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APPLIED SCIENCE DIVISION

LITTON SYSTEMS, INC.

LITTON INDUSTRIES

RE-ORDER NO. 65-957

18 August 1965

Suntracker Balloon Flights

Flights 3026, 3028, 3029, and 3031

"This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, pursuant to a subcontract issued under Prime Contract NAS 7-100 between the California Institute of Technology and the United States of America represented by the National Aeronautics and Space Administration."

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Report No.: 2919
Project No.: 59541

APPLIED SCIENCE DIVISION
Litton Systems, Inc.
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1 of 36

I. INTRODUCTION

A. General

Flights #3026, #3028, #3029, and #3031 were a planned series of four flights conducted during July and August, 1965 for Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under subcontract No. 95 1247 to JPL. This contract provides for all necessary balloon flight services including those required for flight preparation, functional verification of the flights and data acquisition systems, tracking of the balloon aloft by aircraft, and the recovery and return of equipment after its descent to the surface. In addition, the contract requires the meteorological services needed for balloon flight planning, control, tracking, and recovery operations; and launch, recovery, and auxiliary vehicles and services. Balloons, power supplies, a solid-state telemetry transmitter and other equipment required for the flights was supplied separately under purchase order #BQ50315798.

B. Flight Objectives

1. Launch and ascend to an altitude of 80,000 feet ±4,000 feet, a balloon system with suntracker, solar cells, and instrumentation mounted on top of the balloon, and with telemetry and other instrumentation and power supply mounted below the balloon.

2. Telemeter altitude and solar cell data during ascent and during a floating period of four hours minimum. The floating period shall commence before 11:00 CDT and shall be maintained until at least 15:00 CDT.

3. Descend to surface level with balloon and payload intact.

4. Deflate balloon automatically upon impact by firing an explosive cord which opens the side of the helium filled balloon bubble for the purpose of recovering the top-mounted sun tracker and solar cells with minimum damage.

5. Recover and return all equipment except the balloon to the Litton facility.

II. FLIGHT NO. 3026

A. Flight Preparations

1. Project Personnel Assignments - Litton personnel responsible for preparations and flight operations on Flight #3026 were as follows:

Balloon Engineering and Operations Manager:	K. H. Stefan
Project Engineer:	R. D. Conlon
Flight Leader:	M. H. Lueders
Instrumentation:	M. K. Koivu
	E. J. Minnich
	L. V. Nelson

2. Pre-Flight Checkout

Required repairs and preventative maintenance were performed on all ground-station electronic support equipment. A new telemetry bus was outfitted to house the equipment previously installed in a tornado-damaged bus. Because of late delivery of a new solid-state telemetry transmitter, a vacuum tube transmitter similar to the unit used on all previous solar cell flights was checked out for use on this flight. The transmitter tested good in all respects. Modulation levels were set, and the telemetry antennas trimmed for the transmitter.

A Leeds and Northrup, Model K3, voltage potentiometer was set up for final calibration, and the voltage reference output was revised for 100 millivolts full scale output. Final adjustment of the reference system placed the full scale reference voltage within 40 microvolts of the desired 100-millivolt setting. Subcarrier frequencies corresponding to the voltage reference points were stable and very consistent.

Primary temperature channels were calibrated using a resistance decade box to simulate temperature levels of 0, 20 and 40 degrees C. Preliminary checkout of the suntracker revealed some instability when operating at supply voltages above and below nominal voltage. Careful sensitivity adjustments improved stability so that the suntracker was stable over a voltage range of 18 to 26 volts. The suntracker power leads were wired to operate from the 24-volts tap of the main battery to insure the proper operating voltage range during the flight. An addition to the balloon destruct mechanism was made for this year's flight program. To minimize system damage due to high ground winds at touchdown, four normally open microswitches were installed, one on each corner, below the battery container. The previously used tilt switch with its time delay was still retained. The impact switches are armed only after launch by existing circuitry. The closing of any or all of the switches on impact immediately fires the balloon rip circuitry and deflates the system more rapidly than the tilt mechanism would.

Following final setup, the entire system was operated in the sun for several hours as a long-term stability test. As a final check, the entire top-mounted payload was attached to the mounting disc and was then attached to the balloon top-end fitting. The assembly was then operated with the auxiliary power pack on the flat-bed of a truck as the truck maneuvered within the line-of-site vicinity of the telemetry bus. The tracker and the entire telemetry system performed as desired during this checkout.

B. Field Operation

1. Launch

Preparation began at 0600 CDT on 28 July 1965 with the weight-off of components and set-up of the telemetry bus. Wind velocity was three to four miles per hour at the start of balloon layout, but it increased to 10 mph during the inflation period. Launch preparations and instrumentation checkout proceeded without incident and launch was accomplished in eight to ten mph winds at 08:58 CDT. Bubble downwind dynamic launch technique was used with the lower payload mounted on the front of the launch truck.

2. Tracking and Recovery

A four-man crew consisting of a Cessna 170 pilot and observer/radioman, and on the ground, a truck driver and an assistant driver/radioman, handled the tracking and recovery operations directed by the telemetry-control base station. Flight No. 3026 took a south-southeasterly course during ascent to a point over Pine Island, Minnesota. During the four and one-half hour float period, the direction was southwest to a position ten miles south of Waseca, Minnesota. During descent the balloon system moved southeast to an impact point 15 miles southwest of Mason City, Iowa. Direct line distance from the launch site to the impact point was 145 miles due south. The lower payload touched down in a field of tall corn; the impact switch actuated the rip panel, but the lower payload was dragged about 200 yards by surface winds until the balloon was sufficiently deflated to lay over into the corn. System damage was minor; the tracker had a sheared drive pin and a quantity of battery acid had spilled. The corn field was damaged, but no special recovery problems were encountered and the system was returned to the Litton plant early the following morning.

C. Flight Results

1. Balloon

The balloon used (see Figure 1) was similar in design to the one used on the final flight of the 1964 series, employing two helium ducts to provide a redundant valving system. An improved polyethylene

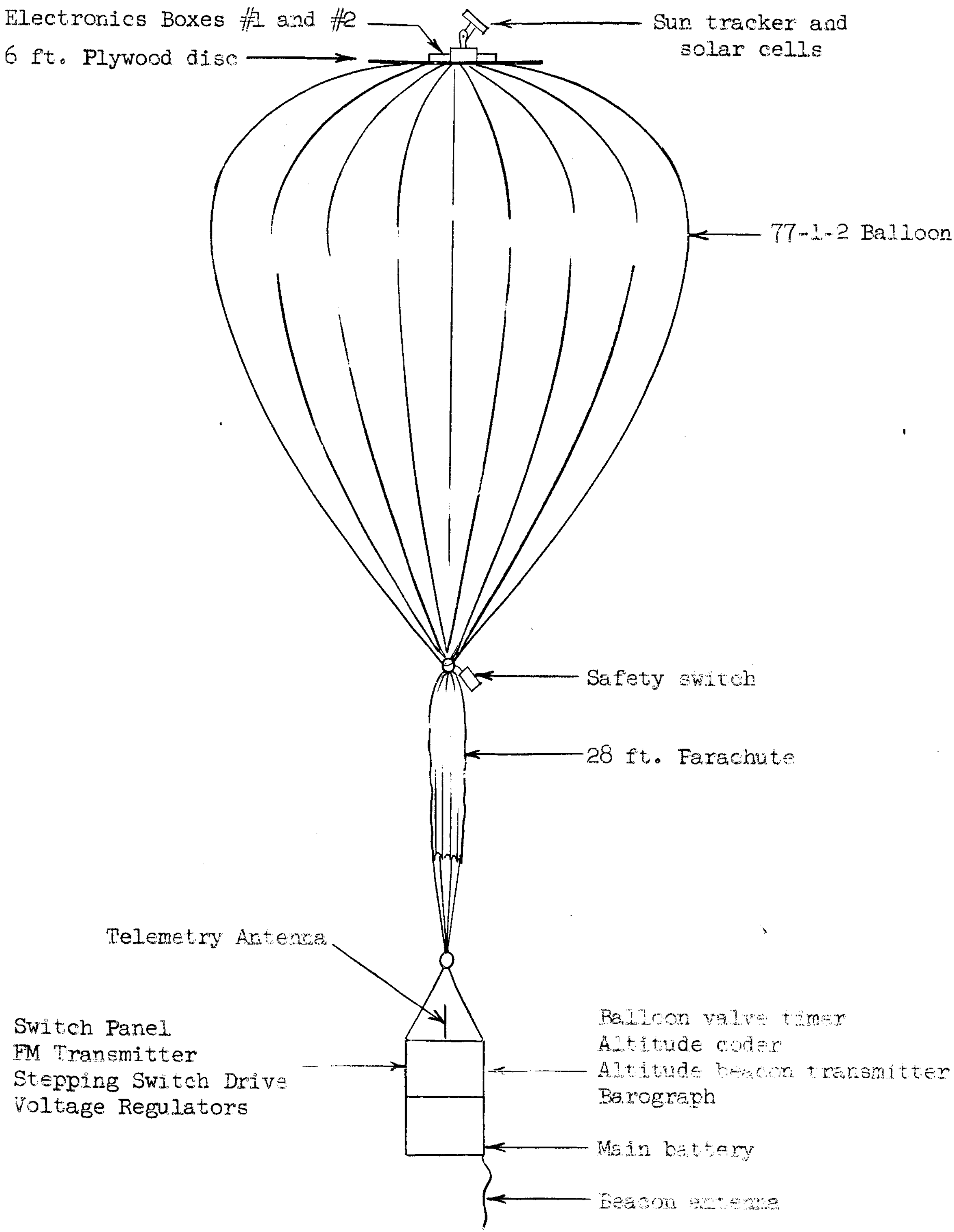


Figure 1. Balloon Flight Configuration

film material was also used. The new film is superior to the material previously used, having ductility at extremely low temperatures, high impact strength, high tensile strength, and excellent sealability. An operational specification sheet and a load altitude curve of this balloon are included in the appendix to this report.

Using 8% free lift the average rate of rise was 882 feet per minute to an average float altitude of 78,500 feet. The maximum altitude recorded during the float period was 78,900 feet. The float period began at 10:27 CDT and the system remained above 76,000 feet for a period of 4 hours and 55 minutes.

2. Instrumentation

The solar tracker turned on as programmed at 9,800 feet altitude. The telemetered on-sun signal indicated normal tracker operation throughout the flight. Secondary temperatures were telemetered continuously during the flight and recorded every half hour; compilation of the reduced temperature data is shown on page A-3 of the appendix.

Signal strength of the telemetry transmitter remained at a high level at the ground station throughout the flight. Both analog and digital data were recorded cleanly, accurately, and continuously during the entire flight. Digital records indicated the seven calibration voltages remained stable for launch through the float period. All the solar cell output channels had outputs within a few percent of their predicted voltages. After 1-1/2 hours into the float period the analog trace revealed that the 24-position commutating switch was operating erratically on a few channels: Channels number 3 and 5 were open-circuited occasionally, and positions 1, 3, and 24 were often skipped. Fortunately, the reference voltages and solar cell output voltages were stable enough to permit extrapolation between missed data points.

III. FLIGHT NO. 3028

A. Flight Preparations

1. Project Personnel Assignments

(Same as #3026 except: Flight Leader: C. N. Wise.)

2. Pre-Flight Checkout

The solid-state telemetry transmitter was received on 28 July 1965 and was installed the day following the first flight. Checkout revealed that the antenna loading was critical and might conceivably cause a telemetry failure during flight. The unit was returned to the factory on 2 August 1965. Litton received the unit again on 6 August 1965; it passed all checkout tests, including an altitude thermal response test of 5-1/2 hours duration when the temperature at the transmitter's mounting plate reach +154°F. The regulator dropping resistor plate reached a temperature of +186°F during this test. To evaluate the thermal characteristics of the instrument container during an actual flight, a small mechanical temperature recorder was attached to the transmitter case mounted on the inside surface of the lower instrument panel.

Because the new transmitter has an input impedance less than the vacuum tube unit, it requires an amplifier stage preceding its modulation input. A single stage amplifier employing a silicon transistor and associated coupling components accomplished the required amplification and also improved the system's noise level by reducing transmission line impedances between the top and bottom telemetry components. This circuit was mounted in Electronic Box #2. A schematic of the additional circuitry is shown in Figure 2.

During checkout, some instability was noticed in the subcarrier output frequency. The problem was traced to the 20-volt voltage regulator. An available spare unit was used to replace the faulty

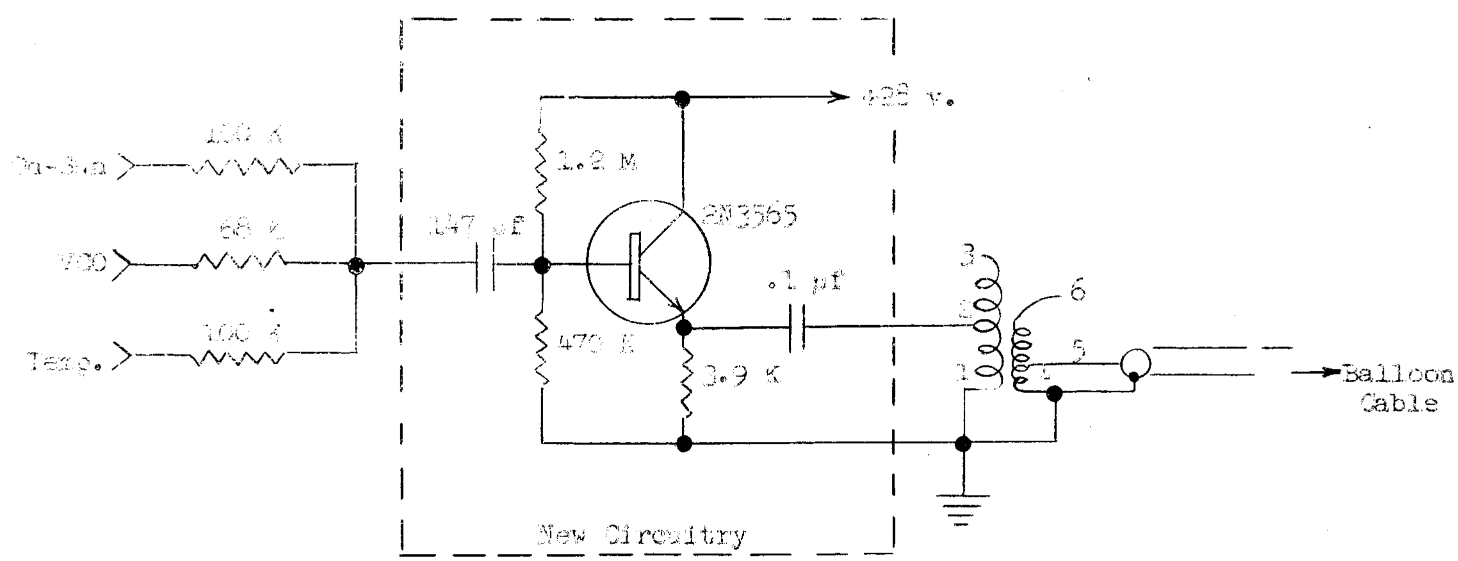


Figure 2. Schematic of Box #2 Modulation Amplifier

unit. After repair the total regulated output voltage was a stable 27.6 volts, and the subcarrier output frequency was shifted to a stable operating range. The final calibration, using the K3 voltage potentiometer, placed the calibration voltage levels within 91 microvolts, maximum, of the desired levels. A tabulation of these calibration levels is given on page A-7 of the appendix.

The stepping switch problem encountered during Flight No. 3026 was believed to be due to dirty contacts and rotor misalignment. The improper alignment was believed due to wear during the many hours of use of the switch. A spare stepping switch, which had been used only slightly, was substituted for the original unit. The four decks of the replacement switch were wired in parallel pairs for greater reliability against dirt accumulation, broken contacts, and readout errors due to contact resistance. The new switch performed satisfactorily during several hours of system checkout preceding this flight. Calibration of the temperature channels was checked, and the system was judged ready for flight.

B. Field Operation

1. Launch

Preparations began on schedule on 9 August 1965. Balloon layout began at 07:05 CDT with wind velocity of 3 mph from the northwest. The system check was completed by 08:15, inflation began at 08:20 and was complete at 08:35. Launch was accomplished at 08:44 in winds of 6 to 7 mph. Launch was very smooth and without incident.

2. Tracking and Recovery

The flight took a southerly course during ascent. The sun's reflection from the balloon during the time its ascending position was over the western limits of St. Paul, Minnesota, resulted in numerous unidentified flying object (UFO) reports from St. Paul residents.

The system reached float equilibrium above a point one mile north of Pine Bend, Minnesota at 10:35 CDT. The float trajectory moved the system to the southwest above a point 10 miles west of Northfield, Minnesota, at the initiation of descent. During descent the balloon system moved south to an impact point 8 miles southeast of Waseca, Minnesota. Impact position was 80 miles south-southwest of the launch site. The system landed in a farm yard close to a house and the balloon deflated across high voltage power lines. Recovery was accomplished by the two-man ground tracking crew without difficulty after the local power company had disconnected the power. The tracker had not touched the ground and was in perfect condition; the only damage to the lower unit was battery acid spillage. The equipment was returned to the plant that evening.

C. Flight Results

1. Balloon

The balloon used for flight No. 3028 was identical to the unit used on the previous flight (see Figure 1). Using 8% free lift, the average rate of rise was 707 feet per minute. The system floated between 78,000 and 79,000 feet during the entire float period and remained above 76,000 feet for a period of four hours and 40 minutes.

2. Instrumentation

The solar tracker turned on just below 10,000 feet. The telemetered on-sun signal indicated normal tracker operation with nearly continuous tracker angle corrections due to balloon rotation on ascent. After float equilibrium was attained, the on-sun sensor indicated only infrequent corrections. The solar cell data recorded with the analog recorder presented a positive indication that the tracker was, in fact, pointed directly at the sun at all times, except during the brief and infrequent rewind periods.

The 24-position data stepping switch that had been replaced during the preflight checkout malfunctioned again during this flight. Occasional open circuit readings were obtained on several channels during the course of the flight. Fortunately, the condition was intermittent so that data was not lost for any significant time interval. Another discrepancy showed up at 13:20 CDT about two-thirds of the way through the float period. At that time the telemetered voltage reference frequencies indicated a shift in value. The 100 millivolt frequency shifted from 6844 cps down to 6823 cps. The other voltage calibration channels were shifted proportionally downward in frequency. The calibration frequencies remained at this new level until one-half hour after descent commenced. At 15:35 CDT the reference levels returned to their original frequency readings. Reliable telemetry data was received during the remainder of the descent until the system reached the radio horizon at about 4500 feet at 16:13 CDT. A table of telemetered secondary temperature data obtained on this flight can be found on page A-4 of the appendix.

IV. FLIGHT NO. 3029

A. Flight Preparation

1. Project Personnel Assignments

(Same as Flight #3028.)

2. Pre-Flight Checkout

Several instrumentation problems encountered on the previous flight were analyzed and the circuitry repaired or reworked during the three-day period between Flight #3028 and Flight #3029. The temperature recorder attached to the telemetry transmitter on Flight #3028 revealed that 4-1/2 hours after launch the temperature reached a high of over 170°F. The temperature remained above this high level for 2-1/2 hours until the air flow and the cooler atmosphere encountered during descent dropped the temperature more than 100°F. (See time vs. temperature curves on page A-8 of appendix.) The subcarrier frequency shift encountered on Flight #3028 occurred during the time the instrument panel temperature was at its peak value. The solid-state transmitter, 8-volt regulator diode, and dropping resistors were capable of withstanding this extreme temperature rise; the 20-volt self-contained regulator mounted nearby has a maximum temperature rating of 150°F. Tests revealed that the 20-volt regulator did lose regulation at the extreme temperatures, allowing the voltage supply to the subcarrier oscillator to rise from 27.6 to 35 volts. The test verified that this voltage increase results in a frequency decrease of the magnitude recorded during the flight.

Several steps were taken to prevent a temperature buildup in this area of the instrumentation during future flights. The dropping resistors in the 8-volt regulator section were a major heat contributor. The regulator design was changed from a brute-force shunt configuration to a series regulator using a silicon power transistor as the series control element. A circuit diagram of the revised configuration is shown in Figure 3. This design eliminates two large dropping resistors and requires only an additional transistor, biasing resistor, and temperature compensating diode. The same reference diode is used, but its shunt current is reduced by a factor of 32 times. Current drain from the battery is reduced by 520 milliamps, voltage regulation is slightly better, and temperature response is improved. The series transistor has low power dissipation and is mounted on a large heat dissipator attached to a cool area of the instrument panel away from the transmitter. The 20-volt regulator that overheated on the previous flight was checked and judged to have suffered no permanent damage; its mounting position was also moved away from the transmitter mounting position. A heat dissipating fin had been installed on the outside surface of the instrument panel before the last flight; this panel was painted flat white on its upper surface and black on its shaded areas. The top of the instrument container was also sprayed flat white and, in addition, just before launch a sheet of white cardboard was attached as a sun-shield just above the instrument box.

A hard look at the stepping switches that had malfunctioned on both of the preceeding flights revealed a weakness that appeared correctable. The stepper was occasionally driving the common switch contacts past the detented stop position. Increasing tension of the detented spring showed no appreciable improvement. It was determined that reversing the detent wheel itself on the drive shaft brought about a noticeable improvement in detent action; further checkout showed no further tendency to bypass the detent and cause open circuit readings or skipped positions.

Final calibration of the reference voltages showed them to be essentially the same as when checked before Flight #3028. The maximum variation from the desired levels was a deviation of -85 microvolts at the 80 millivolt level. (See Appendix, page A-7.) An on-sun system checkout showed that the tracker was operating satisfactorily.

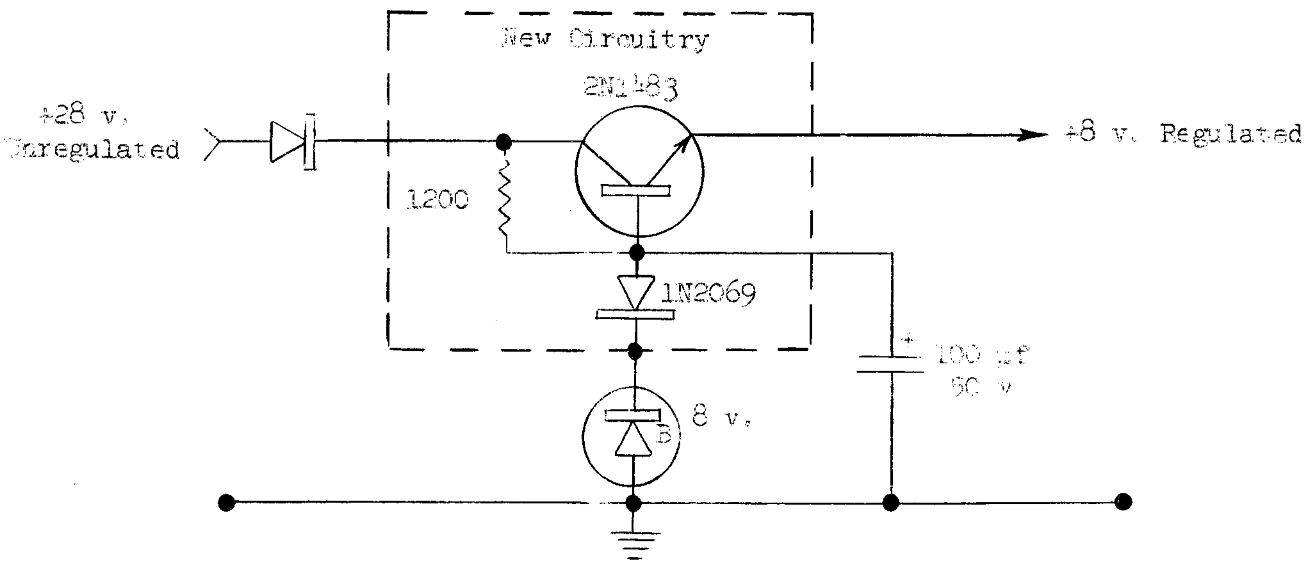


Figure 3. Schematic of Eight Volt Regulator Redesign

B. Field Operation

1. Launch

The weather forecast for 13 August 1965 was good in all respects except that ground winds were expected to be of higher velocity than desired by 08:30 CDT. To keep the program on schedule, it was decided to prepare to launch the flight earlier than usual to beat the expected increase of surface winds. Preparations began one hour earlier than usual. Initial system checkout was complete and balloon layout commenced at 06:15. Inflation began at 07:15 and was completed by 07:35 CDT. Winds were calm during inflation and it became obvious that there would be no wind problems as predicted earlier. Some extra time was used for system checkout and for resetting the valve control and backup timers so that the flight would remain at float for a longer period. The 07:56 launch was accomplished smoothly in winds of only two miles per hour from the southeast.

2. Tracking and Recovery

The flight moved north after launch until it reached 6,000 feet where it turned southeast until it reached float above a point two miles northeast of Pine Bend, Minnesota. The track was southwest during the extended float period to a point two miles east of Gaylord, Minnesota, at an altitude of 65,000 feet on descent. Descent course was varied but generally eastward to an impact two miles north of Belle Plaine, Minnesota. As the system neared the surface it appeared to be moving toward a water impact in the Minnesota River, but the actual touchdown was about one mile north of the river in an open field. The balloon was ripped open immediately, but as it deflated the system was dragged a few hundred feet into a deep weed patch where it came gently to rest. Battery acid spillage and a sheared elevation drive pin were the only damages to the equipment. Recovery was easily accomplished, and there was no damage to farm land or fences. Distance from the launch site was only 45 miles and the equipment was returned to the plant that evening.

C. Flight Results

1. Balloon

The balloon design and material were identical to that used on the previous two flights. Using 8% free lift the average rate of rise was 770 feet per minute to a maximum altitude of 78,500 feet. The system remained at this altitude until 12:00 CDT when it sagged to 76,000 feet. The average altitude for the duration of the float period held at about 76,000 feet. The balloon held above the 75,000 feet level until 15:00 when the helium valve opened. There was no definite reason for the slight altitude drop; it could not definitely be correlated with cloud cover or surface characteristics, although there were high cirrus clouds below the balloon during the first portion of the float period followed by clearer conditions as the track moved over the darker Minnesota River Valley. Total float time on this flight was 5 hours and 23 minutes.

2. Instrumentation

The telemetry data of solar cell outputs indicated that, except for brief rewind periods, the solar tracker was properly locked on the sun. The on-sun indicator was, however, more active than usual. A near constant warble of the one thousand cycle note was heard during the float period. Since the analog recording of the data did not show any variation of solar cell outputs nor any noise due to transients from the drive motors, the problem was believed to be due strictly to a high sensitivity setting of the on-sun sensor's circuitry.

The data stepping switch that caused minor problems on the first two flights performed flawlessly this time. No skipped or open circuit readings were observed during the entire flight. The reference frequencies were also exceptionally stable during the total flight time. The on-board recording of the lower instrumentation panel temperature revealed one cause of the improved stability. In contrast to the extremely high temperatures encountered on the previous flight, the temperature profile revealed a rise to only 109°F during the extended float period. At launch the reading was +100°F, and the minimum reading was +40°F, obtained during ascent and matched again during descent. (See the temperature profiles in the appendix, page A-8.)

From the standpoint of data stability and instrumentation reliability this flight was the best of the series to date.

V. FLIGHT NO. 3031

A. Flight Preparation

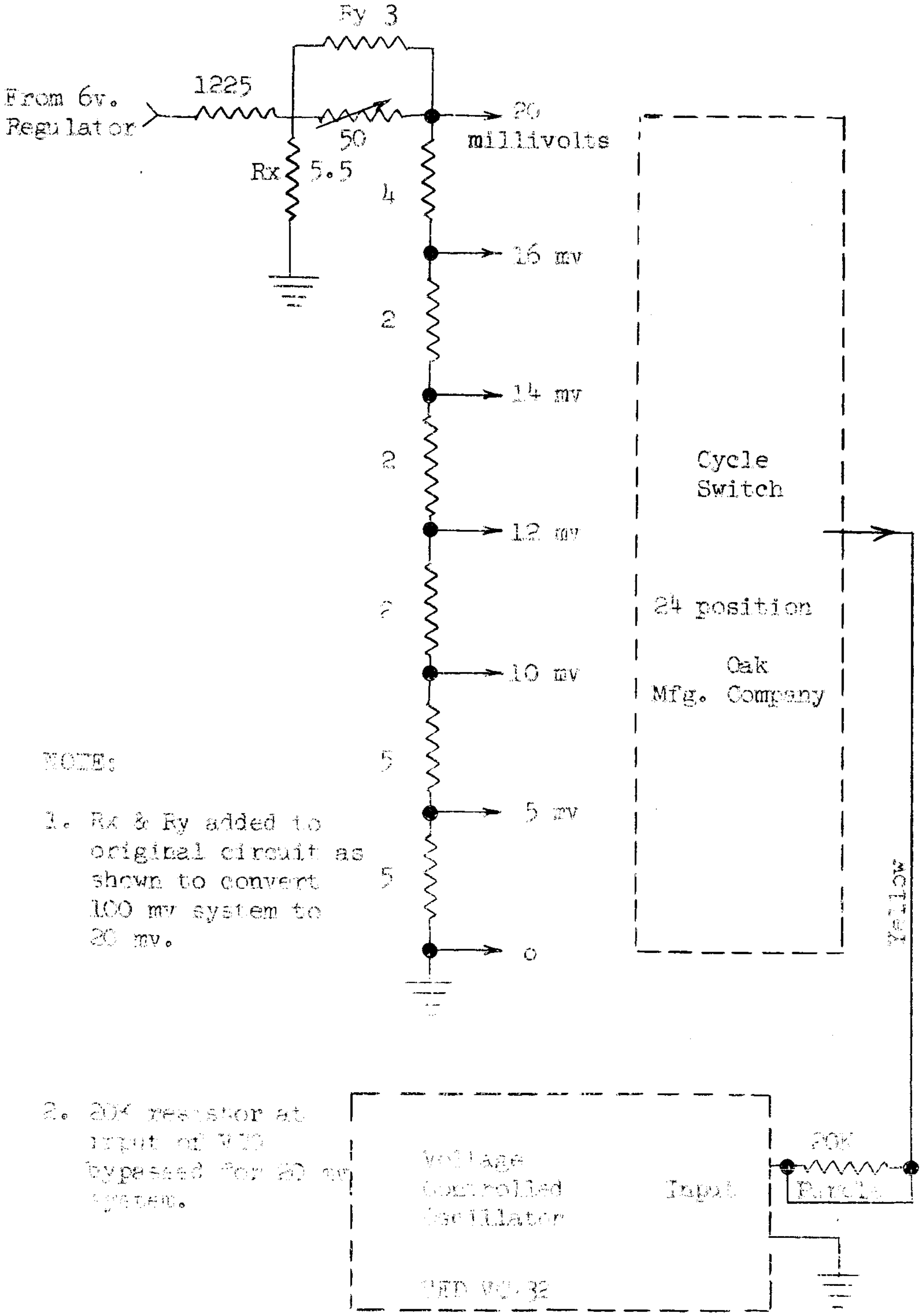
1. Project Personnel Assignments

(Same as Flight #3028.)

2. Pre-Flight Checkout

The solar cells supplied by JPL for this flight were identical to the cells flown on the final flight of the 1964 series, flight #3014. These cell modules contain spectral response filters that divide the solar cells' response spectrum into one-tenth micron units. In addition to the filtered cells, two unfiltered cells were flown with special sun shades for a sky brightness experiment. The maximum outputs of these individual filtered and shielded cells was thus reduced, and it was necessary to increase the telemetry system's sensitivity to obtain the desired resolution. The 100-millivolt full-scale telemetry was modified to a 20-millivolt system using the same modification used on Flight #3014. The circuit modification is shown in Figure 4. Following this modification the system was recalibrated with the Leeds and Northrup K3 instrument and the trimming resistors readjusted to the new calibration points of 20, 16, 14, 12, 10 and 5 millivolts. The final pre-flight calibration voltages and VCO frequencies are presented on page A-7 of the appendix. Following the reference modification, the temperature reference voltage and regulated VCO voltages were checked, and the temperature channels were recalibrated.

During initial tracker checkout in the sun a lock-up condition was observed in which the tracker reached a near vertical position and would not return to its normal attitude during rewind. Since there was a remote possibility that this could happen on an actual flight, the sensitivity controls and limit switches were adjusted to eliminate



NOTE:

1. Rx & Ry added to original circuit as shown to convert 100 mv system to 20 mv.

2. 20K resistor at input of VCO bypassed for 20 mv system.

Figure 4. 20 Millivolt Calibration Circuit (Revised 100 mv system)

this condition. After initial adjustment it became necessary to reset the controls to reduce jitter and to insure reliable operation over an acceptable voltage range. After considerable manipulation, a compromise adjustment point was obtained that greatly minimized the possibility of lock-up but did not result in jitter or voltage sensitivity problems. The on-sun complete system checkout preceeding the flight indicated that all systems were performing perfectly.

B. Field Operation

1. Launch

Following checkout, the first opportunity to launch this final flight was on 26 August 1965. Predicted weather conditions for the launch and track areas were good, but the northern half of Minnesota was expected to have ground fog in the morning. When the crew arrived at the launch site, weather conditions were good and preparation began as usual. At dawn a thick fog was seen to the north; it soon covered the launch area. Our weather forecasters expected the ceiling to lift by 08:00 CDT, so preparations were held at approximately the launch minus one-hour point.

By 08:15 the fog had not lifted; the Twin Cities, only ten miles to the south, had clear conditions throughout the morning. At this point the crew was informed that clouds were moving into the area above the fog and that there was a possibility of thundershower activity in the recovery area. The flight attempt was cancelled at 08:30.

Weather was bad on the 27th and predicted poor for the 28th. A last minute weather check at 01:00 CDT, 28 August 1965 indicated that conditions might improve and permit the launching of the final flight. The crew were called at the usual time; surface temperature was 39°F, the sky was clear and wind was light from the north. Launch preparations and instrumentation checkout proceeded without incident, and launch was initiated at 08:51 CDT. The "Bubble downwind dynamic launch technique with the lower payload mounted on the front of the launch truck" was used on this flight as on all previous launches of this series.

C. Tracking and Recovery

The system drifted rapidly to the southeast and attained float 80 miles and 134 degrees from the launch site, one mile west of Kellogg, Minnesota. Float winds carried the system northeast to a point just north of Mondovi, Wisconsin, at the termination of the float period. High velocity winds during descent again carried the deflating balloon far to the southeast to an impact four miles west of Lyndon Station, Wisconsin. Direct line distance from the launch site to the impact was 193 miles southeast. As the balloon was deflating after impact, surface wind dragged the lower payload about 200 yards across a swampy farm area. This impact was similar to the first and third flights: they all touched down in open areas and were drawn along the ground until the balloon had completely deflated. Damage on all was identical; each suffered battery acid damage, and the tracker on each system had only a sheared drive pin. All equipment on this flight was returned to Litton the following morning.

D. Flight Results

1. Balloon

This balloon was identical to those used on the three previous flights (see Figure 1). Using 8% free lift, the rate of rise was 700 feet per minute. The maximum altitude recorded during the float period was 78,000 feet, and the balloon remained above 77,200 feet for the entire period. The system penetrated 76,000 feet at 10:29 CDT and remained above that level for four hours and 49 minutes.

2. Instrumentation

The solar tracker, data cycling switch, reference voltage system and all other airborne instrumentation worked flawlessly throughout the flight. The solar cell voltages obtained via the telemetry system should be completely free of error due to the system itself; this should yield significant information on the solar spectrum and sky brightness at the altitudes flown.

Several minor problems plagued the monitoring and tracking crews. First, the recovery truck's communications set did not operate. An open antenna lead was located and repaired, and the truck was dispatched shortly after launch. The aircraft had good communications during checkout before launch, but after take-off on the tracking mission its receiver went out. The plane landed later at Durand, Wisconsin, and the crew were able to get the unit working again. From that point on, communications were satisfactory. Received signal strength of the telemetry transmitter dropped to near the noise threshold just as the system attained float. The quarter wavelength whip antenna was quickly replaced with a stacked Yagi antenna, but this did not improve the situation appreciably. The telemetry receiver was next replaced with a standby unit, and the normally high signal level was restored. Trouble with the original receiver was later diagnosed as a faulty RF stage. Signal strength remained strong to the radio horizon on descent despite the 200 miles slant range. Fortunately, the minor operational problems in no way prevented completion of the flight objectives.

VI. CONCLUSIONS AND RECOMMENDATIONS

The four identical balloons used on this program performed flawlessly. The only discrepancy during this program, as far as the balloons were concerned, was that all flights floated below the desired nominal 80,000 feet level. A simple solution to this is to build a slightly larger balloon for future flights of the same system. Another solution is to eliminate 28 lbs. from the system weight. Using silver zinc in place of lead-acid batteries would be one way of reducing weight so that the same balloon design could be retained.

Several significant improvements were made in the instrumentation during this flight program:

> Incorporation of the solid state transmitter improved reliability and reduced power consumption.
>
> The modulation amplifier constructed for use with the new transmitter offered indirect system improvement by transferring the modulation voltage from the upper payload to the transmitter more efficiently and at a lower noise level.
>
> The redesigned voltage regulator improved reliability considerably by completely eliminating a high temperature problem caused by high power dissipation.
>
> The new circuit, a series transistor configuration, reduced power dissipation from 17.1 watts to .5 watt. Current drain from the battery was thus reduced by more than .5 ampere.

The data cycle switch, a problem on the first two flights, should be replaced before any future flights. A high reliability unit of the present design or a new switch with better design features could be obtained for future flights. Several design improvements can be made on the solar tracker to significantly improve reliability. A voltage regulator should definitely be added to the tracker's electronics circuitry to eliminate sensitivity variations due to battery voltage fluctuations. Anti-backlash gears would improve pointing accuracy and reduce jitter at high sensitivity settings. Regulator and gear changes will improve performance. Of course, a complete re-design of the control circuitry could be undertaken which would eliminate the relays and improve overall reliability.

In conclusion, the success ratio of this series of flights was significantly improved compared to the previous years' operations. Four successful flights were completed out of four attempts. As discussed above, there is still room for further improvement mainly in the area of instrumentation reliability. Litton looks forward to the opportunity to satisfy the demanding requirements of Jet Propulsion Laboratory in the areas of balloon operation, balloon design, and high accuracy airborne electronic systems of this type in the future.

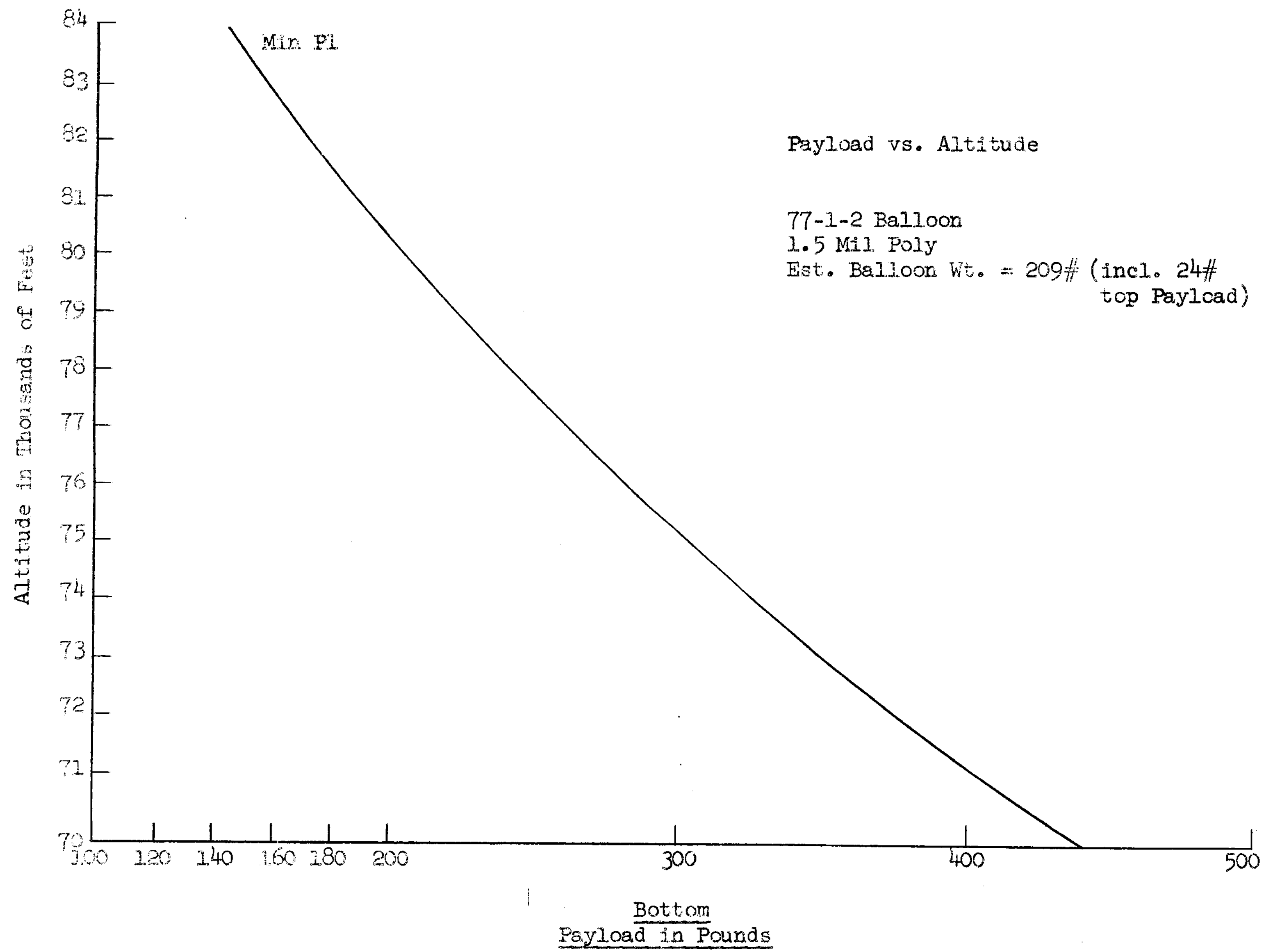
APPENDIX

Flight Data

APPLIED SCIENCE DIVISION
LITTON SYSTEMS, INC.

Operational Specification Sheet
For 77-1-2 Balloon

Fabric Parameter (Σ) - - - - - - - - - - - - - - -	0.25
Payload (Design)- - - - - - - - - - - - - - - - - -	206#+24# lbs to 80K Top PL
Material (Balloon Wall and Duct)- - - - - - - - -	1.5 Mil Polyethylene
Volume (Theoretical)- - - - - - - - - - - - - - - -	174,785 ft^3
Surface Area (estimated)- - - - - - - - - - - - -	15,730 ft^2
Inflated Height - - - - - - - - - - - - - - - - - -	64.1 ft
Deflated Length (Gore Length) - - - - - - - - - -	108 ft
Load Tapes- -	None
Fittings; top - - - - - - - - - - - - - - - - - - -	Inverted EV-13 230822
Fittings; bottom- - - - - - - - - - - - - - - - - -	4" Dia. Integral
Number of Ducts - - - - - - - - - - - - - - - - - -	Two
Location of Duct- - - - - - - - - - - - - - Lo-Duct	35' from base
Hi-Duct	35'-6" from top apex
Inflation Tube- - - - - - - - - - - - - - - - - - -	20" Layflat x 3 Mil x 70' Lg.
Inflation Attachment- - - - - - - - - - - - - - - -	20' from top apex
Destruction Device- - - - - - - - - - - - - - - - -	Prima Cord
Descent Valves- - - - - - - - - - - - - - - - - - -	One located 34'-6" from top apex
Estimated Balloon Weight- - - - - - - - - - - - - -	185 lbs (Incl. 25# of cable)
Engineering Specification Sheet - - - - - - - - -	233501
DRS -	730
Load Altitude Curve - - - - - - - - - - - - - - - -	233521


Payload vs. Altitude
77-1-2 Balloon
1.5 Mil Poly
Est. Balloon Wt. = 209# (incl. 24#
top Payload)
Min Pl
Altitude in Thousands of Feet
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
100
120
140
160
180
200
300
400
500
Bottom
Payload in Pounds

Telemetered Secondary Temperature Data; Flight 3026, 28 July 1965

Time From Launch	Temperatures V.C.O.	Disc	Box #1	Tracker	Box #2
L-1/2 Hrs	+46°C	+16°C	+35°C	+19°C	+28°C
L (08:58 CDT)	45	+15	41	19	28
L+1/2	45	-27	36	+9	27
L+1	45	-28	27	-1	23
L+1-1/2	46	-10	23	+5	21
L+2	46	+4	25	17	24
L+2-1/2	47	9	26	21	29
L+3	47	14	36	27	30
L+3-1/2	47	9	36	29	34
L+4	48	13	36	31	35
L+4-1/2	48	16	40	32	35
L+5	48	13	40	33	36
L+5-1/2	48	15	39	33	39
L+6	48	13	40	34	38
L+6-1/2	48	+3	41	30	34
L+7	47	-23	39	+18	33
L+7-1/2	46	-34	29	-12	23
L+8	+45°C	-4°C	+26°C	-6°C	+21°C

FLIGHT 3028

Time From Launch	V.C.O.	DISC	Box #1	Tracker	Box #2
L-1/2 Hr.	+45°C	+15°C	+25°C	+18°C	+27°C
L (08:44 CDT)	+45	+18	+36	+20	+28
L+1/2	+45	+ 3	+39	+22	+30
L+1	+45	-30	+32	+ 5	+26
L+1-1/2	+44	-27	+22	- 1	+21
L+2	+44	+ 2	+23	+ 8	+21
L+2-1/2	+44	+ 7	+27	+17	+22
L+3	+45	+12	+35	+22	+26
L+3-1/2	+45	+12	+39	+30	+29
L+4	+45	+13	+41	+31	+32
L+4-1/2	+46	+14	+42	+31	+33
L+5	+46	+19	+48	+33	+34
L+5-1/2	+46	+19	+48	+33	+36
L+6	+47	+15	+48	+33	+37
L+6-1/2	+47	+13	+45	+32	+36
L+7	+46	- 5	+39	+27	+35
L+7-1/2	+45	-32	+36	+ 8	+30
L+8	+44	-35	+27	-13	+31
L+8-1/2	+44	+ 2	+26	0	+21

FLIGHT 3029

Time From Launch	V.C.O.	DISC	Box #1	Tracker	Box #2
L-1/2 Hr.	+47°C	+21°C	+40°C	+24°C	+33°C
L (07:56 CDT)	+47	+23	+47	+27	+36
L+1/2	+46	-14	+41	+16	+33
L+1	+46	-49	+30	- 2	+26
L+1-1/2	+44	-13	+22	- 1	+20
L+2	+45	0	+25	+11	+24
L+2-1/2	+45	+11	+34	+19	+22
L+3	+46	+ 2	+32	+22	+28
L+3-1/2	+46	+12	+36	+26	+28
L+4	+46	+ 6	+42	+29	+30
L+4-1/2	+47	+ 9	+40	+29	+34
L+5	+47	+ 7	+42	+30	+34
L+5-1/2	+47	+ 4	+37	+29	+35
L+6	+46	+ 9	+40	+29	+33
L+6-1/2	+46	+15	+47	+30	+32
L+7	+47	+12	+48	+31	+33
L+7-1/2	+47	- 7	+45	+27	+34
L+8	+46	-34	+37	+14	+32
L+8-1/2	+47	-42	+32	+ 6	+26
L+9	+45	+12	+28	+ 8	+21

FLIGHT 3031

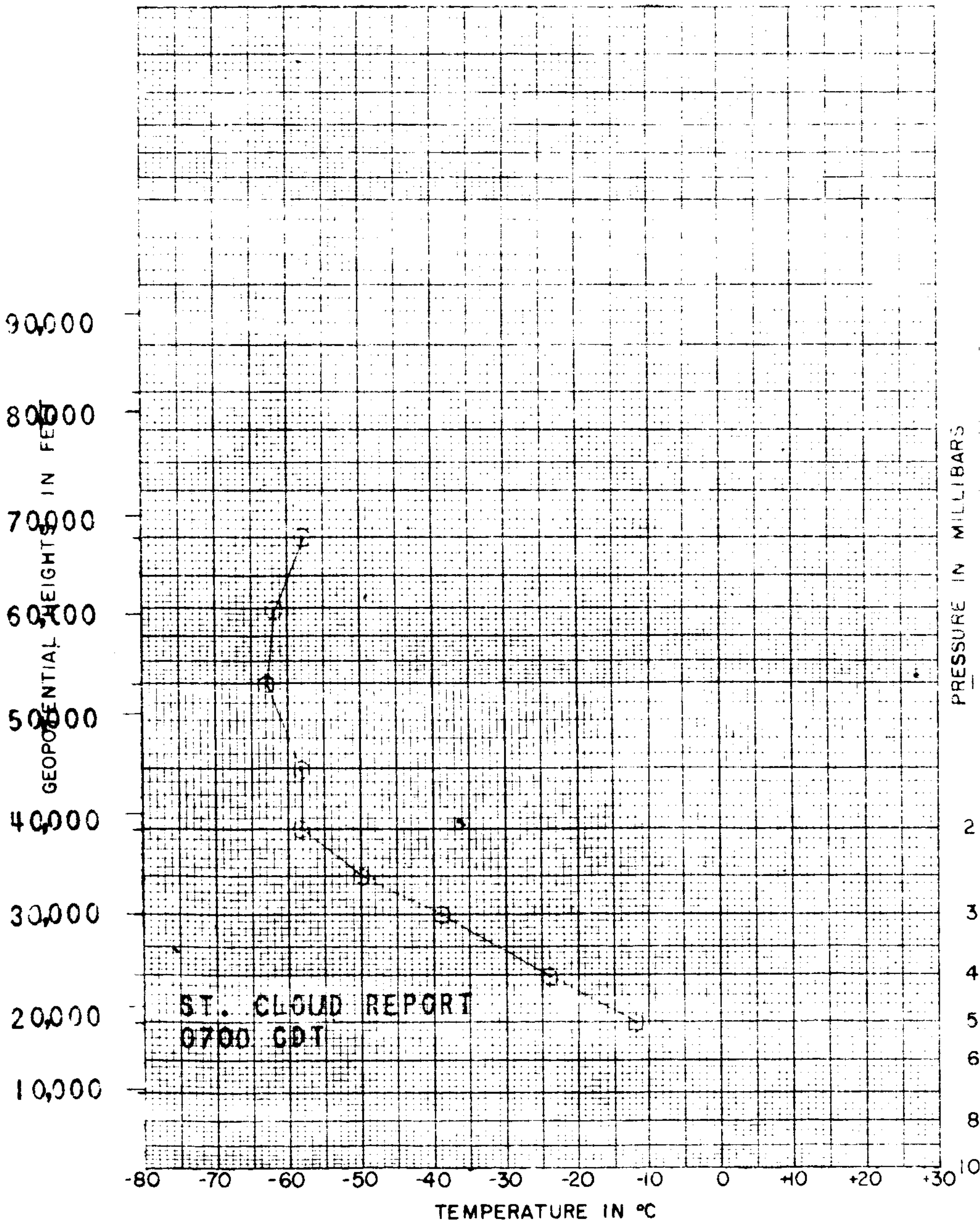
Time From Launch	V.C.O.	Disc	Box #1	Tracker	Box #2
L-1/2 Hr.	+45°C	+ 6°C	+28°C	+ 7°C	+22°C
L (08:51 CDT)	+45	+ 6	+33	+ 8	+22
L+1/2	+46	-26	+28	+ 1	+22
L+1	+45	-32	+21	- 8	+22
L+1-1/2	+45	+13	+19	+ 3	+21
L+2	+45	+20	+26	+17	+25
L+2-1/2	+46	+27	+28	+22	+29
L+3	+46	+27	+29	+24	+30
L+3-1/2	+46	+30	+29	+25	+33
L+4	+46	+30	+31	+26	+35
L+4-1/2	+47	+32	+32	+28	+37
L+5	+47	-31	+33	+28	+36
L+5-1/2	+46	+29	+36	+30	+36
L+6	+47	+27	+35	+26	+36
L+6-1/2	+47	+11	+36	+24	+36
L+7	+46	-25	+32	+ 3	+30
L+7-1/2	+45	-36	+26	-13	+23

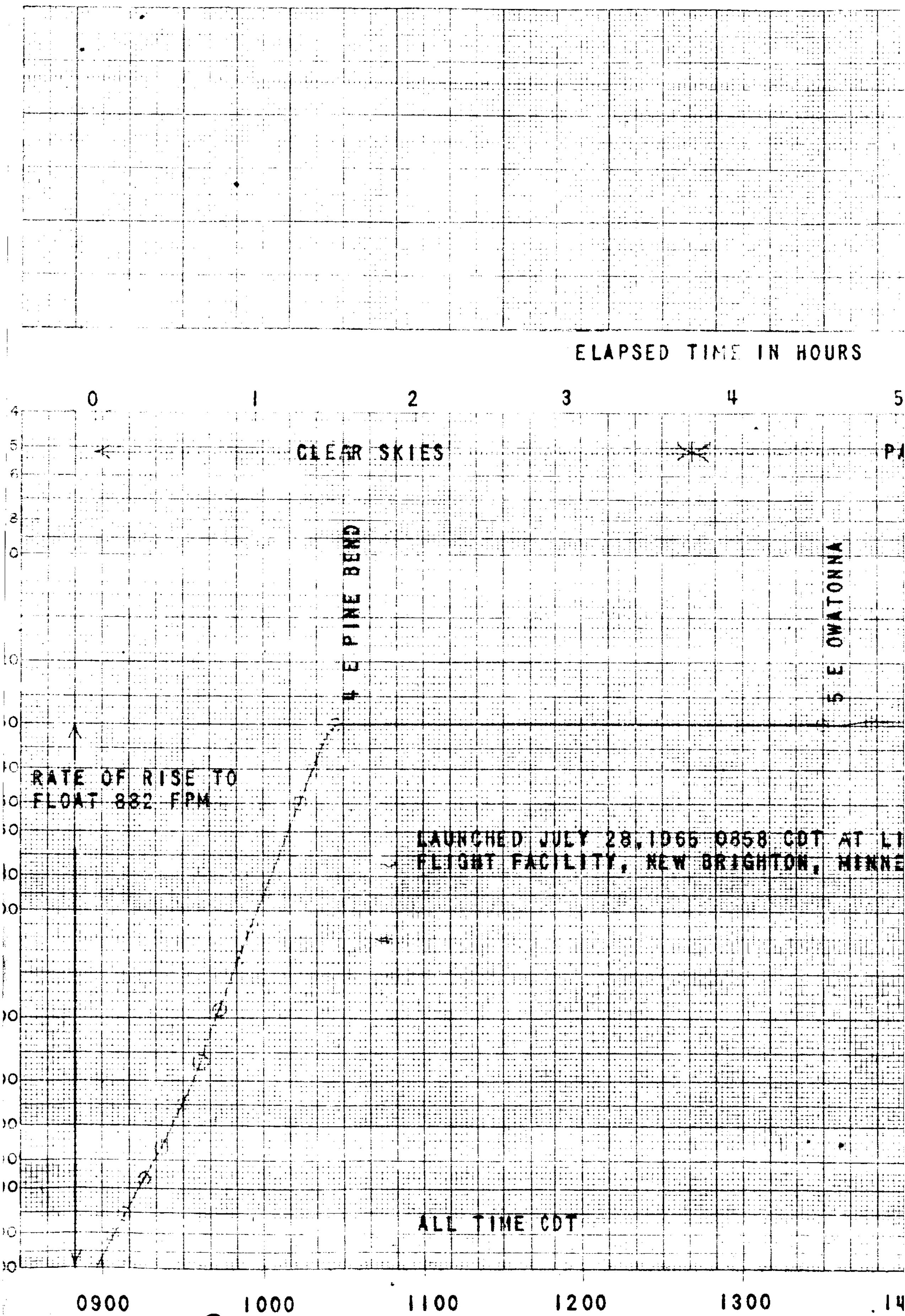
FLIGHT NO. 3026	DATE JULY 28, 1965
FOR JPL 59541	
LOAD ON BALLOON 257 LBS.	
FREE LIFT 35.5 LBS= 8 %	

BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77 I 2	4DRS771	1.5 MIL.	183.5LBS.

ALTITUDE DATA

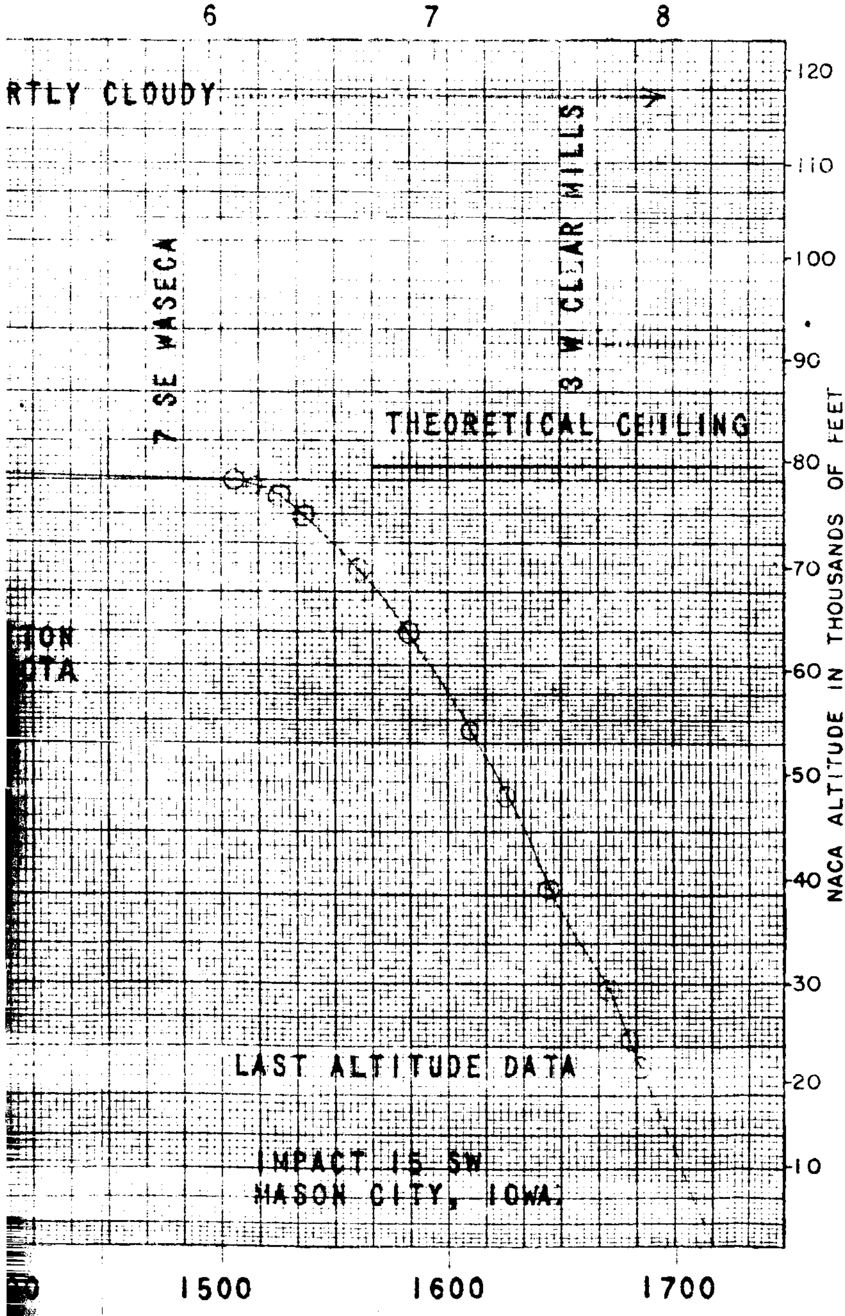
TEMPERATURE DATA





2

LITTON IND. APPLIED SCIENCE DIVISION, 2295 WALNUT ST. ST. PAUL,



[redacted] 3

NESOTA

NOV 29 AF

32

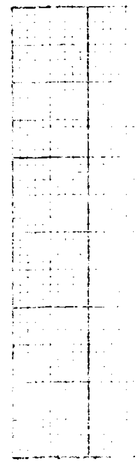
FLIGHT NO. 3028 DATE AUGUST 9,1965

FOR JPL

LOAD ON BALLOON 250 LBS.

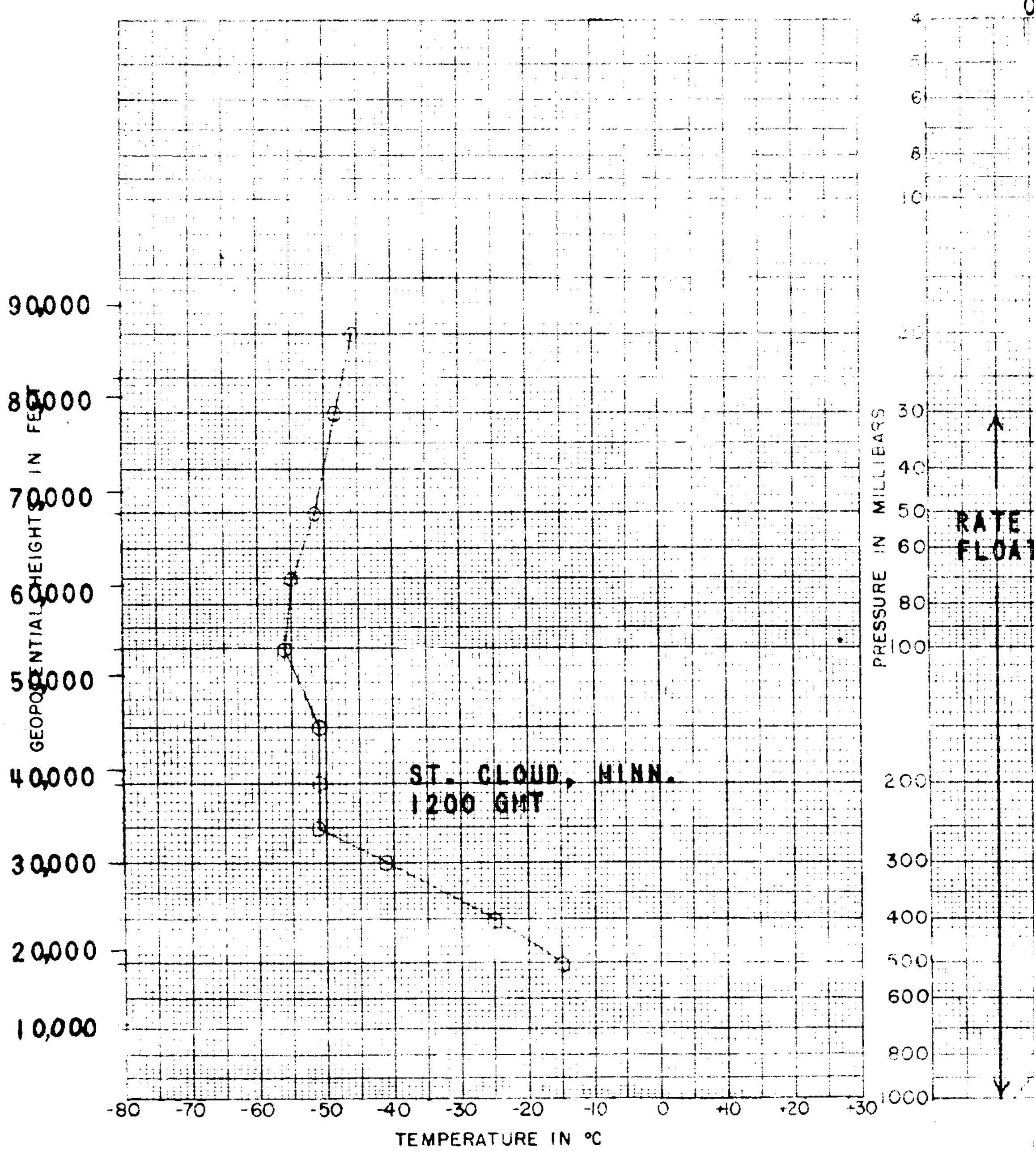
FREE LIFT 35 LBS= 8 %

BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77 I 2	2DRS771	1.5 MIL.	186 LBS.

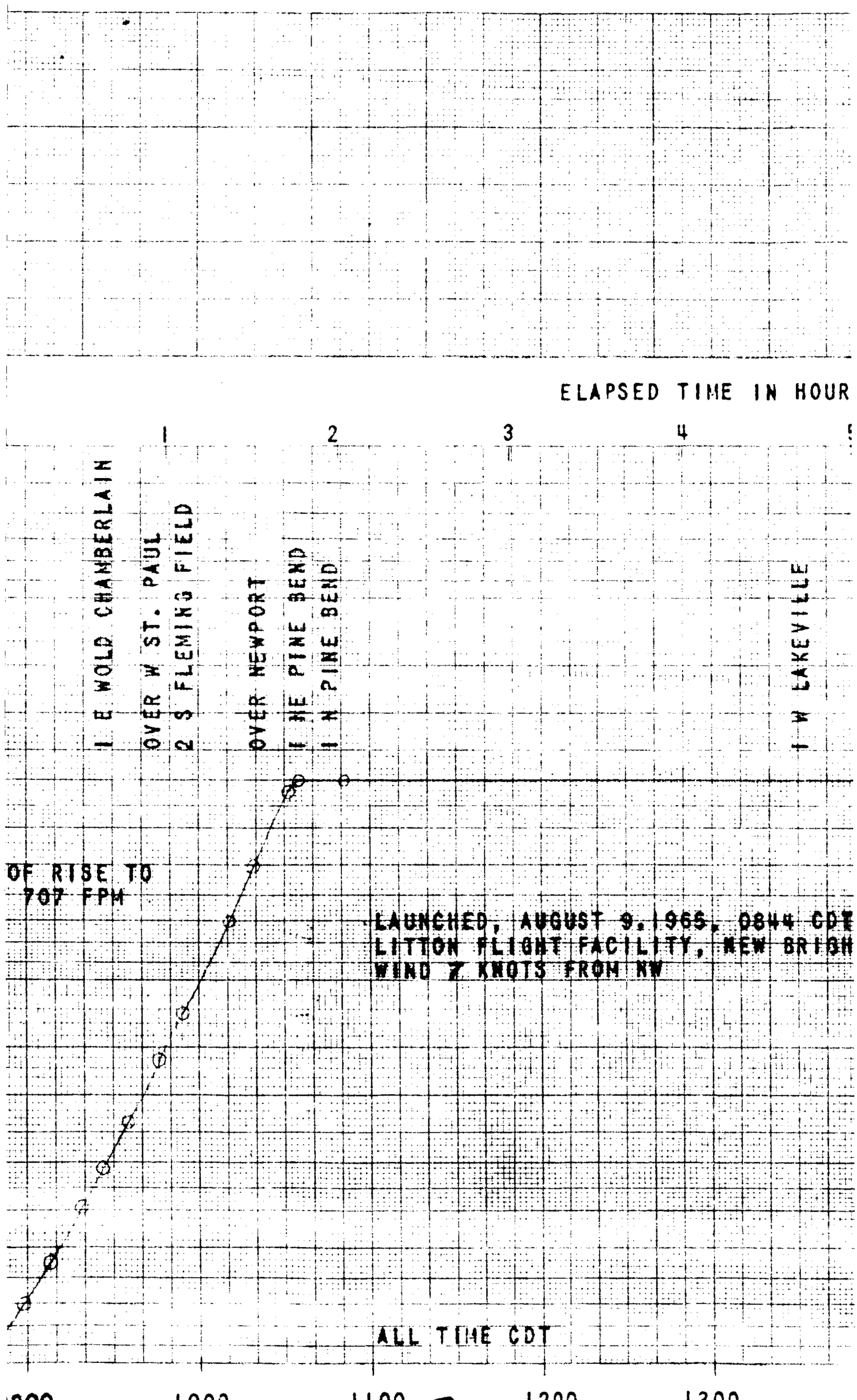


ALTITUDE DATA

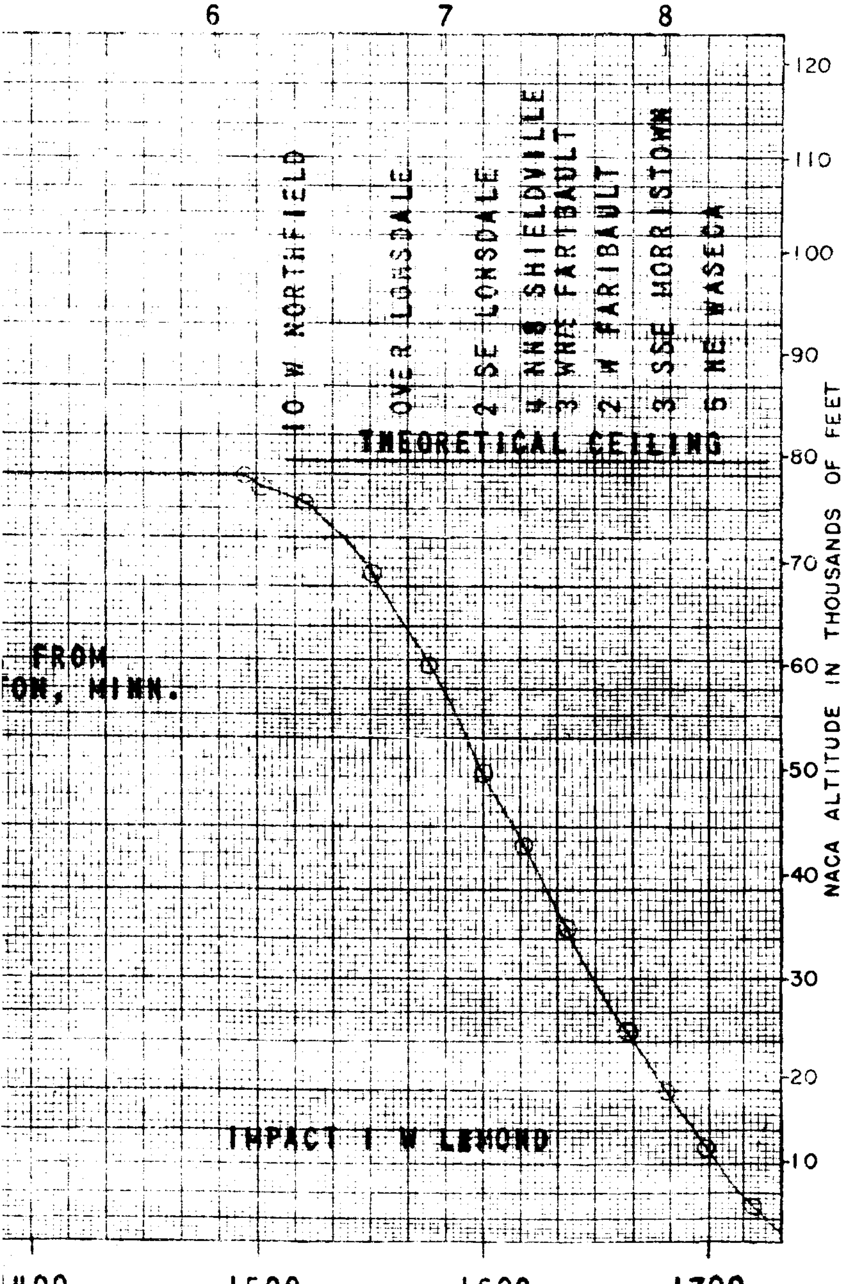
TEMPERATURE DATA



LITTON


ELAPSED TIME IN HOUR
1
2
3
4
1 E WOLD CHAMBERLAIN
OVER W ST. PAUL
2 S FLEMING FIELD
OVER NEWPORT
1 NE PINE BEND
1 N PINE BEND
1 W LAKEVILLE
OF RISE TO
707 FPM
LAUNCHED, AUGUST 9, 1965, 0844 CDT
LITTON FLIGHT FACILITY, NEW BRIGH
WIND 7 KNOTS FROM NW
ALL TIME CDT
900
1000
1100
1200
1300

2



NNESOTA

3

NOV 20,

FLIGHT NO. 3029 DATE AUGUST 13, 1965

FOR JPL 59541

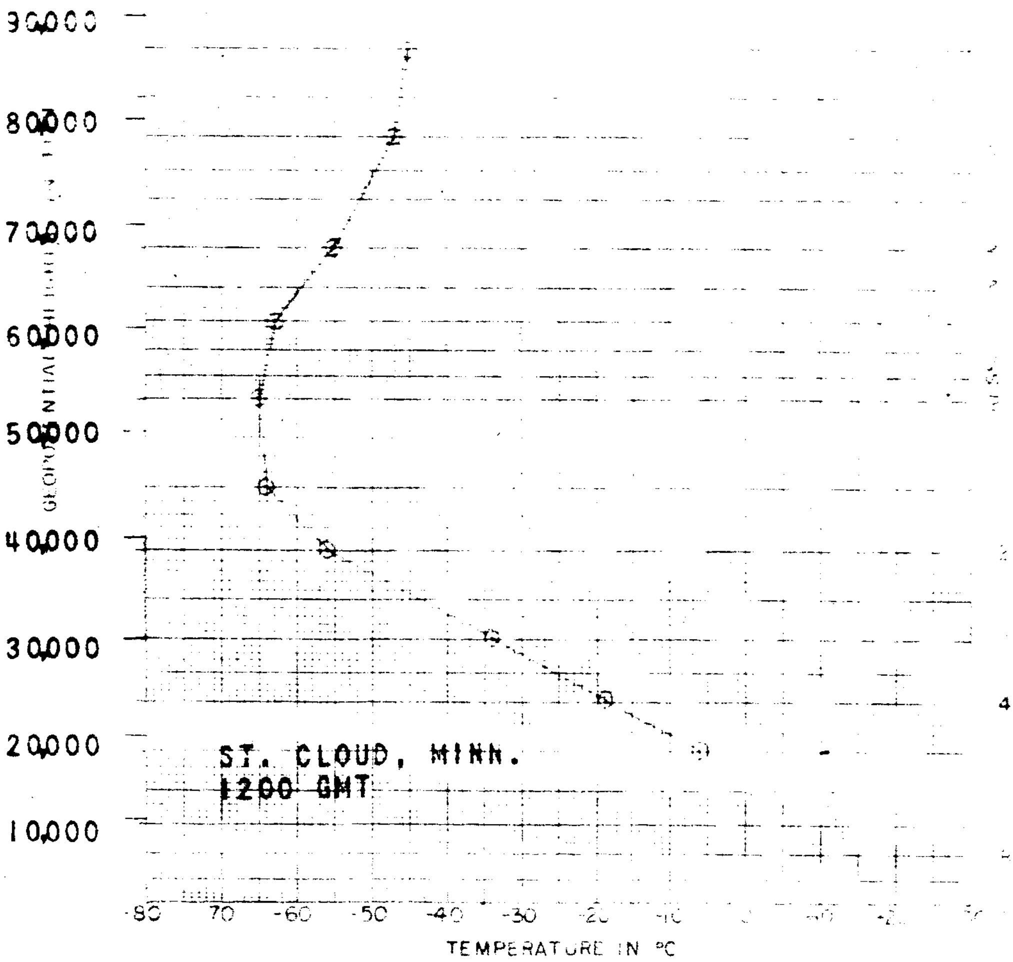
LOAD ON BALLOON 249 LBS.

FREE LIFT 35 LBS= 8 %

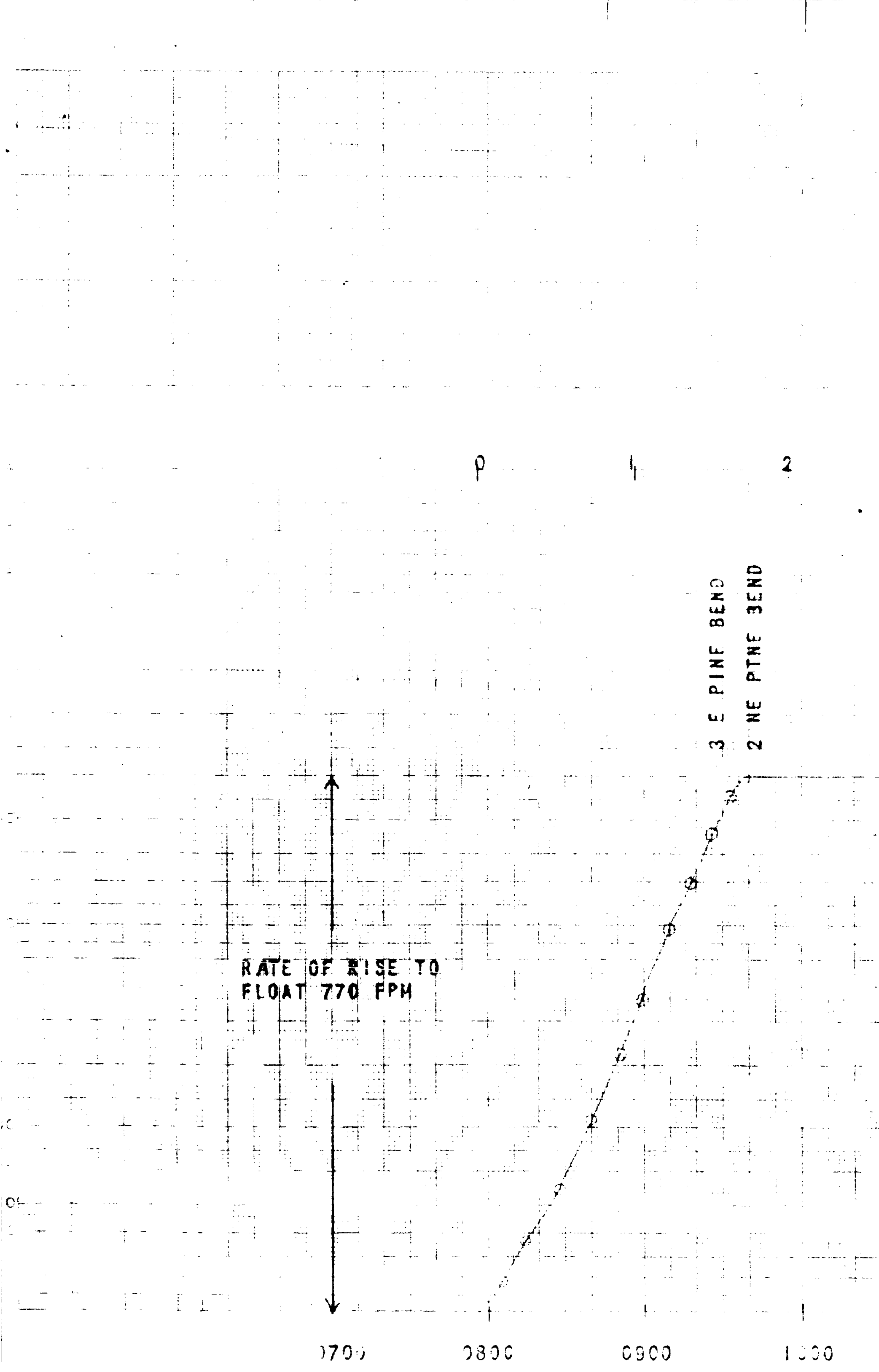
BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77 I 2	4DRS771	1.5 MIL.	188 LBS.

ALTITUDE DATA

TEMPERATURE DATA

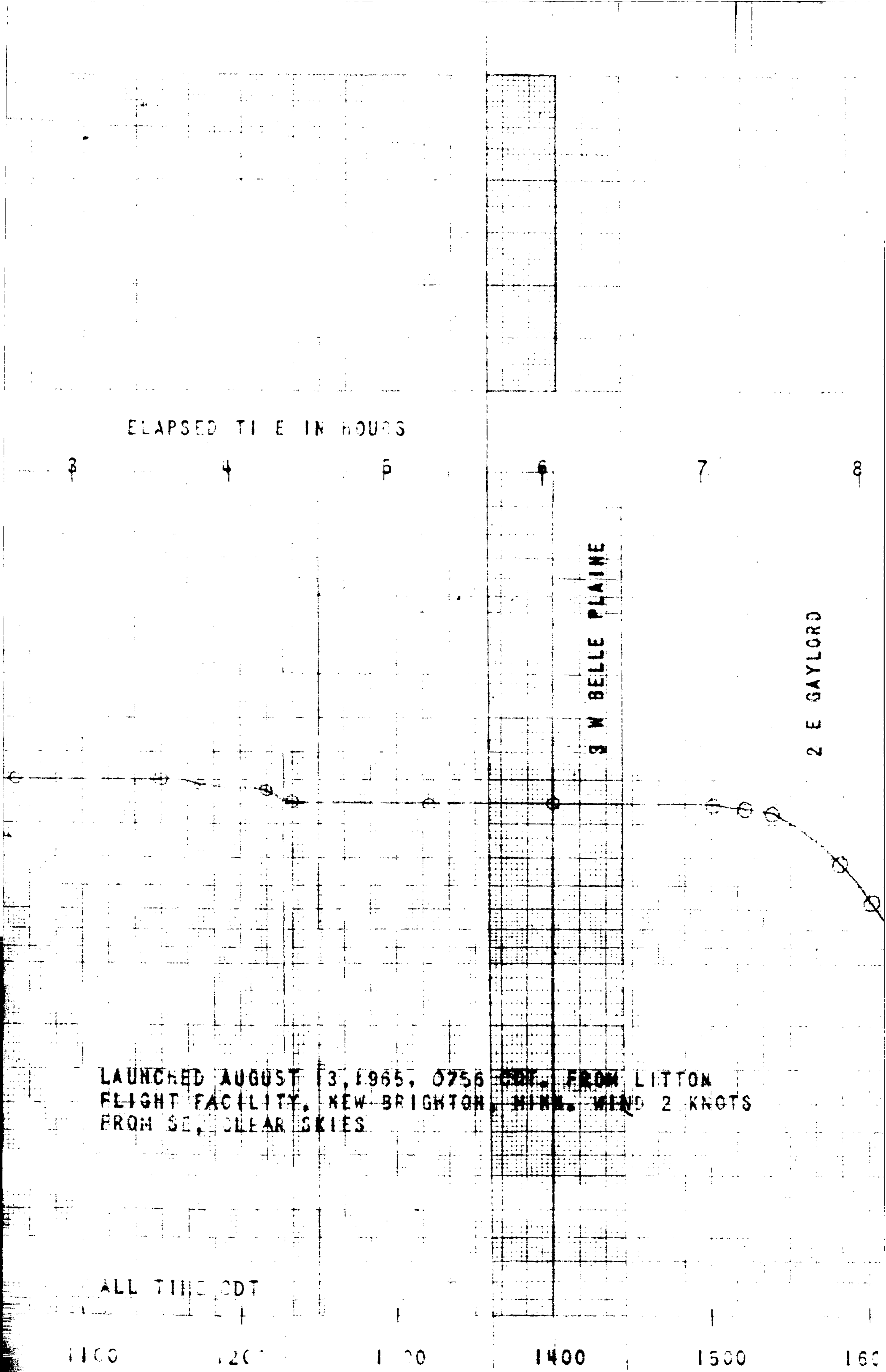


1

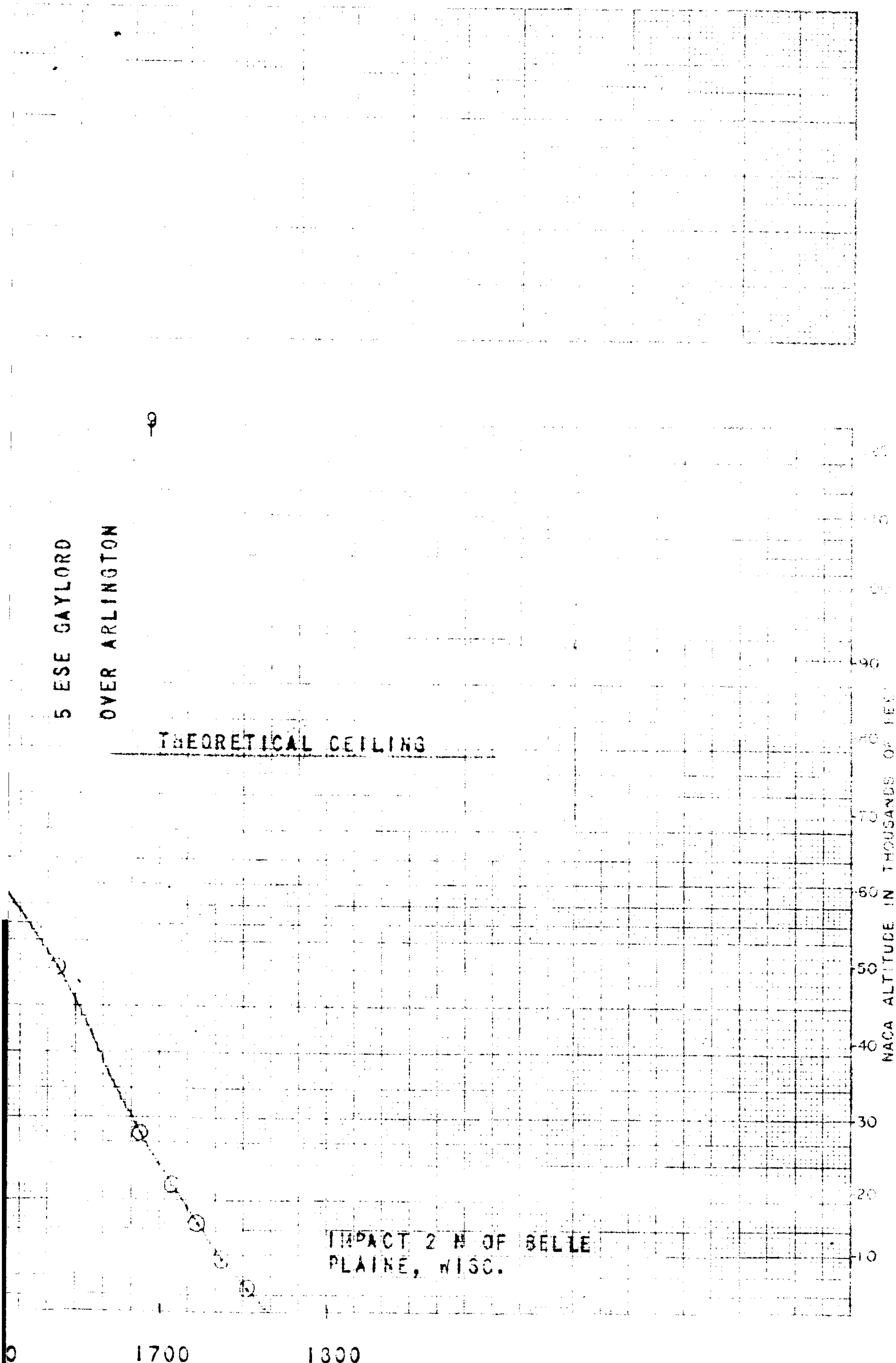


2

LITTON IND. APPLIED SCIENCE



IVISION, 2295 WA NI T. ST. PAUL, MINNESOTA



4

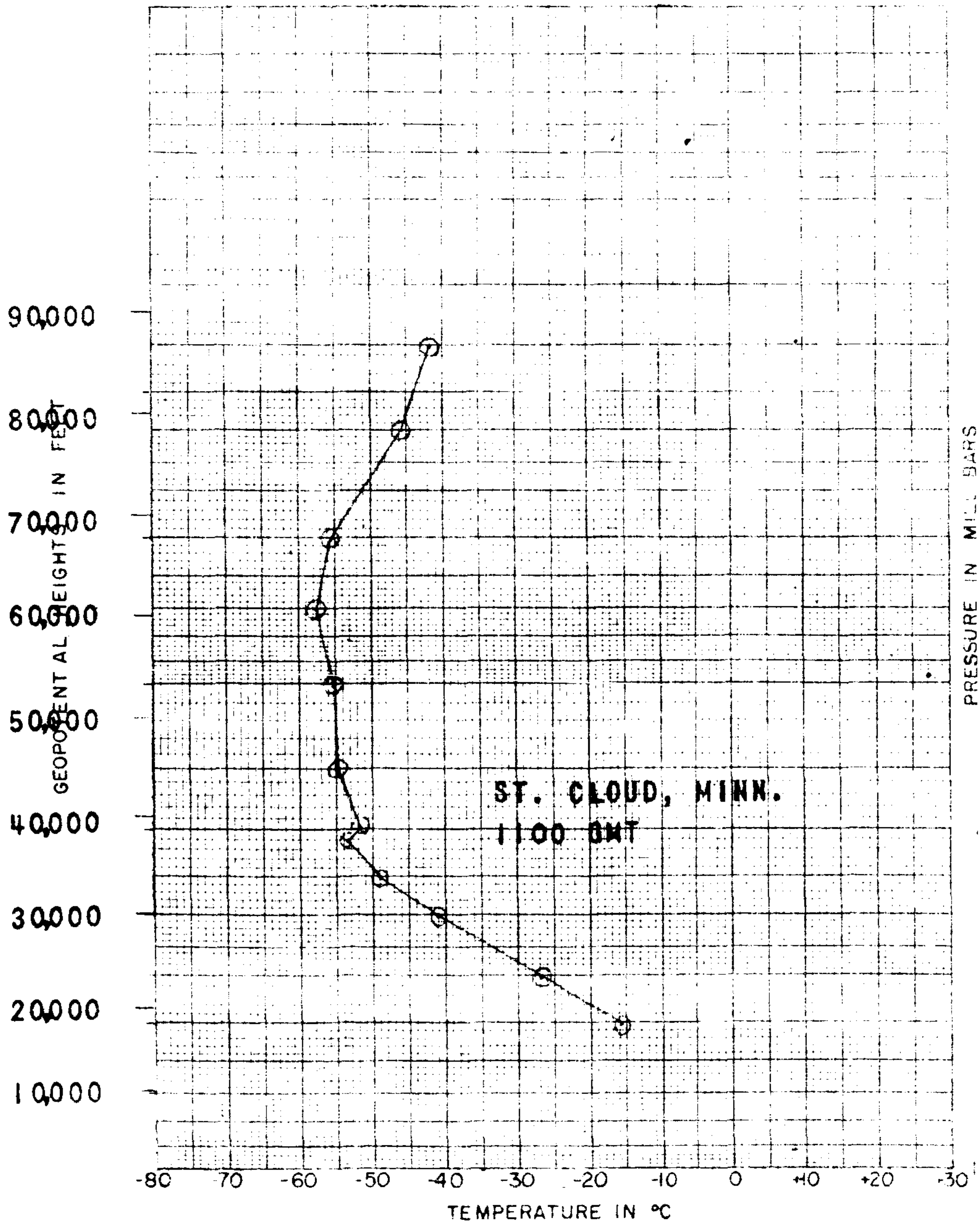
NOV 29,65 AF

34

FLIGHT NO. 3031		DATE AUGUST 28, 1965	
FOR JPL 5954			
LOAD ON BALLOON 257 LBS.			
FREE LIFT 36 LBS= 8 %			
BALLOON TYPE	NUMBER	MATERIAL	WEIGHT
77-1-1	4DRS771	1.5 MIL	187 LBS.

ALTITUDE DATA

TEMPERATURE DATA



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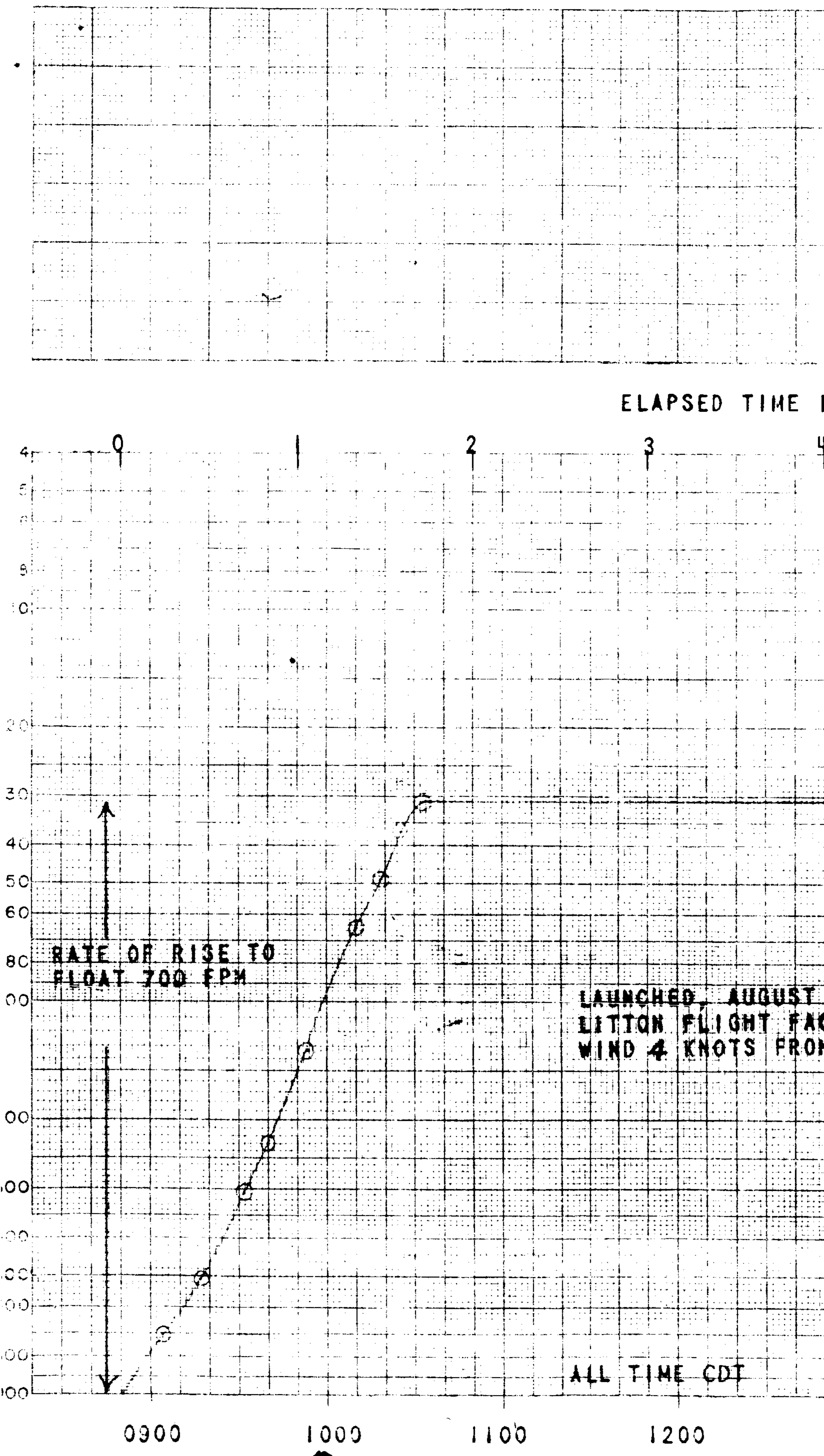
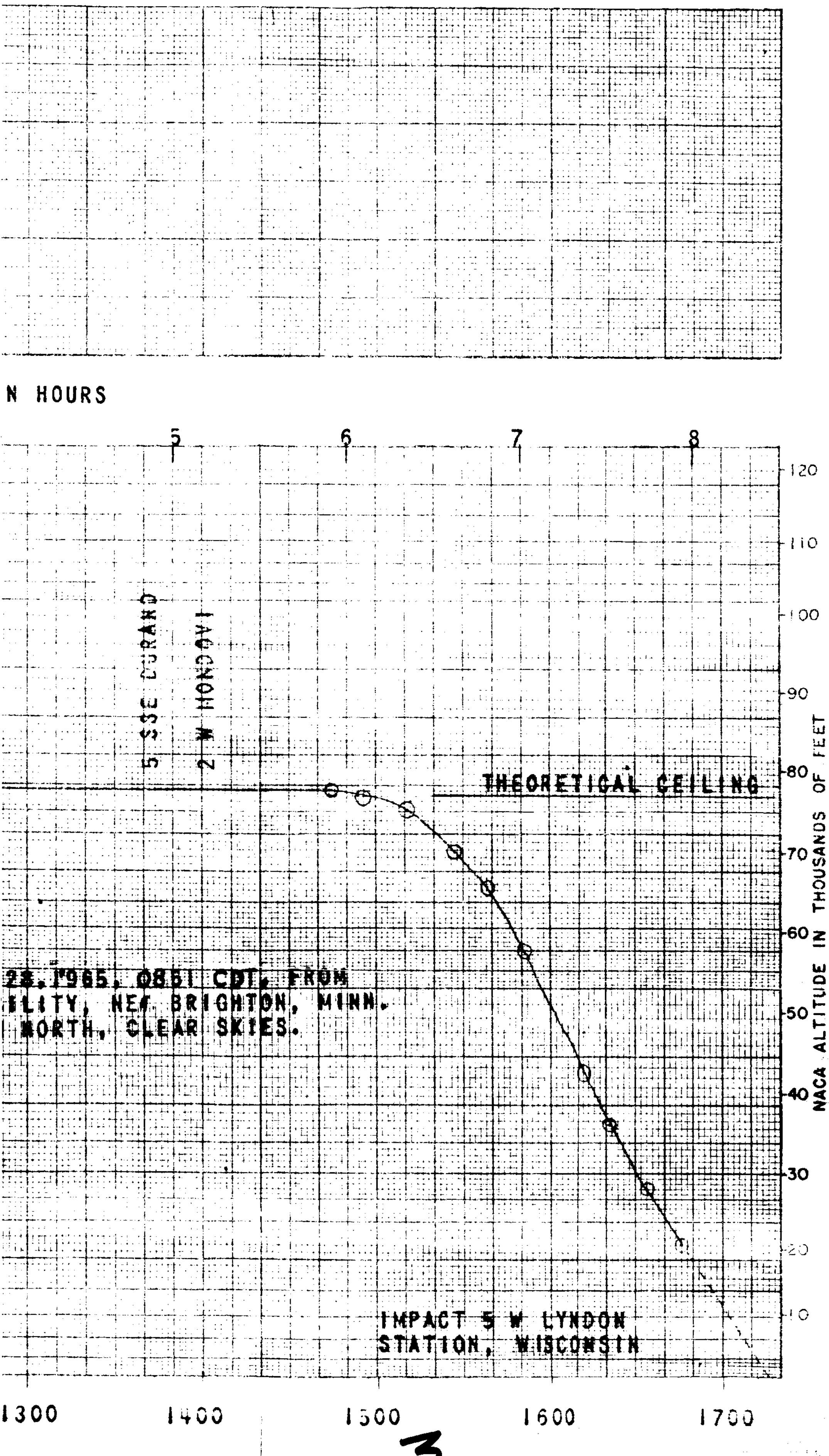


2

LITTON IND. APPLIED SCIENCE DIVISION, 2295 W



LNUT ST. ST. PAUL, MINN. 3 NOV 29 AF