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Staniforth, A.; Steele, K.A.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/21274208
Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB), 1964-08

ERB-682 [redacted]

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

INSTALLATION AND PERFORMANCE OF PAYLOAD IN BLACK BRANT I ROCKET AA-I-26 FIRED AT FORT CHURCHILL APRIL 1963

A. STANIFORTH AND K. A. STEELE

OTTAWA

AUGUST 1964

ABSTRACT

The National Research Council of Canada provides engineering assistance to research groups from Canadian universities, and scientists within the Council, in the high-altitude rocket sounding program of the Associate Committee on Space Research. This report deals with the engineering aspects of preparing the payload and launching rocket AA-I-26 at the Churchill Research Range.

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INSTALLATION AND PERFORMANCE OF PAYLOAD

IN BLACK BRANT I ROCKET AA-I-26

FIRED AT FORT CHURCHILL APRIL 1963

- A. Staniforth and K.A. Steele -

INTRODUCTION

The National Research Council is currently engaged in a sounding-rocket program with various research groups from Canadian universities and with scientists from within the Council who are interested in performing measurements in the upper atmosphere.

The program is coordinated by the Associate Committee on Space Research of the National Research Council. Functions concerned with general engineering assistance, liaison, assembly, telemetry, payload checkout, and, in general, all aspects of nose cone preparation not directly a part of the experimenter's equipment have been performed by the Space Electronics Section of the Radio and Electrical Engineering Division.

This report deals primarily with the engineering aspects of launching rocket AA-I-26 (22:03:38 CST, April 5, 1963). Brief summaries of the results of the experiments are also included since analysis has not been completed in most cases.

DESCRIPTION OF VEHICLE

Vehicle AA-I-26 is of the Black Brant I type in that it uses Black Brant I fins and nozzle, although the nose cone is of Black Brant II design. The outline and dimensions of the vehicle are shown in Fig. 1.

The nose cone is a magnesium casting weighing about 116 pounds empty. It consists of two main sections — a conical part and a cylindrical part, separated by an airtight bulkhead on which the telemetry package is mounted. The conical section contains about $3\frac{1}{2}$ cubic feet of space in which the pressure is maintained at a few pounds above atmospheric pressure throughout the flight. The cylindrical section contains about $2\frac{1}{2}$ cubic feet of unpressurized space. A section of the nose cone, the telemetry package, and the H-frame on which some of the instrumentation is mounted are shown in Fig. 2.

The information is transmitted from the rocket to a ground station using a PAM/FM/FM telemetry system consisting of ten subcarrier oscillators, one of which is modulated with a 30-segment 10-rps commutator or time multiplexer. The system is packaged into a unit about 16" in diameter and 4.0" deep.

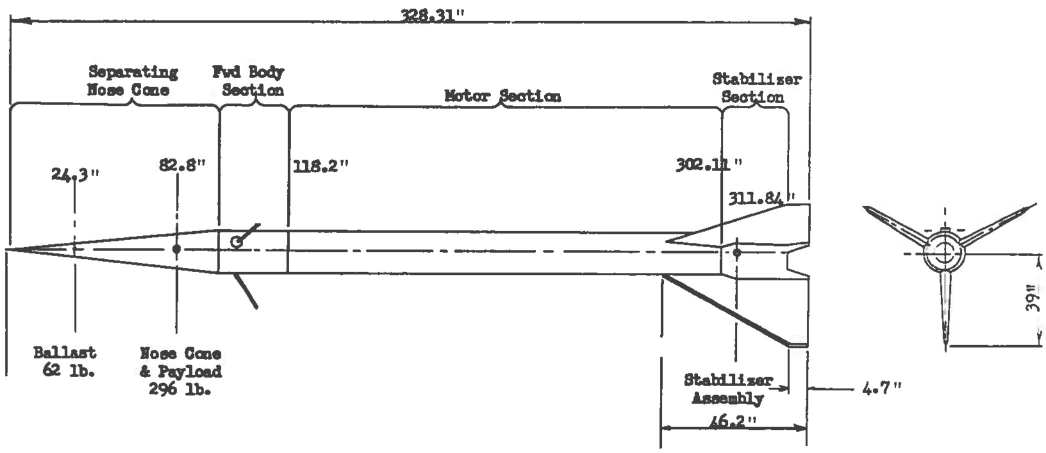

Fig. 1 Vehicle configuration

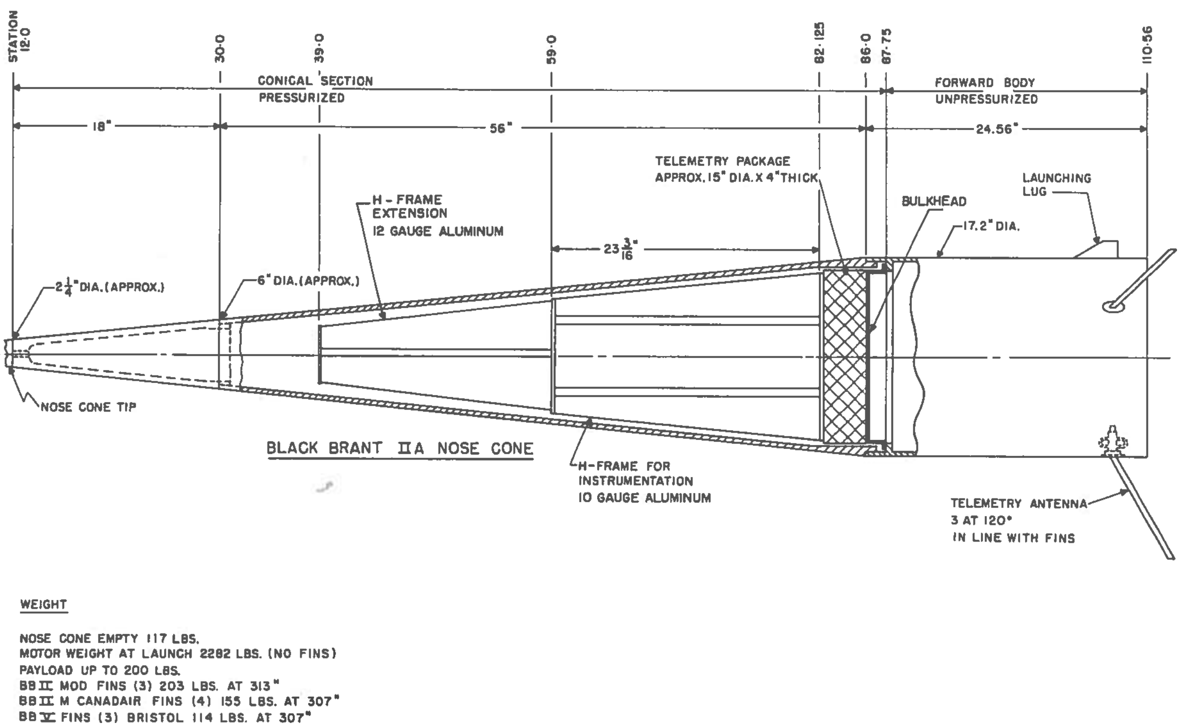

Fig. 2 Cross section of nose cone showing instrument support structure

An aluminum sheet-metal H-frame, about 23" long and tapered to fit in the nose cone, is bolted to the top of the telemetry package. On top of this frame is mounted a "cross" of sheet aluminum about 20" long, and again tapered at the nose cone angle. This frame is used to mount the magnetometer sensing heads in a position as far as possible from magnetic materials and current-carrying conductors. The H-frame assembly is shown in Plate I.

A plate is mounted under the telemetry package bulkhead, on which are the timers, event oscillators, and several cable junctions as shown in Plate II. The cosmic ray units are mounted on supports secured to the walls of the parallel section. The remainder of the equipment in the cylindrical section is mounted on or through the outer walls.

Components that are ejected or that are extended outside the rocket are preferably mounted in the unpressurized cylindrical section to avoid sealing problems. The antennas for telemetry and the radar beacon are usually mounted on this section. Some views of the components in this section are shown in Plate III.

PLANNING THE ROCKET PAYLOAD

Rocket AA-I-26 had as payload the following instrumentation:

1) Primary

   a) Cosmic ray experiment concerned with the study of particles associated with auroral activity (NRC)

   b) Langmuir probe for measurement of the fine structure of electron density and electron energy spectrum inside and outside auroral formations (NRC)

2) Secondary

   a) Micrometeorite detector, an acoustic-type impact counter to determine impact rates and energy distribution inside and outside major meteor showers and the association with auroral activity (NRC)

   b) Potential gradient experiment, consisting of a small ejected package containing its

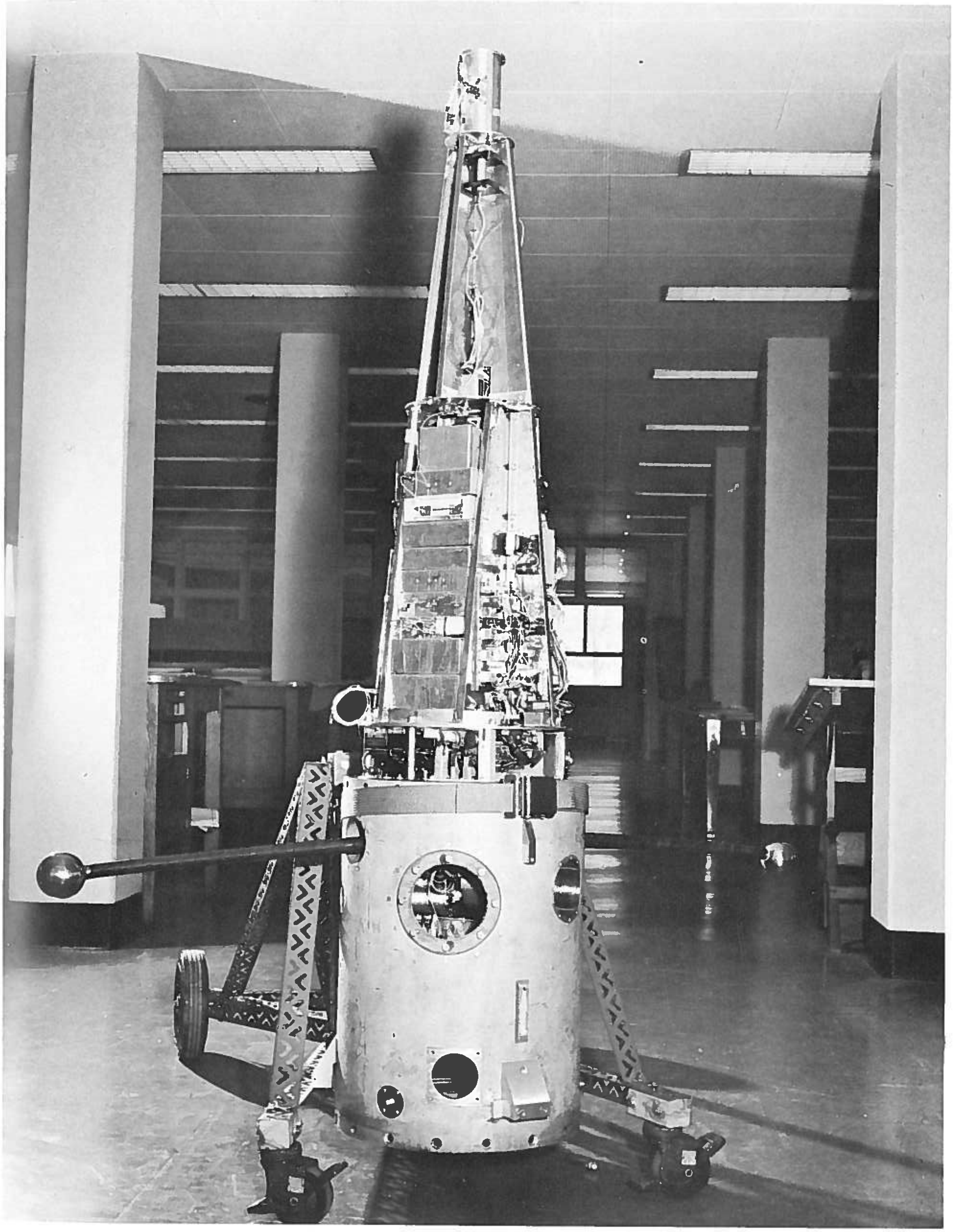

Plate I — Nose cone with conical shroud removed

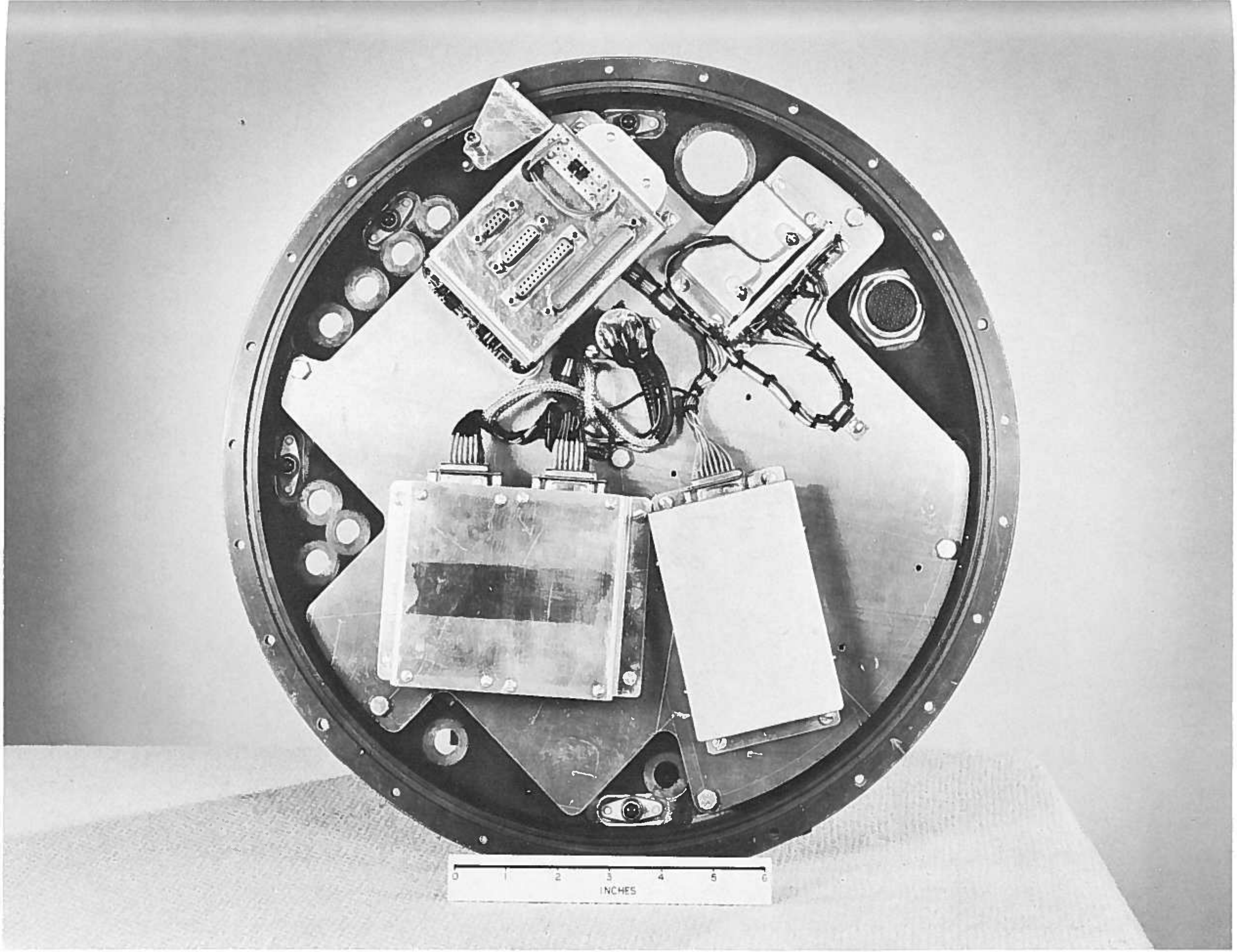

Plate II — Instrumentation mounted below telemetry package

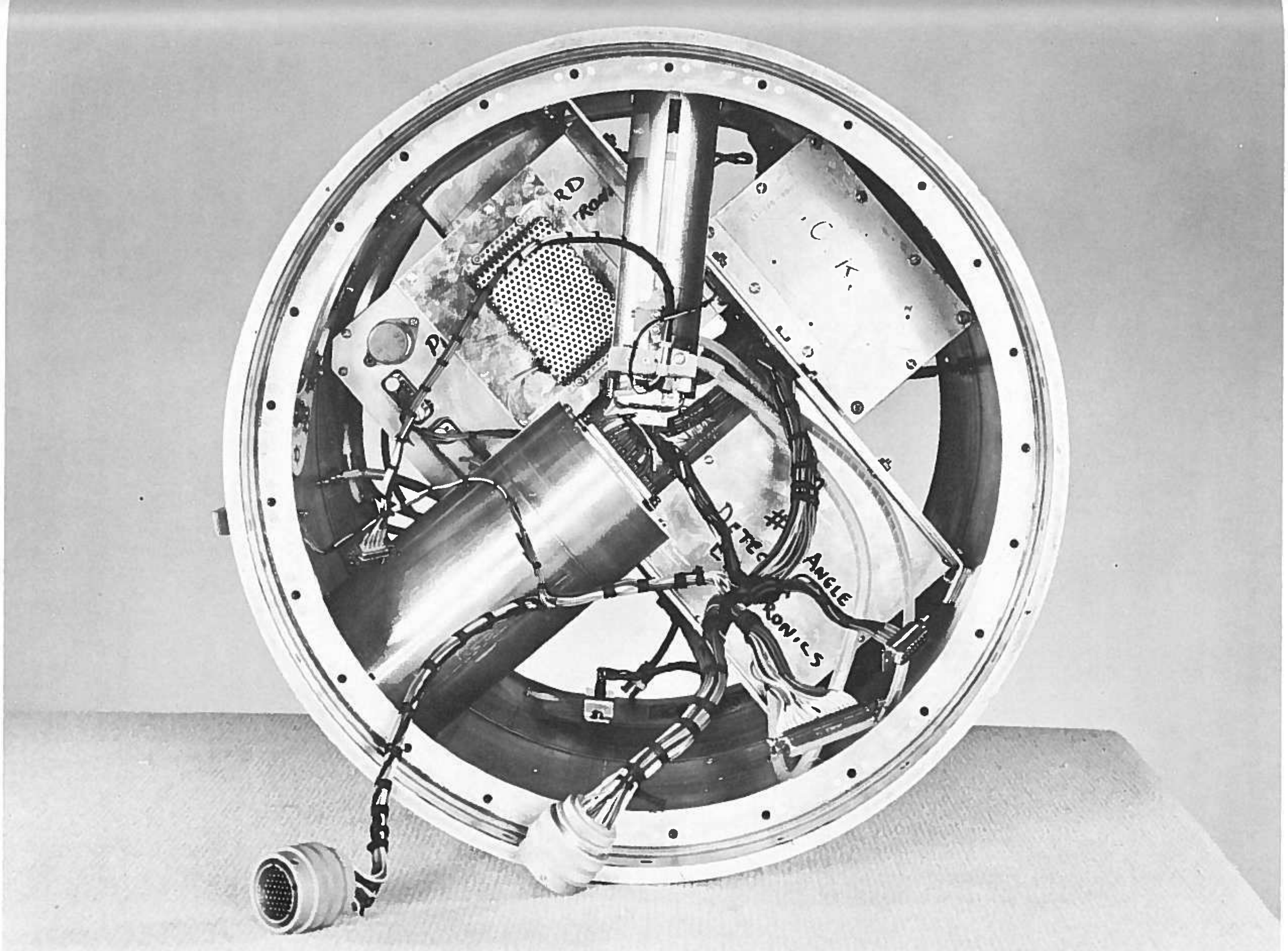

Plate III — Instrumentation inside cylindrical section showing ejectable potential gradient experiment (at left), extendible beacon (above), and three cosmic ray detectors (behind) own transmitter (University of Saskatchewan)

c) Flux-gate magnetometer experiment concerned with measurements on components of the earth's magnetic field (University of Alberta)

3) Engineering Measurements

a) Flight testing of a new radar beacon

b) Flight testing a rocket-borne light for obtaining trajectory data with ground-based cameras

c) Nose cone environment:
   i) Low-frequency accelerometer measurements in three mutually perpendicular directions (one on the roll axis)

   ii) Temperature measurements at a number of locations within the nose cone

4) Other Equipment

a) Timers for initiating ejection and extension of equipment

b) Telemetry calibrator unit for introducing alternate 0 v and 5 v reference levels to all continuous channels at 10-second intervals during flight

c) Event oscillator unit for indication by means of telemetry of various events during the flight

As an aid to planning and for reference, a set of forms called "Engineering Work Sheets" were prepared. These detail such items as telemetry, umbilical connector, and battery allocations. At least a general idea of the placement of the various pieces of instrumentation in the nose cone is necessary prior to filling out these forms. Also, most of the data on the forms must be known before wiring diagrams can be drawn.

In the following paragraphs some notes of explanation will be made concerning the work sheets for rocket AA-I-26 found in Appendix I.

Angular orientation of equipment or sensors is always referred to the position of the forward launch lug on the rocket. The position is generally given in degrees clockwise or counterclockwise from the launch lug looking forward (CWLF or CCWLF).

General Requirements

The General Requirements Sheet outlines general information on ground support, transmitters in the nose cone, primary experiments, and experiment launch conditions. The list of batteries for nose cone instrumentation may appear out of place on this sheet but is a convenient reference for this requirement.

Telemetry

The telemetry sheet gives allocations on the continuous channels (3.9 kc/s through 52.5 kc/s) and on the commutator used on the 70.0 kc/s subcarrier channel, for experimental data and monitoring. The commutator is a 30-position mechanical unit operating at 10 rps. The right-hand side of the sheet lists the data inputs to each of the commutator bars. The master bars (28, 29, and 30) are for frame synchronization, and the 0 v and 5 v calibrate (channels 1 and 2) provide reference amplitudes used in data reductions. The frame synchronization and calibration signals are used in automatic decommutation.

Most of the items commutated are self-explanatory: battery monitors, and low-frequency data such as that from magnetometers and an accelerometer. (Note, however, that the accelerometer is supercommutated (channels 12 and 27) to obtain 20 samples per second.)

The light operation monitor (13) and the Langmuir probe timer monitor (22) are of the same kind. Both the light and the pair of large spherical Langmuir probes are extended out from the surface of the nose cone after a time interval referenced from lift-off. The monitors provide several different voltage levels depending on whether or not the timers have operated, whether the squibs have fired (and then open-circuited), and whether the light filaments have open-circuited or not. They are indicators of proper function or malfunction.

The output from a subcommutator is connected to commutator channels 25 and 26, two bars being used for reliability. On this rocket most of the data on the subcommutator are temperature measurements.

On the top left-hand side of the telemetry sheet are listed four channels all lower in frequency than the 3.9 kc/s subcarrier band (IRIG #9). These channels are so-called "event oscillators". Each of these units is a separate subcarrier oscillator, but they are not designed to have the stability or linearity of the units used for continuous-experiment information transmission. They are used as event indicators, and usually are not turned on until a switch is closed. The potential gradient exit event and nose cone pressure switch are examples of this form of operation. The Langmuir probe extension event is somewhat different in that there are two extending probes and thus two exit switches. The 950 c/s unit is used in a 4-level mode: "off" when both probes are inside the nose cone, "on" at frequency f_1 when probe #1 is out, on at f_2 when probe #2 is out, and on at f_3 when both probes are extended. The light monitor on the 660 c/s unit is also slightly different. It is not connected to a switch but to a cadmium sulfide cell mounted to view the extended light. This oscillator functions when the light is on, and a change in its operating frequency is an indication of a change in light output.

Subcommutator

The subcommutator on rocket AA-I-26 was used for temperature data and data from one magnetometer monitor. The unit is basically a 20-position switch driven by a stepping motor (a Cyclonome switch made by Sigma). The drive unit is a multivibrator circuit driven from the main commutator master pulse. Thus, the subcommutator steps forward one position every $\frac{1}{10}$ second, and each position is scanned on the main commutator once every 2 seconds. In this rocket data from 8 temperature monitors and a temperature bridge voltage monitor were sampled twice per revolution of the subcommutator. A ninth temperature sensor and the Z-axis Schonstedt magnetometer bias were monitored once per two seconds. All the sensors except those at the nose tip (station 12) and the dummy quadraloop (dielectric) were of the nickel-alloy resistance-wire type. The latter two were thermistor sensors.

All of the subcommutator positions are used for data inputs so that there is no master pulse for frame identification. Since the information output was taken to two channels on the main commutator, frame identification was achieved by causing one of the commutator channels to be grounded for one position of the subcommutator. Thus commutator channel 26 was grounded by a cam-operated microswitch each time the subcommutator rested on position 1. This admittedly limits the reliability available from an otherwise redundant commutator channel.

Umbilical Cable

The umbilical or pull-away connector on the rocket nose cone is a 50-pin Cannon connector, type DD50 C7. Lines for relay control, battery charging, external power, and monitoring are connected to the nose cone instrumentation through this connector. These lines are used for checkout of all instrumentation functions after assembly, and also at the launch site for final payload checks during the countdown prior to launching.

Most of the 50 lines are used for relay control of battery circuits. Latching relays are used for on/off internal battery control, and in some cases switch the battery load to external umbilical lines for operation on external power. A typical four-line plus ground battery control is shown in Fig. 3. This has been the preferred circuit for use with silver-zinc batteries. The load may be energized from

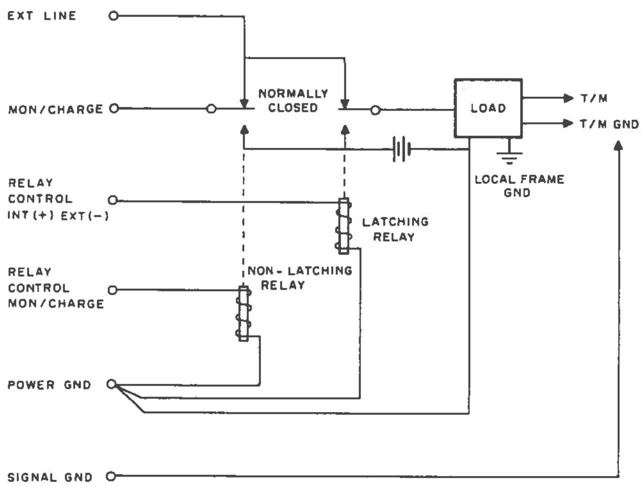

Fig. 3 Circuit of typical four-line battery control

external power using the external line, and at the same time the voltage at the load may be monitored on the monitor/charge line. Also, the battery may be charged through the monitor/charge line or, in the case of silver-zinc batteries, it may be discharged off the peroxide peak through this line.

Another battery control circuit is shown in Fig. 4. This circuit uses fewer lines and has less flexibility of function. It allows on/off control and battery monitoring or charging. The load cannot be operated on external power. This form of control has generally been used on nickel-cadmium batteries, especially in those cases in which the life on load of the battery is 2 hours or more. (It is not so necessary then to provide means for operating equipment on external

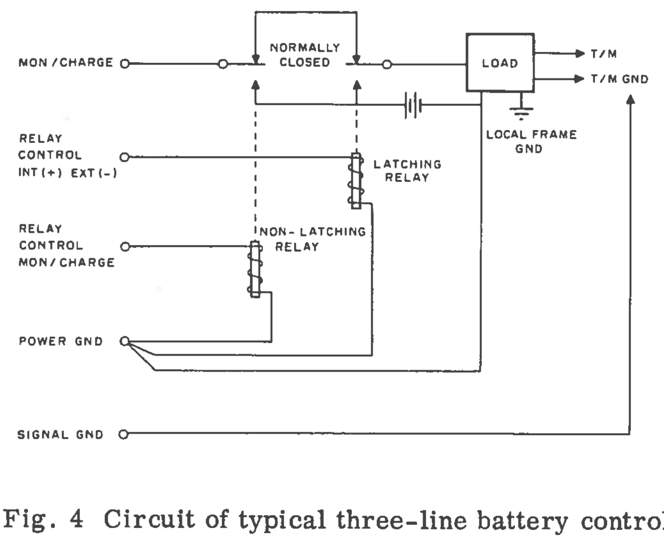

Fig. 4 Circuit of typical three-line battery control

power to save the batteries.)

Owing to the low temperatures expected, heaters were installed in the nose cone. Calrod elements were placed in the conical section and power was supplied through umbilical lines 34 and 35. The only requirement for heating in the forward-body section was for the mercury battery supply of the cosmic ray experiment. A heater and thermostat were mounted in close proximity to this battery (power was supplied through umbilical lines 17 and 18). None of these heaters were actually used during the launch phase. The temperature at a central location in the conical section was monitored through umbilical line 10.

Batteries

The battery work sheet merely lists all battery supplies in the payload, with pertinent data concerning capacity, type, load, and switching functions provided.

Nose Cone Weights and Centre of Gravity

This sheet comprises a list of all components in the nose cone payload. The total weight and centre of gravity information is sent to the Canadian Armament Research and Development Establishment (CARDE) who use this data in calculating vehicle performance and wind weighting. This sheet is also used as a check list in mounting equipment in the nose cone.

PREPARATIONS FOR LAUNCHING

Maps of the Fort Churchill area and the Churchill Research Range launch site are shown in Figs. 5 and 6.

The main group of User personnel arrived at Fort Churchill on March 20, 1963. Equipment was set up in the User Area in the Operations Building at the launch site. From March 21 to March 27, equipment was made ready and the nose cone instrumentation was checked and batteries charged. Umbilical cables to connect between the Range terminations and the console and vehicle connectors were also assembled. During the same period equipment at Defense Research Northern Laboratories (DRNL) was set up for a backup telemetry station and radar receiver. An NRC telemetry antenna and a group of S-band antennas were mounted on the roof of the DRNL building for the backup station.

The control console, battery chargers, external power supplies, and monitor equipment were moved to the blockhouse preparatory to launching the vehicle. The nose cone was taken to the blockhouse on April 2 and all testing was completed there at 5:30 pm on April 5. Only one countdown was run on AA-I-26, and it was launched at 22:03:38 CST, April 5. Launch requirements were: winds less than 15 knots, clear visibility, launch trajectory into an auroral formation,

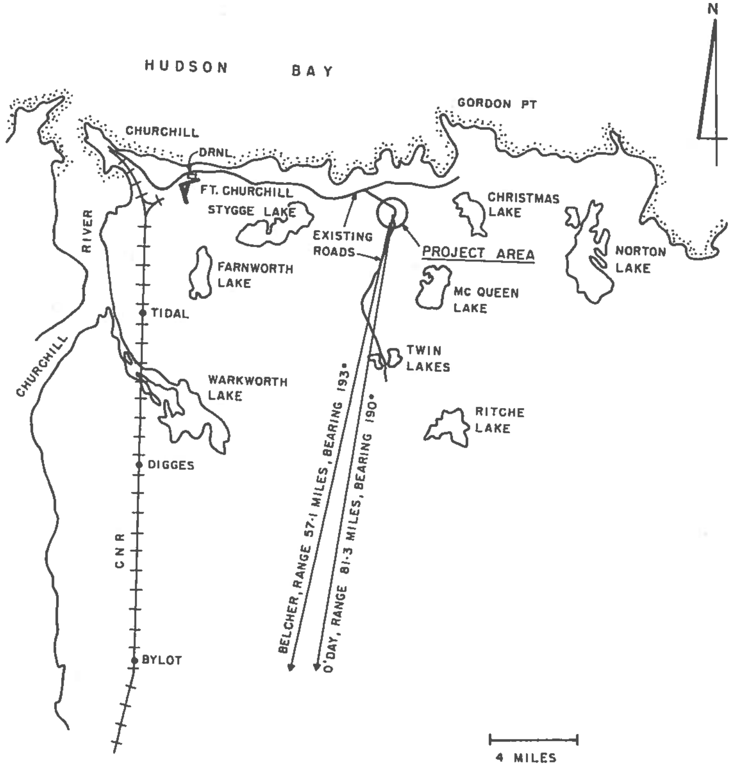

Fig. 5 Churchill area

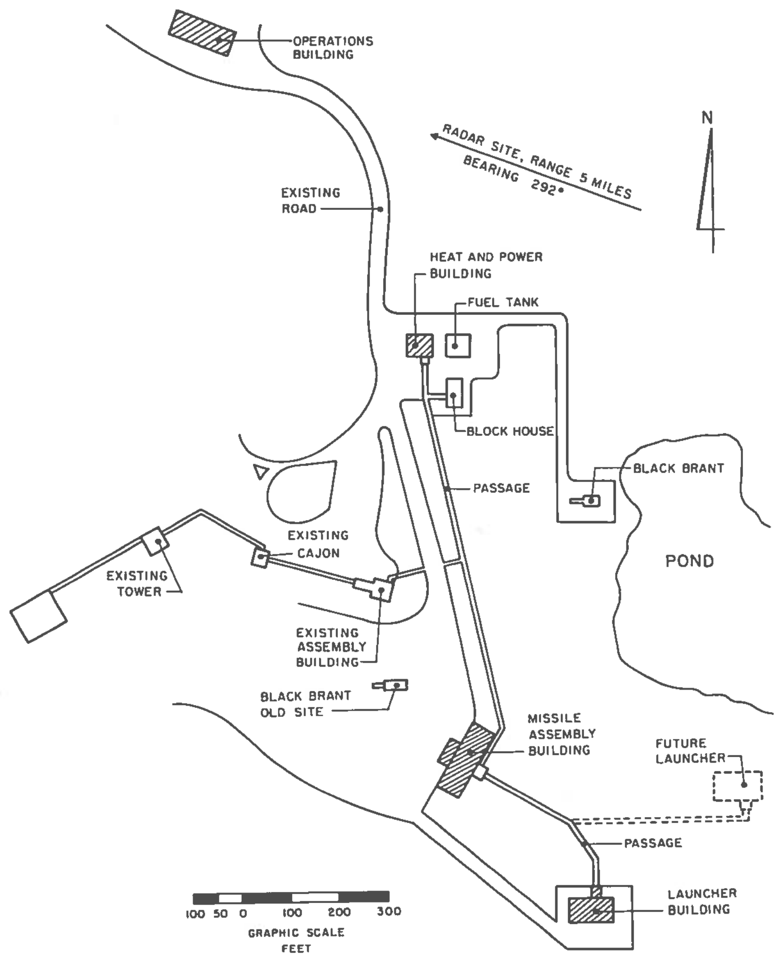

Fig. 6 Churchill Research Range launch site

firing to take place during a pass of the Alouette satellite. Just prior to lift-off surface wind was 6 knots and visibility 15 miles. There was some ground haze in the vicinity of the camera stations at Belcher and O'Day, so no camera data are available. There was considerable auroral activity during the time of launching, but there is doubt that the vehicle passed through an auroral formation. The launching did not take place during a sufficiently close pass of the Alouette satellite.

ROCKET PERFORMANCE

Trajectory data taken from the real time radar plotting board is shown in Fig. 7. This trajectory data is approximate and subject to some error. Data from analysis of the ADR radar tapes are not yet available.

The radar beacon, a Canadian Aviation Electronics model 16106/01/2/810 modified by us, operated satisfactorily. The radar on beacon track remained locked on the beacon from lift-off to impact.

Sound-ranging equipment was operated, and detected impact, but no data have been received from the Range. It is not known how well radar and sound-ranging impact data are correlated.

The stabilizer assembly (fins) was aligned for a nominal zero-roll rate. Analysis of the telemetry signal-strength records indicated a roll rate of about 0.40 revolution per second. The only aspect-sensing devices on this rocket were magnetometers and these did not operate during the flight. It may be possible to assume that large precession or tumbling of the vehicle did not occur, as otherwise the actual trajectory and impact would likely have differed to a greater extent from the predicted values. However, data from a preliminary analysis of cosmic ray detector records indicate the possibility of a half-angle cone of precession of either 55° or 55°/2, and of period approximately three to four minutes. Signal-strength measurements, discussed on page 14 of this report, indicate a period of approximately 160 seconds.

Meteorological conditions at the time of launching AA-I-26 are given in Table I. This table is a form supplied by the Churchill Research Range and also contains a summary of radar data.

The Canadian Armament Research and Development Establishment (Valcartier, Quebec) calculates vehicle performance and wind-weighting data for determining trajectory and launcher azimuth and elevation settings. A comparison of actual with predicted performance is of interest to the experimenter, the vehicle designer, and the launch site safety officer. It may be noted from the test summary on page 9 that actual (from radar) apogee and impact range fall short of predicted values.

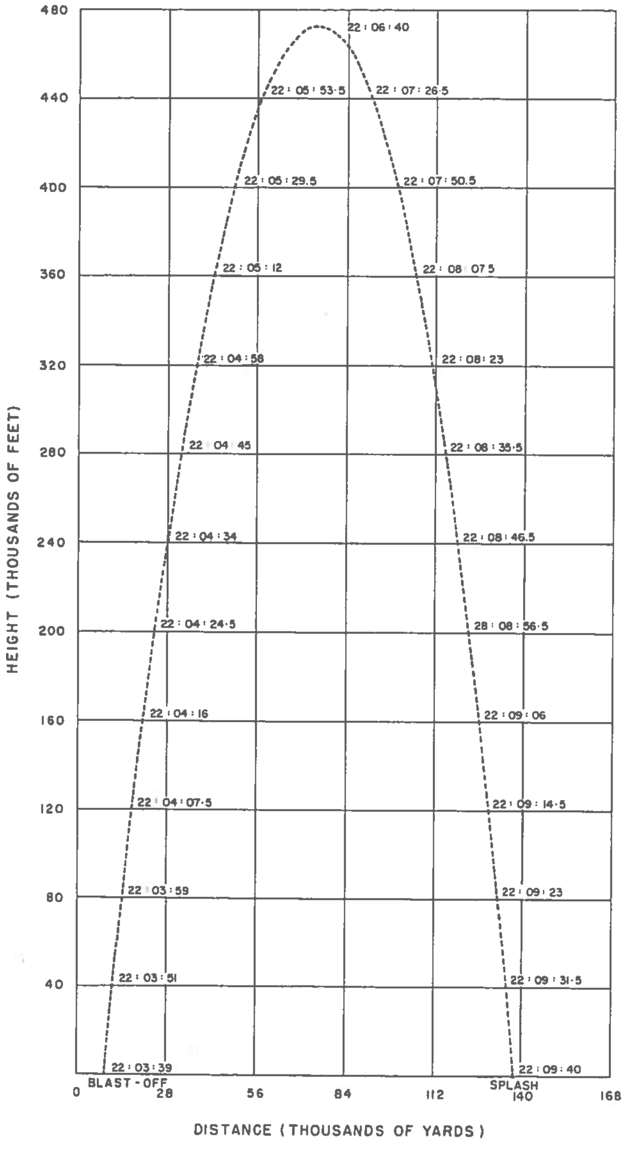

Fig. 7 Rocket trajectory

CHURCHILL RESEARCH RANGE
FORT CHURCHILL CANADA

METEOROLOGICAL/IMPACT PREDICTION TEST SUMMARY

1. Test Number: 91 Support Of: NRC

2. Date: 5 April 1963 Scheduled Time: 2130 CST Actual Time: 2203:38 CST

3. Vehicle Type: BLACK BRANT AA I-26 Objective: Cosmic ray - Langmuir probe magnetometer experiment

4. Sustainer Serial NBR: ______ Weight: ______
( ) Stage Serial NBR: ______ Weight: ______ Vehicle Length: ______
( ) Stage Serial NBR: ______ Weight: ______ Vehicle C.G: ______
Payload Serial NBR: ______ Weight: ______ MFG. Date: ______

5. Surface Observation Time: T + 5 mins Cloud (Amount, Type, Height) 1/10 ST 1500'
VSBY: 15 mis WIND: E 6 kts PRESS, (STA.): 1016.2 mbs TEMP: -4.0 F D.P. -4.0 F RH: 100%
Remarks: ______

6. Supporting Rawinsonde Obs: Time: 1715 CST Alt: 96,227' Time: ______
Alt: ______ Time: ______ Alt: ______

7. Supporting Pibal Obs: Time: 1658 CST Alt: 3215' Time: 1905 CST Alt: 1498'
Time: 2003 CST Alt: 2877' Time: 2102 CST Alt: 2549' Time: 2146 CST Alt: 3215'

8. Vehicle Performance: Predicted:
Sustainer Impact Azimuth: 080° Range: 180.3 kyds. Time: T + 371
(N/A) Stage Impact Azimuth: ______ Range: ______ Time: ______
(N/A) Stage Impact Azimuth: ______ Range: ______ Time: ______
Apogee Azimuth: 080° Alt: 170 kyds Range: 90.1 kyds Time: +190 secs
Other: ______

Vehicle Performance: Actual:
Sustainer Impact Azimuth: 088.0° Range: 130.8 kyds Time: T + 367 sec. By: Radar
(N/A) Stage Impact Azimuth: ______ Range: ______ Time: ______ By: ______
(N/A) Stage Impact Azimuth: ______ Range: ______ Time: ______ By: ______
Apogee Azimuth: 088° Alt: 156.6 kyd Range: 66 kyds Time: T+163 sec By: Radar

9. Data Acquisition (Arcas)
AN/GMD-1A
AOS: ______ Time: ______ Alt: ______ Elev: ______ AZ: ______
LOS: ______ Time: ______ Alt: ______ Elev: ______ AZ: ______

Radar: AN/MPA-12 AN/MPQ-18 AN.MPS-19
AOS: T : 0 Time: 2203:38 CST Alt: Surface Range: 8 Kyds AZ: 114.2°
LOS: T+367 Time: 2209:45 CST Alt: Surface Range: 138.2 kyds AZ: 90.05°

10. REMARKS: ______

This difference may be explained, at least in part, by a higher payload weight than used in the calculations for predicted performance. The predicted values were based on a nose cone weight of 310 pounds, whereas the actual weight as measured at the Range was 334 pounds. Using an approximation that there is 1000 feet loss in altitude per pound additional weight, then apogee should have been about 24,000 feet lower than predicted, whereas the actual apogee was 40,200 feet lower than predicted.

EXPERIMENTS

1) Cosmic Ray and Low Energy Particle Experiments (E.E. Budzinski, NRC)

Two packages were placed on rocket AA-I-26 to study the intensity and angular distribution of low energy electrons and the intensity of cosmic ray protons and alpha particles.

One package consisted of an array of seven thin-window Geiger counters arranged in an arc and separated from each other by angles of 20°. These counters were sensitive to electrons with energies greater than about 40 KeV and protons of energy greater than 500 KeV, and the array would indicate not only the intensity of these particles but also their angular distribution. The numbers of detectable electrons far exceed those of protons, and it would be the intensity and distribution of electrons that would be provided by the experiment.

This experiment functioned quite well, with failure in only one counter, which tended to go into a "buzzing" condition at higher particle intensities. Analysis of the results depends a great deal on the use of magnetic aspect data but, because of the non-availability of these data, perhaps less can be done with the data than was expected.

The second experiment carried a variety of detectors, mainly to study higher energy particles. Two thin-walled Geiger counters, one shielded only by the surrounding material, the other by additional lead, were operated separately and also in coincidence. Both operated satisfactorily and gave data on the intensity of cosmic rays.

A solid-state silicon-junction particle detector, sensitive to protons of energies above 1 MeV and alpha particles of energies above 5 MeV, failed to operate. A thin-window Geiger counter mounted at 45° to the rocket axis also failed to operate.

That the Geiger counter was not working was known from laboratory check-outs, but since its function was essentially covered by one of the counters in the angle detector package, it was decided to forego the replacement of the faulty counter for reasons of available time and the effort required.

During tests of the entire nose cone in the laboratory it was discovered that there was interference from telemetry on several experiments, especially that using the silicon-junction detector. This was overcome by braid-shielding all interconnecting leads among the packages.

The time of failure of the silicon-junction detector is not known. The checkout procedure was chosen to be fairly simple, since it was not possible to have someone well versed in the experiments accompany the payload to Churchill.

2) Plasma Probe Experiment (A.G. McNamara, NRC)

This rocket successfully met practically all of the desired experimental conditions. Its trajectory passed through strong visual aurora while ground-based equipments were recording conditions of strong magnetic disturbance, radio wave absorption, and spectral emissions. The only major element missing from the data was evidence of auroral radar reflections from the area covered by the trajectory.

The experiment consisted of four Langmuir probes mounted on the rocket nose cone and designed to measure electron density, temperature, and spatial structure of the ionization within the aurora.

Final horizontal checkout during the countdown revealed a short-circuited coaxial cable carrying the signal from one of the extending probes. However, in view of the unparalleled auroral activity which was in progress during the countdown, it was decided to proceed without delay and to fly with the remaining three probes.

The two extending probes were timed to be released at about 70 km altitude; a failure of unknown origin caused extension to occur at about 35 km. In spite of the severe aerodynamic stresses, the probes survived and operated throughout the flight. All three of the operating probes gave good data throughout the flight.

The probe circuits were potted in 2 lb/ft^3 foam. This performed very effectively both in shock mounting and in temperature control. An electrical thermometer imbedded in one of the circuits registered less than 1°C temperature change during the flight. In-flight calibrations showed that no drift occurred in the amplifiers.

The rocket roll period of about 2.5 seconds was compatible with the sweep rate which was used, and gave reasonably good altitude resolution.

3) Potential Gradient Experiment (D.W. Johnson, Univ. of Sask.)

This experiment consisted of one electronic unit contained in a cylindrical package of $3\frac{1}{2}$ inches diameter by 5 inches long which was ejected from the nose cone at T + 40 seconds. The unit contained two 100 milliwatt oscillators. One oscillator was crystal-controlled at 231.4 mc/s, while the other was variable (as a function of the potential gradient) about a mean 5 kc/s offset from the frequency of the crystal-controlled oscillator. The experimental data were thus contained in the magnitude and rate of change of frequency difference between the two oscillators.

One end of the completed package was insulated from the remainder of the assembly. This insulated end was connected to a voltage-sensitive capacitor in the variable-frequency oscillator circuit. A change of potential between the insulated and uninsulated parts of the package would, therefore, result in a frequency shift of the variable-frequency oscillator.

For interpretation of the data it was necessary that the package tumble during its flight. This was necessary because there was no means of determining the altitude of the package during its free fall, and hence no means of knowing whether the results reflected the maximum potential gradient of a region.

The signal was received on an AM receiver and the detected output was recorded on a track of the telemetry magnetic tape. As the data were recorded at a low signal-to-noise ratio, some signal processing had to be done. The tape was played back through a narrow-band (a few cycles/second) filter tuned to the 5 kc/s signal and recorded on a paper strip chart. The errors caused by wow and flutter of the recorder were checked by also playing back an unmodulated subcarrier oscillator.

4) Micrometeorite Experiment

This experiment included an electronic unit and two crystal microphones, one resonant at 50 kc/s and the other at 100 kc/s. The microphones were mounted diametrically opposite each other on the conical section of the nose cone. The object was to count the number of micrometeorite impacts during flight, separate the impacts into three energy levels, and record ambient noise by means of associated electronic circuitry. Both systems performed perfectly throughout the flight with no apparent loss of sensitivity due to aerodynamic heating. No impacts were recorded in the two higher energy levels and ambient noise was negligible. However, data at the lowest level are confused by electrical interference from other equipment in the rocket (e.g., from the mechanical commutator and the "in flight" calibration relays).

5) Magnetometers

The magnetometers, both the Schonstedt units and the unit from the University of Alberta, did not operate during the rocket flight. It is suspected that the latching relay control on the battery supply did not latch to internal power, as none of the equipment connected by this relay operated during flight.

6) Low-frequency Accelerometers

Records from the accelerometers during, and for a short period after the thrust portion of the flight are shown in Fig. 8. The Z-axis accelerometer output is of considerable interest as it is directly related to motor performance. Lateral acceleration was quite low. The principal disturbance occurred at the onset of motor burnout and lasted about 10 seconds from T + 15 to T + 25 seconds, with a peak to peak amplitude of $\frac{3}{4}$ g at approximately 2 c/s. All accelerometers were low-frequency devices (natural resonance of about 30 c/s).

7) Parallactic Cameras

Cameras were operated at Belcher and O'Day south of the launch site for photographic triangulation on aurora and the rocket-borne light. Ground haze conditions in the general area of these stations prevented useful data from being obtained.

The light on the rocket was extended and turned on at T + 45 seconds. Monitor equipment in the rocket indicated the light functioned until T + 95 seconds.

8) Temperature Measurements

Most of the temperature sensors in the rocket were connected in a bridge circuit to positive and negative voltage sources. The negative supply was taken from the same source as used for the magnetometers. This supply was not connected to its loads during flight so none of the temperature sensors using this negative supply gave useful data.

Data were obtained from a thermistor measurement on the edge of a small block of dielectric situated on the surface of the nose cone at station 90. The circuit was not connected to the negative source. The measurement was made because the configuration of the dielectric and its support was in some aspects similar to that for a quadraloop antenna. It was desired to know how hot the dielectric might become for future applications. A plot of the reduced data is shown in Fig. 9. The dielectric material was Fluorosint.

It may be of interest to note some of the temperatures monitored during checkout of the instrumentation while the vehicle was on the launcher. Heaters installed in the nose cone were not used at any time. A temperature sensor mounted about midway up on the H-frame in the conical section was monitored periodically by means of an external line. This monitor indicated a temperature of 75°F at the beginning of tests at approximately T - 3 hours. The temperature

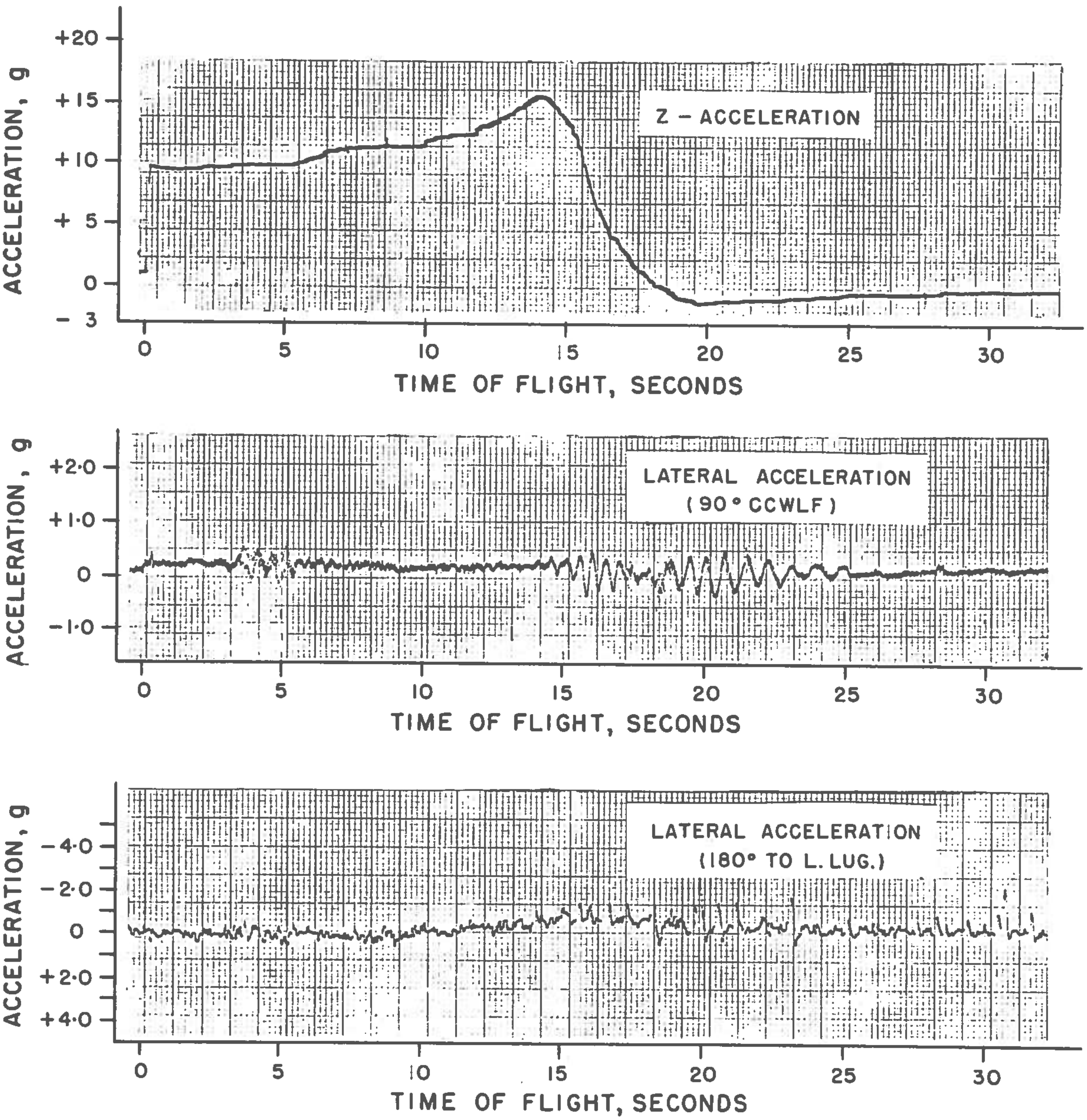

Fig. 8 Low-frequency nose-cone accelerations

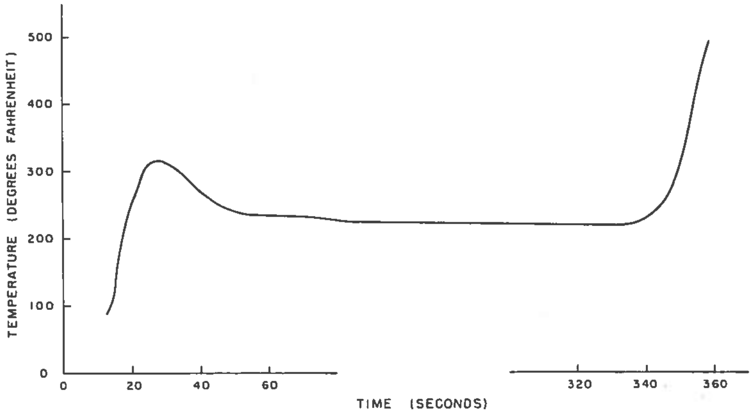

Fig. 9 Surface temperature at station 90

fluctuated to some extent during the countdown, probably owing to instrumentation being in operation for part of the time. At T - 40 minutes the reading was 80°F (during vertical checks following elevation of the launcher).

Temperatures were monitored through the subcommutator external line during horizontal checks (T - $2\frac{1}{4}$ hours). Temperatures at the top of the H-frame and inside the nose cone surface at stations 40, 70, and 90.5 were all between 75°F and 80°F. The temperature near the voltage regulators and transmitter in the telemetry package (probably the hottest region in the telemetry package) was 110°F. This was probably the warmest region in the nose cone. A sensor mounted on an amplifier just below the bulkhead indicated 90°F. This high temperature was very likely a result of heat from the telemetry package being transmitted through the bulkhead.

9) Signal Strength (F.V. Cairns, NRC)

The telemetry antenna system consisted of three blade antennas mounted at 120° intervals on the circumference of the rocket skin, together with power dividers and feed cables. The transmitter power was divided equally between one blade and the other two in parallel, with a phase shift of 180° between the single blade and the two in parallel.

The recorded value of the signal strength at the terminal of the receiving antenna exceeded 80 μv for the first 65 seconds of the flight. After 65 seconds a regular pattern of variation was readily discernible. Between 65 seconds and 320 seconds this variation (between 20 μv and approximately 80 μv) persisted with a period of 2.45 seconds. At approximately 320 seconds indications of turnover on re-entry were observed, and for the last 40 seconds of the flight the signal strength varied between 5 μv and 25 μv (except for 2 or 3 drops to about 2 μv) in a cyclical manner. A signal of 2 μv provides an S/N ratio of 10 db (assuming 500 kc/s bandwidth and 6 db noise figure) at the receiver input. The received signal strength was, therefore, adequate to ensure that there was no significant degradation of telemetered data because of receiver noise.

The calculated gain of the rocket antenna system assuming that transmitter power, receiving antenna gain, and slant range are known, gives an indication of the performance of the antenna system, and facilitates comparison of the variations of recorded signal strength with measured radiation patterns. Since the altitude of the rocket was not determined, the comparison of signal strength with measured patterns must be done in a general way.

The maximum and minimum gain during a cycle of roll was calculated at 20-second intervals. The values of the maxima were found to be always less than 1, and were less than 0.5 during most of the flight (relative to isotropic).

The minimum gains were, at times, less than 0.03. It had been expected that the gain would be about 0.5 at the maxima and not less than 0.1 at the minima during the part of the flight before turnover. There is, therefore, the possibility that there was a deficiency in the antenna system. However, since the gain was computed assuming normal transmitter power, it is possible that the result was due to low transmitter power. A third possibility is that the rocket was in an unfavorable attitude, from the point of view of receiving antenna flooding, throughout the portion of the flight considered.

The computed value of the gain of the rocket antenna system changed in a regular way during the period of cyclical variation of signal strength. 280 seconds after lift-off it had the same value as 120 seconds after lift-off. This variation could be interpreted as the effect of precession, with a period of roughly 160 seconds.

A similar gain computation was carried out for the 231.4 mc/s radiation from the ejected package. Since velocity imparted to the package did not exceed 10 ft/sec, its trajectory for this purpose was considered to be the same as that of the rocket. There is a possibility that the package was separated from the rocket by aerodynamic drag in the first 10 seconds after ejection. The signal strength from the package fluctuated violently during this period, and these fluctuations are believed to have been caused by fluttering of the antenna because of the combined effect of aerodynamic pressure and tumbling of the package.

The gain of the ejected package antenna should be approximately the same as that of a dipole; i.e., a maximum of 1.6 or 0.8 allowing for polarization loss (linearly polarized package antenna and circularly polarized receiving antenna). The recorded maximum gains were below this by a factor of 10, or more, throughout its flight. Sometimes the factor was as high as 50. This reduction must be attributed to some factor in the package or to an error in calibration. It is not likely that the calibration error was more than ±3 db, so it seems that the low signal strength must be attributed either to a loss in the antenna system or to low transmitter power. There is, however, a possibility that the package was oriented so that the ground receiving antenna was always pointed to a region near the minimum of the package radiation pattern. This does not seem very likely, but the available data do not rule it out.

CONCLUSIONS

Only a preliminary assessment of the results of the scientific experiments is given here. Further information on the experiments will be published in due course by the scientists concerned.

A number of observations may be made concerning the engineering aspects of launching the rocket and preparing the instrumentation. Standardization of packaging, components, and wiring methods can be of considerable advantage. This is particularly true when several rockets are being instrumented to be launched during the same period of time. The only specific change proposed in future instrumentation wiring, as a result of a failure, is the addition of a positive umbilical line indication that all latching relays in the nose cone are latched to "flight" position prior to lift-off. Failure of some circuits in rocket AA-I-26 (magnetometers and temperature bridge) is considered to be due to a latching relay not being energized to the flight position.

APPENDIX I — ENGINEERING WORK SHEETS

GENERAL REQUIREMENTS BBIIA/BBI FINS	ROCKET NUMBER: AA II 26 (1)

GROUND SUPPORT:

RADAR — TRAJECTORY

T/M MAG. TAPE AND SOME PAPER RECORDS. 1 FM Rx FOR NOSE CONE T/M. 1 AM Rx FOR POT. GRAD. PKG. FIELD STRENGTH ON BOTH Rx.

PARALLACTIC CAMERAS AT BELCHER & O'DAY

MAGNETOGRAMS & RIOMETER RECORDS BEFORE & DURING FLIGHT

VEHICLE ASSEMBLY, FIN ALIGNMENT, IGNITER & SQUIB INSTALATION

WEATHER DATA FOR EXPERIMENTS AND VEHICLE PERFORMANCE

300 SQ. FT PREP. AREA FOR NOSE CONE CHECKOUT

5000 W. 115~ 60cps. IN PREP. AREA AND BLOCKHOUSE

DUPLICATE Rx & RECORDING AT DRNL.

BATTERIES:

	TYPE	VOLTS	MA.
[illegible]	AgZn HR5	+26.2	5000 + 100
[illegible]	NiCd S-102	-6.5	750
P.G.	AgZn HR01	-21	150
MICROM.	Hg	-12	
LIGHT, SUBCOM., [illegible]	AgZn HR5	+12	7500 / 120 / 4000/2 SQUIBS.
[illegible]ERS, D.C. AMP., TEMP.	NiCD.	+12	225
	NiCD	-18.	
LANG. PROBES	NiCd	+±12 GND	15
	NiCd	±12 FL	50
COSMIC RAY	Hg	—	—

PRIMARY NOSE CONE INSTRUMENTATION:

	TYPE	POWER	FREQ.
BEACON ANTENNA 2 QUADRALOOP LIN. POLARIZ.	CAE #16106/01/2/810 NRC MODIFIED	150 WATT PEAK PULSE	2.7 TO 3.0 KMC
DOVAP NONE			
T/M TX ANTENNA 3 BLADE LINEAR POLARIZATION	TELEDYNAMICS 1004 A	5 WATT	219.5 Mc PREF. 218.0 Mc ALT.
~~T/M TX ANTENNA~~ POTENTIAL GRADIENT LINEAR POLARIZATION	1 XTAL CONTROL. 1 VARIABLE ≈ 5Kc OFFSET FROM XTAL CONT.	100 MW. 100 MW	231.4 Mc 231.4 Mc

EXPERIMENTS:

COSMIC RAY

MAGNETOMETER

POTENTIAL GRADIENT — EJECTED PKG. AT T + 40 SEC.

LANGMUIR PROBES — 2 PROBES ERECTED AT T + 50 SEC

LIGHT — ERECTED AT T+45 SEC.

MICROMETEORITE

LAUNCH CONDITIONS:

a) NEAR PASS OF ALOUETTE PREFERED.

b) AURORA PREFERED

c) DARKNESS & NO CLOUD COVER

ROCKET CONFIGURATION: BBIIA WITH BBI FINS

TELEMETRY — ROCKET NUMBER: AA II 26 (2)

EXPERIMENT:	POWER	SUB-CAR. CHANNEL
POTENTIAL GRADIENT EXIT EVENT	T/M +26V	180 cps BEEP
LIGHT MONITOR EXT.	T/M +26V	660 cps.
PRESSURE SWITCH (NOSE CONE)	T/M +26V	950 cps
LANGMUIR PROBE EXTENSION EVENT	T/M +26V	IRIG BAND #1 400 cps
LINEAR ACCELEROMETER -3 TO +20G Z-AXIS SIG.	T/M CAL. +5V	3.9 Kc. BW 59
LINEAR ACCELEROMETER ±10G +G 90° C.C.W.L.F.	T/M CAL. +5V	5.4 Kc. BW 81
BUCKMASTER MAGNETOMETER 180° TO L. LUG	MAGNET. +12V -18V	7.35 Kc. BW 110
BUCKMASTER MAGNETOMETER 90° CW L.F.	MAGNET. +12V -18V	10.5 Kc. BW 160
COSMIC RAY STD.	Hg.	14.5 Kc. BW 220
LANGMUIR PROBES	±12 V FL. ±12 V GND	22 Kc. BW 330
COSMIC RAY PITCH	Hg	30 Kc. BW 450
LANGMUIR PROBE	±12V FL. ±12V GND	40 Kc. BW 600
LANGMUIR PROBE	±12V FL. ±12V GND	52.5 Kc. BW 790
T/M COMMUTATOR 30 x 10/s	T/M +26V HR-5	70 Kc. BW 1050

EXPERIMENT:	POWER	COMMUTATOR CHANNEL
CALIBRATE 0	CAL. GND	1
" 5V	T/M CAL.	2
BEACON -6.3V	BEACON	3
" R.F.	"	4
" MOD.	"	5
" RX	"	6
SCHONSTEDT MAGNETOMETER 90° CW LF SIG	MAGNET. +6V	7
" BIAS	"	8
BUCKMASTER MAGNETOMETER 180° TO L. LUG SIG	MAGNET. +12V -18V	9
" 90° CWLF SIG	" "	10
SCHONSTEDT MAGNETOMETER Z-AXIS SIG.	MAGNET. +6V	11
LINEAR ACCELEROMETER ±10G 180° TO L. LUG SIG	T/M CAL. +5.0V	12
LIGHT OP. MONITOR	LIGHT HR-5	13
POTENTIAL GRAD R.F. MON.	MAGNET. ±12V	14
T/M +250V MON.	T/M DC/DC CONV.	15
T/M +26V	HR-5	16
LANGMUIR PROBES TEMP.	±12V GND ±12V FL.	17
" " PROGRAM	"	18
" " BATTERY 3	"	19
" " " 4	"	20
" " " 5	"	21
" " TIMER MONITOR	LIGHT HR-5	22
MICROMETEORITE 50Kc SIG	-12V Hg	23
" 100Kc SIG	-12V Hg	24
9 TEMPERATURE SUBCOMMUTATE SIG.	+12V SQUIB +26V T/M -6V MAGNET.	25
9 TEMPERATURE SUBCOMMUTATE SIG	+12V SQUIB +26V T/M -6V MAGNET.	26
LINEAR ACCELEROMETER ±10G 180° TO L. LUG SIG	T/M CAL +5.0V	27
MASTER	T/M +26V	28
MASTER	"	29
MASTER	"	30

ENG.WORK SHEET:	SUBCOMMUTATOR TEMPERATURE		ROCKET: AA II 26 (3)		
STATUS:	PREP.DATE:		EXP.DATE::	FIR.DATE: MARCH/63	

INPUT	DC 37 PIN	SEQUENCE	INPUT	DC 37 PIN	SEQUENCE
-6V MONITOR	1	1	-6V MONITOR	20	11
INSIDE BOTTOM SOLID NOSE TIP STA. 12	2	2	INSIDE BOTTOM SOLID NOSE TIP STA. 12	21	12
INSIDE SKIN STA. 40	3	3	INSIDE SKIN STA. 40	22	13
TOP OF H-FRAME	4	4	TOP OF H-FRAME	23	14
INSIDE SKIN STA. 70	5	5	INSIDE SKIN STA. 70	24	15
BOTTOM OF H-FRAME	6	6	SCHONSTEDT Z-AXIS MAGNETOMETER BIAS	25	16
T/M PACKAGE	7	7	T/M PACKAGE	26	17
INSIDE SKIN STA. 90.5	8	8	INSIDE SKIN STA. 90.5	27	18
POTENTIAL GRADIENT R.F. MONITOR AMPLIFIER	9	9	POTENTIAL GRADIENT R.F. MONITOR AMPLIFIER	28	19
DUMMY QUADRALOOP STA. 90.5 120° CCWLF	10	10	DUMMY QUADRALOOP STA. 90.5 120° CCWLF	29	20
WIPER 1 to 10	13		WIPER 11 to 20	14	

MARKED, IF USED, GROUNDS ON POSITION 1 ONLY GND COMM. CH. 26

UMBILICAL | ROCKET NUMBER: AA II 26 (4)

EXPERIMENT:	FUNCTION: (GND TO)	NO.	EXPERIMENT:	FUNCTION: (GND TO)	NO.
BEACON *	RELAY CONTROL NEG. MONITOR 16	1	LANGMUIR PROBES AND MICROMETEORITE	EXT. CHARGE LATCH 16	26
"	CONTROL INT. (+)/CHARGE(-) 16	2	"	MONITOR/FLIGHT RESET 16	27
"	EXT. LINE CHARGE 16	3	"	GND CKT. EXT. LINE +12V 16	28
"	EXT. LINE POWER/MONITOR	4	"	GND CKT EXT. LINE -12V 16	29
MAGNETOMETER A, BATTERIES	POWER ON INT. RESET 16	5	"	FLOATING CKT EXT. LINE +12V	30
"	MONITOR/CHARGE EXT. LINE (+) 16	6	"	FLOATING CKT EXT. LINE -12V	31
COSMIC RAY	POWER OFF LATCH 16	7	"	RELAY CONTROL EXT. LINES 16	32
"	POWER ON RESET 16	8	SUBCOMMUTATOR	CONTROL ON (+)/OFF (-) 16	33
MAGNETOMETER BATTERIES	POWER OFF/CHARGE LATCH 16	9	CONICAL SECTION HEATER		34
EXT. H-FRAME TEMP.	44	10	CONICAL SECTION HEATER		35
POTENTIAL GRADIENT	ELECTRONICS TO INT. (+)/EXT. (-) 16	11	T/M	+5.0V T/M CAL.	36
"	CHARGE LINE TO OFF (+)/BATTERY (-) 16	12	"	+150V #1	37
"	EXT. LINE POWER (-) 16	13	"	+150V #2	38
"	EXT. LINE CHARGE (-) 16	14	T/M	INT. CALIB. RESET 16	39
MAGNETOMETER BATTERY	MONITOR/CHARGE EXT. LINE (+) 16	15	"	EXT. CALIB. LATCH 16	40
POWER GND	*	16	"	RELAY CONTROL EXT. LINE	41
FORWARD BODY HEATER		17	"	MONITOR/CHARGE EXT. LINE	42
FORWARD BODY HEATER		18	"	EXT. POWER 26.2V	43
LIGHT TIMER	SHORT } EXT. SHORT TO UMB. 16	19	"	CALIBRATE GND	44
POT. GRADIENT TIMER	SHORT	20	"	CALIBRATE SIG.	45
LANGMUIR PROBE TIMER	SHORT	21	"	RELAY CONTROL CALIBRATE SIG.	46
ALL TIMERS	ARM RESET 16	22	"	INT. POWER RESET	47
"	OFF LATCH 16	23	"	EXT. POWER LATCH	48
TEMPERATURE	RELAY CONTROL EXT. MONITOR 16	24	"	RELAY CONTROL 250V + COMMUTATOR	49
"	EXT. LINE MONITOR	25	"	EXT POWER GND	50

ENG.WORK SHEET: Batteries | ROCKET: AA II 26 | (5)

STATUS: | PREP.DATE: | EXP.DATE: | FIR.DATE:

NO.	BATTERIES TYPE	BATTERIES VOLTS	EXPERIMENT	LOAD MA.	LIFE ON LOAD	TEMP. RANGE °F	UMBILICAL CH'RG	UMBILICAL ON/OFF	UMBILICAL MON
1	18xHR-5	26	T/M	5000	1 HR.	-20° TO +165°	YES	YES	YES
			CALIBRATOR	50,200/ 50MS/10SEC					
			TIMER (6)	25,22EA. /3MS/35SEC.					
			TEMPERATURE	10					
			EVENT CIRCUIT	20					
2	5x5-102	-6.3	BEACON	750		0° TO +115°	YES	YES	YES
3	14xHR01	-21	POTENTIAL GRADIENT	150		-20° TO +165°	YES	YES	YES
4	Hg	-12V	MICROMETEORITE	6-10			NO	YES	No
5	9xHR-5	+12V	LIGHT	7500		-20° TO +165°	No	No	No
			SQUIBS (6)	4000 pk /2 squibs					
			SUBCOMMUTATOR	120				YES	
6	10xNiCd	+12	BUCKMASTER MAGNETOMETERS (2)	150 @ +12V	2 HRS	0° TO	YES	YES	YES
7	10xNiCd +5xNiCd	-18		-18V	2 HRS	115°			
			POTENTIAL GRADIENT R.F. MONITOR AMPLIFIER	4 @ ±12V					
			TEMPERATURE	40 @ -18 (6V FROM ZENER)					
			SCHONSTEDT MAGNET. (2)	120 @ +12 (6V FROM ZENER)					
8	NiCd	+12 FL	LANGMUIR PROBES	15		0° TO +115°	YES	YES	YES
9		-12 FL	" "	15					
10		+12 GND	" "	35-40					
11		-12 GND	" "	35-40					
12		+12 GND	" "	50-80 PK. IN PULSES					
13	Hg		COSMIC RAY		20 HRS.	32° TO 105°	No	YES	NO

WORK SHEET: NOSE CONE WEIGHTS & C.G. || ROCKET: BB II A AA II 26 (6)

MAR 18 1963

ITEM	SERIAL NO.	DESCRIPTION	WEIGHT LBS.	STATION INS.	MOMENT
1		NOSE CONE & STD. FOR'D BODY (NO HOLES)	116	70	8120.0
2		T/M PACKAGE + BULKHEAD (INCL. BATTERY BOX BUT NO BATTERIES)	28.5	84.3	2400.0
3		T/M BATTERIES	5.175	84.5	437.0
4		COSMIC RAY SUPPORT STRUCTURE	7.0	101.0	707
5		COSMIC RAY STD PKG. DETECTOR	4.25	98.25	417.5
6		" " " " ELECTRONICS	7.38	100.1	739.0
7		" " PITCH UNIT DETECTOR	2.937	103.97	305.0
8		" " " " ELECTRONICS	6.875	100.1	688.0
9		LANGMUIR PROBE PLANAR	1.5	90.67	136.0
10		" " LONG PROBES (2)	5.0	90.35	451.0
11		POTENTIAL GRADIENT (WITH TIMER & BMR)	3.687	93.25	344.0
12		LIGHT	0.7	94.57	66.2
13		BEACON ANTENNA (2)	0.5	101.24	50.6
14		T/M BLADE ANTENNA (3)	1.7	107.5	183.0
15		DUMMY QUADRALOOP	0.5	90.35	45.2
16		T/M ANTENNA SPLITTERS (2)	0.4	102.375	41.0
17		LANGMUIR SMALL PROBES	0.1	76	7.6
18		BUCKMASTER MAGNETOMETER DETECTORS (3)	1.2 (3.1)	39	46.8
19		" " ELECTRONICS (3)	1.5 (3.0)	78.78	118.2
20		SCHONSTEDT " DETECTOR	0.2	39	7.8
21		" " ELECTRONICS	0.25	66.15	16.5
22		MAGNETOMETER SUPPORT STRUCTURE	1.5	49	73.5
23		CYCLOSWITCH SUBCOMM. & TEMP. DIVIDER	2.5	68.15	170.4
24		PRESSURE TRANSDUCER	0.3	79.15	23.7
25		T/M ANTENNA CABLE	0.8	96	76.8
26		LANGMUIR PROBE ELECTRONICS	10	72	720.0
27		MICROMETEORITE ELECTRONICS	2.	72	144.0
28		" DETECTORS (2)	0.385	72	27.7
29		BEACON ELECTRONICS & COUPLER	4.3	74.9	322.0
30		LIN. ACCELEROMETER ±10G YAW	0.375	60.15	22.5
31		" " " PITCH	0.375	61.9	23.2
32		" " -3 TO +20G	0.375	63.6	23.9
33		T/M CALIBRATOR	0.5	72.3	36.1
34		T/M COMMUTATOR	1.062	77	81.7
35		MOTOR PRESSURE TRANSDUCER	0.75	110	82.5
36		LIGHT TIMER	0.25	88	22.0
37		LANGMUIR PROBE TIMER	0.25	88	22.0
38		MAGNETOMETER BATTERIES (±12V)	1.5	69.2	104.0
39		LIGHT BATTERIES (9x HR-5) + CASE	2.59 + 1.0	74.2	266.0
40		H-FRAME + CHANNEL TO T/M TOP PL.	10.1	71.13	719.0
41		H-FRAME MTG. FIXTURES	5.0	71	355.0
42		MAGNET. LATCH RELAY	.03	68	.2

STATUS: ESTIMATE | PAGE 1 OF 2 | PREP. DATE: 22/11/62 | FIR. DATE: MARCH/63

[illegible] WORK SHEET: NOSE CONE W'GHTS & C.G. ROCKET: 88 II A AA II 26 (7)

MAR 18 1963

ITEM	SERIAL NO.	DESCRIPTION	WEIGHT LBS.	[illegible] IN.	[illegible]
43		TEMP. MONITOR RELAY	.03	68	.2
44		TEMP. SUBCOMM. LATCH RELAY	.03	68	.2
45		LANG. PROBE BATTERIES ±12V	1.5	63.5	95.2
46		WIRING	5.0	84	420.0
47		DUMMY LAUNCH LUGS (2)	4.62	107.5	497
48		LAUNCH LUG	—	—	—
49		ALARM SCO PACKAGE	0.75	88	66.0
50		H-FRAME HEATERS (4)	2.0	71	142.
51		COSMIC RAY PKG. HEATERS (2)	1.0	100	100.
52	—	MAT'L REMOVED: COSMIC RAY PITCH	.025	104	2.6
53	—	" " " STD	.03	98	2.9
54	—	" " LANG. PROBES LONG (2)	.43	90.3	38.9
55	—	" " " " PLANAR	.2	90.7	18.1
56	—	" " POTENTIAL GRADIENT	.31	93.25	28.9
57	—	" " LIGHT	.05	94.6	4.7
		± 7 lbs @ STA. 72			
		C.G. STATION 77.9 ±0.25	255.181 ±7		19868.1

STATUS: | PAGE 2 OF 2 | PREP. DATE: | [illegible] DATE: