THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Electrical Engineering
Space Physics Research Laboratory

Sounding Rocket Flight Report

NASA 18.50 THERMOSPHERE PROBE EXPERIMENT

Prepared on behalf of the project by

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ORA Project 07065

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ACKNOWLEDGMENTS

Over one hundred employees of the Space Physics Research Laboratory of The University of Michigan contributed to the success of the NASA 18.50 Thermosphere Probe Experiment. Some of the personnel with specific responsibilities are listed below:

Carignan, G. R.	Laboratory Director
Caldwell, J. R.	Electronics Engineer
Campbell, B. J.	Design Draftsman
Crosby, D. F.	Electron Temperature Probe Engineer
Freed, P. L.	Head Technician
Grim, G. K.	Electronics Engineer
Kartlick, W. G.	Omegatron Technician
Kimble, R. G.	Telemetry Technician
Maurer, J. C.	Payload Engineer
McCormick, D. L.	Machinist
Niemann, H. B.	Neutral Particle Scientist
Pate, R. W.	Omegatron Engineer
Poole, G. T.	Head Programmer

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1. INTRODUCTION

The results of the launching of NASA 18.50, a Nike-Tomahawk sounding rocket, are presented and discussed in this report. The payload, a Thermosphere Probe (TP), described by Spencer, Brace, Carignan, Taeusch, and Niemann (1965), was jointly developed by the Space Physics Research Laboratory (SPRL) of The University of Michigan and the Goddard Space Flight Center (GSFC), Laboratory for Atmospheric and Biological Sciences (LABS). The TP is an ejectable instrument package designed for the purpose of studying the variability of the earth's atmospheric parameters in the altitude region between 120 and 350 km. The NASA 18.50 payload included two omegatron mass analyzers (Niemann and Kennedy, 1966), an electron temperature probe (Spencer, Brace, and Carignan, 1962), and a solar position sensor. This complement of instruments permitted the determination of the daytime molecular nitrogen density and temperature and the electron density and temperature in the altitude range of approximately 140 to 284 km over Wallops Island, Virginia.

A general description of the payload kinematics, orientation analysis, and the techniques for the reduction and analysis of the data is given by Taeusch, Carignan, Niemann, and Nagy (1965) and Carter (1968). The orientation analysis and the reduction of the nitrogen data were performed at SPRL, and the results are included in this report. The electron temperature probe data were reduced at GSFC, and are not discussed here.

The NASA 18.50 payload described herein was specifically designed and implemented to serve as an engineering flight test vehicle for a second generation omegatron system, as well as to provide a direct comparison of this new system with the previously reported standard omegatron (OM I). A description of the Omegatron II system (OM II) and discussion of the engineering test results are included in Section 6 of the present report.

2. GENERAL FLIGHT INFORMATION

The general flight information for NASA 18.50 is listed below. Table I gives the flight times and altitudes of significant events which occurred during the flight. Some of these were estimated and are so marked. The others were obtained from the telemetry records and radar trajectory information.

Launch Date: 18 September 1967
Launch Time: 14:10:00.090 EST, 19:10:00.090 GMT
Location: Wallops Island, Virginia
Longitude: 75°29'W
Latitude: 37°50'N

Apogee Parameters:

Altitude: 284.624 km
Horizontal Velocity: 522.26 m/sec
Flight Time: 263.92 sec

TP Motion:

Tumble Period: 5.557 sec
Roll Rate: -17.16 deg/sec

TABLE I

TABLE OF EVENTS

(NASA 18.50)

Event	Flight Time (sec)	Altitude (km)
Lift Off	0	0
1st Stage Burnout	3.3 (est.)	1.3 (est.)
2nd Stage Ignition	12.0	6.7
2nd Stage Burnout	21.0	19.2
Despin	43.0 (est.)	65.9 (est.)
TP Ejection	45.6	69.1
Omegatron Breakoff	81.6	136.2
Omegatron Filaments On, M28	82.5	137.6
Peak Altitude	263.9	284.6
L.O.S.	500.0	—

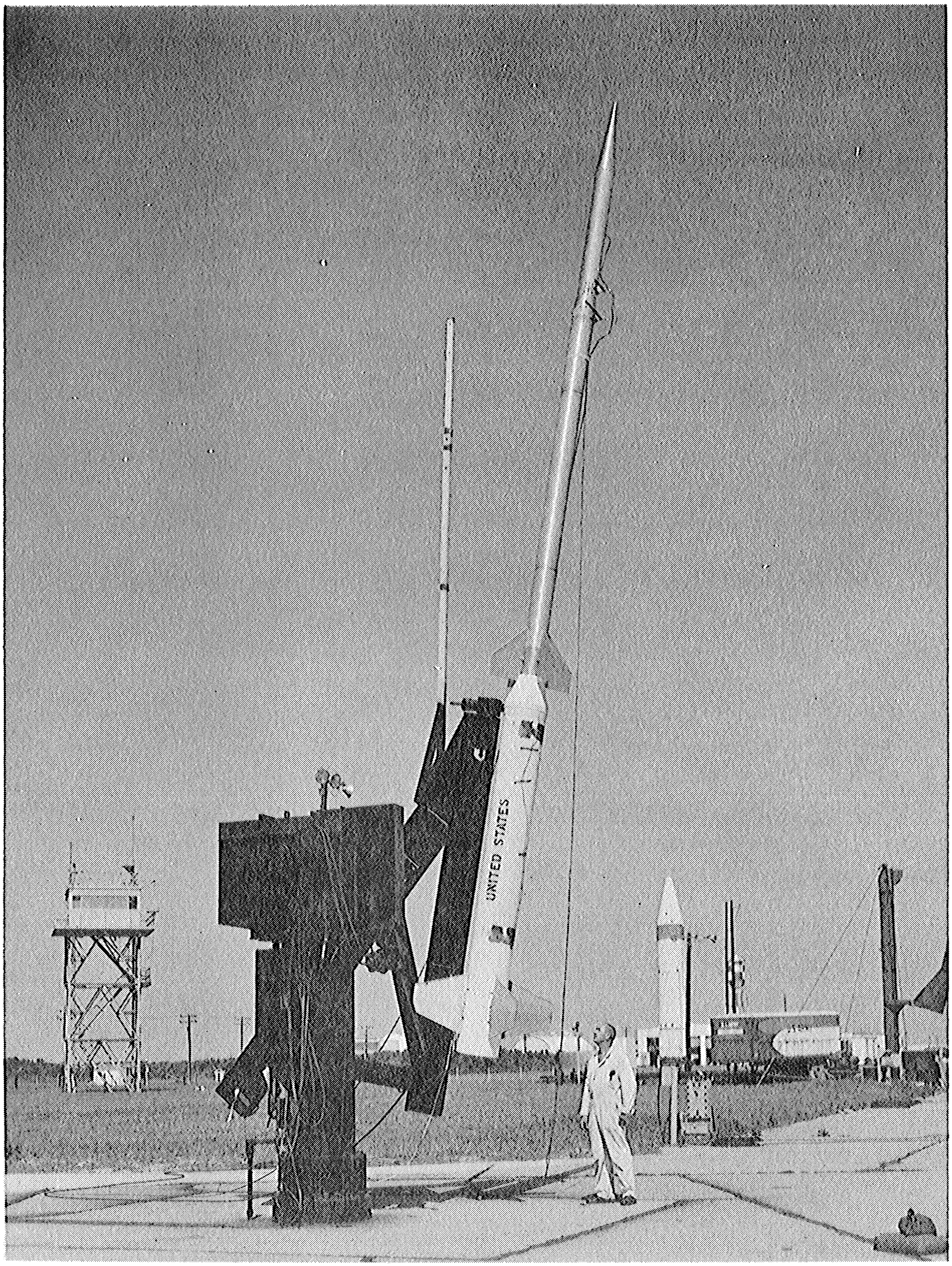
3. LAUNCH VEHICLE

The NASA 18.50 launch vehicle was a two-stage, solid propellant, Nike-Tomahawk combination. The first stage, a Hercules M5E1 Nike motor, had an average thrust of 49,000 lb and burned for approximately 3.6 sec. The Nike booster, plus adapter, was 145.2 in. long and 16.5 in. in diameter. Its weight unburned was approximately 1325 lb. The sustainer stage, Thiokol's TE416 Tomahawk motor, provided an average thrust of 11,000 lb and burned for about 9 sec. The Tomahawk, 141.1 in. long and 9 in. in diameter, weighed 530 lb unburned. The TP payload, which was 90.2 in. long and weighed 181 lb, including despin and adapter modules, made the total vehicle 376.5 in. long with a gross lift-off weight of 2036 lb. The vehicle is illustrated in Figures 1, 2, 3, and 4.

The launch vehicle performed flawlessly and reached a summit altitude of 284.6 km at 263.92 sec of flight time.

NASA W-67-474

Figure 1. Nike-Tomahawk with thermosphere probe payload.



NASA W-67-475

Figure 2. Nike-Tomahawk with thermosphere probe payload.

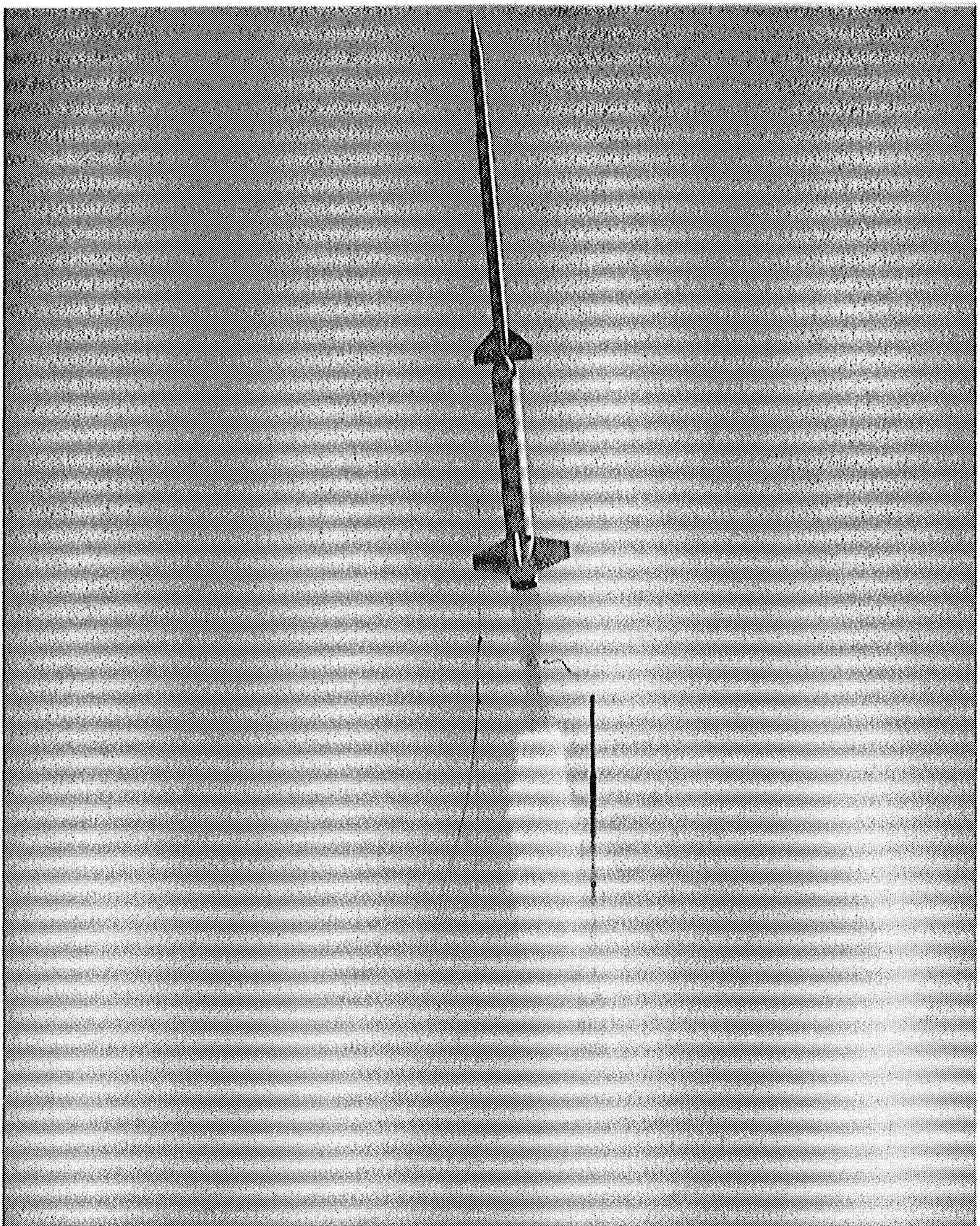


Figure 3. Nike-Tomahawk with thermosphere probe payload.

ROCKET NO. 18:50

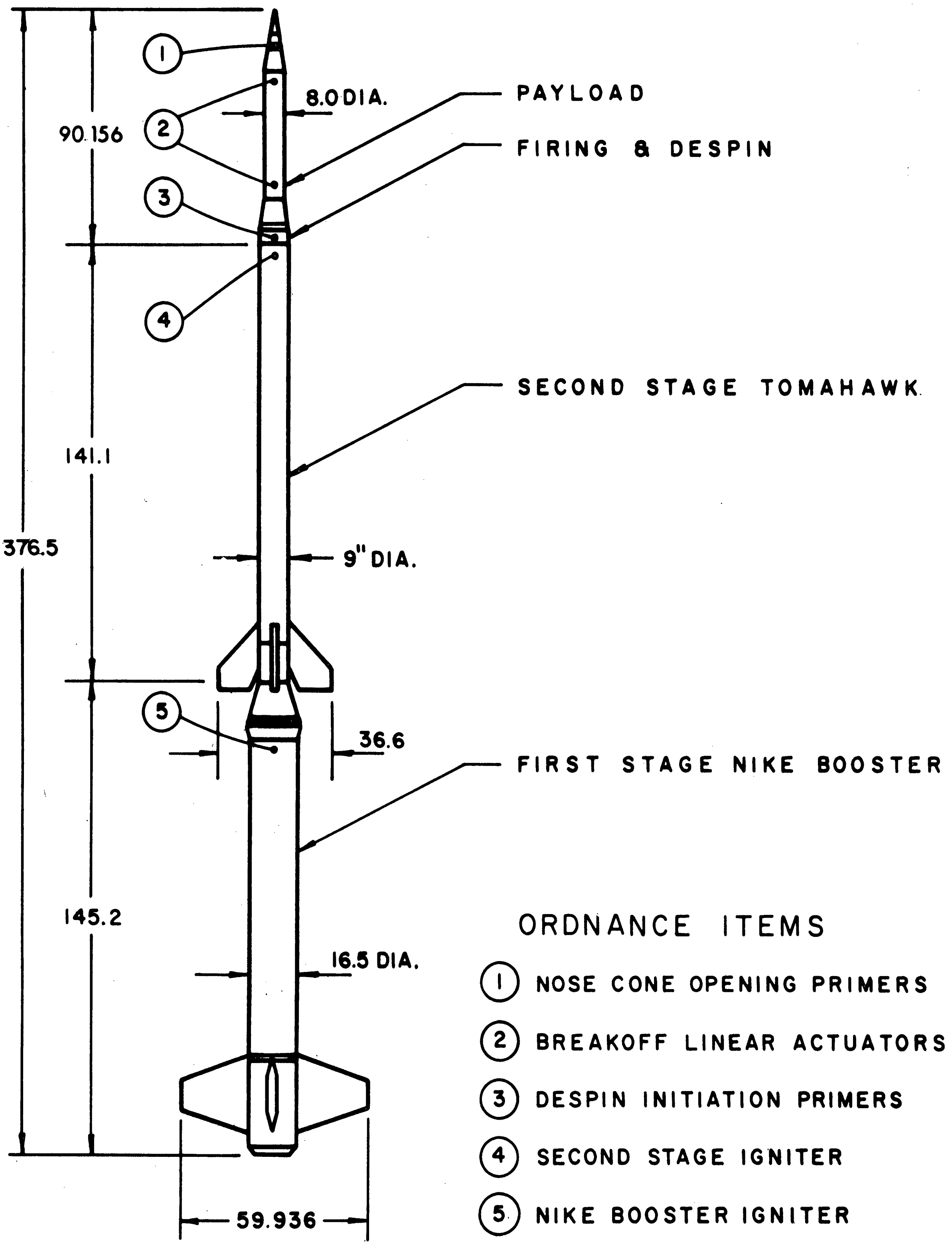


Figure 4. Nike-Tomahawk dimensions.

4. NOSE CONE

A diagram of the NASA 18.50 payload, including the nose cone, the despin mechanism, and the adapter section is shown in Figure 5. An assembly drawing of the 8-in. nose cone is given in Figure 6.

The payload is programmed to despin at 65 km altitude (43 sec after launch), and the ejection begins at 70 km (45 sec after launch). The ejection system is designed for a tumble period of 4 sec by using a 2.2 lb Neg'ator* force and by limiting the travel of the plunger to 0.75 in. (Carter, 1968). The breakoff devices of both OM I and OM II are removed at 136 km (82 sec after launch), and the filaments of the omegatrons are turned on approximately 2 sec later.

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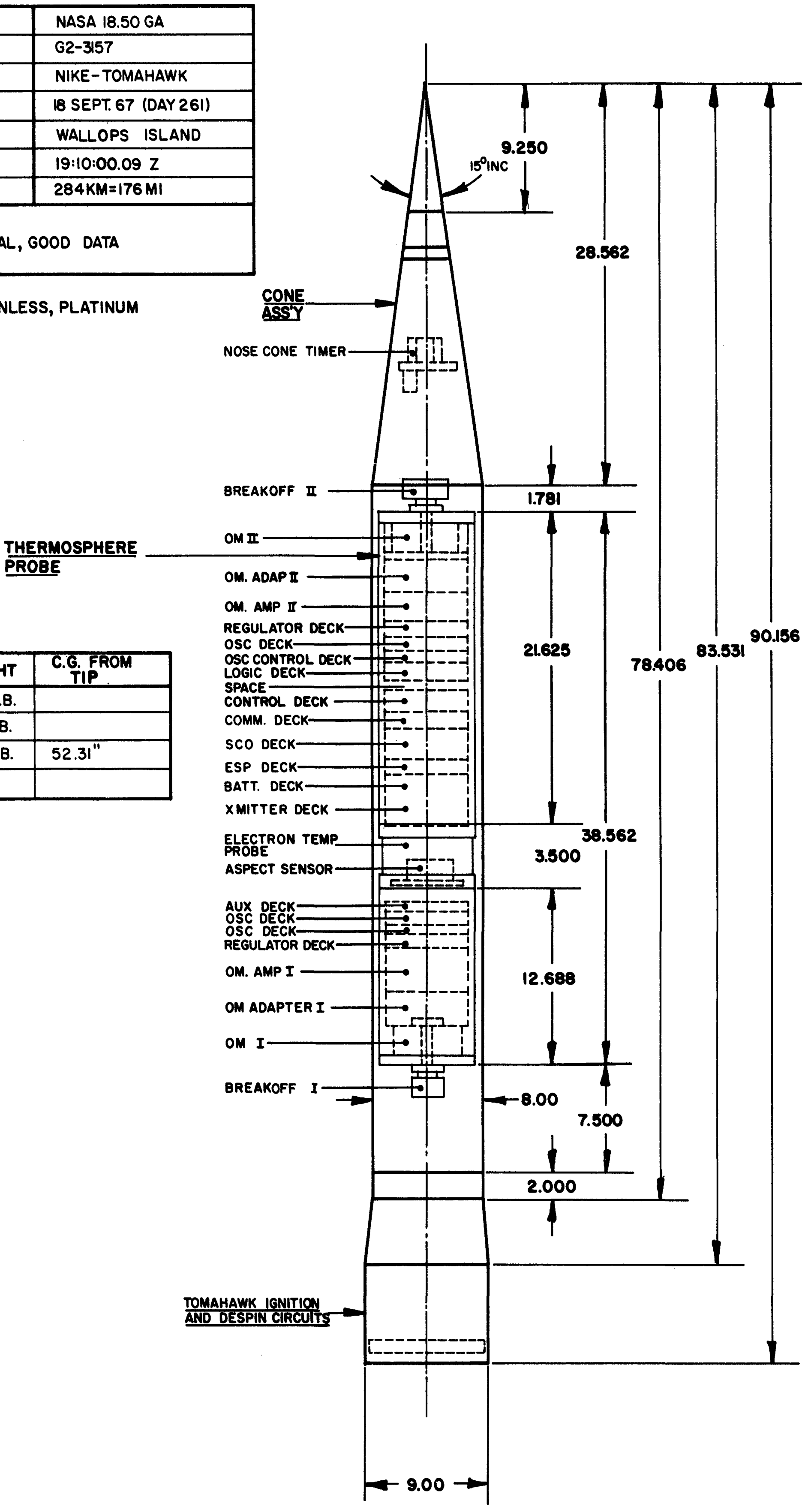
*Neg'ator is a trade name.

ROCKET NO.	NASA 18.50 GA
LAUNCH RANGE NO.	G2-3157
TYPE OF ROCKET	NIKE-TOMAHAWK
DATE OF LAUNCH	18 SEPT. 67 (DAY 261)
LOCATION	WALLOPS ISLAND
TIME	19:10:00.09 Z
ALTITUDE	284 KM=176 MI
RESULTS ALL SYSTEMS NORMAL, GOOD DATA	

MISC. NOTES:
1) TWO PROBES: STAINLESS, PLATINUM

NAME	WEIGHT	C.G. FROM TIP
NOSE CONE	103 LB.	
PROBE	78 LB.	
COMBINED	181 LB.	52.31"



DRAFTSMAN MLH	
NASA 18.50 GA PAYLOAD OM I / OM II	4-4-68 10-18-67
B-E 457	DATE

Figure 5. Thermosphere probe instrumentation design.

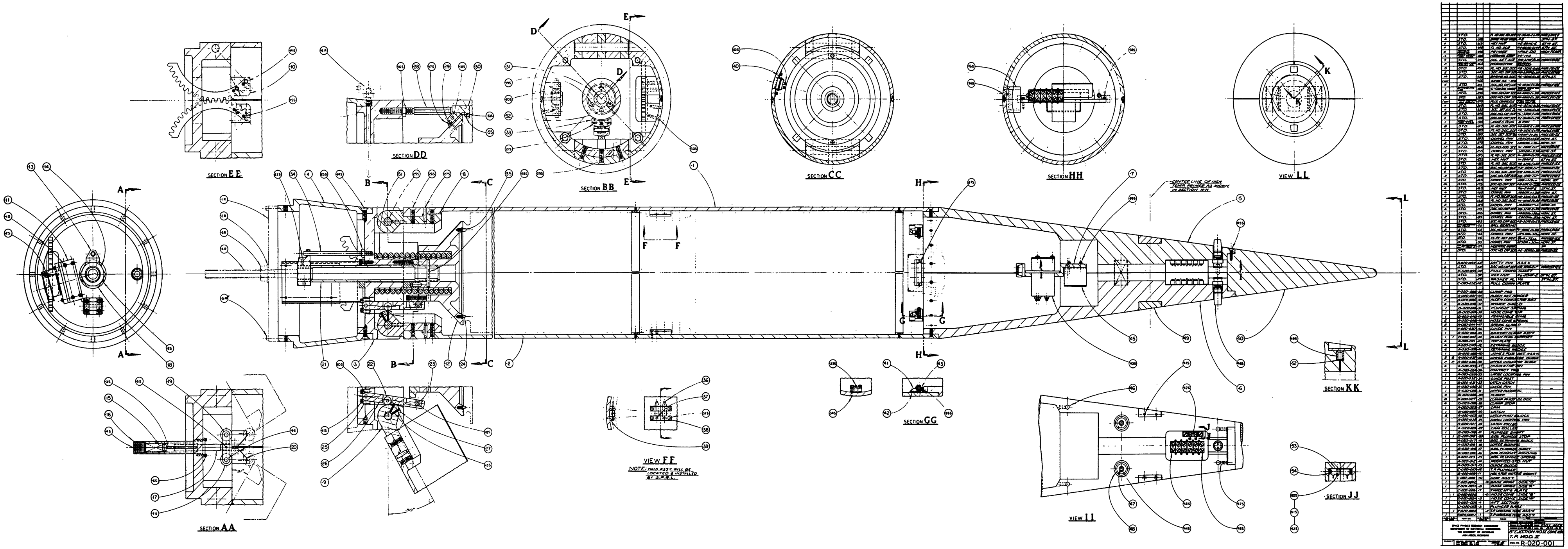
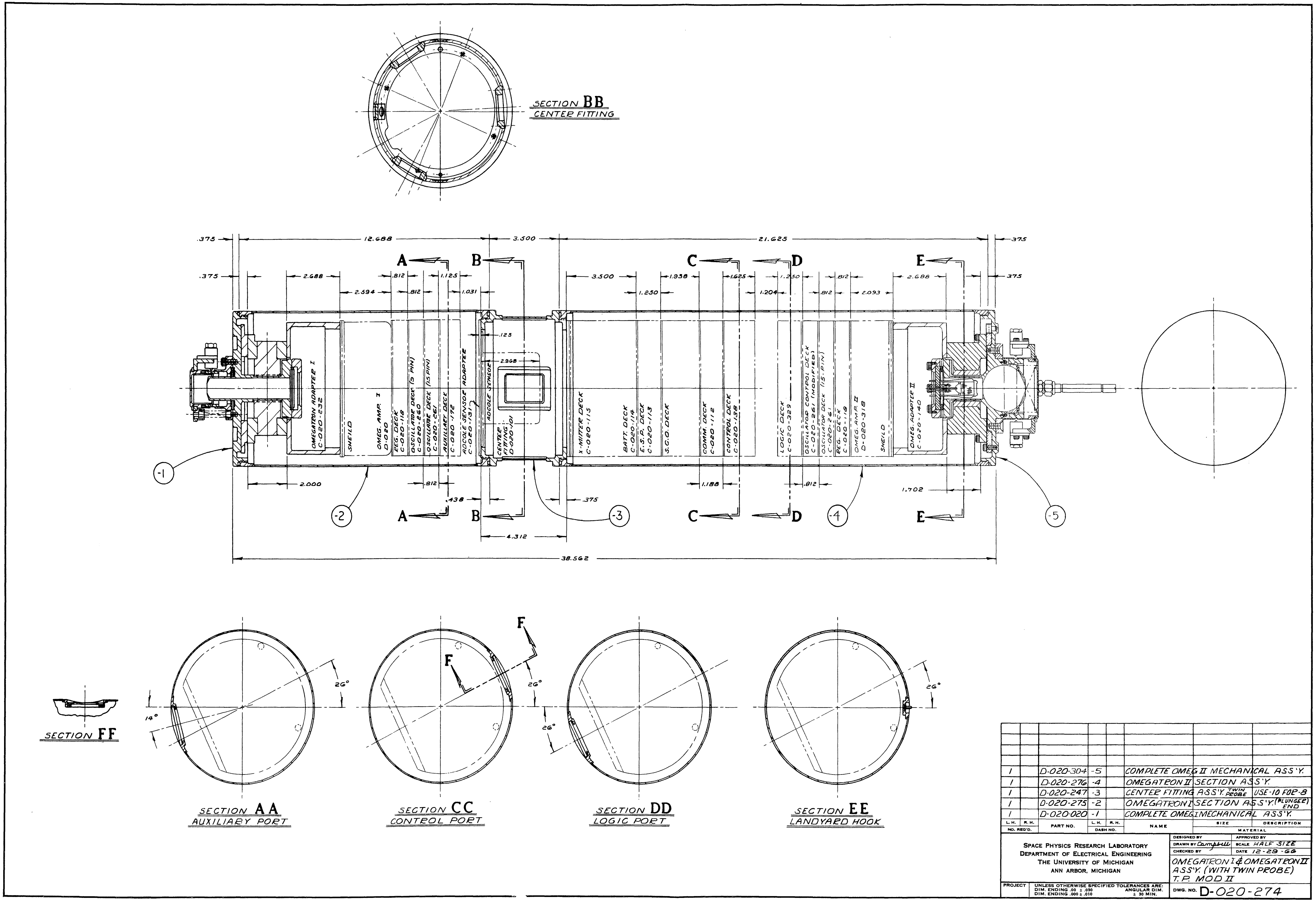


Figure 6. Assembly drawing, 8-in. nose cone.



NO. REQ'D. L.H.	NO. REQ'D. R.H.	PART NO.	DASH NO. L.H.	DASH NO. R.H.	NAME	SIZE	DESCRIPTION
1		D-020-304	-5		COMPLETE OMEG II MECHANICAL ASS'Y.		
1		D-020-276	-4		OMEGATRON II SECTION ASS'Y.		
1		D-020-247	-3		CENTER FITTING ASS'Y. TWIN PROBE		USE -10 FOR -8
1		D-020-275	-2		OMEGATRON I SECTION ASS'Y. (PLUNGER END)		
1		D-020-020	-1		COMPLETE OMEG I MECHANICAL ASS'Y.		

Figure 7. Thermosphere probe assembly.

5. THE THERMOSPHERE PROBE (TP)

The TP used for the NASA 18.50 payload was a cylinder 38.6 in. long and 7.25 in. in diameter which weighed 78 lb. The major instrumentation for this payload included two omegatron mass analyzers and an electron temperature probe. Supporting instrumentation included a solar aspect sensor for use in determining the attitude of the TP. Figure 7 is an assembly drawing of the Thermosphere Probe. The diagram in Figure 5 shows the location of instrumentation and supporting electronics in the nose cone. Figure 8 is the system block diagram.

5.1. OMEGATRONS

The omegatrons used in the payload were of two designs. The first, designated as OM I, was described by Niemann and Kennedy (1966). The second, referred to as OM II, incorporated several innovations in structure, function, and circuitry.

Further discussion of the new design is contained in Section 6 of the present report. Table II lists the operating parameters of the gauges and associated electronics. The characteristics of the linear electrometer amplifier current detectors, used to monitor the omegatron output currents, are also listed. The breakoff configuration and omegatron envelope for each omegatron are shown in Figures 9 and 10. The calibration of the NASA 18.50 OM I, performed at SPRL during August 1967, is shown in Figure 11.

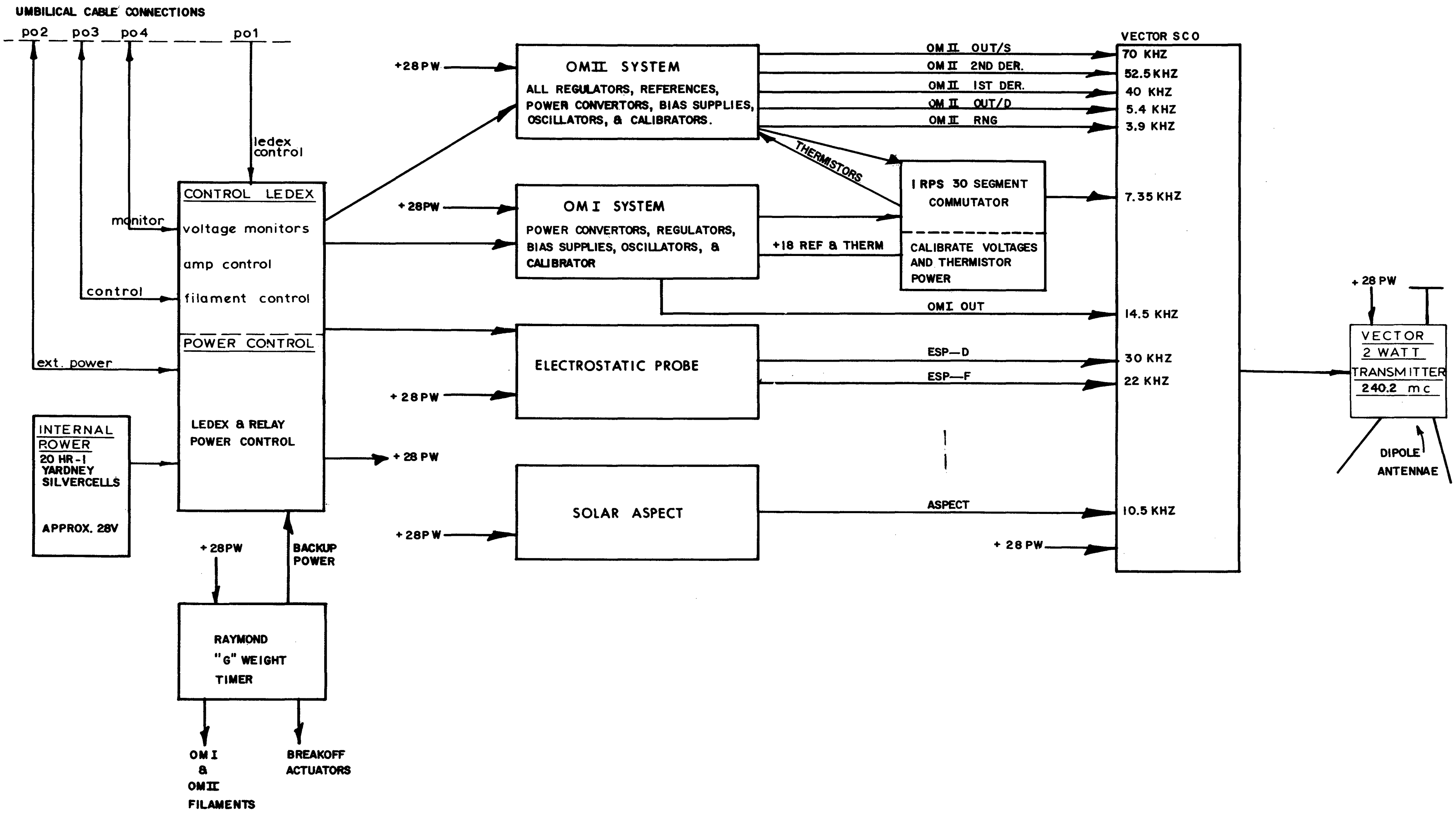


Figure 8. Thermosphere probe system block diagram.

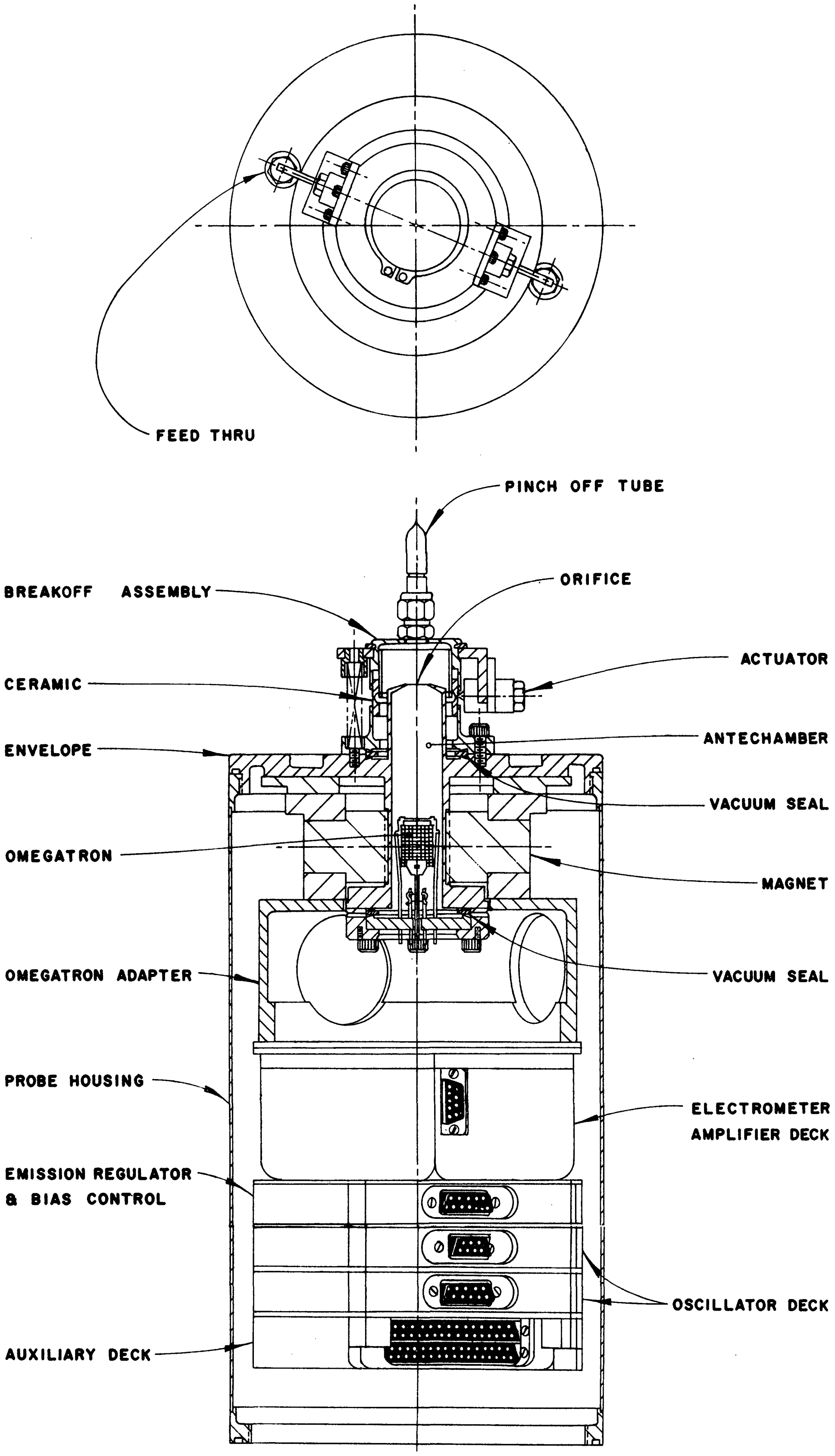


Figure 9. Omegatron I.

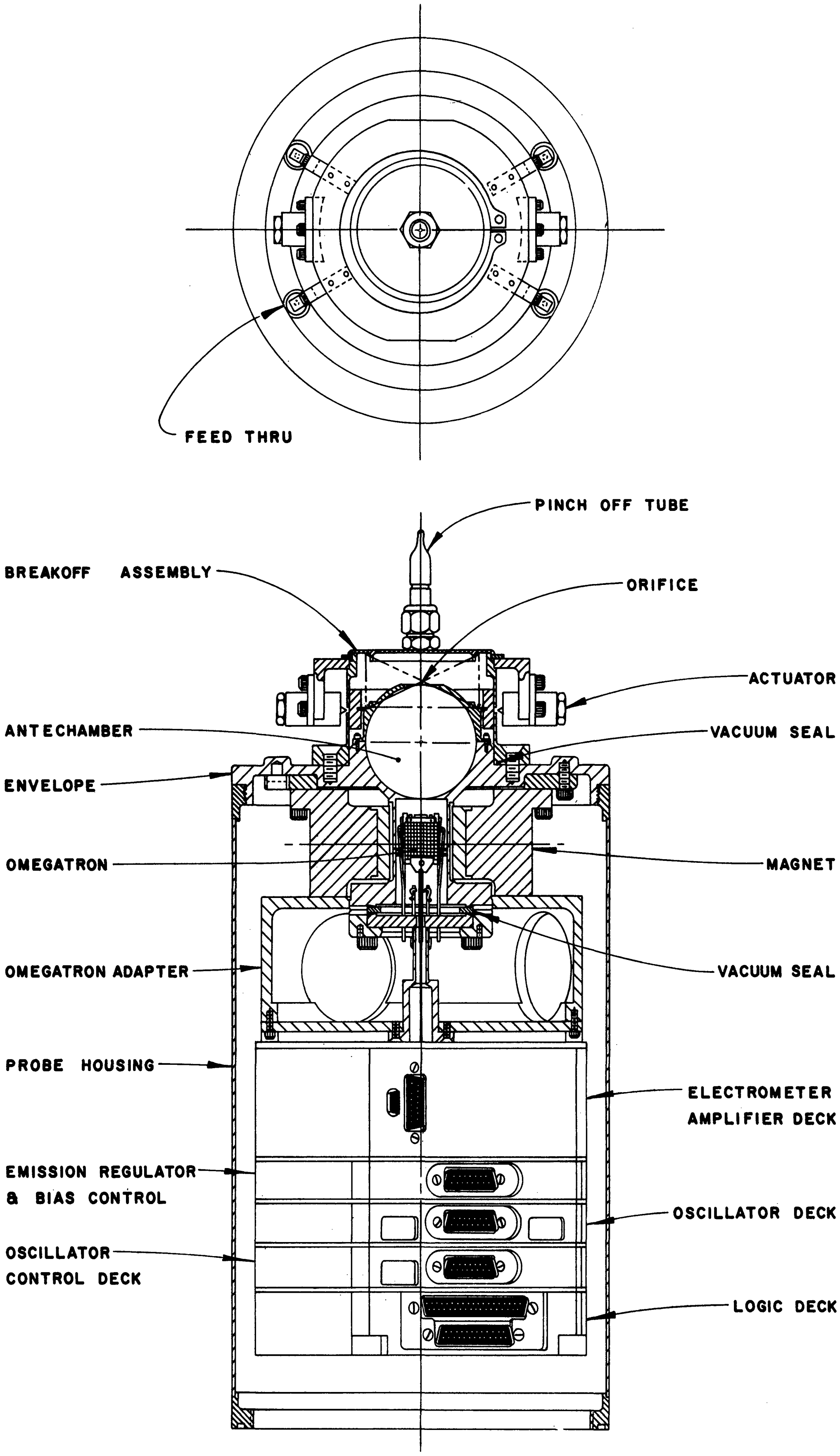


Figure 10. Omegatron II.

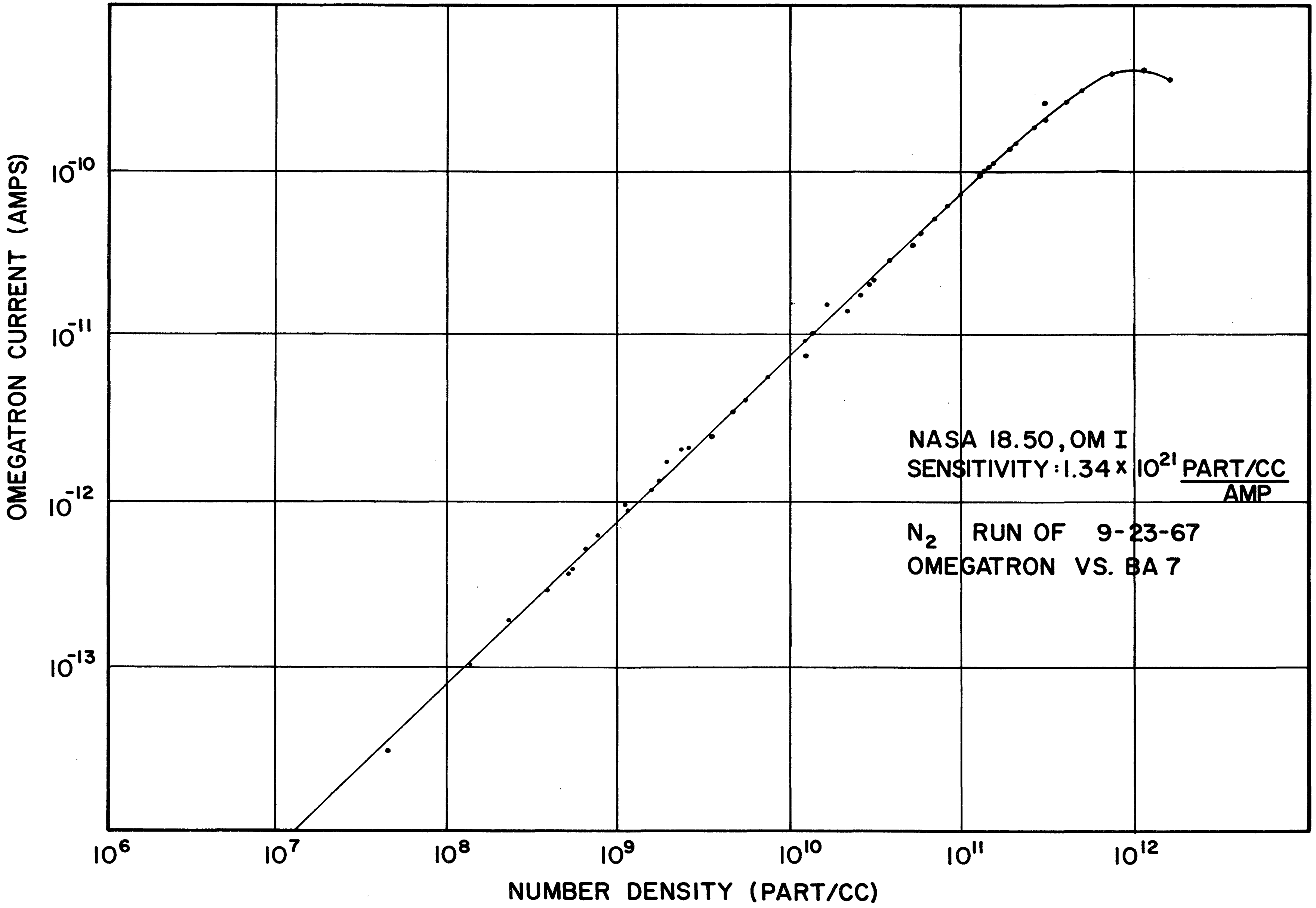


Figure 11. OM I final calibration.

1/9/68

TABLE II

OMEGATRON DATA

(NASA 18.50)

Omegatron Gauge Parameters	OM I	OM II
Beam Current:	1.85 µA	1.93 µA
Electron Collector Bias:	75.50 V	76.65 V
Filament Bias:	-86.38 V	-93.05 V
Cage Bias:	- 0.17 V	- 0.20 V
Top Bias:	- 0.59 V	- 0.60 V
RF Amplitude, Mass 28:	4.00 V_{p-p}	3.95 V_{p-p}
RF Frequency, Mass 28:	143.58 kHz	144.62 kHz
Monitors		
Filament		
OFF:	0.11 V	0.12 V
ON:	3.39 V	3.38 V
Beam		
OFF:	0.66 V	0.66 V
ON:	3.68 V	3.68 V
Thermistor Pressure (zero pressure)		
Filament OFF:	2.55 V	2.81 V
Filament ON:	2.39 V	2.68 V
Bias:	3.96 V	4.07 V
RF:	3.26 V	3.37 V
Calibration		
Sensitivity:	2.40 x 10^{-5} A/torr	2.05 x 10^{-5} A/torr
Maximum Linear Pressure (5%):	8 x 10^{-6} torr	5 x 10^{-6} torr

TABLE II (Continued)

Electrometer Amplifier

OM I

Range	Range Indicator	Range Resistor	Mass 28 ZPV
1	0.0 V	9.119×10^{9} Ω	5.014 V
2	0.7 V	2.479×10^{10} Ω	5.008 V
3	1.4 V	6.738×10^{10} Ω	5.007 V
4	2.1 V	1.832×10^{11} Ω	5.000 V
5	2.8 V	4.979×10^{11} Ω	4.990 V
6	3.5 V	1.353×10^{12} Ω	4.989 V
7	4.2 V	3.679×10^{12} Ω	4.960 V
8	4.9 V	1.000×10^{13} Ω	4.977 V

TABLE II (Concluded)

Electrometer Amplifier

OM II

Range	Range Indicator	Range Resistor	Mass 28 ZPV	Bias
1-1	0.85 V	0.91×10^{12} Ω	0.034 V	+ 3.037 V
1-2	1.01 V	0.91×10^{12} Ω	0.034 V	- 0.985 V
1-3	1.19 V	0.91×10^{12} Ω	0.034 V	- 4.949 V
1-4	1.38 V	0.91×10^{12} Ω	0.034 V	- 8.902 V
1-5	1.55 V	0.91×10^{12} Ω	0.034 V	-12.868 V
1-6	1.74 V	0.91×10^{12} Ω	0.034 V	-16.890 V
1-7	1.89 V	0.91×10^{12} Ω	0.034 V	-20.643 V
2-1	2.41 V	1.56×10^{11} Ω	0.050 V	+ 3.037 V
2-2	2.56 V	1.56×10^{11} Ω	0.050 V	- 0.985 V
2-3	2.76 V	1.56×10^{11} Ω	0.050 V	- 4.949 V
2-4	2.95 V	1.56×10^{11} Ω	0.050 V	- 8.902 V
2-5	3.12 V	1.56×10^{11} Ω	0.050 V	-12.868 V
2-6	3.30 V	1.56×10^{11} Ω	0.050 V	-16.890 V
2-7	3.48 V	1.56×10^{11} Ω	0.050 V	-20.643 V
3-1	3.92 V	3.22×10^{10} Ω	0.050 V	+ 3.037 V
3-2	4.07 V	3.22×10^{10} Ω	0.050 V	- 0.985 V
3-3	4.25 V	3.22×10^{10} Ω	0.050 V	- 4.949 V
3-4	4.43 V	3.22×10^{10} Ω	0.050 V	- 8.902 V
3-5	4.61 V	3.22×10^{10} Ω	0.050 V	-12.868 V
3-6	4.79 V	3.22×10^{10} Ω	0.050 V	-16.890 V
3-7	4.97 V	3.22×10^{10} Ω	0.050 V	-20.643 V

Miscellaneous	OM I	OM II
+28 power current all on:	340 mA	420 mA
Preflight gauge pressure (N_2):	8×10^{-6} torr	1×10^{-2} torr
Magnetic field strength:	2800 gauss	2800 gauss

5.2. ELECTROSTATIC PROBE (ESP)

The ESP system consists of two cylindrical Langmuir probes immersed in the plasma and an electronics package which measures the current collected by the probes. The cylindrical Langmuir probes and the mounting configuration are shown in Figure 12. Probe 1, the lower probe, is made of stainless steel, while probe 2 is made of platinum. The electronics unit consists of a dc-dc converter, a ramp voltage generator, a three range current detector, range switching relays, and associated logic circuitry.

There are two outputs, a data channel, and a probe and ΔV monitor channel. The data channel output is a voltage proportional to the collected probe current, and the probe and ΔV monitor output is a signal showing whether the system is measuring in its high or low ΔV mode and which probe is connected to the current detector. System timing and output format are shown in Figure 13. The following are the specifications of the Electrostatic Probe system for NASA 18.50:

(a) Input Power
1.5 W at 28 V

(b) Sensitivity

Range 1	20 μA full scale	(full scale output is defined as 4.5 V)
Range 2	2 μA full scale	
Range 3	0.2 μA full scale	

(c) Ramp Voltage (ΔV)

	Magnitude	Slope
High ΔV	-2.9 V to +4.8 V	30.8 V/sec
Low ΔV	-1 V to +1.8 V	11 V/sec
Period	250 msec	

High-Low ΔV alternate every 4.5 sec

(d) Output

Voltage	-0.6 V to + 5.8 V
Resistance	2000 Ω
Bias Level	+0.5 V

(e) Calibration Sequence (Synchronized with ΔV)
Occurrence of calibration every 54 sec
Duration of calibration 1.5 sec

(f) Timing (see Figure 13)
High-Low ΔV alternate every 18 sweeps (4.5 sec)
Probes switch with every ΔV sweep (0.25 sec)
Detector ranges change sequentially every 2 ΔV sweeps (0.5 sec)

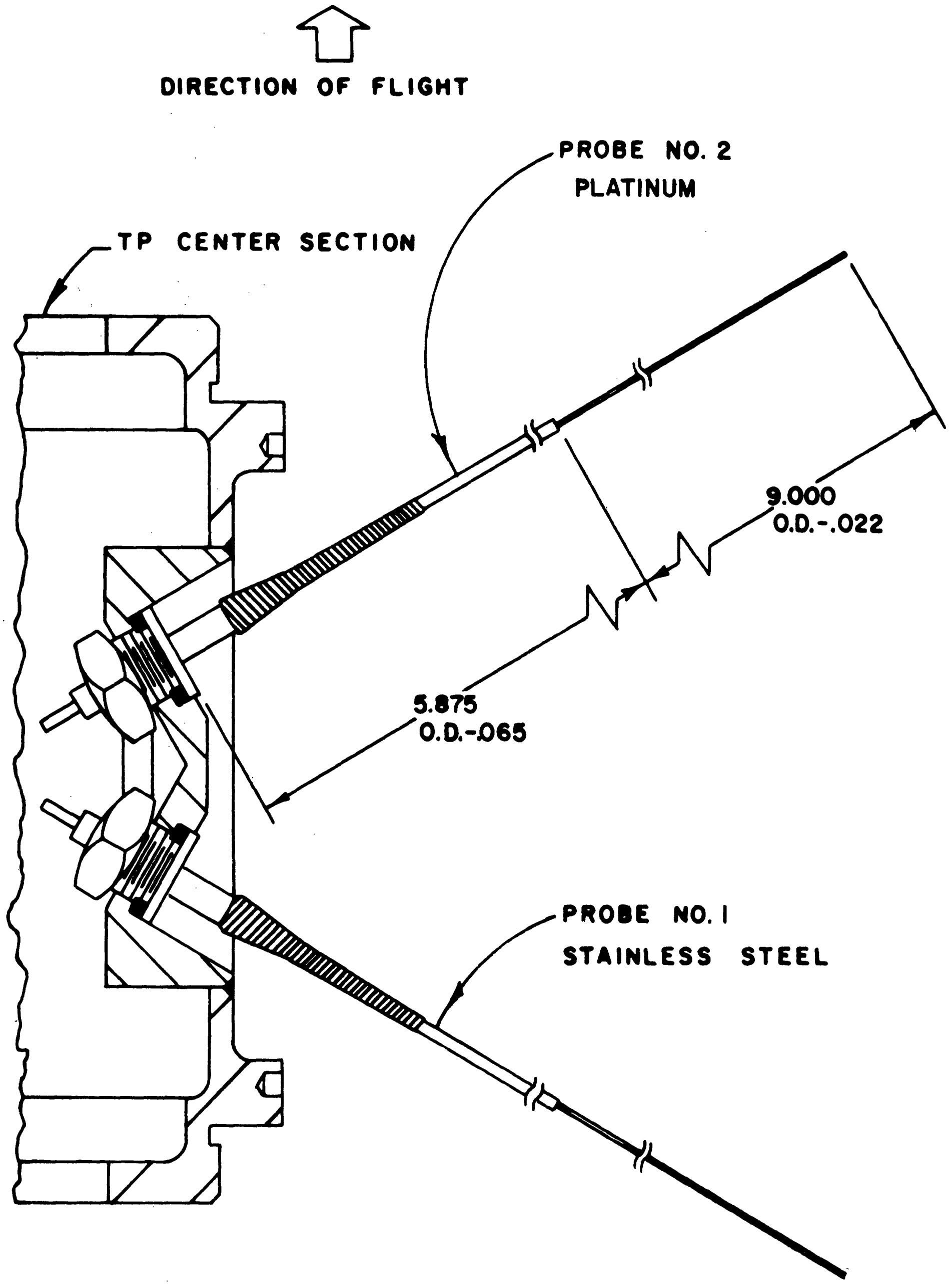


Figure 12. Electrostatic probe mounting configuration.

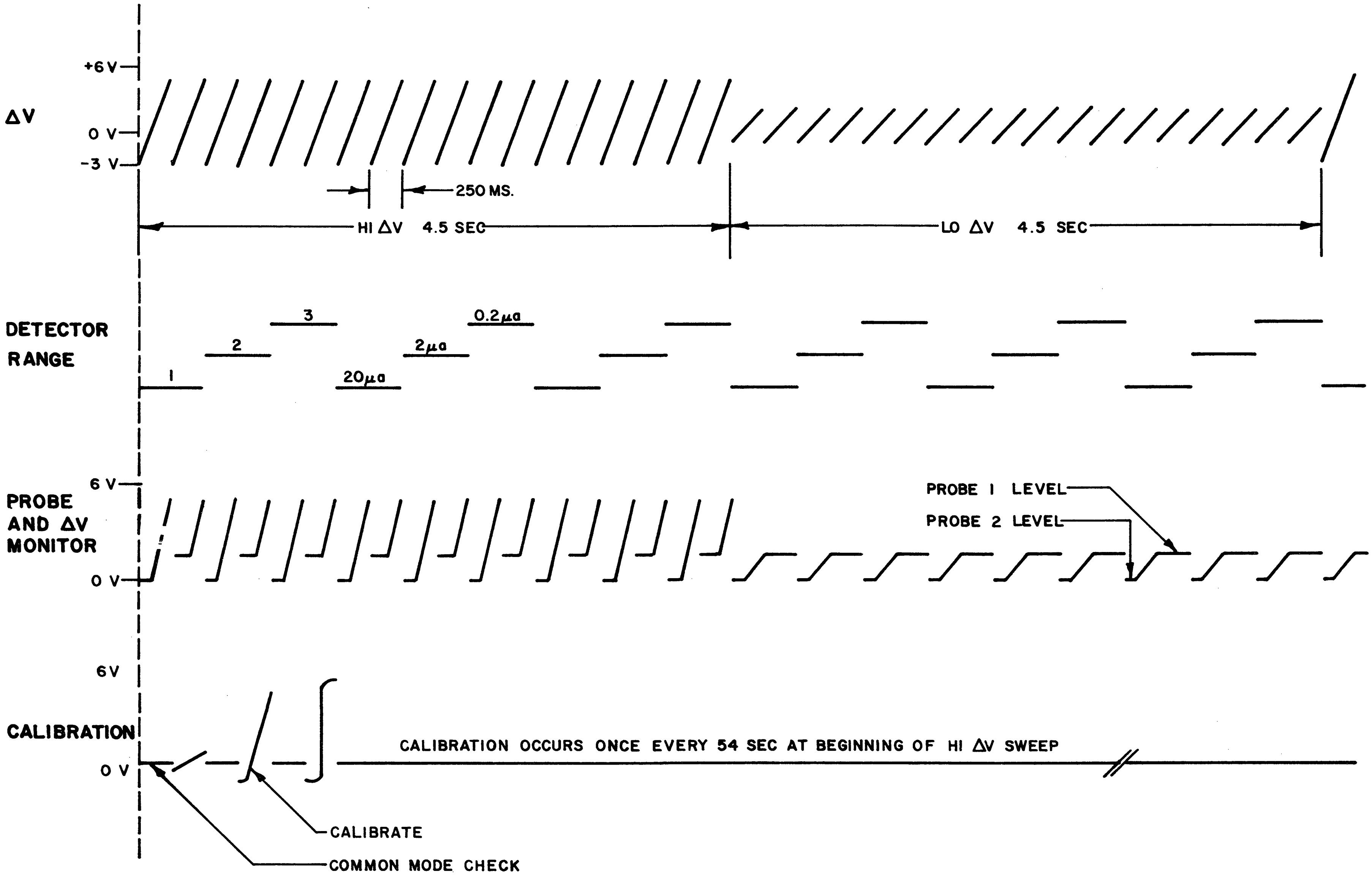


Figure 13. Electrostatic probe system timing and output format.

5.3. SUPPORT MEASUREMENTS AND INSTRUMENTATION

5.3.1. Aspect Determination System

The NASA 18.50 TP utilized a solar aspect sensor made by Adcole Corporation which is identical to the ones used on previous daytime shots. This system functioned properly throughout the flight. The attitude of the TP was determined by using the method of referencing the solar vector and the velocity vector (Carter, 1968). The resulting minimum angle of attack for OM I, determined to an estimated accuracy of ±5 degrees, is plotted vs. altitude in Figure 14.

5.3.2. Telemetry

The payload data were transmitted in real time by a ten channel PAM/FM/FM telemetry system at 240.2 MHz with a nominal output of 2.5 watts. The telemetry system used ten subcarrier channels, as outlined below.

Transmitter: Driver TRPT-251RB01, Serial No. 1041
Power Amplifier TRFP-2V, Serial No. 222
Mixer Amplifier TA59A, Serial No. 1033
Subcarrier Channels (SCO Type TS58)

IRIG Band	Serial No.	Center Frequency	Function	Low Pass Filter Used
18	3345-25	70 kHz	OM II OUT/S	500 CD
17	1742-5	52.5 kHz	OM II 2nd der	790 CD
16	1729-5	40 kHz	OM II 1st der	600 CD
15	1720-5	30 kHz	ESP-D	450 CD
14	1717-5	22 kHz	ESP-F	330 CD
13	3044-25	14.5 kHz	OM I OUT	220 CD
12	3211-25	10.5 kHz	Aspect	400 CA
11	1980-25	7.35 kHz	Commutator	160 CD
10	1676-5	5.4 kHz	OM II OUT/D	80 CD
9	1661-5	3.9 kHz	OM II RANGE	60 CD

Instrumentation power requirements totaled approximately 40 watts, supplied by a Yardney HR-1 Silvercell battery pack of a nominal 28 V output.

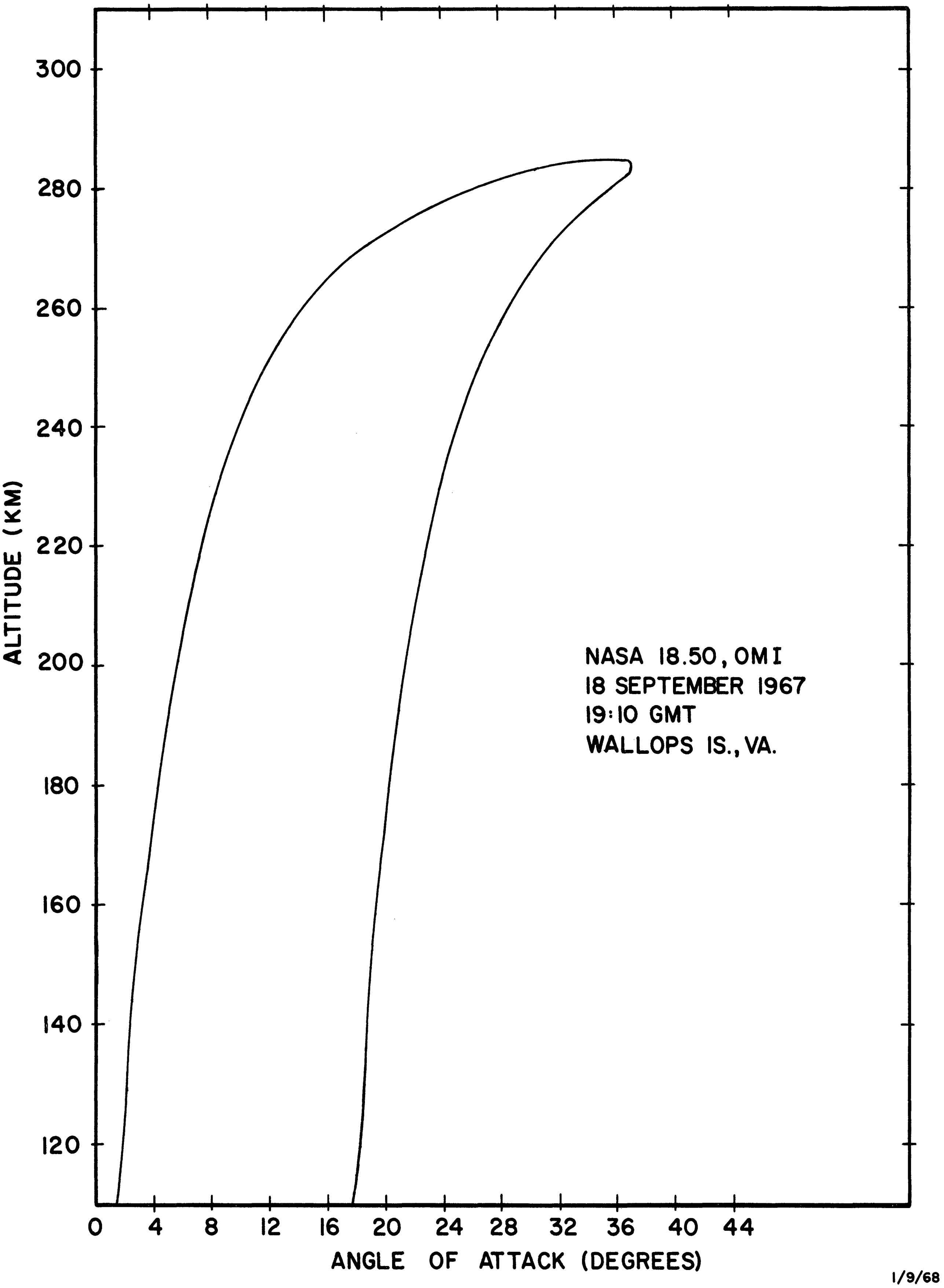


Figure 14. Minimum angle of attack vs. altitude (OM I).

5.3.3. Housekeeping Monitors

Outputs from various monitors throughout the instrumentation provided information bearing on the operations of the electronic components during flight. These outputs were fed to a thirty-segment commutator which ran at one rps. The commutator assignments were as follows:

COMMUTATOR FORMAT FOR 18.50

(OM I G5, OM II G6)

Segment Number		Segment Assignment
1	OM I	Amplifier Range
2		Output
3		Filament Monitor
4		Beam Monitor
5		Bias Monitor
6		RF Monitor
7		Internal Pressure Monitor
8		Thermistor-Gauge Temperature
9		Thermistor-Amplifier Temperature
10		Thermistor-Filament Regulator Temperature
11		Thermistor-Transmitter Temperature
12	OM II	Thermistor-Filament Regulator Temperature
13		Thermistor-Amplifier Temperature
14		Thermistor-Gauge Temperature
15		Internal Pressure Monitor
16		RF Monitor
17		Bias Monitor
18		Beam Monitor
19		Filament Monitor
20		OUT/D
21		Comparator Ramp Monitor
22		Open
23		Battery Voltage Monitor
24		0 V Calibration
25		1 V Calibration
26		2 V Calibration
27		3 V Calibration
28		4 V Calibration
29 and 30		5 V Calibration

6. ENGINEERING RESULTS

The launching of the NASA 18.50 Thermosphere Probe was normal and all systems performed as expected. The prime objective of this flight was to obtain data from a new omegatron system designated the Omegatron II, which was designed to provide high resolution measurements of the density variation within the chamber as the TP tumbled. These data are used to determine the ambient N_2 kinetic temperature directly from the measurement of the OM II.

The data obtained from the OM II were as anticipated. However, the reduction techniques and the analysis are considerably more complex than those required for the standard omegatron. Consequently, at the present time, we do not have complete results. A report describing the total OM II system and theory is in preparation, and the results from the NASA 18.50 flight will be included.

7. ANALYSIS OF DATA

The telemetered data were recorded on magnetic tape at the Wallops Island Main Base and the GSFC Station A ground Station facilities. Appropriate paper records were made from the magnetic masters, facilitating "quick look" evaluations. The aspect data were reduced to engineering parameters from paper records. The omegatron and housekeeping data were reduced by computer techniques from the magnetic tapes.

7.1. TRAJECTORY AND ASPECT

The position and velocity data used to determine aspect, ambient N_2 density, and ambient temperature as a function of time and altitude were obtained by fitting a smooth theoretical trajectory to the FPQ-6 and FPS-16 radar data. The theoretical trajectory is programmed for computer solution similar to that described by Parker (1962). The output format is shown in Figure 15. The analysis of minimum angle of attack (α_{min}) as described by Carter (1968) is also incorporated in the program. The output of the computer furnishes α_{min}, altitude, and velocity as a function of time. A plot of α_{min} vs. altitude for OM I has already been given in Figure 14. Figure 16 shows the occurrence of significant events during the flight.

7.2. AMBIENT N_2 DENSITY

The neutral molecular nitrogen density was determined from the measured gauge partial pressure as described by Spencer, et al., (1965, 1966), using the basic relationship:

$$n_a = \left(\frac{\Delta n_i u_i}{2\sqrt{\pi}\, V \cos \alpha_{min}} \right) K(S_o, \alpha)$$

where

n_a = ambient N_2 number density
Δn_i = maximum minus minimum gauge number density during one tumble, A x ΔI, where A is the sensitivity of the gauge
u_i = $\sqrt{2kT_i/m}$, most probable thermal speed of particles inside gauge
T_i = gauge wall temperature
V = vehicle velocity with respect to the earth
α_{min} = minimum angle of attack for one tumble
$K(S_o,\alpha)$ = the reciprocal of the normalized transmission probability as defined by Ballance (1967), referred to as the geometry correction factor.

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                    NASA 18.50  CM 1




LAUNCH TIME (GMT)

        YEAR  1967
         DAY   261
        HOUR    19
      MINUTE    10
      SECOND        .000

INITIAL CONDITIONS

                    TIME        60.000 SECONDS FROM LAUNCH
                ALTITUDE   323234.0    FT
                   RANGE    87023.0    FT
                VELOCITY     6322.3    FT/SEC
    FLIGHT PATH ANGLE          73.3309 DEGREES UP FROM LOCAL HORIZONTAL PLANE
                 AZIMUTH      119.6900 DEGREES EAST OF LOCAL NORTH
               LONGITUDE      -75.2200 DEGREES (+EAST)
                LATITUDE       37.7213 DEGREES (+NORTH)

NO WIND SPECIFIED

CONE CORRECTION          -.40

MOMENTUM VECTOR INPUT BY SPECIFYING PHI LS = 351.0 AND THETA LS = 142.0
COMPUTED MOMENTUM VECTOR IN EARTH FIXED COORDINATES IS    .930215   .328469  -.163730

MOMENTUM VECTOR INPUT BY SPECIFYING PHI LS = 355.0 AND THETA LS = 143.0
COMPUTED MOMENTUM VECTOR IN EARTH FIXED COORDINATES IS    .914231   .371487  -.161799



PEAK PARAMETERS

TIME      ALTITUDE F       ALPHA V*COS ALPHA        PHI V      RANGE F  VELOCITY F       VXFX         VZFX      AZIMUTH     LATITUDE
          ALTITUDE M                                           RANGE M  VELOCITY M       VYFX                 ELEVATION    LONGITUDE

 263.92       933806        38.18      410.56       57.75       431085     1713.46     1447.03       -29.37      123.097       37.227
              284624        35.57      424.81       61.20       131395      522.26     -917.13                    -.000      -74.208
```

Figure 15. Trajectory program output format.

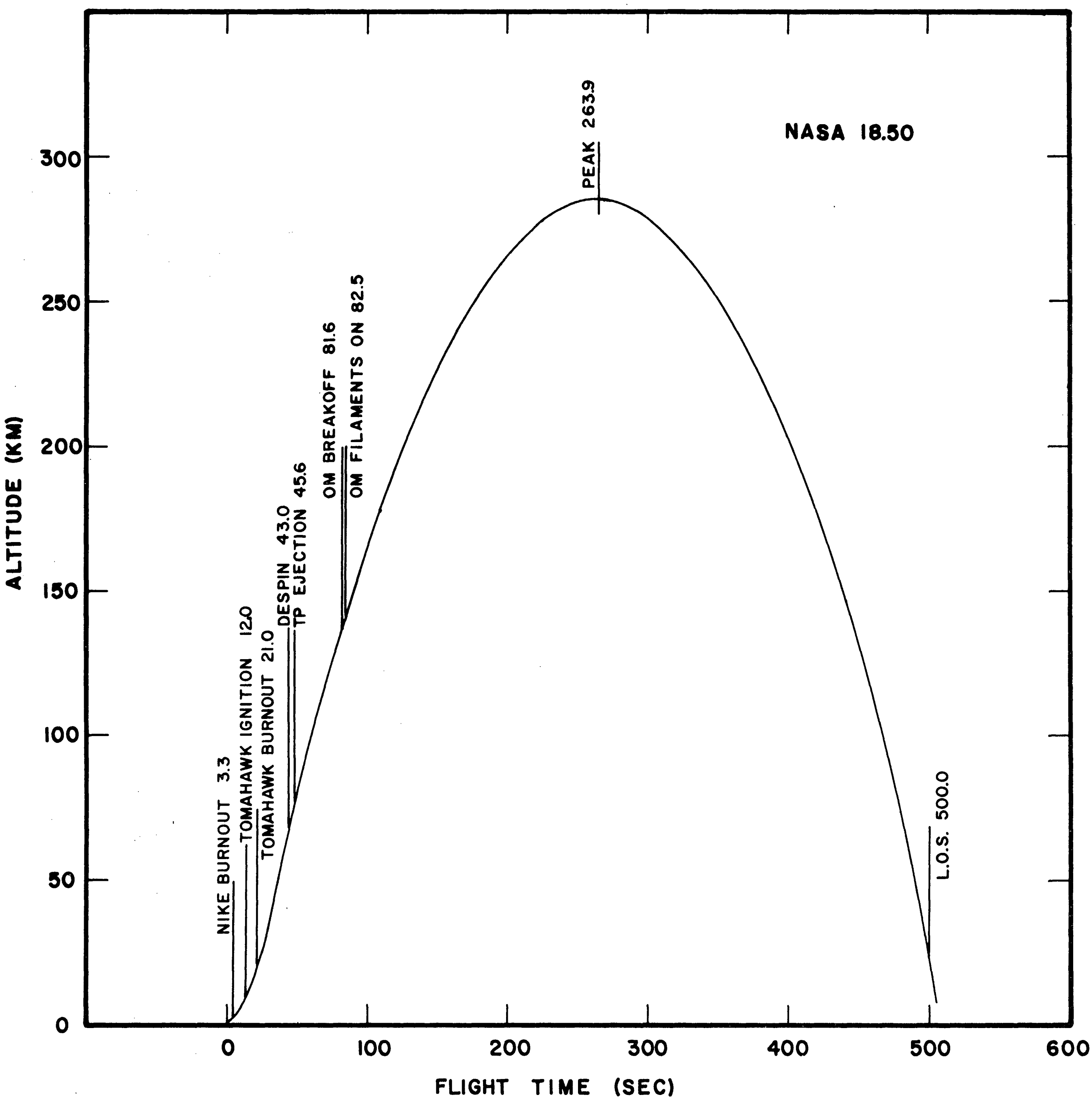

Figure 16. Sequence of events.

ΔI, the difference between the maximum (peak) omegatron gauge current and the minimum (background) gauge current vs. flight time for OM I is shown in Figure 17. The background current is the result of the outgassing of the gauge walls, and the inside density is due to atmospheric particles which have enough translational energy to overtake the payload and enter the gauge. The outgassing component is assumed constant for one tumble and affects both the peak reading and the background reading, and, therefore, does not affect the difference. From calibration data obtained by standard techniques, the inside number density, Δn_i, is computed for the measured current.

By using the measured gauge wall temperature, the most probable thermal speed of the particles inside the gauge, u_i, is computed. The uncertainty in this measurement is believed to be about ±2% absolute.

V, the vehicle velocity with respect to the earth is obtained from the trajectory curve fitting described previously and is believed to be better than ±1% absolute.

Cos α_{min} is obtained from the aspect analysis described by Carter (1968). Since the uncertainty in cos α_{min} depends upon α_{min}, for any given uncertainty in α_{min}, each particular case and altitude range must be considered separately. Figure 14 shows that the minimum angle of attack for the upleg is generally less than ten degrees, so with an assumed maximum uncertainty in α_{min} of ±5 degrees, the resulting uncertainty in cos α_{min} is less than ±2%. The data for low angle of attack were used as control data.

$K(S_o,\alpha)$, the geometry correction factor vs. altitude is shown in Figure 18. As can be seen, the maximum correction for OM I is about 12%, or $K(S_o,\alpha) = .88$ at about 140 km altitude for the upleg data. The correction factor, determined from empirical and theoretical studies, is believed known to better than 2%.

The resulting ambient N_2 number density, obtained from the measured quantities described above, is shown in Figure 19 and is tabulated in Table III. The uncertainty in the ambient density due to the combined uncertainties in the measured quantities is thought to be 10% relative and 25% absolute.

7.3. TEMPERATURE

The ambient N_2 temperature profile shown in Figure 20, tabulated in Table III, was obtained by integrating the density profile to obtain the pressure and then by relating the known density and pressure to the temperature through the ideal gas law. The assumption that the gas is in hydrostatic equilibrium and behaves as an ideal gas is implicit. Since the temperature depends only upon the shape of the density profile and not upon its magnitude, it is estimated that the uncertainty in its magnitude is ±5% absolute.

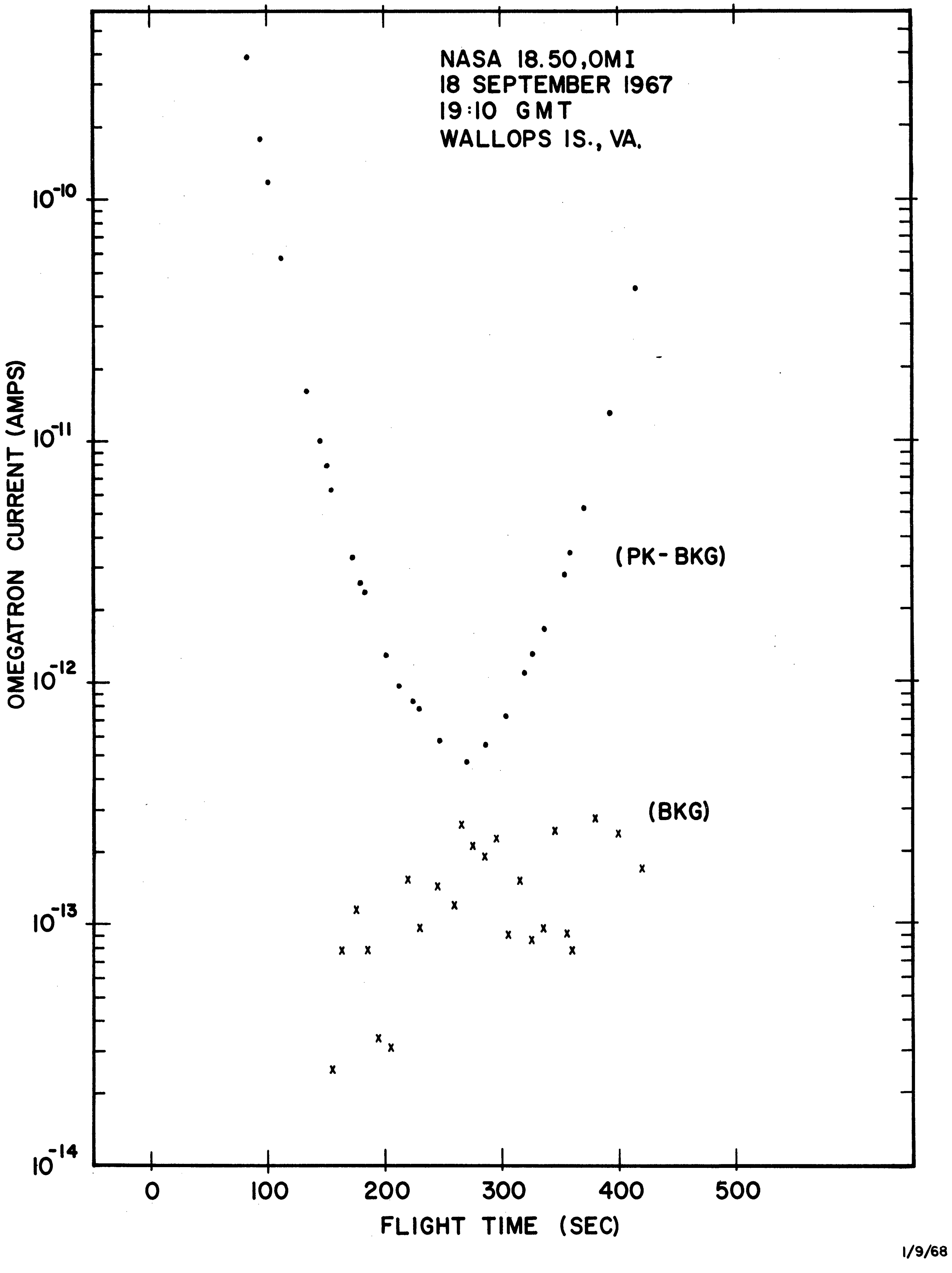

Figure 17. OM I current vs. flight time.

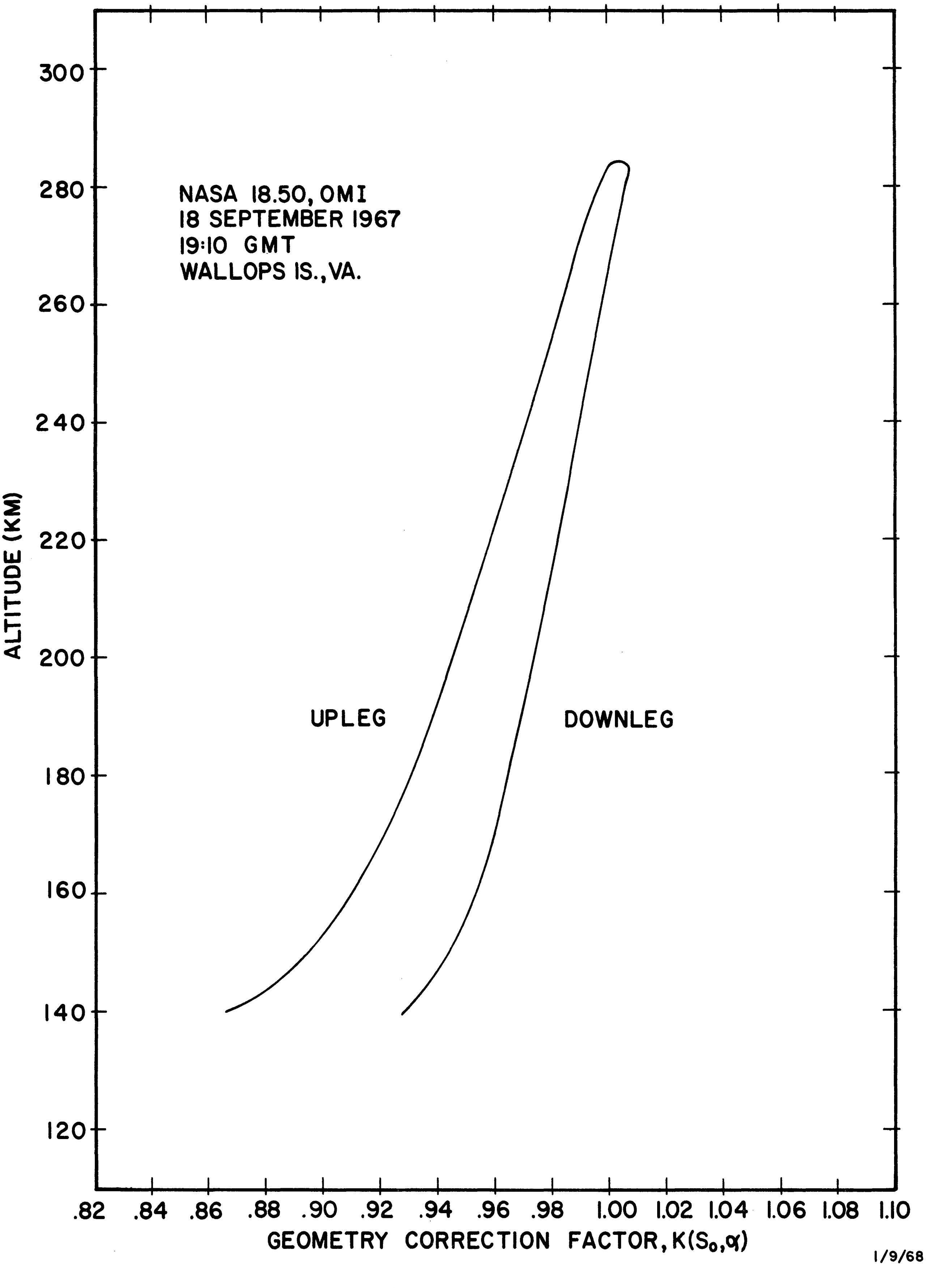

Figure 18. $K(S_o, \alpha)$ vs. altitude for OM I.

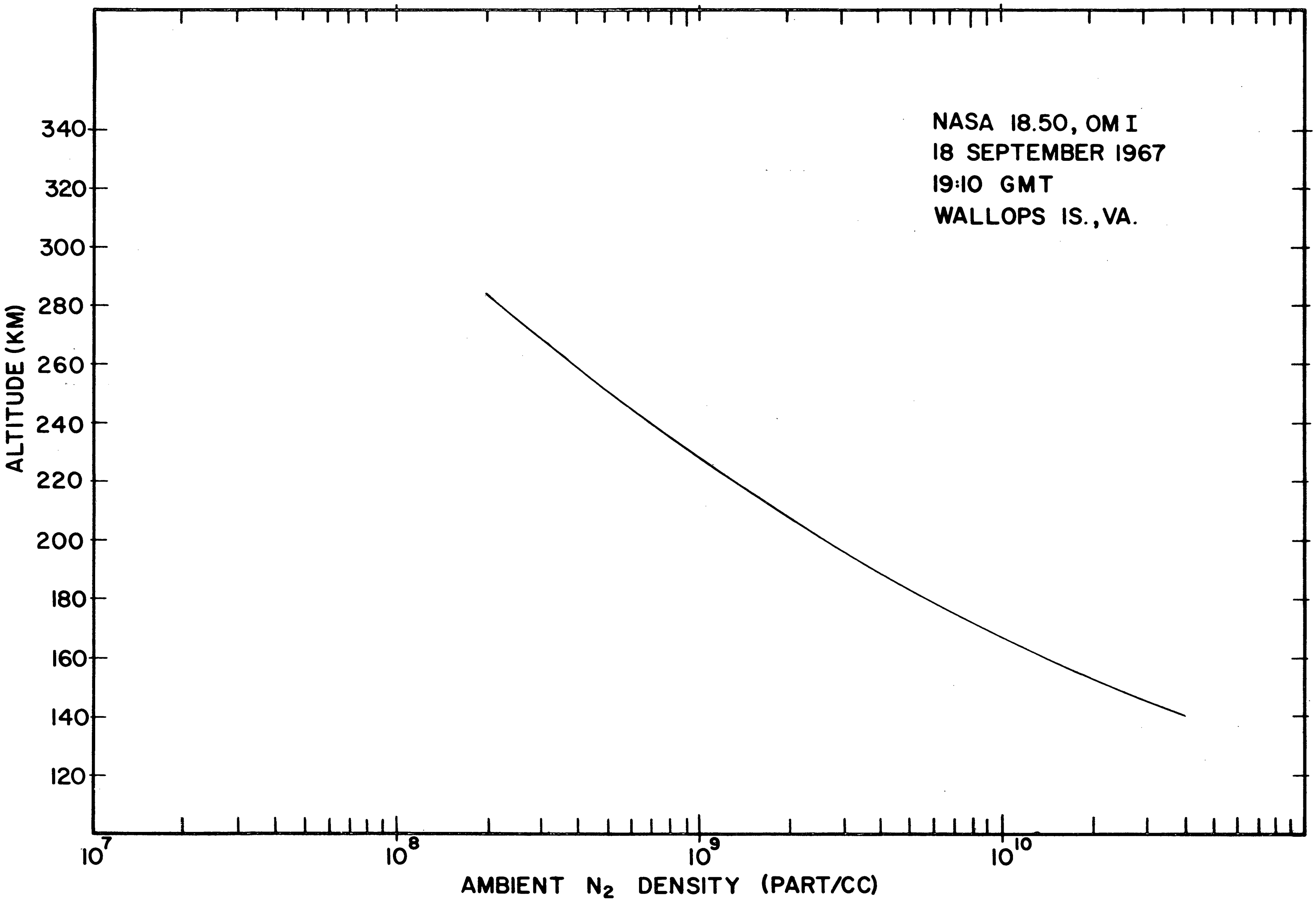

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Figure 19. Ambient N_2 density vs. altitude (OM I).

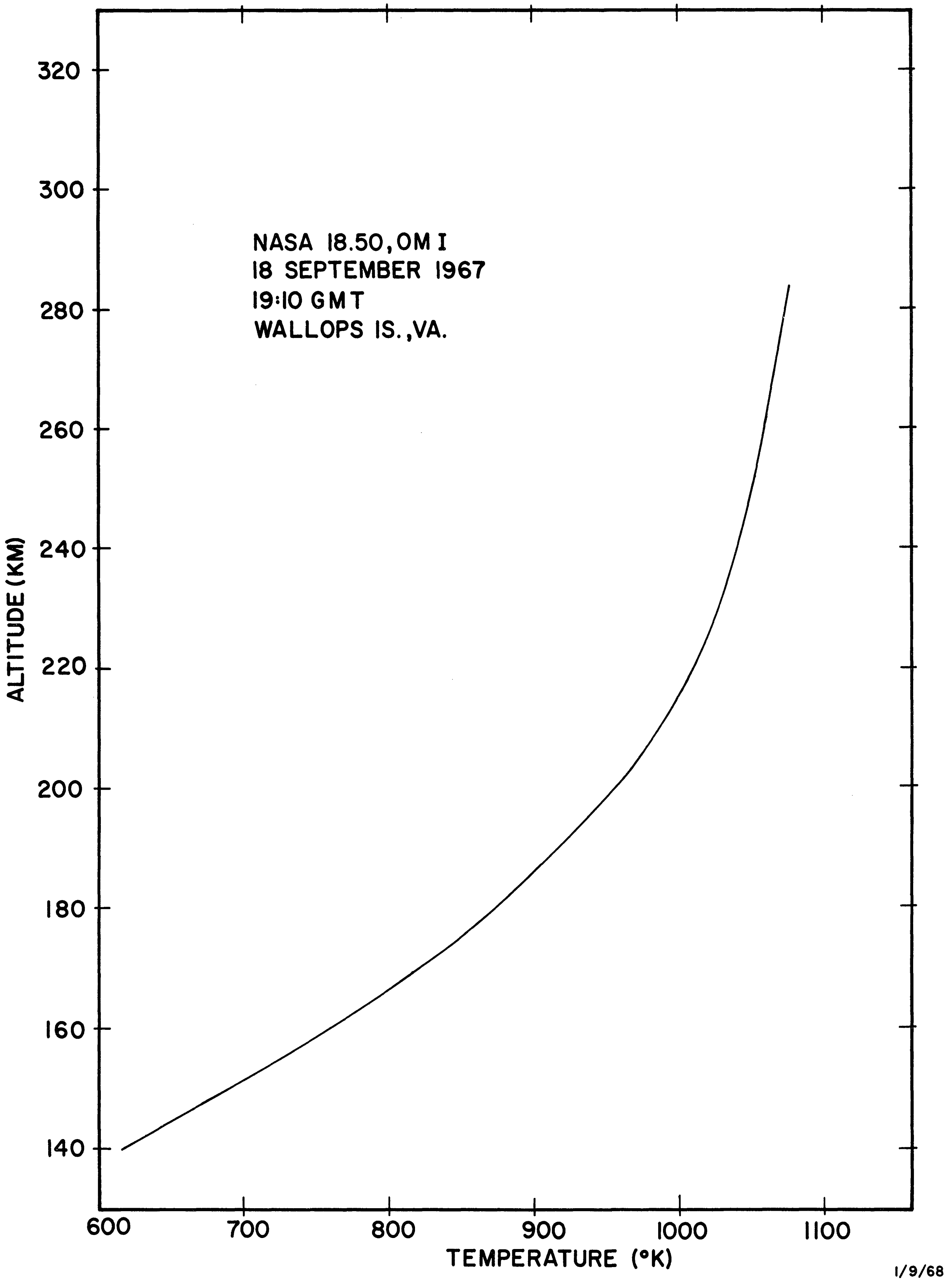

Figure 20. Neutral particle temperature vs. altitude (OM I).

TABLE III

N_2 AMBIENT DENSITY DATA

(NASA 18.50)

18 September 1967
14:10 EST
19:10 GMT
Wallops Island, Virginia

Altitude km	OM I Temperature °K	OM I Density part/cc
140	616	4.07×10^{10}
145	653	3.00
150	690	2.24
155	726	1.70
160	760	1.31
165	792	1.03×10^{10}
170	822	8.20×10^{9}
175	849	6.60
180	873	5.32
185	895	4.36
190	916	3.60
195	936	2.97
200	955	2.47
205	971	2.04
210	987	1.71
215	998	1.45
220	1010	1.23
225	1018	1.04×10^{9}
230	1027	8.95×10^{8}
235	1034	7.65
240	1039	6.57
245	1045	5.63
250	1050	4.86
255	1055	4.16
260	1059	3.60
265	1063	3.11
270	1067	2.69
275	1070	2.32
280	1074	2.00
284	1076	1.79×10^{8}

7.4. GEOPHYSICAL INDICES

The 10.7 cm solar flux ($F_{10.7}$) and the geomagnetic activity indices (a_p) for the appropriate periods are shown in Figures 21 and 22.

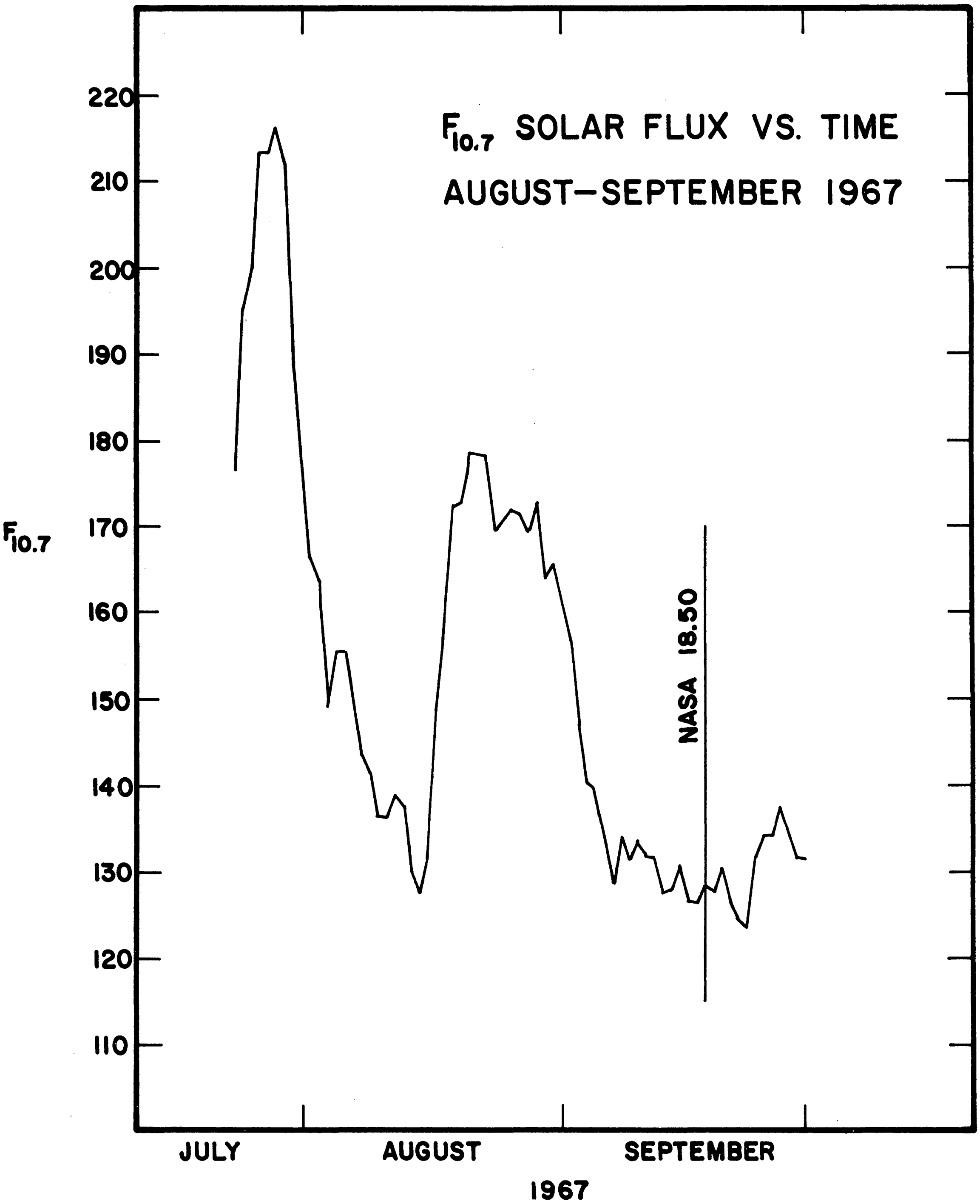

Figure 21. Solar flux at 10.7 cm wavelength.

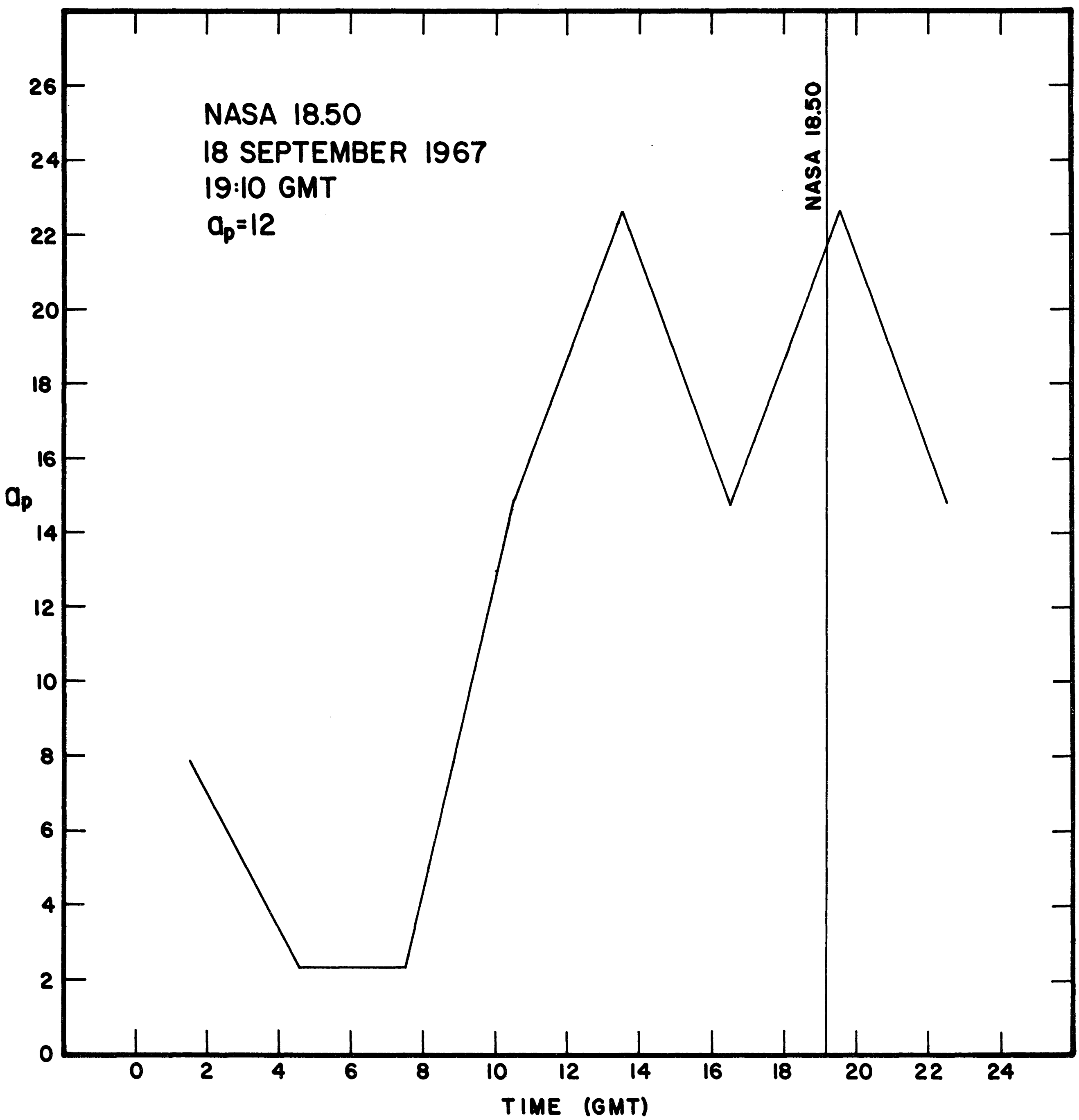

Figure 22. Three hour geomagnetic activity index (a_p).

8. REFERENCES

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APPENDIX

DETERMINATION OF THE TOTAL PAYLOAD MOMENTS OF INERTIA

Bendix Aerospace
Systems Division

SYSTEMS TEST DEPARTMENT

REPORT NO. TR- 2240
LR NO. 3099

TEST REPORT

REPORT NO. TR- 2240 **DATE** 6 Sep 67

PERFORMED FOR: The University of Michigan
2455 Hayward
Ann Arbor, Michigan

TEST: Sinusoidal - Random Vibration and Moment of Inertia Determination

ITEM: Nike - Tomahawk Payloads, Ser. Nos. 18.49 and 18.50
Thermosphere Probe, Ser. No. 18.50

TEST DATE: 6 Sep 67

PERFORMED AT: Bendix Aerospace Systems Division

WORK ORDER NO: 86661-441-01-3099

AUTHORIZATION: P.O. R-79473

REQUESTED BY: J. Maurer

REPORT SENT TO: J. Maurer

PERFORMED BY: Lyle M. Skjei
L. M. Skjei, Section Engineer

APPROVED BY: R. H. Culpepper
R. H. Culpepper, Project Engineer

jk

REFERENCE

(a) Nike-Tomahawk Vibration Test Specification, dated 22 Apr 66, Rev. 6 Dec 66 (copy attached as Appendix A).

INTRODUCTION

Two Nike-Tomahawk Payloads, Ser. Nos. 18. 49 and 18. 50, were vibrated along each of three orthogonal axes according to Reference (a), except as described in Table 1. The purpose of the tests was to determine if the test items could withstand the vibration environment specified.

The mass moments of inertia of the Thermosphere Probe 18. 50 were determined experimentally on the trifilar test stand. The purpose of the tests was to determine the mass constants about the roll (X) and pitch (Y) axis.

SUMMARY OF RESULTS

Visual examination of the test items following the test disclosed no apparent structural degradation as a result of the applied vibration.

The University of Michigan personnel, who performed the functional check of the test item during and after vibration, reported satisfactory operation.

The moments of inertia of the Thermosphere Probe Assembly S/N 18. 50 are shown below.

	lb ft sec^2
Roll Axis (X)	0. 0906
Pitch Axis (Y)	3. 1201

METHODS AND DATA

Vibration

The test items were tested individually. Each test item was attached to a fixture provided by The University of Michigan and mounted on the vibration exciter for vibration in the Z axis and on the slip plate for vibration in the X and Y axes. The test setups are shown in Figure 1.

An accelerometer, mounted on the fixture, was used to control the vibration input to the test item. For the sine tests, the accelerometer was the detector for a constant displacement/acceleration servo system. The output of this accelerometer was measured with a true rms voltmeter and recorded on an X-Y recorder. These recordings are shown in Figures 2 through 11.
The sensitivity of the accelerometer system was checked prior to the test by subjecting the accelerometer to a sinusoidal vibration of 0.25 in. double amplitude at a frequency of 44 cps, to give an acceleration of 25 g peak. Vibration displacement was measured with an optical wedge, frequency was measured with an electronic counter, and accelerometer system output was monitored with a true rms voltmeter. Calibration dates are shown on the attached list of test equipment.

Testing of each test item was performed in accordance with the requirements as shown in Appendix A. The University of Michigan personnel functionally operated the test items during and after each axis of vibration.

For the random vibration portion of the test (Tests 3, 6, 8 and 9 of Appendix A) the vibration system was equalized to the required spectrum shape without the test item mounted. Prior to the random vibration test, with the test item mounted the spectrum equalization was touched up at approximately half level. This required from 10 to 35 seconds of vibration.

The random spectrum was checked using the ASD-40 spectral density analyzer.

Moment of Inertia Determination

The test items were mounted on the trifilar pendulum apparatus as shown in Figure 12 and the platform was allowed to oscillate through approximately 1 inch. The period of oscillation of the combined test item and platform was determined. At the conclusion of testing the period of oscillation of the platform alone was determined.

$$I_{\text{test item}} = I_{\text{combined test item and platform}} - I_{\text{platform alone}} \text{ or}$$

$$I = \frac{w_t a^2 p^2_t}{4\,\pi^2 L} - \frac{w_p a^2 p^2_p}{4\,\pi^2 L}$$

Where: w_t = Platform plus test item weight

a = 20 inches

L = Filament length, 107.88 inches

w_p = Platform weight, 21.05 lbs

p_t = Period in seconds, combined test item and platform

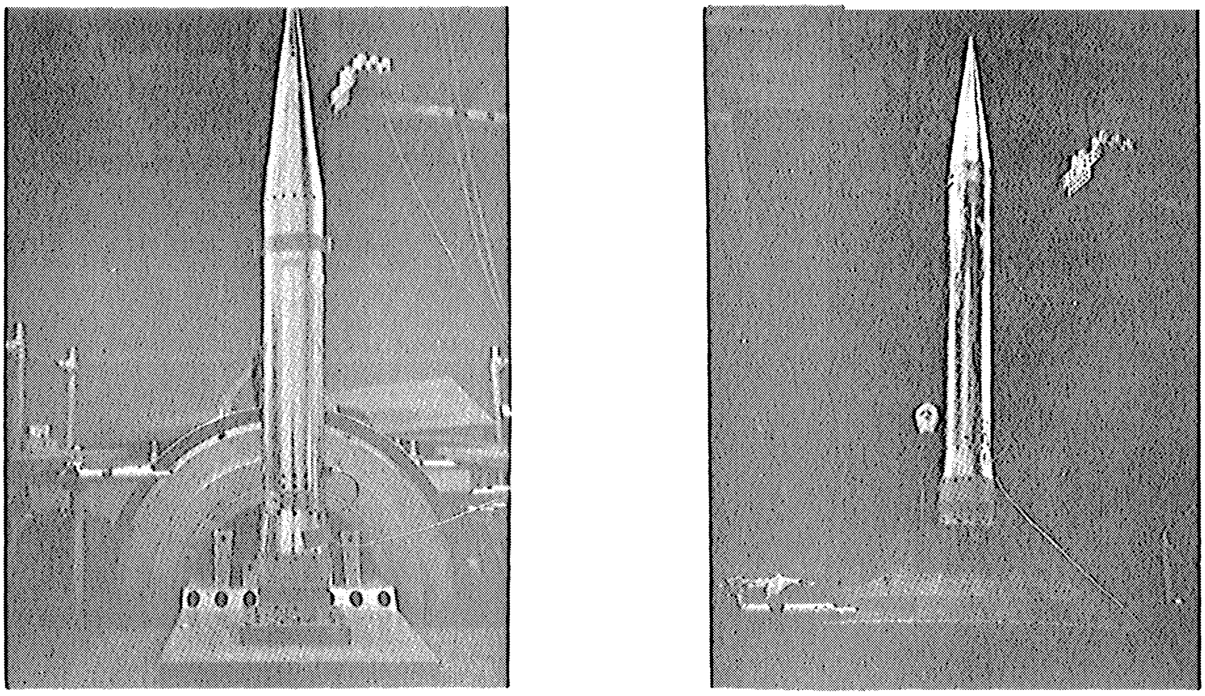
p_p = Platform period in seconds, 1.52114

I = Test item moment of inertia in lb in sec^2

Testing was witnessed by The University of Michigan personnel: J. Maurer, P. Freed, B. Halpin, D. Phillips, M. Street, J. Vidolch, D. Haseltine, R. Pate and S. Dietrick who returned test item to The University of Michigan.

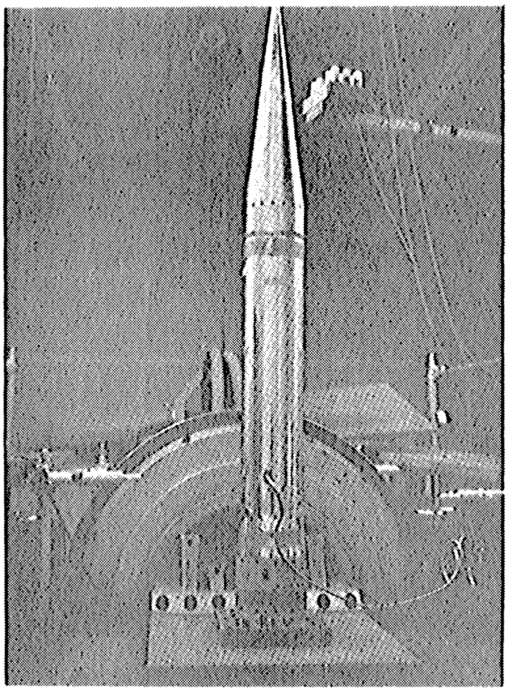
Figure 1

TEST SETUP
Sinusoidal Random Vibration



X -Axis

Y -Axis

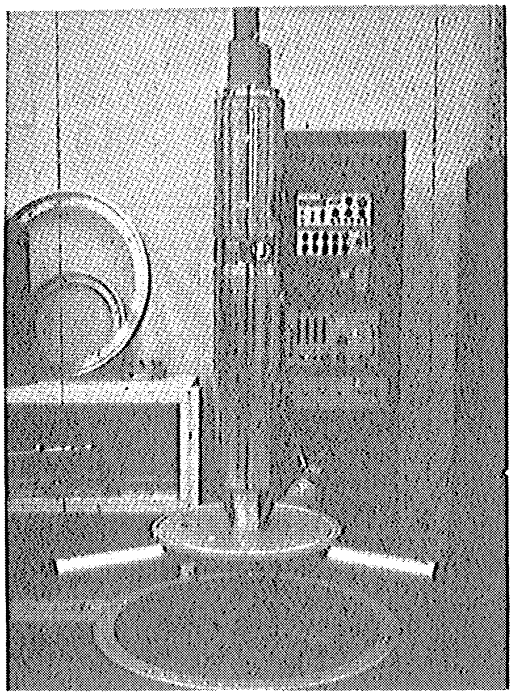


Z -Axis

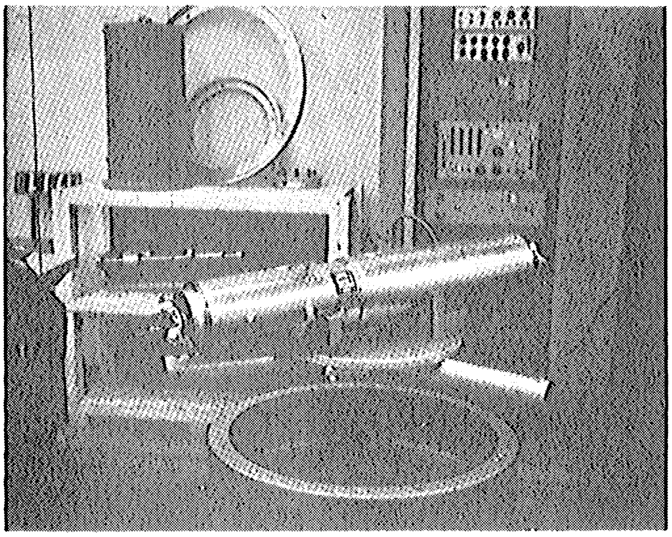
Figure 12

TEST SETUP

Moment of Inertia Determination



Spin Axis (X)



Pitch Axis (Y)

SYSTEMS TEST DEPARTMENT

TEST EQUIPMENT

Test: S-R Vibration and Moment of Inertia Date Used: 6 Sep 67
Test Item: Nike-Tomahawk Payloads 18.49 and 18.50, Thermosphere Probe 18.50

Item Manufacturer	Model No. Serial No.	BxS No. Accuracy	Scale Range Quantity Measured	Calibration Date	
				Last	Next
Vibration System Ling	PP/175-240 249 13 30			N/A	N/A
True RMS Voltmeter Bruel and Kjaer	2409 72900	11237 2%	0-300 mv g	3/21 67	9/21 67
Oscillator Bruel and Kjaer	1018 70666	50567	5-2000 Hz	6/6 67	12/6 67
Logarithmic Converter F. L. Moseley	60B 840	11220	10 db/in	8/14 67	11/14 67
X Y Recorder F. L. Moseley	2D 110	10010 2%	1 mv/in g	7/15 67	10/15 67
Filter Analyzer Ling	ASD 40 60	50417 2%	0-1 $1g^2/cps$	4/10 67	10/10 67
Accelerometer Endevco	2221C FC 87			6/29 67	12/29 67
Slip Sync Chadwick Helmuth	103 AR 1350	9215		5/11 67	11/11 67
Trifilar Stand BSD	BSD 13239B			5/8 67	11/8 67