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THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
Department of Electrical Engineering
Space Physics Research Laboratory

Final Report

MEASUREMENT OF THE EARTH'S ATMOSPHERE

D. R. Taeusch
A. F. Nagy

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OFFICE OF RESEARCH ADMINISTRATION · ANN ARBOR

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MEASUREMENT OF THE EARTH'S ATMOSPHERE

Prepared on behalf of the project by:

D. R. Taeusch
A. F. Nagy

ORA Project 04673

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INTRODUCTION:

This is the final report describing the research effort supported under Task Order Contract NASr-54(01). This research was directed toward the research and development of rocket probe techniques to measure the temperature, pressure and density of the earth's atmosphere. The effort was divided into three tasks, namely:

1. Analysis of data from nine (9) IGY rocket flights.
2. Collection and analysis of Pitot-Static pressure data from three (3) rocket probe flights at altitudes between 40 and 140 kilometers.
3. Collection and analysis of data from pressure gages and an electron temperature probe in a separable package at an altitude of approximately 250 kilometers.

The results of the three efforts will be discussed separately.

TASK I. IGY DATA

The analysis of the IGY rocket data was completed and an interpretation of these results was published in the Journal of Geophysical Research.

References:

Spencer, N. W., Boggess, R. L., and Taeusch, D. R., "Seasonal Variation of Density and Temperature Over Churchill, Canada, during Solar Maximum," J. Geophysical Research, 69 (7), 1367-1379, April 1, 1964.

TASK II. PITOT-STATIC DEVELOPMENT

As a result of the IGY program data, described under Task I of this report, a need was apparent for the development of an improved

pressure measurement system to be used on sounding rockets. The effort under this task was directed toward such a development of a Pitot-Static probe similar to that described by Ainsworth, Fox and La Gow (1961); however, different in that it would utilize radioactive ionization gauges, rather than diaphragm gauges, for the transducers. The radioactive ionization gauges were to be improved versions of those described by Spencer and Boggess (1959). The improved versions are called Densatrons, a single "black box" which includes an ionization gauge, a multi-range linear electrometer amplifier, and all required power conversion for gauge operation.

The result of this effort was a Pitot-Static probe design shown in Figure 1. The probe contains three Densatron units, one for an impact or pitot pressure measurement, one for the ambient or static pressure measurement within a manifolded chamber with ten orifices symetrically located about the axis of the probe, and one for measuring the roll modulated pressure on the side of the tube for atmospheric wind determination. Other instrumentation included a magnetometer and optical sun-earth aspect sensor for aspect determination, the TM transmitter and a DOVAP transponder. Two such payloads were launched under the contract. NASA 14.19 was launched on June 6, 1962; NASA 14.20 was launched on December 1, 1962, both at Wallops Island, Va. The data from these flights are presented in Figures 2 through 7 and tables 1 and 2.

REFERENCES

1. Ainsworth, J. E., D. F. Fox, and H. E. LaGow, Upper-atmosphere structure measurement made with the pitot-static tube, J. Geophys. Res., 66 (10), 3191-3212, October 1961.

2. Spencer, N. W., and R. L. Boggess, A radioactive ionization gage pressure measurement system, J. Am. Rocket Soc., 29, January 1959.

Fig. 1

AMBIENT PRESSURE, TEMPERATURE, AND DENSITY

OVER WALLOPS ISLAND, VIRGINIA

UNIV. OF MICH., PITOT-STATIC PROBE

NASA 14.19

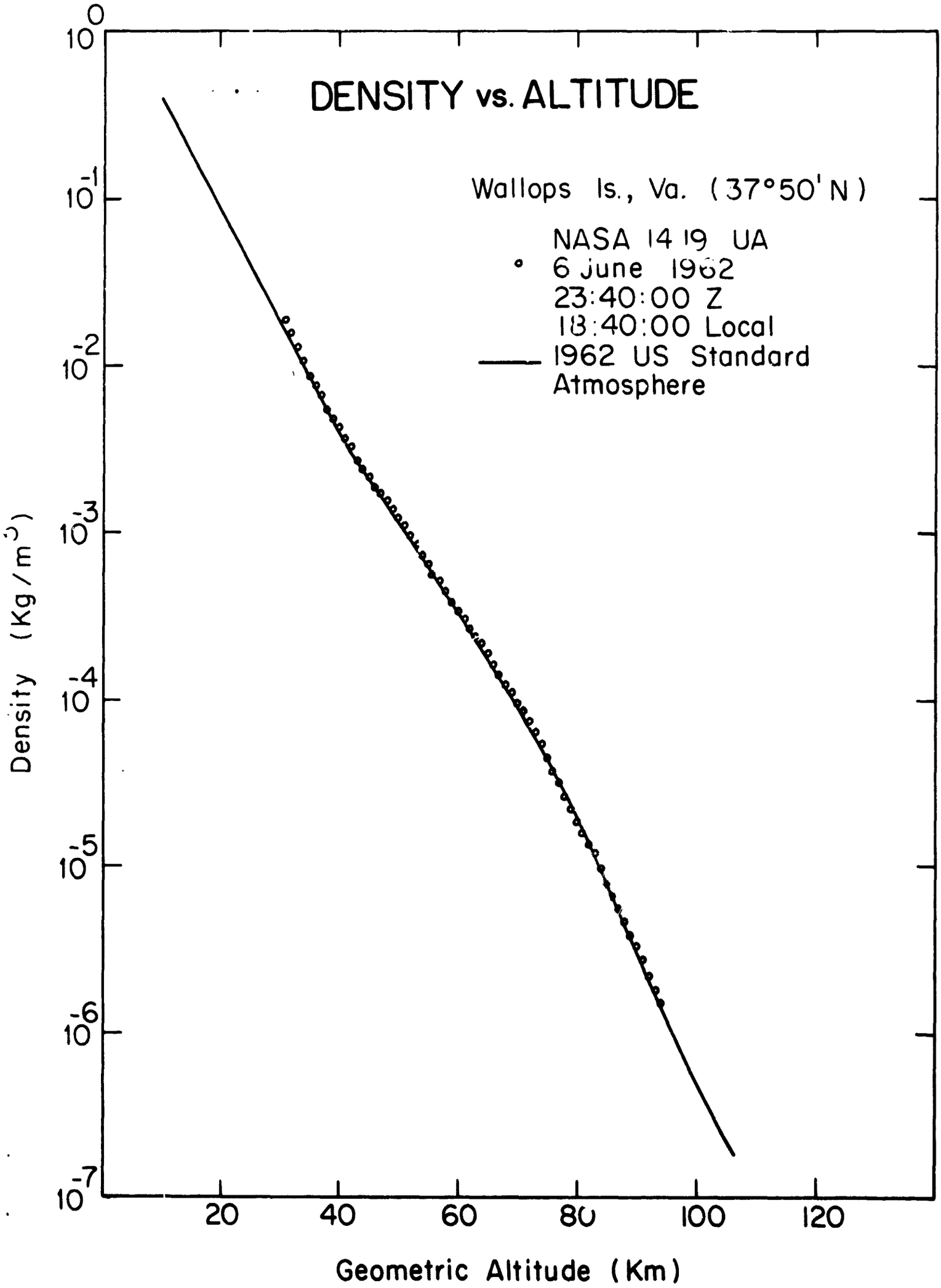
6 June, 1962

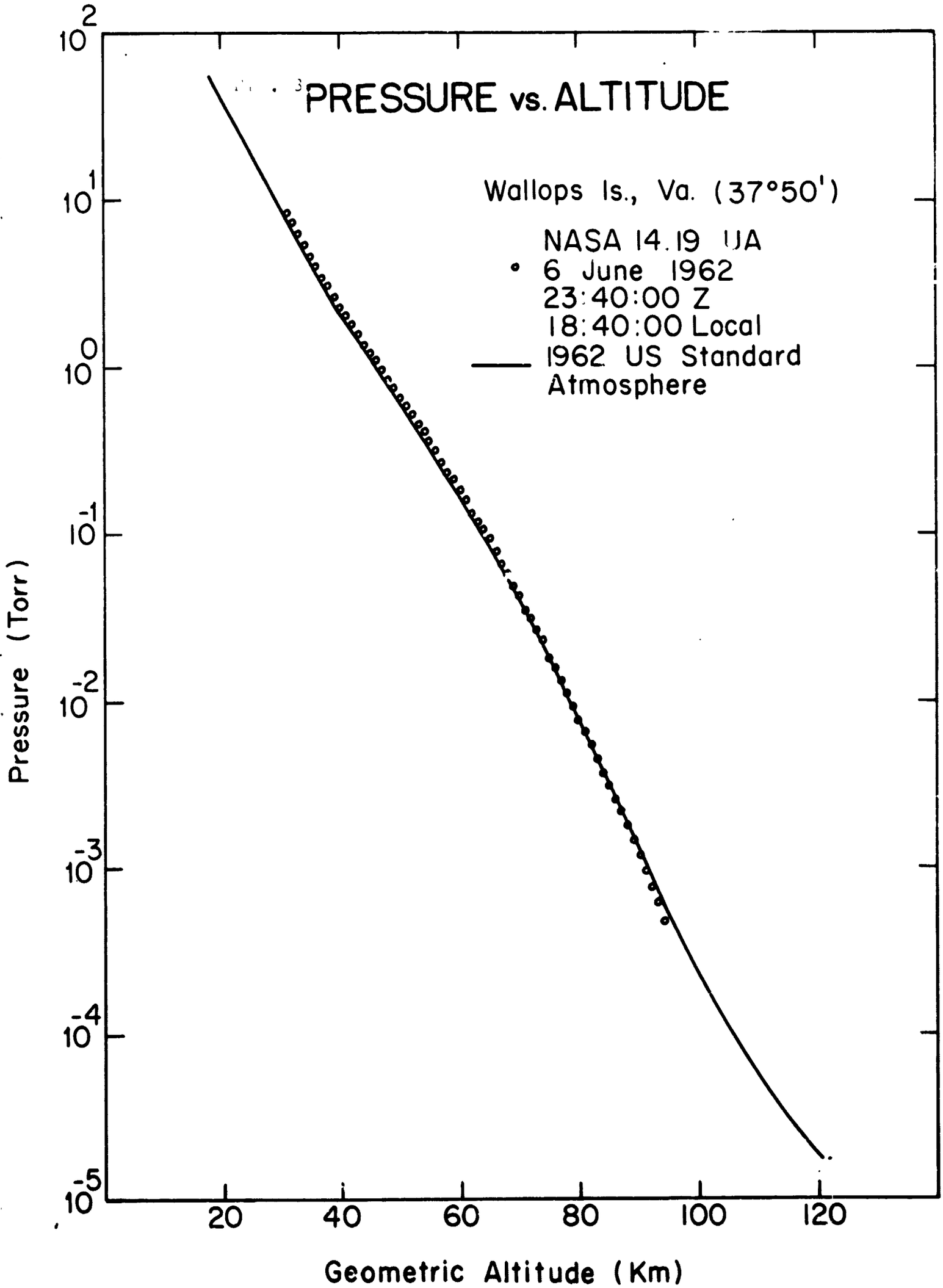
23:40:00 Z

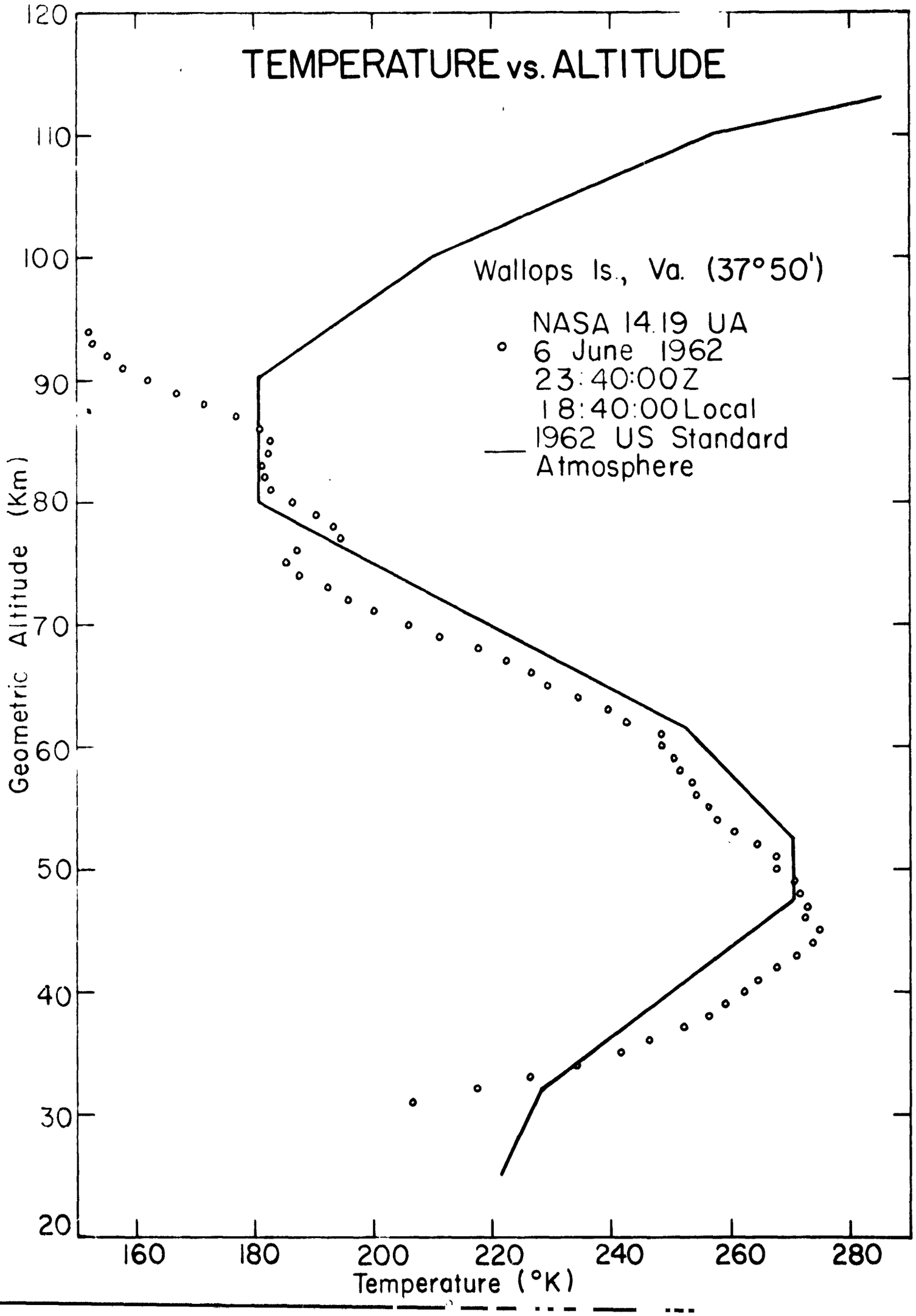
Geometric Altitude (km.)	Ambient Pressure (mm Hg)	Ambient Density (Kg/m^3)	Ambient Temperature (°K)
31	8.46×10^{0}	1.90×10^{-2}	206.7
32	7.20	1.54	217.2
33	6.19	1.27	226.4
34	5.35	1.06×10^{-2}	234.5
35	4.64	8.93×10^{-3}	241.2
36	4.04	7.61	246.7
37	3.52	6.50	252.0
38	3.0[illegible]	5.59	256.3
39	[illegible].70	4.85	259.0
40	2.37	4.20	262.3
41	2.09	3.66	264.7
42	1.84	3.19	267.3
43	1.62	2.78	271.0
44	1.43	2.43	273.9
45	1.26	2.14	274.6
46	1.12×10^{0}	1.90	272.5
47	9.86×10^{-1}	1.68	272.5
48	8.71	1.49	271.4
49	7.69	1.32	270.6
50	6.79	1.18	267.2
51	5.98	1.04×10^{-3}	267.3
52	5.28	9.26×10^{-4}	264.7
53	4.64	8.27	260.6
54	4.07	7.33	257.8
55	3.57	6.47	256.1
56	3.12	5.71	254.3
57	2.74	5.01	253.7
58	2.40	4.42	251.8
59	2.10	3.89	250.1
60	1.83	3.42	248.8
61	1.60	3.00	248.2
62	1.40	2.68	242.3
63	1.22	2.36	239.5
64	1.06×10^{-1}	2.09	234.9
65	9.16×10^{-2}	1.85	229.8
66	7.91	1.62	226.7
67	6.81×10^{-2}	1.42×10^{-4}	222.8

NASA 14.19 Continued

Geometric Altitude (Km.)	Ambient Pressure (mm Hg)	Ambient Density (Kg/m^3)	Ambient Temperature (°K)
68	5.85×10^{-2}	1.25×10^{-4}	217.3
69	4.99	1.10×10^{-4}	210.8
70	4.24	9.59×10^{-5}	205.6
71	3.59	8.34	200.1
72	3.04	7.20	195.9
73	2.56	6.17	192.4
74	2.14	5.31	187.5
75	1.79	4.49	185.3
76	1.50	3.71	187.2
77	1.27	3.04	194.6
78	1.07×10^{-2}	2.57	193.7
79	9.01×10^{-3}	2.20	190.2
80	7.55	1.88	186.6
81	6.30	1.60	183.0
82	5.25	1.34	182.0
83	4.38	1.12×10^{-5}	181.4
84	3.64	9.29×10^{-6}	182.1
85	3.04	7.72	182.8
86	2.53	6.50	180.8
87	2.10	5.51	176.8
88	1.73	4.69	171.4
89	1.42	3.94	166.9
90	1.16×10^{-3}	3.32	161.9
91	9.35×10^{-4}	2.75	157.9
92	7.56	2.26	155.4
93	6.09	1.85	152.9
94	4.88×10^{-4}	1.49×10^{-6}	152.0


DENSITY vs. ALTITUDE
Wallops Is., Va. (37°50' N)
NASA 14 19 UA
6 June 1962
23:40:00 Z
18:40:00 Local
1962 US Standard Atmosphere
Density (Kg/m³)
Geometric Altitude (Km)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
20
40
60
80
100
120


PRESSURE vs. ALTITUDE
Wallops Is., Va. (37°50')
NASA 14.19 UA
6 June 1962
23:40:00 Z
18:40:00 Local
1962 US Standard Atmosphere
Pressure (Torr)
Geometric Altitude (Km)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
20
40
60
80
100
120


TEMPERATURE vs. ALTITUDE
Wallops Is., Va. (37°50')
NASA 14.19 UA
6 June 1962
23:40:00Z
18:40:00 Local
1962 US Standard Atmosphere
Geometric Altitude (Km)
Temperature (°K)
120
110
100
90
80
70
60
50
40
30
20
160
180
200
220
240
260
280

AMBIENT PRESSURE, TEMPERATURE, AND DENSITY

OVER WALLOPS ISLAND, VIRGINIA

UNIV. OF MICH., PITOT-STATIC PROBE

NASA 14.20

1 Dec., 1962

20:34:00 Z

Geometric Altitude (Km.)	Ambient Pressure (mm Hg)	Ambient Density (Kg/m^3)	Ambient Temperature (°K)
33	4.53×10^{0}	1.05×10^{-2}	200.5
34	3.84	8.45×10^{-3}	211.0
35	3.31	6.24	246.5
36	2.90	5.23	257.3
37	2.54	4.81	244.8
38	2.20	4.41	231.7
39	1.90	3.84	229.7
40	1.64	3.29	231.4
41	1.42	2.78	237.1
42	1.23	2.34	244.7
43	1.09×10^{0}	1.93	259.9
44	9.50×10^{-1}	1.64	269.1
45	8.39	1.43	272.6
46	7.41	1.27	270.9
47	6.54	1.13	268.7
48	5.76	1.01×10^{-3}	265.0
49	5.07	9.03×10^{-4}	260.8
50	4.45	8.00	258.5
51	3.91	7.02	258.7
52	3.43	6.11	261.0
53	3.02	5.28	265.3
54	2.66	4.59	268.8
55	2.35	4.03	270.4
56	2.07	3.54	271.7
57	1.83	3.13	271.2
58	1.62	2.77	271.0
59	1.42	2.49	265.8
60	1.25	2.21	263.6
61	1.10×10^{-1}	1.97	260.1
62	9.68×10^{-2}	1.75	257.0
63	8.50	1.54	256.3
64	7.46	1.36	254.8
65	6.53	1.22	248.7
66	5.71	1.08×10^{-4}	245.5
67	4.98	9.50×10^{-5}	243.6
68	4.34×10^{-2}	8.23×10^{-5}	245.2

NASA 14.20 Continued

Geometric Altitude (Km.)	Ambient Pressure (mm Hg)	Ambient Density (Kg/m^3)	Ambient Temperature (°K)
69	3.80×10^{-2}	7.11×10^{-5}	247.9
70	3.32	6.12	251.9
71	2.91	5.35	252.2
72	2.54	4.67	253.0
73	2.23	4.09	253.0
74	1.95	3.61	251.4
75	1.71	3.22	246.4
76	1.49	2.92	236.4
77	1.28	2.61	228.5
78	1.11×10^{-2}	2.28	226.3
79	9.59×10^{-3}	1.95	228.4
80	8.29	1.67	230.4
81	7.18	1.42	234.8
82	6.24	1.20	241.6
83	5.45	1.03×10^{-5}	245.6
84	4.76	8.88×10^{-6}	249.1
85	4.17	7.81	248.1
86	3.64	6.89	245.7
87	3.18	6.07	243.1
88	2.76	5.37	239.2
89	2.41	4.73	236.3
90	2.09	4.16	233.0
91	1.81	3.67	228.8
92	1.56	3.22	225.6
93	1.35	2.84	220.5
94	1.16×10^{-3}	2.49	216.0
95	9.92×10^{-4}	2.17	212.4
96	8.48	1.86	211.9
97	7.26	1.60	210.6
98	6.18	1.37	209.7
99	5.26	1.17	208.9
100	4.49	1.00×10^{-6}	208.4
101	3.82	8.54×10^{-7}	208.0
102	3.26	7.33	206.6
103	2.78	6.21	207.8
104	2.37	5.19	212.5
105	2.04	4.33	218.3
106	1.75	3.60	226.2
107	1.51×10^{-4}	3.09×10^{-7}	227.6

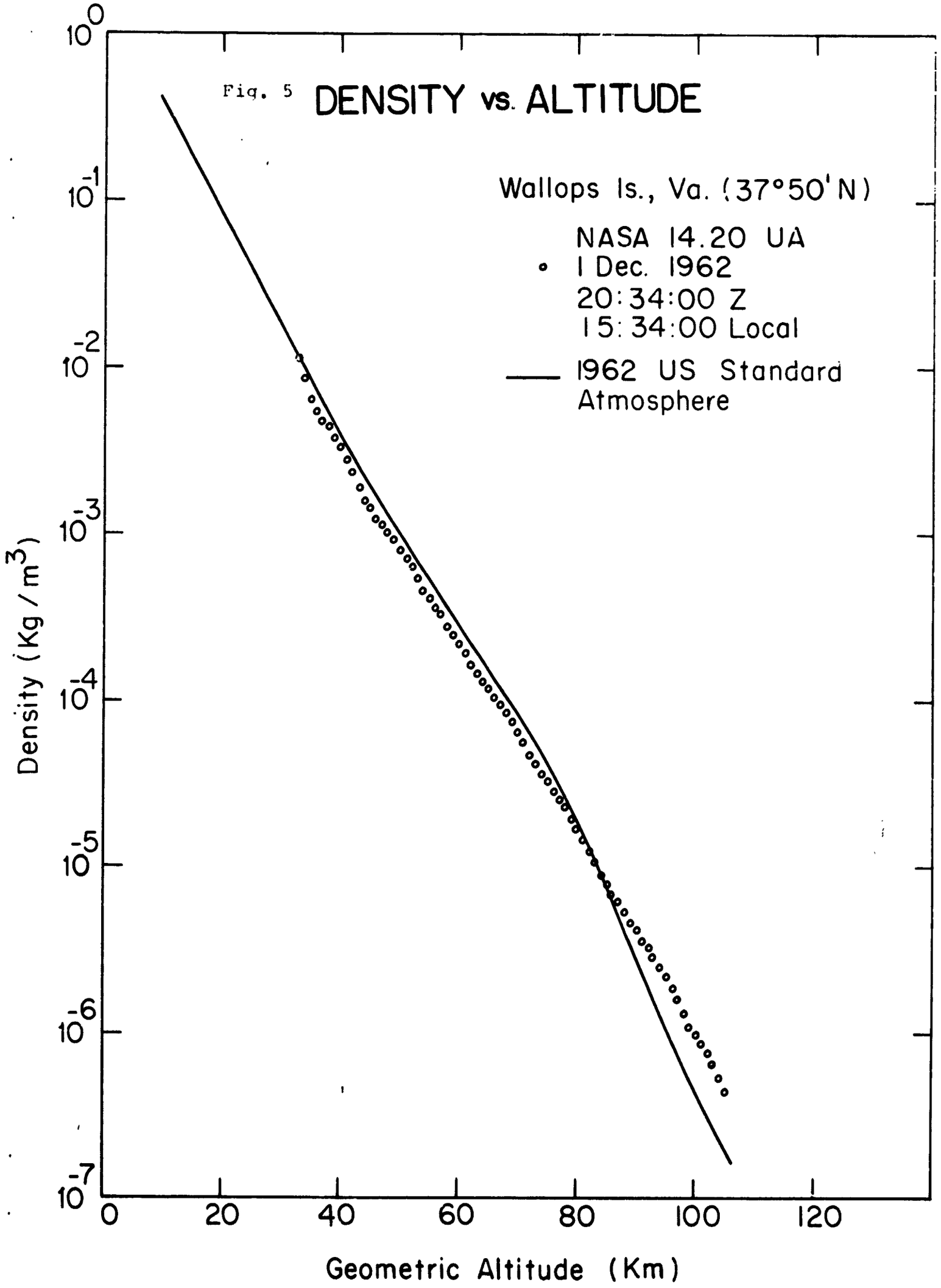


Fig. 5 DENSITY vs. ALTITUDE
Wallops Is., Va. (37°50' N)
NASA 14.20 UA
1 Dec. 1962
20:34:00 Z
15:34:00 Local
1962 US Standard Atmosphere
Density (Kg / m3)
Geometric Altitude (Km)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0
20
40
60
80
100
120

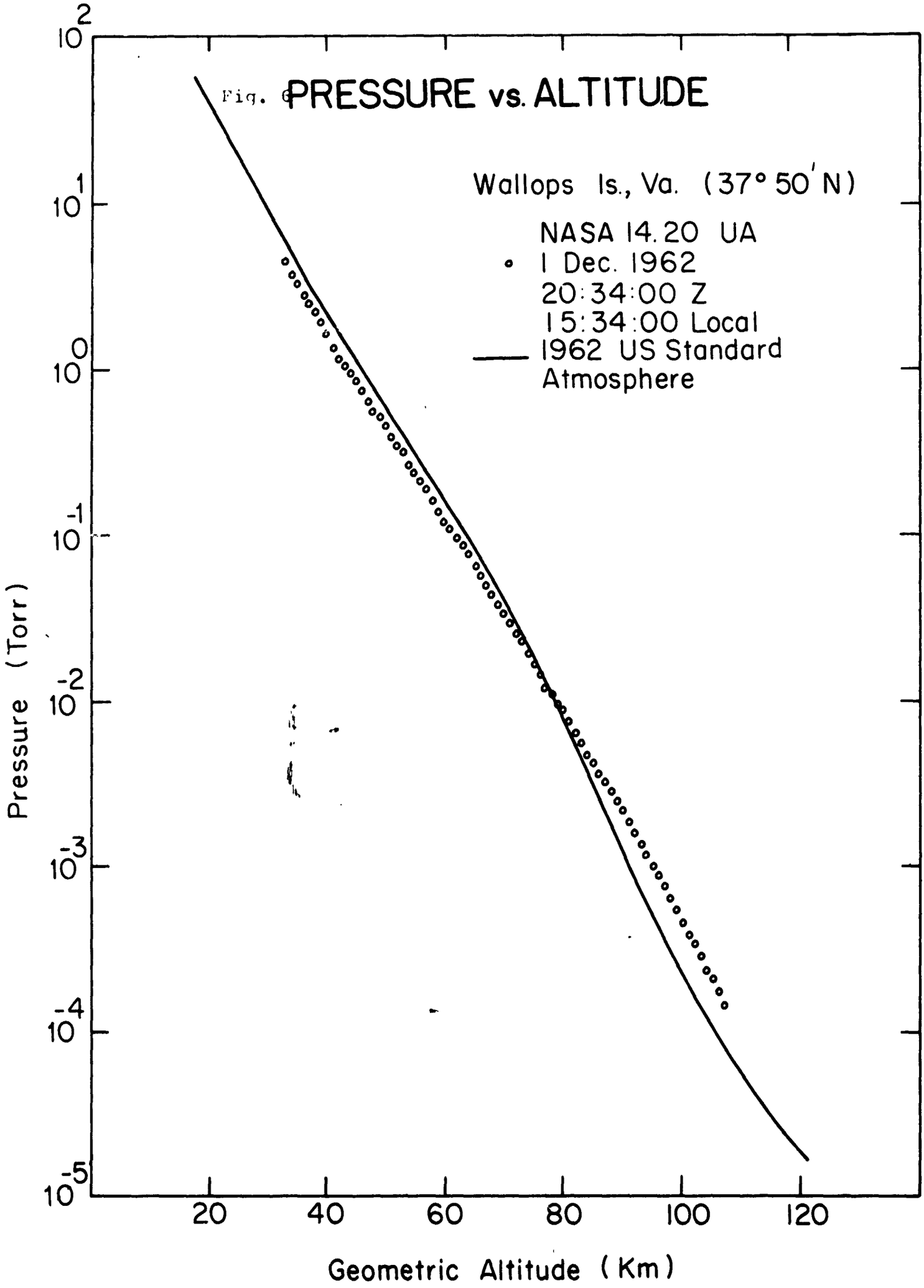


Fig. 6 PRESSURE vs. ALTITUDE
Wallops Is., Va. (37° 50' N)
NASA 14.20 UA
1 Dec. 1962
20:34:00 Z
15:34:00 Local
1962 US Standard Atmosphere
Pressure (Torr)
Geometric Altitude (Km)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
20
40
60
80
100
120

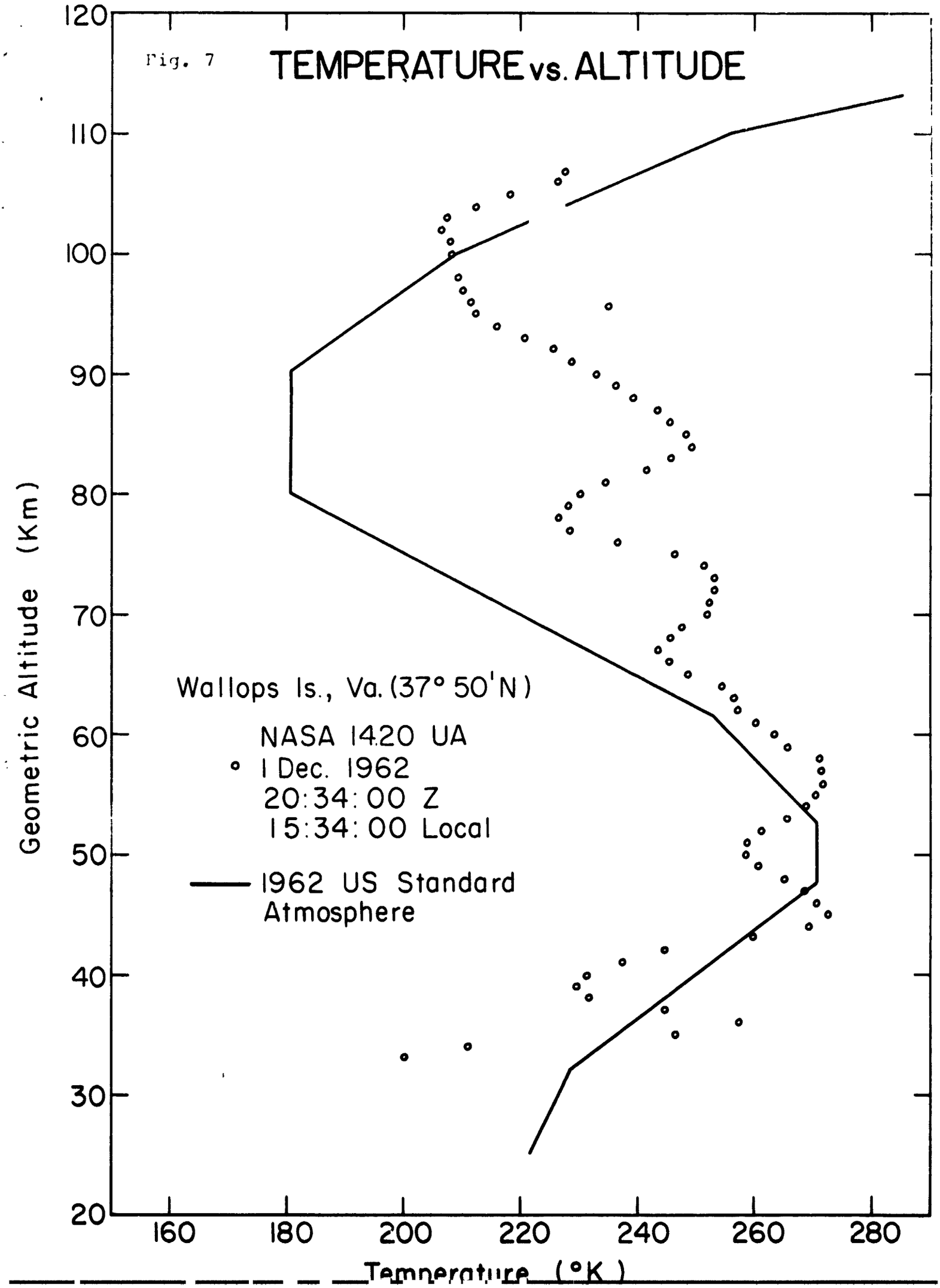
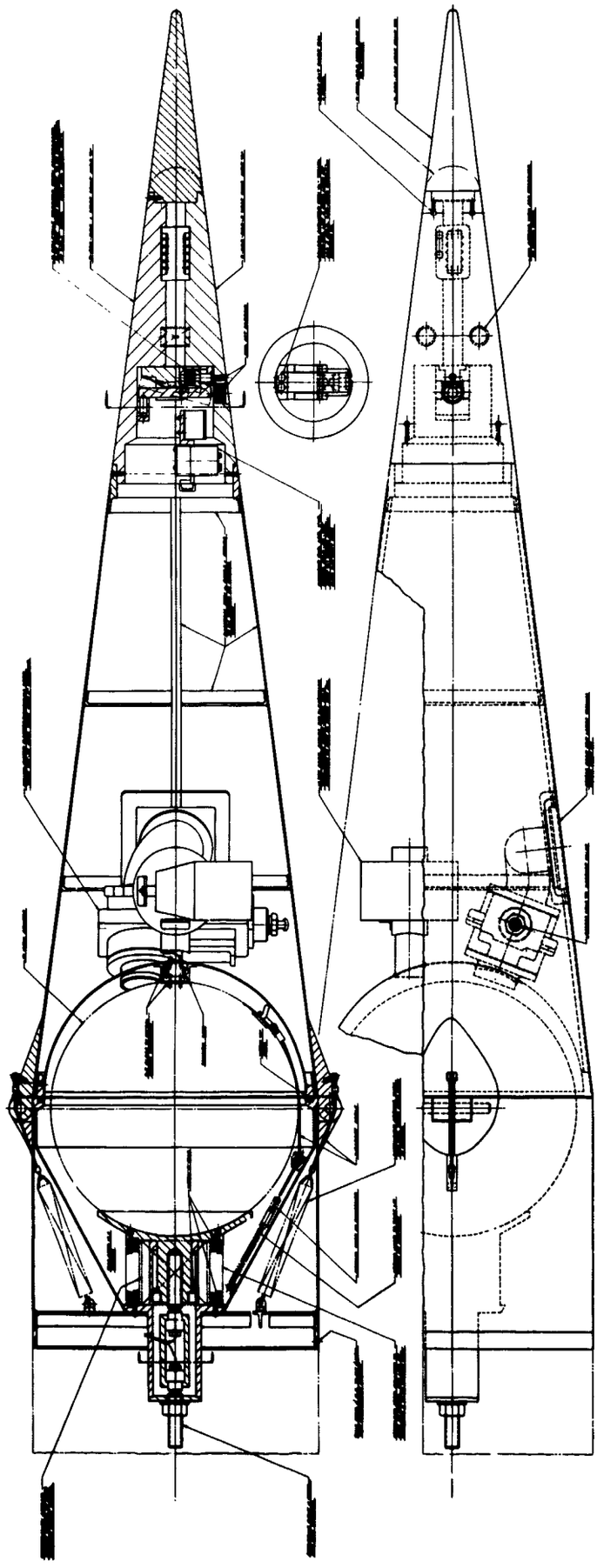


Fig. 7
TEMPERATURE vs. ALTITUDE
Wallops Is., Va. (37° 50' N)
NASA 1420 UA
1 Dec. 1962
20:34:00 Z
15:34:00 Local
1962 US Standard Atmosphere
Geometric Altitude (Km)
Temperature (°K)
120
110
100
90
80
70
60
50
40
30
20
160
180
200
220
240
260
280

Fig. 8



TASK III. 13" SPHERE EXPERIMENT

The Space Physics Research Laboratory has been engaged in the development of an ejectable self-contained payload to measure the physical parameters of both the neutral and charged particles in the upper atmosphere since the late 50's. Early support for this project was received from both the Army Signal Corps and the Ballistic Research Laboratory. After the formation of NASA, strong support for the continuation of this program was received through contract NASr-54(01).

The purpose of this report is to describe the work done on this project under contract NASr-54(01). The developmental work leading to the flight payload was described in detail in an earlier report[1]. The payload was a 13 inch stainless steel sphere carrying the following experiments:

1. Two Bayard-Alpert ionization gauges to measure the total density of the atmosphere.
2. An omegatron mass spectrometer tuned to molecular nitrogen to measure the N_2 concentration and temperature.
3. A cylindrical Langmuir probe for the measurement of electron density and temperature, as well as the equilibrium potential of the sphere.
4. A simple ion trap experiment to study the density and energy distribution of the ambient ions.

A detailed discussion of these experiments along with the circuit diagrams of the supporting electronics was given in the referenced report. The standard Aerobee nose cone was modified - as shown in Figure 8 - to carry the payload under vacuum to a pre-established altitude and then eject it with a slow spin.

The launching of Aerobee NASA 4.18 took place on March 17, 1962. Due to the premature closing of a G-reduction switch in the rocket despin system, the flow of fuel to the Aerobee motor was terminated about 10 seconds before normal burnout time. This resulted in a peak altitude of only about 48 miles. The nose cone opening and payload ejection took place in the planned manner; however, none of the experiments could operate in a meaningful manner at these low altitudes.

Despite the fact that no geophysical data were obtained from this flight, a great deal was learned from this project; resulting in the highly successful TP experiments - Goddard Space Flight Center Contract No. NAS5-9113 - which are, in effect, second generation "13 inch spheres".

References:

Nagy, A. F., Spencer, N. W., Niemann, H. B., Carignan, G. R., "Measurements of Atmospheric Pressure, Temperature, and Density at Very High Altitudes", University of Michigan Scientific Report 02804-7-4, August 1961.