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FLIGHT TEST ENGINEERING ANALYSIS REPORT
FOR
THE HEXAGON PROGRAM SATELLITE VEHICLE NUMBER THREE (S)

Prepared and Submitted by the
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FOREWORD

This report describes the performance of the third HEXAGON Program Satellite Vehicle (SV-3). The vehicle was launched on 7 July 1972 and after a 58 day primary mission and a 10 day SOLO mission was deboosted on 13 September 1972.

This report does not explicitly cover the SOLO mission; however, results from SOLO are used as appropriate when they contribute substantially to the understanding of primary mission events.

CONTENTS

(b)(1)
(b)(3)

ABBREVIATIONS

ACS	Attitude Control System
ARM	Attitude Reference Module
BV	Booster Vehicle
DV	Deboost
ECS	Extended Command System
EDAP	Electrical Distribution and Power
ESD	Emergency Shutdown
FDU	Failure Detector Unit
FOSR	Flexible Optical Solar Reflector
FST	Flight Support Team
FT	Film Transport
FTFD	Field Test Force Director
HS	Heat Shield
H/S	Horizon Sensor
IRA	Inertial Reference Assembly
IV	Isolation Valve
MCLR	Master Clear Off
MCM	Mapping Camera Module
MCP	Mapping Camera Payload
MCS	Minimal Command System
MLI	Multi Layer Insulation
MMC	Martin Marietta Corporation
MONO	Monoscopic Photographic Operations
MWC	Mid West Contractor
NVR	Non Volatile Residue
OA	Orbit Adjust
OAS	Orbit Adjust System
OB	Optical Bar
PACS	Primary Attitude Control System
PDA	Positional Drive Assembly
PDWN	Pitch Down

PFA	Post Flight Analysis
PGR	Pitch Gyro Rate
PL	Payload
PIP	Predicted Impact Point
PMU	Programmable Memory Unit
QCM	Quartz Crystal Microbalance
RACS	Redundant Attitude Control System
RCS	Reaction Control System
REA	Reaction Engine Assembly
REM	Reaction Engine Module
RV	Re-entry Vehicle
RWV	Rewind Velocity
SBAC	Satellite Basic Assembly Contractor
SECO	Stage II Engine Cut-Off
SGLS	Space-Ground Link System
SPC	Stored Program Command
SRM	Solid Rocket Motor
SS	Sensor System
SSC	Sensor System Contractor
SV	Satellite Vehicle
TCT	Test Control Team
TM	Telemetry
TT&C	Tracking, Telemetry and Command
TU	Take Up
TVC	Thrust Vector Control
VTT	Vandenburg Targeting Team

Section 1
SUMMARY OF GENERAL SYSTEM PERFORMANCE

1.1 SV SYSTEM PERFORMANCE

The SV-3 was injected into a nominal 96 by 137 nm orbit on 7 July 1972 by a Titan IIID Booster Vehicle. Ascent events were all nominal and proper stabilization of the SV allowed deployment of the Solar Arrays on the first rev. The Subsatellite was properly ejected on Rev 13. The four RVs were separated from the SV with their film loads on Days 9, 23, 37 and 58. All RVs were successfully recovered in the air. Following an extended SOLO operation period (which is not described in this report), the SV was successfully deboosted after 68 days in orbit on Rev 1104. The performance of the SV with respect to the primary mission objectives is summarized for each of the four mission segments as follows.

Segment One

Operational photography began on Rev 5 after completion of the Sensor Subsystem (SS) health checks. All subsequent operations throughout RV-1 demonstrated nominal characteristics, with no anomalies or malfunctions experienced. Approximately 27,400 feet of film per camera was exposed and stowed in RV1 which was recovered on Rev 132. Overall quality was somewhat reduced by a non-optimum focus setting. Also the quality was affected to varying degrees throughout the mission by haze and specular reflections due to the sun angle. As a result of RV-1 PFA evaluation the SS camera focus was adjusted for maximization of image resolution and the exposure requirements profiles were adjusted for optimum photographic information content.

Segment Two

Operational photography progressed normally until Rev 314 when there was an indication of minor disturbances in the B camera fine film path. Operations were continued with a manual limitation of 15 inches per second to the rewind velocity when going from a 120 degree scan to a 30 degree scan. Similar disturbances were reported on Revs 348 and 350 but no further action was taken before the recovery of RV-2 on Rev 359. Approximately 27,400 feet of film per camera was recovered. Both take-ups experienced sheared core pins with the accompanying loose and snarled outer layers of film. Overall quality of the acquired photography was comparable to segment one. The focus adjustment of +8 microns on the Forward (A) camera and -8 microns on the Aft (B) camera on Rev 166 was offset by other sensor system factors contributing to image smear degradation. Evaluation of the imagery placement on the film verified the B camera mistracking characteristic beginning on Rev 314. This mistracking also apparently contributed to a serpentine film track on the RV-2 B takeup.

Segment Three

The aft camera (B) fine film path disturbances continued into RV-3 operations. After an ESD on Rev 364, all stereo operations were limited to a 15 inches per second rewind velocity. An additional constraint to exclude 30 or 120 degree scan angles was implemented on Rev 395. On Rev 399, B camera operations were suspended for the balance of RV-3 since a film edge foldover on the RV-3 B camera takeup on Rev 364 had doubled the rate at which the takeup radius should have increased and a catastrophic failure appeared probable. The forward camera was then run in mono in a normal manner with the constraints removed and with both optical bars running to minimize torque. RV-3 was recovered on Rev 586 with 17,600 feet on the forward and 3300 feet on the aft camera. Overall quality of the acquired photography was fair to good, with the aft camera noticeably better than the forward. A performance trend existed wherein the photographic quality improved in the aft and degraded in the forward camera as the mission progressed.

Segment Four

The cameras during RV-4 were operated under the following constraints: (1) limit rewind velocity to a maximum of 5 ips, (2) eliminate all 120^{o} scan angles and (3) eliminate operations at ±45^{o} scan centers. Throughout RV-4 the aft camera (B) functioned normally. The forward camera (A) operated normally up to Rev 719 when it experienced a fold in the film similar to that on the aft camera in RV-3. Both cameras continued to operate; however, the aft camera was also operated in mono to best utilize the aft camera film. RV-4 was recovered on Rev 927 with 22,636 feet on the forward and 29,965 feet on the aft camera. The core pin sheared on the A side under retrieval loads. Overall quality of the acquired photography showed no change from that acquired during the RV-3 segment of the mission. The forward camera continued to exhibit greater variability than the aft with some instances of the forward imagery being better than the aft. Haze/smoke and poor weather conditions continue to be one of the significant contributers to image quality degradation. Segment 4 was terminated on Rev 927 to assure successful recovery using RCS 2. Degradation in maneuver capability of these thrusters was anticipated but the timing of such degradation was uncertain.

SOLO Phase

The SOLO phase extended from Rev 927 to deorbit on Rev 1104. SOLO objectives were:

a. Demonstrate 75 day vehicle life
b. Obtain engineering information on REM leaks and thruster degradation
c. Perform a list of SOLO experiments

The flight was terminated on Rev 1104 because of high leak rates on RCS 2 thrusters which resulted in a vehicle tumble.

The results of the SOLO experiments and the evaluation of data obtained will be presented in a SOLO Report.

1.2 SUBSYSTEM PERFORMANCE

With the exception of the Reaction Control System, the performance of the SV Subsystems throughout the mission was generally excellent. Except for the RCS, all primary equipment functioned throughout the four mission segments and no backup equipment was required. Subsystem performance is summarized as follows:

Attitude Control System

The ACS met performance requirements in all operating modes.

Reaction Control System

Although REM leakage developed on both the primary and secondary systems, control of the vehicle was satisfactory and propellant consumption did not restict the mission. Only after extensive SOLO operations did the secondary system leakage increase sufficiently to trigger the FDU. On SV-4 the secondary system will be fed directly from the OA tank.

Electrical Distribution and Power

With the beta angle constraint and the Bay 3 battery location, the EDAP system performed normally throughout the mission even through the ascent contamination of the aft section reoccurred. The amp-hour unit operated improperly at the beginning and end of the mission but was useful during most of the mission. For this mission its total loss would have been acceptable because of the large power margin.

Orbit Adjust System

The OAS continued to perform flawlessly and meet all requirements.

Tracking, Telemetry, and Command

With the observance of the antenna pattern recommendations, the TT&C System meets all requirements.

Lifeboat II

Health checks show performance requirements to be satisfied. The battery capacity was entirely adequate due to proper tank heater management. A Lifeboat II deboost was successfully performed.

Structures and Mechanisms

All performance requirements were again met.

Thermal Control System

All active and passive thermal control designs performed within requirements. Evaluations of the ascent contamination and the RV spin up motor contamination were successful.

A more detailed discussion of these subsystems is presented in subsequent sections of this report.

1.3 ANOMALY SUMMARY

Significant anomalies and malfunctions are listed chronologically in Table 1-1. The list includes a description of the anomaly, the mission consequences, the changes indicated for subsequent vehicles and a cross-reference to the appropriate paragraphs where detailed discussions may be found.

Table 1-1

ANOMALIES

Day	Descriptions	Impact	Cross Reference Paragraph
1	Left solar array erection delayed	No effect on mission. Delay duplicated in test. Erection release mechanism redesigned for SV-4 to eliminate possible interference between fittings.	14.3
1	Amp-hour unit reading erratic	Output was not representative of actual power used. Normal operation from Rev 9 to 870. Problem under investigation. No change for SV-4.	5.7
19	RCS 1 REM leak	Primary REM valves started to leak. Switched to RCS 2 on day 27. Study of problem continues.	2.2 and subparagraphs
20	Disturbance in B camera fine film path	Restrict RWV to 15 ips when go from 120 to 30 degree scan. Failure analysis continuing on cause of tracking problems.	1.1 and 7.1
23	RV-2 retro truss separation delayed	No impact on RV performance. MWC corrective action underway. No change for SV-4.	8.3
23	Outer wraps on RV-2 A and B sides loose and tangled. Core pins sheared	Core locking pins not designed for retrieval loads – shearing expected. No design change contemplated.	8.1
23	ESD on Side B tracking discrepancy at high RWV	Restrict all stereo RWV to 15 ips. No 30 or 120 deg scan ops. B takeup filled early. MONO A ops only. Early drop of RV-3 to conserve film.	1.1, 7.2 and 7.3

Table 1-1 (Cont.)

Day	Descriptions	Impact	Cross Reference Paragraph
45	ESD on Side A-high tension in film path	Cleared jam but fold in A takeup caused intermittent use of MONO B ops to use B film	1.1, 7.2 and 7.3
51	RCS 2 REM leak	Vehicle control and fuel consumption satisfactory to complete mission. RCS 2 will be fed from OA tank only on SV-4 to eliminate NVR	2.2.3.2 and 2.2.4
62	ACS 2 Hard Start	ARM thermal design on SV-4 modified to allow dual IRA operation.	2.1.5
68	Tumble	After 10 days solo ops leak sufficient to activate FDU. RCS 2 used to capture tumble.	2.2.3.2

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Section 2
ATTITUDE CONTROL

2.1 ATTITUDE CONTROL SYSTEM

The SV-3 Attitude Control System (ACS) performed as expected and met all specifications that could be measured. The summaries presented in this section detail those requirements that could be verified from flight data. The performance of the control force equipment elements is reviewed in subsection 2.2.

2.1.1 BV/SV Separation

BV/SV separation was completed at approximately 539.4 seconds vehicle time. (Vehicle time starts 67 sec before lift-off.) Master clear off (MCLR), which enables the pitch, roll and yaw integrators to accumulate angle, was at 510.8 sec and SECO, which terminates BV attitude control, occurred at 527.4 sec vehicle time. The SV attitude changes from SECO to BV/SV separation and the attitude and rates as measured at BV/SV separation are shown in Table 2-1. Also, the times in which the SV attitudes and rates came back within the specified limits following BV/SV separation (capture) are shown in Table 2-1.

2.1.2 Subsatellite/SV Separation

The significant Subsatellite/SV separation events of Rev 13.5 were as follows:

Event	Vehicle Time (sec)
Course Mode	69989.0
Neg Yaw Rate	69989.6
Stop Yaw Rate	70025.0
Separation	70084.8
Pos Yaw Rate	70103.0
Stop Yaw Rate	70138.4
Fine Mode	70168.4

Table 2-1

BV/SV SEPARATION

	Rate and Attitude at BV/SV Separation						Capture			
	Rate (deg/sec)		Attitude (deg)				Attitude		Rate	
			H/S at Sep		(SECO-Sep)					
	Specified	Actual	Specified	Actual	Specified	Actual H/S/Int.	Specified[1] (deg)	Actual[2] (time in sec)	Specified[3] (deg/sec)	Actual[4] (time in sec)
Pitch	±0.752	-0.15	-21.7 to +13.0	+1.2	±3.5	-.16/ -.37[5]	±0.70	667.7	±0.014	120
Roll	±0.786	-0.26	±10.6	+1.2	±3.0	+1.06/ +1.025	±0.70	667.7 Plus 520	±0.021	667.7
Yaw	±0.752	+0.175 +.084	-11.4 to +11.1	–	+4.5 to -3.5	–/ +1.46	±0.64	667.7 Plus 520	±0.014	667.7

(1) Attitude in degrees to be achieved in 1500 sec

(2) Actual time required to achieve specified attitude (switched to fine mode plus settling time)

(3) Rate in deg/sec to be achieved in 1500 sec

(4) Actual time required to achieve specified rate

(5) Relative to the local horizontal

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The ACS parameters just prior to the instant of separation (70084.8 seconds vehicle time) were as follows:

Event	Actual	Specified
Pitch H/S	+0.20 deg	±1.0 deg
Roll H/S	-0.76 deg	±1.0 deg
Roll Integrator	-0.14 deg	
Yaw Integrator	+0.14 deg	
Pitch Integrator	+0.23 deg	
Roll Gyro Rate	+0.03 deg/sec	±0.1 deg/sec
Pitch Gyro Rate*	-0.04 deg/sec	±0.1 deg/sec
Yaw Gyro Rate	+0.01 deg/sec	±0.1 deg/sec
Yaw Attitude (-25.0 deg desired)	-25.23 deg	-25±1.0 deg

The yaw attitude was obtained by integrating the yaw gyro rate.

The maximum SV rates observed following the yaw separation impulse were:

Pitch Gryo Rate	-.04 deg/sec
Roll Gyro Rate	±.31 deg/sec
Yaw Gyro Rate	+.16 deg/sec

With the Subsatellite located on the vehicle -Y side along the -Z axis at 11.47 in., a positive roll rate such as shown above was expected.

2.1.3 Payload Operations

Stereo and Mono payload operations with one OB were used on SV-3. The vehicle rate and attitude specification limits were met in all cases during these operations.

* Geocentric program rate of -0.0687 deg/sec was included

2.1.4 Recovery

The pitch-down maneuvers preceding the RV separations were all within specification and are summarized in Table 2-2, and the RV separation performance summary is shown in Table 2-3.

The pitch up maneuver following RV1 was designed to produce the minimum contamination of the aft section. The pitch up maneuvers following RV2, 3 and 4 to the local horizontal was to conserve RCS propellants.

2.1.5 ACS 2 Hard Start

During the ACS 2 Health Check experiment performed during SOLO (Rev 991) one of the RACS gyros failed to start. Although this anomaly occured after the end of the primary mission, it has caused design and operational impact on SV-4 and is therefore, discussed in this report.

Since this is the second of three flights to have had gyro restart failures, an intensive effort was launched to modify the ARM thermal design to allow both IRAs (PACS and RACS) to be operated simultaneously throughout the entire mission of SV-4. A design modification consisting of (1) adding heat conducting straps between the IRA mounting tray and the Bay 6 external doors and (2) changing the Bay 7 external paint pattern from bare aluminum with black stripes to 100 percent white. (This latter change will help keep the TT&C module, particularly the tape recorders, within upper temperature limits). The effect of running both IRAs without heat straps is to increase gyro temperatures by about 30°F. With the heat strap modification, this increase should be no more than 15°F. With single IRA operation, gyro temperatures are expected to be 180 to 195°F. Therefore, with the heat straps in, dual IRA operation should produce gyro temperatures between 195 to 210°F. A temperature of above 205 may be too high to allow continuous gyro operation, hence there is a significant probability that the RACS may have to be shut off in spite of the heat strap modification. In this case, the mission will continue in the single IRA mode as on SV-1 through -3. The equilibrium temperature level for the gyros should be reached within the first three or four revs of flight. A predicted curve of gyro heat-up versus time for dual IRA operation will be available to facilitate a shut off RACS if gyro temperatures exceed the 205°F.

Table 2-2

PITCH DOWN PERFORMANCE PRECEDING RV SEPARATION

	Pitch Down Angle		Maneuvering Time to ≤0.1 (deg/sec)		Pitch Down Coast Rate		
RV/Rev	Desired ±3.0 deg	Actual (PDWN) (deg)	Spec (sec)	Actual (sec)	Command Rate (deg/sec)	Coast Rate Expected (deg/sec)	Coast Rate Actual – PGR (deg/sec)
1/132	-40.7	-39.9	150	84	-0.705	-0.75 ±0.05	-0.71
2/359	-43.4	-43.0	150	86	-0.705	-0.75 ±0.05	-0.72
3/586	-41.3	-41.5	150	78	-0.705	-0.75 ±0.05	-0.72
4/927	-43.1	-42.8	150	83	-0.705	-0.75 ±0.05	-0.73

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Table 2-3

SUMMARY OF RV/SV SEPARATION PERFORMANCE

RV/Rev	Peak Pitch Rate (deg/sec)	Maximum Pitch Integrator Angle (deg)	Impulse Induced by RV (lb-sec)	Pitch Down Prior to Sep (deg)	Pitch-up Following RV Sep to Removal of Maneuver Command (deg)	Pitch Inertia (After Sep) (slug-ft^2)	Pitch Thruster Moment Arm (ft)	Roll Angle	
								Spec (deg)	Meas. H/S (deg)
1/132	1.94	12.0	117	-39.9	96.0 (1)	100914	14.2	±1.0	-0.26
2/359	2.32	15.4	129	-43.0	43.1 (2)	79269	12.9	±1.0	-0.04
3/586	2.16	11.7	117	-41.5	42.5 (2)	64046	11.7	±1.0	-0.02
4/927	2.68	24.0	159	-42.8	51.1 (2)	53671	10.9	±1.0	-0.04

(1) To removal of maneuver command

(2) To connection of H/S

2.2 REACTION CONTROL SYSTEM

2.2.1 Flight Summary

History of the RCS performance is shown in Fig. 2-1 and tabulated in Table 2-4.

Satisfactory vehicle attitude and rate control were provided by the RCS at all times during the 58 days of the active mission. The Failure Detector Unit (FDU) turned the system off and the vehicle tumbled (Rev 1089→1092) during the SOLO mission.

2.2.2 Propellant Consumption

RCS propellant consumption for the mission was 1021 lb as shown in Fig. 2-2. Propellant was consumed only from RCS tanks 1 and 2 until the 22nd day when isolation valve 3 was opened to allow usage from the OAS tank as well.

REA chamber and REM mount temperatures are shown in Fig. 2-3. Abrupt temperature increases can be noted when leakages developed and precede the onset of excessive propellant consumption. The mount temperatures lag the REA chamber temperatures; therefore, the detection of the leakage is not as sharp on the standby side when only the mount temperatures are available. These indicators were used during the flight to initiate more intensive data analysis to monitor the onset of leakage.

2.2.3 Thruster Performance Degradation

Thrust characteristics for the primary RCS (RCS-1) were determined from actual chamber pressure and temperature data. Thrust characteristics for the secondary RCS (RCS-2) were determined from the number of pulses and the pulse width data for the valve drivers.

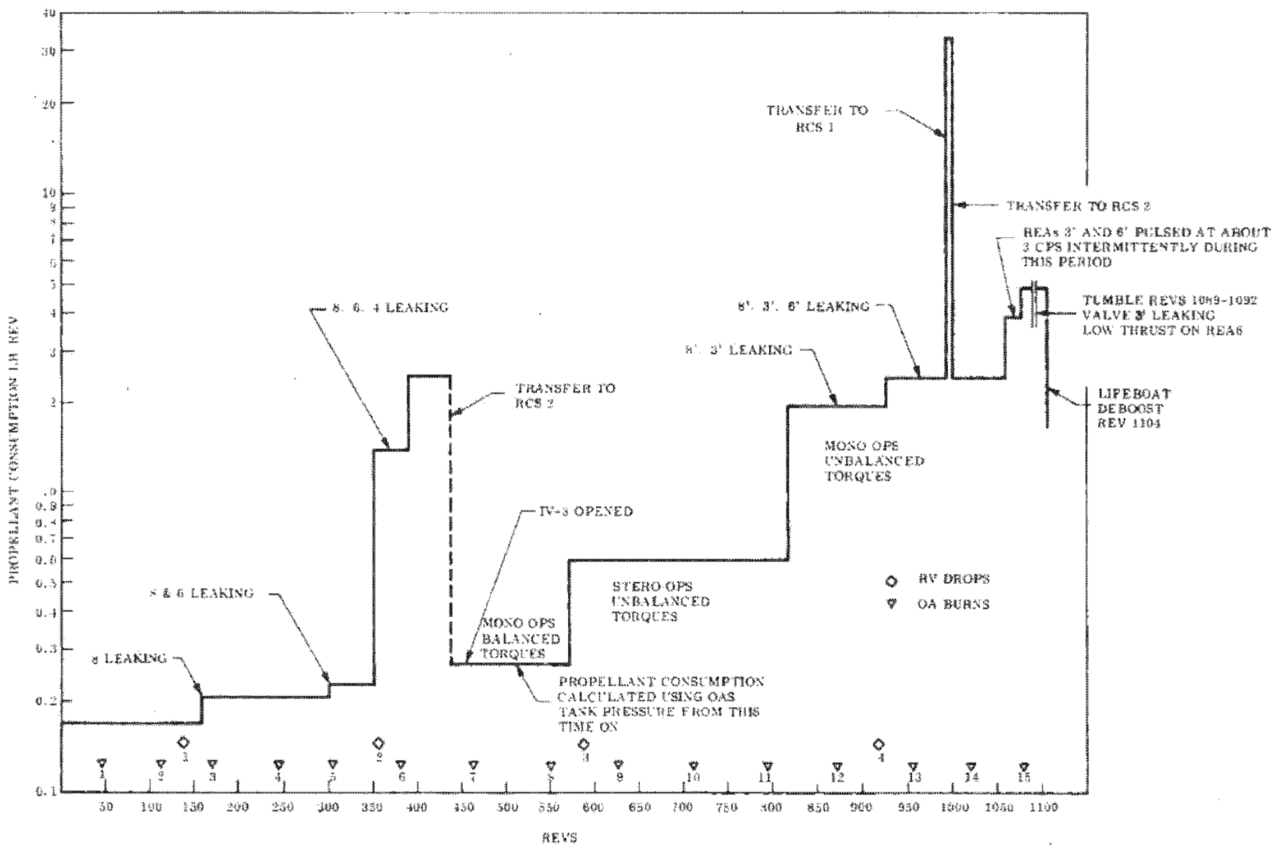

Fig. 2-1 RCS Usage Summary

Table 2-4

FLIGHT SUMMARY OF REACTION CONTROL SYSTEM

Rev	Events	Average Propellant Usage (lb/rev)	Significant Events During Rev Interval					
			OA Firings	RV Events	Pitch Maneuvers	Stereo Ops	Mono Ops 1 Bar	Mono Ops 2 Bar
0-174		0.17	2	1	2	147	-	-
175	REA8 Leaking	0.22	REA8 Temp Increased 100° to 460°					
305	REA6 Leaking	0.26	REA6 Temp Increased to 800°					
350	REA4 Leaking		REA4 Temp Increased to 900°					
		1.40	3	1	2	104	-	-
395								
		2.50	1	-	-	22	-	-
428	Start Mono Ops		Mono Ops Utilizing Both OB's and One FT					
		2.50	-	-	-			11
436	RCS-1 to RCS-2							
		0.27	2	-	-			116
574	Start Stereo Ops		Stereo Ops With Unbalanced Torques					
		0.60	3	1	2	177	-	-
801	Start Mono Ops		Mono Ops Utilizing One OB and One FT					
		0.60	-	-	-	-	26	-
825	REA8' Leaking		Increase Activity on Opposing REA and REM Mount Temp Rise. Veh Continuously Riding Pos Yaw Dead Band					
		2.0	-	-	-	-	49	-
870	REA3' Leaking		REA3' Stopped Pulsing Although Reqd to Overcome Aero Torque					
		2.0	1	-	-	-	16	-
905	REA6' Leaking		REA3' Started Pulsing at an Increased Rate Veh Riding Pos Pitch Dead Band. REM Mount Temp Increase					
		2.5	1	1	2	-	9	-
990	RCS-2 to RCS-1	34 Decreasing to 12	An Immediate Increase in REA Temp Was Noted. REA 3, 4, 5, 6 & 8 are Leaking					
998			-	-	-	-	-	-
999	RCS-1 to RCS-2							
		2.5	-	-	-	-	-	-
1060	REA3' & 6' Leaking		At This Time it Was Noted That REA3' Started Firing at Approx 3 cps					
		4.0	-	-	-	-	-	-
1089	Tumble		Immediately Prior to the Tumble, REA3' Slowed its Pulse Rate And Then Stopped Pulsing. REA6' Then Came on Steady State For 27 sec Causing the FDU to Close the Isolation Valves.					
		5.0	-	-	-	-	-	-
1092	RCS-2 → RCS-2		Tumbling Capture With RCS-2 Sequence Successful					
		5.0						
1104	Lifeboat Deboost							

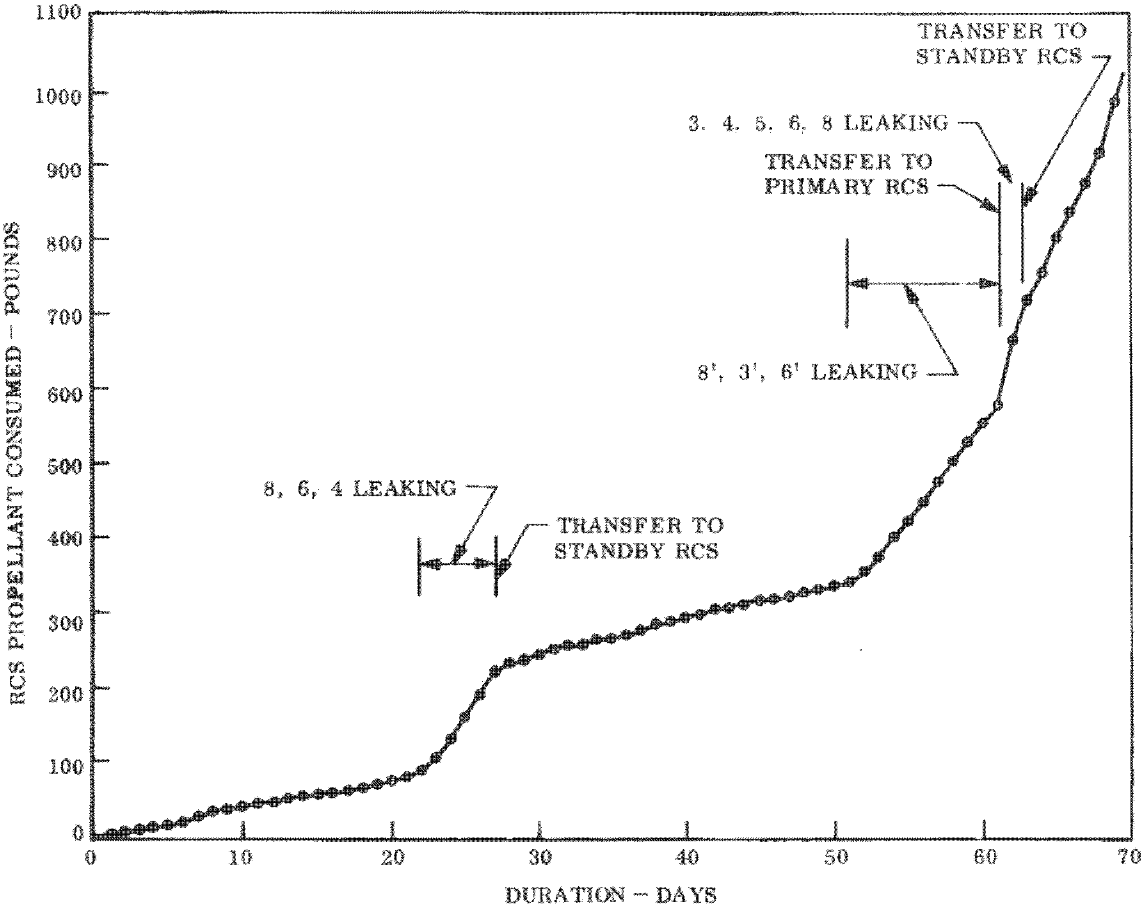

Fig. 2-2 RCS Propellant Consumption

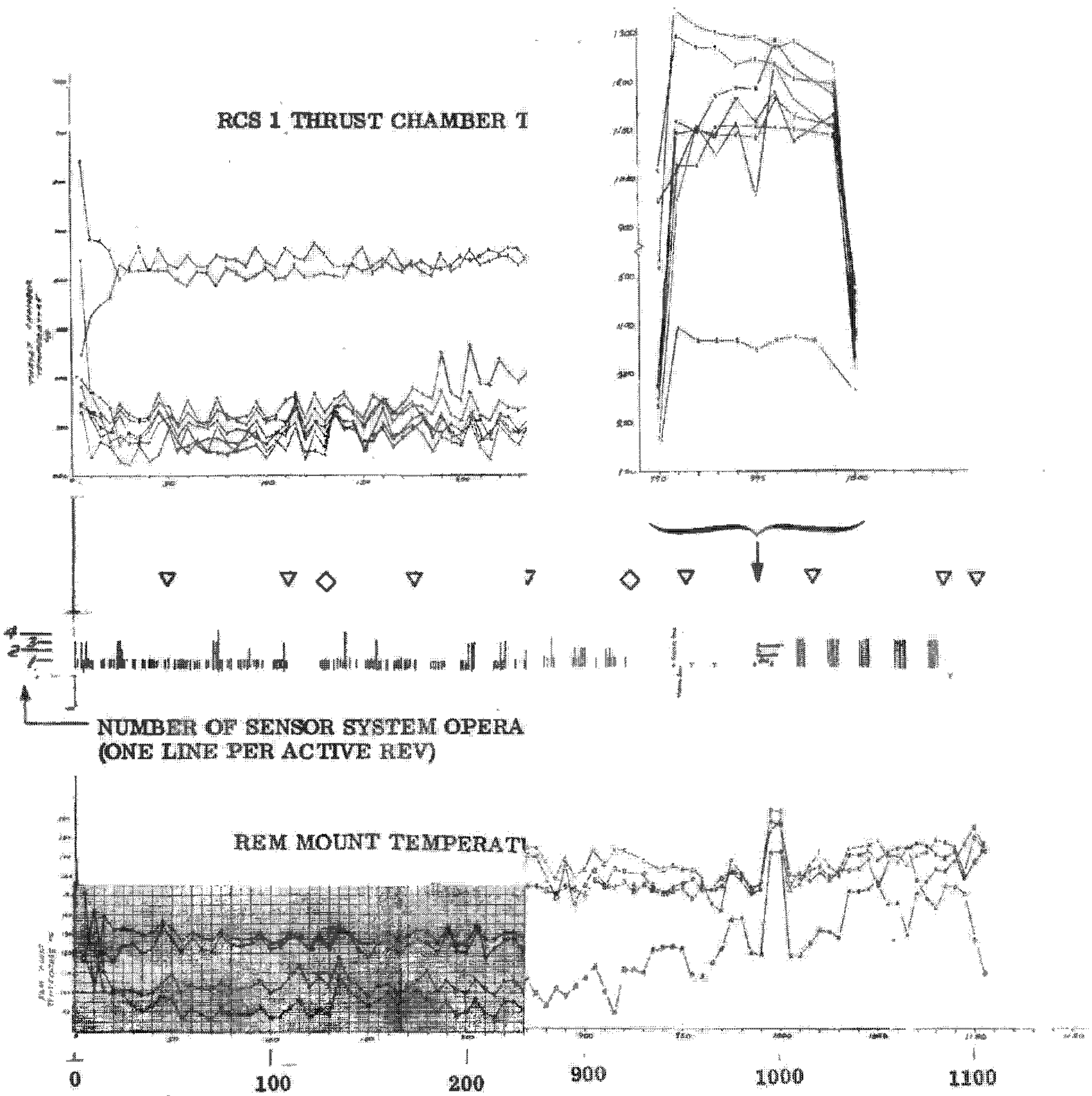

Fig. 2-3 History of RCS Performance

2.2.3.1 Primary RCS. The first indication of thruster degradation was a sluggish pulse to pulse peak chamber pressure buildup observed on Rev 162. Fig. 2-4 shows how REA4 required seven pulses to reach 45 psi whereas REA8 starting with the same chamber temperature required only three. On Rev 227, REA1 and 4 appear sluggish as compared to REA5. However, no significant loss in performance of RCS-1 was detected before the transfer to RCS-2 on Rev 436.

When the transfer was made back to RCS-1 on Rev 990, the pulse shape tailoff on REA3 was noted and is shown for Rev 991 in Fig. 2-4. REAs 3, 4, 5, 6 and 8 were observed leaking. Vehicle control was maintained during this period when the RCS-1 was used; however, propellant consumption was 34 pounds per rev on Rev 990 and gradually reduced to 12 pounds per rev by Rev 999.

2.2.3.2 Standby RCS. The standby RCS was activated on Rev 436. Payload operations at this time consisted of Mono Ops with both OBs and a distinctive REM mount temperature pattern can be seen in Fig. 2-3 during this period. A second pattern developed when stereo operations were resumed with unbalanced supply units on Rev 574. A third pattern can be observed after Rev 801 when Mono Ops with one OB was the payload mode of operation. REA8' started leaking on Rev 825, REA3' on Rev 870 and REA6' on Rev 905. RV-4 was separated on Rev 927 and the SOLO mission was begun. During SOLO a series of experiments including yaw arounds, pitch downs, payload operations, etc., were conducted to test the capability of RCS-2. RCS-2 maintained control until the tumble on Rev 1089 when the FDU sensed REA6' firing in a steady state mode for 27 seconds. Capture of the tumbling SV was successfully accomplished without difficulty using RCS-2 and vehicle stability was maintained through the start of the deboost sequence.

2.2.4 Corrective Action

The RCS propellant plan (propellant cleanliness, tanking and orbit utilization) implemented on SV-3 was successful in providing orbital life without a significant increase in fuel consumption to 22 days for RCS 1 and to 24 days for RCS 2. However, the problem of REA valve leakage caused by RCS tank diaphragm generated NVRs (Non Volatile Residues) still exists. Action has been taken to eliminate RCS tanks No. 3 and 4 from the RCS 2 system. This has been accomplished on SV-4 by cutting and capping the propellant lines to the tanks 3 and 4, thus leaving only the OAS tank to feed RCS 2. The RCS 2 thrusters on SV-4 will not experience NVRs and should be leakage free.

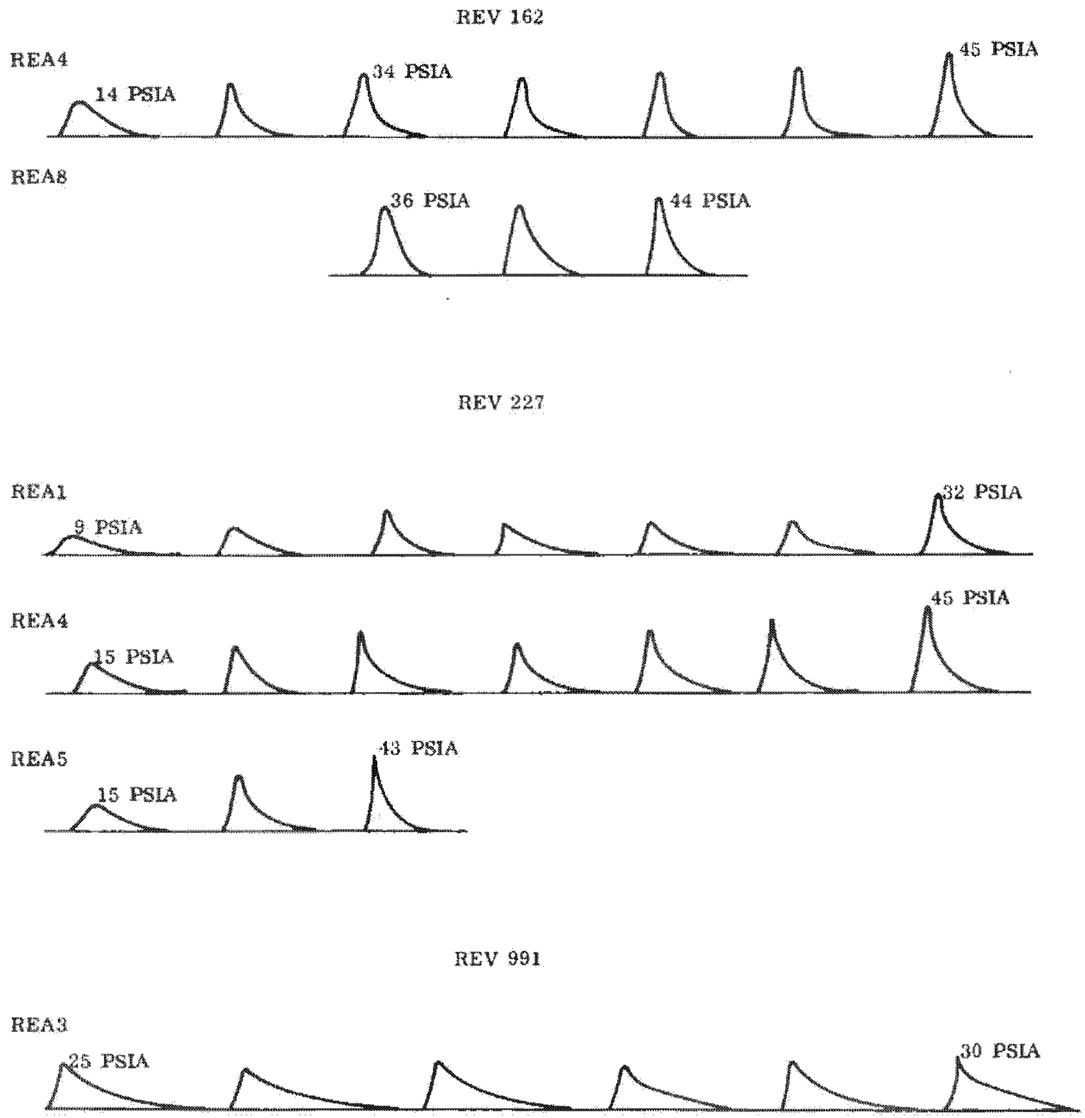

Fig. 2-4 Primary RCS Pulse Shape Characteristics

Section 3

ORBIT ADJUST

3.1 ORBIT CONTROL

The Orbit Adjust System was utilized twelve times during the active mission for drag makeup, perigee location control and ground trace control. The OA firings were all normal and the engine performance was well within specifications.

The OAS was successfully utilized three times during the SOLO phase of the mission for drag makeup.

3.2 DEBOOST

The final firing of the OA engine was for the Lifeboat II deboost on Rev 1104. The firing duration was 343.7 seconds to achieve a planned negative velocity increment of 150 ft/sec (see para. 6.2 for additional comments).

Table 3-1

OAS PERFORMANCE

OA Firing No.	Rev Number	Impulse Delivered (lb-sec)	Planned ΔV (ft/sec)	Achieved ΔV* (ft/sec)	Percent Error In ΔV
1	46	9900	16.18	16.24	+ .37
2	111	9555	15.45	15.73	+1.78
3	176	11892	21.18	21.54	+1.67
4	241	9616	17.20	17.33	+ .75
5	306	15929	28.52	28.82	+1.04
6	387	12283	24.34	24.49	+ .61
7	468	19190	38.45	38.75	+ .77
8	549	12276	24.98	24.88	- .40
9	629	13467	29.97	29.90	- .23
10	712	16316	36.48	36.62	+ .38
11	793	13691	30.72	30.98	+ .84
12	874	18716	42.43	42.76	+ .77
13	955	14487	37.62	37.74	+ .32
14	1022	17996	46.10	47.14	+2.25
15	1086	11291	30.53	*	-
Deboost	1104	54750	-150.00	-	-

* Determined from Best Fit Ephemeris data. This data is not available for OA15.

Section 4
TRACKING, TELEMETRY AND COMMAND

4.1 TRACKING

4.1.1 Accuracy

An evaluation of tracking accuracy is being prepared by the FTFD and will be available through that office.

4.2 TELEMETRY

4.2.1 General Performance

Telemetry system performance was satisfactory throughout the flight.

4.2.1.1 Usage Summary Through Revolution 1104.

SGLS	Side 1	Side 2
• Number of ON/OFF cycles	1167	85
• Operational Time (min)	7185	572
PCM		
• Total Operational Time (min)	19,391	286
• Number of ON/OFF cycles	7690	92
Tape Recorder	**No. 1**	**No. 2**
• Number of ON/OFF cycles Record	6523	7
• Record Time (min)	11,756	164
• Reproduce Time (min)	2214	30
• ON/OFF cycles Reproduce	853	7

4.2.2 Down Link Signal Strength Fluctuations

Dropout predictions were made by the SBAC flight support team (FST) and were provided to test control team (TCT) to insure acceptable signal strength levels for command loading and tape recorder playback. The methods for predicting dropouts resulted in excellent station pass planning with esentially no data loss. In addition, further experimentation with different station antenna polarizations (vertical; right hand circular) was conducted by those stations possessing that capability. The objective was to provide data for establishing values of possible gain differences between such polarizations. Data resulting from these experiments is being evaluated to determine if any gain can be attributed to polarization of the station antennas.

4.2.3 Instrumentation

The following comprises the list of anomalous instrumentation existing at liftoff.

ID No.	Description	Status
A614	Bay 2 Internal Skin Temp 5	Reads Open
B052	Primary REA No. 2 Chamber Temp	Erratic — Unreliable

4.3 COMMAND

4.3.1 Uplink Operation

The vehicle SGLS command equipment was utilized to receive approximately 9.5 million bits with 4 anomalies being experienced. This error rate is well within specification.

4.3.2 GFE Command System

4.3.2.1 Extended Command System. The ECS responded satisfactorily in all command modes resulting in the loading of 120,896 SPC's in memory; of these 120,896 SPC's loaded, 79,477 were output by both PMU's for decoder processing. The remainder were erased prior to their time label matches.

4.3.2.1.1 ECS Clock Operation. The accuracy of the clock throughout flight has been determined to be 0.152 parts in 10^6. The clock oscillator frequency changed 0.072 Hz in 68 days.

4.3.2.2 Minimal Command Subsystem. The MCS responded correctly to all commanding. A clock test was performed during solo operations, and the accuracy of the clock was .205 parts in 10^5.

4.3.2.3 Remote Decoder/Backup Decoder. Both sides of the Remote Decoder were utilized for each of the four recoveries. Performance of both sides was determined to be acceptable through analysis of telemetry data.

4.3.2.4 Command System Usage Summary Through Rev 1104.

System	Total Operating Time (hours)
ECS	1656
MCS	25
Remote Decoder	6
Backup Decoder	25

4.3.3 375 MHz Receiver

The 375 MHz Receiver was powered during the entire mission and was used during the MCS clock rate experiment with no anomalies.

4.3.4 Data Interface Unit

The data interface unit performed satisfactorily throughout the flight. The operation counter accurately processed 13,860 counts on Side A, and 12,841 counts on Side B.

Section 5

ELECTRICAL DISTRIBUTION AND POWER

5.1 SOLAR ARRAYS

Solar Arrays were extended on Rev 1. Power output from each leg equaled or exceeded the specification value. Degradation for 60 days of flight was calculated from flight data to be 4.3 percent. This is within the design allowable of 5% for 30 days even with the high solar flare activity encountered during the flight.

5.2 MAIN BUS VOLTAGE

The Main Bus voltage varied from a low of 28.1v to a high of 31.8v. The allowable range was 25.5v to 33v. Low voltage data was obtained just prior to sunrise with a buss load of 17±5 amps. High voltage data was gathered during the charge cycles.

5.3 POWER CAPABILITY AND USAGE

Power usage ranged from 201 to 320 amp-hours/day. This is well below the 424 amp-hours/day capability. Excess capability was demonstrated by K2 charge relay cutoffs occurring on Rev 3 and on essentially every rev thereafter except those with heavy payload operations.

5.4 TYPE 29 BATTERY PERFORMANCE

All batteries operated in a desirable environment (43 to 51°F) and performed normally throughout the mission.

5.5 PYRO BATTERY PERFORMANCE

Pyro Battery 1 stabilized at 48°F thus minimizing self discharge to ~ 10 percent of launch capacity. Twenty (20) days after launch, the battery left the peroxide operating region which indicated that a computed 3 amp-hours had been removed, leaving 10 amp-hours for continued use. Cell degradation life still available was 67 days. Pyro Battery 2 followed the same pattern with the exception of being in the peroxide region until day 44.

5.6 LIFEBOAT BATTERY PERFORMANCE

The Lifeboat battery operated normally in a 49°F environment throughout the 4 segment mission. 155 amp-hour remained at the end of the 4 segment mission from an initial capacity of 353 amp-hours. Remaining cell degradation life was 67 days.

5.7 AMP-HOUR METER ANOMALY

The amp-hour unit operated improperly from launch through Rev 9. The output was not representative of the actual power used. The character of the malfunction was incrementing in 10 or 15 amp-hour steps and occasional negative incrementing rather than 5 amp-hour steps. During Rev 9 the unit returned to normal operation until Rev 870 at which time it started incrementing in steps of ±10 to 50 amp-hours and continued in this condition until the end of the flight.

Failure analysis action has been directed to the supplier, Gulton Industries. The initial analysis indicates a resistor wired in series in the +18v power converter burned out or shorted out allowing the voltage to rise to 24v. This in turn forced the -5 volt output to increase to -6.6 volts thereby creating faulty readings. The supplier will attempt to duplicate the failure in test to confirm the failure mechanism. No changes have been implemented in SV-4. There is no history of failure of this kind in previous flight on in ground test.

Because of the substantial power margin on SV-3, the malfunctioning of the amp-hour unit did not cause any operational difficulties.

Section 6

LIFEBOAT II

6.1 HEALTH CHECKS

The Lifeboat II data that was examined is summarized in Table 6-1. The magnetometer sensor data indicates equivalent attitude errors as follows:

Magnetometer	Attitude Error
Q	<0.5 degrees
P	<0.5 degrees
R	0.7 degrees

The rates measured on the three Lifeboat II rate gyros were within 0.03 degrees/sec of the rates measured on the ACS gyros.

6.2 USAGE

The SV was successfully deboosted on Rev 1104 using Lifeboat II. The vehicle yawed around, pitched the nose up and was stabilized in approximately 180 seconds after initiation of the deboost sequence at system time 62272 seconds. The OA burn began 310 seconds after initiation and burned for 344 seconds. No significant perturbation was observed in either attitudes or rates during the burn. The Lifeboat was reset 672 seconds after initiation.

After uncontrolled flight for 1102 seconds, Lifeboat was again activated to simulate an RV5 drop at system time 64047 sec. At the time of execute initiation, very large attitude errors were observed together with X, Y and Z rates of 0.48, 0.24 and -0.32 deg/sec respectively. The vehicle again was stabilized in approximately 180 seconds. Tape recorder data is available until system time of 64433 seconds and shows no loss of control. However, the real time data starting at 64518 seconds showed loss of control with large attitude errors and large X, Y and Z rates. Control was not regained through the remainder of the operation. All data ceased at 64695 seconds.

In summary, Lifeboat II parameters were within specification and no anomalies were noted.

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Table 6-1

LIFEBOAT II OPERATION

Rev	Mode	Q Magnet. (milligauss)		R Magnet. (milligauss)		P Magnet. (milligauss		Y Axis Gyro (deg/sec)	
		Observed	Theoretical	Observed	Theoretical	Observed	Theoretical	Observed	Theoretical
18.3	S-N, DB	-20	-19.7	201	207	Not in use	-	-0.08	-0.068
	S-N, RV	-20	-18.4	Not in use	-	Neg. Sat	Neg. Sat		
	N-S, RV	-20	-18.2	Not in use	-	Neg. Sat	-		
132.3	N-S, RV	14	-	Not in use	-	Saturated and moves through null with pitch up		1.85 1.70	1.85 1.73
586.3	N-S, RV	30.2	32	Not in use	-	204	203	-	-
927.3	N-S, RV	32	-	Not in use	-	Saturated and moves through null with pitch up		-	-
1104	-	-	-	-	-	-	-	X Axis Gyro 0.40 Z Axis Gyro 1.09	 0.41 1.08

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Section 7
SENSOR SYSTEM

7.1 COARSE FILM PATH

Both coarse film paths exhibited proper operation during the mission when commanded with supply, loopers, steerers, and takeups functioning normally with the following exceptions:

- Post flight inspection of the RV-2 B-side (aft looking camera) takeup revealed a serpentine film stack attributed to the fine film path disturbances noted on Revs 314, 348 and 350. The sides of the stack were uneven in two places, with a maximum of 3/4 inch offset toward the outboard edge in one area and 1/4 inch offset toward the outboard edge in the other area.
- Following the ESD on Rev 364 in RV-3, the B-side radius pot takeup increased at a rate almost double the rate on the A side. This continued through Rev 399 at which time B-side photographic operations were suspended to avoid a possible catostrophic failure. It was concluded that the fine film path disturbance which generated the ESD was accompanied by a film edge fold-over in the RV-3 B camera takeup. Post flight analysis corroborated this conclusion and 2200 feet of film were found to be in the fold-over ranging from 1/4 to 1 inch in width. The integrity of the takeup stacking was not affected by the fold. To avoid propagating the disturbance by drawing affected film from RV-3 to RV-4, the normal Prep 1 Sequence was modified to provide a minimum wrap on the B camera takeup. Prep 2 commanding was executed normally. All recovery operations were completed by Rev 570.
- In RV-4 following the ESD on Rev 719, the A camera radius pot increased at a rate almost double that predicted (similar to the B side on RV-3) indicating a fold which was confirmed by post flight inspection. The film stack was spongy on the inboard side (folds were on outboard side) with indications of mistracking on both inboard and outboard sides from the outer wraps down to 4.5 inches

from the core, which was the point at which the film damage began. The fold precluded utilizing the full supply load; however, the A camera continued to operate and transport film until the takeup reached a point of physical interference at a radius in excess of that readable on telemetry instrumentation. As the A radius pot approached its upper limit, the builder-roller did not lower to the stack after a short 5 ips rewind on Rev 852. Subsequent operations of the A side were eliminated.

7.2 FINE FILM PATH

The fine film path of the B camera exhibited tracking disturbances on RV-2 and RV-3 and the fine film path of the A side exhibited tracking disturbances on RV-4 as noted in the following:

- Minor tracking disturbances in the B side fine film path on Rev 314 were attributed to a slight tracking discrepancy during large rewinds. The combination of a 120 degree scan angle operation followed by a 30 degree scan angle operation at high scan centers (which was the case on Rev 314) is particularly conducive to mis-tracking disturbances. To continue the mission in a conservative manner, the command messages were subsequently manually altered to limit rewind velocities (RWV) commands to 15 ips when going from a 120 to a 30 degree scan. Further disturbances on Revs 348 and 350 of the B side fine film path were evidenced by a corresponding distortion of the metering capstan servo summed error telemetry signal. These disturbances on Revs 348 and 350 were also attributed to a minor off tracking condition during large rewind velocities. Post flight evaluation of the imagery placement on the film verified the B camera mis-tracking beginning at Rev 314. The wander of the film was sufficient in some instances to allow some edge rubbing but was not sufficient to induce major damage or deformation of the film.
- The RV-2 B camera fine film path disturbances continued into the RV-3 operations. A major disturbance on Rev 364 induced an ESD of the Sensor Subsystem. The disturbance was attrubuted to a slight tracking discrepancy during high velocity rewinds. Subsequent stereo operations were limited to a RWV of 15 ips. Further restrictions excluding 30 or 120 degree scan operations were

implemented on Rev 395 following analysis of the disturbance modes on RV-2. After Rev 399 the B camera operations were suspended and the A camera monoscopic operation was run with the temporary restraints removed; i.e., all scan modes, no negative scan centers, and a maximum RWV of 55 ips.

- Throughout RV-4, the B camera functioned normally. Just prior to the completion of the rewind following the last operation on Rev 719, the A camera film path experienced a disturbance of sufficient magnitude to raise path tension to the point of triggering an ESD. The film path was subsequently cleared of the material present at the time of the disturbance, and stereo operations continued, but constrained to only 30 and 60 degree scan angles, no $\pm 45^{\circ}$ scan centers and only 5 ips RWV. To utilize all the film possible, monoscopic operation of the B camera was utilized for the remainder of the mission.

7.3 COMMAND AND CONTROL

Sensor system performance with respect to the Command and Control Subsystem was nominal throughout the mission. All ESD's experienced were attributed to Coarse and Fine Film Path anomalies discussed in paragraphs 7.1 and 7.2.

7.4 OPTICAL BAR PERFORMANCE

Optical bar performance was nominal through the mission. The B camera optical bar was run to minimize torque disturbances to the SV during A camera mono operation in RV-3.

7.5 INSTRUMENTATION

All instrumentation was operative throughout the mission

7.6 PNEUMATICS

The pneumatics system performance was nominal throughout the mission. There was no leakage as experienced on SV-2. Gas usage was 32.2 pounds of the 34.2 pounds loaded.

Section 8
RE-ENTRY VEHICLES

8.1 SUMMARY

The recovery statistics are shown in Table 8-1 and Fig. 8-1. Performance of the RV Subsystems is summarized in Table 8-2. Data indicate that all RV events (on-orbit, re-entry and recovery) occurred as planned (except for delayed separation of the propulsion truss on RV-2) and the RV flights followed the predicted trajectories. The delayed truss separation had no subsequent effect on the flight.

All payloads were recovered in good condition. The outer wraps were loose on sides A and B on RV-2 and on side A on RV-4 due to payload rotation after the aerial retrieval induced shearing of the core pins. Aerial retrieval loads exceeding the core pin strength were anticipated. Due to malfunctions of the payload sensor system, unbalanced payloads resulted on RV's 3 and 4.

All subsystems performed satisfactorily and met all mission requirements.

8.2 RE-ENTRY VEHICLE PERFORMANCE

All RV on-orbit functions were normal and occurred on time. The SV provided a satisfactory pitch angle for each RV separation. All other SV/RV interface functions were nominal.

Stability margins during the retrograde and exoatmospheric coast phase were high for each flight. Onboard data show body transverse rates less than 3 deg/sec for the balanced payload conditions and less than 12 deg/sec for the unbalanced payload conditions. These rates are well within the predicted values. The spin and residual spin rates were also as predicted during this phase. Separation of the propulsion truss on RV-2 was delayed as discussed in Par. 8.3 but had no adverse effect on RV behavior.

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Table 8-1

RV RECOVERY SUMMARY

	RV-1	RV-2	RV-3	RV-4
RV Serial No.	16	15	14	13
Recovery Rev No.	132	359	586	927
Recovery Date (1972)	14 July	29 July	12 August	2 September
Payload Weight, (lb) (A; B)	A = 216.2 B = 218.1	A = 215.0 B = 217.0	A = 155.5 B = 26.7	A = 179.8 B = 228.7
Unbalance Percent	1.0	1.0	58.2	18.5
SV Orbit (hp x ha/ωp)*	96.2 x 134.9/156.4	96.4 x 139.0/131.9	98.9 x 132.3/148.8	95.7 x 142.4/123.4
SV Pitch Angle (deg)	-40.9	-43.2	-41.8	-42.9
Nominal PIP Latitude	23.4 N	25.9 N	19.0 N	16.8 N
Impact Location Error (BFE vs. Test Report TWX)				
Overshoot (nm)	8.1	20.0	1.65	8.1
Crosstrack (nm)	1.9 W	2.2 E	0.9 E	1.0 W
Recovery (Aerial)				
Altitude (ft)	12,700	10,500	12,300	11,700
Parachute Condition	Minor Damage	Minor Damage	No Damage	No Damage
Retrieval Pass	1	2	1	1
RC/Payload Condition	Good	Good	Good	Good

*h_p = Altitude of Perigee (nm), h_a = Altitude of Apogee (nm), ωp = Arg of Perigee (deg)

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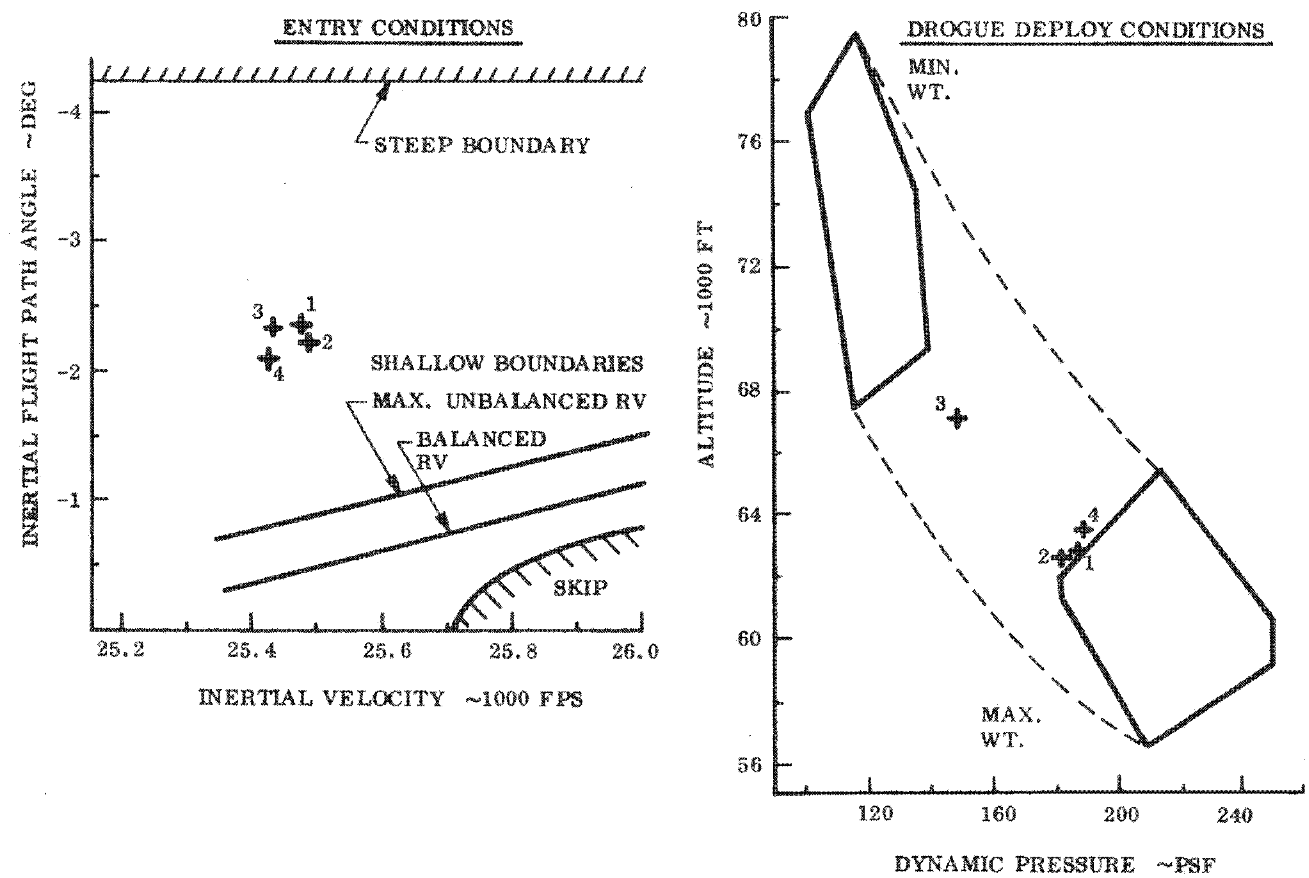

Fig. 8-1 SV-2 Re-entry Parameter Comparisons

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Table 8-2

RV SUBSYSTEM PERFORMANCE SUMMARY

RV Subsystem/Function	Performance Assessment
On-Orbit Thermal Protection	Normal • T_{PL} Container = $T_{ref}{}^{+0^oF}_{-7^oF}$ • Power Usage (Watts/RV) Maximum = 20 (First Day in Orbit) Stabilized = 6 (Sixth Day in Orbit) Allowable = 20.0
Trim and Seal	Normal
Electrical Power & Distribution	Normal • All Batteries Activated • All Voltages > 25.5 Volts
Sequential Subsystem	Normal • Primary and redundant systems in each RV were verified to have functioned properly by telemetered data and factory test. Physical separation of RV-2 propulsion truss did not occur until areo-entry although sequential and pyro systems functioned normally.
Pyro Subsystems	Normal • All primary and redundant pyrotechnics in each RV were verified by factory inspection to have functioned properly.
Spin Stabilization	Normal
Retro Motor	Normal
Tracking, Telemetry, Instrumentation	Normal
Heat Shield	Normal
Base Thermal Protection	Normal
Structure	Normal
Recovery System	Normal

Figure 8-1 shows the entry conditions to be well within previously established entry boundaries. The residual roll rate was nearly constant during the exoatmospheric coast phase, decreased during the early period of the entry phase and after 120 sec reversed. This reversal has been typical for all four RVs of this mission and for all RVs of previous missions. The roll reversal has not significant effect on the capability of the RVs to enter successfully. Angle of attack was low throughout the significant heating portion of all four entries due to roll reversal and associated phenomena. The small range dispersions indicate the predicted entry trajectory was followed.

Figure 8-1 also shows conditions at time of drogue chute deployment. Data indicates drogue performance was essentially as predicted.

The main parachutes incorporated modifications to the parachute design used on SV-2. Parachutes on RV's 1 and 2 sustained minor damage but their performance was not impaired. Retrievals were made on the first pass for all RV's except RV-2 when the recovery forces executed an intentional pull-off to assess the parachute oscillations. The parachute stabilized below 15,000 feet and retrieval was made on the second pass.

8.3 RE-ENTRY VEHICLE SUBSYSTEM PERFORMANCE

Review of the Re-entry Vehicle subsystems indicates two anomalous conditions:

- Delayed retro truss separation on RV-2
- Roll reversal during the early period of atmospheric entry.

The retro truss on RV-2 did not separate when planned although the release subsystems functioned normally. Separation occurred at the beginning of aerodynamic encounter at a dynamic pressure of less than 1 PSF at about 300,000 feet. The delayed separation is attributed to minor friction or interference of the separating elements. MWC has initiated corrective action to preclude a recurrence.

The roll reversal has been observed on all missions. The cause remains unknown, but the consequences are understood for nominal orbits and are acceptable. The Multi Layer Insulation (MLI) which surrounds the RV in orbit was deleted from RV-1 to evaluate its effect on the roll reversal phenomenon. The only effect was to delay the roll reversal to a 20,000 foot lower altitude (266,000 ft versus 285,000 ft typical). All other roll reversal associated behavior remained unchanged.

(b)(1)
(b)(3)

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Section 10
SUBSATELLITE

10.1 SUBSATELLITE PERFORMANCE SUMMARY

A 445 lb subsatellite system mounted on the -Y side of the SV forward section was carried into orbit. The separation sequence was loaded on Rev 12 and after a yaw left maneuver of 25 degrees by the SV (see Section 2.1.2) the subsatellite was separated on Rev 13.5 at 0 degrees latitude on the decending node. All subsatellite separation events were within desired tolerances and a nominal orbit was achieved by the subsatellite.

Section 11

STELLAR-TERRAIN SUBSYSTEM

There was no Stellar-Terrain Subsystem flown on SV-3.

Section 12
THERMAL CONTROL

12.1 FORWARD AND MID SECTIONS

The Forward and Mid Section structural temperature control is summarized in Table 12-1. The data indicates that the Forward and Mid Section thermal design provide good control of payload temperature levels. No design changes are forth coming as a result of flight performance.

12.2 ACTIVE THERMAL CONTROL

The Active Thermal Control System performed normally throughout the primary mission. T_{REF} which represents the average Mid Section film path temperature varied between 69°F and 73°F during the mission but was usually between 71°F and 73°F.

The RV heater zones which are actively controlled relative to T_{REF} were generally within 1°F of T_{REF} indicating adequate performance of the Active Thermal Control System.

12.3 AFT SECTION

Acceptable Aft Section temperature control was achieved with all equipment within design temperature limits. The orbital beta angle for this vehicle ranged from 33 deg at launch to 34 deg at deboost. A summary of critical temperatures is shown in Table 12-2.

The temperature level of the Aft Section was about 10°F above nominal predictions due to an external vehicle contamination problem which occurred during launch. This is considered to be the same contamination problem as occurred on SV-1. The contamination event was identified as SRM staging from the special contamination experiments (see paragraph 12.4).

Table 12-1

FORWARD AND MID SECTION TEMPERATURES FOLLOWING INITIAL TRANSIENT

Parameter	Design Limits (^{o}F)	SV-3 Actuals
T_{FWD}	47/93	78/82
$\overline{T}_{TCA}$	48/92	72
$\overline{T}_{FWD} - \overline{T}_{TCA}$	<20	6/10
T_{SU}	49/91	74
$\overline{T}_{SU} - \overline{T}_{TCA}$	6/-4	2

Definitions:

T_{FWD} – Average radiation temperature of the Forward Section derived from the average bulkhead temperature

$\overline{T}_{TCA}$ – Average radiation temperature of the forward compartment structure in the Mid Section

$\overline{T}_{SU}$ – Average radiation temperature of the aft compartment structure in the Mid Section

Table 12-2

SV-3 AFT SECTION CRITICAL COMPONENT TEMPERATURES

Critical Component	Design Limits (°F)	SV-3 Actuals[2] (°F)
EDAP		
PDJB	-30/170	55/58
CCC's	-30/170	74/86
Batteries, Bay 3	35/70	44/47
Batteries, Bay 1	35/70	46/49
PDA's	-30/160	(3)
Solar Arrays	-125/225	-68/145
ACS		
IRA	50/130	108/116
HSA Heads	0/130	62/86
FCEA	-30/160	99/106
OAS		
Tank	65/100	79/93
Quad Valve	35/200	109/111[1]
Catalyst Bed	–	123/151[1]
T&T		
Tape Recorders	20/130	87/105
Transmitters	-30/170	86/108
PCM Master	-30/170	96/115
PCM Remote, Bay 2	-30/170	48/58
PCM Remote, Bay 10	-30/170	101/110
COMMAND		
PMU A	-40/145	102/106
PMU B	-40/145	111/116
Clock	-40/153	113/116
MCS	-40/149	93/101
RCS		
Tanks	40/140	67/99
REM Valves	≥45	85/182
Plumbing, Bay 12	35/140	76/96

(1) Data with OA engine not firing
(2) Stabilized orbital operation (most equipment 70 to 90°F at lift-off) (Does not include temperature excursions during engineering tests)
(3) Instrumentation deleted on SV-3

12.4 CONTAMINATION EXPERIMENTS

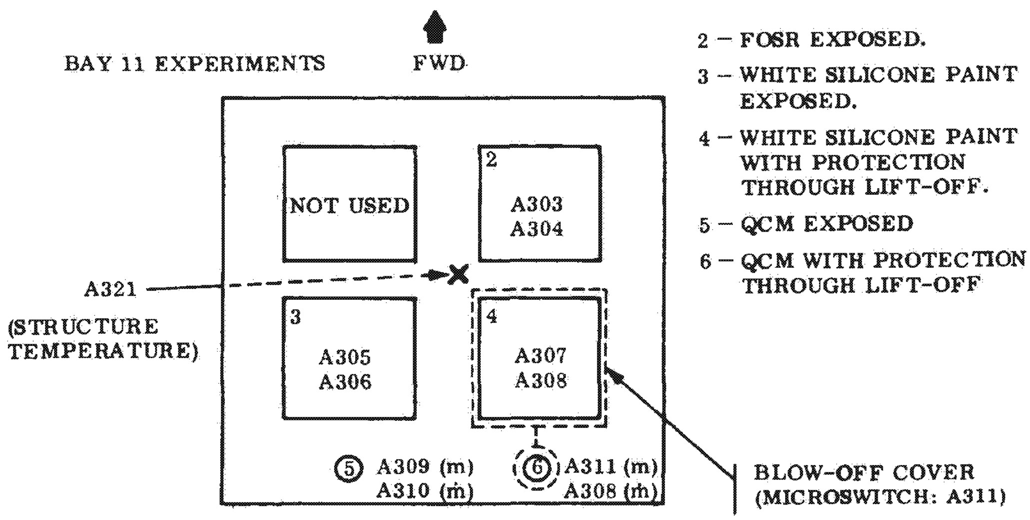
12.4.1 Description

Additional contamination experiments were flown on SV-3 to measure two distinct contamination environments. The first group of experiments, installed on Bays 5 and 11 of the Aft Section as shown in Fig. 12-1, were designed to measure the ascent contamination in terms of mass deposit at locations 180 degrees apart and the effect of this mass deposit on the surface properties of white silicone paint and FOSR (Flexible Optical Solar Reflector). Note that the blow-off shield was again used as on SV-2 to isolate the effects of the ground lift-off cloud. Note also that the QCM's (Quartz Crystal Microbalances) have a mass rate channel added for this flight to help interpret the readings of the mass channel. A proposed one-bay model of a fiberglass cloth contamination shield was to be flown on Bay 12. This experiment was deleted, however, after wind tunnel tests indicated mechanical deficiencies in the cloth shield design. The second set of experiments were installed on the forward bulkhead at Station 1642 as shown in Fig. 12-2. These devices were designed to monitor the mass deposit produced by the RV spin motors and to assess the effect of this mass deposit on the surface properties of black and white silicone paints, and aluminized Kapton. These are the thermal control surfaces to be used on the MCP module on SV-5.

The stationary calorimeter panel is used as a reference while the moveable panel is exposed to the RV spin motor plumes then flipped up and compared with the stationary panel. The "conductivity experiment" incorporated in the stationary panel in Fig. 12-1 was an SBAC piggy-back experiment whose objectives are unrelated to this program and are not reported on here.

12.4.2 Results

12.4.2.1 <u>Aft Section.</u> Ascent telemetry data showed that the blow-off shield came off properly between 9 and 10 seconds after liftoff. Orbital temperature data for the three calorimeters indicated the following apparent solar absorptivity (α):



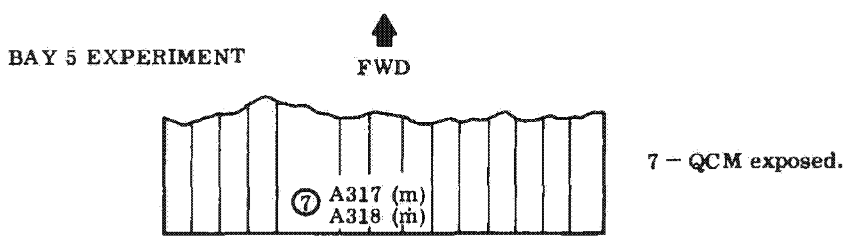


Fig. 12-1 8003 Aft Section Contamination Experiments

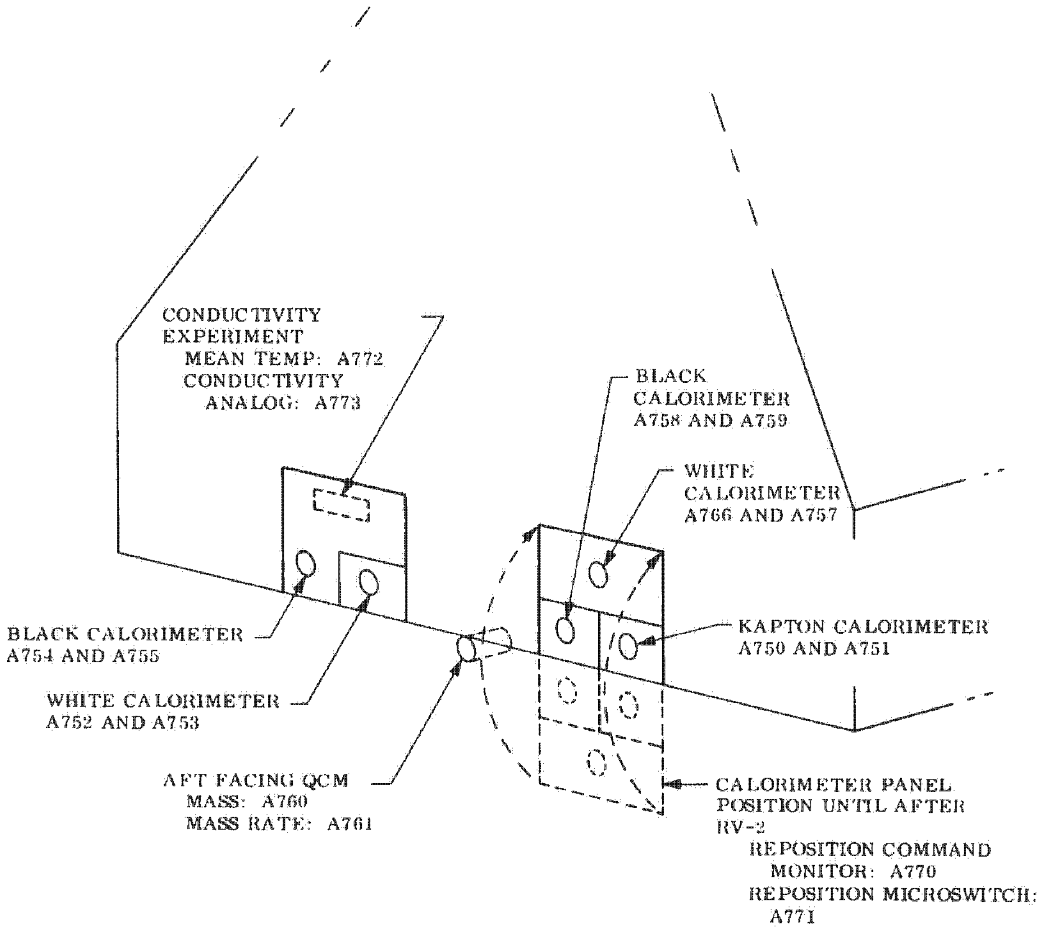


Fig. 12-2 Station 1642 Contamination Experiments

Exposed Throughout Ascent	α
White silicone calorimeter	0.42
FOSR calorimeter	0.23
Exposed After Lift-off	
White silicone calorimeter	0.40

The nominal, uncontaminated α for white silicone and FOSR is 0.18 and 0.14, respectively.

The mass deposition measured during ascent by the three Aft Section QCM's is shown in Fig. 12-3. The results are shown in TM volts. The calibration curves for conversion to actual mass deposit in grams/cm^2 is presented in Fig. 12-4.

12.4.2.2 Station 1642. The spin-up event for the first RV caused negligible change in the mass deposition level measured by the Station 1642 QCM. Therefore, it was decided to wait until after the second RV was released to flip the exposed calorimeter panel up to its read-out position adjacent to the fixed reference calorimeter panel. The second RV spin-up produced a very slight increase in measured mass deposit (about 0.1×10^{-5} g/cm^2) and the calorimeter panel was flipped. The third and forth RV spin-up events were still monitored by the QCM and these events both caused small decreases in the level of mass deposit (about 0.5×10^{-5} and 0.25×10^{-5} g/cm^2, respectively). After the exposed calorimeter panel was flipped up, the temperature cycling of the white and black calorimeters were compared directly with their counterparts on the fixed reference panel:

	Temperatures (^{o}F)		
Calorimeter	Max.	Min.	Orbit Avg.
Exposed White	13	-62	-23
Reference White	12	-59	-22
Exposed Black	163	-53	47
Reference Black	146	-59	41

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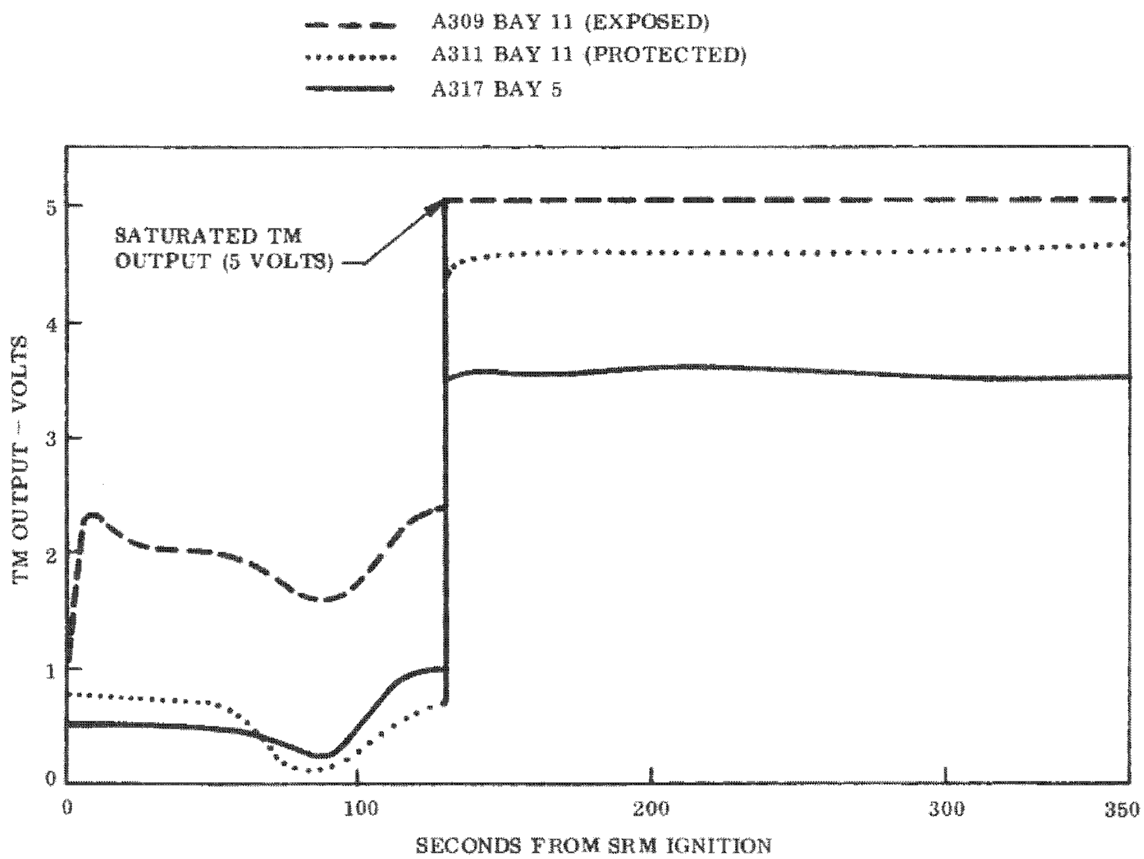

Fig. 12-3 SV-3 QCM Mass Deposit During Launch

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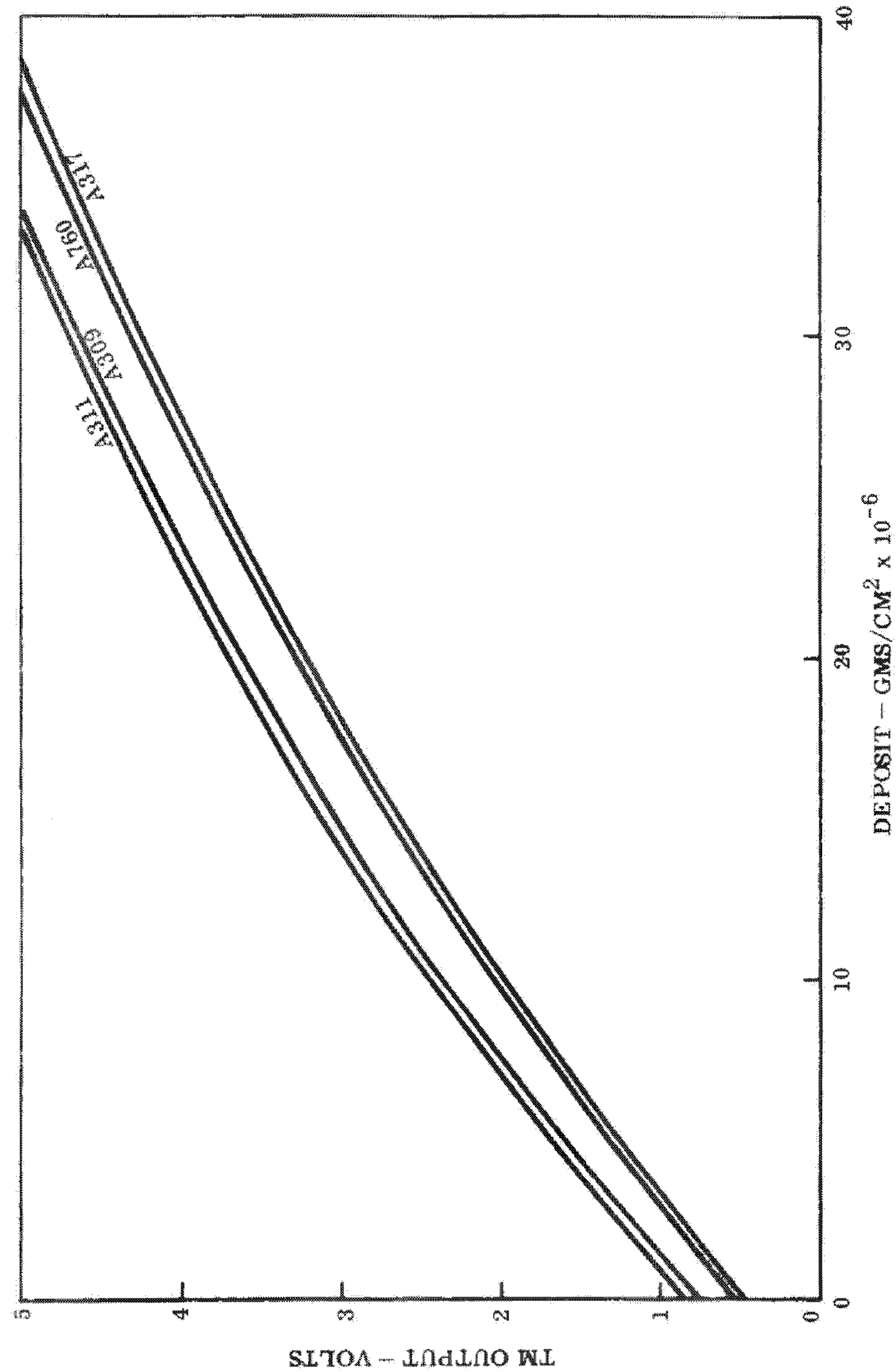

Fig. 12-4 SV-3 QCM Calibration Data

12.4.3 Conclusions

12.4.3.1 Aft Section. The first point to note on the QCM data of Fig. 12-3 is that the Bay 11 exposed QCM was saturated at 5.0 TM volts at SRM staging. By plotting the other two QCM outputs in fine detail during SRM staging, it can be estimated that another 10 percent of mass deposit should be added to the level indicated at TM saturation. Another point to be made is that the dip in indicated mass deposit between 60 and 100 seconds after liftoff is felt to be caused by temperature gradients induced in the QCM during ascent aeroheating and does not indicate an actual mass loss. The QCM protected from the liftoff cloud showed less deposit than the Bay 11 exposed QCM but the Bay 5 exposed QCM showed even less deposition both at liftoff and at SRM staging. It may be concluded that the liftoff deposition does not appear to be uniform around the circumference of the aft section.

Similarly, the deposition at SRM staging is not circumferentially uniform either but is more nearly so than the liftoff deposition. Although the non-uniformity of the measured deposition is academically interesting, the basic information provided by the aft section QCMs confirms the conclusion reached on SV-2 — the SRM staging event causes significant contamination of aft section surfaces. The calorimeter data agrees with the QCM data in that the white silicone sample protected from the liftoff cloud showed slightly less degradation than the white silicone sample exposed throughout ascent. As on SV-2, the FOSR sample suffered less degradation than white silicone and this characteristic plus FOSR's inherent resistance to ultraviolet degradation is sufficient justification to proceed as rapidly as possible to substitute FOSR for white silicone paint on future vehicles.

12.4.3.2 Station 1642. In view of the fact that very little mass deposit was recorded on the Station 1642 QCM during the spin-up of the first two RVs, it was expected that the exposed calorimeters would show very little degradation. The orbital temperature comparisons between the exposed and reference calorimeters verified that there was very little change to the exposed surface properties. Note that the thermal isolation of the calorimeter slugs in both the exposed and reference panels was not as good as expected, hence it was impossible to back out accurate values for the actual α and ϵ of the surfaces. Accordingly, the direct comparison of orbital temperatures was used as a basis for assessing degradation. Note also that the decrease in mass deposit on the QCM at the time of spin-up of RVs 3 and 4 cannot be explained with certainty. Two possible phenomena may have caused the decrease: (1) the transient heating of the QCM outer crystal during spin up may cause a thermally-induced frequency shift, or (2) volatile contaminants on the QCM may actually be driven off by the heating during spin motor impingement.

The above uncertainties notwithstanding, the conclusion to be reached from the Station 1642 experiment is clear — the MCM thermal control surfaces will not be appreciably degraded by the RV spin-up events and the present thermal design is adequate.

12.4.4 Action for Subsequent Vehicles

As noted above, the MCM thermal design will not be jeopardized by the RV spin motor contamination; hence, no changes to the MCM paint pattern is indicated and no further experiments are planned. With respect to the ascent contamination environment, the approach to a solution has changed considerably due to two factors. The first is the failure of the fiberglass cloth shield in the wind tunnel tests. This failure indicated that a redesign of the shield and perhaps a shift to a different shielding concept is required in order to accomplish the complete protection of aft section surfaces during ascent. The second factor was that the relatively narrow Beta range imposed on SV-2 and SV-3 would be adequate for the next few flights provided that the Beta range could be shifted to bracket zero (noon launch). Feasibility studies show that the latter objective can be met in the presence of ascent contamination by relocating equipment away from the hot Bays 11, 12 and 1. In particular, relocating the type 29 batteries to Bay 10 and 3 will allow a launch window around noon. In addition, the incorporation of FOSR in lieu of white silicone paint should allow an even wider launch window. In view of these possibilities, contamination shield redesign efforts have been relegated to a non-priority position and detailed thermal analysis of the Bays 10 and 3 battery installation as well as FOSR implementation efforts now have full priority.

At this time, the plan for subsequent vehicles is as follows:

SV-4

- Fly the same as SV-3: (batteries in Bays 1 and 3, Beta angle restricted to approximately +35 to +25 degrees.)
- Fly FOSR on standard corrugated Bay 12 door to verify proper orbital performance.
- Fly one exposed QCM in Bay 12 door to provide one more data point on ascent contamination.

SV-5 and -6

- Move batteries to Bay 10 and 3 and shift Beta angle range to approximately 0 to -10 degrees.
- Assuming successful demonstation of FOSR performance on SV-4, substitute FOSR for white silicone paint on most aft section external surfaces.

Section 13
MASS PROPERTIES

The history of the SV mass properties throughout the flight are tabulated in Table 13.1.

Table 13-1

SV-3 MASS PROPERTIES

Description	Weight (lb)	SV Sta (in.)	$\overline{Y}$ (in.)	$\overline{Z}$ (in.)	I_x (slug-ft^2)	I_y (slug-ft^2)	I_z (slug-ft^2)	I_{xy} (slug-ft^2)	I_{xz} (slug-ft^2)	I_{yz} (slug-ft^2)
SV launch wt.	23005	1987.9	-0.08	3.11	6825	166145	166074	-1212	1722	-39
Separation from Stage 2	20007	2002.3	-0.08	3.60	4675	132748	132601	-1210	2013	-39
Solar arrays deployed	20007	2002.8	-0.08	3.60	5831	133764	134716	-1210	2021	-261
Subsatellite ejected	19616	2006.5	0.76	3.94	5643	130669	131497	-525	2297	-320
Before Drop 1	19496	1997.1	0.81	4.52	5620	138309	139139	-586	2772	-330
After Drop 1	17952	2024.7	0.88	3.41	5408	100914	101889	-489	1275	-326
Before Drop 2	17728	2014.6	0.96	4.06	5405	106511	107470	-570	1750	-340
After Drop 2	16194	2040.5	1.05	2.79	5188	79269	80381	-473	417	-336
Before Drop 3	15780	2034.0	1.12	3.46	5241	79799	80877	-539	397	-342
After Drop 3	14496	2054.1	1.26	2.34	5052	64046	65249	-429	-469	-334
Before Drop 4	13974	2043.2	1.29	2.97	5047	64802	65982	-457	-103	-335
After Drop 4	12446	2064.3	1.43	1.20	4819	53671	55013	-385	-1021	-330

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Section 14
STRUCTURE AND DYNAMICS

14.1 PRELAUNCH WINDS ALOFT LOADS ANALYSIS

Table 14-1 presents a chronological tabulation of the winds aloft computer runs for SV-3. The results are plotted on Fig. 14-1.

The loads and control analysis computer simulations leading to launch were accomplished without violating any of the established vehicle constraints and resulted in repeated Go for Launch recommendations.

An R-17 day preliminary winds loads data check run was accomplished on 16 June 1972. These data checked the Martin Marietta (MMC) and the Vandenberg Targeting Team (VTT) independently generated data well within the acceptable limits. MMC verified the LMSC data results as being correct on 22 June 1972 by letter (MMC 72-Y-31366).

14.2 ASCENT ENVIRONMENT

No instrumentation was provided to evaluate the ascent environment on SV-3.

14.3 SOLAR ARRAY

The erection and deployment time histories are shown in Fig. 14-2 for the left (-Y) solar array and in Fig. 14-3 for the right (+Y) solar array. Since the arrays were deployed and erected in the proper position for the flight beta angle, no positioning was necessary and none was performed during the basic mission. Positioning to the standard positions of ±18 and 0 degrees were accomplished on both arrays during the SOLO mission.

The times for deployment of the arrays were similar to those for SV-1 and SV-2. The times from the start to completion of erection were also similar; however, the left array delayed 1338 sec before starting to erect as compared to the expected delay of 70 to 156 sec as experienced on the other flight arrays. The delay was attributed to an interference in the erection release mechanism. The suspected interference was simulated in the laboratory and did prevent the mast from erecting; however, an almost imperceptible force was then sufficient to initiate the mast erection. The fitting has been redesigned to prevent a recurrence of this anomaly on subsequent SVs.

The right array has taken longer to deploy than the left array on SV-1 through SV-3. One possible explanation is that the sun heats the left array more quickly after sunrise for the beta angles flown by these vehicles and the warmer array deploys in less time. The longer time, in itself, is not significant. Study of this phenomenon is continuing.

Table 14.1

SUMMARY OF WINDS ALOFT LOADS ANALYSIS

	BALLOON RELEASE TIME				
	T-30	T-12	T-6	T-3	T-0
	3800 RUN AT STC TIME				
	T-24	T-8.5	T-3	T-1	---
SV Structural Loads:					
Bending Mom, % Limit Load	53.75	49.37	54.23	50.61	55.01
Critical SV Station	1956	1956	1789	1956	1956.0
Elapsed Time, seconds	47.38	55.36	61.05	53.41	54.52
Altitude, feet	25,003	34,006	41,194	31,724	33,000
SRM Side Force					
% Allowable	42.55	34.46	44.46	36.60	40.93
SRM No.	1	2	1	2	2
Pitch or Yaw	Pitch	Pitch	Pitch	Pitch	Pitch
TVC Usage for Control:					
% Allowable Expended	49.5	56.9	58.4	49.8	54.7
SRM No.	1	1	1	1	1
Expended, pounds	1053.5	1211.7	1241.8	1061.1	1166.95
Vehicle Response:					
Maximum $\bar{\alpha}q$, % allowable	29.15	25.59	31.32	22.93	26.96
Maximum $\bar{\alpha}q$, deg-psf.	1113.3	835.4	1222.3	71.92	1166.95
Elapsed Time, seconds	62.3	41.4	61.13	39.2	54.72
Altitude, feet	42,999	19,000	41,307	16,998	33,233

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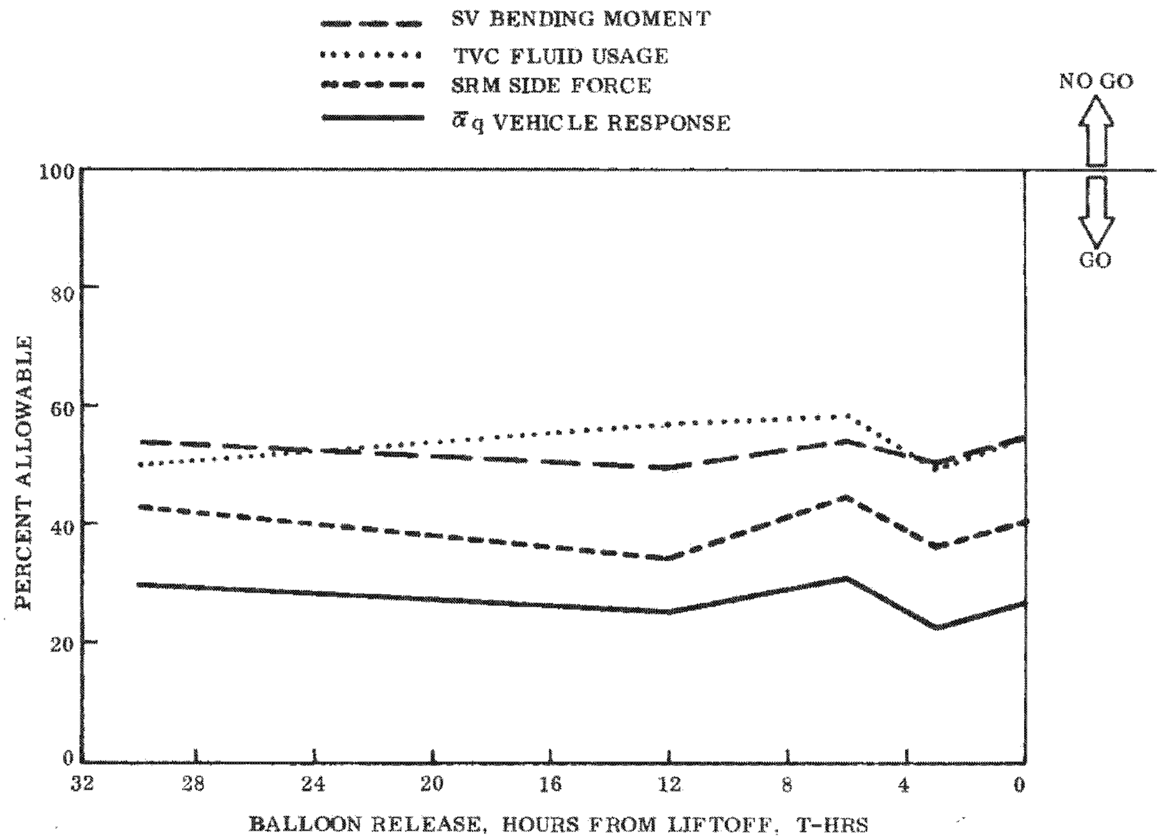

Fig. 14-1 Critical Parameter Summary

BIF003W/2-068274-72

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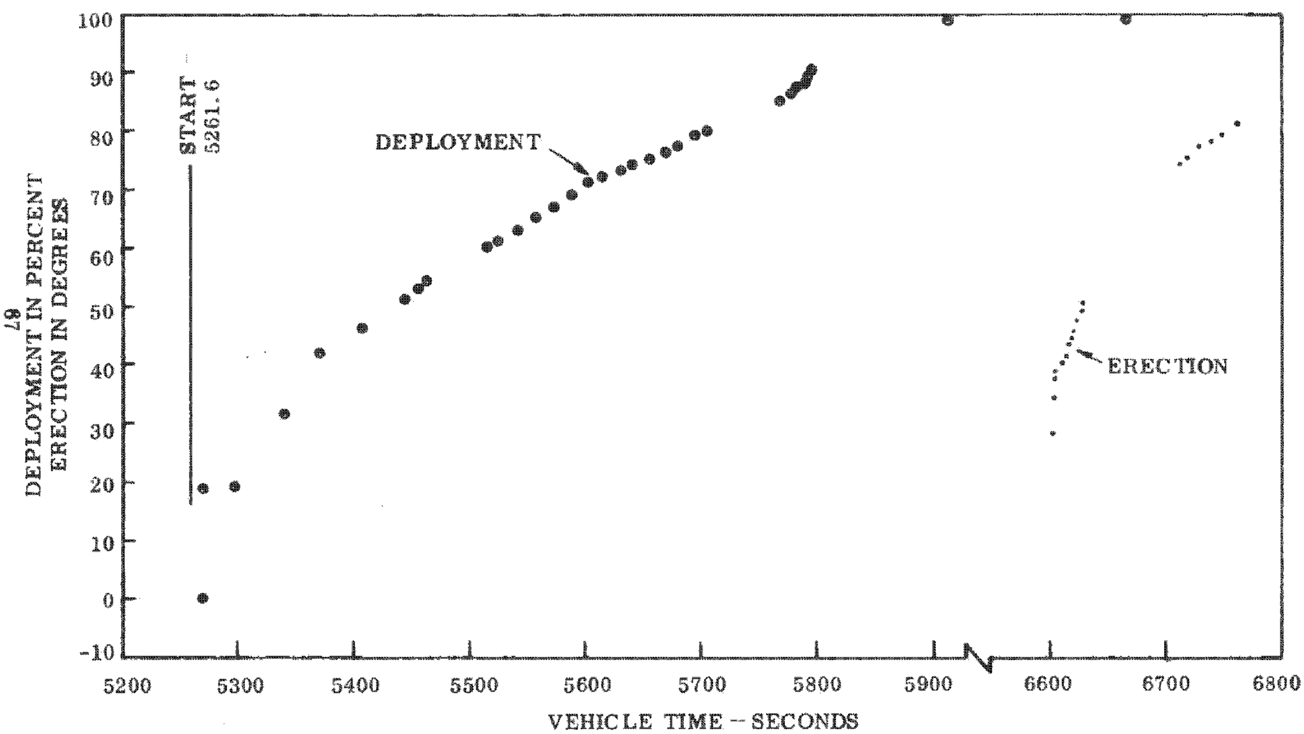

Fig. 14-2 Left Hand Solar Array Erection and Deployment Time Histories

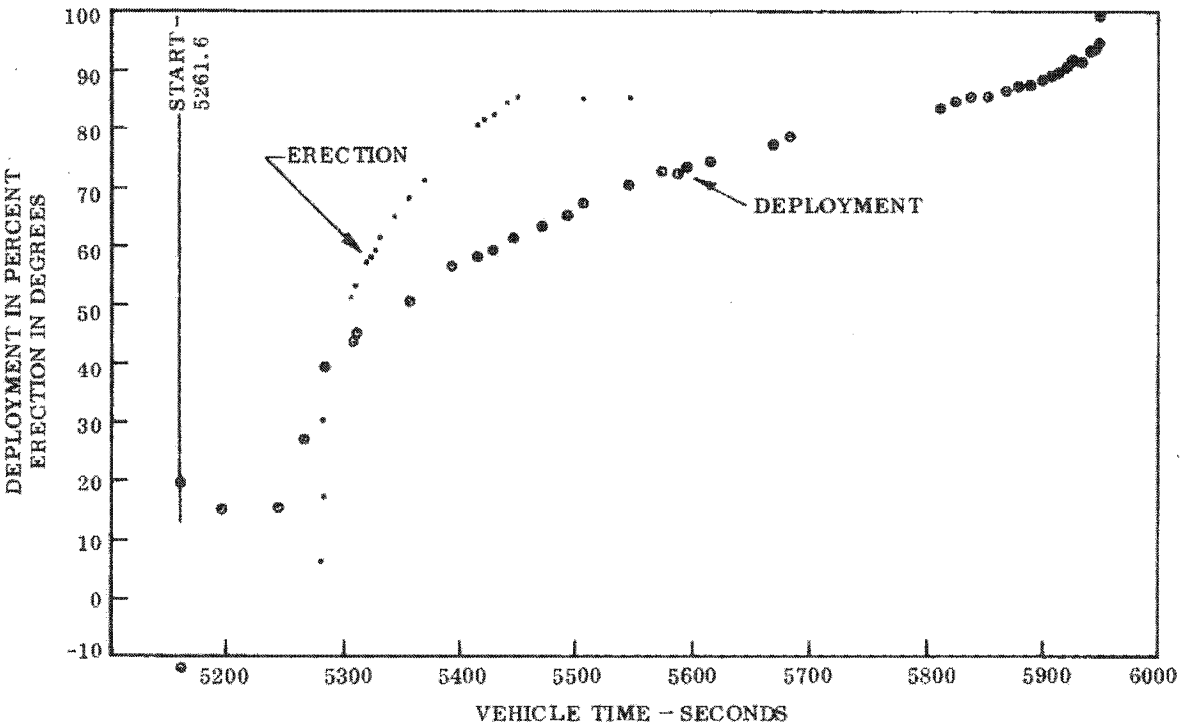

Fig. 14-3 Right Hand Solar Array Erection and Deployment Time Histories

BIF003W/2-068274-72

Section 15
SOFTWARE

There were no software problems which impacted flight objectives.