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October 1967

VEHICLE 726 ANOMALY INVESTIGATION REPORT (U)

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Program TA

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[redacted]

CY # [redacted]

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[redacted]

8 November 1967

To: [redacted]

From: [redacted]

Dear Sir:

Three copies of our final report on the Use 726 anomaly are attached and additional copies are being distributed per your direction.

You will note that our final conclusion is the same as our preliminary one which was documented in [redacted] dated 7/27/67 - the most probable cause was a partial failure of the phenolic nylon heat shield which precipitated an unusual chain of events. These events, in turn, resulted in parachute deployment at such a low altitude that air recovery was virtually impossible.

In parallel with our post-flight analysis of Use 726, we conducted a thorough investigation of all heat shields in the field to ascertain whether any contain potential failure characteristics. All of these shields have now been reapproved for flight. We also conducted a complete review of the design, manufacturing and inspection of phenolic nylon heat shields. Certain minor improvements are being made in each of these areas as the result of this review.

Very truly yours,

[redacted] Manager
[redacted] Program

/rl
cc: [redacted]

[redacted]

[redacted]

[redacted]

FOREWORD

Anomalous performance of the General Electric Satellite Re-entry Vehicle (SRV) No. 726 was observed during re-entry on 1 July 1967. An investigation of the SRV No. 726 Pre-Flight, Flight, and Post-Flight history was conducted, and the results are presented herein.

[redacted]

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1.0 Introduction

During the re-entry portion of the Program TA Vehicle 726 flight the SRV experienced an erratic motion history. This resulted in a delayed parachute deployment which necessitated a water recovery.

To determine the possible reason or reasons for this failure the available data, consisting of recovery subsystem and axial acceleration data were examined to determine the cause of the anomaly. A point mass trajectory was calculated based on initial conditions at deboost, and from axial acceleration data and a roll rate history derived from the signal strength, the vehicle dynamics were investigated as far as practical based on the amount of data available. The shield process and inspection histories were investigated and the recovered capsule was subjected to system and component tests. The results of these investigations are presented herein.

2.0 Flight Summary [redacted]

Program TA SRV 726 was launched from AFWTR on June 16, 1967. The flight duration was 15 days of an on-orbit operation, terminated by deboost recovery which occurred during revolution 240 on 1 July 1967.

The launch, orbital, and deboost phases were normal. However, during re-entry, an apparent roll acceleration was initiated shortly after the end of blackout, at an altitude of approximately 89,000 feet. About 12 seconds later a perturbation in the SRV axial accelerometer data was observed. This motion data was monitored by three different telemetry receiving stations. The data received by these stations, indicating anomalous SRV behavior, was as follows:

(a) The telemetry signal strength exhibited the typical periodic variations in signal strength. However, the frequency increased rapidly, which signified a corresponding increase in roll rate.

(b) Axial accelerometer data, which normally increases from saturation (-5g's) to -1g, remained essentially at the -5g saturation level with spurious excursions above zero. On one spurious excursion the level reached +3.9g's.

(c) The recovery subsystem inerital switches repeatedly opened and closed in response to the anomalous axial acceleration. This caused repeated recycling of the programmer 34 second timers, so that drogue ejection was delayed until an altitude of about 20,000 feet. The planned drogue ejection altitude was about 55,000 feet.

After thermal cover ejection, the presence of spurious noise pulses was observed on the axial accelerometer data channel for a period of approximately 31 seconds.

Because of the delayed chute deployment, the capsule was not sighted until it was too low for an air snatch. Consequently, a water recovery was necessary.

[redacted]

A visual examination of the recovered capsule revealed numerous dents and scratches on the capsule skin.

The aforementioned anomalies are analyzed and correlated in paragraph 4.

[redacted]

2.1 Conclusions

From the analysis given in paragraph 4, the following conclusions were made:

(a) The orbital temperature data does not indicate any abnormal temperature environment

(b) The re-entry trajectory of SRV 726 was very close to the planned trajectory. The anomaly occurred after the peak deceleration, dynamic pressure and heating rate altitudes.

(c) The thrust cone separation sequency was normal with clean electrical disconnect and separation.

(d) Early re-entry of SRV was normal until 89,000 feet as indicated by axial acceleration data and roll rate derived from signal strength measurements.

(e) At 89,000 feet the presence of a "fin" of about 5 square inches effective area could have caused a roll torque of about 8 ft. lbs. The vehicle experienced a roll acceleration until apparent removal of the "fin" at approximately 69,000 feet altitude. At this time the roll rate peaked at 300 rpm and began to decrease.

(f) It is postulated that the effective "fin" was most likely created by a circumferential section of the shield breaking loose and thereby, providing a protuberance in the airstream.

(g) The capsule internal temperature sensors indicated that the internal skin temperatures were greater than $100^{\circ}F$ but less than $150^{\circ}F$. These temperatures are consistent with temperatures experienced on other flights of the SRV 726 type configuration where re-entry anomalies did not occur.

(h) Repeated closures of the inertial switches repeatedly recycled the 34 sec. timers, resulting in a delayed chute deployment.

(i) As verified by post-flight component and subsystems tests, all subsystems and subsystem components operated normally. The telemetered accelerometer data was representative of the axial component of acceleration, as sensed by the accelerometer in its location off the C.G. The recovery subsystem inertial switches operated normally by opening and closing in response to the axial component of acceleration, as sensed in their location off the C.G.

(j) The process and assembly inspection histories of shield no. 306 indicates that it was a prime shield. No reason could be found to reflect doubt in the integrity of the shield.

(k) The anomaly experienced by SRV 726 was probably caused by a random structural failure of the shield.

C [redacted]

2.2 Vehicle Configuration

The configuration of SRV 726 was similar to other TA vehicles previously flown, i.e. there were no distinct differences or significant changes in vehicle configuration.

The SRV system consists of the necessary hardware to survive the powered flight, orbital and re-entry environments. The SRV is comprised of two major assemblies, the thrust cone (T/C) assembly and the capsule/forebody assembly.

The thrust cone assembly provides the deboost capability of the SRV for de-orbit operations. Upon receiving the transfer signals from the spacecraft, the T/C thermal batteries are activated and the SRV/spacecraft electrical separation is accomplished. Electrical separation initiates the T/C programmer sequence. The T/C programmer provides a sequence of output signals which spins up the SRV, fires the retrorocket, despins the SRV, and finally electrically and physically separates the T/C assembly from the capsule/forebody assembly.

The capsule/forebody assembly is comprised of the recovery capsule which is enclosed in the heat shield. The capsule contains the recovery subsystem components which enable an air snatch or water recovery, and the tracking beacon and telemetry components. Upon ejection of the thermal cover, the recovery capsule is free to disengage from the heat shield. However, the capsule remains in the heat shield due to aerodynamic drag until deployment of the drogue, which is attached to the capsule structure. Deployment of the drogue and deceleration chute decreases the capsule velocity, introducing a difference between the capsule and heat shield velocities. This velocity difference causes the capsule to separate from the heat shield. Deployment of the recovery chute decreases the capsule rate of descent sufficiently to enable an air snatch recovery or structural survival of the capsule upon water impact.

On the date of recovery, the SRV 726 heat shield (S/N 306) was 9½ months old. The history of this heat shield and post-flight tests of some recovered capsule components are discussed in paragraph 4.0.

2.3 SRV Mass Properties

The weight and balance data of the capsule and available data of the SRV are presented in Table 2-1.

2.4 Sequence of Events

Table 2-2 lists the sequence of events from arming of the recovery subsystem through deboost, thrust cone separation, and recovery subsystem operations.

The predicted times were supplied to General Electric by an associate contractor. The actual values were obtained from analog records from the [redacted] Tracking Station (deboost area) and a telemetry ship (recovery area). Aircraft data were also available from the recovery area but it was not as clean as the ship data.

Table 2-1 S/N 726 Weight and Balance Data

	Weight	C.G. Position			Moments of Inertia			Products of Inertia		
		X INCHES	Y INCHES	Z INCHES	I_X lbs in^2	I_Y lbs in^2	I_Z lbs in^2	I_{XY} lbs in^2	I_{XZ} lbs in^2	I_{YZ} lbs in^2
RV	285	13.72	+.001	-.001	24878	27465	25842	+59	-19	-85
SRV	374.5	18.24	0.00	0.00	29804	NA*	NA*	+115	+10	NA*

NA* not available at this time.

[redacted]

[redacted]

[redacted]

2.5 Observed Anomalies

During the re-entry of vehicle no. 726, various anomalies were indicated by vehicle telemetry. These anomalies are described in the following paragraphs.

2.5.1 Roll Acceleration

After despin the vehicle roll rate was approximately 10 rpm. This was within the specified value of 10 ± 6 rpm. After blackout, the roll rate was approximately 8 rpm. However, during re-entry between approximate altitudes of 96,000 and 69,000 feet, the vehicle experienced an anomalous roll acceleration which resulted in a peak roll rate of 300 rpm at an approximate altitude of 69,000 feet. The roll rate history after blackout, as derived from signal strength variations, is shown in Figure 2-2.

2.5.2 Axial Acceleration

Upon acquisition of telemetry data, after blackout, the telemetry ship data (channel 7) indicated that the recovery subsystem G switch closure had occurred as planned. This data is shown in figure A-2.

A comparison between measured axial acceleration and the axial acceleration calculated from point mass trajectory are shown in figure 2-3. After blackout, when axial acceleration decreased in magnitude below the accelerometer saturation level, the accelerometer output and the calculated acceleration remain in very close agreement for approximately thirteen seconds. Therefore, from this correlation, it was concluded that the deboost phase was satisfactory and re-entry, until approximately 76586 seconds (altitude 89,000 feet), was normal. However, after this time, the axial accelerometer data indicates an anomalous motion history which repeatedly saturated at the -5G level and spuriously peaked as high as +3.8 G's.

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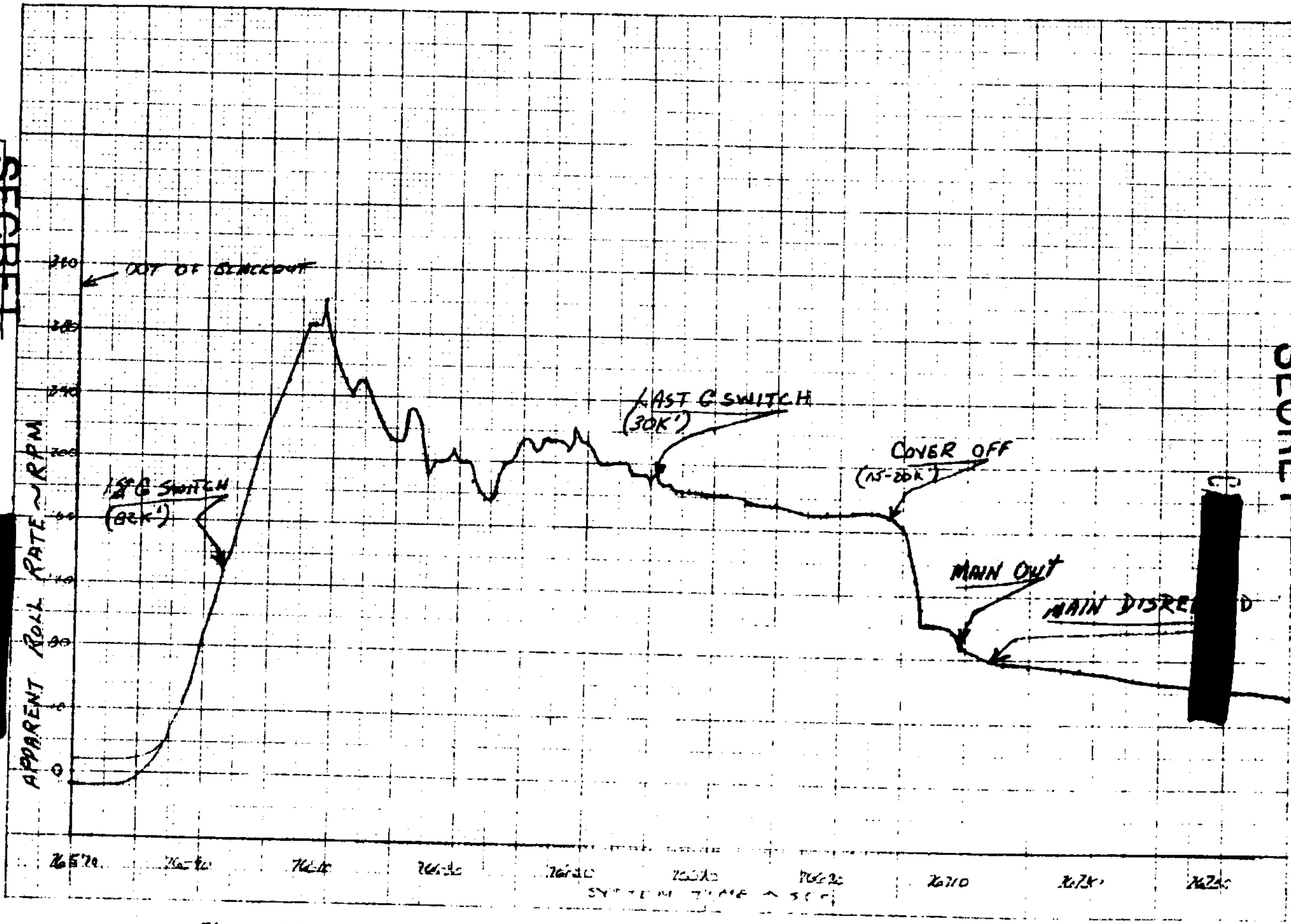

Figure 2-2 SRV 726 Derived Roll Rate History

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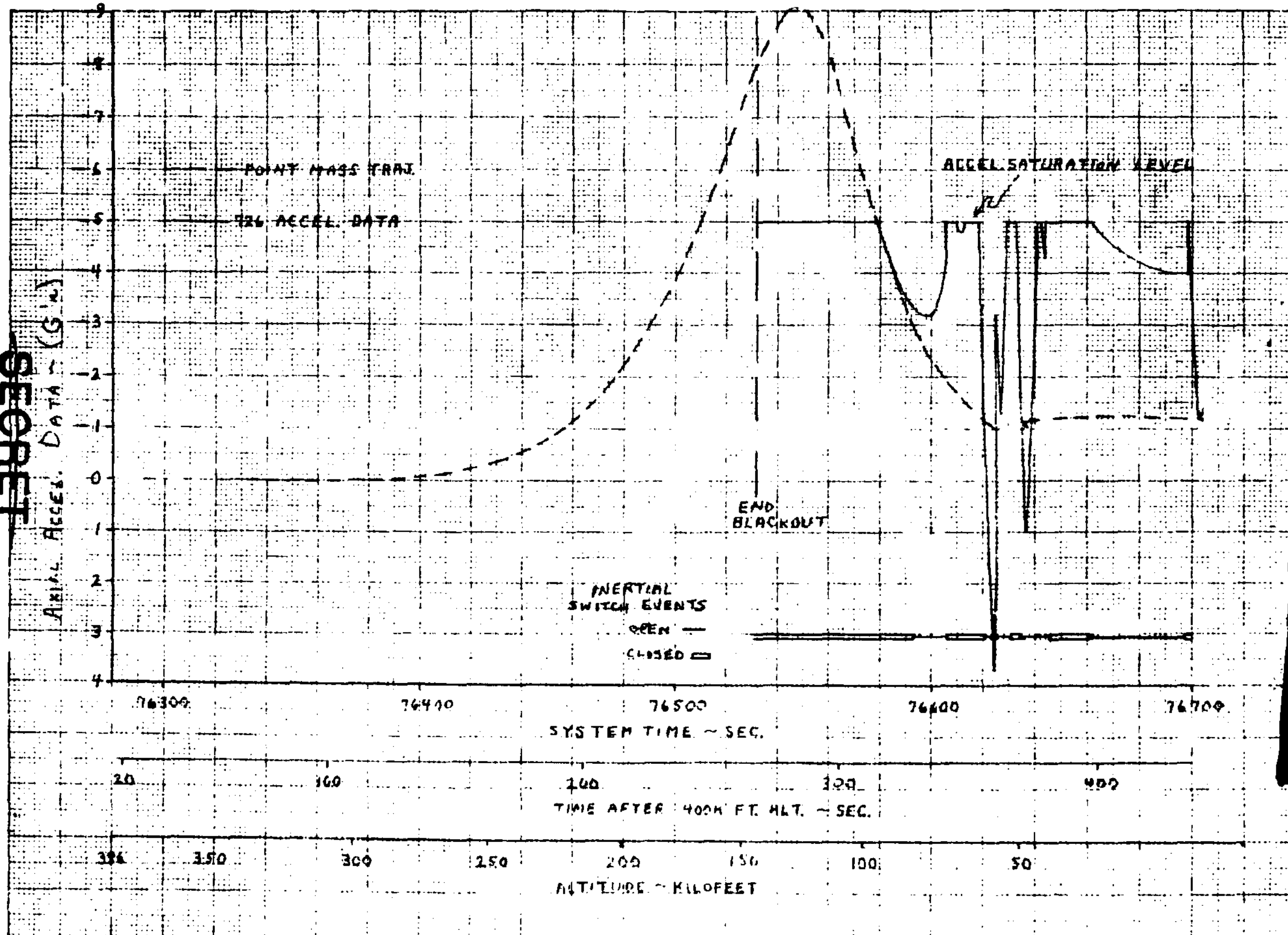

Figure 2-3 SRV Axial Acceleration Data and Inertial Switch Events

[redacted]

2.5.3 Inertial Switch (3G's)

Anomalous indications were also present on the inertial switch telemetry monitor (see figure A-2). The switch contact openings and closures are shown with the axial acceleration data in figure 2-3. As shown, the switch opening and closure times correspond fairly well, in time, to excursions of the axial accelerometer data above and below the 3G level. Therefore, the switch is responding to the anomalous axial accelerations. (Note: Only one of four inertial switches is monitored.)

[redacted]

Table 2-2 SRV 726 Sequence of Events

Event	Planned Occurrence Δt (sec)	Planned Occurrence Tolerance (sec)	Predicted Time (sec)	Measured Occurrence Δt (sec)	Measured Occurrence Event Time (sec)	Remarks
Arm	0	----	76042.35	0	75968.06	
Transfer	75	---	76042.35	74.89	76042.95	
Electrical Disconnect	0.9	+0.43 -0.40	-----	0.85	76043.80	
Separation(SRV)	1.10	±0.50	-----	1.16	76044.96	
Spin	2.30	±0.30	----	2.22	76047.18	Roll rate = 60.6 rpm
Retro	7.55	±0.45	76054.20	7.26	76054.44	
Despin	10.75	±0.54		10.39	76065.03	Roll rate = 10 rpm
Electrical Separation(T/C)	1.50	±0.15	76066.45	1.51	76066.54	Mechanical separation: 760[redacted]4
G Switch Closed**	---	----	----	---	------	Planned A_x = 3 G's Rising
G Switch Open*	535.95	----	76602.40	526.52	76661.76	A_x = 3.2 G;s falling
Chute Thermal Cover	34.0	±1.5	76636.40	36.26	76698.02	Relays K9 and K10 actuated indicating piston fire at 76697.99 sec.
Drogue Out	0.63	±0.08	----	0.43	76698.45	Time out of tolerance

*Last G switch opening and closing event times. Anomalous switch openings and closures followed. See paragraph 2.3.2.

**Occurred during blackout. Therefore, event time not available.

[redacted]

Table 2-2 SRV 726 Sequence of Events (continued)

Event	Planned Occurrence Δ t (sec)	Planned Occurrence Tolerance (sec)	Predicted Time (sec)	Measured Occurrence Δ t (sec)	Measured Occurrence Event Time (sec)	Remarks
Main Chute Out	10.25	+3.00 -2.20	-----	10.39	76708.84	
Main Chute Reefed	0.52	±0.13	---	0.49	76709.33	
Main Chute Dereefed	4.50	±0.80	76652.30	4.61	76713.94	

3.0 Anomaly Investigation

3.1 Mission Profile

The following orbital parameters for the SRV 726 flight were supplied by an associate contractor. These conditions apply for deorbit.

Height or perigee (h_p)	102 nautical miles
Height of apogee (h_a)	196 nautical miles
Inclination angle (i)	80°
Latitude of Perigee (θ_p)	65.8° north latitude
SRV 726 Weight	374.5 lbs.

The boost phase of flight was normal with no unusual shocks or vibration transients reported.

The temperature history given in table 3-1 was obtained from an associate contractor (Reference 2). These temperatures are within the expected values.

Table 3-1 SRV 726 Orbital Temperature History

Revolution No.	Bat. Temp. (°F)	T/C temp. °F near retro	T/C temp. skin (°F)
95	65	76	34
105	74	70	62
111	79	68	60
120	80	66	60
127	81	66	60
136	75	67	61
143	77	64	58
152	75	65	61
159	73	64	58
168	80	64	60
175	76	61	58
184	82	62	60
191	76	61	58
200	81	64	60
207	73	60	59
215	80	59	60
223	80	62	60
232	79	64	64

3.2 Deorbit/Re-entry Parameters [redacted]

The following deorbit/re-entry parameters, as obtained from an associate contractor, were normal.

Latitude at retrofire	55° N. Latitude
Velocity (relative)	25,250 ft./sec.
Path Angle (relative	2°
Impact	22° N. Latitude
	149° W. Longitude

A profile of deboost/recovery events during re-entry is given in figure 3-1. During the deboost phase, telemetry coverage was available from [redacted] only. [redacted] acquired at 79568 seconds and faded at 76211 seconds.

3.3 Recovery

Late deployment of the recovery chute precluded successful air snatch of the vehicle. Therefore, a water recovery was made at a location 23 nautical miles uprange and 5 nautical miles west of the predicted impact location. These locations, as well as the reported locations of the telemetry ship and aircraft, are shown in figure 3-2.

After blackout, telemetry coverage was available from the ship and aircraft from the end of blackout at 76533 seconds until 77376 sec. The telemetry ship data was much cleaner than the aircraft data. Therefore, the ship data was utilized as the basis for the analysis presented in paragraph 4.

[redacted]

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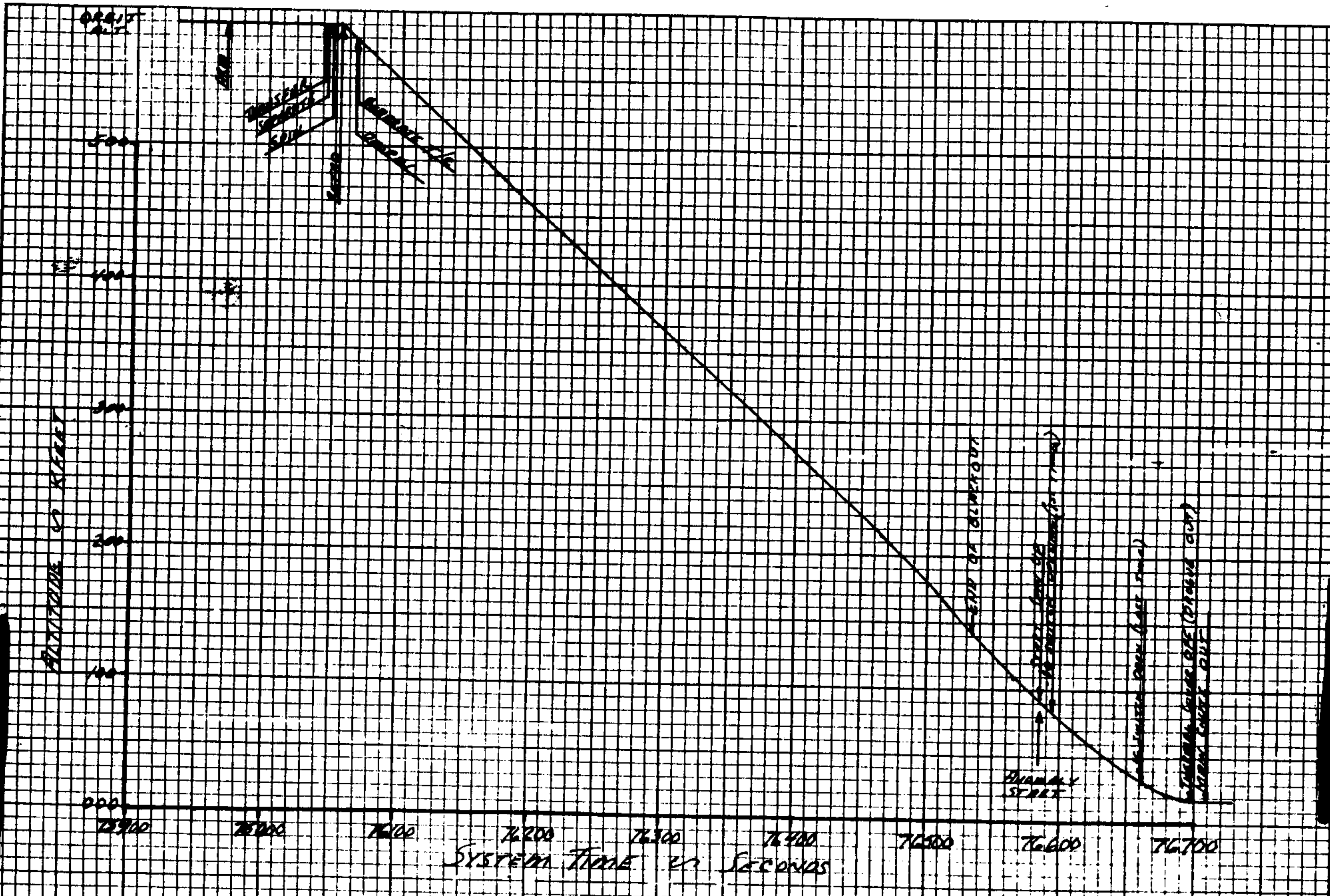

FIGURE 3-1 DEBOOST/RECOVERY PROFILE

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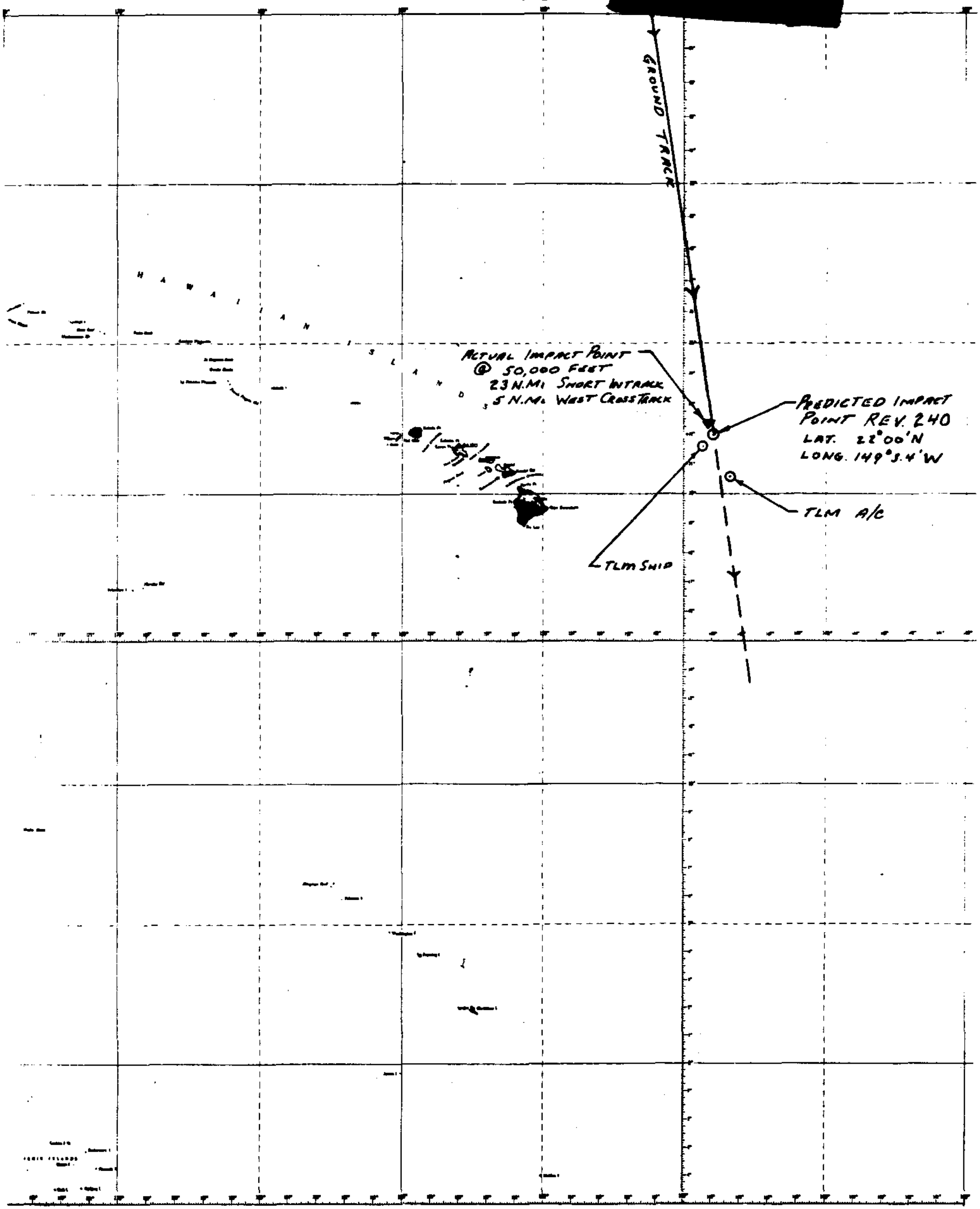


FIGURE 3-2 RECOVERY MAP VEHICLE 726

Table 3-2 Previous TA Vehicle Roll Rate Histories

Shield S/N	SRV S/N	Recovery Date	After Spin-up	After Despin	After Blackout	Peak	Drogue Out
225			N/A	N/A	62.8	92	60
229			N/A	N/A	32.2	43	41.4
230			N/A	N/A	49.0	54.6	53.6
243			N/A	N/A	*	4-5 RPM	(only 1 cyc. visible)
259			23	14	-	-	25-27
279			37	34	No sig. strength avail.		
271			60	48	46.2	46.2	46.6
256			N/A	N/A	*10	(very noisy)	
277			N/A	N/A	*12	(very noisy)	
281			57	8	-	-	23*
306			60.6	10.2	8-9	300	171

* These rates are difficult to determine and should be considered as approximate values only.

** These R/V's records were from [redacted] and all four have a 10 cps modulation on the signal strength trace. This is believed to be put on the tape by the receiving station antenna which has a 10 cps sweep rate.

3.4 Other Flights [redacted]

Analog records of re-entry roll rate data on past TA flights sent to GE-RSD for further analysis of roll rate data after spinup, exhibited apparent roll rates which were higher than the planned roll rate value after despin. However, in these cases, the magnitudes of the peak roll rate values were not as high as the roll rate of SRV 726.

A limited investigation was performed to determine the cause of the high roll rates. From this investigation it was concluded that the mass asymmetries of these vehicles were not sufficient to cause the high roll rates (Refer to paragraph 4.2.1). The roll rates during re-entry for each of these vehicles are given in table 3-2.

[redacted]

4.0 Analysis

4.1 Hardware Review

To achieve a high degree of confidence in the vehicle flight performance, the recovered capsule was subjected to a thorough inspection procedure. This procedure included a visual inspection to assess any apparent structural damage, an inspection of the internal temperature indicating tapes to ascertain the maximum internal temperature experienced by the capsule, and electrical system and selected component tests. The results of these investigations are presented in the following paragraphs.

4.1.1 Shield History (Reference 1)

Shield S/N 306 was manufactured on 13 September 1966 and subsequently designated for use on vehicle no. 726. Based on manufacturing records of phenolic this shield and other shields fabricated from the same lots of phenolic nylon and glass, no significant processing incidents occurred which would have degraded shield integrity.

During assembly a discrepancy was noted with two 0.358" holes which were mislocated through the aft edge of the forebody and interface bushing bosses. The bossess were removed and new ones were installed. The mislocated holes in the shield were filled with compound M&P 100; and after proper curing, new holes were drilled. The radial and circumferential position of the pin puller lugs and all components installed in the aft phenolic glass ring were checked.

This dimensional discrepancy was not of a critical nature. Thus, the manufacturing and process and assembly inspection records indicate that shield no. 306 was a prime shield and no incident occurred which would degrade shield integrity.

At the date of recovery from orbit (7/1/67), the shield age was slightly less than 10 months. This age is well within the maximum allowable age of seventeen months.

4.1.2 Post Flight Visual Inspection

During the visual inspection of the recovered capsule, specific attention was given to the internal temperature indicators, the capsule attachment ring shape and flatness, and the condition of the capsule outer skin.

Five temp sticks were located on the interior capsule wall. Each indicator covered the temperature range of 50 to 250°F in 50° F. steps. Four indicators were located at station 19.7, at radial locations of 0, 90, 180 and 270 degrees. The last indicator was located on the inside of the nose tip.

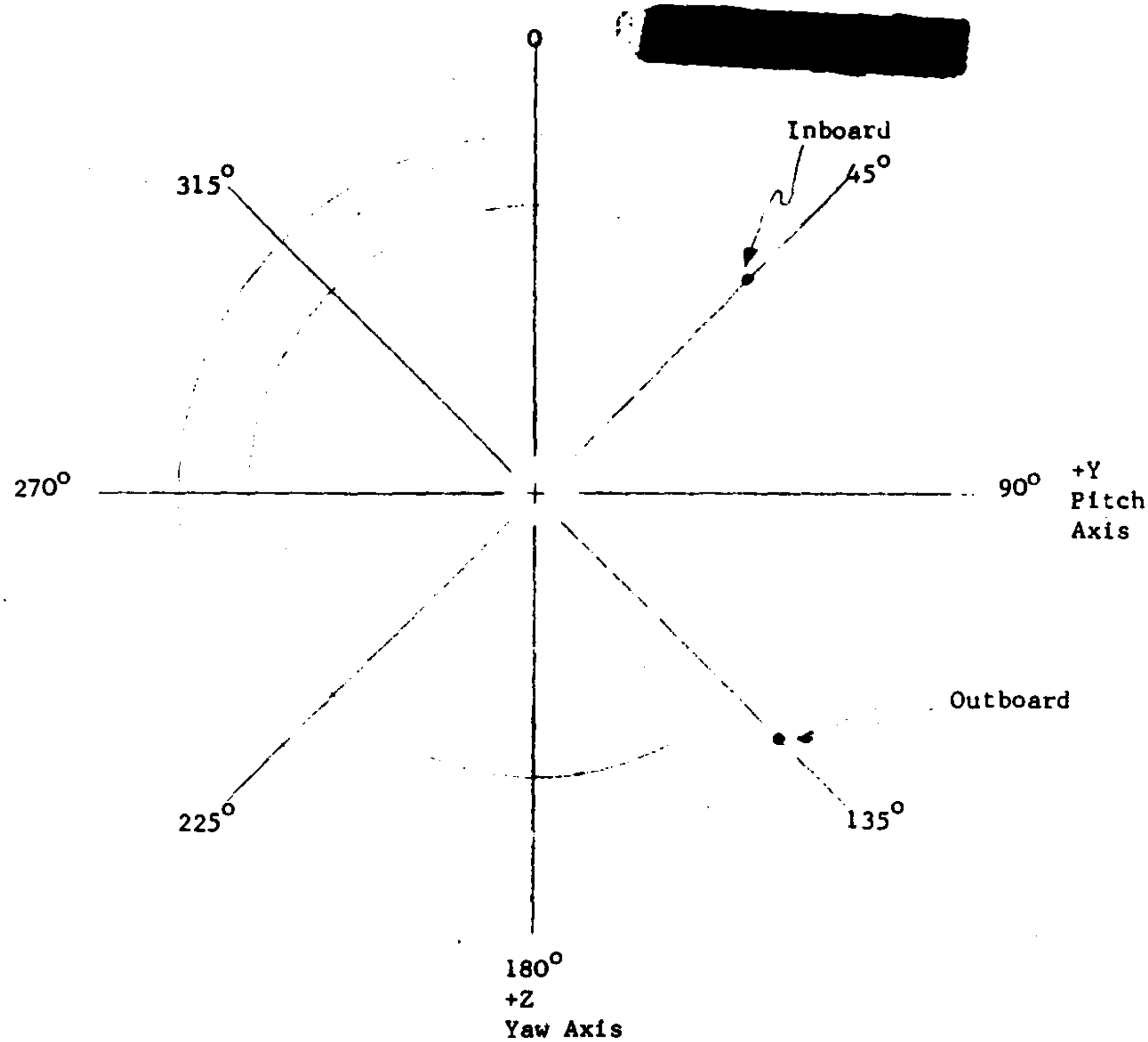
All temp sticks at station 19.7 indicated that the inner capsule wall temperature was greater than 100°F. but less than 150°F. The nose tip temp stick did not indicate any temperature rise at all, which means that the temperature at this location was less than 50°F.

The range of capsule temperatures experienced by vehicle 726 is consistent with temperature ranges which were experienced by previous recovered vehicles.

Measurements were taken on the aft mounting ring to determine the ring flatness. An outboard reference point (see table 4-1) was established at the 180° radial location, and measurements with respect to this point were made at inboard and outboard points, spaced 45°, around the ring. The inboard and outboard points were approximately one-half inch from the inner and outer edges, respectively. The measurements are listed in table 4-1. The deviations

Table 4-1 Mounting Ring Plane Measurements

[redacted]



Radial Location	Inboard (inches)	Outboard (inches)
180°	+.003	0.000
225°	-0.004	-0.006
270°	+0.008	+0.016
315°	+0.010	+0.014
0°	+0.016	+0.023
45°	+0.003	+0.002
90°	+0.013	+0.020
135°	+0.003	+0.002

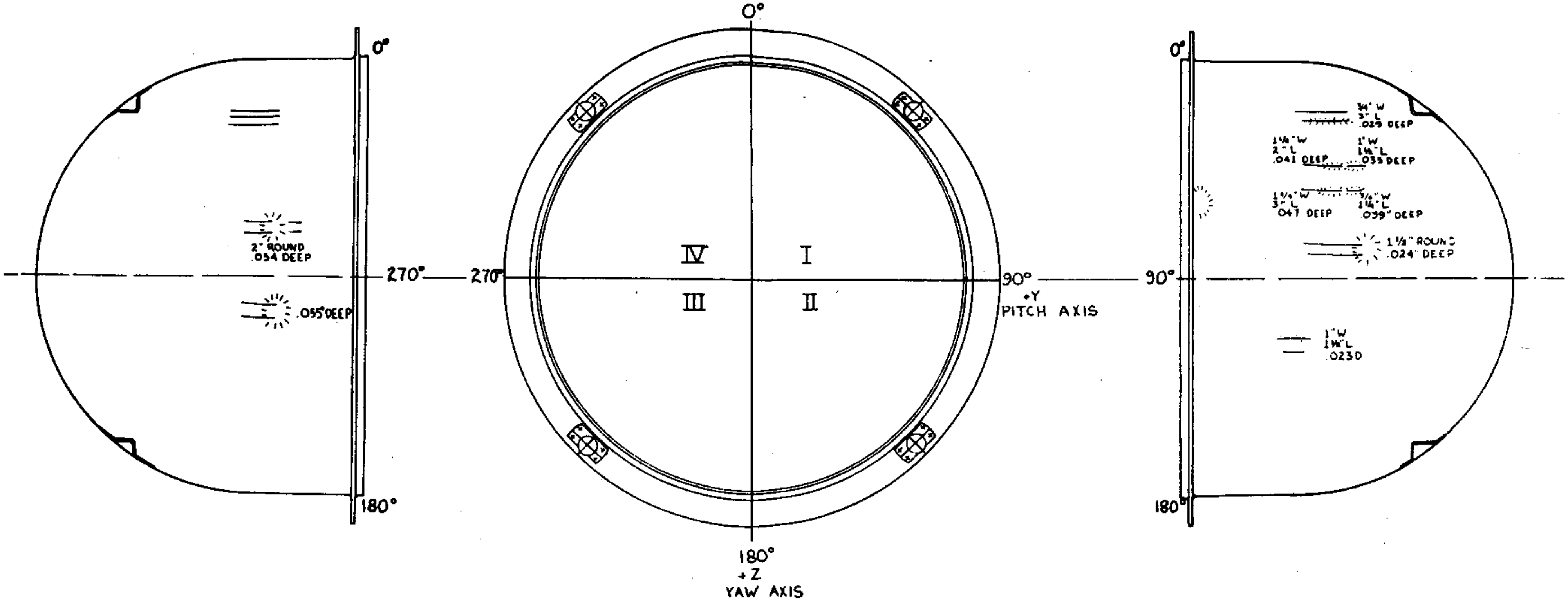
listed are expected as a result of stress from the chute deployment shock. However, the values do not reflect any effects of overheating.

Post flight inspection of the recovered capsule exterior showed numerous dents and abrasions of the skin. The location of these dents and abrasions is shown in figure 4-1.

On the basis of accelerometer data (see Appendix figure A-2), it was concluded that the capsule damage was caused by the capsule "hanging up" on the shield at the time of chute deployment.

Approximately 0.1 seconds after the firing of the chute thermal cover pistons, the accelerometer data shows an abnormal peak. For the next 32 seconds, spurious noise pulses are present in the accelerometer data. Post-flight accelerometer test data (see paragraph 4.1.4.2) did not show any noise indications, such as those shown in figure A-2, when subjected to acceleration along its sensitive axis. However, when the accelerometer was subjected to lateral shocks, at about 45 degrees from its sensitive axis, similar noise pulses appeared in the test data. Therefore, on the basis of the accelerometer test data, and the capsule damage, it was concluded that upon deceleration of the capsule by ejection of the thermal cover (at this time the deceleration normally separates the capsule from the shield), the capsule bound in the shield and relative motion between the capsule and the shield damaged the walls of the capsule. The spurious noise pulses which appear in the accelerometer data for approximately 32 seconds after chute thermal cover ejection are indicative of lateral shocks which were a result of capsule and shield relative motion. Further, if the capsule temporarily bound in the shield it is apparent

[redacted]



Figu [redacted]

that the vehicle centerline was angularly displaced significantly from the velocity vector. No estimates are available on what the magnitude of this displacement would have to be in order to cause this binding condition.

4.1.3 Post-Flight System Test

To achieve a high degree of confidence in the capsule electrical systems flight performance, the recovered capsule was subjected to the pre-flight systems test.

In the test procedure (reference 2), external power supplies were used to simulate the vehicle batteries, the spacecraft generated discretes and the arm and transfer signals.

Initially, the telemetry system and the recovery beacons were energized. After proper operation of these components was noted, the telemetry subsystem was reset and the command reset was applied to the recovery programmer. The programmer circuits reset properly and the test sequence was initiated. The programmer events, during flight and during the systems test are compared in table 4-2. The system test events were monitored from existing telemetry monitoring points.

All events occurred within the specified tolerances. It may be noted that during flight (see Appendix figure A-1 and table 4-2) the drogue ejection time did not occur within the 34$\pm$1.5 second tolerance after the final G switch opening. The cause of this is attributed to the anomalous motions experienced during re-entry and the effect of axial components of this motion on the inertial switches, which are offset from the vehicle centerline (see paragraph 4.2.1).

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Table 4-2 Comparison of Post-Flight _est Data and Flight Data

Post Flight Test Events	Event Designation	Event Tolerance (sec)	Flight Data Δt (sec)	Post Flight Test Data Δt (sec)	Remarks
Simulated arm signal	-----	-------	-------	-----	Recovery batteries activated.
					Recovery beacons no.1&2 energize by battery voltages.
Simulated Transfer signal	T_o	------	------	-----	Ignite no.1 & 2 thermal battery matches. Initiate SRV-adapter IFD and separation
Simulated SRV-adapter IFD (T/C programmer gate removed from ground)	T_1	------	------	-----	Initiate T/C programmer sequence
T/C Programmer Sequence:					
Spin	T_2	T_1+3.4 ±0.3	3.38	3.29	Ignite spin rockets. Initiate de spin timer.
Retro	T_3	T_2+7.55 ±0.45	7.26	7.39	Ignite despin rockets. Init[redacted] retro timer.
Despin	T_4	T_3+10.75±0.54	10.39	10.6	Ignite retro rocket. Initia[redacted] separation timer.
T/C Disconnect	----	T_4+1.5 ±0.15	1.51	1.48	Ignite T/C disconnect and separation squibs.
[redacted]imulated G switch [redacted]losure	----	-----	----	----	Set relays K1,K2,K3, K4. [redacted]hibit recovery programmer [redacted]ec timers.
[redacted]imulated G switch [redacted]pening	T_5	------	----	----	Enable 34 sec. timers.

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Table 4-2 Comparison of Post flight Test Data and Flight Data (continued)

Post Flight Events	Event Designation	Event Tolerance (sec)	Flight Data Δt (sec)	Post Flight Test Data Δt (sec)	Remarks
Recovery programmer 34 sec. timer timeout	----	34 ±1.5	36.26*	K7,K8: 33.93 K9,K10: 33.56	Fire thermal oover ejection pistons. Set relays K7,K8, K K10. De-energize backup tir Reset relays K1,K2, K3, K4, K7, K9, and K11.

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*Out of specification

[redacted]

[redacted]

4.1.4 Component Tests

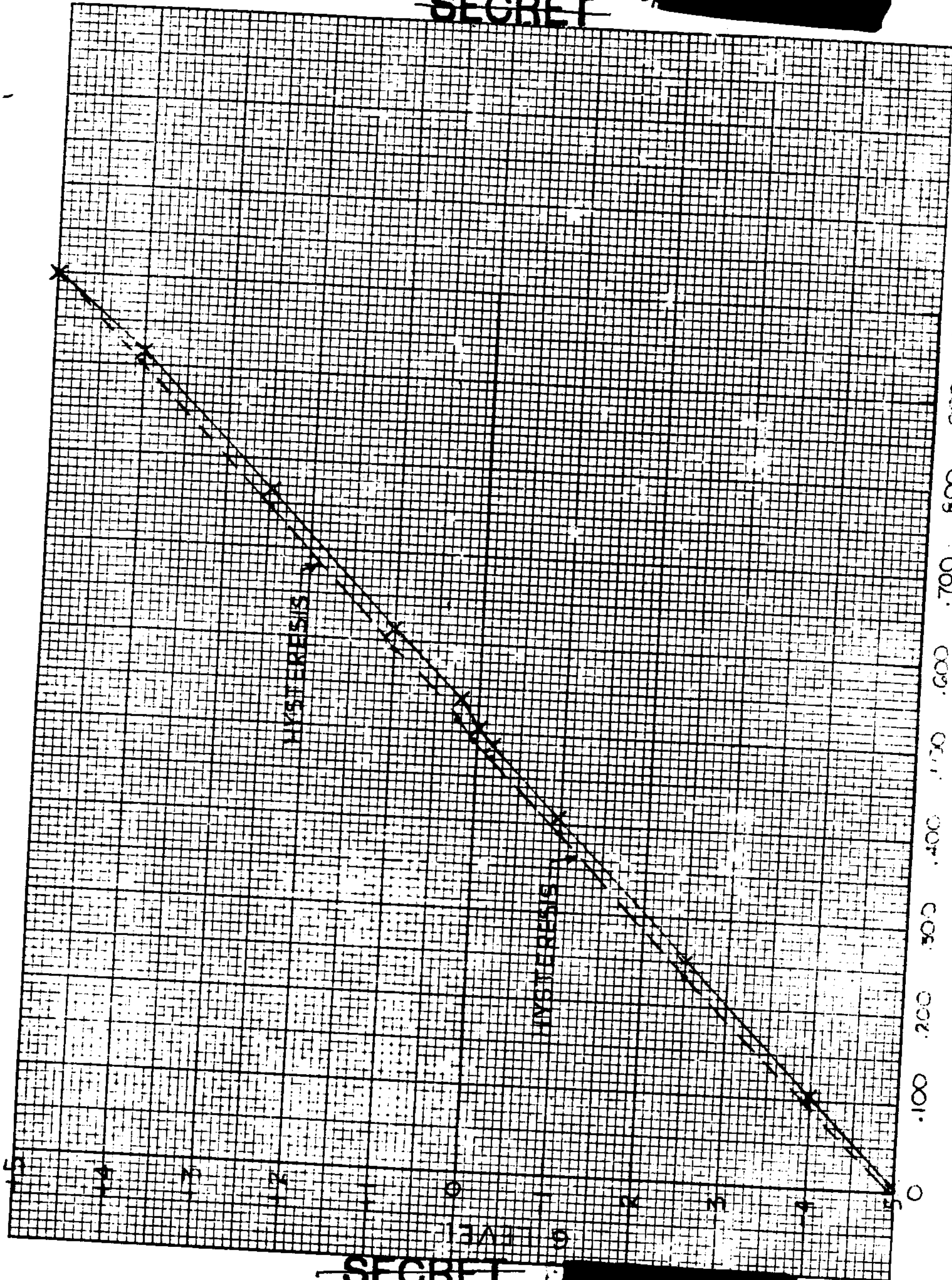
4.1.4.1 Inertial Switches

The four inertial switches (Serial Numbers 680, 686, 690, and 694) were removed from the recovered vehicle and tested on an accelerator table (reference 4). Each inertial switch, in turn, was fastened on the table at 5.4 inches from the center, so that a radial acceleration of 3G's was present when the table was rotated at approximately 140 rpm. To simulate 3G's rising and falling, the rotation rate of the table was varied between 135.3 and 144.9 rpm to obtain radial acceleration levels between 2.8 and 3.2 G's, respectively. For each switch, the rotation rate of the table was changed at three different rates so as to subject each inertial switch to acceleration rates of 0.1G/second, and 0.25G/second. As the radial acceleration was varied above and below the 3G level, the table rotation rate at which the switch contacts opened and closed were recorded. Corresponding levels of radial acceleration were calculated for each of these table rotation rates. These data are presented in table 4-3.

The calculated G levels at which the switch contacts operated were all within the specified tolerance of 3 $\pm$ 0.15 G's. Therefore, it was concluded that the inertial switches performed satisfactorily during flight.

4.1.4.2 Axial Accelerometer

The axial accelerometer was removed from the recovered capsule and tested on the accelerator table (reference 3). The speed of the table was varied to obtain various levels of acceleration. In order to obtain calibration data for each half of the accelerometer range, the accelerometer position was changed 180 degrees. For the various acceleration levels, the $\frac{\text{output voltage}}{\text{supply voltage}}$ ($\frac{Vo}{Vs}$) were recorded. Acceleration was then plotted as a function of $\frac{Vo}{Vs}$. The resulting curve, as shown in figure 4-2, indicated that the accelerometer



HYSTERESIS
HYSTERESIS
.100
.200
.300
.400
.600
.700
.800

[redacted]

Table 4-3 Inertial Switch Test Data

Acceleration Rate (G's/second)	Switch Contact Events	Table Speed (rpm)	Calculated Radial Acceleration(G's)
	Switch S/N 680		
+0.1	Open	143	3.128
-0.1	Close	140	2.998
+0.143	Open	141.6	3.067
-0.143	Close	140.1	3.003
+0.25	Open	143	3.128
-0.25	Close	140	2.998
	Switch S/N 686		
+0.1	Open	142	3.084
-0.1	Close	140	2.998
+0.143	Open	141.8	3.076
-0.143	Close	140.1	3.003
+0.25	Open	142	3.084
-0.25	Close	140	2.998
	Switch S/N 690		
+0.1	Open	142	3.084
-0.1	Close	139	2.995
_0.143	Open	140.6	3.024
-0.143	Close	139.6	2.981
_0.25	Open	142	3.084
-0.25	Close	139	2.955
	Switch S/N 694		
+0.1	Open	143	3.128
-0.1	Close	140	2.998
+0.43	Open	141.6	3.067
-0.43	Close	140.7	3.028
+0.25	Open	143	3.128
-0.25	Close	140	2.998

[redacted]

[redacted]

response was near linear over the entire range. The maximum hysteresis was approximately 0.2G. During this test, no noise was present on the accelerometer output.

The second portion of the test consisted of subjecting the accelerometer to shocks from a direction of approximately 45° from its sensitive axis to simulate relative motion between the capsule and the shield. The shocks consisted of tapping the accelerometer with a hard object. The test data indicated noise pulses which were very similar to the noise pulses on the accelerometer flight data. It is believed that the noise pulses present in the flight data are the result of lateral shocks for the following reasons:

a) The noise pulses are unidirectional towards -5G's. This level is also representative of zero volts input, or an open circuit condition which could be caused by lifting the accelerometer wiperarm from the resistive element as a result of lateral shock. If the pulses were the result of an axial component of the shocks, the direction would be randomly above and below the ambient acceleration level.

b) An intermittent connection between the accelerometer and the subcarrier oscillator was considered as the noise source. However, during post flight systems test, the telemetry system did not exhibit any type of noise condition. If the telemetry system was the source, this would have been readily apparent during systems test.

4.1.4.3 Parachute Swivel

The parachute swivel assembly was tested (reference 4) to ensure its integrity under the high roll rate conditions imposed at the time of chute deployment (86 rpm).

The swivel was placed in a bench test fixture and 200 lbs of weight was suspended from the free end. The test fixture rotated the swivel at 100 rpm for a 10 minute period. During this period, the swivel showed no sign of binding. This test served to ascertain the performance of the swivel.

The major correlatable parameter is the flight time from end of retro burn to 3G descending. This time interval agreed to within 3 seconds indicating that the computed trajectory is a good simulation of the actual one. Figures 4-3 and 4-4 present the trajectory parameters vs. altitude. The significant features to be noted are that data was recorded during peak loading and the anomaly did not occur until well after the time of peak loads and pressures. Figure 4-5 shows a typical angle of attack convergence history. Again although there is no way to determine the actual angle of attack, the vehicle has good mass properties so there is no reason to think that the angle of attack would have varied from the typical by a significant amount.

At approximately 89,000 feet a very abrupt change occurs in the flight. The vehicle begins a very rapid spin-up which appears to be accompanied by large lateral rates. The spin rate history as derived from signal strength, is shown in Figure 4-6. The spin rate quickly reaches a peak value of 300 rpm then abruptly stops spinning-up. Beyond this the spin begins to decrease and vary erratically, the dotted curve in this region indicates that the rates are approximate because of the vehicle motions which result in a signal strength record from which it is difficult to derive the spin rate.

Using the dynamic pressure history arrived at in the simulated trajectory and the relationship

$$I_x \dot{p} = C_l \; q_\infty S d$$

or

$$C_l = \frac{I_x \dot{p}}{q_\infty S d}$$

where

I_x = roll moment of inertia

$\dot{p}$ = roll acceleration

q_∞ = free stream dynamic [redacted]

[redacted]

4.2 Re-entry Dynamics

4.2.1 Flight Dynamics

It is believed that vehicle 726 experienced a violent motion history near the time of planned chute deployment as a result of a large "effective fin", on the heat shield. As a result of these motions, the axial acceleration components sensed by the recovery programmer G switches caused repeated recycling of the programmer 34 seconds timers. Consequently, chute deployment was delayed for approximately 35,000 feet below the planned chute deployment altitude.

Flight data, from SRV separation to [redacted] (rev. 240) loss of signal, indicates normal performance from SRV separation through spinup to approximately 60 rpm, retrofire, and despin ato about -10rpm. The vehicle roll rate after blackout is constant and near the despin rate (approximately -8rpm), indicating that the vehicle trajectory and motion were normal. (Combinations of mass asymmetries can account for roll rate variations of approximately ±5 rpm even without the development of aerodynamic asymmetries. Aerodynamic asymmetries can account for roll rate variations up to ±20 rpm by the time of G switch opening.) Also the measured axial acceleration history follows the predicted values, down to an approximate altitude of 89,000 feet. Therefore, although data is not available from [redacted] loss of signal to 140,000 feet during re-entry, the re-entry is considered normal until 89,000 feet altitude.

Tracking data is not taken on these flights so a composite trajectory was put together coupling a Keplerian orbit section from de-boost to re-entry (400,000 feet) then a point mass simulation to the ground. The re-entry conditions thus arrived at are:

$h = 400{,}000$ feet

$V = 25252$ fps (relative geodetic)

$\gamma = 2.005$ deg.

[redacted]

SECRET [redacted]

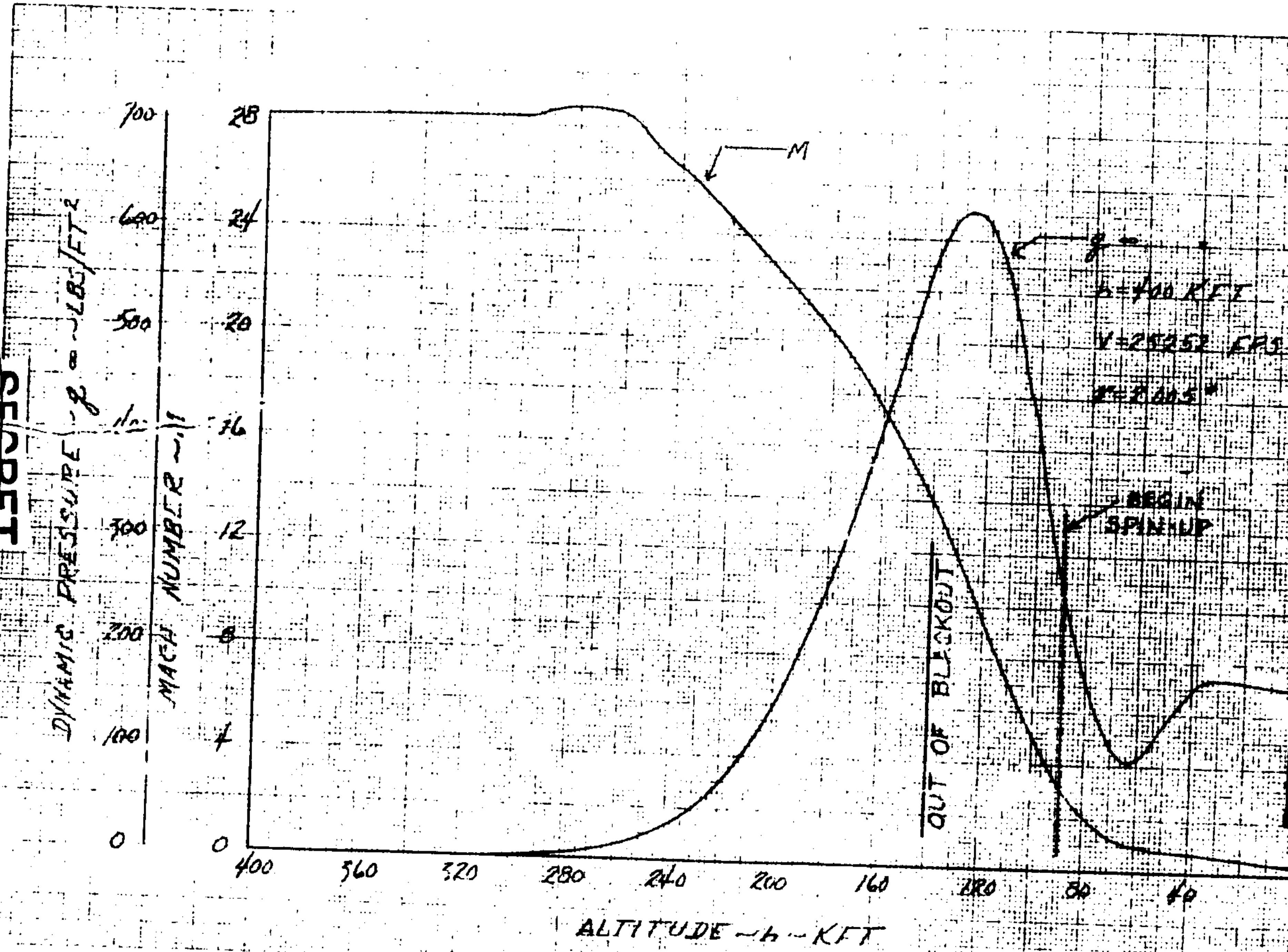


Figure 4-3 Point Mass Trajectory Parameter

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SECRET [redacted]

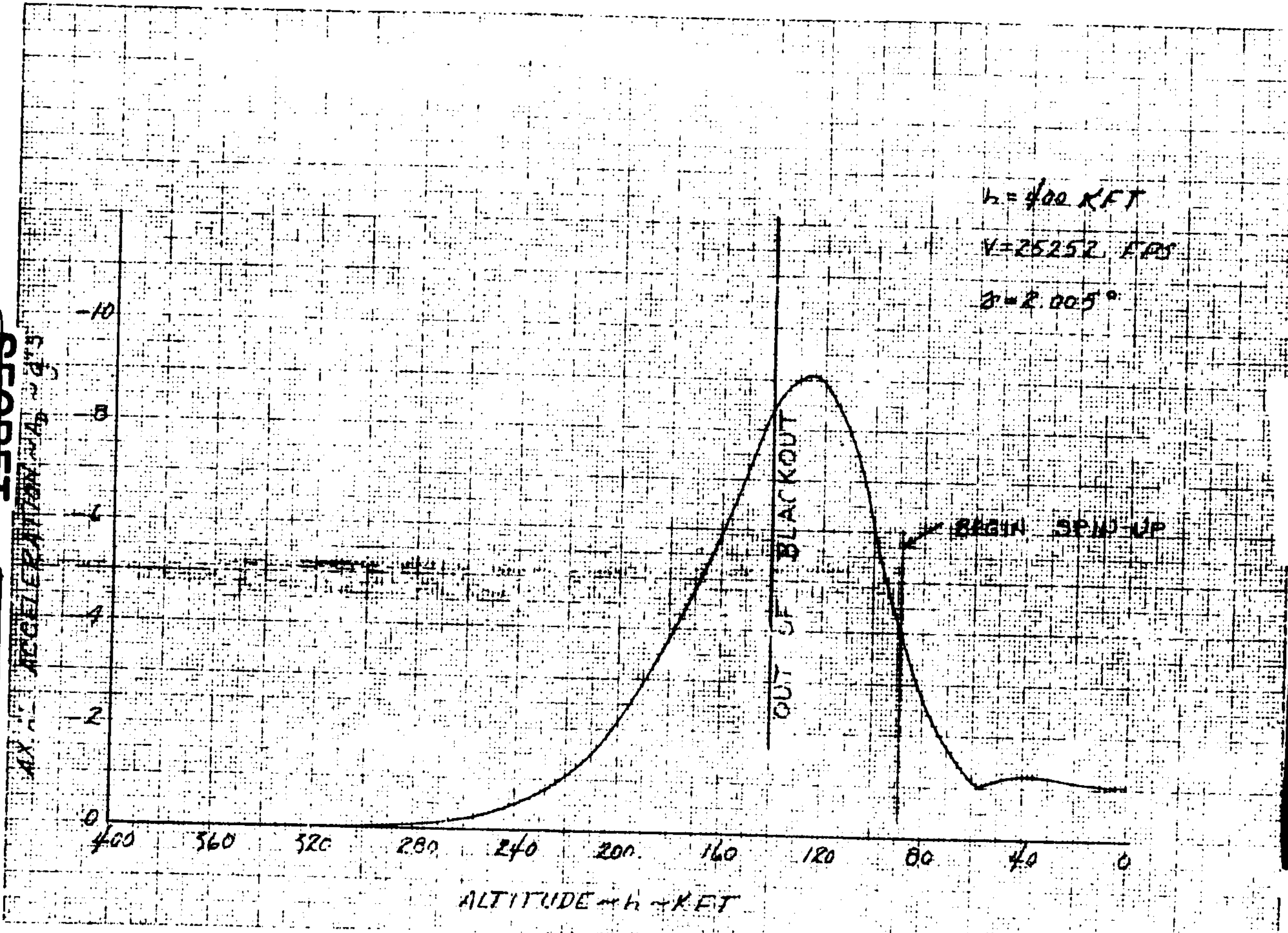

Figure 4-4 Point Mass Trajectory Axial Accel. History

[redacted]