Fourth Black Brant II rockets launched at Churchill Research Range, March 1965, AE-II-24, AD-II-52, AA-II-53, AA-II-60

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

FOURTH BLACK BRANT II ROCKETS LAUNCHED AT CHURCHILL RESEARCH RANGE MARCH 1965

AE - II - 24, AD - II - 52, AA - II - 53, AA - II - 60

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OTTAWA

JULY 1967

ERRATA TO NRC REPORT ERB-715

Page 31 Caption should read Fig. 13. Attitude history of AA-II-53.

32 Caption should read Fig. 12. Attitude history of AD-II-52.

In the diagram 'Flight Azimuth 111.1°' should be 'Flight Azimuth 102.8°'.

ABSTRACT

The engineering aspects associated with the launching of four scientific sounding rockets are described. The vehicles, AE-II-24, AD-II-52, AA-II-53, and AA-II-60, were launched from Churchill Research Range in March, 1965. The launchings were a continuation of the series sponsored by the National Research Council's Associate Committee on Space Research. The report includes a description of payloads, the objectives of the experiments, the launching phase, and a discussion of the processed engineering data. The payload for AE-II-24 was fabricated by the University of Toronto for high-altitude pressure measurements, and presented some unusual pre-launch problems in a requirement for continuous vacuum pumping until just before lift-off.

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FOUR BLACK BRANT II ROCKETS

LAUNCHED AT CHURCHILL RESEARCH RANGE

MARCH 1965

AE-II-24, AD-II-52, AA-II-53, AA-II-60

A. Staniforth and D.H. O'Hara

I. INTRODUCTION

The sounding rocket payloads described here were launched as part of a continuing investigation of phenomena associated with aurora. This program is sponsored by the National Research Council's Associate Committee on Space Research and is designed to facilitate participation by many small groups. The Data Systems Section (formerly Space Electronics Section) of the National Research Council's Radio and Electrical Engineering Division provides engineering assistance [1] to some of these groups which do not otherwise have resources to build instruments and to launch sounding rockets. This assistance includes coordination and assembly of the payload, testing and final check-out of the payload, as well as payload control during the launching. In addition, assistance may be given to experimenters in the design or construction of their instruments and with the reduction of data [2].

The Black Brant II rockets reach an altitude of approximately 100 miles with a nominal payload of 150 lb. Usually, more than one experiment is required to fill the payload compartment volume of 6 cubic feet. Experimenters from the University of Alberta, Calgary, the University of Saskatchewan, the University of Toronto, the Upper Atmosphere Research Section of NRC's Radio and Electrical Engineering Division, and the Cosmic Ray Section of NRC's Division of Pure Physics participated in the launchings described here. The payload of AE-II-24, supplied by the University of Toronto, was the first complete payload designed and built by a Canadian university.

The vehicles consisted of a CARDE 15KS25000 propulsion unit, a standard cast-magnesium Black Brant II nose cone, and a 4-fin stabilizer fabricated by Canadair. Nose cones of vehicles AE-II-24 and AA-II-60 had 8.8-inch extensions to the forward body (Figure 1). The preflight performance characteristics and wind-weighting data were obtained from CARDE.

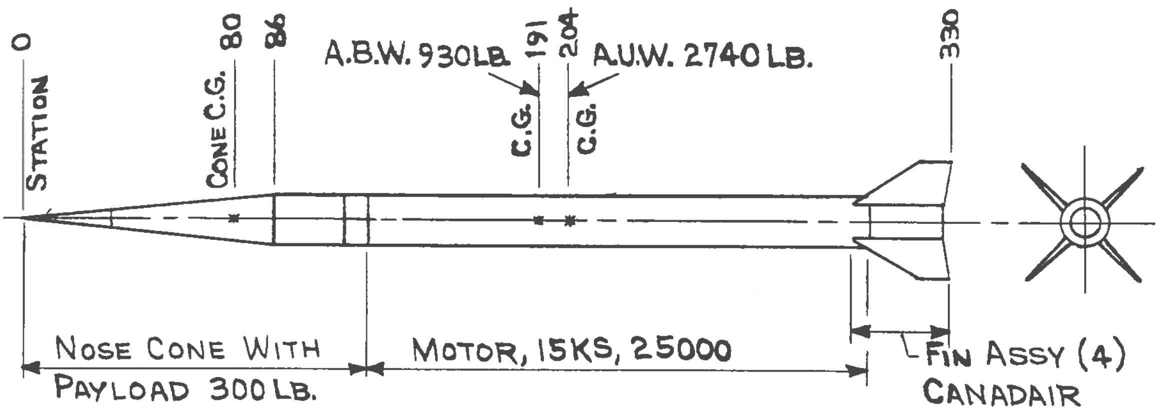

Fig. 1. Black Brant II rocket with extension

II. LAUNCHING OPERATIONS

COMMUNICATIONS

A considerable number of people in diverse locations must communicate during the countdown in preparation for the launching of a rocket. Figure 2 shows schematically the extent of this network. The balloon ground station and launch area, the ionospheric inhomogeneities ground station and DRNL observing station are located about 12 miles west of the rocket range complex itself. These stations are connected by the CRR communication system. However, data from the Prince Albert radar, which is 600 miles to the southwest, are received by teletype.

The mission controller and user controller share the same console; hence, the MC can refer directly to the UC for all decisions.

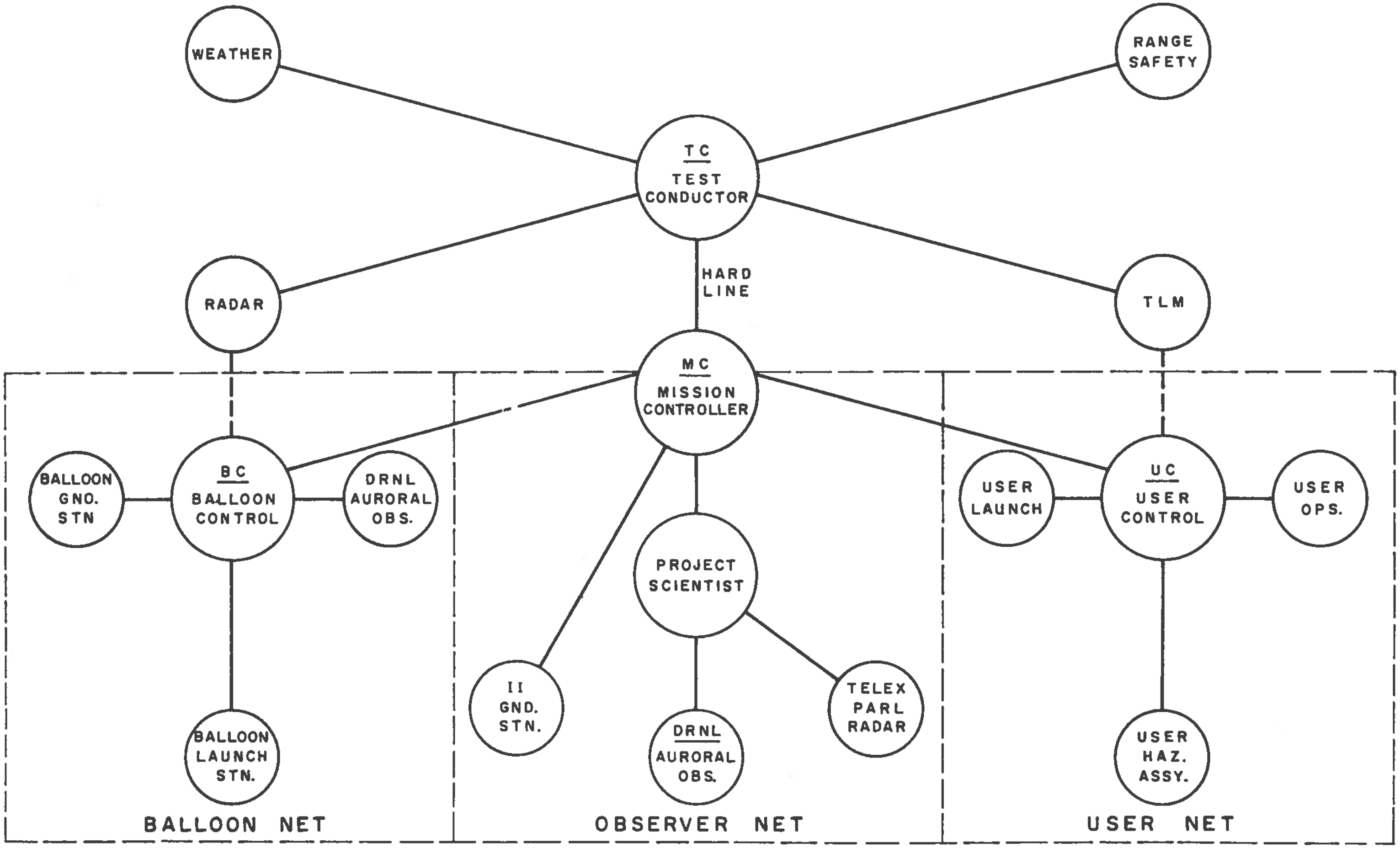

Fig. 2. Communications plan

LAUNCH CONDITIONS

Vehicle AE-II-24 was scheduled to be launched in the daytime between sunrise and sunset; otherwise, it had to meet no other launch conditions except those imposed by range safety restrictions.

The three auroral rockets contained a wide variety of experiments by different experimenters. The length of time each rocket remained on the launcher was limited to provide equal chances of launching all vehicles. These rockets were scheduled to be put on the launcher in the order AD-II-52, AA-II-53, and finally AA-II-60. AA-II-60 was scheduled last because it required the most stringent launch conditions.

Vehicles AD-II-52, AA-II-53, and AA-II-60 were instrumented to study phenomena associated with aurora. Clear skies and solunar darkness are necessary to permit visual observation of aurora during the countdown, both by the project scientist and the optical instruments operated by the support agencies. Owing to the limited period available for this set of firings and likelihood of poor auroral activity, desirable launch conditions were specified in detail with definite procedures for relaxation of launch requirements after unsuccessful attempts to launch a vehicle. These conditions are listed for each of the vehicles.

AD-II-52

Auroral radar echoes on trajectory of 10 db above noise and visual aurora in trajectory of minimum intensity I and maximum intensity III.

AD-II-53

For the first two attempts:

Aurora in trajectory, visual intensity II or radar echoes 10 db above noise.

For succeeding attempts:

Clear sky with no evidence of aurora.

AD-II-60

(1) Unusually great events: any one sufficient for launching.

A. Aurora (visual) intensity III on trajectory

B. Aurora (radar) 20 db on trajectory

C. Balloon X-ray count of 1000/sec.

D. Riometer absorption 3 db

(2) Simultaneous occurrence of:

A. Balloon X-ray count of 100/sec.

B. Radar aurora 10 db or visual aurora intensity II

C. Clear sky at ground observing stations

Condition (1) or (2) was most desired. However, if a major failure in observing equipment occurred, then the following launch conditions prevailed:

(3) If balloon instrumentation inoperative, simultaneous occurrence of:

A. Riometer 1.5 db absorption

B. Aurora visual intensity II or radar 10 db on trajectory

C. Clear sky at observing sites

(4) If auroral radar inoperative, simultaneous occurrence of:

A. Balloon X-ray count of 100/sec.

B. Visual aurora intensity II

C. Clear sky at observing sites

(5) If auroral radar and balloon instrumentation inoperative, simultaneous occurrence of:

A. Riometer 1.5 db absorption

B. Visual aurora of intensity II

C. Clear sky at observing sites

After two days on the launcher without satisfying any of the above conditions, conditions were to be relaxed to accept any two of:

A.	Aurora (radar)	10 db on trajectory
B.	Riometer	1 db

C. Aurora (visual) Intensity II on trajectory

D. Balloon X-ray count 50/sec

III. DIARY MARCH 1965 LAUNCHINGS

March 9 First group arrived at Churchill to start preparations of the trailer ground station for the ionospheric inhomogeneities experiment.

March 10 Remainder of launch team arrived at Churchill and began preparing the payloads and checkout equipment for the launchings.

March 12 Vacuum pumping started on AE-II-24 nose cone.

March 15 Scheduled launching of AD-II-52, but aborted 21:05* during horizontal check because of a faulty commutator.

March 16 AE-II-24 installed on launcher and a preliminary horizontal check carried out. Scheduled launching was aborted in afternoon as further vacuum pumping was required. The vehicle was left on rails all night with pumps operating.

March 17 AE-II-24 launched successfully at 15:13* AD-II-52 was placed on the launcher at 17:20 and scheduled for firing. At 01:45 on March 18, a good auroral event occurred but the heat shield had frozen and could not be opened in time. The ambient temperature was -36° F. The launching was aborted 02:45 owing to insufficient aurora.

March 18 Trouble corrected in the commutator of AD-II-52, which was causing interference. AD-II-52 launched into good aurora and 1 db absorption on the 30 MHz riometer at 00:28 on March 19.

March 19 AA-II-53 was prepared for launching and installed on launcher at 21:30. Aborted at 03:26, March 20, owing to insufficient aurora.

March 20 and 21

AA-II-60 was prepared for launching.

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*All times are Central Standard Time

March 22 — Continuing check-out of AA-II-60. Launching of AA-II-53 cancelled at 16:30 on account of high winds.

March 23 — Continuing check-out of AA-II-60. Some payload modifications carried out on AA-II-60 and AA-II-53. AA-II-53 scheduled and launched at 00:40 on March 24 into good aurora.

March 24 — AA-II-60 scheduled and launched at 23:34 into a strong visual and radar aurora with 1.5 db absorption.

March 25 and 26

Equipment packed.

March 27 — Launch team returned to Ottawa.

PAYLOADS

The payloads for these four sounding rockets contained two classes of instrumentation:

(a) Measurements of phenomena in the upper atmosphere

(b) Engineering measurements of the vehicle performance, rocket attitude, and ambient conditions in the payload.

A summary of the contents of these payloads is given in Table I, followed by a more detailed description of each experiment.

IV. PAYLOADS - EXPERIMENTS

ROCKET AE-II-24

The University of Toronto Institute of Aerospace Studies was responsible for the instrumentation of vehicle AE-II-24. The National Research Council provided a standard telemetry system, and two magnetometers and three linear accelerometers for monitoring vehicle performance. In addition to consultation during the design and construction of the payload, the Data Systems Section provided direct assistance in check-out and launch phases of this operation.

<u>TABLE I</u>

Payload Composition

	AE-II-24	AD-II-52	AA-II-53	AA-II-60
Nose cone conical section	5 atmospheric pressure gauges 8 temperature sensors	Two channel photometer $\frac{1}{4}$ inch diam.extendible plasma probe 2 Micrometeorite transducers 2 magnetometers 3 linear accelerometers 2 vibration accelerometers TLM package	Neutron detector Micrometeorite (2 transducers) Plasma probe electronics Radar beacon 2 magnetometers 3 linear accelerometers TLM package	Neutron detector Micrometeorite. Plasma probe electronics 2 magnetometers 3 linear accelerometers 2 vibration accelerometers TLM package
	Radar beacon 2 magnetometers 2 sun-sensors (attitude determination) 3 linear accelerometers	Planar probe Planar trap probe Photometer, NRC EFP[1]-1A package (ejected) EFP[1]-1B package (ejected) Plasma probe 6-inch sphere (ejected) Radar beacon 1 vibration accelerometer I.I.[2] package(ejected)	Planar probe Planar trap probe $\frac{1}{4}$ inch diam.extendible plasma probe Plasma probe 6-inch sphere (ejected) EFP[1]-1A package (ejected) EFP -III probe (2) I.I.[2] package(ejected) X-ray detector TLM No. 2 transmitter 1 vibration accelerometer	2 plasma probes (extendible) Planar probe Planar trap 7 cosmic ray detectors X-ray detector Photometer, NRC Auroral scanner (extended) EFP -1B packages (2) (ejected) Acoustic measurements TLM No. 2 transmitter TLM No. 3 transmitter $\frac{1}{4}$ inch diam. extendible probe

[1] Electric field probe

[2] Ionospheric inhomogeneities

The nose cone instrumentation was designed to measure atmospheric pressure with a composite orifice-type probe, especially at altitudes above 100 km [3]. Gauges to measure static pressure and stagnation pressure at lower altitudes were also included. Three sets of pressure gauges were included in the instrumentation: high-pressure, strain-gauge type; medium-pressure, thermopile type; and low-pressure, cold-cathode type.

This vehicle presented unique operational problems during check-out, installation on launcher, and countdown. The conical section of the nose cone, which contained the low-pressure gauge, was evacuated to 10^{-4} mm of Hg pressure. To maintain this pressure, continuous pumping was required until 90 seconds before launch. Preparation of nose cone and pumping began in the operations area at the range. After about two days of pumping, a sufficiently low pressure was reached to permit a complete instrumentation check. Once satisfactory operation was confirmed, the payload was transported to the launch bay and mated with the motor. The complete vehicle was then installed on the launcher in preparation for the countdown.

The assembled nose cone was mounted on the dolly shown in Plate I. The cone was supported at about five feet from the ground. This height permitted the diffusion pump to clear the ground. The diffusion pump was supported by a duct, six inches in diameter, which was coupled to the nose cone exhaust port. The duct was supported at the coupling by a safety belt around the cone. The clasp on the safety belt could be released by a bellows actuator. In addition, a mechanical pump, the low voltage dc power supply for the thermoelectric coolers on the diffusion pump, and cooling air blowers were installed on this dolly.

During transportation from the operations building to the launch bay (a distance of nearly $\frac{1}{2}$-mile), pumping was continued using power from a portable generator carried on the truck towing the dolly (Plate I). Just before moving the nose cone from operations, the cooler's power supplies were disconnected and taken to the launch bay for installation on the launcher. Although provision was made to operate the coolers from battery power during transit, this was unnecessary because of the low outside temperature.

In Plate II, the vehicle is shown installed on the partially elevated launcher with the heat shield closed. As the heat shield could not be closed completely, sheets of polyethylene were used to cover the gaps. These sheets can be seen taped to the shield. Also visible in this photograph is the cooler power supply, mounted on top of the launcher boom and the cable of No. 6 conductors leading from the supply to the coolers on the diffusion pump. The two black conduits leading from the diffusion pump over the heat shield are the cooling air ducts from the blowers. The hose in the foreground, at the bottom of the picture, leads to the mechanical pump about 20 feet away, located so that it will not be damaged by motor blast on ignition. The white cords in the photograph are shock ropes to take the weight of the pumping system when it is released from the rocket. A frame visible to the right of the diffusion pump was installed to contour the large duct from the rocket to the diffusion pump as the rocket is raised to the vertical position. This frame also prevented the pump from fouling the telemetry antenna which was in line with the exhaust port on the rocket.

At 90 seconds prior to launch, pumping on the nose cone was stopped and the pumping system swung away from the rocket. All operations on the rocket had to be controlled remotely from the blockhouse at this time. The equipment set-up with inter-unit cabling is shown diagrammatically in Figure 3. The following sequence of events occurred:

1. Spring loaded exhaust valve in rocket nose cone was closed by firing a bellows actuator.

2. All power was removed from pumping system. This stopped mechanical pump, removed power from diffusion pump, coolers, blowers, and heaters, opened an exhaust valve in line from diffusion pump to rocket, and closed a valve in line from mechanical pump to diffusion pump.

3. Coupling on vacuum duct to rocket exhaust port was released by firing a bellows actuator, permitting vacuum system to fall away from the nose cone.

4. Heat shield was then opened, lifting all pumping hardware well away from the vehicle.

These operations were monitored in the blockhouse on closed circuit television.

An unsuccessful attempt to launch AE-II-24 was made in June, 1964. Breakdown occurred in the high-voltage wiring in the evacuated nose cone. Although the system had been tested in an evacuated state, this low pressure had never been maintained for long periods. It was only after several hours at low pressure that breakdown occurred. Since the exact location of the fault was uncertain, and at least two days were required to check success of any modifications, this test was terminated and the payload was returned to Toronto.

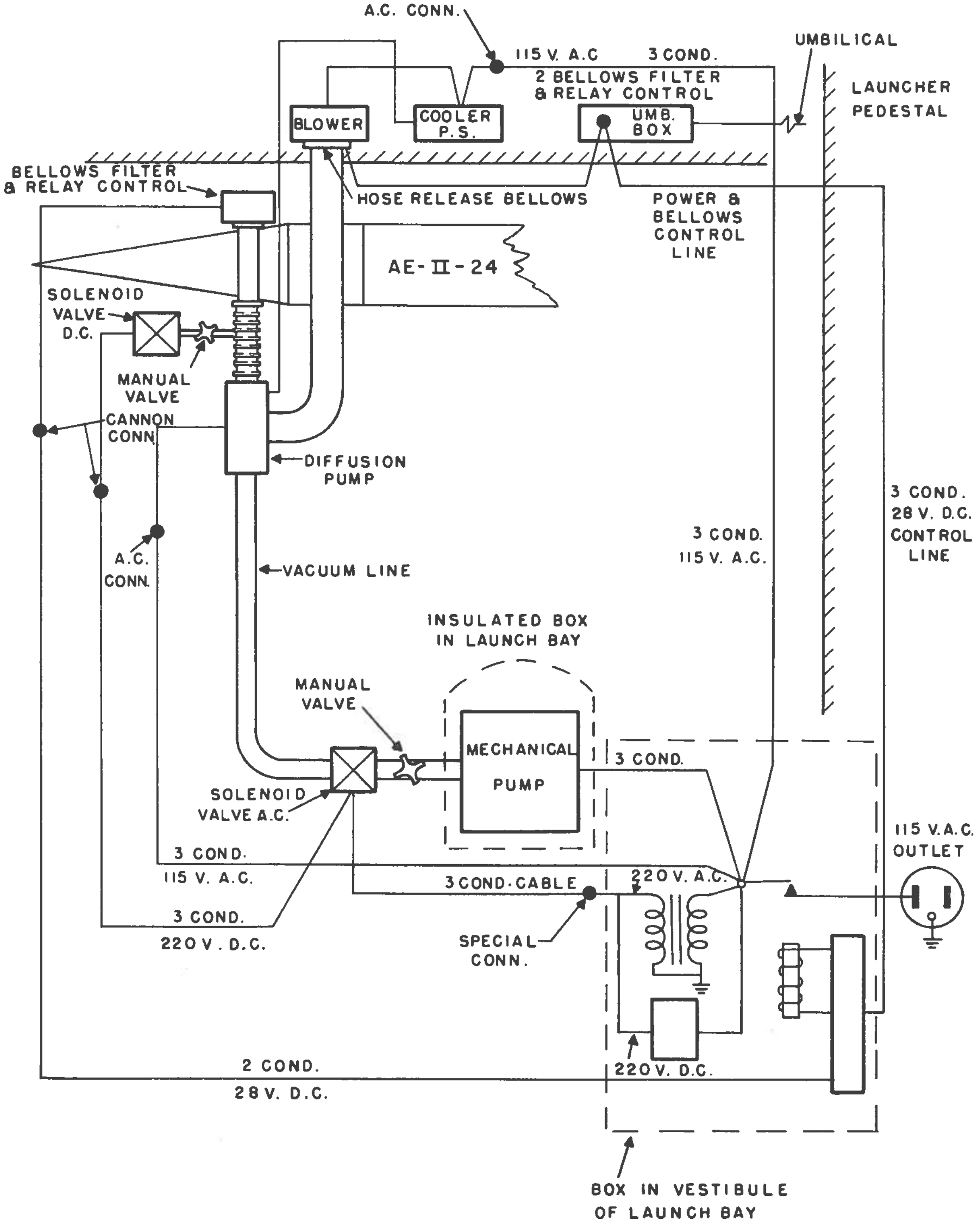

Fig. 3. Vacuum pumping system on launcher - AE-II-24

The modified payload was sent to Ottawa in December, 1964. At this time, complete instrumentation checks of the evacuated nose cone were carried out.

Assembly of the payload at Churchill was started on March 11. The payload was transferred to the launch bay on the afternoon of March 16 for a scheduled launch late that afternoon. During transit, the diffusion pump struck a piece of ice. Although damage was slight, the pump had to be stopped for repairs. The resulting increase in nose cone pressure precluded launching that day. However, the vehicle was installed on the launcher, and pumping continued throughout the night. AE-II-24 was launched at 15:13:29.5 CST, March 17, 1965. Despite an outside temperature at the time of launching of -12° F, all stages of the operation were successfully carried out.

X-RAY DETECTOR

Department of Physics, University of Alberta, Calgary

The objective of this experiment was to determine the spectrum and flux of precipitating particles responsible for auroral X-ray events. The detector consists of a Harshaw Scintillator (using an RCA 6199 photomultiplier) and electronics which include upper and lower level discriminators to pass pulses representing energies between 15 kev and 150 kev.

AURORAL SCANNER

Department of Physics, University of Alberta, Calgary

The scanner consists of a 5577 Å photometer which views a rotating mirror. The rotating mirror causes the photometer to scan in an arc, starting from a direction parallel to the rocket axis toward the fins of the rocket, sweeping upwards and continuing until parallel to the axis in the direction of the nose cone. At this point, the other side of the rotating mirror begins another scan. An optical trigger system provides a synchronizing pulse each time a new sweep begins. The mirror rotates at 3000 rpm, thus providing a complete scan each 10 milliseconds. The photometer has an angular resolution of 2 degrees providing about 100 picture elements for each sweep. As the rocket spins, the entire sky is scanned.

The scanning device, the optical system, and the associated electronics were provided by the University of Alberta, Calgary. The mounting, the extension mechanism, and the timed release system were designed and fabricated by the Data Systems Section of NRC. The high voltage supply for the photomultiplier was also designed and fabricated at NRC. Figure 4 shows a simplified cross-sectional view of the complete assembly.

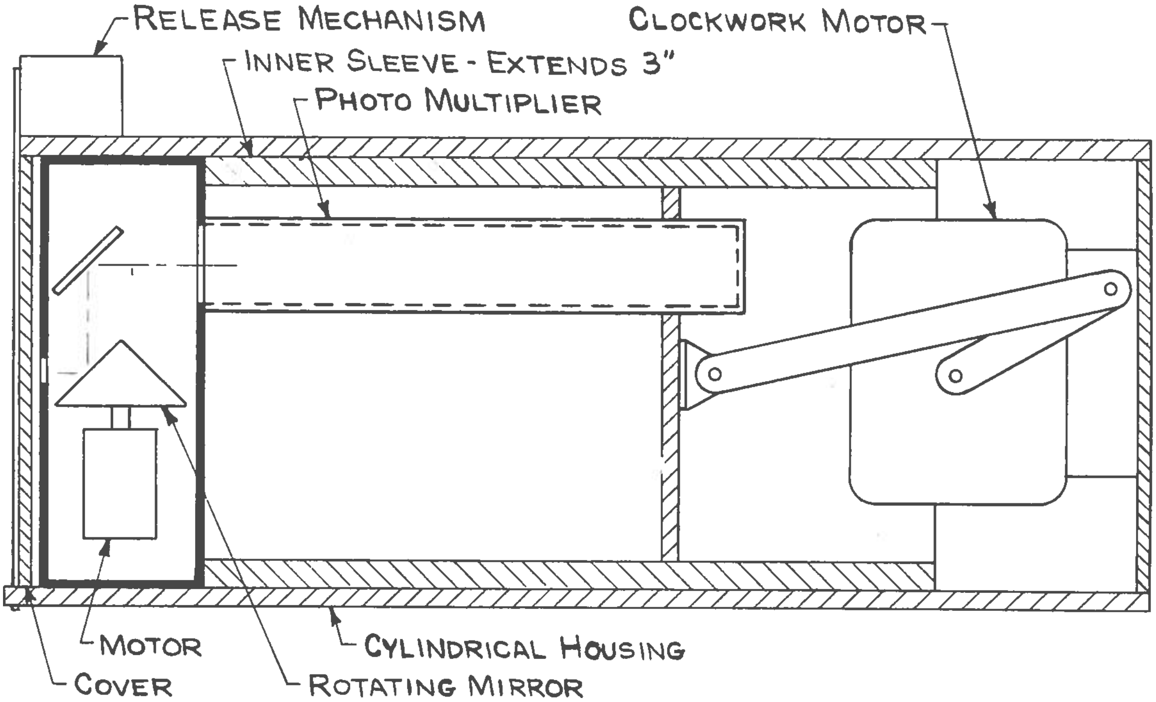

Fig. 4. Auroral scanner extension assembly

At T + 40 sec, at an altitude of 170 kft, the timer fired the bellows actuators which released the outer cover and allowed the mechanical motor to drive the scanner out through the action of a crank linkage. This resulted in a very low starting and stopping acceleration, with a positive lock in the extended position.

TELEMETRY FOR X-RAY EXPERIMENT AND AURORAL SCANNER

Both the X-ray instrumentation and the auroral scanner required wide-band data transmission channels. To accommodate these experiments, a separate telemetry link was used, Link 2. The output signal of the X-ray equipment consisted of pulses of 25 μsec length and variable amplitude, with pulse spacing at least 25 μsec. Maximum and minimum pulse heights generated are set by the discriminator levels in the X-ray electronics. This information was used to modulate a transmitter directly. The auroral scanner output was connected to a wide-band 70-kHz subcarrier oscillator (IRIG Band E). The X-ray pulses were scaled and the weighted output fed to a 40 kHz subcarrier oscillator (IRIG Band 16).

In vehicle 60 the modulation levels were set as follows: The amplitudes of the 70-kHz and 40-kHz subcarrier oscillators were adjusted to a 6:1 ratio and the combined signal was set at 60-kHz deviation (read on the telemetry receiver meter). Then the amplitude of X-ray pulses corresponding to the upper discriminator level was adjusted until the peak-to-peak voltage of the total signal at the input of the transmitter was twice that with subcarriers alone viewed on an oscilloscope.

In vehicle 53, there was no auroral scanner. The 40-kHz subcarrier oscillator was used for the X-ray scaler signal, (adjusted to a 20-kHz deviation of the transmitter). Then the X-ray pulse signal, viewed on an oscilloscope at the transmitter input, was added and adjusted so that the peak-to-peak amplitude was five times that of the SCO alone.

TWO-CHANNEL PHOTOMETER

Department of Physics, University of Saskatchewan

The object of this experiment was to measure the rotational temperature with height in aurora. The instrument was the first of a type of rocket-borne photometers which will be used to correlate optical measurements to such quantities as characteristics of the energetic particle spectrum. A narrow-band interference filter was used to obtain two closely spaced wavelength channels. This two-channel photometer was designed to measure the rotation temperature from the 4278-Å band of the N_2^+ ion. At T + 45 sec, the upper section of the nose cone, above station 30, was ejected to provide a forward looking window. The ejection assembly was designed and built by the Data Systems Section.

ELECTRIC FIELD PROBES (EFP)

Department of Physics, University of Saskatchewan

The object of this experiment was to study electric field miscrostructure in auroral formations [4]. The probe was contained in a small cylindrical package, which was ejected at an altitude of approximately 80 km. The signal was transmitted directly to ground receivers and recorded. The package, referrred to as EFP-1A, contained two oscillators - one crystal controlled and the other varied by the ambient electrical field. The field characteristic data were obtained from the magnitude and rate of change of frequency difference between these two oscillators, by using a receiver with an AM detector. The EFP-1B package contained a single variable frequency oscillator requiring a receiver with an FM detector and with crystal controlled local oscillators. In either type of EFP, variations in the external electric field potential caused a change in voltage across a varactor in the tank circuit of the oscillator, thus changing the frequency. A second method of electric field investigation used two sensors mounted perpendicular to each other on the rocket skin. This instrumentation is referred to as EFP-III.

NEUTRON DETECTOR

Department of Physics, University of Alberta, Calgary

In this equipment, neutron intensities in the range from a few hundred keV to a few MeV are measured [5]. The detector consists of a combination of plastic scintillator and an anthracene crystal, from which pulses caused by charged particles, neutrons, and γ-rays are separated by pulse discriminator techniques. The detector is located in the tip of the rocket and isolated from the rest of the rocket body by a block of polyethylene to reduce effects of albedo neutrons produced in the rocket.

PHOTOMETER

Upper Atmosphere Research Section

Radio and Electrical Engineering Division, NRC

This unit was included in the payloads to indicate the presence of visual aurora in the vicinity of the rocket. The detector is an IP21 photomultiplier tube illuminated directly through a small hole in the rocket skin, and having an angle of view of about 16°. The instrument is turned on by a 50-kft altitude switch to avoid saturation of the tube by ground lighting before launching.

IONOSPHERIC INHOMOGENEITIES PACKAGE (I.I.)

Physics Department, University of Western Ontario

This ejected package contains a small transmitter at 108 MHz which is used as a source of radio waves to be studied from ground-based instruments as the package approaches, enters, and passes behind the ionospheric inhomogeneities [6] associated with aurora. The technique involves precision measurements of the phase and amplitude of the radio wave propagated through ionospheric inhomogeneities in order to reconstruct, from the resulting diffraction pattern, the characteristics of the irregularities.

ENERGETIC PARTICLE COUNTERS

Cosmic Ray Section

Division of Pure Physics, NRC

These experiments were designed to study energetic particles associated with aurora [7]. The intensity and spectrum of low-energy electrons were measured using a CsI(Tl) crystal mounted on a photomultiplier. Spectrum measurements were made at four points: > 25 keV, > 40 keV, > 70 keV, and > 120 keV. Three thin-window Geiger counters, with a threshold of 30-40 keV were used to measure the pitch angle distribution. A CsI(Tl) crystal mounted on a photomultiplier, connected in the current mode, measured the energy flux carried by electrons with energies greater than 6 keV. Protons with energies greater than 150 keV were segregated and detected in a silicon junction detector.

MICROMETEOROID DETECTORS

Upper Atmosphere Research Section

Radio and Electrical Engineering Division, NRC

The MkIII [8] micrometeoroid detector system consisting of two microphones, each followed by its own amplifier and simple processing circuit, was flown on vehicles AD-II-52 and AA-II-53. The processing circuit consists primarily of a capacitor which rapidly charges to the peak of the signal and then discharges slowly. The amplifier and microphone are tuned, the former electrically and the latter mechanically, to detect the 812 kc/s component of the impact-induced waveform. Advantages of this system are greater isolation from vehicle environment by virtue of the higher operating frequency, and non-critical setting of the amplifier gain. Mounting of two or more such systems per vehicle gives greater discrimination between small particles impacting in the vicinity of the microphone and larger particles impacting at some distance away.

The last of the three-microphone MkII detector systems, built to detect the point of impact on the sensing surface by means of the amplitudes of the first peak of the impact-induced waveform arriving at each of the microphones, was flown on vehicle AA-II-60. Gain settings were critical and were therefore staggered to assure some results from the experiment. As a result, the ability to locate the impact points was reduced. Operating frequency was 125 kc/s.

PLASMA PROBES

Upper Atmosphere Research Section

Radio and Electrical Engineering Division, NRC

Several types of plasma probe were used to measure electron density, temperature, and the spatial structure of ionization in aurora. These included probes with planar geometry and of the Langmuir type [9], as well as an ejected sphere probe.

Spherical Plasma Probe

The spherical plasma probe experiment was designed to carry a Langmuir type probe away from the disturbed environment near the rocket. Studies have indicated no major unanticipated perturbations caused by the presence of the rocket. However, on-board measurements must be interpreted with reference to probe and vehicle attitude data. Data from an optimally designed ejected probe are virtually independent of attitude.

The probe consists of an insulated 3-mm sphere on 12-inch extension, mounted on a metal 6-inch sphere. This larger sphere contains the necessary electronics for measurement and telemetry. Half the sphere contains probe circuitry, and the other half the telemetry transmitter, two subcarrier oscillators, and batteries. The telemetry antenna is mounted on this second half.

The probe circuitry was designed and fabricated by Upper Atmosphere Research Section. Over-all design and construction of telemetry system, probe extension, and ejection mechanism were the responsibility of the Data Systems Section. A simplified cross-section view of the complete assembly as it is mounted in the rocket is shown in Figure 5.

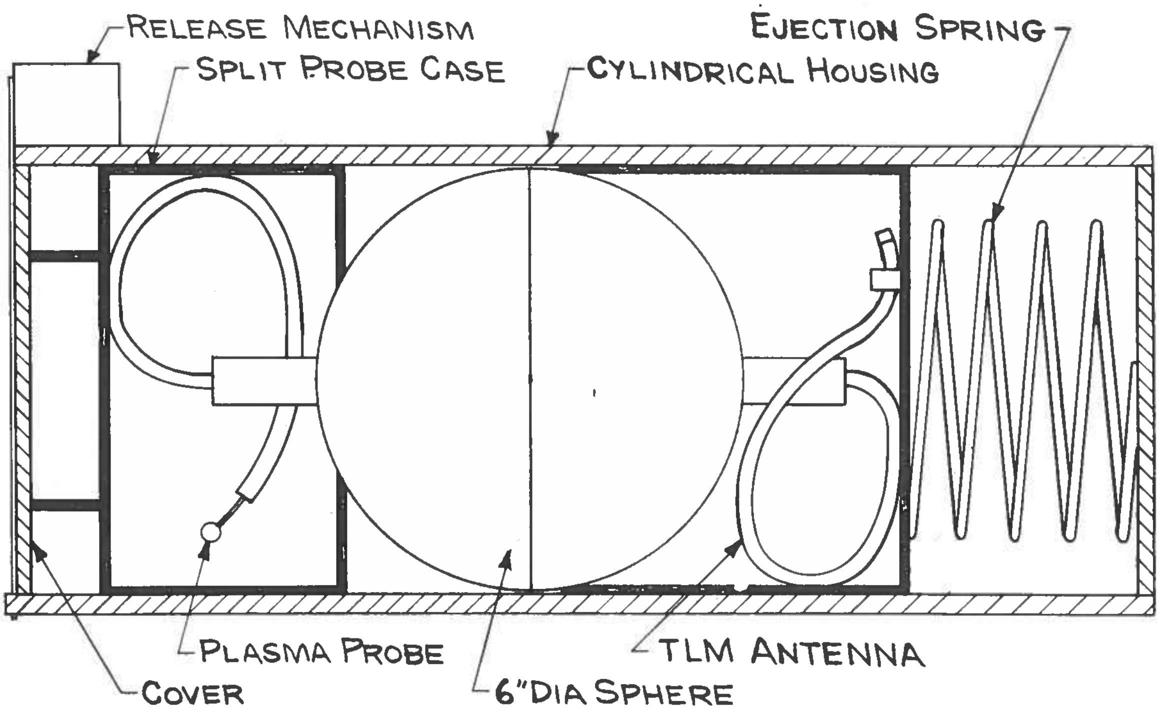

Fig. 5. Spherical plasma probe ejection assembly

The telemetry transmitter [10] is a phase modulated stabilized transistor oscillator, with a frequency deviation of about 10 kHz. Power is obtained from an 18-volt nickel-cadmium battery at 100-mA drain and transmitter output is nominally 50 mW. The combined output of a 3.9 kHz and 10.5 kHz subcarrier oscillator modulates the transmitter. Subcarrier oscillators take their power from four 9-volt carbon-zinc cells, with drain of approximately 20 mA.

The sphere, when loaded into the Fibreglas cylinder, compresses the spring to about 30-lb force and is held in place with a cover and release mechanism, which is operated by either one of two bellows actuators. The sphere is ejected normal to the rocket axis with a velocity of about 7 ft/sec. Both the firing of the bellows actuator and exit of the sphere are monitored on rocket telemetry.

Telemetry Performance and Angular Rotation of Ejected Spherical Plasma Probe

AA-II-53

From the shape of the signal strength pattern, it appeared that the probe tumbled with a period of about $7\frac{1}{2}$ sec with the axis of rotation not perpendicular to the plane containing the probe and the antenna. During the flight, this axis changed to become more nearly perpendicular. The angle between the plane of rotation and the line to the receiving station was approximately 70°, increasing to 85°.

AA-II-52

The amplitude of the signal strength is consistent with a transmitter power of 75 mW and a matched dipole antenna. The probe tumbled with a period of about 2 sec. The axis of rotation appeared to change during flight from about 10° to 30° from the perpendicular to the plane containing the probe and the antenna. The angle to the receiving site from the plane of rotation was approximately 70°.

The experiments all operated satisfactorily with the exceptions discussed in the following paragraphs.

COMMENTS ON ABNORMAL OPERATION OF PAYLOADS

AD-II-52

(1) Two channel photometer: This instrument failed at 88 sec after lift-off. Although mode of failure is uncertain, it appears that the high voltage supply was lost as the result of a voltage regulator failure.

(2) EFP packages: Both packages failed to eject. The reason for failure is unknown, but modifications made at the range are discussed under Ejected Packages section. Although ejection did not occur, some useful data were recovered. As pre-detection recording was used for both these packages, pre-detection filtering provided about 20 db signal enhancement [11].

(3) Subcommutator: The subcommutator stopped at T + 176 sec.

(4) The bellows actuator battery monitor shows that this battery fell to approximately 9 volts when the bellows were fired, and recovered to about 10 volts only by the end of flight, although for a period of about 50 sec, from T + 100 sec, the battery voltage rose to 11.2 volts. This battery is nominally 12 volts and is loaded only during bellows firing unless some sustained arcing took place in the actuators. All bellows apparently fired according to their monitors so, although battery or load behaviour appeared abnormal, the battery performed its function.

AA-II-53

(1) X-ray experiment: The scalar output showed a dc output shift during high counting rates.

(2) The subcommutator began sampling alternate segments after T + 259 sec.

AA-II-60

(1) Plasma probes: One of the extendible probes, the spherical trap, apparently failed to extend, so no usable information was received on either the 22.0 kHz or 40.0 kHz SCO's. The bellows actuators fired, the retaining door mechanism released, but probe data indicate that the probe itself did not extend. Probe release was monitored on the telemetry through two switch closures, the first occurring for door release and the second occurring when the probe was fully extended. Telemetry indications of these switch closures were not independent as the door release switch had to close before the state of the second switch could be determined. The indication from telemetry is that the extension switch closed before or simultaneously with the door release switch.

(2) NRC photometer: The photometer failed at T + 59 sec. Cause of failure is unknown.

(3) Link No. 5: The transmitter frequency shifted during flight, probably caused by RF voltage breakdown in the antenna. However, most of the data were recovered by using the record from Twin Lakes to fill in where dropouts occurred in the Launch Site record. A more detailed discussion is given in a later section entitled "Signal Strength, Link No. 5, AA-II-60".

V. PAYLOADS - ENGINEERING ASPECTS

FORWARD BODY ACOUSTIC MEASUREMENTS

Introduction

On rocket AA-II-60, a separate telemetry link was used to provide information about the nature of acoustic levels in the forward body casting. Two separate measurements were attempted.

(1) The determination of the magnitude and frequency spectrum of sound as detected by a high-level microphone during the powered portion of the flight, and while the rocket was still within the dense lower atmosphere.

(2) The determination of the magnitude and frequency spectrum of low-level vibrations in the forward body casting during the portion of the flight from T + 30 sec to impact. These data were provided by an accelerometer attached directly to the casting to measure longitudinal vibration.

The information channel with a nominal bandwidth of 0 to 5 kHz was provided by a high-gain logarithmic amplifier feeding a 70-kHz subcarrier oscillator which, in turn, frequency modulated a transistor transmitter. Space considerations on the outside of the forward body limited the antenna to a single quadraloop.

Results

Before lift-off, the sound level was approximately +60 db. A weak line appeared in the spectrum at approximately 380 Hz.

During the igniter burning, sound level in the forward body rose to approximately +95 db, and when motor burning and forward motion of the vehicle commenced, the level rose to a maximum of +125 db at approximately 260 msec after first motion.

Maximum energy was observed around 380 Hz with other peaks at 90, 210, 240, 340, 460, 1090, and 1650 Hz. The sound level dropped to a minimum of 85 db at approximately 1.2 sec and then increased to a maximum of 117 db at approximately 2.7 sec. During this interval, the energy at 1090 Hz increased to dominate the spectrum while the lower-frequency peaks almost disappeared.

The sound level again decreased to a minimum of approximately 85 db at 3.25 sec with 1090 Hz and 1650 Hz being the principal energy peaks. A low-frequency pulse (5 Hz, 120 db) occurred at 3.6 sec. At approximately T + 4 sec, a new peak appeared at 2400 Hz which increased rapidly in amplitude and frequency to become a strong line at 2600 Hz with a sound level of 115 db. After T + 5 sec, the sound level decayed rapidly to disappear in receiver noise at a sound level of about 70 db.

At approximately 13.5 sec after lift-off, lines appeared at 114 Hz and at the 2nd, 4th, 5th, 7th, and 8th harmonics of 114 Hz. The brightest line was at the 7th harmonic (approximately 800 Hz). These lines can be attributed to motor burning vibrations coupled through the shock mounting of the microphone.

The vibration accelerometer portion of the experiment produced results which were interesting but the measured levels are probably of little value.

The output of the accelerometer contained lines at 170 and 380 Hz (about 0.0001 g) on which were superimposed low-frequency (0-10 Hz) random fluctuations, (approximately 0.1 g) and occasional sharp, rapidly decaying signals which, when fed through an audio amplifier and speaker, sound as though the forward body was being randomly struck by a hard object. These signals had peak-to-peak values of the order of 0.001 g.

Discussion

The sound levels detected by the microphone in the forward body were well below anything which could cause physical damage to instrumentation. As an example, a peak level of 125 db corresponds roughly to a pressure of 0.006 $lb/inch^2$.

No attempt has been made to interpret the spectra other than to suggest that the broad peaks are probably due to resonances in the forward body excited by motor burning and wind noise. The 200 msec pulse which appears at 3.6 sec is very likely due to passage through Mach 1.

The results of the accelerometer measurement point out that a fair amount of low-level vibration exists throughout the flight. Heating and cooling of the vehicle skin is probably the principal source of these sounds, although small aerodynamic forces and meteorites may play some part. The predominant line at 380 Hz observed before and throughout the flight is very likely due to commutator gear noise modified by the resonances in the forward body.

VIBRATION ACCELEROMETERS

Vehicles AA-II-53, AD-II-52, and AA-II-60 were instrumented with vibration accelerometers. All three vehicles showed significant vibration towards the end of motor burning. Although AE-II-24 did not have a vibration transducer, evidence of vibration at about 100 Hz was seen on the thrust axis linear accelerometer from T + 8.5 to T + 14.5 sec. The onset of vibration is very sudden. Figure 6 is typical of the amplitude vs. time characteristic of the envelope of the vibration waveform. Although the times from lift-off at which vibration begins are not the same, the end of vibration in these three vehicles occurs at about 15 sec.

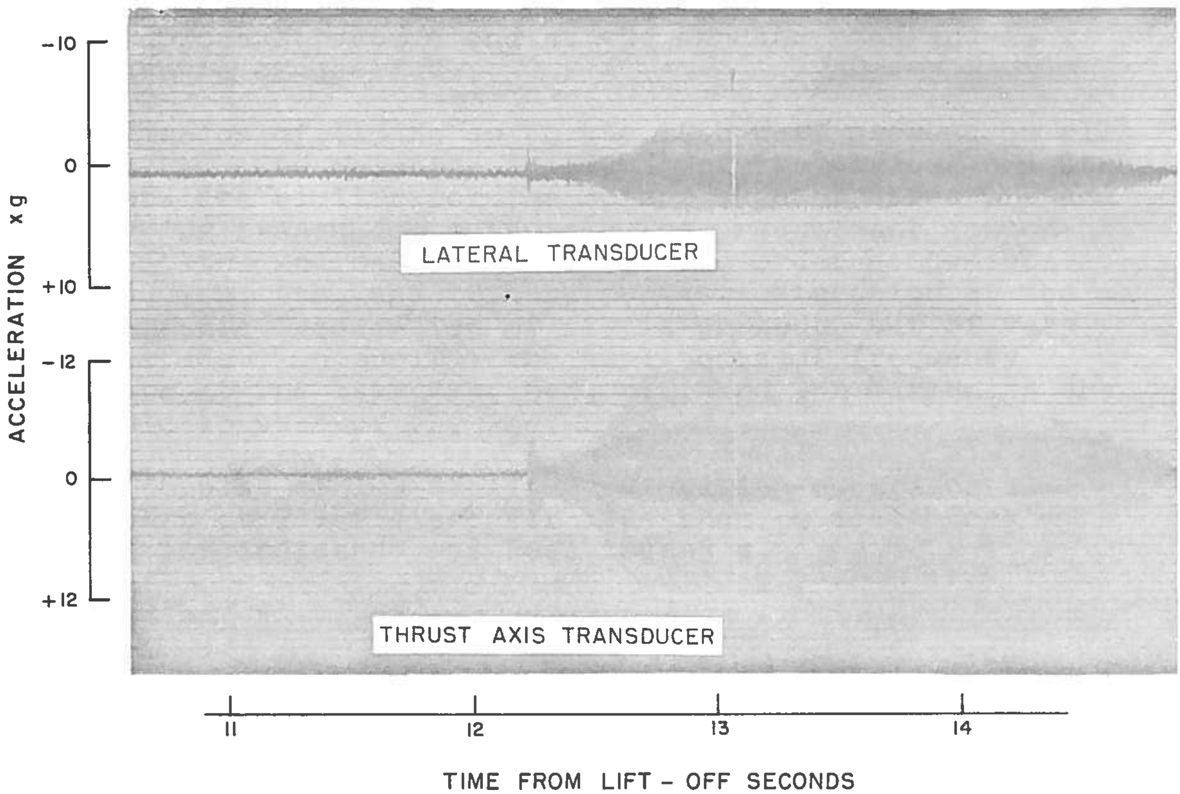

Fig. 6. Vibration accelerometer records - AA-II-60

All transducer outputs were examined after playback with a data bandwidth of one thousand hertz. The figures quoted for peak acceleration were read from these records. Data were also examined, with the aid of a spectrum analyzer, to determine the dominant frequencies at which the vibration occurred. Again, this examination was for frequencies below 1200 Hz. A brief examination of some of the transducer outputs indicated that vibration of significant amplitude does occur at frequencies greater than 1200 Hz.

Vibration AD-II-52

This vehicle was instrumented with three vibration transducers. All were mounted to measure vibration in the longitudinal axis. One unit was mounted on the supporting chute for the ejected plasma probe sphere in the forward body at station 96, one on the annular ring at station 87.7 that supports the instrument frame in the conical section, and a third in centre of shelf V of this instrument frame at station 75. The major incidence of vibration begins at T + 12 sec and continues to T + 15.25 sec. The peak levels of acceleration measured during this period were 8 g at the sphere support structure and at the annular ring and 15 g in the centre of shelf V.

Harmonics of 115 Hz up to the 10th were present on all transducers. The relative amplitude of the various frequency components are similar for the sphere support structure and annular ring transducer outputs. The predominant component appears at the 2nd harmonic with second order components at 1st, 6th, 7th, 9th, and 10th harmonics. Vibration at the other harmonic frequencies of 114 is present, but of very low amplitude. On shelf V the amplitudes of frequency components at the 1st, 4th, 5th, 8th, and 9th harmonics are comparable to that of the 2nd.

An impulse of low-amplitude vibration occurs on all transducers at T + 2.4 sec for less than $\frac{1}{10}$ sec. Peak acceleration indicated was less than 3 g.

Vibration AA-II-53

Two transducers were mounted in this vehicle, both indicating vibration on the longitudinal axis. One was mounted at the top plate of the telemetry package at station 87 and the other on the support structure for the X-ray photomultiplier tube at station 94 in the forward body. Vibration begins at T + 13.3 sec and lasts until T + 15.0 sec. The initial burst of vibration on the transducer on the X-ray tube has a peak amplitude of about 15 g which lasts for about 200 msec before dying away and then building up to an amplitude of 8 g. The peak amplitude at station 87 was also 8 g.

As in AD-II-52, vibration at 115 Hz and up to the 10th harmonic of this frequency was present. However, at the photomultiplier support structure, only the 1st and 2nd harmonic components have significant amplitude and the 2nd harmonic component is considerably larger than the 1st. At the station 87 transducer, the 8th and 9th harmonic components also have significant amplitude, but again the 2nd harmonic component dominates. From lift-off to the beginning of the high-level vibration at T + 13.3 sec, there is a low-amplitude vibration of predominantly 160 Hz at the X-ray photomultiplier support structure, which is not evident at the station 87 transducer. This frequency is likely the resonant frequency of the tube support structure.

Vibration AA-II-60

Two transducers were mounted at station 87, one in the longitudinal axis and the other in the lateral plane. Both were mounted at the top of the telemetry package. Vibration begins at T + 12.2 sec and lasts until T + 14.9 sec. Peak accelerations are 10 g on the longitudinal axis and 4 g in the lateral plane. At about T + 10 sec, vibration occurs for less than $\frac{1}{10}$ sec. Peak amplitude at this time is 2.5 g in the longitudinal plane and 2 g in the lateral plane.

The same frequency components are present here as in the previous flight. The components at 115 and 230 Hz dominate in the longitudinal-axis vibration. In the lateral plane, vibration components at 115, 230, and 805 Hz dominate.

These results correlate fairly closely in time and frequency with the high-level acoustic measurements which are described in detail in the previous section.

SIGNAL STRENGTH, LINK NO. 5, AA-II-60

Telemetry link no. 5 (227 MHz for the microphone and accelerometer) consisted of a transmitter with a nominal power output of 1 watt and a single quadraloop antenna. The power applied to the antenna in this case fell between the power of previous rocket telemetry links (2.5 watts to 0.5 watt per antenna). Voltage breakdown has always occurred on quadraloop antennae on Black Brant II rockets with 2.5 watts per antenna but never with $\frac{1}{2}$ watt per antenna.

The signal strength record indicates that voltage breakdown occurred on this antenna at altitudes of 147,000 feet to 220,000 feet on the ascending leg of the trajectory, and intermittently from 242,000 feet to 124,000 feet on the descending leg of the trajectory. The region of the upper atmosphere in which voltage breakdown was present was smaller than the average, but within the extremes of previous launchings on which 2.5 watts per antenna had been applied.

During breakdown, the reduction in signal strength was much greater on this firing than on any previous firing. For the greater part of the time when voltage breakdown occurred, the signal fell below the receiver threshold. However, for one brief period there was a measurable signal during breakdown and, in this case, the power at the receiving antenna fell 27 db. The average reduction in signal power on other firings was 12 db. The apparent increase in absorption is believed to be due to the combined effect of absorption in the plasma and transmitter frequency pulling. The change in impedance of the antenna that occurs at the time of a voltage breakdown alters the oscillating frequency of the transmitter. It has been assumed that this change in frequency placed the transmitter frequency outside the nominal passband of the receiver.

INSTRUMENT FRAME, AD-II-52

The support structure for instrumentation in the conical section of vehicle AD-II-52 is shown in Figure 7. This is a departure from the H-structure used previously [12]. The four vertical supports are made from half hard aluminum channel, 1 inch by $\frac{1}{2}$ inch by $\frac{1}{8}$ inch. Cast aluminum brackets are used to support the shelves on the channel legs. The shelves are of sandwich-type construction. The plates are of 65ST-6 aluminum, the top plate 0.102 inch thick, the bottom plate 0.032 inch thick, and they are spaced $\frac{1}{4}$ inch apart. Aluminum spacers are used at the mounting brackets only, with remaining space filled by 3M tape, type 4008, a polyurethane foam material with a pressure sensitive adhesive on both sides. This type of shelf construction is used to absorb and damp out shock and vibration resonances.

Each shelf and its instrumentation may be removed independently for servicing. All interconnecting wiring between shelves is through two wiring harnesses, one for power and relay control and the other for data. At each shelf, all wiring passes through a distribution board, thus providing ready access to all lines for monitoring. The ability to monitor data and supply voltages, etc., at the instrumentation is an advantage during initial checkout of the payload, especially if difficulty is encountered during this checkout. Considerable space is required for these distribution boards and, in practice, they provide more test points than are necessary. In future, these boards will be deleted and only the more significant test points will be

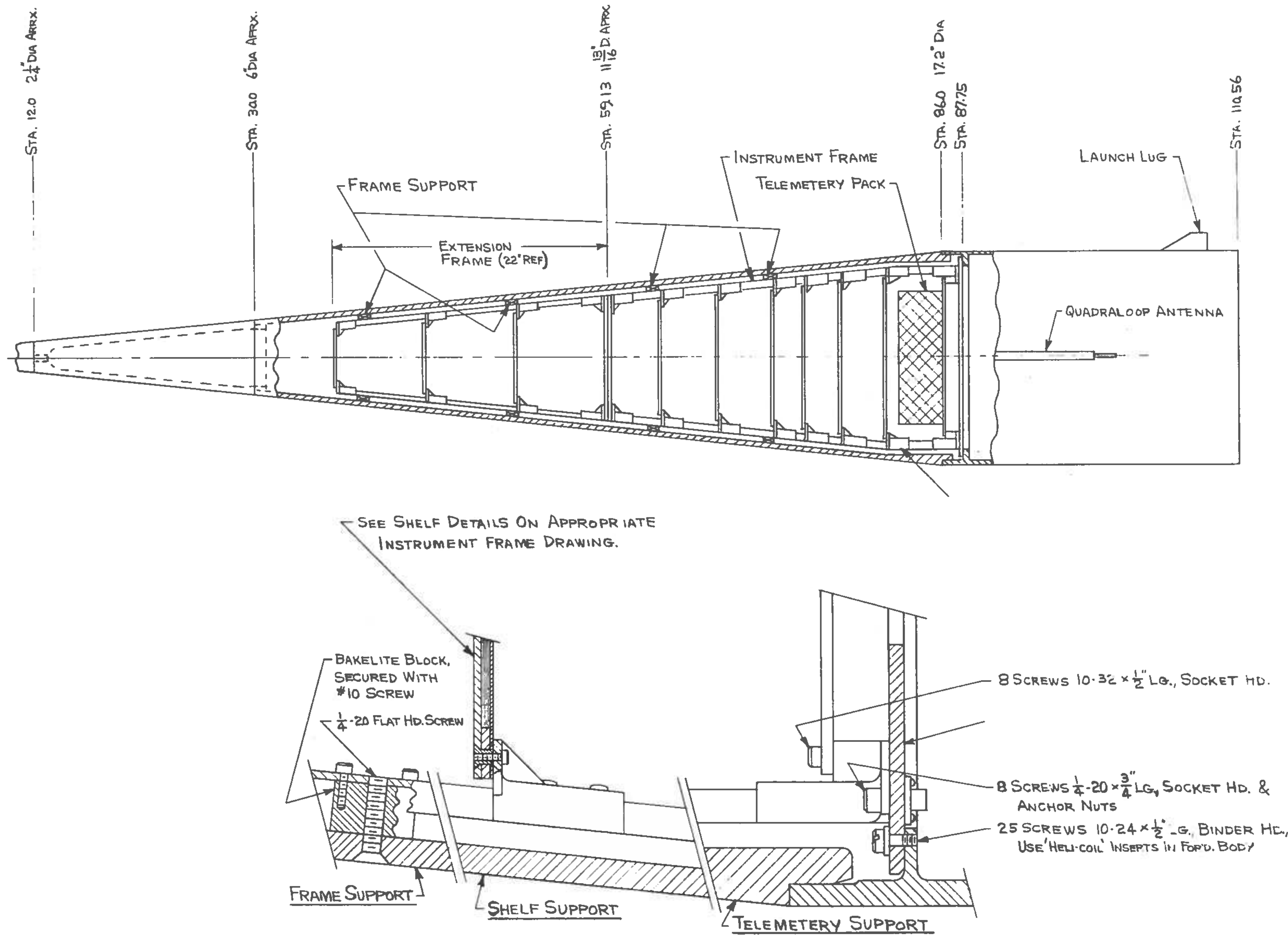

Fig. 7. Instrumentation frame - AD-II-60

accessible without removing connectors. For more detailed checking, a test patch board can be inserted at the connectors.

Although the maximum number of shelves and approximate shelf spacing are fixed in the standard design, there is some flexibility as shelves can be deleted or shifted several inches. This permits advance construction or purchase of the mounting hardware and wiring harnesses before payload composition has been decided. Excess wires have been included in the harnesses to provide adequate flexibility. One possible disadvantage to this standardization is that physical layout of instrumentation on the shelves must be detailed before the wiring interconnections between shelves may be detailed. However, once this planning is complete, construction and wiring may proceed very rapidly since each shelf is an integral unit for construction purposes and several can be fabricated in parallel. With the H-frame, electrical planning is somewhat easier, but mounting of components and interconnecting wiring must be done by the same person.

Vibration testing on a mock-up frame and vibration measurements on flight AD-II-52 showed no severe resonances. During the flight, a vibration transducer mounted in the centre of the shelf at station 75 indicated an amplitude about twice that at the base of the structure. This was a severe test since the shelf had very few other components mounted on it to help dampen vibrations.

EJECTED PACKAGES

Vehicles AA-II-53, AD-II-52, and AA-II-60 all contained instrument packages that were to eject from the rocket above the dense atmosphere. These packages were allocated as follows:

AD-II-52:	2	EFP's
	1	I.I.
	1	Plasma probe sphere
AA-II-53:	1	EFP
	1	I.I.
	1	Plasma probe sphere
AA-II-60:	2	EFP's

Vehicle AD-II-52 was the first vehicle in the series to be launched. The I.I. package and the plasma probe sphere ejected as planned, but neither of the EFP packages ejected.

The indication from the RF monitor is that the packages remained firmly in their cannisters, since motion of less than one-quarter of an inch is sufficient to interrupt this monitor. The I.I. package was mechanically similar to the EFP packages.

Initially, two causes for failure were postulated. Firstly, the lanyard which is firmly attached to the support cannister and hooked over the edge of the ejected package and whose purpose is to induce a tumbling motion to the package was suspected. Although it was difficult to envision the lanyard as the source of trouble, it was decided to remove it since the only previous failure had occurred on a package so equipped. The second possible cause suggested was that the support cannister collapsed, owing to high acceleration during powered flight, and caused the package to jam. This cylindrical support cannister is mounted by a single flange to the rocket skin. Additional support was added, such that the cannister was supported at both ends. This structural support was added to both the EFP and I.I. package in the AA-II-53 and EFP packages in AA-II-60.

During the installation of the EFP packages in rocket AA-II-53, it was found that slight eccentricity in the mounting flange caused the cannister to distort when mounted in the rocket. Although this distortion was not sufficient to cause the package to bind in its cannister, the packages were filed to give a very loose fit in their cannisters.

The above three modifications; i.e., removal of lanyard, increased structural support to cannister mounting, and loose fit between package and cannister were made for flight AA-II-53. Both packages in this vehicle ejected successfully. Since data interpretation is greatly simplified if the EFP packages tumble throughout their flight, it was decided to install the lanyard for the flight in AA-II-60. Successful ejection occurred for both packages in this rocket. The reason for failure of the EFP packages to eject in AD-II-52 is still unknown. In future firings, the cylindrical cannister that contains the ejected package will be supported throughout its length and not at one end only.

The two plasma probe spheres ejected successfully in both AA-II-53 and AD-II-52.

PAYLOAD TEMPERATURE

All vehicles were fired from the enclosed Universal launcher. The auroral rockets remained elevated for several hours in sub-zero weather, before being launched. When elevated, the rocket is enclosed in a Fiberglas shroud through which hot air is pumped. The success of this system is attested to by the fact that the shroud had to be opened on several occasions to lower the payload temperature to about 80°-90° F.

Several temperature measurements were made in these payloads to provide an indication of package environment. These results have been summarized in Table II. All the sensors used were Fenwal K109 thermistors, with the exception of one RdF RN100 sensor used to measure skin temperature at station 57 in vehicle AD-II-52. Sensors which are on metallic surfaces are cemented in place with a conducting cement. In all cases, sensors were shielded from radiation of heat from the rocket skin.

In vehicle AD-II-52, the sensor on the timer circuit board and that on the beacon mounting plate were roughly at the same station: a higher temperature at lift-off of the beacon plate sensor is due to heat generated by the beacon. This same sensor shows a much faster rate of rise early in the flight also because, although the sensor is shielded, the plate had a direct view of the skin.

Apparently a small amount of foam plastic provides a very effective heat shield. The temperature of the tube of the two-channel photometer at station 57 reached only a moderate level although the skin temperature at this station, only a couple of inches away, exceeded 400° F. The loss of temperature data for the later parts of flights AD-II-52 and AA-II-53 resulted from subcommutator malfunction.

BATTERIES

The major portion of payload power was supplied by either silver-zinc cells or sealed nickel-cadmium cells. In a few instances very light loads were supplied by mercury cells or carbon-zinc cells. Batteries using either of the latter cells had adequate capacity for checkout and launch phases and therefore did not require replacement. However, the poor low-temperature characteristics of carbon-zinc cells place an unnecessarily severe temperature limitation on a payload using these cells. The numbers and types of cells used in each rocket are detailed in the engineering work sheets in Appendix I.

All silver-zinc cells used were of the dry-charged type. In addition to requiring minimum effort for preparation, they exhibit only a limited peroxide peak on their first discharge cycle. If necessary, the major portion of rated capacity can

TABLE II

AD-II-52

Time \ Station	75 Shelf V	57 U of S photometer container	91 Timer circuit board	93 Beacon mounting plate	87 Heat sink main trans-mitter	57 Rocket skin
0	66	57°	55°	62°	64°	0
10	66	57°	57	68	64	85°
20	66	57°	62°	81	64	325
30	67	60°	62°	83	65°	380°
60	67	60°	62°	83	66°	405
120	71	63°	66°	85	75°	405
176	76	67°	70°	88	85°	405
240	83	-	-	-	-	-
300	88	-	-	-	-	-
360	96°	-	-	-	-	-

AA-II-53

Time \ Station	99 Battery box	96 EFP-III electronics	59 Top of H-frame
0	72	79	92
10	72	80	94
20	73	81	96
30	74	82	98
60	77	84	105
120	85	86	120°
180	100	92	137
240	110	97	148
300	-	-	160
360	-	-	166

AA-II-60

99 Battery box	59 Top of H-frame
60°	73
60°	75
62°	77
62°	77
63°	78
65°	85
67°	92
68°	99
75°	106
89°	117

be obtained shortly after filling, although a 24-hour soak period is recommended before they are used.

Although provision to charge silver-zinc batteries was made, in practice this was unnecessary. By not charging silver-zinc cells when installed in the payload, the risk of electrolyte leakage due to gassing and subsequent self-discharge is avoided. Nickel-cadmium cells are charged when possible throughout the checkout and countdown to keep these cells near their peak capacity.

No charging line was provided for the beacon batteries in all these payloads nor for the battery for link no. 5 instrumentation in AA-II-60. However, these batteries could be changed easily in the assembled payload.

In payload AE-II-24, the ±14.6-volt silver-zinc supplies had to be balanced within ±.1 volts for optimum performance of the instruments. By careful selection of the cells, this condition was satisfied.

LIFT-OFF INDICATION

Several types of lift-off timing indicator were used for these launchings and their signals compared. These indicators were as follows:

1. Longitudinal vibration transducer
2. Nozzle flash indicator
3. Longitudinal linear accelerometer (potentiometer type)
4. Break-away umbilical connector
5. First motion indication on the IRIG time signal (increased amplitude)

The vibration and flash indications occurred about 150 milliseconds ahead of the remaining indications, and these were grouped in a period of about 40 milliseconds. Since the differences in lift-off timing were consistent among the rockets, it appears that any time measurement is acceptable provided the same method is used for all vehicles.

VI. VEHICLE PERFORMANCE

LINEAR ACCELEROMETERS

Each vehicle was instrumented with three mutually perpendicular linear accelerometers. There was a +20 g, -3 g accelerometer mounted on the longitudinal axis and two ±5 g accelerometers were mounted in the lateral plane. Accelerometer data indicate a normal flight for all vehicles although AE-II-24 seems to have had a shorter burning motor than the others. The thrust-axis accelerometer outputs were typical for these vehicles and peak accelerations are summarized in Table III. The lateral accelerometers on vehicles AD-II-52, AA-II-53, and AA-II-60 show low-amplitude oscillation, typically less than 0.4 g at a rate of about 2 per second during the later stage of motor burning.

TABLE III

Maximum thrust acceleration

Vehicle	Maximum acceleration	Time of occurrence
AD-II-52	18.2 g	14.1 sec
AA-II-53	18.2 g	13.7 sec
AA-II-60	16.3 g	13.5 sec
AE-II-24	17.7 g	12.5 sec

TRAJECTORIES

The principal source of trajectory information was an MPS19 radar used in conjunction with a DPN41 beacon in the rocket. Secondary sources included a second MPS19 radar skin tracking the vehicles and telemetered data of altitude switch closures. Good trajectory data were obtained on all four tests. Beacon performance was satisfactory. The radar on skin track was less successful, typically obtaining a valid track for only a small portion of the flight, except in the case of AA-II-60 where valid track from shortly after lift-off to impact was obtained. Once the radar on skin track lost the target, it was switched to a passive mode and slaved to the radar on beacon track. Radar performance is summarized in Table I.

Trajectory information, as received from CRR, consists of analog output from plotting boards. The trajectory plots presented in Figures 8, 9, 10, and 11 are a best fit ballistic trajectory computed from data taken from the plotting boards.

The altitude switches were mounted in the cylindrical foward body section of the nose cone. The 50-kft switches and one of the 70-kft switches in AD-II-52 relied on incidental venting of this forward body section to equalize pressure inside and outside. The remaining 70-kft switches were vented by a small tube directly to the outside surface of the nose cone. Corrected times of flight above the reference altitude were computed by the method outlined by Steele [13]. Corrected time of flight for the vented 70-kft switches includes a correction for the difference in pressure at the switch and the free stream pressure. An analysis by R.F. Meyer, High Speed Aerodynamics Section, NAE, NRC, indicates that the pressure at the switch will be low, resulting in an error of approximately one second, both on the up-leg and on the down-leg of the trajectory. A value of g of 30.56 ft/sec^2 was used to calculate rocket apogee. This value was obtained by averaging the equivalent g for the free fall of seven Black Brant II rockets from apogee to 60,000-ft altitudes using radar data.

The forward section of the cone from station 30 of vehicle AD-II-52 was removed on the up-leg of the trajectory at about 175 kft. Radar indication is that this vehicle broke up at about 70 kft on re-entry. The altitude switches on this vehicle closed early when compared to radar trajectory. This premature closure likely resulted from a ram pressure through the hole left by the ejected tip section.

Altitude switches in AD-II-52 apparently operated about 40,000 ft above normal set point. No accelerometer data are available during this period, but acceleration induced operation is not likely since it does not explain the early operation of the 70-kft switches.

The differential on the 50-kft switches is 3,500 ft maximum, or 24 mm Hg (0.47 psi) and on the 70-kft switches is 5,000 ft or 13 mm Hg (0.25 psi). For the 70-kft switches to operate at 125,000 ft, the ram pressure must have been about 20 mm Hg or 0.4 psi and for the 50-kft switches to operate at 110,000 ft, a ram pressure of 70 mm or 1.35 psi varying $\pm$0.23 psi for a few seconds must have occurred.

The altitude at which turnover takes place, as indicated

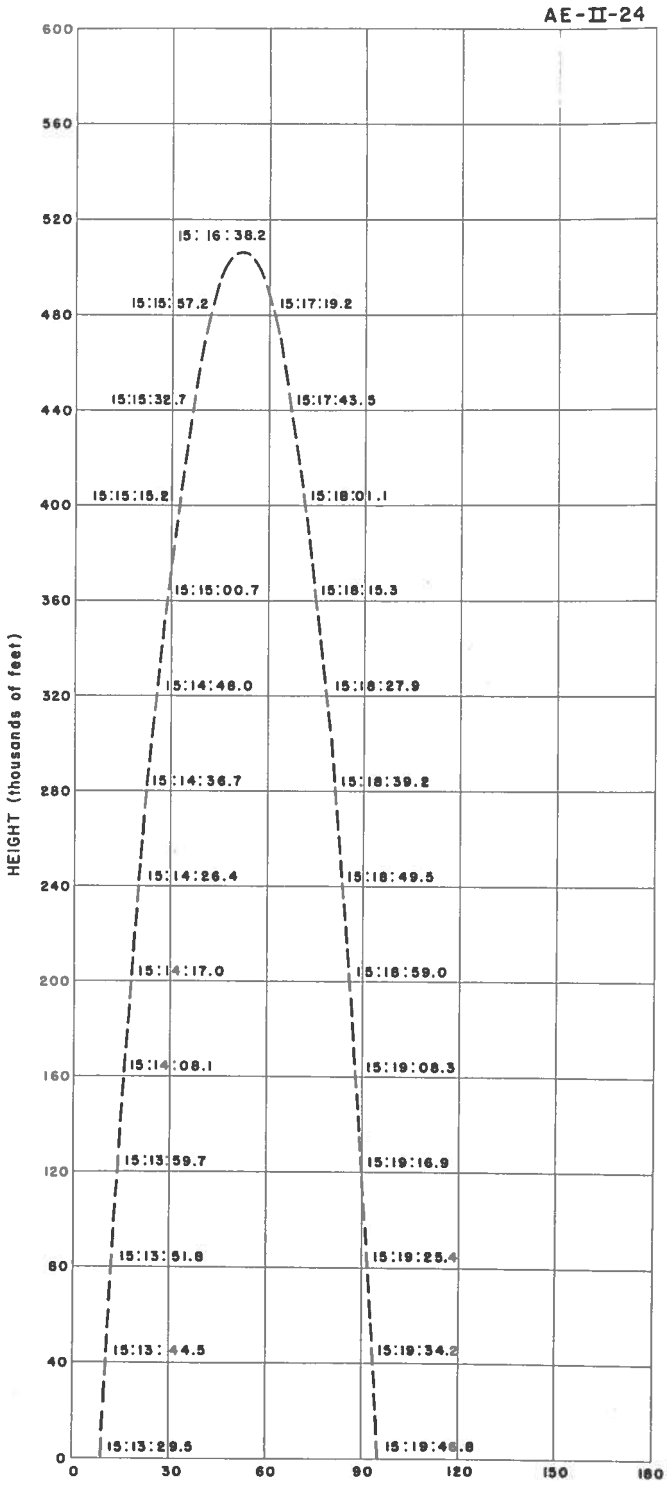

Fig. 8. Trajectory of AE-II-24

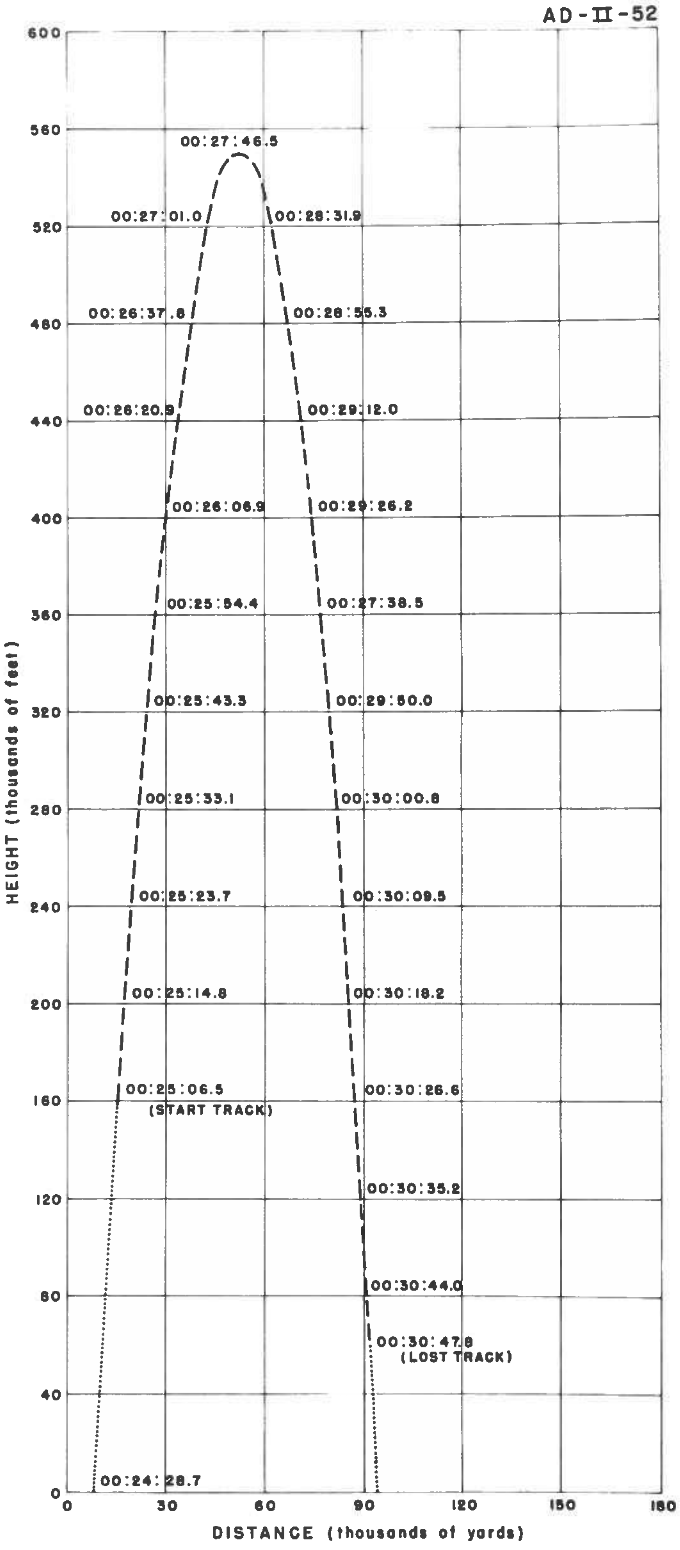

Fig. 9. Trajectory of AD-II-52

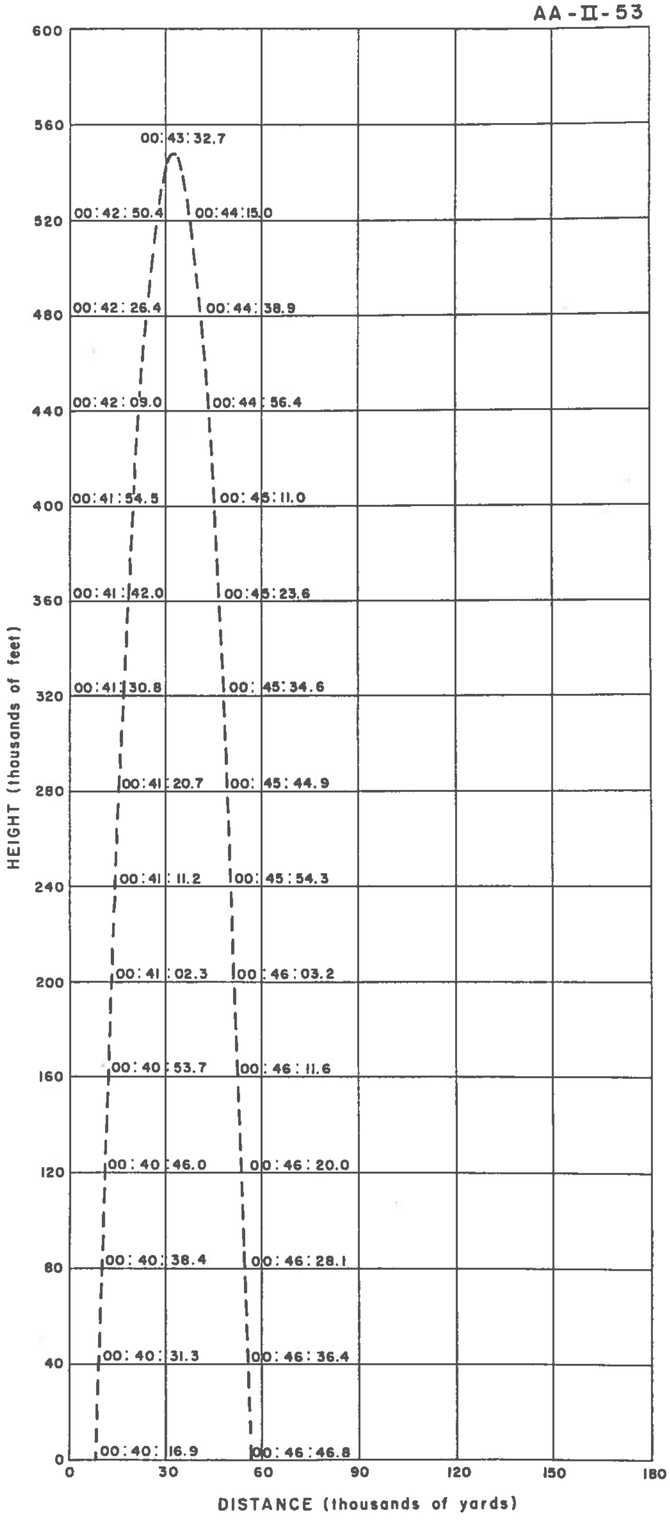

Fig. 10. Trajectory of AA-II-53

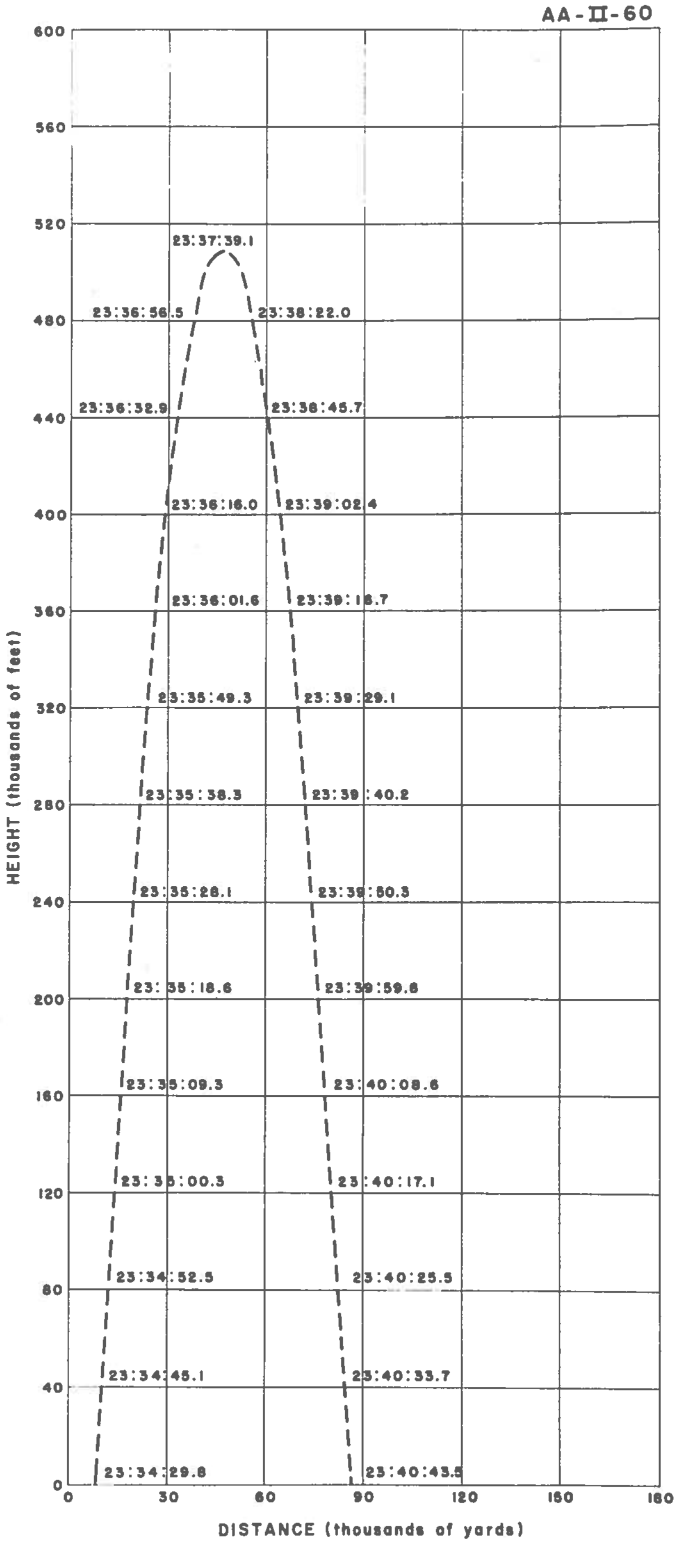

Fig. 11. Trajectory of AA-II-60

by the magnetometers, is similar for all four rockets. These heights were 210 kft for AD-II-52, 207 kft for AA-II-53, 215 kft for AA-II-60, and 205 kft for AE-II-24.

SUMMARY OF ROCKET APOGEES (kft)

	AD-II-52	AA-II-53	AA-II-60	AE-II-24
Radar	551	546	508	506
70-kft vented switch	513	540	491.5	-
70-kft unvented switch	523	-	-	-
50-kft unvented switch	525	546	498	-

ATTITUDE HISTORIES

Attitude of Rocket AD-II-52

The attitude history of rocket AD-II-52 has been determined from telemetry and signal strength records and is shown in Figure 12. The roll rate, roll direction, cone angle, and precession rate have been calculated using data from two rocket-borne magnetometers. These instruments were mounted on mutually perpendicular axes at right angles to the longitudinal axis of the rocket.

Data from one of the experiments, a planar trap plasma probe, showed roll-periodic fluctuations. These were surmised to occur when the probe crossed the wake of the rocket. From the time relation of these data to the magnetometer record, and with calculated velocity vectors, an approximate time-attitude plot was established within the limits imposed by the low sampling rate of the planar trap data.

A photometer mounted on board indicates several sources of light. A light source, consistent with the position of the moon, was detected and the rocket motion was calculated assuming that this source was the moon.

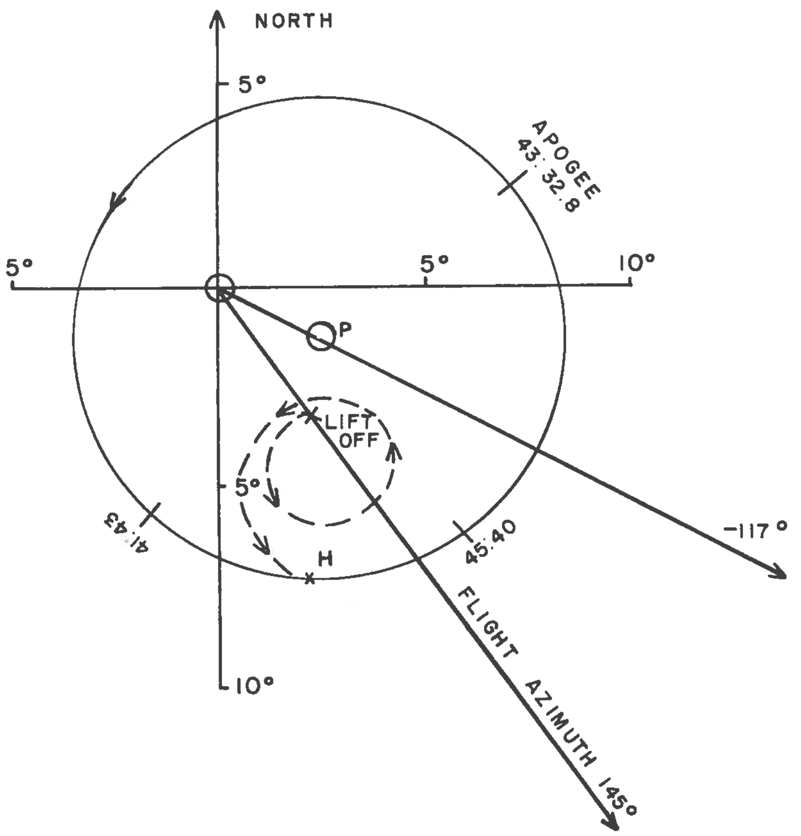

Fig. 12. Attitude history of AD-II-52

Signal strength records from the main telemetry provided reasonable correlation for the calculated motion. Ballistic considerations were also consistent with this motion.

For the period between 06:26:20 (T + 111) and 06:29:42 (T + 313) approximately, the rocket angular motion was a regular coning with the following constants:

Roll period	1.256 sec
Roll direction	Clockwise looking forward
Coning period	105 sec
Coning ($\frac{1}{2}$) angle	11.2°
Angle of precession cone to Earth's magnetic field	12°

Azimuth of angular momentum vector	264°
Angle of angular momentum vector to the zenith	11°

The following relation may be used to calculate times at which the forward launch lug was oriented in a northerly direction:

$$06:25:39.25 + n(1.2553) \quad (UT)$$

rounded off to the nearest $\frac{1}{10}$ sec. This is valid for n up to 192 within a probable error of $\pm\frac{1}{10}$ sec.

For the period between 06:25:40 (T + 71) and 06:26:20 (T + 111) approximately, the departure of the vehicle from a regular coning motion was not enough to affect the equation.

Attitude of Rocket AA-II-53

The attitude history of rocket AA-II-53 is shown in Figure 13. The roll rate, roll direction, cone angle, and

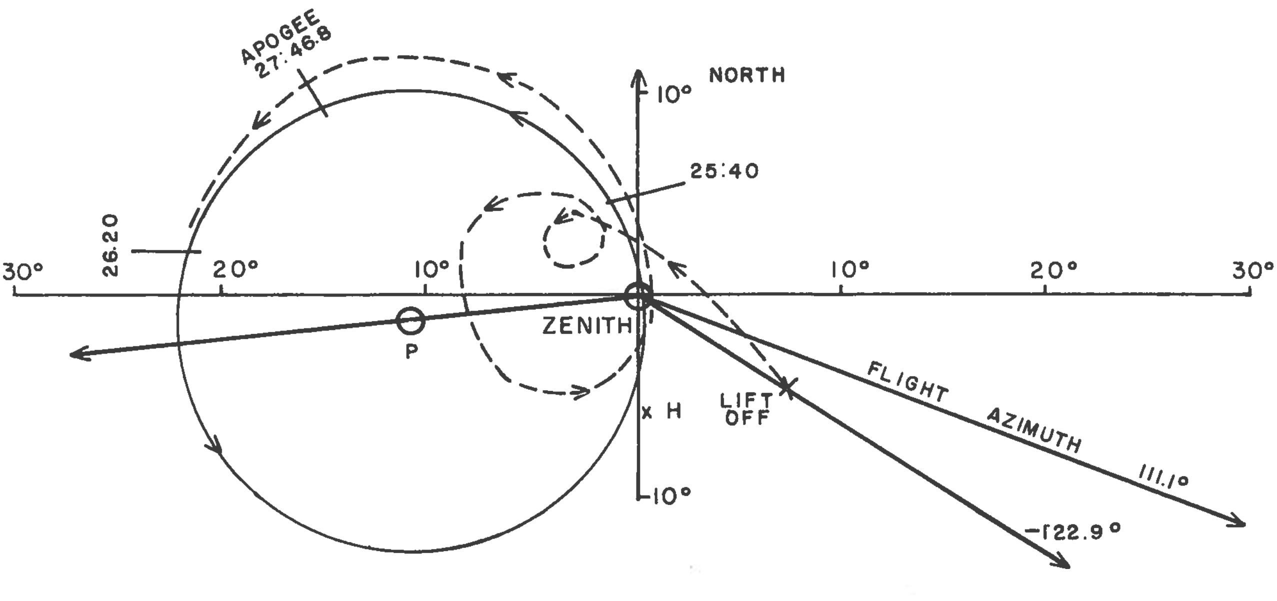

Fig. 13. Attitude history of AA-II-53

precession rate have been calculated using data from two rocket-borne magnetometers. These instruments were mounted on mutually perpendicular axes at right angles to the longitudinal axis of the rocket.

One of the experiments, a planar plasma trap, showed roll-periodic fluctuations. These were surmised to occur when the trap crossed the wake of the rocket. From the time relation of these data to the magnetometer record, and with the calculated velocity vectors, a best fit motion was established.

For the period between 41:43 (T + 86) sec and 45:40 (T + 323) sec approximately, the rocket angular motion was a regular coning with the following constants:

Roll period	0.8060
Roll direction	Clockwise looking forward
Coning period	75 sec
Coning ($\frac{1}{2}$) angle	6°
Angle of precession cone to Earth's magnetic field	6°
Azimuth of angular momentum vector	117°
Angle of angular momentum vector to the zenith	3°

Signal strength records from the main telemetry transmitter correlated with the calculated motion. Since a uniformly strong radar signal was received, AGC records were of no value. NRC photometer data were not useful since the moon was probably below the horizon even at an altitude of 100 miles.

The following relation may be used to calculate times at which the forward launch lug was oriented in a northerly direction:

$$06{:}41{:}42.90 + n(0.8060) \quad (UT)$$

rounded off to the nearest $\frac{1}{10}$ sec. This is valid for n up to 300 within a probable error of $\pm\frac{1}{10}$ sec.

Attitude of Rocket AA-II-60

The attitude time-history of rocket AA-II-60 has been determined using primarily data from two rocket-borne magnetometers and the signal strength record of a ground-based telemetry receiver. The results are depicted in Figure 14.

Roll rate, roll direction, coning rate, and coning angle with respect to the earth's magnetic field were obtained from analysis of the payload magnetometer records. One magnetometer was mounted near the longitudinal axis of the rocket, and the other about two inches radially from it. Both magnetometers were oriented normal to the rocket longitudinal axis and to each other. Small differences were observed in the duration of successive half periods (e.g., periods between zero crossings) of the magnetometer signal records. This was considered to be due to a displacement of the actual spin axis from the longitudinal axis of the rocket at the location of the magnetometers, station 55. This displacement was calculated to be approximately 4 inches.

One of the rocket telemetry transmitters, the 227.0 MHz link, used a single quadraloop antenna mounted on the surface of the nose cone. Fairly well defined nulls appear on the received signal strength (AGC) record made at the launch site telemetry station. These were assumed to occur at times when the antenna on the rocket was opposite the side directed toward the receiver site. However, the calculated aspect history fitted the data best if it was assumed that the null in the signal which was radiated from the rocket occurred at 160° (clockwise viewed forward) relative to the antenna instead of at 180°. This assumption is plausible in view of the asymmetrical nature of the received signal strength record about the nulls. The aspect of the rocket from the receiver site during the period of interest was within 30° of viewing directly at the tail.

The time relation between the nulls of the telemetry signal strength record and the magnetometer records was used to determine the position of the precession cone. The position of the rocket relative to the receiving site was obtained from radar tracking data. In determining the aspect history, some emphasis was placed on the fact that during one period of the flight the roll dependent variations in the received telemetry signal strength largely disappeared. It was concluded that this would not likely occur except when the rocket longitudinal axis coincided with the direction from the receiver site to the rocket, thus providing an unambiguous attitude for the rocket at one period of the flight.

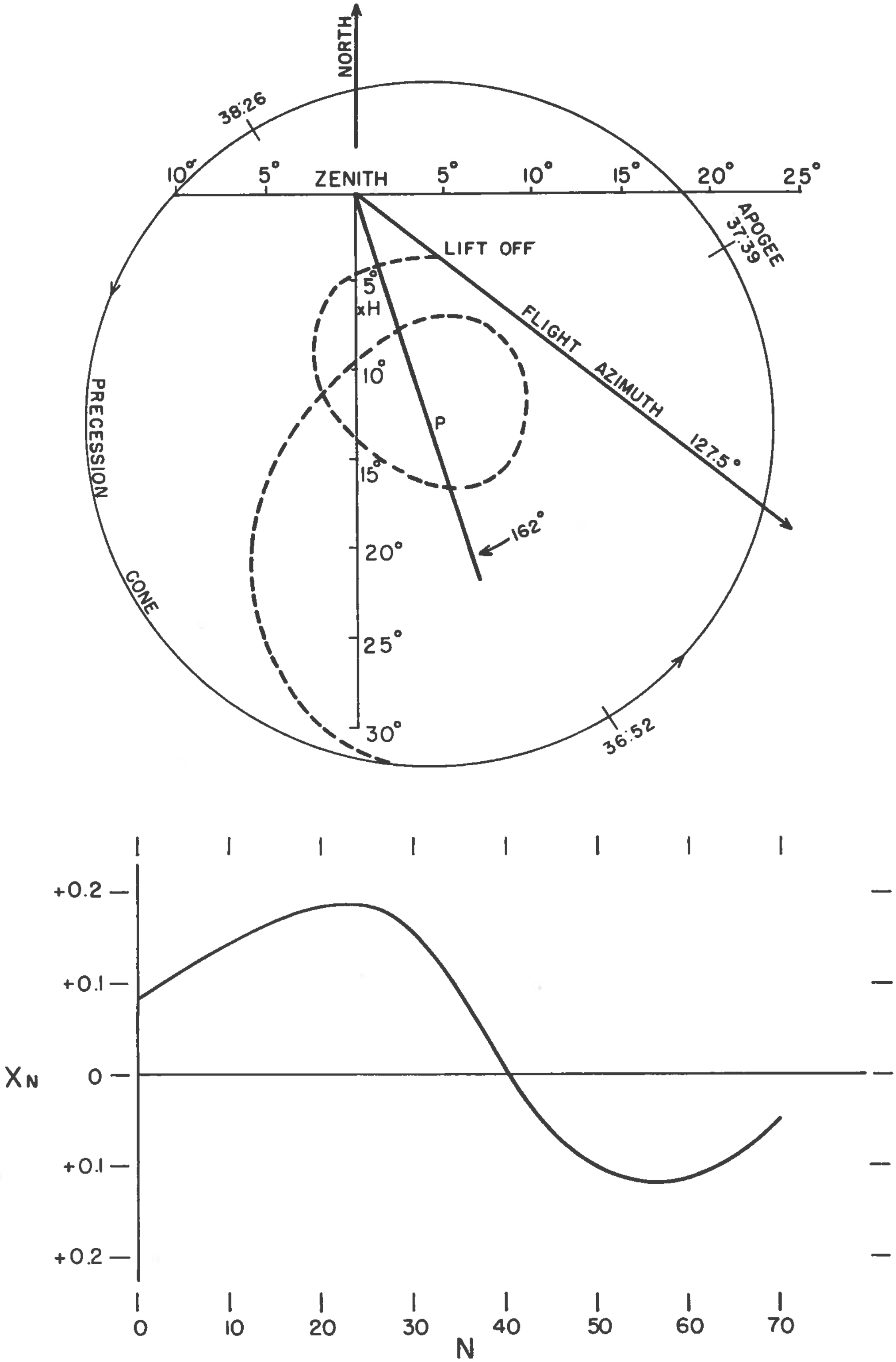

Fig. 14. Attitude history of AA-II-60

For the period between T + 142 sec and T + 285 sec, approximately, the rocket angular motion followed a regular coning motion whose constants were found to be:

Roll period	2.082 sec
Roll direction	Clockwise, looking forward
Coning period	188 sec
Coning ($\frac{1}{2}$) angle	19.3°
Angle of precession cone to Earth's magnetic field	7.5°
Zenith distance of precession cone	13.7°
Azimuth of precession cone (angular momentum vector)	162° (from North)

A check on the calculated attitude time history was made by plotting the directions of nulls in the received radar signal at the DPN-41 radar beacon carried in the nose cone. Nulls were assumed to occur at 90° to the location of the pair of quadraloop beacon antennas on the surface of the nose cone. Agreement at several positions of the rocket was good even though the location of a null could not be made very precisely. (The beacon receiver nulls were not as distinct as the 227.0 MHz telemetry AGC nulls partly because the former were commutated data.)

The location of nulls in the planar trap plasma probe signal were also used as a check on the attitude history. These nulls are assumed to occur when the probe is in the wake of the rocket during a roll period. Good correlation of the wake directions taken from velocities derived from the tracking radar data was obtained for the determined attitude history.

Nulls in the received signal strength records of the ground-based receivers tuned to the other two rocket-borne telemetry links were not used in the analysis as they were fairly broad and indistinct. One null per roll cycle was predominant indicating that there may have been an asymmetry in the radiation patterns of the quadraloop antennas. The power division may also have been unequal.

The rocket payload included a photometer, but this was not useful for an attitude reference as the moon was below the horizon during the flight.

The following relation may be used to obtain times at which the forward launch lug was oriented in a northerly direction:

$$23{:}36{:}51.93 + n(2.0617) + X_n$$

rounded off to the nearest $\frac{1}{10}$ sec. This is valid for n up to 70, to within a probable error of $\pm 30°$. The correction X_n is plotted in Figure 14 and is made because the cone of precession places the rocket axis fairly close to the polar direction during part of the flight.

VII. GROUND INSTRUMENTATION

PRE-DETECTION RECORDING

Pre-detection recording was used on the signal from the EFP packages and the ejected sphere plasma probe. This is the same system as that used previously [14], except that both first and second local oscillators in the ground-based receivers were crystal stabilized to improve their short term stability. This modification was required for the EFP-1B which used the receiver local oscillators as the reference signal. Rapid frequency variations of the reference oscillator could not be differentiated from changes in frequency of the transmitted signal caused by variations in the field characteristics.

GROUND TELEMETRY SYSTEM FOR SPHERICAL PLASMA PROBE

The plasma probe telemetry was designed to use two separate ground receiving systems. The primary system used pre-detection recording and a phase-lock tracking filter as a phase demodulator. The backup system used direct FM detection and post-detection recording.

The favorable orientation of the probes in both vehicles 52 and 53 resulted in high signal strength levels with no deep nulls occurring until late in the trajectory. Since signal levels were high, the phase detection system was not required, and the backup system provided high quality records.

Some measurements were made using the pre-detection recorded signal to verify the performance of the phase-lock tracking filter. Flutter on the recorded signal was considerably higher than expected, resulting in an over-all signal-to-noise ratio which was unacceptably poor. However, good results were obtained by replacing the phase detector with an FM tunable discriminator. It is suggested that the same system be used in future firings, but that pre-detection recordings be made at both main telemetry and Twin Lakes to try to reduce the recorded flutter. In the event that flutter is still high, the tunable discriminator can be used as an alternative detection system.

VIII. CONCLUDING DISCUSSION

The 4-fin stabilizers made by Canadair appear to control the rocket flight within predictions but with some uncertainty of spin rate. Referred to a nominal rate of 0.45 rps the observed rate was 75% high on AD-II-52 and 170% high on AA-II-53. Predicted rates on AA-II-60 and AE-II-24 were realized. Some experiments require rocket spin for angular scanning. Spin rate then must be high enough to provide adequate coverage but below a limit set by the data rate of the telemetry channel. A slightly different technique of alignment was used for AD-II-52 and AA-II-53 than for AE-II-24 and AA-II-60. Although slightly more elaborate, the alignment technique used for AE-II-24 and AA-II-60 is justified for payloads that require angular scanning.

The heavier payloads (over 300 lb) with a 9-inch extension section in the forward body did not appear to affect the rocket performance other than for the expected reduction in apogee.

The new instrument frame tried in the AD-II-52 payload is an improvement over the H-frame design. Future Black Brant II payloads will use this type of instrument frame.

A relatively elaborate pre-launch vacuum system was operated continuously during transfer to the launcher and on the launcher until immediately before lift-off, under severe winter conditions for rocket AE-II-24. The success of this operation indicates the flexibility of the CRR launch facility and its ability to handle unusual payloads.

A summary of the results of vehicle and payload performance is given in Table IV. Before the success of an experiment can be determined, considerable analysis by the scientist concerned is required. However, it is relatively easy to pick out the obvious failures due to equipment malfunction. Normal operation as indicated in Table IV then means that the

TABLE IV

Black Brant vehicle performance

ITEM	AE-II-24	AD-II-52	AA-II-53	AA-II-60
OR No./Test No.	119/5	152/5R137	154/5R143	151/5R
Time of launch (CST)	15:13:29.5 17 March 1965	00:24:28.6 19 March 1965	00:40:16.9 24 March 1965	23:34:29.7 24 March 1965
Time to impact (sec)	377.3	395	390	375
Time to Apogee (sec)	188	198.5	197	186
Apogee (kft)	506 (154.5 km)	551 (168 km)	546 (166.5 km)	508 (155 km)
Roll rate (rps)	3.16	0.79	1.22	0.48
Cone $\frac{1}{2}$-angle	4.5°	11.2°	6.0°	19.3°
Cone period (sec)	30	105	75	188
Angular momentum vector (a) azimuth (b) zenith distance	 56° 8°	 264° 11°	 117° 3°	 162° 14°
Payload weight (lb)	315	260	285	332
Vehicle performance	Excellent	Excellent	Excellent	Excellent
Tracking (a) Beacon(sec) (b) Skin(sec)	T + 15 to impact T + 7 to T + 119	T + 41 to T + 380 T + 37 to T + 71	T - 0 to impact T + 369 to impact	T - 0 to impact T + 6 to impact
Rocket telemetry	Normal	Normal	Normal	Normal
TLM subcommutator	Normal	Normal to T + 176	Normal to T + 259, then alternate samples	Normal
Signal transfer	Normal	Normal	Normal	Normal
Package ejection	Normal	2 EFP's failed to eject	Normal	Normal
U of T pressure gauges	4 out of 5	-	-	-
Ionospheric inhomogeneities	-	Normal	Normal	-

Black Brant vehicle performance (cont'd)

ITEM	AE-II-24	AD-II-52	AA-II-53	AA-II-60
Magnetometers	Both normal	Normal	Normal	Normal
Vibration - obs. on Z-axis accelerometer (sec)	T + 8.6 to burnout	T + 12 to T + 15	T + 13 to T + 15	T + 11 to T + 14
Altitude switch	-	Normal	Normal	Normal
Accelerometers	Normal	Normal	2 - Normal 1 - 10% zero drift	Normal
Plasma probes	-	Normal	Normal	4 out of 5
NRC photometer	-	Normal	Normal	Normal to T + 59
Cosmic ray detectors	-	-	-	Normal
Neutron detector	-	-	Normal	Normal
X-ray detectors	-	-	Normal to T + 240 Scaler - dc output change during high count	Normal
U of S photometer	-	Voltage Regulator failed in photometer at T + 88	-	-
Electric field probe I	-	RF mon. indicated normal operation in rocket	Normal	Normal
Electric field probe III	-	-	Normal	-
Solar aspect sensor	Normal	-	-	-
Acoustic detector	-	-	-	Some dropouts drifting transmitter frequency
Auroral scanner	-	-	-	Normal

the instrumentation performed as expected, providing data suitable for analysis. This series of firings attained a satisfying degree of success.

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APPENDIX I

ENGINEERING WORK SHEETS FOR ROCKETS

AE-II-24, AD-II-52, AA-II-53 and AA-II-60

ENG. WORK SHEET: GENERAL REQUIREMENTS			ROCKET: AE II - 24
STATUS: FINAL	PREP. DATE:	ISSUE No:	FIR. DATE: MARCH 65

TRIAL COORDINATOR: A. STANIFORTH	PROJECT SCIENTIST: R. N. GRENDA
ROCKET CONFIGURATION: 15 KS 25,000 MOTOR STD. BB II NOSE CONE BB II CANADAIR FINS (4) 3.0 R.P.S. ROLL RATE	LAUNCH CONDITIONS: DAYLIGHT - BETWEEN SUNRISE & SUNSET ELEV: 85° AX: N/R RECOVERY: N/R
PRIMARY EXPERIMENTS: PRESSURE & TEMPERATURE OF UPPER ATMOSPHERE	ROCKET EVENTS: TIME: T/M LINK TLM MULTIPLEX, T+60 SEC. TIP EJECTION, T+60 SEC.

FREQUENCY UTILIZATION	LINK No.	TX.	POWER	FREQ.	MOD.	ANT.	POL.
NOSE CONE T/M	1	TDI	5 W	219.5 MHZ	FM/FM	3 BLADE	R.H.CIR.
BEACON	—	DPN-41	100 W	2900 MHZ	PULSE	QUAD.	LIN.

ENG. WORK SHEET: TELEMETRY		ROCKET: AE II - 24	
STATUS: FINAL	PREP. DATE:	ISSUE NO:	FIR. DATE: MARCH 65

EXPERIMENT:	SUB-CAR. CHANNEL
TIP EJECTION	400 Hz
TIP EJECTION	560 Hz
TIP EJECTION	730 Hz
N I A	960 Hz
	1.3 kHz
	1.7 kHz
HP1 DC AMP. OUTPUT	3.9 kHz
CCG1	BW 59
HP2 DC AMP. OUTPUT	5.4 kHz
CCG2	BW 81
MP1 DC AMP. OUTPUT	7.35 kHz
CCG3	BW 110
MP2 DC AMP. OUTPUT	10.5 kHz
CCG4	BW 160
CCG5	14.5 kHz BW 220
CCG4	22 kHz BW 330
SUN SENSOR/MAGNET. Z1	30 kHz BW 450
SUN SENSOR/MAGNET Z2	40 kHz BW 600
Z AXIS LINEAR ACC $^{+20}_{-3}$ G	52.5 kHz BW 790
COMMUTATOR	70 kHz BW 1050

EXPERIMENT:		COMMUTATOR CHANNEL
CALIBRATE T/M GND.		1
CALIBRATE T/M +5V		2
X-AXIS LINEAR ACC.	CCG2 AC AMP. OUTPUT	3
Y-AXIS LINEAR ACC.	CCG5 AC AMP. OUTPUT	4
HP2 DC AMP. RANGE		5
HP1 DC AMP. RANGE		6
THERMISTOR NOSE CONE #1		7
CCG4 DC AMP. RANGE		8
CCG5 DC AMP. RANGE		9
CCG1 DC AMP. RANGE		10
CCG2 DC AMP. RANGE		11
CCG3 DC AMP. RANGE		12
CCG2 AC AMP. OUTPUT		13
CCG5 AC AMP. OUTPUT		14
THERMISTOR NOSE CONE #2		15
THERMISTOR CCG1		16
THERMISTOR CCG2		17
THERMISTOR CCG3		18
THERMISTOR CCG4		19
THERMISTOR CCG5		20
SUBCOMM. MARK		21
CCG2 AC AMP. RANGE		22
CCG2 AC AMP. OUTPUT		23
CCG5 AC AMP. OUTPUT		24
CCG5 AC AMP. RANGE		25
SUBCOMMUTATOR		26
TIMER FIRING INDICATION		27
THERMISTOR TIP SECTION		28
MASTER		29
MASTER		30

ENG.WORK SHEET: GENERAL REQUIREMENTS		ROCKET: AD-II-52	
STATUS:	PREP.DATE: 1/4/64	EXP.DATE:	FIR.DATE: MAR '65

TRIAL COORDINATOR:

A. STANIFORTH

PROJECT SCIENTIST:

D. W. JOHNSON

ROCKET CONFIGURATION:

15KS 25000 MOTOR

STD. BB II NOSE CONE

BB II CANADAIR FINS (4)

0.4 RPS ROLL RATE

LAUNCH CONDITIONS:

SOLUNAR DARKNESS

AURORA VISUAL INT 1 to 3
RADAR 10 db.

ELEV: 85° AZ. N/R RECOVERY N/R

PRIMARY EXPERIMENTS:

EFP-1A	U of S
TWO CHANNEL PHOTOMETER	U of S
PLASMA PROBE	NRC
EJECTED PROBE SPHERE	NRC
IONOSPHERIC INHOMOGENEITIES	U of WO
MICROMETEORITE	NRC

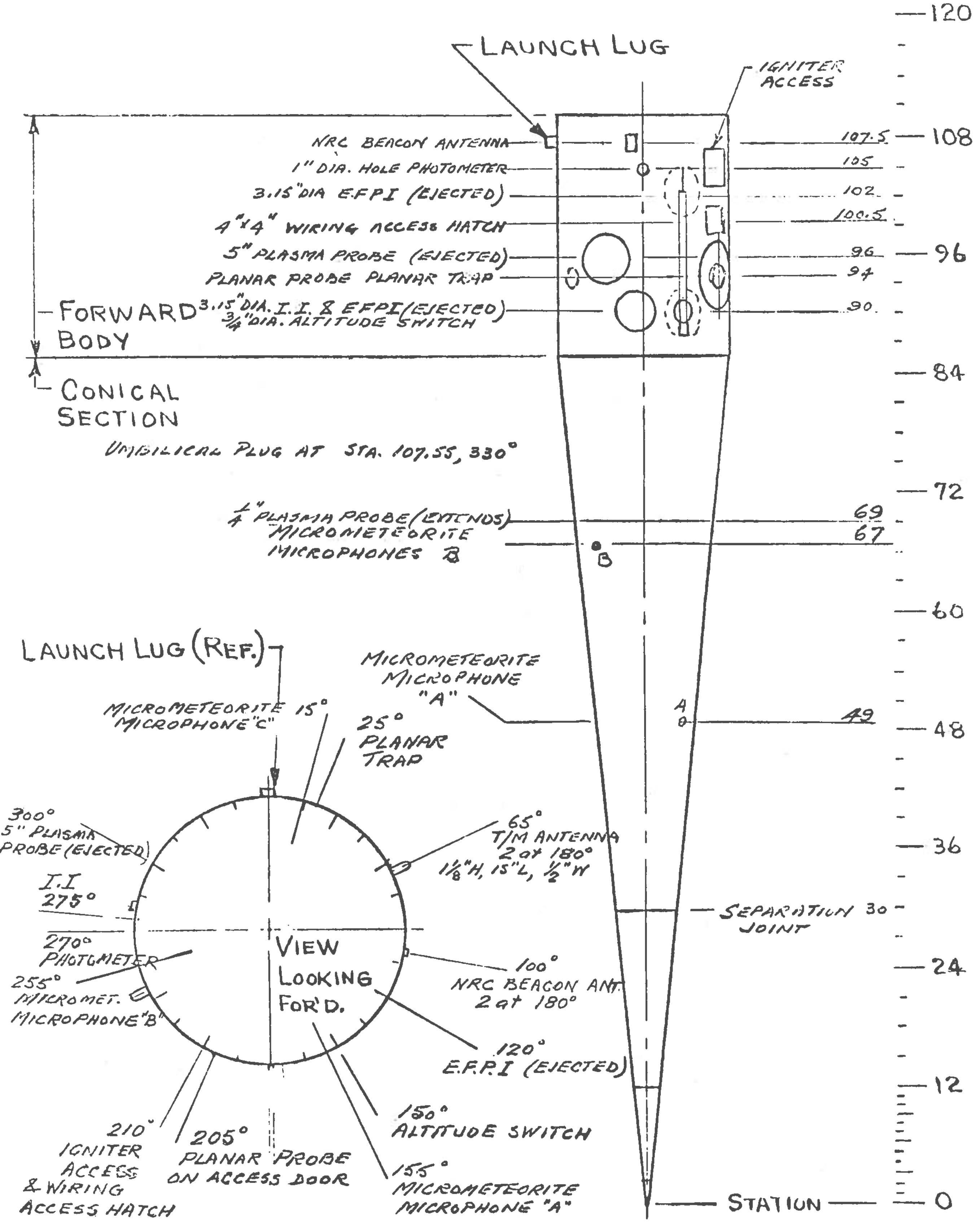
ROCKET EVENTS:

	TIME	T/M LINK
T/M MULTIPLEX	T+30	#1
TIP EJECTION	T+45	#1
1/4"Ø PROBE EXT.	T+45	#1
I.I. EJECTION	T+45	#5
EFP - EJECTION	T+60	#3
EFP - EJECTION	T+60	#4
PROBE SPHERE EJECTION	T+60	#2

FREQUENCY UTILIZATION:

	LINK NO.	Tx.	POWER	FREQ.	MOD.	ANT.	POL.
NOSE CONE T/M	1	CBA	1W	219.5	FM/FM	QUAD	LIN.
BEACON	-	DPN-41	100 W	2900	PULSE	QUAD	LIN.
EFP-1B	3	U of S	50 MW	229	FM	FLEX TAPE	LIN.
EFP-1A	4	U of S	50 MW	231.4	AM	FLEX TAPE	LIN
PLASMA PROBE SPHERE	2	NRC	50 MW	227	FM	SPRING ROD	LIN
I.I.	5	U of WO	250 MW	108 MC	CW	FLEX TAPE	LIN

ENG. WORK SHEET:	Nose Cone		ROCKET: AD-II-52
STATUS.	PREP. DATE: 29/10/64	ISSUE NO	FIR. DATE: MAR 65



ENG. WORK SHEET: TELEMETRY	ROCKET: AD II - 52
STATUS: / PREP. DATE: / ISSUE No:	FIR. DATE: MAR 65

EXPERIMENT:	SUB-CAR. CHANNEL
EFP-IA (231.4) mc EJECTION	400 Hz
EFP-IB (229.0) mc EJECTION	560 Hz
IONOSPHERIC INHOMOGENEITIES EJECTION	730 Hz
5" PROBE EJECTION	960 Hz
NOSE CONE TIP EJECTION	1.3 kHz
70 KFT. ALT. SWITCH VENTED	1.7 kHz
MICROMETEORITE	3.9 kHz BW 59
MAGNETOMETER 180° L.L.	5.4 kHz BW 81
Z-AXIS LINEAR ACC. $\pm{}^{20}_{3}$ G / U OF S PHOTOMETER REFERENCE	7.35 kHz BW 110
± 5G LINEAR ACC 0° / U OF S PHOTOMETER EMISSION	10.5 kHz BW 160
± 5G LINEAR ACC. 90° C.W. L.F. / PLASMA PROBE SWEEP	14.5 kHz BW 220
VIBRATION FWD. BODY / PHOTOMETER NRC	22 kHz BW 330
PLANAR TRAP	30 kHz BW 450
Z-AXIS VIBRATION STA. 87.75 / D.C. SIGNAL P.P. SWEPT ELECTROMETER	40 kHz BW 600
Z-AXIS VIBRATION SHELF V / PLASMA PROBE SWEPT ELECTROMETER AC	52.5 kHz BW 790
COMMUTATOR 10×30	70 kHz BW 1050

EXPERIMENT:	COMMUTATOR CHANNEL
0V	1
5V	2
MAGNETOMETER 270° L.L. C.W. L.F.	3
PLASMA PROBE AUX. SWEPT ELECTROMETER	4
PLASMA PROBE AUX. SWEEP	5
SQUIB +12V MON.	6
T/M +30V	7
U OF S PHOTOMETER EMISSION	8
U OF S PHOTOMETER CAL. LAMP	9
U OF S PHOTOMETER H.V. MON.	10
LINEAR ACC. $\pm{}^{20}_{3}$ G Z-AXIS	11
MICROMETEORITE #2	12
REGULATOR +12V	13
BEACON -6.5V MON.	14
BEACON MOD. MON.	15
BEACON Rx. MON.	16
BEACON RF. MON.	17
MAGNETOMETER 270° L.L. C.W. L.F.	18
PLASMA PROBE AUX. SWEPT ELECTROMETER	19
5" SPHERE RF MON.	20
45" SQUIB MON.	21
60" SQUIB MON.	22
NRC PHOTOMETER PWR. MON. / 70 KFT UNVENTED ALT. SW.	23
EFP-IA 231.4 RF MON.	24
EFP-IB 229.0 RF MON.	25
SUBCOMMUTATOR	26
MICROMETEORITE #2	27
SUBCOMMUTATOR	28
MASTER	29
MASTER	30

ENG. WORK SHEET:	SUBCOMMUTATOR	ROCKET:	AD-II-52
STATUS:	PREP. DATE:	EXP. DATE:	FIR. DATE: MAR '65

INPUT	DC 25 PIN	SEQUENCE	INPUT	DC 25 PIN	SEQUENCE
GND	1	1	PLASMA PROBE β_1/β_2	11	11
T/M +5V	2	2	PLASMA PROBE β_3	12	12
LATCH IND	3	3	PLASMA PROBE β_4	13	13
-6V UV PHOTOMETER	4	4	PLASMA PROBE β_5	14	14
+26.4V COMMUTATOR	5	5	TEMPERATURE SHELF V 160°F K109	15	15
+30V (EXPANDED) T/M	6	6	TEMPERATURE SKIN of UV PHOTOMETER 200°F, K109	16	16
-6V T/M (REGULATED)	7	7	TEMPERATURE ROCKET SKIN STA 57 BN-100	17	17
+26.4 GENERAL NiCd	8	8	TEMPERATURE TIMER PLATE FWD. BODY 160°F K109	18	18
-18V GENERAL NiCd	9	9	TEMPERATURE BEACON SHELF FWD. BODY 160°F K109	19	19
TEMPERATURE CBA TX MAIN T/M 200°F, K109	10	10	±15 TWO CHANNEL PHOTOMETER	20	20
WIPER 1 to 10	13		WIPER 11 to 20	14	

MARKED, IF USED, GROUNDS ON POSITION 1 ONLY

ENG. WORK SHEET:	BATTERIES		ROCKET: AD II - 52
STATUS:	PREP. DATE:	ISSUE NO:	FIR. DATE: MAR 65

No	BATTERIES TYPE	VOLTS	EXPERIMENT	LOAD MA.	LIFE & LOAD	UMBILICAL CHRG	ON-OFF	MONT.
1	20 HR 1	+29	T/M (+)					
			EVENT SCO	60				
2	10x225BH	-12	T/M (-)	50				
3	22x500BH	+26.4	COMMUTATOR	30				
			SUBCOMMUTATOR	120				
			MULTIPLEX RELAYS	30				
			CALIBRATOR & T/M CAL +5V	50/200 50ms/10Sec	230			
4	8 HR1	+12	BELLOWS					
5	5x500BH	-6	2 CHAN PHOT LIGHT 6V ELEC.	1/10x150 120				
6	10x225BH	-12	EFP IA#1 - 229 Mc	200				
7	10x225BH	-12	EFP IB#2 - 2314 Mc	200				
8	4x1604	+36	5" P.P. SPHERE					
9	15x225BH	-16	5" P.P. SPHERE					
10			I.I.					
11	22x500BH	+26.4	MAGNETOMETERS (2)	70				
			VIBRATION ACC (3)	48+17z				
			PHOTOMETER NRC	9+9z				
			TWO CHANNEL PHOTOMETER UofS	60+10	223			
12	15x500BH	-18	(-6V TAP) MAGNETOMETER	2				
			PHOTOMETER NRC	30				
			TWO CHANNEL PHOTOMETER UofS	60+15	107			
13	5xHR3	-6.5	BEACON	3500				
14	5x500BH	-6	UofS TWO CHANNEL PHOTOMETER	100				

ENG.WORK SHEET: GENERAL REQUIREMENTS | ROCKET: AA-II-53

STATUS: FINAL | PREP.DATE: | EXP.DATE: | FIR.DATE: MAR 65

TRIAL COORDINATOR:
H. STANIFORTH

PROJECT SCIENTIST:
A.G. McNAMARA

ROCKET CONFIGURATION:

15KS25000 MOTOR
STANDARD BBII NOSE CONE
BBII CANADAIR FINS (4)
0.4 RPS ROLL RATE

LAUNCH CONDITIONS:

1) SOLUNAR DARKNESS
2) AURORA VISUAL INT. 2
RADAR 10 db.
3) CLEAR SKY NO AURORA

2) for 2 TESTS
3) for SUCCEEDING TESTS.

ELEV.	AZ.	RECOVERY
85°	N/R	N/R

PRIMARY EXPERIMENTS:

PLASMA PROBES ON SKIN
PLASMA PROBE EJECTED SPHERE
IONOSPHERIC INHOMOGENEITIES
EFP - 1A
EFP - III
NEUTRON DETECTOR
MICROMETEORITE DETECTOR
X-RAY DETECTOR

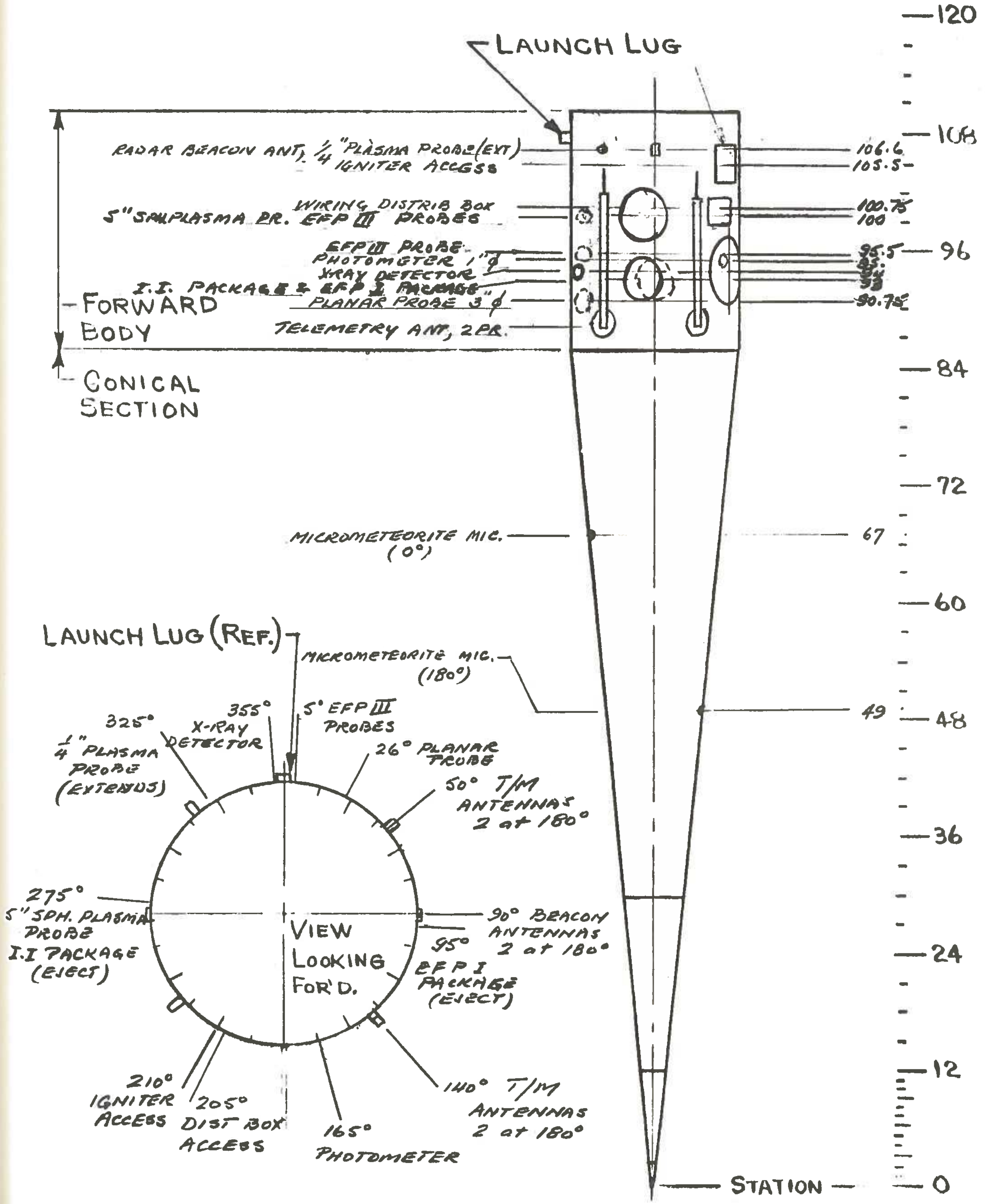
ROCKET EVENTS:

	TIME	T/M LINK
TLM MULTIPLEX	T+30	#1 219.5 mc
I.I. EJECTION	T+55	#5 108 mc
1/4" P.P. ERECTION	T+55	#1 219.5 mc
6" SPHERE EJECTION	T+60	#3 227 mc
EFP-1A EJECTION	T+60	#4 229 mc

FREQUENCY UTILIZATION:

	LINK NO.	Tx	POWER	FREQ.	MOD.	ANT.	POL.
NOSE CONE T/M	#1	TDI	5 W	219.5 mc	FM/FM	QUAD	LIN.
BEACON		DPN/41	50 W	2900 Tx 2800 Rx	PULSE	"	"
TLM #2	#2	CBA	1 W	240.2	FM/FM	"	"
6" SPHERE PROBE	#3	NRC	50 mw	227	FM/FM	SPRING ROD	"
IONOSPHERIC INHOMOGENEITIES	#5	U of W.O.	250 mw	108	CW	FLEX TAPE	"
EFP-1A	#4	U/S	50 mw	231/229	AM	FLEX TAPE	"

ENG. WORK SHEET:	Nose Cone		ROCKET: AA-II-53
STATUS: FINAL	PREP. DATE: 2/11/64	ISSUE #1	FIR. DATE: MAR. 65



ENG. WORK SHEET: Telemetry	ROCKET: AA-II-53

STATUS: FINAL	PREP. DATE:	EXP. DATE:	FIR. DATE: MAR. '65

EXPERIMENT: * No "IN-FLT" CAL.	POWER	SUB-CAR. CHANNEL
MULTIPLEX RELAYS	T/M +26	400 cps
EFP-1A 229.m EJECTION	T/M +26	560 cps
NOSE CONE PRESSURE SW.	T/M +26	730 cps
I.I. EJECTION	T/M +26	960 cps
5" SPHERE PROBE EJECTION	T/M +26	1.3 kc
90 KFt. ALT. SWITCH	T/M +26	1.7 kc
A NEUTRON DETECTOR	+26.4 -18V NiCd	3.9 Kc BW 59
B NEUTRON DETECTOR	+26.4 -18V NiCd.	5.4 Kc BW 81
Z-AXIS ACC. +20/-3 G.	T/M +5V	7.35 Kc BW 110
PHOTOMETER	+26.4 -18	
		10.5 Kc BW 160
EFP III #1	+26.4 -18V	
		14.5 Kc BW 220
EFP III #2	+26.4 -18	
		22 Kc BW 330
1/4" PLASMA PROBE	P.P. +12V	
VIBRATION ACC Z-AXIS FWD BODY	+26.4	30 Kc BW 450
1/4" PROBE SWEEP	P.P +12V	
		40 Kc BW 600
PLANAR TRAP DC		
VIBRATION ACC. Z-AXIS	+26.4	52.5 Kc BW 790
PLANAR TRAP AC.	P.P. +12V	
T/M COMMUTATOR 30 x 10/S	T/M +26V	70 Kc BW 1050

EXPERIMENT:	POWER	COMMUTATOR CHANNEL
CAL. 0V	GND	1
CAL +5V	T/M +5V CAL.	2
MICROMETEORITE #2	M.M	3
MAGNETOMETER 0° to L.L.	+26.4 NiCd.	4
MAGNETOMETER 90° CWLF	+26.4 NiCd.	5
LINEAR ACC. ±5G 0° to L.L.	T/M +5V CAL.	6
LINEAR ACC. ±5G 90° CWLF	"	7
BEACON -6.5V MON	BEACON -6.5V	8
" MOD. MON	"	9
" RX. MON	"	10
" RF. MON	"	11
50K ALT. SW. ON PHOTOMETER	+26.4V	12
5" SPHERE RF MON.	SPHERE	13
LINEAR ACC. Z-AXIS +20/-3 G	T/M +5V CAL.	14
PLANAR SWEEP MON.	[illegible] #12V	15
EFP-1A RF MON.	EFP -24V	16
MICROMETEORITE #1	MM	17
" #2	MM.	18
MAGNETOMETER 0° to L.L.	+26.4V -18V	19
MAGNETOMETER 90° CWLF	"	20
LINEAR ACC. ±5G 0° to L.L.	T/M +5V CAL	21
LINEAR ACC. ±5G 90° CWLF	"	22
REFLECTED PWR. MON.	+26.4 -18V	23 X
INCIDENT PWR MON.	—	24
55" SQUIB MON.	+12V SQUIB	25
SUBCOMMUTATOR	"	26
60" SQUIB MON.	"	27
SUBCOMMUTATOR	"	28
MASTER	T/M +26	29
MASTER	"	30

ENG.WORK SHEET:	SUBCOMMUTATOR		ROCKET: AA-II-53		
STATUS: FINAL	PREP.DATE:		EXP.DATE:	FIR.DATE: MAR. '68	

INPUT	DC 25 PIN	SEQUENCE	INPUT	DC 25 PIN	SEQUENCE
T/M CAL +5V	1	1	PLASMA PROBE ELECTROMETER +12V	11	11
T/M CAL +5V	2	2	NEUTRON DETECTOR H.V. MON.	12	12
INDICATOR LATCH RELAYS	3	3	X-RAY EHT MONITOR	13	13
SQUIB BATT +12V MONITOR	4	4	X-RAY -12V MON.	14	14
T/M +26V MONITOR	5	5	T/M #2 -30V MONITOR.	15	15
MICROMETEORITE B+ MONITOR 3.8V	6	6	TEMPERATURE EFP III AMPLIFIERS	16	16
EFP-III +18V MON.	7	7	TEMP. STATION 59 160°F	17	17
T/M #2 POST REGULATOR VOLTAGE (-4V)	8	8	TEMPERATURE T/M #2 BAT. BOX 160°F.	18	18
+26.4 NiCd.	9	9	T/M 26V MON. EXPANDED	19	19
-18V NiCd	10	10	GND.	20	20
WIPER 1 to 10	13		WIPER 11 to 20	14	

MARKED, IF USED, GROUNDS ON POSITION 1 ONLY

ENG.WORK SHEET:	Batteries	ROCKET: AA-II-53

STATUS: FINAL	PREP.DATE:	EXP.DATE:	FIR.DATE: MAR. '65

NO.	BATTERIES TYPE	BATTERIES VOLTS	EXPERIMENT	LOAD MA.	LIFE ON LOAD	TEMP. RANGE °F	UMBILICAL CH'RG	UMBILICAL ON/OFF	UMBILICAL MON'T.
1	18xHR-5	+26.2	T/M.	5000	>1HR.	-20 to +165	✓	✓	✓
			EVENT SCO	60					
			CALIBRATOR	50,200/					
				50MA/10A					
			MULTIPLEX RELAYS	80					
			SUBCOMM SIGS.	10					
2.	5x HR-3	-6.5V	BEACON	2500	1HR	"	X	✓	✓
3	8XHR-5	+12V	SQUIBS 5" SPHERE	2000	120/3000/		✓	X	✓
			" EFP-1A	2000	~~4000~~/120				
			" I.I.	2000					
			" 1/4" P.P.	1000					
			SUBCOMM.	120					
4	25x1.2SC Ag.Zn	-30V	T/M LINK #2	500		0° to 115°	✓	✓	✓
			X-RAY ELECTRONICS -12V	47+19Z	1.6HR				
			X-RAY EHT.	100					
			SCO. -6V	2+9Z	/675				
5	22x1.2SC	+26.4	CBAL MAGNETOMETERS (2)	70		"	✓	✓	✓
			VIB. ACC. AMPLIFIERS	45					
			NEUTRON DETECTOR +12V	76+30Z					
			NEUTRON DETECTOR H.V.	90					
			PHOTOMETER	18	2.7HR				
			EFP III	45					
			T/M #2 SCO	15+10Z	/				
			ANT. PWR. MONITOR +15V	16	/415				
6	15x500BH	-18V	PHOTOMETER -18V	30		"	✓	✓	✓
			EFP III	40					
		X-RAY	NEUTRON DETECTOR	64+36Z	2HR.				
		T.D. -15V	26V MONITOR	26					
		2+8Z	CBAL MAGNETOMETER -6V	4	/221				
			ANT. PWR. MON. -15V	11					
7.	10x225BH	-12V	EFP-1A	200	1HR	"	✓	✓	✓
8	15x225B	-18V	5" SPHERE			"	✓	✓	?
9	4x1604		" CARBON-ZINC			40°F-117°F	X	X	X
10			I.I.						
11	Hg.	+12V	M.M.		30 HR		X	X	X
12	10x225BH	+12V	P.P.				✓	✓	✓

ENG. WORK SHEET: GENERAL REQUIREMENTS		ROCKET: AA-II-60	
STATUS: FINAL	PREP. DATE: 1/10/64	EXP. DATE:	FIR. DATE: MAR. '65

TRIAL COORDINATOR:
A. STANIFORTH

PROJECT SCIENTIST:
A.G. McNAMARA

ROCKET CONFIGURATION:

15KS 25000 ENGINE

CANADAIR 4-FIN

STANDARD BB II NOSE CONE
WITH BB V IGNITER HOUSING
AND ADAPTER RING.

0.4 R.P.S. ROLL RATE.

LAUNCH CONDITIONS:

SOLUNAR DARKNESS.

VISUAL & RADAR AURORA

RIOMETER ABSORPTION

X-RAY COUNT.

ELEV: 85° **AZ.** N/R **RECOVERY** N/R

PRIMARY EXPERIMENTS:

PLASMA PROBES	NRC
COSMIC RAY DETECTORS	NRC
NEUTRON DETECTOR	U of A.
X-RAY DETECTOR	U of A
AURORAL SCANNER	U of A
EFP-1B	U of S
MICROMETEORITE ACOUSTIC DETECTOR	NRC NRC

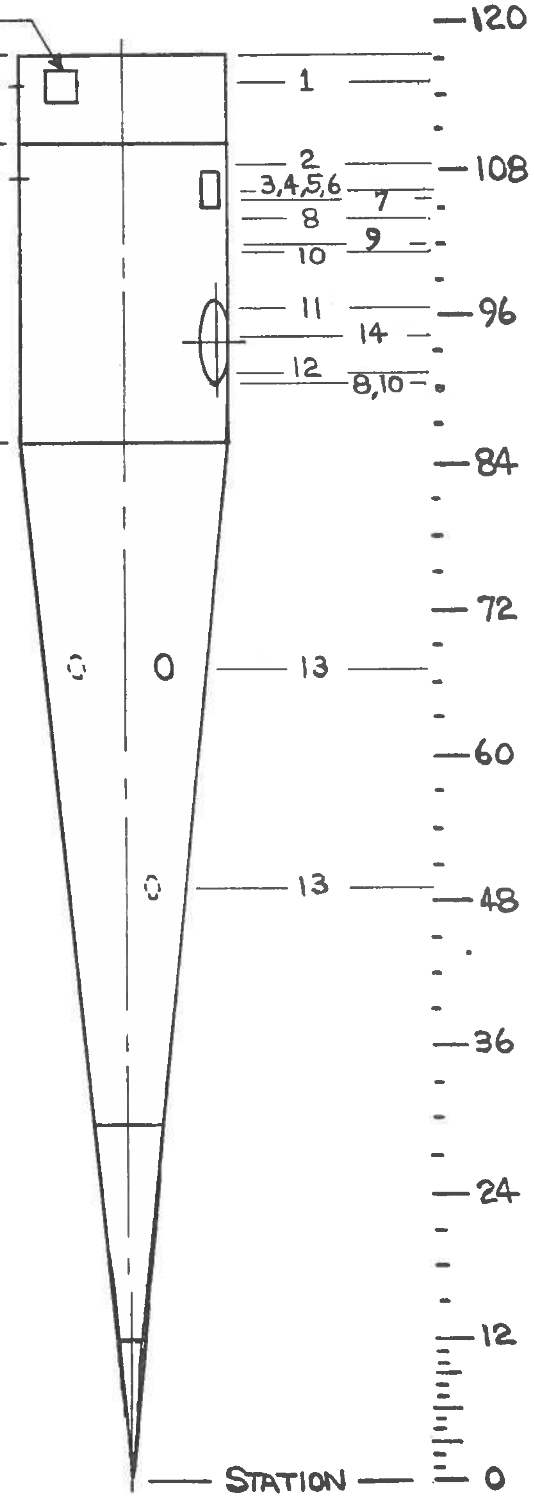
ROCKET EVENTS:

	TIME	T/M LINK
TLM MULTIPLEX	T+30	#1
1/4" ϕ PROBE EXT.	T+40	#1
SCANNER EXT.	T+40	#2
LONG PROBES EXT.	T+60	#1
EFP EJECTION	T+60	#3
EFP EJECTION	T+60	#4

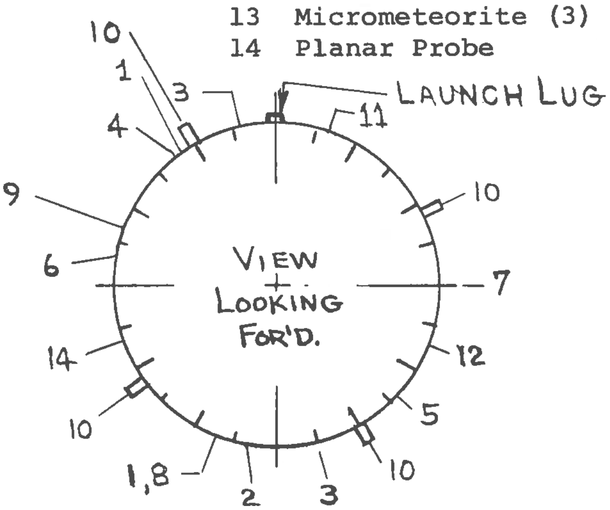
FREQUENCY UTILIZATION:

	LINK NO.	Tx.	POWER	FREQ.	MOD.	ANT.	POL.
NOSE CONE T/M	1	TDI	5 W	219.5	FM/FM	QUAD	LIN.
BEACON	–	DPN-41	100 W	2900 Tx	PULSE	QUAD	LIN.
TLM #2, X-RAY DETECTOR & AURORAL SCANNER	2	CBA	1 W	240.2	FM/FM	QUAD	LIN.
EFP - 1B	3	U of S	50 MW	229	FM.	FLEX TAPE	LIN.
EFP - 1B	4	U of S	50 MW	231.4	FM	FLEX. TAPE	LIN.
TLM #3 - ACOUSTIC	5	NRC	1 W	227	FM/FM	SINGLE QUAD	LIN.

ENG. WORK SHEET: NOSE CONE			ROCKET: AA II-60
STATUS: FINAL	PREP. DATE:	ISSUE NO:	FIR DATE: MAR. 65



ITEM	UNIT
1	Plasma Probe
2	Total Energy Det.
3	Beacon Ant.
4	Wiring Access
5	Photometer
6	Pitch Angle Det.
7	Planar Trap
8	EFP 1 (2)
9	X-ray
10	T/M Antenna (5)
11	Auroral Scan.
12	Langmure Probe (2)
13	Micrometeorite (3)
14	Planar Probe



ENG. WORK SHEET: TELEMETRY LINK #1 218.5MHz	ROCKET: AA II 60

STATUS: FINAL	PREP. DATE: —	ISSUE NO: —	FIR. DATE: MAR. 65

EXPERIMENT:	SUB-CAR. CHANNEL
#1 EFP-1B (229) EJECTION	400 Hz
#2 EFP-1B (2314) EJECTION	560 Hz
SPHERE PROBE EXTENSION	730 Hz
SPHERICAL TRAP EXTENSION	960 Hz
70 KFT. ALT. SWITCH	1.3 kHz
AURORAL SCANNER EXTENSION	1.7 kHz
±5G ACC. 45°CWLF	3.9 kHz
ELECTRON TOTAL ENERGY	BW 59
±5G ACC. 135° CWLF	5.4 kHz
'A' NEUTRON DETECTOR	BW 81
Z AXIS LINEAR ACC.	7.35 kHz
'B' NEUTRON DETECTOR	BW 110
PLASMA PROBE SWEEP	10.5 kHz
PROTON DETECTOR	BW 160
	14.5 kHz
DC PLANAR, DC SIGNAL	BW 220
	22 kHz
SPHERICAL TRAP SIGNAL	BW 330
	30 kHz
COSMIC RAY COMMUTATED	BW 450
Z-AXIS VIBRATION	40 kHz
SPHERICAL TRAP AC SIGNAL	BW 600
LATERAL VIBRATION	52.5 kHz
SWEPT ELECTROMETER	BW 790
TLM COMMUTATOR	70 kHz BW 1050

EXPERIMENT:	COMMUTATOR CHANNEL
CAL 0V	1
CAL 5V	2
MAGNETOMETER 280°CWLF	3
MAGNETOMETER 190°CWLF	4
EFP-1 #1 (229) RF MON	5
EFP-1 #2 (2314) RF MON	6
PLASMA PROBE AUXILLARY SWEPT GEN.	7
PLASMA PROBE TRAP	8
PHOTOMETER DIRECT	9
PLASMA PROBE SWEEP	10
MICROMETEORITE #1	11
MICROMETEORITE #2	12
MICROMETEORITE #3	13
BEACON 6.5V MON.	14
BEACON MOD. MON.	15
BEACON RX. MON.	16
BEACON RF MON.	17
MAGNETROMETER 280°CWLF	18
MAGNETROMETER 190°CWLF	19
40 SEC BELLOW MONITOR	20
60 SEC BELLOW MONITOR	21
PLASMA PROBE AUX. SWEPT ELECTRONICS	22
PHOTOMETER PEAK	23
PHOTOMETER DIRECT	24
PLASMA PROBE SWEEP	25
SUBCOMMUTATOR	26
PHOTOMETER POWR. MON.	27
SUBCOMMUTATOR	28
MASTER	29
MASTER	30

ENG. WORK SHEET: TELEMETRY SUPPLEMENT			ROCKET: AA II 60
STATUS: FINAL	PREP. DATE: —	ISSUE No: —	FIR. DATE: MAR. 65

LINK No. TX. FREQ.	EXPERIMENT	SUB CAR. CHANNEL
LINK #2 240.2 MHz. (T/M #2)	X-RAY PULSE OUTPUT	DIRECT
	X-RAY SCALAR	40 kHz
	AURORAL SCANNER	70 kHz 'E'

LINK No. TX. FREQ.	EXPERIMENT	SUB. CAR. CHANNEL
LINK #5 227 MHz. (T/M #3)	MICROPHONES MULTIPLEX	70 kHz

ENG. WORK SHEET: SUBCOMMUTATOR			ROCKET: AA-II-60
STATUS: FINAL	PREP. DATE: —	ISSUE NO: —	FIR. DATE: MAR. 65

INPUT	PIN	SEQUENCE	INPUT	PIN	SEQUENCE
T/M CAL +5V	1	1	PLASMA PROBE B1/B2 MONITOR	11	11
T/M CAL +5V	2	2	PLASMA PROBE B3 MONITOR	12	12
INDICATOR LATCH RELAYS	3	3	PLASMA PROBE B4 MONITOR	13	13
T/M #2 POST REGULATOR VOLTAGE −4V	4	4	PLASMA PROBE B5 MONITOR	14	14
NI CD +26.4V MONITOR	5	5	PLASMA PROBE B6 MONITOR	15	15
NI CD −18V MONITOR	6	6	AURORAL SCANNER MOTOR & LIGHT BATTERY MONITOR 7.5V	16	16
T/M #2 BATTERY MONITOR −30V	7	7	NOSE CONE PRESSURE SWITCH	17	17
NEUTRON DETECTOR H.V. MONITOR	8	8	TEMP. SENSOR TOP OF H-FRAME STA. 59	18	18
X-RAY, AURORAL SCANNER E.H.T. MONITOR	9	9	T/M +26.2V MONITOR	19	19
TEMP. T/M #2 BATT. BOX	10	10	GND.	20	20
WIPER 1 to 10	13	—	WIPER 11 to 20	14	—

ENG. WORK SHEET: BATTERIES				ROCKET: AA II 60				
STATUS: FINAL		PREP. DATE: —	ISSUE NO: —	FIR. DATE: MAR. 65				

No	BATTERIES TYPE	VOLTS	EXPERIMENT	LOAD MA.	LIFE & LOAD	UMBILICAL CHRG	UMBILICAL ON-OFF	UMBILICAL MONT.
1	18 HR 5	26.2	T/M, PKG.	5000	> 1 Hr	✓	✓	✓
			EVENT OSCILLATORS	60				
			CALIBRATOR	50-200 50ms-10sc				
			MULTIPLEX RELAYS	124				
2	5 HR 3	-6.5	BEACON	3500	1 Hr	✓	✓	
3	8 HR 5	+12	SQUIBS PLASMA PROBE (3)	5000	> 1 Hr	✓	✓	✓
			SQUIBS EFP-1 (2)	4000				
			SQUIBS AURORAL SCANNER	2000				
			SUBCOMM.	120				
4	25×1.2 Sc Ni. Cd.	-30	T/M LINK #2	500		✓	✓	✓
			X-RAY ELECTRONICS	47+19	1.6 Hr			
			X-RAY SCANNER EHT	100				
			CBAL 40 kc SCO -6V	8	674			
5	22×1.2 Sc Ni. Cd.	+26.4	CBAL MAGNETOMETER (2)	70		✓	✓	✓
			VIB. ACC. AMPLIFIER (2)	45				
			NEUTRON DETECTOR +12V	76+30				
			AURORAL SCANNER +15V	15+15	2.8 Hr			
			PHOTOMETER +12V	18				
			NEUTRON DETECTOR HV	90				
			T/M #2 SCO (2)	40	394			
6	15×500 BH Ni. Cd.	-18	CBAL MAGNET. -6V TAP	2		✓	✓	✓
			NEUTRON DETECTOR -12V	64+36				
			AURORAL SCANNER -15V	15+22	2.5 Hr			
			PHOTOMETER -18V	30				
			X-RAY T.O.	2+8	179			
7	10×225 BH	-12	EFP-18 #1 (229.0 mc)	200	40-50 min	✓	✓	✓
8	10×225 BH	-12	EFP-18 #2 (231.4 mc)	200	40-50 min	✓	✓	✓
9	4-HR-1	6	5V FOR AURORAL SCAN. MOTOR	150		✓	✓	✓
9(A)	1-HR-1	1.5	AURORAL SCANNER LIGHT	500		✓	✓	✓
10	10×225 BH	12	PLASMA PROBE	50		✓	✓	✓
11	Hg	12	MICROMETEORITE	30	90 Hr.			
12	20 HR 1	-29	LINK #5 MICROPHONE TLM				✓	

Plate I Transporting AE-II-24 nose cone to the launcher (Churchill Research Range photo)

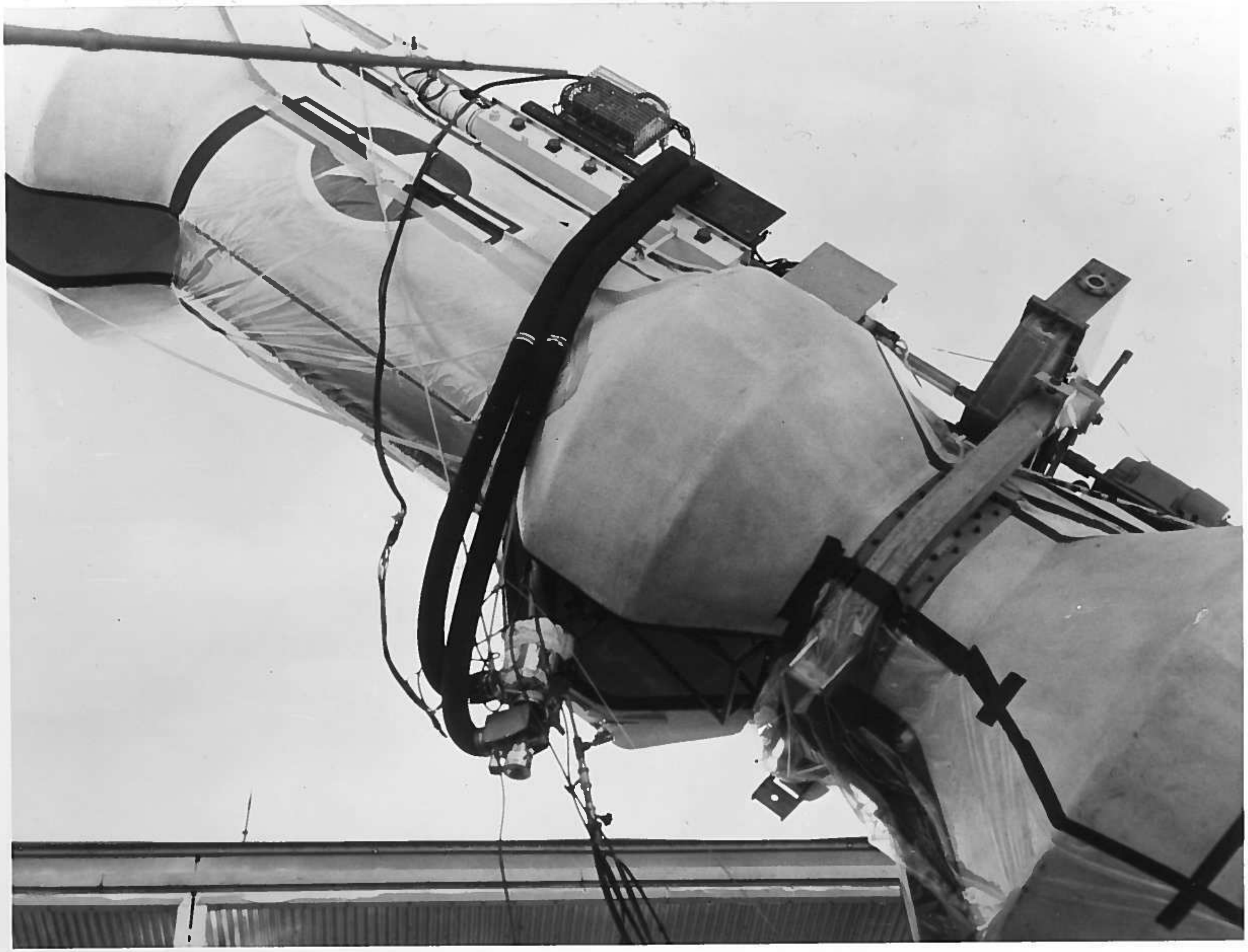


Plate II Vehicle AE-II-24 on universal launcher (Churchill Research Range photo)