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HANDLE VIA BYEMAN CONTROL SYSTEM ONLY—HEXAGON

Performance Evaluation Team Report

MISSION 1205

DIRECTORATE OF SPECIAL PROJECTS
OFFICE OF THE SECRETARY OF THE AIR FORCE

BYE 15296-73

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PERFORMANCE EVALUATION TEAM

MISSION 1205

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PUBLICATION REVIEW

This report has been reviewed and is approved.

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PERFORMANCE EVALUATION TEAM
REPORT NO. 1205/73

FOREWORD

This report was prepared for and by direction of the Director of Special Projects, Office of the Secretary of the Air Force. The report is Volume I of the final mission report for HEXAGON Mission 1205. Volume II is entitled Sensor Subsystem Post Flight Analysis Report, TCS 363510-73.

The report was prepared by the SAFSP HEXAGON Performance Evaluation Team (PET) using reports and data provided by SAFSP, the Technical Advisor (TA) Staff, Post Flight Analysis (PFA) Team, and HEXAGON Satellite Vehicle Integrating Contractor (SVIC).

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PERFORMANCE EVALUATION TEAM
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SUMMARY

SECTION I

SUMMARY

1.1 INTRODUCTION

The fifth HEXAGON Satellite Vehicle (SV) was placed into the nominal 85 x 158 NM orbit by the Titan III D Booster on 9 March 1973. This SV carried the Mapping Camera module and the associated Mark V Re-entry Vehicle (RV) for the first time. Mission planning included a 30-day Mapping Camera mission, a 70-day Panoramic Camera mission, and 5 days of Solo operations. The SV experienced an Attitude Control System anomaly which caused a yaw bias of the vehicle. The bias resulted in some loss in the Panoramic Camera performance even though attempts were made to correct for the bias. No performance degradation was noted on the Mapping Camera imagery. The Panoramic Camera operated throughout the mission, and its RVs were aerially recovered on Revs 196, 424, 651, and 1024. All of the film was transported onto the RVs including 2,000' of SO-255 Color Film in 1205-4. All camera operations were normal. Some Mapping Camera imagery was lost due to system malfunctions; however, the general quality was judged excellent. All the Mapping Camera film was transported onto RV-5 which was aerially recovered on Rev 683. Solo tests were completed and the SV was deorbited over Shemya on Rev 1139 (Day 70). A Vehicle Atmospheric Survivability Test (VAST) was performed to observe the SV breakup survivability and the surface impact footprint during deboost using air, ground, and water based sensors.

MISSION OVERVIEW

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SECTION II

MISSION OVERVIEW

2.1 PREFLIGHT PLANNING

Mission 1205 was the first HEXAGON flight to carry the Mapping Camera module consisting of the Terrain and Stellar Cameras, the associated Re-entry Vehicle (RV), and a Doppler Beacon.

RCS Tanks 1 and 2 were capped and the Primary ACS was hardwired to control the Redundant RCS thrusters which utilized RCS Tanks 3 and 4. This configuration was designed to use the Redundant Thrusters (non-instrumented) until leakage was experienced and then complete the mission on the Redundant ACS and Primary Thrusters (instrumented) with the RCS being supplied directly from the Orbit Adjust 3 (OA) Tank, see Figure 2-1.

The following Block II hardware components were installed as part of a planned phase-in: (1) CUBIC Transponder (SGLS-2), (2) Primary ACS (PACS) Inertial Reference Assembly (IRA) using Ferrotic Gyros for an improved restart capability, and (3) Primary ACS (PACS) Horizon Sensor Assembly (HSA) using a Mylar Bolometer.

2.2 PREFLIGHT CONSTRAINTS

The Mission 1205 orbit was designed to:

A. Maintain solar (beta) angle within +2° to -8° for the planned 75 days.

B. Orbit adjusts to occur on a two-day cycle with every fourth OA to be a positive and negative burn for close control of argument of perigee.

2.2.1 Panoramic Camera System Constraints

The following were the constraints imposed on the panoramic cameras.

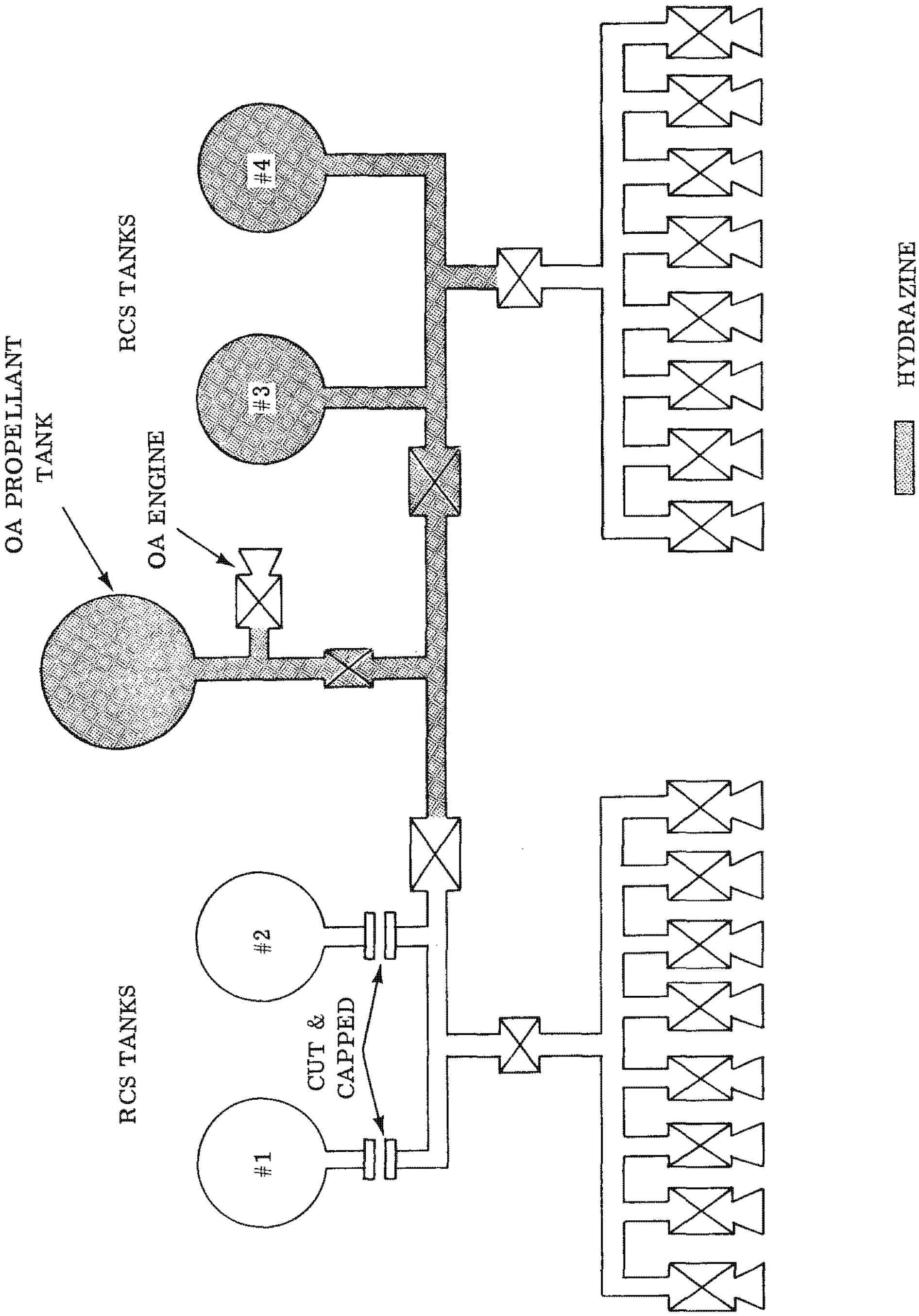
A. Rewind velocity limited to 5 inches/second.

B. No 120° scans.

C. No 30° scans at ± 45° scan centers.

2.3 LAUNCH BASE

The Titan III D BV followed a normal prelaunch readiness cycle. The SV was delivered to the launch pad and mated to the BV without incident. The SV prelaunch activities were delayed by the replacement of the Extended Command System (ECS) module due to a clock reset problem and failure of the SGLS-1 Transponder. The vehicle was launched on 9 March 1973 at 1300 PST near the close of the launch window. The countdown delay was a result of a multipathing problem between the vehicle and the COOK Remote Tracking Station (RTS).



RCS/OA LIFT-OFF CONFIGURATION

FIGURE 2-1

2.4 ASCENT

The BV successfully injected the SV into an 85.3 x 158 NM orbit. The achieved orbit was close to nominal with the deviations shown as follows:

Apogee Altitude (NM)	5.0
Perigee Altitude (NM)	-.019
Period (second)	.378
Eccentricity	.00058
Argument of Perigee (degrees)	7.3

2.5 ORBIT AND RECOVERY

2.5.1 1205-1 (Twelve Days Duration)

Solar array deployment was executed over INDI on Rev 1 with normal deployment and erection. An instrumentation failure gave the appearance of an SS pneumatics leak. An emergency message was generated and loaded to isolate the system. Diagnostic tests verified functional pneumatics operation and the SS health test verified that the panoramic camera was ready to start mission photography by Rev 11.

Satisfactory panoramic camera operations were obtained using estimated pneumatics consumption rates with film path chute pressure as the only data point to verify acceptable pneumatics.

Approximately 27,300' of film per camera were exposed and stored in RV-1. Overall quality ranged from Very Good to Poor, with the majority rated as Fair. Atmospheric haze and weather were the major degrading factors in the Poor rated imagery.

RV-1 was successfully re-entered and aerially recovered on Rev 196 (Day 13). The RV was loaded to 93.9% of capacity and the film load was balanced. No capsule or parachute damage was noted.

2.5.2 1205-2 (Fourteen Days Duration)

As a result of the PFA evaluation on 1205-1, a 12 micron focus advance was made on the Aft Camera. Panoramic camera mission photography continued nominally throughout the segment. The overall photography quality was rated from Very Good to Fair, with the degradation again a result of weather and haze. Approximately 27,400' of film from each camera were exposed and stored in the RV.

ACS-1 pitch bias errors were observed on Revs 230, 253, 269, and 272, but had disappeared by Rev 294. RCS-2 performance remained nominal.

The RTS reported some difficulty obtaining range lock after Rev 270; however, using a range modulation index of .3 radian, sufficient range data was obtained.

RV-2 was successfully re-entered and aerially recovered on Rev 424 with the RV loaded to 94.6% of capacity and balanced. No capsule or parachute damage was noted.

2.5.3 1205-3 (Fourteen Days Duration)

Panoramic camera mission photography continued without problem throughout this segment.

PFA analysis of RV-2 photography showed the focus settings on both cameras were optimum. SS operations were erased on Rev 430 as a result of a Mapping Camera malfunction but were reloaded on the next rev. Overall photographic quality remained Fair with weather and haze degrading the photography. Approximately 28,500' from each camera were exposed and stored in the RV.

RCS-2 propellant use rate had increased to 8 pounds/day and a transfer to ACS-2/RCS-1 was executed on Rev 512. In this configuration, RCS-1 is supplied directly from the OA Tank. On Rev 519 a yaw rate bias was observed, which remained in varying degrees throughout the segment. This rate bias resulted in yaw attitude errors as high as 1.8 degrees. Panoramic camera Vy/h compensation was used to partially offset the yaw error. On Rev 566 the ACS-1 error, detected earlier in the flight, returned and remained throughout the segment.

RV-3 was successfully re-entered and aerially recovered on Rev 651 with the RV loaded to 98.5% of capacity and balanced. The capsule was returned in good condition. There was no capsule damage; however, two tears were noted in the parachute cone.

2.5.4 1205-4 (Twenty-two Days Duration)

Panoramic camera photography resumed after RV-3 recovery and continued without problem throughout the segment. PFA analysis of RV-3 showed resolution degradation from the yaw attitude error and verified that the Vy/h compensation was effective in correcting for this error, especially for scan angles from +10° to -10° of nadir. The yaw bias had decreased to zero by Rev 785 but returned on Rev 817 and remained in varying amounts throughout the segment.

Orbit Adjust Catalyst Bed pressure continued dropping and reached values lower than previously experienced; however, engine performance remained nominal for orbit adjust burns. The OA plan was changed to a three-day cycle to provide longer, more infrequent burns to minimize the rate of bed degradation.

The Forward Camera transitioned from black and white to color film on Rev 971 with 2,000' of film remaining on the Forward stack. Operational photography continued until all film in both cameras was expended on Rev 1016.

Approximately 24,760' of film in the Forward Camera, including 2,000' of color, and 26,400' of film in the Aft Camera were exposed and stored in the RV. Overall quality of the photography was rated Good with less haze and weather degradation than the previous segments. The best color quality was comparable to the corresponding Aft Camera black and white photography.

RV-4 was successfully re-entered and aerially recovered on Rev 1024. The RV was loaded to 89.7% of capacity with a minor imbalance due to mono operation on the Aft Camera. No capsule or parachute damage was reported.

2.5.5 1205-5 (Forty-one Days Duration)

The Mapping Camera Thermal Shutter did not open during the ST Health Test on Rev 8 and again on Rev 13, but operated normally over COOK on Rev 16. ST mission operations started on Rev 20; however, thermal door malfunctions were again noted on Revs 39, 70, 90, and 91. The problem was determined to be a result of cold temperatures and, commencing with Rev 100, operations were restricted to latitudes below 50° N. This latitude constraint was incrementally increased as the apparent sun line moved north, and reached a maximum of 63° N latitude on Day 41.

The Doppler Beacon antenna did not deploy when commanded; however, an acceptable signal was reported by all TRANET stations. The Doppler Beacon System is utilized to provide more precise orbit determination for map making.

Mapping Camera mission photography continued without incident until Rev 430 when the Terrain Camera did not shutdown when commanded but ran five extra frames. ST System MOPs on Revs 436 and 438 showed normal system operation and photography was resumed. Additional shutdown problems occurred on Revs 446, 479, 494, even though ESD commands had been added to all ST operational sequences. ST operations were halted after Rev 494 and resumed on Rev 503 with the ST operating in the backup mode using fixed shutter and film speed settings.

The ST System properly shut down on Rev 657 when the Material Change Detector, located at the beginning of the calibration film, was reached. Two ST calibration attempts were tried. The Rev 665 calibration used the normal Terrain Thermal Door Actuator; however, this did not open the door. The second attempt on Rev 668 used the Emergency Backup Door Actuator but was also unsuccessful. The failure is attributed to the extremely cold environment of the calibration orbit position and vehicle attitude. Runout of both Terrain and Stellar film was programmed and successfully executed on Rev 675.

A total of 1,982 frames was exposed during on-orbit operation. The ST-RV was successfully re-entered and aerially recovered on Rev 683 with 100% of the predicted film weight in the RV. No capsule or parachute damage was reported.

The quality of the acquired photography from the mapping mission was Very Good and exceeded the expected results.

2.6 SOLO TESTING

Non-interference Solo Testing started on Rev 683 and continued through 1205-4. The formal Solo phase started on Rev 1024 and continued to deorbit on Rev 1139. Solo objectives were:

A. To obtain engineering data needed for operations of future HEXAGON missions.

B. To obtain data to evaluate hardware malfunctions experienced during the mission.

C. To test all redundant components and subsystems not used for mission support.

The Solo experiment chronology is shown in Table 2-1. Failures encountered during the Solo phase are discussed in this report. A detailed Solo report will be provided by LMSC approximately 60 days after SV deboost.

2.7 VEHICLE ATMOSPHERIC SURVIVABILITY PROGRAM (VASP)

A VASP Test was conducted on Rev 1139 (Day 71). The purpose of this first test was to determine the breakup and re-entry trajectory characteristics of the SV components during deboost. Data was obtained from Shymea radar, ARIA aircraft, and the ARIS ship. The data is being processed and a preliminary report should be available by the end of August 1973.

2.8 COMMAND LOAD SUMMARY

The software configuration used to support this mission was 'TUNITY MOD 1BR. The system software was MOD 13.1E. A nominal one rev load cycle for the payload revs was used throughout the mission. A total of 853 command messages was generated during the flight of which 795 were loaded into the vehicle.

2.9 ANOMALY SUMMARY

Significant anomalies are listed chronologically in Table 2-2. The list includes a brief description of the anomaly and its effect on the mission. A more detailed discussion is provided in Section IV of this report.

TABLE 2-1

SOLO TEST CHRONOLOGY

Mission Segment 1205-4

Rev or Span	Test Description
744-843	ST-1 Test all normal ST modes of operation not used during mission.
746-795	ST-2 thermal effects on Terrain lens and Terrain thermal door open attempts.
748-797	OPS-2(n) & (o) Doppler Beacon Redundant Systems Test.
762-778	OPS-2(p) - (t) ST Redundant Systems Test.
824-830	ACS-3 obtain REM pulse count as a function of S/A position.
868-917	[redacted] (b)(1)
937-961	(b)(3)
941-973	OPS-4 INDI Rev .9 commanding.
990-1007	OPS-2(1) Redundant TCEA performance.

TABLE 2-1 (CONT'D)

Rev or Span	Test Description	
1004	[redacted]	(b)(1)
1006	ACS-5 HS and magnetic field mapping.	(b)(3)
Solo Test Operations		
1024	RV-4 Recovery.	
1028-1092	ACS-4(A) Ferrotic Gyro Start/Stop Test, 8 cycles/rev.	
1030	SS-1 SS Take-up Select Signature Test.	
1030	SS-2 Instrumentation Power Supply "ON."	
1030	SS-3 Negative Constant Velocity Test.	
1027-1030	OPS-2(a) - (c) SGLS-2/PCM Test.	
1027	OAS-1(b) OAS hot restart.	
1038-1089	OPS-5 RTS Software Tests.	
1041-1083	ST-4 Stellar Shutter inhibit.	
1041-1043	ACS-6 obtain REM pulse count with one S/A displaced.	
1056	OPS-3 commanding at KODI with SV pitched-down.	
1060-1092	ACS-2 Horizon Sensor inhibit under temperature cycling.	
1062-1083	THERM-1 Fly Reverse to test SV thermal characteristics under +8° beta angle.	
1062-1136	ACS-4(b) Ferrotic Gyro Start/Stop Test on 4 rev cycle.	
1063-1068	SS-4 SS pneumatics depletion.	
1077	[redacted]	(b)(1)
1085	OPS-2(d) Backup Timer Test.	(b)(3)
1089	OPS-2(g) MCS Operate Test.	
1095-1097	OPS-2(h) - (k) Redundant Heater Performance Test.	
1097	OPS-2(f) Lifeboat execute.	
1100	ST-3 Stellar capping shutter.	
1101	OPS-2(m) SCC-II select.	
1102	ST-6 ST maximum run time at 3 milliseconds.	
1103	OPS-2(a) SGLS 2 Antenna/Receiver performance at reduced RTS transmit power.	

TABLE 2-1 (CONT'D)

Rev or Span	Test Description
1105	OAS-1 engine washout characteristics - cross plane burn.
1107-1123	ACS-1(A) - (D) pitch and yaw offset investigation.
1128	OPS-2(e) Aft switched bus to LB battery.

TABLE 2-2

SUMMARY OF ANOMALIES

Day	Description	Impact	
1	Panoramic camera instrumentation failure gave the appearance of a SS pneumatics failure.	Delayed start of SS mission photography. SS used predicted pneumatics for remainder of mission.	
1	Stellar Terrain thermal door failed to open.	Delayed start of ST mission photography and required restriction of operation to latitudes to give satisfactory operation.	
1	Doppler Beacon failed to Deploy.	No impact on mission. Adequate signal was received by all TRANET stations.	
2	[redacted]	[redacted]	(b)(1) (b)(3)
4	Redundant Horizon Sensor inhibited on Revs 66/67.	No impact. Primary ACS was controlling SV. Effect could not be repeated during Solo.	
15	Primary ACS pitch bias errors were detected from Revs 230 to 272.	P/L was erased on Rev 272. The errors remained low and disappeared by Rev 294.	
27	Stellar Terrain did not shut down as commanded on Rev 430.	Caused use of extra film and required switch to the backup mode of operation on Rev 510.	
32	RCS-2 REM Leak.	No effect on mission. RCS-2 valves started to leak as expected. Switched to RCS-1 and operated using OA propellant.	
33	ACS-2 experienced a yaw rate bias starting on Rev 519.	The resulting yaw attitude error reduced SS resolution. Vy/h compensation used to offset the yaw error was effective within ± 10 degrees of NADIR. No impact on ST mission.	

TABLE 2-2 (CONT'D)

Day	Description	Impact
36	ACS-1 pitch error.	The pitch error in ACS-1 returned with a magnitude great enough to prevent ACS-1 use as backup to ACS-2.
42	Terrain thermal door would not open during ST calibration tests.	Door did not open using either primary or backup emergency door actuators. Door remained closed after numerous attempts during Solo.
48	Orbit adjust catalytic bed pressure drop reached the lower acceptable limit on Rev 760.	Orbit adjust system performance remained nominal. Longer, more infrequent burns were programmed to delay degradation.
64	SGLS-2 commanded on Rev 1027 had signal strength degraded by 30 decibels.	Required use of SGLS-1 for Solo phase. SGLS-2 uses a Cubic Transponder. SV-6 uses 1 Cubic while SV-7 uses both Cubic Transponders.

SATELLITE BASIC ASSEMBLY SUBSYSTEMS

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SECTION III

SATELLITE BASIC ASSEMBLY SUBSYSTEMS

3.1 INTRODUCTION

The following paragraphs summarize those requirements from the Satellite Basic Assembly (SBA) Subsystems that could be verified from flight data. The performance of the Reaction Control System (RCS) equipment is also discussed.

3.2 ATTITUDE CONTROL SYSTEM (ACS)

The ACS performed as expected with the exception of three anomalies: (a) PACS pitch bias, (b) RACS yaw bias, and (c) RACS H/S inhibit.

3.2.1 BV/SV Separation

BV/SV separation was completed at approximately 544.7 seconds SVT. Vehicle time started 67.6 seconds prior to lift-off. Master clear-off (MCLR), which enabled the pitch, roll, and yaw integrators to accumulate angle, was at 513.7 seconds SVT. 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 3-1. This table also presents the times in which the SV attitudes and rates came back within the specified limits following BV/SV separation (capture).

3.2.2 Payload Operations

The SV attitude specification during payload operations is the same as shown for capture in Table 3-1. There were no payload operations during the first PACS pitch gyro rate bias anomaly while the bias was present. Control was switched to RACS before the pitch bias reappeared. Because the RACS H/S inhibit on Rev 67 occurred while PACS was controlling the vehicle, it did not affect payload operations.

Subsequent to Rev 519, the yaw gyro rate bias anomaly resulted in SV roll and yaw attitude offsets. Calculated yaw attitudes ranged from 0 to -2.9 degrees.

The SS command was adjusted to minimize the effect of yaw attitude errors.

3.2.3 Mapping Camera Module (MCM) Operations

The SV behavior during Stellar Terrain (ST) operations and ST calibration maneuvers are discussed in the following subparagraphs. The ST-RV recovery is discussed in paragraph 3.2.4.

3.2.3.1 ST Operations

A PACS pitch gyro rate bias started on Rev 230 and was intermittent until Rev 276. This rate bias resulted in pitch attitude offsets of varying magnitudes. The only significant offset occurring during an ST operation was on Rev 273 where, from 615716 to 615996 seconds SVT, the SV pitch attitude was -1.2° as measured with the pitch H/S. The SV attitude and rate specification during ST operations

TABLE 3-1

BOOSTER VEHICLE/SATELLITE VEHICLE (BV/SV) SEPARATION

	RATE AND ATTITUDE AT BV/SV SEPARATION						CAPTURE			
	RATE (degrees/second)		ATTITUDE (degrees) HS @ SEPARATION		Δ(SECO - SEPARATION)		ATTITUDE		RATE	
	Specified (deg/sec)	Actual (seconds)	Specified (degrees)	Actual (seconds)	Specified (degrees)	Actual HS/Integrator	Specified[1] (degrees)	Actual[2] (seconds)	Specified[3] (deg/sec)	Actual[4] (seconds)
Pitch	±.752	-.244	-22.85 to 9.63	2.80	-0.49 to -4.03	-1.28/ -1.49[5]	±.70		±.014	
Roll	±.786	-.197	- 7.50 to 10.94	1.40	2.99 to 0.45	1.3/ 0.95	±.70	SEE NOTE 6	±.021	SEE NOTE 6
Yaw	±.752	.156	- 7.66 to 11.50	-	4.48 to 0.66	-/ 2.29	±.64		±.014	

NOTES:
1 Attitude in degrees to be achieved in 1500 seconds.
2 Actual time required to achieve specified attitude (switch to fine mode + settling time).
3 Rate in degrees/second to be achieved in 1500 seconds.
4 Actual time required to achieve specified rate.
5 Relative to the local horizontal.
6 Nominal performance, indicating pointing requirements are satisfied, was observed at a nominal settling time of 520 seconds after the commanded switch to fine mode (662.1 seconds after separation). The total 1182.1 seconds is well within the spec of 1500 seconds and no closer study was performed.

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is presented in Table 3-2.

TABLE 3-2

ST ATTITUDE AND RATE SPECIFICATIONS

	Attitude (degrees)	Rate (degrees/second)
Pitch	±1.2	±.014
Roll	±1.2	±.021
Yaw	±1.14	±.014

The RACS yaw gyro rate bias started on Rev 519 and continued through Rev 683. This rate bias resulted in yaw and roll offsets of varying magnitudes.

3.2.3.2 MCM Calibration Maneuvers

Two large negative pitch maneuvers were executed on Revs 665 and 668 for the purpose of MCM calibration. The command times for the maneuvers resulted in a -153.0° pitch-down on Rev 665 and a -160.5° pitch-down on Rev 668.

A. Rev 665 Maneuver

The yaw rate bias at the start of the pitch-down was zero. The maximum yaw rate bias at any time from the start of the pitch-down to start of pitch-up was .002 degrees/second. A rate bias of .002 degrees/second results in a vehicle rate of -.002 degrees/second with gyrocompassing disconnected.

The maximum vehicle rates measured during the calibration period from 187841.4 to 187948.2 seconds SVT are presented in Table 3-3.

TABLE 3-3

MAXIMUM VEHICLE RATES DURING REV 665 CALIBRATION

(degrees/second)

	Actual	Specification
Pitch Rate	.004	±.014
Roll Rate	.012	±.021
Yaw Rate	-.004	±.014

Since all rates were within specification and times were as commanded, the vehicle attitude should have been within the ±3° of the desired value. During pitch-down the H/S is inhibited so there is no direct confirming evidence of the attitude.

B. Rev 668 Maneuver

The yaw rate bias at the start of the pitch-down was .004 degrees/second. The bias rate did not exceed that value for the remainder of the calibration sequence. The maximum vehicle rates measured during the calibration period from 203701.4 to 204035.4 seconds. SVT are presented in Table 3-4.

TABLE 3-4

MAXIMUM VEHICLE RATES DURING REV 668 CALIBRATION
(degrees/second)

	Actual	Specification
Pitch Rate	.006	±.014
Roll Rate	.016	±.021
Yaw Rate	-.007	±.014

The attitude requirements were not verified for the Rev 668 maneuver for the same reasons discussed for the Rev 665 maneuver.

3.2.4 Recovery

The pitch-down maneuvers preceding RV-1 thru RV-5 separations were all within specification and are summarized in Table 3-5. The RV separation performance summary is shown in Table 3-6. Tables 3-5 and 3-6 are presented on page 3-5.

The ST-RV (RV-5) recovery is performed with the SV yawed 180° and pitched-down, with the release taking place along the SV X-axis. The yaw rate bias was present during the maneuvering and separation sequence. The vehicle rate and attitude parameters at RV-5 separation are listed in Table 3-7.

TABLE 3-7

RATE AND ATTITUDE PARAMETERS AT RV-5 SEPARATION

	Attitude (degrees)	Rate (degrees/second)
Pitch	-63.8	.067
Roll	1.8	0
Yaw	- 2.0	-.003

The yaw attitude is estimated based on simulation and analysis results.

3.2.5 IRA Anomalies

The PACS developed a gyro pitch rate offset of .016 degree/second on Rev 230 that continued intermittently to Rev 276. It did not reappear until Rev 577 after which it was present throughout the mission. Since control was shifted to RACS on Rev 512, this did not affect control of the SV. At Rev 596 the positive offset changed to a negative offset of -.014 degree/second and subsequently changed signs at random intervals. During Rev 671 there was a rapid mode switching between high and low mode with a

TABLE 3-5

PITCH-DOWN PERFORMANCE PRECEDING RECOVERY VEHICLE SEPARATION

RV/Rev	Pitch-Down Angle: Desired ±3.0 Deg (degrees)	Pitch-Down Angle: Actual (PDWN) (degrees)	Maneuvering Time to ≤ 0.1 Deg/Sec: Spec (seconds)	Maneuvering Time to ≤ 0.1 Deg/Sec: Actual (seconds)	Pitch-Down Coast Rate: Command Rate (deg/sec)	Pitch-Down Coast Rate: Coast Rate Expected (deg/sec)	Pitch-Down Coast Rate: Coast Rate Actual (deg/sec)
1/196	-33.6	-33.0[1]	150	71	-.705	-.75 ±.05	-.72
2/424	-37.5	-36.7	150	75	-.705	-.75 ±.05	-.72
3/651	-37.6	-37.5	150	75	-.705	-.75 ±.05	-.73
4/1024	-37.2	-36.7	150	78	-.705	-.75 ±.05	-.71
5/683[2]	-64.4	-63.8	-	-	-.705	-.75 ±.05	-.70

TABLE 3-6

SUMMARY OF RE-ENTRY VEHICLE/SATELLITE VEHICLE SEPARATION PERFORMANCE

RV/Rev	Peak Pitch Rate (deg/sec)	Max. Pitch Integrator Angle (degrees)	Induced Impulse By Rev (lbs/sec)	Pitch-Down Prior to Sep (degrees)	Pitch-Up Following RV Sep to Removal of Maneuver Command (degrees)	Pitch Inertia (After Sep) (slug-ft^2)	Pitch Thruster Moment Arm (feet)	Roll Spec (degrees)	Angle Meas H/S (degrees)
1/196	1.49	5.7	137.7	-33.0	98.8	142464	16.4	±1.0	-.12
2/424	1.36	5.1	131.0	-36.7	99.1	122532	15.6	±1.0	-.08
3/651	1.22	3.9	134.2	-37.5	99.3	109698	14.9	±1.0	-.20
4/1024	1.33	8.4	145.0	-36.7	33.7	86196	13.8	±1.0	-.06

NOTES: 1. Data dropouts.
2. Pitch-down maneuver performed while nose aft.

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cyclic period of .167 seconds.

The RACS developed a positive gyro yaw rate offset of .003 degree/second on Rev 519 which continued throughout the remainder of the flight.

The most probable cause of the rate offsets seen from IRA 1005 (PACS) and 1016 (RACS) is one or more high impedance shorts from the torquer circuits to the case inside gyros X17 (PACS) and Y7 (RACS). This is similar to an anomaly that occurred on the yaw channels of Mission 1204.

The yaw and positive pitch offsets observed correlate well with the characteristics of a torquer short. The negative pitch offset correlates in the high mode but was too erratic to correlate positively in the low mode.

Two steps are being taken in an attempt to resolve this problem: (a) isolation of the torquer circuits and their returns from signal or case ground; and (b) insertion of a diode in the collector circuit of the torquer switching semi-conductors to eliminate reverse offset currents.

3.2.6 Ferrotic Gyro Restart Capability Evaluation

During Solo, a series of Gyro Restart Tests were conducted on the Primary IRA to determine whether or not the gyros would restart after IRA power removal and application. Two different test sequences were conducted. During the first sequence, the gyros were restarted a total of 256 times at 240 second intervals with 8 starts occurring each rev. The second sequence consisted of continuously operating the IRA for four revs followed by an IRA off time of four revs after which the IRA was restarted. This sequence was conducted nine times. The maximum and minimum gyro runup time observed was 12 and 11 seconds respectively. This consistent data gives us confidence that the change from ceramic-to-ferrotic gyro gas spin bearing material solves the gyro hardstart problem experienced on previous vehicles.

3.2.7 Horizon Sensor (H/S) Inhibit Anomaly

An RACS H/S inhibit condition was noted during the POGO pass on Rev 67. This condition also existed during two data sampling periods prior to POGO. Performance prior and subsequent to this period was normal. During the inhibit condition the roll output remained steady while the pitch output tracked the vehicle pitch attitude indicating a one head (or channel) inhibit. The most probable cause is thought to be a cracked solder joint or poor bond in an active component. This type problem could occur abruptly and heal itself just as abruptly.

An attempt was made in the Solo flight to cause a recurrence of the inhibit anomaly by producing a partial temperature cycle, however, the problem did not repeat. Review of history, procedures, and inspection methods have not revealed any areas that could have caused the observed anomaly.

3.3 REACTION CONTROL SYSTEM

3.3.1 Flight Summary

Satisfactory vehicle and rate control was provided by the RCS System during the 71-day flight. RCS Tanks 1 and 2, associated with the primary system (RCS-1), were capped-off, thereby eliminating the NVR source for RCS-1. The standby system (RCS-2) was used until Day 32 when control was switched from RCS-2 to RCS-1. RCS-1 was used for the remainder of the flight with no further leakage being detected. RCS-2 was used before RCS-1 in order to permit better insight into long term thruster performance in the presence of no leakage. RCS-1 has thrust chamber pressure and temperature instrumentation, whereas RCS-2 does not. The data obtained will be used for life and performance predictions for Block II vehicles.

3.3.2 Propellant Consumption

RCS propellant consumption for this mission was computed to be 333 pounds. Propellant was consumed from RCS Tanks 3 and 4 until Day 32 when control was switched to RCS-1. RCS-1 was fed directly from the OAS Tank.

3.3.3 Thruster Performance

The thrust level was determined, prior to Day 32, by using gyro rate information. Results of the study are shown in Table 3-8 for the pitch thrusters. REA 7' consistently indicated a lower thrust than the others; however, the indicated thrust was well above the minimum 2.5 pounds specified.

TABLE 3-8

RCS-2 THRUST LEVELS

	154 (Pitch-Down)		154 (Pitch-Up)		413	
Thrust	Act	Norm	Act	Norm	Act	Norm
2'	4.89	5.13	4.10	4.30	4.39	5.67
3'	5.05	5.30	5.94	6.23	4.39	5.67
Combined	9.94	10.43	10.05	10.54	8.79	11.36
6'	5.17	5.42	5.69	5.97	4.30	5.55
7'	3.69	3.87	4.02	4.21	3.18	4.11
Combined	8.86	9.29	9.71	10.19	7.49	9.68

NOTES: 1. Act denotes actual chamber pressure and thrust.
2. Norm denotes actual values normalized to a feed pressure of 220 pounds/square inch absolute.

After Day 32, the thruster performance of RCS-1 was determined from the thruster chamber pressures and from gyro data when available. Neither RCS-1 nor RCS-2 exhibited the thrust decay observed at Rocket Research during the Extended Life Thruster Evaluation Test (ELTET). The doubling of tailoff time was observed on some RCS-1 Thrusters, but no changes in calculated I_{Bit} or I_{sp} were observed.

3.3.4 Conclusions

A. Elimination of the use of the NVR contaminated fuel from the RCS tanks stopped the RCS valve leakage.

B. Thrust degradation was not experienced; however, pulse shape changes were noted toward the end of the mission.

3.4 ORBIT ADJUST SYSTEM (OAS)

3.4.1 Orbit Control

The Orbit Adjust System (OAS) was utilized 29 times during the active mission and 12 times during the Solo phase.

The engine I_{sp} was slightly higher than for previous engines. However, OA firings were normal and engine performance was well within specifications. The Catalyst Bed pressure drop exhibited a rapid decline and reached values lower than previously experienced in flight or with test engines. This low ΔP and high chamber temperature were the prelude to suspected engine washout which had been observed during ground testing. A long out-of-plane burn was planned prior to SV-5 deboost during Solo. This burn and the subsequent shorter deboost burns discussed in the Thruster Performance paragraph did not show any signs of washout. All ground and flight data indicates that washout is of concern only for burns of approximately 300 seconds or longer. An attempt is being made to correlate engine flow characteristics with flight performance to ascertain the controlling washout parameters. Additional engine injector flow tests are also being run. System performance is summarized in Table 3-9.

3.4.2 Deboost

For the deboost phase of the mission, the OA engine was pulsed five times (155, 150, 150, 150, and 100 seconds) with an off-time of five seconds between pulses. Total firing duration was 705 seconds to achieve a planned negative velocity increment of 298 feet/second. Engine operation was nominal. Pulse firings were employed to assure thrust integrity for each burn precluding engine washout.

3.5 LIFEBOAT II SYSTEM

3.5.1 Bay 10 Battery Induced Errors

For this flight, two Type 29 Batteries were installed in Bay 10 adjacent to the Lifeboat magnetometers in Bay 9. Ground tests indicated that this installation would introduce errors that would be significant but within the Lifeboat attitude specification. Since these errors are a function of the

TABLE 3-9

ORBITAL ADJUST SYSTEM PERFORMANCE

OA Firing No.	Rev Number	Impulse Delivered (lbs/sec)	Planned ΔV (feet/sec)	Achieved ΔV* (feet/sec)	Error ΔV (percent)
1	30	5249	7.89	8.04	1.99
2	62	14923	22.43	22.90	2.10
3	94	19897	29.97	30.63	2.21
4	96	12319	18.85	19.04	1.03
5	127	10299	15.65	15.92	2.05
6	159	9764	14.85	15.18	2.24
7	198	21494	35.25	36.20	2.69
8	257	10654	17.71	18.02	1.76
9	289	11407	18.94	19.35	2.13
10	322	10436	17.53	17.76	1.31
11	354	18662	31.09	31.83	2.41
12	356	8847	14.77	15.16	2.64
13	387	14363	23.82	24.66	3.53
14	426	11902	22.01	22.36	1.58
15	452	6251	11.48	11.79	2.67
16	484	10219	18.78	19.29	2.69
17	516	11215	20.69	21.25	2.71
18	549	11445	21.24	21.75	2.38
19	581	11292	21.27	21.53	1.23
20	614	8638	16.55	16.53	-.17
21	653	19329	40.72	40.83	.26
22	695	9494	20.74	20.76	.06
23	717	11421	25.07	25.06	-.02
24	760	9083	19.26	19.61	1.83
25	792	12521	26.81	27.68	3.23
26	841	21905	47.78	48.64	1.79
27	890	12750	28.39	28.51	.41
28	938	13751	30.67	30.88	.70
29	987	17892	39.99	40.38	.98

TABLE 3-9 (CONT'D)

OA Firing No.	Rev Number	Impulse Delivered (lbs/sec)	Planned ΔV (feet/sec)	Achieved ΔV* (feet/sec)	Error ΔV (percent)
30	1027	7277	18.15	18.49	1.89
31	1027	7362	18.19	18.75	3.09
32	1071	3313	8.65	8.47	-2.08
33	1073	8796	22.27	22.50	1.01
34	1101	6589	16.81	16.92	.68
35	1105	32745	84.50	84.20	- .35
36	1124	3561	9.27	9.55	3.02
Deboost	1139	112445	-298.11	*	-

* Ephemeris data not available.

earth's magnetic field vector, it is difficult to show that Lifeboat meets specification in all cases; however, sufficient data was obtained to show that the attitude error is probably within specification. The most significant errors are due to induced magnetism of the batteries. The errors due to the permanent magnetism of the batteries were -3, -6, and -2 mg for the Q, P, and R Magnetometers, respectively. The tests showed a -2 mg telemetry bias for the Q but none for the P and R Magnetometers. It was also possible to determine the influence of the battery current variation which was shown to be of second order.

The Lifeboat attitude specifications are defined for both the RV recovery and the deboost modes for restricted latitudes and longitudes where the magnetic field is in the order of 500 mg. For other locations, the specification is related to the magnetic field; smaller fields allow a wider deadband. The test and computed test-deduced errors are shown in Table 3-10, together with the specified values.

TABLE 3-10

LIFEBOAT ERRORS DURING RV RECOVERY AND DEBOOST

	Sensors		
	Q (Y-Axis)	P (X-Axis)	R (Z-Axis)
Worst Case Errors (Flight Test)			
ΔMG	16	14	9
Attitude in 500 mg Field (deg)	1.8	1.6	0.7
Actual Error During RV Recovery			
ΔMG	1.9	12.6	N/A
Attitude (deg)	0.3	1.5	N/A
Max Allocated Error for Recovery (deg)	2.42	2.50	N/A
Predicted Error for Deboost			
ΔMG	7	N/A	9
Attitude (deg) (300 to 400 mg Field)	1.5 to 1	N/A	1.9 to 1.3
Max Allocated Error for Deboost (deg)	1.73	N/A	1.64

NOTE: ΔMG is the difference between the predicted magnetic field from DGMAP and the observed value.

3.5.2 Yaw Attitude Determination

Flight tests demonstrated the Q Magnetometer capability to determine yaw attitude errors (in case of an ACS gyro malfunction) of 1° or more provided the magnetic field inclination angle is not large and a satisfactory calibration has been accomplished prior to the ACS failure. The restriction to the method is that the calibration must be for the same latitude and within ± 5° of longitude for the point at which the yaw is to be determined. The tests were spacing approximately a week apart. The test results are shown in Table 3-11.

TABLE 3-11

YAW ATTITUDE ERROR DETERMINATION

	ACS		Magnetometer	
Rev	Roll (degrees)	Yaw (degrees)	Average ΔQ(mg) from Average Baseline	Yaw (degrees)
531	-.5	-1.3 to -1.5	-5.0	-1.3
612	-.2	-.6 to -.3	-1.5	- .3
726	-.4	-1	-3.0	- .8
839	-.5	-1.2 to -1.4	-5.0	-1.2
953	-.3	-.8	-2.5	- .6

3.5.3 Functional Health Check

On Rev 1097, the ACS was deactivated and Lifeboat was allowed to control the vehicle for 30 seconds. The Lifeboat Control System performed normally, pitching-down approximately 17° and yawing approximately 13° up to the time of reset.

3.6 ELECTRICAL DISTRIBUTION AND POWER (EDAP)

3.6.1 Solar Arrays

Solar arrays were extended on Rev 1. Power output from each leg exceeded the specification value. Degradation from the initial output to end of 1205-4 was 7.4 percent. The solar array normally degrades from 3% to 5% during the first 30 days in flight and then levels off. Calculations showed a 4.8% degradation in the first 42 days which is within predictions. However, an additional 1.6% degradation was calculated for the next three days which is abnormal. The only activity occurring in this period was ST-RV drop. Since other drops do not show such a large decrease, it suggests that ST-RV is causing a greater than predicted degradation. This is further substantiated by a degradation of only .97% from Day 45 to Day 71 which included the RV-4 drop.

3.6.2 Main Bus Voltage

The main bus voltage varied from a low of 27 to a high of 31.4 volts. The allowable range was 25.5 to 33 volts. Low voltage data was obtained in the dark with a bus load of 70 amps. High voltage data was gathered during charge cycles.

3.6.3 Power Capability and Usage

Power usage ranged from 270 to 390 amp-hours/day. This is within the 400 amp-hour/day capability. There were 390 amp-hours used on Days 1 and 11. Excess capacity (K2 charge relay cutoffs) occurred on Rev 3 and essentially every rev thereafter with the exception of those with heavy payload operations.

Type 29 Batteries operated in a desirable environment (43° F to 49° F) and performed normally throughout the mission. An SV "Fly Reverse" Experiment was conducted during Solo Revs 1062-1083. Type 29 Battery bay temperatures were observed in order to better characterize battery heat dissipation. Type 29 Battery thermal characteristics will be applied to future SV thermal analysis.

3.6.4 Pyro Battery Performance

Pyro Battery 1 stabilized at 47° F thus minimizing self discharge during the mission. Thirty-seven days after launch the battery left the peroxide region. Lift-off capacity was calculated at 9.3 amp-hours. There were 1.4 amp-hours used during this flight leaving 6.9 amp-hours. Cell degradation life was still available for 37 days. Pyro Battery 2 followed the same pattern with the exception of leaving the peroxide operating region on Day 18. Thirty-four (34) days of cell life were still available at deboost on Day 71.

3.6.5 Lifeboat Battery Performance

The Lifeboat II battery operated normally in a 49° F environment throughout the entire mission. A total of 76 amp-hours remained at the end of the mission from an initial 343 amp-hours at launch. Remaining cell degradation life was 33 days.

3.7 TRACKING, TELEMETRY, AND COMMAND (TT&C)

3.7.1 Tracking

Remote Tracking Stations (RTS), COOK, and POGO reported the inability to achieve range lock on Revs 105 and 106. Range lock was achieved on Rev 107 at HULA and KODI but not at 110 GUAM or 111 POGO and BOSS. Configuration was SGLS with RTS using .1 radian mod index. When the uplink mod index was increased to .3 radian at POGO and BOSS on Rev 111, range lock was satisfactory. The anomaly was attributed to degradation of the turn around ratio within the vehicle transponder, which can be compensated for by increasing the mod index on the uplink. All RTS except HULA and COOK continued to use the .3 radian mod index on the uplink; HULA reported interference with uplink commanding with .3; therefore, HULA and COOK returned to the use of the .1 radian mod index. With this arrangement, the RTS were able to achieve range lock a sufficient number of times each day to satisfy STC requirements.

The RTS measured an approximate 8 db degradation in the vehicle transponder turn around ratio. This is similar to that which occurred in ground testing and is attributed to a degraded potentiometer in the Baseband Assembly Unit of this type of transponder. A new type transponder will be used on SV-7, SV-9, and up. SV-6 and SV-8 will have one of each type.

3.7.2 Telemetry

3.7.2.1 General Performance

Telemetry System performance was satisfactory throughout the flight. Out of a total of 1,136 active station contacts through Rev 1024, PCM Side 1 and SGLS-1 were operated during 1133 station contacts, an estimated average time of 300 seconds per contact for a total on-time of 5,665 minutes. PCM Side 2 and SGLS-2 were operated during Rev 9 KODI and Rev 18 POGO and HULA for an operating time of approximately 18 minutes with normal performance. Most probable cause was loss of pressure in pressurized final stage. Operation of the tape recorders was nominal throughout the flight.

3.7.2.2 Equipment Temperatures

The ranges of selected T&T equipment temperatures through Rev 1024 are summarized in Table 3-12.

TABLE 3-12

TRACKING AND TELEMETRY EQUIPMENT TEMPERATURES

		Temperature Range (degrees)	
Monitor	Identification	High	Low
H20	PCM Master Unit #1	102	60
H22	PCM Remote Unit #1A	96	71
H24	PCM Remote Unit #2A	92	66
H26	PCM Remote Unit #3A	80	60
H80	Tape Recorder #1	91	68
H250	VCTS #1	102	73
H251	VCTS #2	84	70
H373	Time Word DC/DC Converter	81	60
H383	Instrumentation Converter	77	61
H432	PCM Remote Unit #4	91	71
H433	DIU Internal	83	60

The next SGLS usage was during Solo on Day 65 where the transponder output was unusable.

3.7.2.3 Instrumentation

Table 3-13 presents the instrumentation anomalies at lift-off.

TABLE 3-13

INSTRUMENTATION ANOMALIES AT LIFT-OFF

ID No.	Description
B055	Primary REA #5 Chamber Temperature is open circuited and may read any voltage on TM.
A918 A924	Shroud temperature monitors are open circuited and may read any voltage on TM.
C391 C392	Solar Array Force Transducers are not connected and may read any voltage on TM.
C267	Charge Current Controller #4 setting of K1 operation is 40 to 110 millivolts (TM volts) higher than specification value at temperatures below 70° F, but there is no operational impact.

3.7.3 Command

3.7.3.1 Uplink Operation

The vehicle SGLS command equipment was utilized to receive approximately 13.5 million bits with no vehicle problem indications.

3.7.3.2 GFE Command System

A. Extended Command System (ECS)

The ECS responded satisfactorily in all command modes resulting in the loading of 170, 180 Stored Program Commands (SPCs) in memory. Of these 170, 180 SPCs loaded, 77,063 were output by both PMUs for decoder processing. The remainder were erased prior to their time label matches.

In loading the 170,180 SPCs, a total of 239 command rejects occurred, as summarized in Table 3-14.

TABLE 3-14

COMMAND REJECTS DURING 170,180 SPCs

Mission Segment	HULA	COOK	BOSS	KODI	POGO	GUAM
1205-1	74	0	0	0	0	0
1205-2	17	1	3	1	0	0
1205-3	70	1	23	3	0	15
1205-4	5	6	5	13	0	2

The above rejects did not prevent proper loading of the ECS. The HULA rejects during 1205-1 occurred after the RTS changed the uplink PRN ranging mod index from .1 to .3 radian.

The accuracy and stability of the ECS clock, as computed for each flight segment, are listed in Table 3-15.

TABLE 3-15

ECS CLOCK PERFORMANCE

Mission Segment	Accuracy	Stability (Average 6 Hr Period)
1205-1	.0363 parts in 10^6	3.4 parts in 10^{10}
1205-2	.0668 parts in 10^6	2.7 parts in 10^{10}
1205-3	.0923 parts in 10^6	3.03 parts in 10^{10}
1205-4	.1128 parts in 10^6	3.05 parts in 10^{10}

All of these values are well within system specifications.

B. Minimal Command Subsystem (MCS)

The MCS responded correctly to all commanding.

C. Remote Decoder/Backup Decoder

Both sides of the Remote Decoder were used for each of the five recoveries. Performance of both sides was determined to be acceptable through analysis of TM data.

D. Command System Usage Summary

Table 3-16 presents the Command System usage through Rev 1024.

TABLE 3-16

COMMAND SYSTEM USAGE SUMMARY
(hours)

System	Total Operating Time
ECS	1531.00
MCS	4.50
Remote Decoder	6.00
Backup Decoder	0.05

3.7.3.3 375 MHz Receiver

The 375 MHz Receiver was powered during the entire mission with no anomalies.

3.7.3.4 Data Interface Unit (DIU)

The Data Interface Unit performed satisfactorily throughout the flight.

IV

PAYLOADS

SECTION IV

PAYLOADS

4.1 SENSOR SUBSYSTEM

4.1.1 Camera Operations and Performance

Overall, Mission 1205 was a successful HEXAGON operation. The Sensor Subsystem performed well, all the film was transported and recovered, and there was only one anomaly that affected image quality on a portion of the Aft Camera on the fourth segment. In addition, 1205 contained 2,000' of SO-255 Color Film, the second time such film has been flown by HEXAGON. The color film was transported with no problems and the resultant photography is of Fair to Good quality. The details of the evaluation of the SO-255 portion will be covered in a separate PFA report. As with 1204, 1205 operated with both rewind and scan angle constraints. These constraints were:

A. No 120° scan angle acquisitions,
B. No rewinds other than 5 inches/second, and
C. No 30° scans at $\pm 45°$ scan centers.

The rewind constraint significantly affected the efficiency of film utilization. Even though the cameras performed very well, Mission 1205 produced generally only fair image quality. Compared to past HEXAGON missions, the image quality of 1205 was most like that of 1203, even though the altitude of 1205 was lower and the use of high scan angle acquisitions restricted. The reason for the poorer than expected photography is the excessive amount of haze and poor weather prevalent on this mission. It is also felt that this situation was compounded, to some extent, by the relatively late launch time and, hence, post-noon acquisition times over the targets. The Sensor Subsystem demonstrated a functional orbital life of 64 days and the ability to correct for film velocity errors using the On-orbit Adjust Assembly (OOAA).

4.1.2 Camera Data

The Panoramic Camera Data for 1205 is summarized in Table 4-1.

TABLE 4-1

CAMERA STATISTICS

Parameter	Forward Camera	Aft Camera
Camera Designation	A	B
Film	1414/SO-255	1414
Focal Length (inches)	60.0480	59.9716
Equivalent Filter Type	W-2E	W-12
Initial Focus Setting (microns)*	99	27
Supply Footage (feet)	106,127/2,000	109,883
Supply Spool No.	2081	2073
Supply Film Weight (lbs)	869.9	878.8
Optical Set Nos.	018	020
Initial Pneumatics (lbs)	33.99	
Estimated Remaining Pneumatics (lbs)	4.1	

NOTE: *Focus was changed once on the Aft Camera.

4.1.3 Focus

As with past HEXAGON missions, 1205 required a focus adjustment to optimize quality. The Aft Camera required an adjustment of -12 microns from launch nominal while the Forward Camera required no adjustment. This is the second system (1204 was the first) for which only one camera required a focus adjustment. This improvement in flight focus settings is believed to be due to the new procedures/ equipment employed in the focus data collection from Chamber A-2 at the SVIC facility. The new procedures and equipment allow for pitching the vehicle and collecting resolution and focus data at any number of field angles with the same collimator. The 12 micron error is still greater than what is believed to be an acceptable tolerance. Chamber A-2 testing indicated an unexpectedly large field curvature on the Aft Camera. Best focus was selected to account for this large curvature. There is suspicion, however, that some combination of field curvature/film unflatness during chamber testing led to this improper setting. As a result, there are still uncertainties with the new focus setting procedures/equipment which still require resolution.

4.1.4 Photographic Image Quality

The photographic performance of both Mission 1205 cameras was very good. The mean performance (considering all field/scan angles) between the two cameras was essentially the same, approximately 160 cycles/mm. The phenomenon, known as "McDonald's Arches," seen on 1203 and 1204, was not observed on Mission 1205. A special engineering test was run in the attempt to validate the "McDonald's

Arches" under a controlled set of conditions. However, neither this test nor the normal major axis profile analysis showed this phenomenon. The pooled major axis profile data showed a decrease in quality with scan angle on the Forward Camera but not on the Aft.

The inherently good performance of the 1205 cameras is also shown in: (1) the MIP ratings, with this mission achieving the highest average MIP to date; and (2) the CORN tribar targets, with this mission producing the best resolution reading of any to date (1.9' geometric mean, Aft Camera). There were, however, two anomalies which affected image quality, one due to the Attitude Control System (ACS) and the second due to either the camera, the film, or both. The first problem was a random yaw attitude error in ACS-2 (ACS-1 had a pitch attitude error). This yaw attitude error was most prevalent during 1205-3 and -4. Attempts were made to compensate for this yaw error by adjusting Vy and OOAA commands. These attempts were only partially successful due to the relatively rapid changes in the yaw bias error. The effect of the yaw bias on image quality was evaluated analytically and by the visual edge matching (VEM) techniques. In summary, the yaw bias was shown to affect image quality, virtually as predicted. The yaw bias of 1.5° caused approximately a 15% to 20% loss in resolution. The second problem mentioned above was an out-of-focus band that ran approximately down the center of the Aft Camera format on 1205-4. This out-of-focus band was slightly in excess of 1.25" wide, and was most severe between Ops 577 and 620. Between these operations, the out-of-focus became so severe that portions of the imagery were unusable. Measurement of the image doubling that occurred during these operations indicates that the out-of-focus was as much as 60 microns.

Analysis of the combined VEM data indicates that the mean area weighted average 2:1 contrast GRD for Mission 1205 was 2.3' between ±30° of scan, 4.1' for acquisitions beyond ±30° of scan, and 6' for acquisitions beyond ±45° of scan. Based on the 2:1 contrast VEM data, the grand area weighted average (GAWA) resolution of Mission 1205 was 3.1 feet. For average intelligence targets, the GAWA resolution is estimated to have been 6.2 feet. This is the second worst of the HEXAGON missions to date. Only 1203 was worse, producing a GAWA of 6.9 feet. The major reason for the poor "intelligence target" GAWA is haze. The PFA Team and NPIC have both noted the excess haze and poor weather on the mission.

4.1.5 Exposure

Exposure analysis indicated a reasonably good exposure requiring no adjustment to the basic recommendation. Exposure differences between Forward and Aft photography, which continued to be observed with Mission 1205, suggest that an investigation should be made into the use of a scene model with vertical surfaces.

The exposure of snow and sand scenes, using the recommended biases, was found to be satisfactory considering that many of the scanned urban areas contained snow or sand. The exposure was approximately .10 log E above aim criteria for vegetation surround scenes. Uncorrected acquisitions containing these scene conditions were investigated and it was determined that these biases, properly applied, would have been appropriate. The new three-step Mid-East polygon sand bias could not be evaluated below 50° solar altitude because of the absence of these lower solar altitudes in a spring mission.

Object shadow areas were investigated and in many cases found to have sufficient modulation for duping. However, correction for the average .25 log E underexposure on the ON would jeopardize exposure of the highlight areas.

The effective contrast of the CORN tribar resolution targets, as seen at the camera aperture, was estimated by backing out the micro edge effects of the five-step gray scales and determining their relative log exposure via macro sensitometry.

4.1.6 Operational Anomalies

As discussed above, Mission 1205 had two image quality degrading anomalies: (a) the ACS yaw bias problem, and (b) the Aft Camera defocus band on 1205-4. These anomalies were the most severe on the mission. There were, however, other anomalies worth noting, i.e., fine path tracking was a concern particularly on the Forward Camera. After launch, the tracking shifted low by a magnitude which caused this concern. In many cases, the index dot of the time word was not imaged on the film indicating a very marginal tracking situation. This problem was seriously aggravated at the end of 1205-1 where a series of rewind tests were accomplished. During rewind, poor tracking in the fine film path caused edge scuffing that extended for 60 inches. Coupled with the low tracking condition (launch shift of the index dots toward the edge of the film), the Forward Camera exhibited film wander which was most severe with 30° scans. It was this poor tracking performance that was the primary basis for the decision not to rewind for the remainder of the mission. Two puncture-like marks with repeated impressions were noted on Ops 277 and 319 of the Forward Camera. It was concluded that the Op 277 mark was caused by a particulate being ingested in the Take-up during the mission; while the latter is believed to be caused by the inclusion of foreign matter in the Supply prior to the mission.

4.1.7 Command and Control

The Sensor Subsystem was nominal with respect to command and control throughout the mission. Approximately nine minutes after lift-off a failure was experienced in the Instrumentation System Command and Control Unit (ISCCU) resulting in the loss of all SS temperature, nitrogen tank, and regulator pressure TM points. The result was that the SS temperature status throughout the mission was implied using the Mid-section reference temperature, and pneumatics consumption was estimated using camera power on-time and the low pressure transducer in the Forward-section film chutes. Failure analysis indicated the most probable cause is an overstress of the ISCCU as a result of a momentary short at one of the switched transducers. A fix to limit the current to the transducers has been incorporated.

4.1.8 Engineering Tests

There were several special engineering tests run during this mission. Those worthy of special mention are the "McDonald's Arches" Test which was previously discussed, and a series of tests aimed at evaluating the drive capstan dither, the on-orbit lens MTFs, and the in-track and cross-track smear settings.

The Dither Test was aimed at evaluating the effect on image quality of the drive capstan dither. During pause, the velocity servo dithers sending a vibration into the other camera. It has been shown in ground testing that this can increase smear variability during certain photographic operations. The engineering test run to evaluate this phenomenon demonstrated that dither does affect smear variability on-orbit, increasing the in-track component by an approximate magnitude of three times and cross-track by approximately two times.

The Lens MTF Test was accomplished by using a North-South array of in-track/cross-track lines. In this manner, the field was sampled. In general, the MTFs measured on-orbit are lower than similarly measured MTFs from ground testing. This is particularly true off-axis. It is not clear if this is due to measurement difficulties or indeed reflects a lessening of optical quality due to launch and/or orbit effects.

Tests were also run to evaluate the in-track (skew) and cross-track (mean film velocity) settings. These tests consisted of acquiring Double Row East-West Lines (DREWL) with known OOAA biases. Both plus and minus OOAA biases were employed. The lines were traced with a microdensitometer and the resultant data processed via the PFALINES computer program. The results indicated that both the in-track and cross-track settings were proper on the Forward Camera, while only the in-track setting was proper on the Aft Camera. The data further indicated, however, that an adjustment of +3 OOAA counts was required to optimize the Aft Camera cross-track setting. This adjustment was made effective on Op 214.

4.1.9 Exploitation Suitability

Although Mission 1205 provided the best average photographic scale of any 1200 series mission to date, the overall interpretation suitability rating for this mission was only Fair. The PI suitability ratings for Mission 1205 are similar to 1203 but poorer than 1201, 1202, and 1204. Analysis of the imagery has indicated that the majority of the interpretation problems encountered were due to climatic conditions. The extensive high priority coverage of Southeast Asia with its excessive haze and cloud cover, the difficulty of properly exposing regions of melting snow, and areas affected by front-lighting conditions resulted in a large amount of low contrast imagery.

An investigation of the vehicle yaw anomaly showed that mensuration from frames acquired during the vehicle anomaly was less accurate than normal. Also, correct geodetic coordinates for specific targets were difficult to obtain during RV-3 and RV-4.

NPIC has investigated the three methods for determining target coordinate predictions. Based on the study, geodetic positioning in latitude is most accurate when calculated from the nominal attitude; there is no preference in regard to longitude. The results of the geodetic positioning analysis and the 1205 target coordinate validation exercise indicate that the use of nominal attitude data results in the most accurate positioning measurements.

4.1.10 Processing and Reproduction

Defilming of all RVs was accomplished without any major difficulty, even though festooned, tangled film was present in all but RV-2 where the core-locking pin did not shear. Extra cuts were made during the defilming of RV-2 and RV-4 to expedite the processing of several high priority operations for special PI readout teams.

High contrast duplication methods were utilized to provide both entire-part and special target-oriented duplicates.

Results of the NPIC analysis of duplicate image quality are generally consistent with previous HEXAGON missions, except that there is less resolution loss from the ON to the 2nd DP (BH) copies than on earlier missions.

4.2 SURVIVABILITY SYSTEMS

The Survivability Systems performed satisfactorily throughout the mission.

Vehicle support of the Survivability Systems (power, command, telemetry tape recorder, thermal environment, etc.) was provided satisfactorily. The average operating time was approximately 550 seconds per read-in, with an average of approximately 6,620 seconds per day.

4.3 SUBSATELLITE

No subsatellites were flown on SV-5.

4.4 MAPPING CAMERA SUBSYSTEM

4.4.1 Mapping Camera Operations and Performance

Mission 1205 carried the first of the HEXAGON Stellar Terrain Mapping Cameras. The camera operated for 683 revolutions over a period of 42 days. During this time, 1,982 frames were exposed on both the Stellar and Terrain Cameras to satisfy mission objectives; of these, 19 frames were used for the in-flight calibration mode. An additional 195 cycles were operated at the completion of the calibration mode to deplete the Stellar Camera film.

The operation and performance of the first ST Camera System were considered highly successful.

The resolution of the Terrain Camera photography was judged Excellent throughout the mission. Evaluation of these photographs to date indicates a quality level that significantly exceeded the predicted values based on acceptance test results.

The Stellar photography was degraded by corona and radiation fogging. However, in most frames the average number of star images was between 50 and 100 with some frames recording as many as 150 images. The high fog level made it impossible to measure some of the reseau intersections.

Intermittent malfunctions of the Terrain Thermal Door and tape stop switch resulted in the loss of 79 operational frames and the in-flight Stellar calibration.

The weather conditions during photography were generally good with approximately 75% of the mission being cloud free.

4.4.2 Mapping Camera Data

The Mapping Camera data for Mission 1205 is summarized in Table 4-2.

TABLE 4-2

MAPPING CAMERA STATISTICS

Camera Designations	Terrain	Stellar
Film	3400*	3401
Focal Length	12.034	+Y 10.044/-Y 10.361
Filter Type	W-21	None
Supply Footage (feet)	3297	2026
Supply Spool No.	SN 91	SN 054
Supply Film Weight (lbs)	56.1	10.4

NOTE: *Terrain film load included segments of 3401 (22 feet) and 2403 (10 feet) which were added to the end of the Supply for calibration purposes.

Exposure levels of the Terrain photography were basically correct with none being underexposed and only a small percentage of photography falling in the overexposed category. The overexposed frames were, in the majority of instances, snow or sand covered areas. The evenly exposed frames, a feature not normally observed in wide angle camera photography, resulted from the lens and filters effectively yielding the correct exposure over the entire format. The image contrast was excellent, in part attributable to the high percentage of photography taken under low haze and cloud free conditions.

The image quality in ground resolution was outstanding for this scale. Numerous small man-made features were easily detected and occasionally identifiable, e.g., baseball mound, small aircraft on taxiways, individual homes with driveways, etc. The photographic quality was decidedly superior to that of preflight predictions.

Visual edge matching (VEM) was utilized on the Terrain photography at BRIDGEHEAD by the PFA Team, and at the contractor's facility. At the contractor's facility, 63 frames were randomly selected from throughout the mission for analysis. VEM readings were recorded for each frame at various format positions. The average for all frames measured was approximately 70 cycles/mm.

Newton ring patterns are discernible on Terrain frames where homogeneous areas (water, sand, and grasslands) were imaged. These patterns are more easily detected at the larger field angles where the image contrast is lowered by the increased path length through the atmosphere.

4.4.3 Thermal Profile

The control and resulting thermal distribution for the ST Cameras was considered excellent. Predicted levels of stability were achieved.

4.4.4 Calibration Mode Operation

The in-flight calibration was attempted on Revs 665 and 668. In both cases the Terrain Thermal Door did not open.

4.4.5 Anomalies

The following are the anomalies in the Terrain Camera and on the Stellar film which produced conditions affecting mission objectives.

A. Terrain Camera

(1) Anomaly - Thermal door malfunction on Revs 8, 13, 39, 70, 90, 91, 665, and 668.

Analysis - The thermal door did not open when commanded during the above revolutions. Because the anomaly was intermittent, it was necessary to continue the analysis through several revolutions. By Rev 16, the decision was made to transfer to the thermal door redundant electronics to eliminate the probability of a TM problem. Operations were successful until Rev 39 when the door again malfunctioned. At this point the anomaly was observed with both servo electronics circuits. Considering the results on tests being run concurrently in the contractor's facility, the anomaly was determined to be TM and operations continued. With the exception of Rev 70, operations were normal up to Rev 90 where a variation of the anomaly was observed. TM now indicated the thermal doors were not closing. This change promoted further analysis which correlated the malfunction with the cold temperature conditions experienced during operations at latitudes greater than 50° north.

Action - Starting on Rev 100, operations were restricted to latitudes less than 50° north. On Rev 215, and periodically throughout the remainder of the mission, the 50° north restriction was altered based on the change in solar elevation. By the last revolution of mission photography, the restriction had been increased to 63° north. The revolutions and frames affected are noted in the log of operations, Table 4-3.

The thermal door operated normally from Revs 100 to 665. On Revs 665 and 668 the door failed to open during the in-flight calibration. To acquire the desired Stellar field for calibration, it was necessary to operate the camera on the cold side of the orbit as well as forcing it to look skyward, resulting in the coldest possible conditions.

The first calibration attempt on Rev 665 was made using the normal thermal door motor. The second calibration attempt on Rev 668 was made using the backup thermal door motor, which has greater torque but does not have the capability to reclose the door after the photography is taken.

The thermal door has been redesigned to prevent the gear binding and the revised door has been incorporated into the next mission hardware.

(2) Anomaly - Malfunction of the tape stop switch.

Analysis - The tape stop switch sets up the photographic sequence and provides an internal "off"-command to the camera. Malfunction of this switch resulted in both the Stellar and Terrain units transporting more frames than commanded and a random loss of photographic functions. The revolutions and 25 frames affected are also noted in Table 4-3.

Action - Since the possibility existed that the camera system could continuously transport film independent of external commands, and thus deplete the Supply, the decision was made to add an on-off command at the end of each operational sequence to insure that the system would shut down. The continued loss of operational photography caused the decision to be made to transfer to the backup mode. This mode utilizes a separate tape stop switch as well as locking the camera system to the following fixed set of operating parameters:

(a)	Vh	.0457 radian/second.
(b)	Exposure	6.2 milliseconds.
(c)	Overlap	between 70-80 percent.
(d)	Time between frames	8.9 seconds.

There were no anomalies associated with the tape stop switch after transferring to the B-mode on Rev 503.

(3) Anomaly - The Terrain reseau depends on ambient light to expose the intersects on the film during photography. In areas of high density photography it is difficult to segregate the fiducials from the surrounding imagery.

Analysis - This problem is not considered to be a camera malfunction. Based on design concepts this anomaly will be characteristic on future systems.

Action - Investigations have resulted in a proposed solution which can be incorporated on SV-9. The change proposed will mask out the imagery in the immediate area of the fiducials.

TABLE 4-3

MAPPING CAMERA LOG OF OPERATIONS

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
			8-19	12	-D-Thermal door problem - Op 5 Fr R-13, 9 Fr, R-16 diagnostic.
	20-23			4	—
24-26				3	—
	27-28			2	—
29				1	—
	30			1	—
31				1	—
	32-38			7	—
		39		1	-D-Thermal door not open.
40-41				2	—
			42-44	3	Resolve -D- door problem.
	45-54			10	—
55-61				7	—
	62-69			8	—
		70		1	-D-Thermal door not open.
	71			1	—
72-75				4	—
	76-77			2	—
78-79				2	—
	80-88			9	—
89				1	—
		90-91		2	90/1 -D-Thermal door not open - partially open Fr 1. 90/2 Fr 1-7 -D-Thermal door not open; Fr 8-17 door not closed. 90/3 Fr 1-15 door not closed. 91 Fr 1 door not closed - partially open. Fr 2-5 door not open; Fr 6-8 normal.

TABLE 4-3 (CONT'D)

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
92				1	–
	93-96			4	–
			97-99	3	Investigate -D- door. Op 8 Fr R-97 diagnostic MOP.
	100-103			4	–
104				1	–
	105			1	–
106				1	–
	107-119			13	–
120				1	–
	121			1	–
122				1	–
	123-134			12	–
135				1	–
	136			1	–
137				1	–
	138			1	–
139				1	–
	140			1	–
141				1	–
	142-154			13	–
155				1	–
	156-160			5	–
161				1	–
	162-168			7	–
169				1	–
	170-177			8	–
178				1	–
	179-183			5	–
184-185				2	–
	186-187			2	–

TABLE 4-3 (CONT'D)

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
188				1	—
	189-200			12	—
201				1	—
	202-203			2	—
204				1	—
	205-210			6	—
211				1	—
	212-220			9	—
221				1	—
	222-234			13	—
235-237				3	—
	238-239			2	—
240				1	—
	241-242			2	—
243				1	—
	244-248			5	—
249				2	—
	250-251			2	—
252-253				2	—
	254-257			4	—
258				1	—
	259-264			6	—
265-266				2	—
	267-268			2	—
269				1	—
	270-271			2	—
272				1	—
	273-281			9	—
282				1	—
	283-284			2	—

TABLE 4-3 (CONT'D)

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
285				1	—
	286-299			14	—
300-301				2	—
	302-305			4	—
306				1	—
	307-315			9	—
316				1	—
317-318				2	—
	319-331			13	—
332-335				4	—
	336-339			4	—
340				1	—
	341-349			9	—
350				1	—
	351-362			12	—
363				1	—
	364			1	—
365-366				2	—
	367			1	—
368				1	—
	369-381			13	—
382-383				2	—
	384-388			5	—
389				1	—
	390-395			6	—
396				1	—
	397-398			2	—
399				1	—
	400-413			14	—
414-415				2	—

TABLE 4-3 (CONT'D)

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
	416-428			13	—
429				1	—
		430		1	Tape stop problem-18 Fr Prog -17 Fr good, did not shut off on Fr 18. Fr 18-22 no photographic shutoff Fr 23.
			431-439	9	Resolve tape stop problem-ran 2 Fr R-436, 5 Fr R-438 for diagnostic.
	440-443			4	—
444				1	—
	445			1	—
		446		1	Tape stop problem 17 Fr Prog -Fr 1-15 good. No photo on Fr 16-19.
447				1	—
	448-461			14	—
462				1	—
	463-469			7	—
470				1	—
	471-477			7	—
478				1	—
		479		1	Tape stop 9 Fr Prog. No photo Fr 1, 9, 10 - all others were good.
	480-493			14	—
		494		1	Tape stop 15 Fr Prog. No photo Fr 1, and 13-16.
495				1	—
	496			1	—
			497-504	8	Resolve tape stop problem ran 3 MOPs (R 503 4 Fr, 4 Fr, 4 Fr) to check B-mode.
	505-509			5	—

TABLE 4-3 (CONT'D)

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
510-512				3	—
	513-526			14	—
527				1	—
	528-534			7	—
535				1	—
	536-540			5	—
541				1	—
	542-543			2	—
544-545				2	—
	546-559			14	—
560-561				2	—
	562-590			29	—
591				1	—
	592-607			16	—
608				1	—
	609-621			13	—
622				1	—
	623			1	—
624				1	—
	625			1	—
626				1	—
	627-639			13	—
640				1	—
641				1	Change to normal mode. Enable MCD.
	642-654			13	—
655				1	—
	656			1	—
657				1	MCD shutdown on Fr 2026.
	658-664			7	—

TABLE 4-3 (CONT'D)

Revs Successfully Operated	Revs Able But Not Operated	Revs With Anomaly	Revs Inhibit	Rev Totals	Comments
		665		1	Cal Mode -D-Thermal door not open.
	666-667			2	–
		668		1	Cal Mode -D-Thermal door not open.

NOTE: There were 683 operated revs with a total frame count of 1,982.

B. Stellar Camera

It should be noted that the tape stop switch problem, reported under Terrain Camera anomalies, will affect both camera units and, therefore, will not be listed as a separate Stellar anomaly.

(1) Anomaly - Various patterns of plus-density were noted occurring randomly in the early portion of the mission.

Analysis - These images have since been duplicated in the laboratory by simulating an image of the moon. Analysis has determined these images to be reflections of the moon's image formed just outside the lens field of view. Due to the geometric location, these images are reflected off the side of the lens barrel and edges of the reseau mask. These extraneous images had only cosmetic effect on mission photography.

Action - The intensity of the moon is not sufficient to trigger the inhibit sensor located in the baffle assembly, and it is expected that this condition will recur on future flights.

(2) Anomaly -Starting on Rev 178 and recurring randomly throughout the mission, various levels of plus-density were recorded on the Stellar film.

Analysis - It has been determined the plus-density is a result of radiation exposure and is not related to camera system malfunction. The base plus fog density on the entire Stellar mission was higher than expected. The heavier overall background density and the radiation fogging decreased the ΔD to a point where reseau intersects were difficult and impossible to measure.

Film and imagery analysis produced the following points which support the conclusion that the fogging was caused by solar radiations.

(a) On March 19 (Rev 165) and regularly throughout the remainder of the mission, solar activity reports from the Space Environment Service Center indicated a significant increase in low energy activity. Solar radiation warnings were issued in conjunction with these activities.

(b) The emulsion in the fogged areas was desensitized as evidenced by the data block imagery and optical tilting.

(c) The severity of the fogging was directly related to the number of orbits between operations.

(d) The fogged areas did not exhibit the characteristics normally associated with light leak or corona marking.

Action - More detailed radiation data will be requested from AWS during the next flight, and radiation packets will be included in the SV-8 ST-RV. Investigations are also underway for an optional operating mode that will take up a length of Stellar photography upon command. This would enable removing the film from the vulnerable film chutes when warnings of radiation conditions are received.

(3) Anomaly - Dendritic static was recorded, varying from light to heavy, on approximately the first 200' of Stellar film.

Analysis - Dendritic static is normally associated with film handling at ambient pressure. There is some opinion that when handling high speed film at ambient conditions it must be transported at a very low rate, i.e., 3 to 5 feet/minute.

Action - The procedures for film handling at ambient pressure are being evaluated.

4.4.6 Exploitation Suitability

Measurements at DMATC resulted in the following:

A. Terrain film deformation was within expected tolerance with the average measured standard deviation being 8.3 microns against a tolerance of 12.9 microns.

B. Some relatively high residual vectors were found in the Terrain 4300 intersection corner on several frames. This could affect the results obtained from small area transformations from frame-to-frame. This problem is still being investigated.

C. On several frames the residual vectors near the Stellar 0101-0701 intersections were opposite in direction to the "normal" swirl pattern for that area of the format. This could indicate an imperfect platen press. This is presently under investigation.

D. Fiducial positions were measured and compared to preflight measurements. The maximum position difference of 6.3 microns indicates the fiducials were stable throughout the mission. The interference of the Terrain imagery with the fiducial marks made measurements of some of the fiducials difficult.

E. Although no serious problems have been experienced in reading the data blocks, several of the data block dots were larger than specifications.

F. A few of the film tracking measurements and interframe distances were found to exceed engineering specifications. However, they do not appear to significantly affect the mapping mission.

G. The measured 71% overlap was consistently within 1% of the commanded value.

H. The Stellar imagery shows good distribution and an acceptable quantity with approximately the predicted number of sixth magnitude stars being imaged.

4.4.7 Processing and Reproduction

Defilming was accomplished without major difficulty.

The Stellar processing was stopped after 230' because optical titling operators were unable to establish synchronization with the roadmap data. Also, the grid line intersections were difficult to see on the negative because the background exposure was too light relative to the base plus fog level.

In order to overcome these problems, software changes were made in the optical titling system and a different developer (526) was used to process the balance of the Stellar film.

Approximately 72% of the Terrain Camera frames were titled using the optical titling system. The rest of the frames were affected by occasional fiducial mark imagery which simulates the End of Frame Marks, roadmap data errors, and fog or static on the frame mark edge. Only 39.5% of the Stellar film was titled using the optical titling system. The primary problem was poor frame mark detection due to bloomed frame marks, dendritic static marks, intermittent high fog (up to 1.55) which obscured some marks, and 19 missing frame marks. The high fog level, with levels above .70, caused significant optical titler detector problems.

The processing data is presented in Table 4-4.

TABLE 4-4

PROCESSOR AND DEVELOPER DATA

Camera	Material	Processor	Developer
Stellar	Head thru Op 14, Frame 007	Yardleigh 5	17 DN
	Op 14, Frame 007 thru Op 15, Frame 005	Yardleigh 5	524
	Op 15, Frame 005 thru tail	Yardleigh 5	526
Terrain	All operational	Yardleigh 5	Dual Gamma
	2403 Test	Versamat	MX-885
	2403 Test	Versamat	MX-885

After processing, the original negatives were broken down into lengths not exceeding 325' on the Terrain and 240' on the Stellar.

All duplicate copies were printed on the KINGSTON Printer. Duplicate positives of the Terrain were made on SO-467 and for those on the Stellar on 2420. The duplicate negatives of both films were made on 2422. All duplicate processing was accomplished on Viscous Dalton Processors.

RE-ENTRY VEHICLE SUMMARY

SECTION V

RE-ENTRY VEHICLE SUMMARY

5.1 SUMMARY

The recovery statistics are shown in Table 5-1 and Figure 5-1. Performance of the RV subsystems is summarized in Table 5-2. All RV events (on-orbit, re-entry, and recovery) occurred as planned and the RV flights followed the predicted trajectories.

The outer wraps on RV-1, RV-3, and RV-4 were loose due to payload rotation after aerial retrieval induced shearing of the core pins. Aerial retrieval loads exceeding the core pin strength were anticipated. The payload on RV-2 was recovered without loose wrapping.

All subsystems performed satisfactorily and met all mission requirements, see Table 5-2.

5.2 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.

The RVs were adequately spin stabilized during the vacuum coast phase and aerodynamically stable during the atmospheric phase of the re-entry trajectory. Figure 5-1 shows the entry conditions to be well within previously established entry boundaries. Also shown are the conditions at the time of drogue chute deployment which are also within the design envelope.

5.3 RE-ENTRY VEHICLE SUBSYSTEM PERFORMANCE

The only anomaly noted was the activation of the RV-3 recovery light, a component within the Sequential Subsystem, reported by the retrieval crew on board the recovery aircraft. Normally this light is activated during water recoveries by sea water in contact with one of four water sensor switches. Postflight analysis and testing revealed no discrepancy in associated wire bundles, relays, or switches; however, the anomaly was duplicated by shorting the water sensor switches with graphite cloth strands, and also with metallic debris from the propulsion truss separation. Openings of sufficient size to permit entrance of such debris exist in the Aft Thermal Protection Door. A vented protective cap will be installed over the switches to preclude recurrence of this anomaly.

5.4 STELLAR TERRAIN RECOVERY (RV-5)

RV-5 was successfully recovered on Rev 683. Recovery statistics are shown in Table 5-3. All RV subsystems performed normally. The SV provided a satisfactory pitch angle after a yaw reverse and all other interface functions were nominal.

The predicted impact point (PIP), the estimated point of parachute deployment (EPPD), and the air recovery point are shown in Figure 5-2. The miss distance between the PIP and EPPD was calculated to

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TABLE 5-1

RECOVERY VEHICLE RECOVERY SUMMARY

	RV-1	RV-2	RV-3	RV-4
RV Serial No.	24	23	22	21
Recovery Rev No.	196	424	651	1024
Recovery Date (1973)	21 March 1973	4 April 1973	18 April 1973	11 May 1973
Payload Weight (lbs) (Measured weight from recovered RV)				
Forward	217.6	220.6	228.8	200.7
Aft	218.4	220.4	231.2	207.3
Unbalance Percent	.3	.09	1.0	2.9
SV Orbit (hp x ha/ ω p)	86.02 x 144.93/126.81	85.69 x 146.33/131.18	85.95 x 143.91/122.66	86.50 x 149.10/129.12
SV Pitch Angle (degrees)	-33.5	-37.5	-37.8	-37.2
Nominal PIP Latitude	29.0° N	23.5° N	22.0° N	26.0° N
Nominal PIP Longitude	150.85° W	171.03° W	167.0° W	163.8° W
Impact Location Error (EPPD versus Teapot Eval)				
Overshoot (NM)	8.7	5.2	1.52	
Undershoot (NM)				5.44
Cross-Track (NM)	2.7E	3.7E	.36W	.92E
Recovery (Aerial)				
Altitude (feet)	11,000	7,700	14,200	10,300
Parachute Condition	No Damage	No Damage	Minor Cone Damage	Minor Cone Damage
Retrieval Pass	2	3	1	2
Recovery Capsule Payload Condition	Good	Good	Good	Good

NOTES: 1. hp = Altitude of Perigee (NM)
2. ha = Altitude of Apogee (NM)
3. ωp = Argument of Perigee (degrees)

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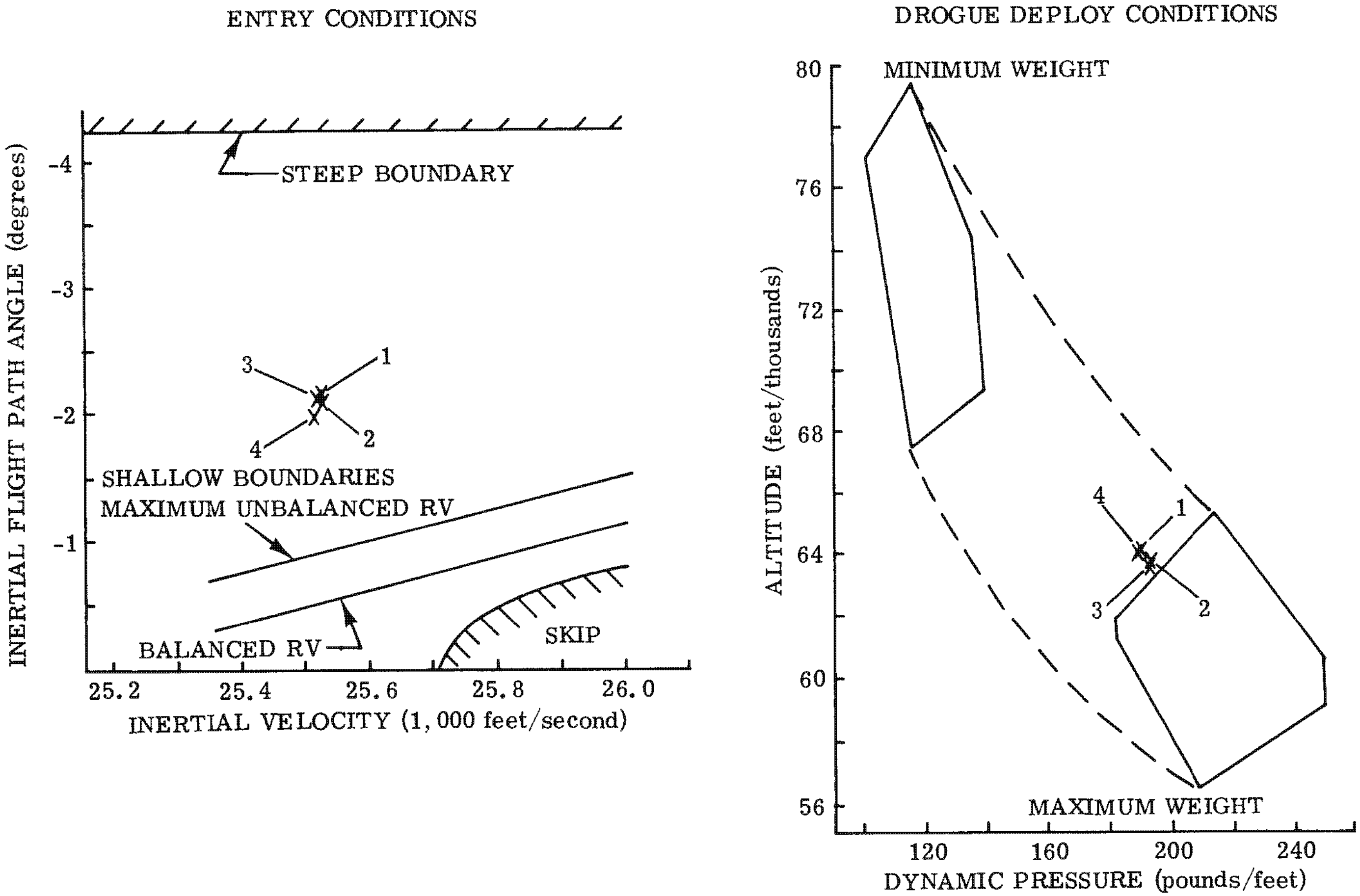
FIGURE 5-1

SV-5 RE-ENTRY PARAMETER COMPARISONS



~~TOP SECRET~~ HEXAGON

BYE 15296-73

Handle via Byeman
Controls Only

TABLE 5-2

RE-ENTRY VEHICLE SUBSYSTEM PERFORMANCE SUMMARY

RV Subsystem/Function	Performance Assessment
On-Orbit Thermal Protection	Normal. T_{PL} Container = $T_{ref}{}^{+2°F}_{-7°F}$ Power Usage (Watts/RV) Maximum = 18 (First Day in Orbit). Stabilized = 7.5 (Fifth Day in Orbit). Allowable ≈ 20.
Trim and Seal	Normal.
Electrical Power & Distribution	Normal during life of mission. All Batteries Activated. All Voltages >2.5 Volts. RV-2 Pyro Battery 2 leaked electrolyte. RV-4 Pyro Battery 2 had a seam rupture occurred onboard retrieval aircraft.
Sequential Subsystem	Normal on RV-1, RV-2, and RV-4. On RV-3, the water sensor switch activated while in tow.
Pyro Subsystems	Normal. All primary and redundant pyrotechnics in each RV were verified by postflight 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.

STELLAR TERRAIN RECOVERY LOCATION

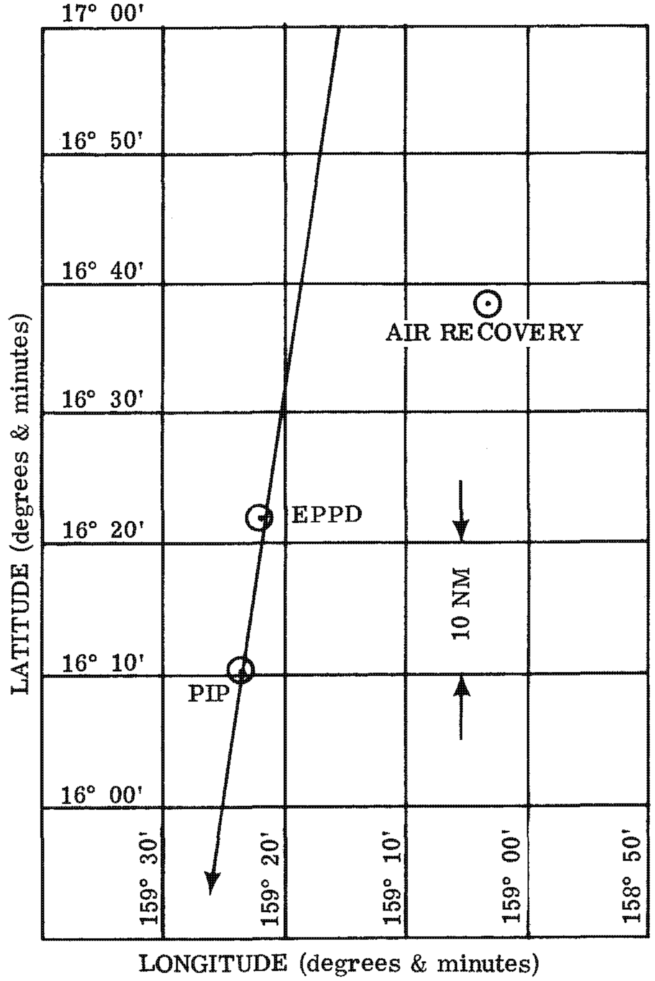


FIGURE 5-2

be 11.68 NM short and 1.46 NM west of the ground track. The capsule was blown 16 NM from the EPPD by a 105 knot wind from 250 degrees.

The capsule was recovered at 12,400' on the first pass with no damage to the chute or capsule.

TABLE 5-3

RV-5 RECOVERY SUMMARY

Recovery Rev	683
Date	20 April 1973
Payload Weight at Recovery (lbs)	65.93
SV Recovery Orbit	
Perigee (NM)	86.3
Apogee	152.0
Perigee Argument (degrees)	129.1
SV Pitch Angle after yaw around (degrees)	-64.4

	PIP	EPPD	Air Recovery
Latitude	16° 10.2'	16° 22'	16° 37'
Longitude	159° 23.4'	159° 23'	159° 03'
Altitude	–	–	12,400 ft

OPERATIONAL SUPPORT

VI

Approved for Release: 2020/12/01 C05131456

SECTION VI

OPERATIONAL SUPPORT

6.1 SOFTWARE

The software configuration used to support Mission 1205 was 'TUNITY MOD 1BR. This update of MOD 1B provided a new algorithm for more efficient employment of the Mapping Camera module. It also provided for use of the Doppler Beacon System. AOES/System II configuration was 13.1E SST, Corrector Tape CT 13.1F.5. A nominal one rev load cycle for the payload revs was used during the mission phase. A total of 853 command messages was generated, of which 795 were loaded into the vehicle. Eight 'TUNITY software problems which were considered flight critical were corrected during the mission. The flight critical software problems (SPR) are summarized below.

6.1.1 SPR MBR-5099 ('TFUNOPT)

In a sequence, an OFF-command executed rather than the ON-command as an expected status fill did not occur. The problem was determined to be flight critical from the potential effect on other status filled commands. A change was made to 'TRANS correcting the problem and was incorporated on the Flight AUX Master.

6.1.2 SPR MBR-5100 ('TLIST/'TOREP)

The 'CFC output in CMG differs from 'CFC in CMU and MPR by one second. The customer uses 'CFC on MPR transmission tape for processing; therefore, this required a manual header change. Changes were made to 'TLIST and 'TOREP correcting this problem and were incorporated on the Flight AUX Master.

6.1.3 SPR MBR-5103 ('TFIELD)

When Slit Data Cards are input in multiples of five, the last four cards do not take effect causing the possibility of commanding improper slits. A change was made to 'TFIELD correcting the problem and was incorporated on the Flight AUX Master.

6.1.4 SPR MBR-5109 ('TPURR)

CHG aborted attempting to read Record 2 of the 'TAE data block. 'TPURR was purging 'TAE improperly. A change was made to 'TPURR correcting the problem and was incorporated on the Flight AUX Master.

6.1.5 SPR MBR-5121 ('THISUM)

CHG passed to MPR that Rev 367 was the last active rev, however, an ST operation occurred on Rev 368. The data existed but the pointer ('TGX) had no entry for Rev 368. The data was recovered in the next day's MPR. A change was made to 'THISUM correcting the problem and was incorporated on the Flight AUX Master.

6.1.6 SPR MBR-5124 ('TCATCHM)

Identical data cards specifying a Stellar Terrain MOP produced different results between the first rev and the intermediate rev of the span in that MOP. The first rev covered two less DEAs. A change was made to 'TCATCHM correcting the problem and was incorporated on the Flight AUX Master.

6.1.7 SPR MBR-5145 ('THISUM)

MPR aborted attempting to read Record 1 of the 'TGX data block because 'THISUM did not write Record 1. MPR was delayed until a change to 'THISUM was made correcting the problem. The change was incorporated on the Flight AUX Master.

6.1.8 SPR MBR-5148 ('THISUM)

CHG aborted on an illegal instruction during Solo. CHG was delayed until a change was made to 'THISUM correcting the problem. This change was incorporated on the Flight AUX Master.

6.2 SATELLITE CONTROL FACILITY (SCF)

The performance of the SCF in support of the fifth HEXAGON mission was commendable. Equipment and operational problems were encountered but were solved without impact on the mission. Command message generation and transmission, and down link TM reception and processing were satisfactory to support the operation.

6.2.1 Readiness

A 64 Rev Development Rehearsal using 'TUNITY MOD 1BR and MODEL 13-1E was begun on 12 February 1973 and successfully concluded on 17 February 1973. A 16 Rev Dress Rehearsal was begun on 28 February and successfully concluded on 28 February 1973.

6.2.2 Orbit Operation

One dedicated CDC 3800 Computer was used throughout the operation; a second computer was used for 629 hours of operation. The computer usage rate was 1.410 computer hours per day. Table 6-1 provides a breakout by RTS of the anomalies that occurred during this operation.

TABLE 6-1

TRACKING STATION ANOMALIES

(occurrences)

Equipment	Guam (GTS)	Hula (HTS)	Kodi (KTS)	Indi (IOS)	New Hampshire (NHS)	Pogo (OL 5)	Vandenberg (VTS)	STC
1230 mTc	0	2	4	0	1	5	0	-
CDC 160A	3	4	8	0	4	21	1	41
1200-bps dataline	0	5	1	0	2	63	1	-
Microwave system	-	-	-	-	-	-	-	-

The paragraphs that follow discuss significant anomalies.

A. IOS, Rev 1

INDI had problems with the search procedures and eventually locked onto a sidelobe. Fix: Sufficient TM data was processed to permit evaluation of vehicle health. Impact: Tracking data, which was needed for early orbit determination, was not available.

B. VTS, Rev 406

Data received from the vehicle tape recorder was noisy because the SGLS-46 antenna operator inadvertently locked the antenna onto a sidelobe. Fix: The operator made several unsuccessful attempts to acquire the mainlobe, and the test controller turned the vehicle tape recorder off. Impact: The vehicle could not be commanded into the desired telemetry configuration.

C. NHS, Rev 573

The command modulation index of the SGLS-60 Transmitter was incorrectly adjusted. Fix: Support was provided by using the SGLS-46 Transmitter. After Rev 590, the incorrect modulation index was discovered and corrected. Impact: Transmission of the desired commands was delayed until Rev 574 at NHS.

D. KTS, Rev 496

A bad prepass disk was on the 1230 MTC. The RTS did not detect the fault during prepass checks. Fix: No recovery from fault during the pass. Impact: RTS could not command.

E. KTS, Rev 650/651

The SGLS-14 Transmitter could not be activated because of arcing in the 21.5 Kv cable. Fix: An outage (JCN31082205) was opened. The cable was repaired and the outage was closed on the following day. Impact: The vehicle could not be commanded into the desired telemetry configuration for recovery.

F. VTS, Rev 754/755

Power failure prevented RTS support. Fix: None. Impact: The failure prevented planned command message loading.

G. OL-5, Rev 1054

A failed driver unit in the SGLS-14 Transmitter prevented the activation of the transmitter. Fix: The station used the helix-antenna to complete as much of the command plan as was possible. Impact: Some of the planned commanding could not be accomplished.

6.2.3 Recovery Operations

As a result of the RV Battery overheating and failure on SV-4, a special battery discharge unit (BDU) was used after each recovery on this mission. The BDU was used to prevent the battery from damaging the contents of the capsule.

6.2.3.1 Recovery 1205-1

The first capsule was aerially recovered on the second attempt. The first attempt was aborted because the capsule's parachute had a high rate of oscillation.

6.2.3.2 Recovery 1205-2

The second capsule was aerially recovered by Venue 1 on the third attempt. Two intentional pulloffs were made because of capsule parachute oscillations of up to 30 degrees.

6.2.3.3 Recovery 1205-3

The third capsule was recovered by Vela 1 on the first attempt. The strobe light was on when the capsule was reeled in, but it had not been observed to be on before the capsule was engaged by the recovery aircraft.

6.2.3.4 Recovery 1205-4

The fourth recovery capsule was recovered by Beast 1 on the second attempt. Parachute and cone oscillations caused the pilot to abort the first recovery attempt. Prior to the recovery, the crew observed a 3' hole in the parachute's cone skirt.

6.2.3.5 Recovery 1205-5

The MK-5 capsule was recovered by Jaggy 1 on the first attempt. The reporting of recovery events by the recovery aircraft crew was impeded by poor HF reception.

6.2.4 Command Message Generation

A one rev load philosophy was employed, whereby the [redacted] add on message is generated each (b)(1)
rev in order to use the latest weather data. There were 853 command messages generated during the (b)(3)
primary mission of which 5% were rejected. The message rejections were primarily caused by violations of hardware constraints and changes in payload selections. Message problems included (a) a bad station pass (SP) message resulting from selection of a bad vector which gave large ephemeris errors, and (b) a computer malfunction which gave random on/off commanding of the SGLS Transponder.

APPENDIX A - REFERENCES

APPENDIX B - GLOSSARY

PERFORMANCE EVALUATION TEAM
REPORT NO. 1205/73

APPENDIX A

REFERENCES

1. HEXAGON Program Preliminary Post Flight Report Flight No. 5. Technical Advisory Report, BIF-107W-71014-73, 30 May 1973, (S/H)

2. Flight Test Engineering Analysis Report for the HEXAGON Program Satellite Vehicle No. 5 BIF-003W/12-069747-73, 27 June 1973, LMSC Integrating Contractor. (TS/H)

3. Satellite Control Facility Operations Evaluation Report, 13 June 1973. (S/H)

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APPENDIX B

GLOSSARY OF TERMS

ACC Mode	Software Option that Finds Areas of Intelligence Value for a Rev Span.
ACS	Attitude Control System.
AFSPPF	Air Force Special Projects Production Facility.
Aft	Aft-looking Camera, Camera B.
AIM	Aerial Image Modulation.
AOB	Air Order of Battle.
AOES/System II	General Purpose Satellite Flight Support Software at STC.
AUGIE	Acronym for Data Compression Technique Used for RTS to STC Data Transmission.
AVE	Aerospace Vehicle Equipment.
BBRT	Bird Buffer Retrieval Tape. Records at STC From Transmissions From RTS.
BRIDGEHEAD	Primary Film Processing and Immediate Post Flight Evaluation Facility.
C-	Camera Power-off Command.
C+	Camera Power-on Command.
CEI	Contract End Item.
CEWG	Color Evaluation Working Group.
Chamber A	Photographic Vacuum Test Chamber Located at East Coast SSC Facility.
Chamber A-2	Photographic Vacuum Test Chamber Located at SVIC Facility.
CIE	Commission Internationale de l'E' clairage (lighting).
CHG	Command History Generator.
c/mm	Cycles Per Millimeter.
CMG	Command Message Generator.
CMU	Command Message Update.
COMIREX	USIB Committee on Imagery Requirements and Exploitation.
CORN	Controlled Range Network.
CORREL	On-orbit Adjust Assembly Calibration Test Program.
CRYSPER	On-orbit Performance Prediction Program Combining Target Acquisition, Atmospheric, Illumination, and Camera Performance Models.
CRYSTAL BALL	Photometric Atmospheric Model Computer Program. Used to Calculate Exposure for Orbital Acquisitions.
CV	Constant Velocity.
CW	Continuous Wave.
DEA	Decision Element Array.

APPENDIX B (CONT'D)

DGMAP	Computer Program for Magnetic Force Field Predictions.
DIM	Dynamic Image Motion.
D log E Curve	Sensitometric Response of Film to Light. Plot of Density to Log of Exposure.
DMAAC	Defense Mapping Agency Aerospace Center.
DMATC	Defense Mapping Agency Topographic Center.
DN	Duplicate Negative.
DP	Duplicate Positive.
DRAP	Pulse Code Modulation TM Data Retrieval and Analysis Program.
ECO	Engineering Change Order.
ECS	Extended Command System.
EM	Electromechanical.
EMI	Electromagnetic Interference.
END	Equivalent Neutral Density.
EOD	Electro-optical Department.
ESD	Emergency Shutdown.
EXSUBCOM	Exploitation Subcommittee of COMIREX.
EXTRFPLS	Focal Plane Position Transducer and LSFS Reading Extractor Program.
FAFNIR	Program that Locates CORN Deployed Targets and Edge Catalog Targets.
FAK	Forward Assembly Kit.
FBS	Film-to-Bar Synchronization.
FFL	Flange Focal Length.
FIDAP	Flash Image Displacement Analysis Program.
FOCMO	Thru Focus Motion Plot and Line Indicated Focus Program.
Fwd	Forward-looking Camera, Camera A.
FPP	Focal Plane Position.
fps	Feet Per Second.
FT	Film Transport.
FTFD	Field Test Force Director.
GAWA	Grand Area Weighted Average.
GMT	Greenwich Mean Time.
GOB	Ground Order of Battle.
GRD	Ground Resolved Distance.
HFLIP	Data Strip and Print Program.

APPENDIX B (CONT'D)

HOPE	Operational Performance Estimated Report. Summarizes Key Performance Related TM Data for Mission Engineering Operations.
HWT	Hardwire Tester.
Hz	Hertz (Cycles Per Second).
IAS	Imagery Analysis Service.
ICD	Interface Control Document.
IMC	Image Motion Compensation.
IOR	Interop Runout.
ips	Inch(es) Per Second.
IR	Infrared.
KALEIDOSCOPE	Radiometric Acquisition Model. Used to Calculate Basic Exposure Time Versus Solar Altitude, Haze Level, and Target Spectral Reflectance Characteristics.
LIFEBOAT	Incorporates Minimal Command System and Tertiary Attitude Reference System for Achieving Alignment to Effect Recovery of Two RVs and to Deboost the SV in case of Mission Terminating Command System or Attitude Control System failure.
LMODE	Off-line Program that Extracts Camera Data From BBRT for MPR Generation.
LSFS	Lateral Separation Focus Sensor.
MAA	Mission Analysis Area.
MACFACT	Mission Accomplishment Factor Program. Used to Process Key Performance Related Electromechanical Data.
MCM	Mapping Camera Module.
MCRECON	TM Cross-track Smear Estimate Program. Processes the Metering Capstan Summed Error Signal to Produce an Estimate of Film Motion and Absolute Smear Levels.
MES	Mission Evaluation Score.
MFA	Measurement Filter Assembly.
MIP	Mission Information Potential.
MIPOLPER	Program which Combines the Optical Transfer Function Program with the Performance Prediction Program.
MONO	Monoscopic Operation.
MPR	Mission Performance Report.
MR	Malfunction Report.
MRB	Material Review Board.
MTF	Modulation Transfer Function.
MWC	Midwest Contractor.

APPENDIX B (CONT'D)

NBS	National Bureau of Standards.
NCVU	Negative Constant Velocity Unit.
NM	Nautical Miles.
NPIC	National Photographic Interpretation Center.
OAK	NPIC Publication that Lists First Phase Exploitation Results.
OAS	Orbit Adjust System.
OB	Optical Bar.
OFK	Orbital Fixed Knowns.
ON	Original Negative.
OP	Camera System Operation.
OTD	Optical Technology Division of SSC.
OOAA	On-orbit Adjust Assembly.
PBF	Plane of Best Focus.
PBM	Power Bus Module.
PCM	Pulse Code Modulation.
PDS	Power Distribution System.
PERFORM	Camera Resolution Performance Prediction Program.
PERSAP	TM Resolution Performance Prediction Program. Estimates From Metering Capstan Telemetry and Measured Optical Performance.
PFA	Post Flight Analysis.
PFALINES	Post Flight Analysis Line Program. Computes 2:1 Resolution Performance and Estimates Image Motion Amplitudes.
PI	Photointerpreter.
PN NEG (-)	Pneumatics-off.
PN PLUS (+)	Pneumatics-on.
psi	Pounds Per Square Inch.
rad/sec	Radians Per Second.
RCS	Reaction Control System.
REV	Orbital Revolution.
RMS	Root Mean Square.
ROM	Rough Order of Magnitude.
RTS	Remote Tracking Station.
RV	Recovery Vehicle.

APPENDIX B (CONT'D)

SAL	Scan Angle Length.
SBA	Satellite Basic Assembly.
SBAC	Satellite Basic Assembly Contractor.
SCF	Satellite Control Facility.
[redacted]	
SETS	Sensor Subsystem Engineering and Technical Support Staff.
SLC-4E	Space Launch Complex-4 East.
SOC	Satellite Operation Center.
SOF	Start of Frame.
Solo	System Engineering Test after Fourth RV Separation.
SS	Sensor Subsystem.
SSC	Sensor Subsystem Contractor.
SSTC	Sensor Subsystem Test Console.
STC	Satellite Test Center.
SU	Supply Unit.
SURVEY	Quick-look Time and Data Characteristics Program.
SV	Satellite Vehicle.
SVFRT	Satellite Vehicle Frame Reference Time.
SVIC	Satellite Vehicle Integrating Contractor.
SVT	Satellite Vehicle Time.
SYNCER	FIDAP Subroutine for Determining Film Synchronization Error.
TCA	Two-Camera Assembly.
TM	Telemetry.
TMOTION	Estimate of Image Smear Program for Laboratory Tests.
TOBACC	Time for OB Velocity Command.
TU	Take-up Unit.
TUNITY	Computer Program for HEXAGON mission support at the STC.
USIB	United States Intelligence Board.
UTB	Ultra Thin Base Film.
VAFB	Vandenberg Air Force Base.
VEM	Visual Edge Match.
Vx/h	Orbital Angular Rate, In-track.

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

APPENDIX B (CONT'D)

Vy/h	Orbital Angular Rate, Cross-track.
WCFO	West Coast Field Office (Contractor).
WCPO	West Coast Project Office (Government).