

THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Electrical Engineering

SOUNDING ROCKET FLIGHT REPORT

NASA 18.02 Thermosphere Probe Experiment

Prepared on behalf of the project by

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PROJECT PERSONNEL

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B. J. Campbell	Design Draftsman	Univ. of Mich.
L. C. Castagnola	Instrumentation Manager	GSFC
P. L. Freed	Chief Technician	Univ. of Mich.
G. K. Grim	Engineer	Univ. of Mich.
R. Haskins	Launch Supervisor	Pan American
W. G. Kartlick	Omegatron Instrument Maker	Univ. of Mich.
B. C. Kennedy	Omegatron Engineer	Univ. of Mich.
T. B. Lee	Electrostatic Probe Engineer	Univ. of Mich.
J. C. Maurer	Payload Engineer	Univ. of Mich.
D. L. McCormick	Machinist	Univ. of Mich.
D. McNabb	Telemetry Supervisor	Pan American
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1. INTRODUCTION

This report describes and discusses the results of the launching of NASA 18.02, a Nike-Tomahawk 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 18.02 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 nighttime molecular nitrogen density and temperature, and electron density and temperature in the altitude range of approximately 140 to 300 km over Ft. Churchill, Canada.

A general description of the payload kinematics, orientation analysis, and data reduction techniques is 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 herein was launched 12 hours after a similar one (NASA 18.03) 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. Also, a Pitot-Static Probe (Horvath, Simmons and Brace 1962; Simmons, 1964) was launched in conjunction with each of the TP payloads for homospheric-heterospheric variation studies.

2. GENERAL FLIGHT INFORMATION

The general flight information for NASA 18.02 is tabulated below. The geophysical indices listed, the 10.7 cm solar radio flux, $F_{10.7}$; the five monthly averages of the solar 10.7 cm flux preceding the launch, $\bar{F}_{10.7}$; and the geomagnetic index, a_p , were obtained from the December, 1965, and January, 1966, 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 atmosphere.

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:	November 10, 1965
Launch Time:	0100 CST 0700 GMT
Location:	Ft. Churchill, Canada Longitude: 93.70°W Latitude: 58.72°N

Apogee Parameters:	
Altitude:	331.3 km
Horizontal Velocity:	233 m/sec
Flight Time:	283.9 sec

Geophysical Indices:

$F_{10.7}$	= 82.0
$\bar{F}_{10.7}$	= 76.3
a_p	= 0.5

TP Motion:

Tumble Period:	1.604 sec/360°
Roll Period:	1.406 sec/360°

TABLE OF EVENTS

Event	Flight Time (sec)	Altitude (km)	Remarks
Lift Off	0	0	0700:01 GMT
1st Stage Burn Out	3.5 (est)	1.4 (est)	
2nd Stage Ignition	12.0	7.0	velocity = 1900 ft/sec
2nd Stage Burn Out	21.0	20.7	velocity = 8000 ft/sec
Despin	43.0 (est)	71.0 (est)	
TP Ejection	45.2	75.7	
Omegatron Breakoff	62.0 (est)	108.8 (est)	
Omegatron Filaments On. M28	62.7	112.2	
Peak Altitude	283.9	331.3	
Omegatron to Mass 16	389.5	281.7	
Omegatron to Mass 32	400.0	271.3	
Omegatron to Mass 28	421.5	247.0	
L.O.S.	544.0	27.1	

3. LAUNCH VEHICLE

The NASA 18.02 launch vehicle was a two-stage Nike-Tomahawk combination. The first stage was the solid propellant Nike booster, which has an average thrust of 49,000 lb and burns for approximately 3.5 sec. The Nike is 135 in. long, 16.5 in. in diameter, and weighed 1338 lb unburned. The center of gravity (CG) was 75.7 in. from the nozzle exit plane (NEP). The second stage was Thiokol's Tomahawk solid propellant motor. The average thrust is approximately 11,000 lb and it burns for about 9 sec. The Tomahawk is 142 in. long, 9 in. in diameter, and weighed 530 lb unburned. The CG was 72.125 in. from the NEP. The payload was 81.15 in. long and weighed 143 lb making the total vehicle 358 in. long and weighing 2011 lb. Drawings and photographs of the vehicle are given in Figures 1, 2, and 3.

The predicted performance for the vehicle was 322 km peak altitude at 281 sec. flight time. The actual performance, as discussed in detail in a later section, was 331.3 km peak altitude at 283.9 sec. of flight time.

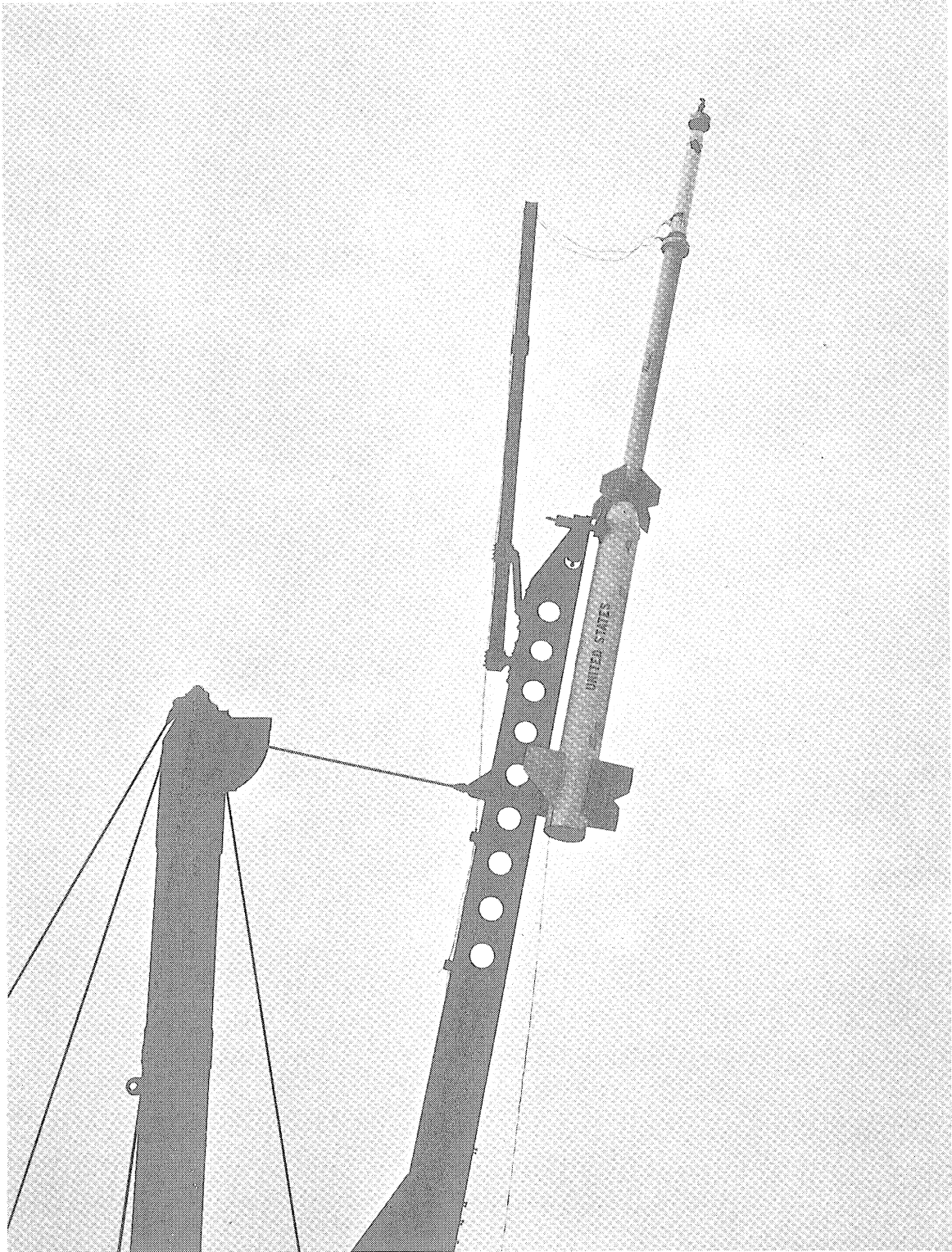


Fig. 1. Nike Tomahawk with thermosphere probe payload.

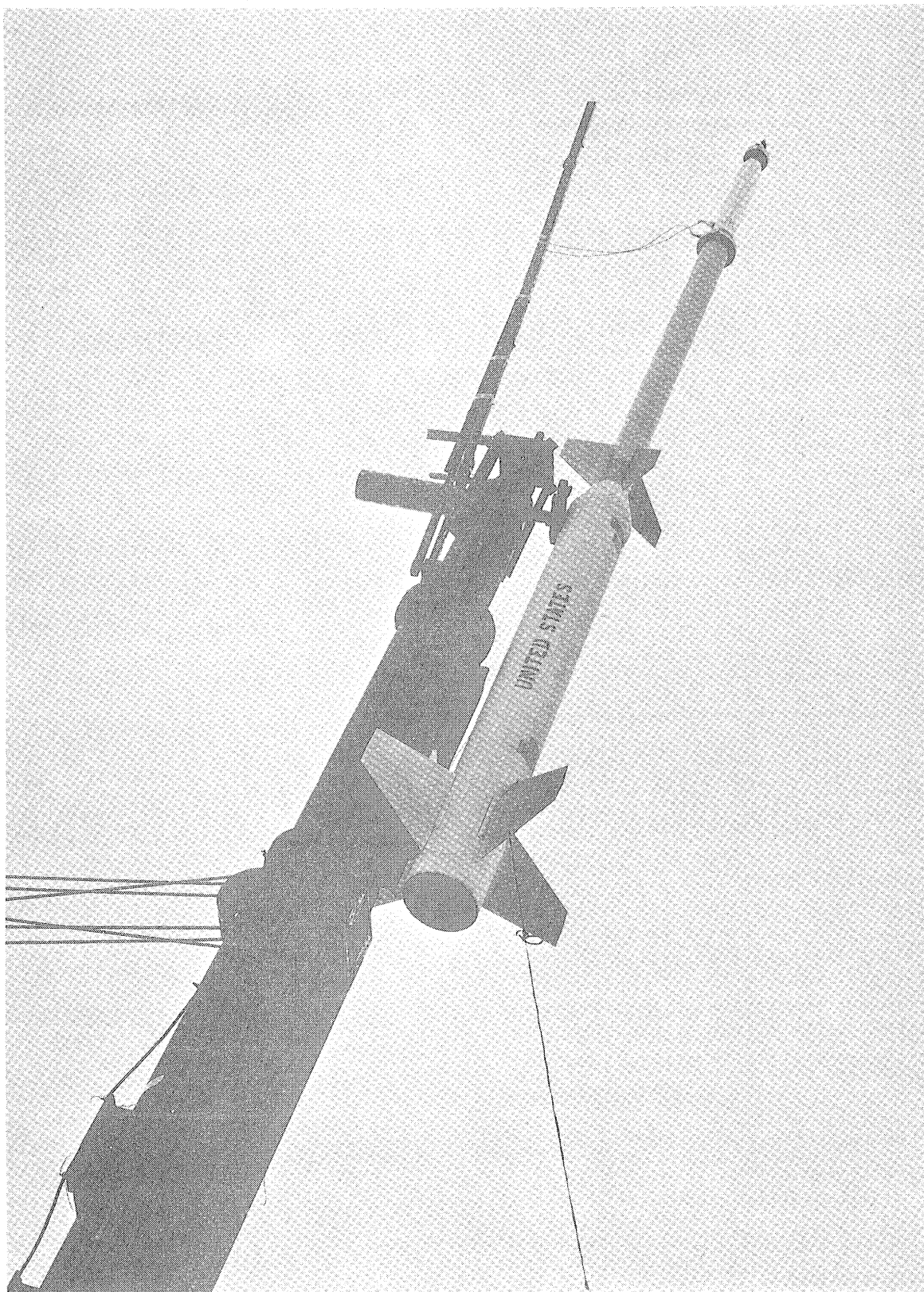
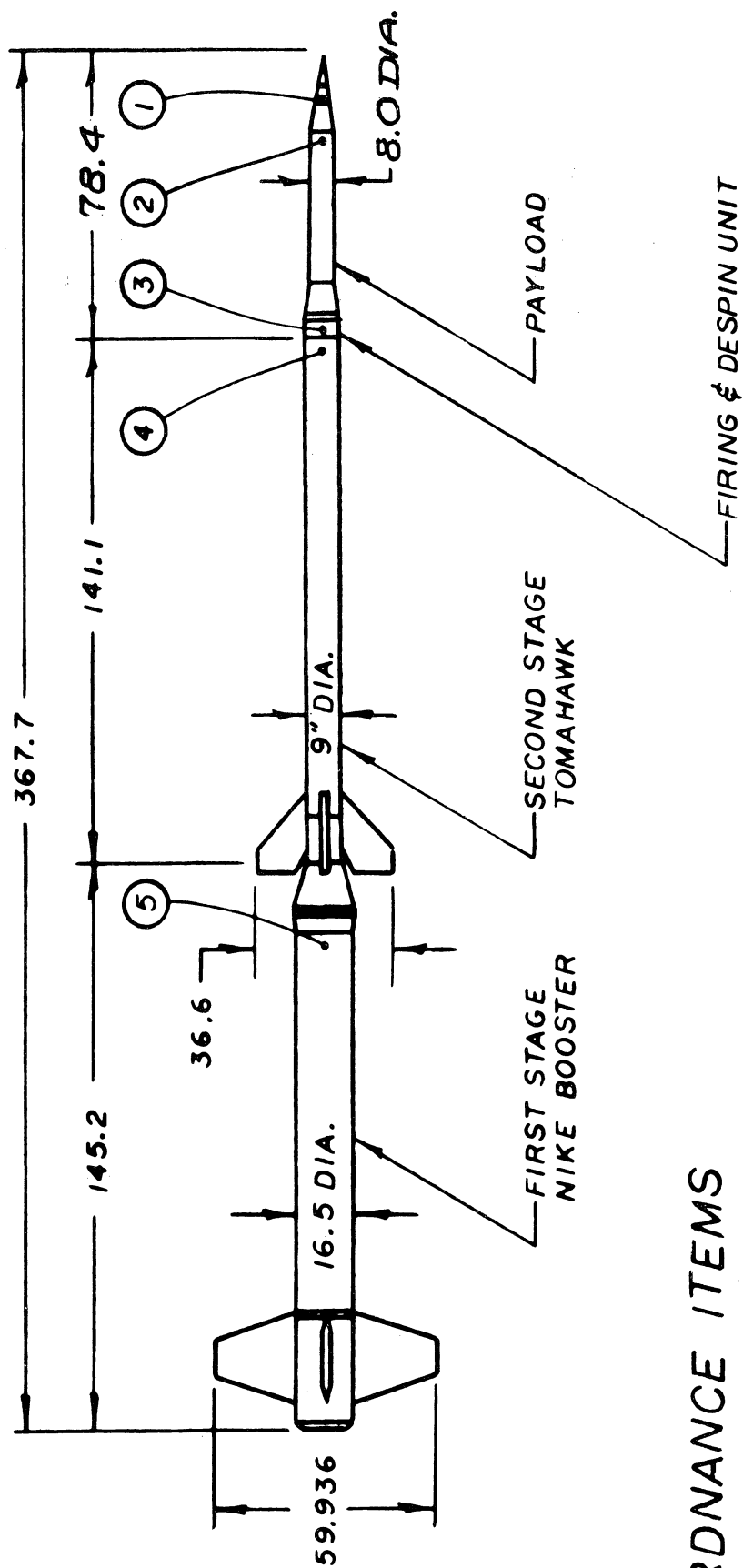


Fig. 2. Nike Tomahawk with thermosphere probe payload.



ORDNANCE ITEMS

- ① NOSE CONE OPENING PRIMERS.
- ② BREAKOFF LINEAR ACTUATORS
- ③ DESPIN INITIATION PRIMERS
- ④ SECOND STAGE IGNITER
- ⑤ NIKE BOOSTER IGNITER

Fig. 3. Nike Tomahawk dimensions.

4. NOSE CONE

A diagram of the NASA 18.02 payload including nose cone, despin mechanism and adapter sections is shown in Figure 4. The weights, dimensions and instrumentation placement are also given on the figure. This payload and the one used on NASA 18.03 are the first 7-1/4" diameter TP's. An assembly drawing of the new 8" nose cone is given in Figure 5.

The payload is programmed to despin at about 70 km altitude and the TP is ejected and tumbled at about 75 km. The breakoff device is removed at about 110 km and the omegatron filament turned on a few seconds later. The timing for this particular payload was described previously.

5. THE THERMOSPHERE PROBE (TP)

The TP used for the NASA 18.02 was a cylinder 30.44 in. long and 7.25 in. in diameter weighing 50 lb. The prime instruments for this payload were an omegatron mass analyzer, and two electron temperature probe units. Supporting instrumentation included a lunar aspect sensor for the determination of the TP aspect. The diagram 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 and the NASA 18.03 model were the first to use the larger magnet and envelope assembly for the 7.25 in. diameter TP. The breakoff configuration, omegatron envelope and magnet are shown in Figures 10, 11, and 12. The NASA 18.02 magnetic field strength was about 2600 gauss, which provided a better resolution and slightly better sensitivity for a given emission current than previous omegatrons have exhibited.

The calibration of the NASA 18.02 and NASA 18.03 gauges was performed in September 1965 at GSFC. The vacuum system used was a Varian 5000 liter per sec—50,000 liter per sec, Vacion-Titanium-Sublimation system under the supervision of Mr. George Newton and Mr. David Pelz. Other gauges used for reference were two Bayard-Alpert ionization gauges designated RVA-1 and RVA-2. RVA-1 was used as the reference in the 10^{-6} to 10^{-5} torr range. A relative calibration of the NASA 18.02 and NASA 18.03 omegatrons was performed at SPRL later in September 1965 on the Varion 40 liter per sec—400 liter per sec Vacion-Titanium Sublimation system using a CVC B.A. gauge as the reference in the 10^{-5} to 10^{-4} torr range. The final calibration is shown in Figure 13.

5.2 ELECTROSTATIC PROBE (ESP)

The ESP, described by Brace, et al (1963), consists of two cylindrical probes, which are placed in the plasma and an electronic unit which measures the collected current. The electronic unit consists of a power converter, ΔV generator, 3 range current detector, and relays with associated logic circuits.

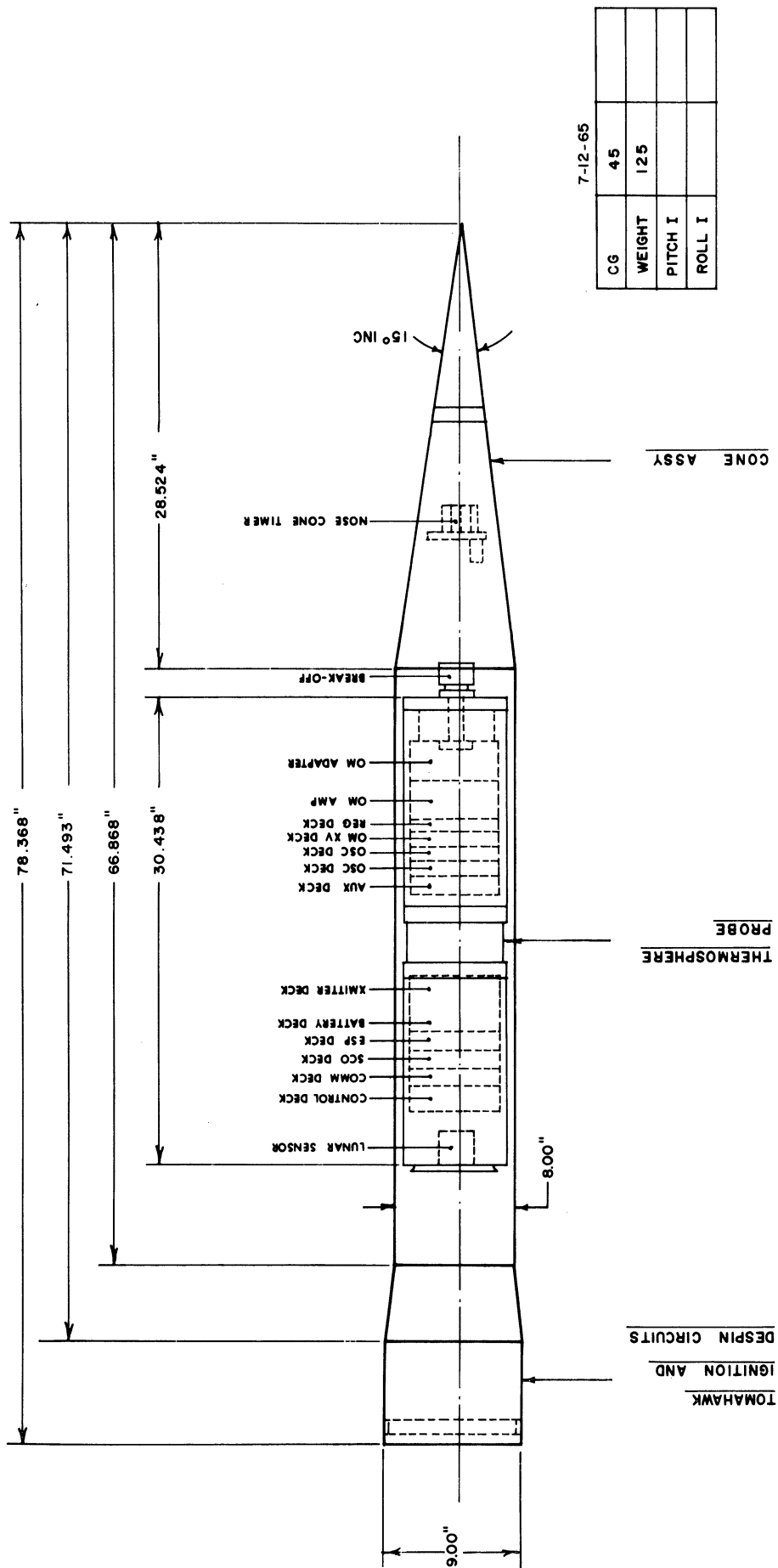


Fig. 6. Instrumentation location.

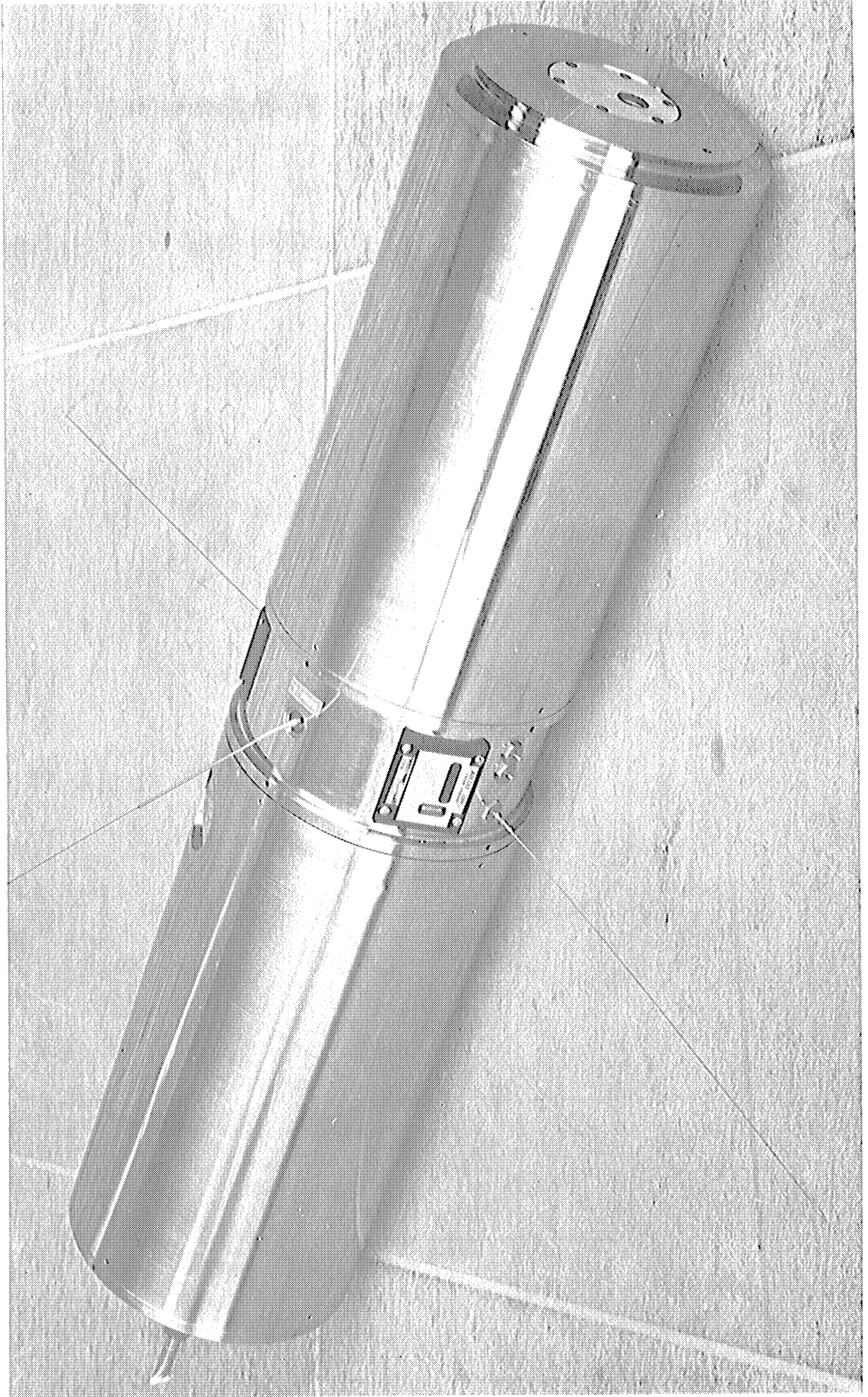
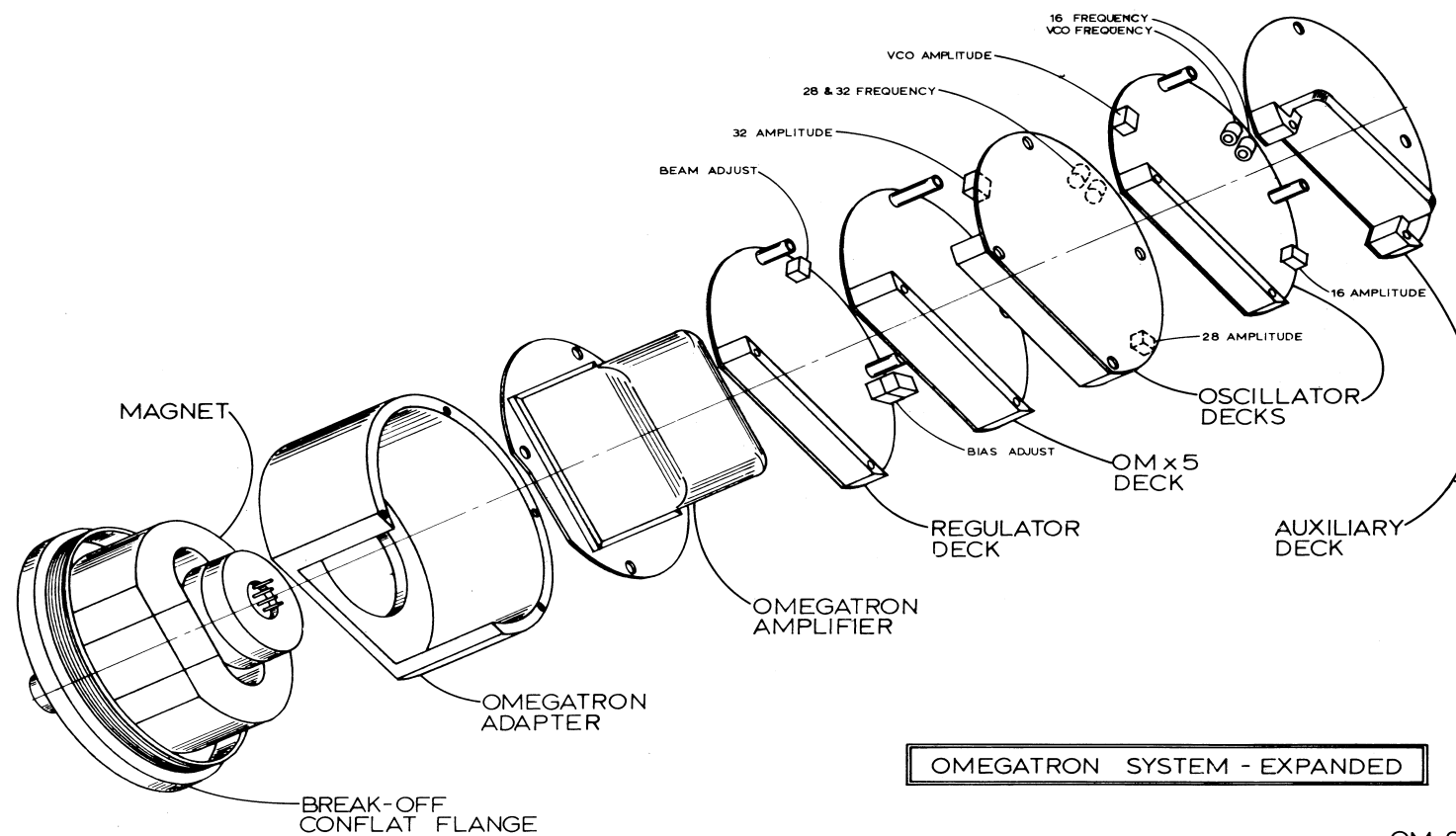
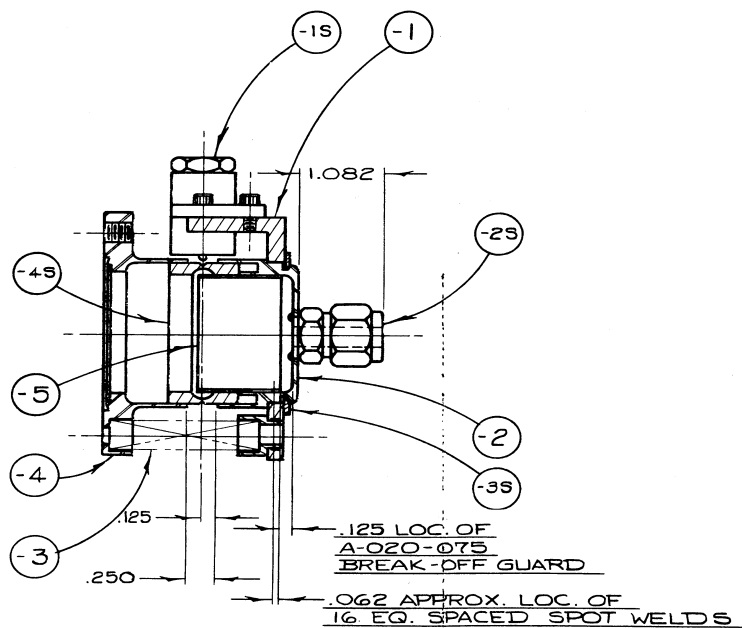


Fig. 8. Assembled TP.



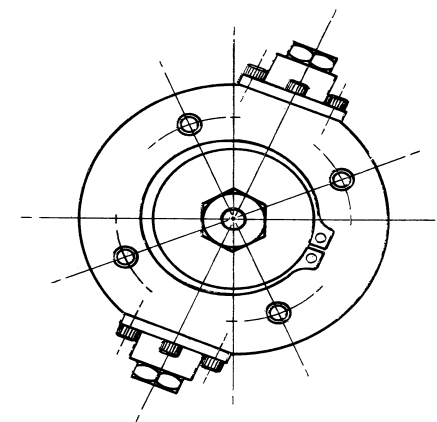
OM-2

Fig. 9. Omegatron expanded view.



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.O.F.M. AFTER BRAZING OF CERAMIC SEAL.
5. LEAK CHECK COMPLETE UNIT.
6. FINAL MACHINING OF CONFLAT GROOVE ON C-020-074 - BREAK-OFF BASE.



1		-4S	BREAK-OFF CERAMIC	COORS		
1	WALDES KOHINOOR #5102-1628	-3S	RETAINING RING	PORCELIN CO.		
1	*600-1-4W-316	-2S	CRAWFORD FITTING CO. SWAGelok (MOD.)	TRUARC		
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.			
L. H. NO. REQ'D.	R. H. PART NO.	L. H. DASH NO.	R. H. NAME	SIZE	MATERIAL	DESCRIPTION
SPACE PHYSICS RESEARCH LABORATORY DEPARTMENT OF ELECTRICAL ENGINEERING THE UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN			DESIGNED BY DRAWN BY CHECKED BY	APPROVED BY SCALE DATE	FULL 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	

Fig. 10. Breakoff configuration.

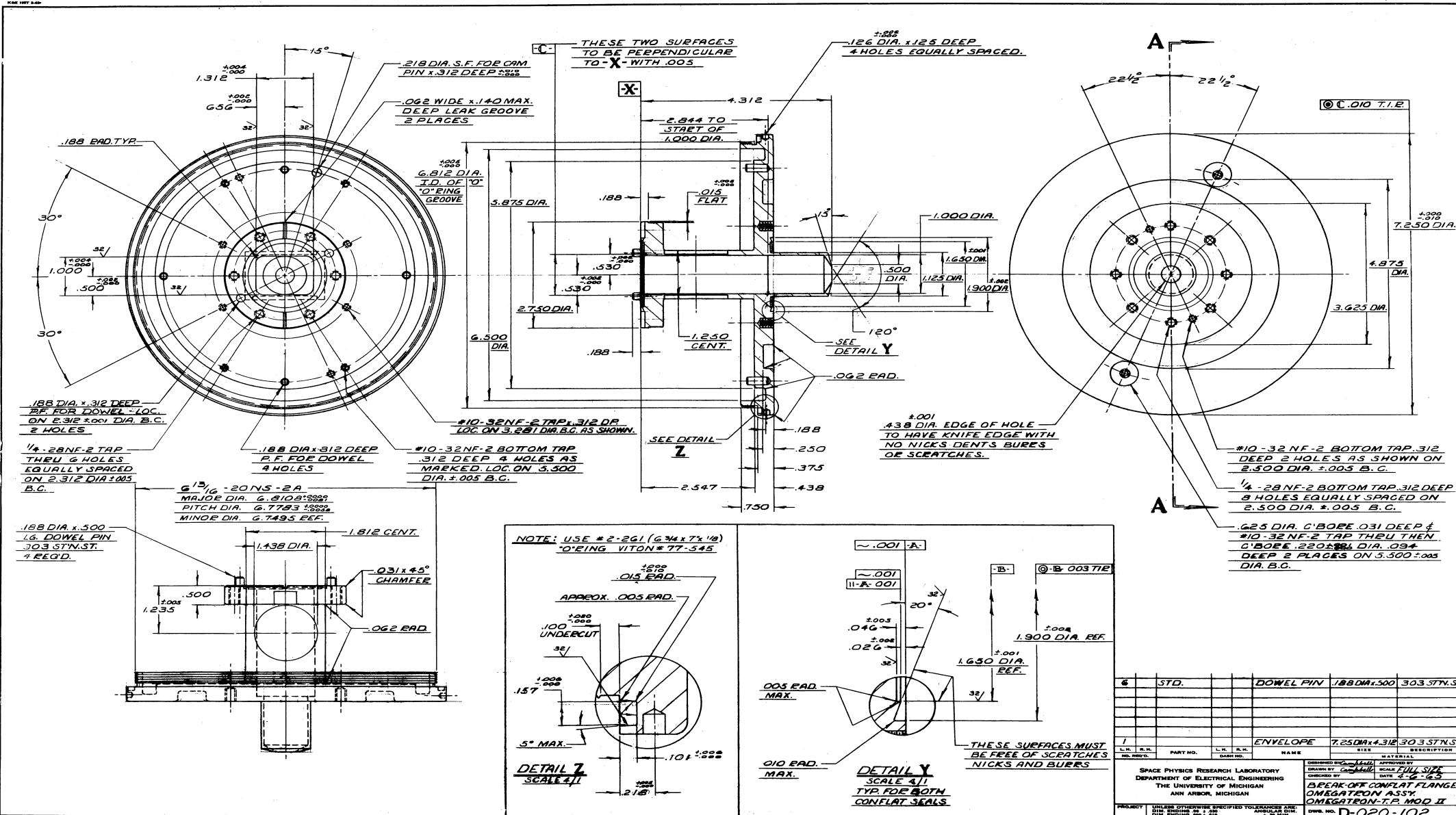


Fig. 11. Omegatron envelope.

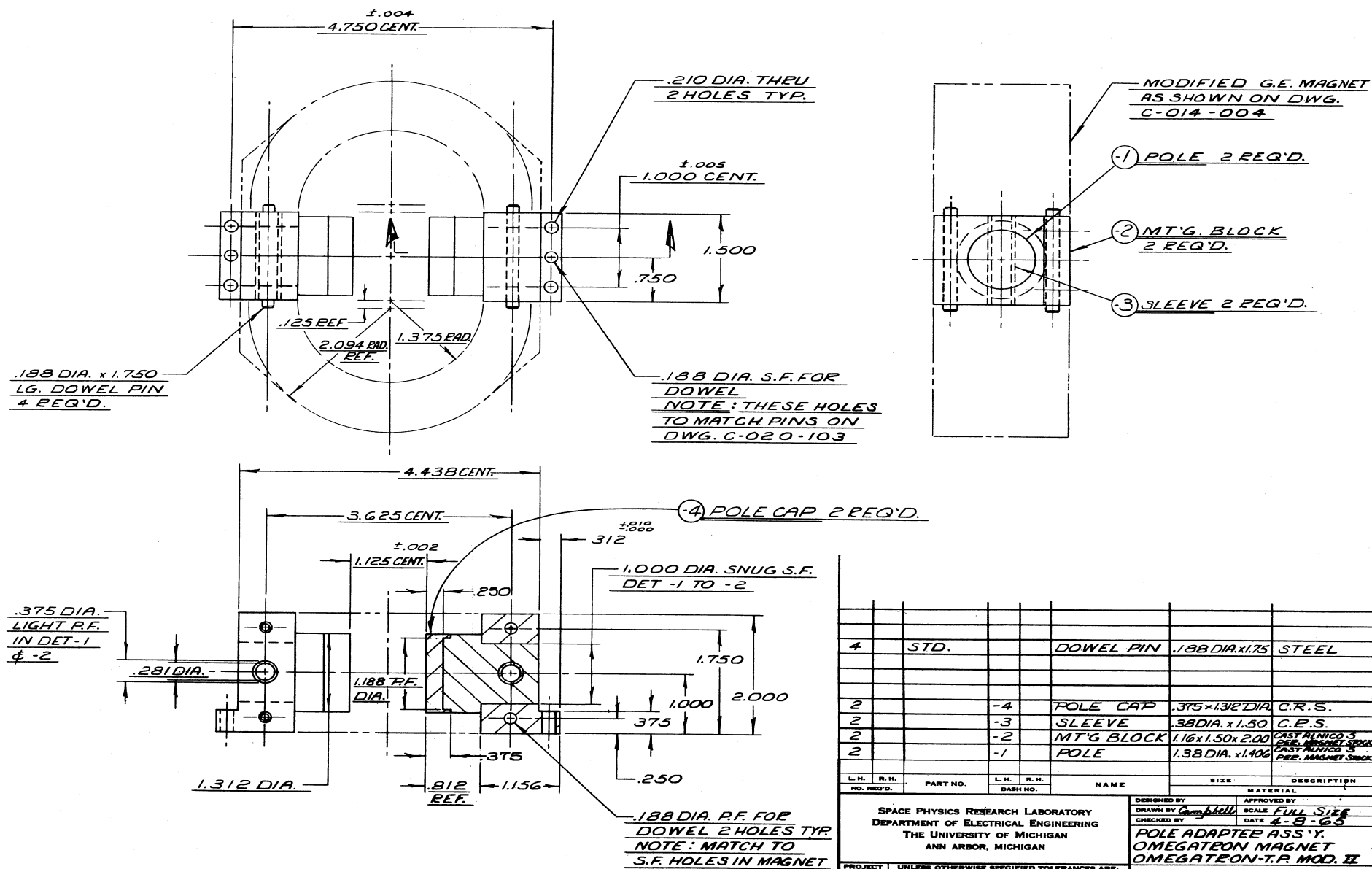


Fig. 12. Omegatron magnet.

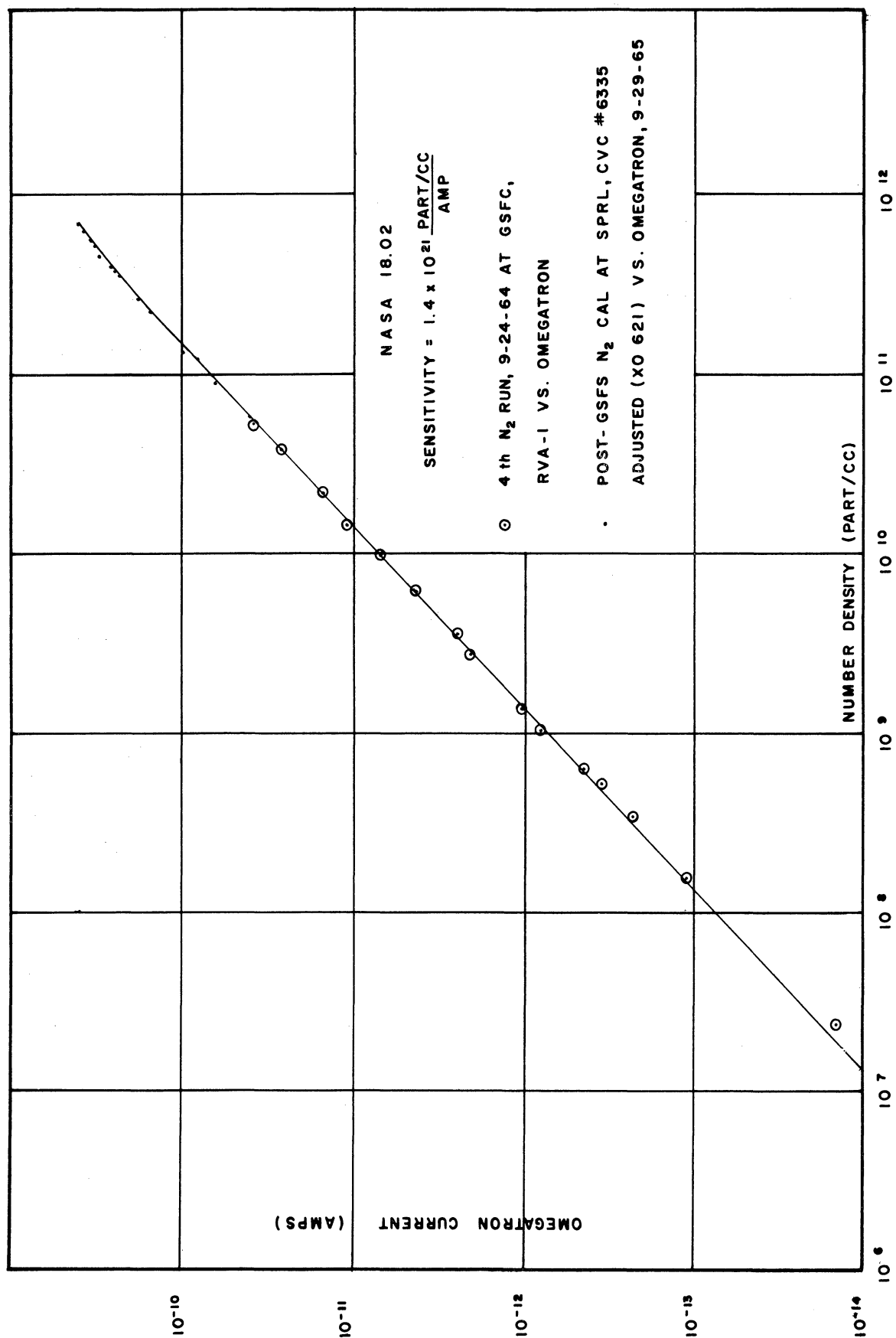


Fig. 13. Omegatron calibration curve.

TABLE 1
OMEGATRON DATA

Omegatron Gauge Parameters

Beam Current	2.0 μ a
Electron collector bias	+70.2 volts
Filament bias	-91.9 volts
Cage bias	- 0.208 volts
Top bias	- 0.609 volts
RF amplitude	
M28	4.0 volts P-P
M32	4.0 volts P-P
M16	4.0 volts P-P
RF frequency	
M28	131.26 kc
M32	116.27 kc
M16	224.66 kc

Monitor

XV +4.5 calibrate	4.490 volts
XV +4.0 calibrate	3.996 volts
Filament	
OFF	0.108 volts
ON	3.111 volts
Beam	
OFF	0.238 volts
ON	2.975 volts
Thermistor pressure Filament OFF	1.643 volts
(zero pressure) Filament ON	1.575 volts
Bias	4.058 volts
RF	
M28	3.303 volts
M32	2.227 volts
M16	1.524 volts

Calibration

Sensitivity	$1.4 \times 10^{21} \frac{\text{part.}}{\text{cm}^3 \text{amp}}$
Maximum linear pressure (5%)	2×10^{-5} torr

Electrometer amplifier

<u>Range</u>	<u>Range Indicator</u>	<u>Range Resistor</u>	<u>M28ZPV</u>	<u>M32ZPV</u>	<u>M16ZPV</u>
1	0.0 v	$2.49 \times 10^{10} \Omega$	4.97v	4.97	4.97
2	0.7 v	5.60×10^{10}	4.97	4.97	4.97
3	1.4 v	1.33×10^{11}	4.97	4.97	4.97
4	2.1 v	3.16×10^{11}	4.97	4.97	4.97
5	2.8 v	8.35×10^{11}	4.97	4.97	4.97
6	3.5 v	1.78×10^{12}	4.97	4.97	4.97
7	4.2 v	4.35×10^{12}	4.97	4.97	4.97
8	4.9 v	1.05×10^{13}	4.96	4.99	4.95

calibrate voltage 0.852 volts

Miscellaneous

+28 power current all on	360 ma
Preflight gauge pressure (N_2)	5.8×10^{-4} torr
Magnetic field strength	2600 gauss

In addition to the measurement of the probe current which is normally carried out in TP experiments, a flight comparison of the two probes, was made during this flight. The probes used were a conventional type which has been employed for these measurements in the past and a segmented probe which is designed to study end effects of a cylindrical Langmuir probe. Figure 14 shows the physical dimensions of the two probes.

The following are the specifications of the NASA 18.02 ESP system:

(a) Sensitivity:

Range No. 1	10.0 μ A full scale (4 v)
Range No. 2	1.0 μ A full scale (4 v)
Range No. 3	0.1 μ A full scale (4 v)

(b) Input Power:

1.55 watts average at 28 v.

- (c) ΔV Slope (dv/dt):
 - HI - 80 v/sec.
 - LO - 26.7 v/sec.
- (d) Output:
 - Voltage -0.5 ~ 6.9 v
 - Resistance - < 2K
- (e) System Bias Level:
 - 0.5 v
- (f) System Calibration:
 - ON - 600 m sec
 - Interval - 28.8 sec.
 - Synchronized with ΔV .
- (g) Sequence:
 - ΔV - HI-LO alternated (period: 3.6 sec)
 - Range - Sequential
 - Probe - See Figure 15

5.3 SUPPORT MEASUREMENTS AND INSTRUMENTATION

5.3.1 Lunar Aspect Determination System

The NASA 18.02 TP utilized a lunar aspect sensor identical to the one described in Sounding Rocket Flight Report, NASA 6.11 Thermosphere Probe Experiment. The system functioned properly throughout the flight, and the aspect was determined to an accuracy of approximately $\pm 5^\circ$. The particulars of the data reduction are described by Taeusch, et al. (1965). The velocity vector reference technique was used for this payload.

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-250 Serial Number 1060
Power Amplifier TRFP-2V-1 Serial Number 221
Mixer Amplifier TA58 Serial Number 993

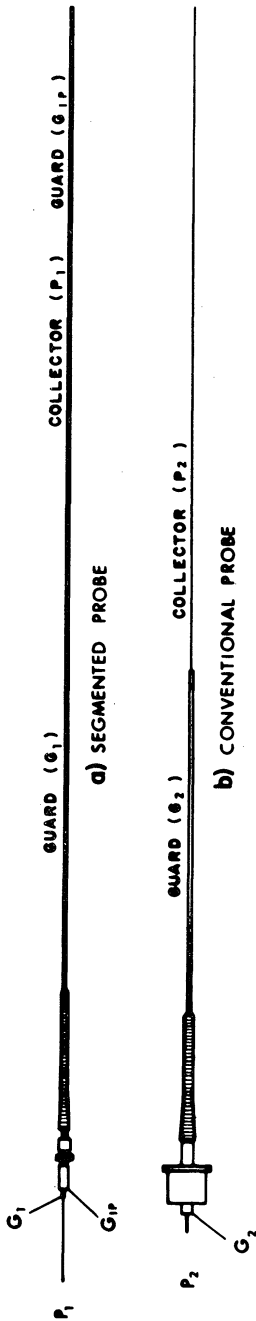


Fig. 14. Electrostatic probes.

	LENGTH (IN.)	COLLECTOR	GUARD	GIP
CONVENTIONAL PROBE				
O.D.	0.022	0.022	0.065	0
AREA (IN ²)	0.023	0.023	1.2	0
SEGMENTED PROBE				
O.D.	2.39	0.083	4.5	2.329
AREA (IN ²)	0.083	0.083	0.083	0.083
		0.023	1.2	0.023

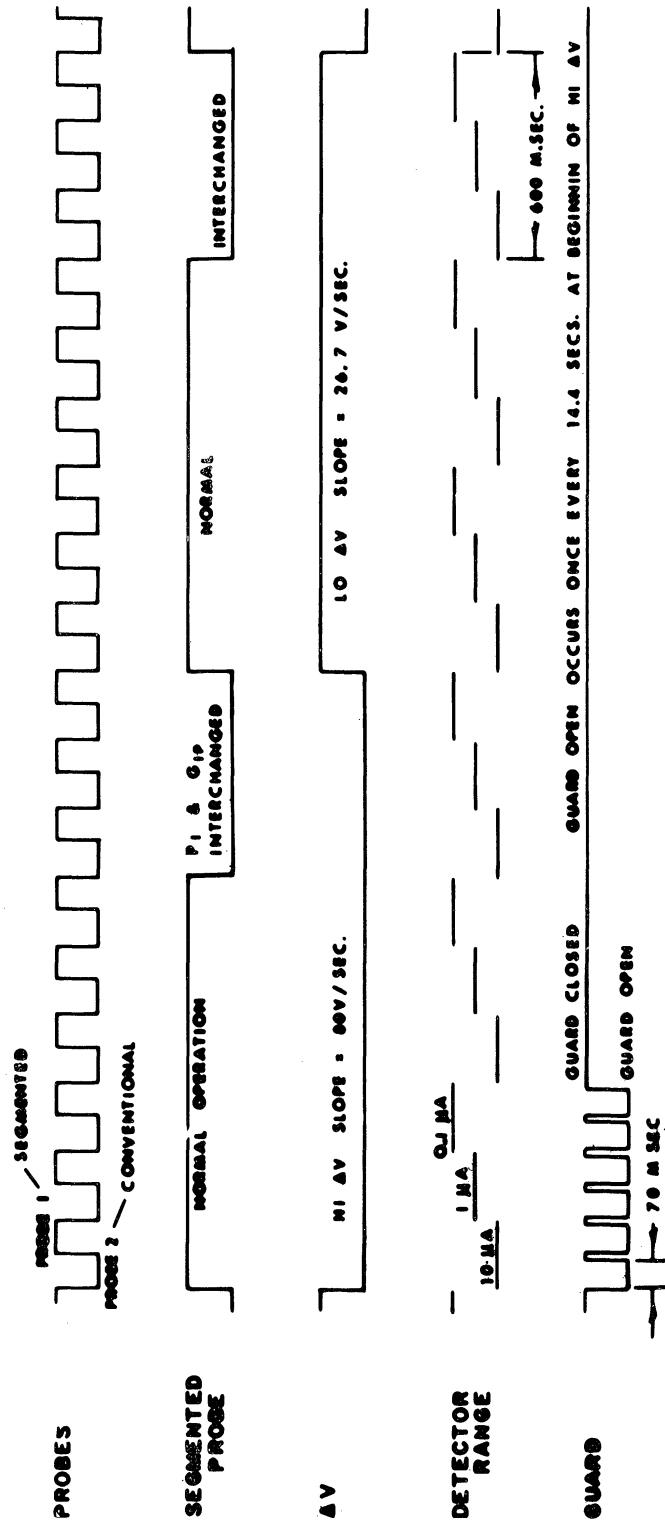


Fig. 15. Probe sequence of operation.

Subcarrier Channels (SCO-type TS58)

IRIG Band	Serial Number	Center Frequency	Nominal Frequency Response	Function
11	1680-5	7.35 k Hz	110 Hz	30 RPS PAM data
12	1988-25	10.5 k Hz	160 Hz	Lunar Aspect Data
13	1702-5	14.5 k Hz	220 Hz	Omegatron X5 amplifier output
16	1730-5	40.0 k Hz	600 Hz	Electrostatic probe data
18	1757-5	70.0 k Hz	1050 Hz	Omegatron amplifier output

Instrumentation power requirements totaled approximately 30 watts, which was supplied by a Yardney HR-1 Silvercell battery pack of a nominal 28 volt output.

5.3.3 Housekeeping Monitors

Outputs from various monitors throughout the instrumentation provide 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 are as follows:

1. Omegatron amplifier range
2. Omegatron amplifier output
3. Omegatron filament voltage monitor
4. Omegatron beam current monitor
5. Omegatron bias voltage converter monitor
6. Omegatron RF voltage and frequency monitor
7. Thermistor - filament regulator temperature
8. Thermistor - omegatron gauge temperature
9. Thermistor - omegatron amplifier temperature
10. Thermistor - omegatron gauge internal pressure
11. Thermistor - transmitter temperature
12. 4.5 v calibrate
13. 4.0 v calibrate
14. Battery voltage monitor
15. Ground control position indicator
16. ESP ΔV monitor
17. ESP ΔV HI-LO
18. ESP 1 or 2 (segmented)

19. ESP (segmented) normal or interchange
20. ESP guard open or closed
21. ESP guard open or closed
22. ESP guard open or closed
23. ESP guard open or closed
24. 0 v calibrate
25. 1 v calibrate
26. 2 v calibrate
27. 3 v calibrate
28. 4 v calibrate
29. 5 v calibrate
30. 5 v calibrate

6. ENGINEERING RESULTS

The Nike Tomahawk was first used in the Thermosphere Probe program in March 1965 on Rocket NASA 12.05 later renumbered NASA 18.01. This first flight used the 6.5" nose cone which had been used previously on Sparobee's throughout the Dumbbell (Carignan and Bruce, 1961) and early TP program. The successful first flight, together with a very successful history in other programs, was used as the basis for a decision to continue the use of the Nike Tomahawk for the TP program. This larger diameter rocket permitted the use of a larger diameter nose cone and since there had been a steadily increasing need for greater instrument diameter, the redesign of a larger, stronger, and refined nose cone was undertaken. 18.02 and 18.03, which were prepared together, were the first to incorporate this new design. The new assembly is shown in Figure 5 in section 4. The new design included the necessary features to handle heavier payload including a larger ejection spring (200 lbs/in with 4 inch travel) and several operational features that had been suggested in using the earlier model. In most respects, however, the design was not significantly changed.

The new design permitted the TP diameter to be increased to 7-1/4" from 6". The Omegatron envelope was redesigned to take advantage of this increase. The magnet was increased in size and was mounted so that its angular position could be adjusted after insertion of the Omegatron gauge, thus eliminating a tedious "cut and try" procedure that had been previously used. The arrangement of the Omegatron electronics subsystems was changed such that the Omegatron could be assembled as an integral system outside the TP. Previously the electronic system had been mounted to the TP center section. This change permitted a shortening of the high impedance collector - electrometer cable by a factor of 3, but more importantly the change greatly simplified the handling of the system during check out, calibration, and assembly.

In 18.02, the larger diameter was not taken advantage of in all circuits since some hardware was already on hand or because of insufficient time to redesign subsystems. In several cases, however, the larger diameter was used to great advantage to simplify packaging and to increase capability.

18.02 and 18.03 were, as indicated, prepared in parallel and 18.03 was launched first by about 12 hours and thus served as the flight prototype for the new design. 18.02 performed essentially as designed and is considered completely successful. The residual roll rate of the TP (1 revolution in 1.4 seconds) was higher than the design value. No satisfactory explanation for this has been made, but it was subsequently decided to increase the included angle of the nose cone halves at ejection from the 135° used in 18.02 to 165°. The despinning effect of the nose cone opening would thus be more effective in reducing roll rate in the TP.

The successful application of the redesigned system on 18.02 and 18.03 makes possible the planning of future flights including other larger instruments to further broaden the capability of the Thermosphere Probe.

7. DATA ANALYSIS

The telemetered data were recorded on magnetic tape at the Churchill telemetry station. One set of real time paper records for quick look evaluation of the results were also obtained. A section of a 10 inch per second record is shown in Figure 16. The omegatron, housekeeping and aspect data were reduced to engineering parameters from paper records, run at 10 inches per second, using a Gerber GDDRS data reader and scanner. The paper records used for data reduction were recorded from the magnetic tape masters. Also, a program was written which allowed digitizing the channel outputs by computer techniques and transferring the outputs into engineering terms for comparison with the "hand read" data. This was a "first step" in a system program now nearing completion which will allow complete automatic data reduction of the omegatron output data in the near future.

Tracking data for trajectory determination were obtained from the MPS-19 Radar. An on-board Vega S Band Radar Beacon was used to facilitate the tracking. Adequate plot-board data were provided to determine the vehicle trajectory.

7.1 TRAJECTORY

The trajectory and velocity information used to determine aspect, density, and temperature data as a function of altitude were obtained by fitting a smooth theoretical trajectory to the radar plot-board data. The theoretical trajectory is programmed for computer solution similar to that described by Parker (1962). The output format is shown in Figure 17. The trajectory is shown in Figure 18. The analysis of minimum angle of attack (α) as described by Taeusch et al. (1965) is also incorporated in the program and the output of the computer furnishes α and $\cos \alpha$ versus time, altitude, etc. A plot of the NASA 18.02 α versus altitude is given in Figure 19.

7.2 AMBIENT N₂ 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:

$$n_{a_{N_2}} = \left(\frac{\Delta n_i u_i}{2 \sqrt{\pi} V \cos \alpha} \right)_{N_2} K(S, \alpha)$$

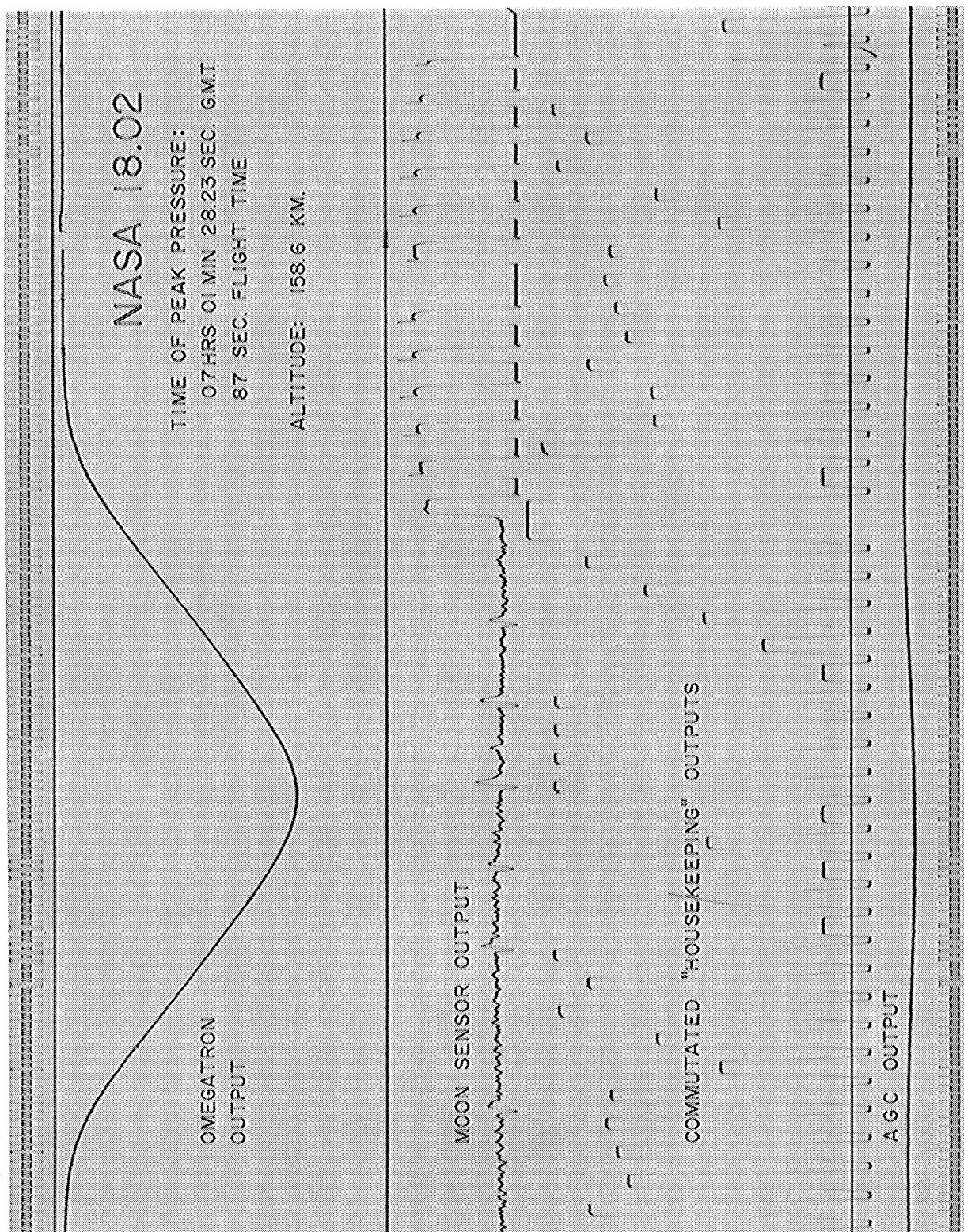


Fig. 16. 10 inch per second paper record.

SPACE PHYSICS RESEARCH LABORATORY
UNIVERSITY OF MICHIGAN
THURSDAY, JANUARY 06, 1966

TRAT 3

-Good-

N A S A 18.02 T P 10

LAUNCH TIME (GMT)

YEAR 1965
DAY 314
HOUR 7
MINUTE 0
SECOND 1.000

INITIAL CONDITIONS

TIME 63.000 SECONDS FROM LAUNCH
ALTITUDE 372200.0 FT
RANGE 66420.0 FT
VELOCITY 6607.5 FT/SEC
FLIGHT PATH ANGLE 82.6680 DEGREES UP FROM LOCAL HORIZONTAL PLANE
AZIMUTH 94.7000 DEGREES EAST OF LOCAL NORTH
LONGITUDE -93.6999 DEGREES (+EAST)
LATITUDE 58.7242 DEGREES (+NORTH)

INPUT MOMENTUM VECTOR

.901810 - .358240 - .241640

cone correction + 4.1°

PEAK PARAMETERS

TIME	ALTITUDE	RANGE	POSITION	INERTIAL VELOCITY	VELOCITY	WRT EARTH	FIXED VEL	AZIMUTH	ELEVATION	ALPHA
SEC	FEET	FEET	LATITUDE	FEET	FEET	METERS	FEET	DEGREES	DEGREES	
	METERS	METERS	LONGITUDE	TOTAL	TOTAL	TOTAL	X	INERTIAL	INERTIAL	COSINE
	V* COS ALPHA			HORIZONTAL	HORIZONTAL	HORIZONTAL	Y	WRT EARTH	WRT EARTH	PHI V
				VERTICAL	VERTICAL	VERTICAL	Z			
283.93	1086951	235104	58.66	1593	486	765	758	94.26	-0.00	74.915
	331303	71660	-92.82	1593	486	765	-101	98.90	-0.00	.260
	61			0	-0	0	-11			-47.7790

Fig. 17. Trajectory program computer output.

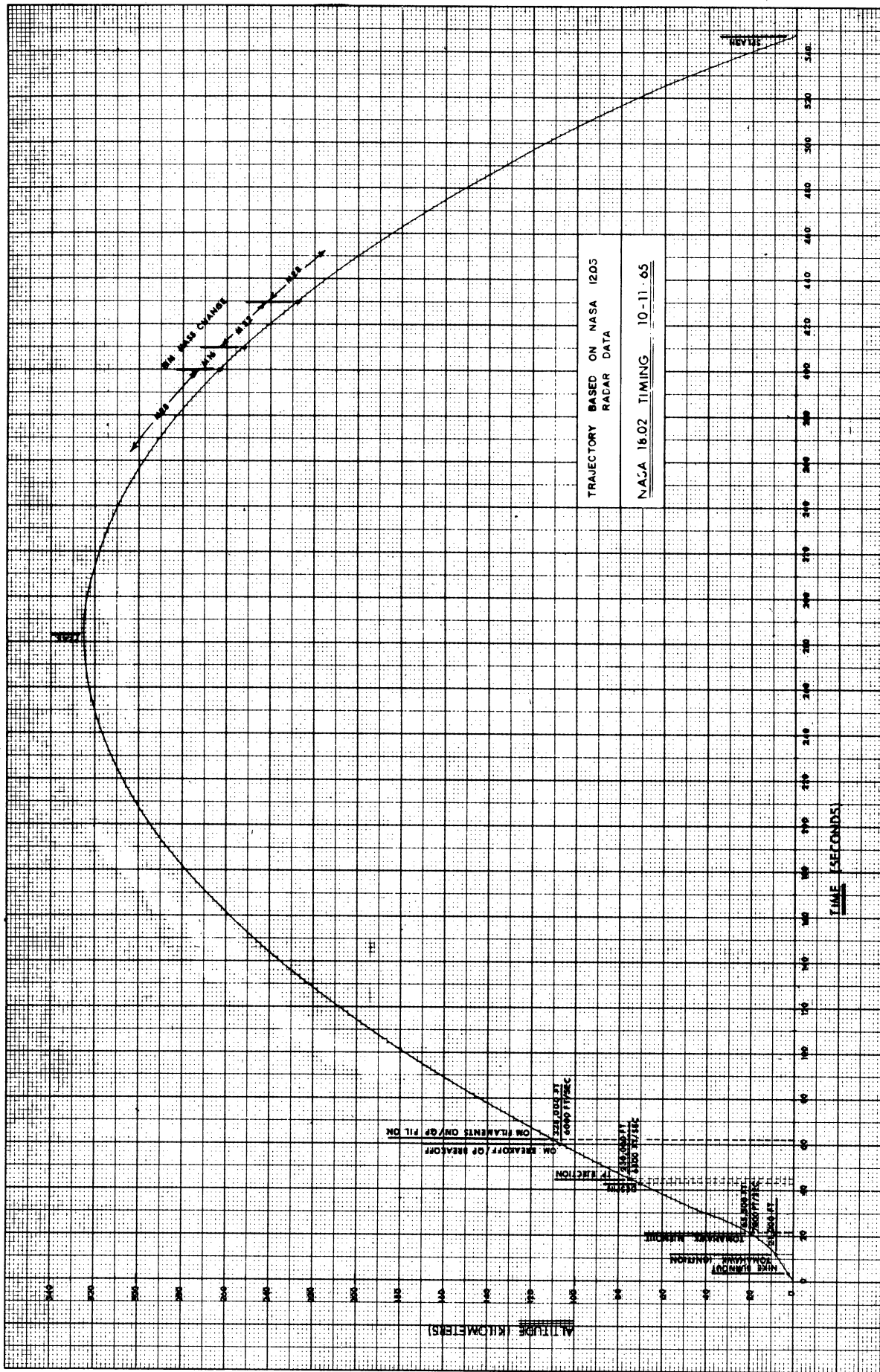


Fig. 18. Trajectory and timing.

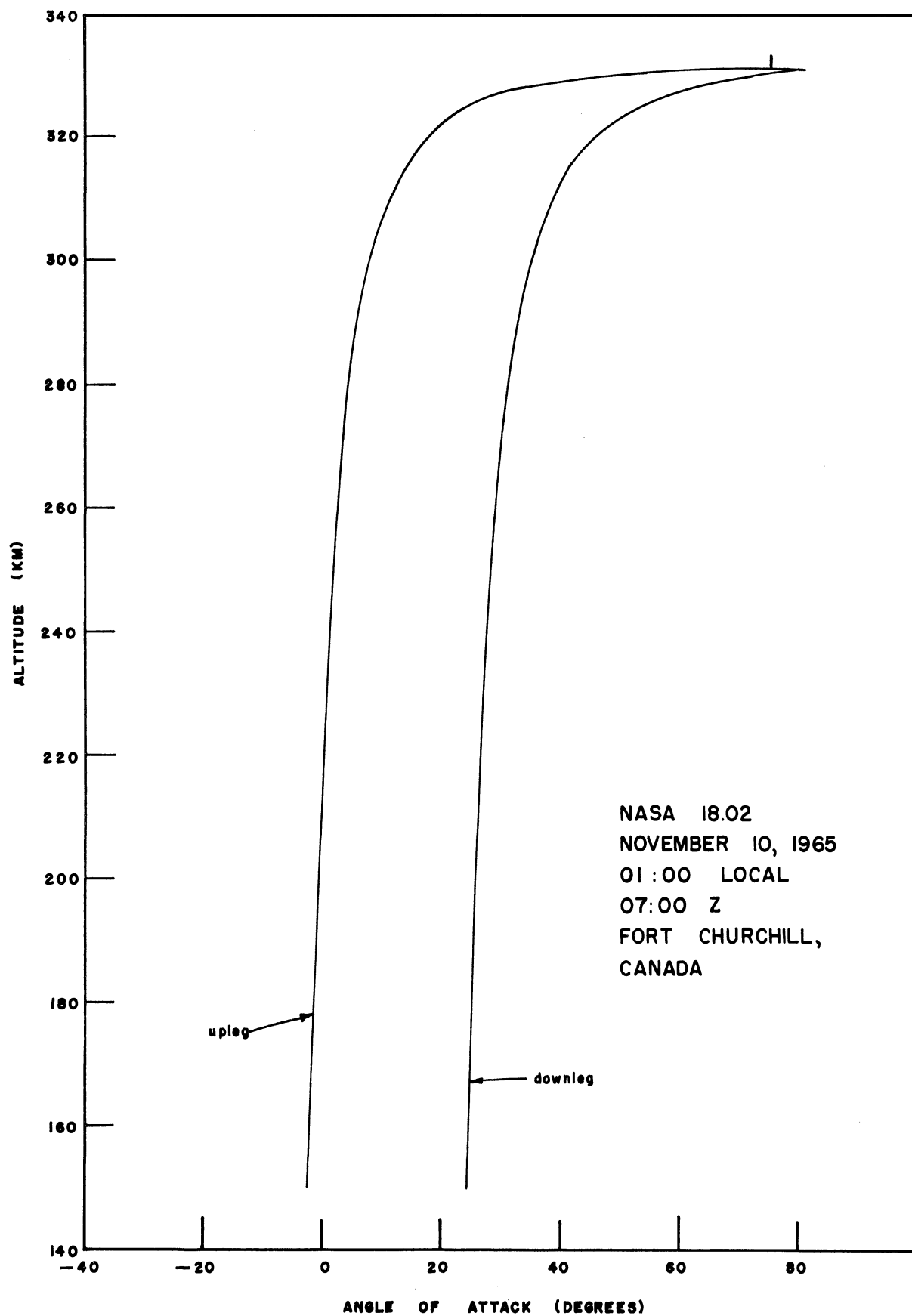


Fig. 19. Angle of attack (α) versus altitude.

where:

n_{aN_2} = Ambient N_2 number density

Δn_i = Maximum minus minimum gauge number density during one tumble

$u_i = \sqrt{\frac{2kT_i}{m}}$ most probable speed 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

$K(S, \alpha)$ = Correction factor required due to imperfect geometry.
(See Spencer, Taeusch, Carignan, 1966; also Niemann and Frederick, 1966)

ΔI_i , the difference between the maximum (peak) omegatron gauge current and the minimum (background) gauge current is shown versus flight time in Figure 20. 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 21. 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.

$\cos \alpha$ is obtained from the aspect analysis described by Taeusch et al. (1965). Since the uncertainty in $\cos \alpha$ 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 19, the upleg data were obtained for angles of attack less than 5° , which results in an uncertainty in $\cos \alpha$ of less than $\pm 1\%$ for

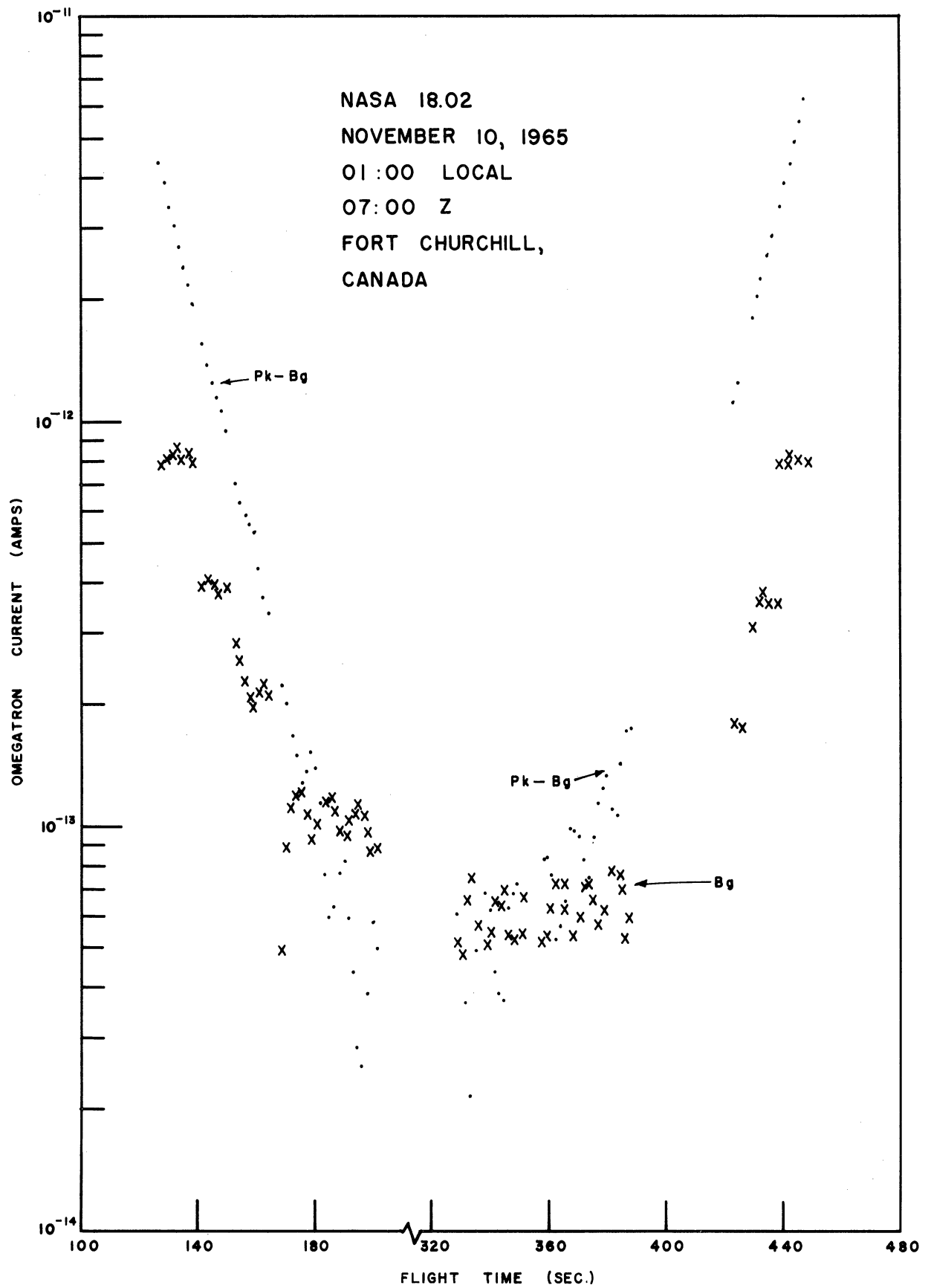


Fig. 20. Omegatron current output versus flight time.

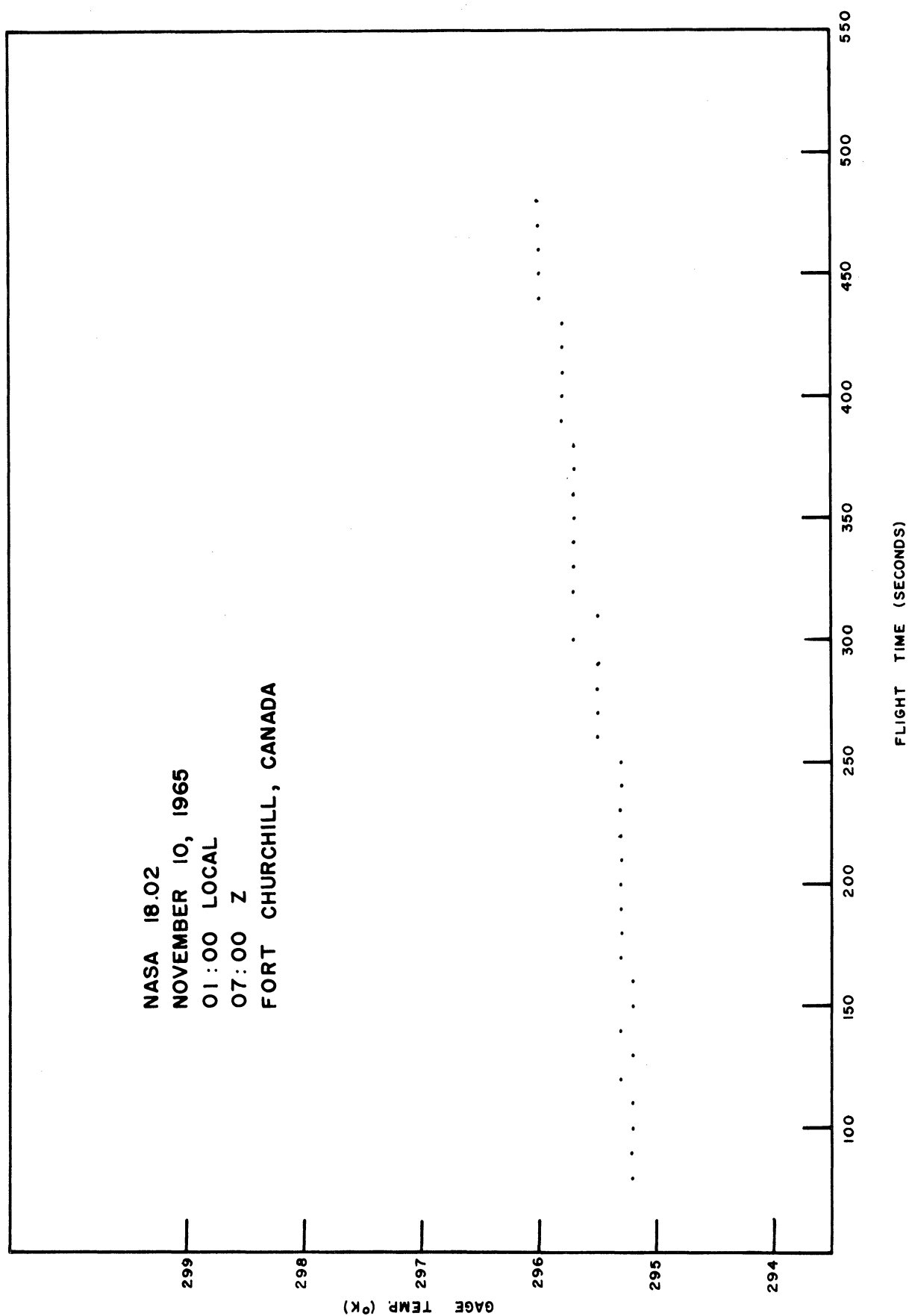


Fig. 21. Omegatron wall temperature versus flight time.

an uncertainty in α of approximately $\pm 5^\circ$. The upleg data were used as control data.

$K(S, \alpha)$ versus altitude is shown in Figure 22. As can be seen, the maximum correction is about 15%, or $K(S, \alpha) = .85$ at about 150 kilometers altitude for the upleg data. The correction factors, determined from empirical and theoretical studies, are believed known to better than 2%.

The resulting ambient N_2 number density, obtained from the measured quantities described above, is shown in Figure 23. The uncertainty in the ambient density due to the combined uncertainties in the measured quantities is $\pm 10.7\%$ rms relative and $\pm 25.3\%$ rms absolute.

7.3 TEMPERATURE

The ambient N_2 temperature profile shown in Figure 24 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 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 $\pm 5\%$ absolute.

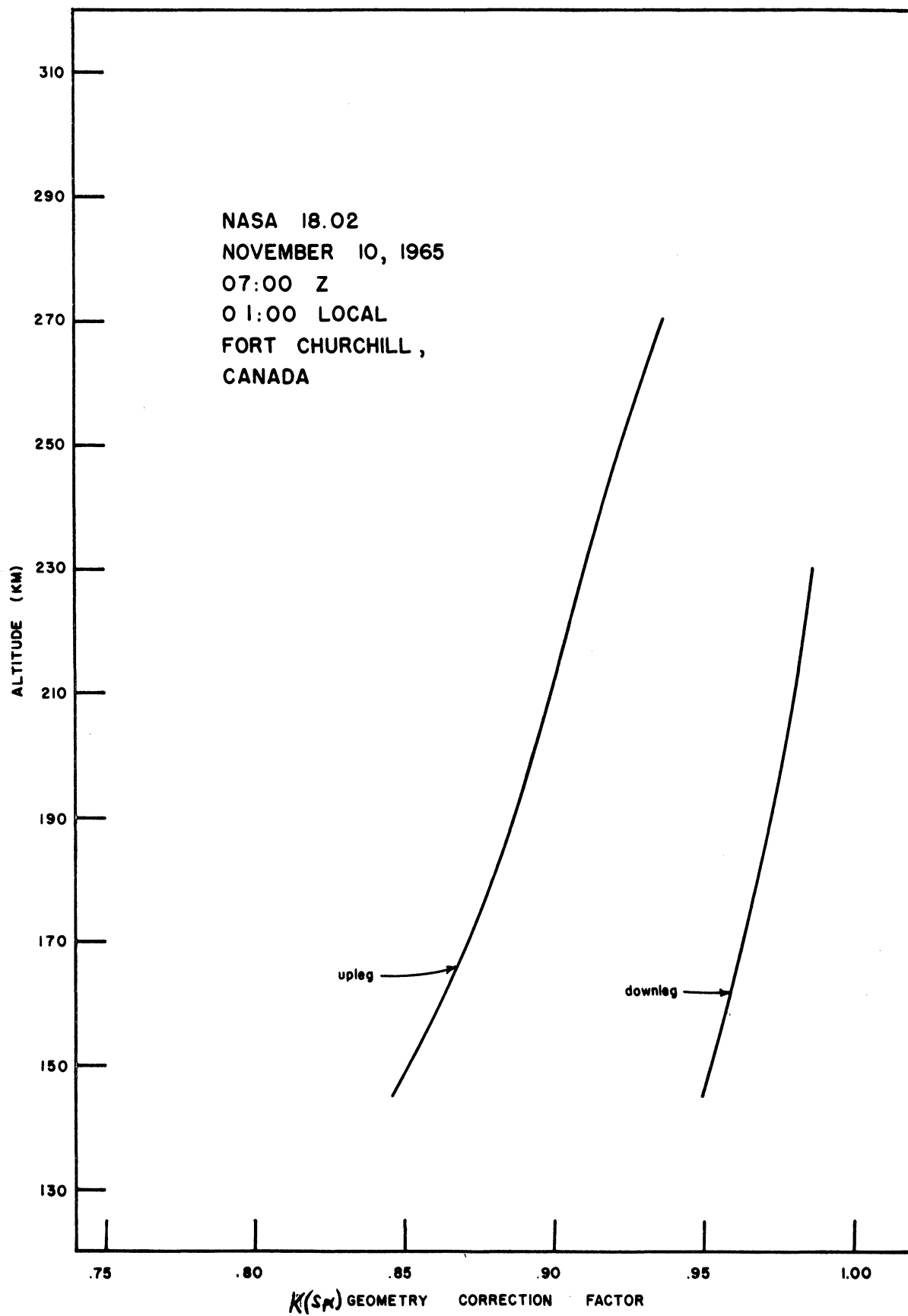


Fig. 22. $K(S, \alpha)$ versus altitude.

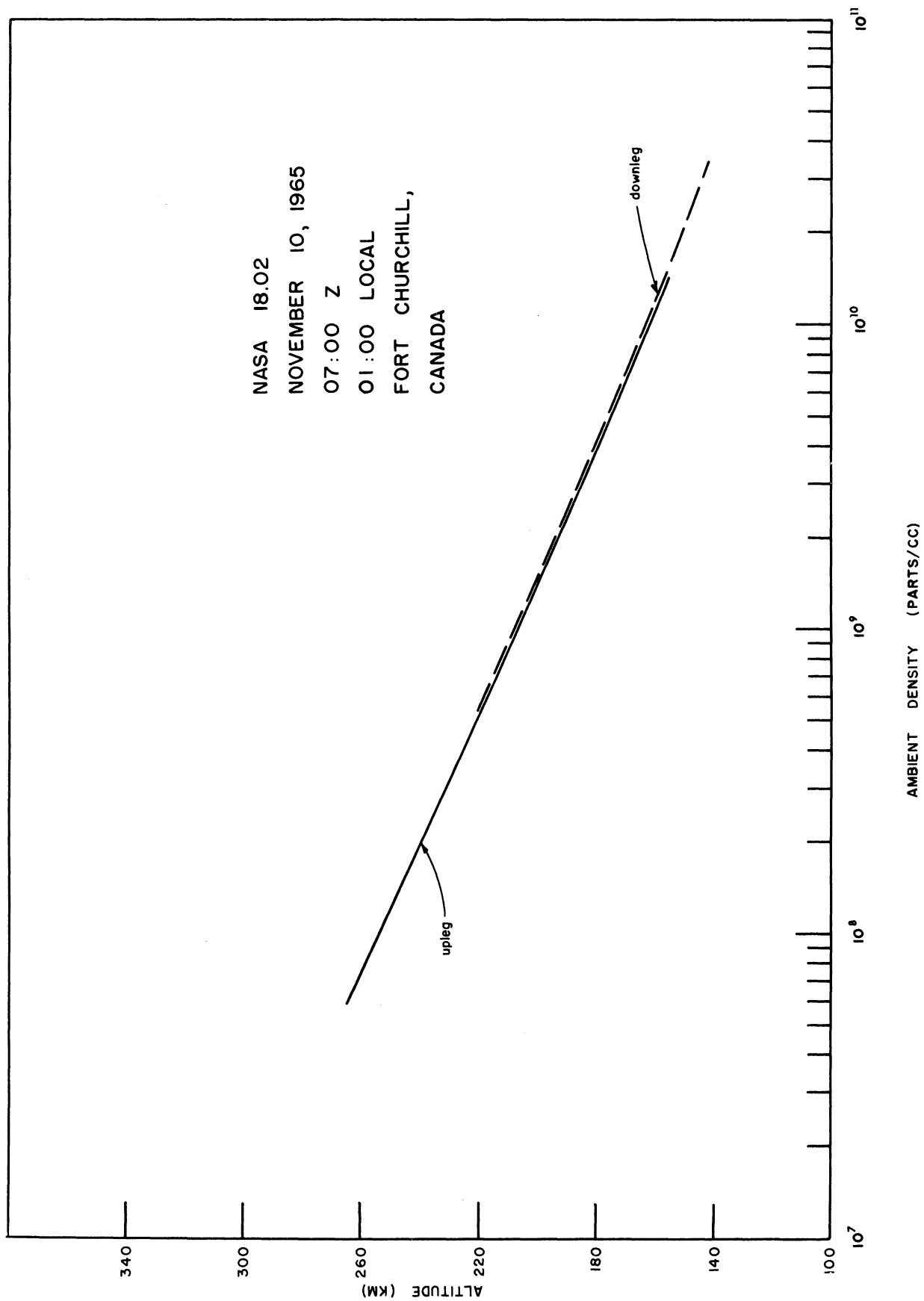


Fig. 23. Ambient N₂ number density versus altitude.

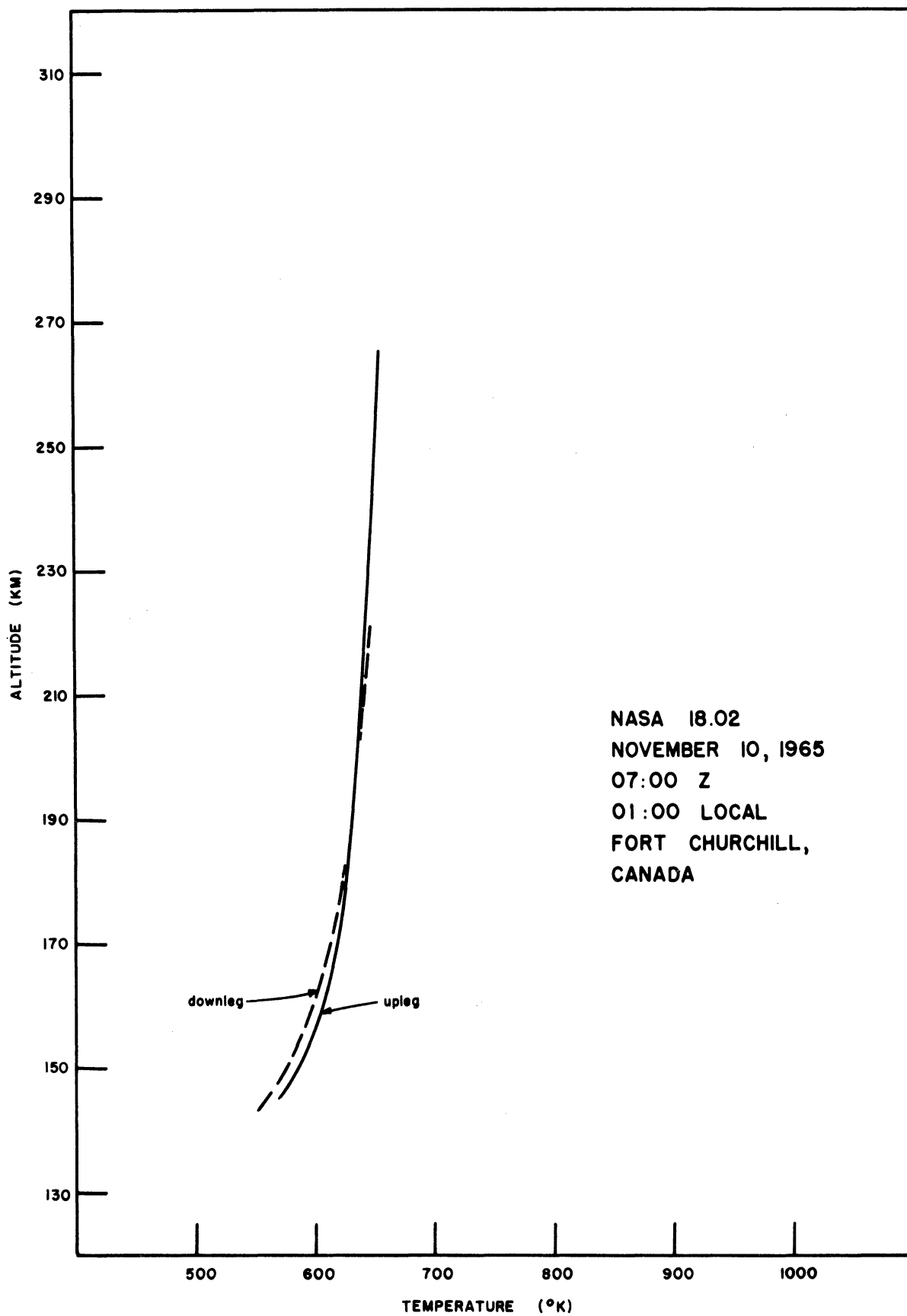


Fig. 24. Ambient N₂ temperature versus altitude.

FINAL N₂ DENSITY AND TEMPERATURE
(After application of η , geometry correction factor)

NASA 18.02
(upleg)

November 10, 1965

07:00 Z

01:00 LOCAL

Fort Churchill, Manitoba

ALTITUDE Km	DENSITY (part/cc)	TEMPERATURE °Kelvin
144	2.74×10^{10}	565
145	2.59	570
150	1.91	587
155	1.43	598
160	1.90×10^{10}	606
165	8.32×10^9	613
170	6.41	618
175	4.98	623
180	3.85	626
185	3.0	630
190	2.33	632
195	1.81	635
200	1.41	637
205	1.09×10^9	639
210	8.49×10^8	641
215	6.62	643
220	5.17	644
225	4.03	646
230	3.13	647
235	2.45	648
240	1.93	649
245	1.52	650
250	1.20×10^8	651
255	9.50×10^7	652
260	7.53	653
265	5.97×10^7	654

FINAL N₂ DENSITY AND TEMPERATURE
(After application of η , geometry correction factor)

NASA 18.02
(downleg)

November 10, 1965

07:00 Z

01:00 LOCAL

Fort Churchill, Manitoba

ALTITUDE Km	DENSITY (part/cc)	TEMPERATURE ° Kelvin
142	3.36×10^{10}	546
145	2.78	560
150	2.04	576
155	1.52	588
160	1.15×10^{10}	598
165	8.74×10^9	606
170	6.69	613
175	5.13	619
180	3.95	624
185	3.06	628
190	2.38	632
195	1.86	635
200	1.45	638
205	1.13×10^9	641
210	8.80×10^8	643
215	6.87	645
220	5.37	647
221	5.13×10^8	647

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