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FINAL REPORT

1970 SOLAR-TRACKER
BALLOON FLIGHTS
3055, 3056, 3057

APPLIED SCIENCE DIVISION
LITTON INDUSTRIES

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FINAL REPORT

1970 SOLAR-TRACKER BALLOON FLIGHTS 3055, 3056, 3057

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TECHNICAL CONTENT STATEMENT

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ABSTRACT

High-altitude solar cell and radiometer calibrations were attempted during July and August 1970 using balloon techniques. Solar cell modules and radiometers supplied by Jet Propulsion Laboratory were flown on Litton-designed, balloon-mounted solar trackers at a nominal 120, 000-ft altitude to obtain near-zero-air-mass performance data. A total of three balloon flights were attempted in 1970. Two flights carried solar cell payloads and one flight attempt was made to obtain solar intensity measurements using JPL-designed radiometers. This report contains operational details of these flights, discussion of problems encountered, instrumentation modifications accomplished during the program, and tabulations of secondary temperatures, calibration voltages, and time-altitude data recorded during the program.

SUMMARY

Three balloon flights were attempted during the 1970 solar calibration program. Two flights were conducted for the primary purpose of obtaining accurate, near-zero-air-mass short circuit current data/measurements from a variety of types and manufacturers of photovoltaic solar cells. Solar cells calibrated in this manner are termed "standard cells," and can serve as reference cells for subsequent intensity measurements. One of the attempted balloon flights included a dual radiometer payload for the purpose of obtaining accurate total solar intensity measurements under the stable, near-zero-air-mass conditions encountered during the balloon system float period. To minimize the effects of ozone and water vapor on the data, a float altitude of 120,000 ft was selected for these flights.

The 1970 balloon flight system was essentially the same as used on nine previous programs of this nature sponsored by JPL. A solar tracker is mounted atop a helium-filled, polyethelene balloon to accurately position the solar payload toward the sun, independent of sun and balloon movements. A telemetry system, balloon control system, and battery power supply suspended below the balloon complete the basic system components. Solar intensity data and temperature data are telemetered to a ground receiving station and recorded for computer analysis. Altitude data and other housekeeping data are also telemetered for monitoring and control purposes.

During the 1970 program, modifications were made to the system to improve payload erection techniques during balloon inflation and to improve telemetry data stability by better temperature control.

This report discusses the operational details of each flight and the problems encountered during the program. The flights conducted with solar-cell payloads were successful; the radiometer flight was not successful. Operationally, two of the three balloon flights were successes. The first flight attempted, with two radiometers as the payload, was aborted at launch because of a rip in the balloon material. This report includes detailed recommendations for improving system accuracy and reliability through the use of solid state temperature controllers and improved methods of commutating the various data.

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FINAL REPORT

1970 SOLAR TRACKER BALLOON FLIGHTS 3055, 3056, and 3057

1. INTRODUCTION

1.1 General

Flights 3055, 3056 and 3057 were a planned series of balloon flights conducted during July and August 1970, for Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under JPL Subcontract 952879. This contract provided for all necessary balloon flight equipment and services. Equipment included balloons, helium, power supplies, antennas, electrical cables, and other miscellaneous expendable hardware. The services included those required for flight preparation, functional verification of the flight control and data acquisition systems, meteorological services, launching, tracking of the balloon by aircraft, recovery and return of the equipment after descent, and data reduction to computer-compatible punch cards. In addition, Litton furnished without cost a radio command control system, an altitude/beacon telemetry system, flight and cutdown programmers, and other necessary control devices.

This report discusses each flight in detail, describes system changes made preceding and during the flight operations, and provides analysis of the system discrepancies occurring during the program. The primary data were delivered to JPL at the conclusion of the final solar cell flight. The Appendix of this report contains information such as temperature data, calibration data, and flight time-altitude profiles of each flight.

1.2 Flight Objectives

The flight objectives were:

1) To launch three balloon systems for ascension to an altitude of 120,000 ft (± 5000 ft); the payload was to include balloon systems with solar tracker, solar cell and/or radiometer payloads, and instrumentation mounted atop the balloon; with telemetry and other instrumentation, and power supply mounted below the balloon.

2) To telemeter and record altitude, temperature and solar cell or radiometer output data during ascent and during a float period of four hours, minimum. The floating period for each of the three flights shall commence two hours before solar noon. The system shall remain at float two hours following solar noon before initiation of descent.

3) To descend to surface with balloon and payload intact.

4) To deflate balloon automatically upon impact by means of a rip panel which opens the side of the helium-filled balloon bubble for the purpose of recovering the top-mounted solar tracker and its payload with minimum damage.

5) To recover and return all equipment, escept the expendable balloon, to Litton.

2. TECHNICAL DISCUSSION

2.1 Flight 3055 (JPL-70-1)

2.1.1 Flight Preparation

2.1.1.1 Project Personnel Assignments

Litton personnel responsible for preparations and flight operations on Flight 3055 were:

Project Engineer:	R. Conlon
Flight Leader:	M. Lueders
Instrumentation:	E. Minnich L. Nelson
Additional Launch, Tracking, and Recovery Crew:	V. Schwalbe J. Chesebro G. Benz

The same key personnel conducted all flights on this program.

2.1.1.2 Pre-Flight Checkout

Required repairs and preventive maintenance were performed on all ground station electronic support equipment to be housed within the Litton telemetry van. All airborne flight equipment was tested and recalibrated to insure both mechanical and electrical stability following the previous flight program. The airborne balloon control equipment selected for these 120,000 ft flights included a Litton Model R16 command receiver, a Model B58 high-altitude transmitter, a Model S12 timer for float-time control, a Model S15 timer for backup system cut-down, a beacon control programmer, a Model B17 recording barograph, and a recording thermograph for lower payload temperature monitoring.

The radio-command controlled ballast system was retained for this series of flights to prevent altitude loss during the float period. Two separate channels of the five-channel receiver were set up to open and release bags of steel shot attached to the lower payload. Three 20-lb ballast bags were used on this flight.

The solar tracker for this flight was the same unit used on the previous year's radiometer flights. Although the radiometers and their electronic instrumentation were redesigned, the basic tracker arrangement previously used did not require modification. The only mechanical work necessary was the installation of new gear pins and installation of new azimuth and elevation drive motors. The electrical modifications required to accommodate the new radiometer payload involved a substantial rewiring of the data commutating switch. The switching sequence and signal wiring arrangement used on Flight 3055 are presented on page 5 of this report. As a preventive maintenance measure, all electromechanical relays, all drive transistors, and all photosensors were replaced on both solar trackers this year. The pressure-actuated switches used to turn on the solar tracker at 20,000 ft on ascent were reset for 60,000 ft to conserve power and reduce tracker operation time.

Although radiometer power requirements were greatly reduced when the units were redesigned, the same power supply arrangement and capacity were used as on Flights 3050, 3051 and 3054. This battery pack thus provided a high safety factor on voltage drop and power capacity.

A 60°C thermostat was installed in the voltage-controlled oscillator (VCO) assembly to improve reference frequency stability over that experienced previously using a 48°C unit. Unfortunately, the 60°C thermostat failed during system checkout and it was necessary to replace it with the original 48°C unit. A simple flat sun shade was devised to cover the box containing the VCO to reduce solar heating in hopes of improving VCO stability at the 48°C temperature level.

The telemetry transmitter, set for the newly assigned frequency of 217.5 MHz, was completely checked out in the system and the telemetry antenna was retuned for this frequency. A new ground station telemetry antenna system was set up next to the telemetry van to simplify antenna homing this year. This system consists of a 30 ft mast, a dual Yagi antenna, and two remotely controlled rotors for azimuth and elevation adjustments.

TELEMETRY CHANNEL SWITCHING SEQUENCE

Channel No.	Function	Description
1	100	100 mv calibration voltage
2	R3	Readout radiometer #3
3	R6	Readout radiometer #6
4	CWA	Chopper wheel advance
5	R6	
6	80	80 mv calibration voltage
7	T1	Temperature 1 Guard #6
8	R3	
9	R6	
10	CWA	
11	T2	Temperature 2 (thermistor) plate
12	70	70 mv calibration voltage
13	SC1	Solar cell 1
14	R3	
15	R6	
16	CWA	
17	R3	
18	60	60 mv calibration voltage
19	SC2	Solar cell 2
20	R3	
21	R6	
22	CWA	
23	R3	
24	50	50 mv calibration voltage
25	SC3	Solar cell 3
26	R3	
27	R6	
28	CWA	
29	R6	
30	25	25 mv calibration voltage
31	T3	Temperature 3 Guard #3
32	R3	
33	R6	
34	CWA	
35	SC4	Solar cell 4
36	0	0 mv calibration voltage

Telemetry Grounds

1) Calibration voltages and thermistors
2) Chopper wheel advance
3) Radiometers (both R3 and R6)
4) Solar cell

The 100 mv (millivolt) on-board reference circuitry was calibrated with a Leeds and Northrup Model K3 voltage potentiometer and Eppley standard cell. Voltages and corresponding subcarrier frequencies were similar in value to those recorded previously, so that the voltage divider did not require adjustment. A chart containing actual voltages and frequencies obtained in the final calibration is given in the Appendix, page A-3. Primary temperature channels were calibrated using a resistance decade to simulate temperature levels from -20 to +80°C. Secondary temperature circuitry was checked; the commutator was cleaned, and the output frequencies monitored and found nominal. Modulation voltage levels from the data subcarrier, temperature subcarriers, and on-sun sensor were checked and found nominal.

The beacon control timer was again incorporated to minimize the possibility of radio-frequency interference on the primary telemetry data during the tracker-on portion of the flight. It was wired so that power is normally removed from the output stage of the B58 transmitter when the system is above the 60,000 ft level. The timer, when actuated by the command system, provides a 2-1/2 min transmitter on time every 10 min for the purpose of altitude telemetry and direction determination if necessary.

The solar tracker with its radiometer payload was checked, adjusted and calibrated in the sun, and then the entire system was moved to the launch site for final checkout. With all components connected as they are in flight, using the balloon and parachute cabling to be flown, the system was actuated while in the sun for flight-simulation testing. After minor on-sun tracker adjustments and a checkout for radio-frequency interference, all airborne and ground-station components were judged ready to fly.

2.1.2 Field Operation

2.1.2.1 Launch

Flight 3055 was delayed three days due to poor weather conditions. Launch preparation began at 0330 CDT on 16 July 1970. Balloon and system layout was completed at 0710 and inflation began at 0720. Surface winds averaged approximately four mph during the pre-launch period, but peaked at approximately eight mph during the inflation period. The top payload was erected above the balloon without shock or balloon stress by the use of two flat nylon handling lines looped around the tracker standoffs. As the balloon gained lift during inflation, the handling lines were used to guide the payload gently into position atop the balloon apex. This method effectively eliminated the shock to the top payload experienced on some previous inflations. Both lines were pulled through the standoffs and removed during a later stage of inflation.

Inflation and all system and instrumentation checklists were completed on schedule. The balloon bubble was released from its restraining platform at 0810 CDT with wind velocity at about nine mph. As the load line between the balloon and the lower payload took up the full load, the nylon line holding the safety parachute in a tightened launch position was stressed and snapped. The sudden release of this line, commonly called the slack chute line, pulled apart the quick-release connector in the main instrumentation electrical cable at the top of the parachute. Breakage of the slack chute line is not a serious problem by itself, but the resulting separation of the electrical cable removed power from the top payload rendering it useless. At this mid point in the launch sequence, the launch vehicle was stopped and the crew was able to pull down and restrain the load train at the base of the balloon long enough to reconnect the instrumentation cable and tape it securely in place. Because of the lack of system lift noted by the launch personnel during balloon bubble release and as the parachute and load line were pulled down for quick repair, there were some doubts about the balloon integrity at this point. Launch proceeded, however, and the launch vehicle was able to move into the proper position to release the lower payload. Seconds after release, the lower payload settled down to the ground and the balloon laid over. As launch personnel ran up to steady the top payload, a long vertical rip was observed in the balloon's skin in the bubble area.

2.1.3 Flight Results

All system components were recovered without damage but, of course, the balloon was not recoverable. This balloon was manufactured in the fall of 1969 and two attempts had been previously made to inflate it in November of last year. Litton's Final 1969 Report No. 3399 describes the previous launch attempt. All holes and stretch marks in the top 55 ft of the balloon were repaired before this attempt. Unfortunately, balloon seam strength, which is meticulously sample-tested during the original manufacture, can only be inspected visually during repair. Inspection following this final launch attempt indicated that the balloon had ripped open along a seam in the bubble area of the balloon. It is the nature of polyethelene material that once a rip is initiated, it propagates easily over a long length of the balloon. We can only speculate as to exactly when and why the balloon ripped. It may have started as the bubble was released from the platform, during the period when it was restrained for the cable repair, or during the release of the lower payload.

It is our opinion that a balloon seam was severely weakened during the previous handling of the balloon and the seam gave way from the shock associated with the release of the bubble from the launch platform's restraining arm. Regardless of the exact timing, this must be classified as an unsuccessful attempt to fly a previously used balloon.

2.2 Flight 3056 (JPL 70-2)

2.2.1 Flight Preparations

Although equipment used on the previous flight attempt was not damaged, all instrumentation was rechecked. A full complement of solar cells were mounted on the previously reconditioned solar tracker. A sketch of the solar cell mounting arrangement is included on Appendix page A-7. The data commutator was completely rewired to the conventional solar cell readout arrangement as shown on the above sketch. The tracker alignment was adjusted in the sun and positive identification of all solar cell channels through the telemetry system was verified. The commutator stepping rate of 20 sec per channel was reduced to 10 sec for solar cell readout.

A new 60°C thermostat was tested and then installed and checked within the VCO module. The higher control temperature caused a shift of the calibration voltages as well as the VCO frequency. A low-temperature-coefficient resistance of 14.5 ohms was installed in parallel with the 50 ohm full scale adjustment potentiometer in Box #1 to improve voltage resolution for accurate resetting of the calibration voltages using a voltage potentiometer and standard cell. Final calibration voltages and frequencies are included on Page A-3 of the Appendix. On-sun sensor sensitivity was the only adjustment required during the final system checkout in the sun at the launch site.

2.2.2 Field Operation

2.2.2.1 Launch

Launch preparations for Flight 3056 were underway by 0345 CDT on 28 July 1970 after a one day weather delay. Balloon layout began at 0615 under calm wind and fog conditions. After layout, all instrumentation checks were normal, and inflation was initiated at 0730. Handling lines were looped around the tracker standoffs during initial inflation and successfully used to erect the top payload. One handling line was cut short and left in place after use due to a twist in the line. The fog lifted as inflation, final checkout and launch were completed without problems in winds of less than two mph. The lower payload left the launch vehicle at 0814 CDT.

2.2.2.2 Tracking and Recovery

The flight ascended on an easterly course to a point 65,000 ft above the Minnesota-Wisconsin border. Winds above this level carried the flight west-northwesterly to a point northwest of the launch site by the beginning of float. The float course was westerly across Minnesota and a short distance into South Dakota. The initial descent course continued west to a point near Aberdeen, South Dakota where the course of the descending system shifted again to the northeast. The system reached the surface at 1830 CDT at a location six miles north of Claremont, South Dakota. Initial impact was in a hay field actuating the balloon release squibs. As the balloon separated from the safety parachute, it laid over downwind into a cornfield. A rip panel on the balloon envelope released much of the remaining helium reducing the chance of draging by surface winds.

The two man recovery crew, guided by the tracking aircraft, were in a position at impact to dash up to the balloon and steady the top payload before it could contact the ground. The tracking aircraft's radio operator had used the radio command control system to open the top mounted helium valve just prior to impact in order to release a maximum amount of helium to further reduce the chance of top-payload damage. All components were recovered without difficulty and were returned to Minneapolis the following afternoon. The farmer was compensated for minor damage to his cornfield.

2.2.3 Flight Results

2.2.3.1 Balloon

The balloons manufactured for this and the following flight were similar to the balloon manufactured for the final 1969 flight in respect to balloon size and placement of the three descent gasports. These balloons differed in film thickness using 1 mil rather than 3/4 mil material. The thicker material resulted in a balloon weight increase of less than five per cent.

The average rate of rise of this balloon was 760 fpm (feet per minute) reaching a float level of 120,700 ft at 1100 CDT. The float level decreased during solar noon when clouds move in below the balloon. Two 20 lb ballast drops at 1341 and 1346 increased the float level from 116,700 ft to 119,000 ft. By the end of the float period the float level had again decreased to 116,700 ft. The maximum altitude during float was 120,800 ft achieved at 1101 with an overall average float level of 119,200 ft.

The balloon descent difficulties plaguing last summer's flights have been overcome by improved sizing and placement of the gasports on these balloons. Balloon specifications as listed on page A-1 of the Appendix include the size and position of the three gasports. The load/altitude curve for this design, shown on page A-2 of the Appendix, is identical to the previous design. Initial descent rate was only 238 fpm between 115,000 and 100,000 ft. Between 99,000 and 94,000 ft on descent, the radio controlled helium valve was actuated twice for a total valving time of 5 min. The descent rate increased significantly below this altitude and no further valving was required. Total descent time was only 3 hrs and 15 min for an overall average rate of 600 fmp. The rate of descent below 62,000 ft averaged 1120 fpm. Visually, the balloon looked very slack at low altitudes and it appeared to the recovery crew that if more helium had been valved out the limp balloon envelope may have collapsed into the parachute.

2.2.3.2 Instrumentation

The solar tracker was actuated at 59,500 ft and immediately locked on the sun. Balloon rotation caused two rewind cycles of the tracker during ascent. The tracker was locked on the sun continuously from 86,000 ft on ascent until the end of data recording on descent. The VCO reference frequencies exhibited extremely high stability throughout the flight which indicated that the new 60°C temperature control operating point provided the desired improvement of data frequency stability. Secondary temperature data from this flight, as shown in Appendix page A-4, indicated a maximum VCO temperature variation of only 4°C with a variation of approximately 1°C from 1/2 hr after the start of float until the end of the data recording period. The maximum variation of any reference frequency was 3 Hz which is significantly better than has been attained previously.

Altitude telemetry readout was a minor problem during this flight. The problem appeared to be due to a telemetry station electronic counter that was unstable when reading pulse periods. As a result of the system descent over clouds and the altitude monitoring difficulties, it was necessary to command on the low frequency beacon transmitter to obtain coded altitude data. As on past flights, the beacon transmitter caused interference with the primary data. Fortunately, only one channel was affected; solar cell channel number 26. The interference appeared minimal on the analog record but if desired, the channel 26 data taken during the transmitter on time could be eliminated. Data recorded between 1101 and 1547 CDT were selected for further processing. These data were reduced to 147 punch cards and submitted to JPL.

2.3 Flight 3057 (JPL 70-3)

2.3.1 Flight Preparation

Although the solar tracker received no damage from the previous flight, elevation shear pins were replaced and new backlash springs installed to reduce tracker hysteresis. New solar cells were installed, except for three modules (BFS505, BFS17A and BFS7001) which were left in place for this flight. Stepping switch wiring was not revised and remained the same as on the previous flight. A sketch of the solar cell module mounting arrangement is included in Appendix page A-8.

The ground station period counter was tested and realigned for the purpose of improving altitude data readout. Radio frequency chokes and bypass filter capacitors were added internally to the altitude sensor to improve the altitude pulse signal input to the telemetry system. During in-plant system checkout, the VCO thermostat that performed in a stable manner on the previous flight began to malfunction. The thermostat was replaced and tested before final calibration was performed. The final primary calibration voltages and frequencies were slightly higher in value at the new thermostat's temperature set point; but were very stable, at the values shown in Appendix page A-3, during the calibration period. The laboratory calibration checklist, flight train assembly and the on-sun system checkout were completed without difficulty on 4 August 1970.

2.3.2 Field Operation

2.3.2.1 Launch

Launch preparations for Flight 3057 were underway before 0400 CDT on 5 August 1970. Balloon layout began at 0620 under calm wind and clear sky conditions. Launch preparation was routine except that just prior to inflation a telemetry check indicated that the secondary temperature commutator had stopped. Inflation was delayed and the tracker sun shield removed to gain access to the commutator drive motor. This motor was started manually, the system reassembled and a final telemetry check was made before initiating the inflation. Inflation began at 0745 and was completed at 0820. The handling lines were again used to erect the top payload, and both lines were cut short and left in place after inflation. Launch was smoothly accomplished at 0828 under very light wind conditions.

2.3.2.2 Tracking and Recovery

The balloon system headed southeast during ascent until reaching 75,000 ft over Red Wing, Minnesota. Above this altitude the course was west-northwest across Minnesota and into South Dakota. At 75,000 ft on descent, above a point 26 miles south of Aberdeen, South Dakota, the course shifted again to the southeast until impact. The lower payload reached the surface at 1902, 4 miles north of Doland, South Dakota. The impact area was an open hay field and surface wind was approximately nine mph. The balloon release squibs actuated on impact and the lower payload was dragged about 50 ft as the balloon's helium was vented through the ripped panel and the previously opened top valve. The recovery crew was again in perfect position and was able to steady the top payload just as it touched down preventing payload damage from the surface wind. The lower payload, tracker and solar cells received no damage and all equipment was returned to the plant in excellent shape the following day.

2.3.3 Flight Results

2.3.3.1 Balloon

The balloon used for this mission was identical to the one used on the previous flight. The average rate of rise of the balloon was 878 fpm using 9.97% free lift. A float altitude of 120,600 ft was achieved at 1046 CDT. The system exceeded the 115,000 ft minimum float level at 1040 and remained above that level for 5 hrs and 6 min. Ballast was released twice before solar noon to maintain an average altitude of 119,300 ft over variable cloud conditions. The minimum altitude recorded was 117,300 ft during the required float period.

The descent characteristics of this system were similar to those of the previous flight. Total descent took 3 hrs and 46 min, with an average descent rate of 516 fpm. The descent phase took 32 min longer than on the previous flight as the top helium valve was not opened during this period. The descent rate reached 1200 fpm between 50,000 and 20,000 ft, then slowed slightly to 1070 fpm to the surface. The final 20 lb ballast reserve was released at 28,000 ft but this had a minimal effect on the descent rate.

2.3.3.2 Instrumentation

The solar tracker performed in a stable manner throughout its programmed "on" period. Similar to the previous flight, there were two rewind cycles on ascent and then continuous homing throughout float and descent. The primary telemetry signal was received continuously and without interference from launch until 35,000 ft on descent, for a total of 10 hrs.

Data frequency stability was good but not as stable as during the previous flight. A series of lower than normal reference readings between 1206 and 1225 indicates that the VCO temperature control thermostat stuck in the open position during this period and then resumed normal operation for the remaining flight time. The 100 mv reference frequency dropped a maximum of 6 Hz during this period. If data taken during this 19-min period is not used, the maximum reference shift is reduced by 50% thereby equalling the stability achieved on the previous flight. The secondary temperature data shown in Appendix page A-5 verified the shift in VCO temperature during this period.

Two minor instrumentation problems occurred during this flight. The secondary temperature commutator stopped cycling during launch, transmitting only a reference frequency during ascent. The commutator commenced operation again just as the system reached float and operated normally the remaining flight time. Altitude telemetry readout was again unstable during float and descent of this flight. The problem this time was due to another electromechanical commutator within the altitude sensing instrument. Because the commutated signal was not steady, it was necessary to turn on the low frequency beacon transmitter for altitude data. Contrary to previous experience, there was no indication of beacon transmitter interference on the analog data so that the transmitter was left on during the remainder of the flight. System improvements to eliminate these two annoying problems, as well as the VCO thermostat problem, will be discussed in the Recommendations section of this report.

Primary data recorded between 1043 and 1606 CDT were selected for reduction to the punch card format. A total of 165 punch cards were processed for this flight and forwarded to JPL.

3. CONCLUSIONS

Operationally, two of the three balloon flights attempted during this program were successfully accomplished. The two solar cell calibration flights were prepared, launched, and reached the specified altitude for the specified time period. The data telemetry system and the balloon control instrumentation operated continuously during these flights. Recovery on each flight was completely successful in that the release mechanism operated properly on impact and there was no damage suffered to any part of either payload. The failure during launch of the first flight attempt has been fully discussed in Section 2.1.3.

3.1 Balloons

The design of two balloons successfully flown on this program proved satisfactory in that they were capable of lifting the system above the nominal 120,000-ft float altitude, remaining at this altitude for the specified interval and descending to the surface at a desirable rate intact. This design varied in several aspects from previously flown designs. A film thickness of 1 mil rather than 3/4 mil was used. This variation increased balloon weight approximately 5% but should theoretically increase the chances of balloon survival under adverse handling, launch, and environmental conditions. The descent characteristics were favorably altered by placement of three gasports on a high duct. A 4-1/2 in. port only 31 ft from the balloon's apex along with two 5-7/8 in. ports 110 and 140 ft from the apex insure a steady and comparatively rapid descent. The overall descent rates of 516 and 600 fpm were very satisfactory although to achieve this average, the low altitude descent rate reached 1200 fpm and the balloon appeared dangerously slack. It is conceivable that the limp balloon may have collapsed into the safety parachute to cause a damaging free fall. The possibility of minor gasport size and position changes for this balloon design, to further optimize the descent characteristics, will be investigated.

Another potential problem area with this balloon has not previously been discussed. It concerns the amount of excess material near the top fitting of the balloon. Balloons used during the past three years have had a tapered gore design to effectively minimize billowing of balloon material around the top payload. The two newly designed balloons used this year, although ordered in the same manner as previously, had a great deal of material billowing up around the tracker disc during inflation. Both balloons were successful inflated, but had the surface wind velocity been greater, the excess material may have come in contact with the top payload. The nylon handling lines used to erect the payload during inflation could not be easily removed because of the excess balloon material. The first flight attempt (3055), using the balloon manufactured in the fall of 1969, was inflated and the payload erected very smoothly. This balloon exhibited no billowing of material and the handling lines could be pulled through the tracker standoffs after erection without force. On the two subsequent inflations, the lines barely kept the tracker away from the balloon skin, and after erection, three out of four lines could not be pulled over the material and removed. The manufacturer will be required to taper the top section of the balloon on future balloon procurements to reduce the chance of balloon damage during inflation and launch.

3.2 Instrumentation

Temperature within the VCO module has typically exceeded the thermostatically controlled temperature during the latter part of the 120,000-ft float period. The VCO reference frequency and voltage exhibit drift proportional to temperature variation above 48°C, the thermostat set point. Thermostats with a 60°C set point were used on the two successful flights this year to provide a control point at or above the maximum expected ambient temperature. Minor modifications were also made to the thermal characteristics of the box containing the VCO. A fiber board and nylon mounting screws were used to insulate the VCO box from the tracker mounting plate to prevent heating of the box through thermal conduction from other components. The urethane foam and metalized plastic insulation used to insulate the cover of this box was removed in favor of a flat white finish and a sun shield shading the box from direct solar heating.

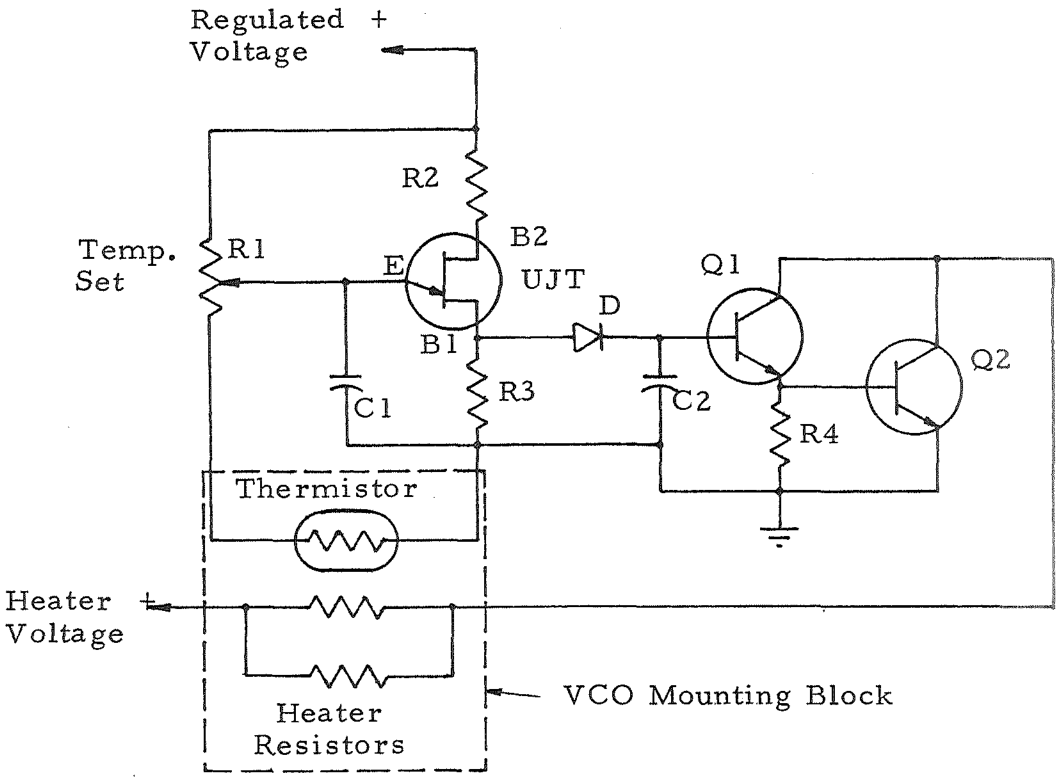
These thermal modifications were quite successful in providing improved reference stability on both flights. Flight 3056 telemetry reference data stability was better than ±0.25% of full scale. Ignoring a 19 min period when the control thermostat failed to close on Flight 3057, reference data stability equalled this figure. Secondary temperature data, although not as accurate as primary data, verified the improved temperature stability of the telemetry components. The VCO thermistor indicated a temperature variation of only 1°C after reaching a stable floating condition on Flight 3056 and, again ignoring the control failure period, approximately a 3°C variation on Flight 3057. Section 4 of this report will present a method of obtaining further data stability improvement with considerably higher reliability.

Solar tracker operation was apparently perfect throughout both solar cell flights. The balloon control and the radio command systems operated flawlessly throughout. The ground telemetry station experienced no failures during the 1970 balloon operations. The minor difficulties experienced with interference free altitude readout are expected to be solved by the use of improved circuitry currently being developed under an Air Force contract.

4. RECOMMENDATIONS

Several options for major system improvements such as liquid cooling systems, new top mounted trackers or new design below the balloon trackers as described previously (1969 Final Report No. 3399) are still available for future program considerations. Considering the minimum damage to equipment on this program, the lowest cost option for future solar cell calibration flights is repair and reuse of the two currently used solar trackers. Replacement of some gears and shear pins with the addition of anti-blacklash springs may be all that is required to satisfy tracking accuracy requirements. Minor design changes on the sun direction sensor mounts could reduce tracker alignment time considerably. Preventative maintenance on the control circuitry (all new relays, transistors and sensors) was accomplished in 1970 and is not required at this time.

One area where a circuit modification would result in a significant improvement in system accuracy is in the VCO temperature control circuit. The present circuit consists of a heating resistor and a bimetal thermostat mounted within the VCO module. Although the thermostat has an operating differential of 1°C, when all thermal paths are considered, the actual thermal circuit differential is greater than 1°C. A more difficult problem has been the reliability of the thermostat. Over the last three years thermostats have failed several times on flights and during checkout between flights. A solid state circuit replacement for the bimetal thermostat will reduce temperature differential and improve reliability. A variety of circuit configurations can be used to replace the thermostat. A trigger circuit containing a negative temperature coefficient thermistor is currently being used for an application similar to this one. The circuit diagram is shown below:

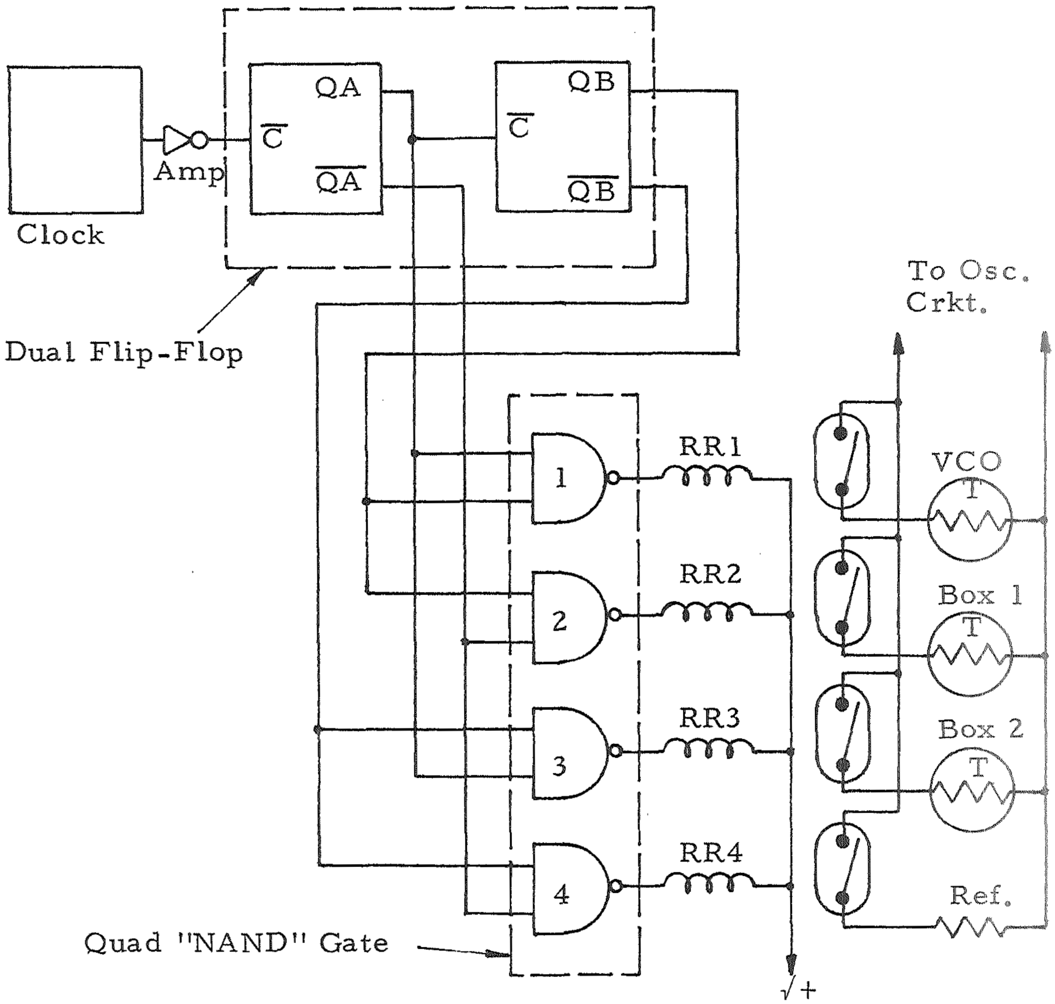


The trigger device in this circuit is a unijunction transistor (UJT) that changes abruptly from a nonconductive to a conductive state when a critical voltage is reached at its emitter (E) terminal. The ratio of the voltage dropped across the thermistor and R1 can be adjusted by R1 so that the UJT conducts at the desired temperature. Since thermistor resistance increases as temperature decreases, the voltage across the thermistor increases until the UJT conducts. When the thermistor's temperature is below the control point, the UJT does not conduct continuously but oscillates at a frequency determined primarily by the R1-C1 time constant. The oscillator pulse output appears across R3 and is coupled through a diode (D), charging capacitor C2. The voltage across C2 is primarily d-c and turns on amplifier stage (Q1) which in turn drives a power amplifier transistor (Q2). The Q1-Q2 amplifier has high current gain so that whenever the UJT stage oscillates full power is applied to the heater resistors. To complete the thermostat cycle, the thermistor senses the heat from the power heater resistors through the mounting block. This heat lowers the resistance of the thermistor reducing the voltage at the emitter of the UJT to return it to a nonconduction state.

The circuit described above is very similar to the "On-Sun" circuit also used in Box #2 except that the photoresistive sun sensor is replaced with a temperature sensitive resistor (thermistor). It is recommended that the above circuit as well as one or two similar circuits incorporating integrated circuitry be evaluated during preliminary preparations for future calibration flights. A highly sensitive and reliable circuit could be selected, evaluated and installed to replace the bimetal thermostat.

The electromechanical switch used to commutate the secondary temperature data has failed or become intermittent during flight a significant number of times. A small size, low cost alternative to this motor driven switch has not been available in the past. A number of solid state switching circuits or solid state driver/reed relay circuits are potentially suitable as high reliability commutator replacements. To make this task practical it is necessary to reduce the number of separate commutator steps from the present 8 to a maximum of 3 to 5. Since the present 8 channel arrangement includes 2 channels for VCO and 2 for reference frequencies, a 6 channel system would provide for all present temperature data. To achieve a less complex circuit, elimination of the ambient air sensor, the tracker back plate temperature sensor and/or the Box #2 chassis temperature sensor could be considered. These sensor readings are normally not vital to the success of a flight.

Assuming a 4 channel capacity, there are integrated circuit packages available that contain both the digital circuitry and the field-effect switching transistors necessary to multiplex four inputs onto a single output line. Unfortunately, there are some disadvantages using these devices in this application. The devices now available require both negative and positive supply voltages. The output transistors also require bias voltages and impedance levels that are not compatible with the existing thermistor controlled multivibrator circuitry. A circuit that uses sealed-in-glass reed switch relays for output signal coupling is compatible with the existing system. The reed switches are theoretically not as reliable as a completely solid state system but a life rating of over 50 million cycles is standard which would not affect flight reliability in any way. A logic diagram of the suggested circuit is shown below:



The "clock" stage consists of a temperature compensated unijunction transistor producing a trigger pulse every 15 sec. This pulse is shaped, inverted and applied to an integrated circuit dual flip-flop counter. The counter has four outputs used to sequentially actuate four gate circuits in another integrated circuit package. Each "NAND" gate drives a single pole reed-switch relay. The relays have low power consumption and are each about the size of an integrated circuit package. The common terminal of each relay contact set are connected together and to the common return side of the secondary frequency oscillator. The normally open contact of each of the four relays are connected to a sensing thermistor or reference resistance. The opposite end of each thermistor or reference resistance is then attached to the high input side of the secondary frequency oscillator to complete the circuit. The counter and gate stages are wired for operation of one of the four relays in a sequential manner providing complete electrical isolation between channels and between the secondary frequency oscillator and the commutator driving circuitry.

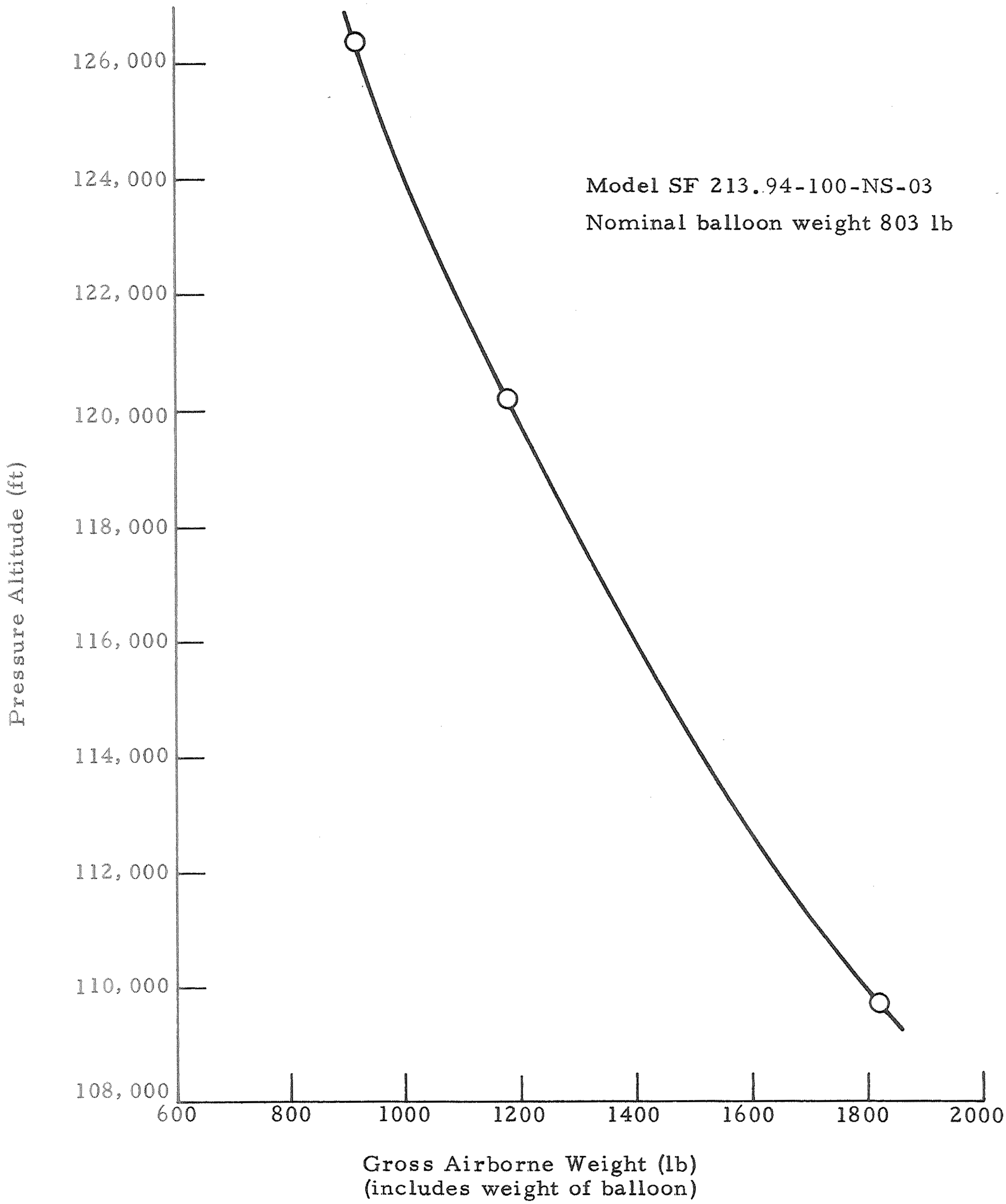
The Applied Science Division of Litton stands ready to initiate the system improvements discussed in this report or other modifications and improvements suggested by Jet Propulsion Laboratory. We again anticipate the opportunity and challenge of satisfying the stringent technical requirements of Jet Propulsion Laboratory in the near future.

APPENDIX A

OPERATIONAL DATA

Operation Specification Sheet
(for SF-213.94-100-NS-03 balloon)

Payload (design)	375 lb to 120,000 ft
Material (balloon wall and duct)	1.0 mil S. F. Polyethylene
Volume (theoretical)	3,460,000 ft^3
Surface Area (estimated)	116,242 ft^2
Inflated Height	138 ft
Deflated Length (gore length)	283 ft
Load Tapes	200 lb
Fittings; top	Plate Hoop and Ring - 27 in. O. D.
Fittings; bottom	5 in. O. D. Wedge and Collar
Number of Ducts	Two
Location of Duct ----- 25 ft^2 ea Lo-Duct	126 ft from base
Hi-Duct	248 ft from base
Inflation Tubes (two)	12.75 in. Diam. x 3 mil x 100 ft long
Inflation Attachment	30 ft from top apex
Destruction Device	Rip Panel
Descent Valves	Three gasports in hi-duct
Gasport Locations	#1--251 ft 10 in. from base #2--173 ft 10 in. from base #3--143 ft 10 in. from base
Gasport Sizes	#1--4.500 in. Diam. #2--5.875 in. Diam. #3--5.875 in. Diam.
Estimated Balloon Weight	803 lb (including cable)
Engineering Specification Sheet	CO 9393



GROSS WEIGHT VERSUS ALTITUDE

FINAL SYSTEM CALIBRATION DATA

Reference Calibration Levels (mv)	Flight 3055		Flight 3056		Flight 3057	
	Voltage (mv)	Frequency (Hz)	Voltage (mv)	Frequency (Hz)	Voltage (mv)	Frequency (Hz)
100	100.004	6843	100.001	6855	100.009	6858
80	80.014	7067	80.010	7076	80.016	7080
70	70.008	7177	70.005	7187	70.010	7190
60	59.996	7288	59.994	7296	60.000	7300
50	50.000	7398	49.997	7405	50.003	7408
25	24.966	7669	24.965	7674	24.968	7678
0	00.003	7935	00.002	7938	00.002	7941

TELEMETERED SECONDARY TEMPERATURE DATA

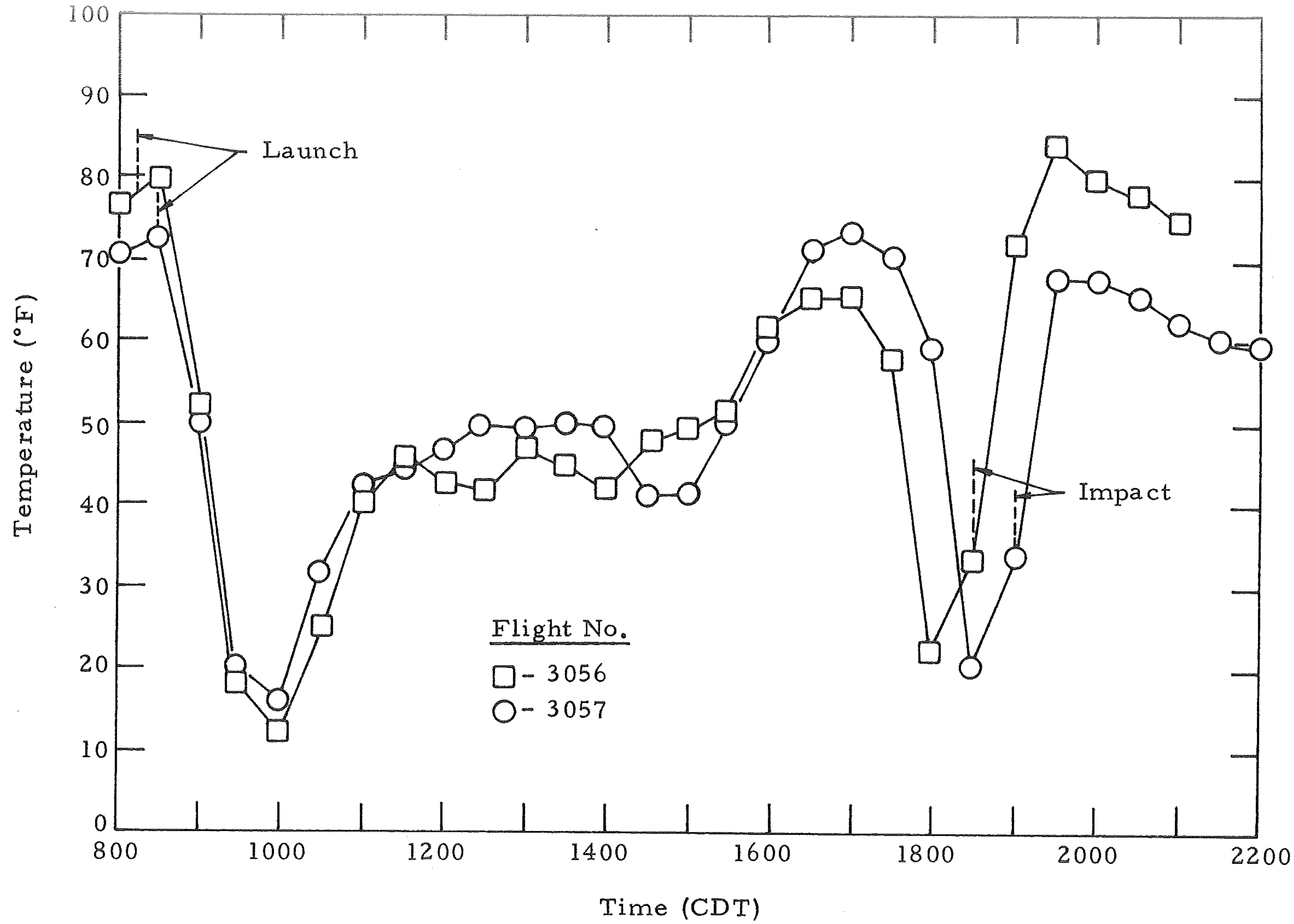
Flight 3056, 28 July 1970

Time from Launch	Temperature (°C)				
	V.C.O.	Disc	Box #1	Tracker	Box #2
L-1/2 hr	+59	+22	+26	+23	+35
L (08:14 CDT)	59	+23	26	23	36
L+1/2	59	-11	22	+18	33
L+1	57	-39	10	-2	25
L+1-1/2	57	-25	0	0	25
L+2	57	+ 1	1	+16	24
L+2-1/2	57	11	7	31	24
L+3 (Float)	56	26	13	42	28
L+3-1/2	59	29	21	48	31
L+4	59	36	26	55	33
L+4-1/2	58	39	28	57	36
L+5 (Solar Noon)	59	35	28	60	40
L+5-1/2	59	37	32	62	41
L+6	59	39	35	65	41
L+6-1/2	59	36	34	65	42
L+7 (End Float)	59	36	34	63	45
L+7-1/2	59	32	33	60	47
L+8	60	+26	33	59	47
L+8-1/2	+59	- 4	+32	+55	+46

TELEMETRY SECONDARY TEMPERATURE DATA

Flight 3057, 5 August 1970

Time from Launch	Temperature (°C)				
	V.C.O.	Disc	Box #1	Tracker	Box #2
L-1/2 hr	+57	+17	+21	+19	+28
L (08:28)	58	12	22	21	31
L+1/2	---	---	---	---	---
L+1	---	---	---	---	---
L+1-1/2	---	---	---	---	---
L+2	---	---	---	---	---
L+2-1/2 (Float)	56	14	12	39	27
L+3	56	23	20	54	34
L+3-1/2	55	21	26	54	36
L+4	54	25	29	57	37
L+4-1/2	58	23	30	60	41
L+5 (Solar Noon)	57	29	32	62	42
L+5-1/2	59	30	36	65	44
L+6	58	26	37	65	42
L+6-1/2	58	25	38	62	44
L+7 (End Float)	58	20	37	65	45
L+7-1/2	60	19	36	62	48
L+8	60	9	35	57	48
L+8-1/2	57	+ 2	34	52	45
L+9	58	- 9	30	42	44
L+9-1/2	58	-32	21	24	40
L+10	+54	-51	+ 7	+ 5	+34



LOWER PAYLOAD TEMPERATURE PROFILES

SOLAR CELL MODULE MOUNTING FOR FLIGHT 3056 (70-2)

BFS-7001 Voc 30 Temp(T1) 29	BFS-7007 34	BFS-7003 35		BFS-518 A 26 B 25 C 24	BFS-17A A 22	LRC-003 A 21 B 20	GSF-005 A 5 B 4	GSF-001 3	AEG-23 2
AFAPL IPC-701 32	AFAPL IPC-703 31	AFAPL IPC-704 33		MSF-8-003 27		BFS-505 19 Temp(B2) 18	GSF-701 10	GSF-702 9	SIE-7001 8
		APL-I 11	APL-II 13	APL-III 14 Temp(B1) 7	APL-IV 15	APL-V 16			

No. = Commutator Channel Number

Temp. = Bead Thermistor Location

SOLAR CELL MODULE MOUNTING FOR FLIGHT 3057 (70-3)

BFS-7001 Voc 30 Temp(T1) 29	BFS-7004 34	BFS-7005 35		BFS-520 Red A 26 Blue B 25 ND-C 24 Temp. 18	BFS-17A A 22	LRC-004 A 21 B 20		GSF-006 A 5 B 4	GSF-004 3	AEG-24 2
BFS-7006 32	BFS-7008 31	BFS-7009 33		MSF-8-004 27		BFS-505 19		GSF-704 10	GSF-705 9	SIE-7002 8

		BFS-7002 11 Temp(B1) 7	BFS-7010 13	BFS-7011 14	BFS-7012 15	BFS-7013 16			

No. = Commutator Channel Number
Temp. = Bead Thermistor Location

JPL PROPERTY LIST

Item No.	Quantity	Description
1	Two (2)	Sun Trackers (Contractor's Drawing No. ASD-236454 Rev. C)
2	Two (2)	Electronics Box No. 1 (Contractor's Drawing No. ASD-236456 Rev. A)
3	Two (2)	Electronics Box No. 2 (Contractor's Drawing No. ASD-236340 Rev. D)
4	One (1)	"T" Cable with connectors (Contractor's Drawing No. ASD-236259 Rev. B)
5	One (1)	Gondola with Instrumentation and Battery Holder (Contractor's Drawing No. GMI-SK1569)
6	One (1)	Solid State UHF Telemetry Transmitter (5W., IERC445)--217.5 MHz
7	One (1)	UHF Antenna
8	One (1)	Electric Helium Valve, EV13
*9	One (1)	Tracker Mounting Disc
10	One (1)	Set Main Power Batteries
11	One (1)	Beacon Antenna
12	One (1)	Set, Squibs, Nylon, One-shot relay

*Repairs required

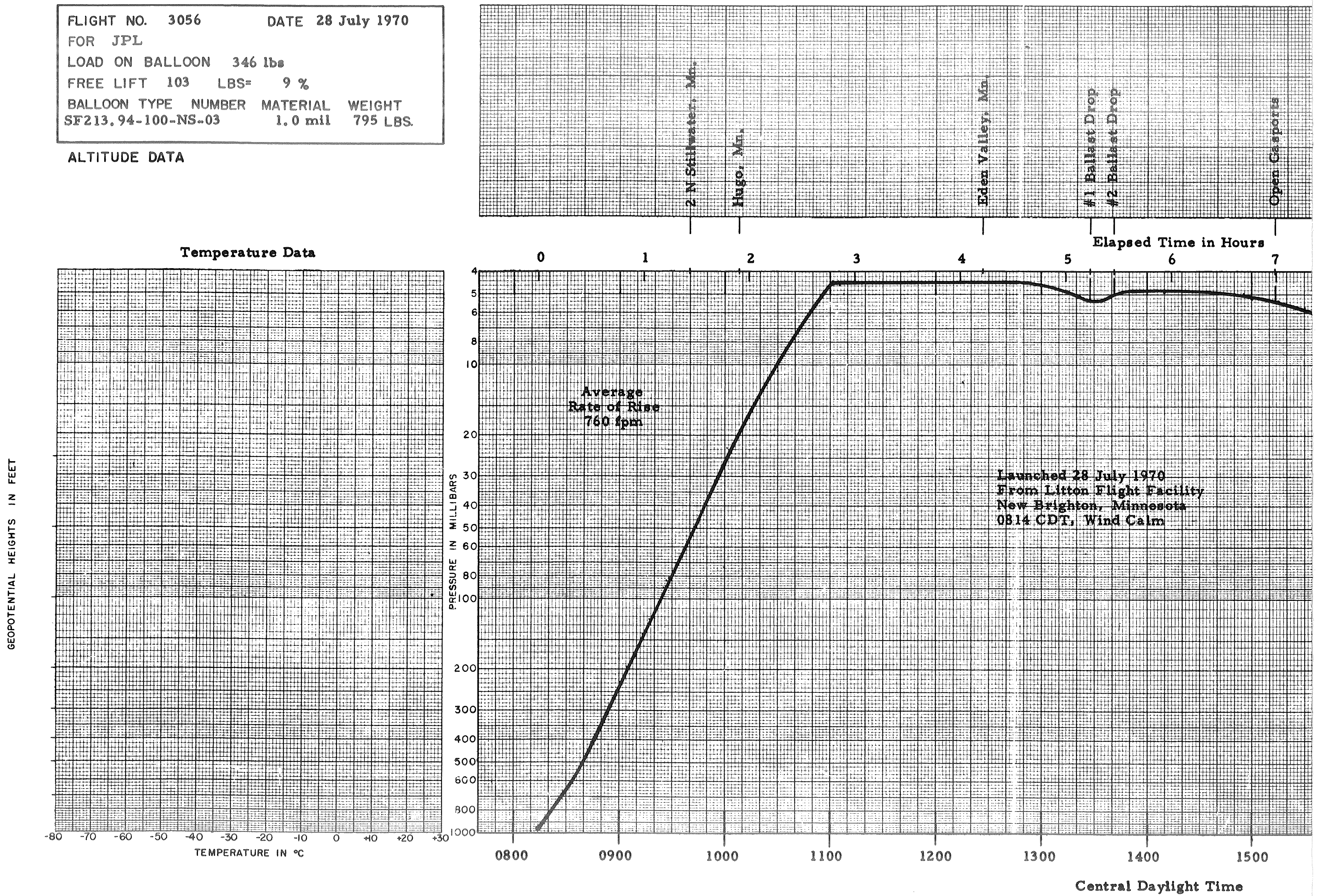
Items 11 and 12 are new and unused

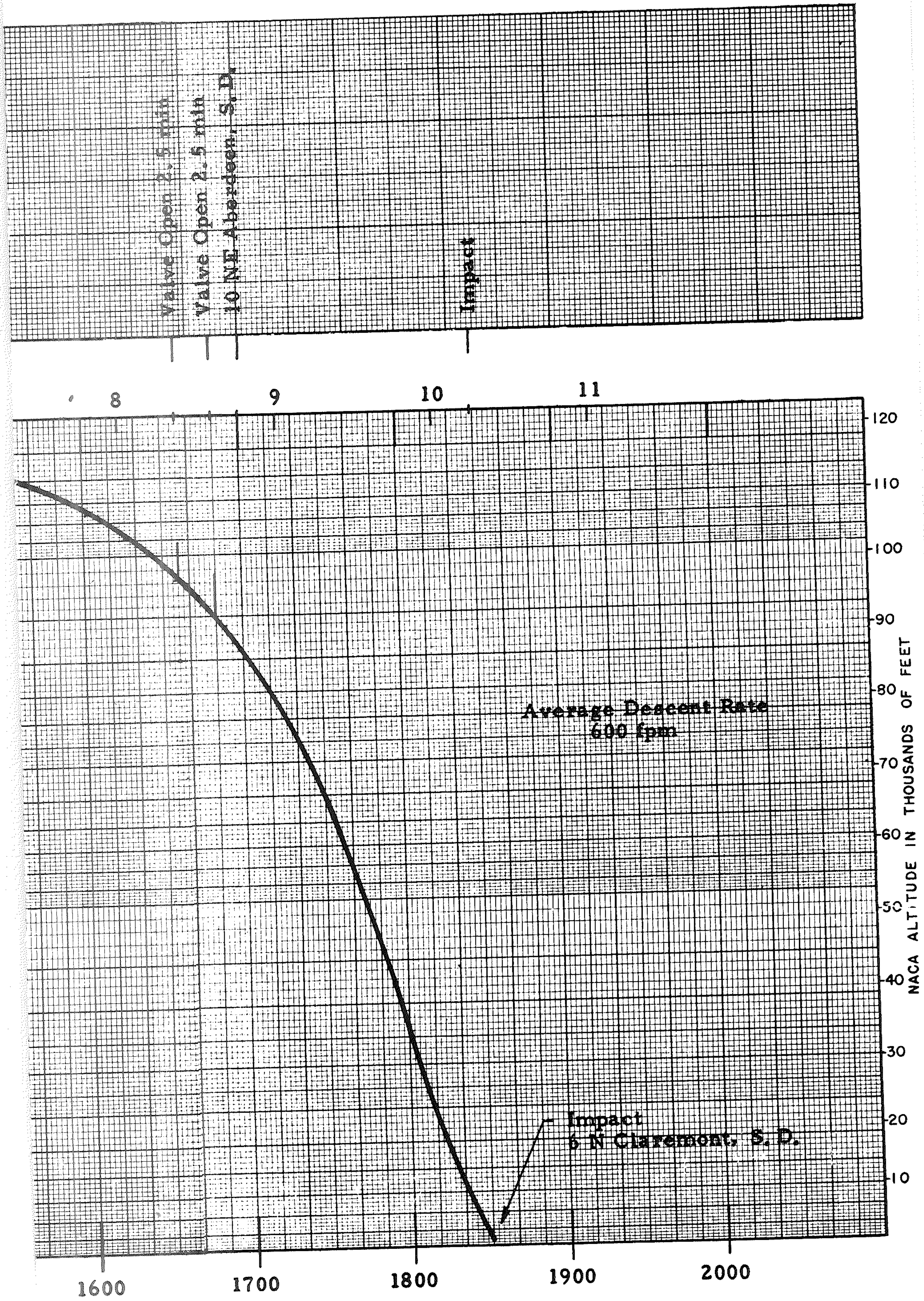
All other equipment is used but in good condition

FLIGHT NO. 3056 DATE 28 July 1970
FOR JPL
LOAD ON BALLOON 346 lbs
FREE LIFT 103 LBS= 9 %

BALLOON TYPE NUMBER	MATERIAL	WEIGHT
SF213.94-100-NS-03	1.0 mil	795 LBS.

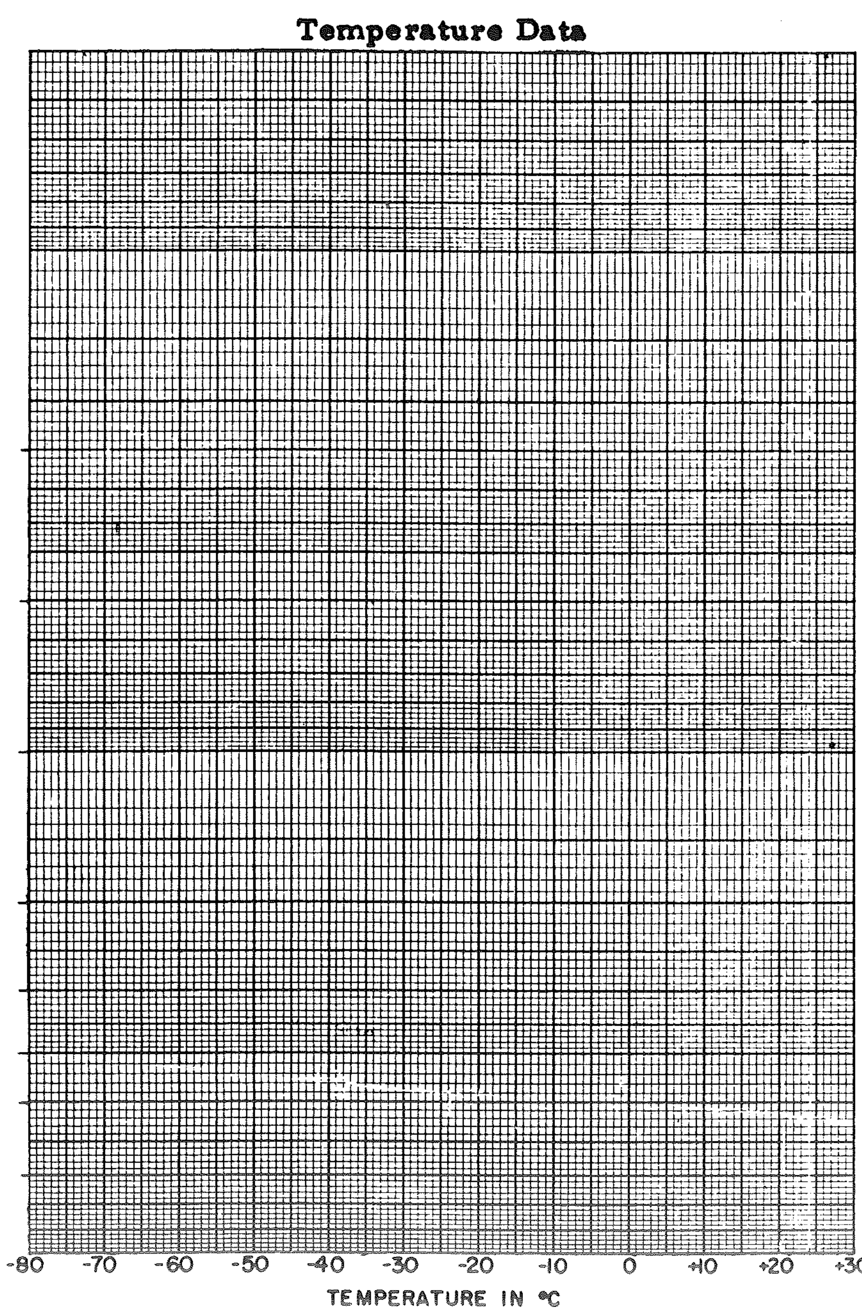
ALTITUDE DATA

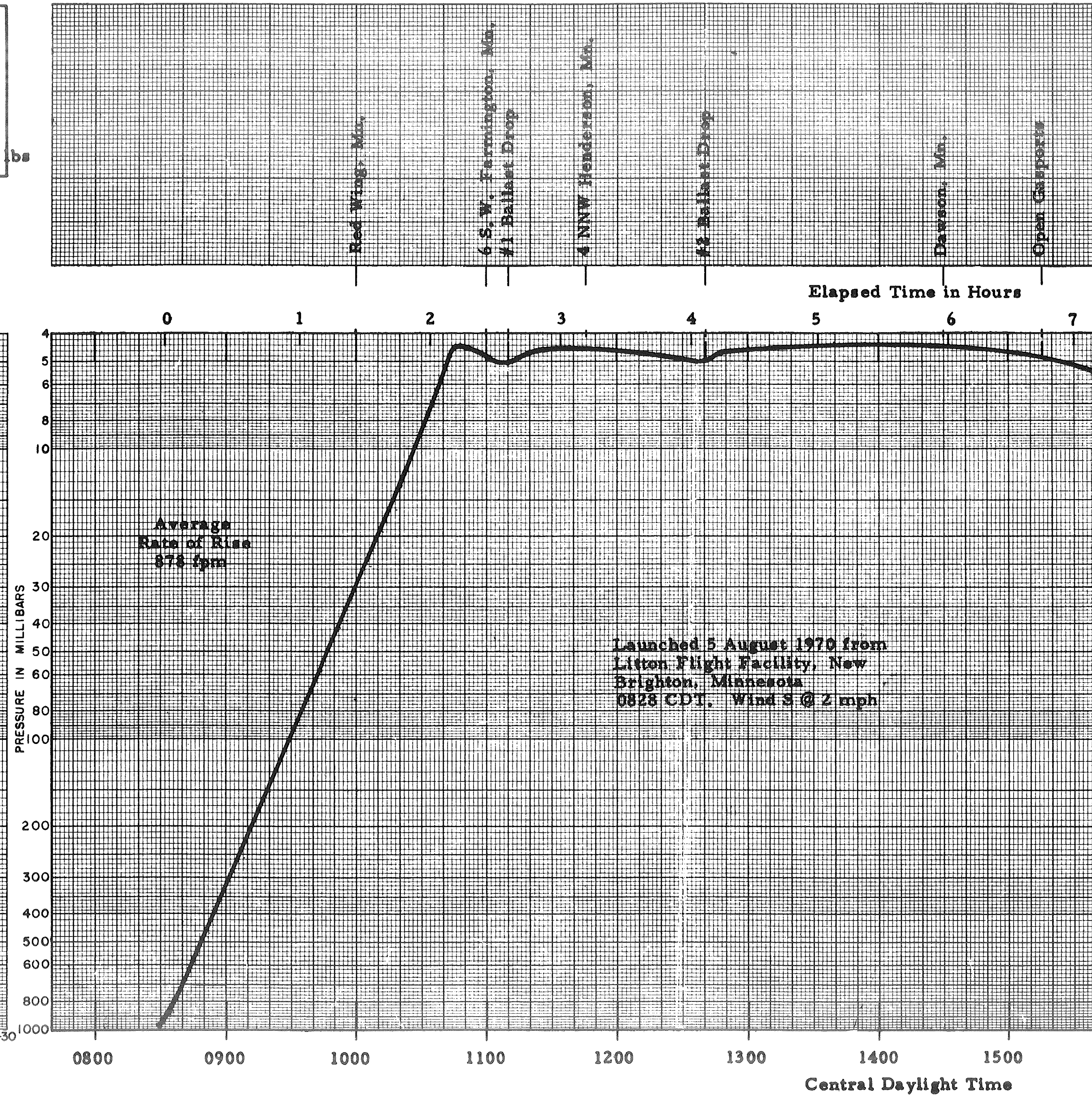


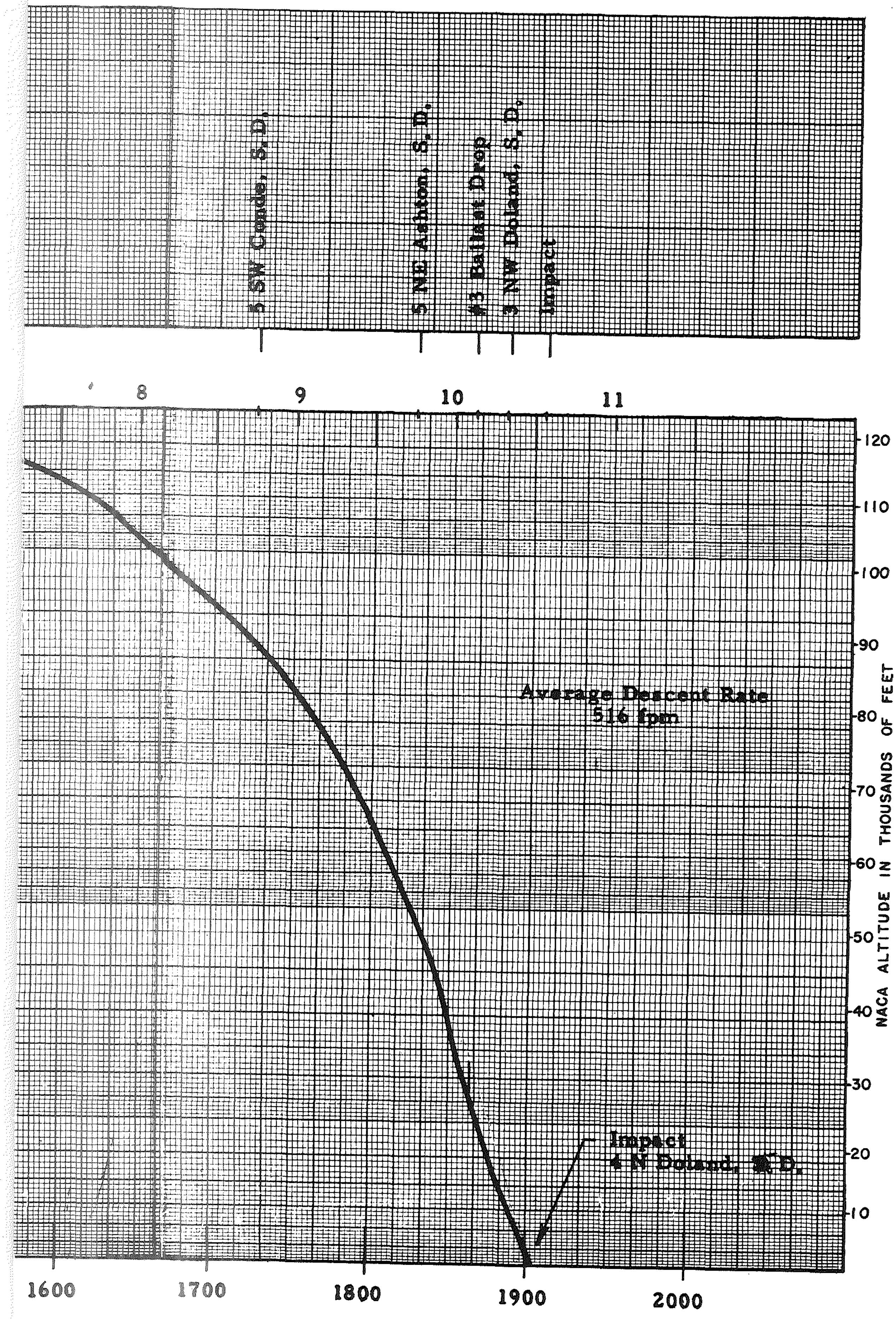

Valve Open 2.5 min
Valve Open 2.5 min
10 NE Aberdeen, S. D.
Impact
8
9
10
11
Average Descent Rate
600 fpm
Impact
6 N Claremont, S. D.
120
110
100
90
80
70
60
50
40
30
20
10
NACA ALTITUDE IN THOUSANDS OF FEET
1600
1700
1800
1900
2000

FLIGHT NO. 3057 DATE 5 August 1970
FOR JPL
LOAD ON BALLOON 352 lbs
FREE LIFT 116 LBS= 9.97 %
BALLOON TYPE NUMBER MATERIAL WEIGHT
SF213, 94-100-NS-03 1.0 mil LBS 811 lbs

ALTITUDE DATA






5 SW Conde, S. D.
5 NE Ashton, S. D.
#3 Ballast Drop
3 NW Doland, S. D.
Impact
8
9
10
11
Average Descent Rate
516 fpm
Impact
4 N Doland, S. D.
NACA ALTITUDE IN THOUSANDS OF FEET
120
110
100
90
80
70
60
50
40
30
20
10
1600
1700
1800
1900
2000