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

SOUNDING ROCKET FLIGHT REPORT

NASA 6.11 Thermosphere Probe Experiment

Prepared on behalf of the project by

D. R. Taeusch and G. R. Carignan

ORA Project 07065

under contract with:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
CONTRACT NO. NAS 5-9113
GREENBELT, MARYLAND

administered through:

OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

July 1966

TABLE OF CONTENTS

Page

LIST OF FIGURES v

PROJECT PERSONNEL vii

1. INTRODUCTION 1

2. GENERAL FLIGHT INFORMATION 2

3. LAUNCH VEHICLE 4

4. NOSE CONE 9

5. THE THERMOSPHERE PROBE (TP) 11

    5.1 Omegatron 11
    5.2 Electrostatic Probe (ESP) 25
    5.3 Support Measurements and Instrumentation 25
        5.3.1 Sun-earth aspect determination system 25
        5.3.2 Telemetry 26
        5.3.3 Housekeeping monitors 26

6. ENGINEERING RESULTS 28

7. DATA ANALYSIS 29

    7.1 Trajectory 29
    7.2 Ambient N_2 Density 29
    7.3 Temperature 33

8. REFERENCES 40

LIST OF FIGURES

Figure		Page
1.	Aerobee 300A with thermosphere probe payload.	5
2.	JATO Bottle—Aerobee combination.	6
3.	Aerobee-Sparrow combination.	7
4.	Sparrow-payload on shake table.	8
5.	Schematic of thermosphere probe payload.	10
6.	Payload diagram.	12
7.	Block diagram.	13
8.	Thermosphere probe in nose cone.	14
9.	Expanded view of omegatron system.	15
10.	Breakoff configuration.	17
11.	Omegatron envelope.	19
12.	Magnet.	21
13.	Omegatron calibration.	23
14.	Trajectory program output format.	30
15.	Trajectory with timing.	31
16.	α vs. altitude.	32
17.	Peak minus background current vs. time.	34
18.	Gauge temperature vs. flight time.	35
19.	Ambient N_2 number density vs. altitude.	36
20.	Ambient N_2 temperature vs. altitude.	37

PROJECT PERSONNEL

N. W. Spencer	Principal Investigator	GSFC
G. R. Carignan	Project Director	Univ. of Mich.
D. J. Beechler	Engineer	Univ. of Mich.
C. F. Bihlmeyer, Jr.	Draftsman	Univ. of Mich.
L. H. Brace	Charged Particle Scientist	GSFC
W. A. Brence	Wallops Island Project Engineer	Wallops Island
J. W. Cameron	Telemetry Engineer	GSFC
B. J. Campbell	Design Draftsman	Univ. of Mich.
E. L. Degener	Technician	Univ. of Mich.
P. L. Freed	Chief Technician	Univ. of Mich.
G. K. Grim	Engineer	Univ. of Mich.
D. N. Harpold	Calibration Physicist	GSFC
W. G. Kartlick	Omegatron Instrument Maker	Univ. of Mich.
B. C. Kennedy	Omegatron Engineer	Univ. of Mich.
G. E. Kraft	Vehicle Manager	GSFC
T. B. Lee	Electrostatic Probe Engineer	Univ. of Mich.
J. C. Maurer	Payload Engineer	Univ. of Mich.
D. L. McCormick	Machinist	Univ. of Mich.
H. B. Niemann	Neutral Particle Scientist	Univ. of Mich.
D. T. Pelz	Calibration Physicist	GSFC
G. T. Poole	Programmer	Univ. of Mich.
G. F. Rupert	Telemetry Engineer	Univ. of Mich.
R. W. Simmons	Data Reduction Manager	Univ. of Mich.
M. D. Street	Technician	Univ. of Mich.
D. R. Taeusch	Neutral Particle Scientist	Univ. of Mich.
G. S. Woodson	Programmer	Univ. of Mich.

I. INTRODUCTION

This report describes and discusses the results of the launching of NASA 6.11, an Aerobee 300 sounding rocket. The payload was the Thermosphere Probe (TP), described by Spencer, Brace, Carignan, Taeusch and Niemann (1965). The TP is an instrumented ejectable package developed by this laboratory in cooperation with the Goddard Space Flight Center, Laboratory for Atmospheric and Biological Sciences (GSFC) for the purpose of studying the variability of the earth's atmospheric parameters in the altitude region between 120 and 350 km. The NASA 6.11 payload included an omegatron mass analyzer (Niemann and Kennedy, 1966), an electron temperature probe (Spencer, Brace and Carignan, 1962), and a lunar aspect sensor. This complement of instruments permitted the determination of molecular nitrogen density and temperature, and electron density and temperature in the altitude range of approximately 140 to 280 km.

General description of the payload kinematics, orientation analysis, and data reduction techniques are given by Taeusch, Carignan, Niemann, and Nagy (1965). The orientation analysis and nitrogen data reduction were performed at this laboratory and the results are included in this report with a discussion of problem areas and probable errors. The electron temperature probe data were reduced at GSFC and are not discussed in this report.

The payload described in this report was launched 12 hours after a similar one (NASA 18.01) described in a separate report. The purpose of this dual launching was to establish the diurnal variation of the parameters measured to provide extra meaning to their use in studying the effect of the energy input to the atmosphere.

2. GENERAL FLIGHT INFORMATION

The general flight information for NASA 6.11 is tabulated below. The geophysical indices, the 10.7 cm solar radio flux, $F_{10.7}$; the five monthly averages of the solar 10.7 cm flux preceding the launch, $\overline{F}_{10.7}$; and the geomagnetic index, a_p, were obtained from the April, 1965, and May, 1965, issues of "Solar Geophysical Data" published by the U. S. Bureau of Standards. $F_{10.7}$ is given for the day preceding the launch and a_p is given for six hours previous to launch for convenient reference to the Harris and Priester (1964) model atmoshpere.

The Table of Events gives flight times and altitudes of significant events occurring during the flight. Some of these were estimated and are so marked. The others were obtained from the telemetry records and radar trajectory, where applicable.

Launch Date:	March 20, 1965
Launch Time:	0042 EST; 05:42 GMT
Location:	Wallops Island, Virginia Longitude: 75.04°W Latitude: 37.54°N
Apogee Parameters:	
Altitude:	326.9 km
Horizontal Velocity:	578 m/sec
Flight Time:	311.1 sec

Geophysical Indices:

$F_{10.7} = 77.0$

$\overline{F}_{10.7} = 75.3$

$a_p = 0$

TP Motion:

Tumble Period = 2.630 sec/tumble

Roll Period = 1.406 sec/roll

TABLE OF EVENTS

Event	Flight Time (sec)	Altitude (km)	Remarks
Lift Off	0	0	
Aerobee Burn Out	53.9	34.4	(5,172 ft/sec)
Sparrow Ignition	54.6	35.4	
Sparrow Burn Out	57.6	41.4	(8,484 ft/sec)
TP Ejection	70.2	70.1	
Omegatron Breakoff	100.0(est)	130.0(est)	
Omegatron Filaments On-to Mass 28	101.6	133.4	
Omegatron to Mass 32	155.00	220.0	
Omegatron to Mass 28	195.20	268.1	
Peak Altitude	311.1	326.9	
L.O.S.	575.0	30.0(est)	

3. LAUNCH VEHICLE

The NASA 6.11 launch vehicle was an Aerobee 300, a three-stage JATO bottle-Aerobee-Sparrow combination. The JATO bottle weighed approximately 600 lb unburned, has a thrust of about 18,600 lb and burns for approximately 2.5 seconds. The Aerobee is a liquid propellent rocket weighing approximately 1350 lb unburned, has a thrust of 4,100 lb and burns for about 52 seconds. The Sparrow weighed 129 lb unburned and has a thrust of about 5500 lb for about 3 seconds. The total vehicle, including booster and payload, weighed about 2188 lb at lift off. The dimensions of the total vehicle and its components are shown in Figure 1. Photographs of the JATO bottle, Aerobee-Sparrow, and the Sparrow-payload combinations are shown in Figures 2, 3, and 4.

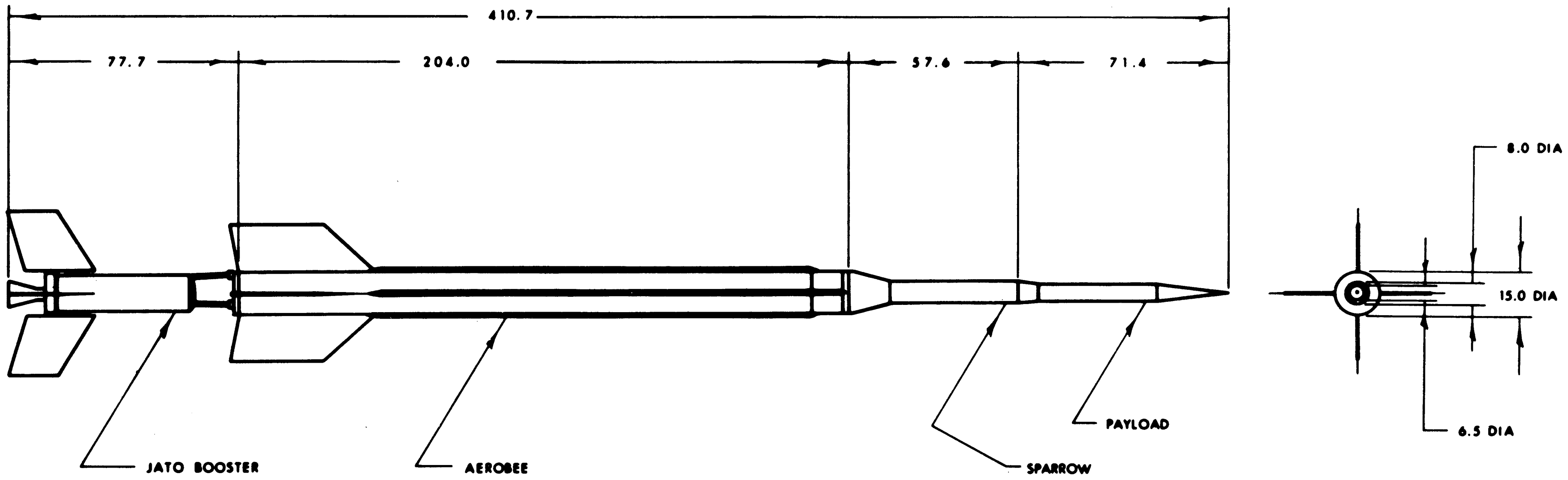
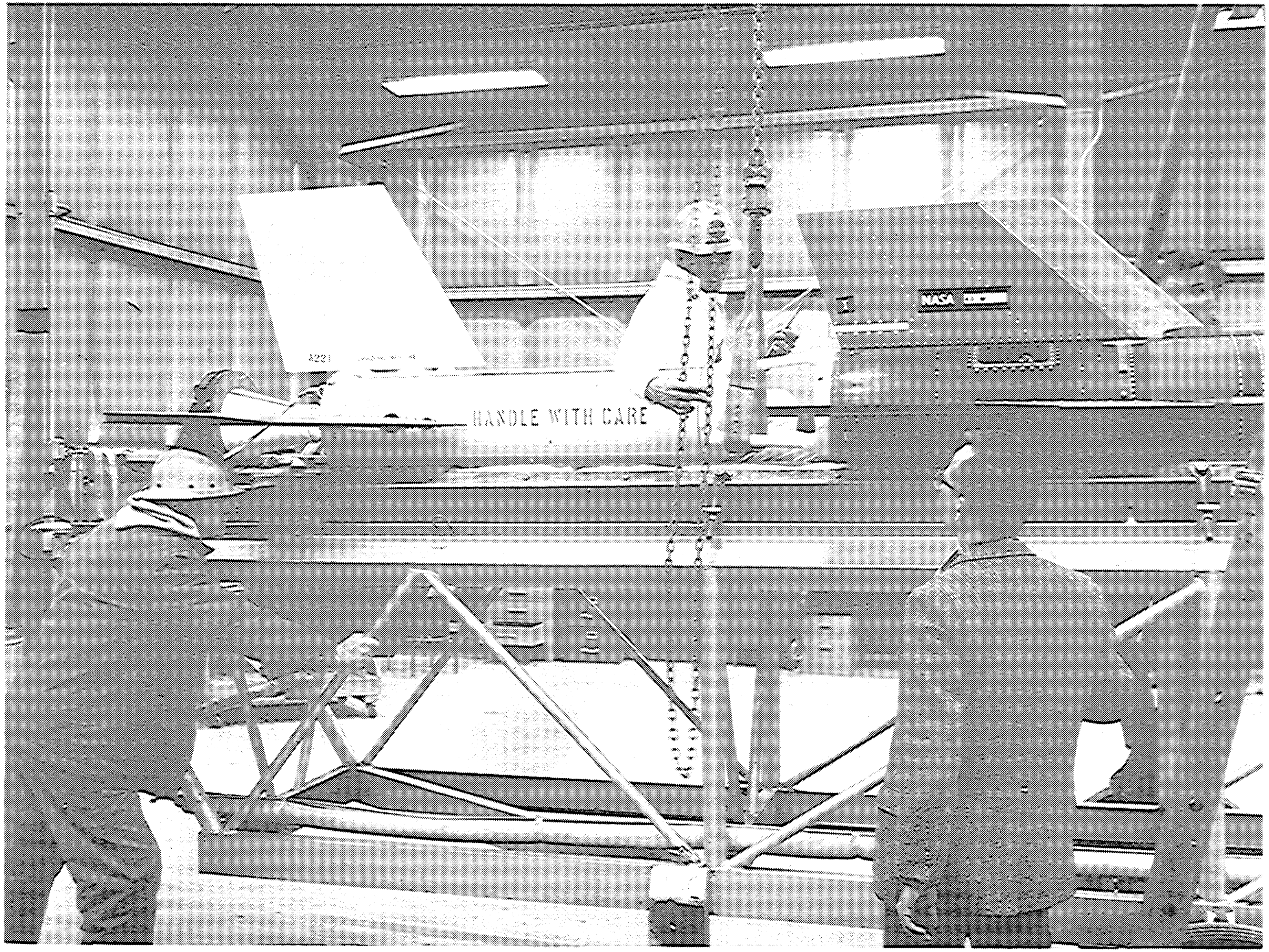
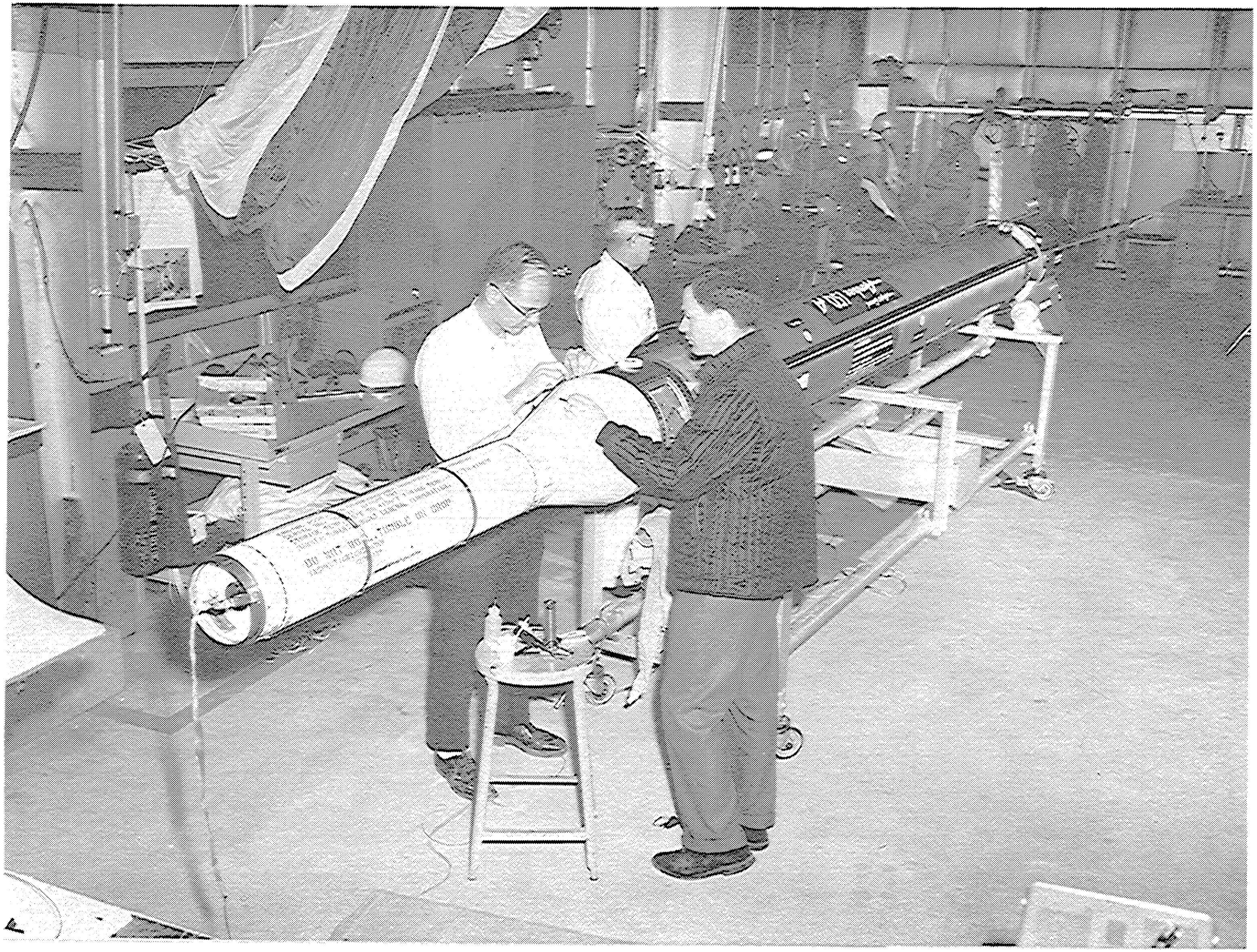


Figure 1. Aerobee 300A with thermosphere probe payload.



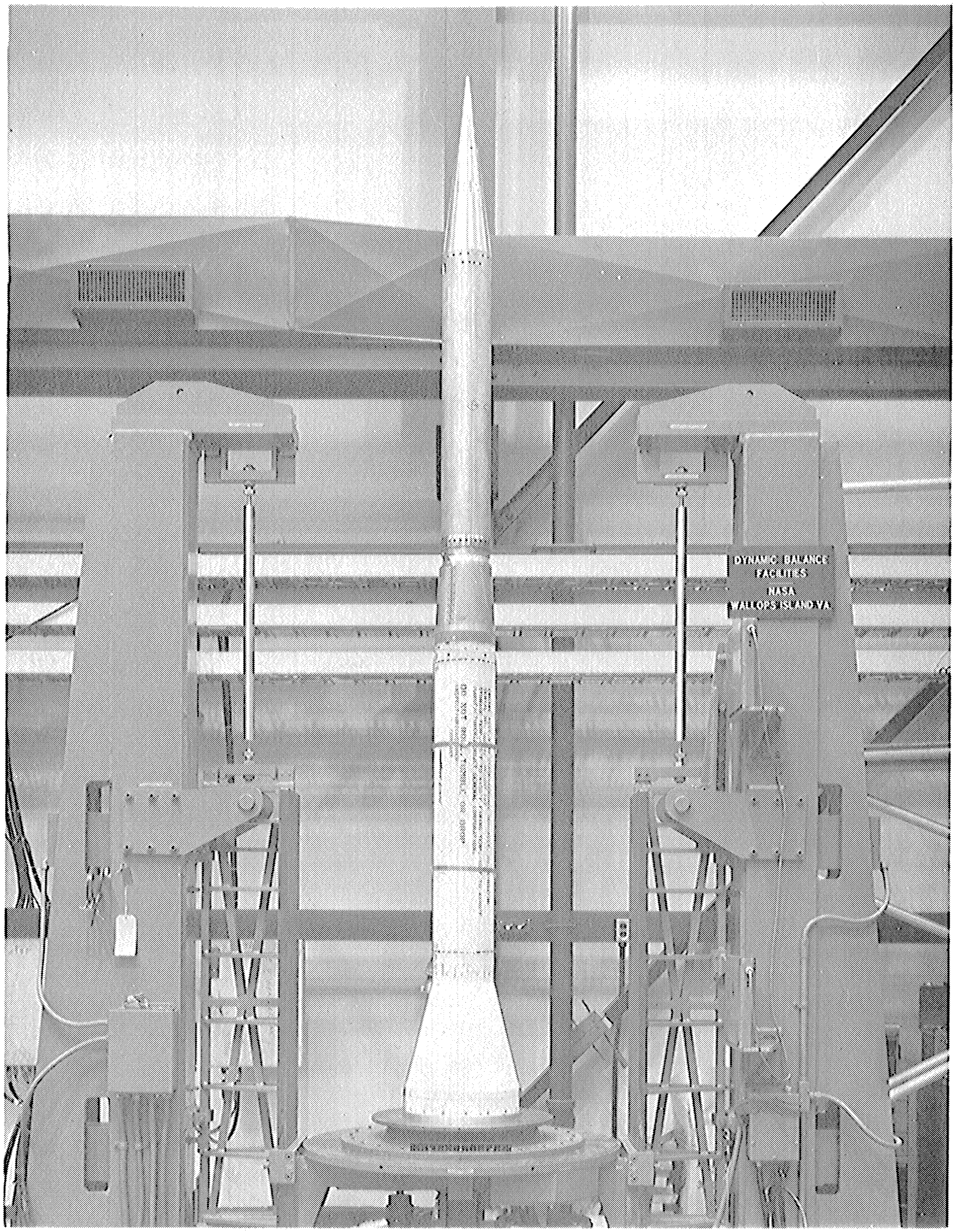
NASA W-65-262

Figure 2. JATO Bottle—Aerobee combination.



NASA W-65-261

Figure 3. Aerobee-Sparrow combination.



NASA W-65-158

Figure 4. Sparrow-payload on shake table.

4. NOSE CONE

A schematic of the total payload which includes the nose cone and adapter section is shown in Figure 5. Section A contains the batteries, timer, and pyrotechnics for the opening of the nose cone. Section B contains the plunger and the volume which holds the TP (E). Section C houses the ejection spring, plunger piston, and the lanyard negator motor. Dimensions and weights of the system are given on the schematic.

The nose cone is programmed to open at about 70 km altitude and the TP is ejected and tumbled. The breakoff device is removed at about 110 km and the omegatron turned on a few seconds later. The timing for this particular payload was described previously.

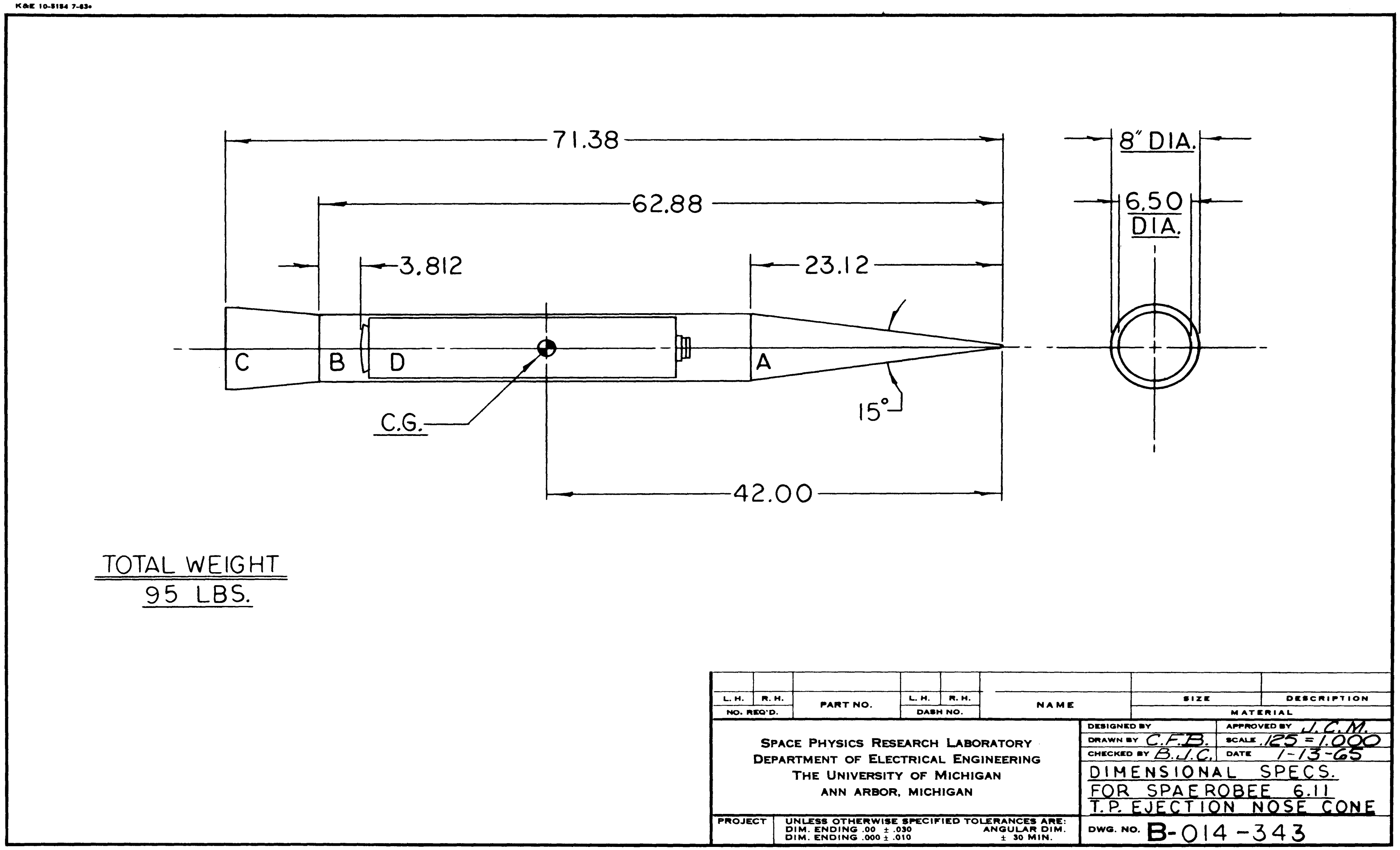


Figure 5. Schematic of thermosphere probe paylaod.

5. THE THERMOSPHERE PROBE (TP)

The TP used for the NASA 6.11 payload was a cylinder 32-7/64 in. long and 6 in. in diameter weighing 43 lb. The prime instruments for this payload were an omegatron mass analyzer (Niemann and Kennedy, 1966), and an electron temperature probe, (Brace, et al., 1963). Supporting instrumentation included a lunar aspect sensor for the determination of the TP aspect. The diagram shown in Figure 6 shows the instrumentation and supporting electronics location; and Figure 7 shows the block diagram. Figure 8 is a picture of the completely assembled TP.

5.1 OMEGATRON

The omegatron used in this payload was of the type described by Niemann and Kennedy (1966). An expanded view of the system is shown in Figure 9. Table I lists the operating parameters of the gauge and associated electronics. The characteristics of the linear electrometer amplifier current detector, used to monitor the omegatron output current, are also listed.

This omegatron was the second flight model to utilize a ceramic breakoff device which allowed vacuum sealing of the gauge. The breakoff configuration is shown in Figure 10. A new omegatron envelope was designed for this breakoff device and is shown in Figure 11. The magnet used for this system is shown in Figure 12.

The calibration of this gauge, and that one used in NASA 18.01, was performed in February, 1965, at GSFC. The system used was an oil diffusion pump calibration system under the supervision of Mr. Carl Reber of GSFC. Other gauges used for reference were (1) a double focusing 180° magnetic deflection spectrometer, (2) a Westinghouse Bayard-Alpert (BA) gauge, (3) two Veeco BA gauges, calibrated by Ball Brothers, and (4) an AW5966 BA gauge. The two Veeco gauges were used as the standard for this calibration. They had been calibrated against a McLeod gauge to a stated absolute certainty of better than ± 25%. As stated Previously, the NASA 18.01 omegatron was calibrated on this system at the same time; therefore, the relative accuracy between the two omegatrons is believed better than ± 10%. A final relative calibration was performed at SPRL on February 26, 1965, at which time the NASA 18.01 omegatron was refocused. The NASA 6.11 calibration was used as the standard after the refocusing and a new sensitivity was determined for the NASA 18.01 gauge. The final calibration is shown in Figure 13.

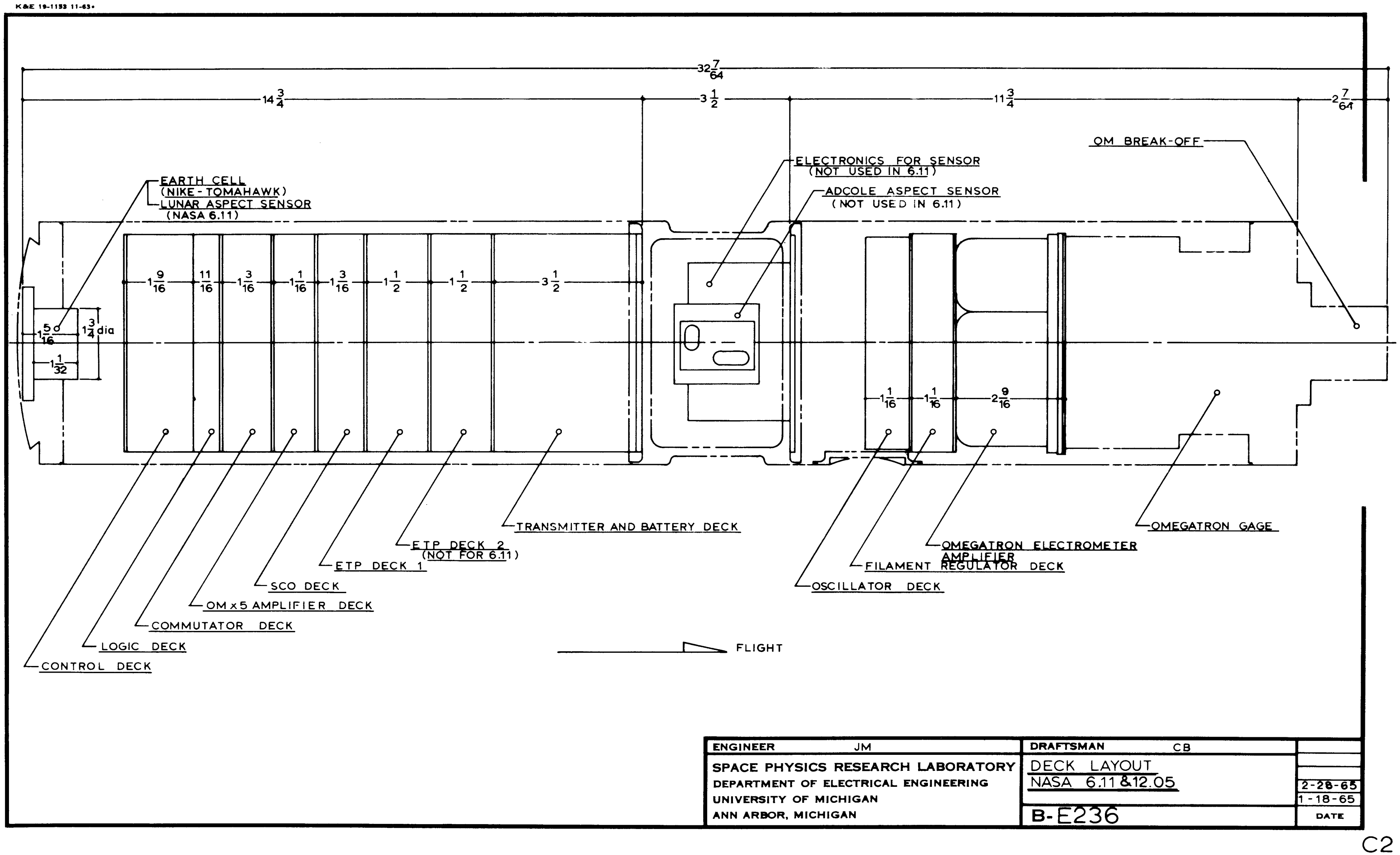


Figure 6. Payload diagram.

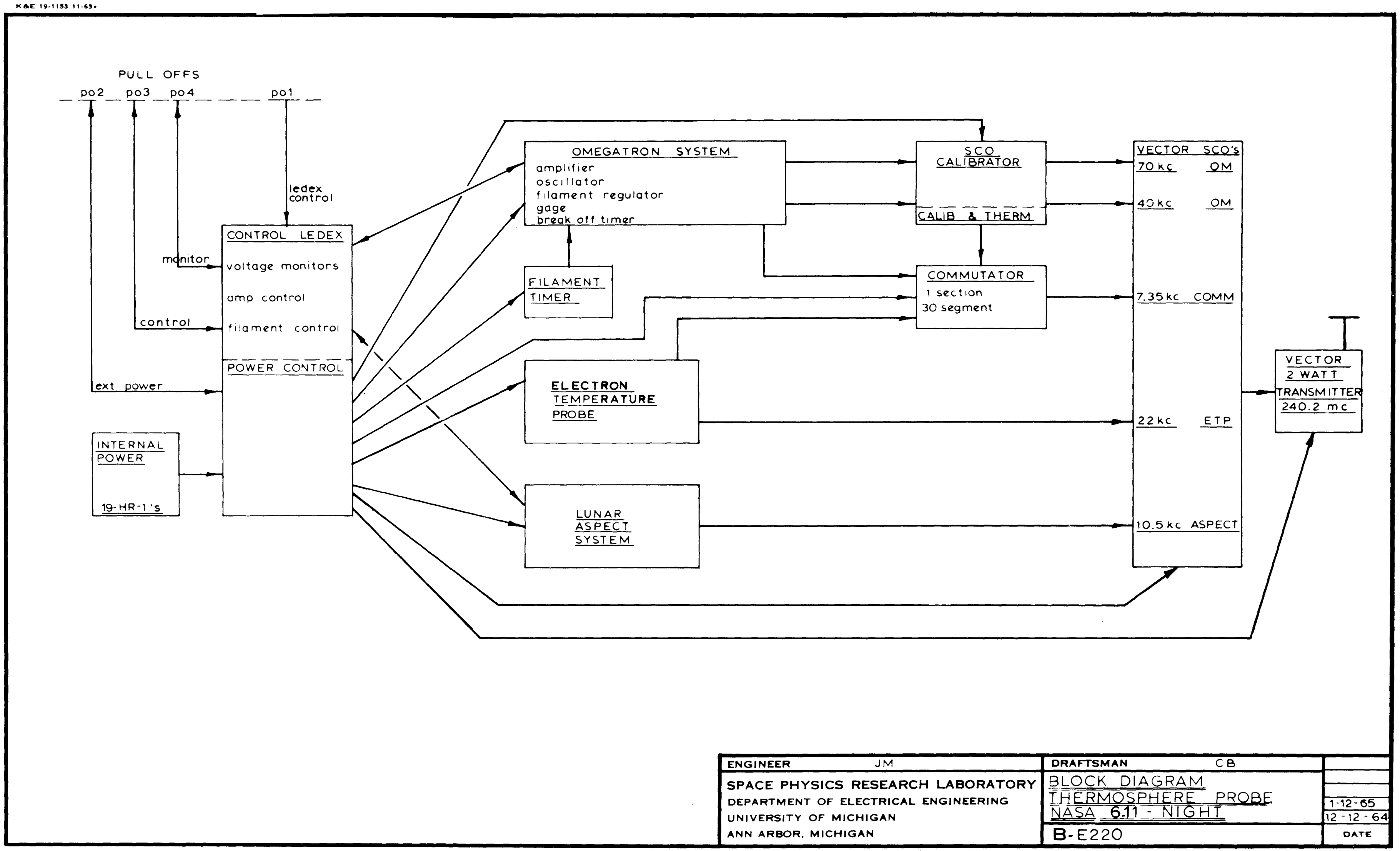


Figure 7. Block diagram.

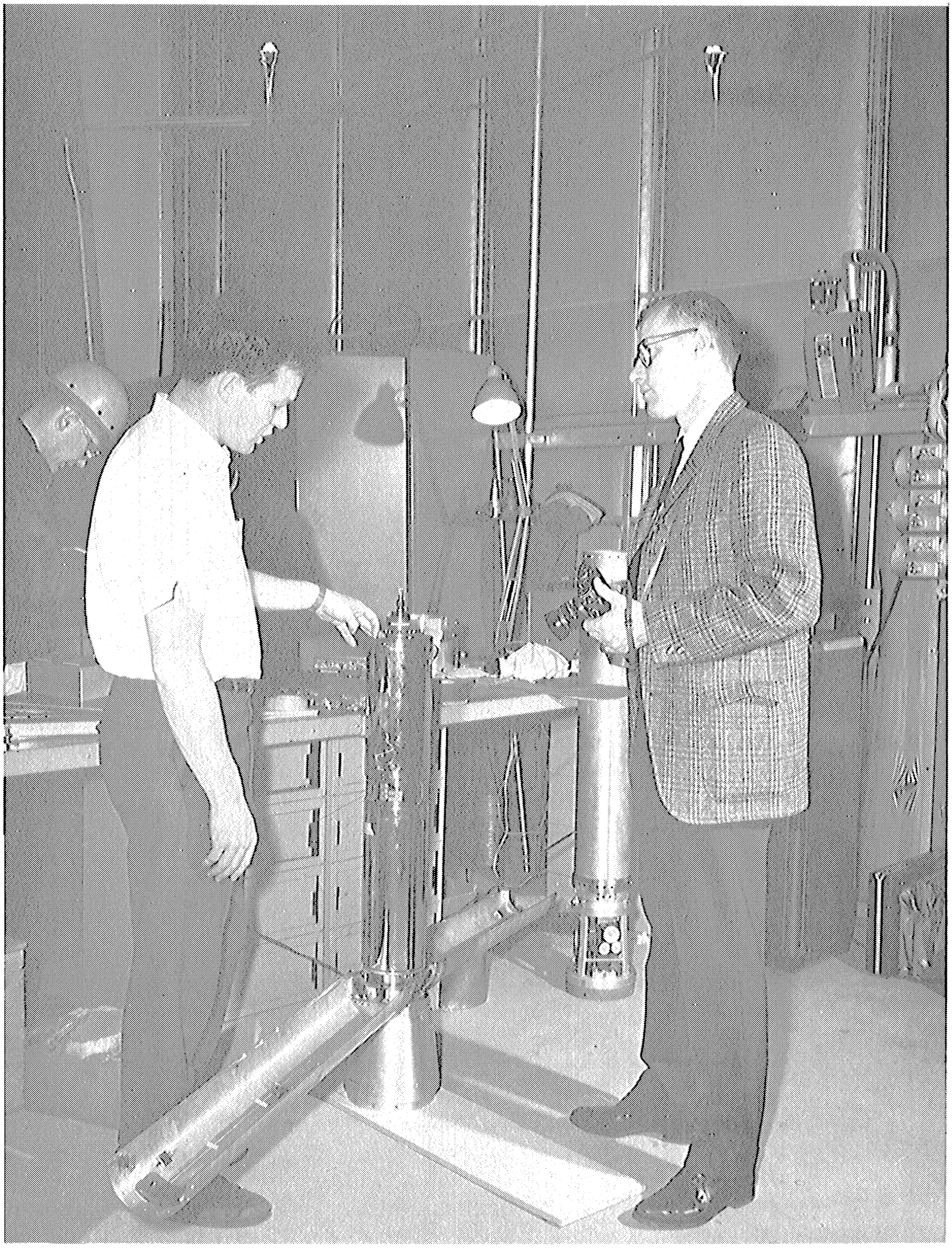


Figure 8. Thermosphere probe in nose cone.

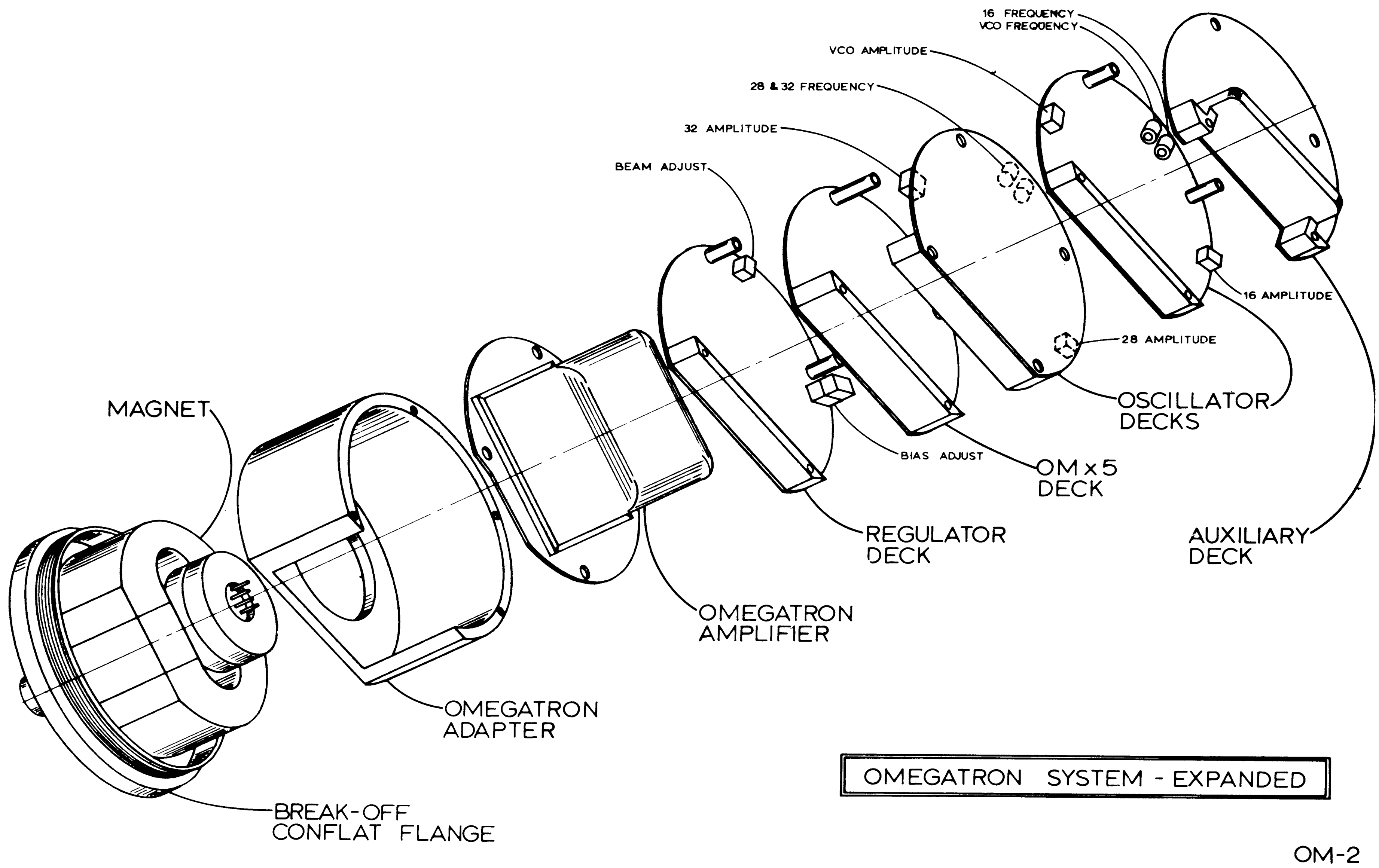
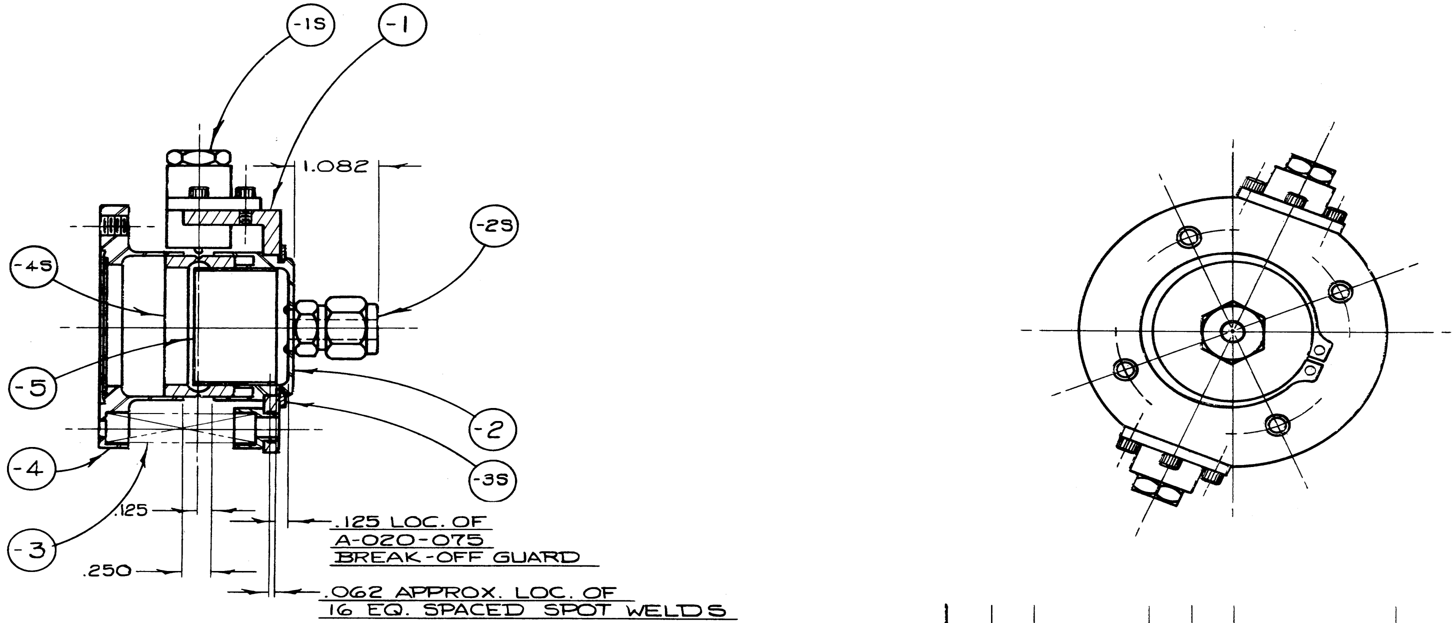


Figure 9. Expanded view of omegatron system.



OPERATION PROCEDURE

1. MACHINE C-020-074 - BREAK-OFF BASE WITHOUT CONFLAT GROOVE.
2. MACHINE C-020-077 - BREAK-OFF HAT & HELI-ARC WELD MODIFIED CRAWFORD SWAGELOK #600-1-4W-316 TO HAT. LEAK CHECK HELI-ARC WELD - MUST BE VACUUM TIGHT.
3. SEND DETAILS C-020-074 & C-020-077 TO COORS PORCELIN CO. TO BRAZE COORS' BREAK-OFF CERAMIC SEAL RING TO DETAILS C-020-074 & C-020-077.
4. SPOT WELD A-020-075 - BREAK-OFF GUARD TO C-020-077 - BREAK-OFF HAT AT U. OF M. AFTER BRAZING OF CERAMIC SEAL.
5. LEAK CHECK COMPLETE UNIT.
6. FINAL MACHINING OF CONFLAT GROOVE ON C-020-074 - BREAK-OFF BASE.

NO. REQ'D. L.H.	NO. REQ'D. R.H.	PART NO.	DASH NO. L.H.	DASH NO. R.H.	NAME	MATERIAL SIZE	MATERIAL DESCRIPTION
1			-4S		BREAK-OFF CERAMIC		COORS PORCELIN CO.
1		WALDES KOHINOOR #5102-168	-3S		RETAINING RING		TRUARC
1		#600-1-4W-316	-2S		CRAWFORD FITTING CO.		SWAGELOK (MOD.)
2		CONAX CORP. #1617-031-01	-1S		LINEAR ACTUATOR		
1		A-020-075	-5		BREAK-OFF GUARD		
1		C-020-074	-4		BREAK-OFF BASE		
4		A-020-079	-3		OMEGATRON BREAK-OFF		SPRING
1		C-020-077	-2		BREAK-OFF HAT		
1		C-020-078	-1		BREAK-OFF ACTUATOR ASS'Y.		

SPACE PHYSICS RESEARCH LABORATORY
DEPARTMENT OF ELECTRICAL ENGINEERING
THE UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

DESIGNED BY	APPROVED BY
DRAWN BY [illegible] MEYER	SCALE FULL
CHECKED BY	DATE 8-18-65

BREAK-OFF PROCEDURE ASS'Y.
OMEGATRON T.P. MOD. II

PROJECT

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:
DIM. ENDING .00 ± .030
DIM. ENDING .000 ± .010
ANGULAR DIM. ± 30 MIN.

DWG. NO. C-020-073

Figure 10. Breakoff configuration.

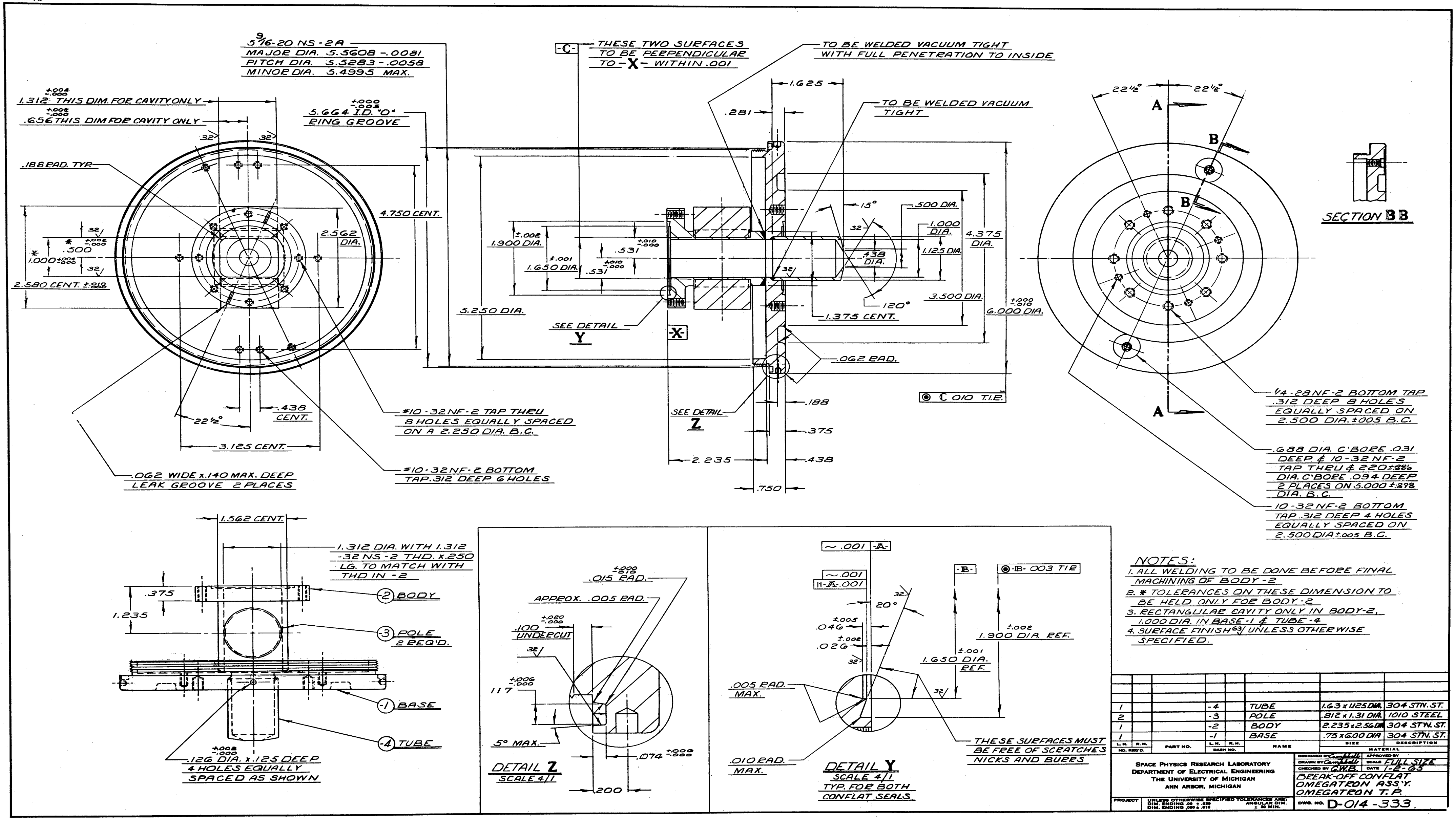


Figure 11. Omegatron envelope.

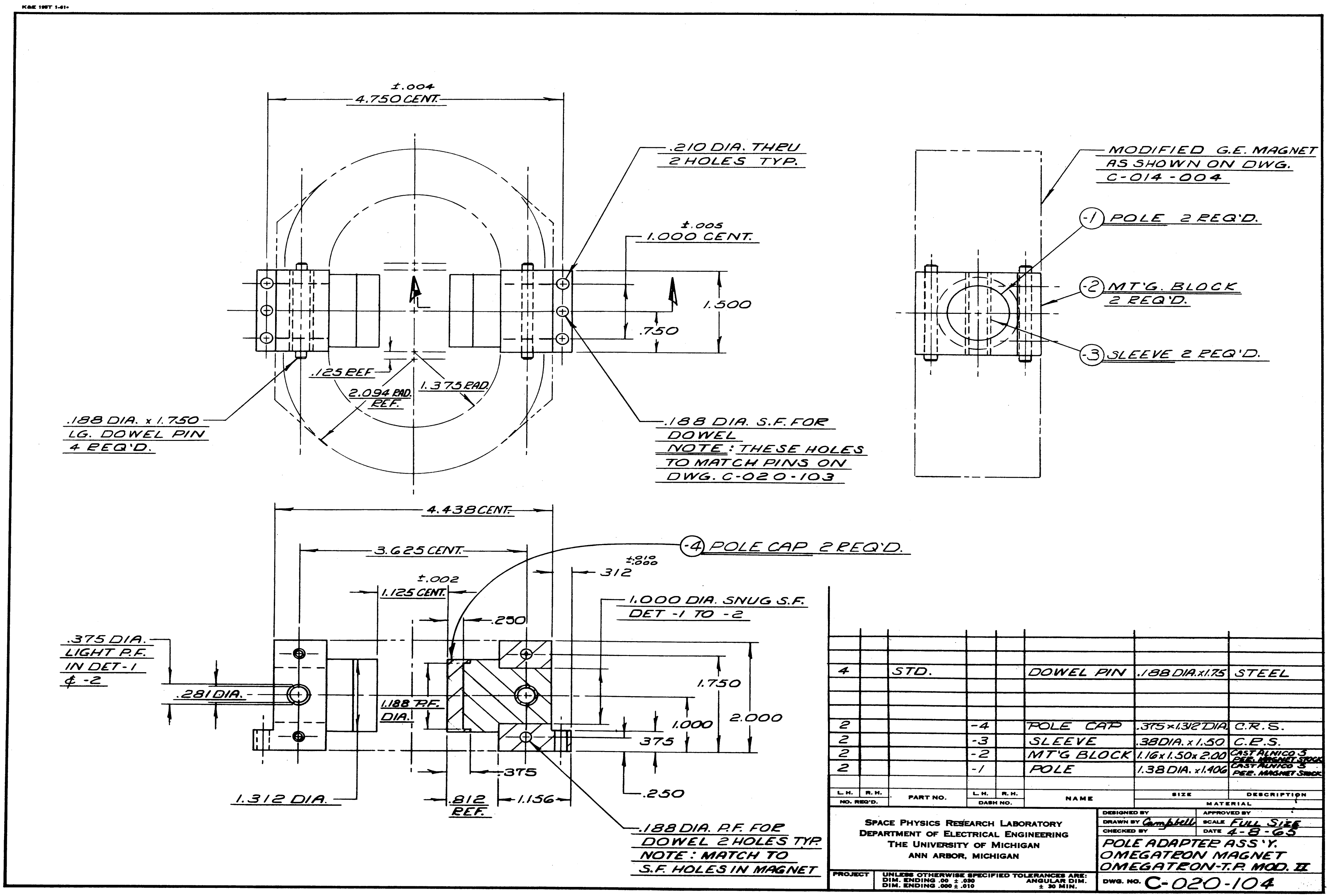


Figure 12. Magnet.

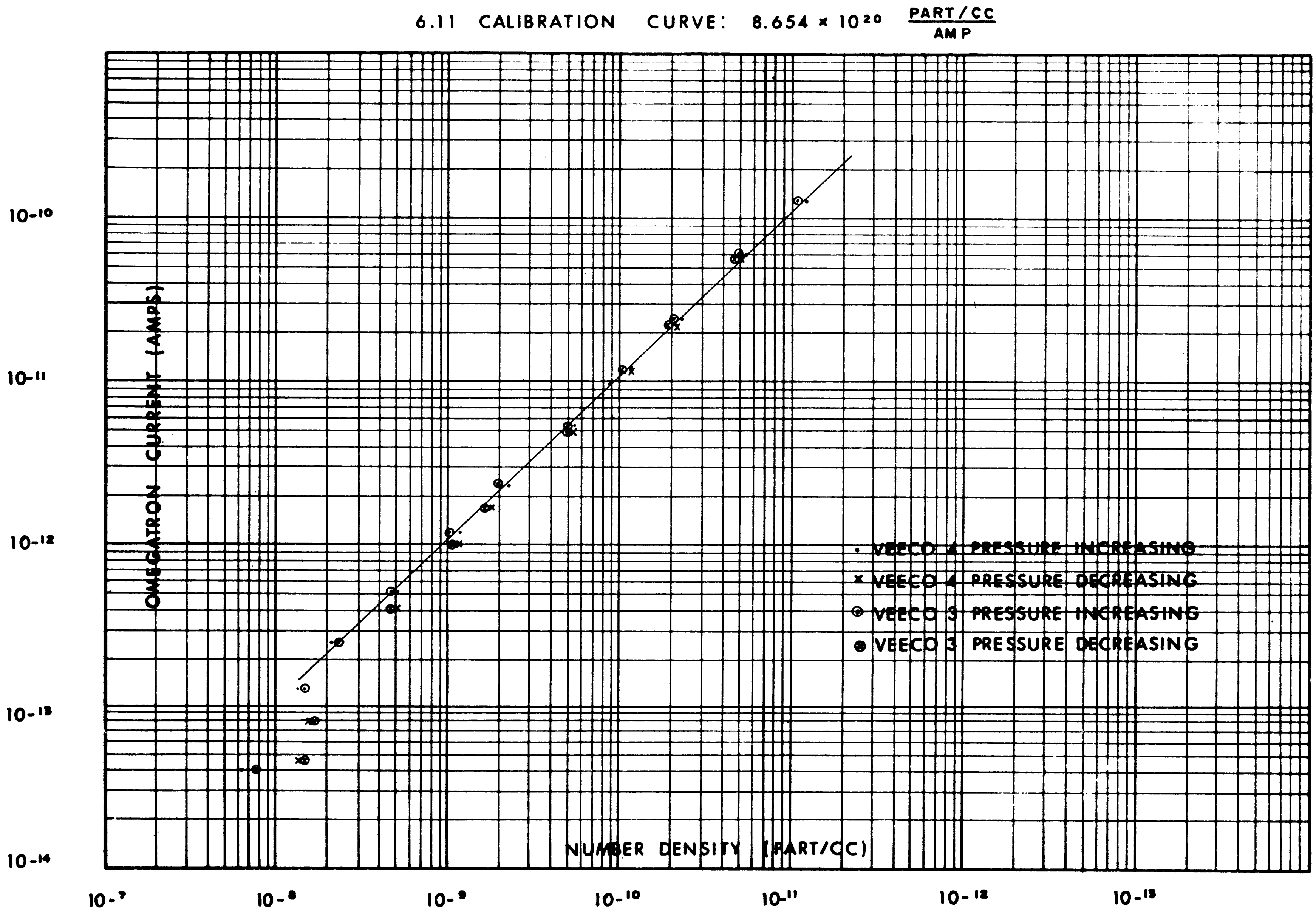


Figure 13. Omegatron calibration.

TABLE I

OMEGATRON DATA
NASA 6.11

Omegatron Gauge Parameters

Beam current	3.96 μa
Electron collector bias	+77.0 v
Filament bias	-91.6
Cage bias	-0.202 v
Top bias	-0.402 v
RF amplitude	
M_{28}	2.62 v P-P
M_{32}	2.57 v P-P

Monitor

Filament	
OFF	2.640 v
ON	4.901 v
Beam	
OFF	4.037 v
ON	2.740 v
Thermistor pressure*	1.86 v
Bias	4.010 v
RF	
M_{28}	3.600 v
M_{32}	1.766 v

Calibration

Sensitivity	3.75×10^{-5} amp/torr
Maximum linear pressure (5%)	$\sim 6 \times 10^{-6}$ torr

Electrometer Amplifier

Range	Range Indicator	Range Resistor	ZPV
1	0.0 v	3.16×10^{10}	5.01
2	~ 0.7 v	1.0×10^{11}	5.01
3	~ 1.4 v	3.16×10^{11}	5.01
4	~ 2.1 v	1.0×10^{12}	5.01
5	~ 2.8 v	3.16×10^{12}	5.01
6.	~ 3.5 v	1.0×10^{13}	5.01
	Calibrate	0.855 v	

Miscellaneous

+ 28 power current all on	270 ma
Preflight gauge pressure	$\sim 10^{-3}$ torr
Magnetic field strength	~ 2200 gauss

*Filament off, zero pressure

5.2 ELECTROSTATIC PROBE (ESP)

The ESP, described by Brace (1963), consists of a cylindrical probe, which is placed in the plasma, and an electronic unit, which measured the collected current. The electronic unit consists of a power convertor, ΔV generator, 3 range current detector, relays, and associated logic circuits.

The following are the specifications of the NASA 6.11 ESP system:

(a) Sensitivity:

Range No. 1	10.0 μA full scale (4 v)
Range No. 2	1.0 μA full scale (4 v)
Range No. 3	.1 μA full scale (4 v)

(b) Input Power:
1.5 watts average at 28 v.

(c) ΔV Slope (dv/dt):
HI - 38 v/sec.
LO - 13 v/sec.

(d) Output:
Voltage 0 ~ 6.9 v
Resistance - < 2K

(e) System Bias Level:
1 v

(f) System Calibration:
ON - 1.2 sec.
Interval - 60 sec.
Synchronized with ΔV.

(g) Sequence:
ΔV - HI-LO alternated
Range - Sequential and HI-LO ΔV per range.

5.3 SUPPORT MEASUREMENTS AND INSTRUMENTATION

5.3.1 Lunar Aspect Sensor

The NASA 6.11 TP utilized a lunar aspect sensor system for the determination of the angular momentum vector of the tumbling TP. This system, designed especially for the TP configuration, consists of a light sensitive element, a current detector and an aperture system of concentric rings which resembles a typical target used for firearms. The system viewed a cone of 60° half angle and the apertures were 5° wide and separated by 5°. The system was mounted such that the axis of the cone of view was along the cylindrical axis of the TP. The output from this system yielded directly the angle between the plane of tumble and the earth-moon vector.

The particulars of the data reduction from this system are described by Taeusch, et al. (1965). The lunar aspect sensor worked as expected during the flight and the aspect of the TP was determined to an accuracy of approximately ± 5°.

5.3.2. Telemetry

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

Transmitter: Driver TRPT 251 RBO-1 Serial Number 845
Power Amplifier TRFP-2V Serial Number 150
Mixer Amplifier-Type TA58 Serial Number 860

Subcarrier Channels (SCO-type TS54)

IRIG Band	Serial Number	Frequency	Nominal Frequency Response	Function
11	1681	7.35 K hz	110 hz	30 pps PAM Data
12	1697	10.5 K hz	160 hz	Lunar Aspect Data
14	1712	22 K hz	330 hz	Electrostatic Probe Data
16	1736	40 K hz	600 hz	Omegatron Data
18	1085	70 K hz	1050 hz	Omegatron Data

Instrumentation power requirements totaled approximately 30 watts, which was supplied by a Yardney HR-1 Silvercell battery pack of nominal 27.8 volts output.

5.3.3 Housekeeping Monitors

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

1. 0 v calibrate
2. 1 v calibrate
3. 2 v calibrate
4. 3 v calibrate
5. 4 v calibrate
6. 5 v calibrate
7. 5 v calibrate
8. ESP ΔV monitor
9. ESP ΔV monitor
10. Omegatron amplifier range
11. Omegatron amplifier output
12. Omegatron filament voltage monitor
13. Omegatron beam current monitor
14. Omegatron bias voltage converter monitor
15. Omegatron RF voltage and frequency monitor
16. ESP ΔV monitor
17. ESP ΔV monitor
18. Thermistor - filament regulator temperature
19. Thermistor - omegatron gauge temperature
20. Thermistor - omegatron amplifier temperature
21. Thermistor - omegatron internal pressure
22. Thermistor - transmitter temperature
23. 4.5 v calibrate
24. 2.0 v calibrate
25. Battery voltage monitor (1 v out = 6.1 v battery)
26. Ground control position monitor
27. ESP ΔV monitor
28. ESP ΔV monitor
29. Omegatron amplifier range
30. Omegatron amplifier output

6. ENGINEERING RESULTS

The Thermosphere Probe instrumentation operated normally throughout the flight. The probe was identical to that described in the report on NASA 18.01 (Taeusch and Carignan, 1966) except that a lunar aspect sensor especially developed for the TP application was used.

The use of the newly developed breakoff device which permits more accurate measurements to higher altitudes also greatly simplifies the field support requirements, an important factor in permitting more wide spread application of the technique.

The launch of 6.11 will probably be the last use of the Aerobee 300A (Spaerobee) for the TP experiment. The new two-stage solid propellant systems, which have essentially the same performance, reduce the cost and operational complexity of carrying out the TP experiment. The Aerobee 300A has been used by the experimenters for a total of thirteen launches of an ejectable experiment package dating back to November 1958 when the Dumbbell experiment was sucessfully flown from Ft. Churchill on rocket ABM 10.200. None of the thirteen rockets failed to perform properly although one was mistakenly cut-down by range safety before third-stage ignition.

7. DATA ANALYSIS

The telemetered data were recorded on magnetic tapes at two stations, Wallops Island Main Base Telemetry Station and Goddard Space Flight Center Station "A." One set of real time "paper" records for quick look evaluation of the results were also obtained. The omegatron, housekeeping and aspect data were reduced to engineering parameters from paper records, run at 10 in/sec, using a Gerber GDDRS data reader and scanner. The paper records used for data reduction were recorded from the magnetic tape masters.

Tracking data for trajectory determination were obtained from FPS-16 and FPQ-6 radars. Continuous data were obtained from +7 to +264 sec by FPS-16 radar and from +65 to +662 sec by FPQ-6 radar.

7.1 Trajectory

The trajectory and velocity information used to determine the aspect, density, and temperature data as a function of altitude were obtained by fitting a smooth theoretical trajectory to the measured radar data. The theoretical trajectory is programmed for computer solution similar to that described by Parker (1962). The output format is shown in Figure 14. The trajectory is shown in Figure 15. The analysis of minimum angle of attack (α) is described by Taeusch et al. (1965) is also incorporated in the program and the output of the computer furnishes α and cos α versus time, altitude, etc. A plot of the NASA 6.11 α versus altitude is given in Figure 16.

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), using the basic relationship:

$$\left(n_a = \frac{\Delta n_i \ U_i}{2 \sqrt{\pi} \ V \cos \alpha}\right)_{N_2}$$

where

n_a = Ambient N_2 number density

Δn_i = Maximum minus minimum gauge number density during one tumble

SPACE PHYSICS RESEARCH LABORATORY
UNIVERSITY OF MICHIGAN
THURSDAY, SEPTEMBER 23, 1965

N A S A 6 . 1 1 T P 7

LAUNCH TIME (GMT)

YEAR	1965
DAY	79
HOUR	5
MINUTE	42
SECOND	.000

INITIAL CONDITIONS

TIME	117.000	SECONDS FROM LAUNCH
ALTITUDE	528083.0	FT
RANGE	150460.0	FT
VELCCITY	6010.0	FT/SEC
FLIGHT PATH ANGLE	70.7380	DEGREES UP FROM LOCAL HORIZONTAL PLANE
AZIMUTH	128.4500	DEGREES EAST OF LOCAL NORTH
LONGITUDE	-75.0668	DEGREES (+EAST)
LATITUDE	37.5911	DEGREES (+NORTH)

THE ''CORRECT'' MOMENTUM VECTOR IS .14650 -.76860 -.62273

PEAK PARAMETERS

TIME	ALTITUDE	RANGE	POSITION DEGREES	INERTIAL VELOCITY FEET	INERTIAL VELOCITY METERS	VELOCITY WRT EARTH FEET	VELOCITY WRT EARTH METERS	FIXED VEL FEET	AZIMUTH DEGREES	ELEVATION DEGREES	ALPHA
SEC	FEET	FEET	LATITUDE	TOTAL	TOTAL	TOTAL	TOTAL	X	INERTIAL	INERTIAL	DEGREES
	METERS	METERS	LONGITUDE	HORIZONTAL	HORIZCNTAL	HORIZCNTAL	HORIZONTAL	Y	WRT EARTH	WRT EARTH	RADIANS
	GEOPOT METE			VERTICAL	VERTICAL	VERTICAL	VERTICAL	Z			COSINE
311.10	1072359	509605	36.96	2978	908	1897	578	1440	115.04	.00	38.825
	326855	155328	-74.12	2978	908	1897	578	-1234	131.63	.00	.678
	310903			-0	-0	-0	-0	-48			.7791

Figure 14. Trajectory program output format.

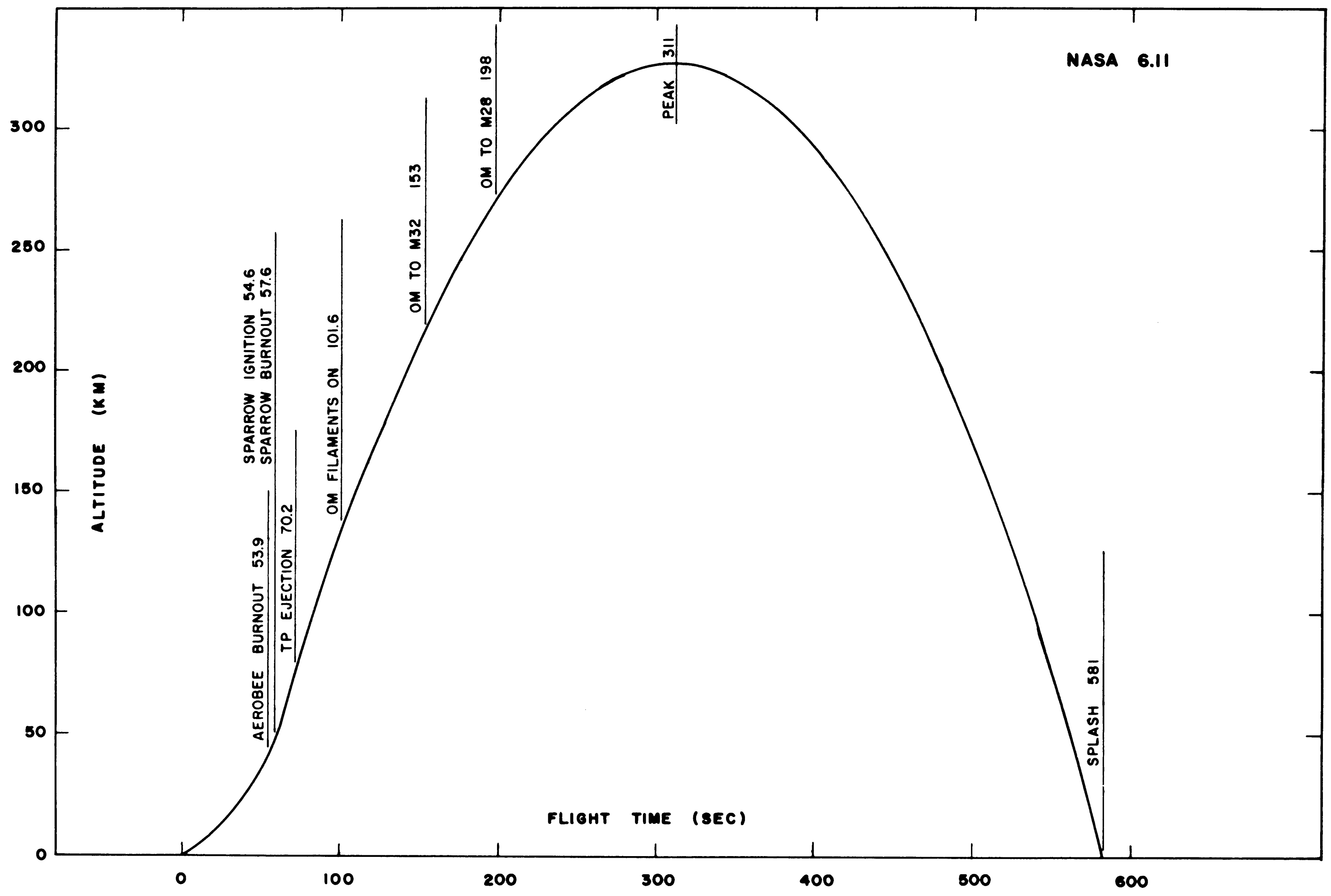


Figure 15. Trajectory with timing.

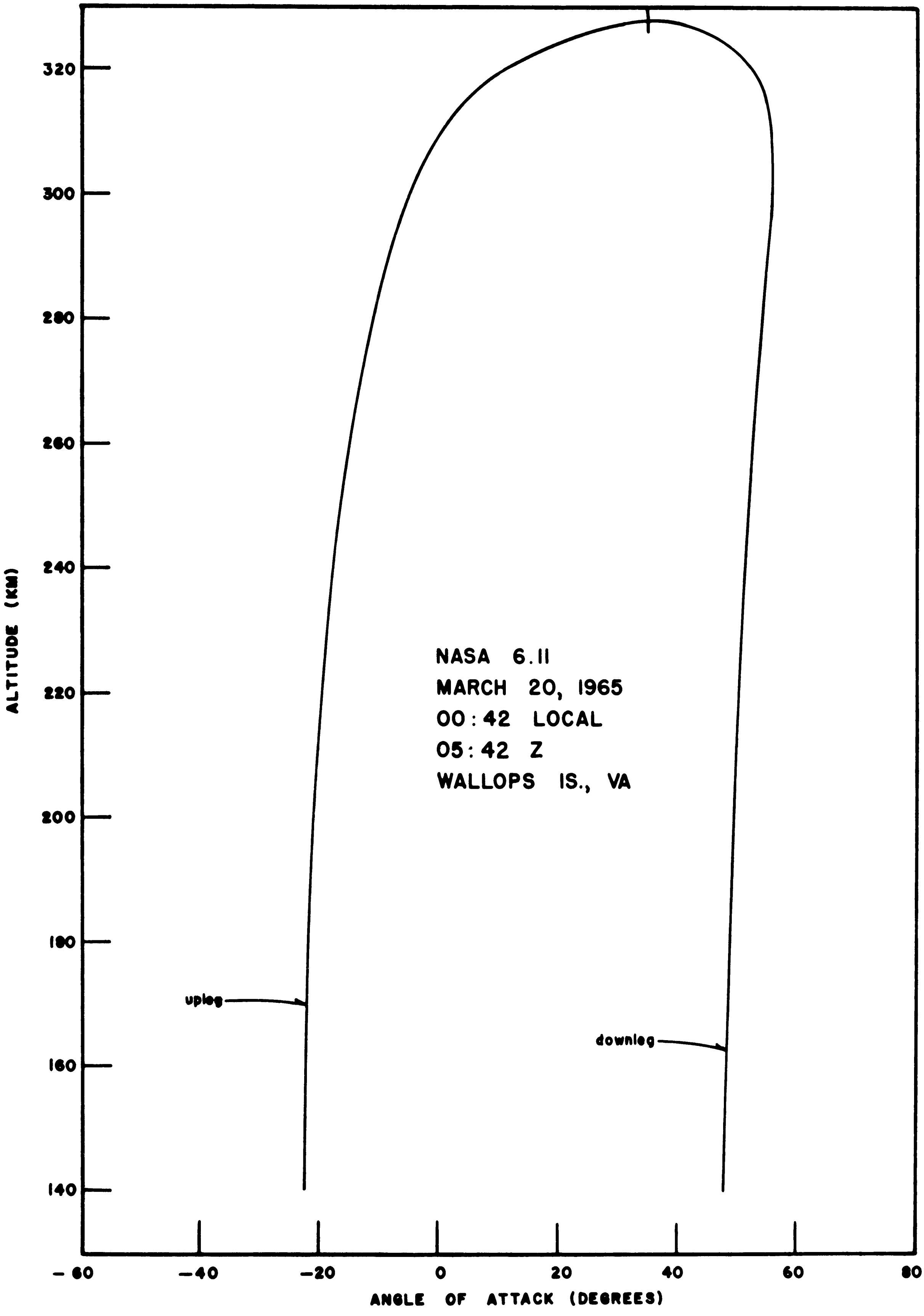


Figure 16. α vs. altitude.

$U_i = \sqrt{2kTi/m}$ most probable velocity of particle inside gauge

T_i = Gauge wall temperature

V = Vehicle velocity with respect to the earth

α = Minimum angle of attack for one tumble

ΔI_i, the difference between the maximum (peak) omegatron gauge current and the minimum (background) gauge current is shown versus flight time in Figure 17. The background current is also shown in the figure. The background current is the result of the outgassing of the gauge walls and the inside density due to atmospheric particles which have high enough energy to overtake the TP and enter the gauge. The outgassing component is assumed constant for one tumble and effects both the peak reading and the background reading; and, therefore, does not effect the difference. From calibration data obtained by standard techniques, the inside number density, Δn_i, is computed for the measured current. As described by Spencer, Taeusch, and Carignan (1965), the uncertainty in these data is believed to be $\pm$ 10.2% rms relative to other measurements using the same calibration system and $\pm$ 25.1% rms absolute.

U_i, the most probable thermal speed of the particles inside the gauge, is computed using the measured gauge wall temperature shown in Figure 18. The uncertainty in this measurement is believed to be $\pm$ 2.2% rms absolute.

V, the vehicle velocity with respect to the earth; is believed known to better than $\pm$ 1% absolute. It is obtained from the trajectory curve fitting described previously and is the most accurately known quantity obtained from the analysis.

Cos α is obtained from the aspect analysis described by Taeusch, et al. (1965). Since the uncertainty in cos α depends upon α, for any given error in α, each particular case and altitude range must be considered separately. As can be seen in Figure 16, the upleg data were obtained for angles of attack less than 30°, which results in an uncertainty in cos α approximately $\pm$ 3% for an uncertainty in α of approximately $\pm$ 5°.

The resulting ambient N_2 number density, obtained from the measured quantities described above, is shown in Figure 19. The uncertainty in the ambient density due to the combined uncertainties in the measured quantities is $\pm$ 10.9% rms relative and $\pm$ 25.4% rms absolute.

7.3 Temperature

The ambient N_2 temperature profile, shown in Figure 20, was obtained by integrating the density profile to obtain the pressure and then relating the known density and pressure to the temperature through the ideal gas law. The

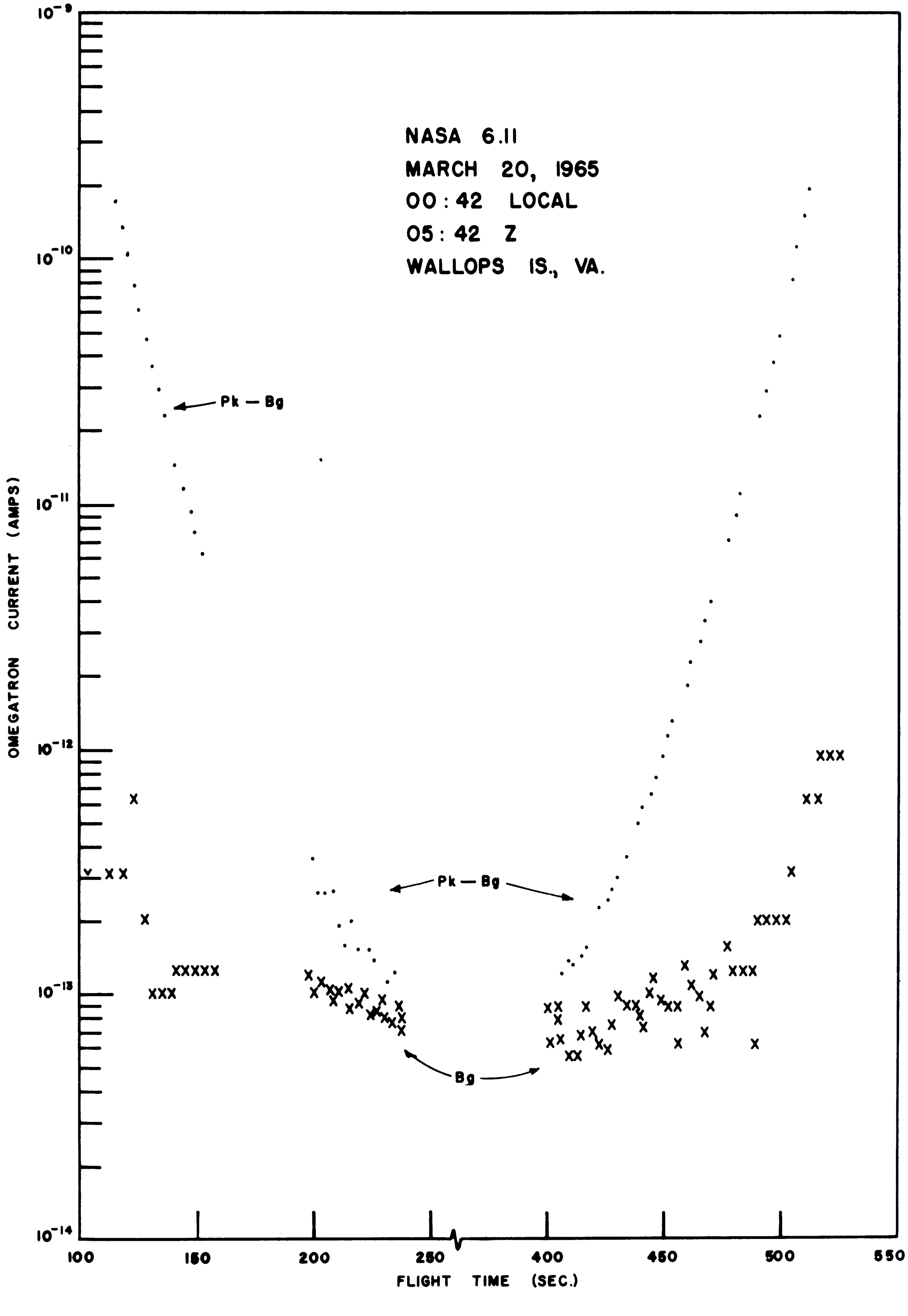


Figure 17. Peak minus background current vs. time.

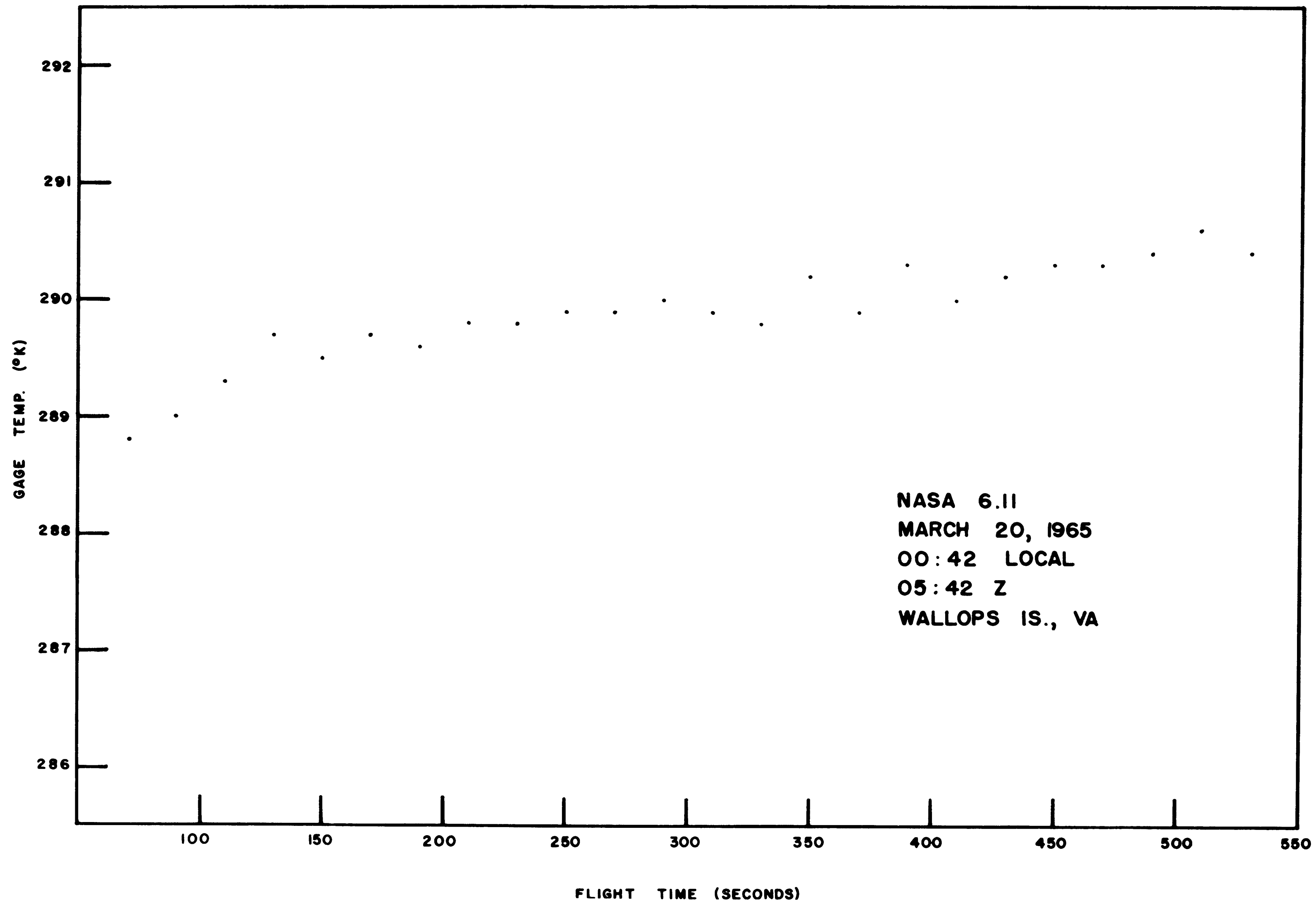


Figure 18. Gauge temperature vs. flight time.

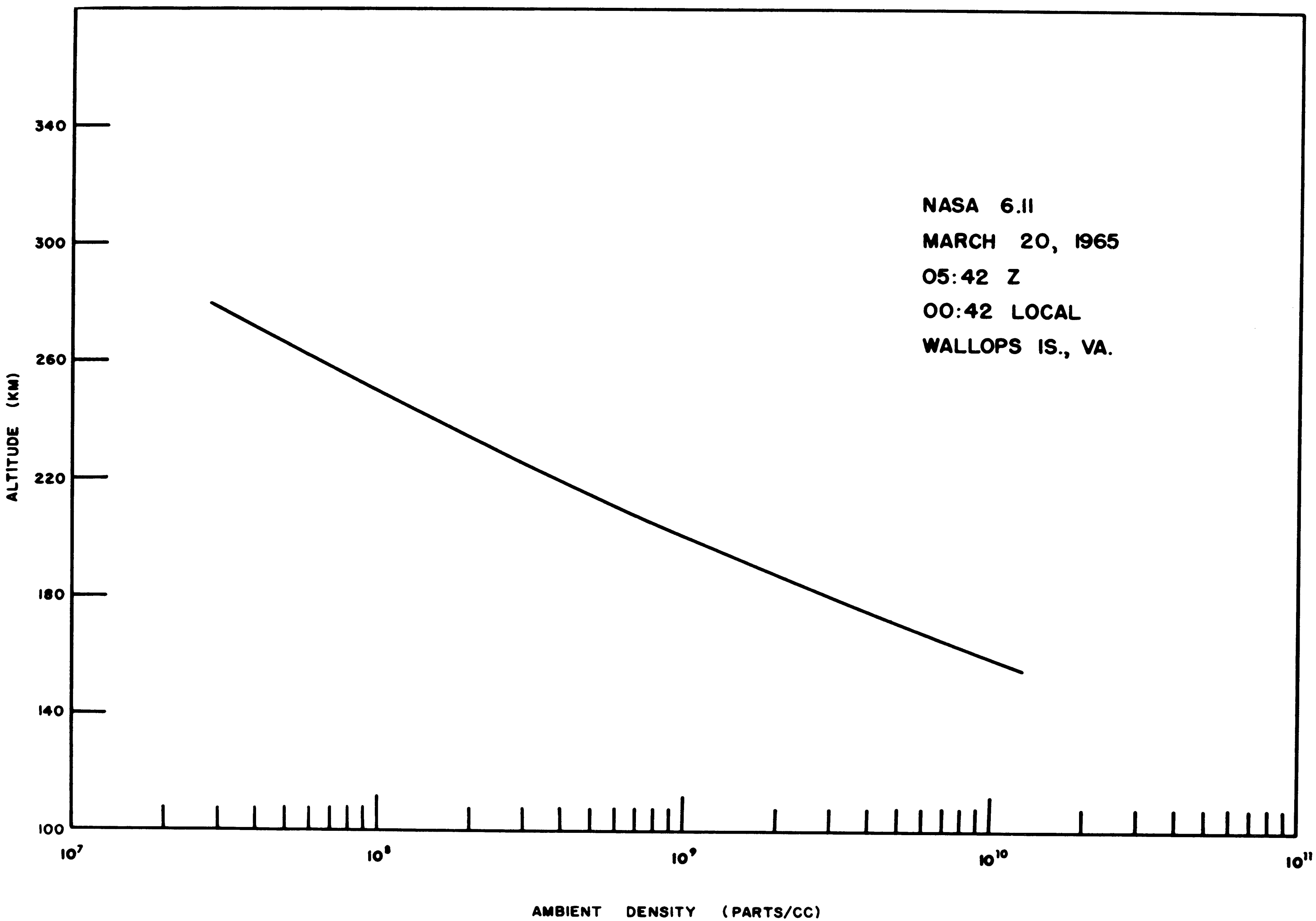
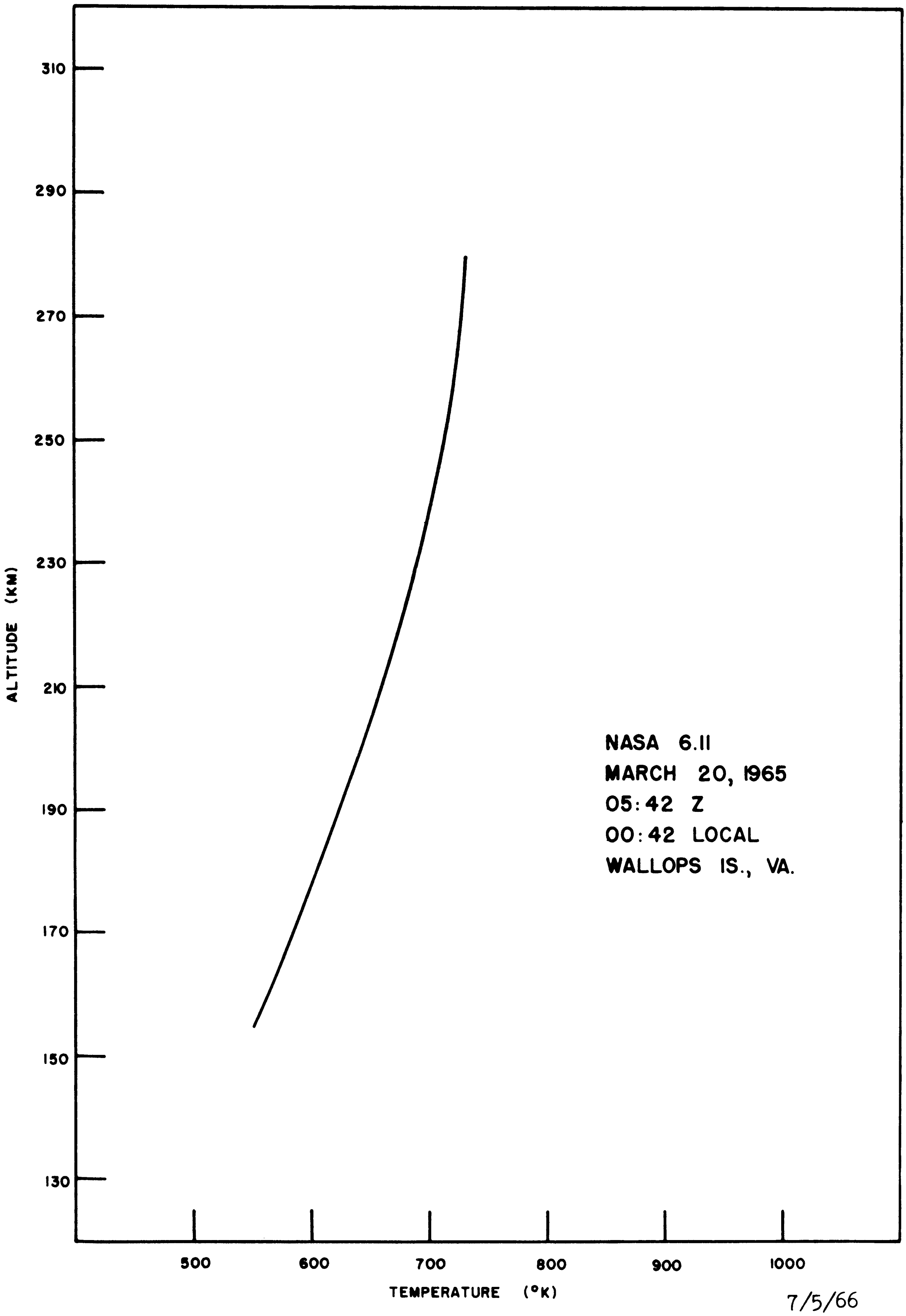


Figure 19. Ambient N_2 number density vs. altitude.



7/5/66

Figure 20. Ambient N_2 temperature vs. altitude.

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 its magnitude, it is believed that the uncertainty in its magnitude is ± 5% absolute.

FINAL N_2 DENSITY AND TEMPERATURE
(after application of η,
geometry correction factor)

NASA 6.11

March 20, 1965

05:42 Z

00:42 LOCAL

Wallops Is., Va.

ALTITUDE	DENSITY (Part/cc)	TEMPERATURE (°Kelvin)
155	1.28×10^{10}	551
160	9.58×10^{9}	562
165	7.18	572
170	5.39	583
175	4.07	594
180	3.04	604
185	2.28	614
190	1.76	624
195	1.35	633
200	1.04×10^{9}	642
205	8.03×10^{8}	651
210	6.28	660
215	4.90	668
220	3.85	676
225	3.04	683
230	2.40	690
235	1.91	696
240	1.52	702
245	1.22×10^{8}	708
250	9.79×10^{7}	713
255	7.89	718
260	6.38	722
265	5.14	725
270	4.13	728
275	3.34	730
279	2.83×10^{7}	731

8. REFERENCES

Brace, L. H., "Transistorized Circuits for Use in Space Research Instrumentation," University of Michgian, Space Physics Research Laboratory, Report No. 02816 1-3-S, October 1959.

Brace, L. H., Spencer, N. W., and Carignan, G. R., "Ionosphere Electron Temperature Measurements and Their Implications," J. Geophys. Res., 68, 5397-5412 (1963).

Harris, I., and Priester, W., "The upper Atmosphere in the Range from 120 to 800 Km," Goddard Space Flight Center, NASA, Institute for Space Studies Report, 1964.

Niemann, H. B., and Kennedy, B. C., "An Omegatron Mass Spectrometer for Partial Pressure Measurements in the Upper Atmosphere," submitted for publication to Rev. Sci. Instr., 1966.

Parker, L. T., Jr., " A Mass Point Trajectory Program for the DCD 1604 Computer," Tech. Doc. Report AFSWC-TDR-62-49, Air Force Spec. Weapons Center, Kirtland AF Base, New Mexico, August 1962.

Spencer, N. W., Brace, L. H., and Carignan, G. R., "Electron Temperature Evidence for Nonthermal Equlibrium in the Ionosphere," J. Geophys. Res., 67, 151-175 (1962).

Spencer, N. W., Brace, L. H., Carignan, G. R., Taeusch, D. R., and Niemann, H. B., "Electron and Molecular Nitrogen Temperature and Density in the Thermosphere," J. Geophys. Res., 70, 2665-2698 (1956).

Spencer, N. W., Taeusch, D. R., and Carignan, G. R., "N_2 Temperature and Density Data for the 150 to 200 Km Region and Their Implications," Goddard Space Flight Center, Report X-620-66-5, December 1965.

Taeusch, D. R., Carignan, G. R., Niemann, H. B., and Nagy, A. F., "The Thermosphere Probe," University of Michigan, Scientific Report 07065-1-S, March 1965.

Taeusch, D. R., and Carignan, G. R. "Sounding Rocket Flight Report, NASA 18.01 Thermosphere Probe Experiment" University of Michigan, ORA Report No. 07065-1-R, May 1966.