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A COMPENDIUM OF NASA AEROBEE SOUNDING ROCKET LAUNCHINGS FOR 1964

by Jon R. Busse, Merrill T. Leffler, George E. Kraft, and Paul S. Bushnell, Jr.

Goddard Space Flight Center
Greenbelt, Md.

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ABSTRACT

This report summarizes information on the 28 NASA Aerobee sounding rocket launchings in 1964. Included are vehicle and subsystem performance data, descriptions of the various Aerobee rockets employed and experiments flown, and brief analyses of malfunctions. Information on each flight is presented in tabular form for purposes of comparison in appendices and cross referenced to the text.

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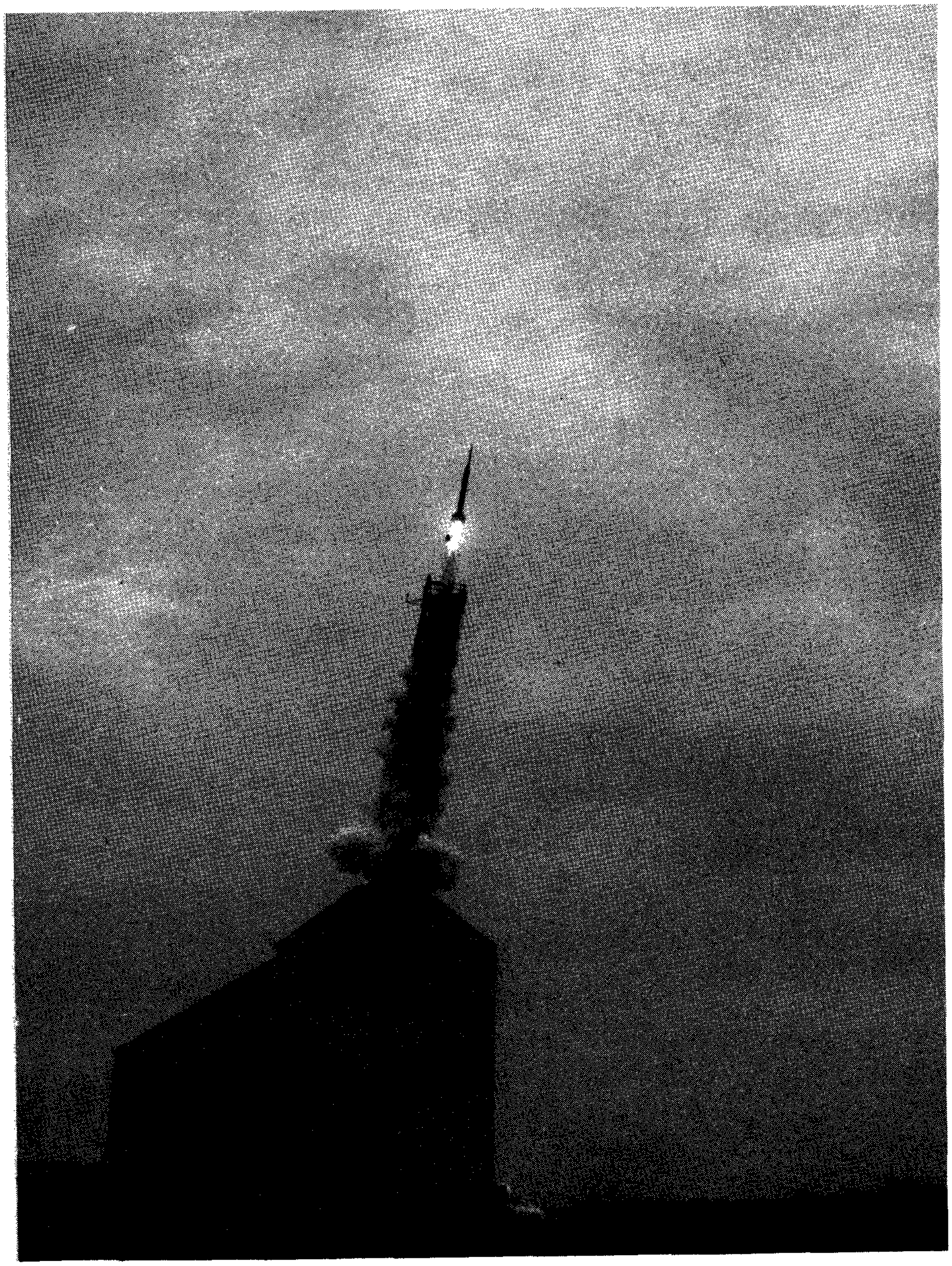

Frontispiece—Aerobee 150A sounding rocket 4.45 GA launched from Wallops Island, Virginia.

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INTRODUCTION

The Aerobee vehicle, with its relative simplicity and low cost, provides an excellent method for the exploration of space from altitudes up to approximately 150 statute miles. It also provides an economical means for evaluating the performance of instrumentation to be used later in more expensive satellite configurations, thereby reducing the possibility of costly failures. For these reasons, it is a popular vehicle for sounding rocket research by GSFC scientists, other scientists, both foreign and American, and universities interested in the wealth of scientific knowledge available through sounding rocket research.

During 1964, the Aerobee vehicle continued to provide a workhorse capability for sounding rocket research. This report provides detailed information concerning each NASA Aerobee launching for the year. Included are vehicle and subsystem performance data, descriptions of the various Aerobee rockets employed and experiments flown and brief analyses of malfunctions. Although vehicle performance was marred in the second quarter by three consecutive failures, subsequent successes increased the vehicle reliability to 84 percent for the year. Information on each flight is presented in tabular form for purposes of comparison in appendices and cross referenced to the text.

THE AEROBEE SOUNDING ROCKET VEHICLE

The Aerobee vehicle is a two-stage, liquid-propelled, fin stabilized, free-flight rocket which is boosted from a launch tower by a 2.5 KS 18,000-lb thrust, solid-grained booster (nominal burning time 2.5 seconds). The sustainer portion of the rocket is ignited by the hypergolic action of a 35 percent furfuryl alcohol and 65 percent aniline fuel mixture (known as ANFA) and an inhibited red fuming nitric acid oxidizer (IRFNA). The sustainer burns for approximately 51.5 seconds.

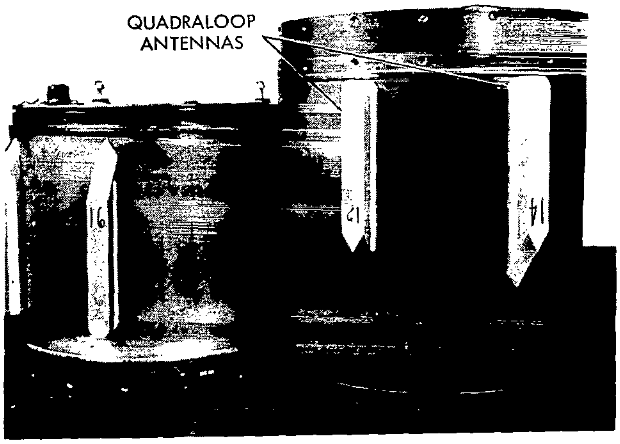


Figure 1—Typical extension section used on Aerobee rockets with quadraloop antennas mounted to outside.

Different systems frequently included in typical rocket configurations are a recovery system; a gas or yo-yo type despin system; a solar pointing control; and an attitude control system. Figure 1 shows a typical extension section used on the rocket. Extensions, which are used to house rocket instrumentation, are available in lengths of 6 to 75 inches.

The fins are canted prior to flight to induce a roll motion in the rocket which is necessary in order to reduce dispersion during flight. Figure 2a shows the service connections on an Aerobee 150 (without extensions); Figure 2b

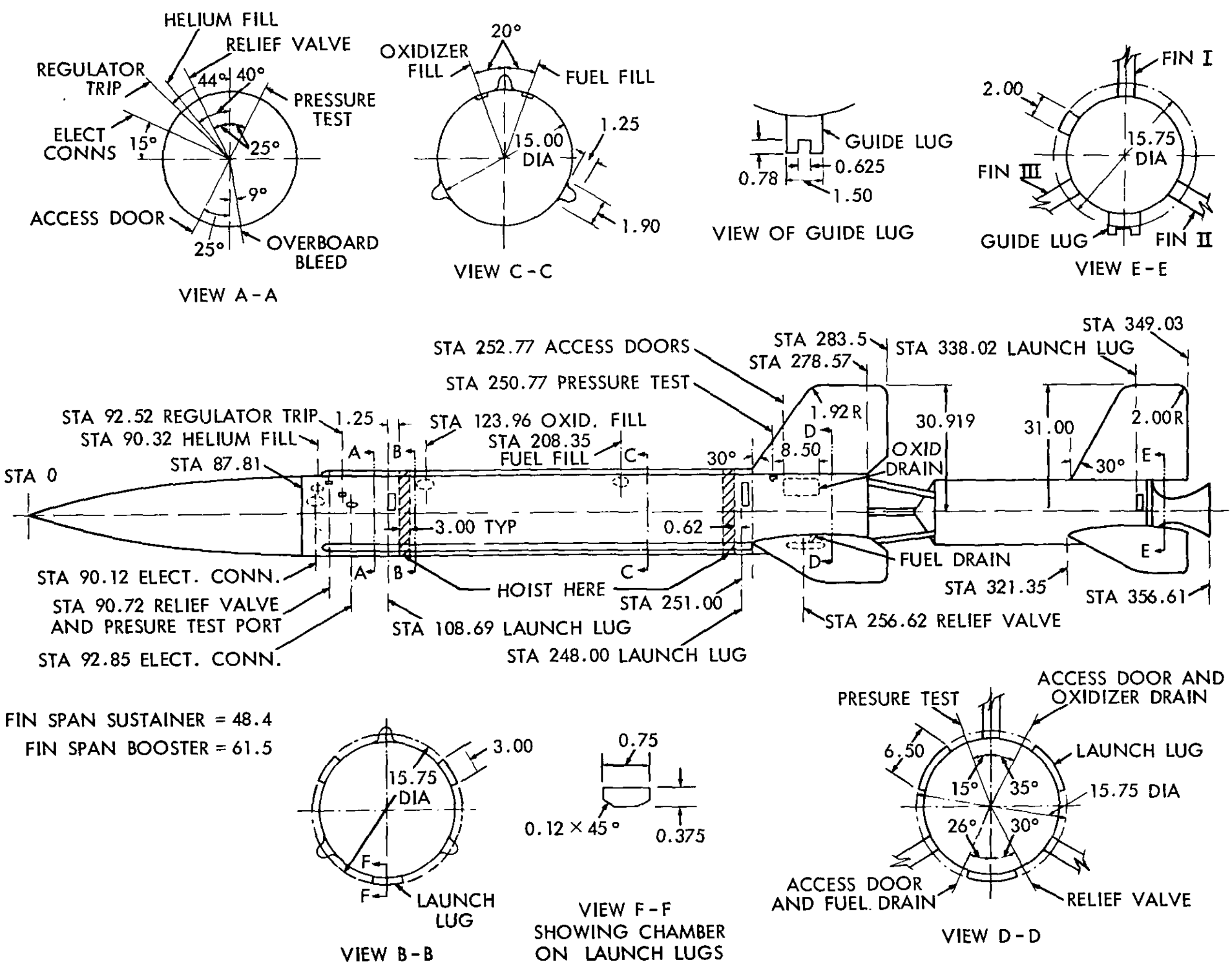


Figure 2a—Aerobee 150 rocket service connections.

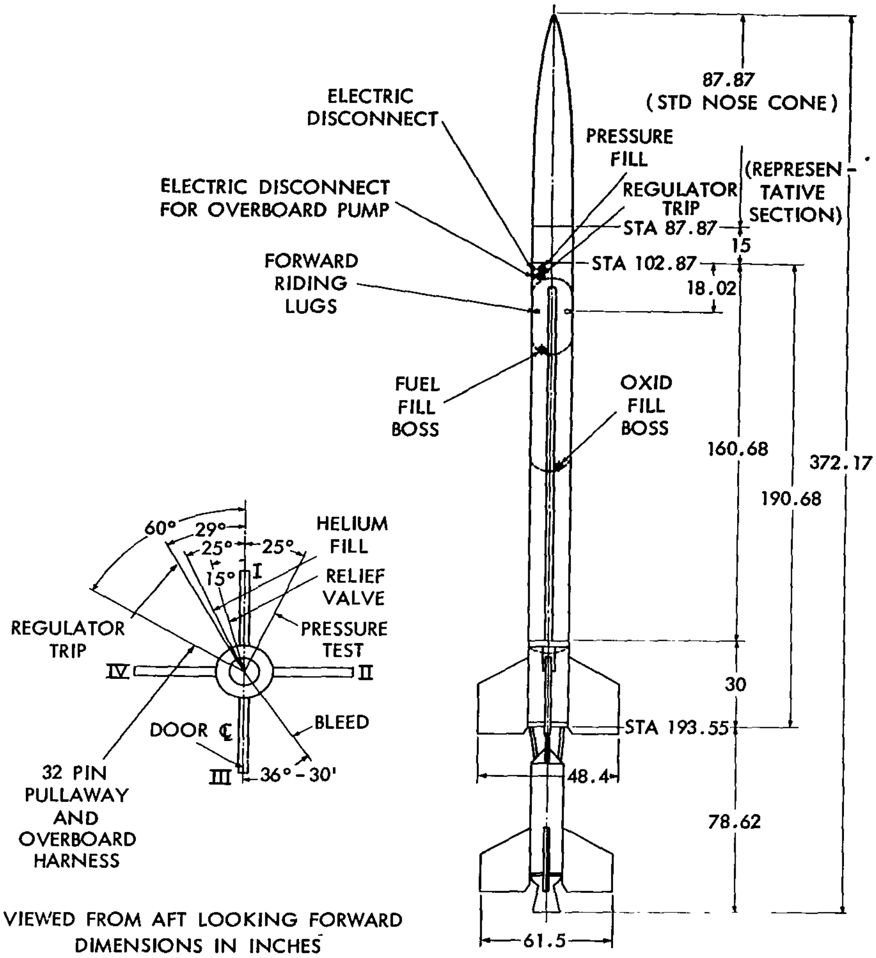


Figure 2b—Aerobee 150A rocket service connections.

shows service connections with dimensional statistics for the Aerobee 150A. Aerobees have been flown with either ogive or cone-cylinder nose cones (Figure 3).

The induced roll rate at burnout for a typical Aerobee is 2.0 rps. For an Aerobee 150 with a 250 lb net payload weight and ogive nose cone, the velocity at burnout will be about 5870 fps at an altitude of 128,000 feet. The expected peak altitude for this configuration is 128 statute miles. With the same configuration, but using a cone-cylinder nose cone, the peak altitude will be approximately 4 percent less.

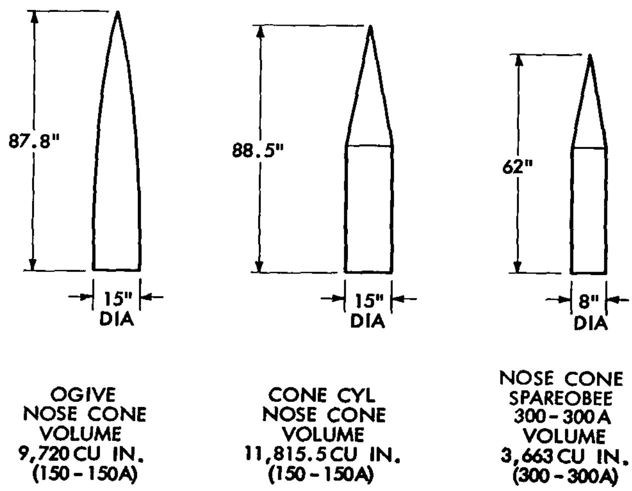


Figure 3—Aerobee rocket payload configurations.

Four-fin Aerobee 150A's are launched only at sea level from the enclosed tower at Wallops Island (WI), Virginia. The Aerobee 300A, a four-fin Aerobee with an additional third stage, is also launched only from WI. These configurations are very similar to the three-fin Aerobee 150's launched at the White Sands Missile Range (WSMR), New Mexico (Figure 4) and at the Churchill Research Range (CRR), Canada, and to the Aerobee 300's, currently launched only from the CRR. More detailed information on each configuration, hardware and launch facilities is provided in Reference 1.

1964 NASA AEROBEE SOUNDING ROCKET FLIGHTS

Twenty-eight Aerobee rockets were launched during 1964. These flights are listed in Table 1 and are described individually in the text that follows. Four Aerobee 150's and one Aerobee 300A were launched from WI, 19 Aerobee 150's were launched from WSMR, and three Aerobee 150's and one Aerobee 300 were launched from CRR. Three consecutive flights from WSMR, flights 4.81 GG, 4.86 NA and 4.113 GA-GI, were unsuccessful. Two of the failures were characterized by aerodynamic instabilities and one, by a propulsion system failure. Following an investigation of the failures, remedial measures were instituted. All of the twenty-one subsequent flights were completely or partially successful.

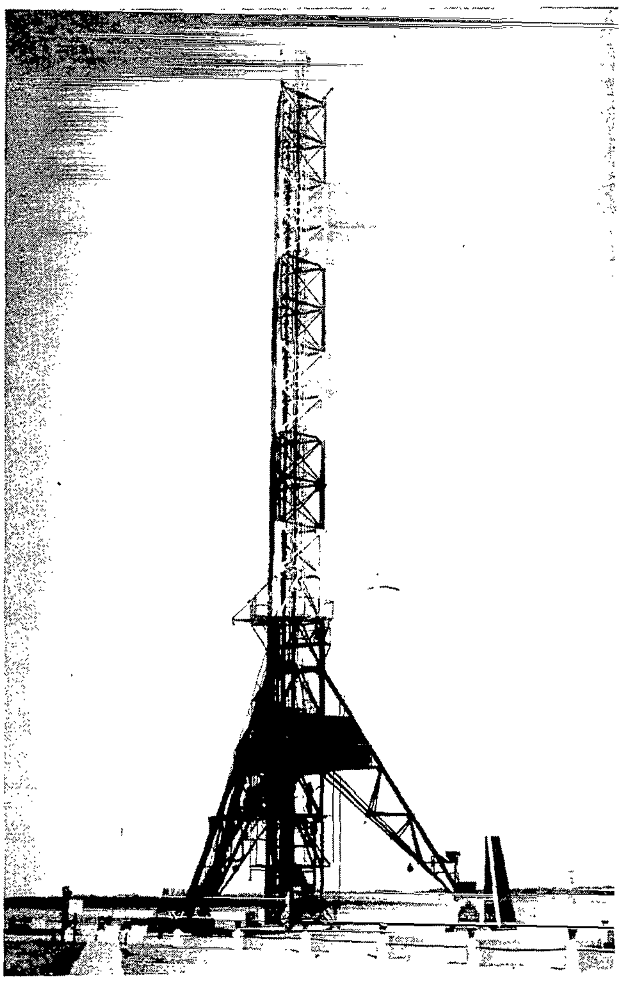


Figure 4—Launch tower, White Sands Missile Range.

Twenty-one recovery systems were flown, of which two failed; however of the failures one was an attempt to recover an Aerobee 150A sustainer with a new technique. Additionally, one payload recovery (4.67 NP) was attempted via an inflatable paraglider included in the payload section of the rocket.

Eight despin systems were flown: five gas and three yo-yo type. All of the gas systems functioned properly, one yo-yo system did not.

Ten rockets had ogive nose cones and the other eighteen had cone-cylinder nose cones. Cone-cylinder nose cones were used on two of the three unsatisfactory flights. Two rockets had a fiberglass ogive nose.

Table 1

1964 Aerobee Sounding Rocket Flights.

Flight Number	Launch Site	Date of Launch
4.88 GT	WSMR	1-28-64
6.09 GA	WI	1-29-64
4.124 UA	CRR	2-27-64
4.15 GG	WSMR	4-3-64
4.81 GG	WSMR	4-9-64
4.86 NA	WSMR	4-14-64
4.113 GA-GI	WSMR	4-21-64
4.67 NP	WSMR	6-10-64
4.107 GE	CRR	7-23-64
4.108 GE	CRR	7-25-64
6.10 GA	CRR	7-28-64
4.82 GG	WSMR	8-11-64
4.126 GG	WSMR	8-22-64
4.122 GG	WSMR	8-29-64
4.55 UG	WI	9-2-64
4.115 NA	WI	9-18-64
4.13 GP-GT	WI	9-27-64
4.120 CG	WSMR	10-1-64
4.123 CG	WSMR	10-27-64
4.116 GS	WSMR	10-30-64
4.52 UG	WSMR	11-3-64
4.109 GG	WSMR	11-7-64
4.110 GG	WSMR	11-14-64
4.118 NA	WSMR	11-16-64
4.45 GA	WI	11-16-64
4.83 GA	WSMR	11-28-64
4.132 GA-GI	WSMR	12-16-64
4.125 UA	WSMR	12-17-64

Flight 4.88 GT

Flight 4.88 GT, the first Aerobee firing in 1964, was at WSMR on 28 January. Peak altitude was 123.7 statute miles. The vehicle and all instrumentation performed as expected and good attitude control was indicated. The primary objective of the flight was to provide a thorough test of the currently used inertial attitude control system (IACS) with an improved inertial reference system. Other intended experimental objectives included:

(1) Observance of performance of two roll-stabilized platforms
(2) Observance of drift of platform mounted gyros during flight
(3) Observance of maneuver accuracy
(4) Observance of general control characteristics.

Prior to T+31 seconds, large and frequent center-of-motion shifts and large transient frequency responses were indicated. These frequencies were a mixture of vehicle roll rate and transient pitch responses resulting perhaps from tower exit, booster burnout and separation, and wind shears. At pitch-roll resonance, large transient disturbances of short duration were observed; these were followed by motions basically at the pitch frequency. This indicates the presence of a large transient disturbance at resonance caused by rapid trim changes near resonance. Thrust chamber misalignments (not measured during rocket build-up) are a possible contributing cause of the trim changes. There was no evidence of pitch-roll lock-in.

The two roll-stabilized gyro platforms functioned well and succeeded in eliminating large gyro spin drifts, but accuracy in performance of large maneuvers was less than desired. Aspect instrumentation in the payload included a Ball Brothers sun tracker, two Adcole wide angle sun sensors, a Whittaker aspect gyro, and two cameras; good data were received from all but the sun tracker's yaw-axis output.

The recovery system shown in Figure 5 was used on this flight and functioned as expected; recovery was effected immediately after impact and the payload was in excellent condition. Figure 6 is a view of the liftoff.

The performance and configuration of flight 4.88 GT is somewhat typical of Aerobees launched from WSMR. Therefore, Figures 7a through 7c are presented to give general

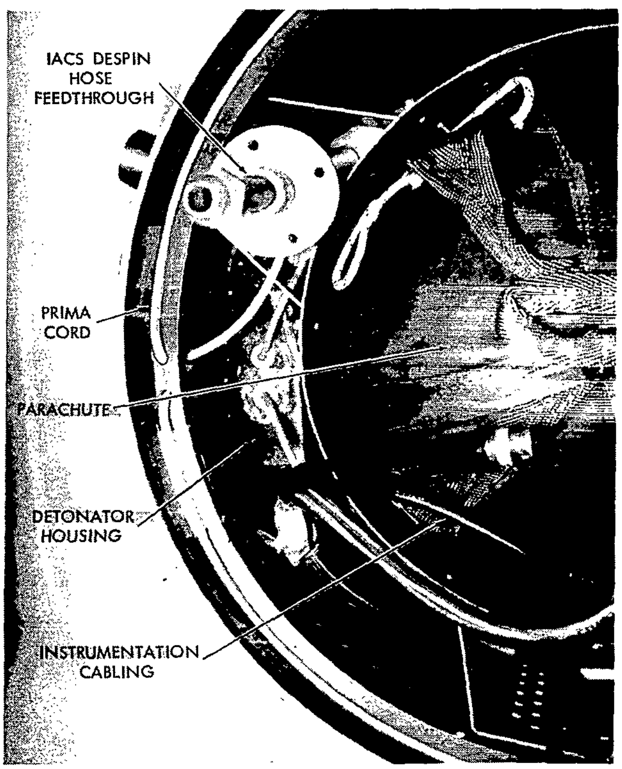


Figure 5—Recovery system flown on NASA 4.88 GT.

Figure 6—NASA 4.88 GT liftoff photo.

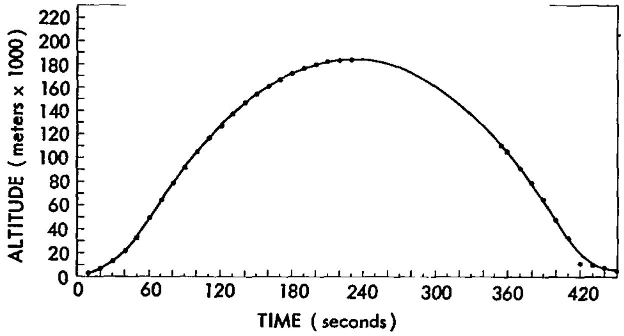


Figure 7a—Altitude vs. time, flight 4.88 GT.

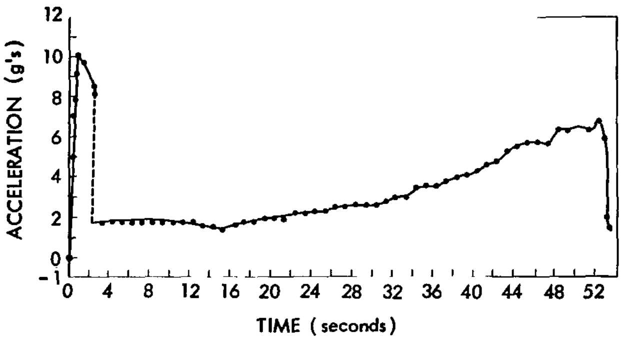


Figure 7b—Acceleration vs. time, flight 4.88 GT.

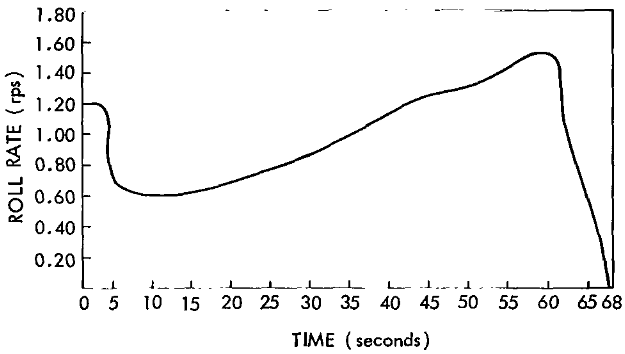


Figure 7c—Roll rate vs. time, flight 4.88 GT.

flight performance characteristics. Figure 7d plots oxidizer tank pressure, indicating a decrease in pressure as the IACS used the residual gas for maneuvers. Figure 8 gives payload dimensions and flight characteristics.

Flight 6.09 GA

Rocket 6.09 GA, an Aerobee 300A, was launched from WI on 29 January, attaining an altitude of 192.3 statute miles, approximately 4 percent lower than predicted.

The scientific payload for this flight was contained in an ejectable cylinder. The cylinder was housed in a 6.5-inch-diameter, clamshell, cone-cylinder nose cone and was successfully

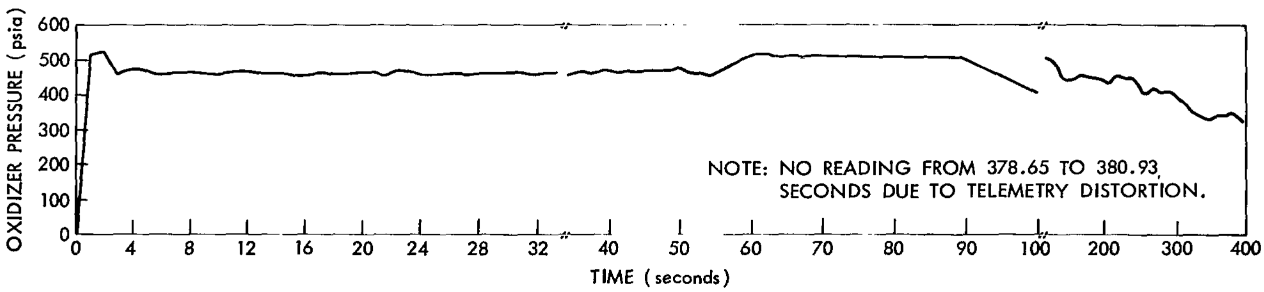


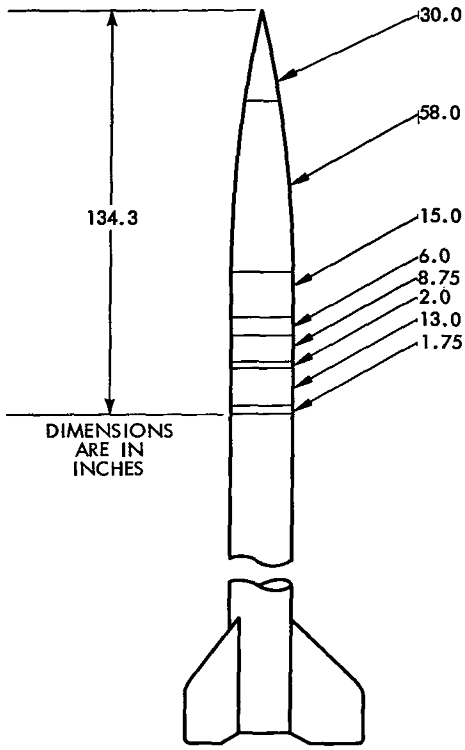
Figure 7d—Oxidizer pressure vs. time, flight 4.88 GT.

ejected at T+97 seconds. Experimental objectives included:

(1) Simultaneous measurement of electron neutral particle temperatures in the 120-360 km region
(2) Measurement of ion and neutral particle density
(3) Measurement of acceleration in three axes
(4) Testing of repellent grid to be used on the S-6 satellite.

Booster chamber pressure was measured during flight (Figure 9); unfortunately, booster wall temperatures could not be obtained due to a lag in the response time, coupled with a later shorting in the temperature sensor. Figure 10 shows the booster, which is marked to indicate the position of one of the temperature sensors. Figure 11 shows booster acceleration from ignition to booster burnout.

Good accelerometer and chamber pressure data were received (Figures 12 and 13). Figure 14 gives payload dimensions and characteristics.



FIRING DATE	28 JAN 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	291.00
APOGEE (ST MI)	123.70
TIME TO APOGEE (SEC)	252.60
CENTER OF GRAVITY (CAL)	10.80
CENTER OF PRESSURE (CAL)	13.95
STATIC MARGIN (CAL)	3.15
RESTORING MOMENT (PER DEGREE)	-0.315
SUSTAINER BURNOUT TIME (SEC)	53.05
ROLL RATE AT BURNOUT (RPS)	1.45
EJECT TIP (SEC)	66.50
NO. OF JOINTS	8

Figure 8—Dimensions and flight characteristics, 4.88 GT.

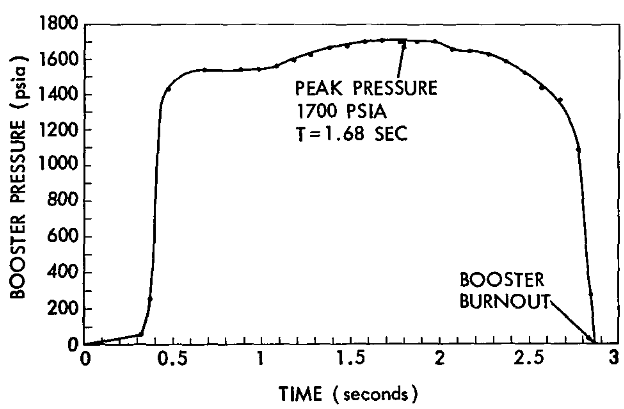


Figure 9—Booster pressure, flight 6.09 GA.

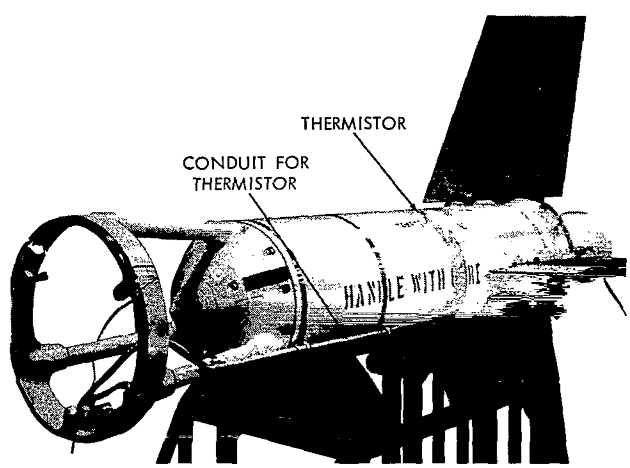


Figure 10—Flight 6.09 GA booster marked to indicate positions of temperature sensors.

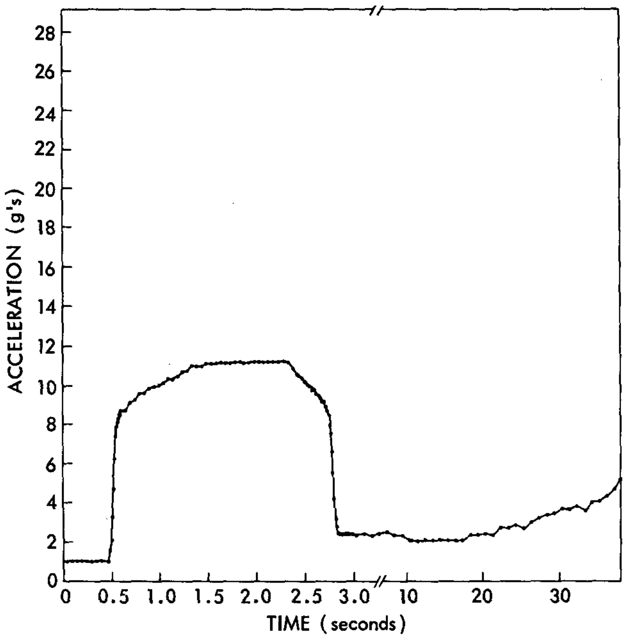


Figure 11—Flight 6.09 GA acceleration.

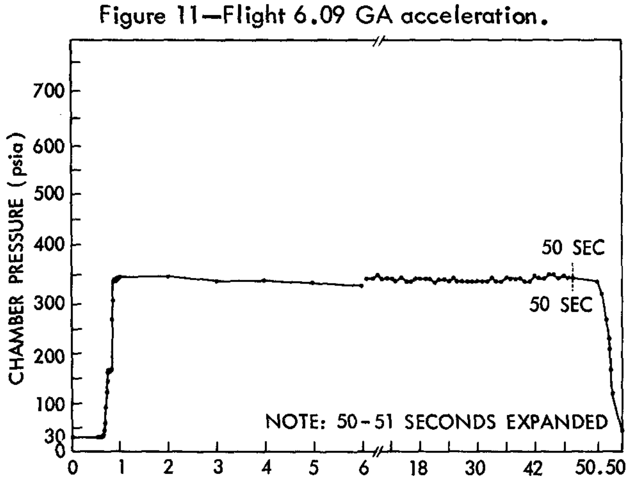


Figure 12—Flight 6.09 GA sustainer chamber pressure.

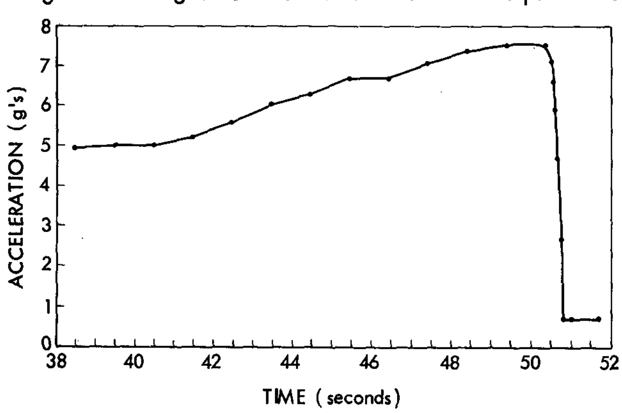
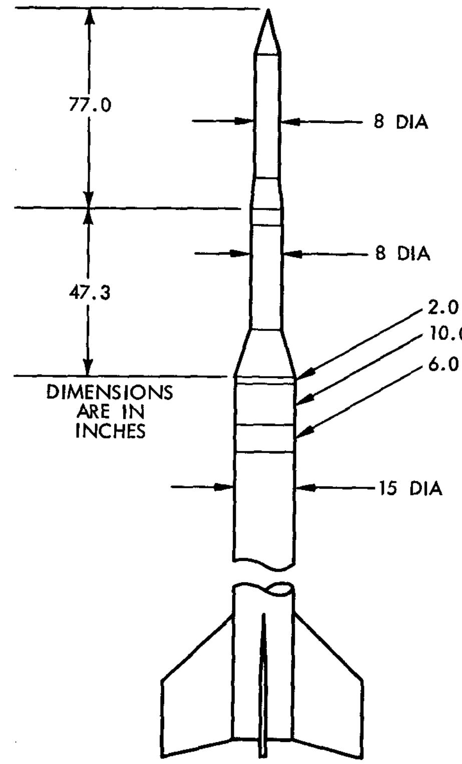


Figure 13—Flight 6.09 GA sustainer acceleration (continuation of Figure 11).



FIRING DATE	29 JAN 1964
LAUNCH SITE	WI
PAYLOAD WEIGHT, 2ND STAGE (LB)	273.05
APOGEE (STATUTE MILES)	192.30
TIME TO APOGEE (SEC)	300.20
CENTER OF GRAVITY, SUSTAINER BURNOUT (CAL)	11.25
CENTER OF PRESSURE, SUSTAINER BURNOUT (CAL)	15.62
STATIC MARGIN, SUSTAINER BURNOUT (CAL)	4.37
RESTORING MOMENT, SUSTAINER BURNOUT (PER DEGREE)	-0.594
CENTER OF GRAVITY, 3RD STAGE IGNITION (CAL)	7.80
CENTER OF PRESSURE, 3RD STAGE IGNITION (CAL)	11.16
STATIC MARGIN, 3RD STAGE IGNITION (CAL)	3.36
RESTORING MOMENT, 3RD STAGE IGNITION (PER DEGREE)	-0.1208
SUSTAINER BURNOUT (SEC)	50.80
THIRD STAGE BURNOUT (SEC)	53.80
ROLL RATE AT BURNOUT, SUSTAINER (RPS)	2.70
ROLL RATE AT BURNOUT, 3RD STAGE (RPS)	unknown
PROBE EJECT (SEC)	~97.00
NUMBER OF JOINTS	9
PAYLOAD WEIGHT, 3RD STAGE (LBS)	84.75

Figure 14—Dimensions and flight characteristics, 6.09 GA.

Flight 4.124 UA

Rocket 4.124 UA was launched at night from CRR on 27 February. Figure 15 shows tower exit. The primary purpose of this flight was to obtain spectral emission data in the ultraviolet region of the upper atmosphere during an aurora. Spectrophotometric instrumentation was carried on board to measure these spectral features (Figure 16).

The vehicle performed normally during the boost phase; however peak altitude was only 75 percent of the predicted 157-statute mile apogee. There were clear indications from telemetry and radar that pitch-roll coupling and lock-in occurred at resonance (approximately T+40 seconds). Aerodynamic instabilities arising out of the coupling condition caused the rocket to cone while precessing about its transverse axis, lowering altitude performance. An early tip ejection occurred at 59 seconds; this was the result of a timer malfunction and had no effect on vehicle performance. Figure 17 shows the acceleration during the propulsion portion of flight and Figure 18 shows thrust chamber pressure for the same period.

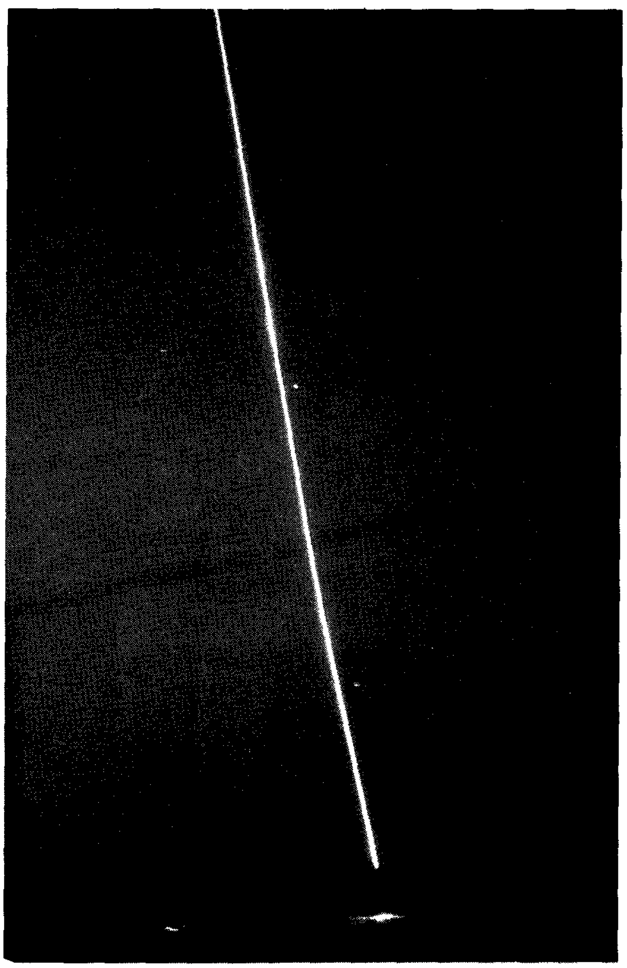


Figure 15—Night liftoff flight 4.124 UA from Churchill Research Range.

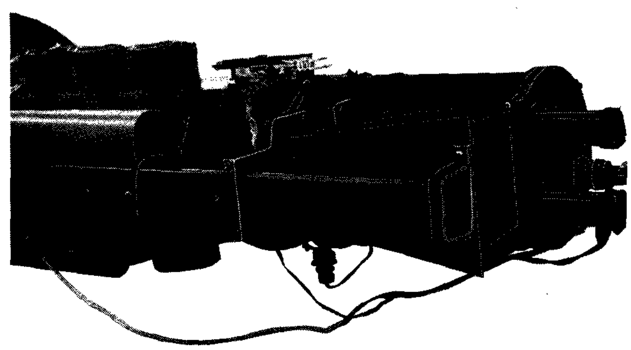


Figure 16—Flight 4.124 UA spectrophotometric instrumentation.

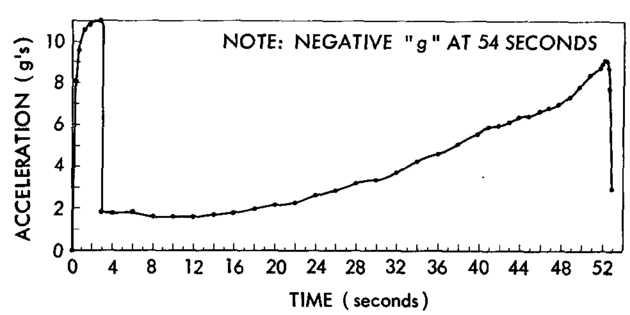


Figure 17—Flight 4.124 UA acceleration vs. time.

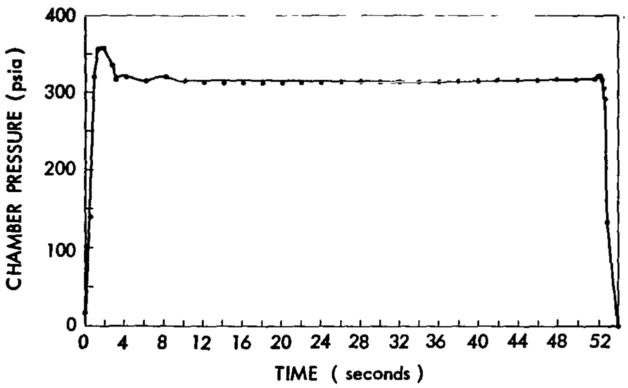


Figure 18—Flight 4.124 UA chamber pressure vs. time.

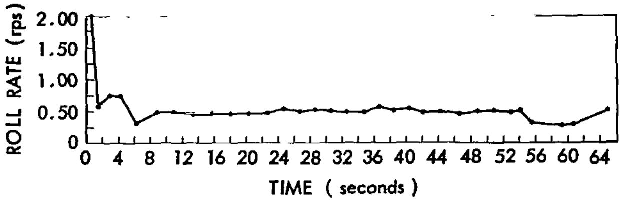


Figure 19—Flight 4.124 UA roll rate vs. time.

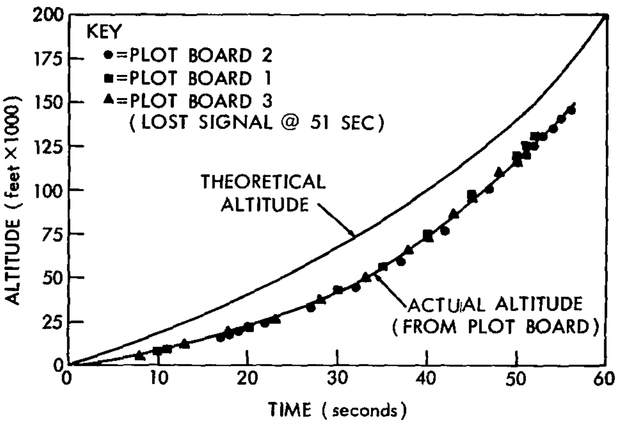
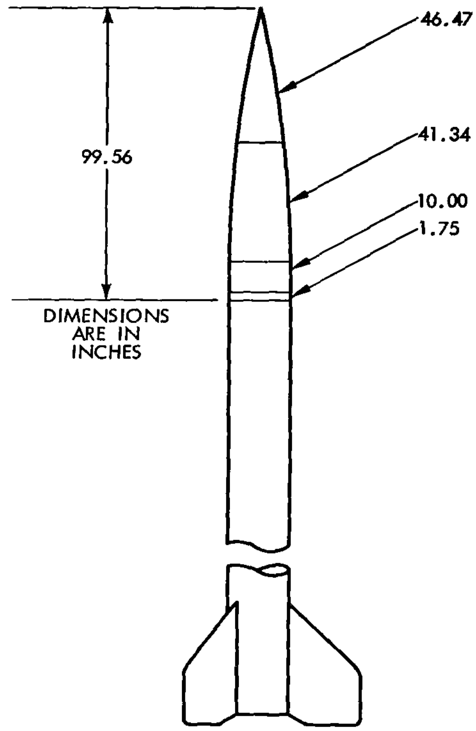


Figure 20—Flight 4.122 UA altitude vs. time.

The roll rate is given in Figure 19. Figure 20 compares actual altitude with predicted trajectory. The flight is not considered a failure, since the vehicle penetrated an auroral event and some experimental data were collected. Also, as we shall observe in the analyses of two other flights (4.81 GG and 4.86 NA), the results of this flight contributed to later Aerobee improvements. Figure 21 gives payload dimensions and flight characteristics.



FIRING DATE	27 FEB 1964
LAUNCH SITE	CRR
PAYLOAD WT (LB)	137.50
APOGEE (ST MI)	100.00
TIME TO APOGEE (SEC)	218.00
CENTER OF GRAVITY (CAL)	10.00
CENTER OF PRESSURE (CAL)	12.20
STATIC MARGIN (CAL)	2.00
RESTORING MOMENT (PER DEGREE)	0.215
SUSTAINER BURNOUT TIME (SEC)	53.00
ROLL RATE AT BURNOUT (RPS)	0.50
TIP EJECT (SEC)	59.03
NO. OF JOINTS	4

PREDICTED 157 S M APOGEE. PITCH-ROLL COUPLED @ 40 SEC

Figure 21—Dimensions and flight characteristics, 4.124 UA.

Flight 4.15 GG

NASA 4.15 GG was launched from WSMR on 3 April. The primary objective was to obtain spectral data on the nebulosities of certain star fields. One camera and spectrograph were pointed out the nose of the nose cone cylinder and another pair were pointed to look out the side of the cylinder. Prior to launching, the tail was drilled with nine 3/4-inch holes to permit outgassing.

Some transient responses were indicated during the first seconds of flight, which were probably due to tower exit disturbances, booster burnout and separation, and wind shear, and were not considered abnormal. Sizeable shifts in the center of motion occurred early in flight, which made it difficult to determine the exact nature of the rocket motion. The frequencies observed seemed to be a mixture of transient oscillations in pitch frequency and fairly steady oscillations in roll rate. Figure 22 plots yaw and pitch frequency and roll rate during propulsion.

Thrust chamber misalignments are thought to be a possible factor responsible for roll rate oscillations observed later; this is not observable in the chamber pressure trace, which is steady and as expected (Figure 23). Other data included for this flight are wind velocities and flight azimuth vs. altitude (Figure 24a) and acceleration vs. time (Figure 24b).

The rocket and instrumentation performed satisfactorily; however, the experimental objectives were not attained because the IACS was unable to erect the rocket to the gyros. This may have resulted from the failure of the fuel shutoff valve to seat properly, thereby allowing residual helium to "blow out" the thrust chamber. There was not enough helium left to erect the vehicle to the pitch gyro. The valve failure was not immediately detected because the regulated helium pressure gauge did not function. Because of the similar vehicle configuration and the availability of IACS gyro outputs, the 4.15 GG flight motion has been analyzed for comparison with two subsequent failures. (Reference 2).

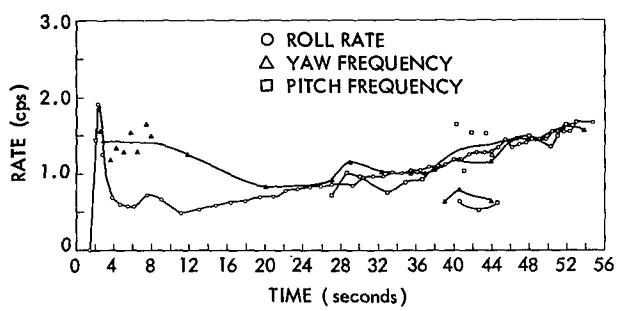


Figure 22—Flight 4.15 GG pitch, yaw and roll rate vs. time.

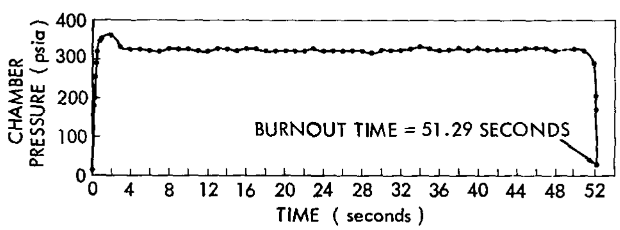


Figure 23—Flight 4.15 GG chamber pressure vs. time.

The rocket achieved an apogee of 118.6 statute miles; the nose tip was ejected at 85 seconds as planned. The recovery system functioned satisfactorily and the payload was recovered in good condition. Figure 25 gives payload dimensions and flight characteristics.

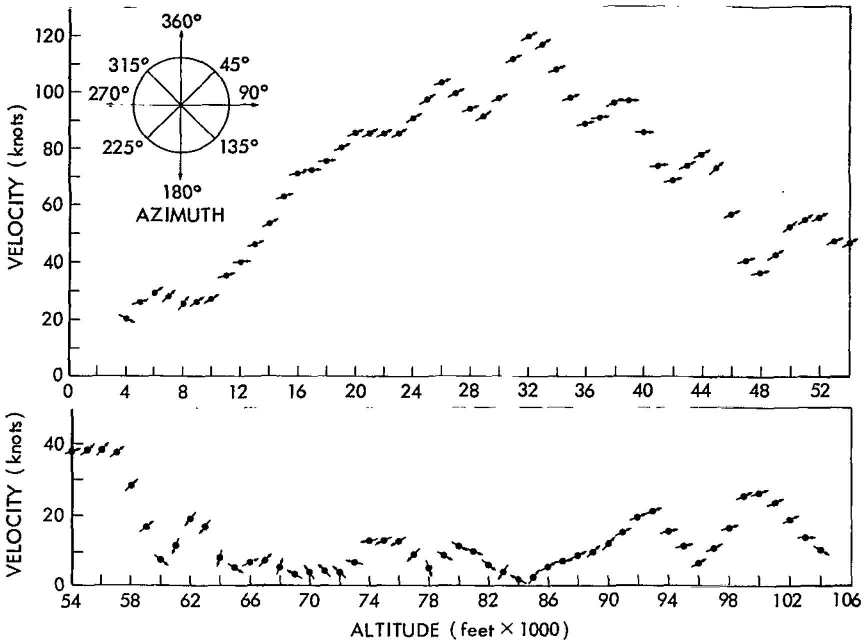


Figure 24a—Flight 4.15 GG wind velocity and azimuth vs. altitude.

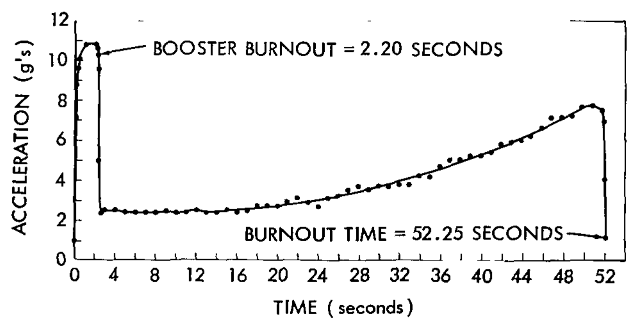


Figure 24b—Flight 4.15 GG acceleration vs. time.

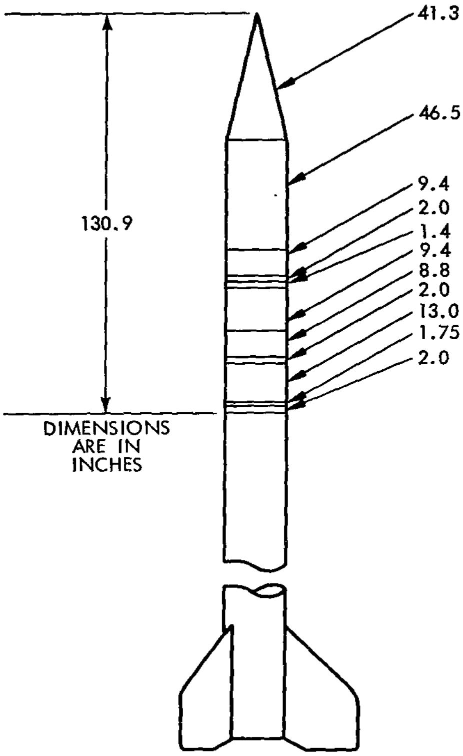
Flights 4.81 GG and 4.86 NA

Flights 4.81 GG and 4.86 NA were consecutive failures. The cause in each case has been attributed to bi-modal instability arising from frequencies that preceded pitch-roll lock-in. It is theorized that the large angles of attack resulting from the bi-modal instabilities permitted lock-in to occur. Flight details, analyses, and conclusions are the subject of Reference 2, currently in preparation. The paragraphs that follow give general comments about each flight and a summary of the conclusions reached and remedial actions instituted.

Flight 4.81 GG

Aerobee 4.81 GG launched on 10 April from WSMR, marked the first vehicle failure of the year. Similar in configuration to 4.15 GG, though longer, the payload housed two cameras and two spectrographs for obtaining data on the spectra of certain star field nebulosities. Rocket instrumentation included a thrust chamber pressure gauge, accelerometer, helium guage, and lateral and longitudinal magnetometers.

Vehicle motion appeared relatively steady until T+29 seconds. At this time, half-amplitudes of motion about center grew to 2° by 32 seconds and to about 7° by 39 seconds. It is assumed that



FIRING DATE	2 APR 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	258.00
APOGEE (ST MI)	118.60
TIME TO APOGEE (SEC)	235.90
CENTER OF GRAVITY (CAL)	11.00
CENTER OF PRESSURE (CAL)	13.20
STATIC MARGIN (CAL)	2.20
RESTORING MOMENT (PER DEGREE)	-0.23
SUSTAINER BURNOUT TIME (SEC)	52.40
ROLL RATE AT BURNOUT (RPS)	1.55
TIP EJECT (SEC)	85.00
NO. OF JOINTS	11

Figure 25—Dimensions and flight characteristics, 4.15 GG.

a low body bending frequency on the order of 1 cps (resulting perhaps from joint slippage) dynamically coupled with an aerodynamic pitching frequency at 29 seconds to cause this large growth in amplitude. At 40 seconds, the nose cone microswitch output indicated a premature tip eject and by 12 seconds the vehicle had "locked in." It is thought that the pitch-roll couple lock-in at 40 seconds resulted from the structural failure of the nose tip and was not a basic cause of flight anomalies. Static tests at GSFC have confirmed that angles of attack larger than design limits created excessive aerodynamic loads on the tip eject mechanism.

Figure 26 shows a representative wind run taken shortly before the flight; there are no indications of wind shears large enough to have predictably contributed to the failure. Figure 27 plots roll rate and pitching frequency vs. time. Figure 28 shows the thrust chamber pressure trace, which is as expected, and the acceleration history. Burnout acceleration is lower than expected and the "dip" at 43 seconds indicates lock-in of the pitch and roll frequencies.

Although the rocket was a failure, the recovery system functioned properly, and the payload was recovered. Conclusions from analysis of flight data (p. 17) have resulted in improvements which should help avoid reoccurrences.

Flight 4.86 NA

Flight 4.86 was launched on 14 April from WSMR. This flight was the second consecutive Aerobee 150 failure and was similar to 4.81 GG. In the early seconds of flight, no unusual motions were detected (Figure 29). However, as on the 4.81 flight, amplitude of motion, resulting in pitch-yaw roll coupling and later in pitch-yaw roll lock-in, which occurred at 40 seconds (Reference 1). Figure 30 shows a useful roll rate comparison illustrating this behavior.

Erratic accelerations were indicated from T+42 seconds until T+48 seconds (Figure 31). Thrust chamber pressure (Figure 32) exhibited no unusual characteristics. Representative wind data for this flight (Figure 33) did not indicate that significant wind shears contributed to the failure.

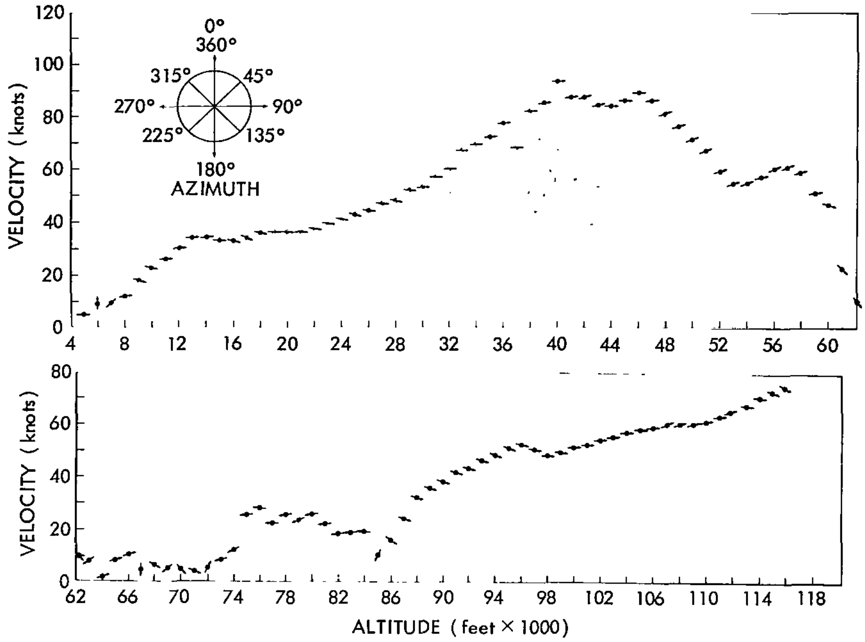


Figure 26—Flight 4.81 GG wind velocity and azimuth vs. altitude.

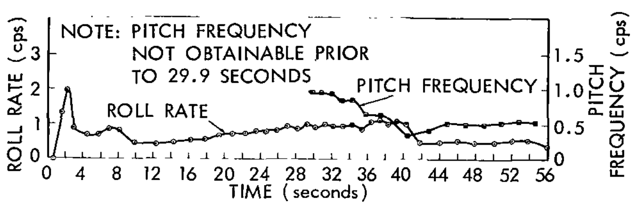


Figure 27—Flight 4.81 GG roll rate and pitch frequency vs. time.

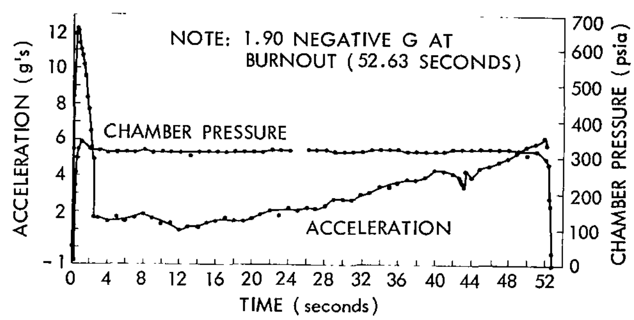


Figure 28—Flight 4.81 GG chamber pressure and acceleration vs. time.

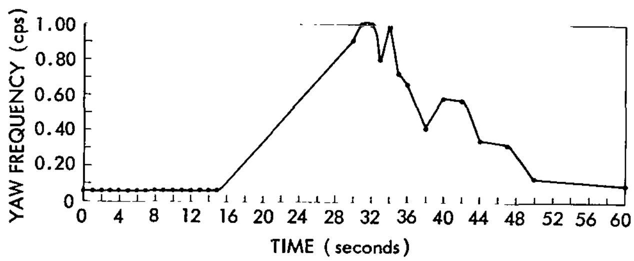


Figure 29—Flight 4.86 NA yaw frequency vs. time.

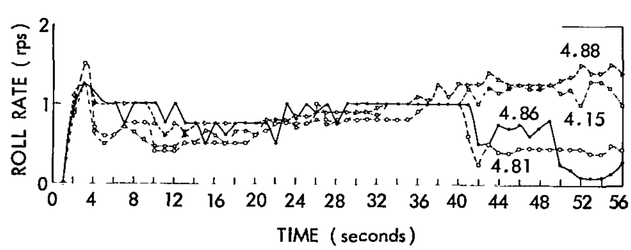


Figure 30—Comparison of roll rate vs. time for flights 4.81 GG, 4.86 NA, 4.88 GG and 4.15 GG.

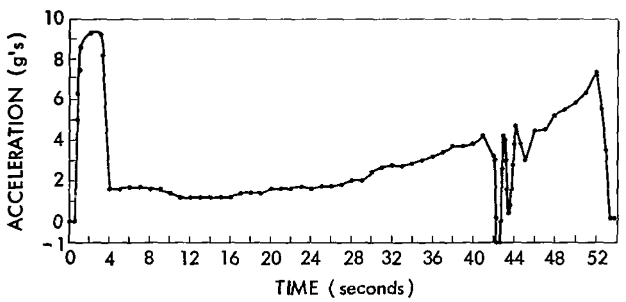


Figure 31—Flight 4.86 NA acceleration vs. time.

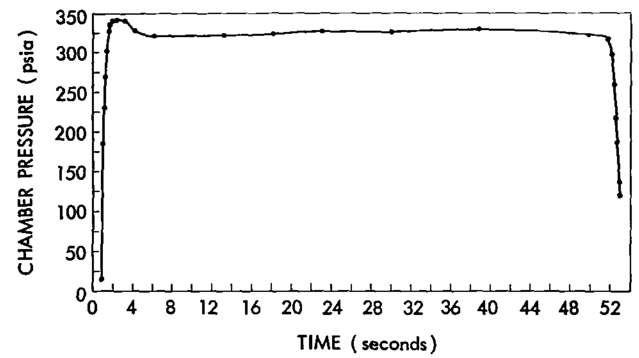


Figure 32—Flight 4.86 NA chamber pressure vs. time.

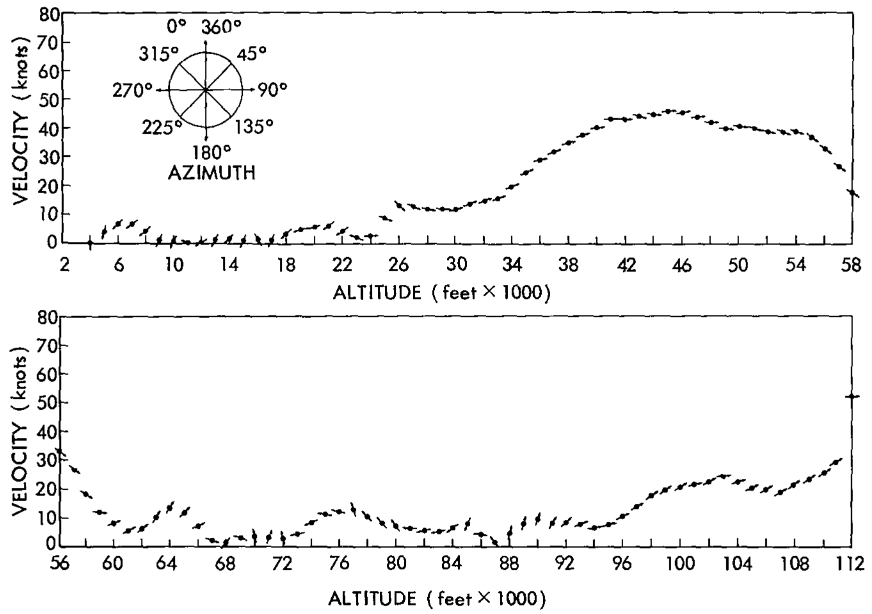


Figure 33—Flight 4.86 NA wind velocity and azimuth vs. time.

At T+61.5 seconds, the forward 55 inches of the cone-cylinder nose cone was ejected by timer command; no experimental objectives could be realized, however, since the IACS was unable to erect the vehicle to the gyros. The IACS had been programmed to yaw the rocket to the nadir soon after burnout, and then yaw it up to the zenith at apogee. On the descending leg of the trajectory, the rocket was to be turned downwards toward the horizon in the north and remain there until payload separation. An Ebert-Fastie optical spectrometer and three photometers were contained in the payload section; they were to measure the sun's ultraviolet light that is scattered by the earth's atmosphere as well as to correlate the fluctuation of this phenomena in the earth's magnetic field by using magnetometers. The recovery system functioned properly and the payload was successfully recovered.

Although an apogee of only 18 statute miles was achieved, vehicle performance instrumentation data and IACS gyro data were invaluable in determining the causes of failure.

Summarizing the general physical and aerodynamic characteristics of the 4.81 GG and 4.86 GA failures:

(1) The payloads used cone-cylinder nose cones and were longer than most payloads flown up until that time.
(2) There were an unusually large number of extensions.
(3) Bi-modal frequencies were observed in pitch and roll prior to coupling and are theorized to have been responsible for causing pitch-roll lock-in.
(4) Pitch-roll coupling occurred at approximately T+40 seconds.
(5) Lock-in occurred at pitch-roll resonance, resulting,in a vehicle failure.

Analysis and Conclusions, 4.81 GG and 4.86 NA Flight Failures

Immediately following the 4.81 GG and 4.86 NA failures, GSFC and the Space-General Corporation (SGC) began intensive analyses of the effects on vehicle performance by several parameters: payload length; joint configuration; fin, thrust chamber, and structural misalignments; and stability changes resulting from the use of cone-cylinder nose cones. Data from these two flights were compared with similar flights and payload configurations, particularly 4.15 GG and 4.88 GT; aerodynamic and aerolastic studies were also undertaken by SGC and GSFC. The primary cause of failure was concluded to be pitch-roll lock-in resulting from bi-modal instabilities arising in the pitch and roll frequencies. It is further concluded that the bi-modal instabilities resulted from a combination of a large number of payload joints, possible thrust chamber misalignments, and payload unbalance. As a result of the various studies, the following corrective measures were taken to allow the continued use of similar payload configurations:

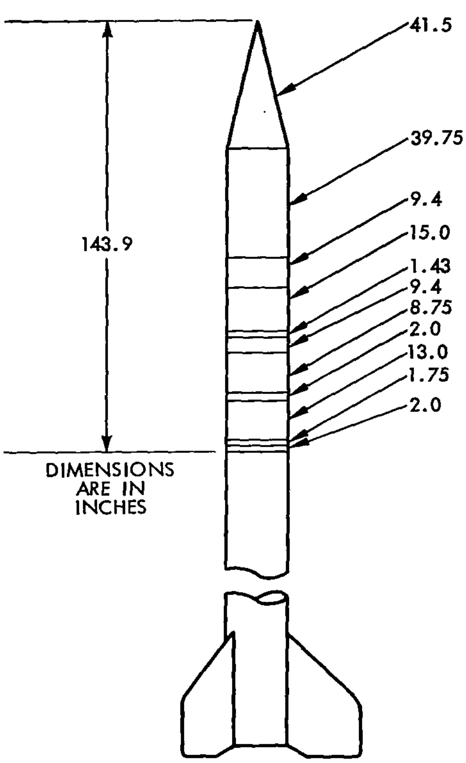
(1) Sixteen screws were added to the aft extensions to increase structural integration.
(2) Screws are individually torqued to 30 in-lb.
(3) Bending tests and dynamic balancing are given greater consideration.
(4) More precise checks are being made for thrust chamber and fin misalignments.
(5) Limiting stability criteria have been set up for various payload configurations.
(6) The number of joints is reduced where possible.

Figure 34a provides payload dimensions and characteristics of flight 4.81 GG. Figure 34b provides similar information for flight 4.86 NA.

Flight 4.113 GA-GI

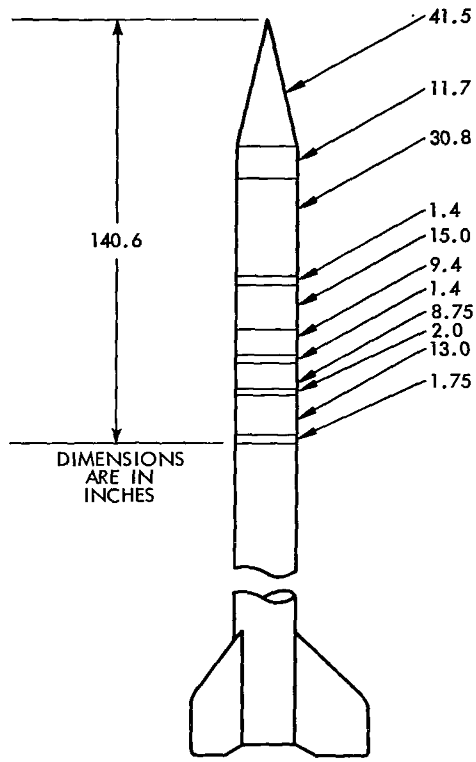
Vehicle 4.113 GA-GI, launched from WSMR on 21 April, reached an altitude of only 7 statute miles owing to a propulsion system failure. The primary objectives of the flight were to recover physical evidence of hypervelocity micrometeorite impacts, to collect samples of low velocity cosmic dust, and to measure electron densities below 120 km; none of these, of course, were realized.

Unusual sounds at liftoff, variously described as a low-pitched scream, whine, and whistle, were noted. The atmosphere around the launch tower contained a significant IRFNA ordor, and all



FIRING DATE	10 APR 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	271.50
APOGEE (ST MI)	45.50
TIME TO APOGEE (SEC)	141.80
CENTER OF GRAVITY (CAL)	10.98
CENTER OF PRESSURE (CAL)	13.40
STATIC MARGIN (CAL)	2.42
RESTORING MOMENT (PER DEGREE)	-0.265
SUSTAINER BURNOUT TIME (SEC)	52.60
ROLL RATE AT BURNOUT (RPS)	0.53
TIP EJECT (SEC)	39.50
NO. OF JOINTS	11

Figure 34a—Dimensions and flight characteristics, 4.81 GG.



FIRING DATE	14 APR 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	277.20
APOGEE (ST MI)	18.8
TIME TO APOGEE (SEC)	77.40
CENTER OF GRAVITY (CAL)	11.34
CENTER OF PRESSURE (CAL)	13.54
STATIC MARGIN (CAL)	2.20
RESTORING MOMENT (PER DEGREE)	-0.244
SUSTAINER BURNOUT TIME (SEC)	53.04
ROLL RATE AT BURNOUT (RPS)	NOT OBSERVED
TIP EJECT (SEC)	61.50
NO. OF JOINTS	11

SUSTAINER FAILED

Figure 34b—Dimensions and flight characteristics, 4.86 NA.

indications are that the rocket exited the tower with an oxidizer-rich mixture ratio in the thrust chamber, accompanied by a low frequency combustion instability. At approximately T+27.5 seconds, observers reported a bright flash (the tail can exploded). Telemetry was lost immediately and the rocket began to tumble, going into a flat spin and slowly falling to an impact approximately 5 miles northeast of the tower. The remains of the rocket were recovered and returned for investigation. Although this failure was unrelated to the previous two, it was the third consecutive one in twelve days. Launch activity was halted pending an analysis. All performance data were immediately reduced; excellent flight photo coverage was also available.

In addition to the tracking cameras, two colored documentary cameras followed the rocket from launch to impact. These films were also analyzed in detail by GSFC. The results of this investigation are summarized in Reference 3. During postflight inspection of the recovered motor, it was observed that the fuel collant tap and the thrust chamber pressure tap were missing (Figure 35) and the thrust structure was bent. The aft bulkhead (fuel tank) and motor structure were cut from the tankage. Analysis of these parts showed that there were great amounts of burned aniline residue deposits on the outside of the bulkhead; there were no indications, however, of intensive heat since the control and instrumentation wiring were clean and intact (Figure 36). No damage was observed on the burst diaphragm ring. Inspection of thrust chamber revealed a trapped "O" ring in the fuel strainer (Figure 37); this mysteriously came off the fuel shutoff valve. It is not considered to have contributed to the failure.

Comparing the performance data (Figures 38 and 39a) with other flights, examination of recovered components, discussions of the reports given by observers at the launch, and frame-by-frame investigation of the photo coverage indicated very strongly that the primary cause of failure was a hard start (an explosive initial combustion generating high chamber pressures). The color of the smoke, and the flame-out and re-ignition that occurred as the rocket traveled up the tower are indicative of a hard start. These conditions, followed

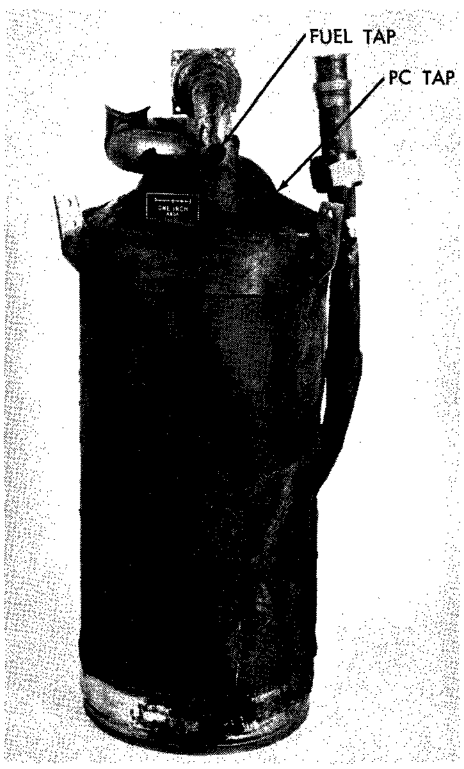


Figure 35—Flight 4.113 GA-GI thrust chamber jacket showing broken pressure chamber and fuel taps.

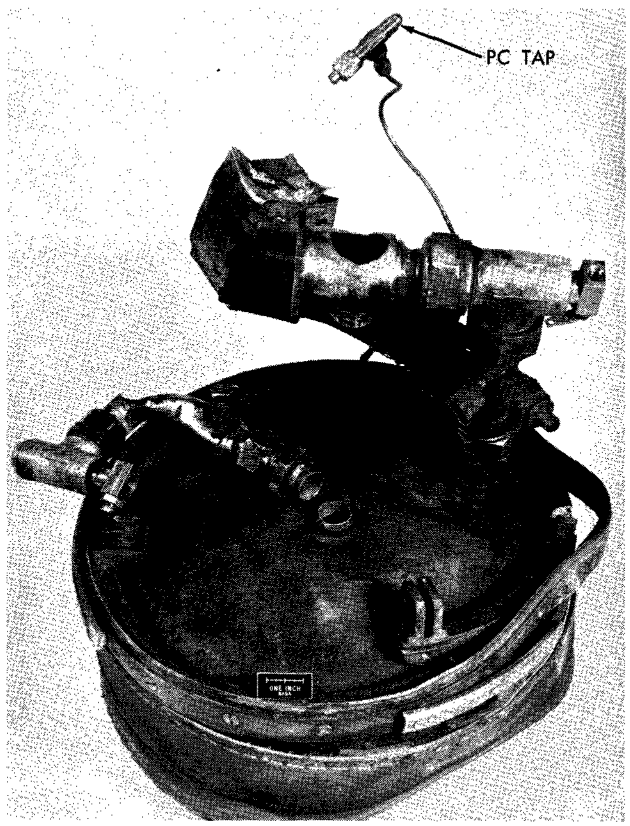


Figure 36—Flight 4.113 GA-GI aft fuel tank bulkhead showing burned aniline deposits.

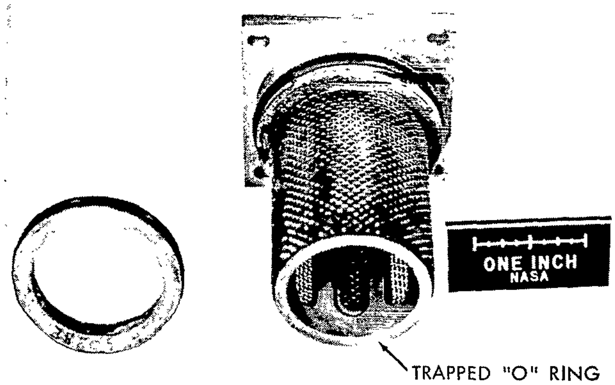


Figure 37—Flight 4.113 GA-GI fuel strainer showing trapped "O"-ring.

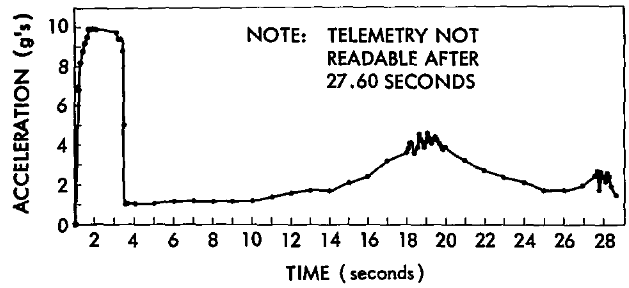


Figure 38—Flight 4.113 GA-GI acceleration vs. time.

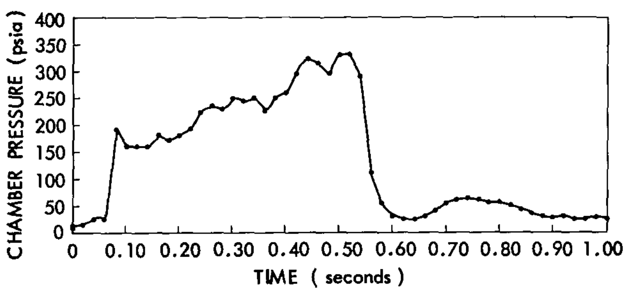


Figure 39a—Flight 4.113 GA-GI chamber pressure vs. time (0-1 second).

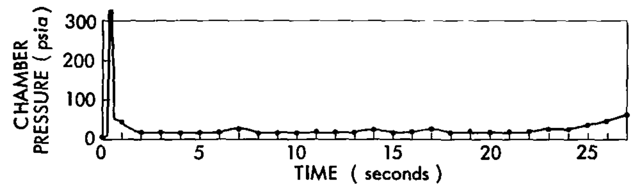


Figure 39b—Flight 4.113 GA-GI chamber pressure vs. time (0-27 seconds; tail can ruptured at 27 seconds).

by the acid-rich smoke almost completely obscuring the booster, indicate unstable combustion, the result of a hard start.

Several factors are deduced as possible causes of the hard start: improper propellant tank ullage, an improper breakage of fuel or oxidizer burst diaphragms and/or an improper bleeding of the thrust chamber jacket. Other flight anomalies resulted from the extreme back pressures generated by the hard start, which were sufficient to break the fuel and thrust chamber pressure taps (Figure 35). With fuel flowing out of the fuel line tap, the motor was operating under an oxidizer-rich condition until approximately T+27 seconds, when the tail can exploded (Figure 39b).

The propulsion system failure on this flight pointed to the need for increased vigilance during rocket preparation. As a result of these investigations, several measures were instituted:

Preflight vehicle hardware checks were increased; propellant temperatures are more carefully regulated; a more efficient method of bleeding air from the thrust chamber jacket is being proposed; quality control for obtaining specified burst pressures of diaphragms has been increased.

Figure 40 plots roll rate and pitch frequency and Figure 41 gives payload dimensions and flight characteristics.

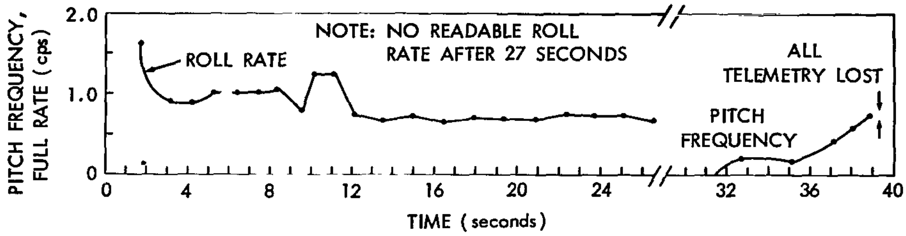
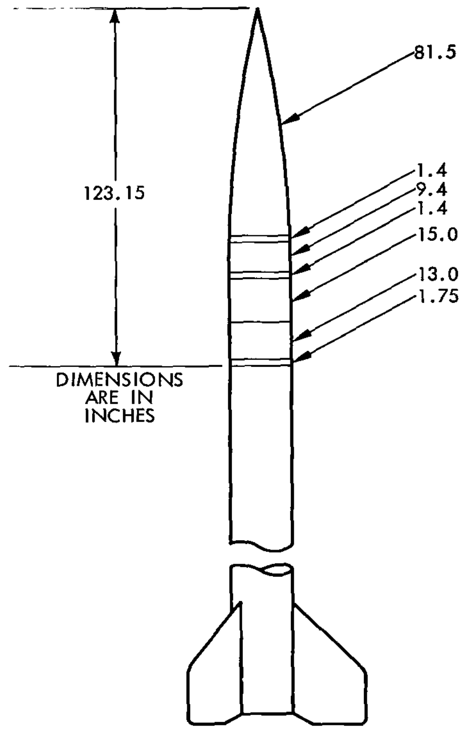


Figure 40—Flight 4.113 GA-GI roll rate and pitch frequency vs. time.

Flight 4.67 NP

Flight 4.67 NP, successfully launched from WSMR on 10 June, was the first Aerobee flight following investigations of the three consecutive failures discussed previously. The primary objective of the experiment was to record micrometeoroid impacts on an inflatable paraglider with capacitor-type sensing instruments. Additional objectives included the collection of micrometeoroids and testing of the paraglider's re-entry capabilities. The payload consisted of an unpressurized standard ogive nose cone, a 39-inch extension which housed the camera, folded paraglider, the packing cannister and the attachment rings, and a 15-inch instrumentation extension with four quadraloop antennas mounted on the external skin. The sustainer was altered by the addition of three retro-nozzles in the tail. These were to further assure separation of the sustainer from the payload after burnout by using residual helium from the propulsion system. Flow to the nozzles was controlled by two conax squib valves. An independent power supply and arming device were added to effect the separation of the payload and the spent sustainer.

The vehicle performed as predicted, attaining a peak altitude of 96.4 statute miles. All instrumentation worked well. However, a switching circuit failed to actuate the nose cone



FIRING DATE	21 APR 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	239.00
APOGEE (ST MI)	6.60
TIME TO APOGEE (SEC)	29.20
CENTER OF GRAVITY (CAL)	10.43
CENTER OF PRESSURE (CAL)	13.60
STATIC MARGIN (CAL)	3.23
RESTORING MOMENT (PER DEGREE)	-0.103
SUSTAINER BURNOUT TIME (SEC)	27.50
ROLL RATE AT BURNOUT (RPS)	NOT OBSERVED
TIP EJECT (SEC)	NOT APPLICABLE
NO. OF JOINTS	

SUSTAINER FAILED

Figure 41—Dimensions and flight characteristics, 4.113 GA-GI.

nose cone prior to re-entry. A back-up ground command successfully shut off the fuel and oxidizer valves, thus conserving the remaining helium for the despin system and the retro-rockets.

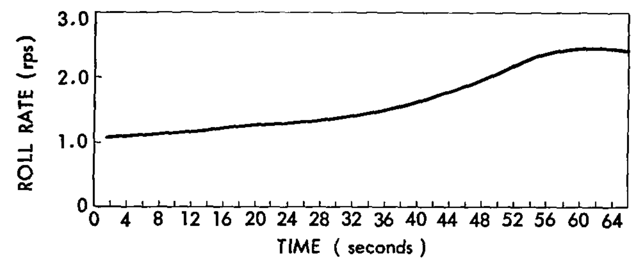


Figure 42—Flight 4.67 NP roll rate vs. time.

Figures 42 through 44 present reduced flight performance data for this flight. These are included to provide examples of a typical heavy Aerobee 150 rocket.

An onboard slow-speed movie camera photographed the paraglider from deployment through apogee and during re-entry. The film showed that the helium retro-firing system performed as expected. The paraglider was ejected, inflated, and began to glide as expected; the heavy nose tip, which did not eject,

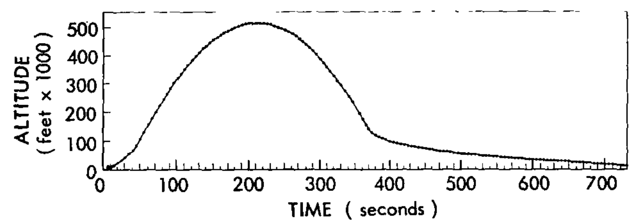


Figure 43—Flight 4.67 NP altitude vs. time.

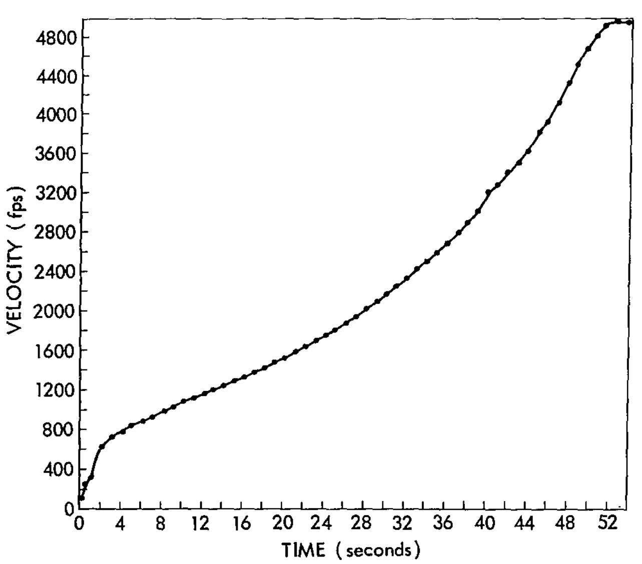


Figure 44—Flight 4.67 NP velocity vs. time.

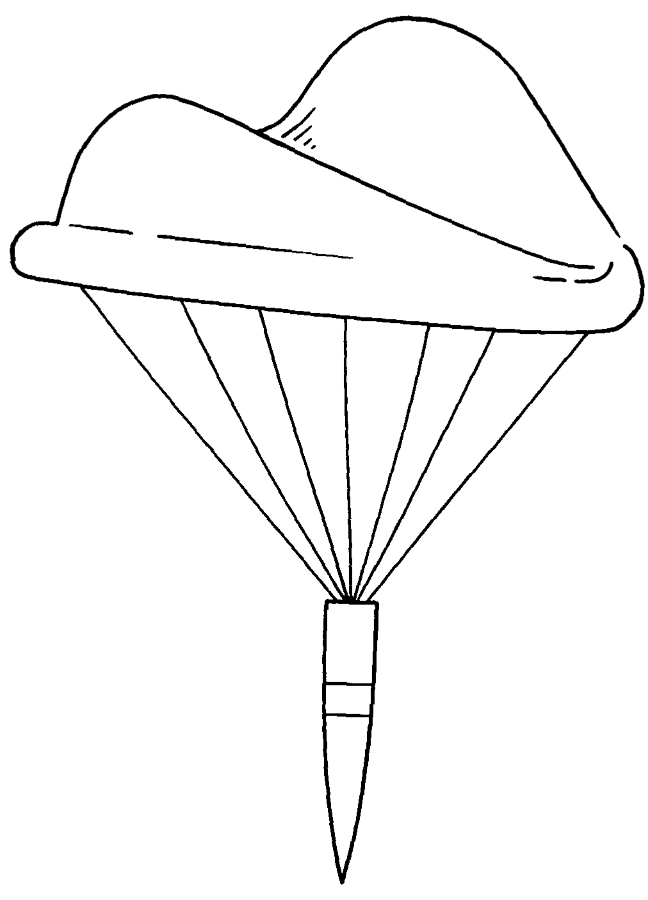


Figure 45—Configuration of inflatable micrometeoroid paraglider used on flight 4.67 NP.

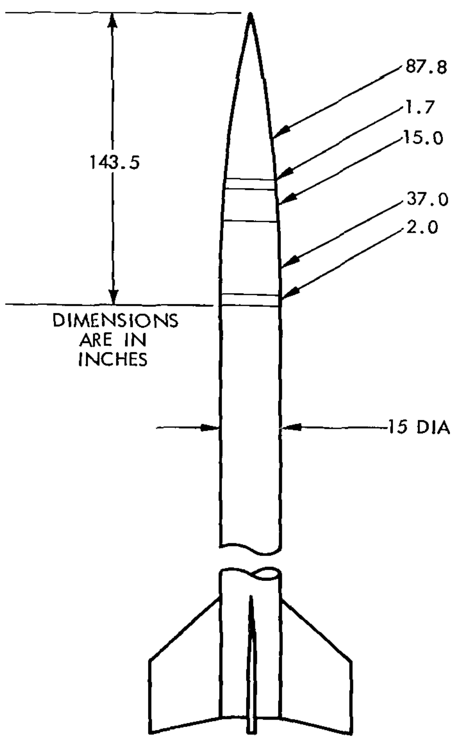
ejected, inflated, and began to glide as expected; the heavy nose tip, which did not eject, caused the paraglider to re-enter at a much more rapid rate than predicted. Although the paraglider membranes ruptured due to excessive loading, the paraglider was recovered. The paraglider, shown in Figure 45, is approximately 14 feet long, exposing approximately 200 square feet of sensors. Figure 46 gives payload dimensions and flight characteristics.

Flights 4.107 GE and 4.108 GE

Flights 4.107 GE and 4.108 GE were launched consecutively from CRR (Figure 47). The scientific objective was to study the very low energy heavy nuclei cosmic rays as a part of the International Quiet Sun Year Studies. Specific objectives were:

(1) Measurement of fluxes and energy spectra of heavy nuclei in the very low energy region (which cannot be studied by balloon)

(2) Examination of the composition and relative abundance of heavy nuclei in this low energy region



FIRING DATE	10 JUNE 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	353.90
APOGEE (ST MI)	96.40
TIME TO APOGEE (SEC)	211.10
CENTER OF GRAVITY (CAL)	11.40
CENTER OF PRESSURE (CAL)	15.00
STATIC MARGIN (CAL)	3.60
RESTORING MOMENT (PER DEGREE)	0.396
SUSTAINER BURNOUT TIME (SEC)	52.10
ROLL RATE AT BURNOUT (RPS)	2.50
NO. OF JOINTS	5

Figure 46—Dimensions and flight characteristics, 4.67 NP.

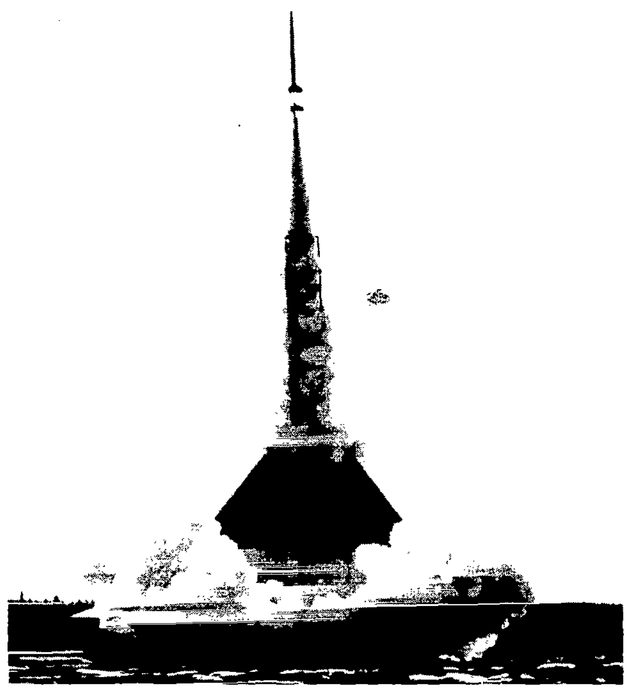


Figure 47—Aerobee rocket 4.107 GE launch from Churchill Research Range.

(3) Study of the ratio of light nuclei ($3 \leq Z \leq 5$) to medium ($6 \leq Z \leq 9$) to heavy ($Z \geq 10$)
(4) Measurement of alpha particles at these energies.

Additional objectives included the launching of each vehicle at the same time a University of Minnesota high altitude cosmic ray balloon was in the air. These data, when compared with the balloon data and the data from a similar Aerobee flight in 1963 (4.91 GS), were useful in studying the effects of solar modulation of cosmic rays. These flights are especially significant in this study since they occurred very close to the minimum of solar activity during the present solar cycle.

Measurements were made by placing large sheets of nuclear emulsions in a recoverable payload. The emulsions were to be exposed after burnout and later retracted before impact.

Both flights were successful. For flight 4.107 GE, rocket altitude performance was greater than predicted while the experimental results were slightly less than expected due to a malfunction within the experiment. The performance of flight 4.108 GE was slightly less than predicted; however, the experimental results were completely successful. In both cases the excellent ground support received and the cooperation provided in the recovery operation contributed greatly to the success of the mission.

Flight 4.107 GE

Flight 4.107 GE was launched on 23 July from CRR. The launch operation and liftoff were normal. The booster and sustainer functioned properly; sustainer burning was 2 seconds longer than predicted. The peak altitude was 4.5 statute miles above that predicted. All instrumentation performed satisfactorily during flight and excellent data were obtained. Figures 48 and 49 show the reduced acceleration and chamber pressure data for this flight.

The recovery package, including a SARAH beacon, functioned as planned and the parachute was easily spotted from the air. A conventional aircraft directed the recovery of the payload by an Air Force helicopter. The nose cone was recovered in excellent condition. Unfortunately, a timer failure prevented two of the three trays, which contained emulsions, from retracting completely. Some of the emulsions were damaged by the re-entry heat and moisture upon landing.

Figure 50 is a view of the experiment section. In this figure, the mechanisms and motors used to extract and retract the emulsion plates during flight are clearly identifiable.

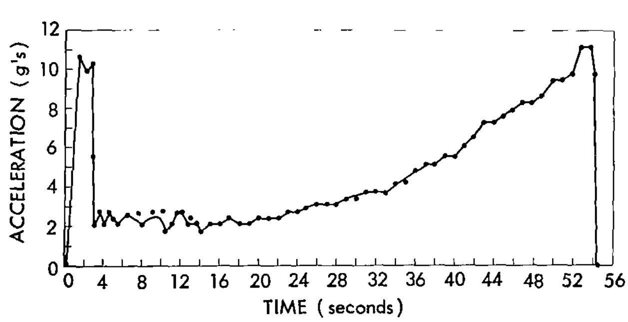


Figure 48—Flight 4.107 GE acceleration vs. time.

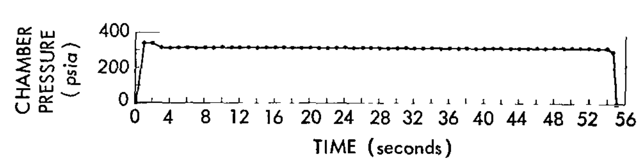


Figure 49—Flight 4.107 GE chamber pressure vs. time.

Figure 51 shows the vehicle configuration during weight and center of gravity determination. Figure 52 gives payload dimensions and flight characteristics.

Flight 4.108 GE

Rocket 4.108 GE was launched on 25 July, two days after flight 4.107 GE. This rocket was identical in payload and mission, and was intended as a back-up rocket in case the scientific objectives of 4.107 GE were not completely met. The rocket and all instrumentation performed well, although the peak altitude attained was slightly lower than predicted. The payload functioned perfectly and excellent data were received.

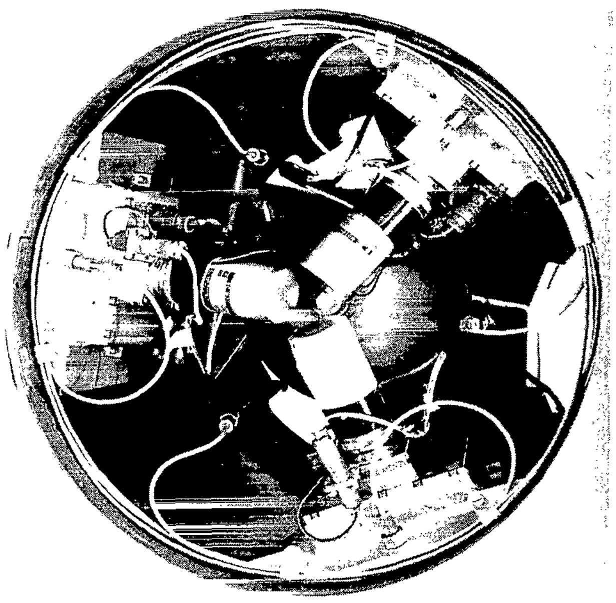


Figure 50—Experiment section, flight 4.107 GE.

At 63 seconds the three emulsion plates were extended and then retracted completely at 435 seconds, prior to re-entry. The recovery system functioned properly, and with assistance from SARAH beacon which was included in the recovery package, a conventional aircraft, used to spot the payload for recovery, had no difficulty in locating the payload. The actual recovery was effected soon thereafter by helicopter. Figure 53 shows this operation. Figure 54 is a picture of the experiment section (minus the extension casing) being tested at CRR by GSFC engineers.

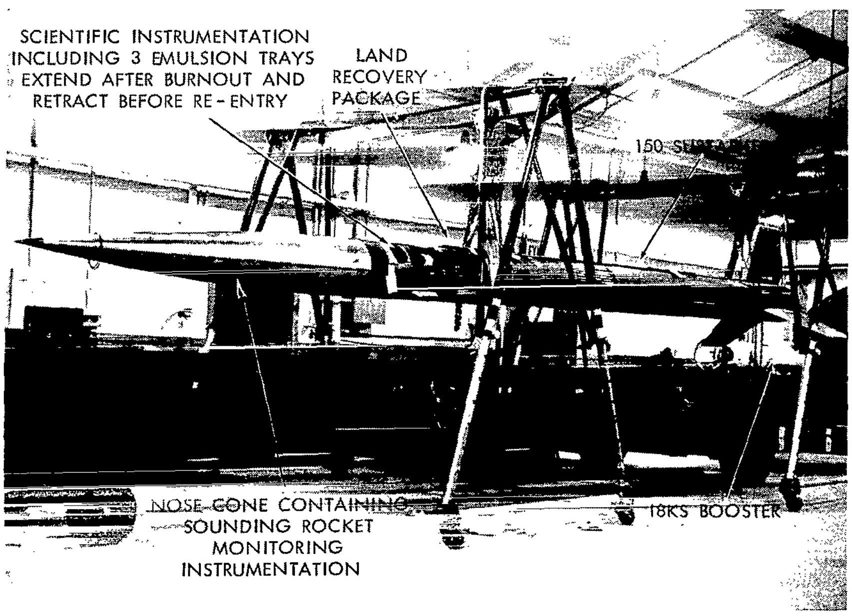
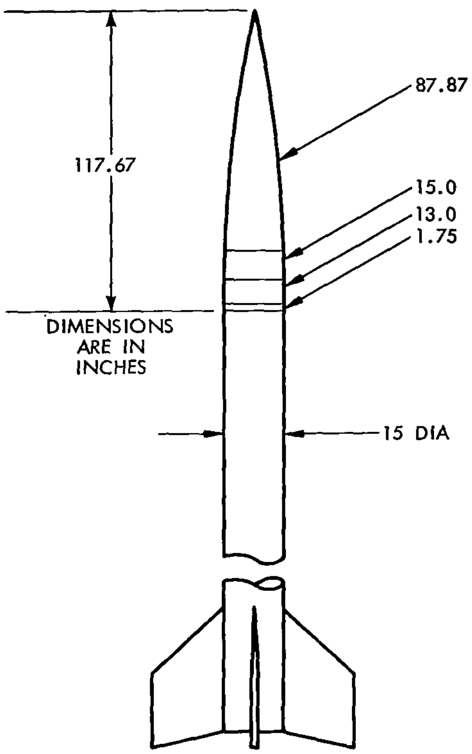


Figure 51—Loading rocket on removable tower rail, CRR, Aerobee 4.107 GE.



FIRING DATE	23 JULY 1964
LAUNCH SITE	CRR
PAYLOAD WT (LB)	185.40
APOGEE (ST MI)	144.50
TIME TO APOGEE (SEC)	267.00
CENTER OF GRAVITY (CAL)	10.82
CENTER OF PRESSURE (CAL)	13.25
STATIC MARGIN (CAL)	2.43
RESTORING MOMENT (PER DEGREE)	-0.245
SUSTAINER BURNOUT TIME (SEC)	53.00
ROLL RATE AT BURNOUT (RPS)	1.80
NO. OF JOINTS	4

Figure 52—Dimensions and flight characteristics, 4.107 GE.

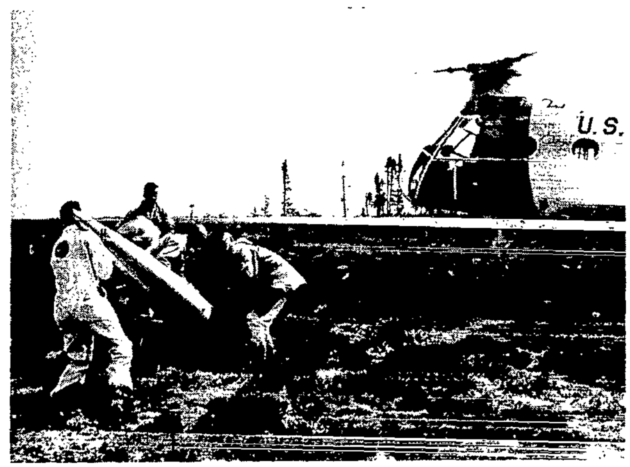


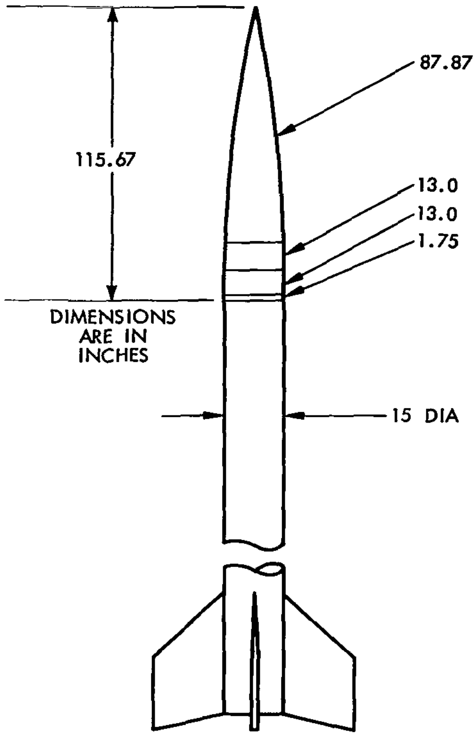
Figure 53—Recovery of Aerobee 4.108 GE payload.

Figure 54—Experiment section without the extension casing, flight 4.108 GE.

At recovery it was noted that the SARAH beacon antenna was shorting on the parachute container support brackets, thus giving an intermittent transmission accompanied by a frequency shift. This was concluded to result from improper positioning of the beacon in the recovery package. Magnetometer data indicated that payload coning throughout the flight was very slight, which was excellent for purposes of the experiment. Figure 55 gives payload dimensions and flight characteristics.

Flight 6.10 GA

Flight 6.10 GA was launched successfully from CRR on 28 July. Its objective was to simultaneously measure the electron and neutral particle temperatures in the high altitude region



FIRING DATE	25 JULY 1964
LAUNCH SITE	CRR
PAYLOAD WT (LB)	179.50
APOGEE (ST MI)	133.70
TIME TO APOGEE (SEC)	251.00
CENTER OF GRAVITY (CAL)	10.70
CENTER OF PRESSURE (CAL)	13.25
STATIC MARGIN (CAL)	2.55
RESTORING MOMENT (PER DEGREE)	-0.255
SUSTAINER BURNOUT TIME (SEC)	51.70
ROLL RATE AT BURNOUT (RPS)	2.20
NO. OF JOINTS	4

Figure 55—Dimensions and flight characteristics, 4.108 GE.

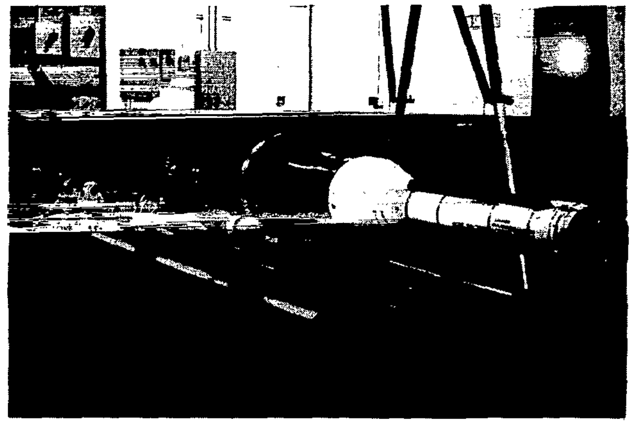


Figure 56—Prepared Spaerobee rocket (Aerobee 300) less nose cone (flight 6.10 GA).

between 120-360 kilometers. A secondary objective was the measurement of ion and neutral particle density in this altitude region.

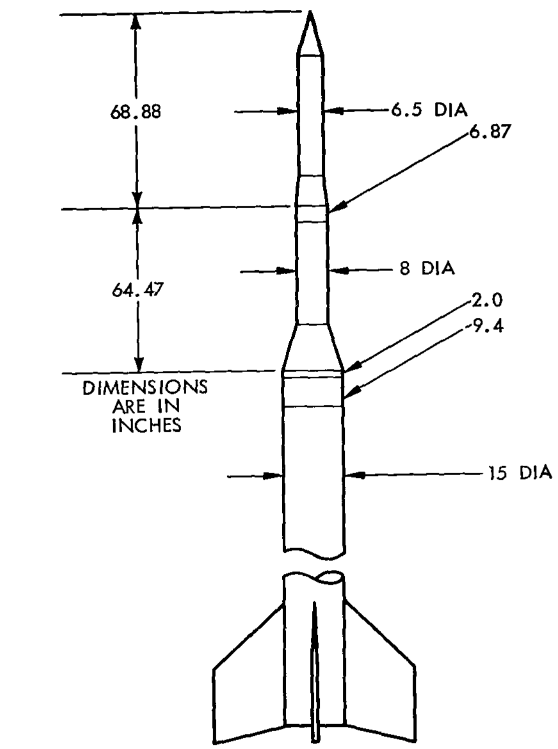
The rocket attained a peak altitude of 159.7 statute miles, approximately 40 miles lower than predicted. DOVAP tracked through the complete trajectory. Evidence indicates the third stage went into a flat spin approximately 10 seconds after third stage burnout.

Unfortunately, the thermosphere probe did not eject at T+88 seconds, as planned. This apparently resulted from centrifugal forces caused by the flat spin, which prevented the clamshell nose cone from opening to the 165° required to release the probe ejection latch; thus one experiment, the omegatron, was lost. As a result of this malfunction, the dipole antennas on the probe were touching the partially opened clamshell, resulting in intermittent telemetry signals. Other experimental results, however, were satisfactory.

Figure 56 shows the prepared rocket, less the nose cone. Figure 57 gives payload dimensions and flight characteristics.

Flight 4.82 GG

Aerobee 4.82 GG was successfully launched from WSMR on 11 August, carrying four spectrographs to obtain spectra of planets in the region between 1600 to 3000 Å. The IACS was supposed to point the instruments at Jupiter, Venus, and Mars. The rocket attained an apogee of 107 statute miles and although slightly below predicted, performance was considered good. The instrumentation rack was located in the nose and a heat shield was utilized to protect the electronics from aerodynamic heating (Figure 58). The IACS was unable to operate, and none of the experimental objectives were met. Upon payload recovery, inspection of the IACS revealed fragments of gas burst diaphragm material in the despin valve. These fragments prevented the valve from properly seating, thereby allowing the rocket to continue spinning up in a counter-clockwise direction. Chemical analysis confirmed conclusively that the fragments were from the gas line burst diaphragm; Figure 59 is a photograph of the trapped particles. As a result of this first-time occurrence, a fine-mesh filter has been added in the helium line between the gas burst diaphragm and IACS line in order to trap and diaphragm particles. Figure 60 gives payload dimensions and flight characteristics.



FIRING DATE	28 JULY 1964
LAUNCH SITE	CRR
PAYLOAD WEIGHT, 2ND STAGE (LB)	253.40
APOGEE (ST MI)	200.00
TIME TO APOGEE (SEC)	305.00
CENTER OF GRAVITY, SUSTAINER BURNOUT (CAL)	10.90
CENTER OF PRESSURE, SUSTAINER BURNOUT (CAL)	14.75
STATIC MARGIN, SUSTAINER BURNOUT (CAL)	3.85
RESTORING MOMENT, SUSTAINER BURNOUT (PER DEGREE)	-0.400
CENTER OF GRAVITY, 3RD STAGE IGNITION (CAL)	8.38
CENTER OF PRESSURE, 3RD STAGE IGNITION (CAL)	11.40
STATIC MARGIN, 3RD STAGE IGNITION (CAL)	3.02
RESTORING MOMENT, 3RD STAGE IGNITION (PER DEGREE)	-0.110
SUSTAINER BURNOUT (SEC)	54.00
THIRD STAGE BURNOUT (SEC)	* UNKNOWN
ROLL RATE AT BURNOUT, SUSTAINER (RPS)	2.00
ROLL RATE AT BURNOUT, 3RD STAGE (RPS)	* UNKNOWN
NUMBER OF JOINTS	8
PAYLOAD WEIGHT, 3RD STAGE (LBS)	96.875

*RADAR ONLY PARTIALLY TRACKED SUSTAINER & COULD NOT TRACK 3RD STAGE. T/M LOST COMPLETELY AT T+88 SEC.

Figure 57—Dimensions and flight characteristics, 6.10 GA.

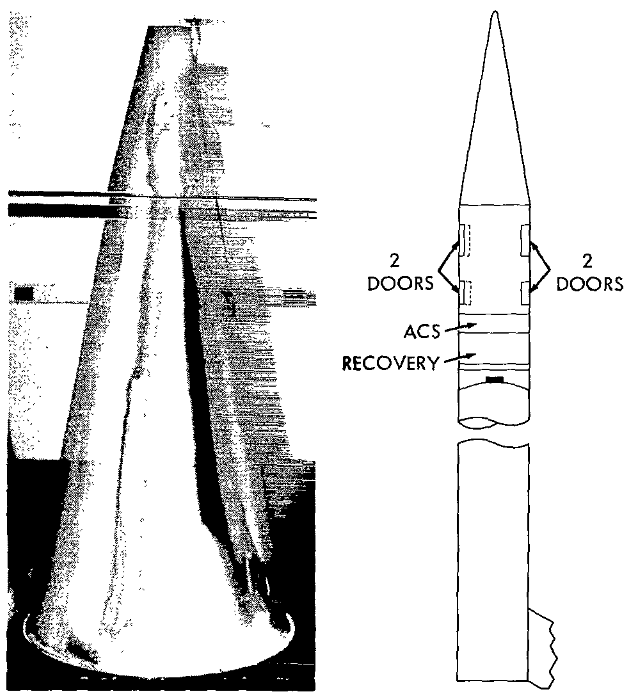


Figure 58—Heat shield used on flight 4.82 GG (located under nose cone).

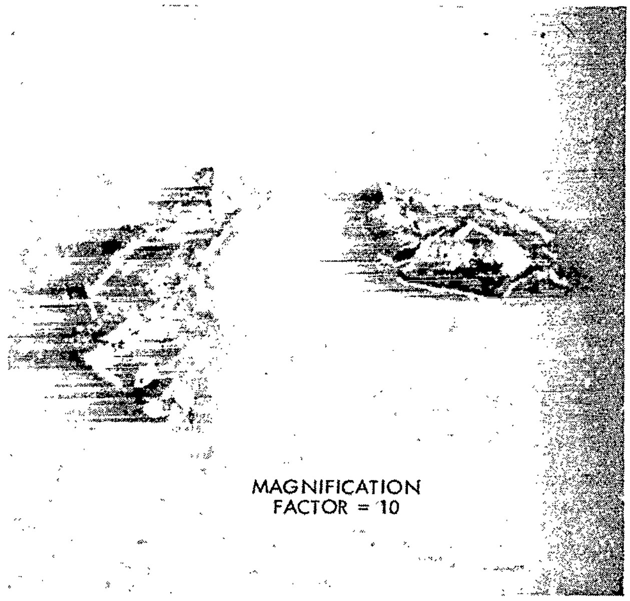
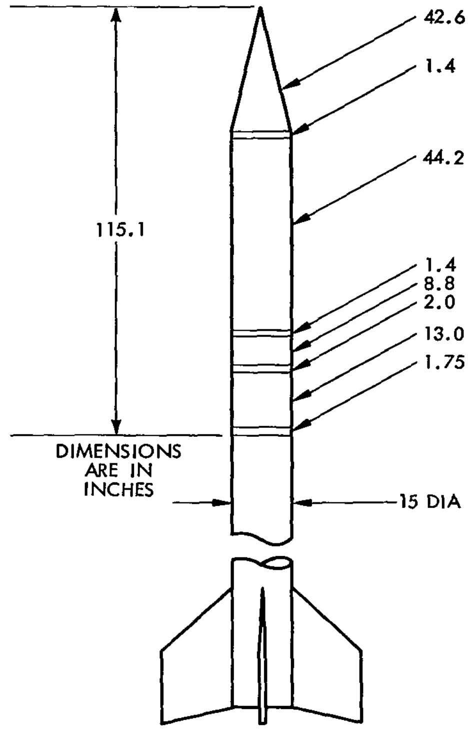


Figure 59—Gas line burst diaphragm fragments.

Flight 4.126 GG

Aerobee 4.126 GG was successfully launched at night from WSMR on 22 August. The rocket configuration included four spectrographs which were to obtain untraviolet spectra data from Mars, Venus, and Jupiter, after being pointed by the IACS. This flight required a morning twilight launch.

Prior to launching the rocket, the tail can was strengthened by the addition of a magnesium liner which was riveted in place with 200 flush-head rivets. The only difficulty was experienced prior to liftoff. The overboard dump valve squib leads were broken and could not be replaced in the tower due to the excess amount of instrumentation in the forward skirt. The valve was closed manually, however, prior to installation of the forward skirt door. The new filter was added to the helium line in the regulator to trap gas burst diaphragm fragments (discussed in 4.82 GG). Rocket performance appeared normal until T+46 seconds except for a slighly low thrust chamber pressure (Figure 61). Starting at T+46 seconds, erratic thrust chamber pressures were observed and burnout occurred several seconds earlier than expected.



FIRING DATE	11 AUG 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	286.00
APOGEE (ST MI)	107.10
TIME TO APOGEE (SEC)	221.33
CENTER OF GRAVITY (CAL)	9.84
CENTER OF PRESSURE (CAL) @ B.O.	12.35
STATIC MARGIN (CAL) @ B.O.	2.51
RESTORING MOMENT COEFFICIENT (PER DEGREE) @ B.O.	-0.284
SUSTAINER BURNOUT TIME (SEC)	52.22
ROLL RATE AT BURNOUT (RPS)	2.25
NO. OF JOINTS	8

Figure 60—Dimensions and flight characteristics, 4.82 GG.

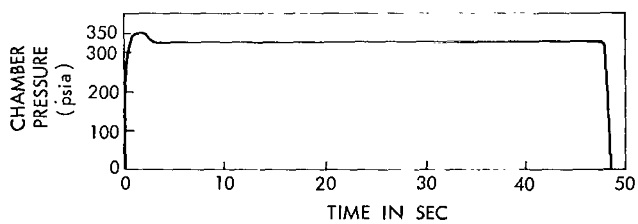


Figure 61—Flight 4.126 GG chamber pressure vs. time.

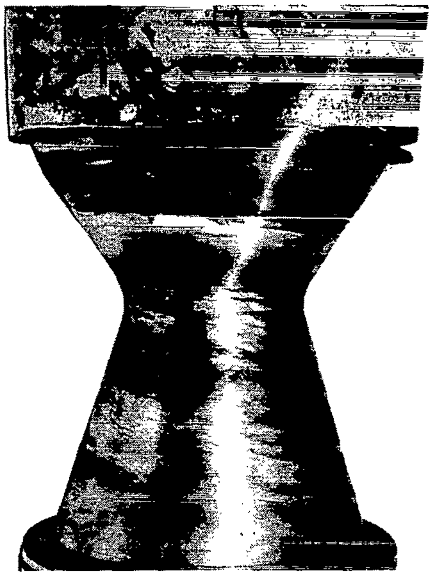


Figure 62—Flight 4.126 GG thrust chamber burn-through.

Postflight inspection of the thrust chamber verified hypotheses that a chamber "burn-through" had occurred. Figure 62 shows the thrust chamber for this flight after it had been returned and inspected at GSFC. The burn-through can easily be seen. This figure, a discussion of the burn-through problem, and photographs of other similar occurrences are the subject of Reference 4. Peak altitude was 77 statute miles, 45 miles short of predicted altitude. The rocket's performance was continuously monitored throughout the flight by an accelerometer (Figure 63) and a thrust chamber pressure gage. Onboard telemetry also monitored the pitch movements of the rocket (Figure 64).

During flight the IACS performed as expected. Although failure to attain altitude shortened the time available for experimental observation, sufficient data were obtained.

The standard recovery system was successfully used in effecting a quick payload recovery. The sustainer was also recovered. Figure 65 gives payload dimensions and flight characteristics.

Flight 4.122 CG

Rocket 4.122 CG was launched successfully to a peak altitude of 110 statute miles from WSMR on 29 August. The primary scientific objective was to collect data on the size, location and flux levels of celestial X-ray sources. Experimental instrumentation included four banks of Geiger counters (Figure 66), a photoelectric detector, two scintillation counters, and a star sensor. A fiberglass ogive nose cone, modified for ejection of three doors (subsequent to burnout), was used.

Vehicle launch operation was normal. Burnout velocity was lower than predicted, and apogee attained was consequently 20 miles below the predicted. The roll rate at burnout was 1.1 rps.

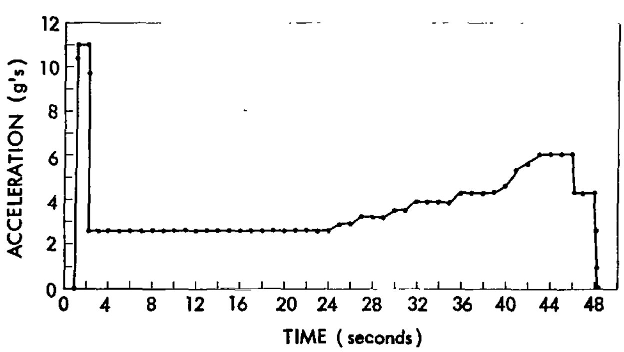


Figure 63—Flight 4.126 GG acceleration vs. time.

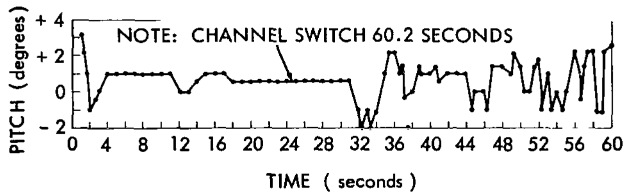
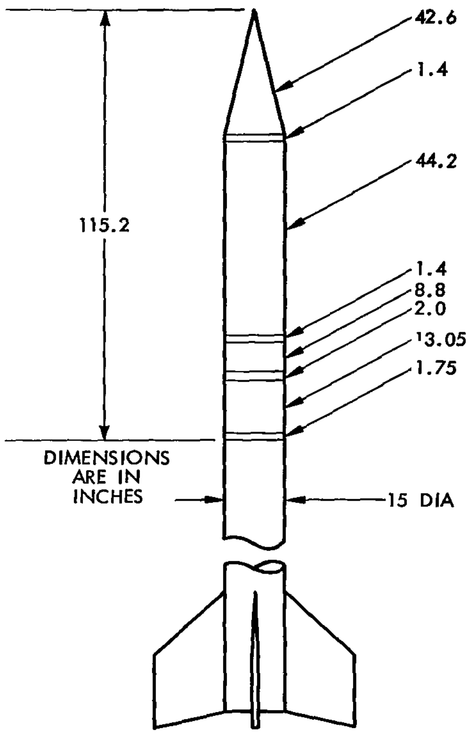


Figure 64—Flight 4.126 GG pitch vs. time.



FIRING DATE	22 AUG 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	265.625
APOGEE (ST MI)	76.60
TIME TO APOGEE (SEC)	190.00
CENTER OF GRAVITY (CAL)	9.81
CENTER OF PRESSURE (CAL)	12.50
STATIC MARGIN (CAL)	2.72
RESTORING MOMENT (PER DEGREE)	-0.278
SUSTAINER BURNOUT TIME (SEC)	48.68
ROLL RATE AT BURNOUT (RPS)	1.90
NO. OF JOINTS	8

Figure 65—Dimensions and flight characteristics, 4.126 GG.

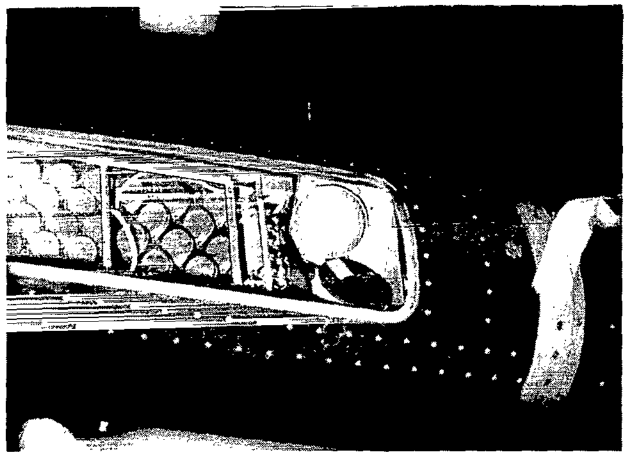


Figure 66—Flight 4.122 CG payload.

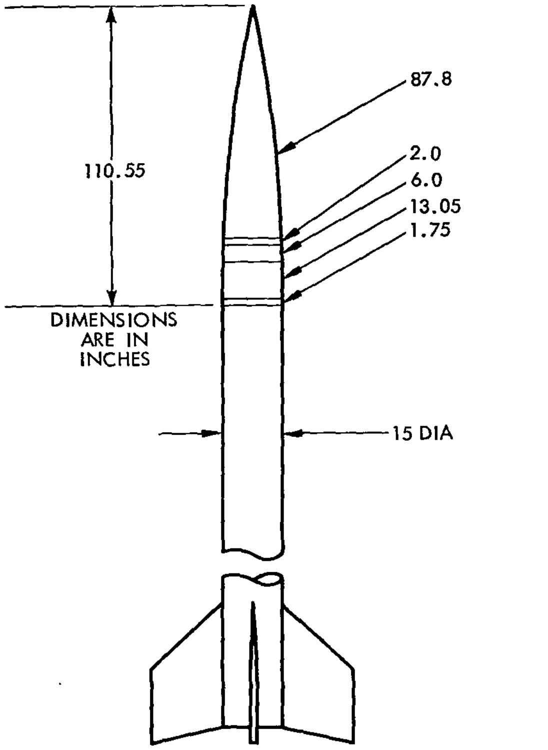
Despite failure to attain anticipated peak altitude, good data were collected. The experiment was reportedly 85 percent successful, illustrating that an experiment is not necessarily compromised when a rocket does not perform exactly as predicted.

The recovery system functioned as planned and the payload and sustainer were recovered. A close inspection was made of the recovered thrust chamber but no abnormal conditions were observed to account for the large altitude underperformance. Figure 67 gives payload dimensions and flight characteristics.

Flight 4.55 UG

Vehicle 4.55 UG was successfully launched from WI on 2 September to a peak altitude of 96.5 statute miles. Although the altitude performance was less than predicted, all rocket and experimental instrumentation functioned well and good quality data were received.

The propulsion system was monitored by a thrust chamber pressure transducer (Figure 68) and an accelerometer (Figure 69). Internal nose cone pressure was also monitored during flight to determine if there was any outgassing. Two magnetometers were used for providing aspect data. A 14.2-inch-diameter, cone-cylinder nose cone was used rather than the standard Aerobee ogive nose cone; this was adapted to the 15-inch vehicle diameter by a transition extension.



FIRING DATE	29 AUG 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	264.125
APOGEE (ST MI)	111.20
TIME TO APOGEE (SEC)	225.70
CENTER OF GRAVITY (CAL)	10.00
CENTER OF PRESSURE (CAL)	13.20
STATIC MARGIN (CAL)	3.20
RESTORING MOMENT (PER DEGREE)	-0.336
SUSTAINER BURNOUT TIME (SEC)	52.00
ROLL RATE AT BURNOUT (RPS)	1.10
NO. OF JOINTS	5

Figure 67—Dimensions and flight characteristics, 4.122 CG.

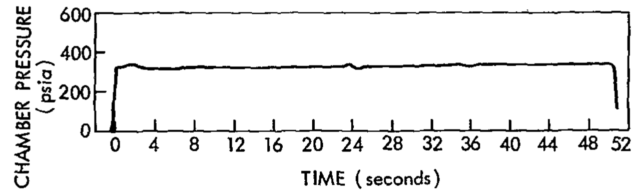


Figure 68—Flight 4.55 UG chamber pressure vs. time.

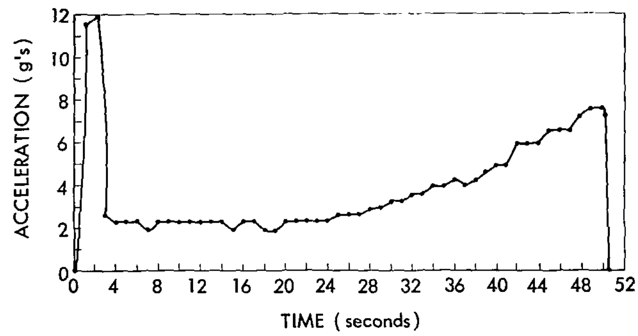


Figure 69—Flight 4.55 US acceleration vs. time.

At approximately 68 seconds of flight, the standard gas-operated despin system (mounted in the regulator section of the sustainer) was activated. Twenty-seven seconds were required to despin the rocket down to 0.04 rps, a rate which contributed to the desirable precessional half angle of approximately 45°. The roll rate prior to despin was indicated by the magnetometer to be 2.5 rps. No IACS system or recovery package was required for the flight. The telemetry system provided good data for 387 seconds and all instrumentation functioned as expected. Despite the low apogee, excellent experimental data were obtained.

The purpose of the experiment was to measure the brightness of stars in the ultraviolet spectral bands. Instrumentation used for these measurements included two sets of four photoelectric photometers with filters. Eight windows were cut in the nose cone to permit experimental telescopes whose axes were perpendicular to the vehicle axis to "look out" during the flight. Figure 70 shows these photometers.

Predicted burnout velocity for 4.55 UG was 5700 fps; actual burnout velocity was 5180 fps at 106,000 feet. Figure 71 shows the altitude plot for the first 62 seconds of flight. Figure 72 gives payload dimensions and characteristics of this rocket and its flight.

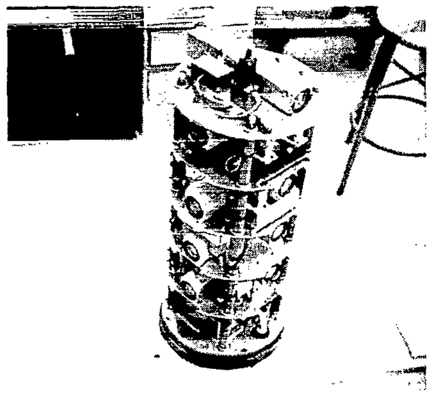


Figure 70—Photometers used on flight 4.55 UG payload.

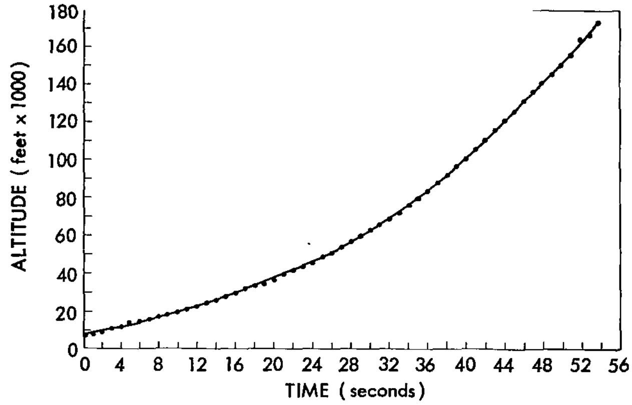


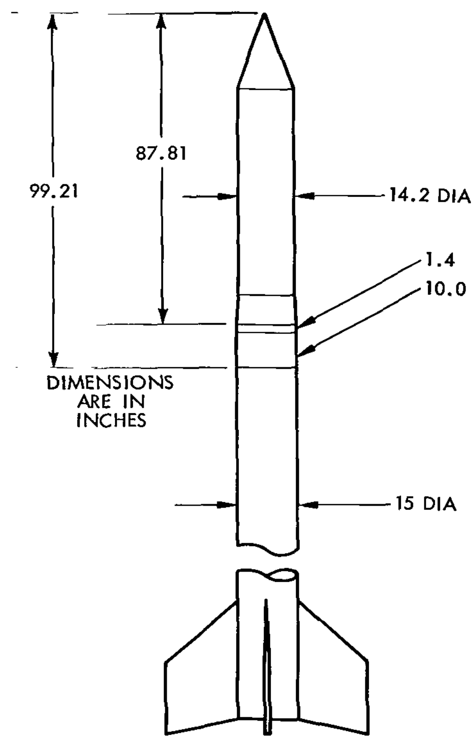
Figure 71—Flight 4.55 UG altitude vs. time.

Flight 4.115 NA

NASA 4.115 NA was successfully launched from WI on 18 September. The vehicle performed satisfactorily, reaching a peak altitude of 105 statute miles. No anomalies were observed on this flight, which was similar in experimental objectives to 4.86 NA, but without a recovery system. The successful performance of this rocket illustrates typical Aerobee 150A rocket behavior using the cone-cylinder nose.

The purpose of the experiment was to measure ultraviolet light emitted from the sun and scattered by the earth's atmosphere (dayglow). An additional objective was to measure the earth's albedo in the wavelength spectral range of 1100-3300 Å. By using the standard IACS, the payload was first pointed in a zenith position for measurement. At 229 seconds, the rocket was programmed to turn over and look downwards to measure the earth's albedo; the vehicle was then programmed to pitch up to zenith. On the downward leg the rocket was pointed at the horizon.

The nose cone configuration consisted of a modified cone cylinder, designed to eject the forward tip at 63 seconds. The fins were set



FIRING DATE	2 SEPT 1964
LAUNCH SITE	WI
PAYLOAD WT (LB)	219.80
APOGEE (ST MI)	97.10
TIME TO APOGEE (SEC)	215.10
CENTER OF GRAVITY (CAL)	9.34
CENTER OF PRESSURE (CAL)	12.32
STATIC MARGIN (CAL)	2.98
RESTORING MOMENT (PER DEGREE)	-0.410
SUSTAINER BURNOUT TIME (SEC)	51.70
ROLL RATE AT BURNOUT (RPS)	2.50
NO. OF JOINTS	4

Figure 72—Dimensions and flight characteristics, 4.55 UG.

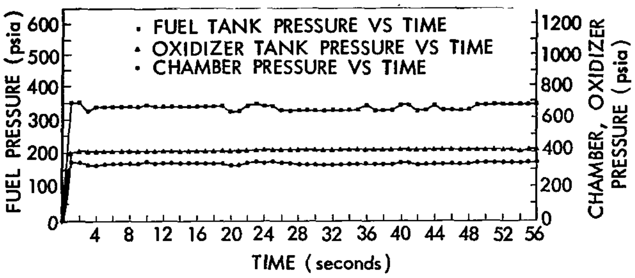


Figure 73—Flight 4.115 NA chamber pressure, fuel pressure, and oxidizer pressure vs. time.

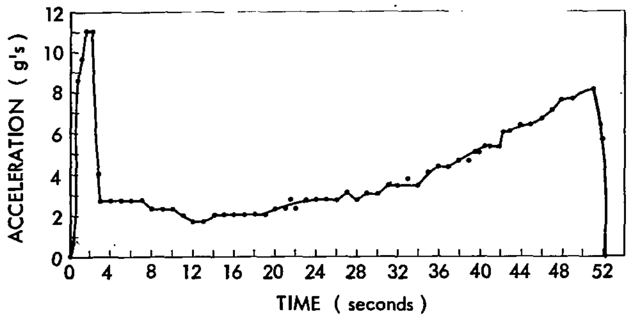


Figure 74—Flight 4.115 NA acceleration vs. time.

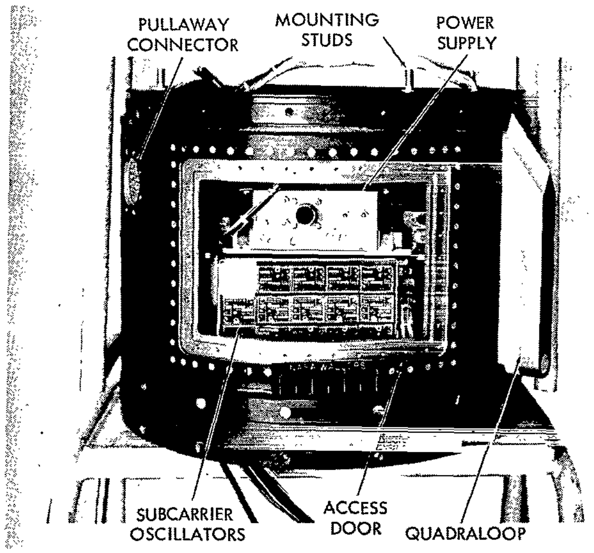
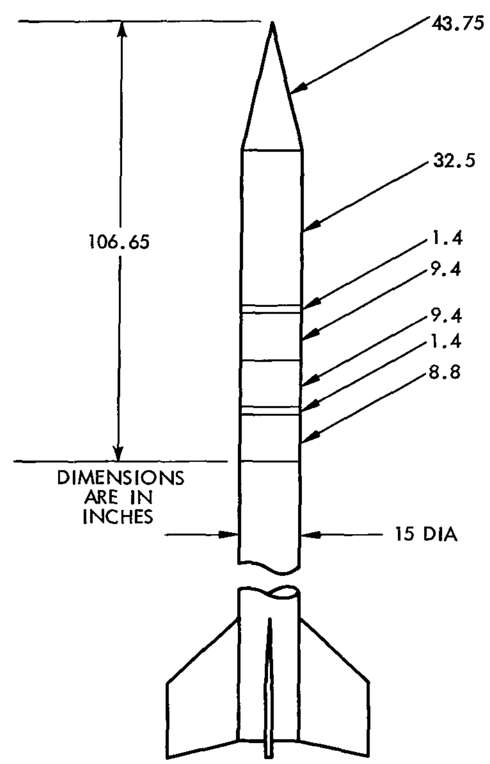


Figure 75—Flight 4.115 NA telemetry can.

for a roll rate of 2.5 rps at sustainer burnout. Sustainer burnout occurred at 114,000 feet at a velocity of 5316 fps; these parameters were very close to nominal. Figure 73 shows the chamber pressure, regulated helium pressure, and oxidizer tank pressure during the flight, Figure 74 provides acceleration information. Good experimental data were continuously received throughout the flight for 450 seconds.

Figure 75 shows the instrumentation and telemetry extension. Figure 76 gives payload dimensions and flight characteristics.



FIRING DATE	18 SEPT 1964
LAUNCH SITE	WI
PAYLOAD WT (LB)	240.00
APOGEE (ST MI)	104.40
TIME TO APOGEE (SEC)	222.10
CENTER OF GRAVITY (CAL)	9.67
CENTER OF PRESSURE (CAL)	12.72
STATIC MARGIN (CAL)	2.96
RESTORING MOMENT (PER DEGREE)	-0.407
SUSTAINER BURNOUT TIME (SEC)	52.20
ROLL RATE AT BURNOUT (RPS)	
TIP EJECT (SEC)	~63.00
NO. OF JOINTS	7

Figure 76—Dimensions and flight characteristics, 4.115 NA.

Flight 4.13 GP-GT

Flight 4.13 GP-GT was fired from WI on 26 September. The primary purpose of the instrumentation was to obtain quantitative propulsion and environmental data in order to solve the consistent 150A underperformance problem. Several other experiments were also flown; objectives included the testing of a new GSFC-designed and fabricated attitude control system; the measurement of low energy gamma rays; the measurement of sodium vapor radiation in the upper atmosphere; the evaluation of a new DOVAP transmitter; the study of nuclear emulsions to be used in cosmic ray studies; and recovery of the sustainer and portions of the payload for postflight evaluation and eventual reflight of the vehicle. This flight was significant in that it substantially advanced the knowledge of the Aerobee 150A propulsion system and provided useful data in solving the underperformance problem. (Reference 5).

The 4.13 GP-GT configuration used a conical nose cone, which was designed for ejection at T+75 seconds. Peak altitude for the 342 lb net payload was 74.5 statute miles; preflight calculations indicated a peak altitude of 85.7 miles. Burnout occurred early at 50.8 seconds, and it has been theorized that oxidizer depletion was the reason for the short burning time and the low apogee. This has been corrected in later flights by decreasing the oxidizer flow rate and has resulted in approaching vehicle performance design parameters.

Figure 77 shows the assembled rocket during DOVAP antenna tuning and prior to installation in the tower. Figure 78a shows the tail can section, which was filled with pressure transducers and power amplifiers. An unsuccessful attempt was made at vehicle recovery by severing at station 72.5. This would have allowed recovery, too, of onboard instrumentation aft of station 72.5. Figure 78b shows the explosive bolts which were to sever the tail fins. Unfortunately severance was not effected.

The recovery sequence was planned as follows:

(1) The barometric actuation box is armed on the upward leg of the trajectory.

(2) During the downward leg of the trajectory, at approximately 200,000 feet, the fins and the payload are severed from the rocket either by command or timer signal.

(3) The sustainer establishes a flat-spin, free-falling mode. This attitude reduces its velocity as it re-enters the atmosphere until a terminal velocity of approximately 250 to 300 fps is reached.

(4) At approximately 20,000 feet, the barometric actuation box initiates second severance.

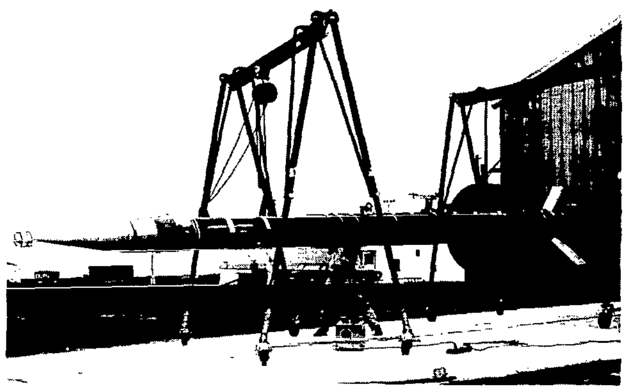


Figure 77—Assembled rocket for DOVAP antenna tuning, flight 4.13 GP-GT.

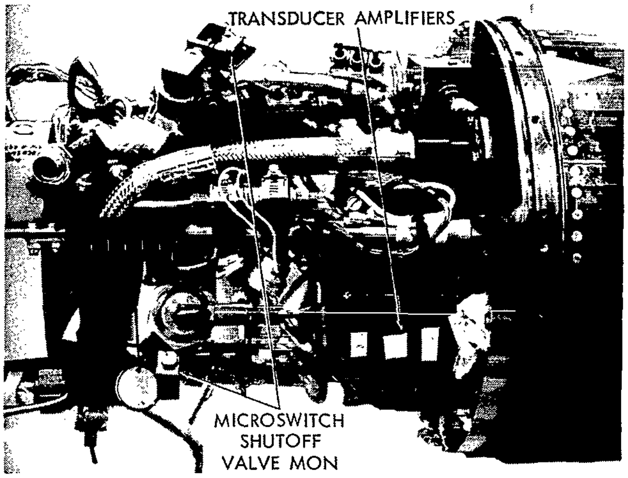


Figure 78a—Flight 4.13 GP-GT tail section with performance instrumentation.

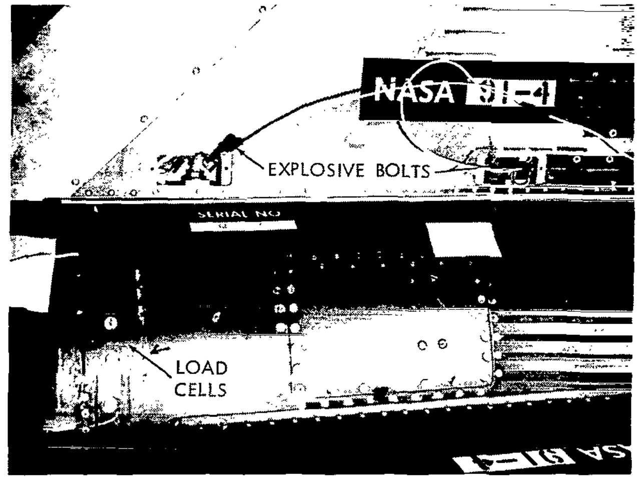


Figure 78b—Flight 4.13 GP-GT tail section.

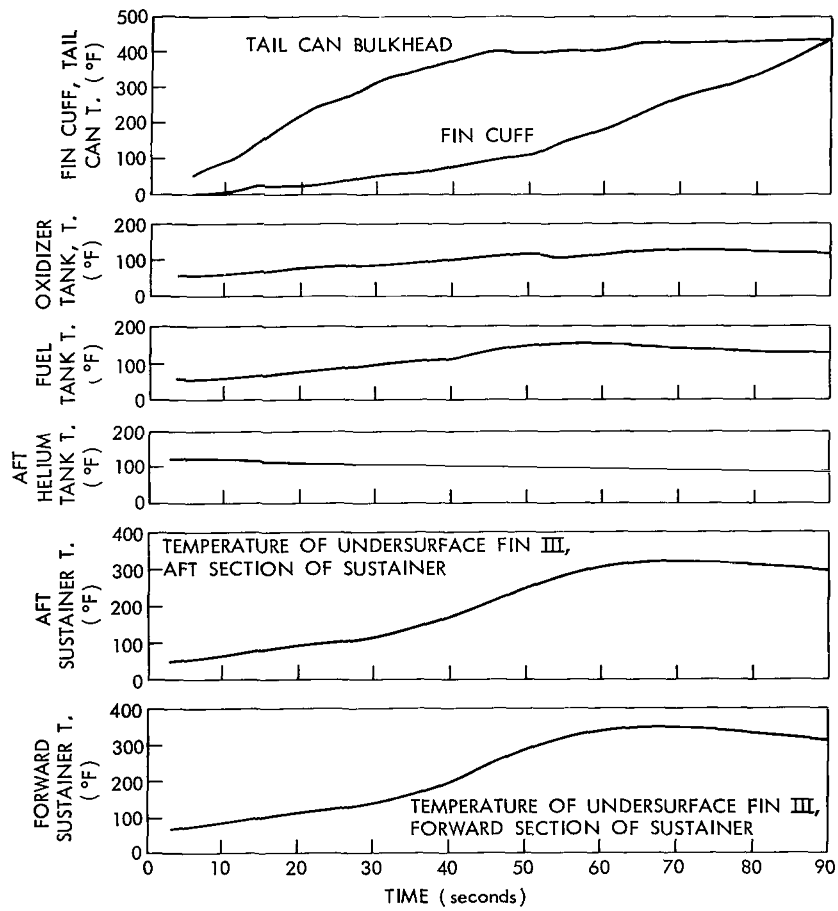


Figure 79—Flight 4.13 GP-GT temperature vs. time (forward section sustainer, aft section sustainer, aft helium tank, fuel tank, oxidizer tank, fin cuff, and tail can bulkhead; sustainer temperature readings taken from under surface of fin III).

(5) Upon severance, the recovery system extension cover separates and is ejected into the airstream, where its aerodynamic drag would extract the reefed FIST ribbon drogue-pilot parachute deployment bag and bridle.

(6) The drogue-pilot parachute inflates to its reefed shape, its drag force initiating the main parachute deployment bag's reefing line cutters. Stabilization and pitch-up of the sustainer are initiated by reefed drogue-pilot parachute.

(7) After 3 seconds, the FIST ribbon drogue-pilot parachute disreefs and opens fully, thus further stabilizing and decelerating the sustainer.

(8) The sustainer then falls in a stable, tail-first position, for approximately 9 more seconds, at which time the main parachute deployment bag's reefing cutter system is activated, causing deployment of the main parachute by the drogue-pilot parachute.

(9) The main parachute opens and decelerates the sustainer to a velocity of approximately 30 fps at water impact.

Figure 79 gives temperature readings for various locations on the rocket. Figures 80 through 83 summarize the pressure transducer outputs which all indicated that no unexpected pressure

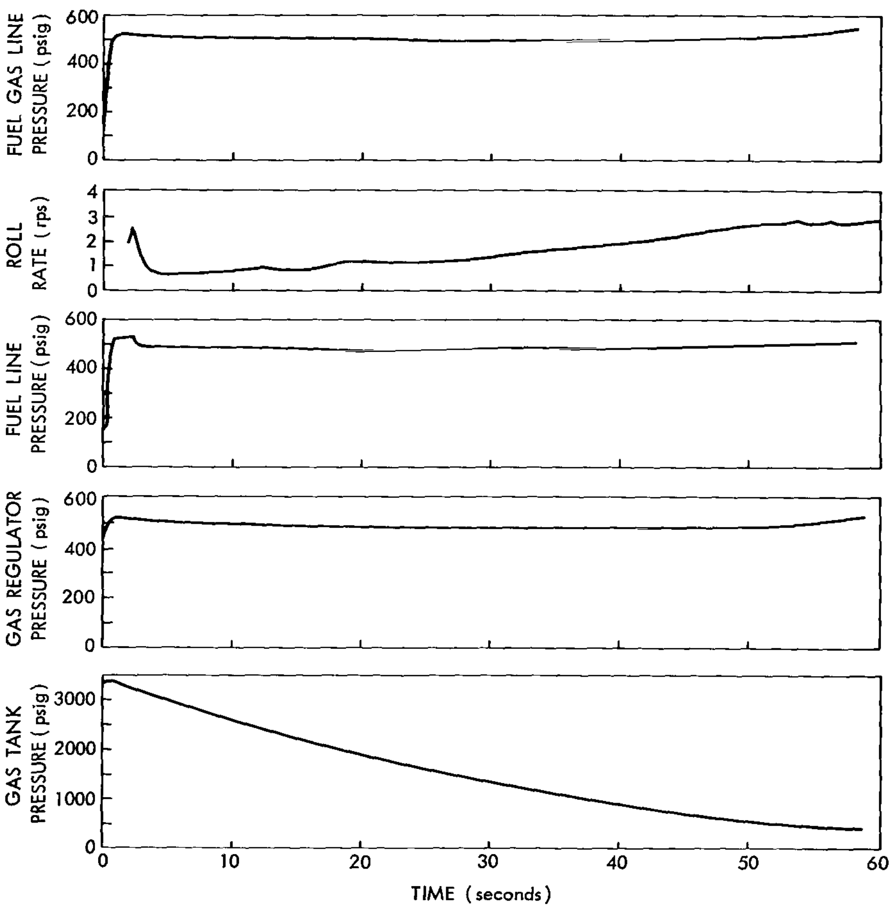


Figure 80—Flight 4.13 GP-GT pressure vs. time.

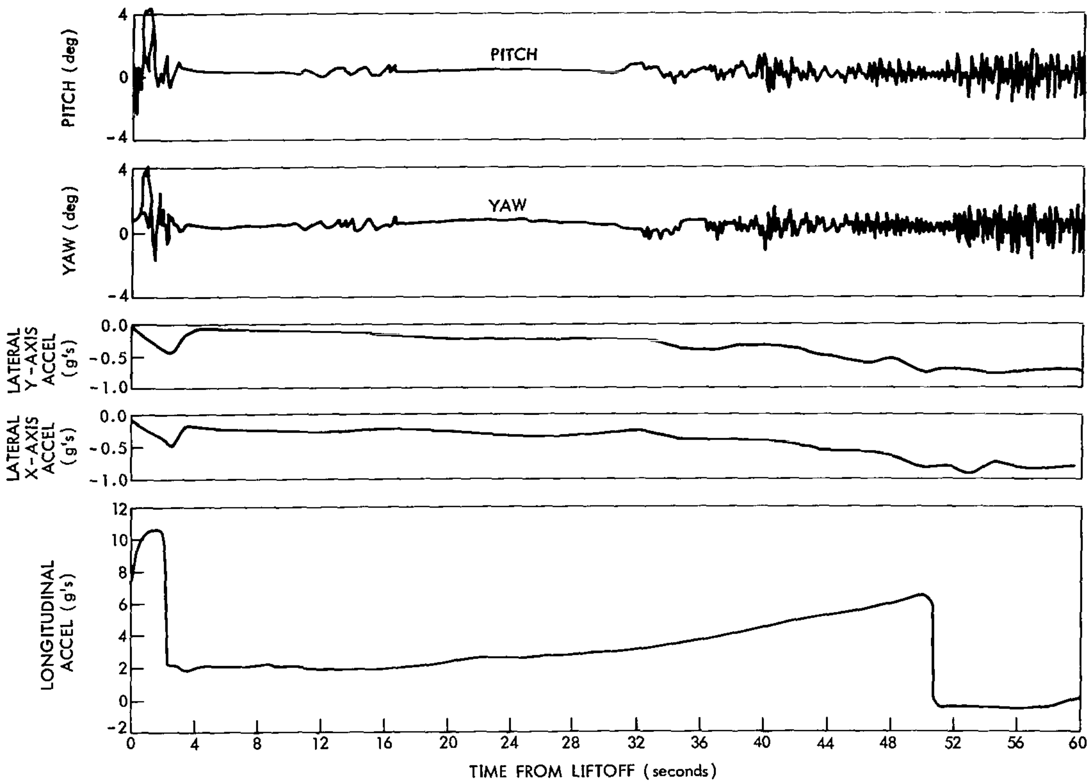


Figure 81—Flight 4.13 GP-GT pitch, yaw, and acceleration vs. time.

drops occurred during flight to account for the altitude underperformance typical of 150A flights. Figure 84 is the booster pressure trace which was also measured during the 2.5 seconds of booster burning. Figure 85 gives payload dimensions and flight characteristics.

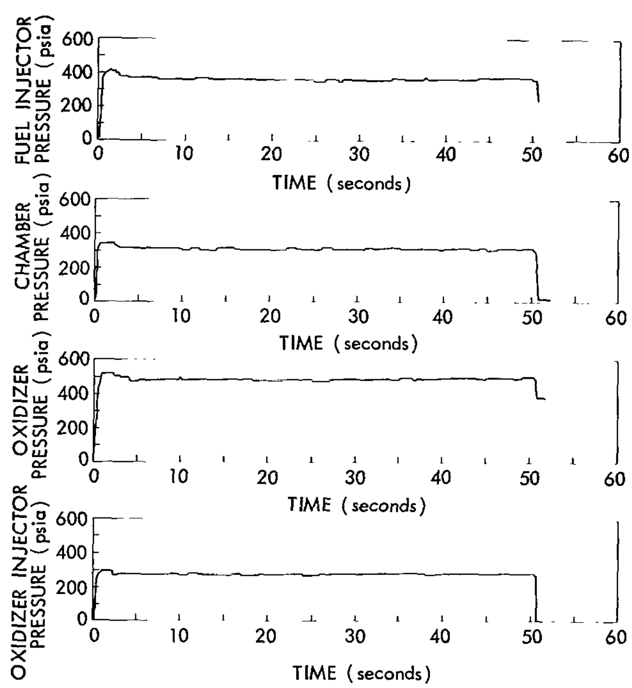


Figure 82—Flight 4.13 GP-GT fuel, oxidizer and chamber pressure vs. time.

Flight 4.120 CG

Vehicle 4.120 CG lifted a 356.9 lb net payload weight to a peak altitude of 89 statute miles from WSMR on 2 October. The payload (Figure 86) was intended for surveying night sky sources which emit photons in the 0.6- to 20.0-kev energy region. The experiment consisted of special gas-filled counters which were used to obtain measurements of the detected X-rays and three photometers. The standard IACS was used; after erecting to the roll, pitch, and yaw gyros, the

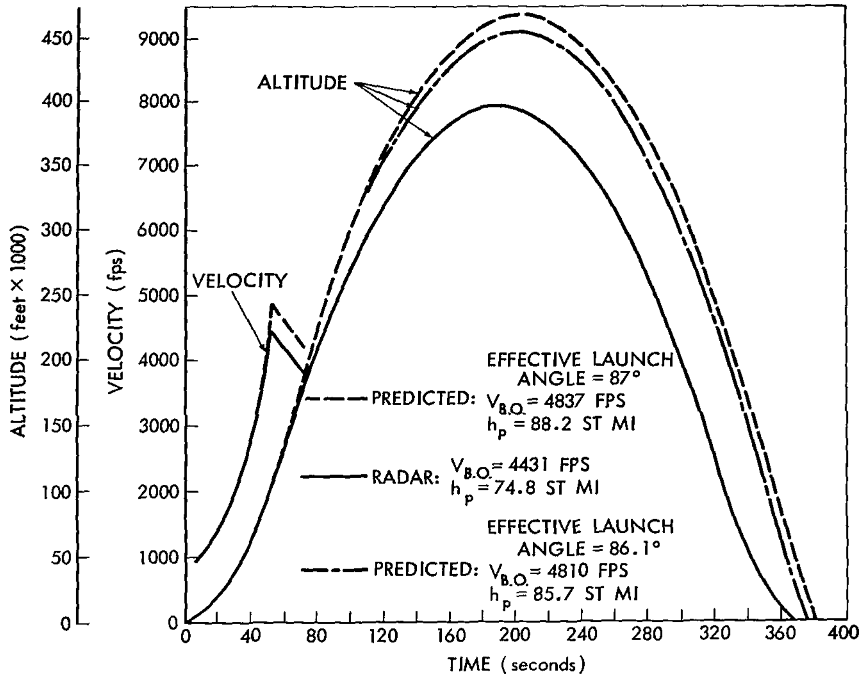


Figure 83—Flight 4.13 GP-GT velocity and altitude vs. time.

rocket was pitched so that its horizontal axis was approximately horizontal and pointing toward the southeast. The experiment required a scanning mode so the vehicle was yawed to the northeast horizon and to the southwest horizon and back. The three-wrap yo-yo despin system did not function due to an improper connection of the squib pin puller and electrical connector which prevented power from reaching the squib. However, the gas despin system, which was in parallel with the yo-yo, despun the vehicle; consequently, IACS performance was not affected.

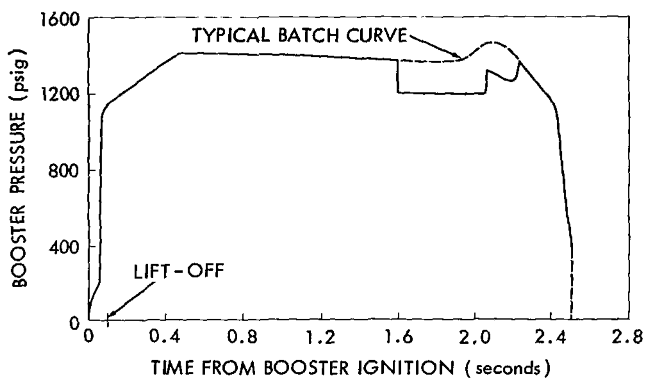
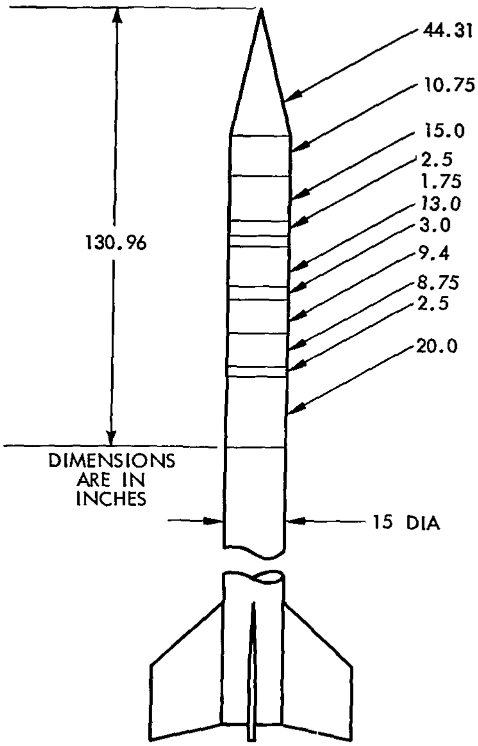


Figure 84—Flight 4.13 GP-GT booster pressure vs. time from booster ignition.

Vehicle performance was as expected; the sustainer burned out at 108,000 feet traveling 4650 fps. The standard recovery package functioned as expected and the payload was quickly retrieved. Figure 87 gives payload dimensions and flight characteristics.

Flight 4.123 CG

NASA 4.123 CG was successfully launched on 27 October from WSMR, attaining a peak altitude of 119 statute miles. Specific objectives for the rocket's payload included the collection of data



FIRING DATE	26 SEPT 1964
LAUNCH SITE	WI
PAYLOAD WT (LB)	341.80
APOGEE (ST MI)	74.50
TIME TO APOGEE (SEC)	203.80
CENTER OF GRAVITY (CAL)	11.06
CENTER OF PRESSURE (CAL)	14.21
STATIC MARGIN (CAL)	3.15
RESTORING MOMENT (PER DEGREE)	-0.453
SUSTAINER BURNOUT TIME (SEC)	51.10
ROLL RATE AT BURNOUT (RPS)	2.10
TIP EJECT (SEC)	~68.00
NO. OF JOINTS	11.00

Figure 85—Dimensions and flight characteristics, 4.13 GP-GT.

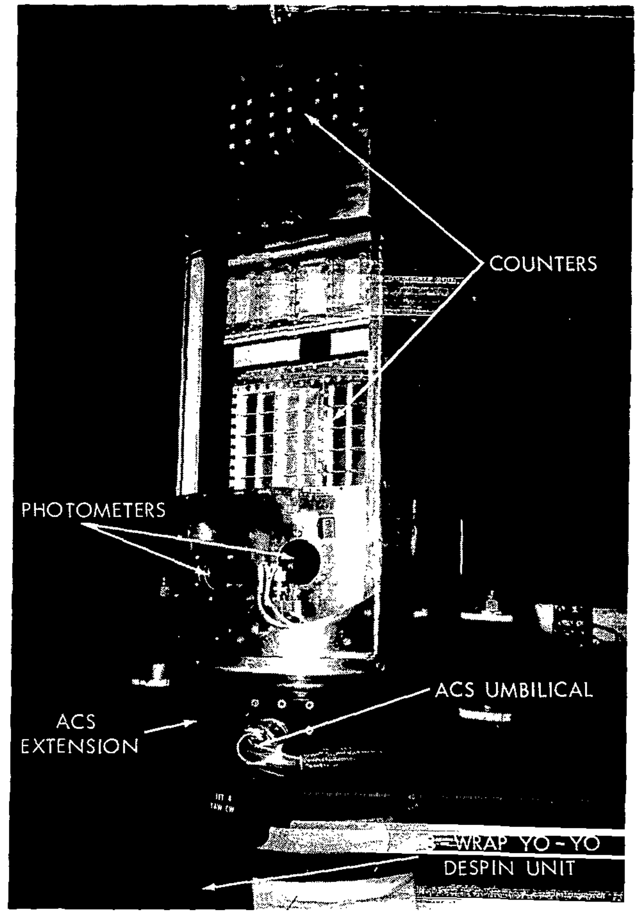


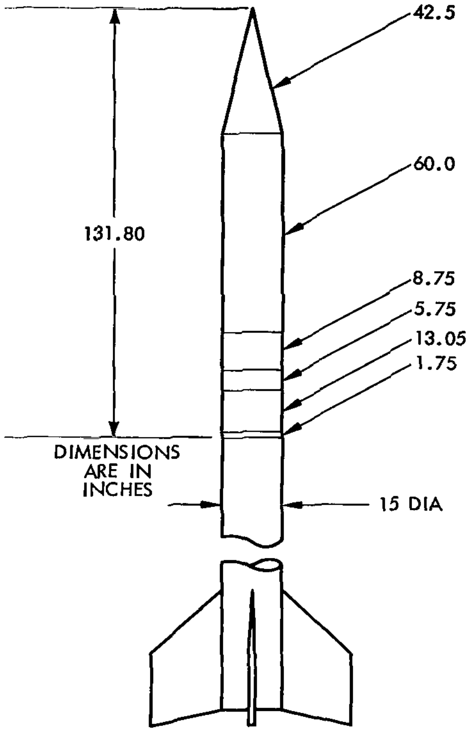
Figure 86—Flight 4.120 CG payload configuration.

on (1) flux levels over a range of 0.1 to 15 Å; (2) location of X-ray sources; and (3) measurement of the angular size of sources. This payload was similar to an earlier flight, 4.122 CG.

The payload shown in Figure 88 was housed in a standard 31-caliber fiberglass ogive nose cone, modified to incorporate three ejectable doors. The payload included four Geiger counters, one photoelectric detector, two scintillation counters and two star sensors. A recovery system was also included.

The fins were canted to induce a roll rate of approximately 2.0 rps at sustainer burnout; actual was 1.8 rps. The rocket performed well. Burnout velocity was 5280 fps at 130,000 feet.

Telemetry instrumentation functioned until parachute system first severance at 250,000 feet (393 seconds), at which time the blast may have severed antenna connectors. The recovery system performed well and the payload was quickly returned in good condition. The experiment was reported successful. Figure 89 gives payload dimensions and flight characteristics.



FIRING DATE	2 OCT 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	356.875
APOGEE (ST MI)	89.40
TIME TO APOGEE (SEC)	203.80
CENTER OF GRAVITY (CAL)	9.90
CENTER OF PRESSURE (CAL)	13.65
STATIC MARGIN (CAL)	3.65
RESTORING MOMENT (PER DEGREE)	-0.438
SUSTAINER BURNOUT TIME (SEC)	51.10
ROLL RATE AT BURNOUT (RPS)	2.10
NO. OF JOINTS	6

Figure 87—Dimensions and flight characteristics, 4.120 CG.

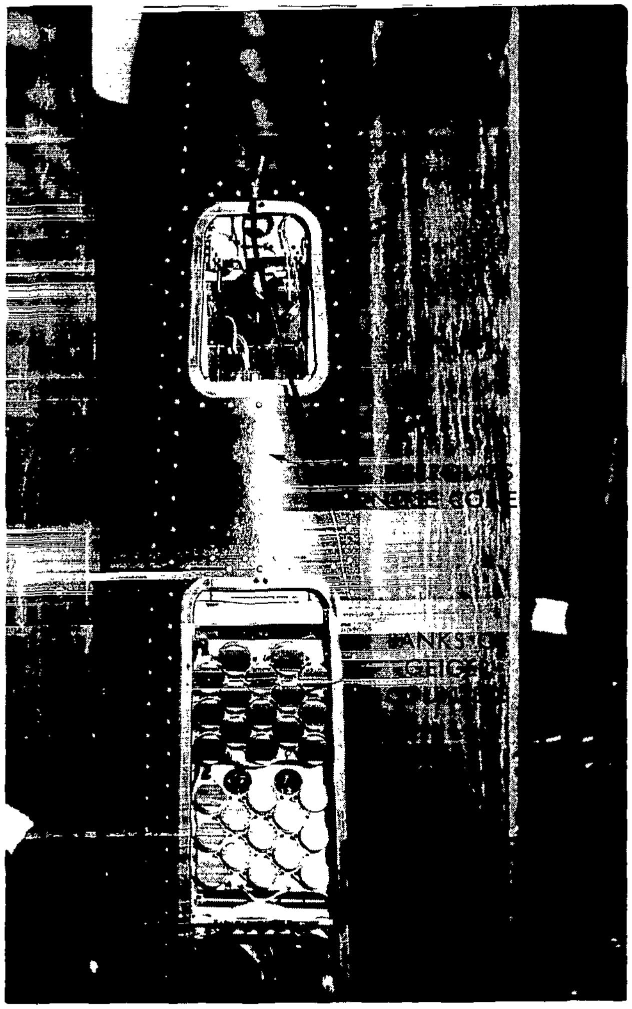
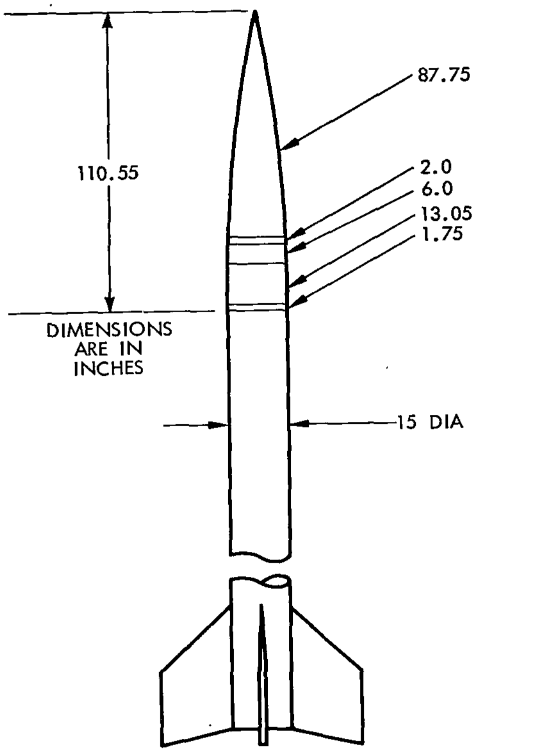


Figure 88—Flight 4.123 CG payload in tower.

Flight 4.116 GS

NASA 4.116 GS was immediately installed in the tower after 4.123 CG and successfully fired on 30 October. Figure 90 shows the rocket being hoisted into the WSMR tower. The payload utilized a Ball Brothers Research Corporation solar pointing control (SPC 300) instrument (Figure 91) for pointing the payload spectrometer at the sun. A solar spectrometer was used for taking solar spectral data in the 1-400 Å region. Additional objectives included adaption of the solar spectrometer for later flight on the OSO-C satellites, measurements of ionospheric electron density using a Faraday rotational unit, and measurements of the solar flux in the 1-10 Å region.

Booster and sustainer operation were normal with the vehicle reaching an apogee of 119 miles, 5 miles greater than predicted. All rocket instrumentation functioned well, and good telemetered data were received.



FIRING DATE	27 OCT 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	267.40
APOGEE (ST MI)	119.60
TIME TO APOGEE (SEC)	235.30
CENTER OF GRAVITY (CAL)	9.90
CENTER OF PRESSURE (CAL)	13.40
STATIC MARGIN (CAL)	3.50
RESTORING MOMENT (PER DEGREE)	-0.37
SUSTAINER BURNOUT TIME (SEC)	53.06
ROLL RATE AT BURNOUT (RPS)	1.80
NO. OF JOINTS	5

Figure 89—Dimensions and flight characteristics, 4.123 CG.

At 375,000 feet on the descent leg of the trajectory, the nose cone was retracted and locked into place. At approximately 300,000 feet, the payload was severed from the rocket for payload recovery. Payload recovery was unsuccessful as the parachute apparently ripped from the payload. Later analysis and flight data has confirmed the cause of the failure; this is the subject of a paper presently in preparation. The payload, after severance, re-entered in an approximately aft-end-first mode; this is determined by the payload center of gravity and

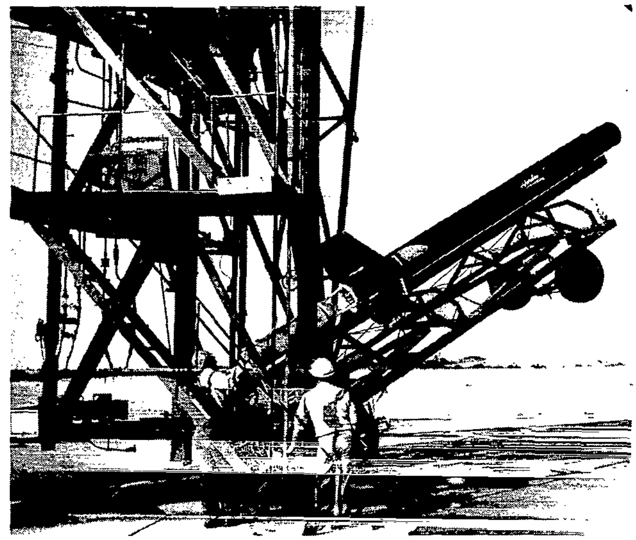


Figure 90—Rocket 4.116 GS being hoisted into WSMR Launch Tower.

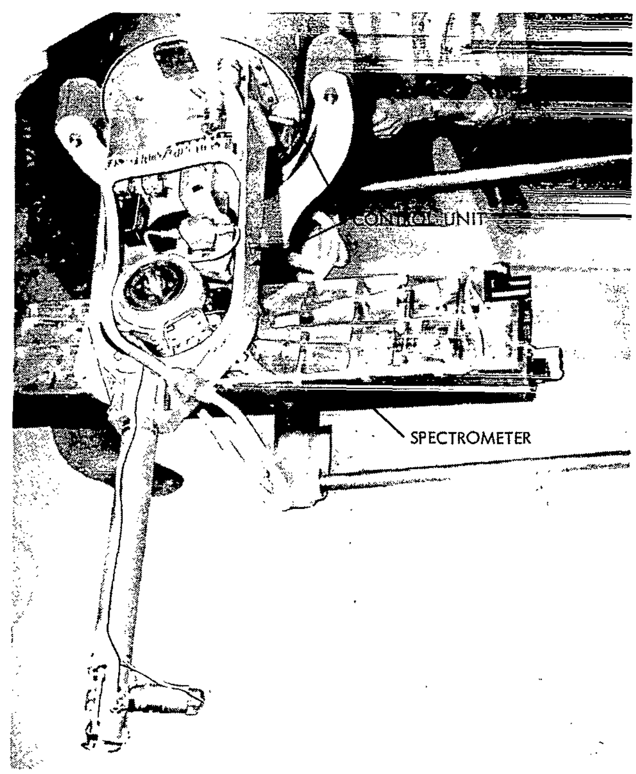


Figure 91—Flight 4.116 GS solar pointing control during checkout.

pressure and its long length. Because second severance is initiated by a 20,000-foot barometric switch, the switch must be able to equalize to ambient pressure; if air is being "rammed" in the parachute extension, as appeared to be the case with the 4.116 GS payload, the barometric switch may sense a 20,000-foot pressure at some altitude higher than 20,000 feet. As the payload re-entered aft-end-first, air was rammed in the 3/8-inch-diameter sensing orifice located on the cover plate. At 70,000 feet, the barometric switches sensed more than 6.5 psi (20,000 feet equivalent), thereby actuating it and thus initiating the prima cord severance. The drogue chute was deployed at a re-entry velocity in excess of 600 fps but was, of course, unable to slow the payload down; the parachute was then deployed, and was ripped from the recovery extension bulkhead.

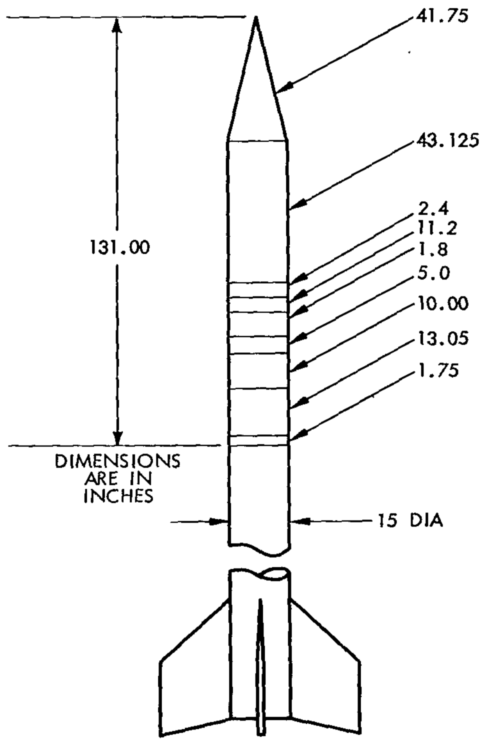
Remedial action taken on recovery systems after this failure included drilling holes on the side of the recovery extension thereby allowing the ramming air to vent out the side ports. This was done as a temporary remedial measure until a more sophisticated and reliable system could be developed. Ram pressure effects on the Aerobee recovery system is a relatively new problem because of the heavier and longer payloads which are being flown and their tendency towards aft-end-first re-entries.

The experiment was reportedly 75 percent successful. Figure 92 gives payload dimensions and flight characteristics.

Flight 4.52 UG

Vehicle 4.52 UG was successfully launched from WSMR on 3 November at 0057 MST. The major experimental objective was to take spectrographs in the ultraviolet of stars centered in the region of Orion. The standard IACS was equipped with a roll-stabilized platform which was to minimize gyro drift, thereby increasing resolution of the spectrograph.

The vehicle performed satisfactorily until T+48.9 seconds, when range safety effected shutoff valve closure. The sustainer was apparently heading off-range, due to an unexpected wind shift which may have resulted from a large wind shear or inadequate wind weighting. The approximately 3-second early shutdown was responsible for an apogee 38 miles short of the predicted one.



FIRING DATE	30 OCT 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	287.40
APOGEE (ST MI)	119.00
TIME TO APOGEE (SEC)	234.40
CENTER OF GRAVITY (CAL)	10.60
CENTER OF PRESSURE (CAL)	13.25
STATIC MARGIN (CAL)	2.65
RESTORING MOMENT (PER DEGREE)	-0.294
SUSTAINER BURNOUT TIME (SEC)	54.45
ROLL RATE AT BURNOUT (RPS)	1.80
NO. OF JOINTS	9

Figure 92—Dimensions and flight characteristics, 4.116 GS.

The IACS was actuated at burnout; 14 seconds were required for despin, but 30 seconds were required to erect the vehicle to local vertical, a longer time than normal. The first maneuver was attempted but the IACS was unable to lock into position; fin impingement contributed to this failure. However, it was also determined that the pitch counter-clockwise relay failed late in flight; this made it impossible to control the vehicle in the pitch axis. Excess fuel left in the tanks because of the early shutdown caused the roll and pitch valves to clog at times; fuel splattering on the IACS extension around the roll valves was evidenced when valve operations were checked following the flight.

The recovery system functioned as expected and the payload was returned in excellent condition. Figure 93 gives payload dimensions and flight characteristics.

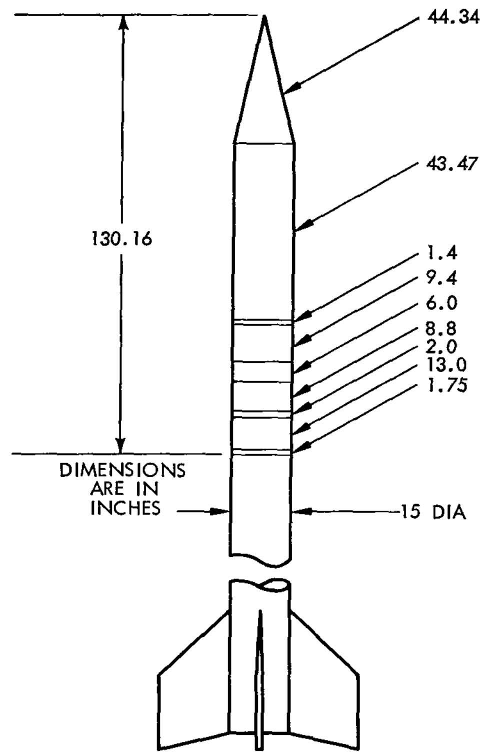
Flights 4.109 GG and 4.110 GG

NASA 4.109 GG and 4.110 GG were flown on 7 and 14 November, respectively at WSMR. The experimental objective was to measure the absolute intensity of specific stars in the ultraviolet region with 50 Å resolution. Each payload included a gas despin system to reduce vehicle roll rate after burnout to approximately 0.05 rps. Good data were reportedly collected and both payloads were recovered with the standard land recovery system. Both had pressurized ogive nose cones which were shortened from 87.8 inches to 84.3 inches.

Each experiment was comprised of four scanning photoelectric spectrophotometers; they were arranged in two pairs pointed 180° apart and were perpendicular to the spin axis of the rocket. The slow spin of the rocket permitted spectral scanning.

Flight 4.109 GG

Vehicle 4.109 GG fired from WSMR on 7 November, reached an apogee of 13 statute miles. Figure 94 illustrates the liftoff at 0348 MST. The vehicle performed satisfactorily and all instrumentation functioned as planned. Despin was initiated at T+69 seconds and 21.3 seconds were required to reduce from 2.0 rps



FIRING DATE	3 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	273.50
APOGEE (ST MI)	78.80
TIME TO APOGEE (SEC)	192.50
CENTER OF GRAVITY (CAL)	10.48
CENTER OF PRESSURE (CAL)	12.88
STATIC MARGIN (CAL)	2.40
RESTORING MOMENT (PER DEGREE)	-0.264
SUSTAINER BURNOUT TIME (SEC)	48.90
ROLL RATE AT BURNOUT (RPS)	1.95
NO. OF JOINTS	9

Figure 93—Dimensions and flight characteristics, 4.52 UG.

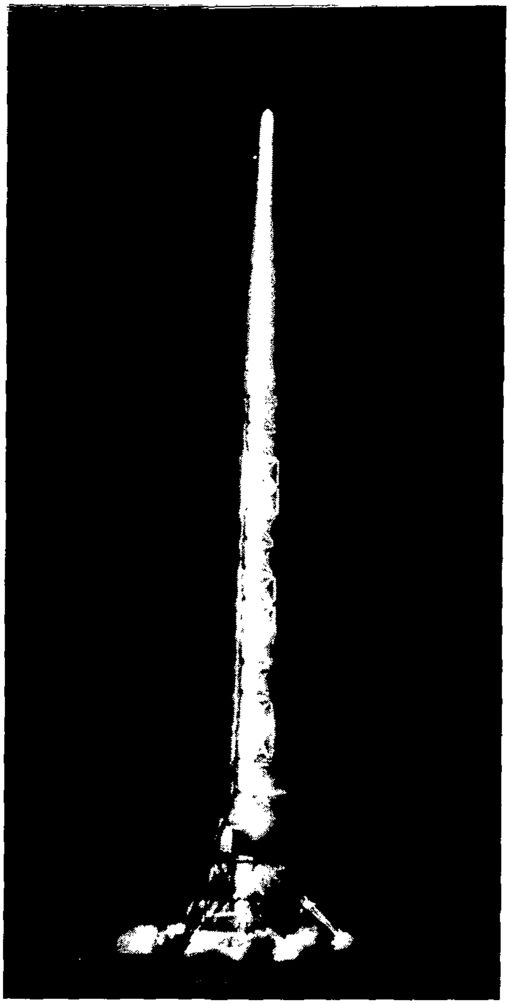
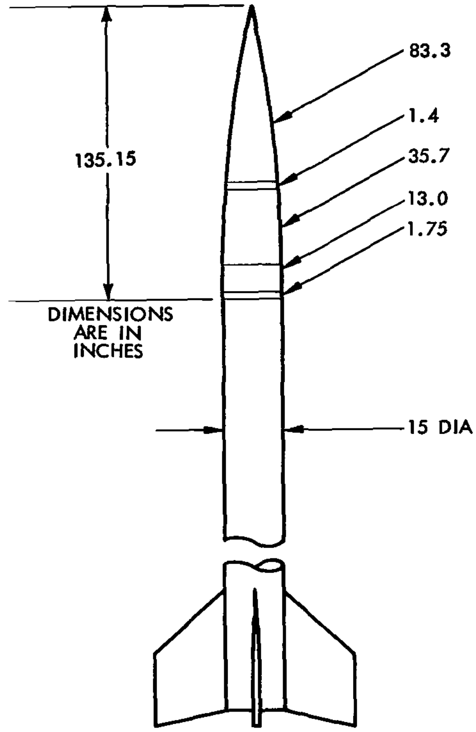


Figure 94—Flight 4.109 GG night launch.



FIRING DATE	7 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	231.60
APOGEE (ST MI)	130.70
TIME TO APOGEE (SEC)	243.90
CENTER OF GRAVITY (CAL)	11.40
CENTER OF PRESSURE (CAL)	14.10
STATIC MARGIN (CAL)	2.70
RESTORING MOMENT (PER DEGREE)	-0.280
SUSTAINER BURNOUT TIME (SEC)	53.20
ROLL RATE AT BURNOUT (RPS)	2.00
NO. OF JOINTS	5

Figure 95—Dimensions and flight characteristics, 4.109 GG.

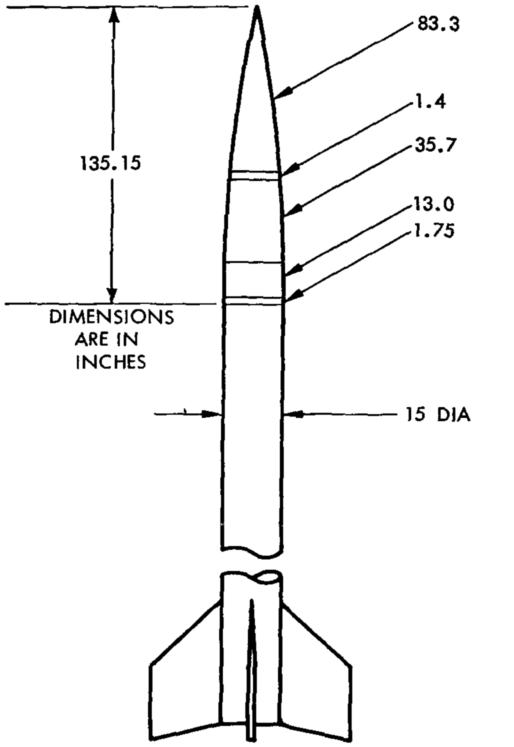
to 0.05 rps. Net payload weight was 231.6 lb. and velocity at burnout was 5900 fps. Figure 95 gives payload dimensions and flight characteristics.

Flight 4.110 GG

Vehicle 4.110 GG launched on 14 November at 0323:45 MST was similarly successful. A net payload weight of 236.5 lb reached a peak altitude of 129 statute miles. Sustainer burnout occurred at 130,000 ft altitude at a velocity of 5600 fps. Figure 96 gives payload dimensions and flight characteristics.

Flight 4.118 NA

Vehicle 4.118 NA was launched successfully from WSMR on 16 November. The flight appeared normal and rocket performance was near predicted. Peak altitude for the 314.8 lb net payload was 97.5 statute miles at T+215 seconds. All rocket instrumentation performed as expected.



FIRING DATE	14 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	236.50
APOGEE (ST MI)	128.80
TIME TO APOGEE (SEC)	243.60
CENTER OF GRAVITY (CAL)	11.33
CENTER OF PRESSURE (CAL)	14.10
STATIC MARGIN (CAL)	2.77
RESTORING MOMENT (PER DEGREE)	-0.280
SUSTAINER BURNOUT TIME (SEC)	53.40
ROLL RATE AT BURNOUT (RPS)	2.10
NO. OF JOINTS	5

Figure 96—Dimensions and flight characteristics, 4.110 GG.

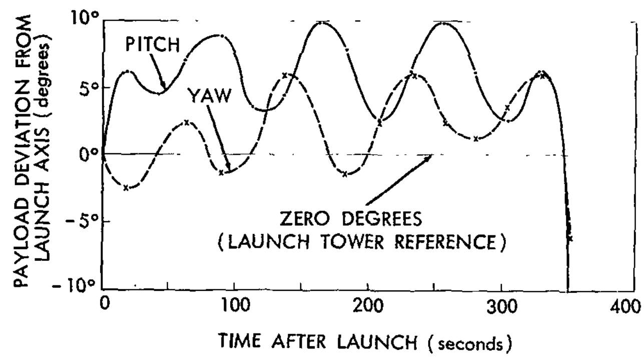


Figure 97a—Payload angular pitch and yaw from launch axis vs. time, flight 4.118 NA.

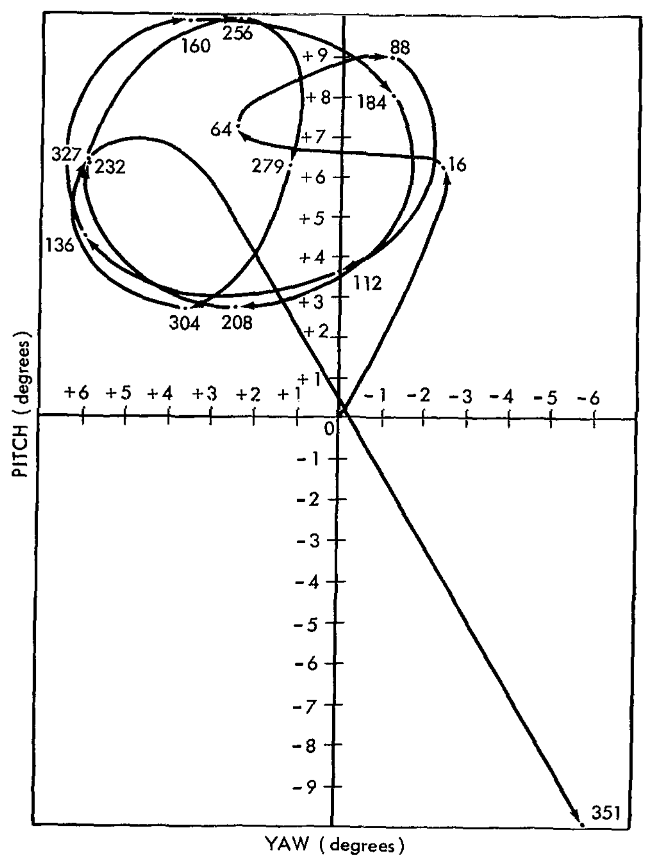


Figure 97b—Flight 4.118 NA payload angular deviation from launch axis vs. time. Points connected by continuous line for visual aid. Coning over exact path drawn is not inferred. Numbers on the curve represent time in seconds after launch.

Primary objectives of this experiment were to evaluate the engineering performance of the Luster micrometeorite sampling experiment, as well as to collect meteoroidic debris during the peak of a Leonids meteor shower. A standard land recovery package was included in the rocket's configuration, and all joints (except the nose cone joint) were strengthened by the addition of sixteen screws.

Attitude during flight was monitored by Whittaker gyro; a three-axis vibration transducer was included to determine unexpected perturbations that could effect payload operation. Figures 97a

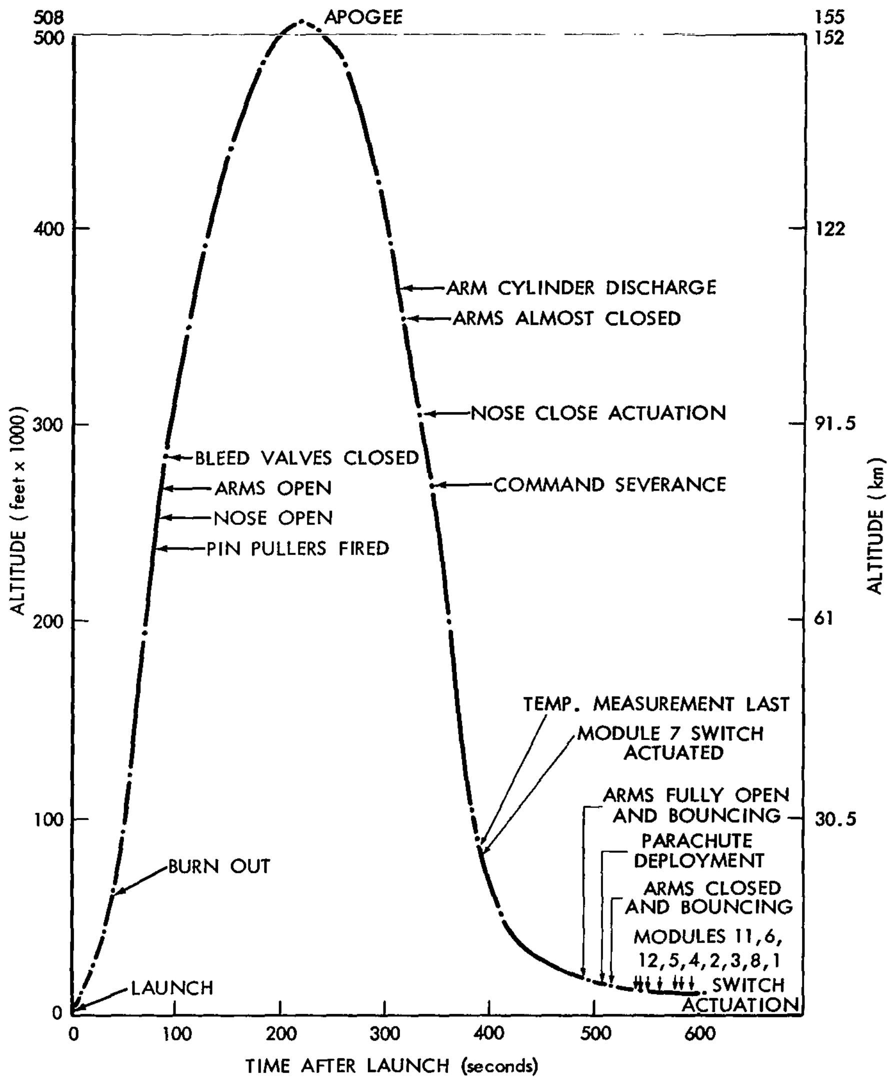


Figure 97c—Flight 4.118 NA payload altitude vs. time.

and 97b show some of the payload angular pitch and yaw measurements taken.* Figure 97c illustrates the vehicle trajectory.*

Figure 98 shows the payload with the collecting arms extended and the nose cone lifted. Figure 99 shows special clean room required for the buildup of this payload for flight. Figure 100 gives payload dimensions and flight characteristics.

*"Preliminary Luster Flight Data Analysis," memorandum prepared by Luster Experiment Staff, Ames Research Center (NASA) January 4, 1965.

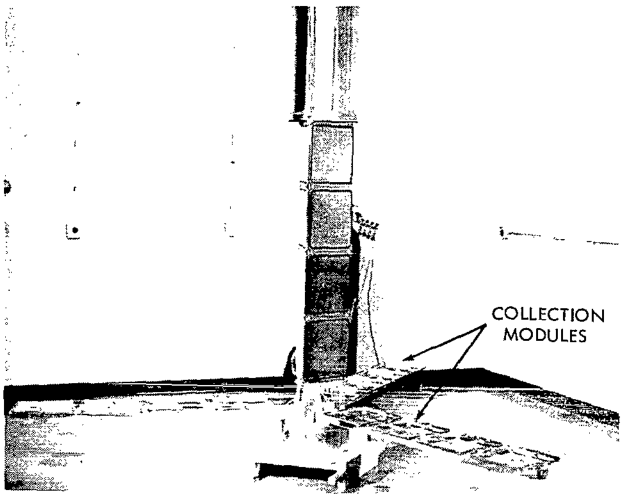


Figure 98—Flight 4.118 NA payload deployed.

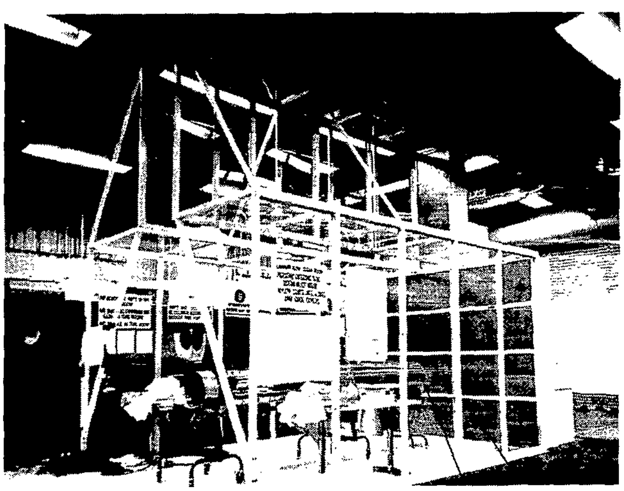
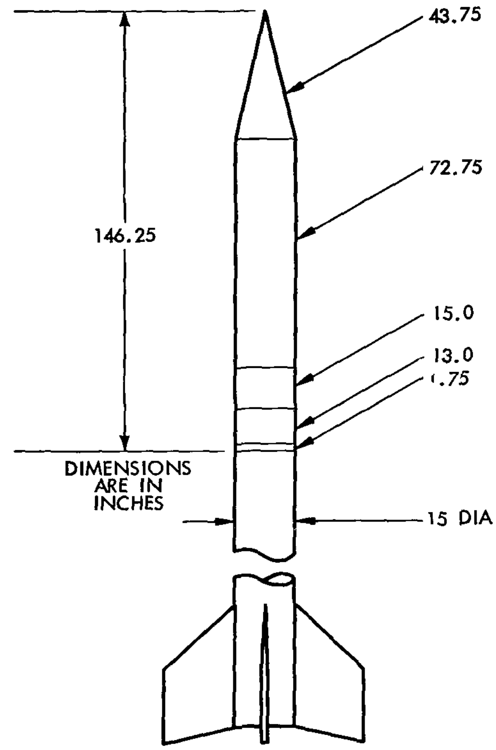


Figure 99—Clean room facility at WSMR (used on flight 4.118 NA).



FIRING DATE	16 NOV 1965
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	314.80
APOGEE (ST MI)	98.50
TIME TO APOGEE (SEC)	211.40
CENTER OF GRAVITY (CAL)	11.20
CENTER OF PRESSURE (CAL)	14.00
STATIC MARGIN (CAL)	2.90
RESTORING MOMENT (PER DEGREE)	-0.33
SUSTAINER BURNOUT TIME (SEC)	52.40
ROLL RATE AT BURNOUT (RPS)	2.00
NO. OF JOINTS	5

Figure 100—Dimensions and flight characteristics, 4.118 NA.

Flight 4.45 GA

Vehicle 4.45 GA was launched successfully from WI on 16 November (Figure 101). An electrostatic probe, an omegaton, and a quadrapole mass spectrometer, all contained in a cylindrical "thermosphere probe," were used to measure the composition, density, and temperature of neutral atmosphere in the 100-250-km altitude region. A secondary flight objective was the measurement of transverse forces acting on the vehicle from liftoff through launch tower exit. These measurements were made using load cells on the aft-rail riding shoes.

The thermosphere probe was contained in a 6.5-inch-diameter cone-cylinder nose cone such as those used on Aerobee 300 and 300A flights 6.01 GA through 6.10 GA. The nose cone, a

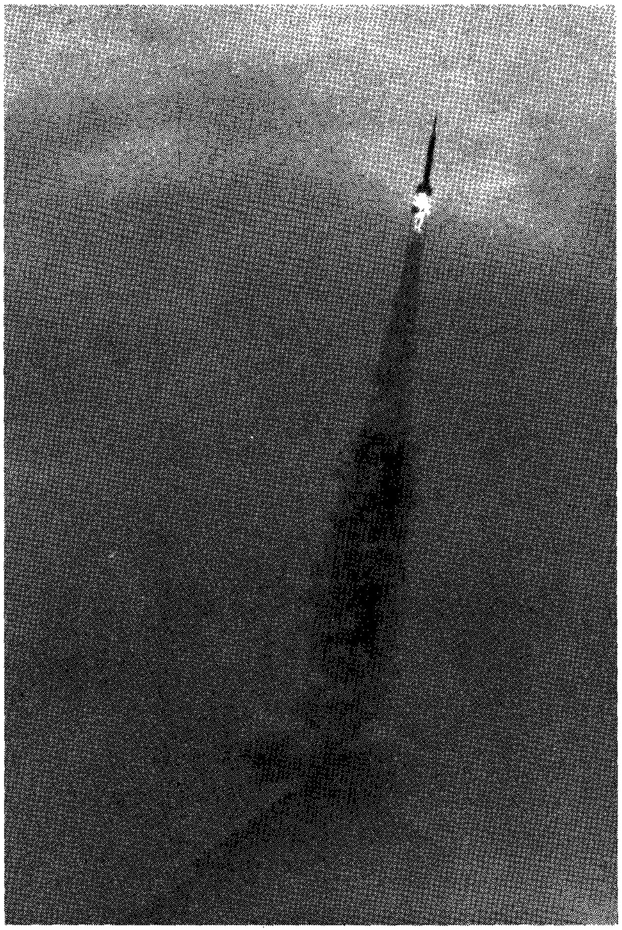
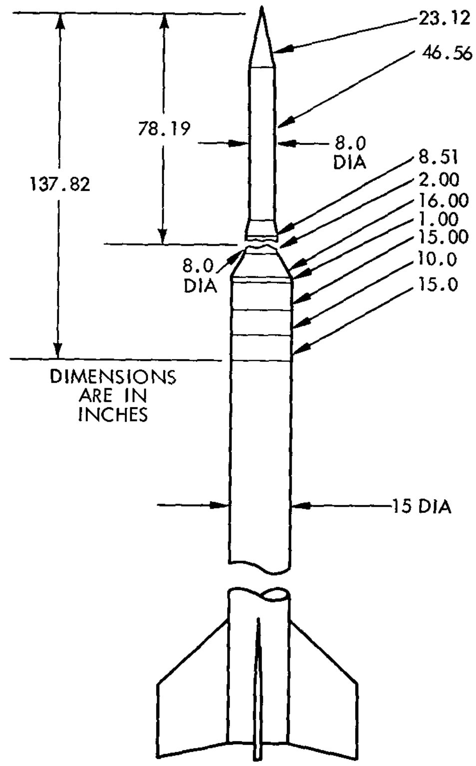


Figure 101—Liftoff of flight 4.45 GA from Wallops Island Tower.



FIRING DATE	16 NOV 1964
LAUNCH SITE	WI
PAYLOAD WT (LB)	177.30
APOGEE (ST MI)	116.50
TIME TO APOGEE (SEC)	231.10
CENTER OF GRAVITY (CAL)@ B.O.	10.07
CENTER OF PRESSURE (CAL)@ B.O.	14.65
STATIC MARGIN (CAL)@ B.O.	4.58
RESTORING MOMENT COEFFICIENT (PER DEGREE) @ B.O.	-0.275
SUSTAINER BURNOUT TIME (SEC)	51.50
ROLL RATE AT BURNOUT (RPS)	2.20
NO. OF JOINTS	9

Figure 102—Dimensions and flight characteristics, 4.45 GA.

clamshell, opened up during flight to eject the thermosphere probe. After the nose cone, a transition section was mounted on a 9.4-inch-long extension, housing instrumentation equipment. A gas despin mechanism was used to reduce roll rate after burnout.

The rocket and instrumentation performed well. Apogee was 117 statute miles. All experiments performed well, and excellent data were reportedly received. Figure 102 gives payload dimensions and flight characteristics.

Flight 4.83 GA

NASA 4.83 GA was launched on 30 November at 2315 MST (1 December Zulu Time), reaching an altitude of 114.3 statute miles. The rocket utilized two fast spectrographs for measurements in the ultraviolet of airglow. Each spectrograph was pointed out the side of the cylinder directly aft of the cone. The IACS, used for pointing the spectrographs at the nightglow horizon, performed as expected.

This vehicle used a tail can which was strengthened by the addition of a magnesium overlay; in addition, the IACS pitch CW and yaw CCW nozzles were relocated to minimize the effect of fin impingement on maneuvers. Each nozzle was moved approximately 6 degrees from fins I and II, respectively, and slightly forward.

Despin was accomplished in 16.5 seconds, and sustainer burnout occurred at 52.4 seconds. The recovery system functioned and the payload was recovered satisfactorily.

Figure 103 shows the payload and nose cone used on this flight. Figure 104 gives payload dimensions and flight characteristics.

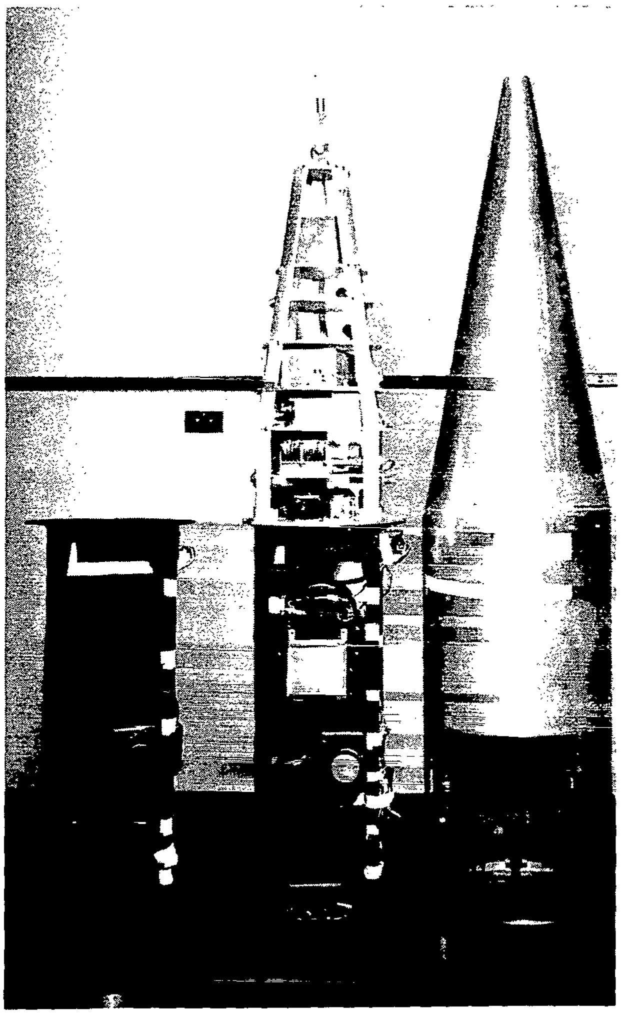
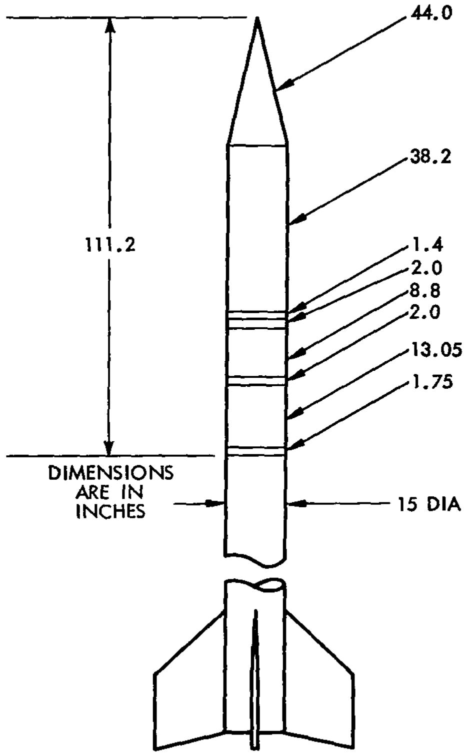


Figure 103—Flight 4.83 GA payload and nose cone with opening for rejectable door.



FIRING DATE	1 DEC 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	237.50
APOGEE (ST MI)	114.30
TIME TO APOGEE (SEC)	231.60
CENTER OF GRAVITY (CAL)	9.91
CENTER OF PRESSURE (CAL)	12.25
STATIC MARGIN (CAL)	2.34
RESTORING MOMENT (PER DEGREE)	-0.252
SUSTAINER BURNOUT TIME (SEC)	52.20
ROLL RATE AT BURNOUT (RPS)	2.60
NO. OF JOINTS	8

Figure 104—Dimensions and flight characteristics, 4.83 GA.

Flight 4.132 GA-GI

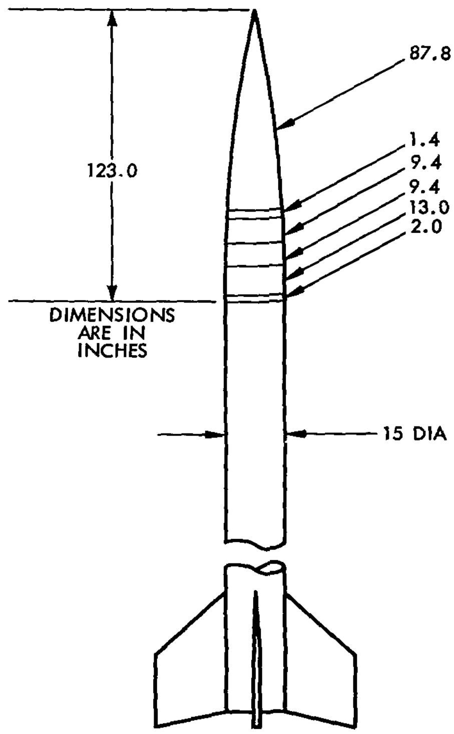
NASA 4.132 GA-GI was launched from WSMR on 16 December. The rocket attained a peak altitude of 128.5 statute miles and performed as predicted.

In addition to measuring the momentum energy of low velocity cosmic dust, the payload collected micrometeoroid data by impacts. The meteoroid collectors were extended (as shown in Figure 105) at approximately T+60 seconds and remained extended until approximately T+457 seconds, when a timer command was used to retract the collectors on the descent portion of the trajectory.

An ogive nose cone was used, and the standard recovery package was successfully employed. Vent holes on the parachute extension had air filters to prevent outgassing contamination on the collecting arms.

No anomalies occurred during flight, and all instrumentation performed as expected. The net payload weight was 243 lb; apogee was 125 statute miles at 250 seconds.

The experiment was reported to have functioned successfully and excellent data were collected. Flight performance was monitored by a chamber pressure guage, an accelerometer, and by longitudinal and roll magnetometers. Figure 106 gives payload dimensions and flight characteristics.



FIRING DATE	16 DEC 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	243.00
APOGEE (ST MI)	128.50
TIME TO APOGEE (SEC)	243.00
CENTER OF GRAVITY (CAL)	10.48
CENTER OF PRESSURE (CAL)	13.50
STATIC MARGIN (CAL)	3.02
RESTORING MOMENT (PER DEGREE)	-0.314
SUSTAINER BURNOUT TIME (SEC)	53.20
ROLL RATE AT BURNOUT (RPS)	1.90
NO. OF JOINTS	6

Figure 106—Dimensions and flight characteristics, 4.132 GA-GI.

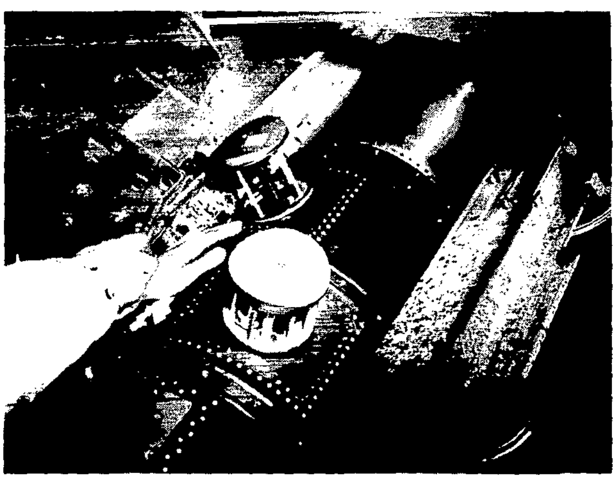
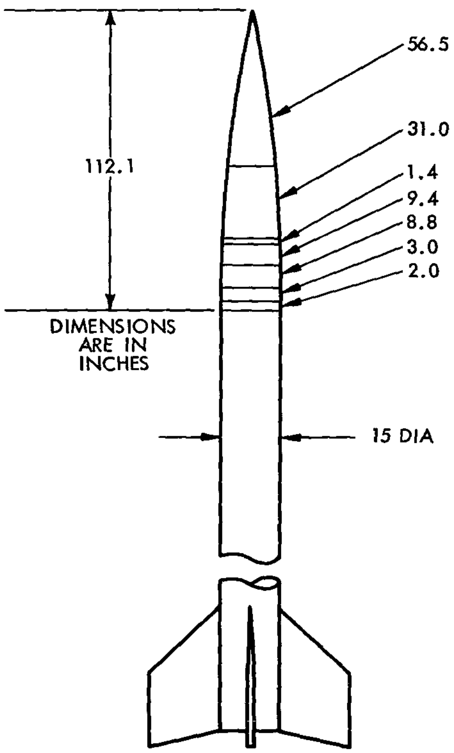


Figure 105—Meteoroid collectors in extended position, flight 4.132 GA.

Flight 4.125 UA

The last Aerobee flight of 1964, 4.125 UA, was fired in the late evening (2355 MST) on 16 December (17 December Zulu Time). The experiment was intended to study the distribution of alpha radiation at the winter solstice when the anti-solar point was as high in the zenith as possible. In order to accomplish this objective, the standard IACS was used for programming the rocket to scan the night sky. The payload used an Ebert-Fastie scanning ultraviolet spectrometer (with a telescope providing a narrow angle of view) and a JPL-supplied, narrow-angle-to-view photometer. The IACS program required the rocket to scan in two directions. A three-wrap yo-yo despin unit was used to despin the rocket, thus conserving helium for use in the programmed IACS maneuvers.



FIRING DATE	17 DEC 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LB)	193.40
APOGEE (ST MI)	145.90
TIME TO APOGEE (SEC)	256.80
CENTER OF GRAVITY (CAL)	10.73
CENTER OF PRESSURE (CAL)	12.90
STATIC MARGIN (CAL)	2.17
RESTORING MOMENT (PER DEGREE)	-0.235
SUSTAINER BURNOUT TIME (SEC)	52.85
ROLL RATE AT BURNOUT (RPS)	1.90
NO. OF JOINTS	7

Figure 107—Dimensions and flight characteristics, 4.125 UA.

The vehicle reached a peak altitude of 145.7 statute miles as predicted and all instrumentation functioned as expected. The tip of the ogive nose cone was ejected during flight. The IACS performed satisfactorily until control was lost during the last yaw maneuver. However, significant experimental data were obtained.

It was determined that this malfunction was due to the lack of sufficient helium pressure, which inhibited roll correction. This precluded proper vehicle maneuvering about the yaw axis. From data received during flight, there was reason to believe that the roll valve had not fully closed during maneuvers from 205 to 218 seconds, resulting in a large drop in the pressure.

The three-wrap yo-yo system despun the rocket from 2.17 rps to 0.3 in 7.36 seconds. Fin impingement from the gas plume was not considered a detrimental effect during this flight. Figure 107 gives payload dimensions and flight characteristics.

ACKNOWLEDGMENTS

This work could not have been accomplished without the active assistance of Walter G. Moon, The authors also wish to express their appreciation for the use of U. S. Army official photographs and U. S. Air Force official photographs used in this report which were taken at WSMR and CRR respectively.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, July 1, 1966
879-20-03-04-51

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Appendix A

Cross Reference Index of 1964 Rocket Launchings

In this appendix all sounding rocket launchings in 1964 are listed in sequence by flight number. For each flight, the launch site and data, the rocket type and performance, the experiment scientist and sponsoring institute, and the rocket auxiliary systems are given.

1964 Compe
Cross Referenc

Flight No.	Launch Site	Launch Date	Rocket Type	Rocket Performance	Experimenter	Type Experiment	
4.88 GT	WSMR	1-28-64	150	Satisfactory	Russell GSFC	Attitude Control	
6.09 GA	WI	1-29-64	300 A	Satisfactory	Brace GSFC	Thermosphere Probe	8 C F
4.124 UA	CRR	2-27-64	150	Partial Sucess	Fastie John Hopkins	Aurora	C
4.15 GG	WSMR	4-3-64	150	Satisfactory	Boggess GSFC	Stellar Spectra	C
4.81 GG	WSMR	4-10-64	150	Unsatisfactory	Boggess GSFC	Stellar Spectra	C
4.86 NA	WSMR	4-14-64	150	Unsatisfactory	Barth JPL	Airglow	C
4.113 GA-GI	WSMR	4-21-64	150	Unsatisfactory	Berg-Aikin GSFC	Astrochemistry Ionosphere	
4.67 NP	WSMR	6-10-64	150	Satisfactory	Kinard LARC	Meteorord Sample Paraglider	
4.107 GE	CRR	7-23-64	150	Satisfactory	Fichtel GSFC	Heavy Cosmic Rays	
4.108 GE	CRR	7-25-64	150	Satisfactory	Fichtel GSFC	Heavy Cosmic Rays	
6.10 GA	CRR	7-28-64	300	Satisfactory	Brace GSFC	Thermosphere Probe	8 Cyl
4.82 GG	WSMR	8-11-64	150	Satisfactory	Boggess GSFC	Stellar Spectra	C
4.126 GG	WSMR	8-22-64	150	Partial Success	Boggess GSFC	Stellar Spectra	C
4.122 CG	WSMR	8-29-64	150	Satisfactory	Gursky American Science & Engineering, Inc.	Stellar Studies	F

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Nose Cone	Inertial Attitude Control System (IACS)	Solar Pointing Control	Recovery System	Despin System	Remarks	Page No.
ɔgive	Yes	None	Yes	None	Good IACS and recovery.	7
Cone - ylinder rustum	None	None	None	None		7
Cone ylinder	None	None	None	None	Failed to reach expected peak alt due to pitch - roll coupling.	10
Cone ylinder	Yes	None	Yes	None	IACS failed. Good recovery.	11
Cone ylinder	Yes	None	Yes	None	Bi - model (structural - aero) coupling followed by pitch - roll coupling. Attitude control system had no oppor - tunity to function. Good recovery.	13
Cone yliner	Yes	None	Yes	None	Bi - model (structural - aero) coupling followed by pitch - roll coupling.	13
ɔgive	None	None	Yes	None	Propulsion system failure. Recovery system had no opportunity to function.	17
ɔgive	None	None	Paraglider	Gas	Paraglider recovery was partial success. Gas system function was good.	21
ɔgive	None	None	Yes	None	Good recovery system operation.	23
ɔgive	None	None	Yes	None	Good recovery system operation.	23
' Cone - nder Cone rustum	None	None	None	None		26
Cone ylinder	Yes	None	Yes	None	IACS failure due to leak in the despin valve. Good recovery.	27
Cone ylinder	Yes	None	Yes	None	Chamber inner liner burn through. Good recovery. Satisfactory IACS.	29
ɔerglass ɔgive	None	None	Yes	None	Good recovery	30

Flight No.	Launch Site	Launch Date	Rocket Type	Rocket Performance	Experimenter	Type Experiment	
4.55 UG	WI	9-2-64	150A	Satisfactory	Bless U. Wisc.	Stellar Studies	14.[illegible] Cone
4.115 NA	WI	9-18-64	150A	Satisfactory	Barth JPL	Dayglow	C
4.13 GP-GT	WI	9-26-64	150A	Satisfactory	Busse GSFC	Rocket Test	C
4.120 CG	WSMR	10-2-64	150	Satisfactory	Fisher Lockheed	Stellar X-Ray	C
4.123 CG	WSMR	10-27-64	150	Satisfactory	Gursky American Science & Engineering, Inc.	Stellar Studies	Fi
4.116 GS	WSMR	10-30-64	150	Satisfactory	Muney GSFC	Solar Studies	C
4.52 UG	WSMR	11-3-64	150	Partial Success	Morton Princeton U. Observatory	Stellar Spectra	C
4.109 GG	WSMR	11-7-64	150	Satisfactory	Stecher GSFC	Stellar Spectra	
4.110 GG	WSMR	11-14-64	150	Satisfactory	Stecher GSFC	Stellar Spectra	
4.118 NA	WSMR	11-16-64	150	Satisfactory	Pochari Ames	Micrometeorord	C
4.45 GA	WI	11-16-64	150A	Satisfactory	Brace GSFC	Thermosphere Probe	Si Sp Cone Con
4.83 GA	WSMR	12-1-64	150	Satisfactory	Hennes GSFC	Middle UV Airglow	C
4.132 GA-GI	WSMR	12-16-64	150	Satisfactory	Berg GSFC	Micrometeorord	
4.125 UA	WSMR	12-17-64	150	Satisfactory	Fastie John Hopkins	Airglow	

ium
(Continued)

Nose Cone	Attitude Control System	Solar Pointing Control	Recovery System	Despin System	Remarks	Page No.
in. dia. Cylinder	None	None	None	Gas	Good gas despin operation.	31
Cone ylinder	Yes	None	None	None	Good IACS.	33
Cone ylinder	Yes	None	Yes	Yo-yo	Recovery was failure. IACS failed. Yo-yo failed.	35
Cone ylinder	Yes	None	Yes	Yo-yo	Good IACS.	38
erglass Ogive	None	None	Yes	None	Telemetry received to 393 sec at separation. Good recovery.	39
Cone ylinder	None	SPC-300	Yes	None	Good SPC operation. Recovery failure.	41
Cone ylinder	Yes	None	Yes	None	Cut down by range safety at 48.85 sec. IACS partial success. Recovery success.	43
Ogive	None	None	Yes	Gas	Telemetry received for 405 sec. Good recovery and despin.	44
Ogive	None	None	Yes	Gas	Good recovery and despin operation.	45
Cone ylinder	None	None	Yes	None	Longest cone cylinder cone flown. Manfunct of the pneumatic system in payload section. Good recovery.	45
nulated erobee Cylinder/ Frustum	None	None	Yes	Gas	Good recovery and gas despin.	48
Cone ylinder	Yes	None	Yes	None	Good IACS and recovery.	49
Ogive	None	None	Yes	None	Good recovery.	51
Ogive	Yes	None	None	Yo-yo	IACS unable to control in last yaw maneuver. First time IACS success fully flown twice. Partial IACS system. Good yo-yo despin.	52

Appendix B

Performance Characteristics Charts

Performance characteristics charts for the Aerobee 150 and 150A are contained on pages 62 through 63. They include the following:

1. Peak altitude vs. net payload for ogive nose cones.
2. Peak altitude vs. net payload for conical nose cones.
3. Altitude and velocity vs. time for various payloads.
4. Summit time vs. net payload for ogivel nose cones.
5. Acceleration vs. time for typical flights.

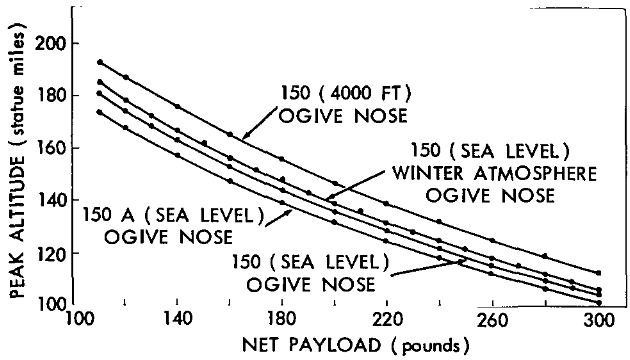

Figure B1—Peak altitude vs. net payload for ogivel nose cones, Aerobee 150 and 150A. Effective launch angle for 150 = 88° and for 150, 87°.

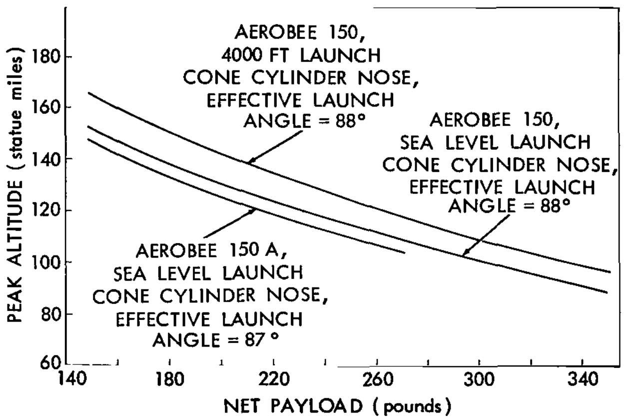

Figure B2—Peak altitude vs. net payload for cone-cylinder nose cones.

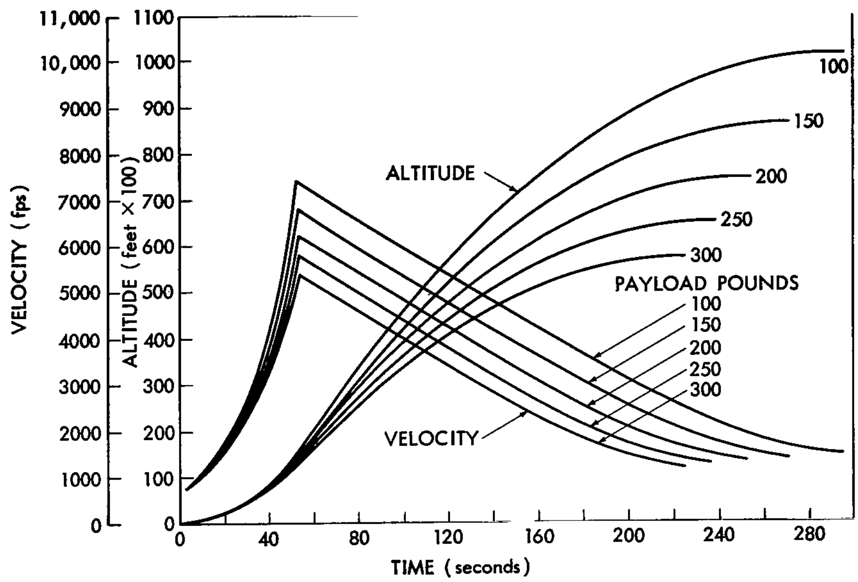

Figure B3—Aerobee 150 velocity and altitude vs. time for various payloads.

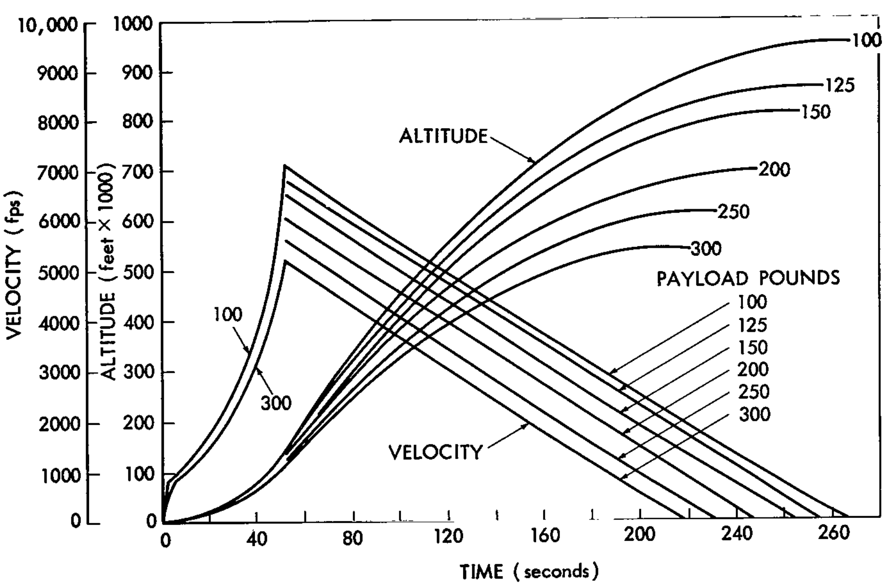

Figure B4—Aerobee 150A velocity and altitude vs. time for various payloads.

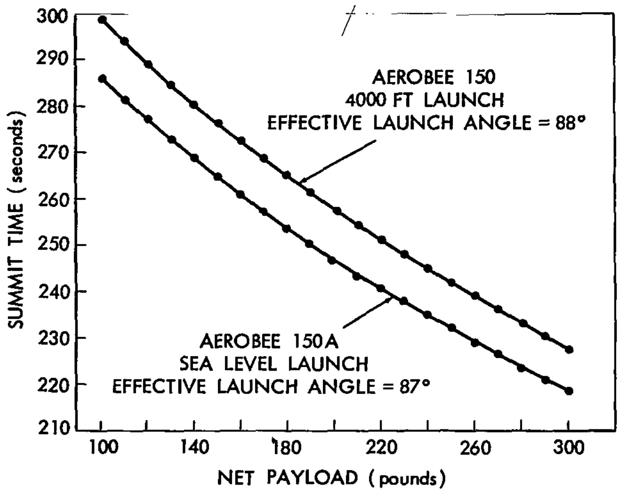

Figure B5—Summit time vs. net payload for Aerobee 150 and 150A sounding rockets with ogivel nose cones.

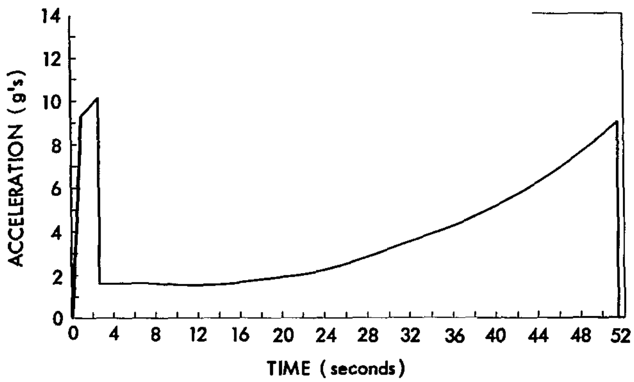

Figure B6—Acceleration vs. time for Aerobee 150A (typical) - net payload = 170 lb, launch angle = 87°; ogive nose.

Appendix C

Index of Reduced Performance Data, 1964 Flights

In this appendix, an index of representative reduced data for 1964 Aerobee flights is given. For each flight, the numbers of the figures that present the data pertaining to the flight are cited.

Index of Reduced Performance
1964 Aerobee Flights

Data	Flight N						
	4.15 GG	4.81 GG	4.86 NA	4.126 GG	4.55 UG	4.115 NA	4.113 C
Roll Rate vs. Time	Figure 22	Figure 27	Figure 30				Figur
Chamber Pressure vs. Time	Figure 23	Figure 28	Figure 32	Figure 61	Figure 68 a	Figure 74	Figur
Acceleration vs. Time	Figure 26	Figure 28	Figure 31	Figure 63	Figure 68 b	Figure 75	Figur
Yaw Frequency vs. Time	Figure 22	Figure 27	Figure 29		Figure 69		
Pitch Frequency vs. Time	Figure 22	Figure 27		Figure 64			Figur
Oxidizer Pressure vs. Time						Figure 74	
Full, Oxidizes and Chamber Pressure vs. Time						Figure 74	
Wind Velocity and Azimuth vs. Time		Figure 26	Figure 33				
Altitude vs. Time				Figure 71			
Temperature Data							
Booster Pressure vs. Time							
Booster Acceleration vs.. Time							
Velocity vs. Time							
Remarks	Typical WSMR cone cylinder	Failure	Failure	Sustained thrust chamber burn - through	WI typical low performance	WI typical IACS cone cylinder	Susta har star

Data,

Number

A-GI	4.67 NP	4.107 GE	4.124 UA	4.88 GT	6.09 GA	4.13 GP-GT
e 39	Figure 42		Figure 18	Figure 7 c		
e 38		Figure 49	Figure 17	Figure	Figure 12	Figure 82
e 37		Figure 48	Figure 17	Figure 7 b	Figure 13	Figure 81
						Figure 81
e 37						Figure 81
				Figure 7 d		Figure 82
				Figure 7 d		Figure 82
	Figure 43		Figure 20	Figure 7 a		Figure 83
						Figure 79
					Figure 9	Figure 84
					Figure 11	
	Figure 44					Figure 83
ner	Typical heavy payload	Typical Churchill	Pitch-roll coupling	Typical ogive WSMR	Insulated booster	Rocket performance

Appendix D

Summary of 1964 Flight Performance Statistics

Flight performance statistics such as net payload weight, apogee, center of gravity, chamber pressure, burnout, roll rate, etc. are provided in this appendix for each Aerobee flight in 1964.

NASA-Langley, 1967 —— 31

Summary of 1964 Flight Performance Statisti
Nasa Aerobee 150 and 150A Flights

Flight No.	Launch Date	Launch Site	Net Payload Wt. (lb)	Time to Apogee (sec)	Apogee (st mi)	Sustainer Burnout Time (sec)	Static Margin at Burnout (calibers)	Ce Gr B (c
4.88 GT	1-28-64	WSMR	291.0	252.6	123.7	53.05	3.15	1
4.124 UA	2-27-64	CRR	137.5	218.0	100.0	53.0	2.0	1
4.15 GG	4-3-64	WSMR	258.0	235.0	118.6	52.4	2.2	1
4.81 GG	4-10-64	WSMR	271.5	141.8	45.5	52.6	2.42	1
4.86 NA	4-14-64	WSMR	277.23	77.4	193.0	53.04	2.2	1
4.113 GA-GI	4-21-64	WSMR	239.0	29.2	6.6	27.5	3.23	1
4.67 NP	6-10-64	WSMR	353.9	211.1	96.4	52.10	3.6	1
4.107 GE	7-23-64	CRR	185.4	267.0	144.5	53.0	2.43	1
4.108 GE	7-25-64	CRR	179.5	251.0	133.7	51.7	2.55	1
4.82 GA	8-11-64	WSMR	286.0	221.3	107.1	52.2	2.51	
4.126 GG	8-22-64	WSMR	265.6	190.0	76.6	48.7	2.72	
4.122 CG	8-29-64	WSMR	264.1	225.7	111.2	52.0	3.2	1
4.55 UG	9-2-64	WI	219.8	215.1	97.1	51.7	2.98	
4.115 NA	9-18-64	WI	240.0	222.1	104.4	52.2	2.96	
4.13 GP-GT	9-26-64	WI	341.8	190.0	74.5	50.8	3.15	1
4.120 CG	10-2-64	WSMR	356.9	203.8	89.4	51.1	3.65	
4.123 CG	10-27-64	WSMR	267.4	235.3	119.6	53.06	3.5	
4.116 GS	10-30-64	WSMR	287.4	234.4	119.0	54.45	2.65	1
4.52 UG	11-3-64	WSMR	273.5	192.5	78.8	48.9	2.40	1
4.109 GG	11-7-64	WSMR	231.6	243.9	130.7	53.2	2.7	1
4.110 GG	11-14-64	WSMR	236.5	243.6	128.8	53.4	2.77	1
4.45 GA	11-16-64	WI	177.3	231.1	116.5	51.5	4.58	
4.118 NA	11-16-64	WSMR	314.8	211.4	97.5	52.4	2.9	
4.83 GA	12-1-64	WSMR	237.5	231.6	114.3	52.2	2.34	
4.132 GA-GI	12-16-64	WSMR	243.0	243.0	128.5	53.2	3.02	
4.125 UA	12-17-64	WSMR	193.4	256.8	145.9	52.9	2.17	

s

ter of vity at rnout libers)	Center of Pressure at Burnout (calibers)	Restoring Moment at Burnout Coefficient (per degree)	Roll Rate at Burnout (rps)	Total No. of Joints
.8	13.95	-0.315	1.45	8
.0	12.2	0.215	0.5	4
.0	13.2	0.23	1.55	11
.98	13.40	0.265	0.53	11
.34	13.54	0.244	Unknown	11
.43	13.6	0.103	Unknown	7
1.4	15.0	0.396	2.5	3
.82	13.25	0.245	1.8	4
.70	13.25	0.255	2.2	4
.84	12.35	0.284	2.25	8
.81	12.5	0.278	1.9	8
.0	13.2	0.336	1.1	5
.34	12.32	0.410	2.5	4
.67	12.72	0.407	-	7
1.06	14.21	0.453	-	11
9.9	13.65	0.438	2.1	6
9.9	13.4	0.37	1.8	5
0.6	13.25	0.294	1.8	6
0.48	12.88	0.264	1.95	9
1.4	14.1	0.280	2.0	5
1.33	14.1	0.280	2.1	5
0.07	14.65	0.275	2.2	9
1.2	14.0	0.33	2.0	5
9.91	12.25	0.252	2.6	8
0.48	13.5	0.314	1.9	6
0.73	12.9	0.235	1.9	7

Summary of 1964 Flight Perfor
NASA Aerobee 30

Flight No.	Launch Date	Launch Site	Net Payload Wt. 2 nd Stage (lb)	Apogee (st mi)	Time To Apogee (sec)	Center of Gravity Sustainer at Burnout (calibers)	Static Margin Sustainer at Burnout (calibers)	Center of Pressure Sustainer at Burnout (Calibers)	Restorin Moment Coefficie Sustaine Burnout (per degre
6.09 GA	1-29-64	WI	273.1	192.3	300.2	11.25	4.37	15.62	0.594
6.10 GA	7-28-64	CRR	253.4	200.0	305.0	10.90	3.85	14.75	0.400

ıance Statistics (Continued)
· and 300A Flights

i nt e)	Center of Gravity 3 rd Stage at Burnout (calibers)	Center of Pressure 3 rd Stage at Ignition (calibers)	Static Margin 3 rd Stage at Ignition (calibers)	Restoring Moment 3 rd Stage Coefficient at Ignition (per degree)	Sustainer Burnout (sec)	3 rd Stage at Burnout (sec)	Roll Rate at Burnout Sustainer (lb)	Total Number Joints	Net Payload Wt. 3 rd Stage (lb)
	7.8	11.16	3.36	0.121	50.8	53.8	2.7	4	84.75
	8.38	11.4	3.02	0.110	54.0	Unknown	2.0	8	96.98

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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