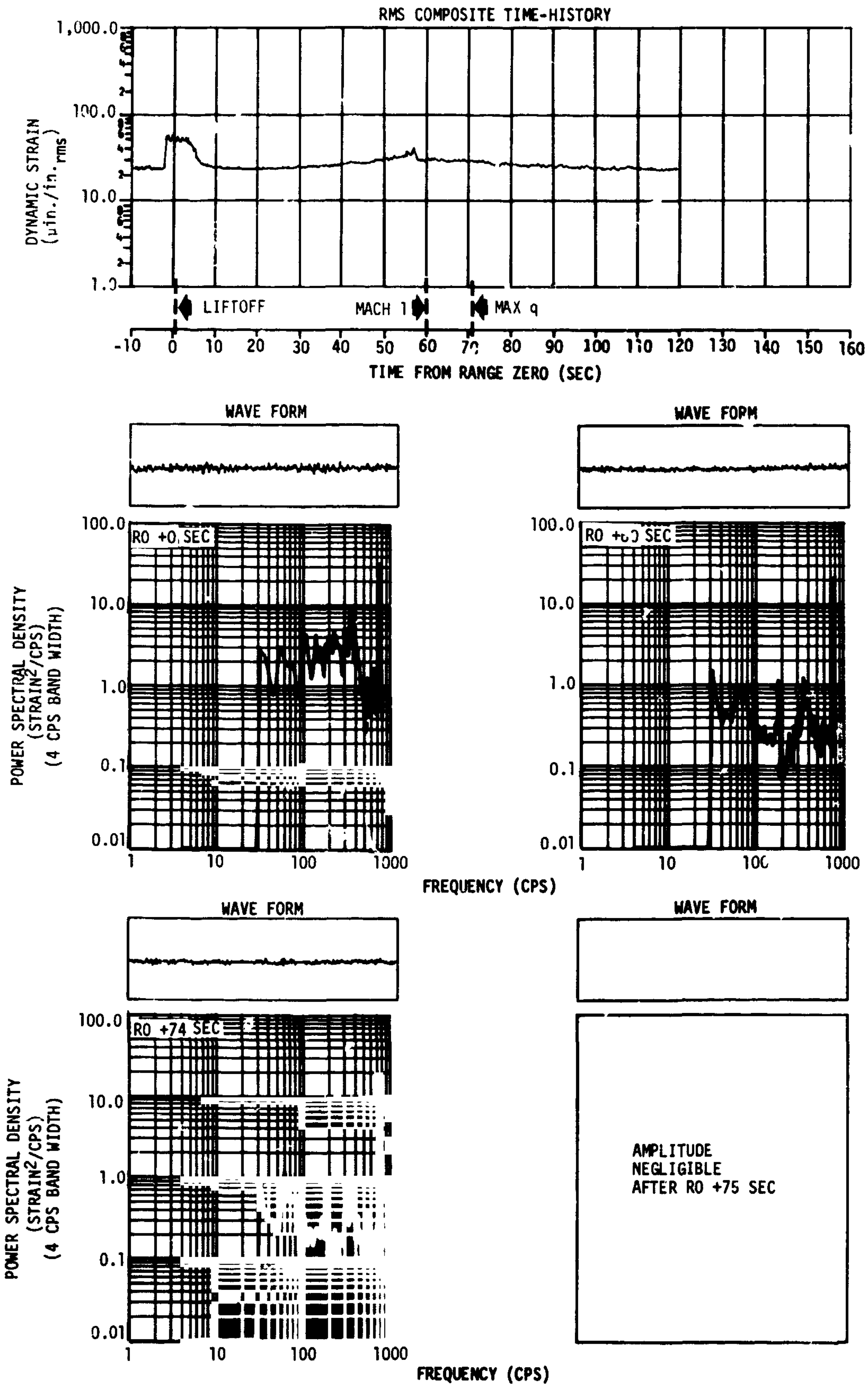


Figure 24-34. Dynamic Strain Measured on Forward Skirt Panel 13 (S0086-426)

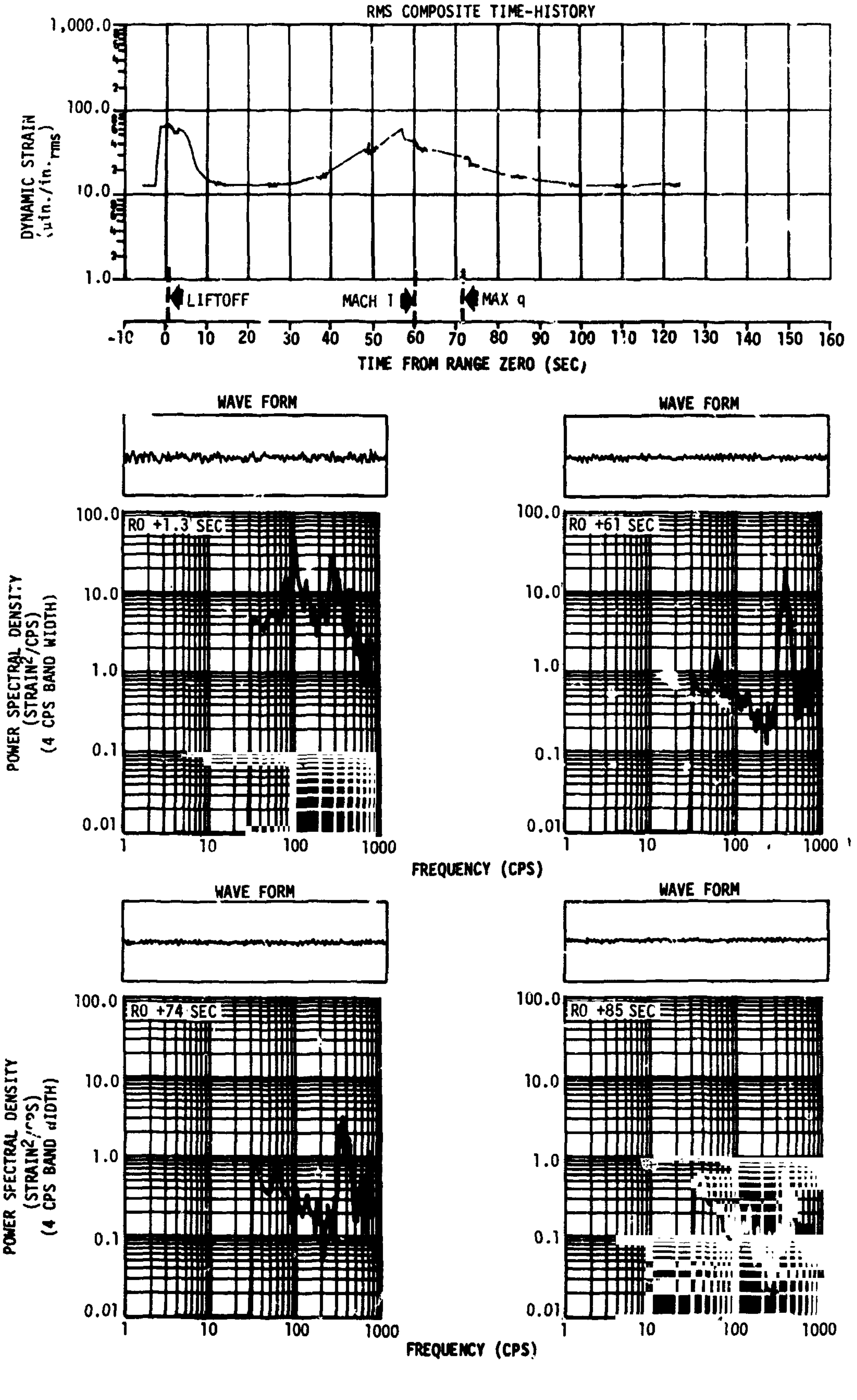


Figure 24-35. Dynamic Strain Measured on Forward Skirt Panel 17 (S0087-426)

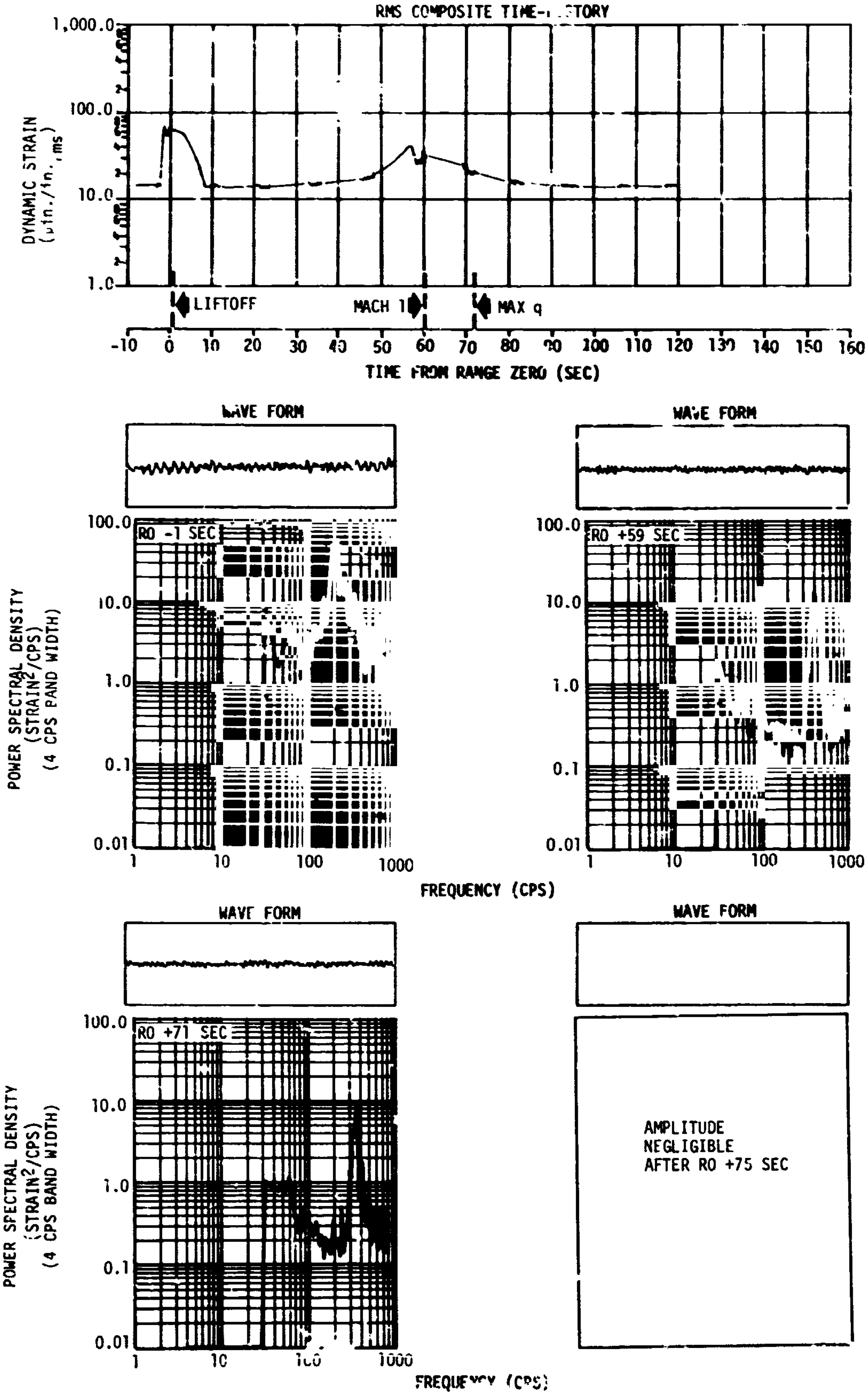


Fig re 24-36. Dynamic S ... Forward Skirt Panel 26 (S0088-426)

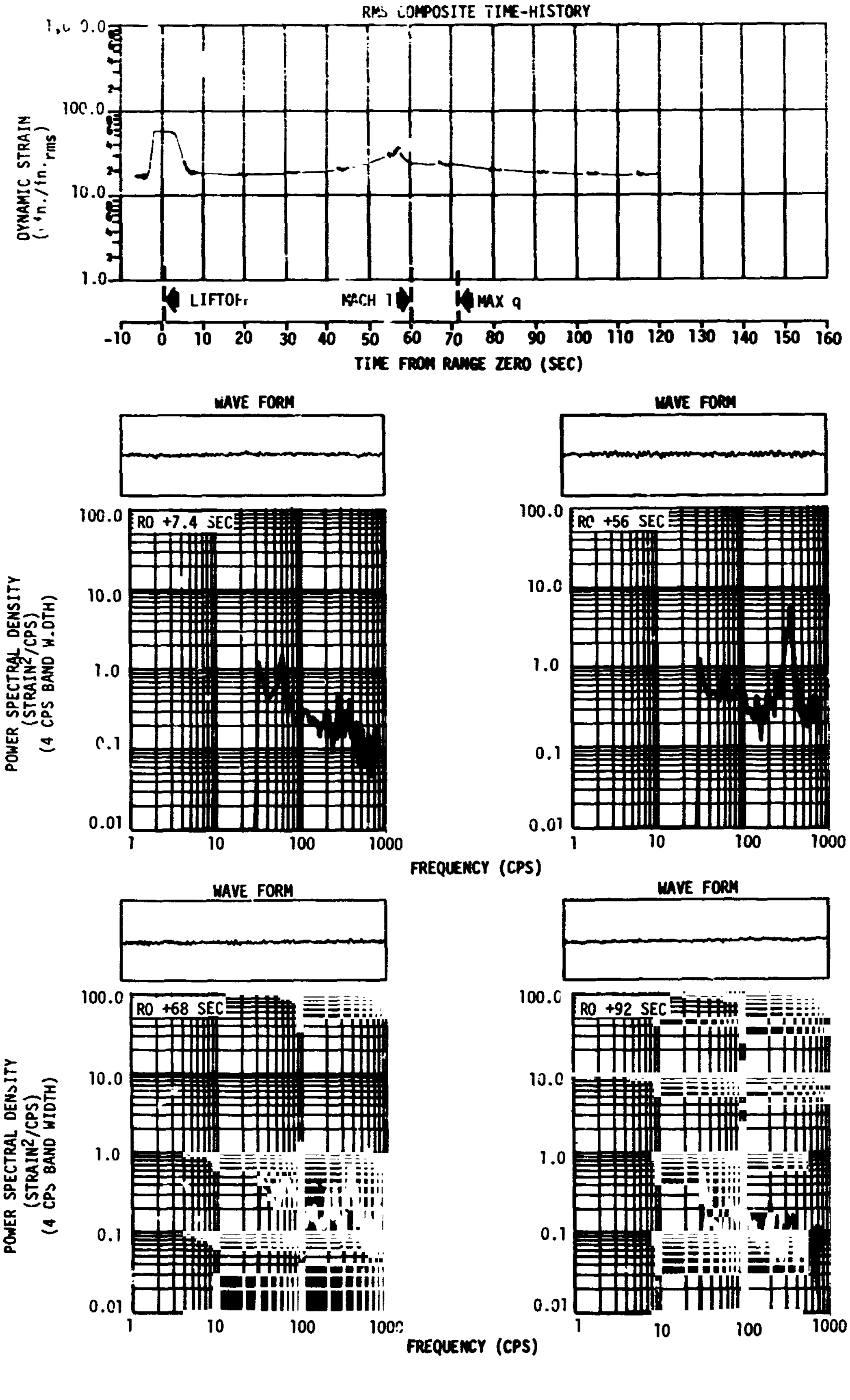


Figure 24-37. Dynamic Strain Measured on Forward Skirt Panel 33 (S0089-426)

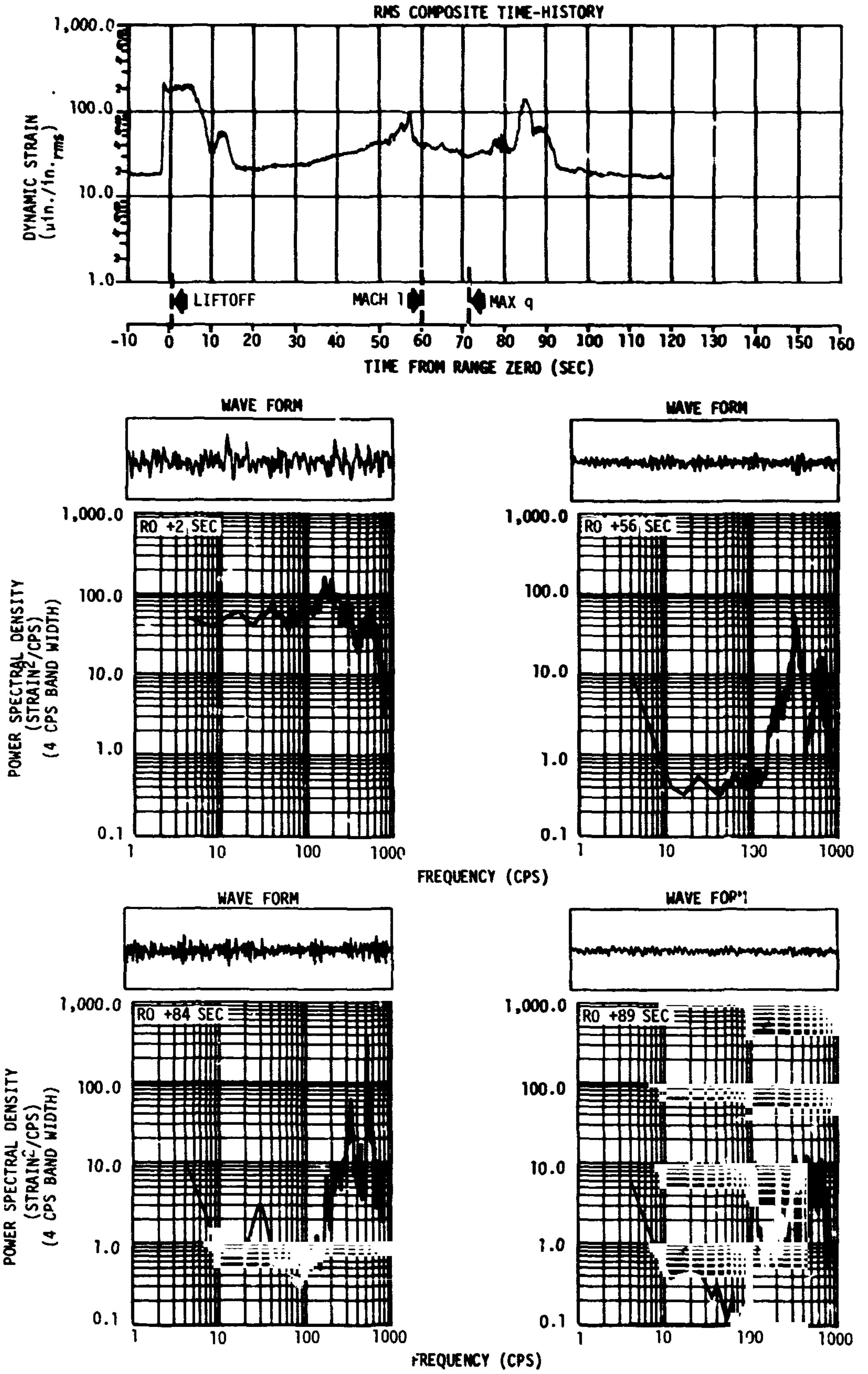


Figure 24-38. Dynamic Strain Measured on Forward Skirt Panel 40 (S0090-426)

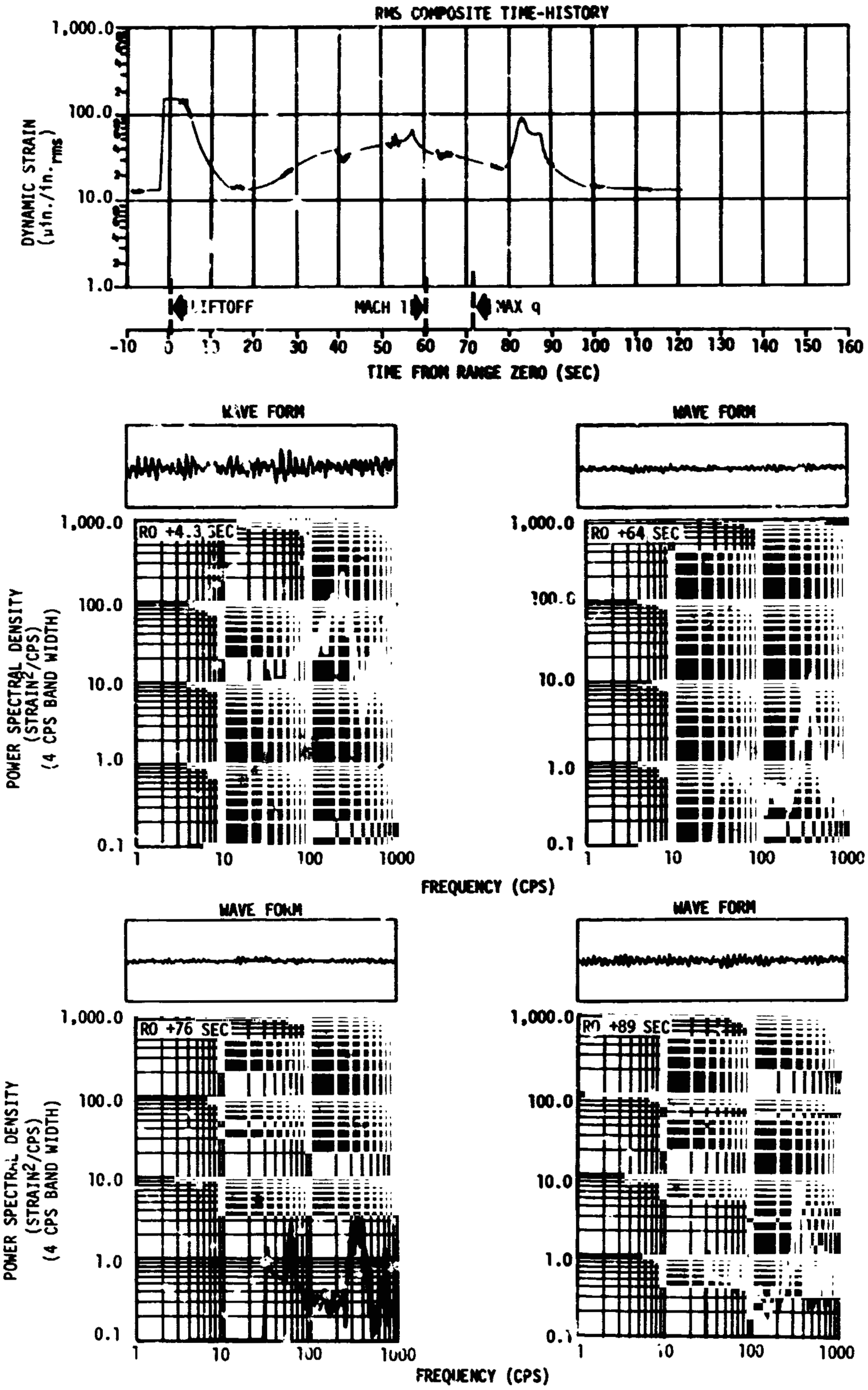


Figure 24-39. Dynamic Strain Measured on Forward Skirt Panel 46 (S0091-426)

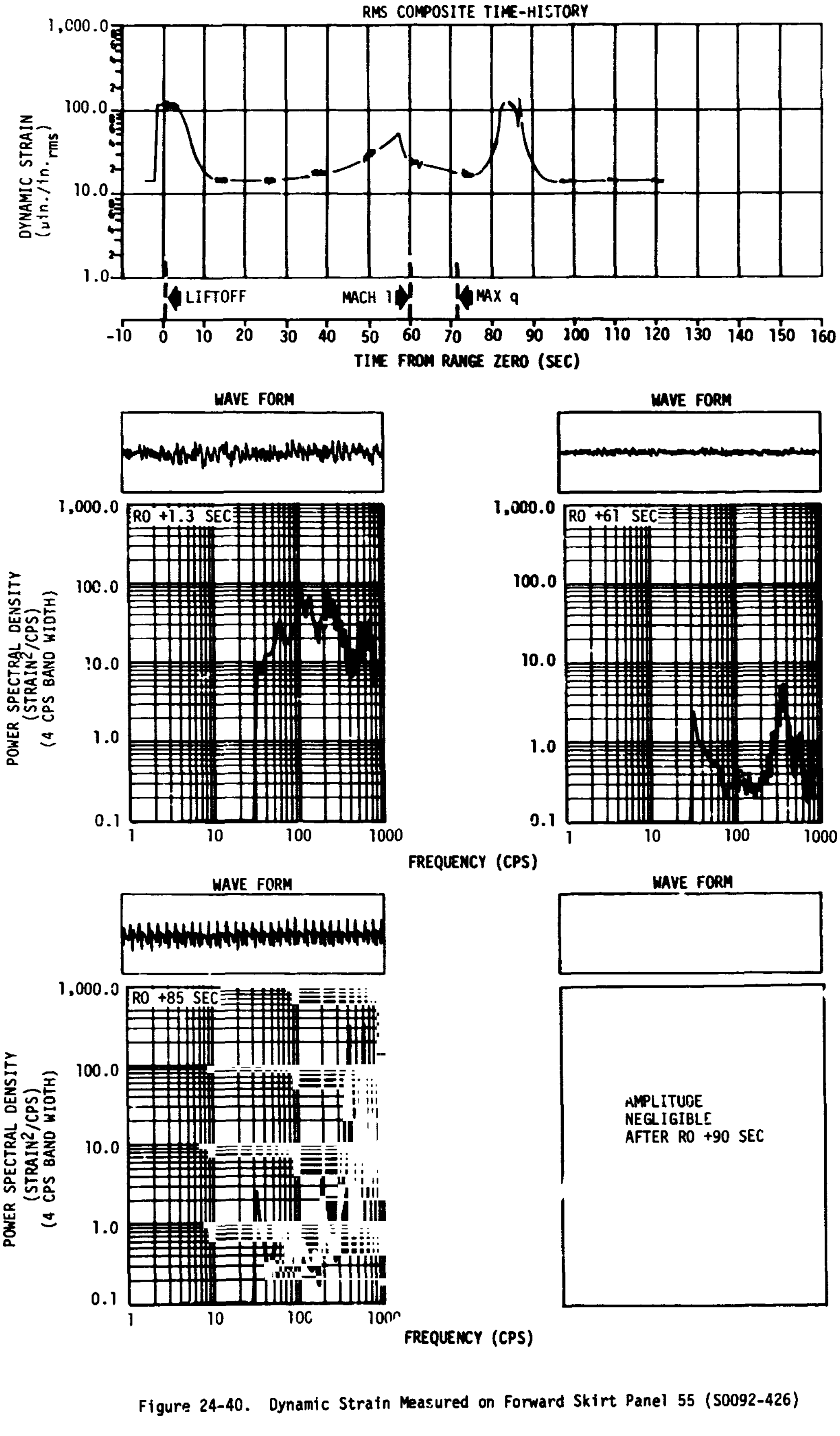


Figure 24-40. Dynamic Strain Measured on Forward Skirt Panel 55 (S0092-426)

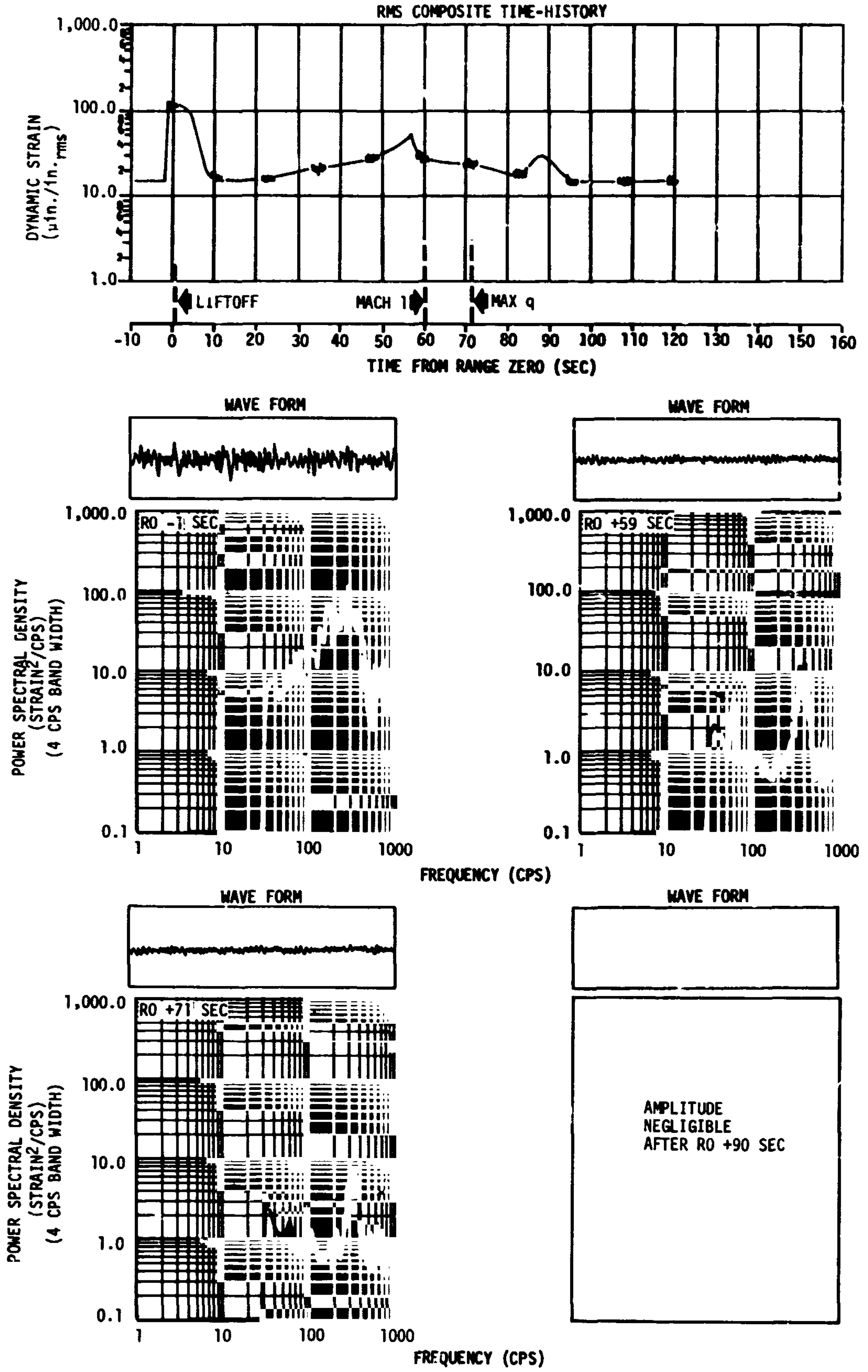


Figure 24-41. Dynamic Strain Measured on Forward Skirt Panel 61 (S0093-426)

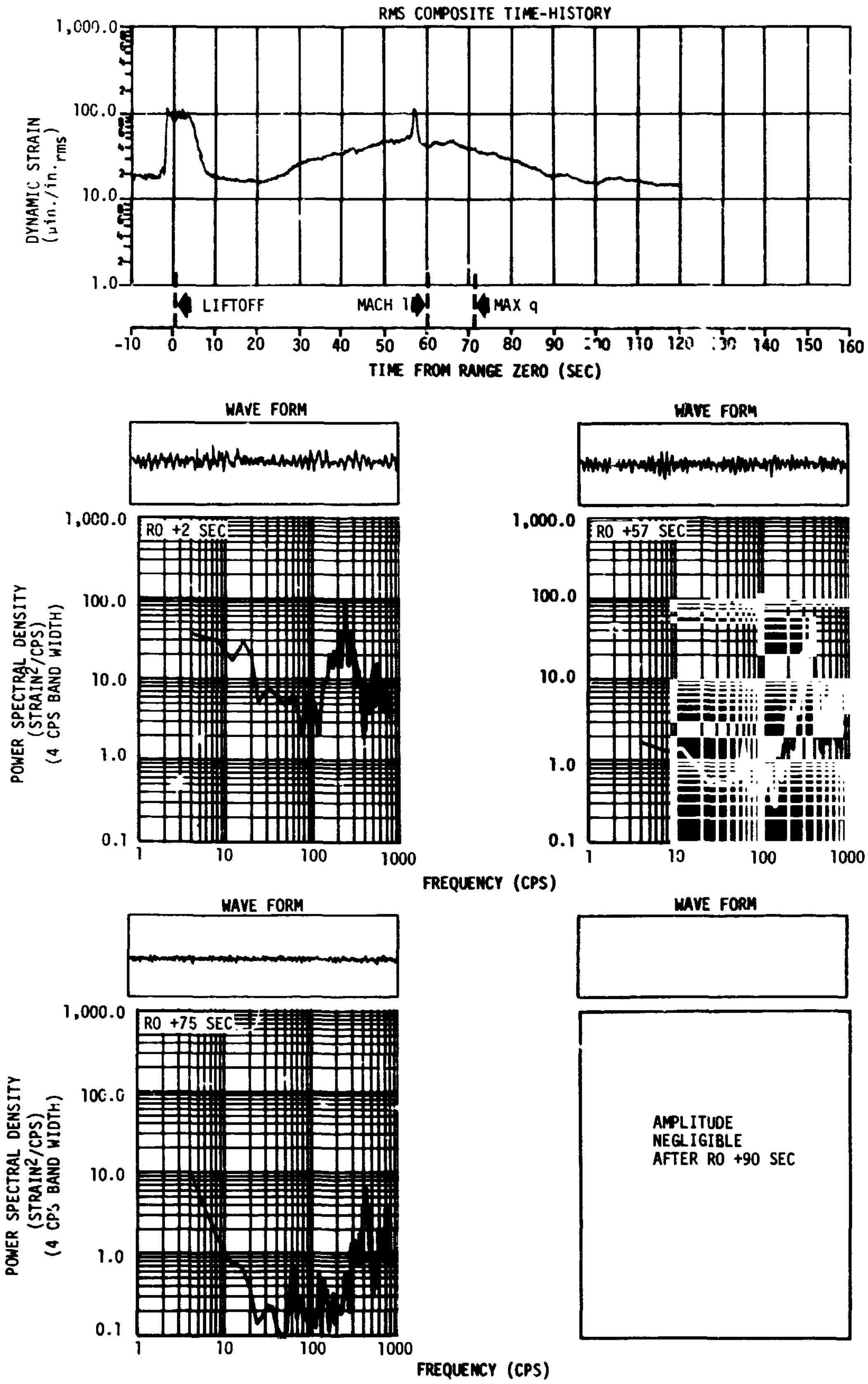


Figure 24-42. Dynamic Strain Measured on Forward Skirt Panel 69 (S0094-426)

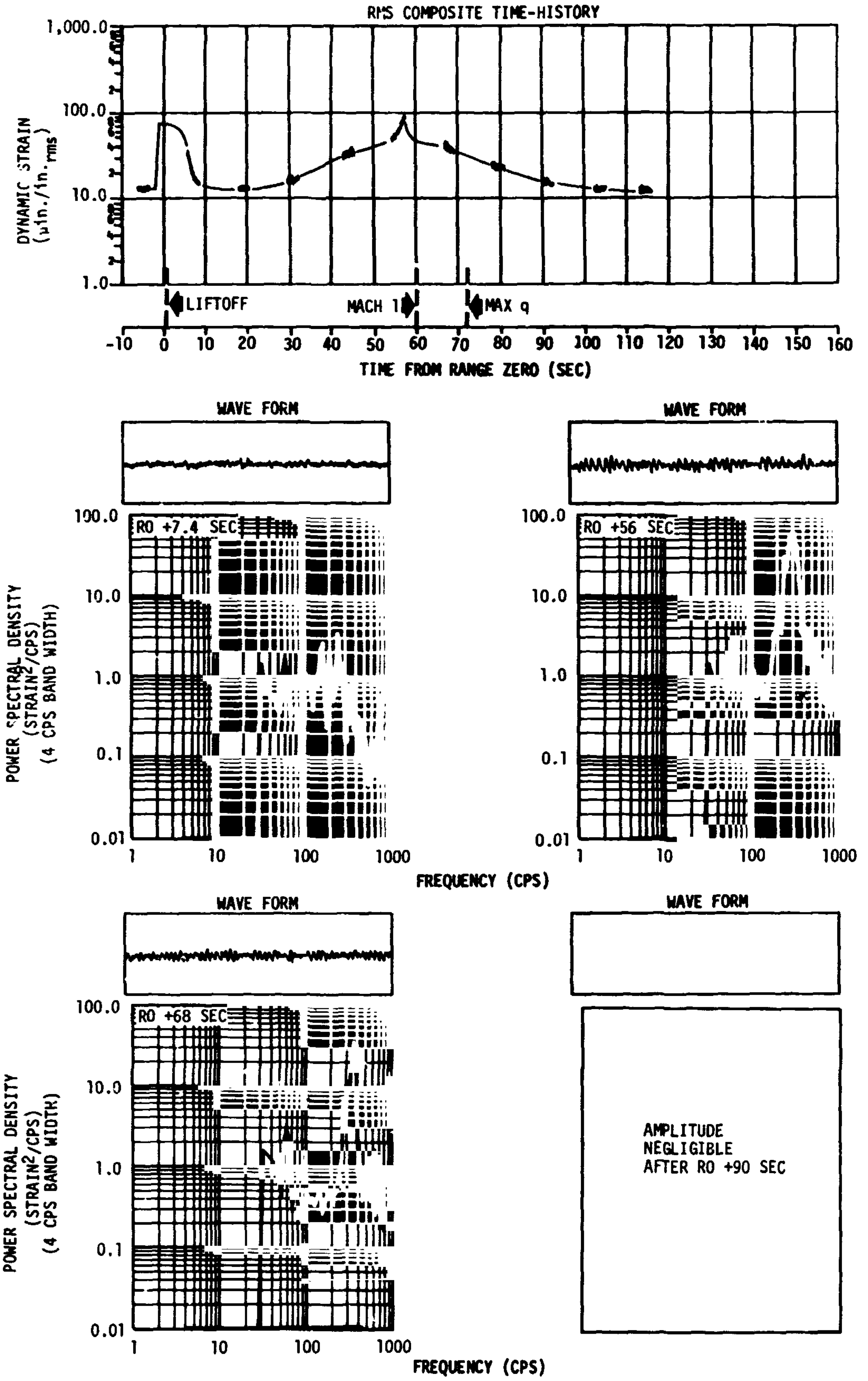


Figure 24-43. Dynamic Strain Measured on Forward Skirt Panel 76 (S0095-426)

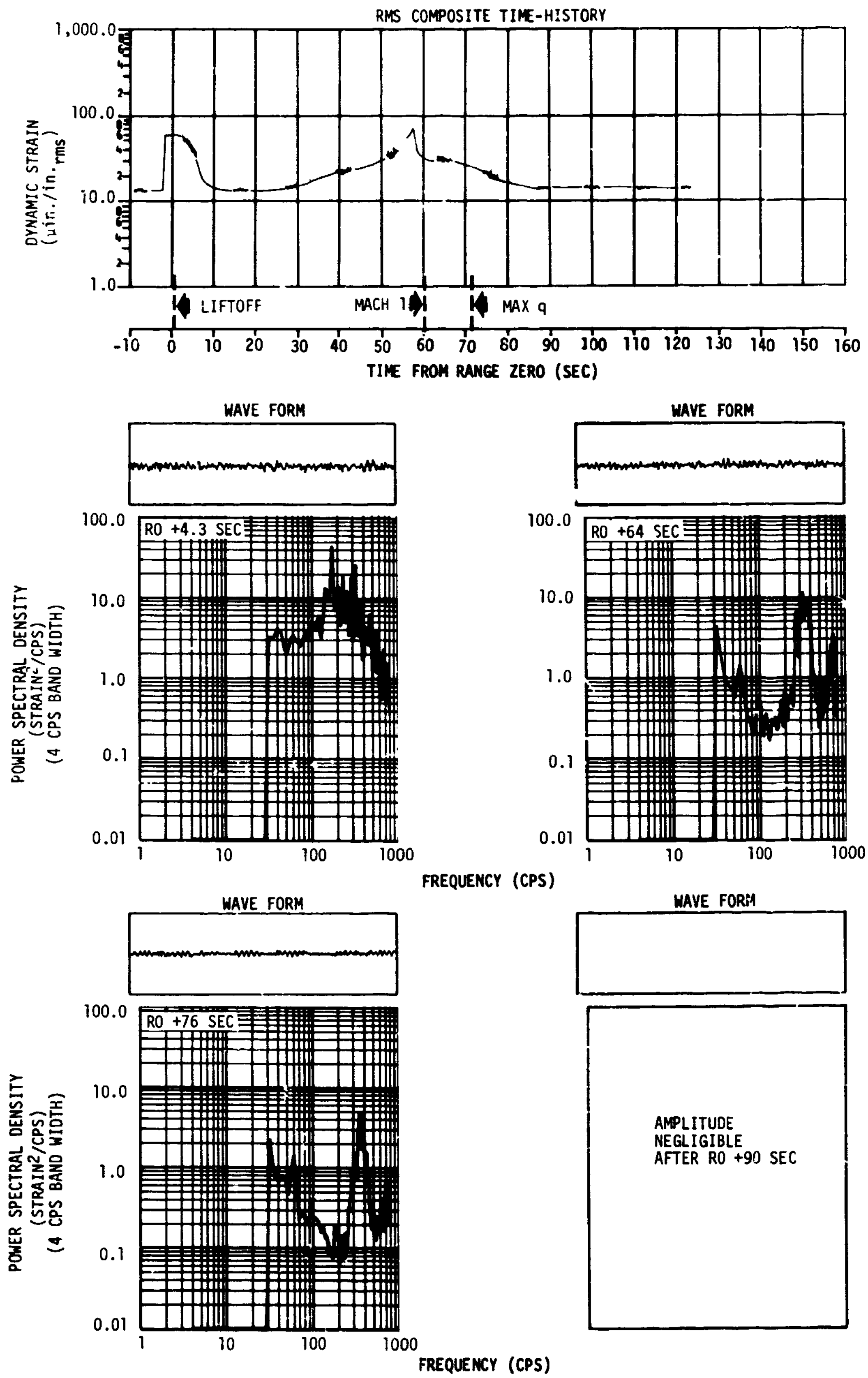


Figure 24-44. Dynamic Strain Measured on Forward Skirt Panel 80 (S0096-426)

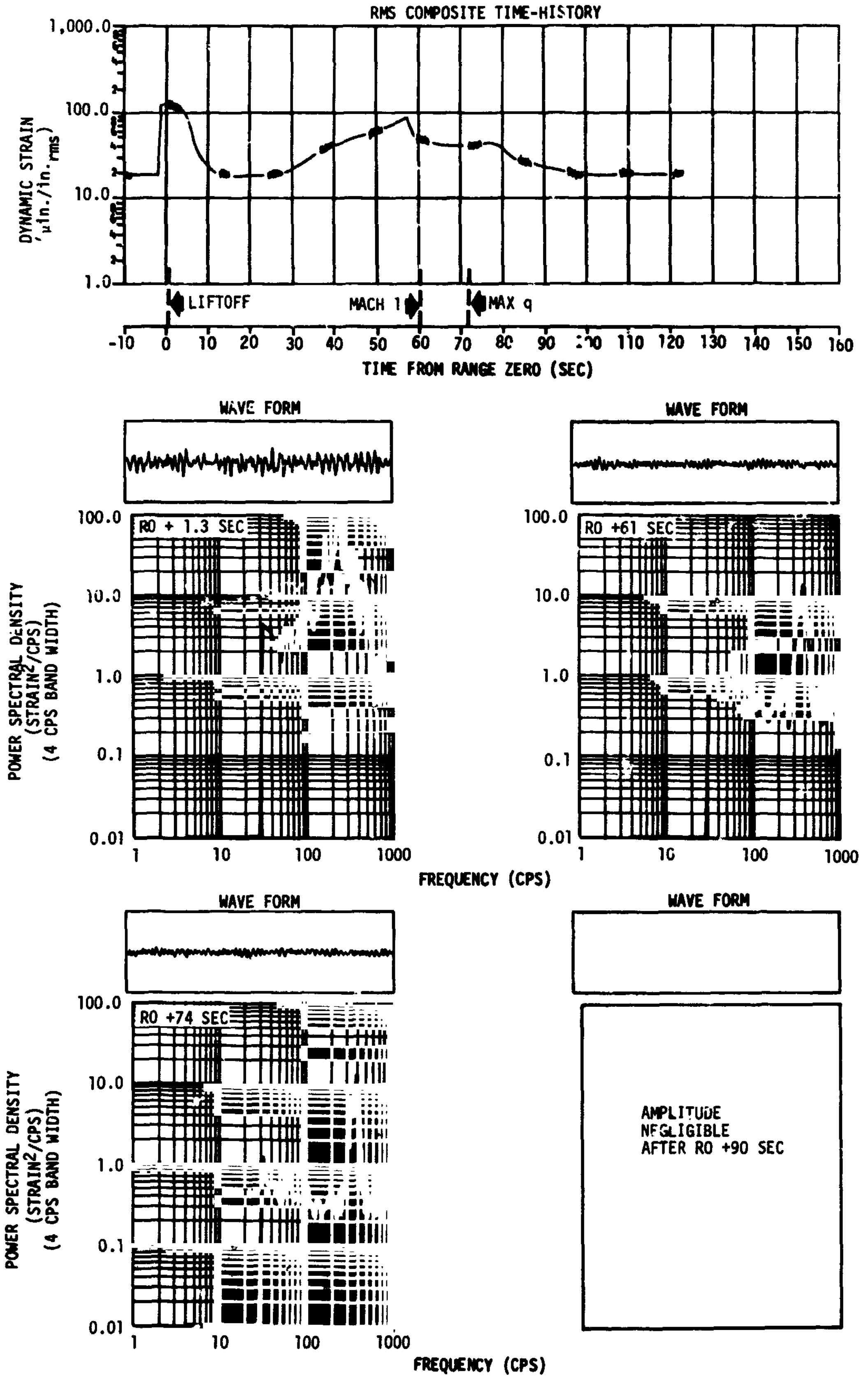


Figure 24-45. Dynamic Strain Measured on Forward Skirt Panel 87 (S0097-426)

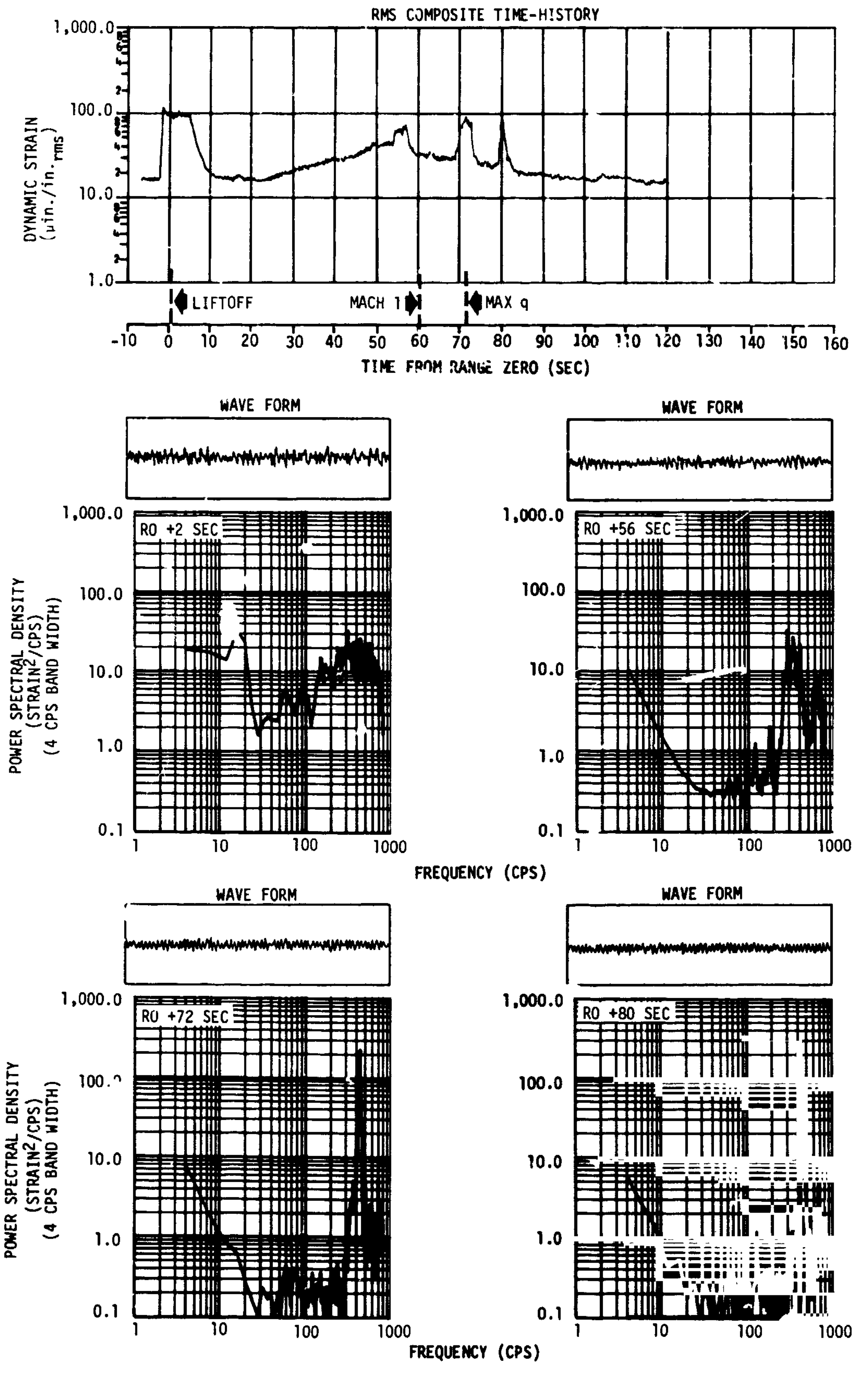


Figure 24-46. Dynamic Strain Measured on Forward Skirt Panel 94 (S0098-426)

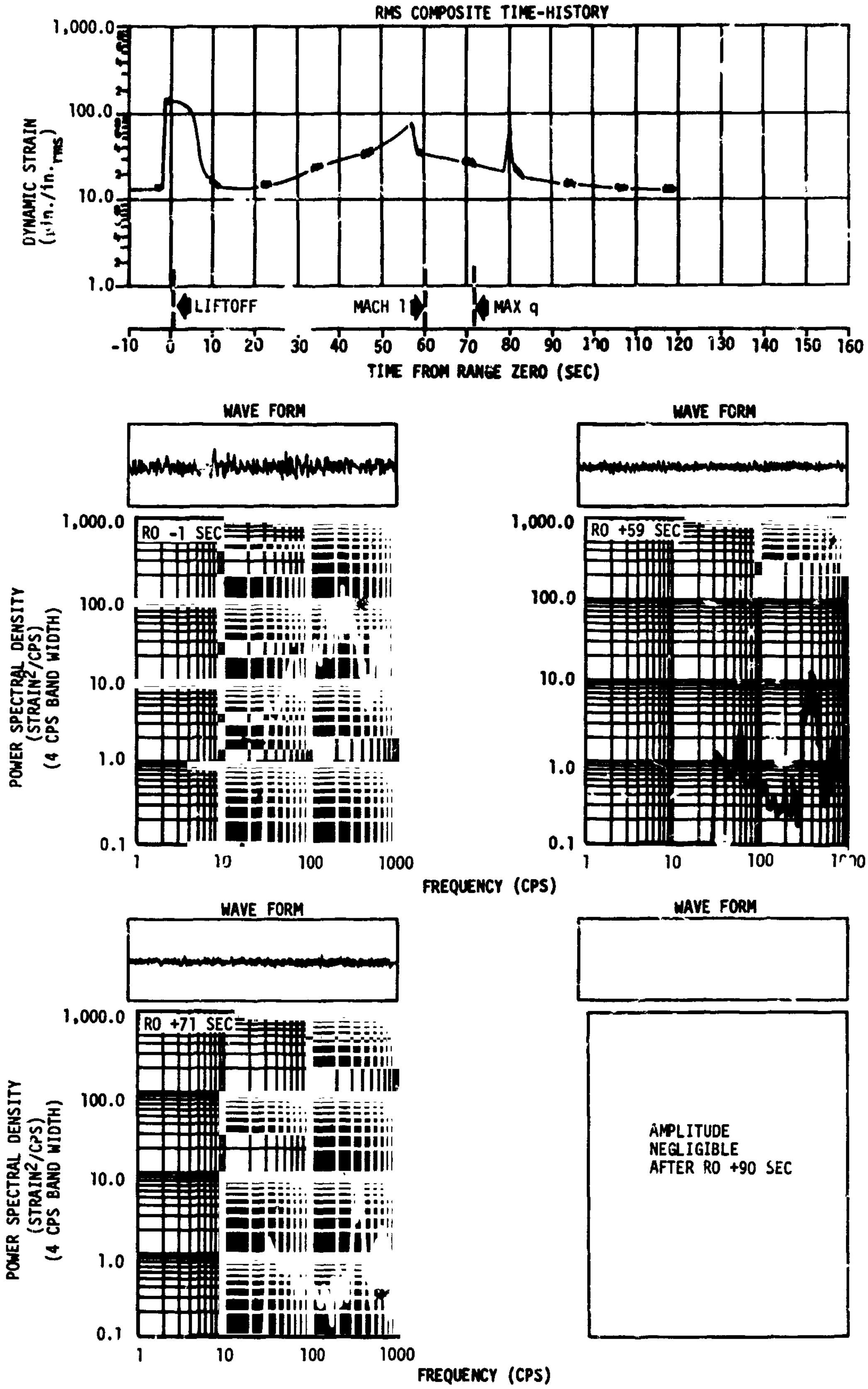


Figure 24-47. Dynamic Strain Measured on Forward Skirt Panel 101 (S0099-426)

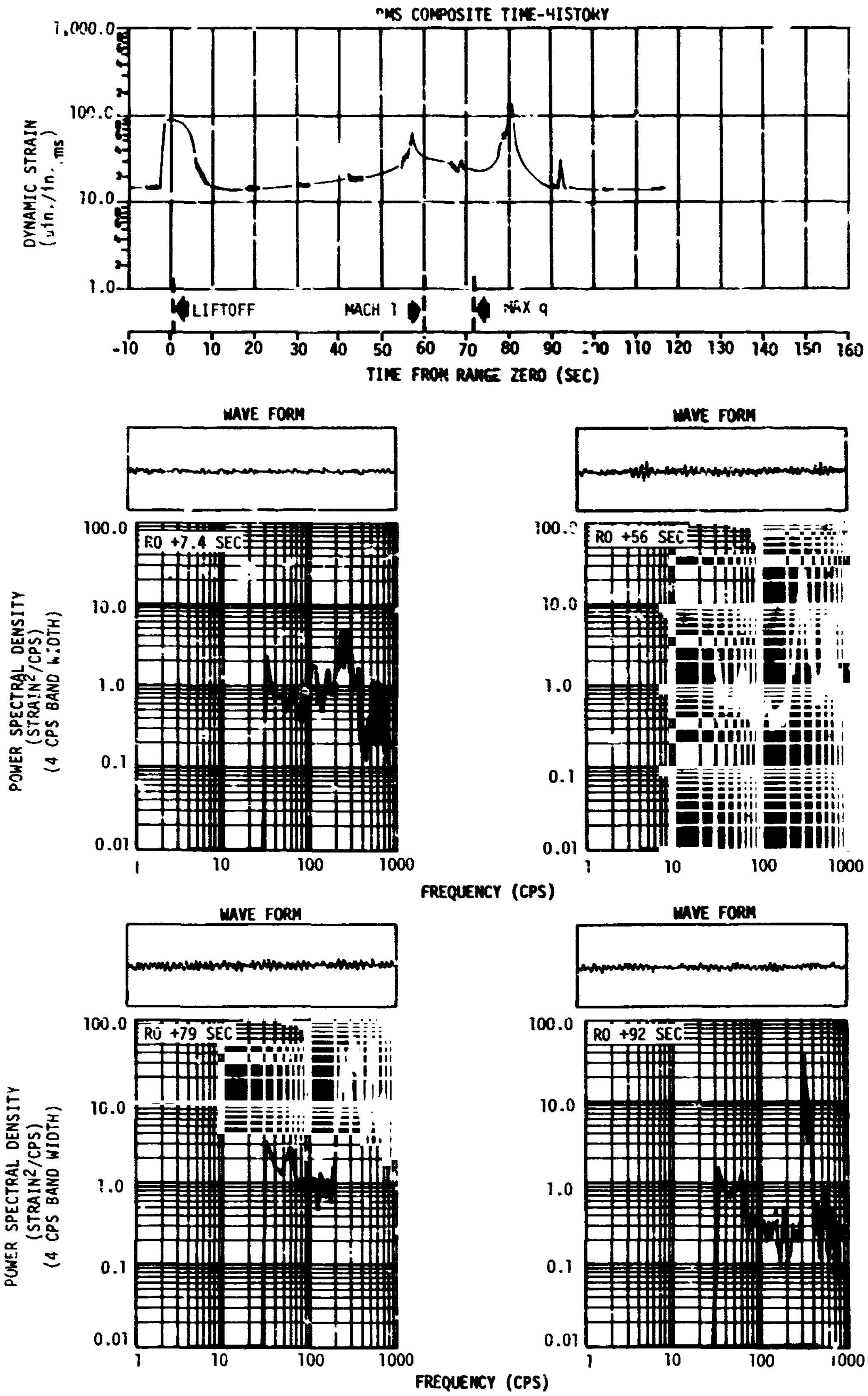


Figure 24-48. Dynamic Strain Measured on Forward Skirt Panel 108 (S0100-426)

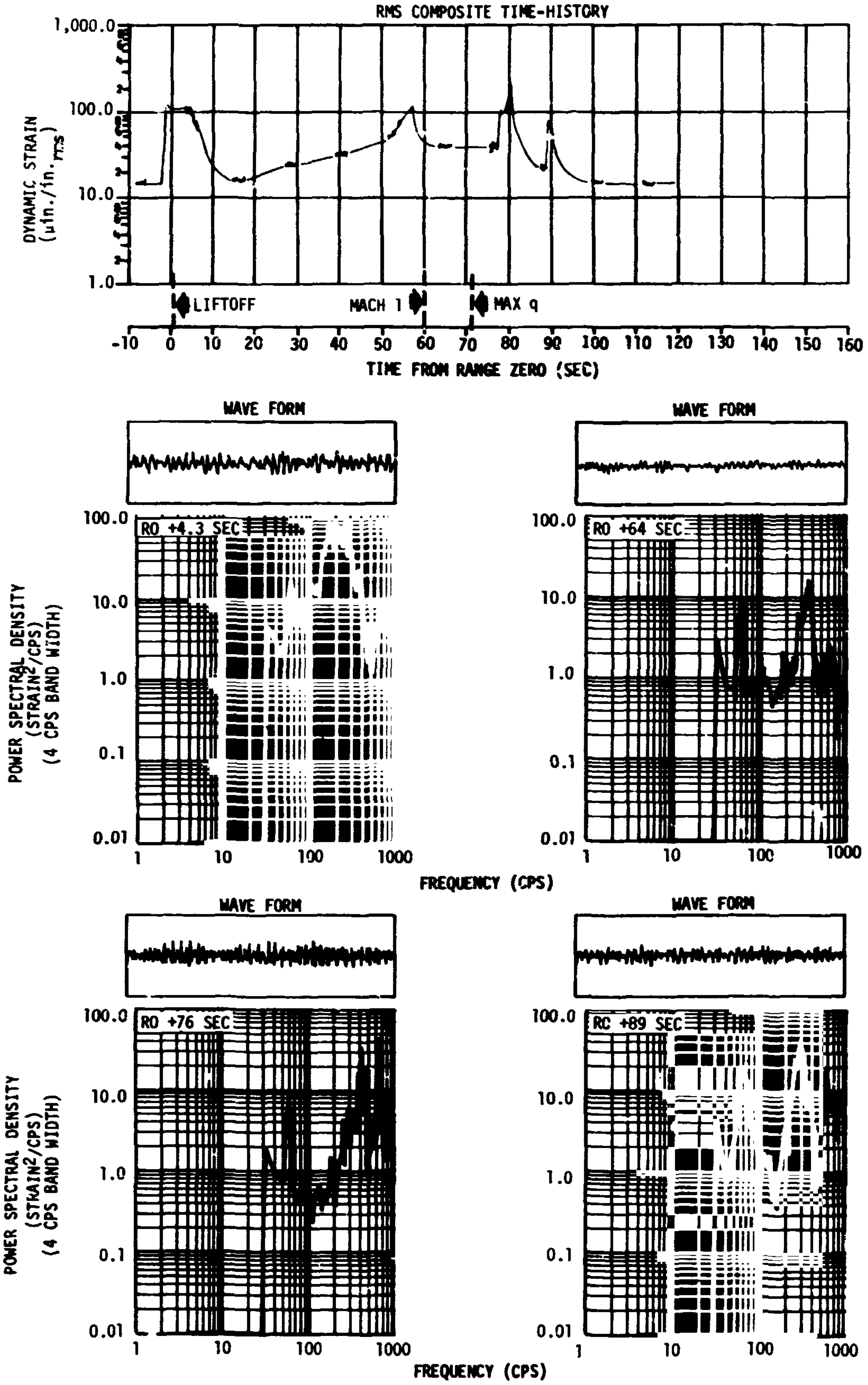


Figure 24-49. Dynamic Strain Measured on Forward Skirt Panel 7 (S0101-426)

SECTION 25

AERO/THERMODYNAMIC ENVIRONMENT

25. AERO/THERMODYNAMIC ENVIRONMENT

The aero/thermodynamic instrumentation consisted of pressure transducers to measure external pressure distribution and internal compartment pressures, and temperature transducers to measure structural temperatures, selected component temperatures, and propellant heating. In general, the data were within stage design limits and the measurement objectives were satisfactorily accomplished.

25.1 Aerodynamic Pressure Environment

Figure 25-1 shows the locations of the S-IVB-204 aerodynamic pressure measurements. Figures 25-2 through 25-25 present comparisons between analytical or wind tunnel data and flight data for the forward skirt, aft skirt, interstage, and the APS and LH2 feedline fairings. Flight data are generally in good agreement with the analytical and wind tunnel data for zero angle-of-attack (α). This is as expected since the angle-of-attack during boost was less than 2 deg.

25.1.1 Forward Skirt

Figures 25-2 through 25-5 present a comparison of the flight data (reduced to coefficient form based on the flight ambient pressure and mach number) and wind tunnel pressure coefficient data from Chrysler Corporation Space Division TN-AP-66-112, dated October 1966. Figures 25-2 through 25-4 show good correlation between the flight and wind tunnel data. The flight data pressure coefficients, figure 25-5, appear to be high. This discrepancy was caused by the LH2 tank and skirt splice flange and was a localized high pressure area as shown in figure 25-6.

Figure 25-7 presents the predicted and measured differential pressures (internal pressure minus local external pressure). The maximum indicated bursting and crushing flight pressure differentials were 2.45 and 0.42 psi, respectively. The predicted values show 2.21 psi bursting and 0.25 psi crushing pressure differentials. The localized pressure rise around the LH2 tank and skirt splice flange was responsible for the slight crushing differential. The crushing differential tapers off to zero approximately 10 in. forward of the flange and appears to be uniform both circumferentially and longitudinally; therefore, no design problem is indicated (reference paragraph 22.2.5). Without this pressure rise, no crushing pressure would be present. Peak values for the flight bursting differentials occur before the predicted values. Since the pressure coefficient dependency on mach number was verified by flight data (figure 25-2 through 25-4), this apparent time shift is attributed to the difference between the actual flight trajectory and the predicted trajectory. Figure 25-8 illustrates the effect that the difference between the preflight and flight trajectory had on the forward compartment internal pressure. The data presented in this figure (internal pressure minus freestream pressure) illustrate that the difference in freestream pressure between two trajectories does not account for the burntime pressure occurring early and falling out of the predicted band. This indicates that the difference between the preflight and flight mach number histories is the cause of the time shift of the peak bursting pressure.

25.1.2 Aft Skirt and Interstage

Figures 25-9 through 25-11 present the pressure coefficient comparison for the aft skirt and interstage. The flight and predicted values compare favorably except for measurement D0120. This measurement location between the LH2 feedline fairing and the APS on the aft skirt, apparently measured the pressure changes brought about by the flow disturbances introduced by these two protuberances; however, the data appear to be good. Two of the three measurements located at vehicle sta 994 (D0122 and D0124) did not appear to function properly. D0122 was marked as a failure since it did not respond as expected. D0124 measured high throughout most of the flight which was not consistent with the trends set by the rest of the aft skirt and interstage data.

Figure 25-12 presents a comparison of the predicted and the measured differential pressures (internal pressure minus local external pressure). The maximum indicated bursting differential pressure was 1.2 psi and the crushing differential pressure was 0.05 psi. Predicted values were 1.2 psi and 0 psi bursting and crushing differentials, respectively.

The flight and predicted values showed good correlation. Figure 25-13 is a comparison between the predicted and flight internal pressure minus freestream pressure. The values also show good correlation within the design load time period (RO +40 to RO +80 sec).

25.1.3 Auxiliary Propulsion System

Figures 25-14 through 25-17 present a comparison of the predicted and measured pressure differentials (internal pressure from the aft skirt and interstage region minus the local pressure over the APS fairing). The comparison shows good correlation on the cylindrical portion of the APS. The predicted values are generally conservative on the nose fairing. A comparison between the predicted and measured APS base pressures, figure 25-18, also shows good correlation.

25.1.4 LH2 Feedline Fairing

Figures 25-19 through 25-25 present a comparison of the predicted and actual differential pressures acting on the LH2 feedline fairing. The measured differentials were calculated in the manner described for the APS. The figures show that the analytically predicted differential pressures are generally conservative.

25.2 Thermodynamic Structural Heating Environment

Locations of temperature measurements on the AS-204 exterior structure are shown in figure 25-26. All structural temperature measurements performed satisfactorily during flight. There were 21 temperature measurements on the structure; one on the forward skirt (C0081), eight on the liquid hydrogen tank (C0075 through C0080, C0106 and C0107), nine on the aft skirt (C0178 through C0185 and C0045), and three on the APS fairing (C0224 through C0226).

All recorded structural temperatures were well below design temperatures as was expected from the relatively cool trajectory flown. Liftoff and maximum struc tural temperatures taken from the data are tabulated in table 25-1.

Analytical simulations of the temperature data were based on the actual flight trajectory, boundary layer transition from turbulent to laminar at the time $T_W/T_{AW} = 0.5$, and a Reynolds analogy factor of 0.833. The flow was assumed to pass initially through a conical bow shock. Air flow on the forward skirt was determined by the Prandtl-Meyer relationships. All other areas were based on a pressure coefficient of zero.

Atmospheric properties were determined from meteorological data taken at the time of launch.

Heating rates on the surface surrounding the APS (C0178 through C0185) were simulated by using aerodynamic heating rates which were 50 percent greater than that experienced in undisturbed regions of the stage (h/ho = 1.5). This value corresponds to the value used in the design analysis of these areas.

The flight data presented were obtained from PCM digital plots. The simulated temperatures agreed reasonably well with the data. However, the temperatures simulated during the subsonic portion of the flight did not show the drop that was experienced by most of the measurements. All previous Saturn IB flight data exhibited a similar cooling trend from RO +10 to RO +60 sec which was not duplicated by analytical simulation.

25.2.1 Forward Skirt

The temperature history of the measurement located on the forward skirt (C0081) is given in figure 25-27.

Temperature simulation was made using a three dimensional heat transfer model. The heat transfer coefficients were based on flow determined by Prandtl-Meyer relationships and boundary layer transition at the time when $T_W/T_{AW} = 0.5$. Maximum temperature of 609 deg R occurred at RO +130 sec. The temperature declined after RO +130 sec until stage separation (RO +146 sec) when retrorocket impingement produced approximately 10 deg R rise in temperature. The simulated maximum temperature was approximately 40 deg R higher than the data.

25.2.2 LH2 Tank

There were eight temperature measurements on the LH2 tank external surface. All of the indicated temperatures at liftoff were between 300 and 375 deg R (figure 25-28). The temperatures never exceeded 505 deg R during boost. The analytical simulations were programmed to start with the same temperature distributions as the sensors (assuming thermal equilibrium conditions). Temperature simulations were somewhat higher (25 to 35 deg R) than the data.

25.2.3 Aft Skirt

There were nine temperature measurements on the aft skirt. All measurements were located in regions where the structure was covered with 0.010 in. Korotherm. Figure 25-27 shows the temperature history of measurement C0045 which was located in a protuberance heating area, h/ho = 1.5 and under 0.010 in. Korotherm. The peak sensor temperature was 582 deg R and the simulation was approximately 30 deg R higher. Figures 25-29 and 25-30 show temperature histories for measurements (C0178 through C0185) located near the APS fairings. Two measurements, located on each side of both APS fairings, were staggered stationwise to be in alignment with the roll rocket-engine centerlines. The measurements nearest the skirt/interstage junction (C0178, C0180, C0182 and C0184) were in the immediate vicinity of an internal frame which acted as a heat sink so that the temperatures measured were relatively low. Measurements furthest forward (C0179, C0181, C0183 and C0185) were thermally removed from any frames. Measurements (C0178 through C0181) nearest the APS fairings showed maximum temperatures 15 to 20 deg R higher than those (C0182 through C0185) located an additional stringer away, as expected. Temperature simulations of the measurements adjacent to the APS fairings were made using a constant protuberance heating factor, h/ho = 1.5. This assumption was also used in deriving temperatures for design.

Peak temperatures adjacent to the APS fairings ranged from 572 to 605 deg R. The peak simulated temperatures were very close for the measurements (C0178 through C0181) located nearest the APS fairings. Simulations were based on the design heating factor of h/ho = 1.5 and did not attempt to account for the decrease in h/ho away from the fairings.

Sensors around the APS were installed on the skin next to one of the stringer legs resulting in lower indicated skin temperature than would be experienced if the measurements were equally spaced between the stringers. No attempt was made to simulate the temperature rise due to retrorocket impingement.

25.2.4 APS Fairing

All three temperature measurements on the APS fairing started at approximately 535 deg R, figure 25-31. Measurement C0225, located on the centerline of the centerbody just aft of the nose radius, provided the highest temperature during AS-204 boost flight, 632 deg R. The maximum temperatures of C0225 and C0226 (570 and 567 deg R respectively) were substantially lower than C0225 because there was more internal structure in the vicinity of the transducer. Temperature simulation of C0225 does not indicate the response rate shown by the flight data between RO +80 and RO +160 sec; however, the peak temperature agrees well with the data. The simulated temperature responses of C0224 and C0226 were consistently 15 to 20 deg R higher than the data.

25.3 Thermodynamic Component Heating Environment

25.3.1 Auxiliary Propulsion System Orbital Temperatures

Orbital temperatures for the APS were determined by ten measurements (C0258 through C0267) mounted internally on various components, on the propellant transfer lines, and on the fairing. The allowable operational limits for the APS propellants and components are 480 deg R minimum and 585 deg R maximum.

Table 25-2 lists the highest and lowest recorded temperatures during the first three orbits for all internally mounted sensors. All recorded temperatures were within allowable values.

Figure 25-32 shows the data from all three fairing measurements (C0224, C0225 and C0226) superimposed on the analytically predicted maximum and minimum values used for APS design. All flight data fall within the analytical values.

Two measurements were selected for correlation based on flight parameters. C0225 mounted internally on the outboard (top) portion of the fairing along the APS centerline was selected to verify that the external fairing surface optical properties remained within their expected range, figure 25-33, and C0260, figure 25-34, located on the main oxidizer transfer line near the rear support bracket was selected since this region was one of the critical thermal areas during the design phase of the APS. Flight data for both measurements, C0225 and C0260, compare fairly well with the analytically predicted values.

25.3.2 Forward and Aft Skirt Components

The following is an evaluation of the S-IVB-204 component heating flight data.

a. All data monitored throughout the flight for the bridge modules, propellant utilization and static inverter assemblies, chill-down inverters and batteries appear to be valid.

b. All component temperatures were within acceptable limits during the first three orbits. The temperature of the LOX chill-down inverter, C0139, equaled its low temperature limit of 470 deg R at approximately RO +15,800 sec.

c. The ground hold temperatures of the aft skirt components ranged from 15 to 50 deg R cooler than those monitored on S-IVB-501 as a result of a cooler purge gas inlet temperature.

25.3.3 Bridge Modules

There were six instrumented bridge modules, three mounted on cold plates in the forward skirt of the vehicle, and three mounted on aft skirt fiberglass panels. Each module dissipated approximately 1/2 watt or less continuously throughout the flight. Temperature histories are shown in figure 25-35 for the first 20,000 sec of flight. The units mounted on the cold plates ranged from 510 to 521 deg R at liftoff and reached temperatures ranging from 518 to 528 deg R at the end of the third orbit. Three modules mounted on aft skirt panels ranged in temperature from 448 to 503 deg R at liftoff with the coldest module located on the panel furthest from the purge gas inlet manifold. At the end of the third orbit, these three modules ranged in temperature from 421 to 479 deg R. The module experiencing the coldest temperature, C0237, was located on a panel opposite a LOX dome segment not covered with aluminized mylar. These temperatures were well within the 620 to 395 deg R upper and lower temperature limits.

25.3.4 Propellant Utilization and Static Inverter-Converter Assemblies

These units were mounted on a forward skirt cold plate and operated continuously up to orbit insertion. The propellant utilization assembly dissipates approximately 36 watts, and the static inverter-converter assembly dissipates approximately 18 watts. The temperature histories are shown in figure 25-36 for the first 17,000 sec of flight. The PU and inverter assemblies were 534 deg R and 528 deg R, respectively, at liftoff and decreased to 502 deg R and 506 deg R at the end of the third orbit. The assemblies remained within the 500 to 570 deg R temperature limits throughout the flight.

25.3.5 Chilldown Inverters

The chilldown inverters were mounted on an aft fiberglass panel and were operated from approximately 600 sec prior to liftoff until approximately 150 sec after liftoff. Temperature histories are presented in figure 25-36. Prior to being energized on the ground, their temperatures were 481 to 496 deg R. They experienced temperature extremes ranging from 525 deg R when they were shut off, to 470 deg R at the end of 17,000 sec of flight. These temperatures were within the upper and lower temperature limits of 610 deg R and 470 deg R.

25.3.6 Batteries

The three batteries mounted on the forward skirt and two batteries mounted on the aft skirt of the vehicle experienced temperatures ranging from 536 to 549 deg R at liftoff. At the end of the third orbit the batteries ranged in temperature from 536 to 617 deg R. The temperatures experienced by the batteries during the flight are presented in figure 25-37 and were within the acceptable limits of 525 and 625 deg R.

25.4 Thermodynamic Propellant Heating Environment

25.4.1 Boost Flight

The net heat transferred to the LH2 during boost was analytically determined using the recovery temperature and tank wall heat transfer coefficient histories based on the flight trajectory. The analysis results together with the minimum and maximum design values are shown in figure 25-38. Initial LH2 tank skin temperatures from flight data were used along with the maximum values of insulation thermal conductivity (as a function of temperature) as determined from S-IVB loading and acceptance firing test data. The wetted areas were determined by using the LH2 mass history. 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. As shown, the total LH2 heating value is within the design range.

25.4.2 Orbital Flight

The LH2 and LOX tank heating rate histories during the orbital flight are presented in figures 25-39 and 25-40. The predictions are based on the actual AS-204 flight trajectory. The general assumptions used in the analyses are presented in table 25-3.

Figure 25-39 presents the LH2 tank liquid residual and ullage heating rates. The LH2 heating curve was generated assuming that the LH2 tank interior walls were fully wet until the residual in the tank was vaporized. Ullage heating is considered to be negligible when the tank walls are wet. The ullage heating curve was generated assuming that the LH2 tank interior walls were completely dry. Based on the LH2 heating rates presented, the transition from a fully wet wall to a completely dry wall condition was estimated to take place at approximately 3,000 sec from engine cutoff.

Figure 25-40 presents the LOX tank liquid residual and gas residual (oxygen and helium) heating rates. In order to determine the LOX residual heating rates, the LOX tank interior walls were assumed to be fully wet until the LOX residual was dumped. During this period the gas residual heating was considered to be negligible. The LOX residual was dumped at approximately 8,000 sec from engine cutoff. Following LOX dump, the tank walls were assumed to be completely dry.

The fully wet interior walls assumption for the LH2 and LOX residual heating rates implies that the tank walls were wet often enough to maintain the internal surface essentially at the liquid cryogenic temperature. An average pressure of 2.5 psia in the LH2 and LOX tanks was used in the ullage and gas heating calculations.

TABLE 25-1
AS-204/S-IVB STRUCTURAL TEMPERATURE DATA (BOOST)

LOCATION (SENSOR NO.)	SENSOR TEMPERATURE			ESTIMATED MAXIMUM STRUCTURAL TEMPERATURE	REMARKS
	INITIAL (deg R)	MAXIMUM (deg R)	PREVIOUS MAXIMUM (deg R)		
Forward Skirt					
C0031	523	609	704 (2)	640	
LH2 Tank					
C0075	354	487	575 (2)	Same as Sensor	Aft 30° I--IV
C0076	366	485	582 (2)	Same as Sensor	Ctr 30° I--IV
C0077	372	503	582 (2)	Same as Sensor	Fwd 30° I--IV
C0078	297	485	528 (1)	Same as Sensor	Ctr on IV
C0079	297	472	515 (1)	Same as Sensor	Ctr 30° III--IV
C0080	314	485	580 (2)	Same as Sensor	Ctr on II
C0106	338	492	595 (2)	Same as Sensor	Aft 30° III--IV
C0107	338	504	598 (2)	Same as Sensor	Fwd 30° III--IV
Aft Skirt (0.01-0.015 Korotherm)					
C0045	512	582	621 (1)	Same as Sensor	
*C0178	525	575	616 (2)	Same as Sensor	L.H. Inbd APS #1
C0179	520	596	632 (1)	Same as Sensor	R.H. Inbd APS #1
*C0180	528	585	606 (2)	Same as Sensor	L.H. Inbd APS #2
C0181	517	605	630 (2)	Same as Sensor	R.H. Inbd APS #2
*C0182	522	560	590 (1)	Same as Sensor	L.H. Outbd APS #1
C0183	522	575	627 (1)	Same as Sensor	R.H. Outbd APS #1
*C0184	520	572	599 (1)	Same as Sensor	L.H. Outbd APS #2
C0185	523	585	633 (1)	Same as Sensor	R.H. Outbd APS #2
APS Fairing					
C0224	532	570	623 (2)	575	
C0225	534	632	713 (2)	650	
C0226	537	567	619 (2)	575	

*All L.H. measurements are near a frame.

(1) AS-202 uninsulated aft skirt.

(2) AS-203 only other flight with same APS measurements.

TABLE 25-2
APS COMPONENT TEMPERATURES
(MODULE II)

MEASUREMENT NO.	LOCATION	RECORDED TEMPERATURE (deg R)				TEMPERATURE LIMITS (deg R)
		AS-203		AS-204		
		MIN	MAX	MIN	MAX	
C0258	Fuel line at tank outlet	538	548	527	536	480-585
C0259	Fuel line between propellant control module and engine No. 2	525	555	536	546	480-585
C0260	Oxid line near support bracket	527	576	528	546	480-585
C0261	Oxid line between control module and engine No. 2	535	559	535	540	480-585
C0262	Oxid tank fwd hemisphere	535	564	516	570	480-585
C0263	Fuel tank constant sect	535	551	527	546	480-585
C0264	Fuel (propellant control module)	535	553	536	543	480-585
C0265	Oxidizer (propellant control module)	535	565	538	543	480-585
C0266	Fuel line between control module and engine No. 3	535	558	538	548	480-585
C0267	Oxid line between control module and engine No. 3	535	560	538	548	480-585

TABLE 25-3 (Sheet 1 of 2)
PROPELLANT HEATING ANALYSIS ASSUMPTIONS

Elliptical Orbit = 80 x 100 nm

Orbit inclination = 31.6 deg

Vehicle orientation:

Velocity vector: from 0 sec to 5,282 sec

Retrograde: 5,282 sec to 7,900 sec

Gravity Gradient: 7,900 sec to 8,950 sec

Retrograde: 8,950 sec to 15,846 sec

Forward skirt external surface

60 in. black paint: $\varepsilon = 0.9$; $\alpha = 0.9$

60 in. white paint: $\varepsilon = 0.87$; $\alpha = 0.42$

Forward dome:

External surface emissivity (ε) = 0.92 zinc chromate

Radiates to 60 deg F cold plates and equipment

Insulation (polyurethane foam) thickness - 1/2 in.

Cylindrical tank:

External surface $\varepsilon = 0.87$; $\alpha = 0.43$

Insulation (polyurethane foam) thickness = 1 in.

Aft dome:

From aft joint to sta No. 273

External surface $\varepsilon = 0.92$ (zinc chromate)

From sta 273 to sta 241

External surface $\varepsilon = 0.05$ (aluminized mylar)

External insulation = 1 in. of fiberglas

From sta 241 to sta 187

External surface $\varepsilon = 0.92$ (zinc chromate)

Below the T/S joint

External surface $\varepsilon = 0.92$ (zinc chromate)

Internal insulation (above common bulkhead): mostly 1/2 in. of polyurethane foam

TABLE 25-3 (Sheet 2 of 2)
PROPELLANT HEATING ANALYSIS ASSUMPTIONS

Aft skirt external surface:

ε = 0.9 and α = 0.9 (black paint)

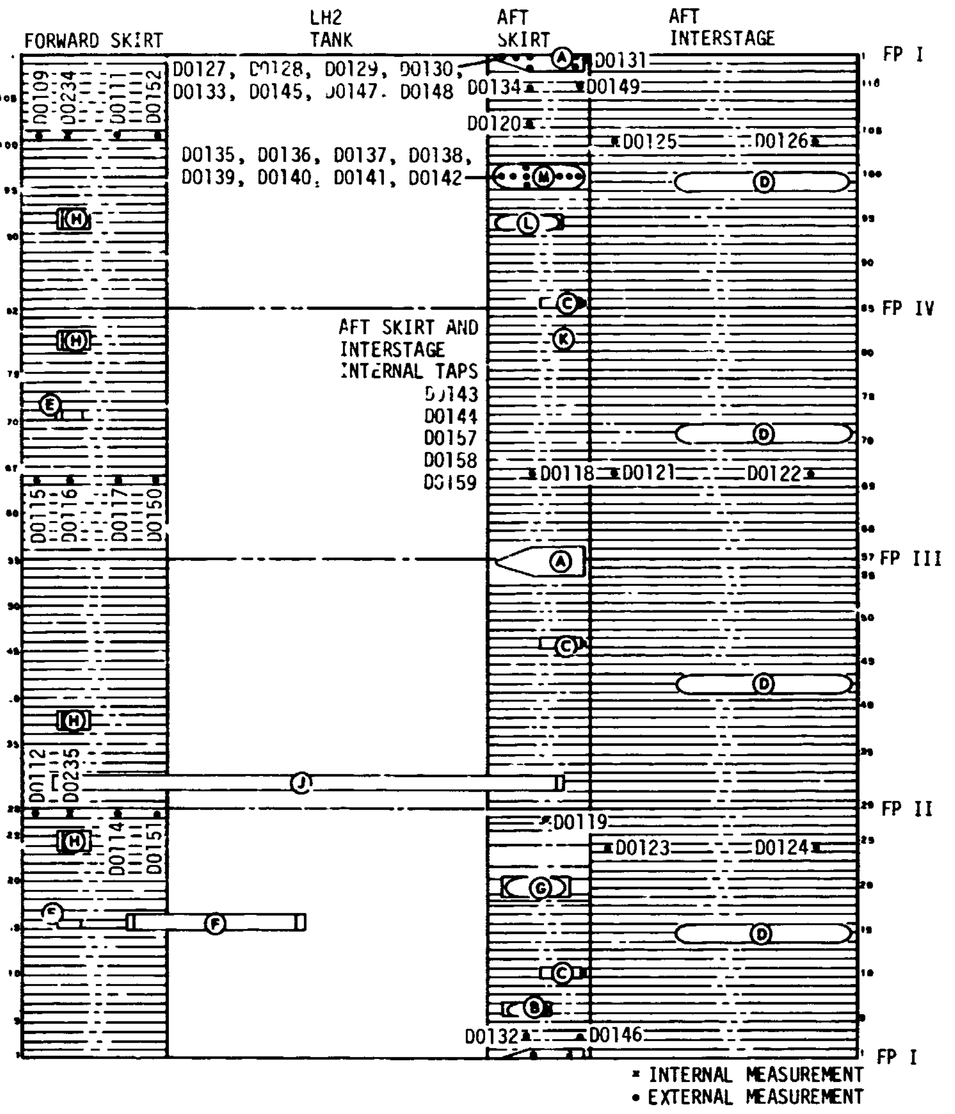
Polyurethane foam specific heat = empirical values

density = 5.2 lb/ft^3

conductivity = maximum values

LH2 and LOX tank residuals (initially)

LH2 = 1,460 lb	from Weights Section
LOX = 2,815 lb	



(A) AUXILIARY PROPULSION SYSTEM
(B) LH2 CHILLDOWN RETURN
(C) ULLAGE ROCKET
(D) RETROROCKET
(E) RANGE SAFETY ANTENNA
(F) AUXILIARY TUNNEL
(G) LH2 FILL AND DRAIN LINE
(H) TELEMETRY ANTENNA
(J) MAIN TUNNEL, M.P.U.
(K) LOX VENT
(L) LH2 CHILLDOWN PUMP
(M) LH2 FEED LINE

Figure 25-1. Pressure Measurement Locations

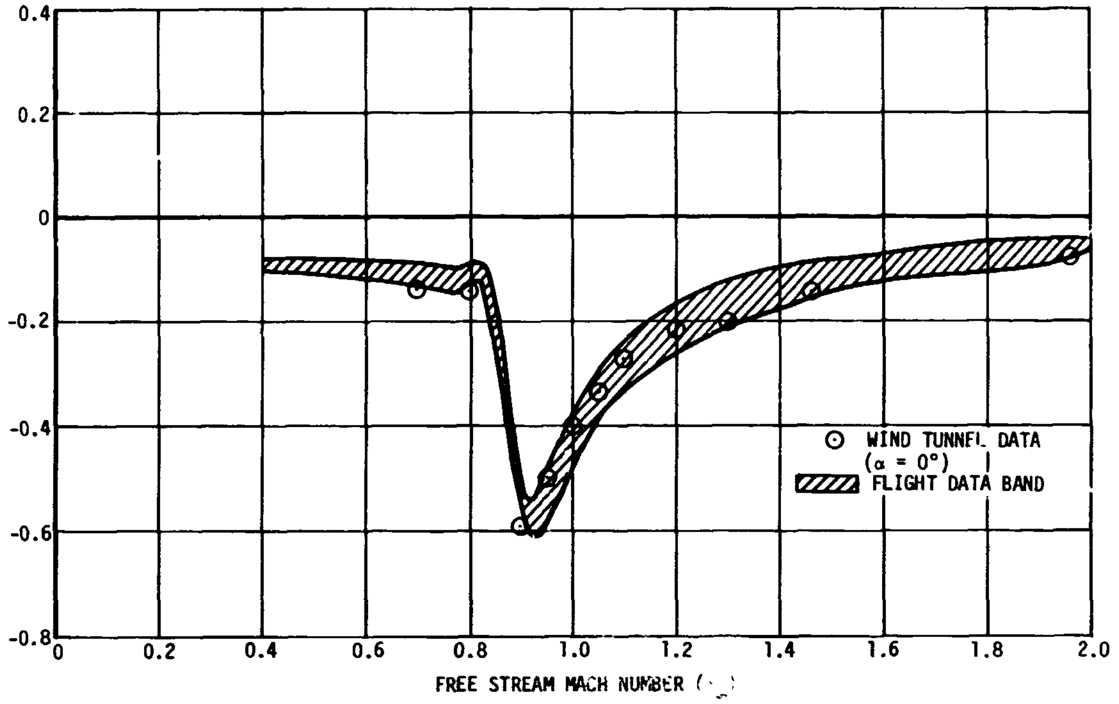


Figure 25-2. Forward Skirt Local Pressure Coefficients-Vehicle Station 1653

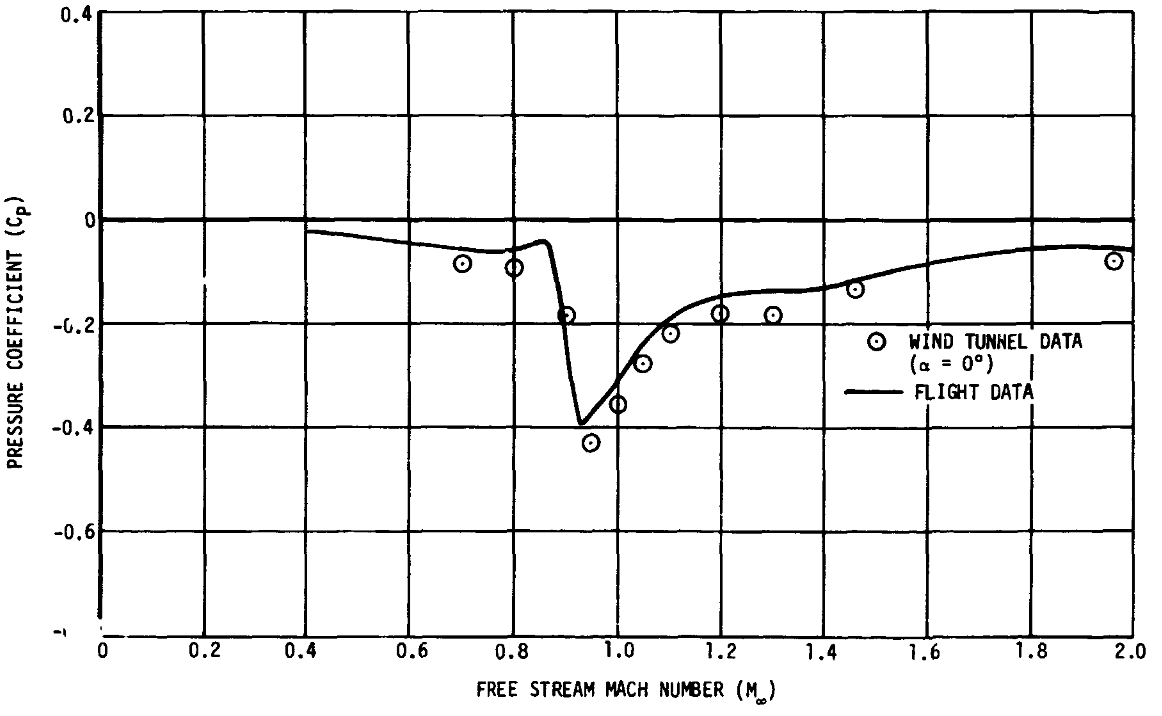


Figure 25-3. Forward Skirt Local Pressure Coefficients-Vehicle Station 1618

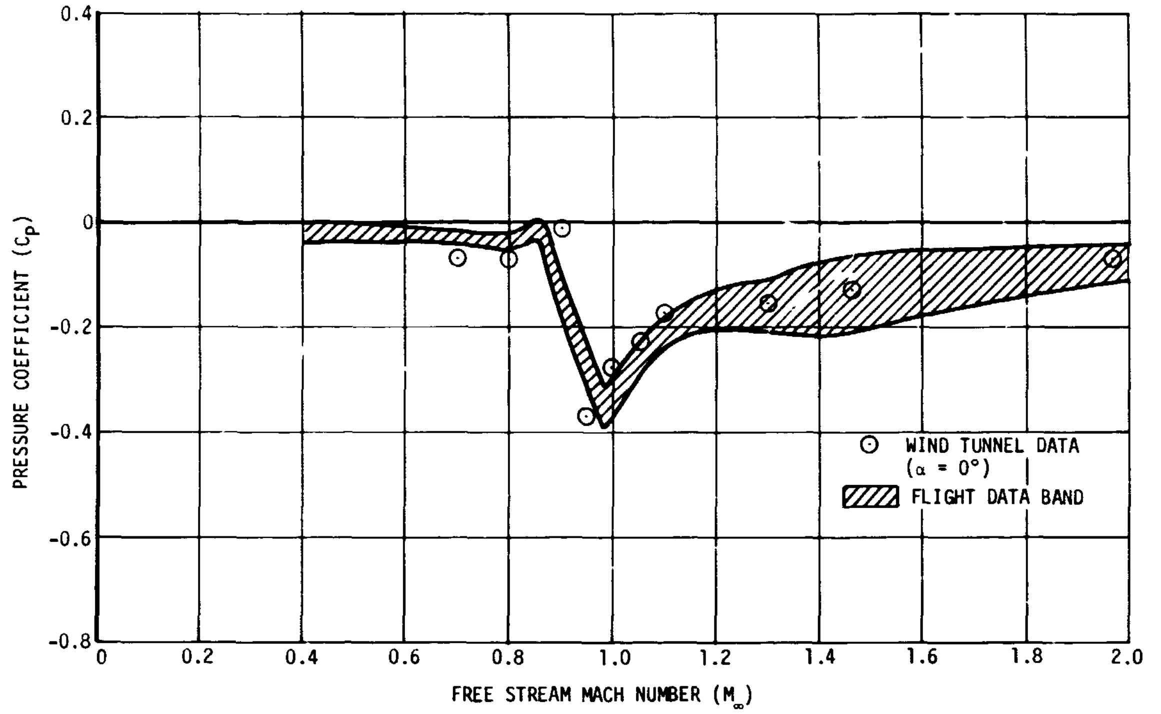


Figure 25-4. Forward Skirt Local Pressure Coefficients-Vehicle Station 1583

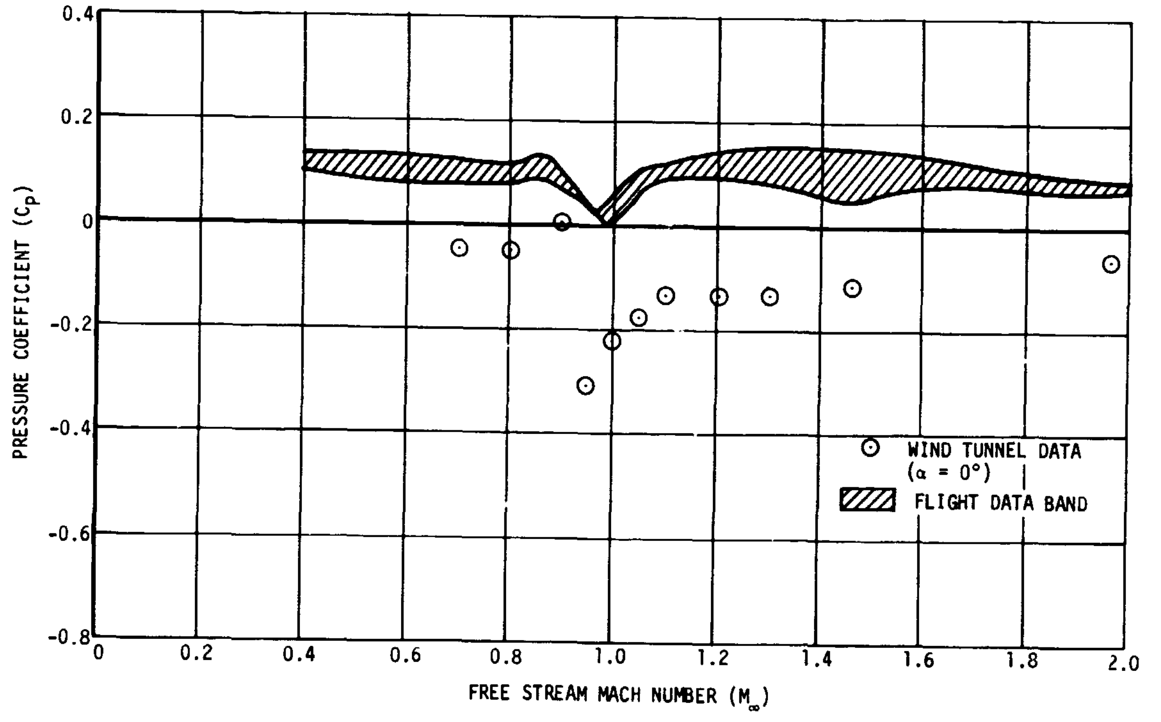


Figure 25-5. Forward Skirt Local Pressure Coefficients-Vehicle Station 1547

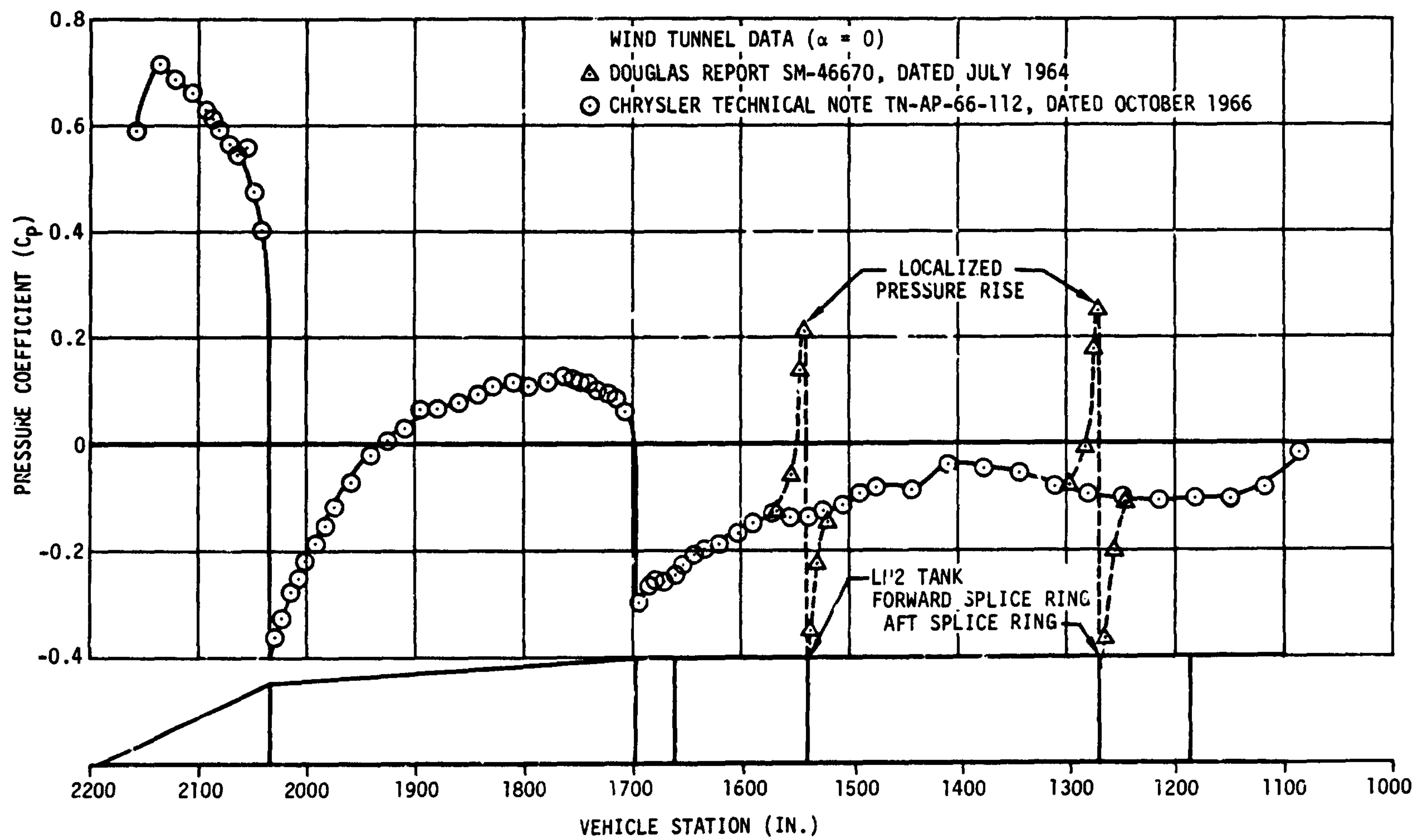


Figure 25-6. Pressure Coefficient Distribution (M_∞ = 1.20)

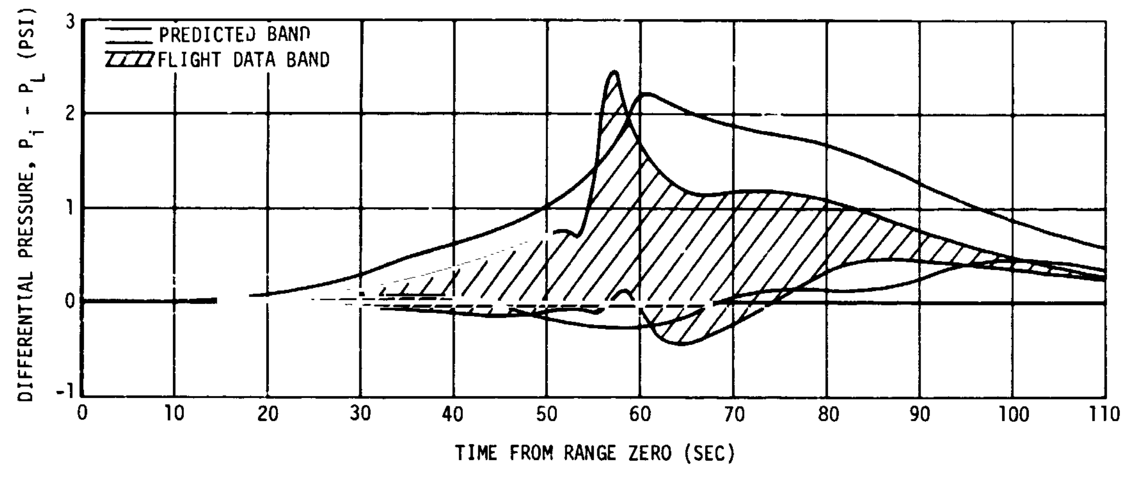


Figure 25-7. Forward Skirt Internal Pressure Minus Local Pressure on Surface

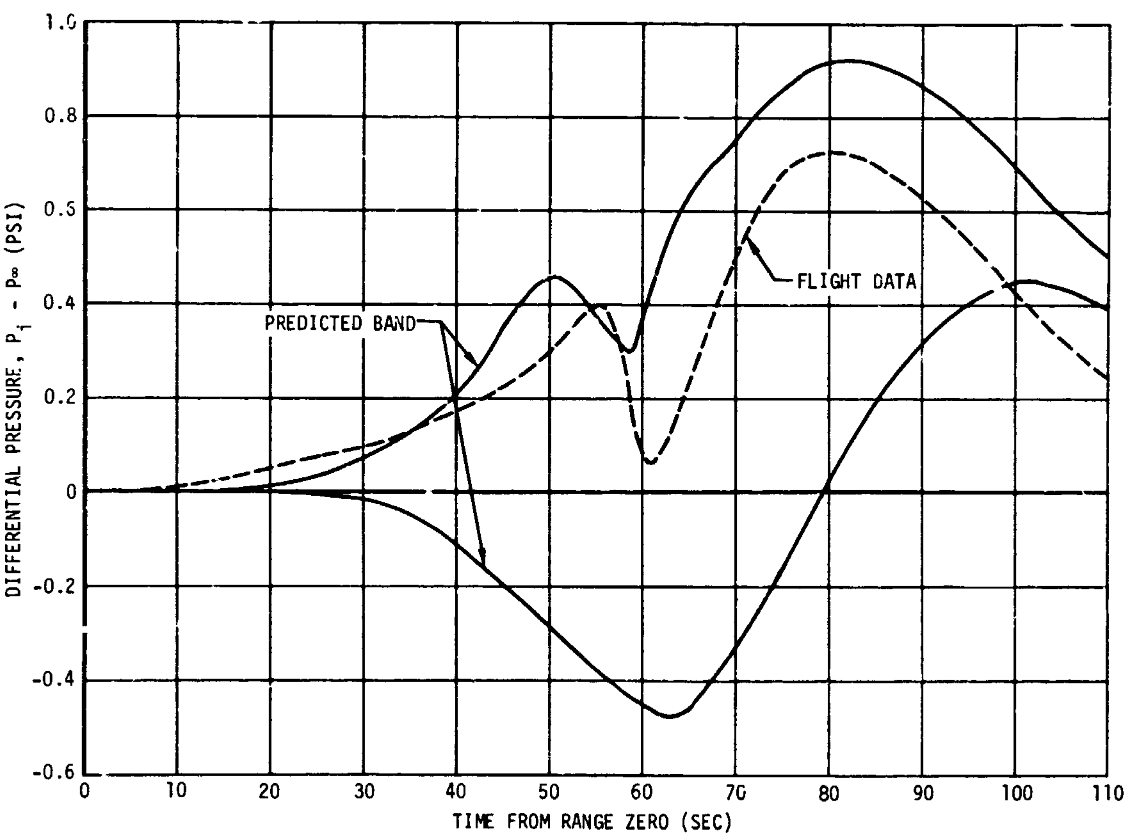


Figure 25-8. Forward Skirt Internal Pressure Minus Free Stream Pressure

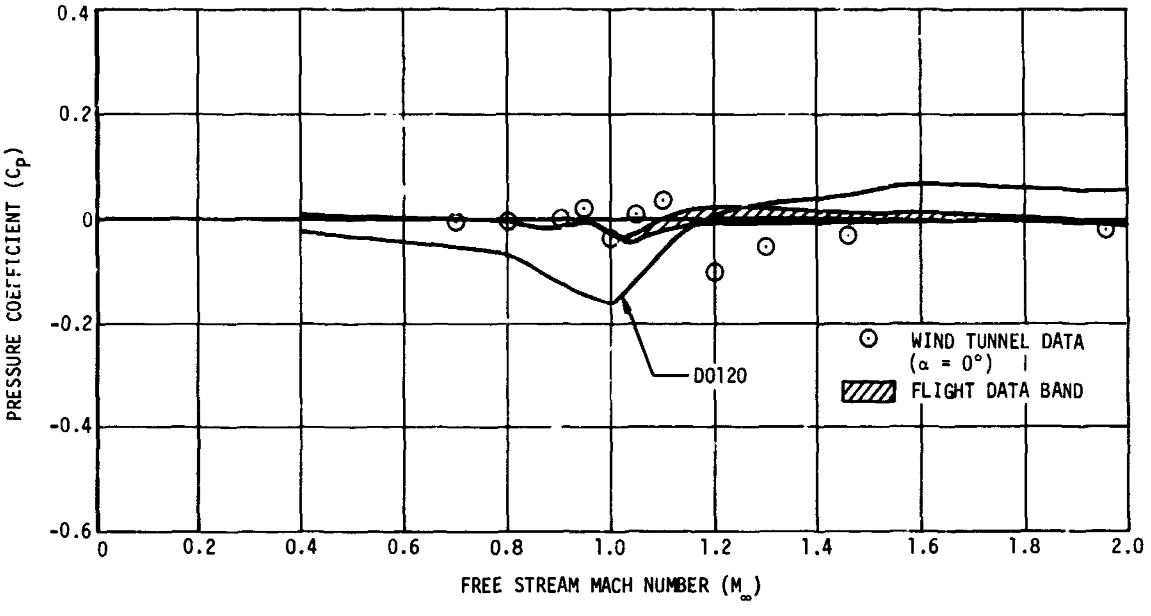


Figure 25-9. Aft Skirt Local Pressure Coefficients-Vehicle Station 1224

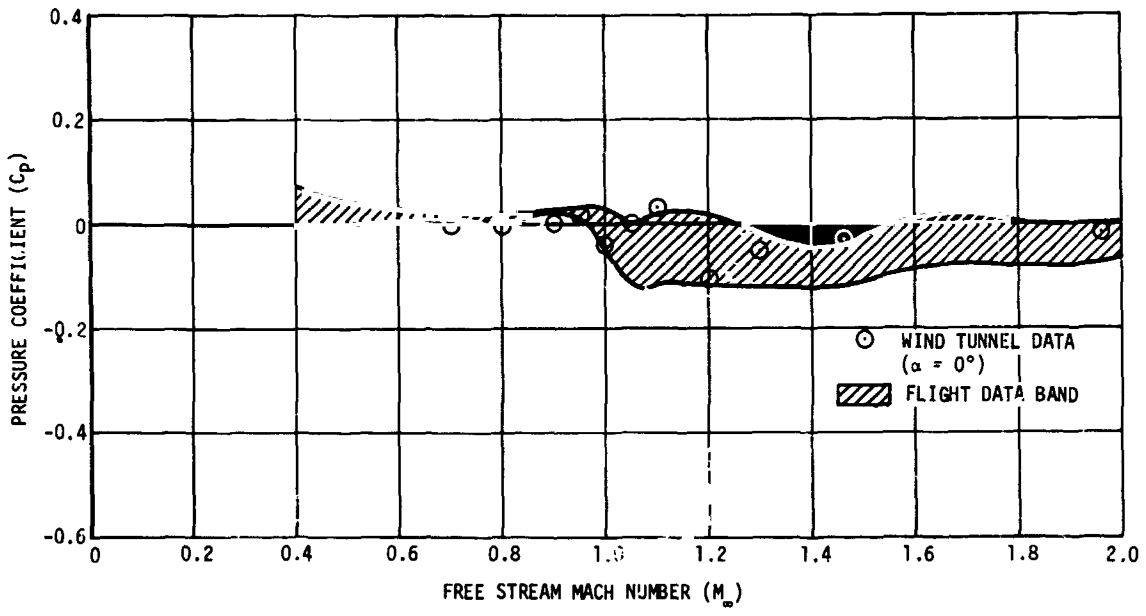


Figure 25-10. Aft Interstage Local Pressure Coefficients-Vehicle Station 1177

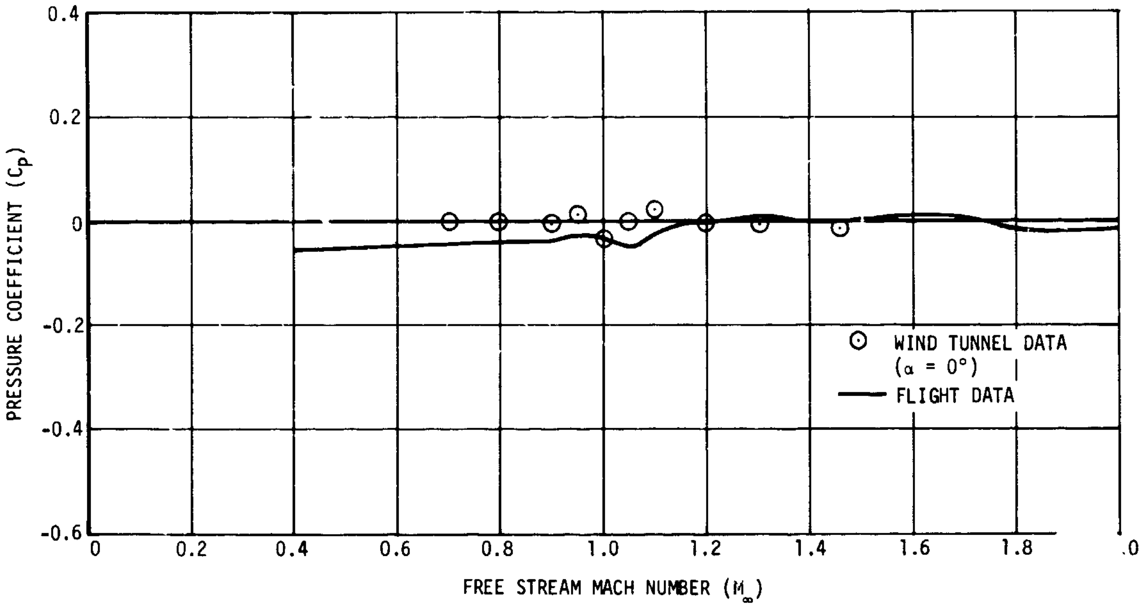


Figure 25-11. Aft Interstage Local Pressure Coefficients-Vehicle Station 994

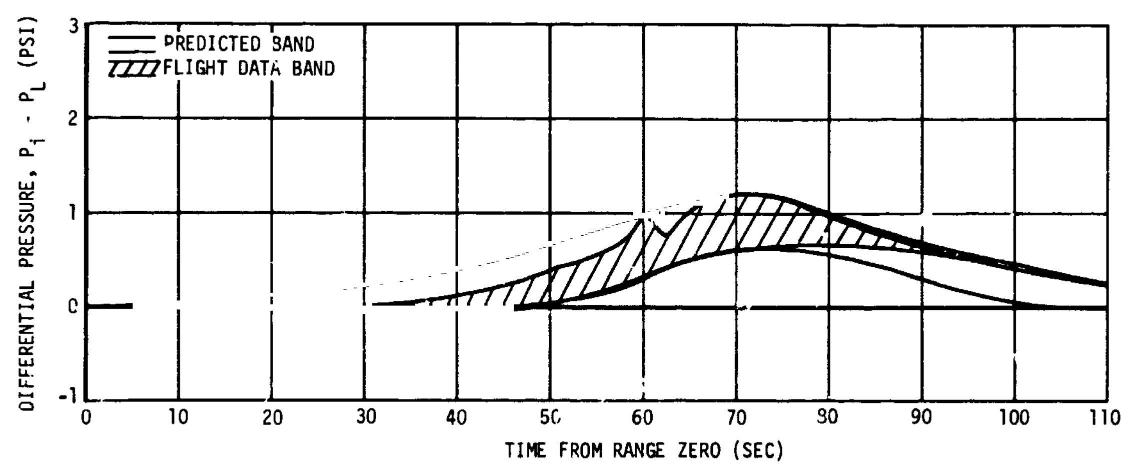


Figure 25-12. Aft Skirt and Interstage Internal Pressure Minus Local Pressure on Surface

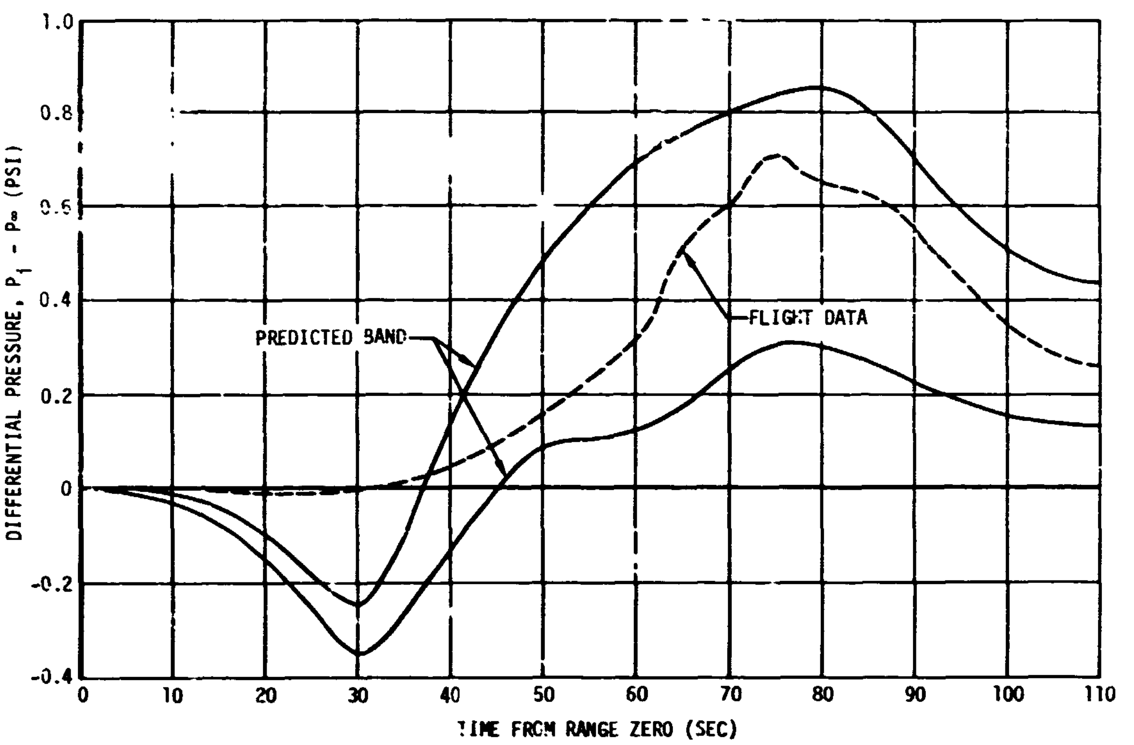


Figure 25-13. Aft Skirt and Interstage Internal Pressure Minus Free Stream Pressure

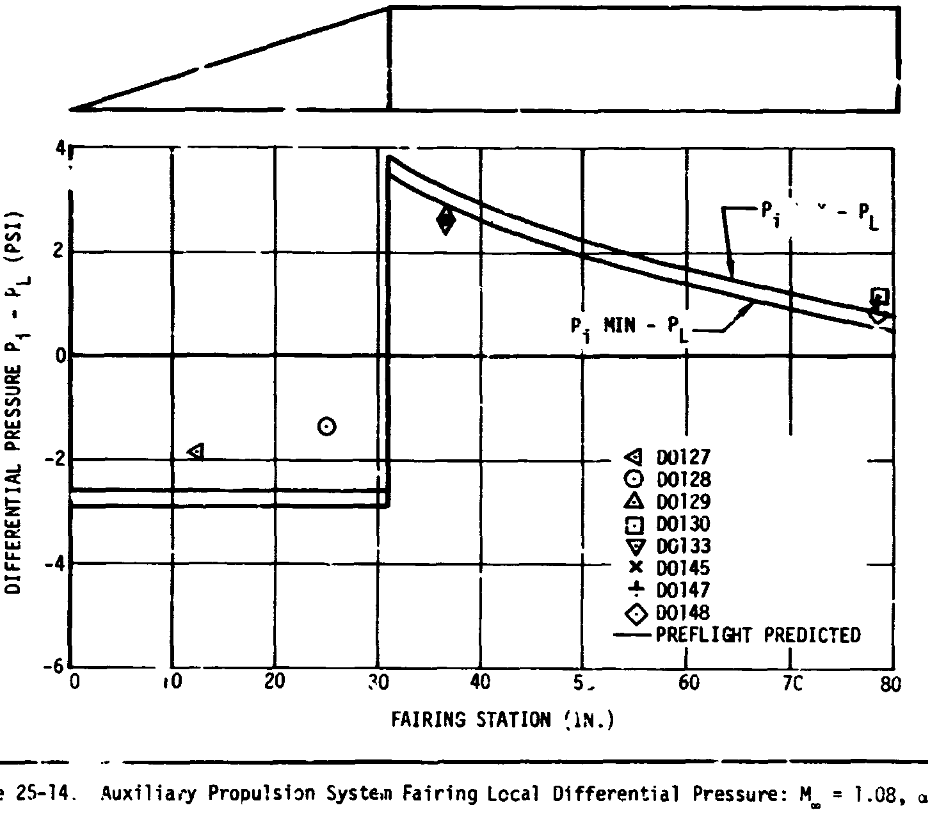


Figure 25-14. Auxiliary Propulsion System Fairing Local Differential Pressure: $M_\infty = 1.08$, $\alpha = 0°$

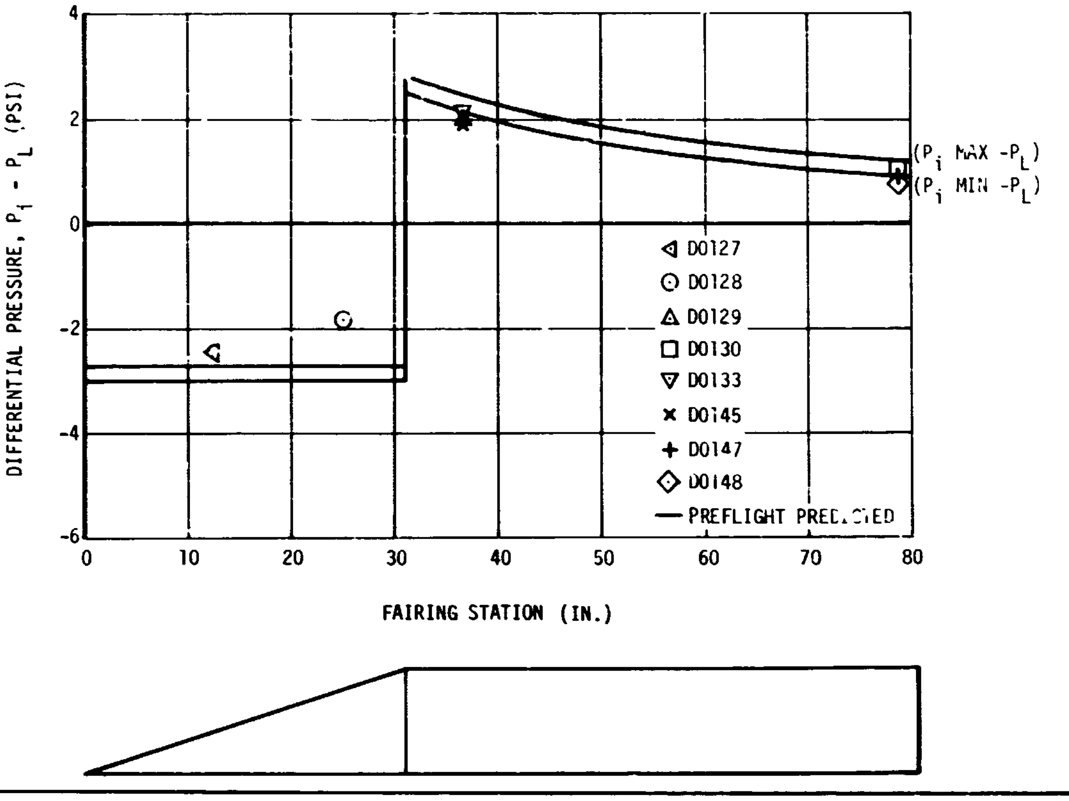


Figure 25-15. Auxiliary Propulsion System Fairing Local Differential Pressure: M_∞ = 1.33, α = 0°

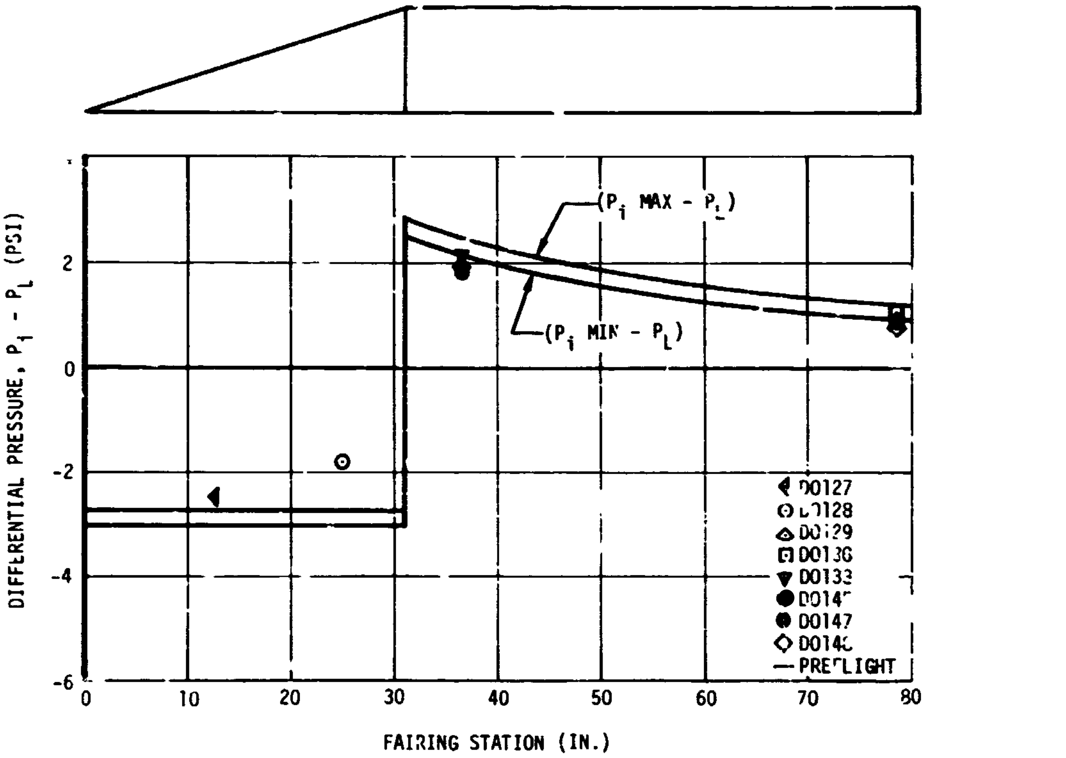


Figure 25-16. Auxiliary Propulsion System Fairing Local Differential Pressure: M_∞ = 1.51, α = 0°

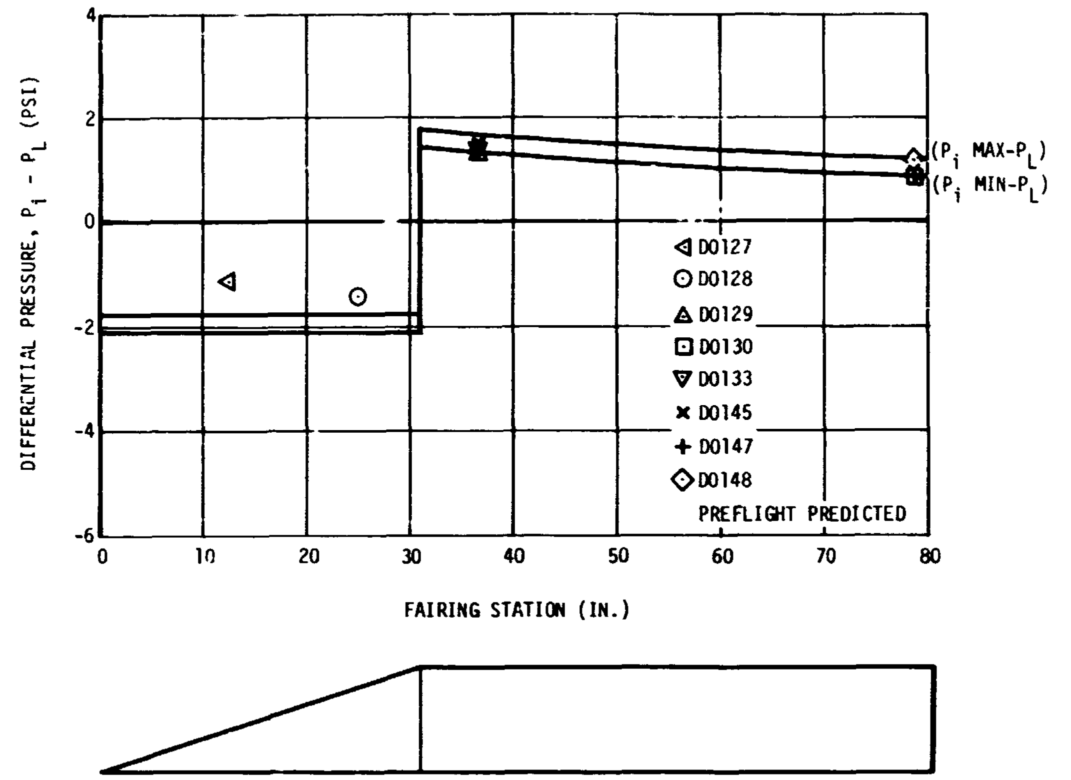


Figure 25-17. Auxiliary Propulsion System Fairing Local Differential Pressure: M_∞ = 1.76, α = 0°

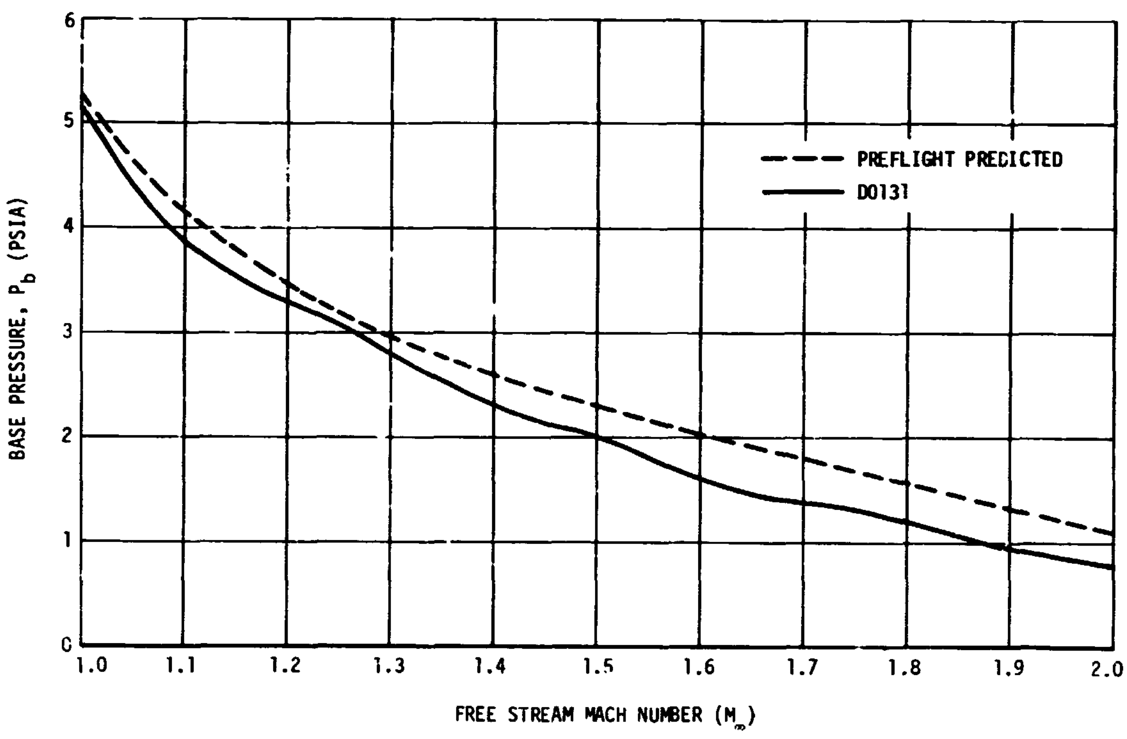


Figure 25-18. APS Fairing Base Pressure: α = 0°

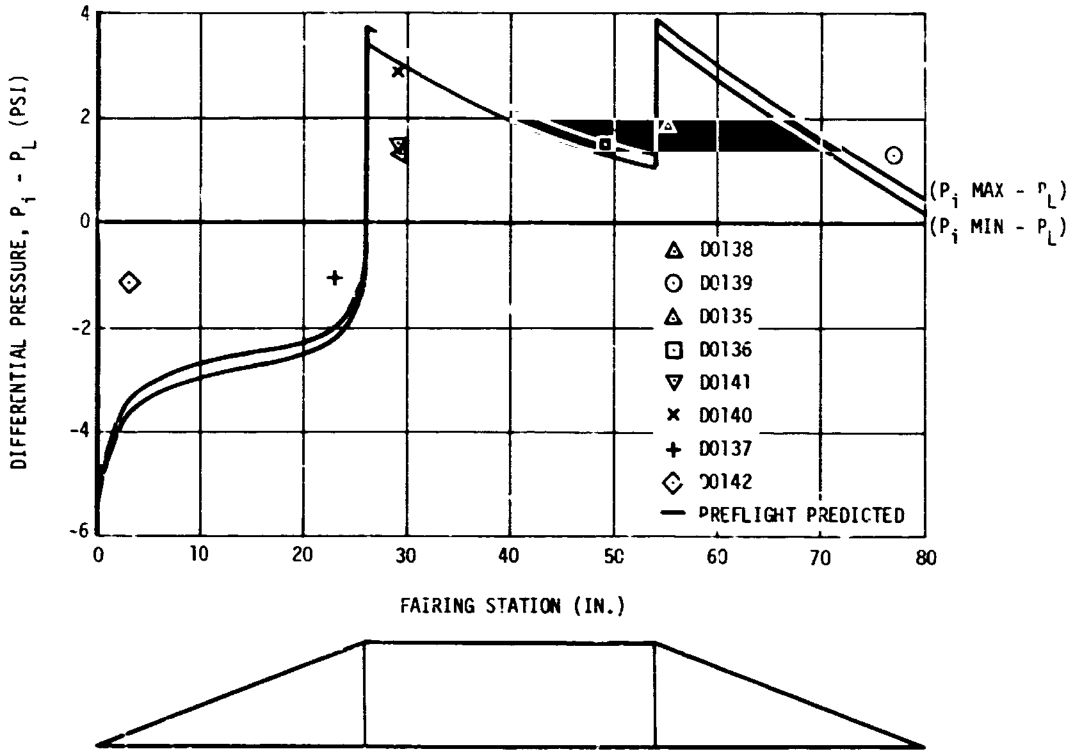


Figure 25-19. LH2 Feedline Fairing Local Differential Pressure: $M_\infty = 1.20$, $\alpha = 0°$

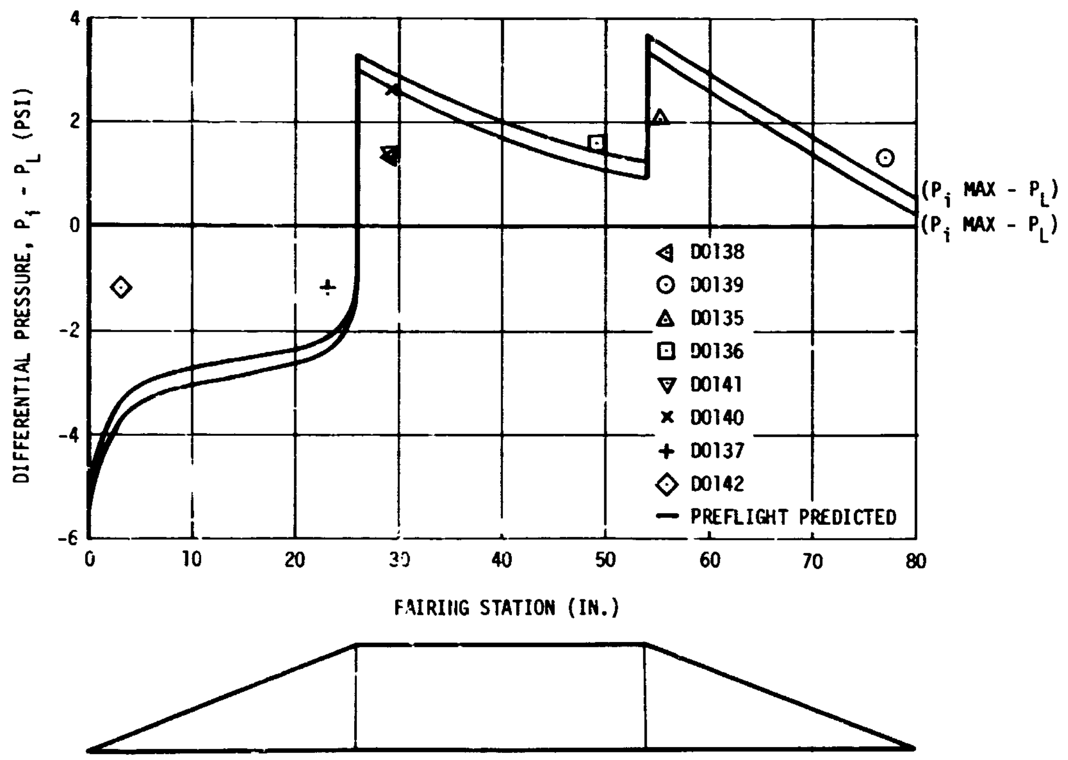
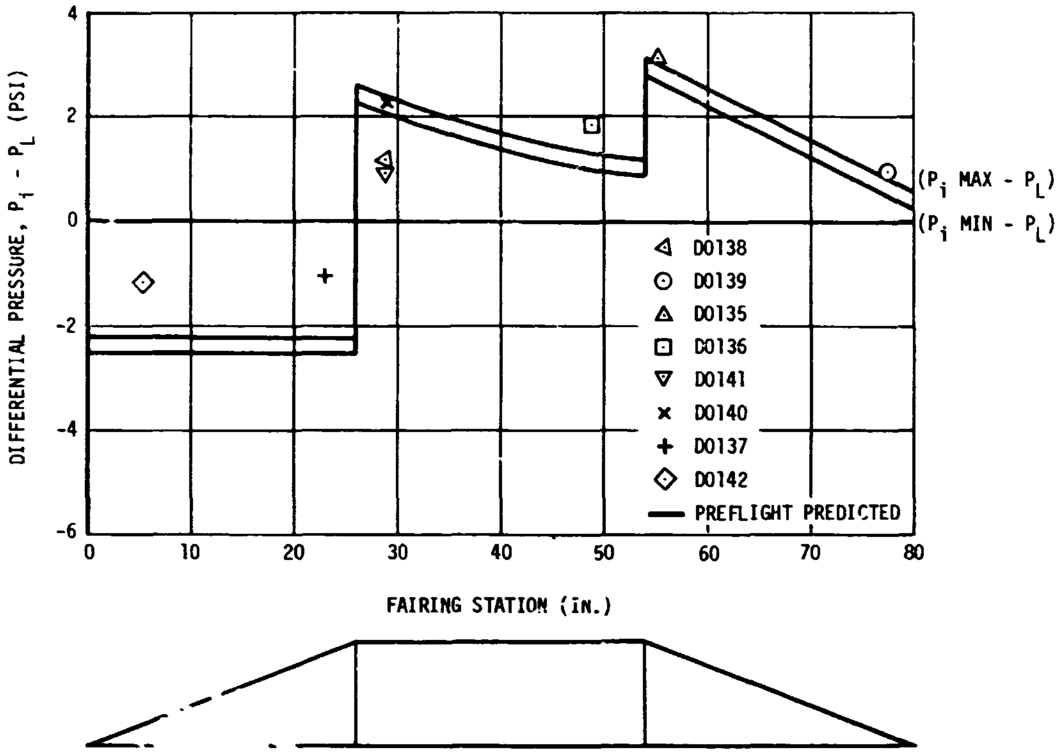


Figure 25-20. LH2 Feedline Fairing Local Differential Pressure: $M_\infty = 1.27$, $\alpha = 0°$



F... ..H2 Feedline Fairing Local Differential Pressure: M_∞ = 1.40, α = 0°

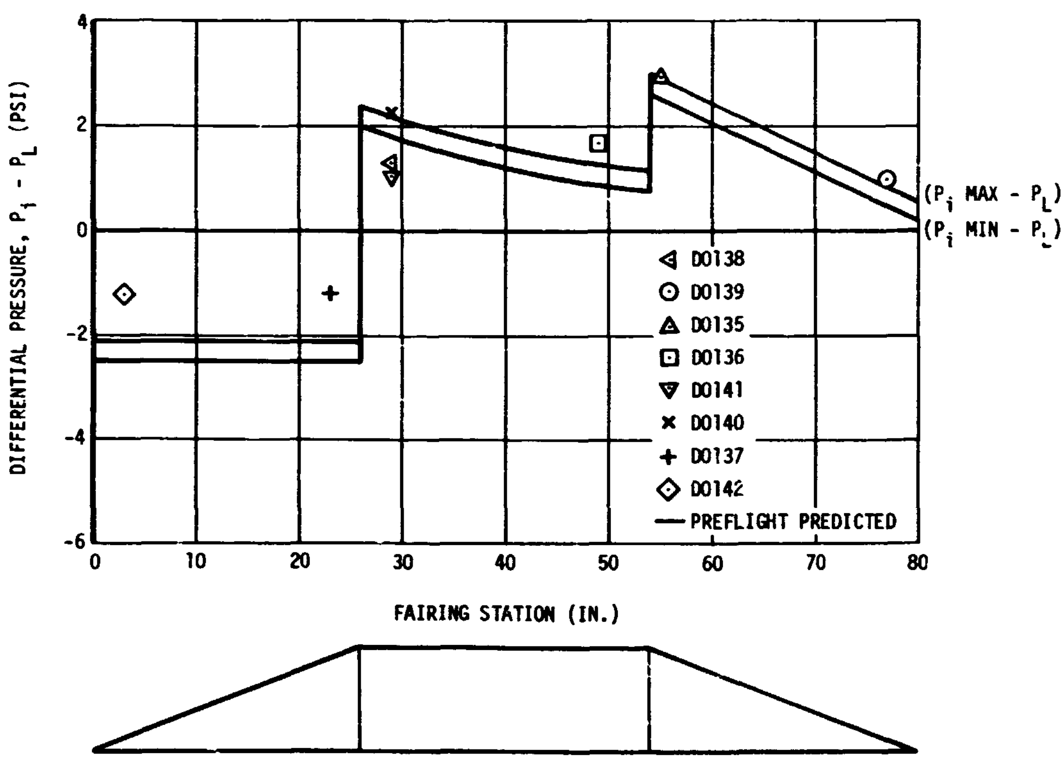


Figure 25-22. LH2 Feedline Fairing Local Differential Pressure: M_∞ = 1.45, α = 0°

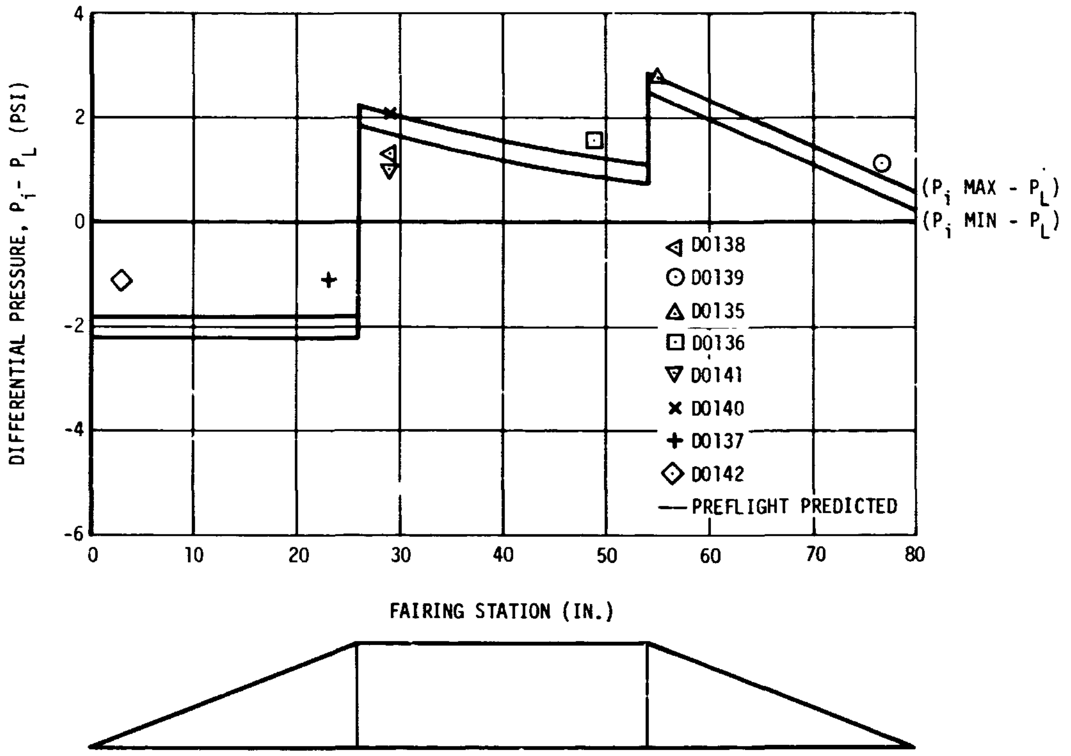
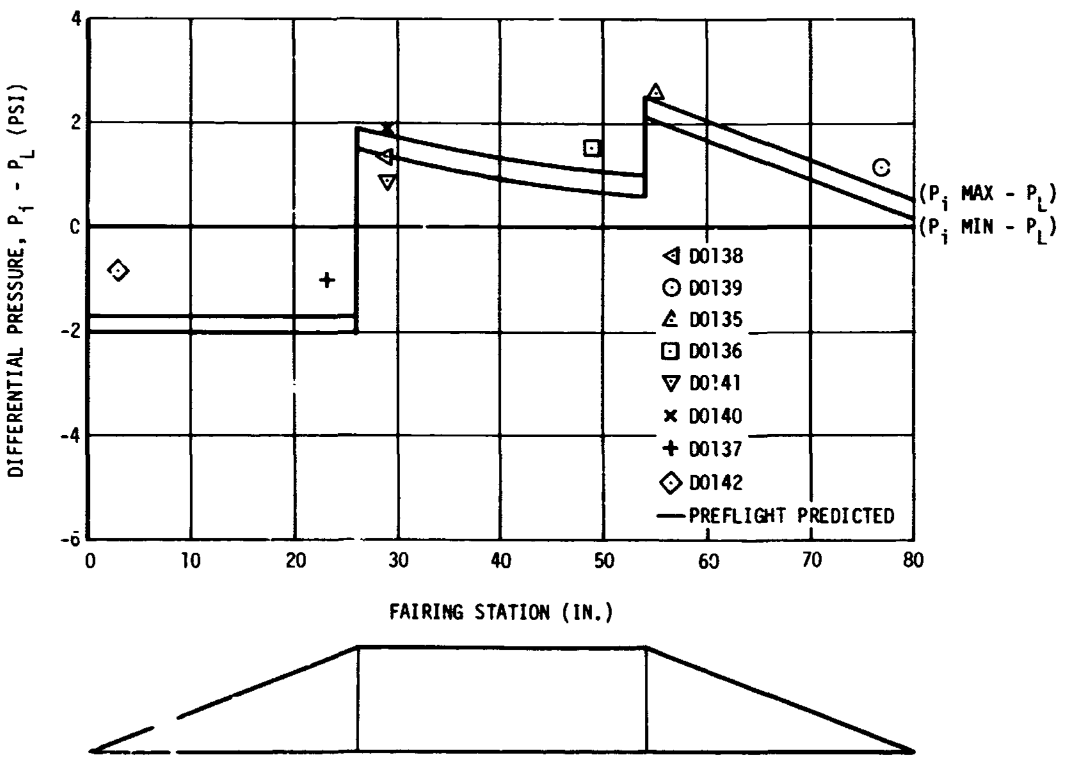


Figure 25-23. LH2 Feedline Fairing Local Differential Pressure: $M_\infty = 1.50$, $\alpha = 0°$



Fi[illegible]4. LH2 Feedline Fairing Local Differential Pressure: $M_\infty = 1.60$, $\alpha = 0°$

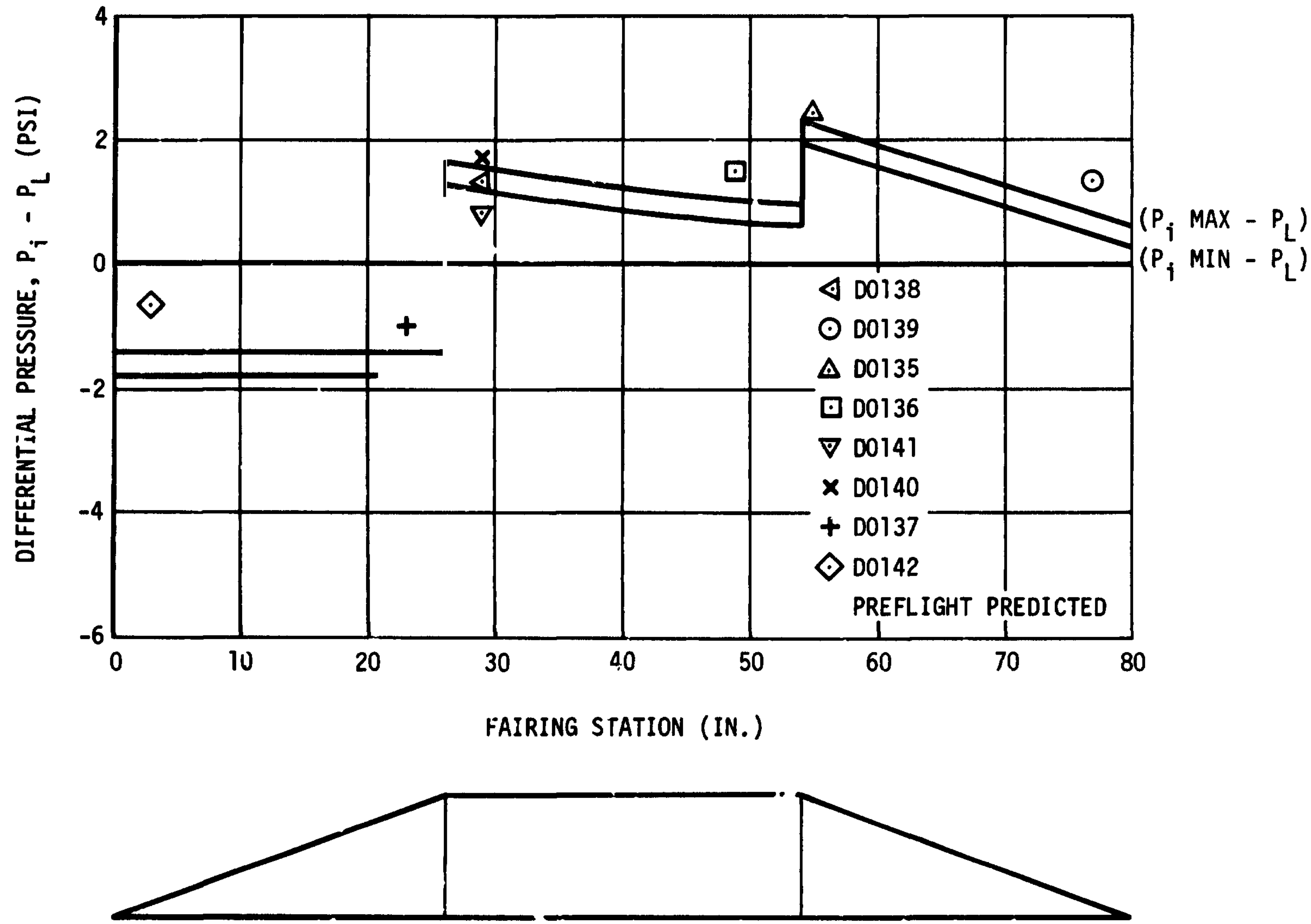
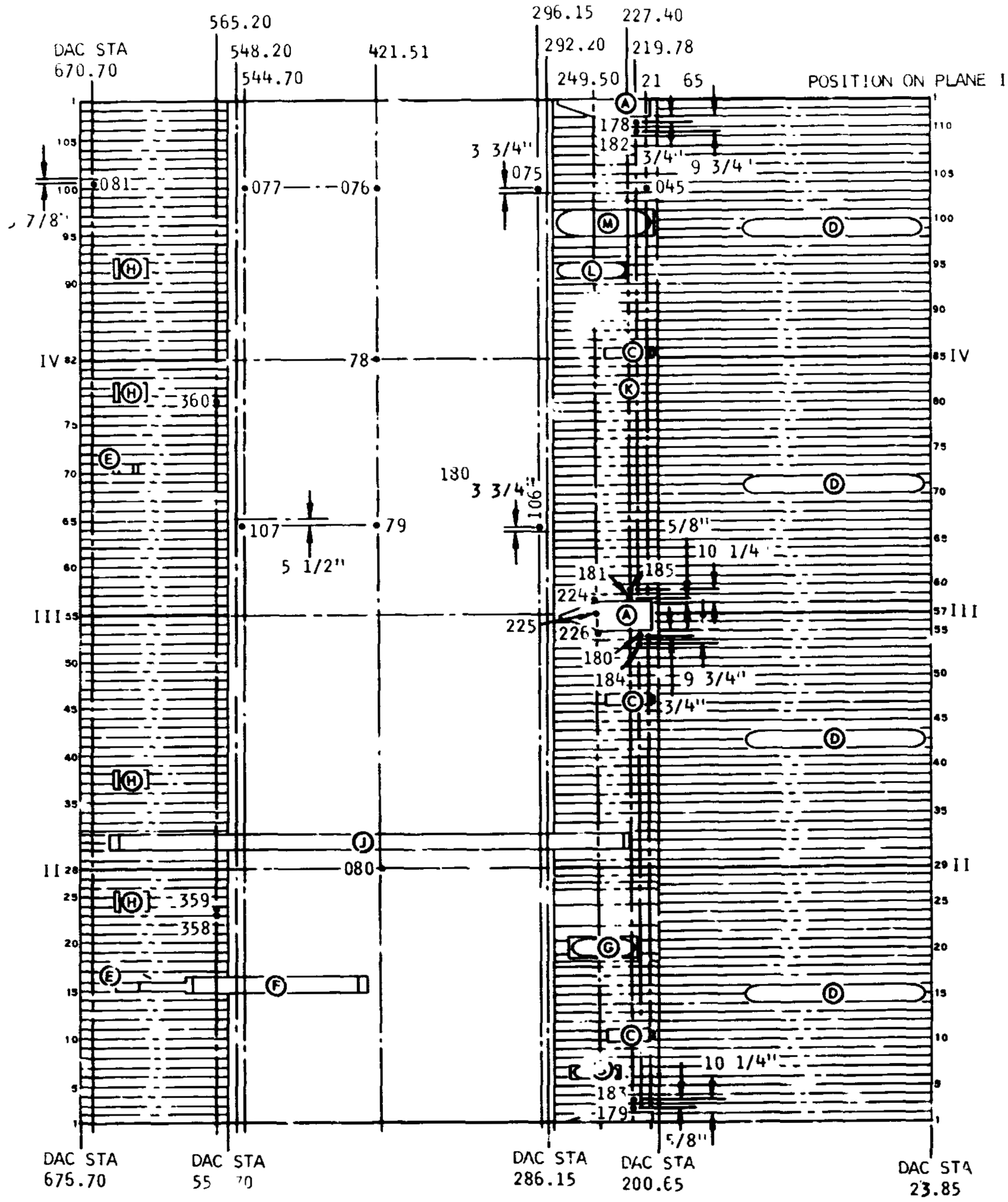


Figure 5-25. Feedline Line Fairing Local Differential Pressure: M_∞ = 1.70, α = 0°



Ⓐ AUXILIARY PROPULSION SYSTEM
Ⓑ LH2 CHILLDOWN RETURN
Ⓒ ULLAGE ROCKET
Ⓓ RETROROCKET
Ⓔ RANGE SAFETY ANTENNA
Ⓕ AUXILIARY TUNNEL
Ⓖ LH2 FILL AND DRAIN LINE
Ⓗ TELEMETRY ANTENNA
Ⓙ MAIN TUNNEL, M.P.U.
Ⓚ LOX VENT
Ⓛ LH2 CHILLDOWN PUMP
Ⓜ LH2 FEED LINE

Figure 25-26. Temperature Measurement Locations

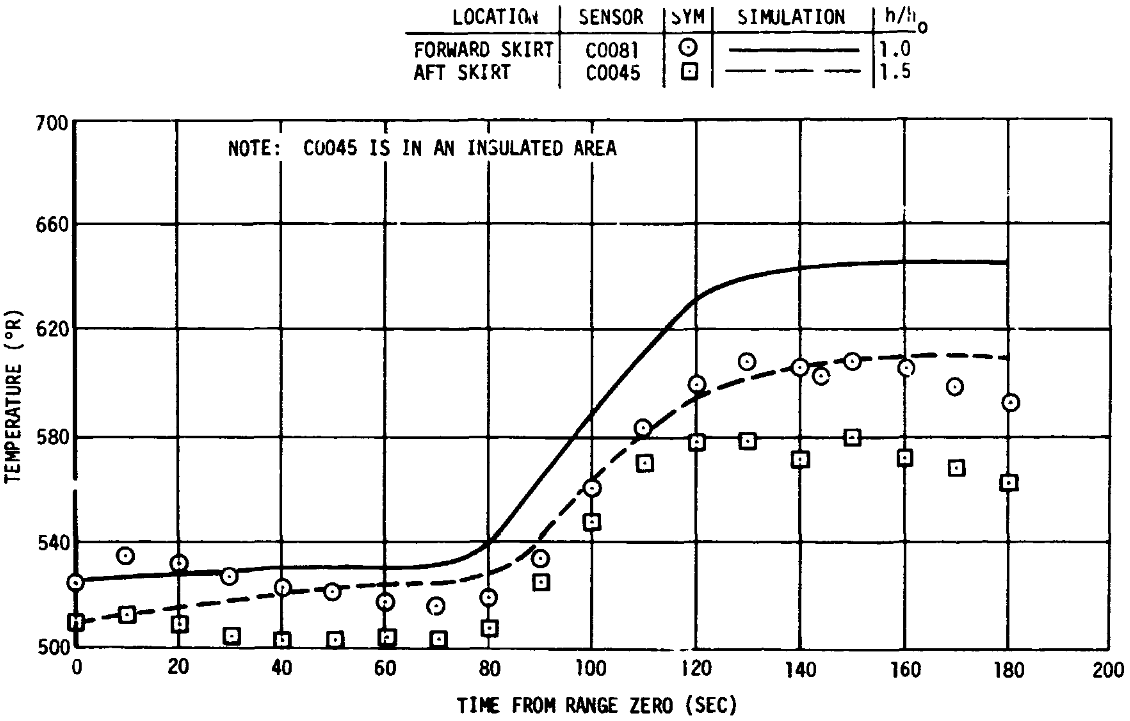


Figure 25-27. Forward and Aft Skirt Skin Temperatures

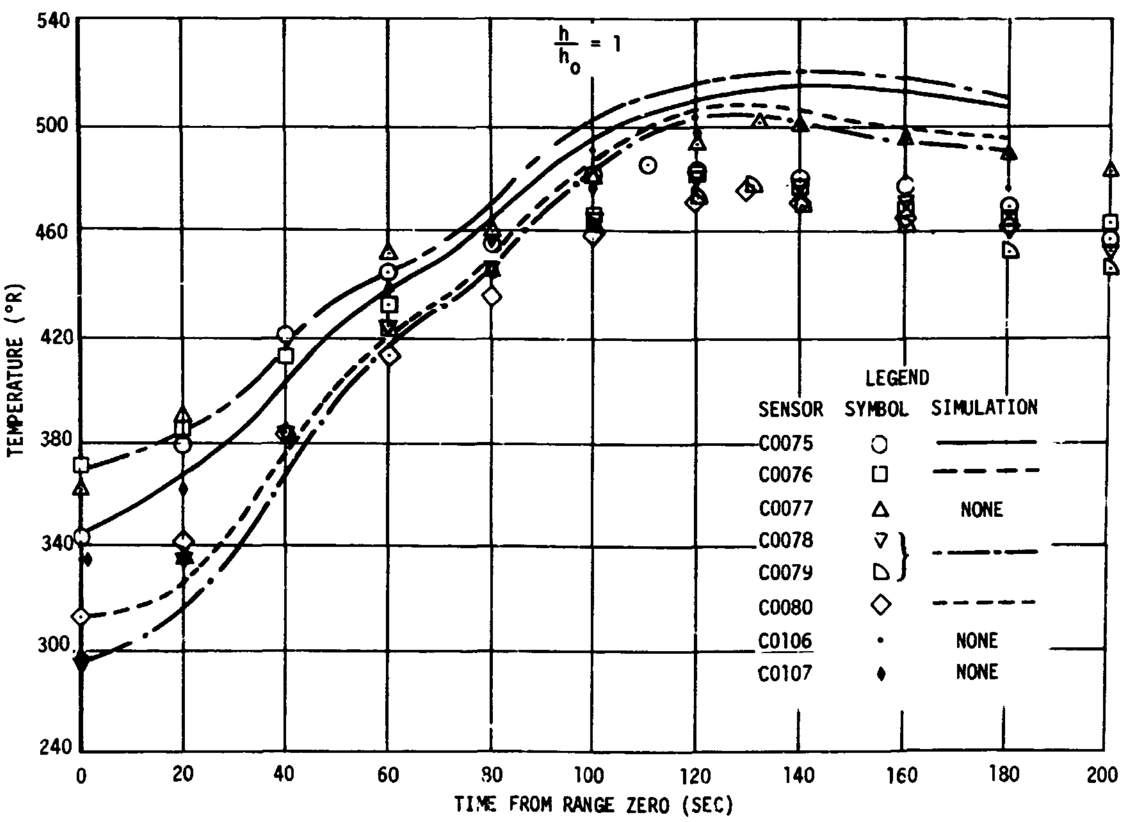


Figure 25-28. LH2 Tank Sensor Temperature

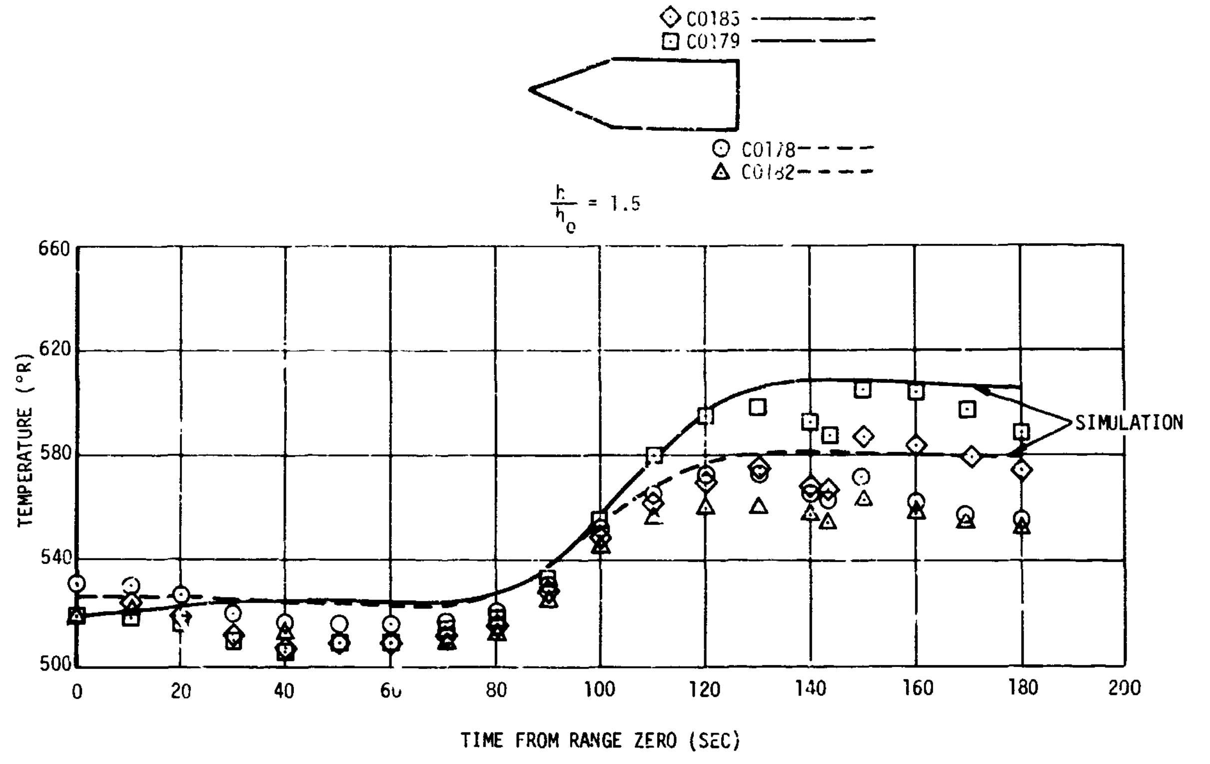


Figure 25-29. Aft Skirt Sensor Temperature Histories (Near APS 1)

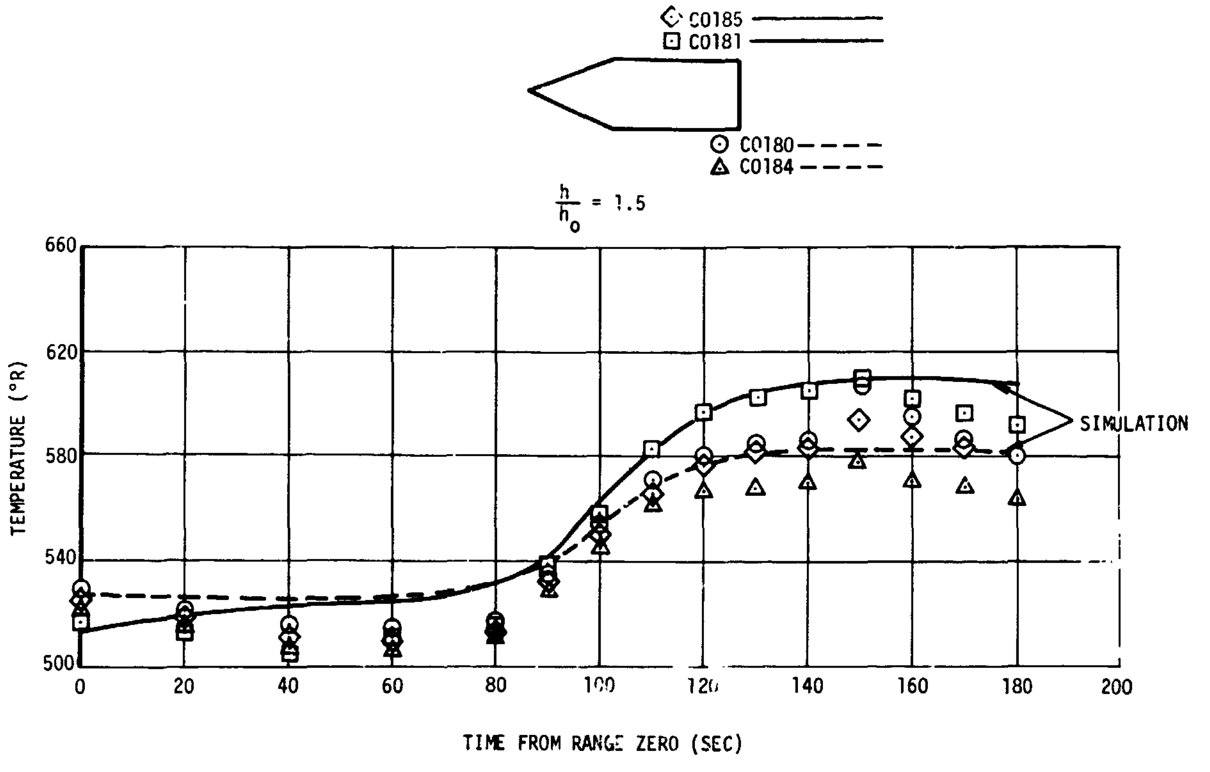


Figure 25-30. Aft Skirt Sensor Temperature Histories (Near APS 2)

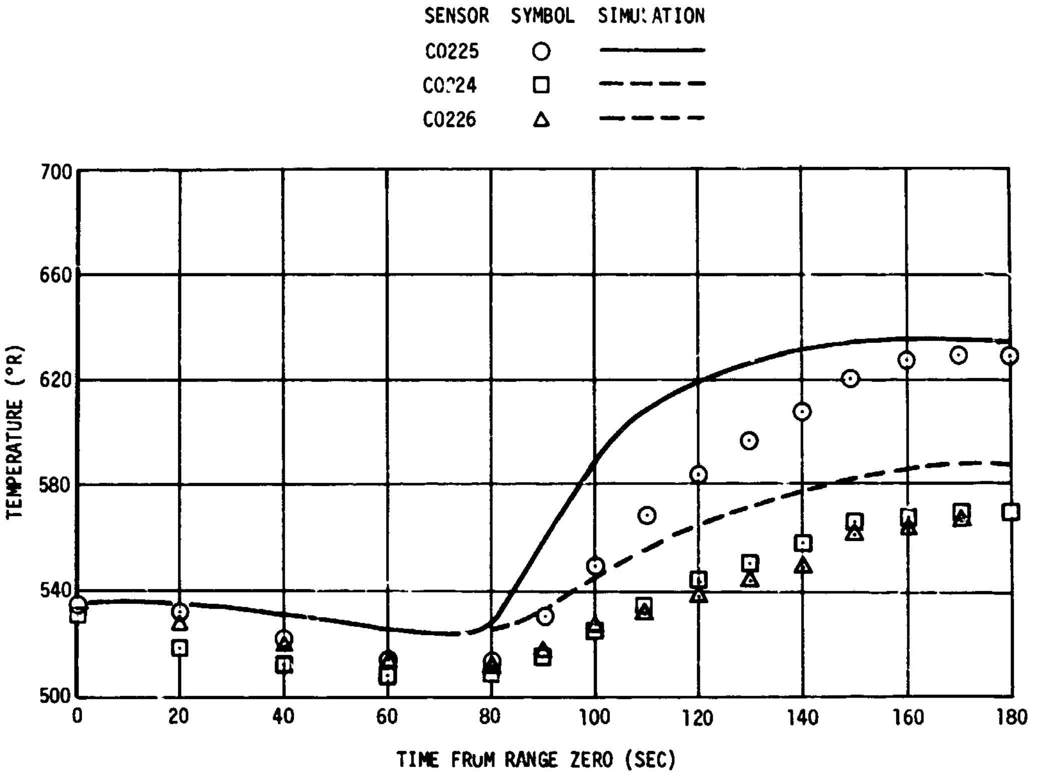


Figure 25-31. APS Fairing Temperatures, Boost

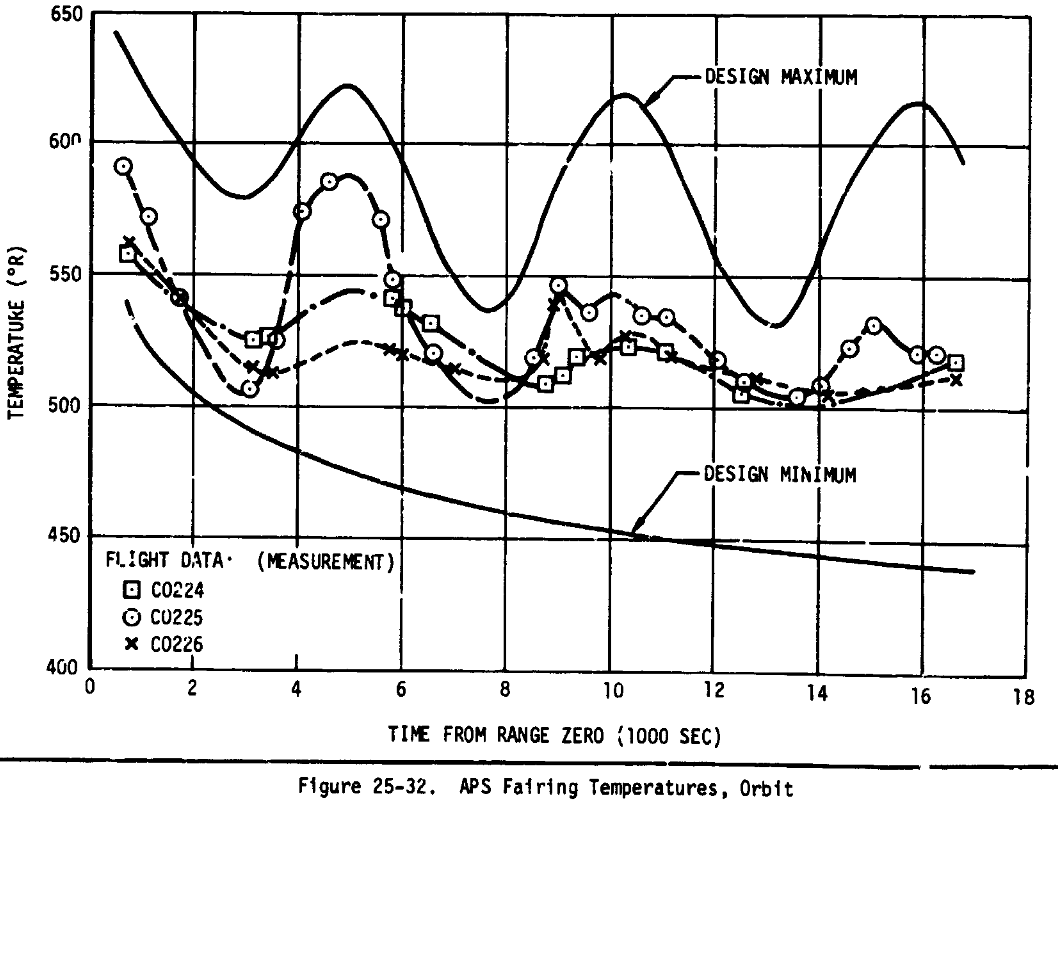


Figure 25-32. APS Fairing Temperatures, Orbit

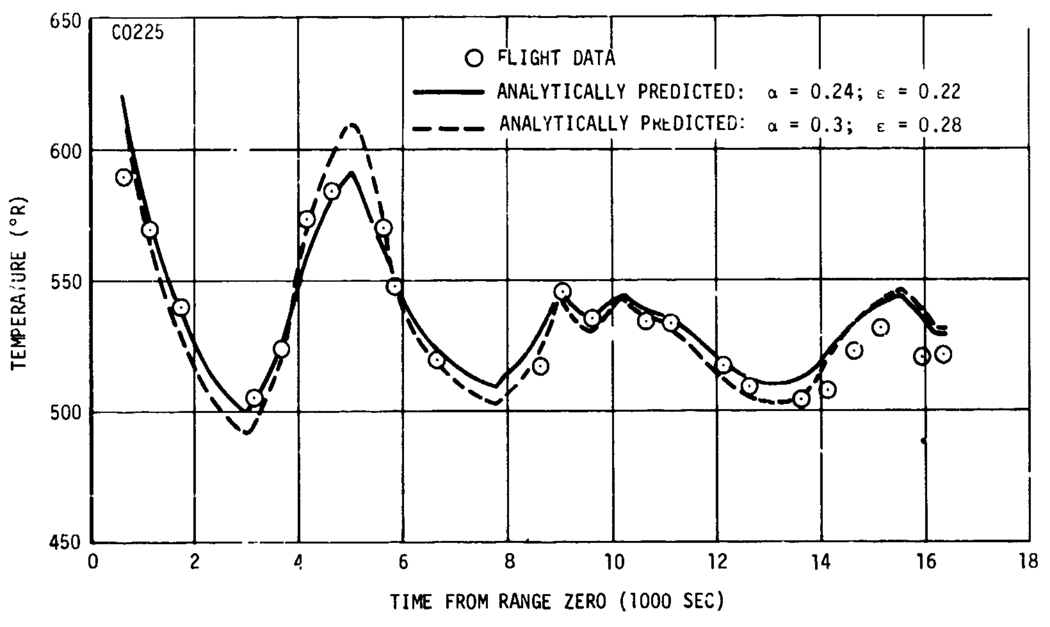


Figure 25-33. APS Fairing Temperature

NOTE: *PROPELLANT FLOW EFFECTS WOULD
INCREASE ANALYTICAL VALUES

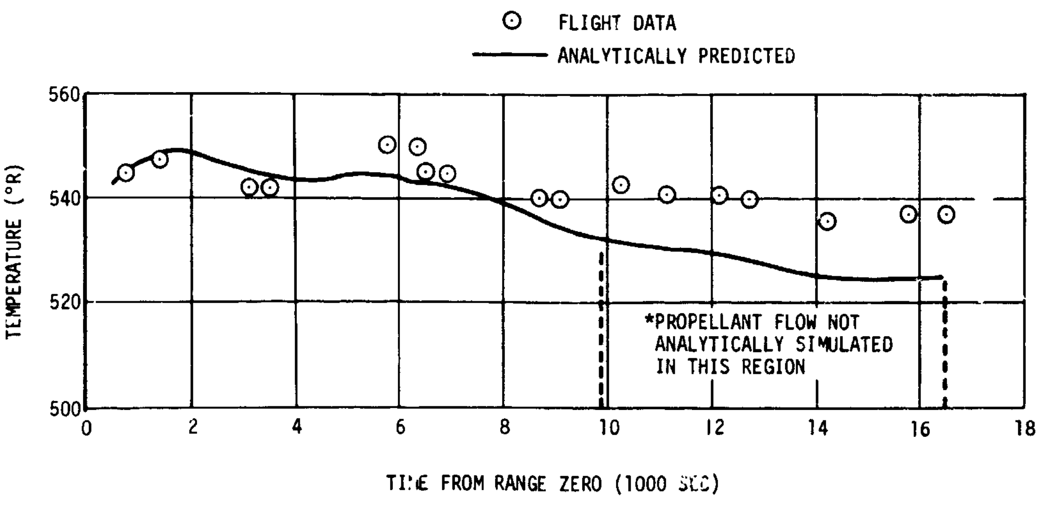


Figure 25-34. APS Oxidizer Transfer Line Temperature

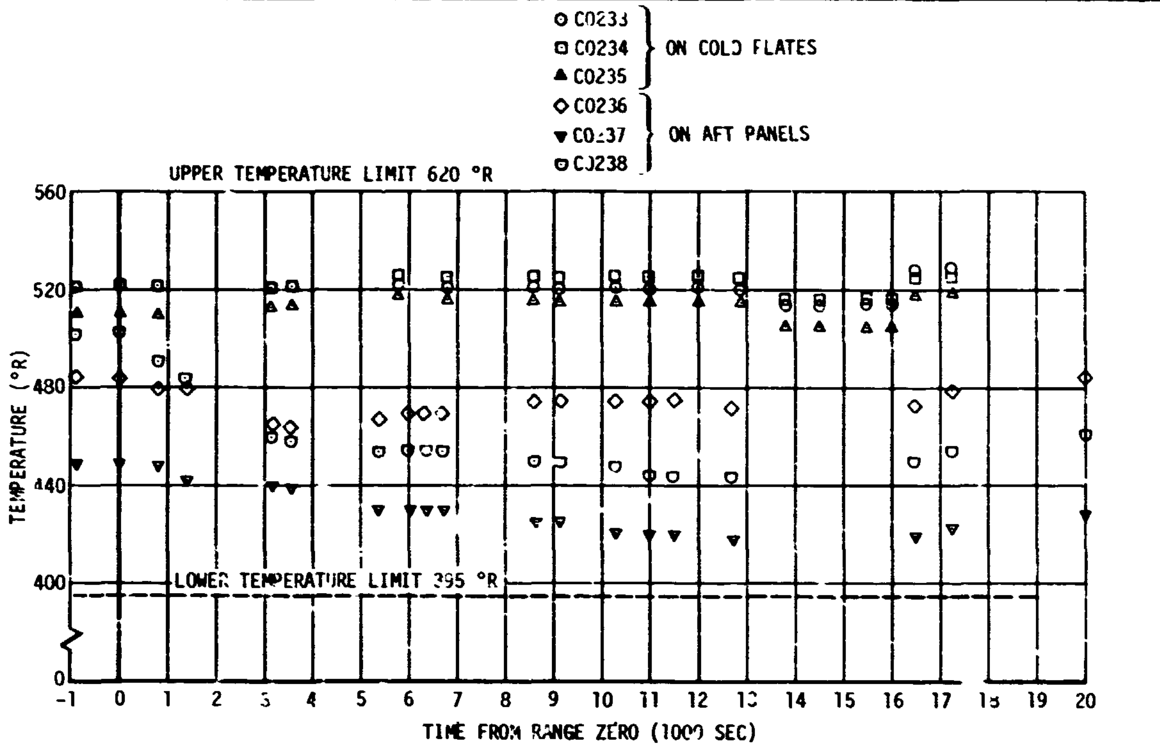


Figure 25-35. Bridge Modules Temperature Histories

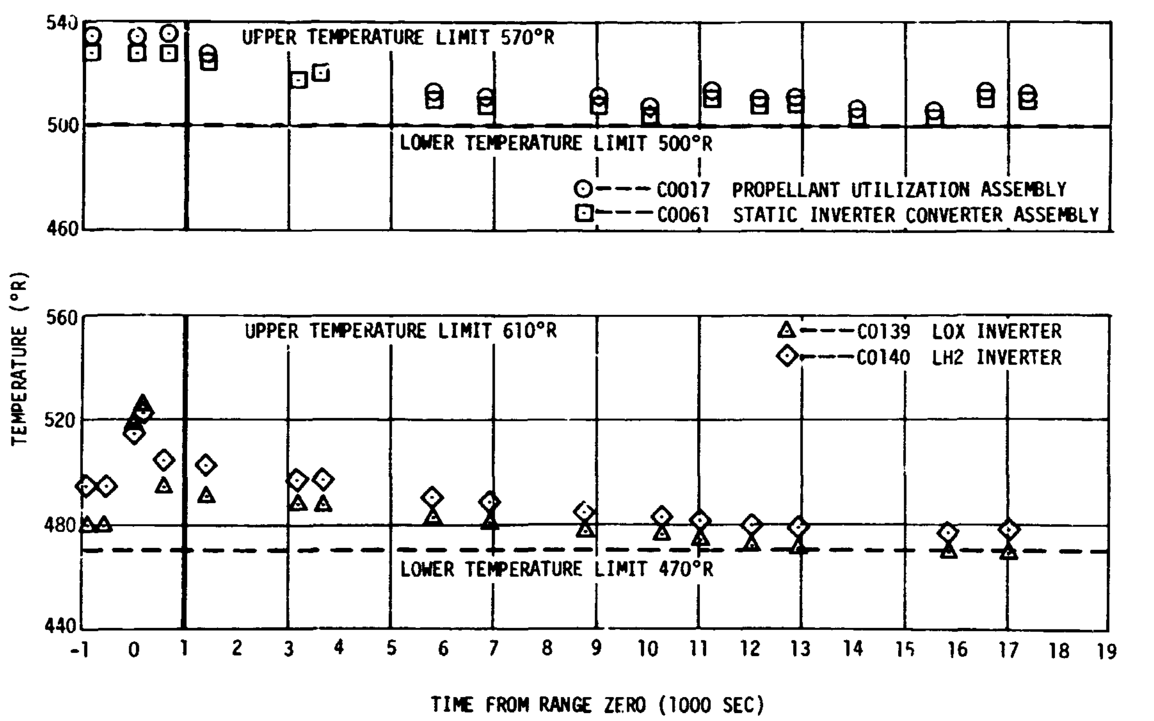


Figure 25-36. PU Static Inverter and Chilldown Inverters Temperature Histories

10

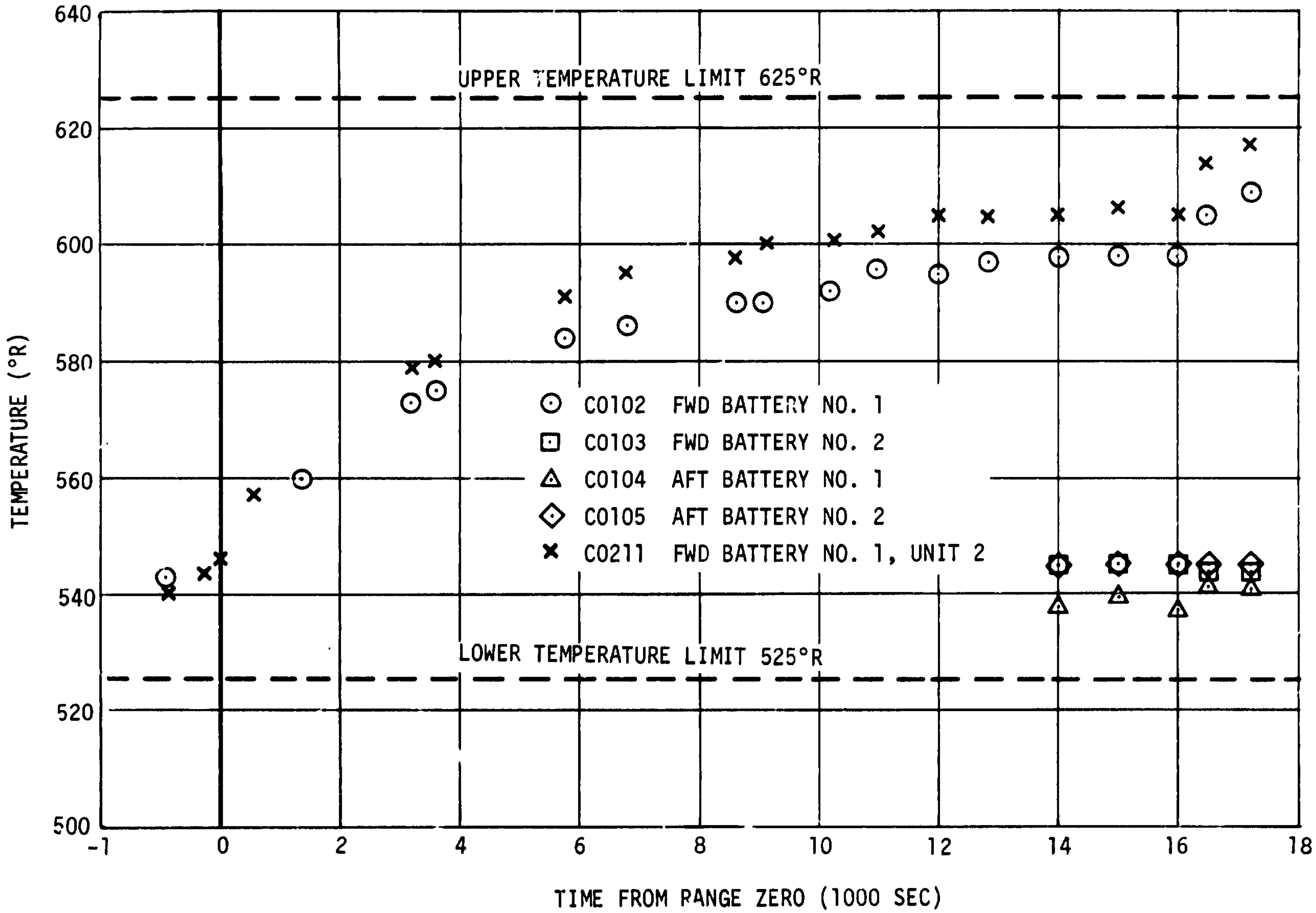


Figure 25-37. Forward and Aft Battery Temperatures

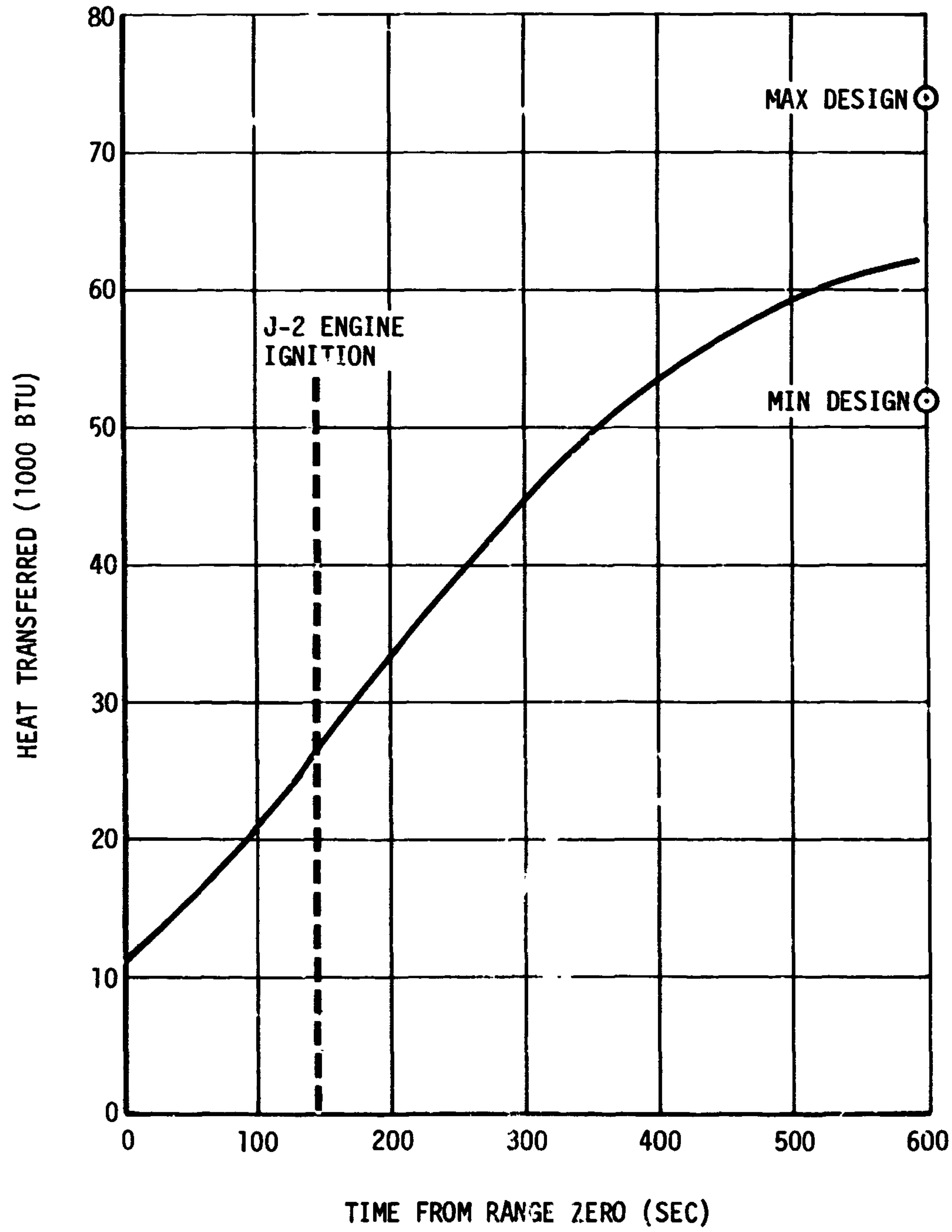


Figure 25-38. Total LH2 Propellant Heating

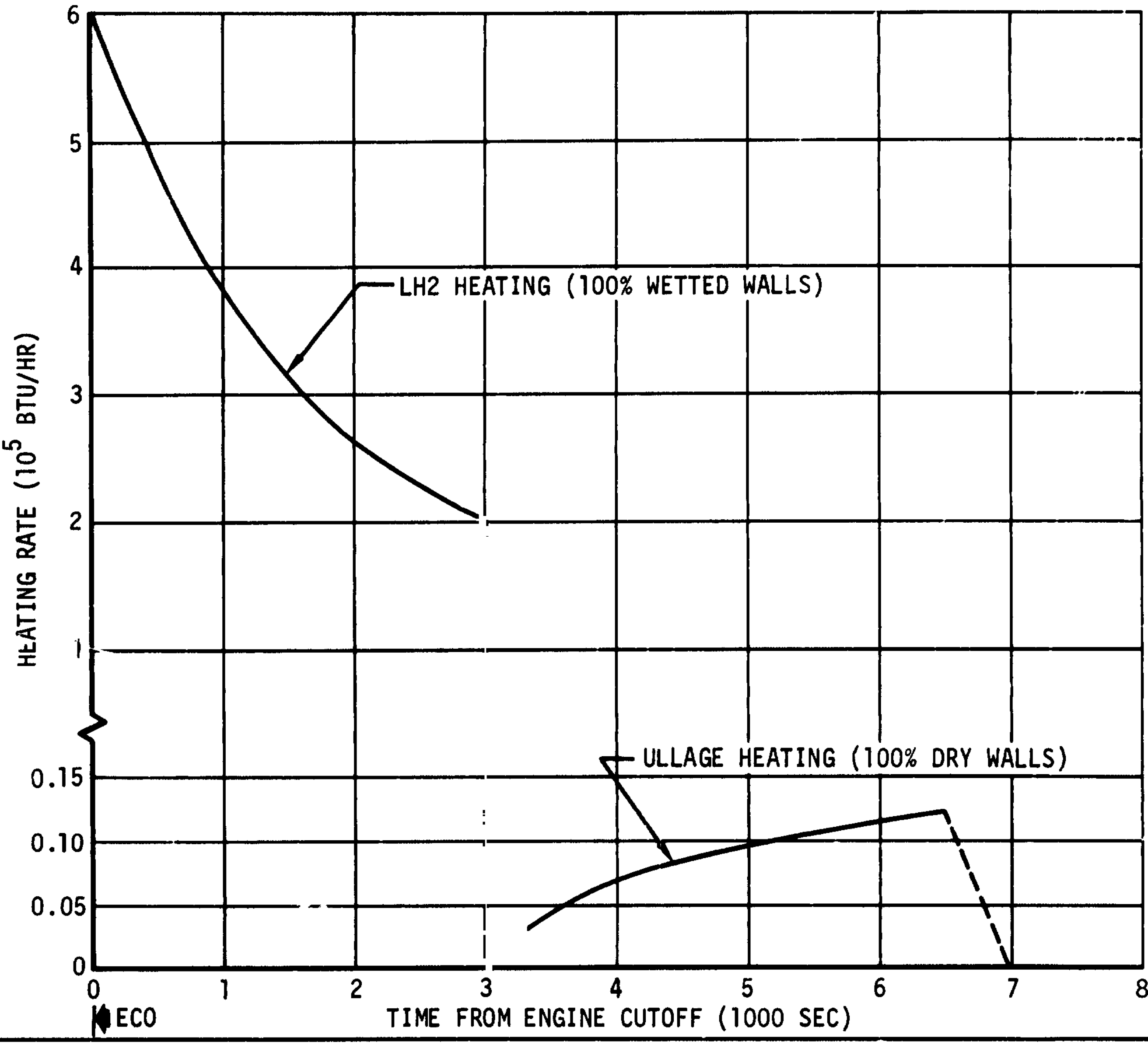


Figure 25-39. LH2 Tank Heating Rates

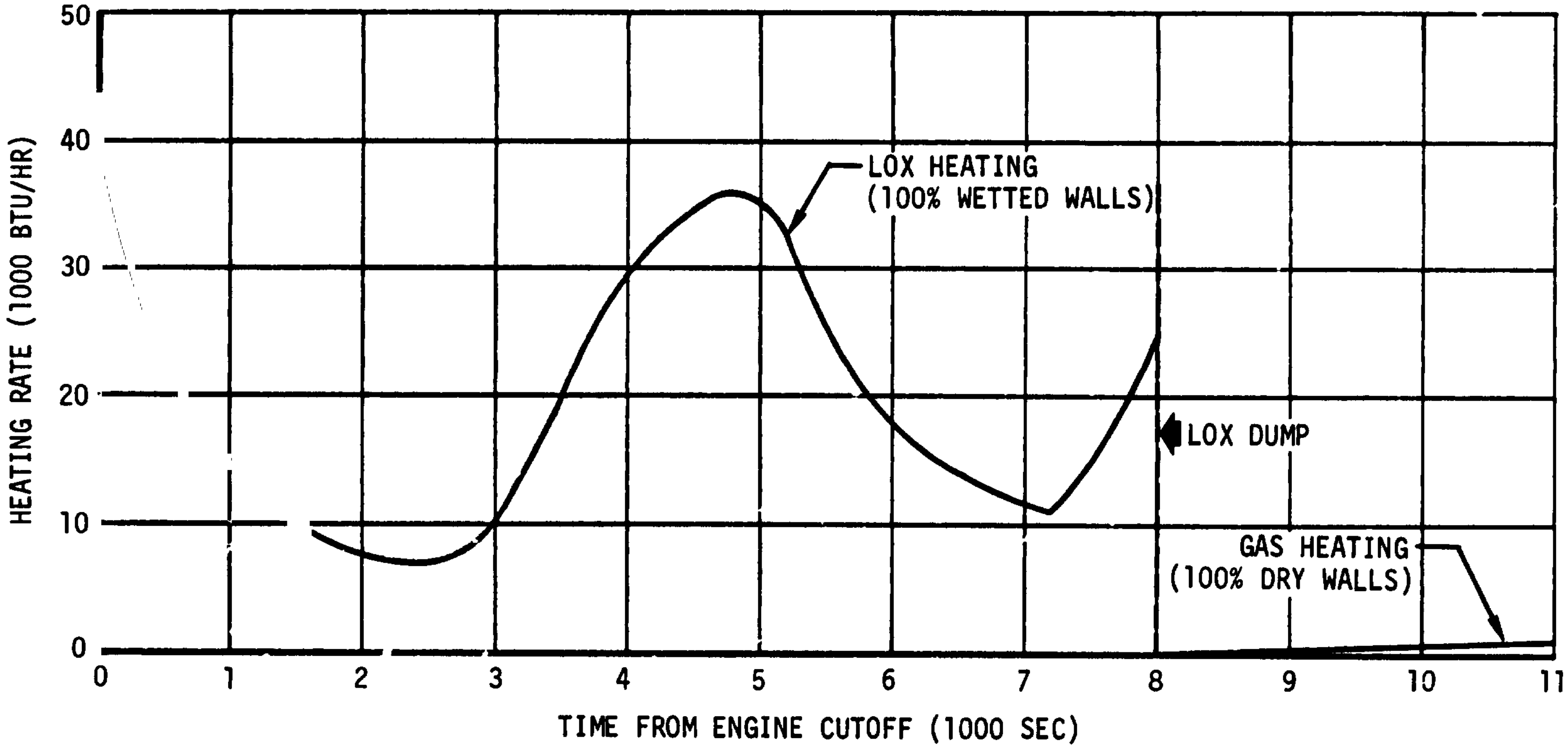


Figure 25-40. LOX Tank Heating Rate

SECTION 26 [redacted]

PROPELLANT DUMP TEST

26. PROPELLANT DUMP EXPERIMENT

The Saturn V S-IVB propellant management schemes have not been fully developed for alternate missions, orbital coast periods, and translunar coast periods [before and after spacecraft (SC) separation]. Additionally, to minimize the probability of S-IVB/IU and SC re-contact during the Saturn V mission and to minimize the probability of S-IVB/IU impact on the lunar surface may require dumping the S-IVB stage propellant residuals. To support the solution of these Saturn V propellant management problems, a propellant dump experiment was conducted on the S-IVB stage after LM-1 separation. The experiment consisted primarily of dumping the S-IVB LOX and LH2 propellants through the J-2 engine approximately one and one-half hours after LM-1 separation from the LV. In addition to dumping propellants, the pneumatic control sphere was vented, and the S-IVB cold helium bottles were dumped through the LOX tank.

LOX dump was successfully completed as planned at approximately RO +8,800 sec. LH2 dump was completed as programmed following LOX dump, although all LH2 had been vented prior to the scheduled dump. Blowdown of the cold helium spheres was initiated as planned at approximately RO +10,350 sec, but was not of sufficient duration to satisfy test requirements. The pneumatic sphere, was vented at the start of the 4th revolution and was also of insufficient duration to satisfy test requirements.

Although experimental requirements for the pneumatic control system and cold helium spheres were technically not met, sufficient information was obtained to insure success on future missions. Detail descriptions of experimental results are provided in the following sections.

26.1 Propellant Dump

At ECC +8,181 sec an experiment was conducted to determine the effectiveness of the engine as a device to dump residual propellants from the respective tanks. Although a wide variety of engine and stage modifications to make this operation feasible were considered, it was determined that, for a Saturn IB vehicle, the required propellant dumps could be achieved with no modifications except the provision of the electrical control necessary for independent operation of the main engine propellant valves.

At the initiation of the propellant dump experiment, it was estimated that the LOX mass was 2,553 lbm with an ullage pressure of 26.3 psia and that the contents of the fuel tank were completely gaseous at essentially 0 psia. The engine helium control sphere pressure was 1,890 psia and, based on the indicated temperature, the mass was 1.44 lbm. The 0.155 lbm deviation from the cutoff value was due to temperature measurement inaccuracies as discussed in paragraph 9.3.

The propellant dump experiment was initiated at ECC +8,181 sec by energizing the mainstage control solenoid valve (MCSV) and the helium control solenoid valve (HCSV). This allowed helium to fill the engine control system, including the 200 cu in. accumulator, which accounted for the initial high sphere pressure decay as shown in figure 26-1. The main oxidizer valve was also opened at this time allowing LOX to flow from the tank. The LOX dump duration was 120 sec and details of the LOX flow are discussed in paragraph 26.1.1. During the 120 sec, the helium pressure decayed due to flow through the system bleed and the LOX pump intermediate seal purge. The decay rate agreed closely with the prediction as shown in figure 26-1, which also shows the effect of the decay on the regulator discharge pressure. The LOX dump was terminated by de-energizing the MCSV thereby closing the main LOX valve. At this time, the control sphere pressure was 750 psia and the regulator discharge pressure was 368 psia which was the valve closing pressure. As shown in figure 26-2, there was positive valve closing.

The HCSV was scheduled to be de-energized 1 sec after the MCSV. This delay accounted for the 70 psi control sphere pressure decay seen in figure 26-1 due to opening of the LOX dome purge control valve when the MCSV was de-energized. The fuel dump was initiated 10 sec later by energizing the ignition phase control solenoid valve (IPCSV) and the HCSV. The control system was again refilled, but the regulated pressure was 280 psia as the control sphere pressure had decayed to 630 psia. The main fuel valve was opened at this time as shown in figure 26-2. As stated previously, there was no fuel to dump so the experiment was essentially a demonstration of the engine capability. The fuel dump was terminated as programmed at 180 sec. During that time the helium pressure decayed as shown in figure 26-1 due to flow through the thrust chamber and GG oxidizer injector purges and the LOX pump intermediate seal purge. The regulator was ineffective when the sphere pressure decayed below 250 psia. The rapid pressure decay continued to 130 psia when, as predicted, the pneumatic force in the LOX dome purge control valve could no longer maintain the valve in the open position. The valve was closed when the sphere pressure had decayed to 100 psia. Below 100 psia the pressure continued to decay, but at a greatly reduced rate, due to the LOX pump intermediate seal purge. The rate of change in system pressure during this period was 0.0667 psi/sec. The experiment was terminated by de-energizing the IPCSV, thereby closing the main fuel valve. At this time the system pressure was 90 psia and, as shown in figure 26-2, there was positive valve closing, successfully concluding this experiment. Assuming a minimum requirement for valve operation of 50 psi, the fuel dump could have continued for 600 additional seconds. The HCSV was de-energized 1 sec later, but there was no noticeable effect because of the low pressure.

26.1.1 LOX Dump

The LOX tank dump was performed as planned, with very little, if any, liquid remaining at the end of the programmed 120 sec. LOX tank ullage pressure, LOX residual, dump thrust, and dump flowrate are shown in figure 26-3. Also shown is the data from the low range chamber pressure transducer.

The LOX dump thrust profile was obtained using low range accelerometer data (A0005) and calculated values of vehicle mass. This profile was then numerically integrated to yield a dump total impulse of approximately 49,000 lb-sec. The impulse contributed by the ingested ullage gas was approximately 5,200 lb-sec, based on a calculated specific impulse of 56 sec and the change in ullage gas mass during gas ingestion. The average LOX specific impulse was then determined to be approximately 17 sec (total impulse contributed by the liquid divided by the total mass of liquid dumped). The residual LOX flowrate curve was then generated by dividing the thrust profile (excluding ullage gas thrust during gas ingestion) by this average LOX specific impulse.

As shown in figure 26-3 the dump period may be divided into three distinct phases: (1) a chilldown phase, (2) a steady-state phase, and (3) a gas ingestion phase. During the first 9 sec of the chilldown phase, the low thrust level indicated all gas flow through the LOX injector. However, the ullage pressure remained constant during this phase, indicating the gas flow was primarily GOX boiloff in the engine feed system, with little if any ullage gas loss. This also indicates at least a partially settled tank condition at dump initiation. During the remainder of the chilldown period the dump thrust increased rapidly, indicating an increase in flowrate as two-phase flow was established. At LOX dump initiation plus 35 sec steady-state liquid flow was established and verified by system conditions and thrust level.

For the next 20 sec, the dump thrust and flowrate remained constant at approximately 757 lbf and 45.3 lbm/sec, respectively. During this steady-state phase, the dump flowrate is limited by the pressure drop through the engine system hardware. At LOX dump initiation plus 55 sec, gas ingestion began as shown by the rapid decrease in thrust due to the decreasing flowrate. During the gas ingestion phase, the LOX flowrate is limited to that provided by the hydrostatic head resulting from dump thrust. Since the ullage pressure did not begin to decrease until 13 sec later, the ullage gas ingestion rate was small during this -sec period. From dump initiation plus 68 sec to dump termination, u gas was ingested through the engine at an average rate of 1.8 lbm/sec and contributed approximately 100 lbf to the total dump thrust. At the termination of LOX dump the total thrust was very nearly 100 lbf; this indicates little if any liquid was flowing and that all of the liquid mass was dumped. This conclusion is further verified by ullage conditions following dump (reference table 26-1).

Analysis of the LOX dump is continuing. Results from the measured chamber pressure during dump are being investigated to further determine dump characteristics. Data from future flights should clarify the remaining areas of interest.

26.1.2 LH2 Dump

Because of the three LH2 tank ventings that occurred after Engine Cutoff Command, the LH2 tank safing was accomplished prior to the LH2 tank dump as discussed in paragraph 26.4.2.

26.2 Cold Helium Dump

Cold helium dump was accomplished by opening the cold helium shutoff valves and allowing the cold helium to flow out through the open LOX tank vent and, thus, demonstrate a backup to the normal method of dumping helium. The normal method will use squib valves to expose the spheres to space and reduce the sphere pressure to approximately 0.0 psia. The S-IVB-204 results indicate that helium dump can be satisfactorily accomplished by the backup method.

During the first 67 sec of dumping, cold helium flowed into the LOX tank, pressurizing it from approximately 0 to 3.13 psia. After reaching this maximum, the ullage pressure should have slowly decreased to 0 psia; however, the indicated pressure only decreased to 2.16 psia (figure 26-4). This area of interest is discussed in paragraph 26.4.1.

At the end of cold helium sphere dump, the sphere pressure and average temperature were 35 psia and 30 deg R, respectively, indicating a residual mass of approximately 11 lbm (figure 26-5). The experiment requirement is a maximum steady-state pressure of 100 psia or less; the maximum allowable pressure at 30 deg R is 5.5 psia. Flowrate integral calculations during engine burn (149 lbm) and during cold helium dump (161 lbm) indicate that 24 lbm remained in the sphere after the experiment. Data accuracy is not sufficient to allow a definite conclusion, but indications are that the dump requirements were not met. On future dumps of this type, longer dump periods will satisfy the requirements.

26.3 Stage Pneumatic Control System

Based on predicted leakage, the pressure was expected to be 1,730 psia at blowdown initiation (figure 26-6) and to decrease to 1,210 psia during the preprogrammed 5 min blowdown. The pressure was actually 3,310 psia initially and had decreased to 1,550 psia when pressure data were lost at 273 sec after the start of the blowdown. The temperature was 398 deg R when the temperature data were lost at 266 sec into the blowdown. Extrapolating the temperature and pressure curves to 300 sec yielded 392 deg R and 1,500 psia, respectively, corresponding to a residual mass of 5.96 lbm (figure 26-7).

After the blowdown, the sphere temperature and pressure increased to 516 deg R and 1,830 psia, respectively, by RO +22,500 sec. Since the experiment requirement is a maximum post dump pressure of 1,500 psia, passivation of the sphere was not technically accomplished. Passivation will be guaranteed on future missions by increasing the duration of the sphere blowdown.

26.4 Vent Systems

26.4.1 LOX Tank Venting

The LOX tank orbital venting operations were satisfactorily accomplished. The only deviations from nominal performance occurred after the cold helium dump when the ullage pressure decay rate was much lower than expected and the vent valve closed indication picked up approximately 800 sec after the close command. Neither of these impaired the mission success.

Three programmed vents occurred during orbit, as shown in figure 26-8. The first vent occurred immediately after J-2 engine cutoff and dropped the ullage pressure from 39.2 to 13.5 psia in 40 sec. The second vent began shortly after propellant dump (RO +9,094 sec) and terminated after the cold helium dump (RO +11,651 sec). The third vent began at RO +14,217 sec and ended at RO +16,981 sec. Ullage pressure, temperature, and mass during orbit are shown in table 26-1.

During the cold helium dump the LOX tank ullage pressure indicated that the vent path was partiall[illegible] [illegible]urther analysis revealed that the vent effective flow area was at maximum when the ullage pressure began to decay, and then decreased during the remainder of the dump. Since the vent valve was fully open during this period (the open indication did not drop out and no abnormal pneumatic gas usage occurred), the restriction may have been due to the formation of snowy or solid oxygen in the vent system.

Evidence exists that this formation may have occurred at the vent valve. When the vent valve was commanded closed at the end of the cold helium dump (RO +11,651 sec), the open indication dropped out, but the closed indication was not received. Pickup of the closed position microswitch occurred sometime between loss of signal at the Redstone Tracking Ship (approximately RO +12,026 sec) and the initial condition scan over Ascension Island Tracking Station (approximately RO +12,536 sec). The blockage may have formed around the vent valve piston; when the valve was commanded closed, the valve may not have closed completely. As the oxygen formation changed state, the valve finally closed. This theory is supported by the ullage pressure (figure 26-8). which began to increase due to heating at RO +11,651 sec, indicating partial sealing had occurred. By RO +12,785 sec, the rise rate increased to 2.3 psia, indicating that a complete seal had probably occurred.

The restriction was absent when the vent valve was commanded open for the third vent at RO +14,217 sec. The vent effective flow area was normal, and the ullage pressure decreased rapidly from 2.5 psia toward 0 psia.

26.4.2 LH2 Tank Venting

After S-IVB powered flight, five LH2 tank vents were programmed (figure 26-9). The mass of GH2 vented, based on an all gas flow analysis, was 1,952 lbm which agrees well with the sum of the best estimated liquid residual and the pressurant in the tank at the end of powered flight.

By the end of the third vent the tank had been completely safed, which had not been expected. This was due to higher than expected boiloff rates and higher than expected vented flowrates during the first and second vents. The high level of vent flowrate was due to colder than expected temperatures at the nonpropulsive vent nozzles caused by liquid entrainment in the vented gas. According to the all-gas-vented analysis, the entrained liquid became saturated gas by the time it reached the nozzles and, thus, little or no liquid was vented overboard. The boiloff rate was greater than expected, apparently due to ullage/ liquid heat transfer. The contribution of each of these factors to the subsequent early safing is currently under investigation.

26.5 Hydraulic System Operation

The auxiliary hydraulic pump was activated prior to the LOX dump experiment to provide gimbal control. Immediately after the auxiliary hydraulic pump start, the inlet oil temperature dropped to the reservoir temperature level. Accumulator gas and reservoir oil temperatures increased by small amounts as the hydraulic pump warmed the oil. The reservoir oil level dropped to a minimum of 32 percent after pump start as 92 cu in. oil volume was pumped into the accumulator. When the pump was stopped the reservoir was refilled to the 90 percent level. Actuator temperatures dropped to a minimum of 12 deg F during orbital coast. Fluid temperature and reservoir oil level activity during this phase is shown in figures 26-10 and 26-11.

During the dump experiment the maximum excursions of the pitch and yaw actuators were -0.85 deg at the time RO +8,834.8 sec and -1.20 deg at RO +8,825.9 sec, respectively. The pitch actuator differential pressure developed a torque of 14,000 in.-lb during this activity.

Figure 26-12 indicates the extent of the pitch and yaw actuator activity during the experiment.

26.6 Attitude Control

At approximately RO +8,438 sec, a maneuver was initiated to position the stage in a nose down attitude for propellant dump. The vehicle was also rolled 85 deg such that a constant roll rate (0.28 deg/sec) during propellant dumping would provide maximum telemetry coverage as the vehicle passed over Carnarvon.

The J-2 engine provided satisfactory control during the first 80 sec of LOX dump during the propellant removal test. The AACS provided control for the remainder of the mission as planned.

The commanded and actual pitch, yaw, and roll vehicle attitude angles during the propellant removal test are presented in figure 26-13. Vehicle attitude errors and angular rates during this interval are presented in figures 26-14 and 26-15, respectively. Pitch and yaw actuator positions are shown in figure 26-16. The control system response compared favorably with the nominal predicted response during LOX dump. light results indicate that the TVC system provided adequate vehicle control when LOX was being dumped through the engine thrust chamber. The maximum attitude errors and rates experienced during the dump experiment are as follows:

Pitch -5.3 deg, +0.3 deg/sec

Yaw -5.5 deg, -0.25 deg/sec;

Roll +2.3 deg, -0.28 deg/sec.

26.7 Data Acquisition System

The data acquisition system performed satisfactorily during the dump experiment period which is defined as from RO +8,774 sec to RO +17,270 sec (last data from Tel-4 prior to Close Helium Control Vent Command).

One event measurement did not perform as expected during the dump experiment period. Measurement K0002-424, Event - Oxidizer Tank Vent Valve - Closed, did not respond when the LOX Tank Vent Closed Command was initiated at RO +11,651.35 sec. However, since measurement K0016-404, Event - Oxidizer Tank Vent Valve 1 - Open, dropped out on the close command, the valve did indicate closing. Due to low pressure in the LOX tank (2 psia), a pressure increase could not be established. The failure of the measurement to indicate closed is believed to be caused by sluggish operation of the microswitch assembly. The malfunction was temporary since proper closing was observed at RO +16,981.22 sec when the LOX Tank Vent Valve Closed Command was initiated near the end of the experiment.

The reduced PCM data did not exhibit any synchronization problems in data reduction or multiplexer synchronization difficulties. The PAM system performance was satisfactory. A_1 and A_2 multiplexer data were shown merged with the PCM data. Several B_0 multiplexer channels were evaluated to verify the B_0 multiplexer PAM link. No difficulties were observed on the FM system. The FM channels for forward and reflected powers for TM1 antenna and TM4 antenna exhibited proper calibration levels during flight calibrations.

There were no requirements to evaluate the single sideband system data during the dump experiment.

The airborne tape recorder performed very well during the dump experiment. Playback PCM data are merged with realtime data in the evaluated PCM data plots. Playback data times are specified in section 17.

The RF system maintained good power levels beyond the dump experiment periods as indicated by data observed at RO +22,680 sec. The PCM transmitter, which exhibited a reduction in power during the orbital period, showed 14 watts.

26.8 Electrical System Performance

The electrical control and electrical power systems operated satisfactorily to provide the necessary control functions and electrical power during the dump experiment. The LOX Tank Vent Valve Event indication did not fully respond to the close command which was exercised at RO +11,651.35 sec. (For additional information, see section 18.) However, it operated properly during the subsequent LOX Vent Valve Command.

Data after the dump experiment were analyzed to evaluate the launch vehicle orbital coast lifetime. Forward No. 1 battery, which provides power to the TM system, decreased below the level required to operate the system on the fifth revolution. The voltage was 29 vdc at Tel-4 (RO +22,680 sec), dropped to 17 vdc at Hawaii (RO +27,150 sec) and was indicating 0 vdc at Guaymas (RO +27,800 sec). The battery voltages for forward No. 2, aft No. 1, and aft No. 2 were at normal levels at RO +27,150 sec. However, since the TM battery voltage was below the level required to operate the system, no data are available to determine the life of these three batteries after RO +27,150 sec (7 hr 32 min).

TABLE 26-1
LOX TANK ULLAGE CONDITIONS DURING ORBIT

EVENT	TIME FROM RANGE ZERO (sec)	PRESSURE (psia)	APPROXIMATE TEMPERATURE (deg R)	MASS (lbm)
Engine cutoff, start of 40-sec vent (first vent)	593	39.2	238	320
End of 40-sec vent	633	13.5	145	240
Start of LOX dump	8,775	26.3	164	660
End of LOX dump	8,895	21.0	160	566
Vent valve commanded open (second vent)	9,095	21.4	160	576
Start of cold helium dump	10,350	0.1 (approx)	100	18
End of cold helium dump; vent valve commanded closed, open indication dropout	11,651	2.1	154	14
Closed indication pickup	*	2.3**	164**	14**
Vent valve commanded open (third vent)	14,218	2.5	180	14
Vent valve commanded closed	16,981	0 (approx)	170	0

*The close indication was picked up sometime between the loss of signal at Redstone Tracking Ship and the initial condition scan over Ascension Island Tracking Station.

**These values are only approximate because the exact time of signal pickup is unknown.

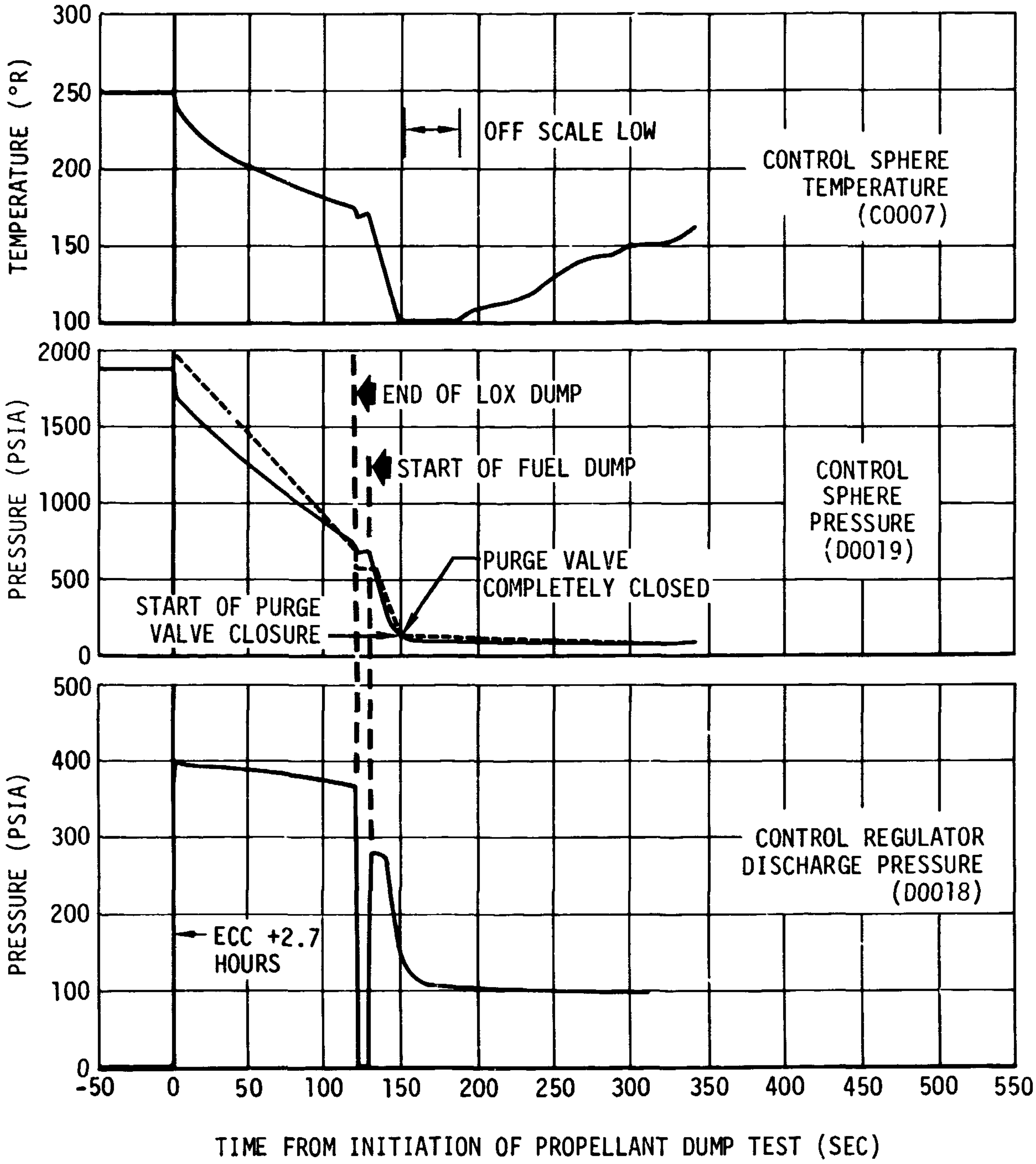


Figure 26-1. Engine Control System Performance During Propellant Dump Test

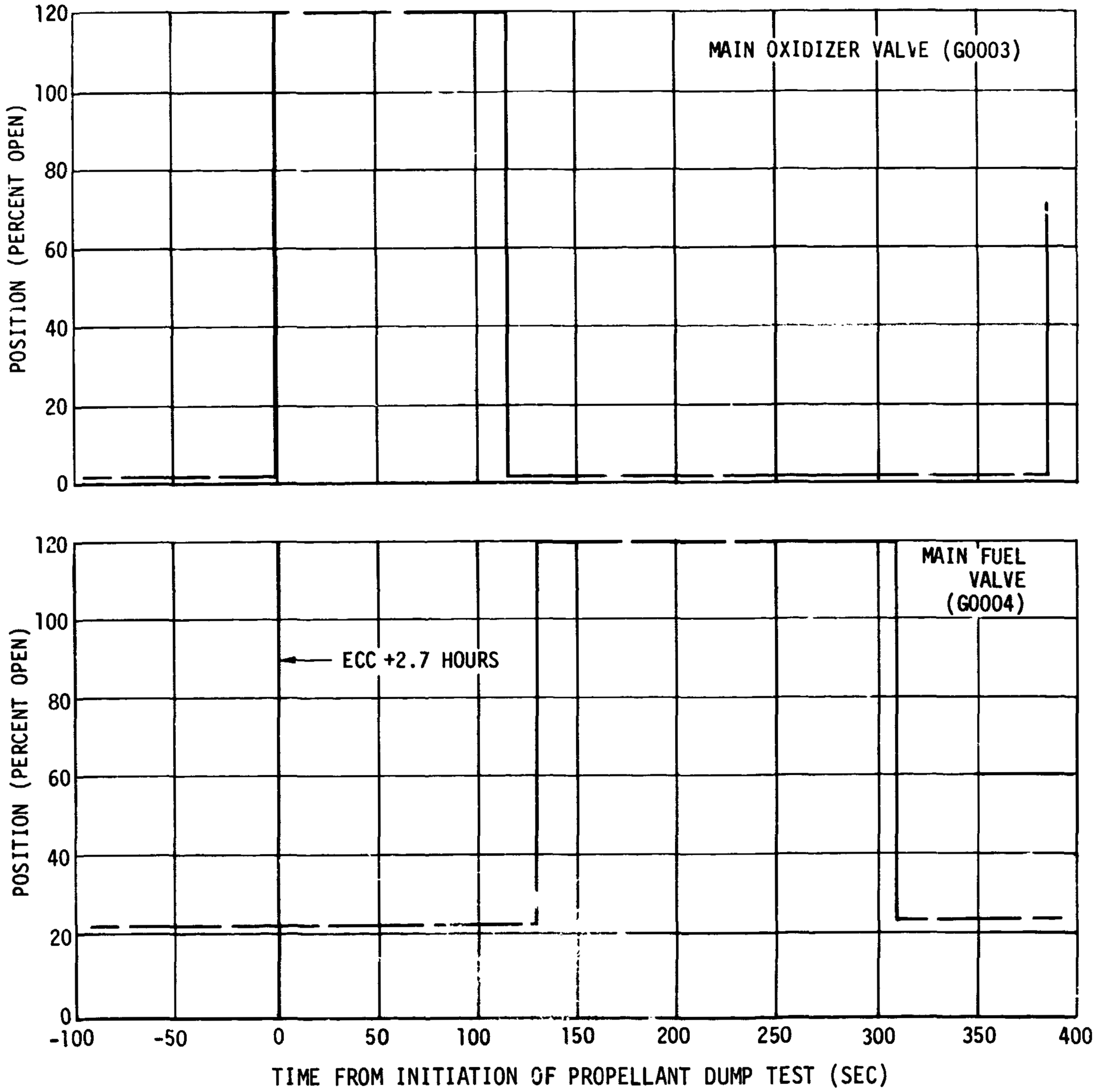


Figure 26-2. Engine Valve Performance During Propellant Dump Test

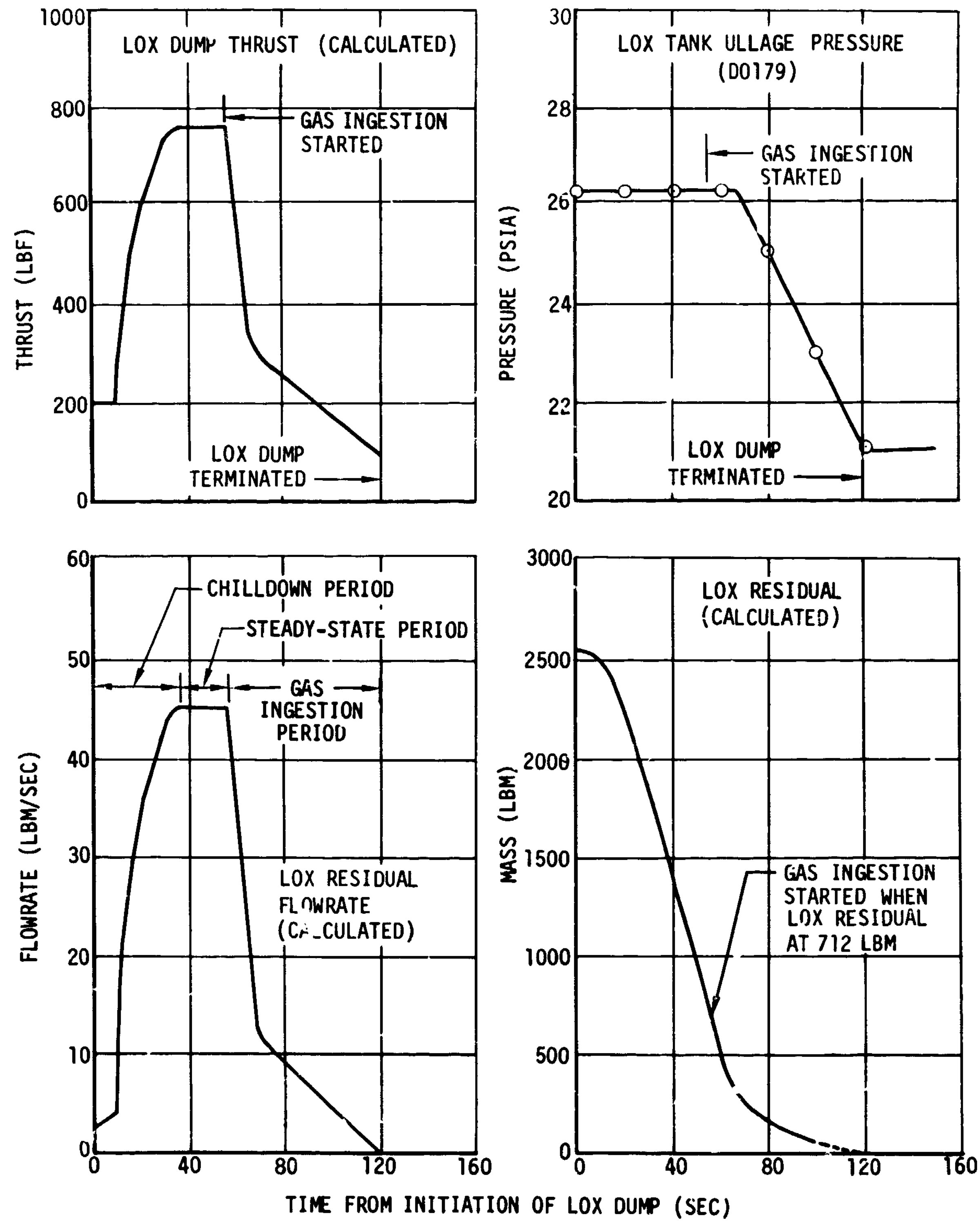


Figure 26-3. LOX Tank Dump (Sheet 1 of 2)

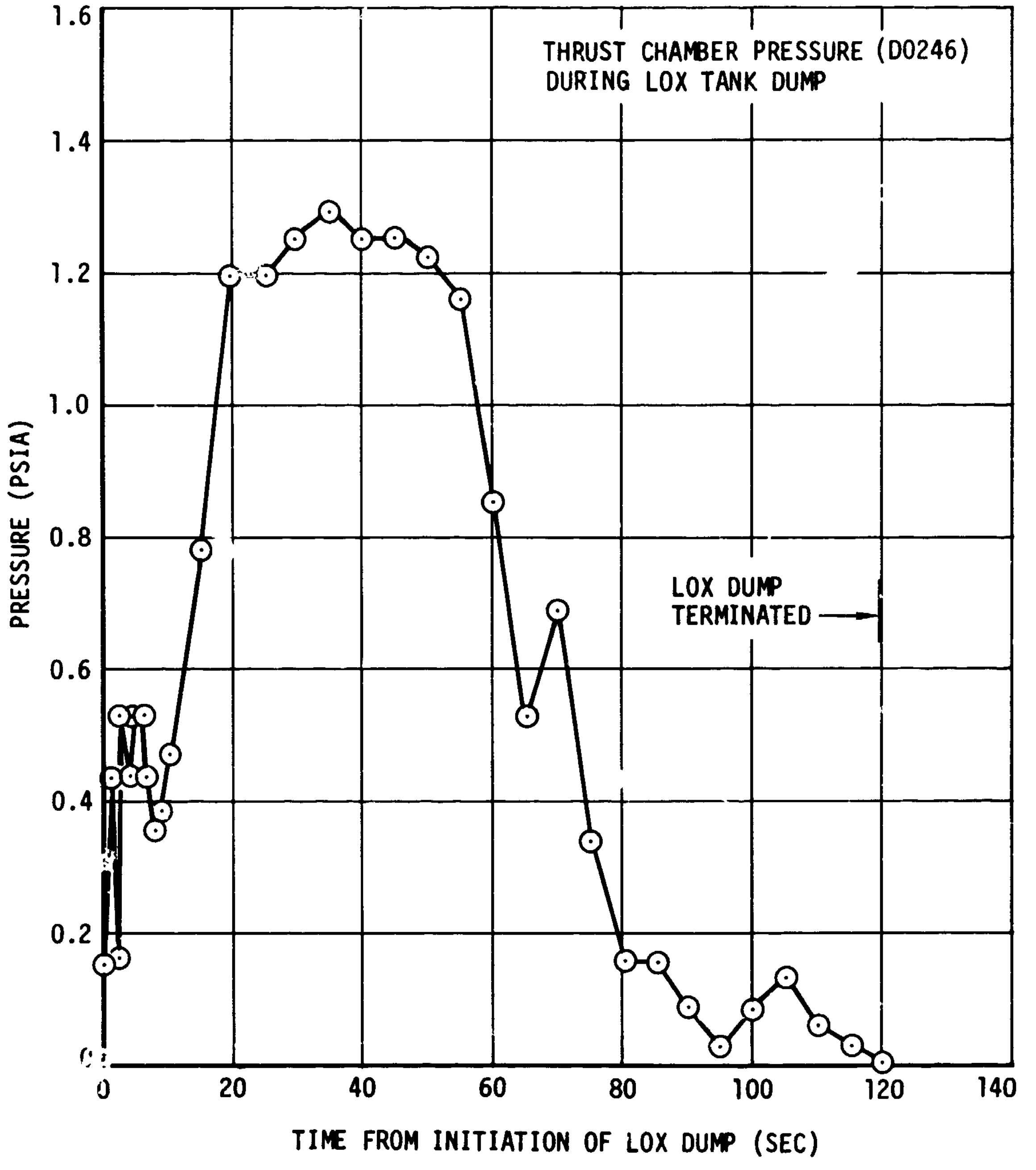


Figure 26-3. LOX Tank Dump (Sheet 2 of 2)

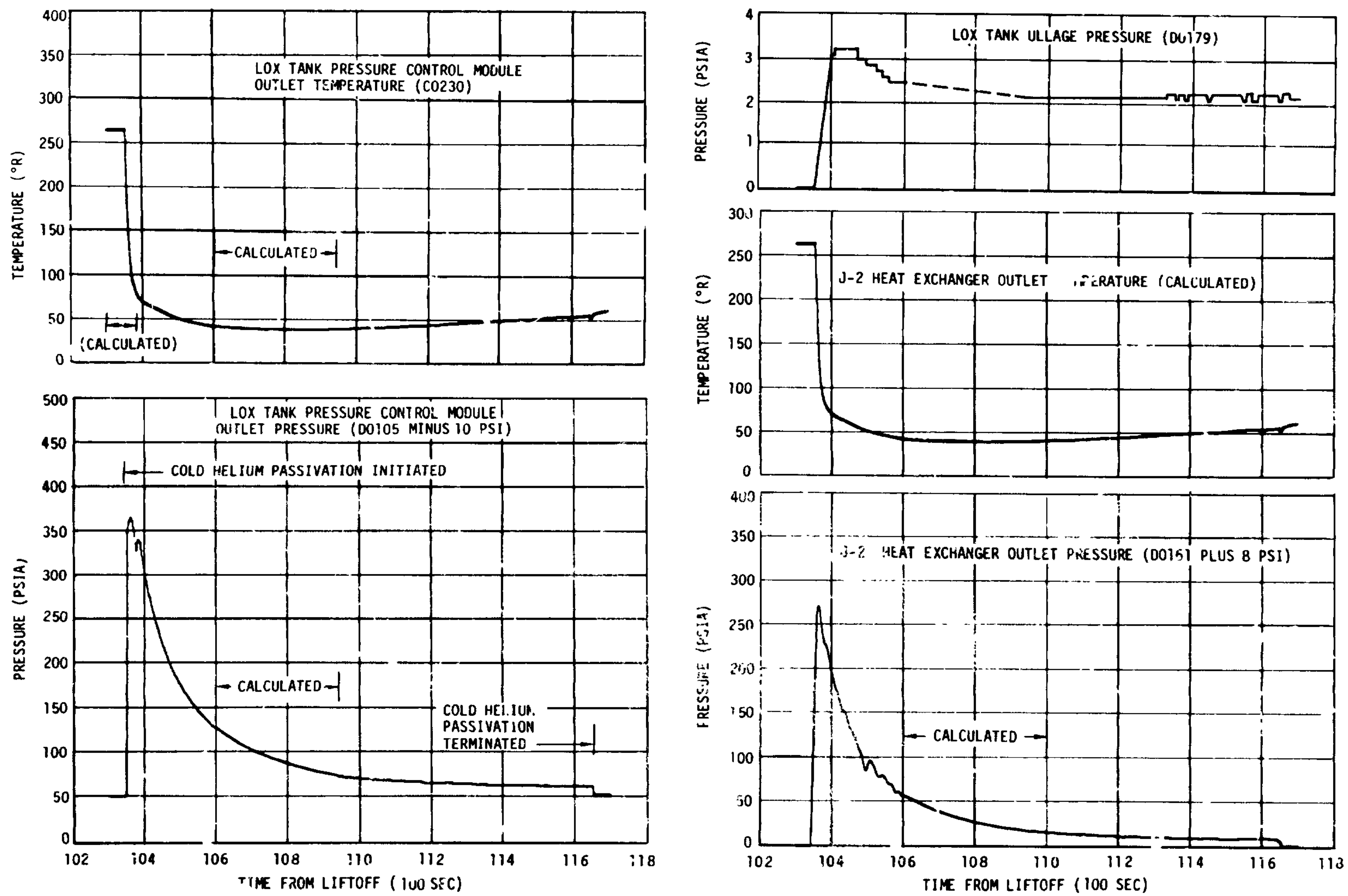


Figure 26-4. LOX Tank Pressurization System During Cold Helium Dump

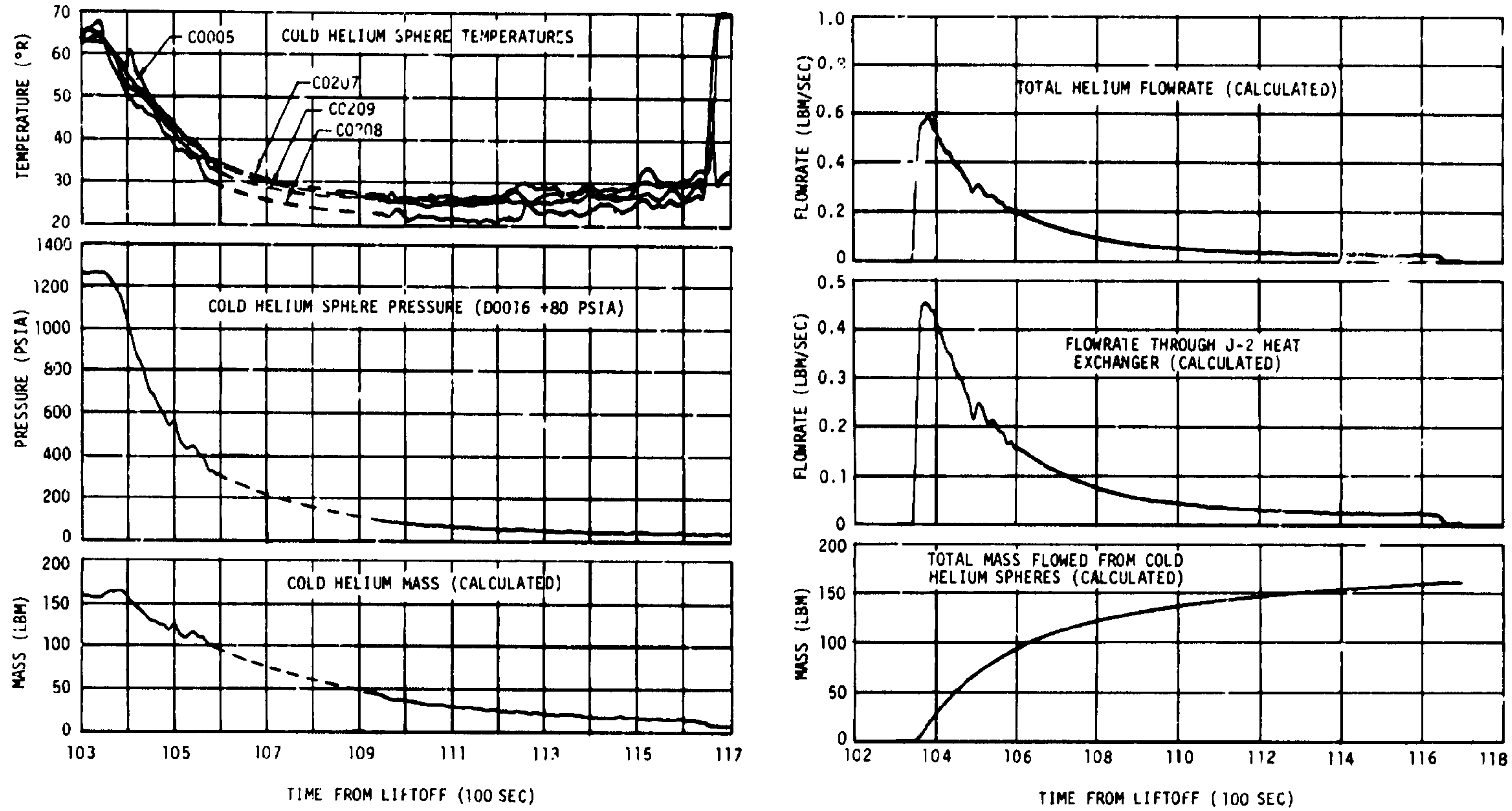


Figure 26-5. Cold Helium Dump

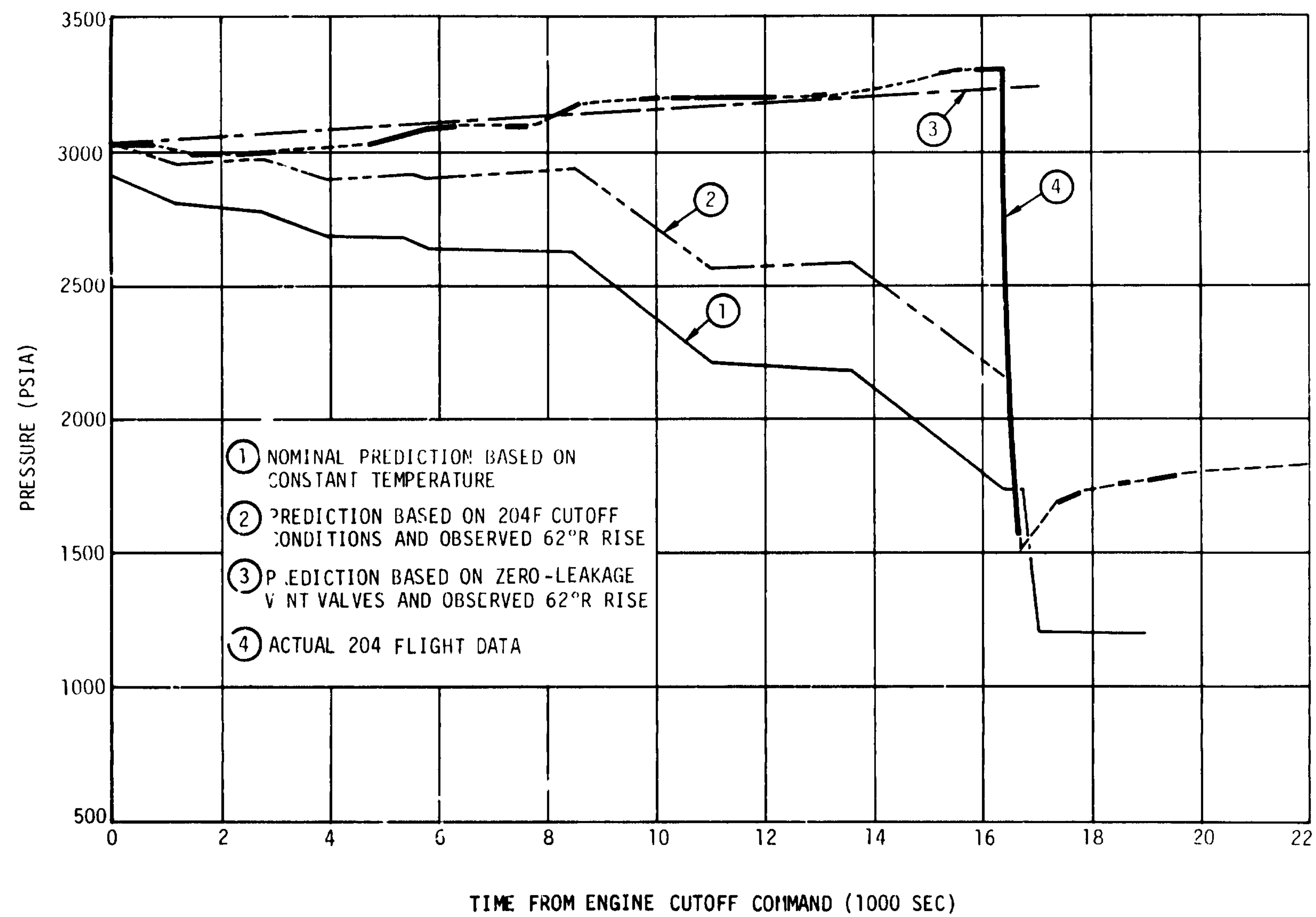


Figure 26-6. Pneumatic Control Sphere Performance During Orbit

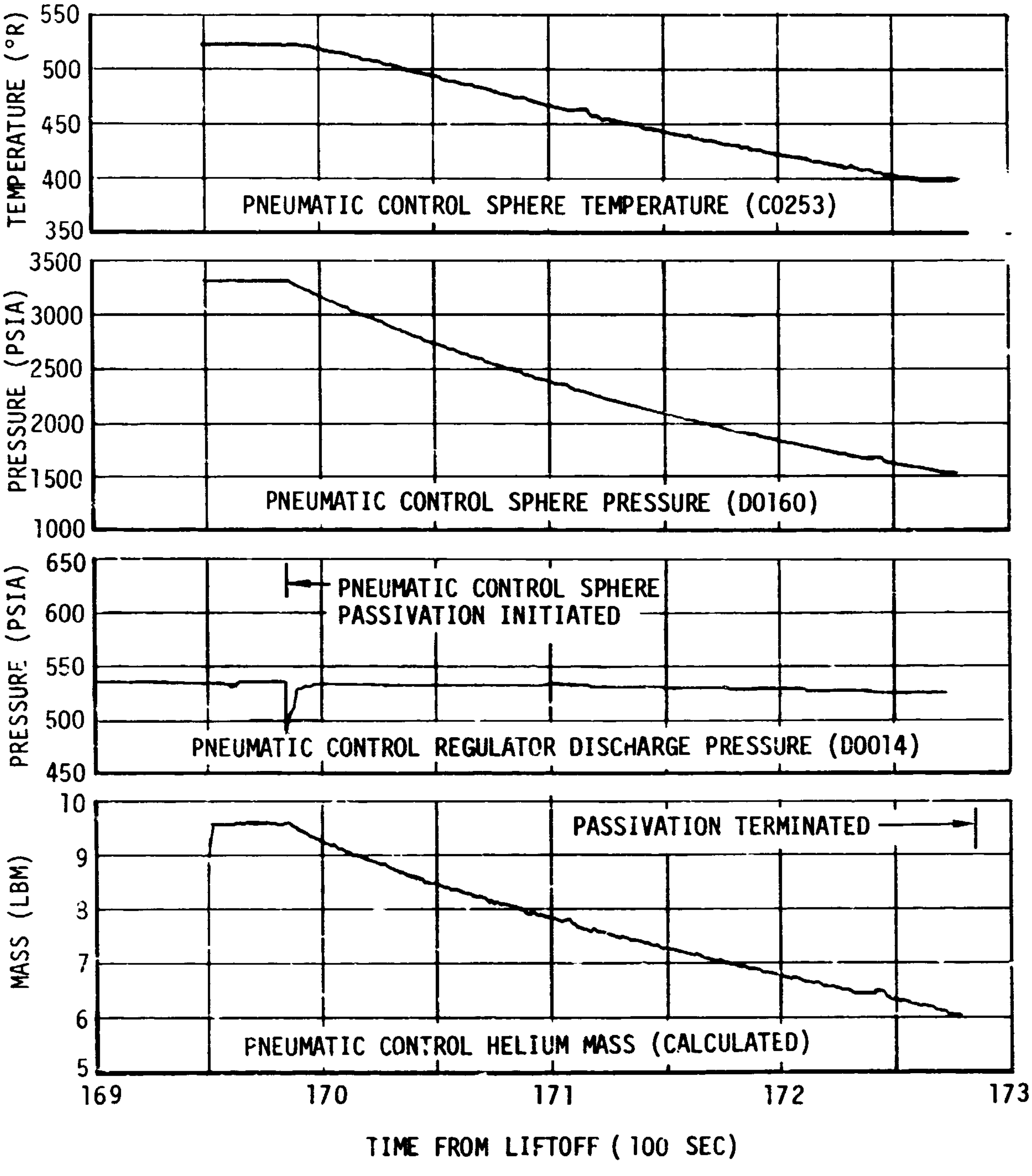


Figure 26-7. Pneumatic Control System Conditions During Propellant Dump Test

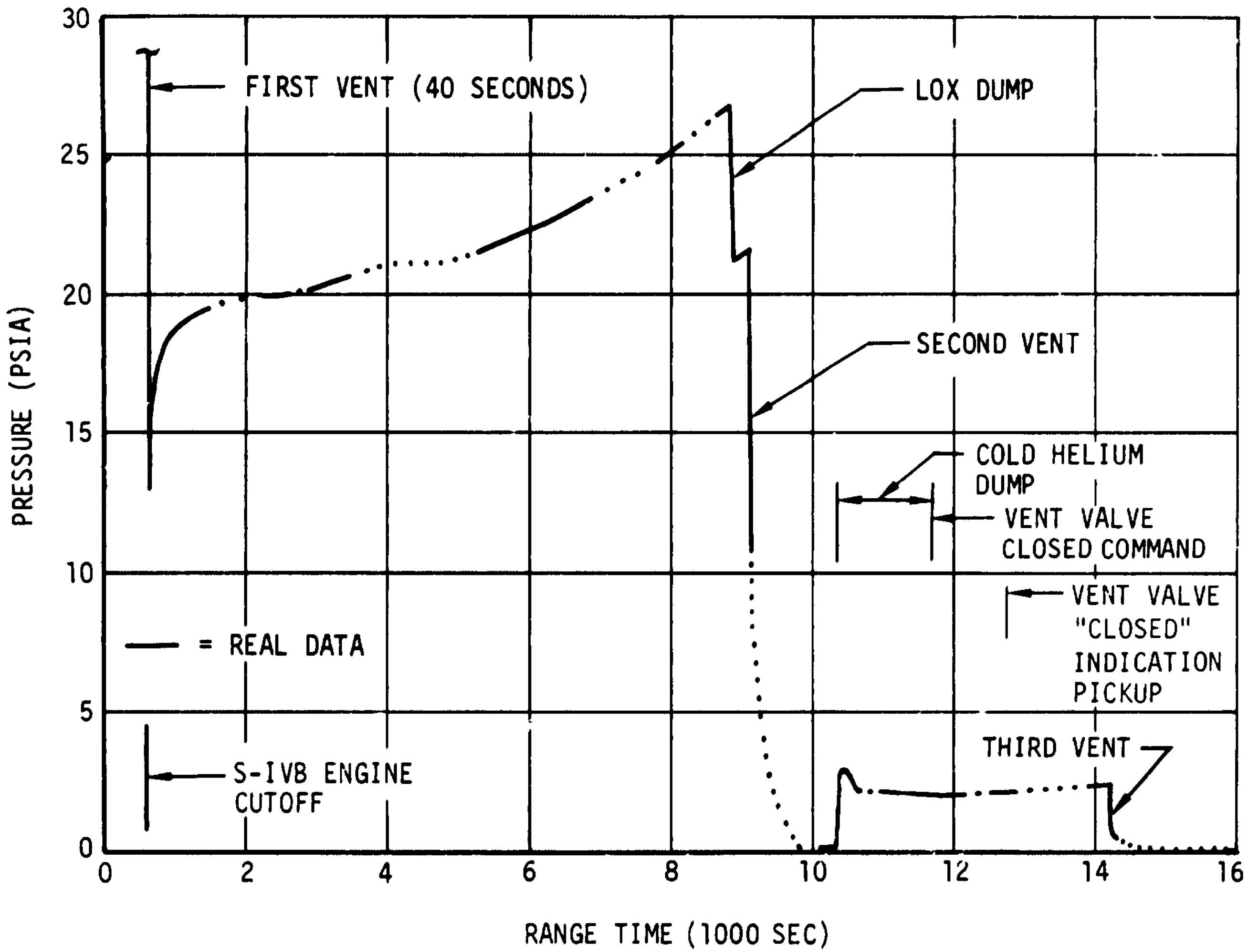


Figure 26-8. LOX Tank Ullage Pressure During Orbit

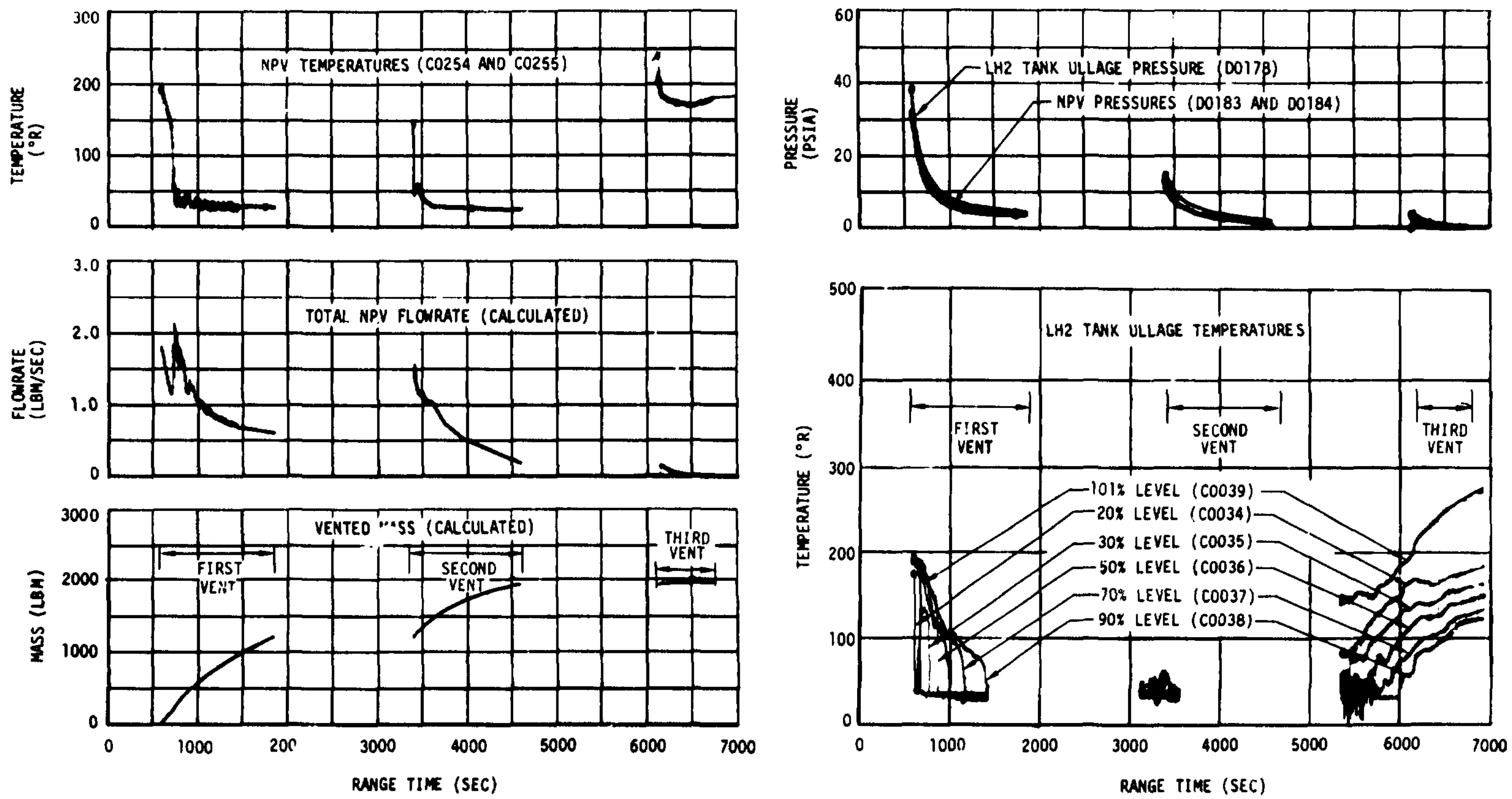


Figure 26-9. LH2 Tank Venting During Orbit

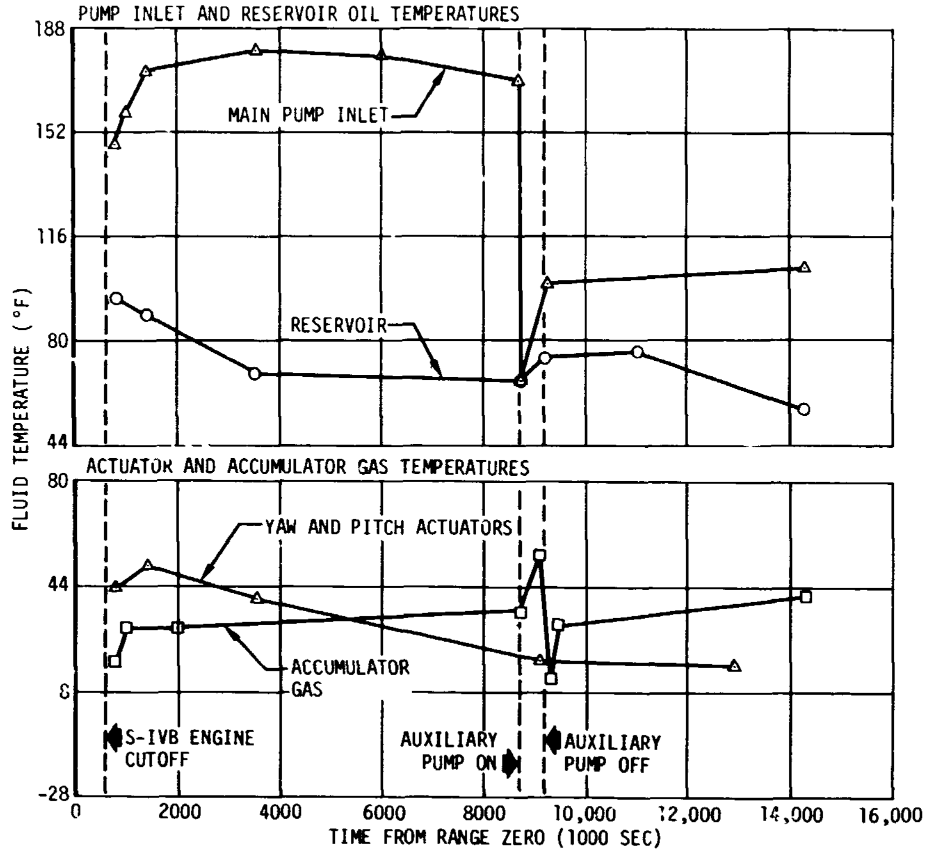


Figure 26-10. Hydraulic System Parameters During Orbital Coast and Propellant Dump

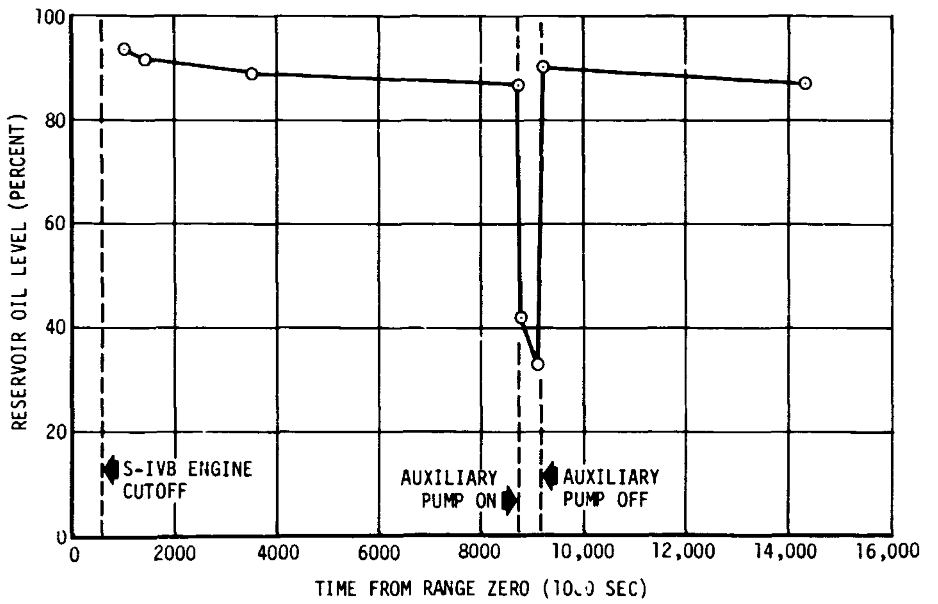


Figure 26-11. Hydraulic Reservoir Oil Level During Orbital Coast and Propellant Dump

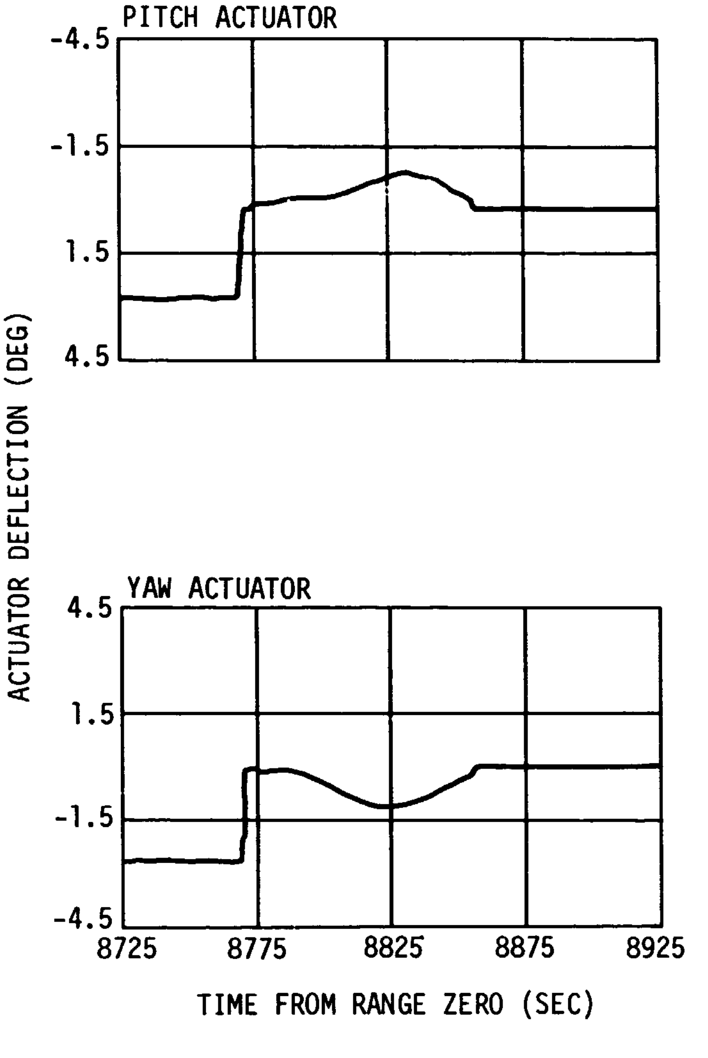


Figure 26-12. Hydraulic Actuator Positions During Propellant Dump

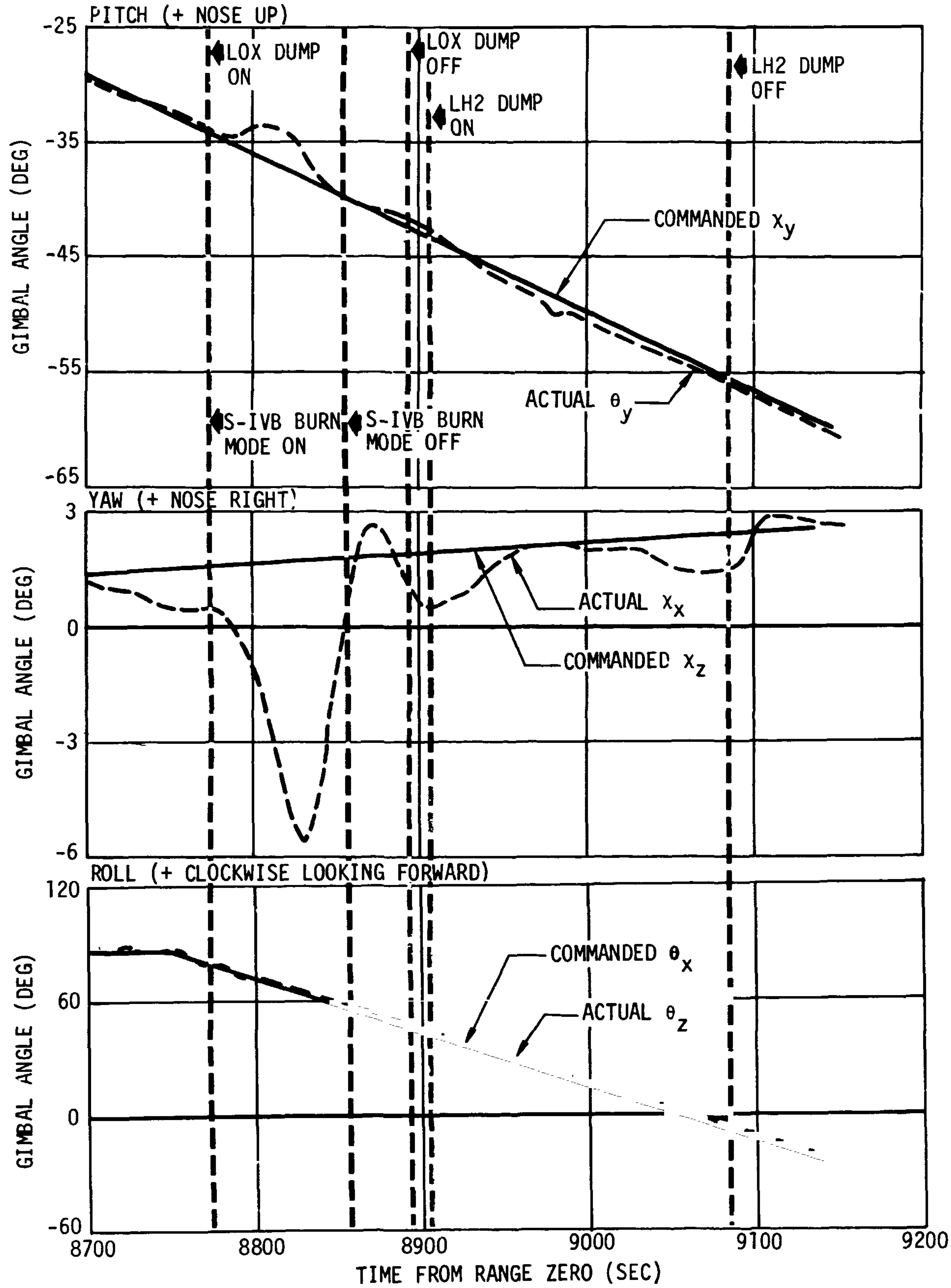


Figure 26-13. Commanded and Actual Vehicle Attitude During LOX and LH2 Propellant Dump

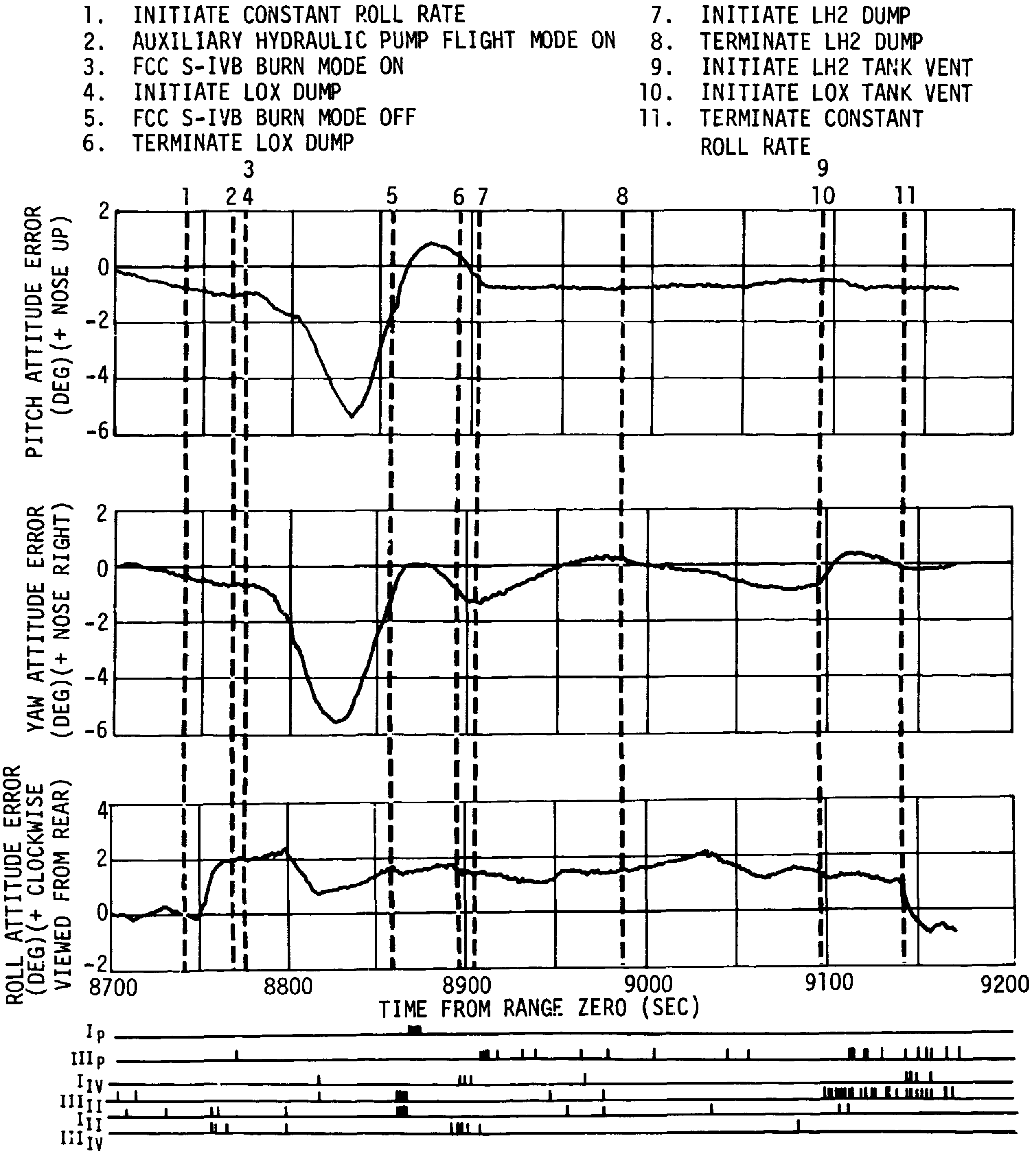


Figure 26-14. Attitude Errors and APS Firings During Propellant Removal Test

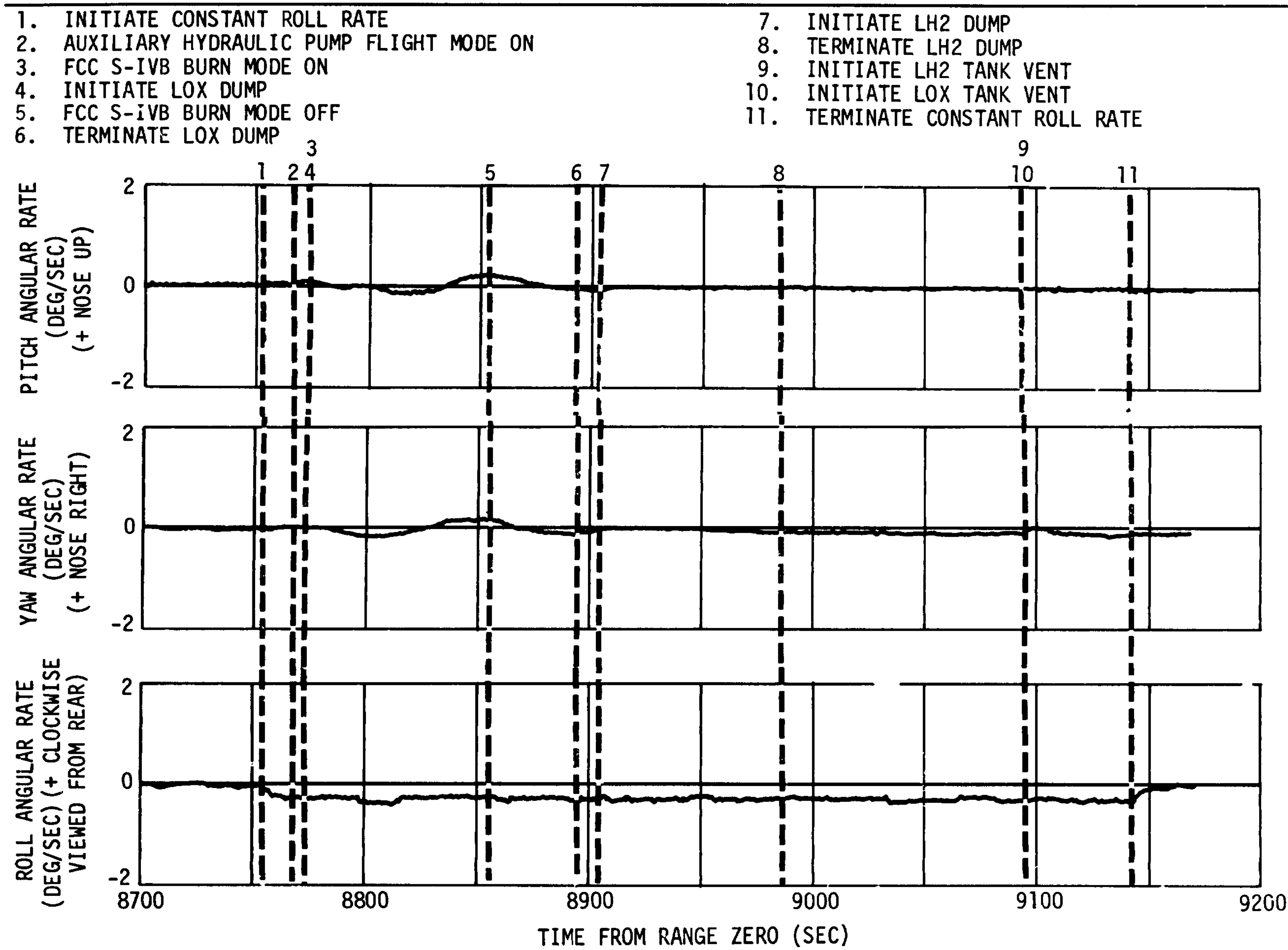


Figure 26-15. Angular Rate Gyros During Propellant Removal Test

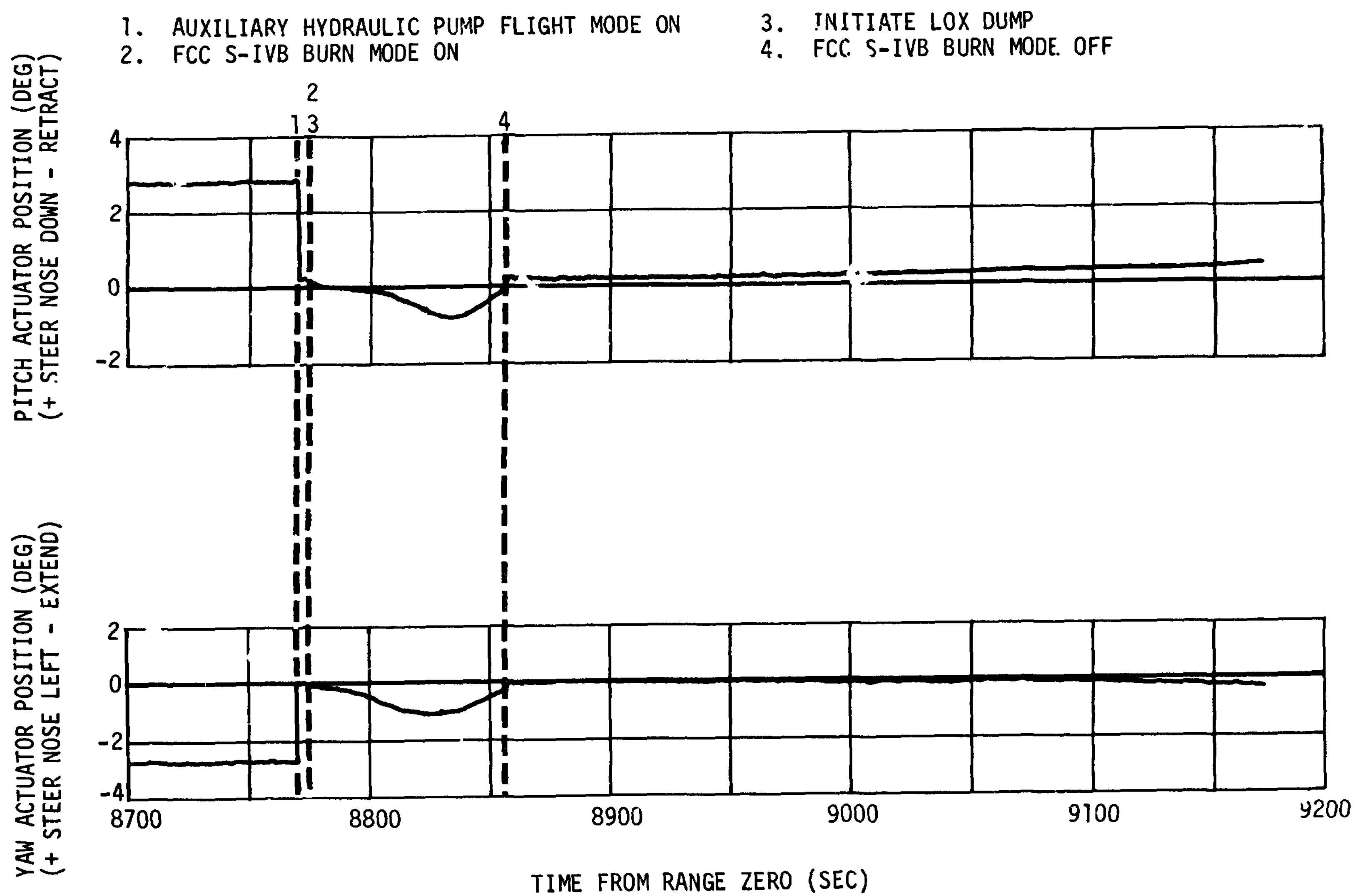


Figure 26-16. Pitch and Yaw Actuator Position During Propellant Removal Test

APPENDIX I

MASS CHARACTERISTICS (WS11)

1. MASS CHARACTERISTICS (WS11)

This appendix presents the mass breakdown summary, the mass characteristics summary, and the propellant data history (tables AP 1-2, AP 1-3, and AP 1-4) as calculated by the WS11 computer program for the AS-204 second flight stage (S-IVB stage, IU. and spacecraft)

Table AP 1-1 defines the terms and abbreviations used in the printouts, and figure AP 1-1 presents the S-IVB stage station numbers.

The mass breakdown, table AP 1-2, is an itemized list of major components (including all gases, propellants, etc.) giving mass, centers of gravity and moments of inertia, including a summation for the indicated time. Table AP 1-2 also presents a jettisoned item summary at the appropriate times. The mass characteristics summary, table AP 1-3, is a time listing of the S-IVB-204 second flight stage mass characteristics. The propellant data history is a time listing of masses, centers of mass, surface levels, liquid volumes and densities for both oxidizer and fuel.

All mass characteristic parameters are time referenced to AS-204 vehicle range zero and progress chronologically from range zero to S-IVB-204 loss of telemetry signal.

TABLE AP 1-1 (Sheet 1 of 2)
COMPUTER PROGRAM WS11 PRINTOUT
ABBREVIATIONS AND DEFINITIONS

TERM	DEFINITION	UNITS
DAC Station	Distance along the x axis from an arbitrary S-IVB stage reference zero. The zero station is located so that the S-IVB stage engine gimbal point is station 100.0. Positive values increase in the forward direction and negative values are aft of station zero.	In.
X Arm	Distance along the centerline of the S-IVB stage from the center of gravity of the item under consideration to DAC station zero.	In.
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
Items Remaining	A listing of all items being considered at the current computing time that will be considered at the next computing time.	None
Y Arm	Distance from the center of gravity of the item under consideration to the centerline of the S-IVB stage along an axis perpendicular to the centerline and coinciding with position II and IV. Position II is positive and position IV is negative.	In.
IYY	Pitch Moment of Inertia of any item or total about an axis through its own center of gravity and parallel to the y axis.	$Lbm\text{-}in.^2$
IXX	Roll Moment of Inertia of any item or total about an axis through its own center of gravity and parallel to the x axis.	

TABLE AP 1-1 (Sheet 2 of 2)
COMPUTER PROGRAM WS11 PRINTOUT
ABBREVIATIONS AND DEFINITIONS

TERM	DEFINITION	UNITS
Time	Time is referenced to range time. All computing was done in the pounds, inches, and pound-inch 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.	Sec
Total Jettisoned	A summation of the items remaining at the current computing time.	None
Total Remaining	A summation of the items remaining at the current computing time.	None
Z Arm	Distance from the center of gravity of item under consideration to the centerline of the S-IVB stage along an axis perpendicular to the H and L axes and coinciding with positions I and III. Position I is negative and position III is positive.	In.
IZZ	Yaw Moment of Inertia of any item or total, about an axis through its own center of gravity and parallel to the Z axis.	$Lbm-in.^2$

TABLE AP 1-2 (Sheet 1 of 6)
MASS BREAKDOWN SUMMARY

S-IB LIFT-OFF — TIME RO +000.36 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)
FROST	100.00	420.40	.0	.0	.16926009+07	.14472090+07	.14472090+07
SEPARATION PKG	34.12	200.69	.0	.0	.57396969+06	.40582613+06	.40582613+06
ULLAGE ROCKETS	399.00	223.71	.2	-.4	.76382521+07	.38351247+07	.38351247+07
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28640584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	193703.00	241.92	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	30.00	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	37266.00	434.35	.0	.0	.00000000	.11723452+09	.11723452+09
LH2 ULLAGE GAS	147.00	616.41	.0	.0	.00000000	.00000000	.00000000
LH2 BEL[illegible]ANK	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD H[illegible]	316.00	494.30	100.1	-27.8	.78180535+06	.10069664+07	.34474996+06
APS P[illegible]ANT	129.00	248.59	.0	.0	.24902577+07	.24788000+07	.47060489+05
GH2-S[illegible] TANK	5.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	297246.26	350.53	.8	-.4	.50115495+09	.12402458+11	.12400870+11
					(SLUG-FT2) .10816932+06	(SLUG-FT2) .26769473+07	(SLUG-FT2) .26766047+07

S-IB/S-IVB SEPARATION — TIME RO +143.50 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	.16141900-01	.13801660-01	.13801660-01
SEPARATION PKG	34.12	200.69	.0	.0	.57396969+06	.40582613+06	.40582613+06
TOTAL JETTISONED	34.12	200.69	.0	.0	.57396971+06	.40582617+06	.40582617+06
					(SLUG-FT2) .12388566+03	(SLUG-FT2) .87593549+02	(SLUG-FT2) .87593549+02

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	389.43	223.71	.2	-.4	.74550948+07	.37431625+07	.37431625+07
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.51762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	193698.09	241.94	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	34.92	318.65	.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	37246.19	434.66	.0	.0	.00000000	.11816209+09	.11816209+[illegible]
LH2 ULLAGE GAS	166.67	616.80	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD HELIUM	316.00	494.30	100.1	-27.8	.78180535+06	.10069664+07	.34474996+06
APS PROPELLANT	129.00	248.59	.0	.0	.24902577+07	.24788000+07	.47060489+0[illegible]
GH2-START TANK	5.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+[illegible]
TOTAL REMAINING	297102.44	350.59	.8	-.4	.49870512+09	.12402522+11	.12400934+11
					(SLUG-FT2) .10764055+06	(SLUG-FT2) .26769611+07	(SLUG-FT2) .26766185+07

TABLE AP 1-2 (Sheet 2 of 6)
MASS BREAKDOWN SUMMARY

S-IVB ENGINE START COMMAND — TIME RO +144.90 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	322.46	223.71	.2	-.4	.61729991+07	.30994292+07	.30994292+07
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	193698.04	241.94	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	34.97	318.65	.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	37246.00	434.67	.0	.0	.00000000	.11817567+09	.11817567+09
LH2 ULLAGE GAS	166.86	616.81	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD HELIUM	316.00	494.30	100.1	-27.8	.78180535+06	.10069664+07	.34474996+06
APS PROPELLANT	129.00	248.59	.0	.0	.24902577+07	.24788000+07	.47060489+05
GH2-START TANK	5.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	297035.46	350.62	.8	-.4	.49742299+09	.12400843+11	.12399256+11
					(SLUG-FT2) .10736381+06	(SLUG-FT2) .26765989+07	(SLUG-FT2) .26762562+07

S-IVB 90% OF THRUST — TIME RO +148.20 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	222.00	223.71	.2	-.4	.42498546+07	.21338288+07	.21338268+07
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	192677.94	241.57	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	36.40	317.76	.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	36978.94	433.66	.0	.0	.00000000	.11415809+09	.11415809+09
LH2 ULLAGE GAS	168.22	615.54	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	58.00	148.00	-39.2	-42.5	.71212492+05	.28966642+06	.28160753+06
COLD HELIUM	314.83	494.30	100.1	-27.8	.77891656+06	.10032379+07	.34347346+06
APS PROPELLANT	128.96	248.59	.0	.0	.24894907+07	.24780365+07	.47045995+05
GH2-START TANK	1.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	295685.43	350.57	.9	-.4	.49554352+09	.12391227+11	.12389626+11
					(SLUG-FT2) .10695815+06	(SLUG-FT2) .26745234+07	(SLUG-FT2) .26741778+07

PROPULLANT UTILIZATION CUT-BACK — TIME RO +470.00 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)
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	49958.25	195.13	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	232.75	260.94	.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	10936.26	332.72	.0	.0	.00000000	.59731889+08	.59731889+08
LH2 ULLAGE GAS	339.39	511.96	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	58.00	148.00	-39.2	-42.5	.71212492+05	.28966642+06	.28160753+06
COLD HELIUM	200.73	494.30	100.1	-27.8	.49662389+06	.63965225+06	.21899449+06
APS PROPELLANT	125.09	248.59	.0	.0	.24146958+07	.24035858+07	.45632534+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITFMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	126956.60	429.10	1.9	-.6	.48942526+09	.10210597+11	.10208059+11
					(SLUG-FT2) .10563758+06	(SLUG-FT2) .22038559+07	(SLUG-FT2) .22033081+07

TABLE AP 1-2 (Sheet 3 of 6)
MASS BREAKDOWN SUMMARY

START E M R SHIFT
ITEMS REMAINING

START ENGINE MIXTURE RATIO SHIFT — TIME RO +492.90 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)
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	39802.00	190.71	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	246.72	257.88	.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	9083.00	324.81	.0	.0	.00000000	.51074421+08	.51074421+08
LH2 ULLAGE GAS	351.57	504.69	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	58.00	148.00	-39.2	-42.5	.71212492+05	.28966642+06	.28160753+06
COLD HELIUM	192.61	494.30	100.1	-27.8	.47653574+06	.61377870+06	.21013629+06
APS PROPELLANT	124.81	248.59	.0	.0	.24093732+07	.23982877+07	.45531948+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	114964.85	449.13	2.1	-.9	.48926014+09	.96803412+10	.96777143+10
					(SLUG-FT2) .10560194+06	(SLUG-FT2) .20894055+07	(SLUG-FT2) .20888385+07

END ENGINE MIXTURE RATIO SHIFT — TIME RO +544.90 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)
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	19967.00	180.51	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	278.44	251.59	.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	5024.00	306.06	.0	.0	.00000000	.40754061+08	.40754061+08
LH2 ULLAGE GAS	379.23	489.55	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	58.00	148.00	-39.2	-42.5	.71212492+05	.28966642+06	.28160753+06
COLD HELIUM	174.18	494.30	100.1	-27.8	.43092074+06	.55502651+06	.19002160+06
APS PROPELLANT	124.18	248.59	.0	.0	.23972870+07	.23862571+07	.45303546+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	91111.18	507.51	2.6	-1.1	.48886038+09	.81059022+10	.81030[illegible]58+10
					(SLUG-FT2) .10551566+06	(SLUG-FT2) .17495786+07	(SLUG-FT2) .17489643+07

S-IVB ENGINE CUTOFF COMMAND — TIME RO +593.34 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)
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	2641.00	164.89	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	308.00	245.56	.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	1427.00	278.93	.0	.0	.00000000	.10934260+08	.10934260+08
LH2 ULLAGE GAS	405.00	475.50	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	58.00	148.00	-39.2	-42.5	.71212492+05	.28966642+06	.28160753+06
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842862+06	.50029660+06	.17128401+06
APS PROPELLANT	123.60	248.59	.0	.0	.23860283+07	.23750502+07	.45090779+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	70225.74	597.16	3.4	-1.4	.48841688+09	.55603179+10	.55572200+10
					(SLUG-FT2) .10541993+06	(SLUG-FT2) .12001394+07	(SLUG-FT2) .11994708+07

TABLE AP 1-2 (Sheet 4 of 6)
MASS BREAKDOWN SUMMARY

S-IVB END OF THRUST DECAY — TIME RO +594.74 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)
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	2521.00	164.65	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	308.00	245.52	.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	1400.00	278.66	.0	.0	.00000000	.10724851+08	.10724851+08
LH2 ULLAGE GAS	405.00	475.39	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842861+06	.50029659+06	.17128400+06
APS PROPELLANT	123.56	248.59	.0	.0	.23852720+07	.23742974+07	.45076487+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	70038.70	598.28	3.4	-1.4	.48834881+09	.55265543+10	.55234574+10
					(SLUG-FT2) .10540524+06	(SLUG-FT2) .11928519+07	(SLUG-FT2) .11921834+07

JETTISON NOSE CONE — TIME RO +638.51 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)
NOSE CONE	1067.00	1094.70	.0	.0	.35881503+07	.29174384+07	.28840584+07
SLA RING	91.00	1047.80	.0	.0	.53660007+06	.26831259+06	.26831259+06
TOTAL JETTISONED	1158.00	1091.01	.0	.0	.41247504+07	.33702080+07	.33368320+07
					(SLUG-FT2) .89028641+03	(SLUG-FT2) .72742593+03	(SLUG-FT2) .72022206+03

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)
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	848.20	3.8	-1.9	.44363558+08	.62222207+08	.61762445+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	2503.75	164.62	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	232.25	245.51	.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	1375.66	278.42	.0	.0	.00000000	.10536300+08	.10536300+08
LH2 ULLAGE GAS	404.83	475.29	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842861+06	.50029659+06	.17128400+06
APS PROPELLANT	122.31	248.59	.0	.0	.23610239+07	.23501609+07	.44618252+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	68761.93	590.59	3.4	-1.5	.48418237+09	.52227356+10	.52196837+10
					(SLUG-FT2) .10450595+06	(SLUG-FT2) .11272757+07	(SLUG-FT2) .11266169+07

TABLE AP 1-2 (Sheet 5 of 6)
MASS BREAKDOWN SUMMARY

START LOX DUMP — TIME RO +8774.35 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	3859.00	837.20	5.9	-1.6	.10939669+09	.77637619+08	.74720742+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	2086.00	163.74	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	650.00	245.36	.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	.00	262.21	.0	.0	.00000000	.00000000	.00000000
LH2 ULLAGE GAS	.00	470.78	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	.00	148.00	-39.2	-42.5	.00000000	.00000000	.00000000
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842861+06	.50029659+06	.17128400+06
APS PROPELLANT	83.00	248.59	.0	.0	.16023396+07	.15949672+07	.30280757+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	35364.14	420.79	5.9	-2.9	.45431686+09	.25607669+10	.25536055+10
					(SLUG-FT2) .98059784+05	(SLUG-FT2) .55271611+06	(SLUG-FT2) .55117039+06

END LOX DUMP — TIME RO +8894.55 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	3859.00	837.20	5.9	-1.6	.10939669+09	.77637619+08	.74720742+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036584+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	.00	157.52	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	557.00	245.36	.0	.0	.00000000	.00000000	.00000000
LOX BELOW TANK	.00	114.94	3.2	6.5	.20603088-02	.48237365-02	.485[illegible]047-02
LH2 IN TANK	.00	262.21	.0	.0	.00000000	.00000000	.000[illegible]00
LH2 ULLAGE GAS	.00	470.78	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	.00	148.00	-39.2	-42.5	.00000000	.00000000	.00000000
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842861+06	.50029659+06	.17128400+06
APS PROPELLANT	82.79	248.59	.0	.0	.15982047+07	.15908514+07	.30202616+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	32817.93	441.05	6.3	-3.2	.45397641+09	.23717425+10	.23645525+10
					(SLUG-FT2) .97986300+05	(SLUG-FT2) .51191707+06	(SLUG-FT2) .51036519+06

END OF PROGRAM — TIME RO +20,000.00 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	3859.00	837.20	5.9	-1.6	.10939669+09	.77637619+08	.74720742+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	.00	157.52	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	.00	245.36	.0	.0	.00000000	.00000000	.00000000
LOX BELOW TANK	.00	114.94	3.2	6.5	.20603088-02	.48237365-02	.48509047-02
LH2 IN TANK	.00	262.21	.0	.0	.00000000	.00000000	.00000000
LH2 ULLAGE GAS	.00	470.78	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	.00	148.00	-39.2	-42.5	.00000000	.00000000	.00000000
COLD HELIUM	.00	494.30	100.1	-27.8	.47189094-02	.60779618-02	.20808809-02
APS PROPELLANT	63.00	248.59	.0	.0	.12161724+07	.12105767+07	.22983030+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	32084.14	444.30	6.0	-3.2	.45169711+09	.23479136+10	.23401189+10
					(SLUG-FT2) .97494336+05	(SLUG-FT2) .50677384+06	(SLUG-FT2) .50509143+06

TABLE AP 1-2 (Sheet 6 of 6)
MASS BREAKDOWN SUMMARY

DEPLUYSLA PANELS
ITEMS REMAINING

DEPLOY SLA PANELS — TIME RO +1193.52 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)
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
ADAPTER	3859.00	837.20	5.9	-1.6	.10939669+09	.77637619+08	.74720742+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	2475.26	164.56	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	260.74	245.50	.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	1067.04	275.06	.0	.0	.00000000	.81531221+07	.81531221+07
LH2 ULLAGE GAS	402.62	474.01	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TANK	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842861+06	.50029659+06	.17128400+06
APS PROPELLANT	106.16	248.59	.0	.0	.20494333+07	.20400038+07	.38729861+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	68434.97	591.43	3.6	-1.4	.54892038+09	.51827212+10	.51775356+10
					(SLUG-FT2) .11847901+06	(SLUG-FT2) .11186389+07	(SLUG-FT2) .11175197+07

LM/S-IVB SEPARATION — TIME RO +3232.53 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)
LUNAR MODULE	31530.00	796.90	1.2	.2	.93377241+08	.10468163+09	.10687309+09
TOTAL JETTISONED	31530.00	796.90	1.2	.2	.93377241+08	.10468149+09	.10687325+09
					(SLUG-FT2) .20154551+05	(SLUG-FT2) .22594461+05	(SLUG-FT2) .23067531+05

3232.530TOTAL SECONDS — 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	3859.00	837.20	5.9	-1.6	.10939669+09	.77637619+08	.74720742+08
INSTRUMNT UNIT	4605.00	699.00	2.9	-8.5	.69703033+08	.37674437+08	.33036684+08
S4B204 DRY STG	23477.14	330.40	6.6	-2.4	.27045029+09	.10234451+10	.10245238+10
LOX IN TANK	2370.56	164.35	.0	.0	.00000000	.00000000	.00000000
LOX ULLAGE GAS	365.44	245.47	.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	342.98	263.32	.0	.0	.00000000	.26122065+07	.26122065+07
LH2 ULLAGE G[illegible]	757.02	470.96	.0	.0	.00000000	.00000000	.00000000
LH2 BELOW TA[illegible]K	48.00	148.00	-39.2	-42.5	.58934476+05	.23972394+06	.23305451+06
COLD HELIUM	157.00	494.30	100.1	-27.8	.38842861+06	.50029659+06	.17128400+06
APS PROPELLANT	101.36	248.59	.0	.0	.19566664+07	.19476638+07	.36976767+05
GH2-START TANK	7.00	88.40	-22.0	14.6	.00000000	.00000000	.00000000
SERVICE ITEMS	30.00	127.20	14.2	9.3	.43548299+05	.59060907+05	.25966091+05
ENV CONT FLUID	43.00	662.70	.0	.0	.66116800+06	.33193332+06	.33193332+06
TOTAL REMAINING	36530.50	419.31	5.6	-2.9	.45494906+09	.25877925+10	.25803280+10
					(SLUG-FT2) .98196238+05	(SLUG-FT2) .55854931+06	(SLUG-FT2) .55693817+06

TABLE AP 1-3 (Sheet 1 of 2)
MASS CHARACTERISTICS SUMMARY

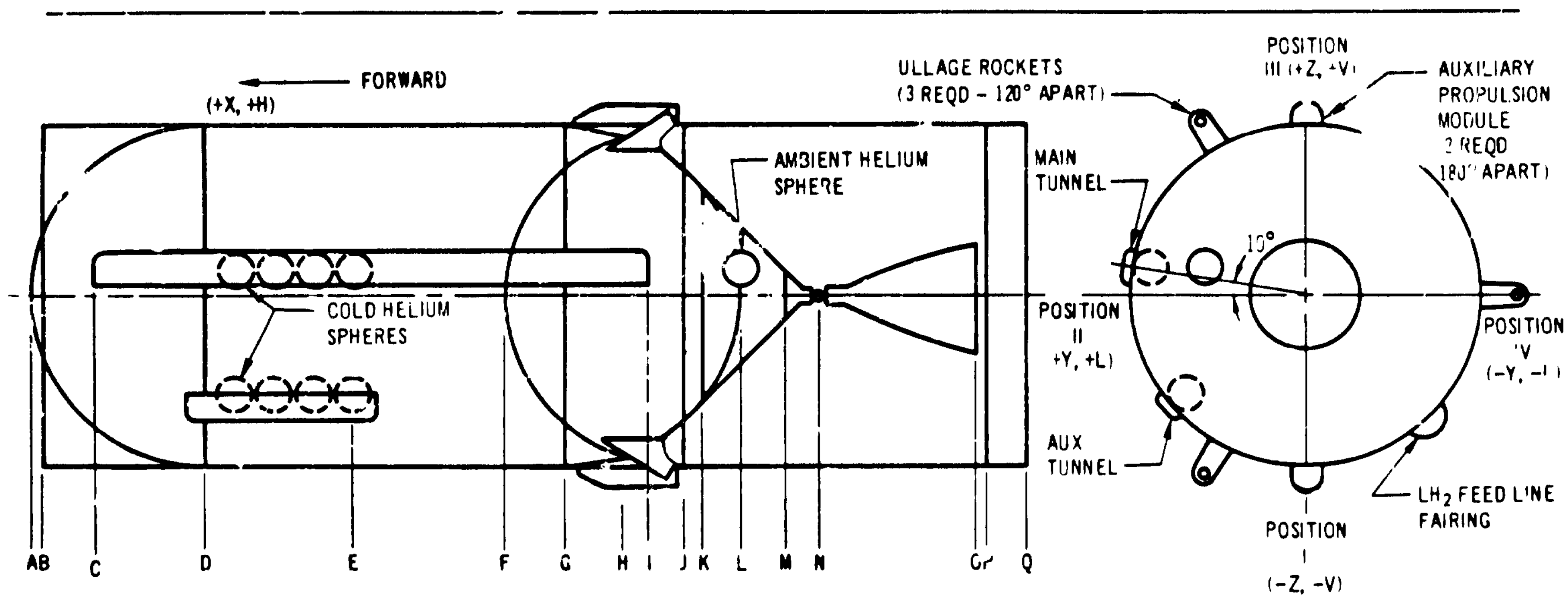
TIME (SEC)	MASS (LBM)	X ARM (STA-IN)	Y ARM (STA-IN)	Z ARM (STA-IN)	IXX (SLUG-FT2)	IYY (SLUG-FT2)	IZZ (SLUG-FT2)
.360	297246.26	350.53	.8	-.4	.10816932+06	.26769473+07	.26766047+07
1.000	297245.61	350.53	.8	-.4	.10816697+06	.26769476+07	.26766050+07
38.000	297208.45	350.54	.8	-.4	.10803131+06	.26769593+07	.26766168+07
88.000	297158.22	350.54	.8	-.4	.10784797+06	.26769756+07	.26766329+07
100.000	297146.16	350.55	.8	-.4	.10780397+06	.26769798+07	.26766372+07
143.300	297146.12	350.57	.8	-.4	.10780397+06	.26772660+07	.26769233+07
143.500	297136.55	350.58	.8	-.4	.10776444+06	.26772142+07	.26768716+07
143.500	297102.44	350.59	.8	-.4	.10764055+06	.26769611+07	.26766185+07
144.900	297035.46	350.62	.8	-.4	.10736381+06	.26765989+07	.26762562+07
145.900	296908.27	350.58	.8	-.4	.10716790+06	.26755383+07	.26751948+07
147.000	296295.98	350.59	.9	-.4	.10695414+06	.26749033+07	.26745591+07
148.200	295685.43	350.57	.9	-.4	.10695815+06	.26745234+07	.26741778+07
150.000	294743.06	350.57	.9	-.4	.10695612+06	.26736324+07	.26732860+07
155.520	291853.14	350.60	.9	-.4	.10694989+06	.26708094+07	.26704598+07
155.520	291631.14	350.69	.9	-.4	.10603258+06	.26695769+07	.26692273+07
160.000	289285.69	350.73	.9	-.4	.10602751+06	.26671854+07	.26668335+07
170.000	284050.32	350.89	.9	-.4	.10601618+06	.26615158+07	.26611582+07
176.000	280909.10	351.03	.9	-.4	.10600937+06	.26578914+07	.26575305+07
180.000	278814.95	351.14	.9	-.4	.10600482+06	.26553806+07	.26550175+07
190.000	273579.58	351.45	.9	-.4	.10599342+06	.26655915+07	.26652228+07
198.200	269286.58	351.82	.9	-.4	.10598405+06	.26608690+07	.26604959+07
200.000	268343.99	351.91	.9	-.4	.10598196+06	.26597951+07	.26594208+07
210.000	263107.43	352.45	.9	-.4	.10597029+06	.26536077+07	.26532278+07
220.000	257870.86	353.10	1.0	-.4	.10595859+06	.26470436+07	.26466581+07
230.000	252634.29	353.85	1.0	-.4	.10594684+06	.26400965+07	.26397051+07
240.000	247397.71	354.71	1.0	-.4	.10593504+06	.26327542+07	.26323571+07
250.000	242161.15	355.69	1.0	-.4	.10592319+06	.26250003+07	.26245974+07
260.000	236924.57	356.77	1.0	-.4	.10591129+06	.26168106+07	.26164019+07
270.000	231688.01	357.98	1.1	-.4	.10589934+06	.26081576+07	.26077430+07
280.000	226451.43	359.32	1.1	-.5	.10588732+06	.25990070+07	.25985865+07
290.000	221214.87	360.80	1.1	-.5	.10587524+06	.25893205+07	.25888940+07
300.000	215978.29	362.42	1.1	-.5	.10586309+06	.25790511+07	.25786185+07
308.000	211789.04	363.83	1.2	-.5	.10585332+06	.25703825+07	.25699452+07
310.000	210741.73	364.20	1.2	-.5	.10585086+06	.25681486+07	.25677101+07
320.000	205505.16	366.13	1.2	-.5	.10583856+06	.25565525+07	.25561079+07
330.000	200268.58	368.25	1.2	-.5	.10582617+06	.25441971+07	.25437462+07
340.000	195032.02	370.55	1.3	-.5	.10581368+06	.25310070+07	.25305499+07
350.000	189795.44	373.05	1.3	-.5	.10580110+06	.25168958+07	.25164323+07
360.000	184558.88	375.82	1.3	-.6	.10578840+06	.25011000+07	.25006303+07
370.000	179322.30	378.81	1.4	-.6	.10577558+06	.24843591+07	.24838828+07
380.000	174085.73	382.07	1.4	-.6	.10576263+06	.24662425+07	.24657597+07
390.000	168849.16	385.62	1.4	-.6	.10574954+06	.24465724+07	.24460830+07
400.000	163612.60	389.49	1.5	-.6	.10573630+06	.24251541+07	.24246579+07
410.000	158376.02	393.72	1.5	-.6	.10572288+06	.24017716+07	.24012684+07
420.000	153139.45	398.34	1.6	-.7	.10570928+06	.23761824+07	.23756722+07
430.000	147902.88	403.40	1.6	-.7	.10569546+06	.23481123+07	.23475949+07
436.000	144760.94	406.66	1.7	-.7	.10568706+06	.23299497+07	.23294280+07
440.000	142666.31	408.94	1.7	-.7	.10568141+06	.23172456+07	.23167209+07
450.000	137429.74	415.03	1.8	-.7	.10566711+06	.22832166+07	.22826844+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-FT2)	IYY (SLUG-FT2)	IZZ (SLUG-FT2)
460.000	132193.17	421.72	1.8	-.8	.10565251+06	.22455843+07	.22450444+07
470.000	126956.60	429.10	1.9	-.8	.10563758+06	.22038559+07	.22033081+07
480.000	121720.03	437.27	2.0	-.8	.10562229+06	.21574287+07	.21568727+07
490.000	116483.46	446.32	2.1	-.9	.10560658+06	.21055778+07	.21050134+07
492.900	11496[illegible].85	449.13	2.1	-.9	.10560194+06	.20894055+07	.20888385+07
500.000	111707.91	455.39	2.1	-.9	.10559094+06	.20533534+07	.20527805+07
510.000	107120.66	464.99	2.2	-.9	.10557509+06	.19978204+07	.19972388+07
520.000	102533.42	475.53	2.3	-1.0	.10555877+06	.19368871+07	.19362967+07
530.000	97946.17	487.37	2.4	-1.0	.10554192+06	.[illegible]8669710+07	.18663715+07
540.000	93358.93	500.54	2.5	-1.1	.10552446+06	.17887848+07	.17881755+07
544.900	91111.18	507.51	2.6	-1.1	.10551566+06	.17495786+07	.17489643+07
550.000	88912.25	514.69	2.7	-1.1	.10550656+06	.17066202+07	.17060010+07
560.000	84600.64	529.99	2.8	-1.2	.10548816+06	.16146523+07	.16140227+07
570.000	80289.03	547.27	2.9	-1.3	.10546892+06	.15094307+07	.15087902+07
580.000	75977.42	566.83	3.1	-1.3	.10544872+06	.13890003+07	.13883483+07
590.000	71665.81	589.04	3.3	-1.4	.10542736+06	.12509844+07	.12503201+07
593.340	70225.74	597.16	3.4	-1.4	.10541993+06	.12001394+07	.11994708+07
593.400	70217.72	597.20	3.4	-1.4	.10541931+06	.11998283+07	.1199159[illegible]+07
593.760	70169.63	597.49	3.4	-1.4	.10541553+06	.11979579+07	.11972894+07
593.920	70148.25	597.62	3.4	-1.4	.10541385+06	.11971258+07	.11964572+07
594.740	70038.70	598.28	3.4	-1.4	.10540524+06	.11928519+07	.11921834+07
600.000	70023.05	598.36	3.4	-1.4	.10540457+06	.11924139+07	.11917460+07
633.710	69922.76	598.86	3.4	-1.4	.10540024+06	.11896248+07	.11889607+07
638.510	69919.93	598.88	3.4	-1.4	.10539966+06	.11895592+07	.11888956+07
638.510	[illegible]761.93	590.59	3.4	-1.5	.10450595+06	.11272757+07	.11266169+07
684.000	68735.15	590.71	3.4	-1.5	.10450044+06	.11266837+07	.11260302+07
839.000	68634.34	591.16	3.4	-1.5	.10444180+06	.11243691+07	.11237723+07
1193.420	68435.02	592.05	3.4	-1.5	.10443772+06	.11199118+07	.11193181+07
1193.520	68434.97	591.43	3.6	-1.4	.11847901+06	.11186389+07	.11175197+07
1853.600	68063.75	593.13	3.6	-1.5	.11847134+06	.11100711+07	.11089573+07
3232.530	68060.50	594.23	3.6	-1.5	.11845778+06	.11019587+07	.11008582+07
3232.530	36530.50	419.31	5.6	-2.9	.98196238+05	.55854931+06	.55693817+06
3398.530	36530.11	419.56	5.6	-2.9	.98194604+05	.55823304+06	.55662347+06
4598.530	35398.28	420.28	5.9	-2.9	.98123167+05	.55439698+06	.55278987+06
6143.720	35394.64	420.47	5.9	-2.9	.98107959+05	.55380148+06	.55220917+06
6355.000	35387.45	420.49	5.9	-2.9	.98105817+05	.55371622+06	.55212587+06
6500.000	35378.85	420.51	5.9	-2.9	.98089070+05	.55361918+06	.55204508+06
6743.540	35370.34	420.53	5.9	-2.9	.98085643+05	.55351837+06	.55194749+06
8440.000	35364.74	420.75	5.9	-2.9	.98062272+05	.55284403+06	.55129590+06
8774.[illegible]50	35364.14	420.79	5.9	-2.9	.98059784+05	.55271611+06	.55117039+06
8894.550	32817.93	441.05	6.3	-3.2	.97986300+05	.51191707+06	.5103651[illegible]+06
8904.340	32817.91	441.05	6.3	-3.2	.97986226+05	.51191685+06	.51036505+06
9084.550	32817.59	441.05	6.3	-3.2	.97984885+05	.511912[illegible]5+06	.51036245+06
9094.350	32817.57	441.05	6.3	-3.2	.97984812+05	.51191273+06	.51036229+06
9094.550	32817.57	441.05	6.3	-3.2	.97984811+05	.51191276+06	.51036231+06
9450.000	32259.94	444.43	6.4	-3.3	.97976028+05	.50722039+06	.50566891+06
10349.530	32258.34	444.44	6.4	-3.3	.97969332+05	.50720046+06	.5056555[illegible]+06
10800.000	32100.53	444.20	6.0	-3.2	.97562807+05	.50697733+06	.50522832+06
19999.599	32084.14	444.30	6.0	-3.2	.97494339+05	.50677390+06	.50509149+06
20000.000	32084.14	444.30	6.0	-3.2	.97494336+05	.50677384+06	.50509143+06

TABLE AP 1-4
S-IVB-204 PROPELLANT DATA HISTORY

	OXIDIZER					FUEL				
TIME (SEC)	MASS (LBM)	CENTER MASS (STA-IN)	SURFACE LEVEL (STA-IN)	LIQUID VOLUME (FT^3)	LIQUID DENSITY (LB/FT^3)	MASS (LBM)	CENTER MASS (STA-IN)	SURFACE LEVEL (STA-IN)	LIQUID VOLUME (FT^3)	LIQUID DENSITY (LB/FT^3)
.36	193703	242	312	2728	71.00	37766	434	579	8497	4.39
1.00	193703	242	312	2728	71.00	37266	434	579	8497	4.39
38.00	193702	242	312	2728	71.00	37261	434	579	8501	4.38
88.00	193700	242	312	2729	70.99	37254	435	580	8506	4.38
100.00	193700	242	312	2729	70.99	37252	435	580	8507	4.38
143.30	193698	242	312	2729	70.98	37246	435	580	8515	4.37
143.50	193698	242	312	2729	70.98	37246	435	580	8515	4.37
143.50	193698	242	312	2729	70.98	37246	435	580	8515	4.37
144.90	193698	242	312	2729	70.98	37246	435	580	8516	4.37
145.90	193698	242	312	2729	70.98	37165	434	579	8497	4.37
147.00	193210	242	311	2722	70.98	37076	434	579	8477	4.37
148.20	19267[illegible]	242	310	2715	70.98	36979	434	578	8455	4.37
150.00	191880	241	309	2703	70.98	36833	433	577	8422	4.37
155.52	189431	240	306	2669	70.98	36387	431	573	8321	4.37
155.52	189431	240	306	2669	70.98	36387	431	573	8321	4.37
160.00	187445	240	303	2641	70.98	36024	430	571	8239	4.37
170.00	183010	238	299	2578	70.98	35215	427	564	8056	4.37
176.00	180349	237	296	2541	70.97	34729	425	561	7947	4.37
180.00	178575	237	294	2516	70.97	34405	424	558	7873	4.37
190.00	174139	235	291	2456	70.97	33596	421	552	7690	4.37
198.20	170503	234	288	2402	70.97	32933	418	547	7540	4.37
200.00	169704	234	287	2391	70.97	32787	418	546	7507	4.37
210.00	165269	233	283	2329	70.97	31978	415	540	7324	4.37
220.00	160834	231	280	2266	70.97	31168	412	534	7140	4.37
230.00	156399	230	277	2204	70.96	30359	408	528	6956	4.36
240.00	151964	229	274	2141	70.96	29550	405	521	6773	4.36
250.00	147529	227	271	2079	70.96	28740	402	515	6589	4.36
260.00	143094	226	268	2017	70.96	27931	399	509	6405	4.36
270.00	138659	225	266	1954	70.96	27122	396	503	6221	4.36
280.00	134224	223	263	1892	70.95	26313	393	497	6037	
290.00	129789	222	261	1829	70.95	25503	390	491	5853	
300.00	125354	221	258	1767	70.95	24694	387	485	5669	
308.00	121806	220	256	1717	70.95	24047	384	480	5521	
310.00	120919	219	256	1704	70.95	23885	384	478	5484	4.35
320.00	116484	218	253	1642	70.95	23075	381	472	5300	4.35
330.00	112049	217	251	1579	70.94	22266	377	466	5115	4.35
340.00	107614	215	248	1517	70.94	21457	374	460	4931	4.35
350.00	103179	214	246	1454	70.94	20648	371	454	4746	4.35
360.00	98744	213	244	1392	70.94	19838	368	448	4561	4.35
370.00	94309	211	241	1329	70.94	19029	365	442	4376	4.35
380.00	89874	210	239	1267	70.93	18220	362	436	4191	4.35
390.00	85439	208	237	1205	70.93	17411	359	429	4006	4.35
400.00	81004	207	234	1142	70.93	16601	355	423	3821	4.34
410.00	76569	205	232	1080	70.93	15792	352	417	3636	4.34
420.00	72133	204	229	1017	70.93	14983	349	411	3450	4.34
430.00	67698	202	227	955	70.92	14173	346	405	3265	4.34
436.00	65037	201	225	917	70.92	13688	34[illegible]	401	3153	4.34
440.00	63263	200	224	892	70.92	13364	34[illegible]	399	3079	4.34
450.00	58828	199	221	830	70.92	12555	339	393	2893	4.34
460.00	54393	197	219	767	70.91	11746	336	386	2708	4.34
470.00	49958	195	216	705	70.90	10936	333	380	2522	4.34
480.00	45523	193	213	642	70.90	10127	329	374	2337	4.3[illegible]
490.00	41088	191	210	580	70.89	9318	326	368	2151	4.33
497.90	39802	191	209	561	70.89	9083	325	366	2097	4.33
500.00	37094	189	207	523	70.88	8529	322	362	1965	4.33
510.00	33279	188	204	470	70.87	7748	319	356	1790	4.33
520.00	29465	185	201	416	70.86	6968	315	350	1610	4.33
530.00	25650	184	198	362	70.84	6197	312	344	1431	4.32
540.00	21836	182	195	308	70.83	5406	308	338	1252	4.32
544.90	19967	181	193	282	70.83	5024	306	335	1164	4.32
550.00	18143	179	191	256	70.82	4645	304	332	1077	4.32
560.00	14566	177	187	206	70.80	3903	299	326	906	4.31
570.00	10989	174	183	155	70.77	3160	294	319	734	4.30
580.00	7412	171	178	105	70.75	2418	289	310	563	4.29
590.00	3836	167	172	54	70.72	1675	281	300	391	4.29
593.34	2641	165	169	37	70.72	1427	279	297	333	4.28
593.40	2636	165	169	37	70.72	1426	279	297	333	4.28
593.76	2605	165	169	37	70.71	1419	279	296	331	4.28
593.92	2591	165	169	37	70.71	1416	279	296	331	4.28
594.74	2521	165	169	36	70.71	1400	279	29	327	4.28
600.00	2519	165	169	36	70.70	1397	279	296	327	4.28
633.71	2504	165	169	35	70.70	1378	278	296	322	4.28
638.51	2504	165	169	35	70.70	1376	278	296	322	4.28
638.51	2504	165	169	35	70.70	1376	278	296	322	4.28
684.00	2501	165	169	35	70.70	1350	278	295	316	4.28
839.00	2493	165	169	35	70.69	1264	277	294	296	4.28
1193.42	2475	165	169	35	70.68	1067	275	290	250	4.28
1193.52	2475	165	169	35	70.68	1067	275	290	250	4.28
1853.60	2441	164	169	35	70.65	700	270	282	164	4.27
3232.53	2371	164	169	34	70.61	343	263	273	80	4.27
3232.53	2371	164	169	34	70.61	343	263	273	80	4.27
3398.53	2362	164	169	33	70.60	300	262	271	70	4.27
4598.53	2300	164	168	33	70.56	0			0	
6143.72	2221	164	168	32	70.50	0			0	
6355.00	2210	164	168	31	70.49	0			0	
6500.00	2203	164	168	31	70.49	0			0	
6743.54	2190	164	168	31	70.48	0			0	
8440.00	2103	164	168	30	70.42	0			0	
8774.35	2086	164	168	30	70.41	0			0	
8894.55	0			0		0			0	
8904.34	0			0		0			0	
9084.55	0			0		0			0	
9094.35	0			0		0			0	
9094.55	0			0		0			0	
9450.00	0			0		0			0	
10349.53	0			0		0			0	
10800.00	0			0		0			0	
19999.60	0			0		0			0	
20000.00	0			0		0			0	



	INSTALLATION	STATION
A.	FWD BULKHEAD (FWD END)	684.6
B.	FWD SKIRT (FWD END)	676.7
C.	MAIN TUNNEL (FWD END)	647.7
D.	FWD SKIRT (AFT END)	554.7
	FWD BULKHEAD (AFT END)	553.0
E.	COLD HELIUM SPHERES (8 REQD - 26.9 ℄ TO ℄)	454.0
F.	COMMON BULKHEAD (FWD END)	335.2
	AFT BULKHEAD (FWD END)	287.8
G.	AFT SKIRT (FWD END)	286.1
	LH_2 FEED LINE FAIRING (FWD END)	286.1
	AUXILIARY PROPULSION MODULE (FWD END)	285.5
	ULLAGE ROCKET (FWD END)	245.3
H.	COMMON BULKHEAD (AFT END)	244.4
I.	MAIN TUNNEL (AFT END)	220.9
	AUXILIARY PROPULSION MODULE (AFT END)	205.1
	ULLAGE ROCKET FAIRING (AFT END)	204.6
	LH_2 FEED LINE FAIRING (AFT END)	202.7
J	AFT SKIRT (AFT END)	200.6
	INTERSTAGE (FWD END)	200.6
K.	THRUST STRUCTURE/AFT BULKHEAD TANGENT POINT	186.9
L.	AMBIENT HELIUM SPHERES	158.6
	AFT BULKHEAD (AFT END)	156.3
M.	THRUST STRUCTURE SKIN (AFT END)	121.4
N.	GIMBAL STATION	100.0
O.	ENGINE NOZZLE (AFT END)	-16.0
P.	INTERSTAGE (AFT END	-23.9
	AERODYNAMIC FAIRING (FWD END)	-23.5
Q.	AERODYNAMIC FAIRING (AFT END)	-50.9

Figure AP 1-1. S-IVB-204 Configuration Station List

APPENDIX 2

FLIGHT TEST RECONSTRUCTION (PA49)

1. FLIGHT TEST RECONSTRUCTION (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-204 stage flight. The performance analysis and associated plots are presented in section 9.

Table AP 2-1 defines the printout symbols; table AP 2-2 is the digital printout for engine burn.

TABLE AP 2-1
PROGRAM PA49 PRINTOUT SYMBOLS

FSUB1	Stage thrust from AA89 (lbf)	FSUB3	Predicted stage thrust (lbf)
WDOTT1	Total flowrate from AA89 (lbm/sec)	WDOTT3	Predicted total flowrate (lbm/sec)
WDOTO1	LOX flowrate from AA89 (lbm/sec)	WDOTO3	Predicted LOX flowrate (lbm/sec)
WDOTF1	LH2 flowrate from AA89 (lbm/sec)	WDOTF3	Predicted LH2 flowrate (lbm/sec)
EMR 1	Engine mixture ratio from AA89	EMR 3	Predicted engine mixture ratio
ISP 1	Specific impulse from AA89 (sec)	ISP 3	Predicted specific impulse (sec)
MSUBO1	LOX mass on board from AA89 (lbm)	MSUBO3	Predicted LOX mass on board (lbm)
MSUBF1	LH2 mass on board from AA89 (lbm)	MSUBF3	Predicted LH2 mass on board (lbm)
FSUB2	Stage thrust from G105 (lbf)	THRUST	Composite stage thrust (lbf)
WDOTT2	Total flowrate from G105 (lbm/sec)	T FLOW	Composite total flowrate (lbm/sec)
WDOTO2	LOX flowrate from G105 (lbm/sec)	O FLOW	Composite LOX flowrate (lbm/sec)
WDOTF2	LH2 flowrate from G105 (lbm/sec)	F FLOW	Composite LH2 flowrate (lbm/sec)
EMR 2	Engine mixture ratio from G105	*EMR*	Composite engine mixture ratio
ISP 2	Specific impulse from G105 (sec)	*ISP*	Composite specific impulse (sec)
MSUBO2	LOX mass on board from G105	O MASS	Composite LOX mass on board (lbm)
MSUBF2	LH2 mass on board from G105 (lbm)	F MASS	Composite LH2 mass on board (lbm)

TABLE AP 2-2 (Sheet 1 of 6)
ENGINE PERFORMANCE PROGRAM

TIME				
FSUB 1	FSUB 2	FSUB 3	THRUST	WDOTT1
WDOTT2	WDOTT3	T FLOW	WDOTO1	WDOTO2
WDOTO3	O FLOW	WDOTF1	WDOTF2	WDOTF3
F FLOW	EMR 1	EMR 2	EMR 3	*EMR*
ISP 1	ISP 2	ISP 3	*ISP*	MSUBT1
MSUBT2	MSUBT3	P MASS	MS BF1	MSUBF2
MSUBF3	F MASS			
.000				
.000	96166.442	.000	48083.221	.0 0
1.024	.000	.512	.000	.000
.000	.000	.000	1.024	.000
.512	.000	.000	.000	.000
.000	93894.528	.000	44947.264	193783.000
193783.000	193273.000	193783.000	37393.000	37393.0 0
37440.000	37393.000			
1.000				
.000	.000	.000	.000	6.122
1.995	6.122	4.058	.000	.000
.000	.000	6.122	1.995	6.122
4.058	.000	.000	.000	.000
.000	.000	.000	.000	193782.660
193782.690	193272.610	193782.690	37389.819	37390.284
37435.470	37390.052			
2.000				
35428.355	22253.531	36042.079	28840.943	97.958
98.845	99.029	56.402	55.167	46.666
55.341	50.916	42.791	52.180	42.688
47.495	1.289	.894	1.320	1.092
361.669	225.135	363.956	293.402	193755.110
193765.790	153244.340	193750.450	37359.732	37365.294
37405.049	37362.513			
3.000				
153134.330	154789.750	[illegible]	158962.040	337.117
362.123	344.187	[illegible]	282.348	294.780
289.195	288.5 4	[illegible]	67.343	54.940
61.055	5.	[illegible]	5.259	4.756
483.910	427 4	[illegible]	455.681	193587.460
193603.520	19307	[illegible]	37313.072	37307.235
37355.127	373			
4.000				
187034.530	[illegible]	191350.010	185305.920	435.064
425.705	444.925	430.884	364.759	350.879
374.243	357.819	73.309	75.825	70.682
73.065	5.188	4.627	5.295	4.908
429.901	430.221	430.095	430.061	193249.840
193268.200	192726.670	193259.020	37250.884	37233.717
37295.667	37242.300			
5.000				
191970.420	188095.140	196775.800	190032.770	446.736
435.635	457.057	441.186	371.747	358.758
382.147	365.252	74.989	76.877	75.5 9
75.933	4.957	4.657	5.061	4.812
429.718	431.772	429.964	430.745	192881.070
192913.720	192348.060	192897.160	37177.245	37156.747
37222.756	37166.996			
6.000				
195895.750	190458.140	176764.640	193181.947	454.132
443.275	458.568	448.703	376.434	365.757
381.957	371.095	77.698	77.517	76.611
77.608	4.845	4.718	4.985	4.762
431.363	429.684	429.085	430.524	192510.510
192550.730	191965.610	192528.620	37100.222	37079.033
37145.951	37089.627			
7.000				
221879.880	212565.060	197294.390	217197.481	520.488
498.697	459.781	509.592	419.987	419.344
383.040	429.065	80.501	79.353	76.741
79.927	5.450	5.285	4.991	5.375
426.95	426.241	429.105	426.219	192092.280
192170.690	191583.120	192131.480	37020.169	37000.541
37068.913	37010.355			
8.000				
221746.087	216362.190	202091.160	219054.430	520.534
508.145	471.592	514.339	440.081	427.974
394.263	434.027	80.453	80.171	77.329
83.312	5.470	5.338	5.098	5.4.4
425.999	425.788	428.529	425.894	191651.960
191745.180	191195.920	191638.570	36939.144	36920.127
36971.576	36929.636			
9.000				
221925.870	217858.080	214666.490	219891.970	521.218
511.531	503.266	516.369	440.665	431.071
424.547	435.868	80 543	80.460	78.720
80.501	5.471	5.358	5.393	5.414
425.791	425.894	426.546	425.843	191211.150
191315.600	190789.470	191263.380	36858.107	36839.106
36913.261	36848.606			
10.000				
221851.920	218994.980	220519.150	220423.450	521.376
514.269	517.990	517.818	440.914	433.374
438.882	437.144	80.462	80.886	79.1 8
80.574	5.480	5.358	5.546	5.419
425.512	425.845	425.721	425.679	190770.130
190882.660	190353.480	190826.390	36777.054	36757.843
36833.920	36767.443			
15.000				
221794.290	221234.780	220738.120	221514.530	522.518
519.715	517.904	521.117	441.914	438.956
438.703	440.435	80.604	80.760	79.271
80.682	5.483	5.435	5.539	5.459
424.472	425.884	426.214	425.078	188561.770
188696.630	188157.770	188679.200	36371.540	36350.770
36436.215	36361.120			
20.000				
221922.350	222108.840	222052.190	222015.600	524.208
523.009	523.979	523.508	443.519	442.084
443.764	442.802	80.689	80.924	80.215
80.807	5.497	5.463	5.532	5.480
423.348	424.675	423.800	424.011	186346.780
186491.440	185949.650	186419.110	35965.447	35943.383
36035.764	35954.415			
25.000				
222304.530	222484.770	222594.790	222394.650	524.838
524.487	524.978	524.663	444.185	443.811
444.895	443.998	80.652	80.678	80.173
80.665	5.507	5.501	5.548	5.504
423.568	424.194	424.008	423.881	184126.340
184274.250	183726.080	184200.300	35559.105	35536.444
35632.875	35547.774			
30.000				
222827.430	222715.700	223124.520	222771.560	525.824
526.699	525.896	525.261	445.191	443.825
445.768	444.508	80.632	80.874	80.179
80.753	5.521	5.488	5.563	5.5 5
423.768	424.464	424.274	424.115	181901.660
182050.030	181497.730	181975.850	35152.882	35129.738
35230.212	35141.309			
35.000				
223301.750	223915.050	223703.260	223606.400	526.661
526.694	526.968	526.777	446.031	445.993
445.861	446.012	80.630	80.901	80.087
80.765	5.532	5.513	5.580	5.522
423.995	424.972	424.526	424.484	179671.750
179823.790	179254.170	179747.780	34746.697	34723.120
34827.755	34734.908			
40.000				
223763.050	224318.260	224282.700	224040.650	527.487
527.742	528.005	527.615	446.884	446.973
447.954	446.929	80.603	80.769	80.041
80.685	5.544	5.534	5.597	5.539
424.295	425.053	424.776	424.629	177436.830
177972.590	177025.110	177514.750	34340.555	34316.315
34425.525	34328.435			
45.000				
224024.760	223171.930	224316.250	223598.350	528.065
527.203	528.215	527.634	447.461	446.174
448.072	446.818	80.604	81.029	80.116
80.816	5.551	5.506	5.593	5.529
424.237	423.313	424.668	423.775	175199.370
175360.690	174783.000	175280.010	33934.473	33909.130
34023.224	33921.796			
50.000				
224129.920	224480.730	224380.730	224305.320	528.228
527.147	528.495	527.664	447.628	446.115
448.291	446.872	80.600	81.025	80.234
80.813	5.554	5.506	5.589	5.530
424.305	425.846	424.565	425.075	172950.590
173127.550	172540.020	173044.080	33528.442	33500.941
33620.518	33514.697			

Appendix 2
Flight Test Reconstruction (PA49)

TABLE AP 2-2 (Sheet 2 of 6)
ENGINE PERFORMANCE PROGRAM

55.000				
224219.880	225304.290	224449.010	224762.080	528.354
526.951	528.781	527.652	447.760	445.986
445.484	446.873	80.594	80.965	80.297
80.779	5.556	5.508	5.585	5.532
424.373	427.562	424.465	425.968	170720.850
170893.830	170296.070	170807.340	33122.449	33092.952
33217.356	33107.700			
60.000				
224339.250	224279.990	224519.900	224309.620	528.558
527.269	529.070	527.919	447.991	446.457
448.677	447.229	80.577	80.802	80.393
80.690	5.560	5.525	5.581	5.543
424.428	425.362	424.367	424.895	168479.890
168655.680	168051.170	168568.290	32716.501	32685.543
32813.718	32701.047			
65.000				
223765.220	224681.570	224582.540	224223.400	527.018
527.897	529.090	527.457	446.515	447.097
448.637	446.807	80.501	80.800	80.453
80.651	5.547	5.533	5.576	5.540
424.588	425.617	424.470	425.100	166240.370
166418.100	165805.630	166329.210	32310.625	32278.4 5
32409.684	32294.516			
70.000				
223542.230	223686.600	224247.860	223664.410	526.573
527.061	527.610	528.817	446.064	446.226
447.168	446.145	80.509	80.835	80.442
80.672	5.541	5.520	5.559	5.530
424.712	424.404	425.026	424.558	164007.360
164186.760	163565.040	164097.060	31905.055	31871.329
32005.584	31888.192			
75.000				
224269.230	223878.930	224111.650	224074.070	528.024
525.836	527.078	526.930	447.417	444.945
446.622	446.181	80.606	80.891	80.455
80.749	5.551	5.501	5.551	5.526
424.733	425.758	425.196	425.245	161775.610
161961.240	161328.550	161858.420	31499.435	31444.674
31601.435	31482.030			
80.000				
224420.620	224133 0	224273.530	224277.120	528.319
528.020	527 1	528.164	447.693	447.139
447.251	447 415	80.616	80.881	80.530
80.748	5 553	5.578	5.554	5.541
424.791	424.479	424.937	424.635	159536.290
159729.350	159094.100	159632.820	31093.357	31057.438
31197.172	31075 397			
85.000				
224554.040	225400.620	224397.650	224979.330	528.614
528.513	527.918	528.563	447.920	447.505
447.339	447.728	80.693	80.973	80.579
80.845	5.551	5.527	5.552	5.539
424.798	426.488	425.061	425.643	157295.790
157494.560	156855.610	157395.180	30687.030	30650.376
30792.494	30668.703			
90.000				
224699.900	225181.140	224521.880	224940.520	528.948
528.370	528.055	528.659	448.173	447.304
447.427	447.739	80.775	81.067	80.678
80.921	5.548	5.518	5.544	5.533
424.805	426.180	425.186	425.493	155053.990
155259.060	154616.690	155156.520	30280.305	30242.486
30387.570	30261.397			
95.000				
224114.090	225064.040	224353.580	224589.060	527.444
527.567	526.954	527.505	446.684	446.668
446.352	446.886	80.760	80.883	80.602
80.820	5.531	5.523	5.538	5.527
424.906	426.607	425.756	425.757	152813.610
153022.770	152378.950	152918.170	29873.247	29834.921
29992.525	29854.084			
100.000				
224343.600	224765.470	224228.730	224404.540	527.277
527.007	526.432	527.117	446.414	446.046
445.831	446.254	80.814	80.911	80.601
80.863	5.524	5.513	5.531	5.519
424.947	426.494	425.940	425.721	150579.680
150794.[illegible]	1[illegible]46.490	150687.260	29466.184	29427.347
[illegible]	[illegible]46.781			

105.000				
223973.350	222804.450	224104.410	223388.900	526.953
525.754	525.972	526.354	445.995	444.859
445.398	445.427	80.957	80.895	80.574
80.925	5.509	5.499	5.528	5.504
425.035	423.781	426.077	424.405	148347.240
148569.940	147916.410	148458.590	29058.637	29019.742
29172.759	29039.189			
110.000				
223882.320	223804.520	224275.940	223843.430	526.657
523.581	525.736	525.174	445.609	442.725
446.129	444.167	81.057	80.855	80.617
80.957	5.497	5.475	5.535	5.486
425.093	427.450	425.784	426.271	146116.410
146346.020	145685.960	146231.210	28650.551	28612.205
28767.931	28631.378			
115.000				
224676.150	224399.860	224474.270	224538.010	528.604
525.397	526.922	527.000	447.323	443.915
446.307	445.619	81.281	81.481	80.615
81.381	5.503	5.448	5.535	5.486
425.037	427.106	425.878	426.071	143879.940
144117.810	143452.860	143998.880	28241.451	28203.706
28362.971	28222.578			
120.000				
224789.310	224296.410	224532.620	224542.860	528.815
527.708	527.108	528.261	447.382	446.500
446.485	446.941	81.433	81.209	80.623
81.320	5.494	5.498	5.538	5.496
425.081	425.039	425.971	425.060	141641.470
141885.150	141218.880	141753.310	27831.625	27794.310
27957.972	27812.967			
125.000				
224935.600	226447.200	224356.070	225691.400	529.139
525.752	526.174	527.445	447.752	444.598
445.599	446.175	81.387	81.154	80.515
81.270	5.502	5.478	5.530	5.490
425.098	430.711	426.392	427.904	139401.920
139653.200	138985.420	139577.560	27421.505	27384.953
27553.011	27403.229			
130.000				
225098.260	224986.280	224242.580	225037.270	529.461
528.717	525.868	529.090	448.101	447.608
445.313	447.854	81.361	81.111	80.555
81.236	5.508	5.518	5.528	5.513
425.127	425.531	426.424	425.329	137160.640
137420.920	136756.130	137290.780	27011.559	26975.924
27148.282	26993.731			
135.000				
224331.780	221379.170	224138.960	222855.480	527.495
525.121	525.565	526.378	446.283	443.955
445.025	445.124	81.211	81.155	80.540
81.193	5.495	5.471	5.524	5.463
425.276	421.578	426.471	423.424	134926.730
135189.990	134528.280	135058.340	26602.224	26556.947
26743.659	26584.585			
140.000				
224273.200	225506.660	223820.560	224889.930	527.256
525.802	525.015	527.034	446.095	445.639
444.783	445.867	81.170	81.164	80.232
81.167	5.496	5.491	5.544	5.493
425.351	428.067	426.313	426.709	132693.990
132961.990	132301.650	132827.990	26193.237	26158.013
26339.101	26175.625			
145.000				
224205.080	221486.660	224004.170	222846.370	527.109
524.255	525.897	525.682	445.983	443.131
445.604	444.547	81.126	81.124	80.293
81.125	5.497	5.462	5.550	5.480
425.350	422.479	425.947	423.914	130462.059
130737.667	130074.903	130599.862	25784.544	25749.000
25934.444	25766.772			
150.000				
224032.410	223681.890	224113.270	223867.150	526.779
524.351	526.121	525.565	445.758	443.315
445.797	444.531	81.021	81.045	80.374
81.034	5.502	5.470	5.559	5.486
425.325	426.598	425.973	425.957	128231.186
128512.459	127844.420	128371.821	25376.190	25340.157
25529.495	25358.188			

TABLE AP 2-2 (Sheet 3 of 6)
ENGINE PERFORMANCE PROGRAM

155.000				
223947.290	228135.010	224222.510	226041.150	526.553
523.333	526.345	524.943	445.608	442.283
445.990	443.946	80.944	81.050	80.356
80.997	5.505	5.457	5.550	5.481
425.309	435.927	425.999	430.618	126001.117
126289.202	125612.974	126145.159	24968.170	24931.917
25124.390	24950.043			

160.000				
224673.470	222192.010	224138.740	223432.740	528.386
527.139	525.608	527.763	447.375	445.994
445.265	446.085	81.010	81.145	80.343
81.077	5.522	5.496	5.542	5.509
425.207	421.506	426.437	423.355	123754.981
124060.778	123281.023	123912.880	24560.110	24523.271
24719.148	24541.690			

165.000				
224660.000	224789.480	224109.620	224724.740	528.397
528.591	525.523	528.494	447.421	447.651
445.169	447.536	80.977	80.940	80.354
80.958	5.525	5.531	5.540	5.578
425.173	425.262	426.450	425.217	121526.723
121828.532	121152.799	121677.677	24152.159	24114.294
24313.992	24133.226			

170.000				
224699.200	225201.820	224255.260	224950.510	528.513
528.105	525.596	528.309	447.535	446.951
444.952	447.243	80.978	81.154	80.644
81.066	5.527	5.507	5.517	5.517
425.154	426.434	426.608	425.794	119287.409
119595.274	118925.609	119441.341	23744.227	23705.406
23908.812	23724.817			

175.000				
224778.030	224681.210	224171.600	224729.620	528.755
529.277	525.402	529.016	447.793	448.064
444.763	447.928	80.961	81.213	80.619
81.087	5.531	5.517	5.517	5.524
425.108	424.506	426.667	424.807	117047.249
117359.097	116699.292	117203.173	23336.348	23296.400
23503.748	23316.374			

180.000				
224059.790	224557.060	224088.170	224308.430	526.960
528.168	525.209	527.564	446.092	447.043
444.614	446.568	80.868	81.124	80.595
80.996	5.516	5.511	5.517	5.513
425.193	425.163	426.665	425.178	114810.005
115122.806	114473.820	114966.404	22928.727	2288?.637
23098.808	22908.182			

185.000				
223909.700	223239.480	224004.810	223574.590	526.981
525.778	525.015	526.879	446.133	445.5?0
444.445	445.816	80.848	81.274	80.5?0
81.063	5.518	5.481	5.515	5.500
424.892	423.783	426.663	424.337	112577.671
112894.006	112249.191	112735.838	2252?.429	22479.210
22693.991	22500.315			

190.000				
223641.250	224263.770	223921.700	223952.520	526.698
526.933	524.823	526.816	445.885	445.765
444.277	445.025	80.814	81.169	80.545
80.991	5.517	5.492	5.516	5.505
424.610	425.602	426.662	425.106	110346.311
110666.208	110025.406	1105?6.259	22114.258	22070.633
22289.296	22092.445			

195.000				
223409.160	223818.610	224092.870	223613.90?	526.5?3
525.908	525.748	526.205	445.714	444.936
445.175	445.310	80.789	81.002	80.573
80.895	[illegible]	5.593	5.525	5.5?5
424.326	[illegible]	426.236	424.536	108115.847
108439.302	[illegible]	108277.576	21707.244	21652.356
21884.651	21884.?			

200.000				
223183.830	223377.550	224162.210	223280.480	526.325
526.049	525.967	526.167	445.550	445.159
445.379	445.359	80.866	80.893	80.568
80.828	5.517	5.503	5.528	5.510
424.042	424.032	426.207	424.337	105848.056
106215.033	105572.971	106050.543	21300.337	21234.464
21479.892	21277.401			

205.000				
223136.030	223932.380	224207.200	223534.200	526.279
525.743	526.120	526.011	445.525	444.771
445.562	445.148	80.754	80.972	80.559
80.863	5.517	5.493	5.531	5.505
423.988	425.935	426.152	424.962	103656.739
103990.583	103343.242	103823.662	20893.551	20846.992
21075.169	20870.271			

210.000				
223039.350	223801.710	224252.390	223620.530	526.170
526.358	526.294	526.239	445.395	445.441
445.745	445.418	80.724	80.918	80.549
80.821	5.517	5.505	5.534	5.511
423.933	425.189	426.097	424.561	101427.732
101755.367	101112.998	101596.539	20486.842	20438.963
20670.493	20462.903			

215.000				
223708.050	224401.850	224048.550	224054.950	527.878
527.783	525.364	527.831	447.073	446.683
444.875	446.878	80.805	81.100	80.489
80.953	5.533	5.508	5.527	5.520
423.787	425.178	426.464	424.483	99195.410
99540.911	98883.343	99368.161	20080.017	20031.498
20265.938	20055.757			

220.000				
223749.290	224595.260	223953.870	224172.270	528.056
528.027	525.179	528.041	447.267	447.069
444.718	447.158	80.809	80.959	80.441
80.884	5.535	5.522	5.527	5.578
423.723	425.348	426.434	424.535	96957.894
97309.777	96657.381	97133.835	19672.970	19623.400
19861.657	19648.185			

225.000				
223837.650	224690.870	223859.470	224264.260	528.359
526.902	524.995	527.631	447.567	445.655
444.581	446.601	80.512	81.247	80.434
81.030	5.538	5.485	5.527	5.512
423.647	426.438	426.403	475.042	94718.996
95079.219	94432.207	94898.607	19265.930	19215.441
19457.513	19240.710			

230.000				
223970.840	224147.500	223543.130	224059.160	528.768
528.398	524.552	528.583	447.737	447.257
444.450	447.597	80.831	81.140	80.182
80.985	5.542	5.512	5.549	5.527
423.571	424.202	426.160	473.887	92478.698
92845.493	92207.748	92662.095	18858.863	18807.670
19053.518	18833.266			

235.000				
224037.960	225513.130	223466.840	224775.550	529.0?7
529.007	524.390	529.007	448.165	447.9?9
444.290	448.023	80.842	81.107	80.1?0
80.974	5.544	5.522	5.547	5.533
423.507	426.295	426.146	424.901	90236.969
90610.208	89983.919	90473.588	18451.818	18399.490
18649.607	18425.054			

240.000				
223362.750	223419.700	223390.850	223591.230	527.411
524.035	524.229	525.733	446.091	443.198
444.131	444.944	80.721	80.855	80.097
80.789	5.536	5.481	5.545	5.508
423.508	427.092	426.133	425.307	87997.53?
88378.592	87760.886	88188.063	18044.909	17991.248
18245.709	18018.078			

245.000				
223326.410	223037.980	223329.200	223182.190	527.384
52?.121	524.069	527.253	446.063	446.156
443.979	446.419	80.721	80.967	80.090
80.844	5.533	5.510	5.544	5.522
423.467	423.125	426.145	423.293	85762.551
86146.727	85538.031	85954.653	17638.313	17583.532
17841.835	17610.922			

250.000				
223248.910	222740.880	223247.880	222894.890	527.266
528.036	523.910	527.651	446.564	447.119
443.327	446.841	80.702	80.917	80.083
80.810	5.533	5.526	5.542	5.510
423.108	421.829	426.157	422.019	83527.703
83912.748	83317.135	83770.021	17231.790	17175.952
17437.997	1 203.870			

TABLE AP 2-2 (Sheet 4 of 6)
ENGINE PERFORMANCE PROGRAM

255.000				
223237.610	223154.880	223449.600	224196.241	527.312
528.002	524.842	527.657	446.615	447.097
444.717	446.857	80.696	80.905	80.175
80.80[illegible]	5.535	5.526	5.550	5.540
423.350	426.428	425.746	424.889	81293.287
81675.267	81094.903	81484.277	16825.327	16758.391
17034.128	16796.859			

260.000				
223198.370	224763.470	223517.750	223980.921	527.3[illegible]0
527.034	525.017	527.167	446.625	446.052
444.884	446.339	80.673	80.982	80.153
80.828	5.536	5.508	5.552	5.522
423.286	425.466	425.734	424.877	79058.877
79442.092	78868.920	79250.459	16418.915	16360.963
16630.079	16389.950			

265.000				
223108.290	222824.370	223566.250	222966.331	527.146
526.015	525.193	525.580	446.489	445.243
445.053	445.861	80.657	80.702	80.140
80.719	5.535	5.512	5.553	5.524
423.236	423.608	425.722	423.473	76624.648
77208.864	76642.097	77016.755	16012.601	15953.879
16225.991	15983 215			

270.000				
223098.840	223681.470	223654.810	223390.151	527.216
526.501	525.369	526.859	446.585	445.512
445.221	446.049	80.631	80.989	80.148
80.810	5.539	5.501	5.555	5.520
423.164	424.845	425.710	424.005	74590.478
74975.740	74414.433	74783.108	15606.365	15546.532
15821.866	15576.449			

275.000				
223016.070	222289.290	223524.430	222652.681	527.076
526.082	524.578	525.879	446.455	445.817
444.475	446.136	80.620	80.865	80.103
80.745	5.538	5.513	5.549	5.525
423.120	422.056	426.103	422.599	72356.507
72741.990	72187.301	72549.248	15200.175	15139.474
15417 776	15169.825			

280.000				
222989.[illegible]80	222552.190	223683.160	222770.940	527.087
526.575	524.687	526.831	446.480	445.597
444.299	446.038	80.608	80.978	80.398
80.793	5.539	5.503	5.527	5.521
423.063	422.641	426.317	422.851	70122.711
70512.371	69963.435	70317.391	14794.068	14732.415
15013.682	14763.242			

285.000				
223568.990	223929.350	223610.270	223749.173	528.599
528.455	524.611	528.527	447.901	447.513
444.243	447.707	80.698	80.943	80.368
80.820	5.550	5.529	5.528	5.540
422.947	423.743	426.240	423.345	67886.661
68278.705	67740.101	68082.683	14387.911	14325.428
14610.089	14356.669			

290.000				
22[illegible]63.740	224028.030	223537.350	223844.391	528.919
526.778	524.535	527.849	448.225	446.019
444.187	447.122	80.693	80.759	80.348
80.725	5.555	5.523	5.528	5.539
422.064	425.279	426.163	424.072	65644.544
66041.472	65517.049	65843.008	13981.485	13918.356
14206.395	13949.921			

295.000				
223693.520	224843.350	223464.740	224268.447	529.098
527.704	524.400	528.401	448.425	446.910
444.132	447.068	80.672	80.794	80.329
80.733	5.559	5.532	5.529	5.545
422.783	426.079	426.085	424.431	63431.381
63803.726	63294.285	63602.553	17575.064	13511.161
13802.800	13543.113			

300.000				
223559.290	224504.990	222755.130	224032.140	529.144
528.661	523.653	528.903	448.785	448.210
444.205	448.498	80.359	80.451	79.448
80.405	5.585	5.571	5.591	5.578
422.492	424.667	425.406	423.583	61157.161
61564.393	61071.603	61360.776	13168.698	13103.927
13399.357	13136.313			

305.000				
223342.190	222911.810	222716.920	223[illegible]27.000	528.892
528.977	523.604	528.934	448.827	448.640
444.138	448.733	80.065	80.337	79.466
80.201	5.606	5.584	5.589	5.595
422.283	421.402	425.354	421.843	58911.479
59324.543	58848.779	59118.010	12761.985	12696.591
12996.020	12729.288			

310.000				
223417.150	224745.680	222605.830	224081.410	529.044
527.883	523.370	528.463	448.931	447.894
443.903	448.412	80.113	79.989	79.466
80.051	5.604	5.599	5.585	5.602
422.304	425.749	425.332	424.027	56665.128
57162.999	56627.121	56874.064	12355.120	12289.814
12592.679	12322.467			

315.000				
223498.850	223801.470	222548.670	223650.160	52[illegible].239
527.313	523.336	528.276	449.105	447.332
443.842	448.218	80.134	79.981	79.456
80.058	5.604	5.593	5.583	5.599
422.303	424.419	425.287	423.361	54418.156
54841.597	54405.785	54629.877	11948.117	11882.937
12189.239	11915.527			

320.000				
222876.150	224183.170	222465.370	223529.670	527.641
525.701	523.095	527.171	447.554	446.527
443.569	447.041	80.087	80.174	79.525
80.130	5.588	5.570	5.578	5.579
422.401	425.637	425.287	424.019	52177.639
52604.507	52185.088	52391.072	11541.354	11475.832
11785.616	11508.593			

325.000				
222850.937	224484.500	221104.350	223667.720	527.577
525.391	519.504	526.484	447.495	445.293
440.052	446.395	80.081	80.098	79.452
80.089	5.588	5.559	5.539	5.574
422.404	427.272	425.607	424.838	49938.451
50369.341	49969.761	50153.895	11134.571	11069.173
11382.243	11101.872			

330.000				
222824.520	223311.950	212436.330	223068.240	527.532
527.281	498.332	527.391	447.404	447.104
419.345	447.254	80.098	80.177	7[illegible].988
80.137	5.586	5.576	5.309	5.581
422.415	423.516	426.295	422.965	47699.855
48135.447	47819.240	47917.651	10727.677	10662.386
10979.772	10695.031			

335.000				
222742.920	221951.480	204773.130	222347.200	527.279
526.039	478.877	526.659	447.162	446.117
400.796	446.639	80 117	79.922	78.081
80.020	5.581	5.582	5.133	5.562
422.439	421.930	427.611	422.184	45462.120
45902.499	45767.165	45682.310	10320.709	10255.745
10581.093	10288.227			

340.000				
222561.630	222967.060	198446.750	222814.340	527.067
527.042	463.209	527.054	446.935	446.767
385.797	446.852	80.131	80.274	77.412
80.202	5.578	5.566	4.986	5.572
422.454	423.054	428.417	422.754	43225.674
43668.578	43799.762	43447.126	9913.740	9848.953
10186.354	9881.347			

345.000				
222397.940	221710.410	194395.100	222054.170	526.389
527.260	453.320	526.825	446.219	447.512
376.437	446.865	80.170	79.748	76.893
79.959	5.566	5.612	4.896	5.589
422.497	420.495	428.825	421.495	40990.888
41435.786	41893.040	41213.337	9506.703	9442.270
9794.433	9474.451			

350.000				
218330.690	218297.970	191880.880	218314.330	515.958
516.007	447.248	515.982	435.851	436.092
370 747	435.971	80.106	79.916	76.501
80.011	5.441	5.457	4.845	5.449
423.155	423.052	429.076	423.104	38776.453
39228.968	40024.550	39002.[illegible]	9098.941	9036.270
9405.264	9067.605			

TABLE AP 2-2 (Sheet 5 of 6)
ENGINE PERFORMANCE PROGRAM

355.000				
210763.460	213471.140	190076.100	21211 300	496.208
502.454	442.422	499.321	417.138	423.180
366.223	420.159	79.070	79.254	76.199
79.162	5.276	5.340	4.805	5.318
424.. 3	424.874	429.626	424.811	36645.030
37076.534	38179.53	36860.783	9695.129	8631.983
9017.535	8663.556			
360.000				
203816.300	206300.350	188857.980	205058.320	478.287
482.064	439.	480.176	400.035	403.639
63.478	401.837	78.252	78.425	76 007
78.339	5.112	5.147	4.76.	5.129
426.138	427.952	429.725	427.045	34604.035
35001.465	36353.453	34802.750	8295.875	8230.727
8631.089	8263.301			
365.000				
197948.300	199769.190	188009.940	198858.740	463.421
467.523	437.438	455.472	385.884	389.951
361 567	387.917	77.537	77.571	75.871
75.554	4.977	5.027	4.755	5.. 2
427.146	427.293	429.798	427.219	32639.857
33015.381	34539.392	32027.619	7900.385	7834.173
8245.486	7867.279			
370.000				
193183.570	193858.240	187 43.710	193920.900	453.528
453.75	436.073	453.641	376.589	377.255
360.297	376.922	76.940	76.499	75.776
76.719	4.895	4.931	4.755	4.913
427.721	427.232	429.845	427.475	30732.992
31095.855	32732 634	30914.424	7508.141	7442.653
7860.476	7475.397			
375.000				
191207.220	191118.420	187086.410	191142.82	446.640
444.940	435.209	445.790	370.148	368.983
359.491	369.566	76.492	75.955	75.718
76.224	4.839	4.858	4.748	4.848
428.102	429.538	429.877	428.820	28866.374
29228.899	30931.321	29047.637	7118.601	7055.789
7475.864	7087.195			
380.000				
188959.220	188634.820	186790.240	188797.020	441.133
438.225	434.492	439.680	365.062	362.9-4
358.823	364.008	7 .071	75.273	75.669
75.672	4.799	4.822	4.742	4.810
428.350	430.451	429.905	429.430	27027.594
27400.111	29133.508	27213.852	6731.324	6571.085
7091.520	6701.204			
385.000				
186960.590	185408.890	186346.540	186184.740	436.315
431.869	433.431	434.086	350.670	356.508
357.245	358.589	75.624	75.360	75.585
75.497	4.769	4.731	4.734	4.750
428.509	429.318	429.934	428.914	25211.577
25501.845	27339.594	25406.711	6346.114	6288.239
6707.501	6317.176			
390.000				
185930.190	185455.260	185054.110	185192.73	433.824
431.794	431.783	432.809	358.421	356.641
356.339	357.526	75.403	75.163	75. 4
75.282	4.7.3	4.745	4.723	4.749
428.584	429.499	429.971	429.042	23414.599
23817.754	25351.910	23616.277	5962.767	5906.336
6324.055	5924.55			
395.000				
185050.940	185169.130	184935.460	185110.030	431.729
430.439	430.070	431.084	355.522	355.3 7
354.743	355.914	75.208	75.133	75.328
75.170	4.740	4.729	4.709	4.735
428.627	430.186	430.015	429.407	21625.324
22037.899	23772.158	21831.612	5580.372	5524.660
5941.264	5552.516			
400.000				
184825.570	184964.550	184260.350	184875.560	431.192
429.948	428.458	430.570	356.032	354.974
353.241	355.503	75.160	74.974	75.217
75.067	4.737	4.735	4.695	4.736
428.641	430.202	430.055	429.422	19842.795
20251.448	22000.242	20052.122	5198.66	5143.515
5559.055	5171.089			

405.000				
184558.840	185044.740	183718.520	184851.790	430.778
430.210	427.171	430.494	355.637	355.184
352.150	355.410	75.141	75.026	75.121
75.083	4.733	4.734	4.685	4.734
428.604	430.127	430.082	429.395	18061.794
18483.804	20235.184	18275.298	4817.195	4762.668
5177.370	4789.931			
410.000				
184170.780	183964.360	183372.580	184167.570	430.111
428.719	426.356	429.415	355.058	353.848
351.305	354.453	75.053	870	75.051
74.962	4.731	4.726	4.681	4.728
428.659	429.103	430.093	428.881	16282.702
16719.535	18474.972	16501.118	4435.	4381.985
4796.091	4408.975			
415.000				
184274.260	184403.920	183170.780	184339.090	429.885
427.858	427.892	428.871	354.861	352.950
350.896	353.926	75.024	74.867	74.996
74.945	4.730	4.715	4.679	4.722
428.659	430.993	430.087	429.825	14505.337
14952.807	16717.630	14729.072	4055.008	4001.557
4415.132	4028.282			
420.000				
183574.000	183067.870	183119.270	183320.930	428.166
425.170	425.785	426.668	3 3.273	350.527
350.817	351.900	74.892	74.642	74.965
74.768	4.717	4.696	4.680	4.707
428.745	430.576	430.075	429.661	12733.236
13185.311	14961.526	12959.273	3674.450	3621.634
4034.381	3648.042			
425.000				
183592.540	183381.350	183155.360	183486.950	428.204
426.309	425.898	427.257	353.304	351.442
350.958	352.373	74.900	74.867	74.940
74.884	4.717	4.694	4.583	4.706
428.750	430.160	430.046	429.455	10965.002
11424.004	13205.213	11194.503	3294.209	3242.212
3653.768	3268.211			
430.000				
183419.590	182954.070	183042.880	183186.830	427.787
426.377	425.658	427.082	352.935	351.679
350.772	352.307	74.852	74.697	74.886
74.775	4.715	4.708	4.684	4.712
428.764	429.090	430.023	428.927	9196.980
9664.284	11448.579	9430.632	2914.084	2862.967
3273.320	2888.526			
435.000				
183500.770	183272.000	182446.960	183386.390	427.925
426.520	424.297	427.257	353.141	351.890
349.577	352.516	74.853	74.631	74.720
74.742	4.718	4.715	4.678	4.716
428.745	429.691	429.998	429.219	7429.536
7902.658	5595.283	7656.097	2534.068	2483.974
2893.425	2509.021			
440.000				
183395.440	183072.5 0	181583.320	183233.980	427.720
425.831	422.301	427.275	352.879	352.313
347.796	352.596	74.841	74.518	74.505
74.6.	4.715	4.728	4.668	4.721
428.774	428 712	429.985	428.843	5662.378
6142.569	7949.810	5902.474	2154.190	2105.236
2517.505	2129.713			
445.000				
183232.310	183593.300	180849.670	183412.810	427.352
426.927	420.617	427.139	352.583	352.502
346.312	352.542	74.769	74.425	74.304
74.597	4.716	4.736	4.661	4.726
428.762	430.335	429.963	429.398	3896.694
4381.535	6212.800	4139.114	1774 575	1726.953
2136.650	1750.764			
448.100				
182981.770	181362.440	180539.040	182172.100	426.766
425.977	419.913	426.372	352.074	351.635
345.707	351.854	74.692	74.344	74.205
74.518	4.714	4.730	4.659	4.722
428.764	425.752	429.944	427.260	2803.348
3291.514	5138.996	3047.431	1539.397	1792.555
1902.837	1515.976			

TABLE AP 2-2 (Sheet 6 of 6)
ENGINE PERFORMANCE PROGRAM

448.200				
182950.400	182412.550	180530.550	182681.470	426.660
425.474	419.893	426.090	351.999	351.194
345.691	351.597	74.687	74.299	74.203
74.493	4.713	4.727	4.659	4.720
428.770	428.708	429.944	428.739	2768.112
3256.342	5104.387	3012.227	1531.818	1485.010
1895.300	1508.413			
448.300				
182942.850	182557.500	180522.140	182750.180	426.679
424.035	419.875	425.357	352.005	349.715
345.675	350.861	74.674	74.319	74.200
74.496	4.714	4.706	4.659	4.710
428.760	430.525	429.943	429.042	2732.860
3221.263	5069.779	2977.071	1524.234	1477.466
1887.762	1500.850			
448.400				
182963.210	183456.930	180512.800	183215.070	426.742
420.488	419.856	423.610	352.057	346.255
345.659	349.156	74.675	74.233	74.197
74.454	4.715	4.684	4.659	4.689
428.754	436.319	429.942	432.537	2697.645
3186.431	5035.173	2942.038	1516.654	1469.916
1880.226	1493.290			
448.[illegible]				
183779.220	182938.270	180511.650	163008.750	427.044
419.596	419.851	423.300	352.289	345.521
345.655	348.905	74.714	74.075	74.146
74.395	4.715	4.664	4.659	4.650
428.753	435.986	429.942	432.369	2688.481
3177.459	5026.176	2932.970	1514.683	1467.965
1878.265	1491.334			

APPENDIX 3

OBSERVED TRAJECTORY (AA83)

1. OBSERVED TRAJECTORY (AA83)

This appendix presents a detailed tabulation of the AS-204 ob .rved trajectory from guidance reference release (RO -4.956 sec) to S-IVB/LM separation (RO +3,235.242 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 for the powered flight phase of the mission. Vehicle radar parameters were calculated for KSC launch complex 37B, Cape Tel 4, Grand Bahama, Grand Turk, and Bermuda, sites one through five, respectively. Table AP 3-4 presents the observed trajectory for the orbital phase of the flight. Vehicle radar parameters were calculated for Bermuda. Apollo Ship, Canary Island, Tananarive, and Carnarvon, sites one through five, respectively.

TABLE AP 3-1
TRACKING HISTORY

STATION	TIME FROM RANGE ZERO
C-Band Radar Stations	
Cape Kennedy	0 sec to 468 sec
Patrick	42 sec to 467 sec
Grand Bahama	112 sec to 493 sec
Grand Turk	328 sec to 473 sec
Bermuda	347 sec to 700 sec
Glotrac Station	
Glotrac I	0 sec to 469 sec
O D O P Station	
O D O P Transmitter	0 sec to 385 sec

TABLE AP 3-2 (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 DD-Y SB E DD-Z SB E	$\ddot{X}_e$ $\ddot{Y}_e$ $\ddot{Z}_e$	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)
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 D-Y SB GS D-Z SB GS	$\dot{X}_{gs}$ $\dot{Y}_{gs}$ $\dot{Z}_{gs}$	Components of gravitational velocity vector, in space-fixed coordinate system (same orientation as X_S, Y_S, Z_S) (ft/sec)
D-XI D-ETA D-ZETA	$\dot{\xi}$ $\dot{\eta}$ $\dot{\zeta}$	Components of inertial platform velocity vector, in space-fixed coordinate system (same orientation as XI, ETA, ZETA) (ft/sec)
D-X SB S D-Y SB S D-Z SB S	$\dot{X}_s$ $\dot{Y}_s$ $\dot{Z}_s$	Components of volecity vector of vehicle, in space-fixed coordinate system (same orientation as X_S, Y_S, Z_S) (ft/sec)
D-X SB SFE D-Y SB SFE D-Z SB SFE	$\dot{X}_{SFE}$ $\dot{Y}_{SFE}$ $\dot{Z}_{SFE}$	Components of velocity vector in space-fixed ephemeris coordinate system (same orientation as X_{SFE}, Y_{SFE}, Z_{SFE}) (ft/sec)

TABLE AP 3-2 (Sheet 2 of 3)
LIST OF SYMBOLS (PROGRAM AA83)

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
D-X SB E D-Y SB E D-Z SB E	$\dot{X}_e$ $\dot{Y}_e$ $\dot{Z}_e$	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)
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)
GAMMA (1I) PR.	γ_{1_I}'	Angle between space-fixed velocity vector and plane normal to vector from geocentric center of earth, positive above plane (deg)
GAMMA (2I) PR.	γ_{2_I}'	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)

TABLE AP 3-2 (Sheet 3 of 3)
LIST OF SYMBOLS (PROGRAM AA83)

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
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 Y SB GS Z SB GS	X_{gs} Y_{gs} Z_{gs}	Components of gravitational position vector, in space-fixed coordinate system (same orientation as X_S, Y_S, Z_S) (ft)
XI ETA ZETA	ξ η ζ	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)
X SB S Y SB S Z SB S	X_s Y_s Z_s	Component of position vector of vehicle, in space-fixed coordinate system (same orientation as X_E, Y_E, Z_E at instant of launch (ft)
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)
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)

TABLE AP 3-3 (Sheet 1 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

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(1I) PR (DEG.)	GAMMA(2I) 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.)

GUIDANCE REFERENCE RELEASE MACH 1

1	-4.9560	112.9700	.3184	90.0000	.0000
2	.0000	1341.6394	32.126	.0000	90.0000
3	113.2	113.2	16960382.000	.000	.000
4	.0	.0	7130924.5	.000	.000
5	.0	.0	9935863.0	.000	.000
6	.000	.000	-519.996	.0000	.000
7	.000	414.590	1236.771	.0007	.000
8	.000	1275.976	.0000	.0021	.000
9	.000	4.186	-90.0000	-80.5650	28.5319
10	.000	71.242	-.9173	521.1607	.0023
11	.000	4.175	.0037	2117.8617	.0205
12	.0000	-.0000	.0000	85.0320	342.0429
13	113.0	37607.9	1008551.6	4035715.2	5183847.2
14	.0000	48.7678	313.8350	311.4563	258.6784
15	89.9829	.1203	-1.3770	-5.5420	-7.1102

RANGE ZERO

1	.0000	112.9700	.3184	90.0000	.0000
2	.0000	1341.6394	32.126	.0000	90.0000
3	113.2	112.0	16957805.000	120.201	-395.592
4	.0	2054.0	7137052.3	-.052	-.559
5	.0	6323.9	9935863.0	.027	.138
6	.000	-.426	-520.442	48.5289	-159.642
7	.000	414.369	1236.583	.0031	-.228
8	.000	1276.047	.0000	.0094	.048
9	.000	4.186	-90.0000	-80.5650	28.5319
10	.000	71.242	-.9074	521.1607	.0023
11	.000	4.175	.0037	2117.8617	.0205
12	.0000	-.0000	.0000	85.0320	342.0429
13	113.0	37607.9	1008551.6	4035715.2	5183847.2
14	.0000	48.7678	313.8350	311.4563	258.6784
15	89.9629	.1203	-1.3770	-5.5420	-7.1102

FIRST MOTION

1	.2000	112.9700	.3184	90.0000	.0000
2	.0000	1341.6394	39.729	.0000	90.0000
3	113.2	111.5	16957700.000	130.005	-428.164
4	.0	2136.9	7137298.9	-.035	-.606
5	.0	6579.1	9935662.9	.022	.147
6	.000	-.443	-520.460	50.4873	-166.084
7	.000	414.360	1236.576	.0033	-.238
8	.000	1276.050	.0000	.0100	.048
9	7.603	4.186	-90.0000	-80.5650	28.5319
10	.064	71.242	-.9070	521.1606	.0023
11	.050	4.175	.0037	2117.8617	.0205
12	.0000	-.0000	.0000	85.0320	342.0429
13	113.0	37607.9	1008551.6	4035715.2	5183847.2
14	1.6120	48.7678	313.8350	311.4563	258.6784
15	89.9629	.1203	-1.3770	-5.5420	-7.1102

LIFTOFF - TB1

.3600	113.2546	.3213	89.4331	124.6238
1.2280	1341.6500	39.870	.0524	90.0001
113.3	111.8	16957618.000	138.292	-455.150
.0	2203.2	7137497.1	-.029	-.644
.0	6783.3	9935863.0	.038	.155
1.228	.771	-519.481	52.4283	-171.238
.010	414.363	1236.999	.0065	-.245
.007	1276.060	.5805	.0129	.049
7.744	4.190	-73.2608	-80.5650	28.5319
.056	71.247	-.5484	521.1631	.0023
.043	4.363	.0039	2117.8318	.0224
.0000	-.0000	.0000	85.0140	342.0436
113.2	37607.8	1008551.5	4035715.1	5183847.3
171.9597	48.7680	313.8350	311.4563	258.6784
89.9569	.1206	-1.3770	-5.5420	-7.1102

5.0000	212.2812	.7670	89.9432	342.3445
43.1623	1342.3272	41.991	1.8426	89.9931
212.4	207.7	16955280.000	515.409	-1596.446
.1	4125.5	7143269.8	.041	-2.309
.4	12704.8	9935910.3	.273	.393
43.162	42.307	-485.963	110.6444	-320.700
-.042	414.116	1251.103	.0009	-.474
.000	1276.152	20.6512	.0415	.047
9.866	4.979	-6.5526	-80.5650	28.5319
-.046	72.329	-.2954	521.7475	.0023
-.018	43.450	.0387	2110.6239	2.2130
.0000	-.0000	.0000	80.6850	342.2015
212.3	37608.7	1008553.6	4035724.4	5183859.2
92.3305	48.7683	313.8350	311.4563	258.6784
89.8799	.2715	-1.3713	-5.5406	-7.1091

START ROLL AND PITCH

9.2180	484.4639	2.0544	89.8272	331.5783
86.7014	1344.3378	42.903	3.6977	89.9798
484.8	475.6	16953303.000	1096.696	-3235.702
-.5	5871.3	7148577.0	-.083	-4.771
.6	18088.1	9936041.0	.602	.519
86.701	85.483	-451.149	165.2165	-456.566
-.256	413.735	1265.693	-.0482	-.695
-.047	1276.230	41.6139	.0773	.008
10.778	7.160	-4.6919	-80.5650	28.5319
-.052	75.320	-.4344	523.3629	.0023
.008	86.994	.0774	2090.7000	8.7651
.0000	.0000	.0000	68.7190	342.6380
484.5	37611.9	1008560.8	4035751.1	5183892.7
31.1303	48.7675	313.8350	311.4563	258.6784
89.9104	.6363	-1.3559	-5.5367	-7.1061

10.0000	555.4597	2.4510	89.8195	335.3819
95.2019	1344.9167	43.088	4.0591	89.9769
555.8	545.6	16952953.000	1229.880	-3602.585
-.7	6194.9	7149567.3	-.093	-5.330
.6	19086.1	9936075.1	.680	.521
95.201	93.916	-444.360	175.4645	-481.755
-.297	413.664	1268.565	-.0569	-.737
-.034	1276.270	45.7118	.0929	-.004
10.904	7.726	-4.6099	-80.5650	28.5319
-.052	76.098	-.4635	523.7826	.0023
.025	95.513	.0849	2085.5235	10.5327
.0000	-.0000	.0000	65.6100	342.7515
555.7	37613.1	1008562.8	4035758.2	5183901.5
20.0469	48.7671	313.8350	311.4563	258.6784
89.8967	.7946	-1.3518	-5.5357	-7.1053

15.0000	1173.8071	6.9641	89.6782	33.9959
153.3488	1350.9202	44.458	6.5177	89.9511
1174.1	1156.5	16950843.000	2272.981	-6413.981
-3.1	8261.9	7155960.2	-.578	-9.702
2.0	25469.5	9936372.9	1.821	.276
153.346	151.630	-398.206	242.1431	-642.802
-.530	413.253	1288.783	-.0974	-1.015
.678	1277.191	73.8724	.4039	-.103
12.334	8.427	-2.8065	-80.5650	28.5319
-.034	56.131	.5071	524.2626	.0022
.324	153.587	.1366	2040.5082	26.6490
.0000	-.0000	.0000	47.9590	342.7202
1174.0	37630.0	1008579.6	4035819.2	5183976.7
15.0330	46.7648	313.8352	311.4563	258.6785
89.8213	1.7360	-1.3167	-5.5270	-7.0985

20.0000	2100.3325	18.8193	88.9586	64.8545
218.5622	1362.9986	45.849	9.2265	89.9019
2100.6	2073.5	16948978.000	3654.822	-10030.585
-6.5	10327.1	7162463.1	-1.172	-15.503
12.6	31863.4	9936821.1	6.359	-.588
218.546	216.394	-347.577	310.9667	-803.838
-.494	413.129	1313.678	-.0457	-1.308
3.942	1280.729	105.8710	1.5273	-.251
13.717	8.404	-1.2013	-80.5650	28.5319
.067	17.016	1.8206	521.3139	.0022
1.056	218.862	.1953	1973.9504	52.6895
.0001	-.0000	.0000	40.5615	341.6120
2100.5	37682.2	1008601.3	4035905.9	5184081.1
44.5856	48.7663	313.8358	311.4565	258.6785
89.6135	3.1435	-1.2641	-5.5139	-7.0884

TABLE AP 3-3 (Sheet 2 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	25.0000	3369.4685	56.2530	87.6574	73.4159	50.0000	16089.2235	2021.2910	75.5767	73.2658
2	290.5266	1384.0169	47.150	12.1067	89.8219	782.5574	1707.7297	56.201	26.3407	87.8185
3	3369.8	3330.7	16947372.000	5385.756	-14452.326	16089.6	15952.5	16943580.000	19651.315	-48633.538
4	-8.1	12393.2	7165108.0	-1.027	-22.813	45.9	22776.3	7205988.4	23.469	-84.777
5	50.7	38286.1	9937438.9	19.968	-2.317	2008.9	72206.7	9944001.1	645.330	-32.682
6	290.284	287.683	-293.827	381.7741	-964.856	757.874	752.362	-10.469	768.6575	-1769.481
7	.293	413.773	1345.032	.2449	-1.618	4.298	417.135	1657.420	1.8142	-3.405
8	11.872	1289.006	141.6313	4.1104	-.449	194.948	1475.227	411.3311	61.4033	-2.196
9	14.983	13.123	-.9092	-80.5648	28.5319	22.211	15.147	.9785	-80.5590	28.5335
10	.251	41.735	2.4186	515.3608	.002[illegible]	-.033	277.150	.4670	477.4937	.0014
11	2.167	291.036	.2612	1865.1452	90.0155	14.534	779.249	.7274	1166.9442	432.1569
12	.0002	-.0000	.0000	46.7595	339.[illegible]416	.0055	-.0000	.0000	27.1497	326.5396
13	3370.0	37810.8	1008618.1	4036009.2	518420[illegible]	16214.4	42612.8	1008047.2	4036119.4	5183858.9
14	62.9522	48.7870	313.8377	311.4569	258.6785	73.3086	49.9774	313.9335	311.4796	258.6773
15	89.1274	5.0610	-1.1920	-5.4960	-7.074[illegible]	82.8812	22.1295	-.4677	-5.3147	-6.9322
		END ROLL								
1	28.6980	4547.4304	118.6898	86.4163	75.6242	55.0000	20162.6460	3198.1972	72.4425	72.9381
2	348.3396	1406.6631	48.292	14.3083	89.7317	913.9091	1829.3299	57.803	28.4367	87.0303
3	4547.7	4498.2	16946360.000	6896.259	-18240.535	20162.7	19996.1	16943653.000	23703.021	-57882.903
4	-5.6	13924.5	7174133.0	.363	-29.237	67.3	24801.4	7214538.2	32.677	-102.807
5	113.4	43072.3	9938016.4	41.194	-4.297	3183.7	79765.2	9946247.7	1014.412	-44.918
6	347.659	344.712	-252.477	435.4506	-1063.931	871.293	864.920	39.410	851.9713	-1930.261
7	1.376	414.758	1373.236	.6182	-1.858	4.495	417.153	1762.796	1.9433	-3.810
8	21.731	1299.174	170.8081	7.2639	-.627	275.787	1557.031	487.2878	86.4931	-2.707
9	16.074	11.336	-.5428	-80.5647	28.5320	22.900	23.512	1.2470	-80.5555	28.5344
10	.311	358.910	1.7814	510.1006	.0020	.230	280.417	.6997	464.4653	.0012
11	3.181	348.720	.3146	1805.8000	125.1098	17.861	907.907	.8594	992.4421	513.0571
12	.0003	.0000	.0000	48.0957	337.3481	.0088	-.0000	.0000	22.3330	322.0055
13	4548.9	37991.3	1008618.5	4036086.6	5184285.6	20412.5	45282.3	1007629.6	4035851.4	5183213.0
14	69.1349	48.8279	313.8408	311.4577	258.6784	73.2102	50.6263	313.9913	311.4933	258.6767
15	88.5690	6.8229	-1.1251	-5.4793	-7.0614	61.0250	26.3850	-.2350	-5.2562	-6.8859
						MACH 1				
1	30.0000	5013.6562	150.4798	85.9389	75.7853	59.7600	24573.4240	4733.8098	69.3566	72.9024
2	369.7779	1416.2286	48.730	15.0956	89.6871	1046.9369	1961.5935	58.167	29.9531	86.2463
3	5014.0	4960.8	16946041.000	7475.753	-19679.103	24573.3	24373.6	16943940.000	27948.780	-67435.095
4	-3.7	14464.6	7175628.1	1.216	-31.712	92.1	26849.9	7223203.2	43.095	-121.888
5	145.2	44767.4	9938246.5	51.740	-5.157	4717.9	87[illegible]20.5	9948750.2	1494.744	-59.073
6	368.849	365.777	-237.603	454.6487	-1125.852	979.633	972.303	79.001	931.3363	-2083.262
7	1.729	415.078	1384.265	.7420	-1.944	5.774	418.217	1877.299	2.3894	-4.210
8	26.133	1303.696	181.8302	8.6633	-.696	369.274	1651.537	563.3474	115.4635	-3.249
9	16.487	9.098	-.3417	-80.5646	28.5320	22.077	42.392	2.1676	-80.5509	28.5356
10	.230	352.893	1.3498	508.7491	.0020	.244	262.119	.4023	443.9735	.0010
11	3.587	370.029	.3344	1774.8769	138.8921	21.263	1032.934	1.0001	827.1560	579.1374
12	.0004	-.0000	.0000	41.0490	337.3211	.0130	-.0000	.0000	33.0000	314.8018
13	5015.9	38078.5	1008614.8	4036112.7	5184312.3	25022.2	48637.0	1007069.0	4035417.1	5182257.7
14	70.5206	48.8495	313.8423	311.4580	258.6784	73.1179	51.4189	314.0669	311.5111	258.6760
15	88.3409	7.5143	-1.0986	-5.4726	-7.0562	79.1297	30.2902	.0177	-5.1926	-6.8354
1	35.0000	7070.4624	339.2543	83.7752	73.8046	60.0000	24808.7810	4822.6774	69.1984	72.8903
2	457.8577	1462.4584	50.489	18.1316	89.3764	1053.6771	1968.5219	58.171	30.0141	86.2037
3	7070.5	7000.3	16944994.000	9935.836	-25710.792	24808.4	24607.1	16943958.000	28172.643	-67936.001
4	5.2	16539.8	7182970.0	5.141	-42.278	93.5	26950.3	7223654.3	43.666	-122.901
5	332.9	51344.2	9939272.1	113.077	-9.359	4806.8	87817.2	9948885.4	1522.548	-59.656
6	455.157	451.578	-180.320	529.8636	-1286.820	984.908	977.527	80.626	935.2793	-2090.975
7	1.563	414.791	1433.028	.7586	-2.285	5.774	418.204	1883.297	2.3918	-4.230
8	49.628	1327.710	229.5719	16.0733	-.993	374.377	1656.692	567.2525	117.0436	-3.278
9	18.053	5.317	.1844	-80.5640	28.5321	22.014	42.651	2.1620	-80.5507	28.5357
10	-.074	314.610	.5757	506.0097	.0018	.197	262.495	.4180	442.9644	.0310
11	5.774	457.719	.4148	1645.0300	198.0844	21.457	1039.497	1.0076	818.9946	582.0457
12	.0009	-.0000	.0000	37.6870	336.3715	.0132	-.0000	.0000	32.7527	314.4418
13	7078.3	36571.7	1008577.4	4036201.2	5184383.3	25269.8	48827.5	1007036.3	4035390.2	5182199.9
14	72.8935	48.9733	313.8514	311.4602	258.6783	73.1135	51.4629	314.0713	311.5121	258.6760
15	87.3036	10.5105	-.9816	-5.4434	-7.0334	79.0324	30.4789	.0311	-5.1892	-6.8327
1	40.0000	9577.1749	672.1073	81.3650	73.4141	65.0000	30010.3570	6979.1345	65.9618	72.9168
2	555.1696	1524.5549	52.151	21.0989	88.9793	1199.8939	2121.3356	60.187	31.0900	85.3693
3	9577.5	9488.4	16944236.000	12777.957	-32547.227	30009.5	29768.7	16944439.000	33054.948	-78792.481
4	14.0	18614.5	7190281.8	9.420	-54.592	124.3	29042.7	7233398.9	56.365	-145.137
5	664.0	58067.2	9940552.1	219.429	-15.173	6962.9	96387.7	9951929.4	2195.711	-77.803
6	548.874	544.735	-122.091	607.3100	-1447.752	1095.069	1087.116	111.409	1017.6443	-2251.612
7	2.056	415.166	1493.061	.9817	-2.643	7.743	419.881	2016.336	3.0359	-4.667
8	83.345	1362.047	283.0773	26.6454	-1.341	469.075	1772.554	649.6516	152.5514	-3.912
9	19.446	6.562	-.0324	-80.5630	28.5324	22.703	49.213	1.9003	-80.5443	28.5374
10	.100	344.905	.6745	499.6395	.0017	.787	281.357	1.1568	419.7608	.0009
11	7.937	555.251	.5065	1497.8953	269.0308	25.000	1183.194	1.1783	653.2216	634.7902
12	.0018	-.0000	.0000	24.6455	334.1071	.0191	-.0000	.0000	33.8215	306.0711
13	9600.3	39403.5	1008489.7	4036254.4	5184369.5	30806.8	53321.1	1006235.2	4034688.8	5180734.9
14	73.1993	49.1790	313.8676	311.4640	258.6781	73.0228	52.4807	314.1778	311.5373	258.6750
15	86.0331	14.0147	-.8390	-5.4077	-7.0055	76.9351	34.1911	.3299	-5.1139	-6.7726
1	45.0000	12572.5108	1207.2106	78.6271	73.4309	70.0000	35784.5570	9755.2181	62.7720	73.2173
2	663.2658	1605.8028	54.281	23.8827	88.4731	1364.6609	2296.6929	63.462	31.8787	84.5954
3	12572.8	12461.2	16943768.000	16013.056	-40188.219	35782.5	35495.6	16945066.000	38354.314	-90451.942
4	26.5	20692.3	7197930.7	15.199	-68.732	175.2	31153.3	7243860.7	75.305	-169.595
5	1197.0	64995.5	9942117.1	388.947	-22.859	9740.5	105586.0	9955398.4	3061.272	-99.085
6	650.235	645.461	-64.505	687.0503	-1608.641	1213.156	1263.220	137.781	1101.9695	-2412.165
7	3.263	416.247	1567.337	1.4251	-3.016	13.123	424.895	2170.483	4.7022	-5.119
8	130.788	1410.221	343.3337	41.4511	-1.742	624.803	1909.588	738.1217	194.5332	-4.613
9	21.037	16.404	.6540	-80.5614	28.5328	23.917	87.366	2.6612	-80.5360	28.5397
10	.411	314.037	1.2490	490.8625	.0015	1.509	289.371	2.2548	394.7508	[illegible]
11	11.132	661.914	.6093	1337.1146	347.5106	29.921	1334.927	1.3709	501.0095	659.0843
12	.0033	-.0000	.0000	21.2802	331.0994	.0267	-.0000	.0000	33.0000	296.8004
13	12629.5	40702.0	1008324.3	4036241.0	5184218.4	37084.8	56824.1	1005183.2	4033689.6	5178735.1
14	73.2661	49.5012	313.8937	311.4702	258.6778	73.0304	53.6743	314.3150	311.5695	258.6737
15	84.5601	17.9393	-.6683	-5.3650	-6.9719	74.7699	37.4049	.6628	-5.0300	-6.7053

TABLE AP 3-3 (Sheet 3 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

MAXIMUM DYNAMIC PRESSURE

1	71.5000	37633.1810	10726.9719	61.7835	73.3344	100.0000	84762.1430	46091.0800	46.9541	72.2510
2	1418.3298	2354.6908	64.823	32.0415	84.3697	2869.1135	3881.8000	89.347	32.6646	79.3685
3	37630.3	37328.0	16945278.000	40026.661	-94106.296	84711.4	83939.3	16950145.000	79573.803	-177242.840
4	196.7	31792.3	7247154.9	82.889	-177.378	509.1	43782.9	7327770.6	194.136	-367.422
5	10713.1	108486.0	9956527.0	3363.986	-106.172	46203.4	180744.7	9988389.2	14369.107	-318.590
6	1249.444	1239.041	143.895	1127.5632	-2460.313	2092.457	2067.971	153.710	1658.4563	-3373.158
7	15.451	427.092	2221.939	5.4141	-5.258	6.392	413.480	565.513	2.1505	-8.163
8	671.052	1956.257	766.0658	208.8263	-4.837	1963.006	3258.973	1527.0468	607.6457	-10.584
9	24.468	110.003	3.2293	-80.5331	28.5404	32.794	50.335	.6970	-80.4282	28.5696
10	1.553	289.000	2.7211	388.8679	.0006	-.066	272.631	.3516	393.1684	.0000
11	31.753	1379.909	1.4278	458.7190	654.5795	61.585	2837.180	2.9195	45.1672	269.4932
12	.0294	-.0000	.0000	33.0000	294.5786	.1263	-.0000	.0000	.0000	296.2017
13	39126.1	60684.2	1004810.3	4033320.6	5178013.6	96493.6	117942.3	992087.1	4018512.5	5149282.4
14	73.0520	54.0654	314.3630	311.5808	258.6731	72.6311	61.8937	316.1553	311.9970	258.6595
15	74.1061	38.2614	.7697	-5.0030	-6.6836	61.3895	45.8328	3.5465	-4.3047	-6.1124

1	75.[illegible]	42162.8260	13274.4814	59.5803	73.3283	105.0000	95667.8660	56537.3450	44.8314	72.2325
2	1552.13[illegible]	2497.9910	67.384	32.3820	83.7620	3213.4205	4241.2515	94.185	32.2561	78.7168
3	42158.6	41818.0	16945804.000	44079.792	-102913.937	95591.3	94687.3	16950839.000	88112.175	-194507.840
4	257.2	33293.1	7255153.6	103.839	-196.354	540[illegible]	45846.1	7346390.1	204.019	-409.630
5	13263.8	115536.8	9959332.0	4157.307	-124.053	5681[illegible]	197849.0	9996440.3	17652.319	-374.869
6	1337.967	1320.392	156.495	1188.4204	-2572.625	2259.369	2231.038	121.516	1756.8273	-[illegible]32.831
7	17.976	429.282	2348.173	6.1820	-5.587	6.106	411.798	3886.175	1.8087	9.723
8	786.532	2072.767	837.5900	244.5059	-5.387	2285.014	3583.450	1694.4319	706.9623	-11.949
9	26.195	103.656	2.9965	-80.5255	28.5424	33.971	36.089	.4363	-80.3969	28.5784
10	-.437	280.406	1.8427	377.4141	.0005	.039	269.473	.1908	397.8301	.0000
11	33.[illegible]52	1508.285	1.5841	367.2091	645.0331	67.293	3189.128	3.2624	27.1103	201.9839
12	.0364	-.0000	.0000	.0000	290.2033	.1552	-.0000	.0000	.0000	297.9534
13	44196.6	65421.1	1003827.6	4032320.6	5176083.8	111200.8	133035.0	988597.4	4013907.2	5140333.0
14	73.1107	55.0271	314.4890	311.6103	258.6717	72.5446	63.0564	316.7032	312.1224	258.6562
15	.2.5324	40.0581	1.0322	-4.9368	-6.6302	59.2746	45.8552	4.2048	-4.1403	-5.9757

1	80.0000	4915[illegible].0700	17646.8460	56.7004	72.6909	110.0000	107435.2460	68844.9160	42.8917	72.2505
2	1763.6075	2721.0633	71.755	32.7801	82.6615	3587.7676	4629.9898	99.756	31.7976	78.1486
3	49186.9	48783.8	16946623.000	50245.856	-116177.966	107322.0	106265.8	16951348.000	97146.882	-212570.770
4	331.9	35423.0	7267371.6	130.075	-225.493	572.8	47903.2	7366680.9	212.930	-454.679
5	17644.5	126352.5	9963815.7	5518.218	-153.083	69104.6	216630.7	10005353.4	21454.491	-438.307
6	1473.228	1459.771	169.243	1277.9509	-2732.981	2433.241	2400.556	79.852	1857.1117	-3692.330
7	11.275	422.021	2541.425	4.1163	-6.071	7.071	411.143	4233.868	1.7844	-9.299
8	969.425	2257.245	957.4488	300.9947	-6.239	2636.544	3937.652	1872.1107	815.3803	-13.449
9	27.752	104.844	2.8541	-80.5125	28.5460	35.629	35.996	.3491	-80.3607	28.5887
10	-1.165	265.913	.8223	373.6257	.0004	.199	280.100	.2692	409.7823	.0000
11	39.721	1709.856	1.8049	258.5886	589.7036	73.410	3564.565	3.5929	15.8789	143.4835
12	.0484	-.0000	.0000	.0000	288.7426	.1886	-.0000	.0000	.0000	302.3983
13	52256.8	73201.8	1002170.9	4030560.6	5172679.0	127646.9	149920.3	984717.5	4008531.1	5129873.0
14	73.0775	56.4481	314.7068	311.6613	258.6697	72.4748	64.1108	317.3440	312.2681	258.6523
15	70.2626	42.1501	1.4414	-4.8336	-6.5466	57.2216	45.6328	4.9223	-3.9617	-5.8264

1	85.0000	56927.5340	22994.9820	54.0504	72.5238	115.0000	120104.1420	82860.0970	41.1097	72.2647
2	2001.3683	2971.4381	75.270	33.0188	81.7528	3993.3102	5049.1153	105.385	31.2990	77.6347
3	56915.4	56439.3	16947495.000	56866.401	-130243.486	119939.8	118708.0	16951623.000	106687.763	-231430.700
4	382.8	37525.9	7280621.8	148.855	-257.092	610.1	49956.5	7388777.0	221.554	-502.641
5	23007.0	138158.4	9968920.6	7182.300	-186.585	83230.9	237269.9	10015184.1	25822.454	-509.602
6	1618.886	1603.234	179.381	1370.5205	-2893.224	2613.699	2576.106	27.157	1959.1775	-3851.642
7	10.100	420.169	2760.729	3.7040	-6.571	7.792	409.992	4608.989	1.6133	-9.889
8	1176.682	2466.282	1084.2722	364.9949	-7.177	3019.113	4323.096	2061.5666	933.3654	-15.095
9	30.013	55.774	1.2878	-80.4966	28.5504	36.790	34.225	.3135	-80.3191	28.6004
10	.011	262.661	.2890	371.8314	.0002	.143	237.727	-.1241	432.3471	.0000
11	42.707	1969.738	2.0843	175.5969	533.9614	79.914	3968.389	3.8941	9.0994	96.5900
12	.0630	-.0000	.0000	.0000	288.0478	.2270	-.0000	.0000	.0000	310.6164
13	61390.7	82257.5	1000196.8	4028364.6	5168406.6	145990.7	168736.8	980476.2	4002323.0	5117766.7
14	72.9530	57.8754	314.9757	311.7241	258.6676	72.4199	65.0555	318.0885	312.4359	258.6473
15	67.9871	43.7127	1.8939	-4.7196	-6.4538	55.2409	45.2183	5.7028	-3.7681	-5.6635

1	90.0000	65414.7510	29420.3320	51.6392	72.4341	120.0000	133709.7400	98836.1690	39.4545	72.2729
2	2262.9941	3245.7267	80.232	33.1160	80.9237	4431.6358	5500.3873	111.486	30.7610	77.1676
3	65394.4	64834.1	16948410.000	63956.439	-145109.920	133475.7	132042.5	16951603.000	116743.286	-251086.700
4	432.7	39624.1	7295020.4	166.971	-291.229	650.0	52002.0	7412821.4	228.723	-553.590
5	29454.4	151058.7	9974679.4	9181.443	-225.005	99351.2	259917.6	10025992.7	30805.282	-589.523
6	1772.482	1754.307	184.184	1465.3716	-3053.342	2799.978	2756.868	-38.489	2062.7711	-4010.753
7	9.651	418.915	3001.862	3.4789	-7.086	7.993	408.039	5013.013	1.2023	-10.493
8	1406.896	2698.456	1220.5117	436.0757	-8.208	3435.033	4742.094	2263.2918	1061.6264	-16.901
9	31.347	9.843	.1650	-80.4776	28.5557	37.848	.000	.0000	-80.2717	28.6138
10	-.251	280.820	.1126	373.2565	.0001	-.029	.000	.0000	450.4322	.0000
11	49.292	2257.860	2.3846	114.3782	455.2892	86.961	4431.636	4.2604	5.3750	68.2933
12	.0806	-.0000	.0000	.0000	288.5997	.2708	-.0000	.0000	.0000	317.0495
13	71722.8	92663.3	997871.8	4025668.7	5163176.1	166393.5	189630.8	975925.3	3995225.7	5103871.2
14	72.8416	59.2831	315.3009	311.7997	258.6652	72.3748	65.8922	318.9484	312.6281	258.6427
15	65.7503	44.8157	2.3938	-4.5938	-6.3509	53.3370	44.6543	6.5503	-3.5587	-5.4863

1	95.0000	74685.4710	37066.6370	49.2462	72.3026	125.0000	148282.8700	116945.0880	37.8760	72.2810
2	2552.1722	3549.4134	84.954	32.9759	80.1008	4905.6314	5987.1229	117.761	30.1655	76.7441
3	74653.0	73994.8	16949316.000	71523.833	-160776.610	147954.8	146290.4	16951216.000	127319.507	-271537.720
4	475.5	41711.0	7310689.6	182.406	-327.980	689.6	54035.6	7438965.4	233.203	-607.597
5	37133.1	165200.4	9981150.5	11560.610	-268.829	117644.6	284754.5	10037841.8	36458.211	-678.909
6	1930.377	1909.270	175.100	1561.3668	-3213.325	2990.178	2940.864	-120.996	2167.2843	-4169.650
7	7.310	415.585	32[illegible]22	2.6258	-7.617	7.851	405.413	5449.132	.5906	-11.112
8	1669.483	2963.160	13[illegible].1750	517.1028	-9.340	3888.958	5199.290	2477.4933	1201.5838	-18.883
9	32.077	10.217	.1701	-80.4549	28.5620	38.129	.000	.0000	-80.2180	28.6289
10	-.417	264.399	.0490	392.7208	.0001	-.001	.000	.0000	481.1460	.0000
11	55.836	2545.671	2.6211	72.9322	350.7301	94.648	4905.631	4.5630	3.2329	47.1198
12	.1016	-.0000	.0000	.0000	296.0330	.3204	-.0000	.0000	.0000	327.6853
13	83379.5	104521.4	995175.4	4022409.4	5156851.4	189027.2	212764.9	971136.2	3987176.6	5088024.9
14	72.7336	60.6313	315.6909	311.8900	258.6625	72.3358	66.6274	319.9374	312.8469	258.6369
15	63.5519	45.5061	2.9438	-4.4557	-6.2373	51.5099	43.9729	7.4680	-3.3326	-5.2939

TABLE AP 3-3 (Sheet 4 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

						S-IB OUTBOARD ENGINE CUTOFF - TB3				
1	130.0000	163839.1800	137379.9000	36.3264	72.2981	142.2500	206012.5900	198385.0900	32.8855	72.3697
2	5418.9381	6513.3932	125.663	29.4900	76.3655	5.2659	7760.3622	61.394	27.6218	75.7056
3	163385.8	161458.3	16950363.000	138418.150	-292782.660	20[illegible]5.3	202328.4	16945561.000	167760.570	-348180.410
4	728.5	56055.3	7467373.8	234.391	-464.732	822.5	60933.5	7547453.5	220.084	-818.367
5	138512.7	311982.7	10050791.2	42843.222	-778.675	200157.5	389975.0	10087410.7	61540.865	-1073.462
6	3181.398	3125.095	-225.584	2271.7997	-4328.316	3549.770	3474.382	-564.386	2496.4239	-4715.985
7	7.940	402.627	5921.347	-.0658	-11.745	8.629	395.086	7042.655	-1.8744	-13.352
8	4366.745	5700.524	2703.8980	1355.0225	-21.057	5605.873	6927.901	3210.2523	1731.0313	-27.305
9	38.058	.000	.0000	-80.1574	28.6460	.623	.000	.0000	-79.9762	28.6969
10	.004	.000	.0000	487.4531	.0000	.230	.000	.0000	429.8494	.0000
11	104.331	5418.938	5.0078	1.7928	31.4713	52.001	6635.266	6.5299	.3332	9.9456
12	.3764	-.0000	.0000	.0000	329.8269	.5436	-.0000	.0000	.0000	309.7176
13	214069.7	238311.3	966199.4	3978103.5	5070043.7	286557.8	312022.0	954372.3	3951175.0	5015884.3
14	72.3016	67.2706	321.0715	313.0952	253.6305	72.2553	68.5173	324.5659	313.8449	258.6111
15	49.7503	43.1961	8.4585	-3.0893	-5.0854	45.6936	40.9990	11.1898	-2.4189	-4.5032

						S-IB/S-IVB SEPARATION SIGNAL				
1	135.0000	180382.3200	160357.9000	34.7658	72.3194	143.5000	210506.7600	205305.2300	32.6209	72.3817
2	5973.5568	7081.4808	133.717	28.7128	76.0249	6633.2795	7761.3854	5.638	27.3944	75.7092
3	179764.1	177535.5	16948918.000	150035.550	-314820.320	209491.8	206659.7	16944835.000	170885.060	-354100.030
4	765.7	58058.0	7498233.0	231.376	-725.066	833.3	61427.0	7556270.7	217.667	-835.162
5	161582.7	341830.6	10064900.5	50030.150	-889.823	207185.7	398655.9	10091424.1	64111.220	-1108.040
6	3368.602	3304.435	-358.894	2374.7493	-4486.738	3520.932	3444.434	-596.860	2499.3251	-4755.452
7	7.940	399.293	6431.583	-.8850	-12.391	8.858	394.774	7045.508	-1.9181	-13.520
8	4933.137	6250.493	2941.6542	1523.3792	-23.439	5621.686	6944.001	3200.5789	1736.1578	-28.024
9	37.270	.000	.0000	-80.0892	28.6652	-27.854	.000	.0000	-79.9557	28.7027
10	.033	.000	.0000	469.6695	.0000	.197	.000	.0000	422.3059	.0000
11	114.337	5973.557	5.6239	.9496	21.0235	4.068	6633.279	6.5860	.2746	8.3372
12	.4394	-.0000	.0000	.0000	323.7520	.5626	-.0000	.0000	.0000	306.9866
13	241712.0	266458.3	961233.2	3967926.4	50[illegible]9717.6	294641.0	320221.1	953311.8	3948145.1	5009710.0
14	72.2714	67.8318	322.3690	313.3761	258.6232	72.2304	68.6188	324.9720	313.9307	258.6089
15	48.0486	42.3389	9.5228	-2.8282	-4.8600	45.3168	40.7708	11.4836	-2.3466	-4.4397

	TILT ARREST					S-IB/S-IVB PHYSICAL SEPARATION				
1	135.2570	181260.3400	161615.7500	34.6870	72.3204	143.5900	210836.7700	205788.5500	32.6020	72.3821
2	6003.3505	7111.9580	134.125	28.6718	76.0082	6632.0392	7760.3634	5.240	27.3774	75.7095
3	180632.4	178387.4	16948825.000	150646.970	-315974.440	209816.9	206978.3	16944795.000	171112.650	-354528.140
4	767.8	58160.6	7499691.4	231.133	-728.254	833.9	61462.4	7556895.4	217.480	-836.379
5	162857.4	343443.8	10065659.4	50423.758	-895.863	207676.8	399266.1	10091712.[illegible]	64262.990	-1110.565
6	3378.282	3313.684	-366.426	2380.0484	-4494.874	3518.269	3441.721	-599.1[illegible]1	2499.3641	-4758.293
7	7.923	399.092	6458.937	-.9361	-12.425	8.828	394.709	7044.723	-1.9342	-13.533
8	4962.597	6280.142	2954.2898	1532.4553	-23.568	5621.878	6944.208	3199.3935	1736.2367	-28.076
9	37.368	.000	.0000	-80.0854	28.6662	-27.981	.000	.0000	-79.9542	28.7031
10	.016	.000	.0000	468.4861	.0000	.215	.000	.0000	421.7520	.0000
11	114.742	6003.350	5.6591	.9175	20.5668	3.678	6632.039	6.5891	.2707	8.2257
12	.4429	.0000	.0000	.0000	323.3437	.5639	.0000	.0000	.0000	306.7852
13	243210.0	267982.4	960978.6	3967369.9	5048601.6	295217.6	320804.7	953244.4	3947936.3	5009281.6
14	72.2700	67.8586	322.4407	313.3915	258.6228	72.2500	68.6257	325.0005	313.9367	258.6087
15	47.9620	42.2925	9.5796	-2.8143	-4.8479	45.2934	40.7575	11.5050	-2.3413	-4.4351

	PROPELLANT LEVEL SENSOR ACTUATION - TB2					S-IVB ENGINE START COMMAND				
1	135.9060	183485.3900	164814.9700	34.4913	72.3238	144.9000	215499.6200	213024.9800	32.3273	72.3924
2	6076.9759	7189.2799	135.190	28.5699	75.9673	6612.0122	7743.5226	1.933	27.1295	75.7191
3	182832.3	180545.1	16948582.000	152195.840	-318898.280	214406.6	211467.0	16943999.000	174388.970	-360788.570
4	772.9	58419.5	7504103.3	230.492	-736.345	844.9	61978.7	7566108.5	214.732	-[illegible]54.223
5	166099.8	347541.5	10067586.3	51425.025	-911.265	215029.3	408351.1	10095891.4	66533.978	-1147.848
6	3402.866	3337.195	-385.459	2393.4758	-4515.416	3478.812	3401.222	-632.733	2499.6213	-4799.635
7	7.933	398.633	6528.334	-1.0499	-12.510	8.825	394.189	7031.663	-2.0386	-13.716
8	5037.266	6355.311	2986.3100	1555.4667	-23.895	5622.854	6945.391	3180.8052	1736.8326	-28.847
9	37.846	.000	.0000	-80.0759	28.6689	-29.147	.000	.0000	-79.9327	28.7091
10	-.011	.000	.0000	465.4048	.0000	.236	.000	.0000	413.9254	.0000
11	115.711	6078.976	5.7493	.8404	19.4443	.282	6612.012	6.6311	.2206	6.7897
12	.4516	.0000	.0000	.0000	322.2781	.5837	-.0000	.0000	.0000	303.9239
13	247016.9	271854.8	960340.0	3965955.5	5045762.8	303658.5	329361.5	952206.8	3944778.0	5002822.4
14	72.2665	67.9258	322.6234	313.4308	258.6218	72.2250	68.7254	325.4273	314.0266	258.6064
15	47.7451	42.1755	9.7236	-2.7790	-4.8173	44.9167	40.5262	11.8100	-2.2660	-4.3690

	S-IB INBOARD ENGINE CUTOFF									
1	138.9700	194226.5300	180569.4300	33.6300	72.3410	145.0000	215853.7300	213578.2200	32.3065	72.3935
2	6444.9834	7562.6957	139.733	28.1234	75.7850	6610.4324	7742.1858	1.905	27.1106	75.7201
3	193441.9	190945.5	16947266.000	159628.120	-332881.980	214754.9	211807.8	16943937.000	174639.200	-361268.690
4	796.3	59636.5	7524610.5	226.132	-775.293	845.8	62018.1	7566811.4	214.523	-855.595
5	182075.5	367559.1	10076971.7	56357.807	-986.903	215591.5	409045.5	10096209.6	66707.622	-1150.735
6	3523.032	3451.995	-475.793	2458.0096	-4612.341	3475.767	3398.120	-635.262	2499.6374	-4802.791
7	8.005	396.410	6862.982	-1.6045	-12.914	8.858	394.183	7030.627	-2.0364	-13.724
8	5396.850	6717.215	3141.2546	1666.2618	-25.493	5622.868	6945.420	3179.3365	1736.8595	-28.907
9	40.945	.000	.0000	-80.0291	28.6821	-29.232	.000	.0000	-79.9311	28.7095
10	.098	.000	.0000	449.1932	.0000	.230	.000	.0000	413.3326	.0000
11	119.160	6444.983	6.2045	.5454	14.6973	.361	6610.432	6.6342	.2172	6.6902
12	.4948	-.0000	.0000	.0000	316.6129	.5852	-.0000	.0000	.0000	303.7060
13	265653.7	290799.0	957371.2	3959003.7	5031758.7	304302.6	330014.3	952129.9	3944536.7	5002328.4
14	72.2505	68.2263	323.5292	313.6247	258.6168	72.2247	68.7328	325.4600	314.0335	258.6062
15	46.7335	41.6101	10.4211	-2.6078	-4.6684	44.8884	40.5086	11.8332	-2.2603	-4.3640

1	140.0000	197917.8600	186098.2100	33.3912	72.3494	150.0000	233190.4800	241276.5800	31.2469	72.4341
2	6520.7192	7640.7117	78.105	27.9742	75.7518	6581.6431	7725.1789	20.638	26.1885	75.7383
3	197084.3	194513.6	16946761.000	162168.790	-337649.440	231786.8	228441.0	16940442.000	187148.580	-385676.740
4	804.1	60044.1	7531725.2	224.284	-788.664	891.4	63985.2	7601885.4	203.707	-925.922
5	187685.0	374529.1	10080227.9	58089.744	-1013.447	243759.2	443828.0	10111953.9	75411.136	-1302.936
6	3540.190	3467.681	-503.489	2472.7147	-4644.900	3349.049	3267.101	-764.120	2507.7461	-4960.412
7	8.169	395.926	6933.468	-1.7102	-13.051	9.022	392.200	7021.079	-2.4315	-14.410
8	5476.017	6796.979	3170.8060	1690.7439	-26.050	5665.847	6989.323	3130.3313	1751.1885	-32.015
9	7.448	.000	.0000	-80.0127	28.6867	-20.571	.000	.0000	-79.8488	28.7325
10	.262	.000	.0000	443.2486	.0000	-.131	.000	.0000	385.0064	.0000
11	67.356	6520.719	6.3194	.4685	13.0954	17.192	6581.643	6.8441	.0980	3.2124
12	.5099	-.0000	.0000	.0000	314.5099	.6611	-.0000	.0000	.0000	293.1094
13	272155.3	297403.0	956398.9	3956569.7	5026835.7	336369.4	362492.8	948747.4	3932505.0	4977550.6
14	72.2454	68.3215	323.8495	313.6929	258.6150	72.2095	69.0653	327.1131	314.3794	258.5972
15	46.3991	41.4165	10.6615	-2.5488	-4.6168	43.5576	39.6592	12.9690	-1.9789	-4.1153

TABLE AP 3-3 (Sheet 5 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	155.0000	250039.8800	269316.4100	30.2073	72.4561	175.0000	313320.7000	386088.7800	26.0673	72.7045
2	6615.4448	7769.7997	24.177	25.3255	75.7172	6815.8473	8010.6559	25.523	21.9162	75.7561
3	248289.7	244524.4	16936299.000	199729.810	-410872.300	309712.0	304006.5	16913188.000	250971.490	-519503.940
4	933.1	65936.9	7637086.5	189.227	-999.713	1098.4	73614.7	7780363.7	103.026	-1330.767
5	272312.0	479001.0	10127553.5	84238.615	-1471.310	391579.6	624800.0	10187133.1	121162.209	-2332.083
6	3254.659	3167.694	-893.483	2525.4720	-5117.776	2881.714	2774.282	-1425.125	2596.6032	-5744.757
7	7.349	388.135	7063.045	-3.4576	-15.109	16.506	386.682	7273.297	-3.0099	-18.030
8	5759.449	7084.039	3112.0562	1781.0823	-35.376	6176.668	7504.962	3039.5382	1914.2625	-51.395
9	-18.274	.000	.0000	-79.7654	28.7558	-18.987	.000	.0000	-79.4177	28.8521
10	-.459	.000	.0000	359.1973	.0000	1.250	.000	.0000	354.5049	.0000
11	19.948	6615.444	7.1223	.0427	1.5175	21.872	6815.847	7.3806	.0014	.0523
12	.7380	-.0000	.0000	.0000	283.1094	1.0579	-.0000	.0000	.0000	281.4788
13	368513.8	395010.0	946260.0	3920432.9	4952393.5	499256.7	527003.7	945609.8	3871280.6	4846844.6
14	72.1962	69.3395	328.8150	314.7321	258.5680	72.1606	70.0877	336.1535	316.2295	258.5487
15	42.3579	38.8542	14.0721	-1.7027	-3.8694	38.3414	35.9014	18.1288	-.6399	-2.9018

ULLAGE ROCKET JETTISON

1	155.5200	251768.7500	272257.7200	30.1002	72.4578	180.0000	328086.6500	416514.6000	25.0476	72.8040
2	6619.6561	7775.1017	24.344	25.2370	75.7143	6876.4692	8080.6237	25.661	21.0783	75.7977
3	249979.9	246167.2	16935831.000	201043.560	-413537.780	323883.7	317627.1	16905724.000	263997.070	-548618.180
4	936.8	66138.4	7640760.4	187.363	-1007.588	1196.9	75556.9	7816873.8	91.216	-1422.819
5	275309.3	482687.0	10129171.0	85165.526	-1489.801	422737.0	662600.5	10204278.7	130821.388	-2600.609
6	3245.140	3157.865	-906.958	2527.3989	-5134.127	2766.852	2673.937	-1561.100	2613.6150	-5900.915
7	7.112	387.643	7067.856	-3.5853	-15.182	22.850	390.123	7331.222	-1.7289	-18.792
8	5769.650	7094.353	3110.4774	1784.3371	-35.740	6286.395	7615.403	3018.7166	1949.3463	-56.059
9	-18.341	.000	.0000	-79.7566	28.7582	-18.963	.000	.0000	-79.3270	28.8769
10	-.458	.000	.0000	356.6216	.0000	1.250	.000	.0000	378.2763	.0000
11	20.162	6619.656	7.1525	.0391	1.4009	[illegible]	6876.469	7.2036	.0007	.0240
12	.7460	.0000	.0000	.0000	282.0920	[illegible]	-.0000	.0000	.0000	290.9595
13	371868.2	398401.5	946653.6	3919173.3	4949750.5	532549.0	560567.9	947829.5	3858711.0	4819131.0
14	72.1949	69.3652	328.9950	314.7693	258.5870	72.1621	70.2261	338.1142	316.6267	258.5376
15	42.2392	38.7725	14.1851	-1.6742	-3.8439	37.4577	35.2027	19.0343	-.3851	-2.6639

GUIDANCE INITIATION

1	159.4700	264753.5000	294759.6900	29.2937	72.4738	185.0000	342435.9900	447449.5200	24.0510	72.9025
2	6654.0044	7817.5601	24.762	24.5719	75.6951	6940.7840	8153.7700	26.030	20.2601	75.8395
3	262655.4	258490.2	16932047.000	211055.640	-434062.740	337582.1	330747.0	16897578.000	277107.840	-578512.650
4	962.4	67663.3	7668749.8	171.606	-1068.665	1327.0	77515.9	7853677.3	85.734	-1518.711
5	298251.9	510863.9	10141432.9	92262.351	-1636.563	454445.1	700955.3	10219321.4	140656.210	-2893.127
6	3173.735	3082.539	-1009.154	2542.2706	-5258.244	2692.680	2574.169	-1697.092	2630.7349	-6056.851
7	5.560	384.123	7105.763	-4.4868	-15.744	29.215	393.495	7390.061	-.4651	-19.567
8	5848.346	7173.888	3099.0320	1809.4497	-38.596	6397.117	7726.759	2998.4770	1984.7914	-60.993
9	-18.016	.000	.0000	-79.6897	28.7769	-18.763	.000	.0000	-79.2347	28.9019
10	-.486	.000	.0000	337.2118	.0000	1.264	.000	.0000	415.5032	.0000
11	20.478	6654.004	7.3938	.0197	.7550	22.327	6940.784	6.9206	.0003	.0116
12	.8077	-.0000	.0000	.0000	274.3034	1.2261	-.0000	.0000	.0000	305.6892
13	397420.2	424225.1	944810.0	3909576.9	4929503.4	566112.7	594391.2	951044.8	3846026.9	4790866.9
14	72.1848	69.5465	330.3821	315.0545	258.5797	72.1672	70.3523	340.1200	317.0336	258.5257
15	41.3686	38.1629	15.0313	-1.4594	-3.6510	36.6065	34.5153	19.8994	-.1345	-2.4274

1	160.0000	266476.6900	297799.3000	29.1869	72.4763	190.0000	356374.8200	478901.4000	23.0710	73.0024
2	6658.8301	7823.4468	24.745	24.4840	75.6929	7009.1351	8230.5186	26.267	19.4557	75.8833
3	264334.7	260121.0	16931509.000	212403.480	-436854.020	350810.3	343368.4	16888750.000	290304.150	-609136.260
4	965.2	67866.7	7672515.3	169.180	-1077.029	1469.4	79492.0	7890778.9	86.630	-1618.508
5	301352.7	514667.3	10143074.5	93221.768	-1657.124	486711.3	739871.2	10234264.0	150670.060	-3210.994
6	3164.272	3072.545	-1022.792	2544.2968	-5274.886	2598.530	2474.298	-1833.936	2647.7575	-6212.571
7	5.361	383.675	7110.940	-4.6001	-15.820	35.863	397.051	7450.289	.8588	-20.354
8	5858.957	7184.609	3097.5429	1812.8380	-38.992	6509.557	7839.748	2978.4778	2020.8175	-66.199
9	-17.979	.000	.0000	-79.6806	28.7794	-18.809	.000	.0000	-79.1407	28.9273
10	-.427	.000	.0000	334.5740	.0000	1.361	.000	.0000	451.2989	.0000
11	20.440	6658.830	7.4283	.0180	.6939	22.591	7009.135	6.6899	.0002	.0061
12	.8160	-.0000	.0000	.0000	273.2279	1.3123	-.0000	.0000	.0000	319.3471
13	400857.9	427698.0	944687.9	3908286.5	4926765.0	599964.9	628491.8	955281.1	3833232.7	4762042.8
14	72.1834	69.5690	330.5707	315.0932	258.5787	72.1753	70.4684	342.1673	317.4503	258.5131
15	41.2558	36.0826	15.1433	-1.4308	-3.6252	35.7831	33.8379	20.6910	.1119	-2.1923

STEERING MISALIGNMENT CORRECTION

1	165.0000	262512.5200	326743.6000	28.1740	72.5169	193.4750	365820.8200	501069.3200	22.4006	73.0727
2	6706.7187	7881.3058	24.962	23.6503	75.6853	7056.7824	8285.7470	26.508	18.9055	75.9151
3	279931.8	275246.9	16926073.000	225172.330	-463620.690	359726.6	351846.0	16882212.000	299525.610	-630962.750
4	990.2	69776.7	7708194.9	144.168	-1157.935	1522.4	80876.3	7916740.3	91.286	-1690.201
5	330819.3	550844.6	10158525.3	102366.364	-1861.658	509468.8	767251.7	10244589.9	157736.290	-3447.569
6	30 3.983	2977.174	-1152.681	2563.0393	-5431.748	2533.082	2404.802	-1929.446	2659.5241	-6320.671
7	5.361	381.090	7161.513	-5.1672	-16.544	40.662	399.644	7492.782	1.8182	-20.909
8	5960.761	7287.400	3082.0554	1845.3495	-42.865	6568.494	7919.018	2964.6373	2046.1313	-69.[illegible]
9	-18.373	.000	.0000	-79.5945	28.8033	-18.878	.000	.0000	-79.0744	28.9450
10	.394	.000	.0000	325.3700	.0000	1.360	.000	.0000	488.2296	.0000
11	20.952	6706.718	7.5868	.0074	.2962	22.886	7058.782	6.4640	.0001	.0040
12	.89	-.0000	.0000	.0000	269.4412	1.3730	.0000	.0000	.0000	332.8475
13	433424.7	460585.1	944055.4	3896061.1	4900646.0	623670.0	652363.7	958037.9	3824277.3	4741674.7
14	72.1714	69.7640	332.3798	315.4650	258.5692	72.1824	70.5440	343.6125	317.7459	258.5039
15	40.2302	37.3378	16.1794	-1.1429	-3.3824	35.2251	33.3724	21.2150	.2806	-2.0297

1	170.0000	298133.1500	356167.0800	27.1146	72.6089	195.0000	369904.1100	510878.5900	22.1085	73.1030
2	6759.1352	7944.0503	25.144	22.7777	75.7188	7081.2120	8310.5622	26.594	18.6657	75.9287
3	295064.3	289882.1	16919973.000	238030.490	-491171.050	363567.6	355490.1	16879237.000	303585.310	-640637.940
4	1030.8	71689.2	7744138.9	121.037	-1242.494	1686.0	81486.6	7928182.0	94.363	-1722.274
5	360968.8	587549.6	10173882.5	111677.931	-2086.208	519543.0	779355.0	10249106.4	160865.190	-3555.584
6	2977.887	2875.828	-1288.433	2579.8874	-5588.370	2504.295	2374.219	-1971.607	2664.6525	-6368.079
7	10.696	383.687	7216.619	-4.1511	-17.281	42.729	400.726	7511.631	2.2231	-21.155
8	6067.762	7395.293	3060.7694	1879.4949	-46.998	6623.462	7954.116	2958.6537	2057.3482	-71.683
9	-19.521	.000	.0000	-79.5069	28.8275	-18.887	.000	.0000	-79.0451	28.9529
10	1.115	.000	.0000	329.9916	.0000	1.343	.000	.0000	509.1691	.0000
11	21.719	6759.135	7.5914	.0031	.1239	22.964	7081.212	6.3429	.0001	.0033
12	.9760	-.0000	.0000	.0000	271.3836	1.3999	-.0000	.0000	.0000	340.2778
13	466221.5	493683.0	944360.3	3883731.3	4874014.1	634120.7	662886.2	960559.7	3820331.2	4732648.6
14	72.1635	69.9349	334.2412	315.8416	258.5593	72.1659	70.5760	344.2520	317.8772	258.4997
15	39.2632	36.6127	17.1761	-.8992	-3.1412	34.9835	33.1694	21.4360	.3539	-1.9585

TABLE AP 3-3 (Sheet 6 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	200.0000	383025.9500	543390.3000	21.1608	73.2096	230.0000	453167.6800	750184.0300	15.8200	73.9962
2	7157.0124	8393.9590	26.801	17.8875	75.9799	7686.5350	8961.8348	28.509	13.4847	76.4301
3	375852.6	367109.6	16869032.000	316950.250	-672866.640	439448.8	426056.2	16792985.000	398813.980	-882501.780
4	1918.0	83500.4	7965897.2	109.207	-1830.075	4417.4	96320.7	8199111.4	449.980	-2565.368
5	552948.7	819415.0	10263649.8	171244.490	-3928.288	765878.3	1072289.6	10349945.7	237539.220	-6835.040
6	2409.578	2273.529	-2110.341	2661.2988	-6523.383	1829.296	1654.573	-2964.271	2775.4427	-7451.210
7	50.419	405.124	7574.371	3.8114	-21.968	118.536	451.371	7980.025	1 4826	-27.136
8	6739.007	8070.038	2938.3562	2094.4376	-77.446	7464.745	8796.201	2801.21[illegible]	2328.1650	-118.104
9	-18.988	.000	.0000	-78.9478	28.9788	-19.311	.000	.0000	-78.3270	29.1392
10	1.739	.000	.0000	575.8243	.0000	2.395	.000	.0000	1230.4894	.0000
11	23.229	7157.012	6.0074	.0001	.0020	25.068	7686.535	4.3459	.0000	.0002
12	1.4690	-.0000	.0000	.0000	363.1280	2.0556	-.0000	.0000	.0000	539.0950
13	668596.2	697591.3	966701.5	3607326.3	4702673.0	883008.6	913218.9	1027964.7	3727148.2	4510006.9
14	72.1987	70.6762	346.3594	318.3145	258.4856	72.3304	71.1924	359.4484	321.1721	258.3780
15	34.2047	32.5087	22.1217	.5917	-1.7258	29.8461	28.6716	24.8952	1.9257	-.3519
1	205.0000	395739.2300	576445.1000	20.2237	73.3324	235.0000	463446.9700	786681.8300	15.0061	74.1271
2	7236.4327	8480.7008	27.163	17.1172	76.0453	776[illegible].4778	9067.8442	28.861	12.8106	76.5084
3	387661.6	378223.0	16858132.000	330397.470	-705871.380	448353.2	434070.1	16777802.000	412729.620	-920142.910
4	2193.5	85541.0	8003928.4	133.469	-1941.976	5040.8	98597.7	8239189.6	554.2[illegible]	-2703.319
5	586936.0	860058.2	10278487.4	181810.560	-4330.515	803517.5	1116585.7	10363696.5	249281.570	-7444.997
6	2313.730	2171.570	-2250.363	2697.4072	-6678.487	1732.461	1550.811	-3109.560	2790.7622	-7605.233
7	60.171	411.476	7638.948	5.9995	-22.795	130.852	459.552	8051.903	22.2542	-28.047
8	6856.310	8187.630	2916.2728	2132.1226	-83.492	7591.197	8922.422	2779.0860	2369.0223	-125.930
9	-19.274	.000	.0000	-78.8488	29.0049	-19.336	.000	.0000	-78.2171	29.1668
10	2.142	.000	.0000	650.4668	.0000	2.524	.000	.0000	1331.2291	.0000
11	23.716	7236.432	5.6963	.0001	.0012	25.445	7787.477	[illegible] 2238	.0000	.0002
12	1.5796	-.0000	.0000	.0000	387.2112	2.1556	-.0000	.0000	.0000	561.9668
13	703406.0	732622.1	974318.7	3794216.1	4672105.6	920155.6	950544.7	1042106.2	3713489.0	4475670.2
14	72.2140	70.7708	348.5144	318.7625	258.4706	72.3593	71.2689	1.6327	321.6901	258.3557
15	33.4439	31.8551	22.7459	.8252	-1.4942	29.1605	28.0506	25.1288	2.1323	-.1258
1	210.0000	408041.3900	61[illegible]053.7400	19.3005	73.4652	240.0000	473332.5800	823784.3500	14.2155	74.2587
2	7319.5004	8570.7687	27.309	16.3574	76.1203	7891.6287	9175.7216	29.082	12.1545	76.5883
3	398968.9	388824.0	16846527.000	343924.720	-739651.140	456773.7	441564.4	16761888.900	426721.480	-958553.720
4	2522.0	87617.3	8042289.4	169.867	-2058.045	5726.4	100916.6	8279632.0	672.617	-2845.867
5	621514.6	901293.9	10293011.1	192566.660	-4763.690	841792.3	1161515.7	10377736.8	261230.160	-8094.855
6	2217.050	2068.641	-2391.572	2713.3411	-6833.397	1635.625	1446.911	-3255.500	2805.9904	-7759.094
7	71.368	419.166	7705.115	8.5996	-23.635	143.402	467.961	8124.824	25.[illegible]997	-28.974
8	6975.291	8306.812	2893.0400	2170.3798	-89.826	7718.936	9049.845	2757.0262	2410.3406	-134.065
9	-19.406	.000	.0000	-78.7481	29.0313	-19.394	.000	.0000	-78.1052	29.1946
10	2.298	.000	.0000	777.1718	.0000	2.536	.000	.0000	1427.2255	.0000
11	23.967	7319.500	5.2575	.0000	.0008	25.681	7891.628	4.1250	.0000	.0002
12	1.6717	-.0000	.0000	.0000	424.3470	2.2573	-.0000	.0000	.0000	583.1157
13	738565.4	767994.6	982820.7	3780996.8	4640933.1	957752.1	986314.0	1057412.3	3699770.5	4440671.7
14	72.2324	70.8613	350.6815	319.2214	258.4544	72.3897	71.3434	3.8017	322.2209	258.3320
15	32.6987	31.2076	23.3066	1.0542	-1.2639	28.4846	27.4346	25.2987	2 3344	.0998
1	215.0000	419932.4600	644224.1300	18.3963	73.5987	24[illegible].0000	482826.8700	861498.8100	[illegible]3.4453	74.[illegible]891
2	7406.0206	8663.8939	27.578	15.6125	76.1968	7998.7182	9288.2163	29.301	11.5140	76.6682
3	409831.7	398909.1	16834215.000	357530.680	-774204.970	464709.0	448538.2	16745245.200	4407[illegible]9.090	-997733.450
4	2907.5	89732.9	8080981.4	219.518	-2178.348	6475.0	103277.4	8320438.8	805.231	-2993.087
5	656691.4	943129.7	10307418.0	203515.230	-5229.258	880708.7	1207085.8	10391466.9	273386.040	-8786.176
6	2120.024	1965.235	-2533.732	2728.9624	-6988.119	1538.364	1342.448	-3402.448	2820.9990	-7912.799
7	82.895	427.083	7772.253	11.2728	-24.489	156.022	476.332	8198.414	27.9383	-29.917
8	7095.616	8427.249	2869.7312	2209.1080	-96.450	7847.840	9178.340	2735.0199	2452 0814	-142.515
9	-19.402	.000	.0000	-78.[illegible]5	29.0580	-19.483	.000	.0000	-77.9914	29.2226
10	2.338	.000	.0000	898.3781	.0000	2.524	.000	.0000	1518.6138	.0000
11	24.178	7406.020	4.9353	.00[illegible]0	.0005	25.926	7998.718	4.0449	.0000	.0002
12	1.7653	-.0000	.0000	.0000	457.3883	2.3607	-.0000	.0000	.0000	602.7305
13	774089.0	803723.9	992421.0	3767672 3	46091[illegible]6.0	995813.3	1026542.0	1073891.3	3686005.7	4405003.0
14	72.2536	70.9483	352.8647	319.6915	258.4372	72.4212	71.4160	5.9490	322.7648	258.3068
15	31.9674	30.5656	23.8024	1.2788	-1.0345	27.8179	26.8237	25.4066	2.5318	.3249
1	220.0000	431415.0600	678963.9700	17.5135	73.7319	250.0000	491932.4600	899833.6600	12.6976	74.[illegible]182
2	7495.9733	8760.0514	27.798	14.8843	76.2741	8109.4242	9403.0106	29.749	10.8908	76.[illegible]79
3	420189.2	408476.5	16821188.000	371214.460	-809531.960	472157.5	454988.7	16727863.100	454931.330	-1037681.[illegible]10
4	3351.4	91888.5	8120013.5	282.704	-2302.955	7286.8	105680.0	8361618.4	952.033	-3[illegible]45.059
5	692473.0	985568.5	10321708.3	214658.540	-5728.681	920273.8	1253302.0	10405087.8	285752.010	-9520.541
6	2022.887	1861.589	-2676.66[illegible]	2744.4944	-7142.658	1441.067	1237.800	-3550.437	2835.9054	-806[illegible]
7	94.640	435.115	7840.356	13.9855	-25.357	168.716	484.662	8273.349	30.7694	-30.875
8	7217.242	8548.900	2846.5398	2248.2959	-103.368	79[illegible]8.573	9308.576	2713.4325	2494.4498	-151.284
9	-19.478	.000	.0000	-78.5412	29.0848	-19.429	.000	.0000	-77.875[illegible]	29.2509
10	2.340	.000	.0000	1014.2242	.0000	2.541	.000	.0000	1605.507	.0000
11	24.430	7495.973	4.6899	.0000	.0004	26.356	8109.424	3.9805	.00[illegible]	.0001
12	1.8605	-.0000	.0000	.0000	487.1691	2.4657	-.0000	.0000	.000	[illegible]20.9599
13	809993.2	839826.6	1003135.6	3754250.3	4576735.4	[illegible]034354.6	1065244.5	1091549.9	3672208.2	[illegible]55.5
14	72.2772	71.0323	355.0579	320.1732	258.4187	72.4536	71.4867	8.0691	323.3221	[illegible]8.2801
15	31.2489	29.9291	24.2326	1.4989	-.8061	27.1599	26.2177	25.4546	2.7246	.5497
1	225.0000	442491.5400	714281.1300	16.6537	73.8646	255.0000	500653.6700	938797.6300	11.9754	74.6478
2	7589.5502	8859.4380	28.215	14.1742	76.3520	8222.5005	9519.8698	29.816	10.2876	76.8290
3	430060.8	417525.0	16807447.000	384975.510	-84563[illegible].180	479120.0	460916.6	16709741.100	469148.140	-1078396.600
4	3854.3	94084.1	8159386.7	359.425	-2431.938	8162.6	108124.3	8403172.7	1113.029	-[illegible]301.861
5	728866.2	1028619.9	10335883.6	225999.030	-6263.441	960495.0	1300171.9	10418601.2	298330.830	-10299.554
6	1925.864	1757.920	-2820.305	2759.9458	-7297.020	1343.964	1133.215	-3698.578	2850.7857	-8219.757
7	106.578	443.234	7909.649	16.7290	-26.239	181.671	493.151	8348.788	33.6536	-31.849
8	7340.365	8671.962	2823.6493	2288.0050	-110.585	8109.887	9439.310	2691.8776	2537.0687	-160.376
9	-19.335	.000	.0000	-78.4350	29.1119	-19.363	.000	.0000	-77.7578	29.2793
10	2.415	.000	.0000	1124.8716	.0000	2.635	.000	.0000	3336.5311	.0000
11	24.799	7589.550	4.4983	.0000	.0003	26.368	8222.500	1.9771	.0000	.0002
12	1.9573	-.0000	.0000	.0000	514.2654	2.5725	-.0000	.0001	.0000	1267.6482
13	846293.[illegible]	876318.8	1014978.8	3740738.9	4543691.9	[illegible]073393.2	1104438.7	1110[illegible]94.7	3658392.5	433[illegible]19.7
14	72.3029	71.1136	357.2547	320.6666	258.3990	72.4868	71.5559	10.1568	323.8931	258.2518
15	30.5420	29.2977	24.5967	1.7146	-.5786	26.5104	25.6168	25.4452	2.9127	.7743

TABLE AP 3-3 (Sheet 7 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	260.0000	508595.6700	978397.3300	11.2774	74.7772	290.0000	551348.3500	1229970.9000	7.5493	75.5407
2	8339.8028	9640.6670	30.418	9.7035	76.9107	9110.6331	10427.3492	32.462	6.5365	77.4073
3	485598.0	466321.6	16690875.300	483439.280	-1119878.500	514297.8	487740.3	16561803.400	570727.500	-1384832.500
4	9103.9	110611.6	8445110.4	1288.619	-3463.575	16176.7	126450.0	8705165.5	2654.422	-4541.768
5	1001377.7	1347700.1	10432008.1	311124.380	-11124.844	1261112.9	1647219.2	10510321.6	392584.450	-17142.256
6	1247.225	1028.829	-3847.754	2865.6834	-8373.020	664.804	397.243	-4764.011	2952.6261	-9289.851
7	194.851	501.745	8426.333	36.5752	-32.840	276.508	553.404	8917.408	54.2451	-39.146
8	8243.711	9572.473	2670.9888	2580.5279	-165.795	9082.137	10405.075	2552.1904	2853.7064	-233.442
9	-19.341	.000	.0000	-77.6380	29.3080	-19.392	.000	.0000	-76.8743	29.4851
10	2.637	.000	.0000	1727.7461	.0000	2.071	.000	.0000	1958.2210	.0000
11	26.973	8339.802	3.9361	.0000	.0002	28.980	9110.633	4.0136	.0000	.0001
12	2.6810	-.0000	.0000	.0000	645.8025	3.3704	-.0000	.0000	.0000	691.8812
13	1112944.5	1144135.9	1130429.2	3644574.5	4293889.9	1362046.1	1394033.8	1275817.1	3562585.6	4052327.4
14	72.5208	71.6235	12.2071	324.4783	258.2218	72.7348	72.0022	23.5392	328.3054	258.0024
15	25.8692	25.0210	25.3813	3.0961	.9988	22.1846	21.5563	24.0334	4.0938	2.3536

1	265.0000	516964.8500	1018646.8800	10.6033	74.9059	295.0000	557161.3200	1274320.4000	7.0077	75.6361
2	8460.5739	9764.6596	30.7?5	9.1380	76.9926	9249.2150	10567.6784	32.743	6.0950	77.4652
3	491592.8	471205.1	16671261.500	497804.940	-1162126.400	5?7380.0	489468.9	16537590.300	585526.410	-1431602.700
4	10111.4	113141.9	8487440.0	1478.827	-3630.285	17562.2	129228.5	8749962.4	2929.373	-4740.277
5	1042934.7	1395899.1	10445311.8	324437.040	-11998.056	1306886.2	1699603.8	10523046.4	406971.450	-18338.917
6	1150.666	924.467	-3997.791	2880.5463	-8526.145	568.141	291.858	-4920.815	2966.9522	-9442.237
7	208.166	510.358	8505.335	39.5074	-33.847	285.681	5?7.162	9001.159	55.7283	-40.261
8	8379.376	9707.394	2650.5735	2624.6238	-179.546	9227.328	10540.945	2537.7728	2901.1653	-245.283
9	-19.277	.000	.0000	-77.5161	29.3370	-19.286	.000	.0000	-76.7392	29.5155
10	2.694	.000	.0000	1784.1814	.0000	2.067	.000	.0000	1983.8831	.0000
11	27.242	8460.573	3.9248	.0000	.0001	29.208	9249.215	4.0447	.0000	.0001
12	2.7913	-.0000	.0000	.0000	657.0409	3.4919	-.0000	.0000	.0000	697.0076
13	1153030.1	1184370.2	1151660.2	3630769.3	4255452.2	1405682.2	1437785.3	1304265.3	3549283.1	4009449.1
14	72.5554	71.6897	14.2164	325.0779	258.1901	72.7707	72.0605	25.2452	328.9993	257.9587
15	25.2360	24.4304	25.2659	3.2747	1.2234	21.5962	20.9975	23.6792	4.2472	2.5822

1	270.0000	524565.7900	1059554.3000	9.9520	75.0352	300.0000	562634.8800	1319387.0000	6.4864	75.7558
2	8584.0046	9891.0645	31.064	8.5903	77.0750	9391.4795	10711.6452	33.240	5.6496	77.5450
3	497104.9	475566.4	16650897.000	512244.670	-1205139.600	519979.3	490664.8	16512594.700	600396.910	-1479254.600
4	11186.1	115715.6	8530164.9	1683.826	-3802.074	19041.3	132031.3	8795184.0	3214.052	-4944.406
5	1085172.7	1444775.3	10458513.6	337371.190	-12920.862	1353390.7	1752713.1	10535694.1	421597.640	-19595.696
6	1054.070	819.922	-4148.441	2895.3131	-8679.136	471.391	186.184	-5077.920	2991.1567	-9594.514
7	221.768	519.146	8535.199	42.4582	-34.871	296.857	564.791	9088.489	58.3989	-41.394
8	8510.155	9843.343	2630.2039	2669.1356	-189.633	9374.879	10695.126	2520.6100	2949.4420	-257.490
9	-19.395	.000	.0000	-77.3921	29.3662	-19.473	.000	.0000	-76.6019	29.5461
10	2.717	.000	.0000	1837.7391	.0000	3.094	.000	.0000	2000.4543	.0000
11	27.609	8584.004	3.9192	.0000	.0001	29.677	9391.479	4.0863	.0000	.0001
12	2.9034	-.0000	.0000	.0000	667.5834	3.6154	-.0000	.0000	.0000	700.518?
13	1193663.9	1225145.5	1174089.7	3616994.7	4216299.0	1449968.0	1482182.0	1333926.8	3536161.0	3965800.0
14	72.5905	71.7546	16.1808	325.6923	258.1566	72.8060	72.1172	26.8956	329.7102	257.9127
15	24.6108	23.8451	25.1024	3.4485	1.4484	21.0151	20.4443	23.2969	4.3852	2.0122

1	275.0000	531801.1100	1101129.9000	9.3203	75.1639	305.0000	567771.3400	1365183.9000	5.9807	75.8941
2	8711.2980	10021.1005	31.460	8.0577	77.1596	9536.9978	10858.8107	33.701	5.2161	77.6417
3	502133.1	479403.7	16629774.600	526757.780	-1248917.400	522092.4	491329.0	16486810.100	615337.330	-1527607.500
4	12329.2	118333.3	8573295.1	1903.816	-3979.028	20576.2	134881.7	8840851.5	3514.984	-5154.249
5	1128100.8	1494336.8	10471614.7	330829.870	-13894.956	1400638.0	1806558.0	10545248.0	436465.950	-20914.437
6	957.142	714.876	-4300.668	2909.8874	-8831.998	373.762	79.436	-5235.533	2995.0015	-9746.585
7	235.514	527.951	8666.807	45.4997	-35.913	315.244	575.497	9178.472	62.0133	-42.546
8	8655.352	9981.618	2610.2112	2714.4606	-200.061	[illegible]	10843.260	2500.8932	2998.4271	-270.068
9	-19.412	.000	.0000	-77.2659	29.3953	19.544	.000	.0000	-76.4622	29.5769
10	2.?00	.000	.0000	1871.1771	.0000	3.2?4	.000	.0000	2015.1088	.0000
11	27.996	8711.298	3.9374	.0000	.0001	30.125	9536.997	4.1311	.0000	.0001
12	3.0173	-.0000	.0000	.0000	674.3557	3.7409	-.0000	.0000	.0000	703.6545
13	1234868.7	1266482.7	1197719.4	3603269.0	4176420.0	1494921.6	1527242.0	1364787.2	3523225.0	3921368.8
14	72.6261	71.8182	18.0974	326.3219	258.1212	72.8416	72.1732	28.4914	330.4383	257.8642
15	23.9932	23.2651	24.8941	3.6174	1.6737	20.4411	19.8966	22.8897	4.5228	3.0457

1	280.0000	538674.2900	1143385.1000	8.7085	75.2924	310.0000	572573.8400	1411723.5000	5.4955	76.0254
2	8841.3134	10153.6416	31.701	7.5405	77.2439	9685.7493	11009.0205	34.256	4.7992	77.7329
3	506675.7	482714.1	16607888.800	541343.130	-1293459.300	523717.1	491459.0	16460233.200	630346.780	-1576721.100
4	13541.5	120995.2	8616833.8	2138.857	-4161.235	22191.7	137783.9	8886969.8	3833.479	-5369.903
5	1171728.3	1544593.2	10484616.0	364516.480	-14922.055	1448638.4	1861140.6	10560705.7	451583.010	-22297.007
6	859.784	609.247	-4453.969	2924.2459	-8984.736	27?.121	-27.497	-5395.443	3008.7586	-9898.753
7	249.434	536.813	8749.248	48.5237	-36.973	330.681	585.121	9269.559	65.3039	-43.?18
8	8795.873	10121.122	2590.2269	2760.2654	-210.836	9676.164	10993.427	2482.5442	3048.1465	-283.023
9	-19.505	.000	.0000	-77.1376	29.4252	-19.478	.000	.0000	-76.3202	29.6080
10	2.812	.000	.0000	1901.9146	.0000	2.993	.000	.0000	2028.7593	.0000
11	28.244	8841.313	3.9597	.0000	.0001	30.658	9685.749	4.1762	.0000	.0001
12	3.1331	-.0000	.0000	.0000	680.5690	3.8684	-.0000	.0000	.0000	706.5746
13	1276655.9	1308399.4	1222550.7	3589611.2	4135804.3	1540560.0	1572982.4	1396843.6	3510498.6	3876144.5
14	72.6620	71.8800	19.9639	326.9671	258.0837	72.8776	72.2285	30.0329	331.1840	25?.8129
15	23.3831	22.6903	24.6442	3.7813	1.8996	19.8740	19.3545	22.4606	4.6549	3.2769

1	285.0000	545189.0700	1186328.6000	8.1169	75.4220	315.0000	577049.4000	1459018.0000	5.0312	76.15??
2	8974.5744	10289.2272	32.113	7.0390	77.3300	9837.9041	11162.4762	34.562	4.3990	77.[illegible]
3	510730.6	485495.?	16585233.100	555999.910	-1338764.500	524854.0	491054.2	16432853.600	645424.890	-1626594.[illegible]
4	14824.3	123702.0	8660790.0	2389.232	-4348.785	23882.5	140732.2	8933549.9	4167.800	-5591.466
5	1216062.7	1595551.1	10497517.1	378433.650	-16003.895	1497403.8	1916496.2	10573075.1	466949.820	-23745.301
6	762.145	503.171	-4608.455	2938.4314	-91??.352	178.548	-134.547	-5556.312	3022.4499	-10050.?22
7	263.736	545.933	8833.116	51.6318	-38.050	345.811	594.303	9362.238	68.4659	-44.9?0
8	8938.264	10262.407	2570.2971	2806.7200	-221.961	9830.203	11145.833	2465.1162	3098.6640	296.359
9	-19.524	.000	.0000	-77.0071	29.4550	-19.569	.000	.0000	-76.1757	29.6392
10	2.854	.000	.0000	1930.9147	.0000	3.103	.000	.0000	2041.4345	.0000
11	28.645	8974.574	3.9852	.0000	.0001	30.953	9837.903	4.2276	.0000	.0001
12	3.2508	-.0000	.0000	.0000	686.4067	3.9980	-.0000	.0000	.0000	709.2852
13	1319042.7	1350910.7	1248582.8	3576042.1	4094443.4	1586902.6	1619422.7	1430101.7	3498017.2	3830115.5
14	72.6985	71.9420	21.7783	327.6281	258.0442	72.9137	72.2831	31.5206	331.9477	257.7587
15	22.7803	22.1207	24.3562	3.9402	2.1252	19.3138	18.81?8	22.0123	4.7613	3.5122

TABLE AP 3-3 (Sheet 8 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	320.0000	581202.5500	1507282.3000	4.5636	76.2877	350.0000	599569.0200	1812291.5000	2.2675	77.0933
2	9993.2073	11319.0026	35.033	4.0121	77.9173	10989.7945	12320.1250	37.785	1.9904	78.5039
3	525501.6	490112.2	16404667.800	660570.790	-1677225.100	518963.4	472997.9	16218177.500	752806.670	-1996953.500
4	25652.1	143729.2	8980595.6	4518.836	-5819.038	38021.9	162791.7	9273132.0	6994.517	-7316.516
5	1546944.2	1972610.5	10585355.5	482570.940	61.242	1661056.3	2325963.2	10657163.8	581844.640	-35888.699
6	60.376	-242.356	-5718.562	3035.8685	302.595	-515.760	-900.585	-6721.873	3112.4323	-11111.977
7	362.115	604.520	9456.819	71.9494	-46.122	463.904	666.886	10655.341	93.3111	-53.840
8	9966.461	11300.310	2447.0044	3149.9323	-310.082	10967.475	12269.055	2343.5139	3472.8803	-400.878
9	-19.744	.000	.0000	-76.0287	29.6707	-19.925	.000	.0000	-75.0923	29.8638
10	3.279	.000	.0000	2053.1552	.0000	3.519	.000	.0000	2104.5872	.0000
11	31.437	9993.287	4.2793	.0000	.0001	34.067	10989.394	4.6343	.0030	.0001
12	4.1297	-.0000	.0000	.0000	711.7910	4.9661	-.0000	.0000	.0000	722.7807
13	1633966.3	1565579.9	1464559.9	3485809.3	3783271.8	1932438.8	1965531.1	1696516.5	3420195.5	3484517.8
14	72.9499	72.3370	32.9555	332.7296	257.7014	73.1703	72.6480	40.5248	337.8202	257.2820
15	18.7604	16.2868	21.5476	4.9020	3.7497	15.5786	15.2169	18.534[illegible]	5.4954	5.2390

1	325.0000	585036.1900	1555427.1000	4.1517	76.4215	355.0000	601622.6000	1866082.9000	1.9443	77.2277
2	10151.9193	11478.7789	35.500	3.6377	78.0129	11166.0279	12497.2717	38.335	1.7053	78.6042
3	525656.5	488628.4	16375665.100	675782.930	-1728620.500	516155.2	468217.9	16184539.700	768399.630	-2052891.500
4	27503.9	146777.4	9028120.0	4867.306	-6052.722	40365.5	166152.3	9323670.3	7470.081	-7589.119
5	1597271.2	2029502.6	10597545.4	498450.340	-26846.780	1916320.4	2387729.4	10668861.4	599349.900	-37934.404
6	-16.546	-351.173	-5882.638	3048.9757	-10354.374	-615.595	-1011.468	-6693.730	3124.7451	-11263.256
7	376.562	614.757	9552.846	75.4453	-47.355	481.512	677.346	10160.730	96.9452	-55.205
8	10144.841	11456.926	2429.0129	3201.9713	-324.199	11138.643	12437.644	2327.6354	3529.3862	-417.476
9	-19.776	.000	.0000	-75.8792	29.7024	-20.000	.000	.0000	-74.9268	29.8967
10	3.261	.000	.0000	2063.9420	.0000	3.548	.000	.0000	2110.2285	.0000
11	31.883	1015 .919	4.3332	.0000	.0001	34.534	11166.027	4.7009	.0000	.0001
12	4.2636	-.0000	.0000	.0000	714.0965	5.1135	-.0000	.0000	.0000	723.9857
13	1661768.7	1714471.8	1500217.3	3473904.6	3735601.6	1985026.7	2018185.9	39393.6	3410893.5	3431686.8
14	72.9864	72.3903	34.3386	333.5301	257.6409	73.2072	72.6979	41.6267	338.7373	257.1971
15	18.2137	17.7612	21.0686	5.0166	3.9898	15.0715	14.7250	18.0118	5.5712	5.5013

1	330.0000	588554.3500	1605565.5000	3.7378	76.5541	360.0000	603379.4200	1920745.9000	1.6363	77.3643
2	10313.2583	11641.0823	35.887	3.2778	78.1082	11346.3245	12678.0118	38.929	1.4328	78.7070
3	525316.1	486600.0	16345838.900	691060.300	-1780771.400	512826.6	462882.0	16149237.200	784053.650	-2109585.700
4	29437.7	149876.2	9076127.5	5273.133	-6292.520	42838.2	169566.1	9374743.0	7963.971	-7868.604
5	1648395.[illegible]	2087182.1	10609646.3	514591.550	-28503.892	1972447.5	2453346.2	1066[illegible]460.2	617140.100	-40064.183
6	-117.770	-460.440	-6047.993	3061.9062	-10506.064	-715.979	-1123.125	-7667.485	3136.7989	-11414.460
7	395.003	624.812	9649.966	78.8923	-49.609	499.659	688.[illegible]43	10268.331	100.6599	-56.593
8	10305.018	11615.181	2411.3845	3254.6317	-338.713	11312.683	12609.409	2311.7748	3566.8707	-434.509
9	-19.897	.000	.0000	-75.7271	29.7343	-20.099	[illegible]	.0000	-74.7585	29.9298
10	3.358	.000	.0000	2073.8699	.0000	3.663	.00	.0000	2115.0957	.0000
11	32.262	10313.258	4.3891	.0000	.0001	35.101	11346.3[illegible]	4.7700	.0000	.0001
12	4.3996	-.0000	.0000	.0000	716.2053	5.2633	-.0000	.0000	.0000	725.0253
13	1730326.4	1763114.9	1537074.7	34623[illegible].9	3687094.6	2038473.7	2071696.4	1783[illegible]83.8	3402172.2	3377951.3
14	73.0230	72.4429	35.6713	334.3494	257.5770	73.2441	72.7473	42.6871	339.5744	257.1672
15	17.6736	17.2412	20.5777	5.1252	4.2327	14.5707	14.2388	17.4876	5.6399	5.7688

1	335.0000	591761.9200	1656007.4000	3.3425	76.6887	365.0000	604865.8200	1976296.2000	1.3458	77.5015
2	10477.0902	11805.7820	36.283	2.9331	78.2060	11530.2224	12862.3100	39.767	1.1751	78.8110
3	524478.8	484024.2	16315184.200	706401.910	-1 33680.600	508995.8	456986.8	16113463.000	799767.550	-2167035.700
4	31455.0	153026.4	9124621.5	5676.513	-6538.840	45382.5	173034.8	9426356..	8476.728	-8155.087
5	1700323.6	2145656.4	10621658.9	530997.480	-30234.589	2029451.3	2513827.4	10691980.3	635220.020	-42280.229
6	-217.145	-570.041	-6214.237	3074.7082	-10657.667	-816.421	-1235.069	-7242.847	3148.7425	-11565.590
7	411.938	635.249	9748.339	82.4619	[illegible]	518.064	699.266	10378.179	104.4479	-58.005
8	10466.737	11774.890	2393.6723	3307.8583	-353.633	11489.607	12783.767	2296.4361	3645.3415	-451.984
9	-19.883	.000	.0000	-75.5724	29.7664	-20.124	.000	.0009	-74.5872	29.9630
10	3.384	.000	.0000	2082.7635	.0000	3.716	.000	.0000	2119.2087	.0000
11	32.616	10477.090	4.4469	.0000	.0001	35.904	11530.222	4.8414	.0000	.0001
12	4.5376	-.0000	.0000	.0000	718.1227	5.4155	-.0000	.0000	.0000	725.9038
13	1779653.7	1812523.8	1575130.6	3451145.3	3637743.1	2092799.2	2120082.2	1828791.9	3394075.5	3323330.0
14	73.0597	72.4950	36 9547	335.1879	257.5094	73.2610	72.7962	43.7077	340.6317	257.0119
15	17.1400	16.7267	20.0770	5.2275	4.4787	14.0762	13.7583	16.9629	5.7015	6.0420

1	340.0000	594605.2200	1707266.2000	2.9662	76.8231	370.0000	606090.0800	2032752.5000	1.0705	77.6384
2	10645.0427	11974.5001	36.872	2.6040	78.3049	11717.8678	13050.3042	40.071	.9301	78.9152
3	523144.5	480899.2	16283693.200	721807.130	-1887347.700	504662.0	453530.5	16076805.300	815540.710	-2225241.300
4	33557.2	156228.6	9173615.2	6097.730	-6791.489	48019.5	176558.8	9478528.5	9008.496	-8443.689
5	1753068.4	2204936.8	10633584.6	547672.130	-32040.905	2087348.7	2578188.9	10703425.4	653595.250	-44584.770
6	-316.558	-679.900	-6382.274	3087.4069	-10809.185	-917.356	-1347.740	-7420.316	3160.4429	-11716.648
7	429.026	645.683	9849.193	86.0375	-51.180	536.596	710.196	10490.167	108.2188	-59.441
8	10631.662	11937.735	2376.6907	3362.1661	-368.963	11669.594	12961.084	2281.6210	3704.8507	-469.907
9	-19.876	.000	.0000	-75.4151	29.7987	-20.392	.000	.0009	-74.4130	29.9964
10	3.461	.000	.0000	2090.8886	.0000	3.593	.000	.0000	2122.5922	.0000
11	33.166	10645.042	4.5073	.0000	.0001	36.222	11717.887	4.9153	.0000	.0001
12	4.6783	-.0000	.0000	.0000	719.8543	5.5702	-.0000	.0000	.0000	726.6265
13	1629769.1	1862716.[illegible]	1614387.5	3440364.2	3587537.0	2148025.6	2181365.4	1875326.6	3386654.7	3267779.2
14	73.0965	72.5466	38.1904	336.0457	257.4378	73.3170	72.8445	44.6903	341.6092	256.9107
15	16.6131	16.2178	19.5683	5.3234	4.7281	13.5882	13.2835	16.4386	5.7557	6.3215

1	345.0000	597272.0500	1759356.9000	2.6079	76.9584	375.0000	607056.0100	2090130.2000	.8080	77.7762
2	10815.6252	12145.7626	37.354	2.2897	78.4039	11909.3275	13242.0230	40.893	.6958	79.0203
3	521312.9	477224.2	16251360.200	737275.580	-1941772.100	499820.3	443506.8	16039255.400	831371.100	-2284201.900
4	35745.8	159483.6	9223114.8	6537.005	-7050.677	50748.8	180136.8	9531261.6	9558.928	-8749.533
5	1806642.6	2255035.6	10645425.8	564619.970	-33924.909	2146152.6	2643443.3	10714796.6	672270.330	-46980.061
6	-416.112	-790.002	-6551.363	3099.9770	-10960.621	-1019.234	-1461.594	-7600.168	3171.7613	-11867.635
7	446.463	656.326	9951.403	89.6836	-52.499	555.458	721.308	10604.238	112.0512	-60.901
8	10798.392	12102.255	2359.8295	3417.1112	-384.709	11852.625	13141.334	2266.8897	3765.3928	-488.286
9	-19.679	.000	.0000	-75.2551	29.8312	-20.274	.000	.0000	-74.2359	30.0300
10	3.533	.000	.0000	2098.1476	.0000	3.963	.000	.0000	2125.2601	.0000
11	33.605	10815.625	4.5697	.0000	.0001	36.949	11909.327	4.9917	.0000	.0001
12	4.0210	-.0000	.0000	.0000	721.4050	5.7275	-.0000	.0000	.0000	727.1963
13	1680691.9	1913713.3	1654848.8	3430033.8	3536464.9	2204170.2	2237563.9	1923093.1	3379958.1	3211298.3
14	73.1334	72.5970	39.3799	336.9231	257.3621	73.3545	72.8924	45.6362	342.6070	256.8032
15	16.0927	15.7145	19.0535	5.4127	4.9814	13.1065	12.8143	15.9156	5.8024	6.6079

TABLE AP 3-3 (Sheet 9 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	380.0000	607771.6600	2148447.7000	.5599	77.9150	410.0000	607162.7100	2519030.8000	-.6382	78.7683
2	12104.4309	13437.3617	41.503	.4739	79.1285	13349.6197	146[illegible]3.1785	45.284	-.6090	79.8017
3	494468.7	435913.3	16000800.900	847257.850	-2343917.300	451450.2	378102.3	15750498.600	943669.860	-2718040.700
4	53574.6	183772.2	9584574.0	10129.113	-9057.743	72618.4	206801.3	9917106.1	13970.413	-11068.940
5	2205879.4	2709606.5	10726094.5	691250.750	-49465.398	2584426.4	3126444.6	10792405.6	811822.260	-66485.233
6	-1121.687	-1576.265	-7782.051	3182.8094	-12018.553	-1749.117	-2282.244	-8917.152	3243.2014	-12922.669
7	574.776	732.705	10720.518	115.9777	-62.387	696.520	803.200	11461.620	140.3504	-71.854
8	12038.634	13324.461	2252.3113	3826.9523	-5[illegible].126	13216.194	14482.472	2170.5852	4217.4501	-630.276
9	-20.574	.000	.0000	-74.0556	30.0638	-21.254	.000	.0000	-72.9068	30.2697
10	3.856	.000	.0000	2127.2343	.0000	4.237	.000	.0000	2125.5549	.0000
11	37.579	12104.430	5.0706	.0000	.0001	41.103	13349.619	5.5949	.0000	.0001
12	5.8673	-.0000	.0000	.0000	727.6180	6.9028	-.0000	.0000	.0000	727.2593
13	2261254.8	2294699.1	1972099.4	3374036.0	3153874.5	2624564.8	2658254.4	2292610.0	3357899.3	2788978.3
14	73.3912	72.9398	46.5471	343.6251	256.6889	73.6094	73.2150	51.3574	350.1500	255.8254
15	12.6309	12.3508	15.3947	5.8413	6.9019	9.9047	9.6849	12.3471	5.9022	8.8724

1	385.0000	608241.1000	2207722.7000	.3248	78.0558	415.0000	606323.2000	2584404.4000	-.7889	78.9132
2	12303.3372	13636.4596	42.058	.2628	79.2374	13570.1783	149[illegible]434	46.131	-.7468	79.9184
3	488602.4	427743.0	15961431.600	863198.730	-2404387.100	442439.2	36639[illegible]	15705421.900	959909.000	-2783030.100
4	56497.3	187464.3	9638470.7	10718.858	-9373.445	76154.0	210847.4	9974792.5	14682.603	-11432.386
5	2266544.2	2776693.0	10737320.2	710541.530	-52052.107	2651023.7	3199364.3	10803227.7	833081.050	-69692.093
6	-1225.016	-1692.060	-7966.323	3193.4945	-12169.404	-1855.372	-2402.519	-9113.789	3252.4013	-13073.127
7	594.394	744.223	10938.936	119.9491	-63.898	717.748	815.227	11593.177	144.5266	-73.529
8	12227.761	13510.593	2237.9108	3889.5711	-526.436	13423.568	14686.215	2158.4006	4286.3416	-652.555
9	-20.710	.000	.0000	-73.8723	30.0977	-21.300	.000	.0000	-72.7035	30.3044
10	3.973	.000	.0000	2128.5293	.0000	4.277	.000	.0000	2123.2366	.0000
11	38.098	12303.337	5.1519	.0000	.0001	41.892	13570.178	5.6912	.0000	.0001
12	6.0497	-.0000	.0000	.0000	727.8946	7.0019	-.0000	.0000	.0000	726.7641
13	2319298.7	2352790.8	2022353.3	3368942.3	3095496.0	2688768.9	2722490.3	2250530.1	3358999.7	2724691.3
14	73.4278	72.9868	47.4246	344.6634	256.5673	73.6454	73.2594	52.0620	351.3039	255.6443
15	12.1615	11.8927	14.8765	5.8723	7.2042	9.4711	9.2598	11.8566	5.8822	9.2453

1	390.0000	608471.0800	2267971.4000	.1035	78.1965	420.0000	605297.2200	2650860.0000	-.9271	79.0603
2	12505.2150	13838.4885	42.528	.0636	79.3475	13794.5927	15128.4489	46.861	-.8735	80.0376
3	482217.9	418991.8	15921135.400	879192.400	-2465611.000	432895.2	354075.2	15659356.900	976193.200	-2848771.700
4	59518.8	191214.4	9692965.7	11328.622	-9696.769	79797.0	214954.4	10033041.7	15415.944	-11804.275
5	2328160.7	2844716.0	10748474.2	730147.780	-54733.551	2718667.5	3273311.9	10813989.5	854687.520	-73011.349
6	-1328.945	-1808.688	-8152.383	3203.9051	-12320.188	-1962.373	-2523.831	-9312.915	3261.2654	-13223.521
7	614.217	755.779	10958.909	123.9400	-65.436	739.567	827.651	11727.440	148.8325	-75.232
8	12419.221	13698.950	2223.6846	3953.0132	-546.222	13634.559	14893.464	2140.3414	4356.4608	-675.356
9	-20.843	.000	.0000	-73.6857	30.1318	-21.476	.000	.0000	-72.4967	30.3394
10	3.990	.000	.0000	2129.1649	.0000	4.438	.000	.0000	2120.4026	.0000
11	38.534	12505.214	5.2355	.0000	.0001	42.569	13794.892	5.7903	.0000	.0001
12	6.2148	-.0000	.0000	.0000	728.0383	7.2640	-.0000	.0000	.0000	726.1589
13	2378320.5	2411857.5	2073861.7	3364732.2	3036153.5	2754373.1	2787823.8	2409767.5	3361350.9	2659392.4
14	73.4644	73.0333	48.2699	345.7217	256.4379	73.6812	73.3333	52.7921	352.4755	255.4493
15	11.6981	11.4401	14.3618	5.8951	7.5157	9.0435	8.8401	11.3720	5.8536	9.6347

1	395.0000	608470.0300	2329208.1000	-.1036	78.3380	425.0000	604094.6300	2718417.7000	-1.0524	79.2089
2	12710.5974	14043.9066	43.226	-.1234	79.4589	14023.7650	15357.2975	47.653	-.9888	80.1588
3	475312.4	409655.1	15879903.400	895237.360	-2527588.600	422814.6	341151.4	15612289.200	992521.180	-2915265.000
4	62639.9	195022.3	9748065.0	11958.357	-10027.846	83550.4	219124.2	10092020.8	16171.043	-12184.754
5	2390741.1	2913687.2	10759557.6	750073.430	-57515.130	2787375.0	3348304.5	10824691.7	876647.610	-76446.530
6	-1433.370	-1926.062	-8340.421	3214.0685	-12470.406	-2070.012	-2646.074	-9514.522	3269.8256	-13373.848
7	634.331	767.449	11080.970	127.9736	-67.000	761.816	840.299	11864.397	153.2157	-76.964
8	12613.578	13890.101	2209.7655	4017.4540	-566.492	13849.212	15104.265	2134.6138	4427.8240	-698.686
9	-20.936	.000	.0300	-73.4960	30.1641	-21.565	.000	.0000	-72.2363	30.3744
10	4.082	.000	.0000	2129.1609	.0030	4.472	.000	.0000	2117.0757	.0000
11	39.166	12710.597	5.3215	.0000	.0001	43.303	14023.764	5.8921	.0000	.0001
12	6.3826	-.0000	.0000	.0000	728.0295	7.4492	-.0000	.0000	.0000	725.4482
13	2438337.2	2471916.4	2126631.2	3361463.2	2975839.5	2820498.5	2854276.4	2470334.6	3365617.0	2593076.6
14	73.5008	73.0794	49.0846	346.7999	256.2996	73.7168	73.3469	53.3969	353.6642	255.2401
15	11.2408	10.9931	13.8509	5.9097	7.8371	8.6216	8.4258	10.8935	5.8155	10.0424

1	400.0000	608245.1300	2391450.9000	-.2955	78.4809	430.0000	602725.0700	2787099.3000	-1.1658	79.3577
2	12919.5708	14253.0453	43.890	-.2972	79.5721	14257.2464	15590.7360	48.622	-1.0936	80.2805
3	467883.9	399730.4	15837728.400	911332.730	-2590319.700	412193.6	327612.4	15564207.000	1008890.690	-2982509.700
4	65862.8	198889.3	9803778.8	12608.477	-10366.809	87415.2	223357.1	10151689.6	16948.039	-12573.969
5	2454300.9	2983621.3	10770572.3	770323.860	-60399.283	2857165.7	3424360.5	10835336.6	898967.820	-79999.406
6	-1538.038	-2043.936	-8530.288	3224.0593	-12621.559	-2178.598	-2769.571	-9719.185	3277.9831	-13524.109
7	654.820	779.314	11205.358	132.0751	-68.590	784.176	852.843	12004.144	157.5760	-78.727
8	12810.970	14084.187	2196.2413	4082.9393	-587.252	14067.973	15319.047	2123.4556	4500.5649	-722.555
9	-20.935	.000	.0000	-73.3029	30.2005	-21.817	.000	.0000	-72.0721	30.4095
10	4.106	.000	.0000	2128.5405	.0000	4.540	.000	.0000	2113.2833	.0000
11	39.788	12919.570	5.4099	.0000	.0001	44.234	14257.246	5.9969	.0000	.0001
12	6.5532	-.0000	.0000	.0000	727.8970	7.6374	-.0000	.0000	.0000	724.6382
13	2499369.0	2532987.6	2180671.3	3359193.7	2914545.3	2888068.6	2921871.3	2532246.8	3370065.6	2525738.3
14	73.5371	73.1250	49.9698	347.8975	256.1521	73.7523	73.3901	54.0332	354.8693	255.0141
15	10.7895	10.5515	13.3446	5.9158	8.1696	8.2054	8.0169	10.4213	5.7686	10.4704

1	405.0000	607806.4600	2454718.3000	-.4737	78.6239	435.0000	601197.8500	2856929.5000	-1.2668	79.5082
2	13132.9460	14466.4744	44.720	-.4591	79.6860	14495.9557	15829.3922	49.546	-1.1872	80.4044
3	459931.0	389214.5	15794596.500	927477.450	-2653803.800	401027.4	31345[illegible].9	15515092.600	1025300.370	-3050505.700
4	69188.4	202815.5	9860122.7	13279.117	-10713.794	91393.1	227653.3	10212067.8	17747.022	-12972.070
5	2518055.7	3054534.6	10781520.9	790904.790	-63380.480	2928062.2	3501502.1	10845926.9	921655.740	-83672.988
6	-1643.357	-2152.740	-8722.793	3233.7470	-12772.146	-2288.346	-2894.265	-9927.059	3285.7556	-13674.303
7	675.492	791.167	11332.477	136.1810	-70.208	807.072	865.692	12147.411	162.0389	-80.5[illegible]9
8	13012.200	14282.000	2183.2951	4149.7123	-608.511	14291.473	15538.452	2112.7255	4574.8814	-746.970
9	-21.116	.000	.0000	-73.1066	30.2350	-21.917	.000	.0000	-71.8543	30.4447
10	4.182	.000	.0000	2127.3310	.0000	4.644	.000	.0000	2109.0512	.0000
11	40.586	13132.945	5.5012	.0000	.0001	45.091	14495.955	6.1050	.0000	.0001
12	6.7265	-.0000	.0000	.0000	727.6387	7.8287	-.0000	.0000	.0000	723.7342
13	2561437.5	2595092.8	2235993.5	3357985.2	2852261.4	2955809.6	2990635.0	2595522.0	3376564.7	2457371.1
14	73.5733	73.1702	50.6270	349.0144	255.9943	73.7877	73.4328	54.6461	356.0900	254.7698
15	10.3431	10.1155	12.8432	5.9133	8.5142	7.7950	7.6133	9.9555	5.7127	10.9209

TABLE AP 3-3 (Sheet 10 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	440.0000	599524.0900	2927932.4000	-1.3550	79.6608	470.0000	587017.8000	3379973.2000	-1.6549	80.6017
2	14739.1036	16072.4802	50.521	-1.2094	80.5307	16304.3682	17637.2330	55.414	-1.5546	81.3225
3	389312.4	298668.8	15464932.800	1041747.870	-3119252.400	307193.8	196418.6	15141077.800	1141105.500	-3547479.300
4	95486.9	232014.6	10273167.8	18568.613	-13379.211	122575.0	259575.4	10655851.5	23983.297	-16020.752
5	3000086.0	3579750.4	10856464.1	944718.580	-87470.030	3457160.8	4073699.2	10918697.0	1091389.700	-113034.600
6	-2398.136	-3019.921	-10137.566	3293.2138	-13824.428	-3063.159	-3805.627	-11472.900	3327.8091	-14723.636
7	830.527	678.882	12293.687	166.6151	-82.342	978.535	960.215	13238.188	194.9456	-93.958
8	14518.965	15761.735	2102.3034	4650.5488	-771.940	15980.270	17194.976	2048.1619	5136.7686	-933.909
9	-22.138	.000	.0000	-71.6326	30.4800	-23.591	.000	.0000	-70.2167	30.6930
10	4.740	.000	.0000	2104.4055	.0000	5.267	.000	.0000	2069.5037	.0000
11	46.012	14739.103	6.2159	.0000	.0001	51.508	16304.367	6.9477	.0000	.0002
12	9.0233	-.0000	.0000	.0000	722.7418	9.2621	-.0000	.0000	.0000	715.2851
13	3026747.6	3060593.0	2660177.9	3384562.5	2387972.5	3472945.9	3506875.9	3078176.4	3468498.1	1950183.1
14	73.8229	73.4753	55.2387	357.3256	254.5050	74.0305	73.7219	58.4126	4.9941	252.3147
15	7.3901	7.2150	9.4962	5.6476	11.3967	5.0746	4.9326	6.8797	5.0682	14.9881

1	445.0000	597715.4200	3000134.1000	-1.4329	79.8133	475.0000	584633.7100	3459889.6000	-1.6663	80.7655
2	14988.1938	16321.4956	51.518	-1.3424	80.6575	16583.9970	17916.7730	57.700	-1.5667	81.4627
3	377043.5	283251.1	15413709.700	1058231.300	-3188749.600	291462.8	177050.3	15083128.200	1157754.900	-3621471.200
4	99698.5	236441.8	10335010.4	19413.091	-13795.546	127533.9	264412.9	10722463.9	24970.679	-16495.655
5	3073260.8	3659128.2	10866950.9	968164.160	-91393.327	3537711.1	4160310.3	10928917.5	1117289.500	-117746.641
6	-2509.723	-3147.429	-10352.282	3300.0860	-13974.483	-3201.387	-3941.944	-11707.929	3331.8536	-14873.223
7	854.082	891.921	12443.582	171.1544	-84.197	1005.106	974.773	13407.926	200.0086	-96.011
8	14751.874	15990.291	2092.5554	4727.9954	-797.474	16240.992	17450.549	2040.2719	5223.5386	-963.014
9	-22.430	.000	.0000	-71.4069	30.5154	-23.766	.000	.0000	-69.9657	30.7286
10	4.716	.000	.0000	2099.3800	.0000	5.364	.000	.0000	2062.8099	.0000
11	46.968	14988.193	6.3303	.0000	.0001	52.710	16583.996	7.0810	.0000	.0002
12	8.2212	-.0000	.0000	.0000	721.6683	9.4811	-.0000	.0000	.0000	713.8546
13	3097907.8	3131772.5	2726234.0	3394188.5	2317541.2	3551989.1	3585927.1	3153041.7	3489099.2	1873807.6
14	73.8580	73.5173	55.8117	358.5751	254.2173	74.0645	73.7618	58.8851	6.3039	251.8069
15	6.9908	6.6219	9.0435	5.5734	11.9008	4.7071	4.5696	6.4669	4.9412	15.7579

START ARTIFICIAL TAU-GUIDANCE STAGING

1	450.0000	595780.1200	3073458.1000	-1.4998	79.9665	476.5000	583908.1700	3484132.8000	-1.6675	80.8149
2	15240.5520	16573.7690	52.298	-1.4053	80.7854	16669.0600	18001.6080	58.046	-1.5683	81.5051
3	364214.3	267193.3	15361407.800	1074748.300	-3258996.900	286654.0	171106.3	15065512.500	1162753.400	-3643814.700
4	104027.9	240933.7	10397605.3	20280.156	-14221.234	129047.6	265878.3	10742615.0	25271.817	-16640.141
5	3147607.7	3739656.0	10877389.8	991959.030	-95445.720	3562131.9	4186544.1	10931976.1	1125144.500	-119197.792
6	-2622.147	-3276.069	-10569.311	3306.5915	-14124.467	-3237.059	-3983.123	-11779.202	3332.9754	-14918.082
7	877.721	904.834	12595.245	175.6653	-86.084	1013.157	979.164	13459.641	201.5370	-96.634
8	14987.607	16221.544	2083.1036	4806.4384	-823.580	16320.309	17528.295	2038.0404	5249.9339	-971.867
9	-22.626	.000	.0000	-71.1772	30.5508	-23.796	.000	.0000	-69.8895	30.7393
10	4.763	.000	.0000	2093.9939	.0000	5.381	.000	.0000	2060.7708	.0000
11	47.684	15240.551	6.4472	.0000	.0001	53.028	16669.059	7.1217	.0000	.0002
12	8.4224	-.0000	.0000	.0000	720.5177	9.5475	-.0000	.0000	.0000	713.4188
13	3170316.6	3204197.9	2793708.8	3405454.0	2246080.2	3575976.4	3609916.6	3175601.9	3495681.0	1850719.8
14	73.8928	73.5589	56.3661	359.8376	253.9039	74.0747	73.7737	59.0240	6.6980	251.6434
15	6.5969	6.4339	8.5974	5.4902	12.4366	4.5978	4.4617	6.3444	4.9015	16.0018

1	455.0000	593730.7000	3148226.6000	-1.5550	80.1216	480.0000	582200.5600	3541188.7000	-1.6664	80.9303
2	15498.6787	16831.8070	53.390	-1.4577	80.9155	16869.6590	18202.3440	58.884	-1.5684	81.6043
3	350820.2	250488.0	15308010.300	1091296.400	-3329993.900	275178.1	156996.6	15023992.500	1174423.100	-3696210.900
4	108476.6	245490.7	10460969.4	21169.937	-14656.434	132626.5	269323.2	10789936.6	25983.434	-16980.918
5	3223146.0	3821352.5	10887782.6	1016231.540	-99630.092	3619579.3	4248213.1	10939100.7	1143627.900	-122635.779
6	-2735.675	-3406.184	-10790.059	3312.6250	-14274.376	-3320.766	-4079.821	-11946.997	3335.3958	-15022.720
7	901.912	918.045	12750.784	180.2769	-88.002	1031.966	989.338	13581.644	205.0847	-98.099
8	15226.647	16457.973	2074.1036	4886.6361	-850.207	16507.360	17711.625	2033.1241	5312.1771	-992.747
9	-22.784	.000	.0000	-70.9435	30.5863	-24.105	.000	.0000	-69.7101	30.7642
10	4.947	.000	.0000	2088.2803	.0000	5.402	.000	.0000	2055.9655	.0000
11	48.698	15496.678	6.5575	.0000	.0002	53.820	16869.658	7.2178	.0000	.0002
12	8.6270	-.0000	.0000	.0000	719.2971	9.7039	-.0000	.0000	.0000	712.3917
13	3243996.1	3277892.3	2862618.6	3418449.8	2173600.0	3632446.4	3660390.9	3229455.0	3511775.1	1796546.4
14	73.9275	73.6002	56.9026	1.1117	253.5613	74.0984	73.8013	59.3433	7.6194	251.2401
15	6.2084	6.0510	8.1580	5.3979	13.0082	4.3446	4.2115	6.0607	4.8060	16.5364

1	460.0000	591578.2100	3224167.7000	-1.5990	80.2800	485.0000	579727.5100	3623901.4000	-1.6664	81.0981
2	15762.2665	17095.3090	54.430	-1.4998	81.0492	17162.0520	18494.6460	60.198	-1.5699	81.7491
3	336855.8	233128.9	15253500.800	1107873.600	-3401740.300	258267.7	136243.6	14963648.200	1191106.900	-3771697.700
4	113048.8	250115.5	10525120.6	22083.348	-15101.309	137855.0	274307.2	10858284.2	27021.822	-17476.708
5	3299901.8	3904243.1	10898130.7	1040866.550	-103949.372	3702793.0	4337434.4	10949246.3	1170414.000	-127675.167
6	-2850.327	-3537.794	-11014.266	3318.1794	-14424.210	-3444.743	-4222.715	-12192.696	3337.3801	-15172.125
7	927.031	931.931	12910.103	185.1042	-89.954	1059.650	1004.411	13758.308	210.3261	-100.223
8	15474.666	16699.257	2065.1430	4968.4935	-877.545	16779.359	17978.092	2024.6194	5402.6534	-1023.119
9	-23.027	.000	.0000	-70.7055	30.6219	-25.641	.000	.0000	-69.4499	30.7937
10	5.064	.000	.0000	2082.2713	.0000	5.673	.000	.0000	2048.9968	.0000
11	49.669	15762.266	6.6912	.0000	.0002	55.095	17162.050	7.3582	.0000	.0002
12	8.8351	-.0000	.0000	.0000	718.0133	9.9305	-.0000	.0000	.0000	710.9021
13	3318976.2	3352885.3	2932985.9	3433241.5	2100110.4	3714348.2	3748297.5	3307441.5	3536592.9	1718458.1
14	73.9620	73.6411	57.4220	2.3968	253.1856	74.1321	73.8406	59.7878	8.9391	250.6039
15	5.8252	5.6732	7.7252	5.2968	13.6201	3.9871	3.8582	5.6610	4.6628	17.5143

1	465.0000	589336.6700	3301408.1000	-1.6315	80.4399	490.0000	577203.3500	3708066.5000	-1.6767	81.2684
2	16030.8677	17363.8220	55.454	-1.5313	81.1847	17463.2090	18795.7000	61.313	-1.5810	81.8967
3	322315.8	215108.7	15197863.300	1124477.600	-3474235.500	240716.1	114754.4	14902047.700	1207792.100	-3847931.400
4	117747.5	254810.2	10590075.0	23021.043	-15556.026	143224.5	279368.2	10927523.8	28086.974	-17983.207
5	3377899.2	3988[illegible].4	10908435.0	1065918.700	-108406.533	3787384.6	4428005.0	10959341.8	1197658.100	-132868.030
6	-2965.940	-3670.727	-11241.759	3323.3065	-14573.964	-3576.945	-4374.298	-12448.619	3336.5863	-15321.432
7	952.533	945.951	13072.697	189.9324	-91.939	1088.151	1019.920	13937.596	215.7116	-102.383
8	15725.285	16945.008	2056.6522	5051.8957	-905.422	17058.284	18251.128	2013.3837	5495.3297	-1054.139
9	-23.291	.000	.0000	-70.4633	30.6575	-26.878	.000	.0000	-69.1848	30.8352
10	5.159	.000	.0000	2076.7012	.0000	5.679	.000	.0000	2041.8685	.0000
11	50.622	16030.867	6.8179	.0000	.0002	56.141	17463.208	7.5035	.0000	.0002
12	9.0468	-.0000	.0000	.0000	716.6736	10.1612	-.0000	.0000	.0000	709.3780
13	3395284.0	3429204.5	3004831.7	3449901.6	2025629.1	3797728.1	3831681.0	3387028.9	3563614.6	1639603.9
14	73.9963	73.6816	57.9251	3.6913	252.7720	74.1656	73.8795	60.2192	10.2620	249.8853
15	5.4473	5.3004	7.2991	5.1868	14.2780	3.6341	3.5091	5.2672	4.5115	18.5233

TABLE AP 3-3 (Sheet 11 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	495.0000	574619.7600	3793718.2000	-1,6846	81,4395	520.0000	560942.8300	4244332.6000	-1,6707	82,3432
2	17768.7910	19101.1710	61.921	-1,5898	82,0456	19281.1350	20612.9670	60.646	-1,5833	82,8455
3	222492.9	92495.1	14839155.200	1224471.000	-3924911.300	120777.6	-30909.0	14504916.500	1307581.100	-4320986.500
4	148736.4	284505.8	10997661.1	29178.787	-18500.598	178496.9	311373.8	11361528.2	35049.310	-21257.506
5	3873380.3	4519949.6	10969378.7	1225368.800	-138217.640	4324292.2	5000117.7	11018345.4	1370906.500	-167434.820
6	-3713.018	-4530.110	-12709.640	3334.6726	-15470.637	-4429.094	-5347.856	-14028.693	3312.2988	-16214.978
7	1116.648	1035.140	14117.894	221.0204	-104.580	1265.396	1114.845	14981.372	248.8363	-116.135
8	17340.603	18527.313	2001.2241	5589.1667	-1085.817	18722.822	19875.915	1910.1607	6051.6214	-1254.456
9	-27.618	.000	.0000	-68.9149	30.8706	-28.660	.000	.0000	-67.4912	31.0454
10	5.743	.000	.0000	2034.5587	.0000	5.861	.000	.0000	1995.6140	.0000
11	56.646	17768.789	7.6516	.0000	.0002	54.781	19281.133	8.4018	.0000	.0003
12	10.3959	-.0000	.0000	.0000	707.8150	11.6308	-.0000	.0000	.0000	599.4820
13	3882615.1	3916570.2	3468241.6	3592902.9	1560077.3	4329659.4	4363606.3	3898567.3	3774948.4	1159391.7
14	74.1990	73.9182	60.6380	11.5864	249.0679	74.3636	74.1073	62.5576	18.1688	242.5120
15	3.2651	3.1639	4.8790	4.3519	19.6381	1.5985	1.4934	3.0173	3.4399	27.5462

1	5[illegible].0000	571979.7100	3880866.3000	-1,6918	81,6137	525.0000	558141.0700	4338885.4000	-1,6319	82,5253
2	180[illegible]3.8370	19406.1050	61.54[illegible]	-1,5980	82,1982	19581.2410	20912.9620	60.663	-1,5481	83,0085
3	20358[illegible].4	69447.4	147[illegible]49.600	1241136.800	-4002637.000	98276.0	-58056.5	14434117.700	1324131.300	-4402432.400
4	154391.8	289720.1	110[illegible]596.7	30297.356	-19029.065	184895.6	316984.1	11436857.0	36306.335	-21844.238
5	3960785.9	4613272.9	1[illegible]979149.6	1253548.50	-143727.310	4418589.5	5100162.7	11027851.6	1401394.800	-173796.420
6	-3852.478	-4689.519	-129[illegible].566	3331.5304	-15619.737	-4571.140	-5510.881	-14290.906	3307.8702	-16363.474
7	1145.576	1050.598	142[illegible]549	226.4128	-106.814	1293.746	1128.890	15150.550	253.8580	-118.565
8	17621.284	18801.638	196[illegible].6426	5682.6404	-1118.165	18996.207	20142.189	1892.8463	6143.7086	-1290.305
9	-28.224	.000	.0000	-68.6400	30.9059	-28.190	.000	.0000	-67.1918	31.0796
10	5.818	.000	.0000	2027.0736	.0000	5.467	.000	.0000	1967.5832	.0000
11	56.146	18073.836	7.9006	.0000	.0003	54.714	19581.240	8.5536	.0000	.0003
12	10.6347	-.0000	.000	.0000	706.2141	11.8899	-.0000	.0000	.0000	697.7623
13	3969018.2	4002974.1	3551[illegible]85.[illegible]	3624512.3	1480026.5	4423546.1	4457489.7	3989421.9	3818728.7	1081394.6
14	74.2322	73.9566	61.0448	12.9108	248.1311	74.3961	74.1443	62.9089	19.4642	240.3539
15	2.9401	2.8224	4.4962	4.1843	20.8762	1.2730	1.1707	2.6610	3.2376	29.8092

S-IVB ENGINE MIXTURE RATIO SHIFT

1	502.8300	570461.0700	3930854.9000	-1,6941	81,7133	530.0000	555377.8000	4434916.7000	-1,5742	82,7059
2	18247.7180	19579.9200	61.429	-1,6010	82,2857	19883.4460	21215.9550	61.671	-1,4951	83,1706
3	192564.5	56046.5	14738[illegible]5.100	1250561.800	-4046960.000	75070.1	-860[illegible]4.4	14362007.500	1340660.600	-4484620.500
4	157657.1	292705.7	11109[illegible]4.4	30942.445	-19333.157	191432.5	322660.6	11513036.5	37587.252	-22443.219
5	4010879.2	4666701.6	10984[illegible]59.2	1269705.400	-146917.980	4514258.0	5201543.1	11037278.0	1432345.100	-180339.080
6	-3932.801	-4781.272	-13122.963	3329.2712	-15704.078	-4710.81[illegible]	-5671.861	-14553.065	3304.0228	-16511.832
7	1162.076	1059.362	14394.156	229.4747	-108.095	1321.[illegible]	1141.702	15321.855	258.5162	-121.035
8	17780.941	18957.597	1977.8348	5735.8488	-1136.774	19272.114	20410.907	1878.2026	6236.7631	-1326.885
9	-28.519	.000	.0000	-68.4823	30.9258	-27.618	.000	.0000	-66.8874	31.1135
10	5.848	.000	.0000	2022.7601	.0000	5.537	.000	.0000	1976.0189	.0000
11	56.468	18247.717	7.8860	.0000	.0003	55.601	19883.445	8.7146	.0000	.0004
12	10.7717	.0000	.0000	.0000	705.2914	12.1531	-.0000	.0000	.0000	695.4384
13	4018592.9	4052548.6	3598694.6	3643448.9	1434559.5	4518938.6	4552874.0	4081877.3	3885053.1	1005190.5
14	74.2509	73.9781	61.2697	13.6596	247.5381	74.4282	74.1408	63.2500	20.7486	237.6966
15	2.7466	2.6308	4.2818	4.0860	21.6393	.9519	.8522	2.3105	3.0303	32.3952

1	505.0000	569285.6500	3969513.300	-1,6956	81.7903	535.0000	552695.6300	4532442.6000	-1,4893	82.8896
2	18360.2630	19712.4150	60.9[illegible]3	-1,6029	82.3535	20188.5760	21520.0940	62.625	-1,4164	83.3359
3	163963.0	45594.2	14709423.[illegible]00	1257784.400	-4081108.000	51176.7	-114766.9	14288590.100	1357173.800	-4567550.000
4	160192.6	295011.8	11140616.7	31442.948	-19568.797	198107.6	328402.1	11590084.3	38891.818	-23054.657
5	4049596.2	4707968.8	10989243.2	1282196.400	-149400.410	4611315.7	5304276.8	11046638.0	1463764.200	-187066.480
6	-3954.947	-4852.208	-13238.223	3327.3543	-15768.725	-4845.341	-5828.079	-14813.288	3301.5829	-16660.044
7	1174.765	1066.091	14472.245	231.8276	-109.086	1349.014	1154.922	15498.285	263.3113	-123.547
8	17902.357	19076.133	1970.5110	5776.3731	-1151.192	19552.018	20683.669	1866.5911	6331.2761	-1364.205
9	-28.769	.000	.0000	-68.3602	30.9411	-26.211	.000	.0000	-66.5781	31.1471
10	5.858	.000	.0000	2019.4191	.0000	5.607	.000	.0000	1964.1733	.0000
11	55.425	18380.262	7.9513	.0000	.0003	56.418	20188.575	8.8786	.0000	.0004
12	10.8777	-.0000	.0000	.0000	704.5767	12.4203	-.0000	.0000	.0000	693.0718
13	4056936.4	4090891.8	3635554.9	3658488.6	1399650.4	4615852.8	4649781.0	4175952.2	3913957.9	931948.8
14	74.2652	73.9946	61.4397	14.2332	247.0482	74.4599	74.2168	63.5812	22.0207	234.3628
15	2.5990	2.4847	4.1186	4.0090	22.2584	.6353	.5380	1.9658	2.8187	35.3480

STOP ARTIFICIAL TAU

1	510.0000	566540.7700	4059649.0000	-1,6986	81,9727	539.0300	550631.5600	4612145.9000	-1,3954	83.0383
2	18662.2230	20014.2660	60.518	-1,6071	82.5151	20436.6510	21768.1100	63.673	-1,3289	83.4701
3	163626.4	20920.7	14642570.600	1274408.700	-4160323.600	31441.3	-138498.6	14228476.000	1370477.800	-4634930.100
4	166141.1	300382.5	11213407.8	32616.103	-20119.984	203589.4	333077.7	11652835.0	39960.676	-23556.681
5	4139797.2	4804021.8	10999047.9	1311308.800	-155240.360	4690570.1	5388080.4	11054147.8	1489434.700	-192625.750
6	-4139.961	-5017.534	-13502.827	3322.3395	-15917.598	-4947.840	-5948.372	-15020.377	3301.2951	-16779.393
7	1204.993	1082.508	14643.736	237.5358	-111.396	1371.471	1165.370	15645.297	267.1219	-125.602
8	18177.848	19344.855	1950.7806	5868.5566	-1184.910	19781.169	20907.162	1861.0805	[illegible]408.7316	-1394.830
9	-29.080	.000	.0000	-68.0754	30.9761	-24.553	.000	.0000	-66.3251	31.1740
10	6.271	.000	.0000	2011.6038	.0000	5.566	.000	.0000	1955.0493	.0000
11	54.845	18682.221	8.1012	.0000	.0003	57.319	20436.650	9.0114	.0000	.0004
12	11.1247	-.0000	.0000	.0000	702.9045	12.6387	.0000	.0000	.0000	691.2464
13	4146359.4	4180313.2	3721637.7	3694868.7	1319209.2	4695091.5	4729013.2	4252969.5	3955277.3	875944.4
14	74.2981	74.0324	61.8233	15.5516	245.7843	74.4652	74.2455	63.8413	23.0362	231.0105
15	2.[illegible]616	2.1506	3.7463	3.8262	23.8099	.3837	.2884	1.6927	2.6458	38.0154

1	515.0000	563752.5300	4151257.4000	-1,6931	82.1592	540.0000	550152.9000	4631477.7000	-1,3687	83.0743
2	18980.1590	20312.1010	60.006	-1,6031	82.6813	20496.7000	21828.1460	63.973	-1,3040	83.5026
3	142563.5	-4581.5	14574400.800	1251007.400	-4240283.300	26630.4	-144281.9	14213881.600	1373680.200	-4651220.200
4	172243.7	305837.9	11287046.1	33818.614	-20682.822	204922.4	334209.3	11668029.0	40220.236	-23678.758
5	4231364.7	4901407.1	11008747.5	1340879.200	-[illegible]0.660	4709784.8	5408386.7	11055952.8	1495660.300	-193982.360
6	-4285.083	-5183.083	-13765.104	3317.2202	-16066.351	-4971.491	-5976.351	-15069.742	3301.5183	-16808.105
7	1235.789	1099.387	14811.[illegible]23	243.[illegible]766	-113.746	1376.895	1167.884	15681.514	268.0404	-126.101
8	18448.775	19608.887	1929.2651	5954.5243	-1219.328	19836.913	20961.568	1860.3855	6427.5835	-1402.275
9	-28.907	.000	.0000	-67.7858	31.0108	-24.262	.000	.0000	-66.2638	31.1804
10	5.983	.000	.0000	2003.6478	.0000	5.598	.000	.0000	1952.9288	.0000
11	54.243	18980.157	8.2503	.0000	.0003	57.581	20496.698	9.3434	.0000	.0004
12	11.3757	-.0000	.0000	.0000	701.2018	12.6917	-.0000	.0000	.0000	690.8218
13	4237267.8	4271218.7	3809309.8	3733676.0	1239046.5	4714315.9	4748236.0	4271668.3	3965478.8	862969.8
14	74.3309	74.0700	62.1958	16.8641	244.2932	74.4915	74.2524	63.9030	23.2793	230.0932
15	1.9281	1.8201	3.3791	3.6363	25.5604	.3237	.2288	1.6276	2.6039	38.6960

TABLE AP 3-3 (Sheet 12 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

1	545.0000	547819.1900	4732042.7000	-1.2188	83.2609	575.0000	538152.3200	5369793.3000	-.4967	84.4549
2	20810.0480	22141.4430	65.353	-1.1636	83.6713	22883.6240	24214.7890	75.742	-.4846	84.7620
3	1472.4	-174520.6	14137895.600	1390191.700	-4735630.200	-164203.2	-373171.6	13652664.000	1488732.600	-5257578.200
4	211877.2	340081.1	11746911.6	41572.282	-24315.733	256805.3	375820.4	12240728.1	50230.391	-28419.978
5	4809695.3	5513903.2	11065249.3	1528043.700	-201090.480	5441335.1	6178355.7	11120057.4	1733197.500	-247943.710
6	-5091.580	-6119.056	-15325.134	3303.1011	-16956.002	-5993.909	-7168.128	-17080.522	3252.6118	-17839.427
7	1405.086	1180.902	15872.279	272.7993	-128.697	1595.539	1271.168	17071.305	305.3378	-145.184
8	20128.578	21246.321	1858.6531	6526.2117	-1441.104	22026.973	23094.548	1783.9151	7165.5896	-1690.575
9	-24.129	.000	.0000	-65.9443	31.2133	-34.696	.000	.0000	-63.9124	31.4009
10	5.709	.000	.0000	1942.5690	.0000	7.036	.000	.0000	1899.5823	.0000
11	58.824	20810.048	9.2093	.0000	.0004	68.001	22883.623	10.2558	.0000	.0006
12	12.9673	-.0000	.0000	.0000	688.7497	14.7150	-.0000	.0000	.0000	680.0991
13	4814359.9	4848271.1	4369054.6	4019654.2	799964.0	5449865.8	5483706.4	4990271.2	4401959.9	682298.6
14	74.5225	74.2675	64.2155	24.5234	224.5069	74.7020	74.4897	65.9211	31.5435	146.1008
15	.0175	-.0751	1.2962	2.3871	42.4202	-1.7266	-1.8083	-.5734	1.0484	51.4873

START CHI TILDE

1	550.0000	545723.5400	4834164.8000	-1.0773	83.4509	578.7900	537459.4000	5454848.6900	-.4116	34.6165
2	21130.7300	22462.0770	66.924	-1.0312	83.8437	23170.7760	24501.9330	77.443	-.4040	84.9110
3	-24297.3	-205465.2	14060617.700	1406707.200	-4820779.400	-187171.3	-400627.6	13587461.600	1501036.000	-5325399.600
4	218974.8	346019.3	11826752.4	42978.541	-24965.795	262903.8	381663.4	12305732.1	51396.600	-28974.380
5	4911076.8	5620855.5	11074533.8	1560924.600	-208394.680	5525307.6	6260360.5	11126788.4	1760519.700	-254464.460
6	-5219.316	-6269.866	-15589.517	3302.1012	-17103.729	-6126.675	-7320.925	-17327.794	3239.8877	-17950.478
7	1434.148	1134.411	16064.697	277.7211	-131.335	1622.935	1284.730	17232.693	310.1415	-147.382
8	20425.712	21536.181	1854.0252	6626.6306	-1480.703	22287.098	23347.341	1768.2296	7252.8807	-1724.170
9	-27.534	.000	.0000	-65.6197	31.2458	-35.074	.000	.0000	-63.6419	31.4232
10	5.948	.000	.0000	1933.2889	.0000	7.416	.000	.0000	1896.4900	.0000
11	60.324	21130.729	9.3766	.0000	.0005	69.535	23170.774	10.3940	.0000	.0006
12	13.2472	-.0000	.0000	.0000	686.8835	14.9481	.0000	.0000	.0000	679.4750
13	4916016.2	4949917.5	4468138.9	4076513.4	745087.6	5534724.4	5568554.3	5073504.1	4457427.7	711417.8
14	74.5529	74.3221	64.5193	25.7519	217.0612	74.7241	74.5144	66.1182	32.4977	136.7051
15	.2632	-.3738	.9717	2.1687	46.3922	-1.9380	-2.0186	-.7979	.8753	48.4246

1	555.0000	543828.2500	4937895.6000	-.9658	83.6446	580.0000	537264.7900	5482229.3000	-.3818	84.6689
2	21463.9340	22795.2280	68.549	-.9268	84.0199	23263.7700	24594.9270	77.968	-.3758	84.9593
3	-50751.0	-237250.3	13981969.800	1423203.600	-4906666.700	-194610.3	-409515.5	13566447.800	1504953.900	-5347141.400
4	226220.8	352026.5	11907558.1	44349.916	-25629.158	264873.0	383220.7	12326614.6	51772.839	-29153.141
5	5013965.4	5729276.8	11083777.1	1594314.100	-215898.800	5552326.1	6294660.4	11128925.1	1769312.800	-256557.270
6	-5364.138	-6438.320	-15871.845	3295.7878	-17251.272	-6168.915	-7369.649	-17407.301	3235.8345	-17985.905
7	1464.438	1208.602	16257.684	282.8639	-134.017	1631.961	1289.285	17285.446	311.7453	-148.089
8	20731.182	21833.685	1842.4746	6729.6167	-1521.080	22371.503	23429.393	1763.4271	7281.1905	-1734.997
9	-30.010	.000	.0000	-65.2897	31.2779	-34.809	.000	.0000	-63.5545	31.4302
10	6.185	.000	.0000	1924.8676	.0000	7.498	.000	.0000	1895.6220	.0000
11	61.743	21463.934	9.5480	.0000	.0005	70.051	23263.768	10.4384	.0000	.0006
12	13.5314	-.0000	.0000	.0000	685.1915	15.0231	-.0000	.0000	.0000	679.2998
13	5019322.6	5053213.3	4568954.3	4136079.6	700899.8	5562045.9	5595872.3	5100314.2	4475483.6	722754.2
14	74.5832	74.3563	64.8148	26.9644	207.0662	74.7311	74.5223	66.1803	32.7682	134.0922
15	-.5793	-.6680	.6530	1.9484	50.2757	-2.0051	-2.0854	-.8692	.8196	47.3525

1	560.0000	542104.6800	5043283.5000	-.8589	83.8437	585.0000	536616.1500	5596547.6000	-.2493	84.8857
2	21805.9850	23137.2360	70.225	-.8263	84.2016	23653.8560	24985.0150	80.124	-.2501	85.1596
3	-77950.9	-269881.5	13901885.200	1439660.700	-4993291.100	-225892.1	-446868.9	13478583.500	1521090.500	-5437436.300
4	233622.3	358107.7	11989333.3	45777.947	-26306.037	273126.0	389713.7	12413593.5	53348.005	-29900.941
5	5118398.4	5839201.7	11092952.9	1628224.000	-223606.770	5665064.0	6412663.3	11137694.6	1806014.000	-265345.040
6	-5516.410	-6614.756	-16163.549	3286.9230	-17398.624	-6344.029	-7571.964	-17739.563	3218.7404	-18132.137
7	1496.422	1224.065	16453.890	288.4077	-136.742	1669.226	1307.802	17507.550	318.2886	-151.040
8	21043.548	22137.714	1827.8206	6834.8321	-1562.245	22726.018	23774.063	1744.8939	7400.0419	-1780.260
9	-30.708	.000	.0000	-64.9542	31.3094	-35.794	.000	.0000	-63.1893	31.4588
10	6.513	.000	.0000	1917.2011	.0000	7.316	.000	.0000	1892.7248	.0000
11	63.233	21805.984	9.7220	.0000	.0005	71.982	23653.855	10.6226	.0000	.0006
12	13.8202	-.0000	.0000	.0000	683.6495	15.3364	-.0000	.0000	.0000	678.7147
13	5124320.2	5158109.4	4671537.9	4198377.8	670251.0	5676140.7	5709952.2	5212333.2	4551889.2	779151.1
14	74.6133	74.3901	65.1024	28.1604	193.9479	74.7601	74.5547	66.4333	33.8744	125.0583
15	-.8716	-.9584	.3393	1.7259	53.4329	-2.2808	-2.3597	-1.1611	.5902	42.7537

1	565.0000	540568.5800	5150369.9000	-.7404	84.0458	590.0000	536240.1800	5712794.1000	-.1093	85.1015
2	22156.0660	23487.2830	71.874	-.7147	84.3865	24054.9330	25386.0960	82.251	-.1171	85.3593
3	-105917.4	-303401.2	13820326.000	1456071.500	-5080651.900	-258059.4	-485244.6	13389039.800	1537138.100	-5528461.800
4	241186.3	364267.8	12072105.3	47234.217	-26996.652	281562.7	396295.4	12501692.0	54954.747	-30663.610
5	5224412.3	5950665.1	11102056.1	1662666.100	-231522.550	5779594.9	6532409.1	11146374.5	1843316.000	-274361.260
6	-5670.199	-6793.267	-16460.586	3277.3643	-17545.775	-6523.557	-7779.366	-18081.205	3200.0170	-18278.109
7	1529.168	1239.908	16655.674	294.0807	-139.512	1705.709	1325.037	17735.256	324.4554	-154.037
8	21363.561	22449.202	1813.8825	6942.5642	-1604.209	23090.552	24128.400	1727.6260	7522.0994	-1826.374
9	-30.778	.000	.0000	-64.6131	31.3405	-35.603	.000	.0000	-62.8178	31.4867
10	6.523	.000	.0000	1910.3583	.0000	7.415	.000	.0000	1891.0462	.0000
11	64.745	22156.065	9.8981	.0000	.0005	73.963	24054.933	10.8081	.0000	.0007
12	14.1137	-.0000	.0003	.0000	682.2716	15.6550	-.0000	.0000	.0000	678.3757
13	5231048.8	5264916.0	4775925.7	4263435.4	655872.5	5792200.6	5825996.4	5326377.2	4631215.6	849143.4
14	74.6431	74.4237	65.3825	29.3393	178.0133	74.7890	74.5858	66.6801	34.9616	114.5281
15	-1.1602	-1.2452	.0304	1.5015	54.9908	-2.5535	-2.6311	-1.4492	.3600	38.2604

STOP CHI TILDE - START CHI FREEZE

1	570.0000	539249.2400	5259191.3000	-.6137	84.2482	591.0200	536200.0400	5736749.8000	-.0770	85.1463
2	22514.2020	23845.3890	73.538	-.5952	84.5720	24137.8970	25469.0620	82.555	-.0863	85.4007
3	-134656.9	-337819.1	13737269.600	1472432.600	-5168748.000	-264731.5	-493200.6	13370561.500	1540400.200	-5547120.500
4	248913.3	370505.5	12155896.3	48718.383	-27701.224	283306.2	397648.8	12519805.3	55286.347	-30821.040
5	5332044.8	6063704.2	11111093.2	1697653.200	-239650.170	5803164.4	6557056.0	11148134.6	1851001.000	-276228.990
6	-5826.748	-6975.087	-16764.117	3266.7322	-17692.712	-6559.495	-7821.083	-18151.038	3196.3680	-18307.854
7	1561.654	1255.094	16861.908	299.5673	-142.325	1713.405	1328.756	17783.105	325.7772	-154.654
8	21691.001	22767.862	1800.8594	7052.7291	-1646.983	23166.254	24202.029	1724.5821	7547.4413	-1835.887
9	-32.177	.000	.0000	-64.2662	31.3710	-35.295	.000	.0000	-62.7412	31.4923
10	6.528	.000	.0000	1904.4785	.0000	7.548	.000	.0000	1890.8637	.0000
11	66.187	22514.201	10.0756	.0000	.0006	74.268	24137.896	10.8460	.0000	.0007
12	14.4119	-.0000	.0000	.0000	681.0866	15.7206	.0000	.0000	.0000	678.3388
13	5339549.6	5373404.0	4882156.6	4331285.9	659702.8	5816123.5	5849916.0	5349896.0	4647761.0	864881.9
14	74.6727	74.4569	65.6553	30.5004	161.1945	74.7948	74.5933	66.7298	35.1811	117.1764
15	-1.4451	-1.5284	-.2737	1.2756	54.2989	-2.6088	-2.6861	-1.5076	.3130	37.3856

TABLE AP 3-3 (Sheet 13 of 13)
OBSERVED TRAJECTORY, POWERED FLIGHT

		S-IVB GUIDANCE CUTOFF			
1	593.3400	536164.2800	5791547.2000	.0040	85.2488
2	24327.5500	25658.7230	83.261	-.0094	85.4958
3	-280041.3	-511452.8	13328269.000	1547307.000	-5589673.100
4	287302.5	400742.0	12561190.7	56045.849	-31181.473
5	5657129.3	6613598.6	11152128.3	1868577.900	-280513.470
6	-6639.206	-7914.051	-18309.063	3188.6397	-18375.468
7	1731.135	1337.393	17893.962	328.6399	-156.065
8	23339.961	24371.075	1718.8527	7605.6022	-1857.658
9	-33.563	.000	.0000	-62.5660	31.5049
10	7.940	.000	.0000	1890.7034	.0000
11	75.066	24327.549	10.9317	.0000	.0007
12	15.8706	-.0000	.0000	.0000	678.3064
13	5870854.1	5904639.1	5403716.4	4685855.1	902341.4
14	74.8081	74.6081	66.8418	35.6773	114.7865
15	-2.7341	-2.8108	-1.6395	.2061	35.4631
		REDUNDANT J-2 CUTOFF - TB4			
1	593.5400	536164.9800	5796290.9000	.0100	85.2580
2	24338.6530	25669.8270	24.717	-.0036	85.5044
3	-281369.7	-513036.1	13324607.200	1548444.700	-5593348.500
4	287648.6	401009.4	12564768.0	56111.608	-31212.696
5	5661798.5	6618273.9	11152472.2	1870099.400	-280885.160
6	-6645.073	-7920.874	-18319.170	3188.3356	-18381.293
7	1732.408	1338.001	17899.658	329.0623	-156.187
8	23349.771	24380.516	1717.6498	7609.0547	-1859.544
9	-31.347	.000	.0000	-62.5508	31.5060
10	4.850	.000	.0000	1890.7069	.0000
11	16.425	24338.651	10.9367	.0000	.0007
12	15.8636	.0000	.0000	.0000	678.3071
13	5875592.7	5909377.0	5408377.1	4689169.2	905673.7
14	74.8093	74.6094	66.8514	35.7199	114.5942
15	-2.7448	-2.8215	-1.6509	.1969	35.3019
1	595.0000	536172.8300	5830943.1000	.0154	85.3220
2	24351.1210	25682.3010	.836	.0017	85.5650
3	-291102.4	-524635.0	13297830.400	1553098.700	-5620216.500
4	290180.8	402963.1	12590895.6	56592.308	-31441.384
5	5895896.4	6653874.8	11154965.0	1881213.300	-283610.190
6	-6685.007	-7965.164	-18354.506	3187.7350	-18423.809
7	1735.400	1337.641	17883.367	329.2251	-157.081
8	23351.149	24379.244	1696.4498	7612.8751	-1873.351
9	-26.411	.000	.0000	-62.4399	31.5138
10	1.509	.000	.0000	1890.7429	.00[illegible]
11	-6.857	24351.119	10.9422	.0000	.0007
12	15.9788	-.0000	.0000	.0000	678.3144
13	5910206.2	5943985.9	5442426.0	4713449.9	930409.2
14	74.8176	74.6187	66.9210	36.0291	113.2536
15	-2.8232	-2.8995	-1.7334	.1296	34.1503
1	600.0000	536207.0400	5949628.2000	.0166	85.5424
2	24352.4040	25683.6060	-.006	.0035	85.7739
3	-324858.9	-564825.3	13205816.900	1569037.400	-5712698.900
4	298876.7	409643.8	12680092.2	58238.491	-32234.499
5	6012560.8	6775657.2	11163248.4	1919279.300	-293096.180
6	-6817.421	-8110.904	-18449.962	3187.6961	-18569.225
7	1742.881	1334.572	17794.173	329.2322	-160.173
8	23313.616	24332.689	1616.7624	7613.2686	-1921.196
9	-26.411	.000	.0000	-62.0601	31.5398
10	1.476	.000	.0000	1890.8978	.0000
11	-7.841	24352.403	10.9422	.0000	.0007
12	16.3040	-.0000	.0000	.0000	678.3457
13	6028743.3	6062506.2	5559086.1	4797561.4	1019758.3
14	74.8457	74.6499	67.1534	37.0646	109.3887
15	-3.0689	-3.1640	-2.0127	-.1005	30.5398
		ORBITAL INSERTION			
1	603.3400	536231.2000	6028911.8000	.0176	85.6898
2	24352.6920	25683.9070	.004	.0048	85.9135
3	-347776.6	-592078.4	13144088.400	1579683.900	-5774881.800
4	304706.0	414097.7	12739424.0	59338.087	-32772.963
5	6090365.3	6856875.2	11168559.3	1944707.900	-299567.040
6	-6905.545	-8207.871	-18512.923	3187.6990	-18666.201
7	1747.802	1332.461	17733.875	329.2263	-162.265
8	23287.599	24300.588	1563.4952	7613.3730	-1953.640
9	-26.378	.000	.0000	-61.8063	31.5565
10	1.476	.000	.0000	1891.0022	.0000
11	-7.940	24352.691	10.9420	.0000	.0007
12	16.5210	-.0000	.0000	.0000	678.3668
13	6107911.8	6141663.3	5637047.7	4854537.2	1082783.5
14	74.8641	74.6703	67.3036	37.7364	107.3040
15	-3.2641	-3.3385	-2.1966	-.2541	28.4024

TABLE AP 3-4 (Sheet 1 of 5)
OBSERVED TR'JECTORY, ORBITAL PHASE

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(1I) PR (DEG.)	GAMMA(2I) 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 * (FT/SEC)	ALPHA SB WIND (DEG.)	MU (DEG.)	RHO (DEG.)
10	DD-Y SB E (FT/SSQ)	E SB * (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.)

ORBITAL INSERTION

1	603.3400	536231.2000	6028911.8000	.0176	85.6898
2	24352.6920	25683.9070	.004	.0048	85.9135
3	-347776.6	-592078.4	13144088.400	1579683.900	-5774881.800
4	304706.0	414097.7	12739424.0	59338.089	-32772.963
5	6090365.3	6856875.2	11168559.3	1944707.900	-299567.040
6	-6905.545	-8207.871	-18512.923	3187.6990	-18666.201
7	1747.802	1332.461	17733.875	329.2263	-162.265
8	23287.599	24300.588	1563.4952	7613.3730	-1953.640
9	-26.378	.000	.0000	-61.8063	31.5565
10	1.476	.000	.0000	1891.0022	.0000
11	-7.940	24352.691	10.9420	.0000	.0007
12	16.5213	-.0000	.0000	.0000	678.3668
13	1082783.5	6790096.2	14533181.0	35863652.0	42260320.0
14	107.3040	286.1779	287.0237	296.3395	329.1712
15	28.4024	-4.7195	-18.0386	-57.4433	-86.2167

1	610.0000	536283.8300	6187005.6000	.0191	85.9840
2	24352.7620	25684.0250	.163	.0070	86.1925
3	-394351.2	-647385.0	13020384.500	1600914.200	-5899841.400
4	316402.1	422981.0	12857138.7	61537.791	-33857.702
5	6245303.5	7018499.4	11178598.7	1995413.200	-312796.700
6	-7061.010	-8400.859	-18637.350	3187.6967	-18859.182
7	1757.539	1328.189	17612.365	329.2149	-166.500
8	23234.206	24234.907	1457.[illegible]531	7613.4238	-2019.488
9	-26.363	.000	.0000	-61.2999	31.5880
10	1.473	.000	.00	1891.2387	.0000
11	-7.987	24352.781	10.941.	.0000	.0007
12	16.9545	-.0000	.0000	.0000	678.4145
13	1214576.1	6637937.9	14382875.1	35779880.0	42253679.0
14	103.9978	286.4228	286.9937	296.4376	326.6088
15	24.7173	-4.3987	-17.7988	-57.2276	-86.0801

START ORBITAL GUIDANCE/NAVIGATION

1	610.7330	536290.0200	6204404.8000	.0192	86.0165
2	24352.8930	25684.1390	.162	.0072	86.2232
3	-399548.6	-653551.0	13006719.600	1603250.600	-5913672.700
4	317690.8	423954.3	12870042.0	61779.097	-33989.917
5	6262331.8	7036260.9	11179662.5	2000993.900	-314279.650
6	-7100.332	-8422.104	-18651.046	3187.6848	-18880.388
7	1758.618	1327.724	17598.993	329.2167	-166.971
8	23228.344	24227.678	1445.3311	7613.4580	-2026.829
9	-26.356	.000	.0000	-61.2441	31.5913
10	1.471	.000	.0000	1891.2659	.0000
11	-8.009	24352.892	10.9412	.0000	.0007
12	17.0022	.0000	.0000	.0000	678.4200
13	1229491.7	6620863.5	14366320.2	35770629.0	42252911.0
14	103.6886	286.4504	286.9904	296.4483	326.3376
15	24.3536	-4.3631	-17.7723	-57.2038	-86.0646

1	630.0000	536463.6400	6661788.2000	.0233	86.8705
2	24355.5390	25686.8530	.136	.0134	87.0328
3	-541231.3	-821183.6	12643935.400	1664664.600	-6282794.900
4	351844.7	449415.3	13205704.4	68122.552	-37328.630
5	6708348.7	7501180.0	11204538.8	2147690.500	-355232.890
6	-7606.350	-8978.140	-19005.763	3187.3879	-19435.450
7	1786.570	1315.124	17242.481	329.2618	-179.719
8	23068.244	24030.770	1136.8126	7614.2791	-2226.430
9	-26.168	.000	.0000	-59.7770	31.6693
10	1.430	.000	.0000	1892.0433	.0000
11	-8.609	24355.538	10.9399	.0000	.0007
12	18.2556	-.0000	.0000	.0000	678.5771
13	1640939.3	6172250.3	13930319.0	35525262.0	42230169.0
14	97.9796	287.2268	286.8985	296.7268	319.9228
15	16.9717	-3.4041	-17.0755	-56.5792	-85.6297

NOSE CONE JETTISON

1	638.5120	536551.3000	6863871.2000	.0252	87.2488
2	24356.5380	25687.8790	.123	.0162	87.3914
3	-606923.4	-898645.0	12481504.500	1691794.900	-6449266.600
4	367103.5	460585.1	13351789.1	70925.311	-38883.208
5	6904390.1	7705343.1	11213634.2	2212504.400	-374575.030
6	-7828.723	-9222.255	-19159.170	3187.2675	-19679.170
7	1798.662	1309.327	17081.944	329.2791	-185.573
8	22993.844	23939.566	1000.2945	7614.5952	-2318.671
9	-26.060	.000	.0000	-59.1281	31.6978
10	1.411	.000	.0000	1892.4350	.0000
11	-8.874	24356.537	10.9391	.0000	.0007
12	18.8094	.0000	.0000	.0000	678.6562
13	1830599.6	5974222.9	13737181.4	35415509.0	42218545.0
14	96.3936	287.6043	286.8554	296.8474	317.4846
15	14.6622	-2.9646	-16.7661	-56.3030	-85.4229

1	650.0000	536680.7100	7136612.3000	.0278	87.7601
2	24356.3970	25687.7710	-.003	.0201	87.8762
3	-698575.8	-1006473.3	12260234.700	1728409.900	-6677222.800
4	387858.5	475580.3	13546764.3	74708.074	-41061.438
5	7167943.5	7979628.3	11224066.3	2299981.100	-401945.220
6	-8127.2[illegible]	-954[illegible].576	-19361.973	3187.2644	-20006.581
7	1814.622	130[illegible].214	16861.496	329.2794	-193.687
8	22886.[illegible]37	23[illegible].176	815.8252	7614.6016	-2447.082
9	-25.921	.000	.0000	-58.2516	31.7305
10	1.376	.000	.0000	1893.0106	.0000
11	-9.332	24[illegible]6.35	10.9371	.0000	.0007
12	19.5569	-.000[illegible]	.0000	.0000	678.7724
13	2091011.5	5707206.8	13476038.9	35266082.0	42201[illegible]28.0
14	94.7561	288.1527	286.7944	297.0080	314.5240
15	12.1225	-2.3536	-16.3470	-55.9301	-85.1325

BEGI. PITCH AT ORBITAL RATE

1	663.8230	5[illegible]7134.1900	7939597.6000	.0353	89.2691
2	24355.7390	256[illegible].1830	-.003	.0314	89.3069
3	-988219.5	-1345638.6	11595529.300	1836212.100	-7370069.600
4	450007.4	5[illegible]9169.1	4105859.5	85845.248	-48034.487
5	7936578.5	[illegible]268.5	11242464.8	2557529.300	-491436.270
6	-8997.713	-10502.904	-19937.614	3187.2725	-20959.835
7	1859.894	1275.906	16194.105	329.2781	-218.990
8	22556.241	23407.104	271.9637	7614.5772	-2851.075
9	-25.540	.000	.0000	-55.6683	31.7877
10	1.300	.000	.0000	1895.0354	.0000
11	-10.321	24355.739	10.9303	.0000	.0007
12	21.7574	.0000	.0000	.0000	679.1813
13	2874331.7	4923650.3	12704149.8	34817540.0	42140436.0
14	91.7919	290.0927	286.5952	297.4669	307.5765
15	6.9286	-.4077	-15.1021	-54.8309	-84.2194

1	700.0000	537389.0500	8323640.4000	.0389	89.9918
2	24355.3790	25686.8440	-.003	.0368	89.9921
3	-1137110.0	-1519188.4	11270854.900	1887772.300	-7712780.400
4	480263.3	539796.3	14365181.9	91172.002	-51680.306
5	8300100.3	9155264.7	11244759.0	2680710.300	-539218.720
6	-9409.432	-10952.831	-20201.473	3187.2767	-21409.776
7	1860.607	1263.064	15865.509	329.2775	-231.830
8	22385.496	23200.306	11.6447	7614.5662	-3057.837
9	-25.354	.000	.0000	-54.4320	31.7945
10	1.261	.000	.0000	1896.1751	.0000
11	-10.768	24355.379	10.9264	.0000	.0007
12	22.8096	-.0000	.0000	.0000	679.4114
13	3253717.2	4550968.2	12333442.0	34598508.0	42105937.0
14	90.9109	291.2461	286.4884	297.6795	304.9728
15	5.1401	.6237	-14.5000	-54.3045	-83.7603

1	750.0000	538331.9400	9510573.9000	.0498	92.2233
2	24354.0770	25685.5530	-.002	.0534	92.1079
3	-1639011.7	-2101102.2	10241289.300	2047134.900	-8817537.500
4	575818.5	601811.8	15132374.6	107635.829	-64319.376
5	9405293.8	10298281.3	11225231.7	3061437.600	-709106.010
6	-10601.220	-12316.765	-20968.848	3187.2910	-22773.757
7	1940.546	1220.416	14813.071	329.2756	-274.472
8	21810.404	22506.789	-792.4804	7614.5317	-3751.240
9	-24.704	.000	.0000	-50.6127	31.7314
10	1.135	.000	.0000	1900.3829	.0000
11	-12.209	24354.076	10.9122	.0000	.0007
12	26.0624	-.0000	.0000	.0000	680.2606
13	4434237.9	3415532.2	11181937.9	33903354.0	41977354.0
14	89.1991	296.3541	286.1012	298.3110	298.8767
15	.9797	4.4748	-12.6068	-52.6749	-82.2834

1	800.0000	539504.6900	10697378.4000	.0606	94.4410
2	24352.4940	25683.9010	-.002	.0697	94.2102
3	-2202657.2	-2750129.8	9175217.600	2206498.000	-9989409.900
4	674208.2	661675.4	15845612.0	124099.542	-79200.004
5	10479973.3	11404607.9	11165560.0	3442163.300	-915677.700
6	-11878.521	-13636.573	-21661.349	3187.3068	-24093.617
7	1993.901	1173.415	13707.994	329.2736	-321.466
8	21165.279	21735.150	-1593.6451	7614.4987	-4524.771
9	-23.975	.000	.0000	-46.8048	31.5417
10	.998	.000	.0000	1905.6153	.0000
11	-13.569	24352.493	10.8946	.0000	.0007
12	29.3145	-.0000	.0000	.0000	681.3158
13	5618722.2	2337630.5	10022781.2	33181195.0	41815691.0
14	88.2588	306.3861	285.6044	298.9086	294.6899
15	-2.1136	10.2452	-10.6509	-51.0415	-80.7519

1	850.0000	540905.4000	11884020.7000	.0712	96.6314
2	24350.6340	25681.8950	-.002	.0857	96.2860
3	-2826223.4	-3463944.9	8076445.000	2365862.500	-11226074.200
4	775090.3	719083.6	16502362.6	140563.190	-96535.764
5	11520690.0	12470307.6	11065964.7	3822887.300	-1162870.900
6	-13057.402	-14907.515	-22276.510	3187.3241	-25364.615
7	2040.158	1122.226	12554.272	329.2717	-372.649
8	20452.271	20882.203	-2388.9572	7614.4672	-5375.615
9	-23.168	.000	.0000	-43.0188	31.2268
10	.851	.000	.0000	1911.8591	.0000
11	-14.924	24350.633	10.8737	.0000	.0006
12	32.5660	-.0000	.0000	.0000	682.5739
13	6802243.9	1458330.0	8857400.6	32432634.0	41621089.0
14	87.6631	331.8318	284.9550	299.4775	291.6338
15	-4.6945	19.9232	-8.6074	-49.4046	-79.1890

TABLE AP 3-4 (Sheet 2 of 5)
OBSERVED TRAJECTORY, ORBITAL PHASE

SLA PANEL DEPLOYMENT

1	900.0000	542531.3600	13070471.6000	.0818	98.7816	1193.5120	556508.3500	20029704.0000	.1420	110.0421
2	24348.5020	25679.5410	-.002	.1014	98.3228	24330.6030	25659.1350	.002	.1825	108.9631
3	-3507693.6	-4239990.6	6948891.600	2525227.400	-12524970.900	-8548052.5	-9890194.0	-32691.825	3460751.000	-21244477.000
4	878097.6	773831.1	17100298.0	157026.670	-116531.657	1503613.7	1031889.3	19326868.0	253669.560	-297229.740
5	12524108.6	13491591.4	10926809.8	4203609.700	-1454475.100	17501584.0	18411090.0	9347966.5	6438513.400	-4241849.700
6	-14194.059	-16125.031	-22812.153	3187.3435	-26582.195	-19832.215	-21978.945	-24272.662	3187.4593	-32436.489
7	2078.831	1067.028	11356.075	329.2698	-427.841	2130.820	673.224	3663.127	329.2596	-821.611
8	19673.757	19957.045	-3175.5481	7614.4375	-6300.674	13932.735	13223.616	-7470.6522	7614.2976	-13033.645
9	-22.286	.000	.0000	-39.2650	30.7892	-15.780	.000	.0000	-18.2795	25.9592
10	.694	.000	.0000	1919.0965	.0000	-.379	.000	.0000	1981.0007	.0000
11	-16.208	24348.501	10.8495	.0000	.0006	-22.537	24330.602	10.6485	.0000	.0005
12	35.8169	-.0000	.0000	.0000	684.0308	54.8808	.0000	.0000	.0000	696.4326
13	7982229.5	1289439.9	7687523.4	31658300.0	41393719.0	14762179.9	7505754.7	1235109.1	26629043.0	39410387.0
14	87.3084	28.1549	284.0830	300.0220	289.2919	66.6214	90.4408	234.0483	302.9299	281.7277
15	-6.9907	23.2855	-6.4364	-47.7640	-77.6064	-18.3149	-5.9748	25.2729	-38.0591	-68.1465

1	950.0000	544379.4700	14256698.8000	.0922	100.8797	1200.0000	556901.6900	20183402.0000	.1433	110.2576
2	24346.1000	25676.8460	-.002	.1166	100.3093	24330.1050	25658.5660	.002	.1841	109.1661
3	-4244864.5	-5075485.3	5796586.200	2684593.400	-13883319.800	-8677055.1	**********	-190170.360	3481430.900	-21455254.000
4	982839.2	825722.6	17637301.0	173490.110	-139383.390	1517430.4	1036225.3	19350056.0	255805.810	-302592.230
5	13487017.2	14464831.4	10748602.6	4584330.500	-1794117.900	17591505.0	18496334.0	9299216.7	6487915.100	-4326963.500
6	-15284.835	-17284.766	-23266.385	3187.3620	-27741.990	-19934.057	-22080.111	-24271.622	3187.4622	-32537.664
7	2109.459	1008.013	10117.740	329.2679	-486.850	2128.277	563.385	3484.632	329.2593	-831.449
8	18832.327	18961.045	-3950.5836	7614.4093	-7296.582	13786.144	13053.378	-7556.9703	7614.2955	-13203.876
9	-21.333	.000	.0000	-35.5523	30.2320	-15.614	.000	.0000	-17.8404	25.8135
10	.529	.000	.0000	1927.3167	.0000	-.405	.000	.0000	1982.7339	.0000
11	-17.439	24346.098	10.8223	.0000	.0006	-22.651	24330.103	10.6430	.0000	.0005
12	39.0669	-.0000	.0000	.0000	685.6838	55.3017	-.0000	.0000	.0000	696.7784
13	9156942.1	2018208.8	6515441.4	30858841.0	41133776.0	14908203.3	7656815.3	1167990.3	26509198.0	39354283.0
14	87.0562	63.6765	282.8679	300.5465	287.4260	86.6193	90.6307	226.7170	302.9917	281.6189
15	-9.1127	13.0035	-4.0693	-46.1200	-76.0109	-18.5465	-6.2651	27.0713	-37.8430	-67.9357

1	1000.0000	546448.7200	15442672.5000	.1026	102.9151	1250.0000	560051.1500	21367632.0000	.1534	111.8623
2	24343.4300	25673.8190	-.002	.1313	102.2349	24326.1200	25654.0200	.002	.1955	110.6768
3	-5035353.9	-5967434.9	4623638.000	2843959.100	-15298122.900	-9692735.7	**********	-1402691.200	3640801.200	-23100827.000
4	1088902.3	874572.2	18111477.0	189953.420	-165276.700	1623254.0	1067475.8	19489791.0	272268.720	-346083.320
5	14406339.2	15386575.2	10531990.5	4965049.900	-2185251.800	18252145.0	19115758.0	8905014.0	6868628.600	-5020398.100
6	-16326.229	-18382.575	-23637.622	3187.3806	-28839.861	-20662.272	-22814.736	-24214.876	3187.4827	-33272.357
7	2131.617	945.388	8843.740	329.2661	-549.468	2102.977	586.253	2103.227	329.2578	-908.576
8	17930.764	17897.825	-4711.2746	7614.3823	-8359.714	12632.548	11716.352	-8206.3998	7614.2778	-14540.844
9	-20.312	.000	.0000	-31.8889	29.5593	-14.307	.000	.0000	-14.4959	24.6419
10	.356	.000	.0000	1936.5060	.0000	-.608	.000	.0000	1993.0573	.0000
11	-18.612	24343.429	10.7921	.0000	.0006	-23.481	24326.120	10.6084	.0000	.0005
12	42.3161	-.0000	.0000	.0000	687.5293	58.5449	-.0000	.0000	.0000	698.9345
13	10325007.6	3057748.8	5344622.1	30034935.0	40841486.0	16026646.8	8819673.7	1323597.2	25574035.0	38904565.0
14	86.8842	76.8317	281.0828	301.0545	285.8917	86.6124	91.8960	161.9761	303.4688	280.8238
15	-11.1204	6.2012	-1.3791	-44.4723	-74.4063	-20.3178	-8.4100	23.3887	-36.1746	-66.3101

1	1050.0000	548736.9700	16628361.0000	.1129	104.8781	1300.0000	563411.8100	22551414.0000	.1633	113.3667
2	24340.4930	25670.4670	.002	.1455	104.0905	24321.8790	25649.2050	.002	.2061	112.0913
3	-5876608.6	-6912645.3	3434228.400	3003325.800	-16766189.800	**********	**********	-2610225.200	3800172.600	-24781110.000
4	1195853.3	920205.0	18521158.0	206416.670	-194386.570	1727557.6	1094815.2	19560265.0	288731.480	-393484.910
5	15279143.3	16253557.7	10277759.7	5345768.000	-2631142.900	18854100.0	19667287.0	8479069.5	7249341.200	-5781725.200
6	-17314.906	-19414.550	-23924.579	3187.4000	-29871.900	-21363.988	-23467.904	-24072.132	3187.5042	-33925.594
7	2144.913	879.375	7538.674	329.2643	-615.476	2067.450	507.001	715.026	329.2562	-987.824
8	16972.123	16771.251	-5454.8877	7614.3575	-9486.207	11439.382	10338.384	-8826.2649	7614.2618	-15918.760
9	-19.225	.000	.0000	-28.2814	28.7757	-12.955	.000	.0000	-11.2203	23.3883
10	.175	.000	.0000	1946.6548	.0000	-.814	.000	.0000	2002.6726	.0000
11	-19.723	24340.492	10.7589	.0000	.0006	-24.233	24321.877	10.5754	.0000	.0005
12	45.5642	-.0000	.0000	.0000	689.5649	61.7866	-.0000	.0000	.0000	700.9930
13	11485231.7	4180304.1	4181336.8	29187282.0	40517098.0	17132238.0	9978528.8	2241181.5	24618988.0	38424408.0
14	86.7677	83.0374	278.2466	301.5498	284.5965	86.6195	92.8986	136.6764	303.9500	280.0945
15	-13.0490	1.9011	1.8960	-42.8210	-72.7950	-22.0688	-10.4319	11.5988	-34.5011	-64.6822

1	1100.0000	551242.7500	17813733.0000	.1231	106.7605	1350.0000	566981.9900	23734716.0000	.1731	114.7683
2	24337.2920	25666.8010	.002	.1590	105.8684	24317.3600	25644.1330	.002	.2158	113.4075
3	-6765913.4	-7907731.2	2232600.600	3162693.100	-18284135.000	**********	**********	-3808481.400	3959545.100	-264[illegible]1970.000
4	1303240.0	962457.2	18864906.0	222879.810	-226876.690	1829826.2	1118145.1	19561264.0	305194.210	-444896.010
5	16102652.4	17062712.0	9986831.0	5726484.900	-3134857.900	19395489.0	20148997.0	8022916.9	7630053.200	-6612868.500
6	-18247.714	-20377.023	-24126.286	3187.4204	-30834.439	-21977.086	-24037.354	-23843.987	3187.5254	-34495.115
7	2148.992	810.206	6207.257	329.2626	-684.639	2021.558	425.908	-674.986	329.2548	-1068.912
8	15959.530	15585.416	-6178.7548	7614.3348	-10671.967	10210.581	8924.452	-9414.3684	7614.2479	-17332.646
9	-16.077	.000	.0000	-24.7350	27.8865	-11.563	.000	.0000	-8.0128	22.0591
10	-.013	.000	.0000	1957.7494	.0000	-1.022	.000	.0000	2012.8573	.0000
11	-20.769	24337.292	10.7230	.0000	.0006	-24.906	24317.379	10.5407	.0000	.0005
12	48.8113	-.0000	.0000	.0000	691.7868	65.0269	-.0000	.0000	.0000	703.1727
13	12636520.6	5331193.7	3039922.1	28316605.0	40160894.0	18224061.0	11131453.2	3341381.9	23644905.0	37914222.0
14	86.6909	86.6164	273.1465	302.0355	283.4790	86.6379	93.7214	127.7551	304.4391	279.4183
15	-14.9206	-1.2909	6.3787	-41.1658	-71.1789	-23.8033	-12.3692	5.2782	-32.8219	-63.0525

1	1150.0000	553964.7200	18998758.0000	.1333	108.5555	1400.0000	570757.4000	24917503.0000	.1827	116.0659
2	24333.8290	25662.8300	.002	.1719	107.5620	24312.6300	25638.8190	.002	.2247	114.6245
3	-7700399.4	-8949132.1	1023031.010	3322061.300	-19848397.000	**********	**********	-4993213.800	4118917.500	-28229168.000
4	1410593.6	1001177.0	19141524.0	239342.850	-262898.800	1929539.1	1137380.2	19492820.0	321656.8[illegible]0	-500401.460
5	16874253.0	17811184.0	9660256.7	6107200.700	-3699252.800	19874632.0	20559217.0	7538196.7	8010763.900	-7515497.400
6	-19121.686	-21266.589	-24242.081	3187.4411	-31724.073	-22519.682	-24521.135	-23531.347	3187.5462	-34978.963
7	2143.539	738.124	4854.283	329.2609	-756.715	1965.208	343.262	-2061.837	329.2536	-1151.554
8	14896.363	14344.625	-6880.2846	7614.3140	-11912.690	8950.189	7479.654	-9968.6344	7614.2359	-18777.404
9	-16.872	.000	.0000	-21.2539	26.8971	-10.135	.000	.0000	-4.6713	20.6604
10	-.206	.000	.0000	1969.7777	.0000	-1.232	.000	.0000	2023.5988	.0000
11	-21.746	24333.829	10.6843	.0000	.0006	-25.496	24312.620	10.5043	.0000	.0005
12	52.0571	-.0000	.0000	.0000	694.1920	68.2655	-.0000	.0000	.0000	705.4708
13	13777841.0	6492603.2	1365386.0	27423654.0	39773179.0	19301224.0	12276905.2	4489555.6	22652662.0	37374439.0
14	86.6438	88.9600	261.8016	302.5151	282.4966	86.6655	94.4157	123.4458	304.9404	278.7853
15	-16.7498	-3.9320	13.8037	-39.5066	-69.5589	-25.5242	-14.2459	1.2284	-31.1361	-61.4210

TABLE AP 3-4 (Sheet 3 of 5)
OBSERVED TRAJECTORY, ORBITAL PHASE

1	1450.0000	574735.4700	26099741.0000	.1922	117.2588	1750.0000	602523.9900	33179734.0000	.2424	122.2341
2	24307.6310	25633.2790	.002	.2327	115.7419	24272.7700	25596.1950	.001	.2603	120.3843
3	**********	**********	-6160278.300	4278289.400	-29988377.000	**********	**********	-12565663.300	5234536.900	-40756452.000
4	2026171.[illegible]	1152450.2	19355215.0	338119.370	-560071.770	2512123.2	1153337.1	17123736.0	436893.360	-1007622.850
5	2029005[illegible]	20896535.0	7026650.1	8391473.900	-8491026.800	21388425.0	21343722.0	3502493.9	10675723.700	************
6	-22996.121	-24917.611	-23135.427	3187.5668	-35375.508	-24235.651	-25412.164	-19115.748	3187.6744	-35870.413
7	1898.354	259.354	-3440.576	329.2523	-1235.457	1280.486	-253.804	-11272.327	329.2465	-1748.597
8	7662.343	6009.194	-10487.1126	7614.2257	-2 247.831	-401.169	-3053.322	-12754.9227	7614.1932	-29310.241
9	-8.677	.000	.0000	-1.7932	19.1985	.439	.000	.0000	15.5704	9.4244
10	-1.442	.000	.0000	2034.8805	.0000	-2.655	.000	.0000	2112.7192	.0000
11	-26.003	24307.630	10.4664	.0000	[illegible]05	-27.229	24272.768	10.2114	.0000	.0004
12	71.5025	-.0000	.0000	.0000	707.8338	90.8666	-.0000	.0000	.0000	724.5177
13	20362851.0	13413565.9	5653840.1	21643165.0	36805519.0	26359570.0	19987883.0	12616074.7	15279761.9	32808744.0
14	86.7006	95.0152	120.9410	305.4586	278.1874	87.0115	97.5286	115.7500	309.3336	275.0463
15	-27.2339	-16.0775	-1.8454	-29.4430	-59.7880	-37.3312	-20.5511	-14.6734	-19.0451	-49.9589

1	1500.0000	578910.7000	27281396.0000	.2315	118.3469	1800.0000	607730.2500	34357270.0000	.2491	122.7071
2	24302.3870	25627.5270	.002	.2397	116.7598	24266.2400	25589.5480	.001	.2615	120.8237
3	**********	**********	-7305393.700	4437661.200	-31765199.000	**********	**********	-13498703.400	5393915.300	-42544496.000
4	2119199.5	1163299.5	19148979.0	354561.850	-623962.610	2572750.7	1138534.5	16530223.2	453355.430	-1097164.200
5	20640478.0	21159797.0	6490112.3	8772183.100	-9540609.300	21334363.0	21153494.0	2858922.9	11056430.300	************
6	-23386.993	-25225.466	-22657.738	3187.5866	-35683.428	-24175.291	-25178.909	-18195.014	3187.6889	-35637.207
7	1821.003	174.483	-4806.280	329.2511	-1320.325	1143.373	-338.134	-12461.080	329.2456	-1832.924
8	6351.264	4518.356	-10967.9881	7614.2173	-21738.642	-1760.430	-4553.376	-12980.2927	7614.1898	-30810.283
9	-7.194	.000	.0000	1.2251	17.6793	1.974	.000	.0000	18.3250	7.6794
10	-1.652	.000	.0000	2046.6858	.0000	-2.840	.000	.0000	2127.1115	.0000
11	-26.425	24302.386	10.4269	.0000	.0004	-27.126	24266.239	10.1655	.0000	.0003
12	74.7378	-.0000	.0000	.0000	710.4080	94.1106	-.0000	.0000	.0000	727.5918
13	21408083.0	14540253.9	6823073.2	20617358.0	36207942.0	27289436.0	21033625.0	13751435.6	14178714.2	32050661.0
14	86.7419	95.5425	119.3126	305.9995	277.6184	87.0735	97.8451	115.4004	310.2182	274.5629
15	-28.9339	-17.8749	-4.4268	-27.7415	-58.1535	-38.9956	-28.2473	-16.5041	-17.2476	-48.3152

1	1550.0000	583278.8100	28462435.0000	.2104	119.3304	1850.0000	613070.2600	35533962.0000	.2551	123.0807
2	24296.9060	25621.5790	.002	.2458	117.6788	24255.5420	25582.8230	.001	.2617	121.1703
3	**********	**********	-8424669.900	4597034.600	-33555182.000	**********	**********	-14384106.800	5553294.200	-44318656.000
4	2208098.1	1169887.4	18874884.0	371044.290	-692114.750	2626279.4	1119542.5	15878375.2	469817.470	-1190894.800
5	20924861.0	21346120.0	5930506.1	9152892.200	************	21212503.0	20888672.0	2205233.1	11437137.000	************
6	-23709.129	-25443.710	-22100.086	3187.6057	-35901.733	-24038.414	-24856.944	-17210.788	3187.7035	-35315.289
7	1733.210	88.946	-6154.098	329.2501	-1405.858	996.602	-421.325	-13604.982	329.2449	-1916.113
8	5021.237	3012.435	-11409.5856	7614.2104	-23244.490	-3112.368	-6036.198	-13159.5640	7614.1882	-32293.101
9	-5.689	.000	.0000	4.1875	16.1087	3.499	.000	.0000	21.0540	5.9149
10	-1.860	.000	.0000	2058.9945	.0000	-3.017	.000	.0000	2141.8106	.0000
11	-26.761	24296.905	10.3861	.0000	.0004	-26.957	24259.541	10.1191	.0000	.0003
12	77.9713	-.0000	.0000	.0000	713.0392	97.3326	-.0000	.0000	.0000	730.7313
13	22436082.0	15655878.3	7992029.9	19576216.0	35582216.0	28197414.0	22062708.0	14876160.0	13069739.6	31267939.0
14	86.7865	96.0136	118.1723	306.5696	277.0729	87.1371	98.1441	115.1027	311.2262	274.0835
15	-30.6258	-19.6455	-6.7279	-26.0301	-56.5176	-40.6562	-29.9352	-18.3015	-15.4192	-46.6695

1	1600.0000	587832.2000	29642824.0000	.2191	120.2100	1900.0000	618528.0800	36709836.0000	.2604	123.3557
2	24291.1930	25615.4530	.002	.2509	118.4996	24252.6930	25576.0410	.001	.2609	121.4251
3	**********	**********	-9514105.000	4756408.100	-35353823.000	**********	**********	-15218784.100	5712673.700	-46074528.000
4	2292348.2	1172188.0	18533947.0	387506.630	-764553.830	2672266.6	1096425.7	15170538.3	486279.520	-1288750.400
5	21142358.0	21460885.0	5349833.9	9533601.000	************	21023320.0	20550249.0	1543744.3	11817842.900	************
6	-23955.610	-25571.675	-21464.562	3187.6241	-36029.760	-23825.589	-24447.542	-16166.654	3187.7157	-34905.927
7	1635.061	3.046	-7479.242	329.2491	-1491.755	841.475	-503.087	-14700.049	329.2442	-1997.872
8	3676.597	1496.972	-11810.3768	7614.2051	-24759.986	-4452.679	-7496.567	-13292.1700	7614.1877	-33753.468
9	-4.168	.000	.0000	7.0983	14.4924	5.011	.000	.0000	23.7628	4.1360
10	-2.065	.000	.0000	2071.7799	.0000	-3.166	.000	.0000	2156.7696	.0000
11	-27.010	24291.193	10.344[illegible]	.0000	.0004	-26.601	24252.692	10.0722	.0000	.0003
12	81.2029	-.0000	.0000	.0000	715.7715	100.5525	-.0000	.0000	.0000	733.9265
13	23446025.0	16759413.8	9157673.3	18520769.0	34928870.0	29062798.0	23074299.0	15989219.4	11954627.8	30461237.0
14	86.8594	96.4402	117.3303	307.1768	276.5464	87.2018	98.4284	114.8445	312.3954	273.6060
15	-32.3106	-21.3948	-8.6552	-24.3073	-54.8802	-42.3134	-31.6157	-20.0728	-13.5512	-45.0218

1	1650.0000	592564.0900	30822532.0000	.2273	120.9865	1950.0000	624088.8500	37884875.0000	.2649	123.5328
2	24285.2600	25609.1680	.002	.2550	119.2234	24245.7130	25569.2250	.001	.2592	121.5888
3	**********	**********	-10569866.000	4915783.200	-37156602.000	**********	**********	-15999835.300	5872053.600	-47807778.000
4	2371436.5	1170191.0	18127418.0	403968.980	-841290.550	2710290.2	1069262.5	14409248.7	502741.520	-1390652.200
5	21292350.0	21497747.0	4750171.5	9914309.600	************	207[illegible]7500.0	20139475.0	876800.5	12198549.200	************
6	-24125.763	-25609.025	-20753.533	3187.6416	-36067.167	23537.628	-23952.284	-15066.394	3187.7270	-34410.706
7	1526.771	-82.914	-8777.026	329.2482	-1577.[illegible]	678.140	-593.133	-15742.488	329.2435	-2077.916
8	2321.717	-22.772	-12168.9844	7614.2016	-262[illegible]	-57[illegible]7.092	-8929.356	-13377.7127	7614.1880	-35186.258
9	-2.637	.000	.0000	9.9623	12.8561	6.5[illegible]	.000	.0000	26.4572	2.3472
10	-2.267	.000	.0000	2085.0179	[illegible]	-3.3[illegible]	.000	.0000	2171.2050	.0000
11	-27.171	24285.259	10.3008	.0000	.0004	-26.[illegible]	24245.712	10.0266	.0000	.0003
12	84.4327	-.0000	.0000	.0000	718.6[illegible]	[illegible]	-.0000	.0000	.0000	737.0464
13	24437107.0	17849882.0	10317922.7	17452095.0	34248456.0	29[illegible]	24067584.0	17089634.0	10835544.9	29631237.0
14	86.8940	96.8308	116.6829	307.8312	276.035[illegible]	[illegible].2674	98.7000	114.6164	313.7794	273.1281
15	-33.9693	-23.1269	-10.8674	-22.5708	-53.24[illegible]	[illegible]3.9676	-33.2900	-21.8231	-11.6317	-43.3718

1	1700.0000	597464.6400	32001527.0000	.2351	121.6609	[illegible]00.0000	629733.6300	39059058.0000	.2685	123.6125
2	24279.1140	25602.7420	.001	.2582	119.8513	[illegible]238.6240	25562.3990	.001	.2565	121.6618
3	**********	**********	-11588244.300	5075159.700	-38958988.000	**********	**********	-16724554.600	6631434.000	-49514158.000
4	2444859.0	1163900.8	17656776.0	420431.220	-922320.070	2739952.0	1038145.7	13597226.4	519203.490	-1496507.500
5	21374433.0	21458627.0	4133658.9	10295017.200	************	20445946.0	19657856.0	206761.3	12579255.800	************
6	-24219.167	-25555.748	-19969.632	3187.6585	-36013.946	-23175.579	-23373.049	-13913.974	3187.737[illegible]	-33831.505
7	1408.467	-168.531	-10042.873	329.2474	-1663.426	507.089	-661.184	-16728.704	329.2430	-2155.965
8	960.989	-1541.335	-12484.1869	7614.1973	-27798.267	-7081.402	-10329.552	-13415.9629	7614.1887	-36586.457
9	-1.099	.000	.0000	12.7846	11.1449	7.974	.000	.0000	29.1426	.5533
10	-2.464	.000	.0000	2098.6757	.0000	-3.495	.000	.0000	2180.8401	.0000
11	-27.244	24279.113	10.2565	.0000	.0004	-25.858	24238.622	9.9920	.0000	.0003
12	87.6606	-.0000	.0000	.0000	721.5179	106.9864	-.0000	.0000	.0000	739.3881
13	25408544.0	16926341.0	11471172.1	16371344.6	33541549.0	30783053.0	25041771.0	18176462.0	9715246.7	28778640.0
14	86.9515	97.1920	116.1690	308.5448	275.5362	87.3334	98.9606	114.4117	315.4557	272.6476
15	-35.6626	-24.8449	-12.7994	-20.8180	-51.6010	-45.6190	-34.9588	-23.5564	-9.6436	-41.7192

Appendix 3
Observed Trajectory (AA83)

TABLE AP 3-4 (Sheet 4 of 5)
OBSERVED TRAJECTORY, ORBITAL PHASE

1	2050.0000	635442.8200	40232372.0000	.2712	123.5949	2350.0000	669818.9200	47253532.0000	.2641	121.4424
2	24231.4490	25555.5850	.001	.2530	121.6445	24168.1510	25516.3480	.001	.2137	119.6362
3	**********	**********	-17390433.000	6190814.400	-51189522.000	**********	**********	-20037273.000	7147084.300	-60374447.000
4	2760879.4	1003181.8	12737371.8	535665.420	-1606209.700	2685904.0	720203.7	6755117.0	634435.720	-2337613.500
5	20059764.0	19107144.0	-464006.3	12959962.200	************	16472602.0	14479299.9	-4372563.7	15244185.900	************
6	-22740.724	-22712.014	-12713.541	3187.7463	-33170.499	-18701.979	-17183.781	-4752.217	3187.7813	-27642.381
7	328.858	-736.969	-17655.310	329.2425	-2231.749	-856.435	-1130.051	-21802.546	329.2404	-2624.824
8	-8361.465	-11692.274	-13406.8602	7614.1898	-37949.182	-15315.652	-18828.827	-12375.3586	7614.2050	-45085.784
9	9.416	.000	.0000	31.8248	-1.2411	17.241	.000	.0000	48.1614	-11.7574
10	-3.633	.000	.0000	2190.5319	.0000	-4.185	.000	.0000	2247.7379	.0030
11	-25.332	24231.447	9.9572	.0000	.0003	-20.597	24188.150	9.7545	.0000	.0002
12	1[illegible]0.2003	-.0000	.0000	.0000	741.7492	129.4408	-.0000	.0001	.0000	755.6080
13	31596611.0	25996087.0	19248791.0	8597457.3	27904171.0	35928112.0	31264076.0	25330383.0	2774875.3	22241107.0
14	87.3995	99.2117	114.2249	317.5420	272.1622	87.7772	100.5767	113.2961	6.6491	269.0007
15	-47.2678	-36.6228	-25.2756	-7.5615	-40.0638	-57.1183	-46.5311	-35.3951	10.1904	-30.0445

1	2100.0000	641197.2000	41404805.0000	.2729	123.4802	2399.9999	675336.9900	48420572.0000	.2586	120.738
2	24224.2140	25548.8090	.001	.2485	121.5370	24181.1630	25510.3140	.001	.2045	118.979
3	**********	**********	-17995180.000	6350195.600	-52829842.000	**********	**********	-20239701.000	7306459.600	-61727996.000
4	2772727.7	964490.9	11832741.1	552127.350	-1719638.900	2637832.2	662356.3	5653810.2	650897.360	-2470198.300
5	19610269.0	18489332.0	-1133137.1	13340667.800	************	15681494.9	13513123.1	-4983298.5	15624890.300	************
6	-22234.568	-21971.631	-11469.390	3187.7544	-32430.143	-17811.425	-16033.231	-3342.704	3187.7845	-26491.842
7	144.023	-810.225	-18519.142	329.2420	-2305.003	-1066.768	-1183.183	-22236.770	329.2402	-2677.955
8	-9613.312	-13012.787	-13350.5119	7614.1914	-39269.700	-16320.071	-19806.861	-12046.9315	7614.2084	-46063.829
9	10.623	.000	.0000	34.5093	-3.0313	18.371	.000	.0000	50.9755	-13.424
10	-3.759	.000	.0000	2200.2432	.0000	-4.225	.000	.0000	2256.7377	.000
11	-24.728	24224.213	9.9225	.0000	.0003	-19.570	24181.181	9.7230	.0000	.000
12	113.4122	-.0000	.0001	.0000	744.1207	132.6404	-.0000	.0001	.0000	758.040
13	32384953.0	26929782.0	20305739.0	7487569.5	27008568.0	36553293.0	32059413.0	26277712.0	2532405.6	21235564.0
14	87.4654	99.4545	114.0519	320.2232	271.6696	87.8327	100.7879	113.1433	32.9053	268.400
15	-48.9144	-38.2824	-26.9830	-5.3474	-38.4051	-58.7543	-48.1730	-37.0594	12.0295	-28.353

1	2150.0000	646973.6500	42576348.0000	.2735	123.2684	2450.0000	680724.3500	49586703.0000	.2518	119.933
2	24216.9470	25542.0940	.001	.2431	121.3392	24174.3720	25504.4900	.001	.1946	118.227
3	**********	**********	-18536718.000	6509577.300	-54431219.000	**********	**********	-20371360.000	7465836.700	-63022625.000
4	2775181.8	922205.7	10886552.3	568589.080	-1836661.800	2579200.3	601953.2	4532740.0	667358.990	-2605338.800
5	19098970.0	17806645.0	-1798274.8	13721371.000	************	14841476.1	12499780.7	-5576556.8	16005595.200	************
6	-21658.839	-21154.628	-10185.963	3187.7622	-31613.165	-16865.824	-14827.427	-1922.541	3187.7892	-25286.054
7	-46.801	-880.698	-19317.264	329.2416	-2375.474	-1278.711	-1232.248	-22592.962	329.2401	-2727.019
8	-10832.959	-14286.521	-13247.1919	7614.1930	-40543.439	-17271.628	-20714.922	-11676.5136	7614.2116	-46971.902
9	12.198	.000	.0000	37.2018	-4.8128	19.443	.000	.0000	53.8297	-15.053
10	-3.872	.000	.0000	2209.9383	.0000	-4.250	.000	.0000	2265.4765	.000
11	-24.046	24216.945	9.8880	.0000	.0002	-18.463	24174.371	9.6925	.0000	.000
12	116.6220	-.0000	.0001	.0000	746.4942	135.8379	-.0000	.0001	.0000	760.213
13	33147475.0	27842126.0	21346444.0	6394047.4	26092599.0	37149515.0	32829446.0	27204073.0	2819389.8	20214749.0
14	87.5306	99.6901	113.8891	323.8058	271.1672	87.8844	100.9962	112.9944	58.7115	267.767
15	-50.5588	-39.9383	-28.6804	-2.9423	-36.7428	-60.3890	-49.8128	-38.7192	10.1530	-26.654

1	2200.0000	652748.1300	43746995.0000	.2729	122.9592	2500.0000	685953.6300	50751916.0000	.2438	119.028
2	24209.6760	25535.4660	.001	.2369	121.0507	2416[illegible].7[illegible]50	25498.8990	.001	.1842	117.381
3	**********	**********	-19013197.000	6668955.600	-55989878.000	**********	**********	-20431860.000	7625214.000	-64255670.000
4	2767958.6	876471.6	9902156.9	585050.740	-1957133.300	2509947.9	539202.1	3395832.9	683820.610	-2742827.200
5	18527572.0	17061533.0	-2457080.6	14102074.500	************	13955261.1	11442848.1	-6150272.4	16386299.900	************
6	-21015.475	-20263.992	-8867.822	3187.7688	-30722.550	-15868.205	-13570.635	-496.668	3187.7927	-24029.273
7	-242.961	-948.143	-20046.984	329.2413	-2442.919	-1491.447	-1277.078	-22869.997	329.2399	-2771.849
8	-12016.621	-15509.086	-13097.3382	7614.1955	-41766.012	-18167.444	-21549.961	-11265.4546	7614.2148	-47806.950
9	13.530	.000	.0000	39.9078	-6.5809	20.452	.000	.0000	56.7286	-16.640
10	-3.972	.000	.0000	2219.5750	.0000	-4.257	.000	.0000	2273.9120	.000
11	-23.289	24209.67[illegible]	9.8538	.0000	.0002	-17.341	24167.755	9.6631	.0000	.000
12	119.8297	-.0000	.0001	.0000	748.8595	139.0332	-.0000	.0001	.0000	762.317
13	33883598.0	28732406.0	22370068.0	5331385.1	25157047.0	37716337.0	33573589.0	28108747.0	3507361.7	19179622.0
14	87.5949	99.9193	113.7338	328.8250	270.6525	87.9316	101.2020	112.8418	76.7179	267.094
15	-52.2013	-41.5908	-30.3693	-.2547	-35.0762	-62.0224	-51.4508	-40.3749	6.5264	-24.943

1	2249.9999	658497.7100	44916743.0000	.2712	122.5521	2550.0000	690997.4300	51916132.0000	.2344	118.021
2	24202.4320	25528.9490	.001	.2299	120.6712	24161.3670	25493.5640	.001	.1731	116.439
3	**********	**********	-19422999.000	6828332.200	-57502227.000	**********	**********	-20421021.000	7784589.400	-65424688.000
4	2750808.1	827445.7	8883034.5	601512.390	-2080896.600	2430056.3	474318.5	2247073.4	700282.190	-2882447.900
5	17897968.0	16256659.9	-3107242.9	14482778.600	************	13025705.5	10346048.0	-6702449.6	16767004.000	************
6	-20306.619	-19302.955	-7519.631	3187.7745	-29761.533	-14821.749	-12267.282	929.961	3187.7952	-22725.928
7	-443.771	-1012.329	-20705.856	329.2409	-2507.104	-1704.140	-1317.520	-23067.025	329.2398	-2812.291
8	-13160.622	-16676.283	-12901.5501	7614.1987	-42933.220	-19004.824	-22309.186	-10815.2397	7614.2188	-48566.189
9	14.817	.000	.0000	42.6327	-8.3308	21.396	.000	.0000	59.6767	-18.17[illegible]
10	-4.058	.000	.0000	2229.1148	.0000	-4.248	.000	.0000	2282.0058	.000
11	-22.460	24202.431	9.8201	.0000	.0002	-16.146	24161.366	9.6349	.0000	.000
12	123.0355	-.0000	.0001	.0000	751.2071	142.2264	-.0000	.0001	.0000	764.34[illegible]
13	34592[illegible]65.0	29599933.0	23375794.0	4326827.4	24202722.0	38253339.0	34291279.0	2[illegible]1037.0	4410912.5	18131194.0
14	87.6577	100.1430	113.5836	336.2637	270.1222	87.9730	101.4059	112.6840	87.9254	266.37[illegible]
15	-53.8419	-43.2402	-32.0507	2.8452	-33.4048	-63.6547	-53.0871	-42.0270	3.0294	-23.221

1	2300.0000	664196.6200	46085589.0000	.2683	122.0467	2600.0000	695828.6000	53079497.0000	.2237	116.912
2	24195.2460	25522.5680	.001	.2222	120.1999	24155.2420	25488.5090	.001	.1615	115.401
3	**********	**********	-19764739.000	6987708.200	-58964835.000	**********	**********	-20338933.000	7943966.800	-66527476.000
4	2723515.9	775296.6	7832787.9	617974.070	-2207783.200	2339548.8	407525.5	1090475.2	716743.740	-3023978.100
5	17212230.0	15394894.3	-3746482.8	14863482.300	************	12055794.6	9213235.2	-7231170.7	17147709.000	************
6	-19534.612	-18274.988	-6146.154	3187.7782	-28733.578	-13729.769	-10921.940	2352.415	3187.7975	-21380.594
7	-648.512	-1073.035	-21291.687	329.2407	-2567.808	-1915.938	-1353.437	-23183.472	329.2396	-2848.207
8	-14261.427	-17784.120	-12660.5859	7614.2016	-44041.067	-19781.262	-22990.075	-10327.4833	7614.2228	-49247.091
9	16.055	.000	.0000	45.3822	-10.0579	22.272	.000	.0000	62.6782	-19.663
10	-4.129	.000	.0000	2238.5162	.0000	-4.221	.000	.0000	2289.7191	.000
11	-21.561	24195.245	9.7869	.0000	.0002	-14.904	24155.241	9.6082	.0000	.000
12	126.2391	-.0000	.0001	.0000	753.5267	145.4171	-.0000	.0001	.0000	766.274
13	35274440.0	30444040.0	24362826.0	3436079.2	23230456.0	38760125.0	34981972.0	29850263.0	5421169.7	17070534.0
14	87.7187	100.3619	113.4363	347.9437	269.5729	88.0075	101.5085	112.5195	95.0779	265.59[illegible]
15	-55.4809	-44.8869	-33.7257	6.4583	-31.7279	-65.2659	-54.7218	-43.6758	.0095	-21.484

TABLE AP 3-4 (Sheet 5 of 5)
OBSERVED TRAJECTORY, ORBITAL PHASE

1	2650,0000	700420,2100	54241766,0000	,2118	115,7021	3000,0000	723817,7100	62312660,0000	,0974	104,5014
2	24149,4130	25483,7540	...	,1495	114,2670	24119,5570	25460,4640	,001	,0550	103,7225
3	**********	**********	-20185930,000	8103345,100	-67562048,000	**********	**********	-17207608,000	9218985,900	-72778501,000
4	2238491,7	339052,3	-69926,5	733205,360	-3167188,500	1250401,3	-167029,0	-7961703,6	848434,380	-4196423,400
5	11048633,8	8048383,9	-7734601,1	17526413,000	***********	3236949,6	-650232,7	-10416630,5	20193312,000	***********
6	-12595,710	-9539,312	3765,789	3187,7989	-19977,971	-3769,622	768,476	13005,996	3187,7952	-9690,170
7	-2125,961	-1384,706	-23219,038	329,2396	-2879,476	-3473,867	-1466,493	-21235,217	329,2395	-2961,262
8	-20494,449	-23590,377	-9803,9226	7614,2263	-49847,404	-23565,312	-254 6,576	-5305,1737	7614,2467	-51663,669
9	23,078	,000	,0000	65,7366	-21,0898	26,606	,000	,0000	88,9052	-28,9413
10	-4,178	,000	,0000	4593,8285	,0000	-3,364	,000	,0000	2333,6412	,0000
11	-13,617	24149,412	4,7915	,0000	,0003	-3,726	24119,557	9,4569	,0000	,0001
12	148,6053	-,0000	,0001	,0000	1536,2144	170,7468	-,0000	,0001	,0000	777,3797
13	39236324,0	35645147,0	30685765,0	6485997,7	15998791,2	41666887,0	39477693,0	35818670,0	14256877,9	8320765,8
14	88,0333	101,8103	112,3467	99,9100	264,7402	87,6467	103,2653	110,7407	112,7200	254,1647
15	-66,9162	-56,3551	-45,3215	-2,6264	-19,7285	-78,3055	-67,7577	-56,7714	-16,8140	-6,3305

BEGIN INERTIAL ATTITUDE HOLD

1	2700,0000	704747,4200	55402891,0000	,1987	114,3902	3000,0430	723819,4900	62313628,0000	,0974	104,4998
2	24143,9160	25479,3200	,001	,1370	113,0361	24119,5550	25460,4 20	,001	,0550	103,7209
3	**********	**********	-19962587,000	8262723,100	-68526654,000	**********	**********	-17207048,000	9219122,800	-72778917,000
4	2126994,4	269134,2	-1230080,6	749666,880	-3311843,600	1250252,1	-167092,0	-7962616,0	848448,520	-4196550,700
5	10007439,1	6855573,7	-8210996,9	17909118,000	***********	3235937,0	-651324,4	-10416658,5	20193639,000	***********
6	-11423,127	-8124,213	5165,213	3187,8000	-18582,875	-3768,478	769,768	13007,024	3187,7951	-9688,878
7	-2333,399	-1411,219	-23173,698	329,2395	-2905,988	-3474,032	-1466,468	-21234,741	329 2 5	-2961,257
8	-21142,281	-24108,119	-9246,4118	7614,2292	-50365,156	-23565,472	-25406,536	-5304,5496	7614,2467	-51663,659
9	23,813	,000	,0000	68,8555	-22,4512	26,606	,000	,0000	88,9083	-28,9420
10	-4,116	,000	,0000	2303,8554	,0000	-3,363	,000	,0000	2333,6440	,0000
11	-12,290	24143,914	9,5593	,0000	,0002	-3,724	24119,554	9,4569	,0000	,0001
12	151,7906	-,0000	,0001	,0000	769,8302	170,7495	,0000	,0001	,0000	777,3803
13	39681565,0	36280305,0	31456904,0	7579753,7	14917216,7	41687090,0	39476073,0	35819419,0	14257824,9	8319824,6
14	88,0483	102,0119	112,1640	103,3548	263,7984	87,6465	103,2655	110,7405	,7207	254,1624
15	-68,5455	-57,9871	-46,9644	-4,9974	-17,9508	-78,3069	-67,7591	-56,7728	-16,8156	-6,3287

1	2750,0000	708783,4200	56562689,0000	,1843	112,9780	3050,0000	725660,2500	63421778,0000	,0776	102,5547
2	24136,7790	25475,2280	,001	,1240	111,7097	24117,1790	25458,7480	,001	,0406	101,8834
3	**** *****	**********	-19669721,000	8422100,800	-69419795,000	**********	**********	-16527795,900	9378363,500	-...5410,000
4	2005210,1	198011,2	-2385949,8	766128,440	-3457703,700	1072551,5	-240164,7	-9009021,9	864895,420	-4344294,500
5	8935526,8	5636976,2	-8658709,0	18289816,000	***********	2054645,7	-1918649,3	-10663587,2	20574012,000	***********
6	-10215,604	-6681,555	6545,889	3187,8000	-17140,216	-2454,355	2209,967	14178,519	3187,7933	-8188,673
7	-2537,316	-1432,836	-23047,699	329,2394	-2927,656	-3638,594	-1458,092	-20645,345	329,2395	-2952,862
8	-21722,857	-24541,616	-8656,9148	7614,2322	-50798,663	-23714,449	-25315,393	-4570,2544	7614,2485	-51572,493
9	24,473	,000	,0000	72,0367	-23,7422	26,791	,000	,0000	92,4611	-29,6912
10	-4,038	,000	,0000	2310,2102	,0000	-3,202	,000	,0000	2336,4872	,0000
11	-10,927	24136,778	9,5374	,0000	,0002	-2,239	24117,178	9,4472	,0000	,0001
12	154,9723	-,0000	,0001	,0000	771,4343	173,7692	-,0000	,0001	,0000	778,1052
13	40095583,0	36886969,0	32283062,0	8688696,4	13827204,4	41907789,0	39904592,0	36443274,0	15354481,9	7232264,6
14	88,0498	102,2141	111,9694	105,9219	262,7447	87,3901	103,4934	110,4227	113,4851	251,0692
15	-70,1740	-59,6179	-48 6047	-7,1876	-16,1455	-79,9297	-69,3835	-58,3983	-18,6043	-4,0550

1	2800,0000	712505,7900	57720840, 00	,1689	111,4671	3099,9999	727077,7000	64430355,0000	,0571	100,5403
2	24134,0380	25471,4940	,001	,1108	110,2890	24115,3370	25457,4690	,001	,0261	99,9788
3	**********	**********	-19308389,000	8581477,100	-70240215,000	**********	**********	-15790580,200	9537740,900	-73597425,000
4	1873335,8	125927,6	-3533515,5	782589,600	-3604523,200	886 9,6	-312754,7	-10025045,7	881356,630	-4491620,500
5	7836302,7	4302839,8	-9076189,8	18670514,000	***********	866746,6	-3180306,6	-10873393,0	20954711,000	***********
6	-8977,134	-5216,330	7903,091	3187,7997	-15674,791	-1111,849	3763,290	15301,558	3187,7909	-6695,342
7	-2736,858	-1449,632	-22841,559	329,2394	-2944,402	-3793,827	-1444,670	-19983,694	329,2395	-2939,439
8	-22234,488	-24889,466	-8037,4987	7614,2353	-51146,522	-23769,076	-25136,296	-3819,5653	7614,2509	-51393,404
9	25,057	,000	,0000	75,2822	-24,9572	26,895	,000	,0000	96,0686	-30,3326
10	-3,941	,000	,0000	2316,0461	,0000	-3,005	,000	,0000	2338,6733	,0000
11	-9,533	24134,036	9,5173	,0000	,0001	-,746	24115,336	9,4397	,0000	,0001
12	158,1497	-,0000	,0001	,0000	772,9104	176,5558	-,0000	,0001	,0000	778,6631
13	40478017,0	37464084,0	33043639,0	9804752,4	12730350,0	42095805,0	40300269,0	37038935,0	16442515,6	6164572,8
14	88,0338	102,4175	111,7612	107,9043	261,5486	86,9955	103,7326	110,0708	114,1462	246,9513
15	-71,8017	-61,2476	-50,2425	-9,2521	-14,3055	-81,5531	-71,0087	-60,0231	-20,3706	-1,5663

1	2850,0000	715890,6000	58877771,0000	,1524	109,8601	3150,0000	728061,7800	64832042,0000	,0362	98,4672
2	24129,7180	25468,1360	,001	,0972	108,7764	24114,0430	2 ,6340	,001	,0115	98,0177
3	**********	**********	-18879801,000	8740854,000	-70986915,000	**********	****** ***	-14998529,300	9697117,500	-73895083,000
4	1731611,9	53130,9	-4668783,6	799050,750	-3752055,600	693339,9	-384548,7	-11006254,9	897817,790	-4638150,300
5	6713251,8	3151476,0	-9461 ,3	19051214,000	***********	-323017,3	-4430824,1	-11045323,8	21335411,000	***********
6	-7711,3 6	-3733 596	9242,175	3187,7983	-14192,252	233,799	5243,342	16371,295	3187,7887	-5215,283
7	-2951,150	-1401 00	-22556,064	329,2395	-2956,169	-3936,792	-1426,267	-19253,149	329,2396	-2921,037
8	-22675,898	-25156,358	-7390,3257	7614,2384	-51407,625	-23769,038	-24869,930	-3055,6840	7614,2536	-51127,046
9	25,563	,000	,0000	78,5926	-26 3902	26,917	,000	,0000	-260,2787	-30,8619
10	-3,828	,000	,0000	2321,3322	,0000	-2,741	,000	,0000	2340,1865	,0000
11	-8,1 1	24129,717	9,4992	,0000	,0001	,7 7	24114,042	9,4345	,0000	,0001
12	161,3210	-,0000	,0001	,0000	774,2502	177,6589	-,0000	,0001	,0000	779,0495
13	40828608,0	38013013,0	33778056,0	10922750,2	11628543,4	42250802,0	40064426,0	37605401,0	17519673,0	5134952,4
14	87,9951	102,6232	111,5369	109,4797	260,1678	86,3644	103,9869	109,6792	114,7231	241,2054
15	-73,4287	-62,8764	-51,8780	-11,2266	-12,4208	-83,1752	-72,6334	-61,6458	-22,1175	1,2302

1	2900,0000	718916,4700	60029400,0000	,1349	108,1603	3200,0000	728631,4300	64077455,0000	,0150	96,3460
2	24125,8490	25465,1690	,001	,0833	107,1748	24113,31	25456,2480	,001	-,0030	96,0099
3	**********	**********	-18385717,000	8900231,100	-71659148,000	**********	**********	-14154309,500	9856494,400	-74119175,000
4	1580322,7	-20128,7	-5787814,6	815511,930	-3700051,100	493004,6	-455299,2	-11949247,9	914278,980	-4783636,700
5	5569927,7	18897 ,9	-9814797,3	19431914,000	***********	-1510913,8	-5065860,5	-11178785,3	21716113,000	***********
6	-6422,158	-2 457	10528,610	3187,7975	-12697,110	1578,468	6705,669	17384,095	3187,7860	-3753,547
7	-3119,324	-1. . ,146	-22192,261	329,2394	-2962,916	-4072,721	-1402,940	-18455,619	329,2396	-2897,710
8	-23045,228	-25524,074	-6717,6472	7614,2415	-51581,150	-23714,406	-24517,227	-2281,2306	7614,2558	-50774,351
9	25,991	,000	,0000	81,9678	-27,1356	26,857	,000	,0000	-256,5884	-31,2750
10	-3,697	,000	,0000	2326,0430	,0000	-2,563	,000	,0000	2341,0169	,0000
11	-6,667	24125,847	9,4830	,0000	,0001	2,237	24113,309	9,4317	,0000	,0001
12	164,4631	-,0000	,0001	,0000	775,4462	175,5930	-,0000	,0001	,0000	779,2016
13	41147190,0	38531548,0	34485754,0	12039110,5	10524122,0	42372661,0	40996182,0	38142239,0	18584766,0	4175949,7
14	87,9262	102,8321	111,2941	110,7614	258,5428	85,2762	104,2615	109,2407	115,2310	232,7342
15	-75,0650	-64,5043	-53,5112	-13,1351	-10,4779	-84,7655	-74,2577	-63,2661	-23,8486	4,4490

S-IVB/LM SEPARATION

1	2949,9999	721564,8800	61176483,0000	,1156	106,3722	3250,2420	728710,6500	63335685,0000	-,0001	94,8280
2	24122,4540	25462,6070	,001	,0692	105,4884	24113,1340	25456,2460	,001	-,0133	94,5727
3	**********	**********	-17827637,000	9059608,700	-72256423,000	**********	**********	-13529716,600	9968830,100	-74233481,000
4	1419795,8	-93593,6	-6886726,8	831973,190	-4048258,100	347916,6	-504407,6	-12589164,5	925881,460	-4885421,800
5	4409941,2	37,1	-10133374,6	19812613,000	***********	-2345051,1	-6524736,6	-11249484,6	21984445,030	***********
6	-5113,567	-736,049	11787,981	3187,7964	-11194,699	2523,462	7721,635	18061,863	3187,7840	-2736,974
7	-3300,519	-1469,247	-21751,456	329,2394	-2964,616	-4160,067	-1383,579	-17854,836	329,2397	-2878,350
8	-23342,059	-25409,491	-6021,7949	7614,2436	-51666,574	-23617,133	-24217,402	-1730,4466	7614,2573	-50474,531
9	26,339	,000	,0000	85,4062	-28,0877	26,765	,000	,0000	253,9693	-31,4949
10	-3,548	,000	,0000	2330,1538	,0000	-2,394	,000	,0000	2341,1849	,0000
11	-5,203	24122,453	9,4689	,0000	,0001	3,202	24113,133	9,4311	,0000	,0001
12	167,6300	-,0000	,0001	,0000	776,4016	173,3613	-,0000	,0001	,0000	779,3046
13	41433263,0	39019897,0	35166198,0	13151181,2	9420127,3	42438591,0	41211794,0	38502599,0	19327641,0	3575655,8
14	87,8159	103,0456	111,0299	111,8213	256,5860	83,9391	104,4715	108,8965	115,5538	224,1371
15	-76,6606	-66,1314	-55,1423	-14 937	-8,4573	-85,9351	-75,4024	-64,4068	-25,0607	6,9897

APPENDIX 4

FLIGHT SIMULATED DATA (AC77)

1. FLIGHT SIMULATED DATA (AC77)

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 which correlated perturbations in thrust, weight flow, and pitch and yaw thrust vector misalignment with the resulting differences in slant range altitude, earth-fixed velocity, and earth-fixed velocity azimuth angle between the observed and simulated trajectories. A complete discussion of the trajectory simulation may be found in section 7.3, Powered Flight Simulated Trajectory Evaluation.

Figures AP 4-1 and AP 4-2 illustrate the major coordinate systems. Tables AP 4-1 and 4-2 present the trajectory parameter definitions while table AP 4-3 furnishes the detailed reconstructed trajectory from S-IVB ignition to guidance commanded cutoff. The ignition and cutoff weights are based on the composite best estimate ignition and cutoff weights as discussed in section

TABLE AP 4-1 (Sheet 1 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
A*	A*	Azimuth angle measured in the plane tangent to the earth's surface at radar station; 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*	D*	Slant range distance between the vehicle and radar station (ft)
ECCENTRICITY	e	Eccentricity of a conic section (dimensionless)
E*	E*	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 (ft)
E/M	E/m	Total energy (ft^2/sec^2)
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 (lb)
AVG F SB L	$\bar{F}_L$	Average longitudinal thrust (lbf)
F SB T	F_T	Total effective engine thrust (lbf)

TABLE AP 4-1 (Sheet 2 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
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)
INCLINATION	i	Equatorial orbital inclination (deg)
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

TABLE AP 4-1 (Sheet 3 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
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)
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)
PERIOD	P	Period of elliptical orbit (min)
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 (lb/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 L	r_L	Earth radius at the launcher (ft)
R SB M	R_M	Total vehicle yaw rate; positive yaw-nose left (deg/sec)
S (BAR*)	$\bar{S}*$	Product of the average earth radius and the central angle traversed during glide (nautical miles)

TABLE AP 4-1 (Sheet 4 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
S SB F	S_F	Downrange distance at terminal altitude (nautical miles)
RANGE	s	Spherical earth ground range (ft). Based on the spherical earth range angle and the average earth radius
SAF	SAF	Space attenuation factor measured from radar station i
TIME	t	Current simulation time, measured from vehicle liftoff (sec)
T SB F	t_f	Time since launch at the terminal altitude (sec)
T (1)	T_1	First stage time to go (sec)
T (3)	T_3	Second stage time to go (sec)
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_R	The temperature specified at a certain altitude (deg R)
V (AP)	V_{ap}	Apogee velocity of the glide phase orbit (ft/sec)
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)

TABLE AP 4-1 (Sheet 5 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
V SB I	V_I	Magnitude of the vehicle's inertial velocity (ft/sec)
V (PER)	V_{per}	Perigee velocity of the glide phase orbit (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	$\bar{\dot{W}}$	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.)

TABLE AP 4-1 (Sheet 6 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
X SB CP Y SB CP Z SB CP	X_{CP}, Y_{CP}, Z_{CP}	Components of vehicle center 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	Position 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)
D-X (V) D-Y (V) D-Z (V)	X^v, Y^v, Z^v	Velocity coordinates in terminal radius
ALPHA* (S-IVB) ALPHA (S-IB)	α' α	Total angle of attack. Angle between the centerline of the vehicle and the vehicle air velocity vector (deg)
ALPHA (S-IVB) ALPHA S3 P (S-IB)	α α_p	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)

TABLE AP 4-1 (Sheet 7 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
BETA (S-IVB) ALPHA SB Y (S-IB)	β α_y	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	True anomaly at start of glide (deg)
BETA (F)	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_{1_I}	Inertial elevation flight path angle. Same as γ_2 except measured to inertial vehicle velocity (deg)
GAMMA (1I) PR	γ_{1_I}'	Inertial elevation flight path angle. Angle between the inertial velocity vector and the X_{L_I}' Z_{L_I}' plane. Angle is positive for an ascending vehicle (deg)
GAMMA (2I) PR	γ_{2_I}'	Inertial azimuthal flight path angle measured in the X_{L_I}', Z_{L_I}' plane. Angle between Z_{LI}, clockwise to the projection of the inertial velocity vector (deg)

TABLE AP 4-1 (Sheet 8 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
GAMMA SB 1F	γ_{1_f}	Inertial flight path elevation angle at the terminal altitude (deg)
GAMMA SB 2F	γ_{2_f}	Inertial flight path azimuth angle, at the terminal altitude (deg)
DELTA (A)	δ_A, δ_B	Vehicle actuator A (yaw) and actuator B (pitch)
D-DELTA (A) D-DELTA (B)	$\dot{\delta}_A$ $\dot{\delta}_B$	Vehicle actuator A (yaw) and actuator B (pitch) gimbal angle rates, respectively (deg/sec)
SMCP	δMCP	Pitch thrust misalignment correction (radians)
SMCY	δMCY	Yaw thrust misalignment correction (radians)
E SB W	ϵ_W	Tabular wind azimuth angle, positive clockwise from north, as a function of altitude (at ϵ_W = zero wind is coming from the north) (deg)
EPS (THETA) EPS (PSI) EPS (PHI)	ϵ_θ, ϵ_ψ, ϵ_ϕ	Autopilot error signal (deg)
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)

TABLE AP 4-1 (Sheet 9 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
D-THETA (M) QRP D-PSI (M) QRP D-PHI (M) QRP	$\dot{\theta}_M$, $\dot{\psi}_M$, $\dot{\Phi}_M$	Vehicle pitch, yaw, and roll attitude Euler angle rates (deg/sec)
THETA SB C	θ_C	Commanded vehicle pitch Euler angle (deg)
THETA (M) QRP PSI (M) QRP PHI (M) QRP	θ_M, ψ_M, Φ_M	Vehicle pitch, yaw, and roll attitude Euler angle (deg)
THETA (P) THETA (Y) THETA (R)	θ_P, θ_Y, θ_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	Longitude of r_f (deg)
XI ETA ZETA	ξ, η, ζ	Vehicle position obtained by integrating $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$. The ξ, η, ζ 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)
D-XI D-ETA D-ZETA	$\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$,	Vehicle velocity obtained by integrating $\ddot{\xi}$, $\ddot{\eta}$, $\ddot{\zeta}$ (m/sec)

TABLE AP 4-1 (Sheet 10 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
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	T	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 SB PHI	T_ϕ	Roll look angle measured from the positive yaw axis (Y_m) clockwise looking forward (fin plane III to IV) to the telemetry line of sight in the roll plane (deg).
TAU SB THETA	T_θ	Total telemetry look angle measured from the positive (nose) vehicle centerline to the telemetry line of sight (deg).

TABLE AP 4-1 (Sheet 11 of 11)
SYMBOL DEFINITION FOR S-IVB STAGE TRAJECTORY
AND RADAR PARAMETERS COMPUTER PROGRAM AC77

PRINTOUT SYMBOL	COMMON SYMBOL	DEFINITION
TAU (1G)	τ_{1G}'	Ratio of $W/\dot{W}$ during third stage operation (sec)
TAU (3G)	τ_{3G}	Ratio of $W/\dot{W}$ during third stage operation (sec)
TAU SB F	τ_f	Time since/to perigee at terminal altitude (sec)
PHI SB C	ϕ_C	Command vehicle 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	ϕ_C	Command vehicle yaw Euler angle (deg)
CHI SB P CHI SB R CHI SB Y	χ_P χ_R χ_Y	Guidance-commanded body attitude angle in the vehicle pitch, roll, and yaw plane (deg)
D-CHI SB P D-CHI SB R D-CHI SB Y	$\dot{\chi}_P$ $\dot{\chi}_R$ $\dot{\chi}_Y$	Guidance - commanded body attitude rates in the vehicle pitch, roll, and yaw plane (deg/sec)

TABLE AP 4-2 (Sheet 1 of 2)
LIST OF COORDINATE SUBSCRIPT DEFINITIONS

ee	Coordinate system on the surface of the spheroid representing the earth and whose origin is at the same latitude and longitude as the launcher. X_{ee} positive downrange, Y_{ee} perpendicular to the surface of the spheroid, positive up, and Z_{ee} crossrange positive in the right handed coordinate system. (English)
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 directions 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 coordinates fixed at the center of gravity of the vehicle. X_m parallel to the longitudinal axis of the vehicle positive forward, Y_m at the zero deg bank angle position, and A_m at the 90 deg bank angle position. (English)
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 λ_x and Y_x axes 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)

TABLE AP 4-2 (Sheet 2 of 2)
LIST OF COORDINATE SUBSCRIPT DEFINITIONS

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. (English)

TABLE AP 4-3 (Sheet 1 of 10)
FLIGHT SIMULATED DATA

#					
1	TIME	WEIGHT	F SB T	ALTITUDE	RANGE
2	V SB I	V SB E	R SB C	R SB L	RANGE ANGLE
3	X SB E	X SB P (M)	X SB S	XI	D* SB 1
4	Y SB E	Y SB P (M)	Y SB S	ETA	A* SB 1
5	Z SB E	Z SB P (M)	Z SB S	ZETA	E* SB 1
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) ORP	DTHETA(M)ORP	F AUX SB X	I SB XX	EPS(THETA)
13	PSI(M) ORP	D-PSI(M)ORP	F AUX SB Y	I SB YY	EPS(PSI)
14	PHI(M) ORP	D-PHI(M)ORP	F AUX SB Z	I SB ZZ	EPS(PHI)
15	CHI SB P	D-CHI SB P	THETA(P)	P SB M	D-EPS(THETA)
16	CHI SB Y	D-CHI SB Y	THETA(Y)	Q SB M	D-EPS(PSI)
17	CHI SB R	D-CHI SB R	THETA(R)	R SB M	D-EPS(PHI)
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 SP SP	AVG I SB SP	WEIGHT FLOW	AVG D-W	AVG F SB L
21	Q	MACH NO.	PRESSURE	TEMPERATURE	X SB CP
22	MU	RHO	RHO PRIME	G(RHO)	G(PSI)
23	ALPHA*	ALPHA	BETA	CHORD FORCE	V SB RM
24	T(1)	TAU(1G)	PHI(T)	X(V)	D-X(V)
25	T(3)	TAU(3G)	SMCP	Y(V)	D-Y(V)
26	D-T(PD)	DELTA-T(3)	SMCY	Z(V)	D-Z(V)
27	SAF(1)			V SB W	F SB W
28	THETA SB C	D-THETA SB C	X SB CG		
29	PSI SB C	D-PSI SB C	Y SB CG		GAMMA SB 1F
30	PHI SB C	D-PHI SB C	Z SB CC		GAMMA SB 2F
31	R(PER)	V(PER)	ECCENTRICITY	PERIOD	BETA
32	R(AP)	V(AP)	INCLINATION	E/M	BETA(F)
33	T SB F	S SB F	V(F)	MU SB F	RHO SB F
34	DELTA SB R1	DELTA SB R2	DELTA SB R3	DELTA SB R4	

#					
1	145.0000	296966.164	46406.105	211383.467	206664.279
2	7740.4306	6611.6694	21121043.25	20909660.25	0.5663
3	208565.371	0.000	401985.328	0.000	296225.936
4	210355.516	0.000	207473.020	0.000	72.2295
5	835.585	0.000	67033.421	0.000	45.2446
6	5606.4549	0.0000	6929.0078	0.0000	5.8933
7	3504.5337	0.0000	3427.4427	0.0000	-0.0441
8	9.0077	0.0000	394.6617	0.0000	0.0273
9	54395.641	46404.541	-608.899	33.615	7.382
10	-407.255	-276.539	-130.788	8490.461	257.786
11	251.799	262.130	-10.349	346.999	-3692.150
12	30.3344	-0.1347	8599.9599	105826.092	0.2356
13	0.1861	0.0322	0.0000	2669257.938	-0.1870
14	0.4000	-0.0000	0.0000	2670913.406	-0.4000
15	-59.4295	0.0000	0.0000	0.0004	0.1350
16	0.0000	0.0000	0.0000	-0.1350	-0.0312
17	0.0000	0.0000	0.0000	0.0312	-0.0000
18	32.5742	27.3794	27.3400	0.3236	-0.0057
19	72.3855	75.8004	75.7201	0.3414	0.0948
20	1086.5504	185.6810	-50.6231	-46.3160	8600.000
21	8.0025	6.5762	0.2643	420.6341	691.524
22	79.9515	28.7038	28.5436	-31.5704	-0.0423
23	1.1554	-1.1518	0.0912	-608.8986	6611.670
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	109.4325			0.0000	0.0000
28	30.5705	0.0000	350.6743		
29	0.0000	0.0000	-0.4489		
30	0.0000	0.0000	-0.7128		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

#					
1	143.5000	297036.000	0.000	206011.994	198385.029
2	7760.3619	6635.2652	21115678.75	20909667.25	0.5436
3	209157.514	0.000	391592.832	0.000	286557.359
4	205065.059	0.000	202297.287	0.000	72.2356
5	8[illegible].379	0.000	61441.275	0.000	45.6935
6	5605.8726	0.0000	6928.1819	0.0000	0.8493
7	3549.7697	0.0000	3473.8431	0.0000	-0.0211
8	8.6299	0.0000	394.8694	0.0000	-0.0012
9	7849.587	0.000	-759.420	11.144	11.144
10	-194.762	0.000	-194.762	276.984	276.984
11	-11.371	0.000	-11.371	-5488.669	-5488.669
12	30.4509	0.0000	8599.9999	105826.092	0.1199
13	0.1775	0.0000	0.0000	2669257.938	-0.1774
14	0.4000	0.0000	0.0000	2670913.406	-0.4000
15	-59.4295	0.0000	0.0000	0.0000	-0.0000
16	0.0000	0.0000	0.0000	0.0000	-0.0000
17	0.0000	0.0000	0.0000	0.0000	-0.0000
18	32.8855	27.6612	27.6218	0.0000	0.0000
19	72.3698	75.7870	75.7057	0.0000	0.0000
20	185.6810	185.6810	-46.3160	-46.3160	8600.000
21	9.9482	6.5300	0.3333	429.6517	690.601
22	79.9767	28.6969	28.5367	-31.5865	-0.0423
23	1.3775	-1.3753	0.0803	-759.4200	6635.265
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	109.1442			0.0000	0.0000
28	30.5705	0.0000	350.6743		
29	0.0000	0.0000	-0.4489		
30	0.0000	0.0000	-0.7128		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

#					
1	148.4000	296371.922	178643.131	223332.842	225440.588
2	7718.7305	6581.8060	21132975.50	20909644.25	0.6177
3	227649.941	0.000	425566.559	0.000	318051.801
4	222108.085	0.000	218958.805	0.000	72.2183
5	867.603	0.000	63374.312	0.000	44.2937
6	5627.4215	0.0000	6950.5857	0.0000	19.5702
7	3413.5334	0.0000	3333.6185	0.0000	-0.1128
8	9.6506	0.0000	393.8890	0.0000	-0.0656
9	180271.299	178639.518	-368.216	38.951	0.150
10	-1038.799	-996.420	-41.076	993.479	1729.723
11	-604.514	-545.383	-61.205	12998.793	-1161.748
12	30.1134	0.2789	2000.0000	105388.495	0.4537
13	0.9843	0.4365	0.0000	2668599.063	-0.9858
14	0.4000	0.0011	0.0000	2670254.594	-0.4000
15	-59.4295	0.0000	0.0000	-0.0048	-0.2758
16	0.0000	0.0000	0.0000	0.2758	-0.4385
17	0.0000	0.0000	0.0000	0.4385	-0.0000
18	31.8571	26.7475	26.7082	-0.1749	-0.3085
19	72.4186	75.8191	75.7409	0.3196	-0.3437
20	433.3141	185.6810	-416.8789	-46.3160	8600.000
21	4.8847	6.7072	0.1551	400.7175	694.146
22	79.8958	28.7194	28.5592	-31.5347	-0.0422
23	1.0733	-0.5981	0.8912	-368.2164	6581.806
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	110.0500			0.0000	0.0000
28	30.5705	0.0000	350.7220		
29	0.0000	0.0000	-0.4491		
30	0.0000	0.0000	-0.7131		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

#					
1	144.0000	297012.832	0.000	207809.533	20[illegible]5.174
2	7753.4711	6627.1516	21117474.00	20909665.00	0.5512
3	202960.447	0.000	395056.938	0.000	289783.609
4	206836.146	0.000	204030.311	0.000	72.2336
5	825.729	0.000	61638.692	0.000	45.5415
6	5605.8767	0.0000	6928.2672	0.0000	0.8552
7	3534.5747	0.0000	3458.2613	0.0000	-0.0182
8	8.7937	0.0000	394.7997	0.0000	-0.0012
9	7894.395	0.000	-705.610	9.576	9.576
10	-167.959	-0.000	-167.988	263.480	263.448
11	-10.769	0.000	-10.770	-4737.048	-4736.442
12	30.4359	-0.0553	8599.9999	105826.092	0.1340
13	0.1778	0.0033	0.0000	2669257.938	-0.1783
14	0.4000	-0.0001	0.0000	2670913.406	-0.4000
15	-59.4295	0.0000	0.0000	0.0002	0.0553
16	0.0000	0.0000	0.0000	-0.0553	-0.0029
17	0.0000	0.0000	0.0000	0.0029	-0.0000
18	32.7825	27.5673	27.5279	0.3169	0.1992
19	72.3755	75.7916	75.7106	0.2487	0.1898
20	185.6810	185.6810	-46.3160	-46.3160	8600.000
21	9.2531	6.5451	0.3086	426.6383	[illegible].901
22	79.9585	28.6992	28.5390	-31.5811	-0.0423
23	1.2793	-1.2767	0.0819	-705.6096	6627.152
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	109.2419			0.0000	0.0000
28	30.5705	0.0000	350.6743		
29	0.0000	0.0000	-0.4489		
30	0.0000	0.0000	-0.7128		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

#					
1	150.0000	295682.441	187767.955	228867.025	234314.158
2	7728.2285	6587.6558	21138502.50	20909636.75	0.6421
3	236674.973	0.000	436708.941	0.000	328316.414
4	277543.482	0.000	224265.148	0.000	72.2137
5	882.782	0.000	64003.684	0.000	43.8728
6	5653.9287	0.0000	6977.4532	0.0000	20.3996
7	3380.8607	0.0000	3299.4551	0.0000	0.0026
8	9.2546	0.0000	392.7582	0.0000	-0.1305
9	187474.107	157764.602	-290.501	-46.430	-3.979
10	23.525	7.286	17.770	-10030.647	2226.687
11	-1199.018	-1121.958	-78.034	-6620.190	521.879
12	30.6755	0.3110	0.0000	105069.[illegible]	-0.1099
13	1.5339	0.1941	0.0000	2668199.688	1.5335
14	0.4000	-0.0006	0.0000	2669856.094	-0.4000
15	-59.4295	0.0000	0.0000	-0.0083	-0.3096
16	0.0000	0.0000	0.0000	0.3096	-0.1963
17	0.0000	0.0000	0.0000	0.1963	-0.0000
18	31.5188	26.4633	26.4239	-0.3424	0.0007
19	72.4268	75.8138	75.7366	-0.0022	-0.1007
20	428.9532	185.6810	-437.7274	-46.3160	8600.000
21	3.8767	6.7899	0.1201	391.7103	695.798
22	79.8696	28.7267	28.5666	-31.5182	-0.0472
23	1.4769	0.3260	1.4400	-290.5008	6587.656
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	110.3258			0.0000	0.0000
28	30.5705	0.0000	350.7222		
29	0.0000	0.0000	-0.4494		
30	0.0000	0.0000	-0.7135		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

Appendix 4
Flight Simulated Data (AC77)

TABLE AP 4-3 (Sheet 2 of 10)
FLIGHT SIMULATED DATA

1	155.4500	293003.184	218376.676	247376.734	264848.270
2	7776.8265	6624.4116	21156987.00	20909610.75	0.7257
3	267759.512	0.000	475010.066	0.000	363396.348
4	245685 297	0.000	241949.082	0.000	72.1985
5	927.704	0.000	66131.665	0.000	42.5380
6	5756.2343	0.0000	7080.9941	0.0000	23.9654
7	3278.4971	0.0000	3191.8422	0.0000	-0.0367
8	7.3032	0.0000	388.2070	0.0000	-0.0745
9	218249.109	218375.393	-126.282	-5.600	-3 [illegible]
10	-333.801	-374.235	40.441	430.836	898.[illegible]
11	-678.311	-647.382	-30.955	778.774	1188.220
12	30.8292	0.0011	0.0000	104935.503	-0.2638
13	1.4285	0.0045	0.0000	2666082.844	-1.4269
14	0.4000	0.0001	0.0000	2667741.438	-0.4000
15	-59.4295	0.0000	0.0000	0.0001	0.0026
16	0.0000	0.0000	0.0000	0.0011	-0.0023
17	0.0000	0.0000	0.0000	0.0045	0.0000
18	30.3883	25.5245	25.4851	-0.1699	-0.0123
19	72.4493	75.7863	75.7122	0.0982	-0.0115
20	422.9369	427.0811	-516.3309	-491.5989	209807.072
21	1.7228	7.0928	0.0489	362.9830	701.857
22	79.7785	28.7521	28.5920	-31.4631	-0.0420
23	2.1612	1.7164	1.3140	-126.2819	6624.412
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.2076			0.0000	0.0000
28	30.5705	0.0000	350.6880		
29	0.0000	0.0000	-0.4521		
30	0.0000	0.0000	0.7175		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

1	159.2500	290816.105	219586.721	259993.309	286449.750
2	7817.2035	6656.8970	21169585.00	20909592.25	0.7849
3	289776.566	0.000	502062.797	0.000	387997.121
4	258013.021	0.000	253940.365	0.000	72 1884
5	953.069	0.000	67600.891	0.000	41.6812
6	5831.8654	0.0000	7157.4520	0.0000	24.2859
7	3209.9201	0.0000	3119.5007	0.0000	-0.0349
8	6.0467	0.0000	385.0670	0.0000	-0.0743
9	219516.621	219585.465	-68.843	-6.483	-2.626
10	-315.213	-348.345	33.113	12.538	492.335
11	-671.590	-654.914	-16.753	-54.921	983.908
12	30.8415	-0.0033	0.0000	104082.854	-0.2760
13	1.4335	-0.0038	0.0000	2662934.719	-1.4326
14	0.4000	-0.0000	0.0000	2664595.125	-0.4000
15	-59.4295	0.0000	0.0000	0.0001	0.0033
16	0.0000	0.0000	0.0000	-0.0033	0.0038
17	0.0000	0.0000	0.0000	-0.0038	-0.0000
18	29.6123	24.8842	24.8447	-0.1709	0.0027
19	72.4669	75.7674	75.6955	0.0909	0.0036
20	421.4357	425.7309	-521.0414	-502.9473	214012.174
21	0.9552	7.3197	0.0255	344.1879	706.393
22	79.7144	28.7700	28.6099	-31.4256	-0.0420
23	2.8878	2.5773	1.3046	-68.8429	6656.897
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.7766			0.0000	0.0000
28	30.5705	0.0000	350.7760		
29	0.0000	0.0000	-0.4546		
30	0.0000	0.0000	-0.7216		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

1	155.4500	292789.184	218376.676	247376.734	264848.270
2	7776.8284	6674.4136	21156987.00	20909610.75	0.7257
3	267759.512	0.000	475010.066	0.000	363396.348
4	245685.297	0.000	241949.082	0.000	72.1985
5	927.704	0.000	66131.665	0.000	42.5380
6	5756.2360	0.0000	7080.9958	0.0000	23.9829
7	3278.4981	0.0000	3191.8431	0.0000	-0.0367
8	7.3032	0.0000	388.2069	0.0000	-0.0745
9	218249.109	218375.393	-126.282	-5.600	-3.584
10	-333.801	-374.235	40.441	430.837	898.323
11	-678.311	-647.382	-30.955	778.775	1188.221
12	30.8292	0.0011	0.0000	104935.503	-0.2637
13	1.4285	0.0045	0.0000	2666082.844	-1.4276
14	0.4000	0.0001	0.0000	2667741.438	-0.4000
15	-59.4295	0.0000	0.0000	-0.0000	-0.0011
16	0.0000	0.0000	0.0000	0.0011	-0.0045
17	0.0000	0.0000	0.0000	0.0045	-0.0000
18	30.3883	25.5245	25.4851	-0.1699	-0.0121
19	72.4493	75.7863	75.7122	0.0982	-0.0131
20	422.9369	427.0811	-516.3309	-491.5989	209807.072
21	1.7228	7.0928	0.0489	362.9830	701.857
22	79.7785	28.7521	28.5920	-31.4631	-0.0420
23	2.1612	1.7164	1.3140	-126.2819	6624.414
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.2075			0.0000	0.0000
28	30.5705	0.0000	350.6880		
29	0.0000	0.0000	-0.4521		
30	0.0000	0.0000	-0.7175		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

1	160.0000	290425.055	221950.656	262456.457	280744.172
2	7825.3885	6663.5585	21172043.50	20909588.75	0.7967
3	294156.079	0.000	507436.547	0.000	392867.012
4	260415.410	0.000	256274.648	0.000	72.1865
5	957.517	0.000	67889.456	0.000	41.5181
6	5846.8515	0.0000	7172.5960	0.0000	24.5813
7	3196.4522	0.0000	3105.2830	0.0000	-0.0285
8	5.8025	0.0000	384.4456	0.0000	-0.0815
9	221888.369	221949.297	-60.926	-12.424	-2.436
10	-257.076	-288.290	31.160	-1269.804	434.803
11	-735.762	-720.957	-14.757	-1466.569	928.159
12	30.8382	-0.0091	0.0000	104082.058	-0.4296
13	1.4303	-0.0080	0.0000	2662531.750	-1.5711
14	0.4000	-0.0001	0.0000	2664192.531	-0.4000
15	-59.5860	0.0000	0.0000	0.0002	0.0091
16	-0.1423	0.0000	0.0000	-0.0091	0.0080
17	0.0000	0.0000	0.0000	-0.0080	-0.0000
18	29.4605	24.7590	24.7196	-0.1861	-0.0581
19	72.4705	75.7638	75.6923	0.0744	-0.0637
20	425.1987	425.4693	-521.9896	-504.3302	214472.627
21	0.8483	7.3666	0.0223	340.4920	707.333
22	79.7016	28.7735	28.6135	-31.4183	-0.0419
23	3.0314	2.7402	1.2985	-60.9262	6663.559
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.8849			0.0000	0.0000
28	30.4140	0.0000	350.7804		
29	-0.1423	0.0000	-0.4552		
30	0.0000	0.0000	-0.7225		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

1	159.7500	290816.105	219586.721	259993.309	286449.750
2	7817.2029	6656.8964	21169585.00	20909592.25	0.7849
3	289775.565	0.000	502062.797	0.000	387997.121
4	258013.021	0.000	253940.365	0.000	72.1884
5	953.069	0.000	67600.891	0.000	41.6812
6	5831.8649	0.0000	7157.4515	0.0000	24.2859
7	3209.9199	0.0000	3119.5004	0.0000	-0.0349
8	6.0467	0.0000	385.0670	0.0000	-0.0743
9	219516.621	219585.465	-68.843	-6.483	-2.626
10	-315.213	-348.345	33.113	12.538	492.335
11	-671.590	-654.814	-16.753	-54.922	983.908
12	30.8415	-0.0033	0.0000	104082.854	-0.2768
13	1.4335	-0.0038	0.0000	2662934.719	-1.4335
14	0.4000	-0.0000	0.0000	2664595.125	-0.4000
15	-59.4295	0.0000	0.0000	0.0001	0.0029
16	0.0000	0.0000	0.0000	-0.0033	0.0038
17	0.0000	0.0000	0.0000	-0.0038	-0.0000
18	29.6123	24.8842	24.8447	-0.1709	0.0040
19	72.4669	75.7674	75.6955	0.0909	0.0052
20	421.4357	425.7309	-521.0414	-502.9473	214012.174
21	0.9557	7.3196	0.0255	344.1879	706.393
22	79.7144	28.7700	28.6099	-31.4256	-0.0420
23	2.8878	2.5773	1.3046	-68.8429	6656.897
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	111.7765			0.0000	0.0000
28	30.5705	0.0000	350.7760		
29	0.0000	0.0000	-0.4546		
30	0.0000	0.0000	-0.7216		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

1	170.0000	285183.574	220691.787	294409.535	349011.563
2	7944.9295	6762.4633	21203947.75	20909539.00	0.9563
3	353653.575	0.000	580201.359	0.000	458282.422
4	291463.961	0.000	286360.422	0.000	72.1666
5	1027.114	0.000	71719.496	0.000	39.4935
6	6056.1776	0.0000	7383.8112	0.0000	24.8966
7	3008.9015	0.0000	2907.4063	0.0000	-0.0856
8	11.6576	0.0000	385.0116	0.0000	-0.0831
9	220678.371	220689.248	-10.875	17.915	0.246
10	-758.523	-755.880	-1.381	-2107.814	-125.515
11	-736.671	-740.870	4.137	7272.567	-41.268
12	25.1147	0.2117	0.0000	104071.401	0.1738
13	-1.9051	0.0088	0.0000	2656895.156	-1.4495
14	0.4000	-0.0015	0.0000	2658560.906	-0.4000
15	-64.7063	0.0000	0.0000	0.0070	-0.2115
16	-3.3540	0.0000	0.0000	0.2115	-0.0103
17	0.0000	0.0000	0.0000	0.0103	-0.0000
18	27.3743	23.0396	23.0002	-0.1923	0.0129
19	72.6081	75.7878	75.7219	0.1962	-0.1496
20	419.3863	424.4717	-526.2198	-514.2355	218216.189
21	0.1547	7.6501	0.0038	325.1700	713.002
22	79.5282	28.8216	28.6616	-31.3237	-0.0417
23	2.1478	-0.6805	-2.0373	-10.8752	6762.463
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	113.2227			0.0000	0.0000
28	25.2937	0.0000	350.8879		
29	-3.3540	0.0000	-0.4631		
30	0.0000	0.0000	-0.7344		
31					
32					
33					
34	0.0000	0.0000	0.0000	0.0000	

TABLE AP 4-3 (Sheet 3 of 10)
FLIGHT SIMULATED DATA

1	180.0003	279852.000	222155.070	328085.742	416514.496
2	8080.6225	6876.4685	21237567.00	20909482.25	1.1413
3	422737.012	0.000	667605.492	0.000	532548.750
4	323893.371	0.000	317627.277	0.000	72.1622
5	1196.737	0.000	75558.400	0.000	37.4577
6	6286.3944	0.0000	7615.4017	0.0000	25.5405
7	2786.8519	0.0000	2673.9355	0.0000	0.0001
8	22.8499	0.0000	390.1214	0.0000	0.0001
9	222153.324	222155.068	-1.743	-0.029	-0.029
10	0.876	0.000	0.876	13805.942	-19.512
11	0.660	0.000	0.660	-8699.386	25.822
12	25.9399	0.0000	0.0000	104060.714	-0.3312
13	-1.9843	0.0000	0.0000	2650821.875	-1.4783
14	0.4003	0.0000	0.0000	2652492.531	-0.4000
15	-64.3874	0.0000	0.0000	0.0000	-0.0000
16	-3.4635	0.0000	0.0000	0.0000	-0.0000
17	0.0003	0.0000	0.0000	0.0000	-0.0000
18	25.0476	21.1175	21.0783	0.0000	0.0000
19	72.8041	75.8576	75.7977	0.0000	0.0000
20	423.2892	423.2892	-524.8304	-524.8304	222155.066
21	0.0243	7.2038	0.0007	379.1767	704.076
22	75.3263	28.8768	28.7169	-31.2244	-0.0415
23	3.3698	2.6926	-2.0293	-1.7430	6876.469
24	0.0003	0.0000	0.0000	0.000	0.0000
25	0.0003	0.0000	0.0000	0.000	0.0000
26	0.0003	0.0000	0.0000	0.000	0.0000
27	114.5272			0.0000	0.0000
28	25.6125	0.0000	351.0872		
29	-3.4635	0.0000	-0.4713		
30	0.0003	0.0000	-0.7466		
31					
32					
33					
34	0.9023	0.0007	0.1875	-0.0001	

1	210.0003	264019.926	225280.801	408035.867	610056.180
2	8570.9819	7319.7809	21317360.25	209093[illegible].75	1.6717
3	621517.323	0.000	901301.328	0.000	738566.398
4	398987.133	0.000	3[illegible]8422.863	0.000	72.2305
5	2499.941	0.000	87596.831	0.000	32.6985
6	6975.5964	0.0000	8307.1044	0.0000	27.4530
7	2217.0641	0.0000	2068.6564	0.0000	-0.0538
8	69.8224	0.0000	417.6175	0.0000	-0.0843
9	225279.239	225279.305	-0.065	0.309	-0.003
10	-441.673	-442.239	0.065	255.674	-1.115
11	-691.487	-691.412	0.041	-74.062	1.767
12	22.3801	-0.0915	0.0000	104026.808	-0.4411
13	-3.7017	-0.0185	0.0000	2647858.906	-1.6116
14	0.4003	0.0000	0.0000	2649545.250	-0.4000
15	-68.0567	0.0000	0.0000	-0.0059	0.0912
16	-5.3148	0.0000	0.0000	-0.0912	0.0191
17	0.0003	0.0000	0.0000	-0.0191	-0.0000
18	19.3003	16.3954	16.3571	-0.1758	0.0017
19	73.4525	76.1551	76.1095	0.1125	-0.0018
20	475.4616	212.6086	-529.4938	-263.8638	112199.295
21	0.0008	5.2578	0.0000	806.5193	680.000
22	78.7481	29.0314	28.8715	-30.9506	-0.0410
23	6.5125	5.5352	-3.4530	-0.0657	7319.781
24	0.0003	0.0000	0.0000	0.000	0.0000
25	0.0003	0.0000	0.0000	0.000	0.0000
26	0.0003	0.0000	0.0000	0.000	0.0000
27	117.3676			0.0000	0.0000
28	21.9433	0.0000	352.2533		
29	-5.3145	0.0000	-0.4967		
30	0.0003	0.0000	-0.7881		
31	189.3243	152401.5645	0.8981	33.4672	178.0817
32	3525.7179	8183.6596	31.7779	50218317.5	
33					
34	1.5195	-0.2805	-1.1016	0.0127	

1	190.0003	274580.656	226158.242	356373.941	478901.469
2	8230.4284	7009.0704	21265802.50	20909430.25	1.3123
3	486711.495	0.000	735876.234	0.000	599964.563
4	350609.808	0.000	342368.297	0.000	72.1751
5	1487.163	0.000	79491.393	0.000	35.7830
6	6509.4954	0.0000	7839.6829	0.0000	26.4999
7	2598.5167	0.0000	2474.2852	0.0000	-0.0478
8	35.3598	0.0000	396.5464	0.0000	-0.0800
9	226156.381	226156.838	-0.456	-1.438	-0.016
10	-408.133	-409.115	0.353	-0.099	-4.749
11	-683.141	-663.230	0.165	-477.550	10.080
12	25.2087	-0.1054	0.0000	104049.994	-0.4791
13	-1.9833	-0.0120	0.0000	2657384.594	-1.5960
14	0.4003	0.0000	0.0000	2659060.250	-0.4000
15	-65.2659	0.0000	0.0000	-0.0036	0.1053
16	-3.5809	0.0000	0.0000	-0.1053	0.0127
17	0.0003	0.0000	0.0000	-0.0127	-0.0000
18	23.0711	19.4948	19.4558	-0.1731	-0.0001
19	72.9983	75.9346	75.8797	0.1036	0.0056
20	428.0397	103.2149	-528.3548	-131.7814	55988.455
21	0.0069	6.6900	0.0002	456.7770	693.800
22	79.1406	28.9273	28.7674	-31.1414	-0.0413
23	4.5763	4.1445	-1.9467	-0.4563	7009.071
24	0.0003	0.0000	0.0000	0.000	0.0000
25	0.0003	0.0000	0.0000	0.000	0.0000
26	0.0003	0.0000	0.0000	0.000	0.0000
27	115.5625			0.0000	0.0000
28	24.7341	0.0000	351.3742		
29	-3.5809	0.0000	-0.4793		
30	0.0003	0.0000	-0.7597		
31					
32					
33					
34	0.8753	0.0647	0.2183	0.0044	

1	220.0003	258756.367	223348.236	431412.012	678964.250
2	8759.6273	7495.6414	21340677.75	20909267.25	1.8605
3	692475.672	0.000	985575.689	0.000	809993.805
4	420185.745	0.000	401474.488	0.000	72.2739
5	3310.808	0.000	91849.468	0.000	31.2486
6	7216.9667	0.0000	6548.6027	0.0000	27.7711
7	2022.7407	0.0000	1861.4567	0.0000	-0.0563
8	92.4933	0.0000	432.9587	0.0000	-0.0880
9	223346.615	223346.652	-0.036	0.319	-0.002
10	-452.659	-453.055	0.042	27.198	-0.571
11	-707.687	-707.708	0.021	77.699	1.146
12	21.5526	-0.0542	0.0000	104015.789	-0.3757
13	-3.7398	0.0004	0.0000	2641236.719	-1.5984
14	0.4003	-0.0000	0.0000	2642928.125	-0.4000
15	-68.8187	0.0000	0.0000	-0.0035	0.0541
16	-5.3396	0.0003	0.0000	-0.0541	0.0000
17	0.0003	0.0000	0.0000	-0.0000	-0.0000
18	17.5131	14.9218	14.8639	-0.1815	-0.0007
19	73.7143	76.3011	76.2598	0.1162	-0.0010
20	424.6343	242.9238	-525.9741	-301.3820	128113.871
21	0.0004	4.6899	0.0000	1062.9777	680.000
22	78.5412	29.0849	28.9251	-30.9228	-0.0409
23	7.4942	6.7192	-3.3496	-0.0356	7495.642
24	0.0003	0.0000	0.0000	0.000	0.0000
25	0.0003	0.0000	0.0000	0.000	0.0000
26	0.0003	0.0000	0.0000	0.000	0.0000
27	118.1695			0.0000	0.0000
28	21.1813	0.0000	352.8989		
29	-5.3396	0.0000	-0.5085		
30	0.0003	0.0000	-0.8029		
31	201.7182	147401.5820	0.8918	33.6577	178.1444
32	3527.4135	8429.2870	31.7660	52574492.5	
33					
34	3.0351	0.3318	-0.7031	0.0172	

1	200.0003	269304.176	224453.477	383025.137	543390.578
2	8394.0027	7157.0976	21292400.50	20909377.00	1.4890
3	552949.164	0.000	819420.250	0.000	668596.063
4	375851.591	0.000	367109.398	0.000	72.1977
5	1903.070	0.000	83492.091	0.000	34.2046
6	6739.1383	0.0000	8070.1590	0.0000	26.8155
7	2409.4865	0.0000	2273.4284	0.0000	-0.0474
8	49.4057	0.0000	404.1080	0.0000	-0.0772
9	224452.043	224452.195	-0.152	-0.653	-0.006
10	-396.490	-397.648	0.138	906.392	-2.041
11	-645.932	-644.844	0.074	-814.129	3.785
12	23.8243	-0.1715	0.0000	104039.243	-0.5812
13	-2.7548	-0.1926	0.0000	2654233.781	-1.8373
14	0.4003	0.0003	0.0000	2655914.438	-0.4000
15	-66.7519	0.0000	0.0000	-0.0082	0.1700
16	-4.5961	0.0000	0.0000	-0.1700	0.1937
17	0.0003	0.0000	0.0000	-0.1937	-0.0000
18	21.1598	17.9255	17.8868	-0.1646	0.0073
19	73.2013	75.0227	75.9726	0.1015	0.0028
20	425.7828	170.1036	-527.1519	-210.9532	39709.641
21	0.0019	6.0077	0.0001	590.6035	680.153
22	78.9478	28.9788	28.8189	-31.0835	-0.0412
23	5.5499	4.8909	-2.6339	-0.1516	7157.098
24	0.0003	0.0000	0.0000	0.000	0.0000
25	0.0003	0.0000	0.0000	0.000	0.0000
26	0.0003	0.0000	0.0000	0.000	0.0000
27	116.5033			0.0000	0.0000
28	23.2481	0.0000	351.7775		
29	-4.5941	0.0000	-0.4889		
30	0.0003	0.0000	-0.7732		
31	177.6497	157575.1719	0.9040	33.2848	178.0252
32	3523.8864	7943.8475	31.7861	47943034.5	
33					
34	0.8125	-0.0851	0.0859	0.0086	

1	230.0003	253481.424	224512.447	453164.785	750183.023
2	8961.5262	7686.3387	21362372.50	20909210.75	2.0556
3	765877.749	0.000	1072293.344	0.000	893005.688
4	439444.913	0.000	426053.133	0.000	72.3256
5	4352.072	0.000	96257.063	0.000	29.8459
6	7464.6264	0.0000	8796.0549	0.0000	28.4968
7	1829.1313	0.0000	1654.4221	0.0000	-0.0563
8	115.8947	0.0000	448.6338	0.0000	-0.0923
9	224510.805	224510.828	-0.023	-1.164	-0.002
10	-443.279	-443.830	0.032	-57.039	-0.345
11	-726.974	-726.959	0.013	-334.409	0.868
12	20.9751	-0.0859	0.0000	104004.736	-0.4241
13	-3.7383	-0.0041	0.0000	2634238.219	-1.6144
14	0.4003	0.0001	0.0000	2635934.750	-0.4000
15	-69.4446	0.0000	0.0000	-0.0056	0.0857
16	-5.3542	0.0000	0.0000	-0.0857	0.0047
17	0.0003	0.0000	0.0000	-0.0047	-0.0000
18	15.8191	13.5215	13.4840	-0.1855	0.0007
19	73.9751	76.4406	76.4123	0.1133	0.0070
20	425.2396	265.6953	-527.9631	-329.6279	140128.814
21	0.0003	4.3460	0.0000	1301.6560	680.000
22	78.3273	29.1394	28.9795	-30.8599	-0.0408
23	8.6653	6.0660	-3.2079	-0.0228	7686.339
24	0.0003	0.0000	0.0000	0.000	0.0000
25	0.0003	0.0000	0.0000	0.000	0.0000
26	0.0003	0.0000	0.0000	0.000	0.0000
27	118.9193			0.0000	0.0000
28	20.5554	0.0000	353.6047		
29	-5.3542	0.0000	-0.5187		
30	0.0003	0.0000	-0.8181		
31	214.9363	142546.6934	0.8852	33.8586	178.2110
32	3529.0134	8681.8750	31.7547	55033310.5	
33					
34	3.8965	0.1964	2.8359	0.0211	

Appendix 4
Flight Simulated Data (AC77)

TABLE AP 4-3 (Sheet 4 of 10)
FLIGHT SIMULATED DATA

1	240.0000	248200.734	225761.355	473328.203	823781.305
2	9176.5452	7891.5860	21382479.25	20909153.25	2.2573
3	841789.835	0.000	1161517.281	0.000	957747.156
4	456769.492	0.000	441561.102	0.000	72.3833
5	5631.814	0.000	100823.604	0.000	28.4844
6	7718.9389	0.0000	9049.8174	0.0000	29.2650
7	1635.6957	0.0000	1446.9976	0.0000	-0.0609
8	140.2004	0.0000	464.7594	0.0000	-0.0949
9	224759.635	225759.652	-0.016	0.056	-0.001
10	-469.645	-470.167	0.025	10.932	-0.235
11	-739.609	-739.635	0.009	0.951	0.690
12	20.1284	-0.0820	0.0000	103993.644	-0.4089
13	-3.7625	0.0050	0.0000	2626845.656	-1.6079
14	0.4000	-0.0000	0.0000	2628547.219	-0.4000
15	-70.2761	0.0000	0.0000	-0.0054	0.0819
16	-5.3720	0.0000	0.0000	-0.0819	-0.0044
17	0.0009	0.0000	0.0000	0.0044	-0.0000
18	14.2169	12.1922	12.1551	-0.1877	-0.0012
19	74.2349	76.6015	76.5680	0.1193	-0.0001
20	428.1509	283.4510	-527.2910	-351.6765	149540.268
21	0.0002	4.1252	0.0000	1522.9166	680.000
22	78.1053	29.1748	29.0349	-30.8017	-0.0407
23	9.5571	9.0548	-3.0971	-0.0163	7891.588
24	0.0009	0.0000	0.0009	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	119.6259			0.0000	0.0000
28	19.7238	0.0000	354.4182		
29	-5.3722	0.0000	-0.5293		
30	0.0009	0.0000	-0.8341		
31	229.0497	137827.6191	0.8782	34.0706	178.2818
32	3530.5131	8941.8456	31.7439	57602556.5	
33					
34	4.3789	0.0407	4.8826	0.0239	

1	250.0000	242939.345	224414.891	491928.230	899829.297
2	9402.3937	8108.9576	21401021.50	20909094.75	2.4657
3	920279.352	0.000	1253302.329	0.000	1034348.992
4	472154.117	0.000	454986.523	0.000	72.4456
5	7157.704	0.000	105552.415	0.000	27.1598
6	7978.1583	0.0000	9308.1251	0.0000	29.7205
7	1441.1567	0.0000	1237.9160	0.0000	-0.0620
8	165.0847	0.0000	481.0336	0.0000	-0.0988
9	224413.149	224413.158	-0.013	-0.361	-0.001
10	-469.391	-468.660	0.022	37.374	-0.171
11	-745.893	-745.865	0.006	-136.814	0.589
12	19.4238	-0.0409	0.0000	103982.513	-0.3467
13	-3.7495	-0.0053	0.0009	2619061.688	-1.6289
14	0.4009	0.0000	0.0000	2620768.438	-0.4000
15	-70.9183	0.0000	0.0000	-0.0027	0.0408
16	-5.3795	0.0000	0.0000	-0.0408	0.0056
17	0.0000	0.0000	0.0000	-0.0056	-0.0000
18	12.6989	10.9286	10.8919	-0.1904	-0.0003
19	74.4921	76.7556	76.7256	0.1197	-0.0011
20	426.7537	297.6457	-525.8611	-369.1218	156953.412
21	0.0001	3.9805	0.0000	1727.0114	680.147
22	77.8757	29.2512	29.0512	-30.7482	-0.0406
23	10.5192	10.1148	-2.9530	-0.0126	8108.958
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	120.2933			0.0000	0.0000
28	19.0817	0.0000	355.3399		
29	-5.3796	0.0000	-0.5403		
30	0.0009	0.0000	-0.8507		
31	244.0163	133270.4785	0.8708	34.2931	178.3587
32	3531.8968	9207.5646	31.7349	60271351.5	
33					
34	4.2265	0.4606	5.4844	0.0261	

1	260.0000	237677.498	222039.369	508991.402	978389.219
2	9639.9968	8339.2896	21418025.00	20909035.25	2.6810
3	1001379.893	0.000	1347696.547	0.000	1112935.422
4	485594.879	0.000	466319.742	0.000	72.5113
5	8936.494	0.000	110445.800	0.000	25.8692
6	8243.2794	0.0000	9571.9989	0.0000	30.0568
7	1247.2649	0.0000	1028.8987	0.0000	-0.0648
8	190.8589	0.0000	497.7549	0.0000	-0.1016
9	222037.544	222037.576	-0.010	0.050	-0.001
10	-478.379	-478.792	0.020	-5.950	-0.137
11	-752.032	-752.031	0.005	10.937	0.544
12	19.9368	-0.0642	0.0000	103971.339	-0.3704
13	-3.7359	-0.0005	0.0000	2610863.875	-1.6312
14	0.4009	0.0000	0.0000	2612575.781	-0.4000
15	-71.4299	0.0000	0.0000	-0.0042	0.0641
16	-5.4183	0.0000	0.0000	-0.0641	0.0010
17	0.0009	0.0000	0.0000	-0.0010	-0.0000
18	11.2782	9.7405	9.7042	-0.1941	-0.0007
19	74.7494	76.9136	76.8869	0.1235	0.0020
20	470.3459	309.2187	-528.2260	-383.4002	163012.275
21	0.0001	3.9360	0.0000	1867.9744	680.480
22	77.6381	29.3065	29.1484	-30.6993	-0.0405
23	11.6359	11.2975	-2.8594	-0.0104	8339.290
24	0.0009	0.0000	0.0000	0.009	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	120.9244			0.0000	0.0000
28	18.5719	0.0000	356.3765		
29	-5.4183	0.0000	-0.5518		
30	0.0009	0.0000	-0.8680		
31	259.9405	128853.9824	0.8629	34.5278	178.4400
32	3533.1865	9479.9369	31.7244	63055789.0	
33					
34	4.2695	0.5133	8.9219	0.0278	

1	270.0000	232400.750	225151.904	524561.523	1059541.936
2	9891.0635	8584.1635	21433534.50	20908974.50	2.9033
3	1085162.209	0.000	1444767.469	0.000	1193653.070
4	497102.398	0.000	475565.395	0.000	72.5796
5	10978.156	0.000	115509.255	0.000	24.6109
6	8535.4923	0.0000	9643.5369	0.0000	31.1702
7	1054.3035	0.0000	820.1776	0.0000	-0.0690
8	267.6441	0.0000	515.0202	0.0000	-0.1073
9	225150.006	225150.016	-0.009	0.419	-0.001
10	-498.160	-498.746	0.019	-5.059	-0.112
11	-774.943	-774.941	0.004	112.571	0.501
12	18.1952	-0.1008	0.0000	103960.118	-0.4177
13	-3.7928	-0.0004	0.0000	2602214.000	-1.6390
14	0.4000	-0.0000	0.0000	2603931.000	-0.4000
15	-72.2181	0.0000	0.0000	-0.0067	0.1005
16	-5.4332	0.0000	0.0000	-0.1005	0.0011
17	0.0009	0.0000	0.0000	-0.0011	-0.0000
18	9.9536	8.6274	8.5916	-0.1972	-0.0003
19	75.0079	77.0755	77.0519	0.1269	0.0007
20	427.1632	316.9614	-527.0820	-395.4227	165165.820
21	0.0001	3.9194	0.0000	1996.1106	680.604
22	77.3923	29.3667	29.2065	-30.6547	-0.0404
23	12.4252	12.1370	-2.7421	-0.0090	8584.164
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	121.5375			0.0000	0.0000
28	17.7819	0.0000	357.5366		
29	-5.4332	0.0000	-0.5639		
30	0.0009	0.0000	-0.8862		
31	277.0066	124543.3242	0.8546	34.7776	178.5246
32	3534.3886	9761.0441	31.7151	65983171.5	
33					
34	4.2578	-0.1568	12.6875	0.0279	

1	280.0000	227125.965	221923.834	536673.258	1143373.016
2	10153.6144	8841.4479	21447583.75	20908913.00	3.1331
3	1171718.829	0.000	1544586.156	0.000	1276644.344
4	506675.199	0.000	492715.543	0.000	72.6499
5	13291.989	0.000	120747.265	0.000	23.3833
6	8796.0898	0.0000	10121.2942	0.0000	31.4364
7	860.0910	0.0000	609.5774	0.0000	-0.0701
8	245.2793	0.0000	532.6570	0.0000	-0.1099
9	221921.916	221921.924	-0.008	0.060	-0.001
10	-494.599	-495.093	0.018	-1.250	-0.097
11	-775.109	-776.047	0.004	8.160	0.473
12	17.3623	-0.0774	0.0000	103948.849	-0.3805
13	-3.8097	-0.0021	0.0000	2593099.344	-1.6493
14	0.4009	-0.0000	0.0000	2594871.531	-0.4000
15	-73.0137	0.0000	0.0000	-0.0051	0.0772
16	-5.4603	0.0000	0.0000	-0.0772	0.0027
17	0.0009	0.0000	0.0000	-0.0027	-0.0000
18	8.7104	7.5776	7.5422	-0.2004	-0.0005
19	75.2652	77.2410	77.2203	0.1278	0.0003
20	471.1337	327.1589	-526.9632	-405.5804	172495.742
21	0.0001	3.9598	0.0000	2074.5532	680.301
22	77.1378	29.4258	29.2655	-30.6144	-0.0404
23	13.0626	12.8107	-2.6404	-0.0081	8841.443
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.00	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	122.1214			0.0000	0.0000
28	16.9863	0.0000	358.8221		
29	-5.4603	0.0000	-0.5764		
30	0.0009	0.0000	-0.9051		
31	295.2089	120357.2061	0.8459	35.0420	178.6154
32	3535.4819	10049.6659	31.7064	69044742.0	
33					
34	1.9313	-0.1294	11.4668	0.0272	

1	290.0000	221862.262	222260.186	551351.148	1229961.719
2	10427.6939	9111.0878	21460199.25	20908850.25	3.3703
3	1261107.569	0.000	1647215.719	0.000	1362039.000
4	514301.703	0.000	487752.227	0.000	72.7217
5	15887.025	0.000	126164.028	0.000	22.1849
6	9082.6550	0.0000	10405.5588	0.0000	32.2314
7	665.1515	0.0000	397.6022	0.0000	-0.0710
8	273.6319	0.0000	550.5235	0.0000	-0.1202
9	222258.074	222258.082	-0.007	-3.219	-0.001
10	-489.886	-489.551	0.017	-849.757	-0.052
11	-829.069	-833.440	0.002	-295.303	0.465
12	16.8795	0.0617	0.0000	103937.529	-0.5091
13	-2.8358	0.7059	0.0000	2583487.500	-2.6972
14	0.4009	0.0002	0.0000	2585214.875	-0.4000
15	-73.6215	0.0000	0.0000	0.0031	-0.0567
16	-5.5347	0.0000	0.0000	0.0567	-0.7063
17	0.0009	0.0000	0.0000	0.7063	-0.0000
18	7.5513	6.5933	6.5563	-0.2149	-0.2196
19	75.5724	77.4094	77.3913	0.1262	-0.0346
20	422.7547	334.2143	-525.7377	-414.2079	176188.707
21	0.0001	4.0159	0.0000	2144.1093	680.000
22	76.8745	29.4859	29.3255	-30.5783	-0.0403
23	13.8238	13.7432	-1.5491	-0.0074	9111.088
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	122.6838			0.0000	0.0000
28	16.3785	0.0000	360.2410		
29	-5.5347	0.0000	-0.5896		
30	0.0009	0.0000	-0.9249		
31	314.6349	116289.3477	0.8366	35.3225	178.7117
32	3536.4729	10346.0652	31.6984	72251024.0	
33					
34	-2.7969	-0.4546	6.9531	0.0183	

TABLE AP 4-3 (Sheet 5 of 10)
FLIGHT SIMULATED DATA

1	300.0000	216603.169	224559.504	562639.609	1319382.609
2	10712.4723	9392.3513	21471424.00	20908786.50	3.6154
3	1353351.219	0.000	1752715.109	0.000	1449966.219
4	519984.902	0.000	490672.383	0.000	72.7926
5	18724.027	0.000	131715.578	0.000	21.0154
6	9375.8384	0.0000	10696.0449	0.0000	33.3556
7	471.3715	0.0000	186.1670	0.0000	-0.0772
8	296.1917	0.0000	562.1143	0.0000	-0.1045
9	224557.791	224557.749	-0.007	5.654	-0.001
10	-519.635	-520.157	0.017	2350.037	-0.077
11	-703.389	-702.796	0.003	46.427	0.455
12	16.1617	-0.0862	0.0000	103926.149	-0.6285
13	-3.8270	-0.0949	0.0000	2573306.906	-3.3547
14	0.4000	0.0000	0.0000	2575039.500	-0.4000
15	-74.4587	0.0000	0.0000	-0.0059	0.0873
16	-7.1849	0.0000	0.0000	-0.0873	0.0955
17	0.0000	0.0000	0.0000	-0.0955	-0.0000
18	6.4867	5.6840	5.6493	-0.1793	-0.0196
19	75.7393	77.5460	77.5304	0.1327	-0.0014
20	426.5775	340.2943	-526.4173	-421.6542	179357.830
21	0.0001	4.0868	0.0000	2197.9807	680.000
22	76.6021	29.5469	29.3864	-30.5462	-0.0403
23	14.5789	14.3651	-2.4724	-0.0069	9392.352
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	123.2272			0.0000	0.0000
28	15.5420	0.0000	361.8052		
29	-7.1849	0.0000	-0.6034		
30	0.0000	0.0000	-0.9456		
31	335.3113	112346.7591	0.8268	35.6199	178.8117
32	3537.3778	10649.4537	31.7038	75603535.0	
33					
34	-4.7344	-0.8718	1.6719	0.0165	

1	310.0000	211330.613	224084.205	572577.469	1411724.359
2	11009.2157	9686.0642	21481297.00	20908721.50	3.9684
3	1448644.094	0.000	1861155.344	0.000	1540561.672
4	523721.625	0.000	491465.723	0.000	72.8637
5	21847.425	0.000	137434.215	0.000	19.8741
6	9676.6024	0.0000	10993.8130	0.0000	34.1153
7	276.0794	0.0000	-27.5203	0.0000	-0.0748
8	327.0904	0.0000	561.5240	0.0000	-0.1343
9	224081.929	224081.928	-0.007	-5.805	-0.001
10	-491.104	-491.566	0.017	-1307.269	-0.067
11	-882.167	-882.358	0.003	-752.430	0.452
12	15.4791	-0.0707	0.0000	103914.708	-0.6374
13	-3.7224	0.0320	0.0000	2562512.188	-3.3631
14	0.4000	0.0001	0.0000	2564250.031	-0.4000
15	-75.1496	0.0000	0.0000	-0.0046	0.0768
16	-7.0877	0.0000	0.0000	-0.0708	-0.0315
17	0.0000	0.0000	0.0000	0.0315	-0.0000
18	5.4952	4.8331	4.7990	-0.2256	-0.0046
19	76.0049	77.7273	77.7141	0.1257	-0.0011
20	424.2921	345.5487	-528.1312	-426.2541	182132.219
21	0.0001	4.1784	0.0000	2236.1469	680.000
22	76.3204	29.6039	29.4482	-30.5180	-0.0403
23	15.1322	14.9780	-2.2561	-0.0066	9686.064
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	123.7536			0.0000	0.0000
28	14.8506	0.0000	363.5212		
29	-7.0877	0.0000	-0.6179		
30	0.0000	0.0000	-0.9675		
31	357.4635	108501.2754	0.8165	35.9370	178.9179
32	3538.1799	10961.9278	31.6550	79128266.0	
33					
34	-3.6328	-0.3149	-1.8125	0.0214	

1	320.0000	206049.613	224283.713	581204.781	1507080.000
2	11319.1377	9993.4744	21489858.50	20908655.75	4.1297
3	1546954.672	0.000	1972621.547	0.000	1633971.016
4	525504.633	0.000	470117.590	0.000	72.9357
5	25266.287	0.000	143344.658	0.000	18.7604
6	9986.7173	0.0000	11300.5670	0.0000	35.0209
7	80.0871	0.0000	-242.6567	0.0000	-0.0827
8	358.6023	0.0000	600.9599	0.0000	-0.1271
9	224281.599	224281.605	-0.006	0.783	-0.001
10	-529.387	-529.938	0.017	503.845	-0.069
11	-814.145	-814.193	0.003	-123.666	0.446
12	14.5595	-0.0921	0.0000	103903.202	-0.6171
13	-3.9696	0.0077	0.0000	2551061.625	-3.3142
14	0.4000	0.0000	0.0000	2552804.750	-0.4000
15	-76.0490	0.0000	0.0000	-0.0064	0.0919
16	-7.2859	0.0000	0.0000	-0.0919	-0.0071
17	0.0000	0.0000	0.0000	0.0071	-0.0000
18	4.5819	4.0444	4.0107	-0.2080	-0.0045
19	76.2674	77.9105	77.8594	0.1354	0.0007
20	423.8993	350.2208	-529.0917	-434.1271	184623.289
21	0.0001	4.2795	0.0000	2269.2800	680.000
22	76.0289	29.6717	29.5109	-30.4936	-0.0403
23	15.4418	15.2708	-2.4021	-0.0064	9993.475
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	124.2649			0.0000	0.0000
28	13.9519	0.0000	365.3940		
29	-7.2859	0.0000	-0.6331		
30	0.0000	0.0000	-0.9903		
31	381.2867	104738.2246	0.8055	36.2770	179.0292
32	3538.8851	11284.7098	31.6875	82849357.0	
33					
34	-2.2344	-0.1870	-4.7969	0.0202	

1	330.0000	200774.158	224183.381	588555.180	1605569.484
2	11640.8399	10313.1713	21497141.75	20908589.00	4.3996
3	1648406.905	0.000	2087193.891	0.000	1730330.781
4	525316.984	0.000	486603.664	0.000	73.0085
5	29015.992	0.000	149456.867	0.000	17.6735
6	10305.0574	0.0000	11615.1649	0.0000	35.9250
7	-117.8536	0.0000	-460.4958	0.0000	-0.0882
8	391.6695	0.0000	621.4762	0.0000	-0.1359
9	224181.089	224181.096	-0.006	0.669	-0.001
10	-550.323	-550.751	0.017	44.736	-0.063
11	-848.332	-848.355	0.002	139.579	0.447
12	13.7878	-0.0647	0.0000	103891.627	-0.5543
13	-3.9185	0.0036	0.0000	2538872.594	-3.3573
14	0.4000	-0.0001	0.0000	2540641.031	-0.4000
15	-76.7574	0.0000	0.0000	-0.0044	0.0045
16	-7.2777	0.0000	0.0000	-0.0645	-0.0031
17	0.0000	0.0000	0.0000	0.0031	-0.0000
18	3.7374	3.3106	3.2774	-0.2168	-0.0006
19	76.5355	78.1908	78.0918	0.1408	-0.0002
20	425.4711	354.3702	-526.9009	-439.3167	6516.602
21	0.0001	4.3891	0.0000	2297.5091	680.000
22	75.7274	29.7354	29.5745	-30.4727	-0.0403
23	15.7917	15.6462	-2.2492	-0.0063	10313.172
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	124.7624			0.0000	0.0000
28	13.[illegible]426	0.0000	367.4359		
29	-7.2777	0.0000	-0.6491		
30	0.0000	0.0000	-1.0144		
31	406.5296	101069.0771	0.7938	36.6405	179.1474
32	3539.4896	11616.8986	31.6796	86765005.0	
33					
34	-0.8359	0.0870	-4.5000	0.0186	

1	340.0000	195509.207	223903.205	594666.109	1707271.813
2	11974.4215	10645.0696	21503184.50	20908521.25	4.6783
	1753083.125	0.000	2204950.906	0.000	1829774.844
	523144.926	0.000	480902.496	0.000	73.0818
	33102.545	0.000	155775.195	0.000	16.6130
6	10631.8463	0.0000	11937.8418	0.0000	36.8463
7	-316.5635	0.0000	-679.8785	0.0000	-0.0904
8	425.6063	[illegible]	642.2579	0.0000	-0.1421
9	223990.855	[illegible]	-0.006	-0.285	-0.001
10	-549.208	[illegible]	0.018	1.631	-0.059
11	-863.234	-863.252	0.002	-82.336	0.457
12	13.2053	-0.0590	0.0000	103879.976	-0.5447
13	-3.8906	0.0028	0.0000	2525933.625	-3.3777
14	0.4000	0.0000	0.0000	2527687.344	-0.4000
15	-77.3304	0.0000	0.0000	-0.0040	0.0589
16	-7.2699	0.0000	0.0000	-0.0589	-0.0024
17	0.0000	0.0000	0.0000	0.0024	-0.0000
18	2.9662	2.6367	2.6040	-0.2209	-0.0007
19	76.8045	78.2949	78.2877	0.1406	0.0012
20	425.1274	358.0948	-526.6677	-443.9046	188764.721
21	0.0001	4.5074	0.0000	2320.9781	680.000
22	75.4154	29.7998	29.6388	-30.4555	-0.0403
23	16.2712	16.1464	-2.1220	-0.0063	10645.070
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	125.2480			0.0000	0.0000
28	12.6696	0.0000	369.6596		
29	-7.2699	0.0000	-0.6659		
30	0.0000	0.0000	-1.0397		
31	434.2257	97491.7686	0.7815	37.0299	179.2711
32	3540.0001	11958.5964	31.6724	90887246.0	
33					
34	-0.8906	-0.0269	-5.8750	0.0185	

1	350.0000	190251.564	223697.883	599589.367	1812294.656
2	12319.6289	10989.0033	21508039.25	20908452.50	4.9661
3	1861069.844	0.000	2325975.500	0.000	1932442.250
4	518983.652	0.000	473001.367	0.000	73.1553
5	37531.905	0.000	162302.912	0.000	15.5788
6	10967.2301	0.0000	12268.7474	0.0000	37.8298
7	-515.8125	0.0000	-900.6002	0.0000	-0.0953
8	460.4316	0.0000	663.3545	0.0000	-0.1485
9	223695.439	223695.447	-0.006	0.117	-0.001
10	-563.678	-564.133	0.018	-24.830	-0.056
11	-877.922	-877.937	0.002	36.764	0.468
12	12.5516	-0.0675	0.0000	103868.239	-0.5388
13	-3.8639	0.0025	0.0000	2512069.719	-3.4005
14	0.4000	-0.0000	0.0000	2513828.844	-0.4000
15	-77.9778	0.0000	0.0000	-0.0045	0.0674
16	-7.2663	0.0000	0.0000	-0.0674	-0.0020
17	0.0000	0.0000	0.0000	0.0020	-0.0000
18	2.2672	2.0222	1.9900	-0.2249	-0.0016
19	77.0749	78.4931	78.4875	0.1445	0.0001
20	423.9724	361.4394	-527.6180	-447.9976	190498.625
21	0.0001	4.6342	0.0000	2339.8857	680.000
22	75.0927	29.8651	29.7038	-30.4416	-0.0403
23	16.6213	16.5131	-2.0030	-0.0063	10989.004
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	125.7221			0.0000	0.0000
28	12.0222	0.0000	372.0854		
29	-7.2663	0.0000	-0.6837		
30	0.0000	0.0000	-1.0665		
31	463.6240	94003.7891	0.7684	37.4474	179.3999
32	3540.4193	12309.9581	31.6660	95228246.0	
33					
34	-0.3516	0.3912	-3.5469	0.0184	

Appendix 4
Flight Simulated Data (AC77)

TABLE AP 4-3 (Sheet 6 of 10)
FLIGHT SIMULATED DATA

1	360.0000	184992.555	223888.676	603377.727	1920748.672
2	12677.9751	11346.3719	21511758.75	20908383.00	5.2633
3	1972461.859	0.000	2450358.750	0.000	2038476.344
4	512825.824	0.000	462884.762	0.000	73.2290
5	42315.159	0.000	169044.217	0.000	14.5706
6	11312.8713	0.0000	12609.5381	0.0000	38.9384
7	-715.9678	0.0000	-1123.0873	0.0000	-0.0999
8	496.4805	0.0000	685.0612	0.0000	-0.1537
9	223886.186	223886.193	-0.006	0.691	-0.002
10	-574.154	-574.657	0.019	190.905	-0.055
11	-883.735	-883.755	0.002	40.946	0.479
12	11.8390	-0.0741	0.0000	103856.410	-0.5350
13	-3.9009	0.0034	0.0000	2496716.844	-3.4046
14	0.4000	-0.0000	0.0000	2498481.375	-0.4000
15	-78.6866	0.0000	0.0000	-0.0050	0.0739
16	-7.3073	0.0000	0.0000	-0.0739	-0.0029
17	0.0000	0.0000	0.0000	0.0029	-0.0000
18	1.6364	1.4645	1.4328	-0.2262	-0.0007
19	77.3482	78.6965	78.6925	0.1471	0.0002
20	425.1473	364.4850	-526.6085	-451.7067	192080.180
21	0.0001	4.7701	0.0000	2354.4349	680.000
22	74.7588	29.9311	29.7697	-30.4309	-0.0403
23	16.8639	16.7630	-1.9523	-0.0064	11346.373
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	126.1861			0.0000	0.0000
28	11.3134	0.0000	374.7658		
29	-7.3073	0.0000	-0.7025		
30	0.0000	0.0000	-1.0948		
31	495.3285	90588.1680	0.7545	37.8977	179.5337
32	3540.7476	12672.7211	31.6598	99820304.0	
33					
34	1.6875	-0.0474	-2.7500	0.0161	

1	390.0000	169169.619	223965.373	608469.930	2267973.469
2	13838.0906	12504.8871	21516636.50	20908169.25	6.2148
3	2328178.563	0.000	2844730.281	0.000	2378322.469
4	482216.320	0.000	418994.328	0.000	73.4495
5	58912.727	0.000	190609.379	0.000	11.6981
6	12419.0382	0.0000	13698.7201	0.0000	42.5950
7	-1328.6695	0.0000	-1808.3809	0.0000	-0.1147
8	611.8284	0.0000	753.3929	0.0000	-0.1782
9	223962.588	223962.596	-0.007	0.067	-0.002
10	-603.262	-603.731	0.021	6.810	-0.050
11	-937.152	-937.161	0.002	1.998	0.522
12	9.3387	-0.0662	0.0000	103820.315	-0.4887
13	-3.8286	0.0015	0.0000	2443462.594	-3.4735
14	0.4000	-0.0000	0.0000	2445243.531	-0.4000
15	-81.1401	0.0000	0.0000	-0.0044	0.0661
16	-7.3038	0.0000	0.0000	-0.0661	-0.0011
17	0.0000	0.0000	0.0000	0.0011	-0.0000
18	0.1046	0.0945	0.0645	-0.2397	-0.0004
19	78.1855	79.3378	79.3376	0.1544	-0.0007
20	424.3534	372.0874	-527.7738	-461.1716	196109.730
21	0.0001	5.2355	0.0000	2373.9915	680.000
22	73.6861	30.1334	29.9713	-30.4167	-0.0405
23	16.9189	16.8472	-1.6508	-0.0070	12504.888
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	127.5254			0.0000	0.0000
28	8.8599	0.0000	384.2786		
29	-7.3038	0.0000	-0.7657		
30	0.0000	0.0000	-1.1899		
31	607.1150	80714.9824	0.7073	39.4893	179.9720
32	3541.1909	13838.0780	31.6446	115349505.0	
33					
34	1.9453	0.3279	-2.1250	0.0110	

1	370.0000	179720.279	223343.367	606088.086	2032756.875
2	13050.4792	11718.1475	21514398.25	20908312.50	5.5702
3	2087366.125	0.000	2578203.844	0.000	2148029.656
4	504660.258	0.000	450532.551	0.000	73.3026
5	47465.479	0.000	176005.951	0.000	13.5881
6	11669.9797	0.0000	12961.4108	0.0000	39.9831
7	-917.4327	0.0000	-1347.7965	0.0000	-0.1039
8	533.7365	0.0000	707.3283	0.0000	-0.1624
9	223340.760	223340.768	-0.007	-0.173	-0.002
10	-580.166	-580.887	0.019	-61.546	-0.052
11	-907.288	-907.269	0.002	-18.561	0.491
12	11.0242	-0.1061	0.0000	103844.486	-0.5656
13	-3.8471	0.0006	0.0000	2480298.750	-3.4395
14	0.4000	0.0000	0.0000	2482068.688	-0.4000
15	-79.5319	0.0000	0.0000	-0.0071	0.1059
16	-7.2886	0.0000	0.0000	-0.1059	0.0002
17	0.0000	0.0000	0.0000	-0.0002	-0.0000
18	1.0702	0.9609	0.9298	-0.2328	-0.0001
19	77.6242	78.9051	78.9024	0.1490	0.0037
20	423.3902	367.2543	-527.5058	-455.1393	193544.070
21	0.0001	4.9156	0.0000	2364.8440	680.000
22	74.4134	29.9979	29.8362	-30.4233	-0.0404
23	16.9413	16.8544	-1.8171	-0.0065	11718.148
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	126.6408			0.0000	0.0000
28	10.4681	0.0000	377.6733		
29	-7.2886	0.0000	-0.7224		
30	0.0000	0.0000	-1.1247		
31	529.6430	87234.8613	0.7398	38.3854	179.6728
32	3540.9857	13048.1559	31.6542	104692563.0	
33					
34	1.9844	-0.2596	-4.1875	0.0141	

1	400.0000	163889.301	224281.457	608247.016	2391449.594
2	14252.7358	12919.3243	21516341.00	20908096.50	6.5532
3	2454317.094	0.000	2983633.406	0.000	2499368.875
4	467886.492	0.000	399737.465	0.000	73.5225
5	65234.367	0.000	198261.934	0.000	10.7895
6	12810.8831	0.0000	14084.0593	0.0000	44.0293
7	-1537.5860	0.0000	-2043.4555	0.0000	-0.1206
8	652.7252	0.0000	777.2225	0.0000	-0.1873
9	224278.574	224278.582	-0.007	0.009	-0.002
10	-614.261	-614.751	0.022	0.498	-0.050
11	-954.276	-954.286	0.002	-6.250	0.546
12	8.6489	-0.0681	0.0000	103808.048	-0.4767
13	-3.8118	0.0017	0.0000	2422643.563	-[illegible]933
14	0.4000	0.0000	0.0000	2424430.063	-0.4000
15	-81.8178	0.0000	0.0000	-0.0045	0.0680
16	-7.3068	0.0000	0.0000	-0.0680	-0.0012
17	0.0000	0.0000	0.0000	0.0012	-0.0000
18	-0.2936	-0.2661	-0.2955	-0.2438	-0.0006
19	78.4715	79.5628	79.5636	0.1570	0.0003
20	424.6641	374.1540	-528.1317	-463.8458	197215.453
21	0.0001	5.4100	0.0000	2373.1354	680.000
22	73.3033	30.2021	30.0398	-30.4174	-0.0405
23	16.9920	16.9280	-1.5637	-0.0073	12919.325
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	127.9566			0.0000	0.0000
28	8.1822	0.0000	388.0325		
29	-7.3068	0.0000	-0.7894		
30	0.0000	0.0000	-1.2256		
31	650.7906	77552.2539	0.6895	40.1142	-179.8667
32	3541.1626	14252.4606	31.6405	121164377.0	
33					
34	-1.8906	0.2466	0.0313	0.0094	

1	380.0000	174442.266	223819.680	607769.273	2148453.219
2	13437.3894	12104.5358	21516008.25	20908241.25	5.8873
3	2205899.313	0.000	2709623.406	0.000	2261259.938
4	494466.492	0.000	435915.086	0.000	73.3762
5	52993.762	0.000	183192.438	0.000	12.6308
6	12038.8562	0.0000	13324.8254	0.0000	41.2806
7	-1121.7661	0.0000	-1576.3212	0.0000	-0.1088
8	572.1642	0.0000	730.0874	0.0000	-0.1699
9	223816.994	223817.002	-0.007	-0.152	-0.002
10	-590.058	-590.591	0.020	10.810	-0.051
11	-921.113	-921.113	0.002	-55.001	0.503
12	10.1081	-0.0763	0.0000	103832.458	-0.5186
13	-3.8443	0.0006	0.0000	2462618.656	-3.4548
14	0.4000	0.0000	0.0000	2464394.094	-0.4000
15	-80.4008	0.0000	0.0000	-0.0051	0.0762
16	-7.3009	0.0000	0.0000	-0.0762	-0.0000
17	0.0000	0.0000	0.0000	0.0000	-0.0000
18	0.5596	0.5041	0.4735	-0.2358	-0.0002
19	77.9031	79.1186	79.1172	0.1512	-0.0007
20	422.4288	369.7794	-529.8336	-458.2982	194889.488
21	0.0001	5.0707	0.0000	2371.3006	680.000
22	74.0560	30.0653	29.9034	-30.4186	-0.0404
23	16.8803	16.8000	-1.7396	-0.0067	12104.536
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	127.0875			0.0000	0.0000
28	9.5992	0.0000	380.8347		
29	-7.3009	0.0000	-0.7434		
30	0.0000	0.0000	-1.1563		
31	566.8360	83941.9717	0.7240	38.9147	179.8195
32	3541.1327	13436.7554	31.6492	109865737.0	
33					
34	2.3828	-0.1047	-5.2813	0.0125	

1	410.0000	158614.980	224124.074	607170.086	2519024.500
2	14682.6909	13349.1826	21515190.75	20908023.00	6.9028
3	2584439.469	0.000	3126453.250	0.000	2624561.219
4	451458.441	0.000	378115.559	0.000	73.5952
5	71971.672	0.000	206155.818	0.000	9.9049
6	13215.9373	0.0000	14482.1901	0.0000	45.4615
7	-1748.3372	0.0000	-2281.4356	0.0000	-0.1268
8	694.9811	0.0000	801.6633	0.0000	-0.1978
9	224121.070	224121.078	-0.008	-0.327	-0.002
10	-625.019	-625.565	0.024	-139.389	-0.049
11	-975.149	-975.138	0.002	1.930	0.572
12	7.9385	-0.0782	0.0000	103795.637	-0.4752
13	-3.7961	-0.0014	0.0000	2399901.844	-3.5235
14	0.4000	0.0000	0.0000	2401693.969	-0.4000
15	-82.5266	0.0000	0.0000	-0.0052	0.0780
16	-7.3213	0.0000	0.0000	-0.0780	0.0019
17	0.0000	0.0000	0.0000	-0.0019	-0.0000
18	-0.6351	-0.5774	-0.6062	-0.2493	-0.0007
19	78.7616	79.7939	79.7956	0.1599	0.0010
20	425.5480	376.0810	-526.6646	-466.2912	198236.605
21	0.0001	5.5949	0.0000	2368.9995	680.000
22	72.9072	30.2713	30.1088	-30.4205	-0.0406
23	17.0003	16.9428	-1.4823	-0.0077	13349.183
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	128.3811			0.0000	0.0000
28	7.4734	0.0000	392.1375		
29	-7.3213	0.0000	-0.8147		
30	0.0000	0.0000	-1.2636		
31	698.3525	74463.4873	0.6705	40.7972	-179.7021
32	3541.0494	14641.4653	31.6265	127349865.0	
33					
34	-7.3[illegible]	0.4371	3.4063	0.0067	

TABLE AP 4-3 (Sheet 7 of 10)
FLIGHT SIMULATED DATA

1	420.0000	153339.975	224268.484	605311.148	2650851.375
2	15128.1483	13794.6284	21513258.00	20907949.00	7.2640
3	2718680.313	0.000	3273320.188	0.000	2754069.156
4	432911.031	0.000	354096.313	0.000	73.6674
5	79139.074	0.000	214297.682	0.000	9.0438
6	13634.4407	0.0000	14893.3304	0.0000	47.0557
7	-1961.6408	0.0000	-2523.0788	0.0000	-0.1324
8	738.7609	0.0000	826.8503	0.0000	-0.2055
9	224265.443	224265.453	-0.008	-0.026	-0.003
10	-631.181	-631.780	0.025	167.161	-0.051
11	-979.353	-979.359	0.002	-126.659	0.599
12	7.1714	-0.0814	0.0000	103783.069	-0.4725
13	-3.8146	0.0012	0.0000	2375009.688	-3.5283
14	0.400	0.0001	0.0000	2376807.500	-0.4000
15	-83.2909	0.0000	0.0000	-0.0054	0.0813
16	-7.3444	0.0000	0.0000	-0.0813	-0.0006
17	0.0000	0.0000	0.0000	0.0006	-0.0000
18	-0.9242	-0.8428	-0.8709	-0.2502	-0.0010
19	79.0568	80.0320	80.0344	0.1614	0.0004
20	425.8233	377.8405	-525.6632	-468.5580	199170.047
21	0.0001	5.7903	0.0000	2361.8602	680.000
22	72.4971	30.3411	30.1783	-30.4258	-0.0406
23	16.9155	16.8611	-1.4394	-0.0082	13794.629
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	128.7995			0.0000	0.0000
28	6.7091	0.0000	76.6284		
29	-7.3444	0.0000	-0.8417		
30	0.0000	0.0000	-1.3043		
31	750.2249	71388.0791	0.6503	41.5454	-179.5316
32	3540.8549	15125.4603	31.6333	133930823.0	
33					
34	-13.9297	0.2644	3.7813	0.0035	

1	430.0000	148068.635	222928.744	602745.180	2767088.938
2	15590.6889	14257.2211	21510616.50	20907874.25	7.6374
3	2857178.813	0.000	3424368.906	0.000	2888064.656
4	412215.156	0.000	327639.563	0.000	73.7391
5	86752.449	0.000	222695.623	0.000	8.2059
6	14068.0264	0.0000	15319.0929	0.0000	48.4397
7	-2178.0785	0.0000	-2769.0441	0.0000	-0.1399
8	784.1977	0.0000	852.8655	0.0000	-0.2165
9	222925.574	222925.584	-0.009	0.090	-0.003
10	-643.787	-644.408	0.027	1.863	-0.051
11	-996.351	-996.364	0.002	5.449	0.626
12	6.3375	-0.0827	0.0000	103770.332	-0.4542
13	-3.7919	0.0020	0.0000	2347762.094	-3.5546
14	0.4009	-0.0000	0.0000	2349565.625	-0.4000
15	-84.1063	0.0000	0.0000	-0.0055	0.0826
16	-7.3480	0.0000	0.0000	-0.0826	-0.0014
17	0.0000	0.0000	0.0000	0.0014	-0.0000
18	-1.1638	-1.0642	-1.0917	-0.2561	-0.0008
19	79.3576	80.2774	80.2804	0.1656	0.0005
20	422.1620	379.4828	-528.0570	-470.6498	200035.787
21	0.0001	5.9970	0.0000	2352.0056	680.000
22	72.0726	30.4112	30.2482	-30.4331	-0.0407
23	16.7239	16.6746	-1.3599	-0.0087	14257.222
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	129.2121			0.0000	0.0000
28	5.8937	0.0000	401.5354		
29	-7.3480	0.0000	-0.8706		
30	0.0000	0.0000	-1.3478		
31	807.0621	68376.5488	0.6287	42.3696	-179.3550
32	3540.5789	15586.1858	.6301	140954810.0	
33					
34	-20.1172	0.0254	3.8438	0.0001	

1	440.0000	142785.805	224750.049	599547.852	2927922.906
2	16072.9609	14739.5946	21507345.00	20907799.00	8.0233
3	3000101.313	0.000	3579760.938	0.000	3026744.750
4	389338.215	0.000	298699.871	0.000	73.8104
5	94828.938	0.000	231357.918	0.000	7.3906
6	14519.4494	0.0000	15762.2169	0.0000	50.6423
7	-2397.9209	0.0000	-3019.7154	0.0000	0.1473
8	831.3908	0.0000	879.7385	0.0000	-0.2295
9	224745.775	224746.785	-0.009	-0.463	-0.003
10	-653.909	-654.551	0.029	67.673	-0.052
11	-1018.483	-1018.497	0.002	-159.750	0.667
12	5.5106	-0.0839	0.0000	103757.409	-0.4546
13	-3.7749	0.0023	0.0000	2317843.000	-3.5697
14	0.4009	0.0000	0.0000	2319652.344	-0.4000
15	-84.9337	0.0000	0.0000	-0.0055	0.0838
16	-7.3453	0.0000	0.0000	-0.0838	-0.0017
17	0.0009	0.0000	0.0000	0.0017	-0.0000
18	-1.3539	-1.2416	-1.2664	-0.2596	0.0009
19	79.663	80.5300	80.5335	0.1669	-0.0031
20	425.7611	381.0277	-527.8706	-472.6369	200866.988
21	0.0001	6.7161	0.0000	2339.7263	684.322
22	71.6339	30.4817	30.3185	-30.4423	-0.0408
23	16.5033	16.4582	-1.2886	-0.0094	14739.595
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	129.6195			0.0000	0.0000
28	5.0663	0.0000	406.9087		
29	-7.3453	0.0000	-0.9016		
30	0.0009	0.0000	-1.3944		
31	869.7809	65394.5215	0.6035	43.2845	-179.1735
32	3540.2263	16066.4556	31.6273	148490528.0	
33					
34	-23.7654	-0.4908	2.1563	-0.0031	

1	450.0000	137501.703	223375.371	595805.945	3073548.313
2	16574.0903	15240.8623	21503527.25	20907723.75	8.4224
3	3147623.563	0.000	3739667.250	0.000	3170314.469
4	364241.858	0.000	267225.969	0.000	73.8812
5	103385.256	0.000	240292.309	0.000	6.5974
6	14987.7795	0.0000	16221.7327	0.0000	52.2668
7	-2622.1585	0.0000	-3276.0989	0.0000	-0.1557
8	880.1341	0.0000	907.2417	0.0000	-0.2424
9	223371.961	223371.973	-0.010	-0.527	-0.004
10	-665.435	-666.103	0.031	-119.319	-0.054
11	-1036.112	-1035.981	0.002	-54.338	0.710
12	4.6204	-0.0855	0.0000	103744.279	-0.4307
13	-3.7649	-0.0172	0.0000	2284894.156	-3.6270
14	0.4009	0.0000	0.0000	2286709.406	-0.4000
15	-85.7995	0.0000	0.0000	-0.0056	0.0852
16	-7.3928	0.0000	0.0000	-0.0852	0.0176
17	0.0009	0.0000	0.0000	-0.0178	-0.0000
18	-1.4997	-1.3790	-1.4052	-0.2657	0.0006
19	79.9753	80.7896	80.7935	0.1709	0.0007
20	422.6869	382.4481	-528.4573	-474.4957	201633.227
21	0.0001	6.4473	0.0000	2325.3556	688.947
22	71.1775	30.5525	30.3890	-30.4529	-0.0409
23	16.1909	16.1479	-1.2308	-0.0102	15240.863
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	130.0279			0.0000	0.0000
28	4.2005	0.0000	412.8046		
29	-7.3929	0.0000	-0.9349		
30	0.0009	0.0000	-1.4445		
31	938.9558	62450.6682	0.5807	44.3006	-176.9849
32	3539.8017	16565.5049	31.6249	156554530.0	
33					
34	-25.9281	-0.3103	1.9688	-0.0088	

1	460.0009	132218.391	223597.695	591601.258	3224154.906
2	17095.5018	15762.5166	21499246.25	20907647.75	6.6351
3	3299916.031	0.000	3904255.000	0.000	3318974.188
4	336879.852	0.000	233158.004	0.000	73.9515
5	112441.949	0.000	249509.863	0.000	5.8256
6	15474.5105	0.0000	16699.1375	0.0000	54.4094
7	-2851.0085	0.0000	-3538.5081	0.0000	-0.1660
8	931.8109	0.0000	936.7033	0.0000	-0.2545
9	223594.193	223594.205	-0.011	0.667	-0.004
10	-682.297	-682.963	0.033	69.875	-0.063
11	-1045.019	-1046.008	0.003	65.298	0.757
12	3.7691	-0.0831	0.0000	103730.918	-0.4080
13	-3.9045	-0.0012	0.0000	2248521.063	-3.6206
14	0.4009	-0.0000	0.0000	2250342.281	-0.4000
15	-86.6283	0.0000	0.0000	-0.0057	0.0829
16	-7.5268	0.0000	0.0000	-0.0829	0.0018
17	0.0009	0.0000	0.0000	-0.0018	-0.0000
18	-1.6015	-1.4766	-1.5020	-0.2680	-0.0025
19	80.2972	81.0609	81.0650	0.1750	0.0004
20	422.917	383.7633	-528.8219	-476.2321	202344.406
21	0.0001	6.6913	0.0000	2309.2076	693.026
22	70.7059	30.6235	30.4597	-30.4649	-0.0410
23	15.8975	15.8479	-1.3213	-0.0112	15762.519
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	130.4201			0.0000	0.0000
28	3.3717	0.0000	419.2837		
29	-7.5268	0.0000	-0.9707		
30	0.0009	0.0000	-1.4985		
31	1015.6129	59539.4741	0.5541	45.4354	-178.7903
32	3539.3077	17084.9968	31.6220	165203742.0	
33					
34	-22.9459	-0.2520	1.8750	-0.0172	

1	470.0009	126945.926	223476.039	587028.672	3379967.063
2	17638.6775	16305.7393	21494597.75	20907572.00	9.2621
3	3451175.688	0.000	4073717.125	0.000	3472943.500
4	307205.563	0.000	196434.834	0.000	74.0216
5	122039.375	0.000	250031.938	0.000	5.0748
6	15950.9131	0.0000	17195.6863	0.0000	56.6383
7	-3084.5926	0.0000	-3807.1470	0.0000	-0.1750
8	986.3293	0.0000	967.9814	0.0000	-0.2702
9	223472.412	223472.426	-0.012	-0.016	-0.004
10	-693.439	-691.072	0.036	-3.456	-0.067
11	-1065.959	-1065.973	0.003	-16.246	0.810
12	2.9698	-0.0773	0.0000	103717.299	-0.3889
13	-3.9339	-0.0033	0.0000	2205267.875	-3.6476
14	0.4009	0.0000	0.0000	2210095.219	-0.4000
15	-87.4083	0.0000	0.0000	-0.0053	0.0771
16	-7.5828	0.0000	0.0000	-0.0771	0.0039
17	0.0009	0.0000	0.0000	-0.0039	-0.0000
18	-1.6593	-1.5348	-1.5585	-0.2733	-0.0005
19	80.5287	81.3431	81.3475	0.1772	0.0003
20	424.0312	385.0196	-527.0188	-477.8261	203003.984
21	0.0002	6.9444	0.0000	2291.6466	694.967
22	70.5173	30.6944	30.5304	-30.4779	-0.0411
23	15.6170	15.5618	-1.2999	-0.0123	16305.740
24	0.0009	0.0000	0.0000	0.000	0.0000
25	0.0009	0.0000	0.0000	0.000	0.0000
26	0.0009	0.0000	0.0000	0.000	0.0000
27	130.8149			0.0000	0.0000
28	2.5917	0.0000	426.4163		
29	-7.5828	0.0000	-1.0095		
30	0.0009	0.0000	-1.5568		
31	1100.9194	56657.0503	0.5254	46.7093	-178.5914
32	3539.7466	17626.2544	31.6186	174493822.0	
33					
34	-19.8750	-1.3710	2.2500	-0.0271	

Appendix 4
Flight Simulated Data (AC77)

TABLE AP 4-3 (Sheet 8 of 10)
FLIGHT SIMULATED DATA

1	480.0000	121678.677	222906.471	582194.789	3541195.375
2	18204.4727	16871.6758	21489688.50	20907496.00	9.7039
3	3619602.813	0.000	4248233.438	0.000	3632452.906
4	275171.825	0.000	156993.686	0.000	74.0913
5	132177.252	0.000	268874.625	0.000	4.3445
6	16508.1997	0.0000	17712.5676	0.0000	58.9394
7	-3323.2310	0.0000	-4082.4169	0.0000	-0.1845
8	1043.5205	0.0000	1000.8500	0.0000	-0.2856
9	222902.742	222902.756	-0.013	-0.294	-0.005
10	-697.582	-698.835	0.038	-7.851	-0.073
11	-1080.062	-1080.029	0.003	-85.297	0.855
12	1.9731	-0.1532	0.0000	103703.505	-0.5703
13	-3.9672	-0.0034	0.0000	2165126.031	-3.6697
14	0.4000	0.0000	0.0000	2166959.531	-0.4000
15	-88.5873	0.0000	0.0000	-0.0106	0.1528
16	-7.6382	0.0000	0.0000	-0.1528	0.0045
17	0.0000	0.0000	0.0000	-0.0045	-0.0000
18	-1.6737	-1.5512	-1.5751	-0.2776	-0.0003
19	80.9692	81.6358	81.6403	0.1796	-0.0063
20	423.2157	386.1857	-520.6882	-479.3077	203611.963
21	0.0002	7.2188	0.0000	2273.0821	704.377
22	69.7103	30.7653	30.6011	-30.4917	-0.0412
23	15.1141	15.0641	-1.2876	-0.0155	16871.677
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	131.2040			0.0000	0.0000
28	1.4127	0.0000	434.0240		
29	-7.6388	0.0000	-1.0502		
30	0.0000	0.0000	-1.6181		
31	1196.2677	53801.0278	0.4946	48.1470	-178.3896
32	3538.1223	18190.5615	31.6153	184484148.0	
33					
34	5.7734	-2.0171	-6.6563	-0.0389	

1	510.0000	106372.093	199791.975	566402.234	4059659.500
2	20015.8445	18683.6487	21473669.50	20907269.75	11.1247
3	4139780.156	0.000	4804005.875	0.000	4146338.969
4	163488.650	0.000	20782.354	0.000	74.2989
5	166190.459	0.000	300431.750	0.000	2.2597
6	18176.6145	0.0000	19343.7402	0.0000	60.4293
7	-4146.3958	0.0000	-5024.1240	0.0000	-0.2005
8	1223.4463	0.0000	1100.9108	0.0000	-0.3004
9	199788.383	199788.402	-0.018	2.483	-0.006
10	-662.868	-663.072	0.040	459.895	-0.071
11	-993.276	-993.303	0.003	189.978	0.869
12	-2.9475	-0.0215	0.0000	103661.651	0.0288
13	-3.6959	0.0033	0.0000	2024454.672	-4.0023
14	0.4000	-0.0000	0.0000	2026306.797	-0.4000
15	-92.9045	0.0000	0.0000	-0.0014	0.0215
16	-7.6981	0.0000	0.0000	-0.0215	-0.0031
17	0.0000	0.0000	0.0000	0.0031	-0.0000
18	-1.7181	-1.6038	-1.6251	-0.2849	0.0085
19	82.0294	82.5635	82.5681	0.1902	0.0110
20	424.6158	17.6401	-470.5157	-20.6534	8743.147
21	0.0003	8.1029	0.0000	2212.4310	721.544
22	68.0753	30.9759	30.8109	-30.5368	-0.0414
23	11.7501	11.7145	-0.9399	-0.0180	18683.649
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	132.3533			0.0000	0.0000
28	-2.9045	0.0000	458.5991		
29	-7.6981	0.0000	-1.1785		
30	0.0000	0.0000	-1.8105		
31	1552.9770	45531.8486	0.3897	53.6616	-177.4519
32	3536.3499	19995.1687	31.6087	218611104.0	
33					
34	138.5313	-1.4260	20.3438	-0.0568	

1	490.0000	116411.467	222015.638	577164.820	3708069.938
2	18795.1531	17462.5161	21484583.00	20907420.00	10.1612
3	3787394.406	0.000	4428012.938	0.000	3797723.625
4	240678.605	0.000	114719.203	0.000	74.1609
5	142908.764	0.000	279053.047	0.000	3.6335
6	17055.9241	0.0000	18248.9211	0.0000	61.3601
7	-3580.1257	0.0000	-4377.5577	0.0000	-0.1948
8	1103.4651	0.0000	1035.2376	0.0000	-0.3016
9	222012.015	222012.031	-0.015	-0.377	-0.005
10	-704.775	-706.245	0.036	-2.293	-0.081
11	-1091.185	-1091.169	0.004	-114.618	0.798
12	-0.7253	-0.1771	0.0000	103689.688	-0.5100
13	-3.9929	-0.0011	0.0000	2120779.000	-3.6869
14	0.4000	0.0000	0.0000	2122618.625	-0.4000
15	-91.2259	0.0000	0.0000	-0.0123	0.1766
16	-7.6815	0.0000	0.0000	-0.1766	0.0023
17	0.0000	0.0000	0.0000	-0.0023	-0.0000
18	-1.6580	-1.5683	-1.5914	-0.2816	-0.0007
19	81.3190	81.9393	81.9437	0.1823	-0.0064
20	422.5096	387.2014	-525.4605	-480.7020	204141.031
21	0.0002	7.5036	0.0000	2253.7646	710.072
22	69.1859	30.8360	30.6714	-30.5061	-0.0413
23	12.9369	12.8748	-1.3004	-0.0148	17462.517
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	131.5905			0.0000	0.0000
28	-1.2259	0.0000	441.8076		
29	-7.6815	0.0000	-1.0914		
30	0.0000	0.0000	-1.6799		
31	1303.4457	50966.7739	0.4615	49.7817	-178.1413
32	3537.5089	18779.4363	31.6119	195255964.0	
33					
34	38.5734	0.5924	4.3750	-0.0506	

1	570.0000	101794.687	191219.814	560750.617	4244362.813
2	20614.5139	19282.5671	21467943.50	20907195.50	11.6309
3	4324276.625	0.000	5000104.438	0.000	4329647.313
4	120582.909	0.000	-31105.730	0.000	74.3666
5	178712.418	0.000	311588.645	0.000	1.5959
6	18772.2783	0.0000	19875.4929	0.0000	60.4372
7	-4433.4282	0.0000	-5352.3336	0.0000	-0.2023
8	1280.0043	0.0000	1129.4098	0.0000	-0.3089
9	191216.223	191216.244	-0.020	0.370	-0.007
10	-639.912	-639.492	0.048	18.655	-0.032
11	-977.343	-977.771	0.001	85.517	1.036
12	-2.4330	0.0634	0.0000	103647.247	0.1298
13	-3.1670	0.0568	0.0000	1969873.172	-3.9873
14	0.4000	-0.0000	0.0000	1971731.672	-0.4000
15	-92.2886	0.0000	0.0000	0.0035	-0.0629
16	-7.1539	0.0000	0.0000	0.0629	-0.0572
17	0.0000	0.0000	0.0000	0.0572	-0.0000
18	-1.6830	-1.5743	-1.5947	-0.2930	-0.0011
19	82.3868	82.8817	82.8862	0.1916	0.0005
20	426.8725	28.6795	-447.9469	-32.4665	13778.202
21	0.0003	8.4040	0.0000	2190.7260	726.060
22	67.4910	31.0448	30.8795	-30.5529	-0.0415
23	12.7342	12.7293	-0.3658	-0.0200	19282.568
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	132.7290			0.0000	0.0000
28	-2.2886	0.0000	468.0348		
29	-7.1539	0.0000	-1.2264		
30	0.0000	0.0000	-1.8823		
31	1691.2787	43048.1963	0.3529	55.8533	-177.0712
32	3535.6927	20591.8623	31.6093	230598340.0	
33					
34	192.2109	-1.4326	12.0000	-0.0436	

1	500.0000	111242.962	213594.412	571901.320	3880865.969
2	19408.4026	18075.9680	21479244.25	20907344.75	10.6347
3	3960777.906	0.000	4613264.875	0.000	3969300.969
4	203504.660	0.000	69372.792	0.000	74.2302
5	154251.461	0.000	289580.223	0.000	2.9390
6	17621.1423	0.0000	18801.6558	0.0000	61.7753
7	-3857.5261	0.0000	-4694.7519	0.0000	-0.2068
8	1164.2446	0.0000	1069.2126	0.0000	-0.3007
9	213590.664	213590.682	-0.016	5.778	-0.005
10	-715.022	-715.740	0.036	710.231	-0.065
11	-1039.822	-1039.414	0.003	671.971	0.794
12	-2.4033	-0.0858	0.0000	103675.771	-0.0982
13	-3.6614	-0.0507	0.0000	2074378.781	-4.0525
14	0.4000	-0.0003	0.0000	2076224.609	-0.4000
15	-92.4878	0.0000	0.0000	-0.0055	0.0853
16	-7.7143	0.0000	0.0000	-0.0853	0.0513
17	0.0000	0.0000	0.0000	-0.0513	-0.0000
18	-1.7070	-1.5898	-1.6120	-0.2788	0.0119
19	81.6728	82.2486	82.2531	0.1920	-0.0145
20	422.0966	6.0308	-506.0232	-7.3268	3093.027
21	0.0002	7.8023	0.0000	2233.5501	716.045
22	68.6401	30.9062	30.7414	-30.5211	-0.0413
23	11.7577	11.7219	-0.9427	-0.0163	18075.969
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	131.9736			0.0000	0.0000
28	-2.4878	0.0000	449.9178		
29	-7.7143	0.0000	-1.1337		
30	0.0000	0.0000	-1.7434		
31	1423.7681	48169.5376	0.4260	51.6401	-177.8255
32	3536.9251	19390.3594	31.6097	206807270.0	
33					
34	78.3828	-2.1309	17.1563	-0.0591	

1	530.0000	97386.722	185855.934	555159.875	4434957.688
2	21215.9231	19884.2312	21462280.25	20907122.50	12.1532
3	4514240.625	0.000	5201529.500	0.000	4518932.000
4	74848.844	0.000	-86239.140	0.000	74.4326
5	191773.725	0.000	323000.699	0.000	0.9490
6	19272.0217	0.0000	20410.9846	0.0000	61.4006
7	-4711.5248	0.0000	-5672.6899	0.0000	-0.2286
8	1331.6777	0.0000	1152.2946	0.0000	-0.3160
9	185852.164	185852.188	-0.022	10.874	-0.010
10	-692.012	-690.573	0.060	192.995	0.001
11	-956.633	-955.652	-0.000	2023.956	1.261
12	-1.4521	0.2015	0.0000	103632.502	0.4154
13	-2.7809	0.0011	0.0000	1910185.125	-4.0718
14	0.4000	-0.0006	0.0000	1912050.109	-0.4000
15	-91.0189	0.0000	0.0000	0.0098	-0.2013
16	-6.8512	0.0000	0.0000	0.2013	-0.0025
17	0.0000	0.0000	0.0000	0.0025	-0.0000
18	-1.5758	-1.4768	-1.4765	-0.2949	0.0007
19	82.7367	83.1951	83.1994	0.2129	-0.0040
20	427.0239	39.1773	-435.2267	-43.2119	18375.543
21	0.0003	8.7176	0.0000	2165.7055	730.766
22	66.8871	31.1126	30.9470	-30.5689	-0.0416
23	14.1579	14.1578	0.0368	-0.0221	19884.232
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	133.1007			0.0000	0.0000
28	1.0189	0.0000	478.3375		
29	-6.8512	0.0000	-1.2782		
30	0.0000	0.0000	-1.9599		
31	1842.6099	40656.6030	0.3147	58.2630	-176.7362
32	3534.8751	21192.9014	31.6129	243003918.0	
33					
34	217.9219	-0.7856	6.4375	-0.0308	

TABLE AP 4-3 (Sheet 9 of 10)
FLIGHT SIMULATED DATA

1	540.0000	93043.872	184769.699	549951.703	4631517.313
2	21827.6433	20496.1438	21456999.50	20907050.50	12.6918
3	4709763.750	0.000	5408371.375	0.000	4714312.063
4	26425.262	0.000	-144491.619	0.000	74.4965
5	205345.570	0.000	334631.527	0.000	0.3212
6	19636.6442	0.0000	20961.7336	0.0000	63.8911
7	-4967.6224	0.0000	-5972.7598	0.0000	-0.1804
8	1382.6492	0.0000	1173.8708	0.0000	-0.3377
9	184766.361	184766.387	-0.024	-20.127	-0.014
10	-521.597	-519.513	0.081	-246.833	0.016
11	-976.572	-976.639	-0.001	-3600.657	1.672
12	1.3025	0.2842	0.0000	103617.371	0.[illegible]15
13	-2.6915	0.0070	0.0000	1843020.969	-4.[illegible]05
14	0.4000	0.0013	0.0000	1844892.609	-0.4000
15	-88.4809	0.0000	0.0000	0.0133	-0.2839
16	-6.6012	0.0000	0.0000	0.2839	-0.0089
17	0.0000	0.0000	0.0000	0.0089	-0.0000
18	-1.3585	-1.2756	-1.2944	-0.3029	-0.0044
19	83.0913	83.5148	83.5185	0.1611	-0.0507
20	426.6933	49.1220	-433.0192	-53.2394	22659.536
21	0.0004	9.0457	0.0000	2136.4313	735.686
22	66.2634	31.1793	31.0135	-30.5838	-0.0417
23	17.2637	17.2625	0.2164	-0.0244	20496.144
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	133.4684			0.0000	0.0000
28	1.5191	0.0000	489.7483		
29	-6.6012	0.0000	-1.3344		
30	0.0000	0.0000	-2.0440		
31	2011.0912	38318.4634	0.2746	61.0251	-176.5759
32	3533.7616	21807.3357	31.6174	256007815.0	
33					
34	201.1953	0.5557	3.6875	-0.0170	

1	550.0000	88717.011	185105.563	545567.219	4834199.125
2	22462.1003	21130.7275	21452544.50	20906980.00	13.2473
3	4911056.250	0.000	562084[illegible].063	0.000	4916017.000
4	-24457.616	0.000	-205650.535	0.000	74.5584
5	219437.309	0.000	346481.227	0.000	-0.2851
6	20476.6177	0.0000	21537.2722	0.0000	67.1288
7	-5215.1804	0.0000	-6265.7993	0.0000	-0.2315
8	1436.2591	0.0000	1196.5414	0.0000	-0.3564
9	185101.811	185101.838	-0.027	0.109	-0.013
10	-638.348	-642.717	0.075	-2.292	-0.002
11	-982.614	-982.462	-0.000	-121.217	1.501
12	-1.8263	-0.5462	0.0000	103601.818	-0.6752
13	-2.8210	-0.0155	0.0000	1771146.688	-4.1489
14	0.4000	0.0000	0.0000	1773025.125	-0.4000
15	-92.4894	0.0000	0.0000	-0.0269	0.5454
16	-6.9723	0.0000	0.0000	-0.5454	0.0193
17	0.0000	0.0000	0.0000	-0.0193	-0.0000
18	-1.0656	-1.0025	-1.0207	-0.3041	-0.0005
19	83.4567	83.8462	83.8492	0.1989	0.0035
20	427.6035	58.5770	-432.3820	-62.7255	26715.394
21	0.0004	9.3788	0.0000	2112.3763	740.681
22	65.6193	31.2446	31.0785	-30.5964	-0.0418
23	14.4358	14.4358	0.0319	-0.0267	21130.729
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	133.8323			0.0000	0.0000
28	-2.4294	0.0000	502.2470		
29	-6.9723	0.0000	-1.3953		
30	0.0000	0.0000	-2.1352		
31	2203.3636	35987.2769	0.2317	64.2054	-176.6132
32	3532.5017	22446.7141	31.6215	2699[illegible]544.0	
33					
34	156.3125	0.0024	-1.0000	-0.0059	

1	560.0000	84404.453	183219.789	542008.820	5043315.438
2	23136.0515	21804.7954	21448917.50	20906911.00	13.8203
3	5112387.750	0.000	5839201.125	0.000	5124332.125
4	-73051.687	0.000	-269987.816	0.000	74.8186
5	234086.789	0.000	358572.043	0.000	-0.8727
6	21044.4634	0.0000	22138.8640	0.0000	69.8398
7	-5308.7453	0.0000	-6607.1179	0.0000	-0.2536
8	1494.4565	0.0000	1222.1590	0.0000	-0.3707
9	183215.967	183215.996	-0.029	5.478	-0.013
10	-665.289	-665.707	0.069	400.947	-0.022
11	-972.592	-972.613	0.001	749.664	1.333
12	-4.5556	-0.0430	0.0000	103585.775	0.0591
13	-2.9690	0.0028	0.0000	1689570.734	-4.1227
14	0.4000	-0.0003	0.0000	1691456.172	-0.4000
15	-94.4819	0.0000	0.0000	-0.0022	0.0429
16	-7.0915	0.0000	0.0000	-0.0429	-0.0025
17	0.0000	0.0000	0.0000	0.0025	-0.0000
18	-0.8388	-0.7905	-0.8073	-0.3042	-0.0020
19	83.2388	84.1946	84.1969	0.2082	-0.0040
20	424.1424	67.5764	-431.9682	-71.7140	30560.930
21	0.0005	9.7230	0.0000	2092.8534	745.845
22	64.9539	31.3082	31.1419	-30.6066	-0.0419
23	12.0927	12.0918	-0.1512	-0.0290	21804.796
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	134.1927			0.0000	0.0000
28	-4.4819	0.0000	316.0140		
29	-7.0915	0.0000	-1.4618		
30	0.0000	0.0000	-2.2347		
31	2429.4089	33614.4292	0.1849	68.0225	-176.4368
32	3531.5927	23123.6143	31.6245	285176056.0	
33					
34	95.3516	1.1892	-12.0625	0.0049	

1	570.0000	80100.912	183592.066	539241.773	5259209.813
2	23843.3879	22512.2129	21446084.50	20906844.25	14.4120
3	5332042.750	0.000	6063714.500	0.000	5339567.625
4	-134667.863	0.000	-337835.492	0.000	74.6773
5	249336.131	0.000	370928.957	0.000	-1.4452
6	21691.9680	0.0000	22769.0679	0.0000	73.7415
7	-5817.0092	0.0000	-6965.3332	0.0000	-0.2631
8	1555.8474	0.0000	1249.3736	0.0000	-0.4001
9	183588.150	183588.184	-0.031	1.191	-0.013
10	-654.924	-658.275	0.069	52.128	-0.024
11	-996.218	-995.919	0.001	63.727	1.269
12	-5.9827	-0.3919	0.0000	103569.151	-0.4133
13	-2.9638	-0.0330	0.0000	1597685.531	-4.2035
14	0.4000	0.0002	0.0000	1599578.203	-0.4000
15	-96.3829	0.0000	0.0000	-0.0203	0.3911
16	-7.1687	0.0000	0.0000	-0.3911	0.0357
17	0.0000	0.0000	0.0000	-0.0357	-0.0000
18	-0.5892	-0.5563	-0.5721	-0.3108	0.0011
19	84.2336	84.5566	84.5582	0.2054	0.0121
20	426.6294	76.1283	-430.3224	-80.2530	34206.036
21	0.0005	10.0750	0.0000	2077.6722	750.375
22	64.2659	31.3699	31.2034	-30.6145	-0.0420
23	11.0443	11.0432	-0.1550	-0.0313	22512.213
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0 00
27	134.5501			0.0000	0.0000
28	-6.3829	0.0000	531.3250		
29	-7.1687	0.0000	-1.5348		
30	0.0000	0.0000	-2.3439		
31	2695.0591	31224.8870	0.1342	72.6045	-176.3057
32	3530.7157	23834.5208	31.6271	301704488.0	
33					
34	7.4688	1.9888	-18.0625	0.0146	

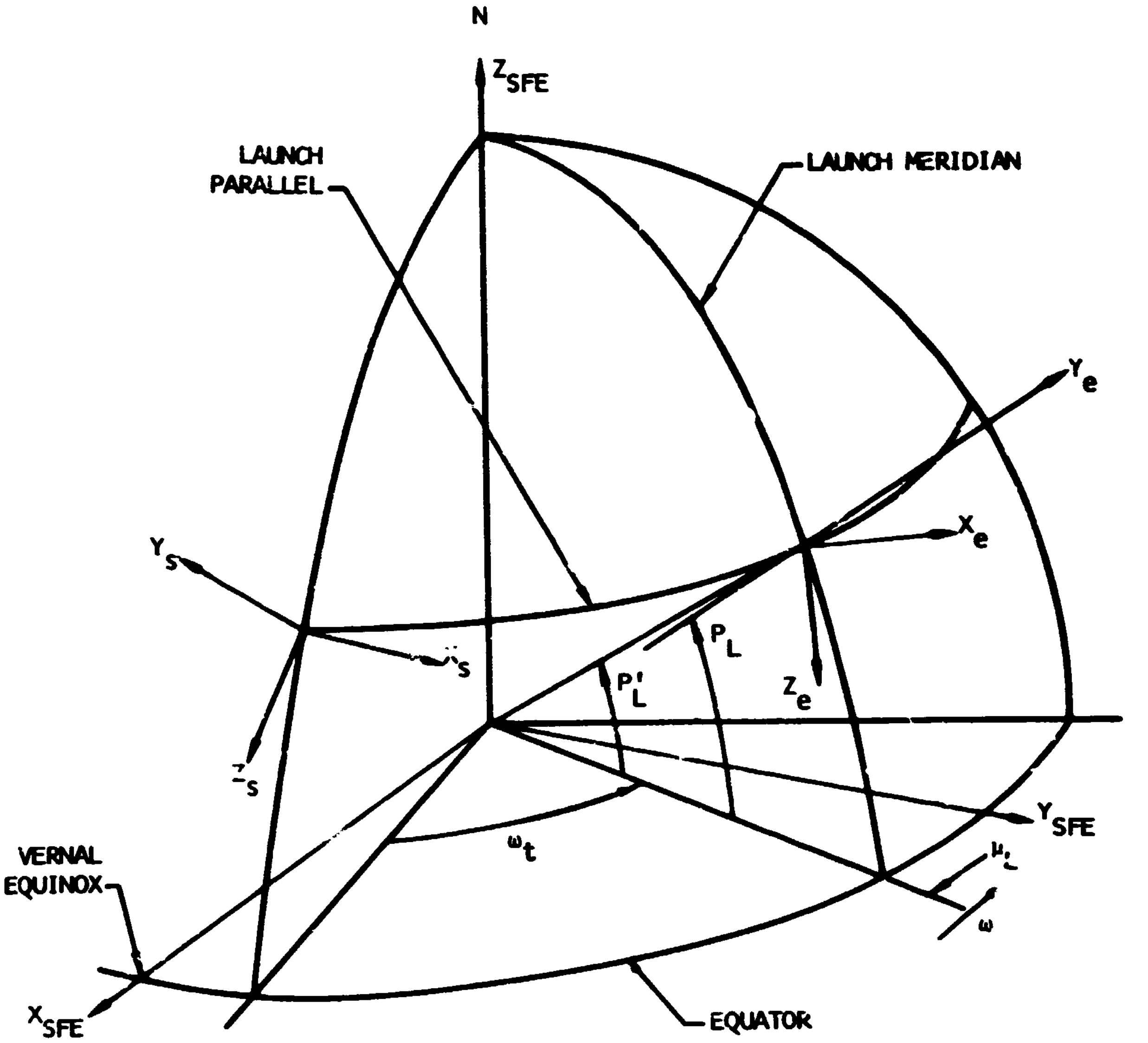
1	580.0000	75805.640	183049.002	537361.219	5482230.313
2	24592.5723	23261.4365	21444138.75	20906779.75	15.0232
3	5552337.188	0.000	6294686.375	0.000	5562070.500
4	-194517.066	0.000	-409427.664	0.000	74.7348
5	265224.793	0.000	383574.012	0.000	-2.0042
6	22373.0095	0.0000	23431.1650	0.0000	77.6895
7	-6156.9666	0.0000	-7357.6'12	0.0000	-0.2497
8	1623.1638	0.0000	1280.5909	0.0000	-0.4147
9	183045.416	183045.451	-0.034	-10.911	-0.013
10	-588.223	-587.302	0.067	1074.184	-0.058
11	-977.061	-977.000	0.003	-2650.774	1.145
12	-7.6151	0.1136	0.0000	103551.839	0.1251
13	-3.2514	-0.0082	0.0000	1492932.891	-4.1362
14	0.4000	0.0005	0.0000	1494833.063	-0.4000
15	-97.4750	0.0000	0.0000	0.0064	-0.1135
16	-7.3872	0.0000	0.0000	0.1135	0.0074
17	0.0000	0.0000	0.0000	-0.0074	-0.0000
18	-0.3527	-0.3336	-0.3483	-0.3058	0.0069
19	84.6473	84.9379	84.9388	0.1838	-0.0414
20	426.2315	84.2934	-429.4507	-88.3756	37676.083
21	0.0006	10.4363	0.0000	2067.3547	752.181
22	63.5543	31.4293	31.2626	-30.6200	-0.0420
23	9.8342	9.8244	-0.4480	-0.0338	23261.438
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	134.9047			0.0000	0.0000
28	-7.4750	0.0000	548.5733		
29	-7.3872	0.0000	-1.6155		
30	0.0000	0.0000	-2.4648		
31	3013.7704	28798.4565	0.0789	78.2380	-175.9273
32	3530.0217	24586.7998	31.6286	319788668.0	
33					
34	-96.4375	2.3325	-24.6875	0.0215	

1	590.0000	71511.851	183228.619	536461.938	5712777.750
2	25383.4900	24052.3564	21443173.00	20906718.00	15.6550
3	5779628.750	0.000	6532460.313	0.000	5792236.750
4	-257841.064	0.000	-485031.633	0.000	74.7915
5	281810.453	0.000	396545.691	0.000	-2.5514
6	23092.5991	0.0000	24130.7258	0.0000	82.4348
7	-6509.6798	0.0000	-7765.5938	0.0000	-0.3171
8	1694.0622	0.0000	1313.5067	0.0000	-0.4570
9	183224.422	183224.459	-0.036	7.782	-0.016
10	-704.770	-702.211	0.074	69.283	-0.038
11	-1015.675	-1015.422	0.002	1456.104	1.147
12	-7.8635	0.2910	0.0000	103533.765	0.6086
13	-3.0808	-0.0304	0.0000	1373989.844	-4.2462
14	0.4000	-0.0007	0.0000	1375897.781	-0.4000
15	-97.2375	0.0000	0.0000	0.0156	-0.2908
16	-7.3249	0.0000	0.0000	0.2908	0.0782
17	0.0000	0.0000	0.0000	-0.0282	-0.0000
18	-0.0769	-0.0729	-0.0865	-0.3175	-0.0050
19	85.0738	85.3327	85.3330	0.2196	-0.0029
20	428.0907	92.0729	-428.0038	-96.1256	40986.488
21	0.0006	10.8040	0.0000	2062.4209	754.020
22	62.8177	31.4860	31.3192	-30.6226	-0.0421
23	9.9689	9.9656	-0.2618	-0.0361	24052.357
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	135.2569			0.0000	0.0000
28	-7.2375	0.0000	567.9528		
29	-7.3249	0.0000	-1.7049		
30	0.0000	0.0000	-2.5986		
31	3400.7659	26341.3542	0.0185	85.2670	-175.3843
32	3529.3166	25381.9048	31.6300	339522740.0	
33					
34	-221.7656	2.5769	-36.2500	0.0277	

Appendix 4
Flight Simulated Data (AC77)

TABLE AP 4-3 (Sheet 10 of 10)
FLIGHT SIMULATED DATA

1	503.3400	70081.121	169995.549	536433.930	5791527.313
2	25656.9556	24325.8118	21443129.50	20906698.25	15.8708
3	5857175.188	0.000	6613462.813	0.000	5870897.438
4	-279776.527	0.000	-511193.078	0.000	74.8102
5	267509.715	0.000	400952.109	0.000	-2.7315
6	23243.3562	0.0000	24374.7917	0.0000	78.0430
7	-6624.7530	0.0000	-7898.8964	0.0000	-0.2090
8	1716.2469	0.0000	1325.3105	0.0000	-0.4179
9	169992.471	169992.506	-0.037	-31.700	-0.018
10	-455.133	-453.429	0.086	1465.016	-0.058
11	-910.166	-909.783	0.003	-6585.331	1.287
12	-5.6163	0.1991	0.0000	103527.544	0.1739
13	-3.2898	-0.0443	0.0000	1330627.969	-4.2024
14	0.4000	0.0340	0.0000	1332738.578	-0.4000
15	-96.4269	0.0000	0.0000	0.0114	-0.1991
16	-7.4916	0.0000	0.0000	0.1991	0.0430
17	0.0000	0.0000	0.0000	-0.0430	-0.0000
18	0.3401	0.0380	0.0248	-0.3066	0.0033
19	85.7199	85.4685	85.4684	0.1528	-0.0011
20	5.2354	94.5778	-418.7674	-98.6285	42054.592
21	0.0006	10.9273	0.0000	2062.2673	754.636
22	62.5659	31.5744	31.3375	-30.6227	-0.0421
23	11.3315	11.3233	-0.4434	-0.0368	24325.812
24	0.0000	0.0000	0.0000	0.000	0.0000
25	0.0000	0.0000	0.0000	0.000	0.0000
26	0.0000	0.0000	0.0000	0.000	0.0000
27	135.3741			0.0000	0.0000
28	-6.4259	0.0000	574.9430		
29	-7.4916	0.0000	-1.7368		
30	0.0000	0.0000	-2.6463		
31	3400.7659	26341.3542	0.0185	85.2670	-175.3643
32	3529.3166	25381.9048	31.6300	339522740.0	
33					
34	-221.7656	2.5769	-36.2500	0.0277	



NOTE: THE Y AXES ARE PERPENDICULAR TO THE EARTH'S SURFACE AT THE LAUNCH SITE

Figure AP 4-1. Coordinate System, AC77 Computer Program

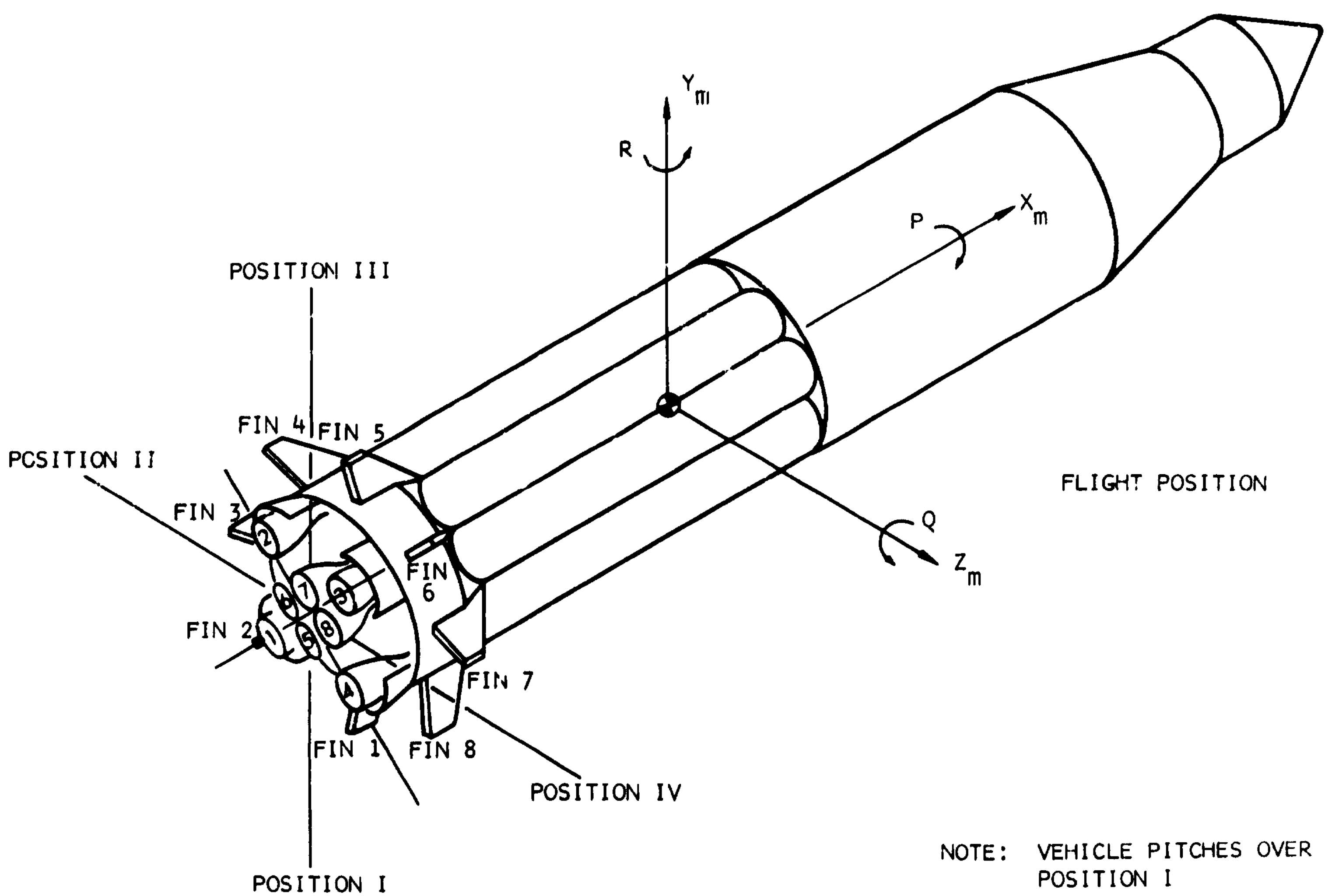


Figure AP 4-2 Body-Fixed Coordinate System Orientation

APPENDIX 5

METEOROLOGICAL DATA (AA99)

1. METEOROLOGICAL DATA (AA99)

A summary of the meteorological data during the AS-204 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 (percent)	CLOUDS (coverage)	BASE (ft)	VISIB (mi)	PRESS at MSL* (mbars)	DRY BULB TEMP (deg F)	RELATIVE HUMIDITY (percent)	WIND** DIRECT-ION (deg)	WIND SPEED (knots)**
2248	30%	High Scattered	4000	10	1018.6	61	90	45	8.2

**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 360,000 ft.

TABLE AP 5-1 (Sheet 1 of 2)
PROGRAM AA99 METEOROLOGICAL DATA

Table of Definitions

Program Symbol	Definition
Alt.	Altitude: Geocentric altitude (feet)
Density	Density: row 2, column B (slugs/ft^3) row 3, column E (lbm/ft^3)
Elec/Ref	Electromagnetic Index of Refraction: (unitless)
Opt./Ref	Optical Index of Refraction: (unitless)
Pit. Shear	Shear of Wind Velocity Pitch Component: (ft/sec/ft)
Press	Ambient Pressure: row 1, column C (mb) row 2, column C (lbf/ft^2)
Rel Humd	Relative Humidity: (decimal)
Temp.	Ambient Temperature: row 1, column B (deg K) row 4, column A (deg C)
Vap. Press	Water Vapor Pressure: (lbf/ft^2)
Vel/Sound	Velocity of Sound: (ft/sec)
Visc.	Coefficient of Viscosity: (slugs/ft-sec)
Wd. Merid.	Meridional Component of Wind Velocity: Component of wind velocity vector measured along lines of longitude, positive north (ft/sec)
Wd. Zonal	Zonal Component of Wind Velocity: Component of wind velocity vector measured along lines of latitude, positive east (ft/sec)

TABLE AP 5-1 (Sheet 2 of 2)
PROGRAM AA99 METEOROLOGICAL DATA

Table of Definitions

Program Symbol	Definition
Wind Dir	Wind Direction: Direction from which wind is blowing, measured clockwise from north (deg)
Wind Pitch	Wind Velocity Pitch Component: Component of wind velocity vector along vehicle flight path, positive downrange (ft/sec)
Wind Vel	Magnitude of Wind Velocity: (ft/sec)
Wind Yaw	Wind Velocity Yaw Component: Component of wind velocity vector perpendicular to pitch component, lying in the local tangent plane, and positive right looking downrange (ft/sec)
Yaw Shear	Shear of Wind Velocity Yaw Component: (ft/sec/ft)

Appendix 5
Meteorological Data (AA99)

TABLE AP 5-2 (Sheet 1 of 6)
METEOROLOGICAL DATA

Line	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	NO. ZONAL	NO. MERID.	DENSITY	VISC.
4	TEMP.	PIT. SHEAR	YAW SHEAR			
1	-.0	289.05	1018.000	6.5617	30.000	.9000
2	33.3361	.0024	2126.134	1121.593	1.0003	1.0003
3	-.2107	4.3906	-.4131	-.1099	.7472	.000000
4	15.000	-15.297247	.00535304			
1	1000.0	291.44	983.053	6.5617	95.395	.5093
2	22.4531	.0023	2053.145	1125.144	1.0003	1.0003
3	-.2440	.9003	-.1550	2.2324	.7170	.000000
4	18.293	.000283	-7.53658990			
1	2000.0	289.69	949.569	8.0000	13.670	.4044
2	15.4932	.0022	1981.124	1121.140	1.0003	1.0003
3	-.3308	6.8513	-1.3011	-.0787	.6968	.000000
4	16.542	.000713	.00678736			
1	3000.0	287.27	914.682	12.0000	16.152	.4429
2	14.3694	.0021	1910.767	1116.394	1.0003	1.0003
3	-.2226	9.6593	-.9535	-.0567	.6777	.000000
4	14.122	-6.705031	.00231123			
1	4000.0	284.43	882.177	16.0000	313.221	.5214
2	14.5080	.0021	1842.462	1110.890	1.0003	1.0003
3	-.3627	13.2891	1.4813	-.0721	.6600	.000000
4	11.253	-1.625369	.00667260			
1	5000.0	282.53	850.252	12.1785	350.696	.4150
2	10.2109	.0020	1775.805	1106.717	1.0003	1.0003
3	-.2602	11.9324	1.6080	-.0253	.6410	.000000
4	9.361	.001379	-2.21179010			
1	6000.0	282.16	819.515	4.3150	305.045	.2147
2	5.1254	.0020	1711.589	1105.417	1.0002	1.0002
3	2.5733	2.2252	3.1350	.4442	.6192	.000000
4	9.011	.004944	-6.88523610			
1	7000.0	281.11	789.721	8.3150	294.149	.3648
2	8.0875	.0019	1649.364	1103.754	1.0002	1.0002
3	4.1482	5.1982	5.5515	.8164	.5985	.000000
4	7.959	-10.103420	-2.25794460			
1	8000.0	279.87	763.866	9.8425	351.101	.3496
2	6.9969	.0018	1519.099	1101.214	1.0002	1.0002
3	.2403	9.5022	1.4714	-.1128	.5793	.000000
4	6.722	-17.068149	-262.31162000			
1	9000.0	276.58	732.920	3.4593	34.058	.2614
2	4.9058	.0018	1530.733	1098.422	1.0002	1.0002
3	-.3152	2.5915	-.4846	-.1523	.5609	.000000
4	5.430	-.447294	-23.44443000			
1	10000.0	276.60	705.653	9.2126	340.696	.2400
2	3.9249	.0017	1474.202	1094.406	1.0002	1.0002
3	-3.1966	9.1462	2.9359	-.1124	.5441	.000000
4	3.434	.0027 9	-5.76089930			
1	11000.0	274.02	679.724	7.9104	333.467	.2418
2	3.2937	.0017	1419.630	1090.394	1.0002	1.0002
3	1.3099	7.8244	5.4544	-.1128	.5278	.000000
4	1.465	-0.610738	-17.68760200			
1	12000.0	273.41	644.377	16.0472	325.653	.1885
2	2.4579	.0016	1366.692	1087.888	1.0002	1.0002
3	5.1658	15.0469	9.5627	-.1030	.5105	.000000
4	***********	-5.937601	.00790671			
1	13000.0	271.71	629.638	19.6853	311.354	.2804
2	3.1967	.0016	1315.379	1084.625	1.0002	1.0002
3	10.0194	16.9384	14.7540	-.0259	.4943	.000000
4	***********	.004091	-23.34319300			

Line	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	NO. ZONAL	NO. MERID.	DENSITY	VISC.
4	TEMP.	PIT. SHEAR	YAW SHEAR			
1	14000.0	269.55	605.993	16.6299	307.693	.2972
2	2.9113	.0015	1255.640	1080.294	1.0002	1.0002
3	9.3869	13.6490	13.1440	-.0952	.4794	.000000
4	-.015	-15.604388	-14.26585150			
1	15000.0	267.65	533.001	18.7402	289.712	.2686
2	2.2727	.0015	1217.620	1076.373	1.0002	1.0002
3	14.0176	11.4722	17.6375	-.1861	.4646	.000000
4	-.019	-9.117277	-55.54230900			
1	16000.0	265.34	560.720	14.7402	282.407	.2748
2	1.7296	.0014	1171.085	1071.686	1.0002	1.0002
3	12.5369	7.5724	14.2633	-.3477	.4508	.000000
4	-.011	-53.309143	-28.32935800			
1	17000.0	263.08	539.015	15.5066	285.443	.2309
2	1.4452	.0014	1125.755	1068.249	1.0002	1.0002
3	12.7967	8.6317	14.8377	-.2579	.4361	.000000
4	-.013	-21.413814	-5.11515480			
1	18000.0	262.50	518.125	19.56	277.653	.1916
2	1.0887	.0013	1082.124	1065.802	1.0002	1.0002
3	17.5828	8.4038	19.3192	-.4252	.421	.000000
4	-.010	.005538	-7.39580730			
1	19000.0	260.40	497.930	16.9449	267.615	.1916
2	.9197	.0013	1039.947	1061.513	1.0002	1.0002
3	15.9702	4.6558	16.6273	1.6384	.4080	.000000
4	-.006	-69.914898	-10.16417030			
1	20000.0	258.34	478.333	22.2047	286.392	.2154
2	.8698	.0013	999.017	1057.304	1.0001	1.0001
3	18.4038	12.2068	21.2752	-.2347	.3951	.000000
4	-.005	-78.480646	-80.54180390			
1	21000.0	255.78	459.311	28.2257	277.191	.2883
2	.9366	.0012	959.289	1052.073	1.0001	1.0001
3	25.5537	11.9726	27.9999	-.1804	.3831	.000000
4	-.007	.006552	-83.33732390			
1	22000.0	253.31	440.864	29.5276	276.823	.3982
2	.5721	.0012	920.752	1046.959	1.0001	1.0001
3	26.7993	12.3957	29.3178	-.3219	.3713	.000000
4	-.006	-392.752420	.00049059			
1	23000.0	250.67	423.005	29.8005	273.667	.3300
2	.6963	.0011	883.463	1041.462	1.0001	1.0001
3	27.6953	10.9643	29.7279	-.4804	.3601	.000000
4	-.005	.001108	-29.67925130			
1	24000.0	248.15	405.701	37.8005	264.696	.3300
2	.5591	.0011	847.323	1036.193	1.0001	1.0001
3	36.6711	9.1939	37.5946	3.6099	.3489	.000000
4	-.003	.009146	-37.72890600			
1	25000.0	245.54	368.972	45.8005	260.520	.3252
2	.4338	.0011	812.384	1030.701	1.0001	1.0001
3	45.2976	6.7571	45.1686	7.5713	.3380	.000000
4	-.002	.008374	-23.79190100			
1	26000.0	242.94	372.740	46.9186	262.797	.3270
2	.3417	.0010	778.483	1025.218	1.0001	1.0001
3	46.0728	8.7475	45.5178	5.9274	.3274	.000000
4	-.001	-18.170144	.70236714			
1	27000.0	240.60	337.044	39.9055	275.021	.3208
2	.2675	.0010	745.702	1020.245	1.0001	1.0001
3	36.6976	15.4859	39.6869	.1139	.3167	.000000
4	-.004	-10.958925	.00750593			

TABLE AP 5-2 (Sheet 2 of 6)
METEOROLOGICAL DATA

	A 1 ALT 2 VAP. PRESS 3 WIND PITCH 4 TEMP.	B TEMP. DENSITY WIND YAW PIT. SHEAR	C PRESS PRESS WD. ZONAL YAW SHEAR	D WIND VEL VEL/SOUND WD. MERID.	E WIND DIR OPT./REF DENSITY	F REL HUMD ELEC/REF VISC.
1	28000.0	238.20	341.835	41.1758	282.175	.3200
2	.2112	.0010	713.936	1015.143	1.0001	1.0001
3	35.6495	20.5397	40.2518	-.1179	.3063	.000000
4	-.004	-33.911072	.00480319			
1	29000.0	235.76	327.190	53.6640	275.930	.3307
2	.1709	.0009	683.349	1009.910	1.0001	1.0001
3	49.5515	21.7243	53.3639	-.1323	.2962	.000000
4	-.003	.012644	-17.71429700			
1	30000.0	233.11	312.918	53.8845	276.880	.3385
2	.1340	.0009	653.543	1004.222	1.0001	1.0001
3	48.8669	22.5859	53.4546	-.2300	.2865	.000000
4	-.003	-6.436619	-21.05043800			
1	31000.0	231.00	299.253	52.4934	282.976	.3229
2	.1018	.0009	625.001	999.648	1.0001	1.0001
3	44.9797	27.0011	51.1211	-.0420	.2765	.000000
4	-.003	-33.145861	.00459784			
1	32000.0	226.82	235.949	55.7743	291.072	.3190
2	.0774	.0008	597.216	994.915	1.0001	1.0001
3	43.2933	35.1525	52.0419	-.0484	.2657	.000000
4	-.002	-68.144144	.00881598			
1	33000.0	226.19	273.217	58.8399	294.365	.3123
2	.0585	.0008	570.625	989.162	1.0001	1.0001
3	43.6020	39.3795	53.6369	-.0177	.2578	.000000
4	-.002	-24.366262	.00417965			
1	34000.0	223.43	260.917	71.3688	288.547	.3945
2	.0448	.0008	544.936	983.112	1.0001	1.0001
3	57.7516	42.7725	58.1424	-.0267	.2492	.000000
4	-.002	.013268	.00340994			
1	35000.0	220.61	248.932	77.5640	290.698	.3300
2	.0328	.0008	520.008	976.884	1.0001	1.0001
3	60.5576	48.5603	72.5997	-.0377	.2409	.000000
4	-.001	-30.730834	.00623408			
1	36000.0	218.88	237.423	87.5118	290.218	.3300
2	.0256	.0007	495.667	973.056	1.0001	1.0001
3	68.7719	54.1102	82.1270	-.0435	.2315	.000000
4	-.001	-4.966582	.00509356			
1	37000.0	217.08	226.428	92.9501	289.669	.3300
2	.0214	.0007	472.995	969.054	1.0001	1.0001
3	73.5932	56.7534	87.5310	-.0415	.2226	.000000
4	-.001	.004274	.00243028			
1	38000.0	215.06	215.798	104.9501	287.330	.2212
2	.0122	.0007	450.79-	964.515	1.0001	1.0001
3	85.5973	60.7195	100.1713	-.0444	.2142	.000000
4	-.001	.011719	.00435991			
1	39000.0	212.33	205.545	113.3491	289.000	.0000
2	.0030	.0007	429.289	956.378	1.0001	1.0001
3	91.7312	66.6251	107.8013	-.0341	.2066	.000000
4	-.000	.005589	.00526790			
1	40000.0	209.79	195.656	114.8294	284.160	.0000
2	.0030	.0006	408.635	952.626	1.0001	1.0001
3	97.1431	61.0798	111.2652	-.0102	.1991	.000000
4	-.000	.005928	8.55645470			
1	41000.0	208.86	186.199	111.5906	278.064	.0000
2	.0030	.0006	388.083	950.504	1.0001	1.0001
3	100.2335	49.0319	110.4812	-.0827	.1993	.000000
4	-.002	.002290	-6.44724350			

	A 1 ALT 2 VAP. PRESS 3 WIND PITCH 4 TEMP.	B TEMP. DENSITY WIND YAW PIT. SHEAR	C PRESS PRESS WD. ZONAL YAW SHEAR	D WIND VEL VEL/SOUND WD. MERID.	E WIND DIR OPT./REF DENSITY	F REL HUMD ELEC/REF VISC.
1	42000.0	209.80	177.235	104.9869	281.000	.0000
2	.0000	.0006	370.161	952.653	1.0001	1.0001
3	91.8235	50.8988	103.0579	-.0485	.1803	.000000
4	-.000	-8.679614	.00193411			
1	43000.0	208.64	168.663	103.5906	282.277	.0000
2	.0000	.0005	352.260	950.005	1.0001	1.0001
3	89.4521	52.1745	101.1968	-.0333	.1725	.000000
4	-.002	-3.553205	.00155528			
1	44000.0	208.03	160.444	99.5906	282.711	.0000
2	.0000	.0005	335.094	948.616	1.0001	1.0001
3	85.5984	50.6763	97.1306	-.0337	.1646	.000000
4	-.002	-63.665998	-11.10456150			
1	45000.0	208.54	152.657	89.9213	271.632	.0000
2	.0000	.0005	318.830	949.786	1.0001	1.0001
3	84.3619	30.3439	89.6288	-3666.6138	.1563	.000000
4	-.002	-97.085522	-4.38788590			
1	46000.0	208.63	145.209	83.1128	261.250	.0000
2	.0000	.0005	303.275	950.452	1.0001	1.0001
3	82.0140	13.4094	82.1437	12.5907	.1484	.000000
4	-.002	-29.043643	-6.34542590			
1	47000.0	208.71	138.137	98.1207	265.512	.0000
2	.0000	.0004	288.504	950.172	1.0001	1.0001
3	95.2830	23.0821	97.7523	7.4917	.1413	.000000
4	-.002	.012956	.00993538			
1	48000.0	208.33	131.483	101.5643	264.827	.0000
2	.0000	.0004	274.608	949.301	1.0000	1.0000
3	98.7376	22.7159	100.9246	8.9075	.1347	.000000
4	-.002	-.369724	-3.35817840			
1	49000.0	207.55	125.048	100.8556	260.259	.0000
2	.0000	.0004	261.167	947.535	1.0000	1.0000
3	99.8003	14.4770	99.3969	17.0741	.1286	.000000
4	-.002	-.182692	-44.24618300			
1	50000.0	207.45	118.900	111.1548	267.680	.0000
2	.0000	.0004	248.327	947.299	1.0000	1.0000
3	106.9668	30.0834	111.0278	4.4435	.1223	.000000
4	-.002	.007792	-2.27952680			
1	51000.0	207.58	113.176	97.8373	269.821	.0000
2	.0000	.0004	236.372	947.591	1.0000	1.0000
3	93.1382	29.9498	97.8347	-1418.8713	.1164	.000000
4	-.002	-10.328588	-148.25251000			
1	52000.0	207.25	107.647	93.8373	267.805	.0000
2	.0000	.0004	224.825	946.892	1.0000	1.0000
3	90.2490	25.5892	93.7394	3.5517	.1109	.000000
4	-.002	-35.527325	-17.81416200			
1	53000.0	207.06	102.406	85.7848	268.471	.0000
2	.0000	.0003	213.879	946.418	1.0000	1.0000
3	82.2020	24.1522	85.6992	-3653.9003	.1056	.000000
4	-.002	-23.253231	-3.10717840			
1	54000.0	206.87	97.369	68.2940	264.143	.0000
2	.0000	.0003	203.359	945.965	1.0000	1.0000
3	66.6300	14.6136	67.8847	-959.5091	.1005	.000000
4	-.002	-6.974877	-6.68861550			
1	55000.0	206.04	92.593	[illegible]	271.328	.0000
2	.0000	.0003	193.304	944.071	1.0000	1.0000
3	52.5606	18.4425	55.6948	-.0874	.0959	.000000
4	-.002	-1.921382	-.20248781			

TABLE AP 5-2 (Sheet 3 of 6)
METEOROLOGICAL DATA

Line	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	56000.0	206.15	63.139	55.7743	259.725	.0000
2	.0000	.0003	144.020	944.331	1.0000	1.0000
3	55.2004	7.4908	54.8701	9.9494	.0912	.000000
4	-.002	.002535	-30.72034200			
1	57000.0	205.50	83.770	55.7743	263.450	.0000
2	.0000	.0003	174.956	944.798	1.0000	1.0000
3	54.4959	11.0374	53.2394	6.3430	.0866	.000000
4	-.002	-26.814619	-51.45160200			
1	58000.0	205.61	79.645	53.4331	277.991	.0000
2	.0000	.0003	166.342	943.032	1.0000	1.0000
3	47.7956	23.1327	52.6048	.5092	.0827	.000000
4	-.002	-25.002596	.01245460			
1	59000.0	206.39	75.715	43.3124	294.127	.0000
2	.0000	.0002	153.134	944.874	1.0000	1.0000
3	32.1517	28.8970	39.5077	-.0645	.0783	.000000
4	-.002	-7.399328	.00412198			
1	60000.0	205.16	71.959	28.5392	292.490	.0000
2	.0000	.0002	150.290	942.053	1.0000	1.0000
3	21.5002	15.0045	26.2617	-.0486	.0749	.000000
4	-.002	-12.025592	-9.30477780			
1	61000.0	204.28	68.461	22.9659	279.175	.0000
2	.0000	.0002	142.983	940.029	1.0000	1.0000
3	20.3071	10.4230	22.5356	-.1889	.0715	.000000
4	-.002	-16.510257	-14.56581710			
1	62000.0	204.54	65.047	22.9659	264.506	.0000
2	.0000	.0002	135.653	940.619	1.0000	1.0000
3	22.3214	4.9497	22.7585	2.2332	.0679	.000000
4	-.002	.001858	-19.55644400			
1	63000.0	205.47	61.795	20.3097	261.619	.0000
2	.0000	.0002	129.061	942.776	1.0000	1.0000
3	20.0250	3.3760	20.0892	2.9773	.0642	.000000
4	-.002	-24.074151	-1.94493710			
1	64000.0	205.87	59.831	13.0209	286.720	.0000
2	.0000	.0002	122.871	943.691	1.0000	1.0000
3	10.7124	7.3701	12.4656	-.3579	.0610	.000000
4	-.002	-10.622555	.00468043			
1	65000.0	206.05	55.930	9.0425	301.030	.0000
2	.0000	.0002	116.811	945.924	1.0000	1.0000
3	6.1200	7.1391	8.0266	-1.0655	.0577	.000000
4	-.002	-4.485655	-2.91092030			
1	66000.0	208.57	53.172	11.3753	273.803	.0000
2	.0000	.0002	111.052	949.851	1.0000	1.0000
3	10.3152	4.2985	11.3288	-2.3065	.0544	.000000
4	-.001	.004226	-6.25469900			
1	67000.0	210.12	50.627	10.8714	275.627	.0000
2	.0000	.0002	105.737	953.305	1.0000	1.0000
3	9.9467	4.3790	10.6150	-1.1001	.0514	.000000
4	-.000	-10.151578	-41.22950000			
1	68000.0	210.16	48.189	6.8714	212.514	.0000
2	.0000	.0002	100.644	953.465	1.0000	1.0000
3	4.9851	.1546	3.5305	5.1931	.0489	.000000
4	-.000	-10.535253	-15.28046800			
1	69000.0	211.57	45.675	12.3045	198.618	.0000
2	.0000	.0001	95.813	956.668	1.0000	1.0000
3	6.3509	-.1125	3.4150	11.6599	.0463	.000000
4	-.000	-15.423231	-13.99912800			
1	70000.0	213.53	43.715	5.4331	275.032	.0000
2	.0000	.0001	91.301	961.076	1.0000	1.0000
3	3.5449	.7745	3.3649	2.7088	.0437	.000000
4	-.001	-80.005597	.00932250			
1	71000.0	214.25	41.643	5.1286	210.879	.0000
2	.0000	.0001	86.972	962.699	1.0000	1.0000
3	-.6550	1.1461	.0225	.3862	.0415	.000000
4	-.001	-15.971320	-3.38070800			
1	72000.0	215.11	39.646	11.6955	124.949	.0000
2	.0000	.0001	82.007	964.630	1.0000	1.0000
3	-.0349	-.1068	-.0872	7.1519	.0393	.000000
4	-.001	-60.129081	-9.13477500			
1	73000.0	216.15	37.798	6.5617	172.102	.0000
2	.0000	.0001	76.942	966.963	1.0000	1.0000
3	1.1477	-.0106	-1.4434	6.4933	.0373	.000000
4	-.001	.009142	.00611476			
1	74000.0	217.30	36.013	7.2961	242.183	.0000
2	.0000	.0001	75.215	969.983	1.0000	1.0000
3	7.0405	-.1217	6.4001	3.0862	.0353	.000000
4	-.001	.005803	.00545847			
1	75000.0	216.18	34.384	12.7296	267.080	.0000
2	.0000	.0001	71.812	971.493	1.0000	1.0000
3	12.2100	3.4959	12.6984	-1.1667	.0336	.000000
4	-.001	.005423	.00439926			
1	76000.0	218.22	32.743	16.4042	273.637	.0000
2	.0000	.0001	68.385	971.573	1.0000	1.0000
3	15.2400	6.0454	16.3622	-1.6277	.0320	.000000
4	-.001	-164.606270	.00222792			
1	77000.0	216.06	31.246	13.5223	277.635	.0000
2	.0000	.0001	65.258	971.226	1.0000	1.0000
3	12.1971	5.6328	13.4025	-.6900	.0306	.000000
4	-.001	-57.587972	-80.69424500			
1	78000.0	217.64	29.793	16.0840	283.610	.0000
2	.0000	.0001	62.223	970.732	1.0000	1.0000
3	13.6047	8.4456	15.6248	-.7414	.0292	.000000
4	-.001	-3.427440	-2.61725810			
1	79000.0	217.75	28.452	12.0840	274.615	.0000
2	.0000	.0001	59.422	970.530	1.0000	1.0000
3	10.9772	4.8042	11.9245	.0377	.0279	.000000
4	-.001	-40.185061	-25.06742200			
1	80000.0	218.07	27.110	9.6425	253.352	.0000
2	.0000	.0001	56.621	971.247	1.0000	1.0000
3	9.7193	.3987	9.3142	2.7861	.0265	.000000
4	-.001	-23.697997	-12.55407350			
1	81000.0	218.27	25.845	24.7086	263.125	.0000
2	.0000	.0001	53.978	971.699	1.0000	1.0000
3	23.7163	6.3038	24.4795	1.4074	.0253	.000000
4	-.001	.017836	-1.22710296			
1	82000.0	217.96	24.626	39.1181	273.872	.0000
2	.0000	.0001	51.432	970.993	1.0000	1.0000
3	36.2916	14.5918	19.0245	-.2472	.0241	.000000
4	-.001	.010396	.00757179			
1	83000.0	217.99	23.526	43.2861	275.807	.0000
2	.0000	.0001	49.134	971.062	1.0000	1.0000
3	39.5056	17.4638	43.0638	-.2739	.0230	.000000
4	-.001	.003202	.00269710			

TABLE AP 5-2 (Sheet 4 of 6)
METEOROLOGICAL DATA

	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	84000.0	216.23	22.428	47.2661	274.587	.0000
2	.0000	.0001	46.843	971.605	1.0000	1.0000
3	43.662	18.1467	47.1340	-.3492	.0219	.000000
4	-.001	.004060	.00067484			
1	85000.0	216.29	21.394	51.2861	271.472	.0000
2	.0000	.0001	44.683	971.726	1.0000	1.0000
3	48.3436	17.0362	51.2420	-66.4951	.0209	.000000
4	-.001	.004812	-24.99480200			
1	86000.0	21?.51	20.419	58.0787	266.595	.0000
2	.0000	.0001	42.646	977.212	1.0000	1.0000
3	56.2632	14.5747	[illegible]	-12.1160	.0199	.000000
4	-.001	.006435	-49.0[illegible]			
1	87000.0	216.98	19.451	62.3360	260.859	.0000
2	.0000	.0001	40.624	973.266	1.0000	1.0000
3	61.5898	9.5999	61.5419	9.9022	.0190	.000000
4	-.001	.004863	-20.33794500			
1	88000.0	219.44	18.597	61.3858	259.290	.0000
2	.0000	.0001	38.841	974.282	1.0000	1.0000
3	60.8893	7.7771	60.3124	11.4194	.0181	.000000
4	-.001	-8.726037	-29.78001400			
1	89000.0	219.85	17.744	54.0473	261.527	.0000
2	.0000	.0001	37.059	975.207	1.0000	1.0000
3	53.3049	[illegible]	53.4200	8.0886	.0172	.000000
4	-.001	-18.159971	.00109911			
1	90000.0	220.27	16.890	44.4357	264.456	.0000
2	.0000	.0001	35.276	976.127	1.0000	1.0000
3	43.3940	9.5369	44.2178	4.3374	.0164	.000000
4	-.001	-12.820499	.00056963			
1	91000.0	220.26	16.132	36.0357	231.211	.0000
2	.0000	.0000	33.692	976.098	1.0000	1.0000
3	35.9[illegible]71	5.8542	36.0643	5.5437	.0156	.000000
4	-.001	-5.482899	-23.26389300			
1	92000.0	220.65	15.400	32.2625	250.033	.0000
2	.0000	.0000	32.164	976.971	1.0000	1.0000
3	32.1551	-.0087	30.2657	10.9080	.0149	.000000
4	-.001	-16.361285	-6.79323390			
1	93000.0	220.96	14.669	30.7926	242.699	.0000
2	.0000	.0000	30.636	977.657	1.0000	1.0000
3	30.3461	-.1137	27.3564	14.0139	.0142	.000000
4	-.001	-15.227778	-1.64767361			
1	94000.0	220.71	13.998	34.7926	254.258	.0000
2	.0000	.0000	29.235	977.106	1.0000	1.0000
3	34.5806	2.5768	33.3609	9.2309	.0135	.000000
4	-.001	.004144	.00693180			
1	95000.0	220.67	13.388	36.0892	263.944	.0000
2	.0000	.0000	27.961	977.011	1.0000	1.0000
3	35.2797	7.4636	35.8594	3.6037	.0129	.000000
4	-.001	-76.381172	.00529468			
1	96000.0	221.08	12.778	35.9475	272.432	.0000
2	.0000	.0000	26.688	977.933	1.0000	1.0000
3	33.6752	12.518	35.8955	-.7373	.0123	.000000
4	-.001	-53.980244	.00514240			
1	97000.0	221.95	12.169	31.9475	283.837	.0000
2	.0000	.0000	25.415	979.857	1.0000	1.0000
3	[illegible]	16.7627	30.9966	-.1740	.0117	.000000
4	-.002	-19.821370	.00408803			

	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	98000.0	222.54	11.607	29.5276	288.037	.0000
2	.0000	.0000	24.242	981.145	1.0000	1.0000
3	23.5725	17.3686	28.0722	-.1244	.0111	.000000
4	-.002	-8.163452	-59.11693100			
1	99000.0	224.04	11.120	22.6300	271.583	.0000
2	.0000	.0000	23.224	984.450	1.0000	1.0000
3	20.6786	8.1707	22.1914	1.1603	.0106	.000000
4	-.002	-9.804940	-37.26677100			
1	100000.0	225.65	10.632	19.6650	253.960	.0000
2	.0000	.0000	22.205	987.988	1.0000	1.0000
3	19.6419	.6704	18.9877	5.4321	.0101	.000000
4	-.002	-1.116811	-21.40912300			
1	105000.0	226.77	8.496	35.9843	311.824	.0000
2	.0000	.0000	17.744	994.795	1.0000	1.0000
3	18.0659	31.1108	26.7953	-.0175	.0079	.000000
4	-.002	-22.447110	-3.67930870			
1	110000.0	236.74	6.562	56.5774	272.755	.0000
2	.0000	.0000	13.706	1011.963	1.0000	1.0000
3	52.9174	17.9966	56.5067	-.5165	.0059	.000000
4	-.003	.008419	.00052134			
1	115000.0	240.29	5.581	27.4804	268.872	.0000
2	.0000	.0000	11.657	1019.529	1.0000	1.0000
3	26.3295	7.7181	27.4259	1.0967	.0050	.000000
4	-.004	-7.121175	-3.48264750			
1	120000.0	243.91	4.513	26.9553	230.304	.0000
2	.0000	.0000	9.425	1027.186	1.0000	1.0000
3	25.0627	-.1001	20.7708	17.1788	.0039	.000000
4	-.001	.006701	-6.30492660			
1	125000.0	248.73	3.665	45.2756	285.600	.0000
2	.0000	.0000	7.654	1037.275	1.0000	1.0000
3	37.7612	24.9038	43.6278	-.0348	.0031	.000000
4	-.004	-8.923853	-4.25485880			
1	130000.0	255.70	2.990	70.5249	281.552	.0000
2	.0000	.0000	6.245	1051.699	1.0000	1.0000
3	61.9471	34.3991	68.6891	-.0363	.0025	.000000
4	-.007	.014183	-.64529806			
1	135000.0	256.72	2.448	83.9632	284.736	.0000
2	.0000	.0000	5.113	1053.811	1.0000	1.0000
3	70.4017	45.3932	80.9032	-.0685	.0020	.000000
4	-.008	-21.913862	.01442627			
1	140000.0	262.51	2.010	77.7165	273.248	.0000
2	.0000	.0000	4.197	1065.615	1.0000	1.0000
3	72.4143	23.1044	77.5545	-.2343	.0016	.000000
4	-.010	.004351	-18.18251200			
1	145000.0	266.61	1.657	114.1207	272.864	.0000
2	.0000	.0000	3.460	1073.921	1.0000	1.0000
3	106.6003	40.5912	113.9339	-.2602	.0013	.000000
4	-.011	.00772	-22.76184700			
1	150000.0	269.87	1.369	138.9764	264.360	.0000
2	.0000	.0000	2.859	1080.449	1.0000	1.0000
3	135.7229	29.7970	133.2670	13.6020	.0011	.000000
4	-.022	-10.963145	-7.14526580			
1	155000.0	270.56	1.133	164.1208	258.000	.0000
2	.0000	.0000	2.367	1081.841	1.0000	1.0000
3	163.2216	17.1556	150.5344	34.1223	.0009	.000000
4	-.044	-33.657461	-143.89300000			

Appendix 5
Meteorological Data (AA99)

TABLE AP 5-2 (Sheet 5 of 6)
METEOROLOGICAL DATA

	A	B	C	D	E	F		A	B	C	D	E	F
1	ALT	TEMP.	PRESS	WIND VEL	WIND DIR	REL HUMD	1	ALT	TEMP.	PRESS	WIND VEL	WIND DIR	REL HUMD
2	VAP. PRESS	DENSITY	PRESS	VEL/SOUND	OPT./REF	ELEC/REF	2	VAP. PRESS	DENSITY	PRESS	VEL/SOUND	OPT./REF	ELEC/REF
3	WIND PITCH	WIND YAW	WD. ZONAL	WD. MERID.	DENSITY	VISC.	3	WIND PITCH	WIND YAW	WD. ZONAL	WD. MERID.	DENSITY	VISC.
4		PIT. SHEAR	YAW SHEAR				4	TEMP.	PIT. SHEAR	YAW SHEAR			
1	160000.0	257.84	.937	185.6167	250.[illegible]2	.0000	1	230000.0	216.61	.055	.0000	.000	.0000
2	.0000	.0000	1.957	1076.377	1.0000	1.0000	2	.0000	.0000	.114	967.977	1.0000	1.0000
3	185.5105	-.0435	174.5108	63.2356	.0007	.000000	3	.0000	.0000	.0000	.0000	.0001	.000000
4	-.021	.002469	.00386574				4	-.001	.000000	.00000000			
1	165000.0	266.57	.774	164.0159	254.000	.0000	1	235000.0	212.20	.043	.0000	.000	.0000
2	.0000	.0000	1.616	1073.822	1.0000	1.0000	2	.0000	.0000	.090	958.076	1.0000	1.0000
3	163.9159	5.7244	157.6622	45.2086	.0006	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.011	-3.719486	-72.83807900				4	-.000	.000000	.00000000			
1	170000.0	263.05	.636	188.5565	261.254	.0000	1	240000.0	207.88	.034	.0000	.000	.0000
2	.0000	.0000	1.333	1066.801	1.0000	1.0000	2	.0000	.0000	.071	948.280	1.0000	1.0000
3	186.7952	30.3320	186.3602	28.6592	.0005	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.012	-6.670328	-3.65974330				4	-.002	.000000	.0000000[illegible]			
1	175000.0	259.90	.525	198.2939	260.360	.0000	1	245000.0	203.65	.026	.0000	.000	.0000
2	.0000	.0000	1.096	1060.307	1.0000	1.0000	2	.0000	.0000	.055	938.573	1.0000	1.0000
3	196.1721	28.8[illegible]	195.4957	33.1522	.0004	.000000	3	.0000	.0000	.0[illegible]30	.0000	.0000	.000000
4	-.005	.013858	-9.22619770				4	-.002	.000000	.00000000			
1	180000.0	2[illegible]7.71	.431	133.0184	259.544	.0000	1	250000.0	199.48	.021	.0000	.000	.0000
2	.0000	.0000	.900	1055.841	1.0000	1.0000	2	.0000	.0000	.043	928.[illegible]	1.0000	1.0000
3	131.6602	17.4774	130.8073	24.1251	.0004	.000000	3	.0006	.0000	.0000	.0000	.0000	.000000
4	-.001	-4.900262	-19.72664900				4	-.002	.000000	.00000000			
1	185000.0	256.81	352	169.1338	258.656	.0000	1	255000.0	195.35	.016	.0000	.000	.0000
2	.0000	.0000	.736	1053.979	1.0000	1.0000	2	.0000	.0000	.033	919.245	1.0000	1.0000
3	167.9321	19.6399	165.7820	33.2152	.0003	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.008	.003018	.01100322				4	-.002	.000000	.00000000			
1	190000.0	256.99	.289	208.8189	269.648	.0000	1	260000.0	191.21	.012	.0000	.000	.0000
2	.0000	.0000	.604	1054.348	1.0000	1.0000	2	.0000	.0000	.025	909.465	1.0000	1.0000
3	198.9893	63.3179	208.8078	-15.7381	.0002	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.008	.003475	.00722421				4	-.001	.000000	.00000000			
1	1[illegible]000.0	255.23	.237	221.4173	271.744	.0000	1	265000.0	187.02	.009	.0000	.000	.0000
2	.0000	.0000	.495	1050.735	1.0000	1.0000	2	.0000	.0000	.019	899.446	1.0000	1.0000
3	208.3870	74.8176	221.3077	-.2131	.0002	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.007	.005048	.00670217				4	-.001	.000000	.00000000			
1	200000.0	2[illegible].58	.194	191.8636	274.520	.0000	1	270000.0	182.71	.007	.0000	.000	.0000
2	.0000	.0000	.405	1047.344	1.0000	1.0000	2	.0000	.0000	.015	889.0[illegible]9	1.0000	1.0000
3	177.2257	73.4076	191.2358	-.0941	.0002	.000000	3	.0000	.0000	.0000	.0[illegible]00	.0000	.000000
4	-.006	-8.394041	.00693809				4	-.001	.000000	.00000000			
1	205000.0	251.93	.158	14.9100	17.730	.0000	1	275000.0	140.65	.005	.0000	.000	.0000
2	.0000	.0000	.331	1043.931	1.0000	1.0000	2	.0000	.0000	.011	883.994	1.0000	1.0000
3	13.5130	6.3013	14.7938	-.0030	.0001	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.005	.001287	.00027493				4	-.001	.000000	.00000000			
1	210000.0	243.35	.129	.0000	.000	.0000	1	280000.0	180.65	.004	.0000	.000	.0000
2	.0000	.0000	.270	1025.996	1.0000	1.0000	2	.0000	.0000	.008	883.994	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0001	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
	-.001	.000000	.00000000				4	-.001	.000000	.00000000			
1	215[illegible].0	234.77	.106	.0000	.000	.0000	1	285000.0	190.65	.003	.0000	.000	.0000
2		.0000	.220	1007.741	1.0000	1.0000	2	.0000	.0000	.006	883.994	1.0000	1.0000
3		.0000	.0000	.0000	.0001	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	.	.000000	.00000000				4	-.001	.000000	.00000000			
1	220000.0	226.19	.086	.0000	.000	.0000	1	290000.0	190.65	.002	.0000	.000	.0000
2	.0000	.0000	.180	989.150	1.0000	1.0000	2	.0000	.0000	.005	883.994	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0001	.000000	3	.0000	.0000	.0000	.0000	.0000	000000
4	-.002	.000000	.00000000				4	-.001	.000000	.00000000			
1	225000.0	221.10	.069	.0000	.000	.0000	1	295000.0	190.65	.002	.0000	.000	.0000
2	.0000	.0000	.144	977.975	1.0000	1.0000	2	.0000	.0000	.004	883.994	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0001	.000000	3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.001	.000000	.00000000				4	-.001	.000000	.00000000			

TABLE AP 5-2 (Sheet 6 of 6)
METEOROLOGICAL DATA

	A	B	C	D	E	F
1	ALT	TEMP.	PRESS	WIND VEL	WIND DIR	REL HUMID
2	VAP. PRESS	DENSITY	PRESS	VEL/SOUND	OPT./REF	ELEC/REF
3	WIND PITCH	WIND YAW	NO. ZONAL	NO. MERID.	DENSITY	VISC.
4	TEMP.	PIT. SHEAR	YAW SHEAR			
	A	B	C	D	E	F
1	300000.0	184.89	.001	.0000	.000	.0000
2	.0000	.0000	.003	894.500	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.011	.000000	.00000000			
	A	B	C	D	E	F
1	305000.0	189.36	.001	.0000	.000	.0000
2	.0000	.0000	.002	905.486	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.001	.000000	.00000000			
	A	B	C	D	E	F
1	310000.0	193.86	.001	.0000	.000	.0000
2	.0000	.0000	.002	[illegible]6.344	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.001	.000000	.00000000			
	A	B	C	D	E	F
1	315000.0	198.34	.001	.0000	.000	.0000
2	.0000	.0000	.001	927.072	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.002	.000000	.00000000			
	A	B	C	D	E	F
1	320000.0	202.81	.000	.0000	.000	.0000
2	.0000	.0000	.001	937.678	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.002	.000000	.00000000			
	A	B	C	D	E	F
1	325000.0	207.28	.000	.0000	.000	.0000
2	.0000	.0000	.001	948.165	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.002	.000000	.00000000			
	A	B	C	D	E	F
1	330000.0	212.81	.000	.0000	.000	.0000
2	.0000	.0000	.001	961.169	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.000	.000000	.00000000			
	A	B	C	D	E	F
1	335000.0	220.[illegible]	.000	.0000	.000	.0000
2	.0000	.0000	.000	978.166	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.001	.000000	.00000000			
	A	B	C	D	E	F
1	340000.0	227.23	.000	.0000	.000	.0000
2	.0000	.0000	.000	994.8[illegible]2	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.002	.000000	.00000000			
	A	B	C	D	E	F
1	345000.0	234.39	.000	.0000	.000	.0000
2	.0000	.0000	.000	1011.302	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.003	.000000	.00000000			
	A	B	C	D	E	F
1	350000.0	241.54	.000	.0000	.000	.0000
2	.0000	.0000	.000	1027.470	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.001	.000000	.00000000			
	A	B	C	D	E	F
1	355000.0	248.66	.000	.0000	.000	.0000
2	.0000	.0000	.000	1043.387	1.0000	1.0000
3	.0000	.0000	.0000	.0000	.0000	.000000
4	-.004	.000000	.00000000			
	A	B	C	D	E	F
1	360000.0	255.75	.000	.0000	.000	.0000
2	.0000	.0000	.000	1059.066	1.0000	1.0000
3	.0000	.0000	.0040	.0000	.0000	.000000
4	-.007	.000000	.00000000			

APPENDIX 6

GLOSSARY AND ABBREVIATIONS

1. GLOSSARY AND ABBREVIATIONS

This appendix (table AP 6-1) lists the commonly used S-IVB-204 stage flight evaluation terms and abbreviations together with their definitions.

TABLE AP 6-1 (Sheet 1 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
AACS	---	Auxiliary attitude control system
ac	---	Alternating current
---	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
APS	---	Auxiliary propulsion system
ar	---	Argon
AS	---	Apollo Saturn
ASI	---	Augmented spark igniter
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)
Btu	---	British thermal unit
CDDT	---	Countdown demonstration test
CDF	---	Confined detonating fuse
CEI	---	Contract end item
C_F	---	Thrust coefficient

TABLE AP 6-1 (Sheet 2 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
C_f	Collapse factor	A measure of the effectiveness of pressurization defined as: $C_f = \frac{M_{actual}}{M_{theoretical}}$, where M_{actual} is the mass necessary to pressurize the propellant tank (lbm), $M_{theoretical}$ is the mass necessary to pressurize the propellant tank if heat and mass transfer across the ullage boundaries are neglected (lbm)
C/He	---	Control helium
CIF	---	Central instrumentation facility
CM	---	Command module
---	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
cont	---	Control
CPIF	---	Cost plus incentive fee
cpm	---	Cycles per minute
cps	---	Cycles per second
CSM	---	Command service module
CVS	---	Continuous vent system
DAS	---	Data acquisition system
db	---	Decibel
dbm	---	10 log P (milliwatts) where p = power
dbw	---	10 log P (watts) where p = power

TABLE AP 6-1 (Sheet 3 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
dc	---	Direct current
deg	---	Degree
---	Depletion Engine Cut-off Command	The time that engine cutoff was, or would be, initiated by the depletion level sensors
DDAS	---	Digital data acquisition system
DEE	---	Digital events evaluation
D/O	---	Dropout
DRSCR	---	Digital range safety command receiver
e	---	Eccentricity
EBW	---	Exploding bridgewire
ECA	---	Electronic 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
ELS	---	Earth landing system
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

TABLE AP 6-1 (Sheet 4 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
eng	---	Engine
---	Engine cutoff transient	Engine operation during the period from the Engine Cutoff Command until the end of thrust decay
EPS	---	Electrical power system
ESC	---	Engine Start Command
---	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
env	---	Environmental
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
FCC	---	Flight control computer
FM	---	Frequency modulation
FPR	Flight performance reserve	Usable mass onboard at predicted guidance cutoff
fps	---	Feet per second
frats	---	Flowrate and turbo speed assembly

TABLE AP 6-1 (Sheet 5 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
ft	---	Foot
FTC	---	Florida Test Center
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
GCC	---	Guidance Cutoff Command
GG	---	Gas generator
GH2	---	Gaseous hydrogen
GMT	---	Greenwich mean time
GN2	---	Gaseous nitrogen
GOX	---	Gaseous oxygen
gpm	---	Gallons per minute
GSE	---	Ground support equipment
h	---	Altitude
h (AP)	---	Apogee altitude
HCSV	---	Helium control solenoid valve
He	---	Helium
HF	---	High frequency
hr	---	Hour
Hx ckt	---	Helium crossover circuit
H/W	---	Hardwire
i	--	Inclination
IECO	---	S-IB stage Inboard Engine Cutoff Command

TABLE AP 6-1 (Sheet 6 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
IGM	---	Iterative guidance mode
IMU	---	Inertial measurement unit
in./in.	---	Inches per inch (strain)
IPCL	---	Instrumentation Program and Components List
IPCSV	---	Ignition control solenoid valve
ips	---	Inches per second
I_{sp}	---	Specific impulse
I_t	---	Total impulse
IU	---	Instrument unit
k	---	Insulation thermal conductivity
kc	---	Kilocycles
KSC	---	Kennedy Space Center
ksi	---	1,000 $lb/in.^2$
lbf	---	Pounds force
lbm	Pounds mass	1/32.1739 slug
LC	---	Launch Complex
L/C	---	Loading Computer
LEM	---	Lunar excursion module
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

TABLE AP 6-1 (Sheet 7 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
LH2	---	Liquid hydrogen
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
LV	---	Launch vehicle
LVDC	---	Launch vehicle digital computer
M	---	Mach number
M	Stage propellant mass flowrate (lbm/sec)	Engine propellant mass flowrate (includes propellant flowrate for gas generator operation)
MCC-H	---	Mission Control Center, Houston
MCSV	---	Mainstage control solenoid valve
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	---	Milliampere
max q	---	Maximum dynamic pressure
μin./in.	Micro inch per inch	Millionth of an inch per inch
MDF	---	Mild detonating fuse
MHz	---	Millihertz
Mod	---	Module
MOV	---	Main oxidizer valve
ms	Millisecond	Thousandth of a sec

TABLE AP 6-1 (Sheet 8 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
MSC	---	Manned Spacecraft Center, Houston, Texas
MSFC	---	Marshall Space Flight Center
mvdc	---	Millivolt - direct current
mxr	---	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_2O_4	NTO	Nitrogen Tetroxide
NPSP	---	Net positive suction pressure
NPV	---	Nonpropulsive vent
OAT	---	Overall test
OECO	---	S-IB stage Outboard Engine Cutoff Command
O-P	---	Zero to peak
oxid	---	Oxidizer
P	---	Geodetic latitude
P	---	Pitch
P_a	---	Ambient pressure
P_c	---	Combustion chamber pressure measured at the injector

TABLE AP 6-1 (Sheet 9 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
PA	---	Pressure actuated
PAM	---	Pulse amplitude modulation
PCF	---	Preconditions of flight
PCM	---	Pulse code modulation
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
ppm	---	Parts per million
---	Propellant residuals	The sum of LOX and LH2 remaining on-board at Engine Cutoff Command. The residuals include both usable and trapped propellants.
PS	---	Pressurization system
psf	---	Pounds per square foot
P/S	---	Pressure switch
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

TABLE AP 6-1 (Sheet 10 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
---	PU system residuals	Those propellant residuals above the main propellant valves determined by the PU system
q	---	Dynamic pressure
qty	---	Quantity
°R	---	Degrees Rankine
RACS	---	Remote analog calibration system
RCS	---	Reaction control system
reg	---	Regulator
RF	---	Radio frequency
RFI	---	Radio frequency interference
RMR	---	Reference mixture ratio
rms	---	Root mean square
Ro	---	Range zero. Defined as the first even Greenwich mean time second prior to vehicle liftoff
RP	---	Reference plane
rpm	---	Revolutions per minute
R/S	---	Range safety
RSCR	---	Range safety command receiver
rss	---	Root sum square
S	---	Surface range (ft)
S&A	---	Safe and arm
scfm	---	Standard cubic ft/min
scim	---	Standard cubic in./min
sco	---	Subcarrier oscillator

TABLE AP 6-1 (Sheet 11 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
sec	---	Seconds
S-IB	---	First stage of the Saturn IB (200) series of vehicles
S-IVB	---	Second stage of the Saturn IB (200) series of vehicles
SLA	---	Spacecraft LEM adapter
---	Slug	English system unit of mass
SM	---	Santa Monica
SM	---	Service module
SPS	---	Service propulsion system
STPV	---	Start tank discharge valve
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
S/V	---	Space vehicle

TABLE AP 6-1 (Sheet 12 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
Sw sel	---	Switch selector
T	---	Countdown time from prospective liftoff or as specifically defined in the text
TCP	---	Test control procedure
Tel 2	---	Telemetry station at KCS
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
---	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
---	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
TPEP	---	Telemetry performance evaluation period
TVC	---	Thrust vector control

TABLE AP 6-1 (Sheet 13 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
---	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
v	---	Volt
V_E	---	Relative velocity
V_I	---	Inertial velocity
V_{RM}	---	Freestream velocity
V_W	---	Wind speed
VAB	---	Vehicle Assembly Building, KSC, Florida
vac	---	Voltage, alternating current
vcl	---	Vehicle checkout laboratory
vdc	---	Voltage, direct current
VCO	---	Voltage controlled oscillator
VHF	---	Very high frequency
VSE	---	Vehicle support equipment
VSWR	---	Voltage standing wave ratio
W	---	Watt
WRO	---	DAC work release order
wt	---	Weight

TABLE AP 6-1 (Sheet 14 of 14)
GLOSSARY AND ABBREVIATIONS

Abbreviations	Terms	Definition
$\dot{W}_T$	---	Time rate of change of total vehicle weight
X_E	---	Downrange distance
$\dot{X}_E$	---	Downrange velocity
XMTR	---	Transmitter
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_Y	---	Yaw angle of attack
γ_{1_I}'	---	Inertial flight path elevation angle
γ_{2_I}'	---	Inertial flight path azimuth angle
μ	---	Longitude
μv	---	Microvolt
αq	---	Product of angle of attack and dynamic pressure
γ_1	---	Earth fixed flight path elevation angle