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COLLEGE OF ENGINEERING
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SPACE PHYSICS RESEARCH LABORATORY

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DESIGN AND DEVELOPMENT OF THREE (3) DENSITY GAGES TO OBTAIN ATMOSPHERIC PROPERTIES FROM 20 KM. TO 80 KM.

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FORWARD

This interim report is prepared by the Space Physics Research Laboratory, Department of Electrical Engineering, The University of Michigan on Contract NAS8-11854 for George C. Marshall Space Flight Center, National Aeronautics and Space Administration. The work reported herein is under the cognizance of Mr. James A. Power and Mr. Alex Hafner of the Measurements Group, MSFC. At the University of Michigan the Project Supervisor is Mr. George Carignan. This report covers work done during the period 1 June, 1965 to 30 June, 1965.

Introduction

During the subject reporting period the third and final density gage was assembled, calibrated and shipped to the Measurements Group, MSFC along with the second density gage. Also during this reporting period the reduction of the data from the pitot experiment aboard SA-8 to obtain the ambient properties of the atmosphere, specifically, density, pressure, and temperature in the altitude region from 12 Km. to 78 Km. has been completed.

This report will be presented in two parts. First, a brief outline of the experimental development and preparation of the now completed third and final density gage will be given. And last, the theory and technique being used for this pitot measurement will be presented along with the results of the measurement obtained during the flight of SA-8 on 25 May, 1965.

Experimental Investigations and Development

The third and final densatron unit to be developed was completed and delivered to the Measurements Group, MSFC on June 24, 1965. The sensitivity or measuring range of this unit was designed to obtain the same as that of the first two densatron units. Thus, this unit has good measuring sensitivity from a density corresponding to a pressure of 500 Torr at normal room temperatures to a density corresponding to a pressure of 4×10^{-2} Torr at normal room temperatures and achieves this in four automatically switching output ranges.

This third densatron unit underwent shake tests, as did the first two units, and under vibration conditions the noise level on the output was noted to be low. The electrometer amplifier for this densatron unit has been temperature compensated in the range from 30°C to 70°C and is limited to less than 2 mv. drift. This amplifier has also been continuously operated for 60 hours at a temperature of 70°C. Finally the dynamic density measuring characteristics of this third unit were carefully examined and noted.

The second of the three densatron units which was delivered to the Measurements Group, MSFC May 19, 1965 was returned to SPRL, Univ. of Mich. and carefully inspected. This unit's calibration was rechecked by being carefully calibrated simultaneously with the third densatron unit.

Requests made by SPRL, Univ. of Mich. to the Measurements Group, MSFC to modify the nose tip of the nose cone as to its internal geometry and thus attempt to gain a check point on the densatrons performance and calibration during the vehicle flight were appreciated and made. This modified nose tip will be employed on the next attempted pitot experiment.

Results of the Pitot Experiment on SA-8

The following presents the final results of the pitot air density experiment flown on SA-8 from Cape Kennedy 25 May, 1965 at 0235 Eastern Standard Time. Excellent atmospheric density in the region 12 Km. to 78 Km. were produced by this flight.

Raw data from this flight were processed manually with very careful attention given to initial smoothing of the densatron output voltage/time profile and subsequent conversion of this data to impact pressure.

The ambient atmospheric density profile was derived from the measured impact pressure through the use of the well-known Rayleigh supersonic pitot tube equation and the equation of state in conjunction with SA-8 trajectory information. The above analysis was made assuming air of constant composition and specific heats.

The ambient temperature profile was derived through simple application of the hydrostatic law to the above density profile. Ambient pressure were determined from the density and temperature information through the use of the equation of state.

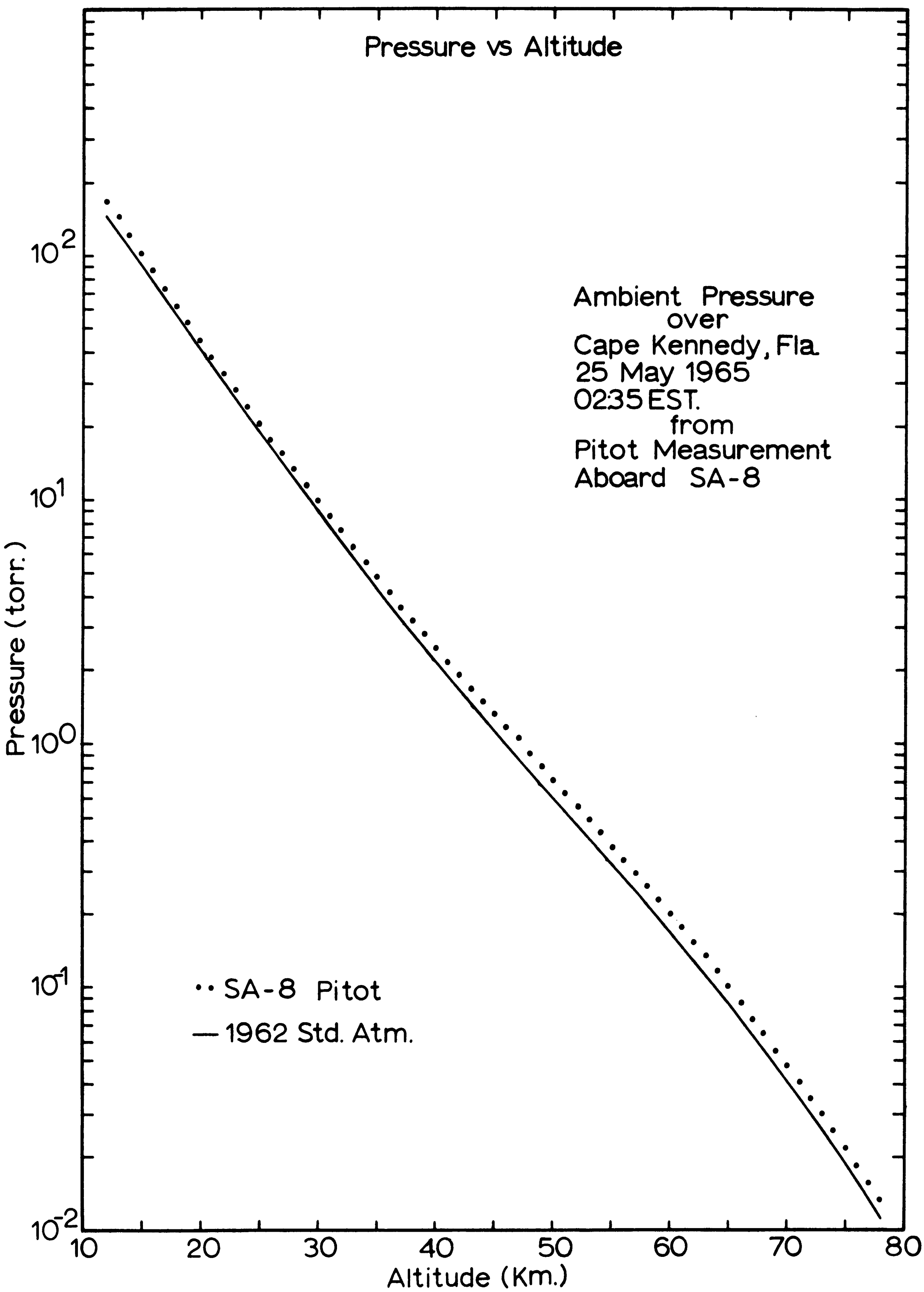
Table I gives the final numerical values for the atmospheric parameters obtained from the experimental air density data of SA-8 at 1/2 Km. intervals for the region 12 Km. to 78 Km. Fig's 1 thru 3 are graphical presentations of the final data with the 1962 Standard Atmosphere and simultaneously measured lower stratosphere data shown for reference. The units of the tabulated results are: Altitude-Km.; Density-Kg/M^3; Temperature-°Kelvin; Pressure-Torr.

TABLE I
AMBIENT PRESSURE, TEMPERATURE, AND DENSITY
FROM SA-8 PITOT EXPERIMENT
CAPE KENNEDY, FLORIDA
25 MAY, 1965
0235 EST

ALTITUDE KM.	PRESSURE TORR.	TEMPERATURE °KELVIN	DENSITY KG/M^3
12.0	1.69 x 10^2	211	3.72 x 10^{-1}
12.5	1.56	207	3.49
13.0	1.43	204	3.26
13.5	1.32	203	3.02
14.0	1.21	202	2.79
14.5	1.12	202	2.56
15.0	1.02 x 10^2	203	2.35
15.5	9.43 x 10^1	204	2.15
16.0	8.68	205	1.97
16.5	7.99	205	1.81
17.0	7.35	204	1.67
17.5	6.77	204	1.54
18.0	6.22	202	1.43
18.5	5.72	203	1.31
19.0	5.26	206	1.19
19.5	4.85	211	1.07 x 10^{-1}
20.0	4.48	214	9.72 x 10^{-2}
20.5	4.14	218	8.81
21.0	3.83	221	8.04
21.5	3.55	223	7.41
22.0	3.29	222	6.89
22.5	3.05	220	6.43
23.0	2.82	218	6.00
23.5	2.61	218	5.55
24.0	2.41	220	5.09
24.5	2.24	223	4.65
25.0	2.07	225	4.28
25.5	1.92	227	3.94
26.0	1.78	227	3.66
26.5	1.66	229	3.36
27.0	1.54	230	3.11
27.5	1.43	230	2.89
28.0	1.33	229	2.69
28.5	1.23	231	2.48
29.0	1.15	231	2.31
29.5	1.07 x 10^1	231	2.14
30.0	9.91 x 10^0	231	1.99
30.5	9.21	232	1.84
31.0	8.56	233	1.71
31.5	7.96	234	1.58
32.0	7.41	236	1.46
32.5	6.90	239	1.23
33.0	6.43 x 10^0	241	1.24 x 10^{-2}

ALTITUDE KM.	PRESSURE TORR.	TEMPERATURE °KELVIN	DENSITY KG/M^3
33.5	6.00×10^{0}	242	1.15×10^{-2}
34.0	5.59	241	1.08
34.5	5.21	240	1.01×10^{-2}
35.0	4.86	240	9.41×10^{-3}
35.5	4.53	243	8.67
36.0	4.22	244	8.03
36.5	3.94	244	7.49
37.0	3.68	245	6.97
37.5	3.44	250	6.39
38.0	3.22	254	5.87
38.5	3.01	258	5.42
39.0	2.82	260	5.03
39.5	2.64	262	4.68
40.0	2.48	264	4.36
40.5	2.33	266	4.06
41.0	2.18	267	3.80
41.5	2.05	268	3.56
42.0	1.92	268	3.34
42.5	1.81	271	3.10
43.0	1.70	273	2.89
43.5	1.60	276	2.69
44.0	1.50	278	2.51
44.5	1.42	280	2.35
45.0	1.33	282	2.20
45.5	1.26	282	2.07
46.0	1.18	280	1.96
46.5	1.11	278	1.86
47.0	1.05×10^{0}	275	1.77
47.5	9.86×10^{-1}	272	1.68
48.0	9.26	271	1.59
48.5	8.70	268	1.51
49.0	8.17	265	1.43
49.5	7.67	266	1.34
50.0	7.20	265	1.26
50.5	6.76	268	1.17
51.0	6.35	268	1.10
51.5	5.96	269	1.03×10^{-3}
52.0	5.60	269	9.66×10^{-4}
52.5	5.26	269	9.09
53.0	4.94	269	8.54
53.5	4.64	269	8.02
54.0	4.36	268	7.57
54.5	4.10	267	7.13
55.0	3.84	267	6.68
55.5	3.61	268	6.25
56.0	3.39	268	5.89
56.5	3.19	267	5.54
57.0	2.99	265	5.25
57.5	2.81	263	4.96
58.0	2.63	260	4.71
58.5	2.47	257	4.46
59.0	2.31	255	4.21
59.5	2.16×10^{-1}	254	3.96×10^{-4}

ALTITUDE KM.	PRESSURE TORR.	TEMPERATURE °KELVIN	DENSITY KG/M^3
60.0	2.02×10^{-1}	254	3.71×10^{-4}
60.5	1.89	251	3.51
61.0	1.77	249	3.31
61.5	1.66	247	3.11
62.0	1.55	244	2.94
62.5	1.44	243	2.76
63.0	1.35	240	2.61
63.5	1.26	236	2.47
64.0	1.17	234	2.32
64.5	1.09	232	2.18
65.0	1.01×10^{-1}	229	2.05
65.5	9.40×10^{-2}	226	1.93
66.0	8.73	225	1.80
66.5	8.11	226	1.67
67.0	7.53	224	1.56
67.5	6.98	224	1.45
68.0	6.48	223	1.35
68.5	6.01	222	1.26
69.0	5.57	223	1.16
69.5	5.17	222	1.08
70.0	4.80	223	1.00×10^{-4}
70.5	4.45	223	9.27×10^{-5}
71.0	4.13	222	8.62
71.5	3.83	221	8.04
72.0	3.55	219	7.54
72.5	3.29	216	7.07
73.0	3.04	214	6.59
73.5	2.81	211	6.19
74.0	2.60	207	5.82
74.5	2.39	204	5.44
75.0	2.20	201	5.10
75.5	2.03	199	4.74
76.0	1.86	196	4.41
76.5	1.71	194	4.09
77.0	1.57	193	3.77
77.5	1.44	193	3.46
78.0	1.32×10^{-2}	192	3.19×10^{-5}



Pressure vs Altitude
Ambient Pressure
over
Cape Kennedy, Fla.
25 May 1965
0235 EST.
from
Pitot Measurement
Aboard SA-8
SA-8 Pitot
1962 Std. Atm.
Pressure (torr.)
10^2
10^1
10^0
10^{-1}
10^{-2}
10
20
30
40
50
60
70
80
Altitude (Km.)

Figure 1.

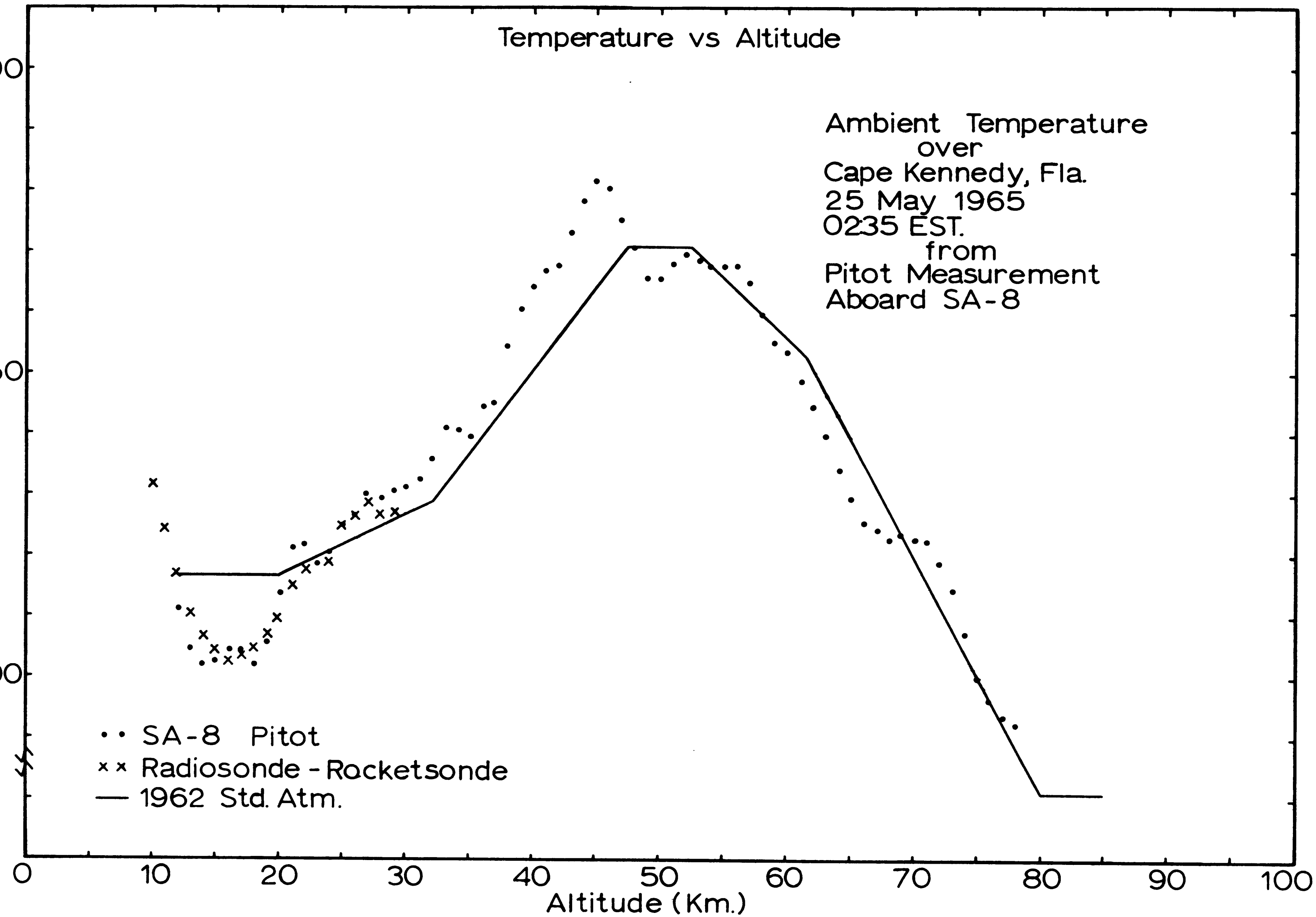

Temperature vs Altitude
Ambient Temperature
over
Cape Kennedy, Fla.
25 May 1965
0235 EST.
from
Pitot Measurement
Aboard SA-8
300
250
200
Temperature (°K)
SA-8 Pitot
Radiosonde - Rocketsonde
1962 Std. Atm.
0
10
20
30
40
50
60
70
80
90
100
Altitude (Km.)

Figure 2.

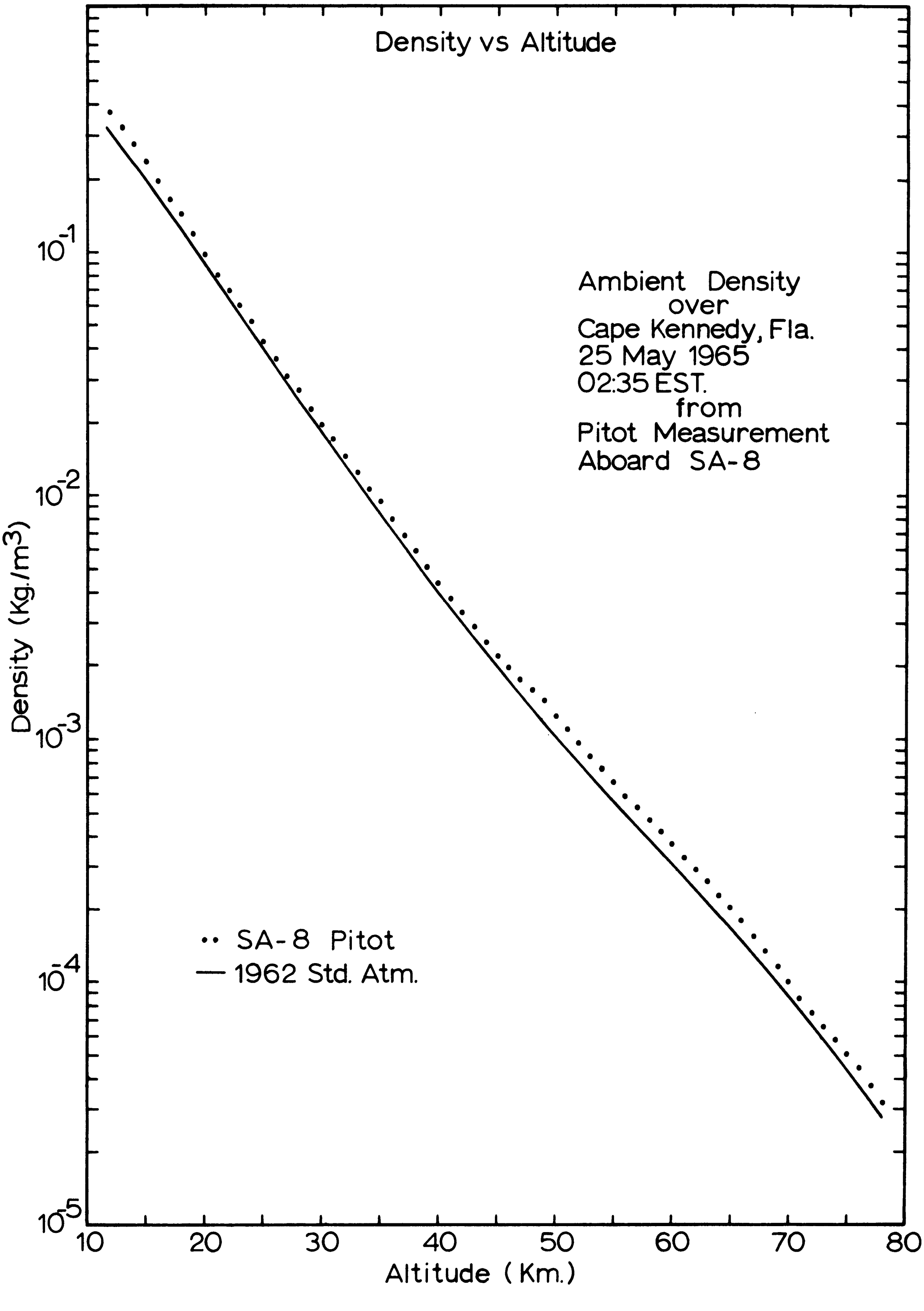

Density vs Altitude
Ambient Density over Cape Kennedy, Fla. 25 May 1965 02:35 EST. from Pitot Measurement Aboard SA-8
•• SA-8 Pitot
— 1962 Std. Atm.
Density (Kg./m³)
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10
20
30
40
50
60
70
80
Altitude (Km.)

Figure 3.

The overall quality of the raw data, the operation of densatron unit during flight, and excellent agreement of the final data with other simultaneous measurements taken in the lower stratosphere lead to a high degree of confidence in these experimental results.