**Payload preparation for research rockets**
National Research Council of Canada

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NATIONAL RESEARCH COUNCIL

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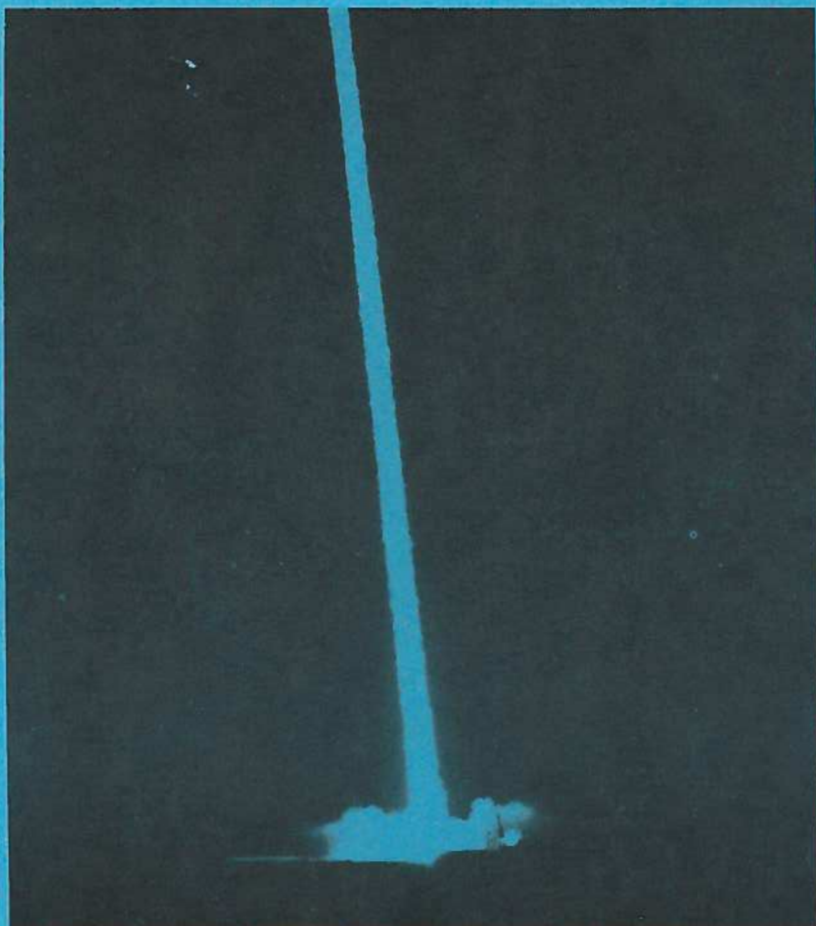



# PAYLOAD PREPARATION FOR RESEARCH ROCKETS

EXTRACTS FROM THE BULLETIN

OF THE

RADIO AND ELECTRICAL ENGINEERING DIVISION

ERB-680 JULY 1964

## FOREWORD

This booklet contains a selection of items which have appeared in the Bulletin of the Radio and Electrical Engineering Division over the past three years. These items deal with the research rocket program, and have been contributed to the Bulletin by the Space Electronics Section and the Upper Atmosphere Research Section. A bibliography of publications arising from the rocket program in this Division is included.

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Vol. 11 Ottawa, July 1961 No. 2

## ENGINEERING ASSISTANCE TO THE HIGH-ALTITUDE ROCKET-SOUNDING PROGRAM

- W.L. Haney -

In Canada, the Associate Committee on Space Research of the National Research Council coordinates all non-defence space research activities. The exploration of space between 35 and 300 km above the earth's surface is of interest to the Committee, since some of the major consequences of the proximity of the earth's magnetic axis are to be found within these heights. Of particular interest is the interaction of solar radiation and particles with the earth's magnetic field.

The Committee can make grants, with the approval of the National Research Council, to university research groups in support of experimental work in the field of space research. Several programs using rockets for high-altitude sounding are being carried out by university groups and by groups of the National Research Council in this Division and in the Division of Applied Physics. These programs are coordinated and partly supported by the Associate Committee.

A considerable amount of engineering coordination and assistance is required to carry out these experiments. Since many of the engineering problems are common to most rocket experiments, a central engineering group can be most useful. This central engineering function is to be provided by the Radio and Electrical Engineering Division.

This group will be responsible for the technical coordination of the rocket-sounding program. This will include liaison with the suppliers of the vehicle, with the various experimenters, and with the launching facility at Fort Churchill, Manitoba. Coordination of the vehicle payload will be carried out by this group, as will the provision of instrumentation not directly part of an experiment. For example, measurement of rocket performance, temperature, and so forth, will be made by the engineering group.

In particular, the provision of standard electronic systems will be arranged through this group. Beacons in the rocket for position-fixing by ground radar, and similar devices are available. One of the major electronic components, a telemetry package, is under development in conjunction with the Canadian Armament Research and Development Establishment (CARDE), the Defence Research Telecommunications Establishment, and a commercial contractor, Bristol Aero-Industries Ltd. The package is a standard fitting for the Black Brant II rocket vehicle. This rocket will be described later. A telemetry package with sufficient capacity and flexibility to meet most users' requirements is being designed and will be provided. It perhaps should be said that a telemetry package is required, since it is not practical at this time to recover the rocket vehicle or any part of it, and, therefore, some method of recovering the results of the experiment is required. The present design of package has 10 FM/FM channels. One of these channels can sample 25 slowly varying quantities; the output of this sampling channel is pulse-amplitude-modulated (PAM). FM/FM is used for the other channels, as it provides a high degree of linearity, as well as a convenient method of recording on magnetic tape. A total bandwidth of 100 kc/s is available for transmission of the experimental results. The system operates in the 215-260 mc/s band.

Advantage has been taken of the Division's model-testing facility by making $\frac{1}{8}$-scale models for use in measuring the characteristics and radiation pattern of the antenna system for the telemetry equipment in the rocket. Plate I illustrates a model of the Black Brant II vehicle, and a model of a rocket vehicle under development (Black Brant III).

As part of a cooperative program of rocket development supported by CARDE, the Department of Defence Production, and Bristol Aero-Industries Ltd., this Division is designing the antennas for the Black Brant III. This rocket, which is relatively economical to manufacture, is designed for high-altitude research. It has high velocity (Mach 7) at low altitudes. The resulting high temperature, which approaches that usually associated with re-entry, poses some unusual problems in the antenna design. The antenna configuration which is being considered can be seen in the photograph on the smaller rocket. This antenna is a shunt-fed inverted L-type. It is also known as a "quadraloop", as it resembles a quarter-loop. It is one of the family classed as transmission line antennas because its characteristics can be determined by treating it as a section of transmission line, and making allowance for radiated energy. New Mexico State University has used this configuration for a number of rocket antennas. It appears to be well suited to our purpose, as it has satisfactory radiation patterns and minimizes the heating problem. Only two elements are required per vehicle.

Antenna coupling networks are being designed for both these rockets. The considerations which must be given priority in the design of the coupling network are reproducibility, wide bandwidth, low cost, light weight, and reliability. A satisfactory basis for design has been achieved for both rockets.

Black Brant II will be used for the experiments in the immediate future. The nominal diameter of this rocket is 17 inches, the length is 27.5 feet, and the total weight is 2500 pounds, excluding the payload which will be about 175 pounds. It is a solid fuel rocket, the motor for which was designed by CARDE. The burning time is 26 seconds, the thrust is 16,000 pounds, and the total impulse is 420,000 second-pounds. The altitude which this rocket will reach is about 125 miles. The rocket motor case is made by Bristol Aero-Industries Ltd., the solid fuel and filling is done by CARDE, and the nose cone section is fabricated by Canadair

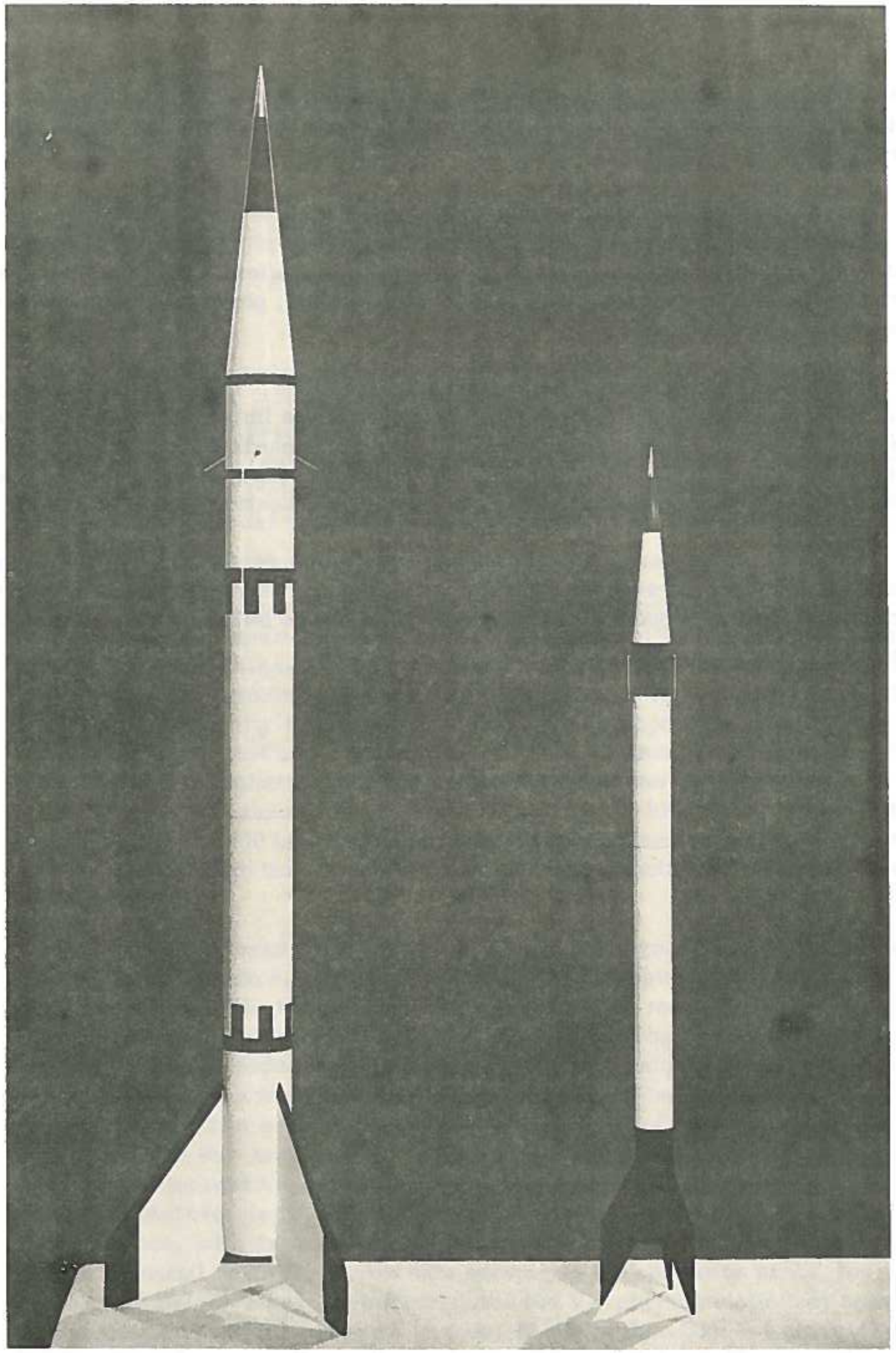

**Plate I — Scale models of high-altitude research rockets used to determine radiation patterns of telemetry antennas shown. (left) Black Brant II (right) Black Brant III to same scale**

Ltd. The final assembly of experiments, environmental testing, and initial check-outs will be made jointly by the experimenters and the Divisional engineering group.

For our experiments the nose cone is pressurized; that is, ground level pressure is maintained throughout the flight. Pressurization simplifies the use of vacuum tubes at high altitudes. Transistors, while lighter and offering other advantages, are significantly more costly than tubes, unless weight, power, and long life are overriding considerations.

Firings will take place at Fort Churchill, Manitoba. This rocket-launching facility is manned jointly by the Canadian Army and the United States Army. The Defence Research Board also maintains the Defence Research Northern Laboratory at Fort Churchill. This laboratory is well equipped for carrying out auroral investigations, both independently and in support of scientific rocket sounding.

The Black Brant series of rockets has had 14 successful firings, including design test firings as well as scientific experiments. Members of this Division provided scientific support for two firings last fall (see Bulletin, vol. 11, no. 1, p. 31).



Vol. 11 Ottawa, October 1961 No. 3

## PLASMA PROBES FOR AURORAL ROCKET RESEARCH

- A.G. McNamara and L.R. McNarry -

Most of our knowledge of the aurora has been obtained by radio, photographic, and spectrographic methods. However, the results must often be deduced indirectly and spatial resolution is poor. Direct localized measurements of some of the quantities by means of rockets should greatly clarify many problems. Measurement of the ionization density, the particle energy spectrum or temperature, and their spatial distribution should help to identify the auroral excitation mechanisms.

The spatial distribution and density of ionization during aurora, and their relationship to the visual emissions of excited atoms and molecules are of special importance. Ground-based radar responds to the presence of ionization, but the range and height resolution is generally inadequate for very detailed correlation. The ionization density inferred from radar data is dependent upon an assumed ionization distribution and reflection mechanism. Plasma probes are capable of providing high-resolution spot measurements along the rocket trajectory. The height of maximum auroral luminosity is typically 100 km, and a rocket reaching a peak altitude of 200 km will spend nearly five minutes above the 100 km level. As it passes through the 100 km level, the rocket velocity will be approximately 1.5 km/s.

The simplest form of plasma probe is the single Langmuir probe. This consists of a conductive surface, immersed in the plasma, to which a variable known voltage is applied while the current being collected is measured. The resulting voltage-vs-current characteristic permits the ambient charge densities and kinetic temperature to be deduced from the probe theory. Unfortunately, a number of complications are added in rocket measurements. The potential of the probe must be referred to some base reference, which is not directly definable for a free object. In our experiments the potential is applied between the probe and the rocket skin, and the plasma potential is subsequently deduced from analysis of the V-I characteristic. Hence, all rocket probe methods must be analyzed as double probes, with the potentials of both probes varying relative to the ambient plasma potential. With the rocket skin serving as the reference probe, the probe areas are generally highly asymmetric, and the V-I characteristic may approach that of the small probe acting as an ideal single probe. The V-I characteristic is also dependent upon the probe geometry, the most tractable geometries for theoretical analysis being the sphere, the cylinder, and the plane. Additional complications in the analysis are introduced by the thickness of the plasma sheath surrounding the probes, the mean free path of the particles, the rocket velocity, the rocket aspect, and perturbations of the medium by the experiment.

Plasma probes of various geometries which will be flown on the rockets are shown in Plate I. Three of the probes illustrated are of the Langmuir type. The probe at the lower left has planar geometry; the central disc is the collector electrode and the ring is a guard electrode. This type of probe is designed to be mounted flush with the rocket skin. The Langmuir probe at the lower right is a small sphere, mounted at the end of a supporting rod which holds it away from the rocket. Another spherical probe is shown at the upper left. A specially devised mechanism is required to extend probes of this size from the rocket, after the rocket is free of atmospheric drag. Addition of one or more screen grids over the collecting electrode allows more selective collection of charged particles. To distinguish these probes from the basic Langmuir collector, they are commonly referred to as "ion traps". One of several designs which will be flown is shown at the upper right in Plate I. The trap is of spherical geometry and employs a single screen surrounding the collector. This system may be envisioned as an "inside-out" triode vacuum tube with a plate and a grid, while the surrounding plasma acts as the emitting cathode.

The rockets to be employed on this program will be Canadian Black Brant solid fuel-rockets. A solid-fuel type is advantageous when it may be necessary to hold the rocket on the launching pad for long periods before firing through a visible aurora. Probe voltages and currents will be telemetered to earth, as well as auxiliary data on rocket aspect and data from other pertinent measurements. Tracking signals emitted from the rocket will define the rocket's position in space very accurately, and permit correlation of the rocket data with ground-based observations.

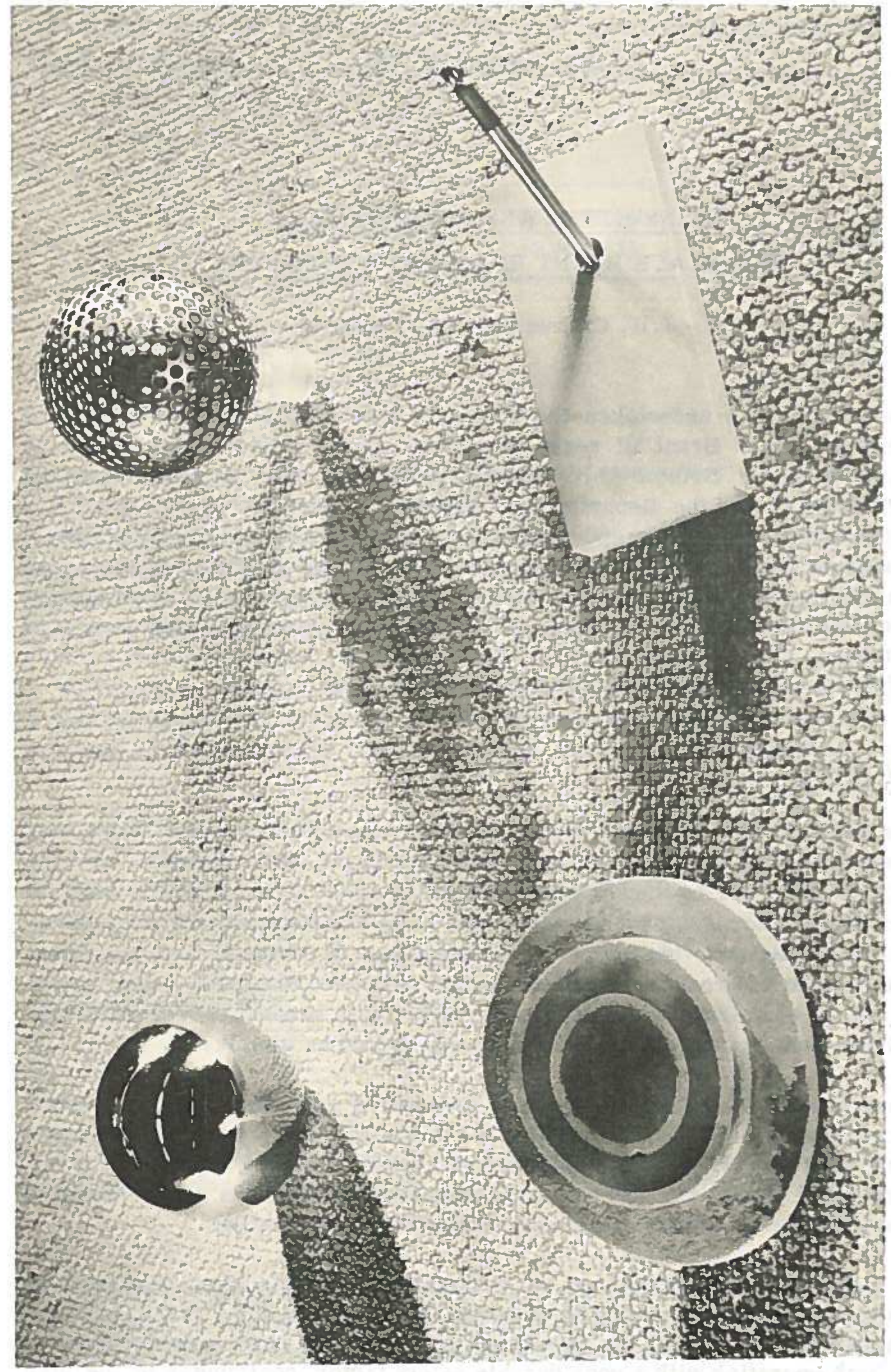

Plate I — Rocket-borne plasma probes. The perforated sphere is an ion trap; the others are Langmuir probes of various geometries.

Vol. 11 Ottawa, December 1961 No. 4

# TRANSMITTER AND ANTENNA FEED FOR BLACK BRANT III ROCKET TELEMETRY

- J.H. Craven and J.K. Pulfer -

This Division has undertaken the design of a number of telemetry devices for use in the Black Brant III research rocket. Development of this rocket is supported jointly by Bristol Aero-Industries Limited, the Defence Research Board (CARDE), and the Department of Defence Production. The National Research Council has assumed responsibility for a solid-state telemetry transmitter, and an antenna system capable of withstanding the high temperatures and large mechanical forces induced by Mach 7 flight, together with the associated feeding networks (Bulletin, vol. 11, no. 2, p. 1). Later requirements included improved blade antennas to suit Black Brant III flight conditions, and provision of a monitoring facility for antenna and transmitter performance.

## TRANSMITTER

Since the telemetry channel provides the only means whereby information may be passed from the rocket to the ground during flight, it is essential that the telemetry transmitter be made as reliable as possible. The reliability must be of a very high order, and must be maintained in an environment of shock, vibration, high altitude, and wide temperature variations. In addition, the transmitter must be capable of producing sufficient output with good efficiency, and, at the same time, of complying with IRIG Standards [1] with respect to frequency stability. Also, tuning, and changing of frequency should be simple.

The usual solid-state UHF transmitter consists of a crystal-controlled oscillator operating at some frequency below 130 mc/s, followed by a chain of amplifiers and multipliers, to obtain the desired output frequency and power level. The number of stages and the sequence of operations depends on the relative importance of power output, efficiency, reliability, and stability.

The radio-frequency portion of our transmitter consists of an oscillator at 56.4 mc/s driving a quadrupler with an output of one watt at 225.7 mc/s (Fig. 1). The simplicity of the circuit, having only one active and one passive semiconductor device, both operating with a considerable safety factor, contributes to the high reliability. High efficiency is ensured by using a relatively low frequency for transistor operation.



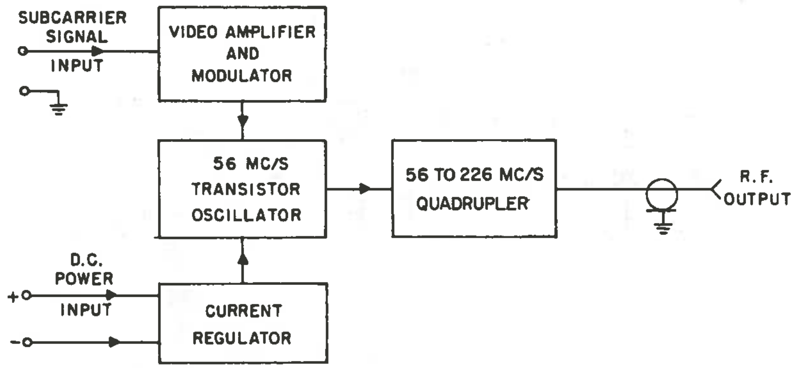


Fig. 1 Functional diagram of transmitter

The transistor power oscillator operates in the familiar tuned-plate, tuned-grid configuration with modifications. Changes are made to adapt the circuit for high-power, high-frequency operation, and to include crystal control but allow frequency modulation with telemetry information.

The basic tuned-base, tuned-collector oscillator circuit is shown in Fig. 2(a). A neutralizing coil is inserted between collector and base to compensate for the reactive component of the transadmittance which is not negligible at 50 mc/s.

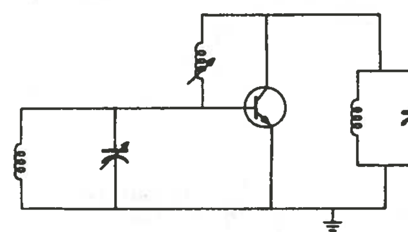

Fig. 2(a) Basic tuned-base tuned-collector oscillator circuit

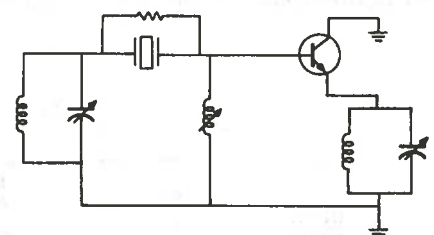

Fig. 2(b) Grounded-collector oscillator circuit modified for crystal control

The circuit is redrawn in Fig. 2(b) to allow the collector to be grounded, since the collector is connected electrically and thermally to the case in high-power VHF transistors. A crystal, shunted by a resistor to lower its Q, is used as a series filter in the feedback path. The base tank circuit is returned to ground, so that it, too, forms a series element of the feedback circuit. The final oscillator circuit, complete with supply voltage bypassing, is shown in Fig. 3.

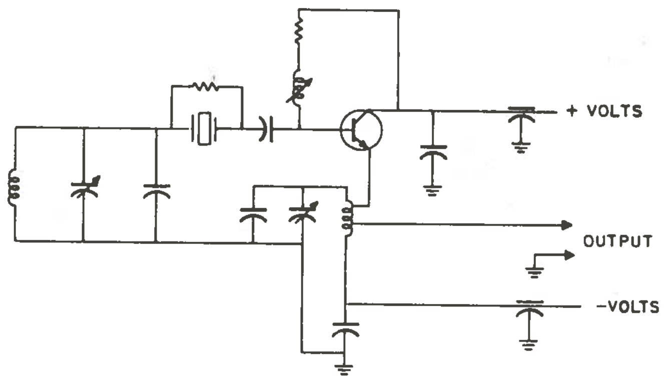


Fig. 3 Complete oscillator circuit

The output of the power oscillator, supplied from a tap on the emitter coil, is capacitively coupled to the input tank circuit of the quadrupler. Under correct operating conditions, the oscillator will supply $2\frac{1}{2}$ to 3 watts to the quadrupler, and the power available at the output tank will be about 1 watt.

The circuit used for amplifying the outputs of the subcarrier oscillators and for frequency modulating the transmitter with the resulting signal is shown in Fig. 4. The amplifier is a standard resistance-coupled amplifier, using a silicon transistor to provide good stability over a wide temperature range. The output of the amplifier is coupled through a capacitor and a radio-frequency choke to a variable-capacitance diode which is connected in parallel with the emitter tank circuit of the oscillator. The diode is biased by the voltage developed by rectified radio-frequency current flowing through a shunt resistor. A modulating po-

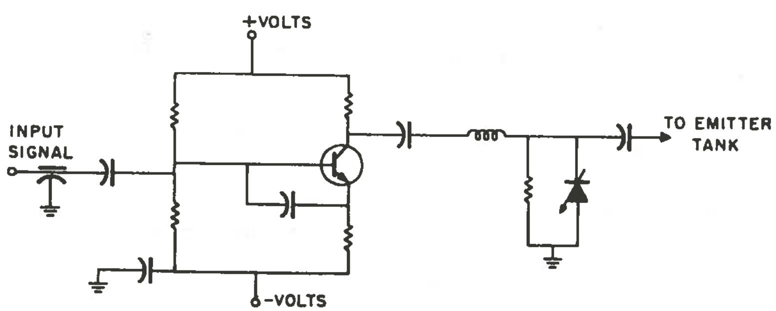


Fig. 4 Video amplifier and modulator circuit

tential of 10 volts peak-to-peak across the diode produces the required ±125 kc/s deviation in the transmitter output.



In order to maintain the current supplied to the transmitter at a fixed value independent of temperature, supply voltage, and load variations, a series regulator has been added to the transmitter. A photograph of the complete transmitter appears in Plate I. The dimensions of the transmitter are 2" × 2" × 4" and the weight is 1 pound.

## ANTENNA COUPLING NETWORKS

### Quadraloop Antenna System

The quadraloop antenna system consists of two shunt-fed quarter-wave radiators mounted on opposite sides of the rocket. It has been developed into a form suitable for Mach 7 flight, in collaboration with Bristol Aero-Industries Limited, which has advised us on heat and mechanical conditions and has fitted the final design into the Black Brant III nose-cone configuration. A matching network is not required at the antenna itself, since, with proper positioning of the feed point, the input is well matched (VSWR < 1.2) when the length of the radiator is correct for the frequency being used. In this respect the quadraloop antenna has a great advantage over the blade antenna.

The two elements of the quadraloop antenna system are designed to be fed 180° out of phase, so that provision must be made to introduce this phase reversal into the feed. This is accomplished by feeding the two antennas from a common point, and making the effective lengths of the connecting cables differ by one-half wavelength.

At the common point the two cables in parallel will present a 2:1 mismatch to the feed from the transmitter, so that a matching network must be inserted at this point. This matching, and the division into two feeds, is carried out in a single unit which has been called a "power splitter". The original matching network consisted of a short length of transmission line from the input connector to the division point, with a short open-circuited stub in shunt across the input. This provided a satisfactory power split with a broad-band match.

However, to overcome voltage breakdown of the antenna at high altitudes, it was considered advisable to apply a d-c bias to the radiators. This involved providing d-c isolation of the radiator from the rocket shell and a means whereby a d-c voltage could be applied to the center conductor of the feed cables. The open-circuited stub of the original design was replaced by a longer one terminated in a feed-through capacitor. The capacitor provided an effective short circuit to the radio frequencies involved, but enabled the d-c voltage to be applied to the center conductor of the feed cables. The appearance of the final unit is shown in Plate I.

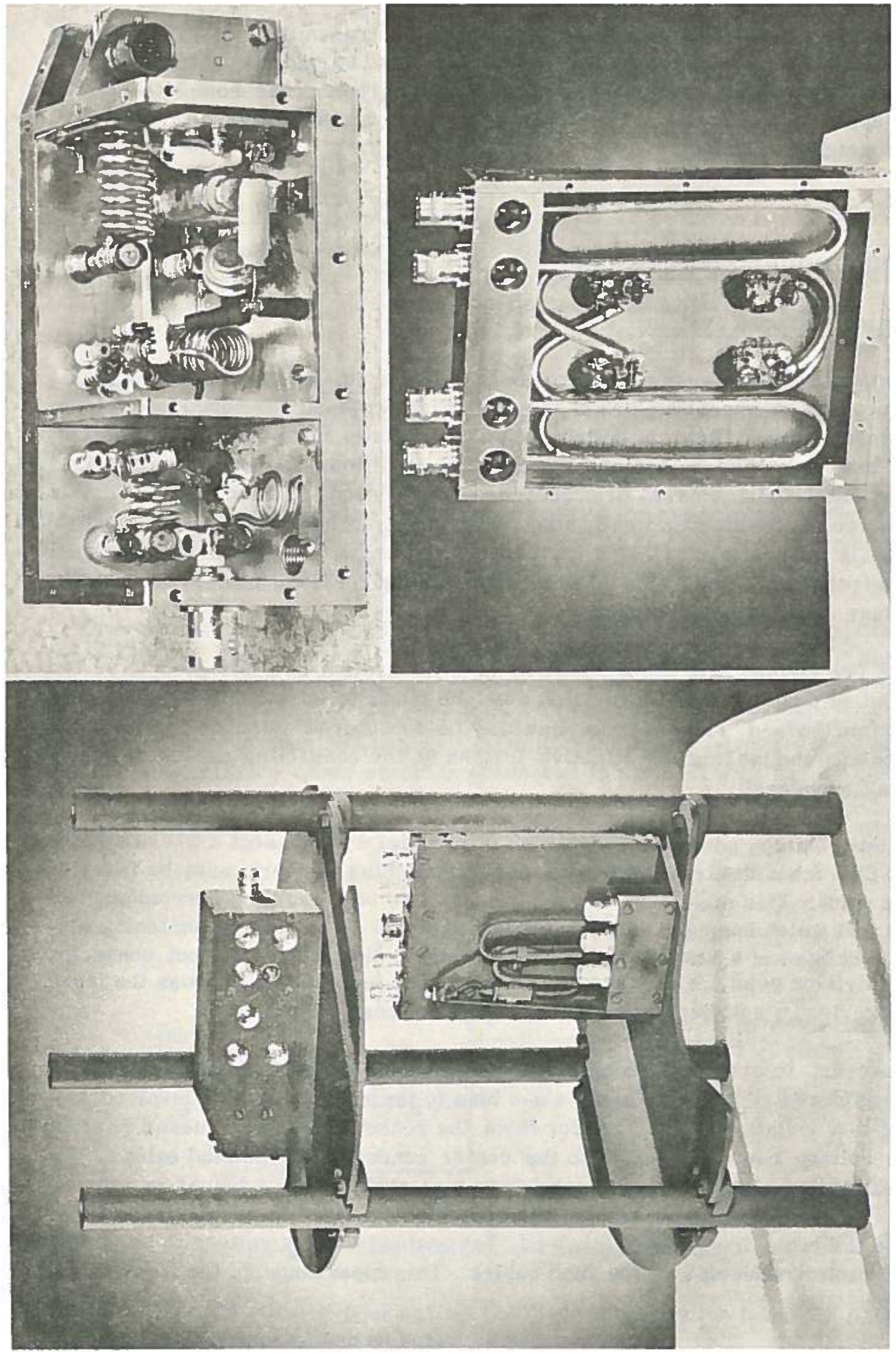

Plate I — Transistor telemetry system for Black Brant III rocket. (at left) The position of components in the rocket frame is shown. This section of the frame is 9½ inches in diameter. The one-watt solid-state transmitter is on the upper deck; the power-splitter is in front of the cross-monitor on the lower deck. The remaining space will be occupied by instrumentation for monitoring rocket performance. (at right, above) interior of transmitter (below) interior of cross-monitor.



## Blade Antenna System

Since both the telemetry transmitter and the quadraloop antenna system have yet to be flight tested, and since it is important that the telemetry on the first two Black Brant III firings be very reliable, these two rockets will also carry a vacuum-tube transmitter operating on a different frequency, and feeding a blade antenna system similar to that used in Black Brant II. The antenna has been improved by casting the blades from stainless steel, and the insulating material at the base of the blade has been changed. In place of the resin and sand mixture previously used, the blade is held in position by blocks of alumina. (Alumina must be cut with a diamond saw; hence the shapes obtainable are limited.) The space between the blocks is then filled with Sauereisen Cement No. 31. The cement itself is capable of withstanding a temperature of 1500°F, and even if it should disintegrate, the blade would still be held by the alumina blocks.

The matching network is fastened securely to the back of the cup in which the blade is mounted. This network is necessary because the blade antenna is not adjustable in length and, in any case, is much shorter than a quarter-wavelength. The matching network must be quite compact, since the space available is limited. The base of the antenna and the matching network must not project more than 2 inches inside the rocket so as to avoid fouling the motor starter, and must not be more than $1\frac{1}{4}$ inches in diameter. The most compact arrangement was obtained by using a short-circuited stub at the base of the blade, a short length of transmission line, and a second short-circuited stub at the input connector. All connections are made within a solid brass junction block and the mineral-insulated copper-sheath transmission line and stubs are wrapped around the junction block to fit inside the $1\frac{1}{4}$-inch-diameter space. In order to protect the stubs from vibration, the whole network is then potted in foamed plastic to form a cylinder, with the connector at the inner end.

The three blade antennas are fed in 120-degree phase sequence; this produces a circularly polarized field concentrated mainly in the fore and aft directions. As before, the phasing is obtained by making one feed cable one-third wavelength shorter, and another one-third wavelength longer than the middle length. In this case a three-way power splitter is required, but since bias is not required on the blade antennas, the simpler type of construction is used.

## Cross-monitor

The presence of two transmitters in the rocket and the availability of spare telemetry channels offered an opportunity to monitor the operation of both the transmitters and the antenna systems to which they are connected. Thus, if one telemetry link should fail, some indication of the probable area of failure would be transmitted by the other link. The cross-monitor (Plate I) devised to provide such information to the transmitter modulator consists essentially of two dual directional couplers, one for each transmitter, and detectors on the four coupled outputs of the couplers.

The radio-frequency power from a transmitter passes through the appropriate directional coupler where a small sample is fed to the associated detector. This detector then produces an output voltage proportional to the voltage of the radio-frequency output passing from the transmitter through the coupler to the antenna. The power reflected back from the antenna, in turn, produces an output in the other detector of the pair. Thus, one detector monitors the transmitter power output, while the ratio of the outputs of the two detectors indicates the proportion of power absorbed by the antenna, and hence the quality of the antenna matching. The other dual coupler, with its associated detectors, performs a similar function with respect to the second transmitter and antenna system.

As a bonus from this arrangement, it was found that the detector outputs from the cross-monitor were a valuable aid in tuning the transmitters, and also in making final adjustments to the quadraloop antenna system. In fact, in the later rockets, which will carry only one transmitter, a monitor consisting of a directional coupler and two detectors will be incorporated for pre-flight alignment and checking.

References

1. IRIG Telemetry Standards Document 106-60, Inter-Range Instrumentation Group, White Sands Missile Range, New Mexico, April, 1961
2. Pulfer, J.K. and Lindsay, A.E., "A preliminary report describing a transistor telemetry transmitter", NRC Report ERB-598, January 1962



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## TELEMETRY ANTENNA SYSTEM FOR BLACK BRANT III ROCKETS

- F.V. Cairns -

### INTRODUCTION

Black Brant III rockets are being developed jointly by Bristol Aero-Industries Limited, the Department of Defence Production, and the Defence Research Board. The National Research Council's contribution is the development of the radio-frequency portion of the telemetry system (see Bulletin, vol. 11, no. 2, p. 1). The development of the antenna will be described below. The design of the antenna involves structural and aerodynamic as well as electrical factors, and therefore the responsibility was shared between the National Research Council and Bristol Aero-Industries Limited. Our responsibility was primarily that of assessing the problem from the point of view of telemetry operation and proposing and designing an antenna. Bristol Aero-Industries Limited was responsible for ensuring that the antenna was structurally and aerodynamically suitable for the Black Brant III rocket and for providing information on aerodynamic heating necessary for the design of the antenna.

Bristol's preliminary estimates of the performance of the Black Brant III rocket indicated that the velocity would be approximately 7500 ft/sec (Mach 7) at an altitude as low as 27,000 feet on some test firings. The estimated maximum nose cone skin temperature in the area where the antenna would be attached was 1400°F, and projections from the skin might be expected to reach temperatures in excess of 2000°F on these test firings. Aerodynamic heating and drag, therefore, appeared to be very important factors in the antenna design.

The main design requirements for the antenna were:

1) low drag (estimated maximum projection, 1 sq. in.),
2) operation across telemetry frequency band of 215-260 mc/s, preferably without adjustment,
3) VSWR less than 2/1,
4) power-handling capacity of 5 watts,
5) radiation pattern to be suitable for rocket-to-ground telemetry,
6) weight to be less than 2 lb.,
7) impedance and radiating characteristics not to be affected by aerodynamic heating or mechanical forces of a firing,
8) impedance and radiation characteristics not to be affected by the rocket ablative coating (since the coating would be removed or charred in flight),

9) antenna to be compatible with, and preferably removable from nose cone fairing,

10) strength to be adequate to survive forces encountered on any Black Brant III firing.

The antenna chosen, after consideration of a number of types, was an L-transmission antenna. This antenna was studied by Prasad and King [1] and has been developed into a rocket antenna by workers at New Mexico State University [2]. It appeared to be potentially capable of meeting the low drag and radiation pattern requirements, and it seemed likely that acceptable compromises on other requirements could be made.

This antenna has been called a "Quadraloop", following the terminology of New Mexico State University, and consists of two shunt-fed radiators mounted on diametrically opposite points of the rocket skin and fed out-of-phase.

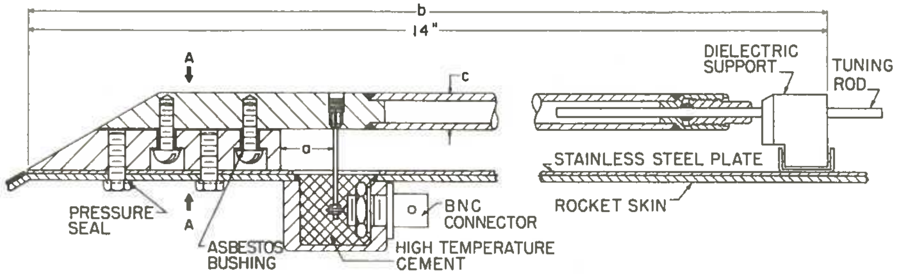


Fig. 1 Details of quadraloop antenna

## DESCRIPTION OF ANTENNA SYSTEM

The antenna system mounted on a Black Brant III rocket nose cone is shown in Plate I. The blade antennas on the nose cone are for a "back-up" telemetry system installed for the first two test firings (see Bulletin, vol. 11, no. 4, p. 6). A sketch of the quadraloop antenna is shown in Fig. 1. The antenna system consists of two quadraloop radiators fed through a matched power divider. A relative phase shift of 180° is obtained by connecting the radiators to the power divider with cables differing in length by a half-wavelength.

The materials for the antenna were believed capable of withstanding the expected temperatures. The radio-frequency characteristics of the asbestos bushings, potting cement, and ceramic support were tested to temperatures of over 1400°F. Stainless steel was used for the current-carrying portion of the antenna because good conductors, such as aluminum or brass, were not expected to be strong enough at the anticipated temperature.

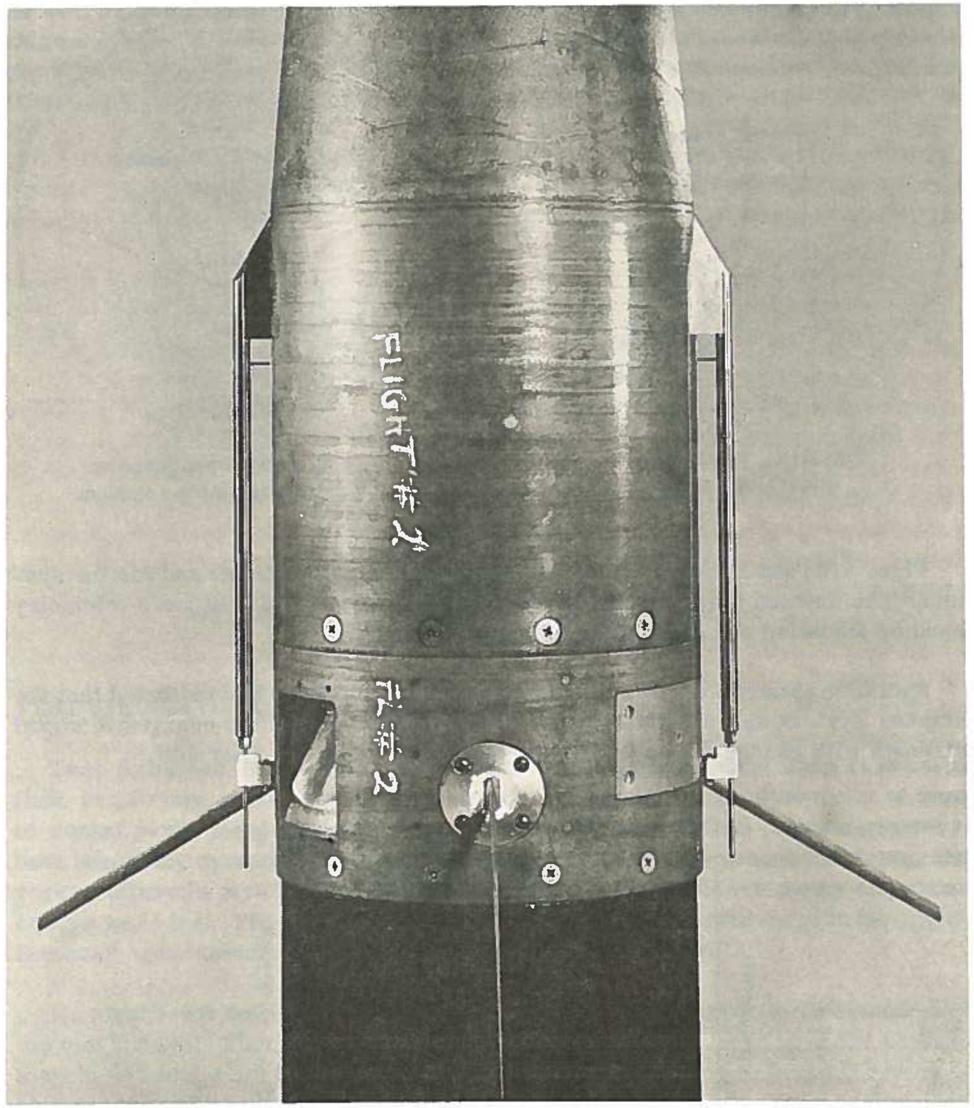


**Plate I — Quadraloop and three-blade antenna systems mounted on nose cone of Black Brant III rocket. The blade system was added on the first two firings to provide duplicate telemetry, since the quadraloop system had not previously been used on a rocket flight. (The receptacle for the break-away connector is near the lower end of the left-hand quadraloop.)**

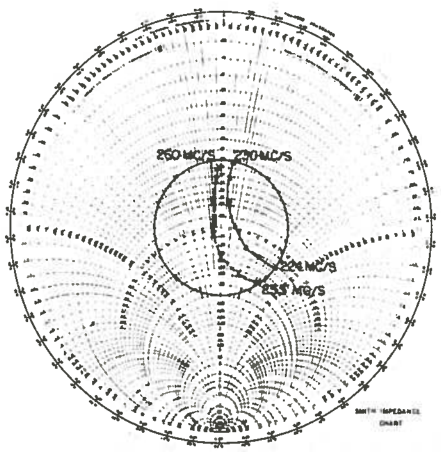

Fig. 2(a) Impedance of quadraloop antenna

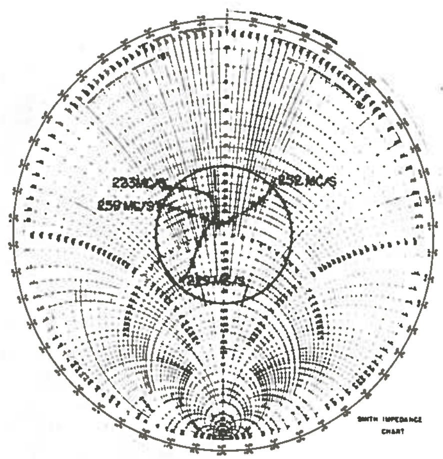

Fig. 2(b) Impedance of quadraloop antenna system

Figs. 2(a) and 2(b) are impedance plots for a single antenna and for the system. The antenna may be tuned to any frequency in the 215-260 mc/s telemetry band by adjusting and locking the tuning rod.

Radiation patterns were measured on a $\frac{1}{8}$-scale model. They indicated that the antenna system was satisfactory for rocket telemetry, as the changes in signal strength with change of rocket attitude were believed to be tolerable.

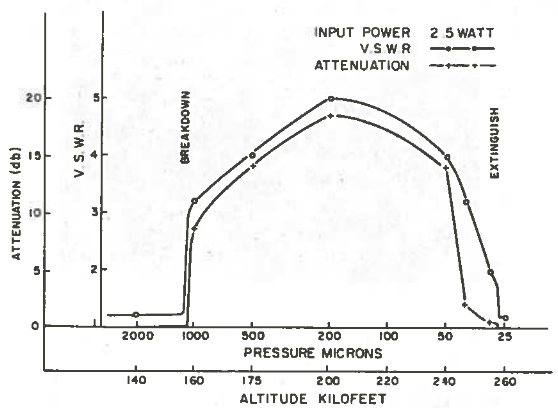


Fig. 3(a) Attenuation and VSWR of quadraloop antenna against pressure

A brief survey of the literature [3, 4, 5] on radio-frequency voltage breakdown at low pressure indicated that this factor would limit the power-handling capacity of the antennas. Since voltage breakdown depends on antenna geometry,



as well as other factors, measurement of the breakdown voltage of this antenna was necessary. A negative bias of 30 volts was applied to the antennas to increase their power-handling capacity. Results of voltage breakdown measurements made in an evacuated bell jar are shown in Figs. 3(a) and 3(b).

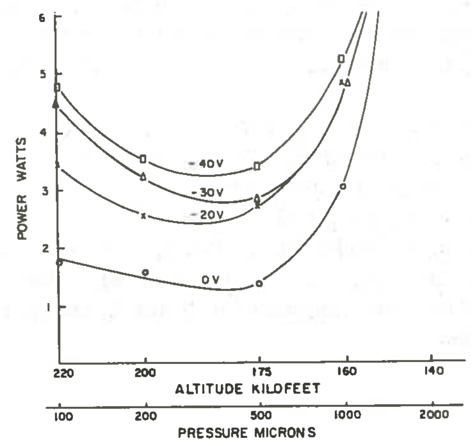


Fig. 3(b) Breakdown power plotted against pressure (altitude) for biased quadraloop

## TEST FIRINGS OF BLACK BRANT III ROCKETS

Test firings of Black Brant III rockets were carried out in June 1962. The first two firings were considered generally satisfactory from the point of view of rocket performance. Telemetry operation on these firings was satisfactory, both telemetry systems operating throughout the flights. On the third firing, the rocket suffered a disturbance early in the flight, after which telemetry and radar contact were lost. The fourth firing also suffered a disturbance early in the flight. However, good telemetry continued to the end of this flight.

No significant defects in the antenna system's performance were revealed by the test firings. There were indications that aerodynamic heating of the antenna may have been more severe than expected. Expansion due to heating seems to have caused an impedance change which is undesirable, but not serious. Received signal strength records were taken during all firings. Radiation pattern details could not be confirmed on these test firings as the rocket attitude was not monitored. However, the variations of signal strength were qualitatively in agreement with those indicated by the measured radiation patterns, and breaks in the telemetry records due to the shape of the radiation pattern were negligible.

The nominal power output of the transmitter used on the test firings was 1 watt. The telemetry and signal strength records indicate that voltage breakdown did not take place.

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Vol. 12 Ottawa, July 1962 No. 2

# A TELEMETRY GROUND RECEIVING STATION

- L.G. Cox -

## INTRODUCTION

The Radio and Electrical Engineering Division provides engineering co-ordination and assistance to research groups carrying out work in the field of space research (see Bulletin, vol. 11, no. 2, p. 1). As part of this program, the Division has supervised the production of a telemetry package for use in Black Brant II high-altitude rockets to telemeter the experimental and vehicle performance quantities to a ground recording station. The basic telemetry package has ten voltage-controlled FM subcarrier oscillators with center frequencies ranging from 3.9 kc/s to 70 kc/s. The controlling voltages for nine of the oscillators are derived from transducers which convert physical quantities to voltage analogs. The controlling voltage for the oscillator that operates at the highest frequency is supplied by a commutator which sequentially samples up to 25 slowly varying quantities. The outputs of the ten subcarrier oscillators are combined in a resistive mixing network and used to frequency modulate a transmitter in the telemetry band of 216-260 mc/s.

The Fort Churchill rocket range is normally used for firing Canadian rockets, the Wallops Island range being used in special circumstances. At either of these ranges the FM/FM telemetry signals from the rocket are received and demodulated, and the composite "video" signal comprising the mixed subcarrier frequencies is directly recorded on one track of an instrumentation tape recorder. Seven tracks are available on a standard tape recorder using half-inch magnetic tape, and the other six tracks are used for other telemetry channels, accurate range timing, signal strength, countdown, and other necessary information. One or more copies of the tape are given to the range user, and the tape processing and data reduction are his responsibility.

## PURPOSE OF STATION

The telemetry ground station is designed as a multi-purpose installation. It is intended to be trailer-mounted for use as a receiving and recording station and as a telemetry check-out station at the rocket range, at universities, and at environmental laboratories. When used as a telemetry check-out station, there are complete facilities for adjustment or repair of the rocket telemetry system, and for the necessary calibration before flight.

Between flights the ground station is used for extraction of flight data from the magnetic tapes, and as normal laboratory test equipment. Preparation of a complete nose cone for flight requires extensive pre-flight testing for calibration, mutual interference, and environmental effects, and testing of the telemetry system as a whole.

## TELEMETRY RECEPTION AND RECORDING

The complete ground station is shown in Plate I and a block diagram of the station in Fig. 1.

A low-noise preamplifier located at the antenna amplifies the telemetry signals which are transmitted on one or more frequencies in the telemetry band. A multicoupler, located on top of rack no. 1, supplies signals to as many telemetry receivers as necessary. A spectrum display is used to examine the frequency spectrum of any of the receiver intermediate-frequency outputs, and gives an indication of the nature of any spurious or interfering transmissions. The video output of the receivers is normally recorded on separate channels of the seven-channel magnetic instrumentation recorder, along with range timing, countdown, signal strength, and other information. The recorder may be seen on the right side of Plate I. It operates with a tape speed of 60 in/sec, and when it is operated in the direct mode, the frequency response of each of the seven channels is ±3 db from 100 cps to 100 kc/s.

The video signal is also applied to a panoramic spectrum analyzer and a bank of discriminators. This spectrum analyzer has a logarithmic sweep covering 390 cps to 100 kc/s, and gives a spot check of the telemetry performance in terms of subcarrier relative amplitudes and frequencies. Each discriminator has an input bandpass filter to reject unwanted frequencies, and the single frequency-modulated signal is converted from a frequency analog to a voltage analog of the original physical quantity being measured in the rocket. A multiple-channel high-frequency direct-printing oscillograph recorder permits recording a few of the discriminator outputs while the rocket is in flight, for examination in flight or immediately after flight. A fluorescent lamp is used to intensify the paper recording so that the traces appear in a few seconds without processing, but the resulting record has low contrast and is unstable in ultraviolet light, such as light from ordinary fluorescent lamps. The remainder of the discriminator outputs will be examined during post-flight data extraction.

Normally, the modulating signal to the highest frequency subcarrier oscillator in the rocket is time-division multiplexed by means of a commutator which sequentially samples up to 25 quantities, plus in-flight calibrating voltages. A typical commutated waveform is shown in Fig. 2. It can be decommutated by hand from an oscillograph recording, but the process is long and tedious, and long strips of high-frequency oscillograph recordings are necessary to resolve the 300 pps rectangular waveform. An automatic decommutator, shown in rack no. 1 (Plate I), can do the work much more efficiently, and at the same time

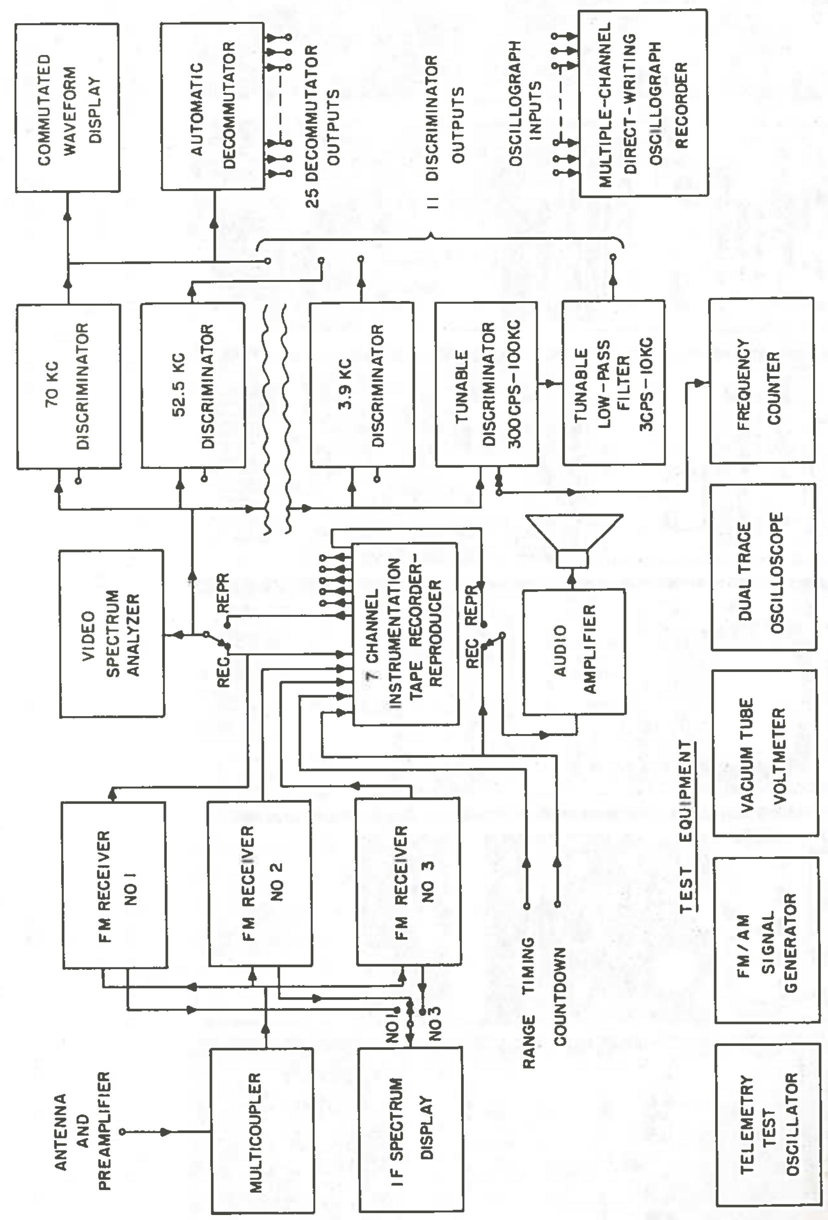


Fig. 1 Block diagram of telemetry ground receiving station

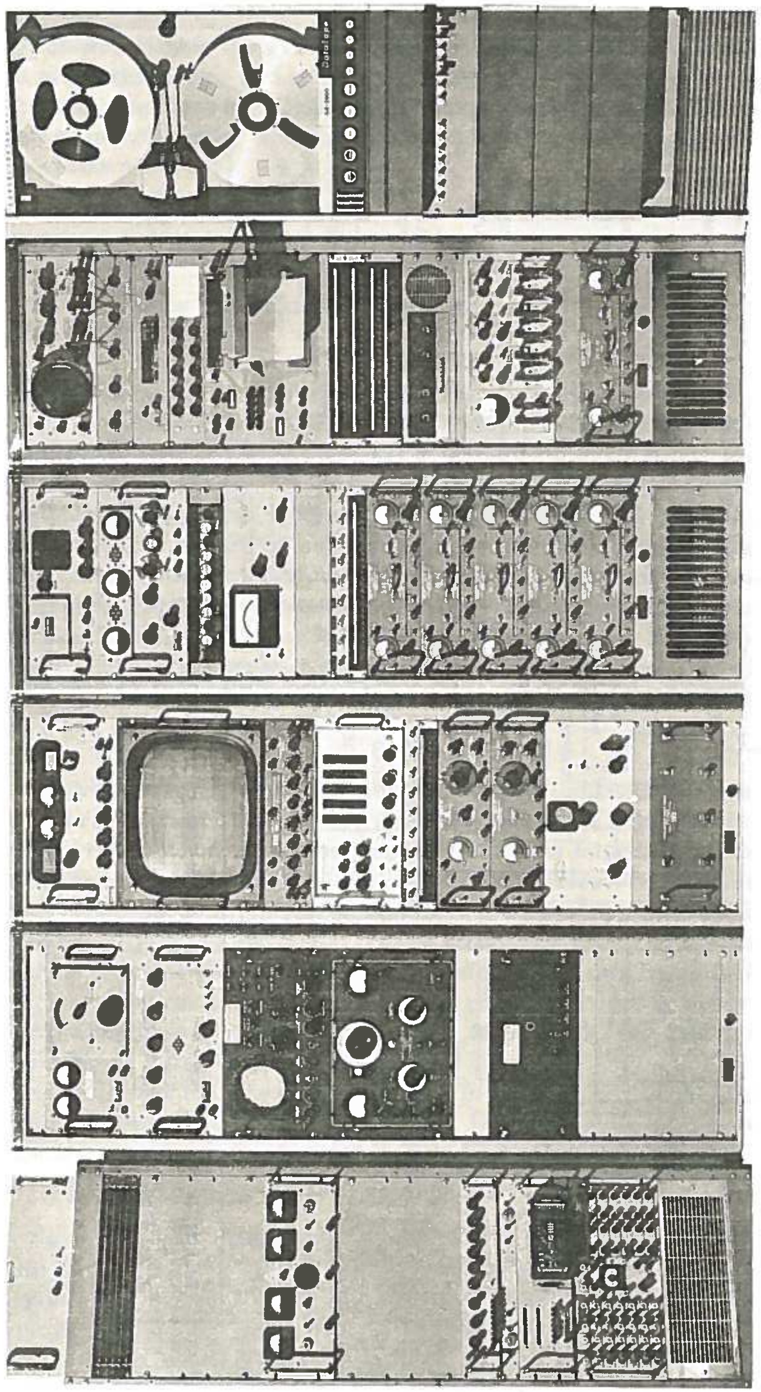

Plate I — Telemetry ground receiving and recording station. (left to right, top to bottom) rack 1: decommutator system; rack 2: receiver, video spectrum analyzer, signal generator; rack 3: receiver, commutated waveform display, frequency counter, tunable discriminator and filter, telemetry test oscillator; rack 4: i-f spectrum display, receiver, vacuum-tube voltmeter, bank of five discriminators; rack 5: general purpose oscilloscope, oscillograph recorder, audio system, bank of four discriminators; rack 6: tape recorder-reproducer



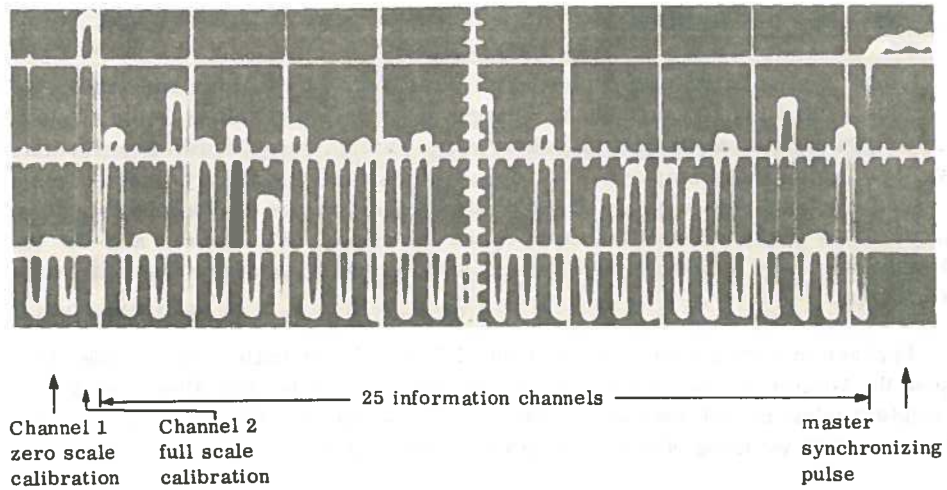


Fig. 2 Commutated waveform

introduce servo-controlled correction of zero and full-scale levels to compensate for subcarrier oscillator or discriminator drifts. The decommutator outputs, 25 in number, are at low frequency, and may be recorded on pen recorders. Two or more commutator channels, equally spaced on the commutator, may be cross-strapped to give a higher sampling rate. The input to the decommutator is displayed on a 17-inch oscilloscope.

## POST-FLIGHT DATA EXTRACTION

The composite video signal comprising ten subcarriers, nine modulated by continuous inputs and one by 25 commutated inputs, is recorded on one track of the magnetic tape during flight. After the flight, the magnetic tape reproducer is used as the signal source for post-flight extraction of the modulating waveforms of the subcarrier oscillators. A rack-mounted audio amplifier with a loudspeaker is employed to listen to the range countdown and intercom information, allowing the zero time on the tape to be easily located. Suitable combinations of discriminator and/or decommutator outputs are recorded simultaneously on the direct-printing multiple-channel oscillograph recorder, at the minimum paper speed necessary for the resolution of the highest recorded frequency. Photographic developing and fixing is used to produce permanent records.

If the modulation on the subcarrier channel has a high-frequency content, and it is required to record this on a low-frequency recorder, such as a pen recorder, the tape reproducer may be run at speeds as low as $1\frac{7}{8}$ in/sec. The subcarrier center frequencies are reduced by the same ratio as the speed, so it is necessary to use a tunable discriminator with a tunable low-pass output filter. A Gaussian (constant-delay) output filter is used with pulsed or commutated data, and a standard (constant-amplitude) output filter with other data. A roll-off rate beyond cut-off of 36 db per octave is used, because a higher roll-off rate will cause excessive ringing with pulse signals.

## RANGE TIME RECORDING

Range timing is recorded on one or two tracks of the magnetic tape. Both Wallops Island and Fort Churchill ranges have employed clock rates of either two or 100 pulses per second with their range timing, but with different formats. Wallops Island range employs WWV-type time codes, with binary-coded decimal time-of-day and day-of-year. The two time-of-day codes at Wallops Island are accurate to within 0.5 milliseconds of the received WWV signal, and the fast time carrier may be interrupted for one-half second before zero launching time, if desired.

The fast timing code used at Fort Churchill was the so-called "G-2" code, which gave the time of day in seconds in binary-coded decimals. The slow timing could be interrupted for 30 seconds before zero time and re-started at zero giving binary-coded counting of 5-second periods after ignition.

Range timing is normally recorded on oscillograph records at low amplitude. If the paper speed is at least 4 in/sec the fast 100 pps timing may be used, but at lower speeds the 2 pps timing is recorded.

## OTHER EQUIPMENT

The various other pieces of equipment seen in the racks are used primarily in the laboratory or in checkout of telemetry prior to firing. Included in this category are a telemetry test oscillator with a frequency range of 200 cps to 100 kc/s, used to modulate the FM/AM signal generator which has a range of 195-270 mc/s. This combination is used to check transmitter frequency deviations due to individual subcarrier oscillators, by a substitution method. An a-c vacuum-tube voltmeter is used when setting up subcarrier oscillator output amplitudes. The discriminators have test points following the input bandpass filters, so that a frequency counter may be used to measure individual subcarrier frequencies in the composite signal. The dual-trace oscilloscope at the top of rack no. 5 has its own switching panel below, and is normally used to monitor the tape recorder or discriminator outputs, although it may be used for other purposes.

Both video and coaxial patch panels may be seen on several of the racks. The input and output terminals of all the equipment are connected to these panels, permitting rapid and easy change of the station function.



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# A NEW TEMPERATURE-ALTITUDE ENVIRONMENTAL CHAMBER

- R. Wlochowicz -

## INTRODUCTION

Environmental testing has played a major role in the development of reliable military equipment. Designers have been concerned with temperature, humidity, pressure, salt spray, and dust. They have studied the environments encountered in the accessible parts of the earth, and the vibration and shock to which packages would be subjected during transit and in the field. The simulation of temperature and humidity conditions favourable to the growth of insulation-destroying fungi, and the simulation of pressure and temperature conditions experienced by high-flying aircraft, are examples of past activities in this field.

Environmental testing is not confined to military equipment. The present wide-spread use of semiconductors with their inherent temperature sensitivity, the general demand for greater reliability in components and equipment, and particularly, the scientific probing of space through rockets and satellites, have made environmental testing a necessity rather than a facility. New environments are being created or discovered, and new chambers are being designed to cope with some of them.

Chambers for simulating both terrestrial and extraterrestrial environments are required. Whether these functions are embodied in a single unit or in separate units is primarily, but not solely, a question of application. In the case of terrestrial environments, where real conditions are relatively well-known, better control of the simulated parameters is demanded. In the case of extraterrestrial environments, only approximate simulation of conditions can be achieved. In spite of the ever-changing picture of conditions in space, considerable progress has been made over the past few years. Chambers, capable of accepting whole vehicles, can be evacuated to $10^{-10}$ mm Hg (700 km altitude), and are equipped with artificial solar radiation and walls cooled to a few degrees Kelvin. At least one very elaborate chamber is equipped with a gun capable of firing small particles at hypervelocities to simulate collision with micrometeorites.

Environmental chambers are available in wide ranges of size, performance, function, accessories, quality, and cost. From this selection, a unit in which the chamber and control console are integrated (Plate I) was chosen to provide environmental testing facilities in the Radio and Electrical Engineering Division. It has features which make it suitable both for general temperature-altitude tests, and for tests connected with the current upper atmosphere rocket sounding program.

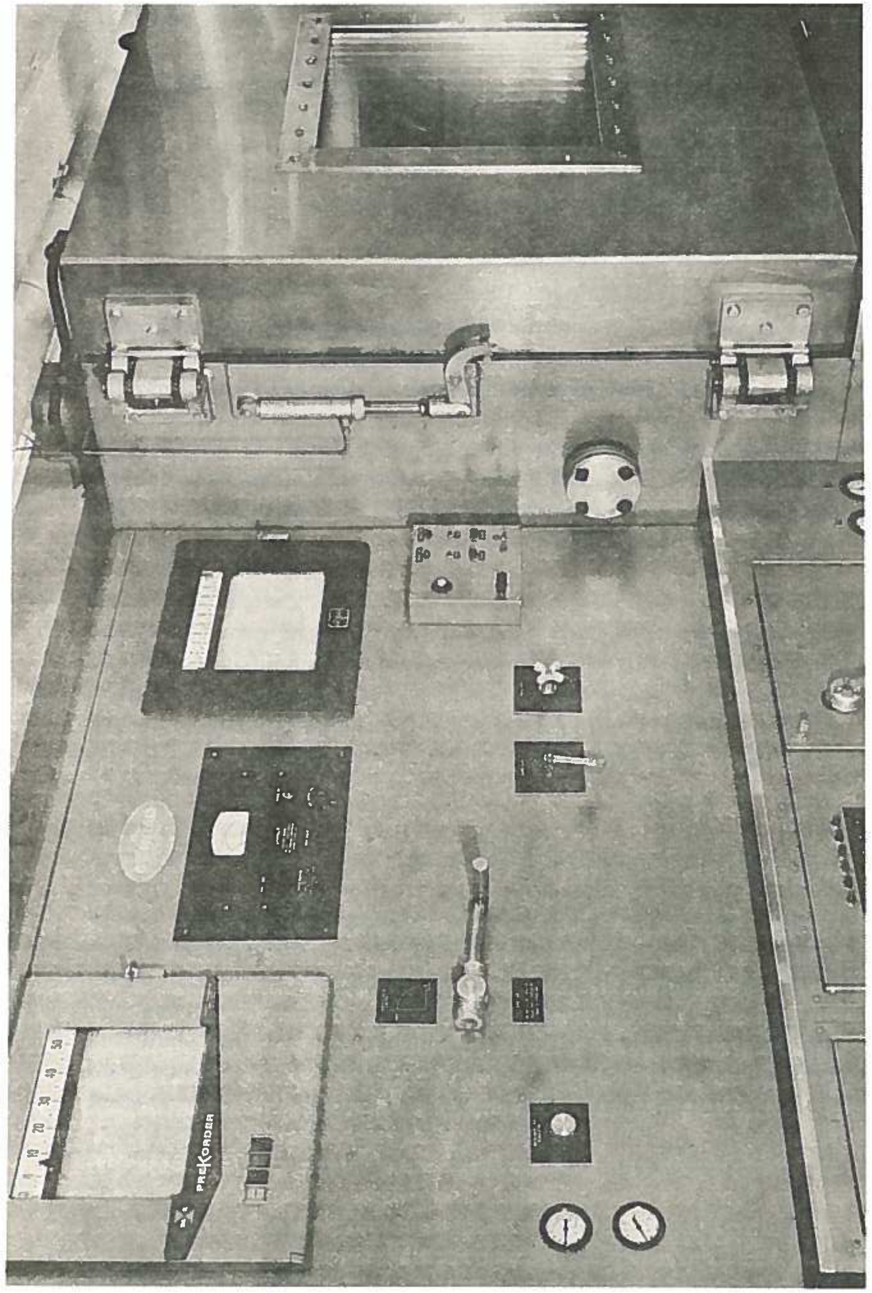

Plate I — Temperature-altitude environmental chamber

Control console: (top row) PreKorder temperature recorder-controller-programmer, pressure-measuring Alphatron ionization vacuum gauge, Bristol pressure recorder-controller (middle row) air supply and controlling air pressure gauges, air supply pressure control, roughing pump throttling valve, air bleed valves, temperature overshoot protective circuit (bottom) electrical panel with main power switch, refrigeration system gauges.

Pressure chamber: stainless-steel-covered door with multipane window, hydraulic closing system, flange and cover of one 5-cm-diameter port (at top) $\frac{3}{4}$ hp motor for air circulation.



## THE CHAMBER

The test space in which the temperature and pressure are controlled, is effectively a double chamber. The inner part, a light, stainless steel, vacuum-tight enclosure has a low thermal capacity — a decided advantage for rapid temperature changes. The outer chamber, the actual pressure vessel, consists of a grid of heavy members covered with steel plate 0.85 cm thick. The two chambers are separated by 23 cm of inorganic insulation, and both the inner chamber and the insulation area are pumped during the vacuum runs. A cubical work area, nearly a meter on edge, is available within the inner chamber. The large stainless-steel-covered door provides full access to the work area; that is, objects with the dimensions of the work area can be inserted for testing. Note the large, multi-pane window centrally located on the door. It is nearly two-thirds of a meter on edge, and provides an excellent view of the test area. This feature is particularly useful for observing electrical breakdown at low pressures.

Other access points are three 5-cm and one 10-cm diameter ports. One of the 5-cm ports is visible in Plate I. The other two are located on the far wall: one horizontally opposite and directly in line with the visible port, the other, directly above that. This arrangement allows for the passage of light beams through the chamber, should this be necessary. The 10-cm port is centered on the far wall; it is sufficiently large to accept waveguide. On the outside, the ports are terminated in flanges to which solid cadmium-plated covers are bolted. No electrical feedthroughs are built into the chamber; instead, these may be part of fixtures which replace the covers and which are custom made for the particular application.

The vacuum seal at the door is achieved through the compression, due to atmospheric pressure, of a neoprene gasket. Initial pressure is applied by a small hand-operated hydraulic system.

## VACUUM SYSTEM

The vacuum system consists of a rotary, mechanical, roughing pump, a 6-inch diffusion pump, a forepump, and pressure monitoring, recording, and controlling instruments. Two modes of operation are provided: low altitude and high altitude. In the former mode, the roughing pump alone is active; it evacuates both the inner chamber and the insulation area. In the latter mode, the roughing pump evacuates both areas until the pressure drops to 0.3 mm Hg. At this pressure, the diffusion pump automatically cuts in; it evacuates the inner chamber while the roughing pump continues to evacuate the insulation area. With a clean, empty chamber, after prolonged pumping, minimum pressures obtained have been $1.7 \times 10^{-2}$ mm Hg (80 km) with the roughing pump alone, and $5 \times 10^{-5}$ mm Hg (110 km) with both roughing and diffusion pumps.

Pressure is measured with an Alphatron ionization vacuum gauge which has a radioactive ionizing source. The advantage of this instrument is that the measured ionization current, and hence the voltage output from the gauge, is linearly related to pressure. The absolute value of the output is, however, dependent on the nature of the gas and is, therefore, sensitive to contaminants. The output voltage is fed to a Bristol strip chart recorder-controller.

A disc and a microswitch in the Bristol instrument control the pressure. The relative position of the depressed portion of the disc is dependent on both the positions of the set pointer and of the recording pen. Since the Alphatron has six ranges from 1000 mm Hg to $1 \times 10^{-3}$ mm Hg, in multiples of ten, for full scale deflection, control is possible over the whole pressure range. Control is maintained by allowing air to flow into the chamber through manually set valves. By setting these valves carefully, pressure fluctuations at a set pressure can be kept very small; in fact, they can be eliminated.

The chamber is not suitable for simulating pressures encountered with diving aircraft, since the flow of air back into the chamber must be balanced; particularly, the pressure in the insulation area must not be allowed appreciably to exceed the pressure in the inner chamber which has little mechanical strength. A safety device exists to prevent accidental rise in differential pressure.

## TEMPERATURE SYSTEM

A cascade mechanical refrigeration unit, 9-kw heaters, an air circulator, and a PreKorder are the major components of the temperature system. The refrigerant, freon 13, flows through the main cooling coils and copper tubing in contact with the underside of the floor in the test area. The cold floor is intended as a heat sink for experiments conducted in vacuum where convection cannot provide cooling. Present temperature limits are -76°C to +260°C. It is planned to extend both limits when the need arises, by using radiant heating and by lining the inner chamber with a shroud through which liquid nitrogen or helium can be circulated.

The PreKorder, a strip chart recorder-controller-programmer, is the heart of the system. Through the program and an electro-pneumatic transducer, it governs the heat flow into, and out of the test area. An important feature of the instrument is the nature of its program. In essence, it consists of two parallel pencil lines drawn on the program chart which underlays the translucent recording chart. The lines must be continuous, as they are electrically active. The pen acts as an electrical probe, but its position is determined by the temperature in the chamber. The regulating electrical output, a function of the position of the probe relative to the pencil lines, ceases when the pen or probe reaches the equilibrium point midway between the lines; that is, when the chamber temperature is the programmed temperature. Programs can be loops for cyclic operation or continuous for more complex, non-repetitive tests; they can be drawn to cover the whole temperature range.



At the time of installation, the only protective device against a breakdown in the temperature-controlling instruments was a high-temperature 260°C cutout. This has since been supplemented by a protective circuit which will stop the test if any of its three elements operates. The elements are:

1) a microswitch which can be tripped by an adjustable arm, located on a disc directly coupled to the movement of the PreKorder pen, and which can be set for any temperature limit;
2) an adjustable thermostat, with its probe mounted in the chamber, which will operate at any set temperature;
3) a small thermostat which can be mounted on the instrument package under test.

## TEST SPACE

The dimensions of the test space are 0.91 m × 0.91 m × 0.91 m.

## PERFORMANCE

### Temperature

| | |
|---|---|
| Range: | -75°C to +260°C |
| Pull-down time: | 20°C to -75°C in 1 hour (200-watt load) |
| Heat-up time: | 20°C to 260°C in 45 minutes |
| Control: | may be programmed over whole range |
| Stability: | ±1°C |

### Altitude

| | |
|---|---|
| Ultimate altitude: | 110 km ($5 \times 10^{-5}$ mm Hg) |
| Pumping rate: | 0 - 32 km (8.2 mm Hg) in 6 minutes |
| | 0 - 96 km ($7 \times 10^{-4}$ mm Hg) in 16 minutes |
| Control: | set altitude will be maintained but cannot be program-controlled |

The performance of the chamber exceeds the manufacturer's specifications. The vacuum and temperature systems can function separately or simultaneously, but simultaneous operation is limited to 20 km altitude, above which the air is too rare for effective temperature control. Controls and protective devices are sufficient to allow long periods of unattended operation. Records of experiments are being filed for future reference, and a number of minor modifications are being planned to increase the versatility of the unit.

Vol. 13 Ottawa, April 1963 No. 1

# A ROCKET-BORNE ACOUSTIC MICROMETEORITE DETECTOR

- R. Wlochowicz -

## MICROMETEORITES

Matter of extraterrestrial origin accumulated by the earth at a rate conservatively estimated at 1000 tons daily, consists largely of particles known as micrometeorites. Their distinguishing physical property is small size, and consequently a high ratio of surface area to mass. Since heat radiation is proportional to area and kinetic energy is proportional to mass, these particles can retain a low temperature while radiating the heat generated during collision with the earth's atmosphere. Their entry is uneventful, as the particles decelerate producing no measurable amount of light or ionization.

The details of the nature and distribution of micrometeorites are still essentially unknown. Photographic, photoelectric, and radio techniques [1] developed in investigating the properties of the larger particles are based on the detection of light or ionization and are not suitable for micrometeorite studies. Our knowledge of micrometeorites, until recently, has been obtained indirectly by extrapolation of measurements made on the larger particles, by observation of the zodiacal light [2], and through the collection of iron spherules from the atmosphere [3], land sediments [4], and deep sea deposits [5].

## MICROMETEORITE DETECTORS

The advent of space travel has stimulated interest in interplanetary matter because of the potential hazard to space vehicles. Rockets and satellites have also given the experimenter the means for placing instruments in remote environments. This investigating technique can provide direct measurements on micrometeorites through systems capable of detecting the impact of these minute particles on a specific sensing surface. Except for the unique "Venus Flytrap" experiment [6] in which many particles were captured by a recoverable nose cone, the many detectors flown can be considered, for simplicity, merely variations within two basic groups: the momentum detectors and the energy detectors. The former respond to momentum transfer manifested by the creation of elastic waves in the target material. The latter respond to energy transfer manifested by deformation and the generation of heat or light.

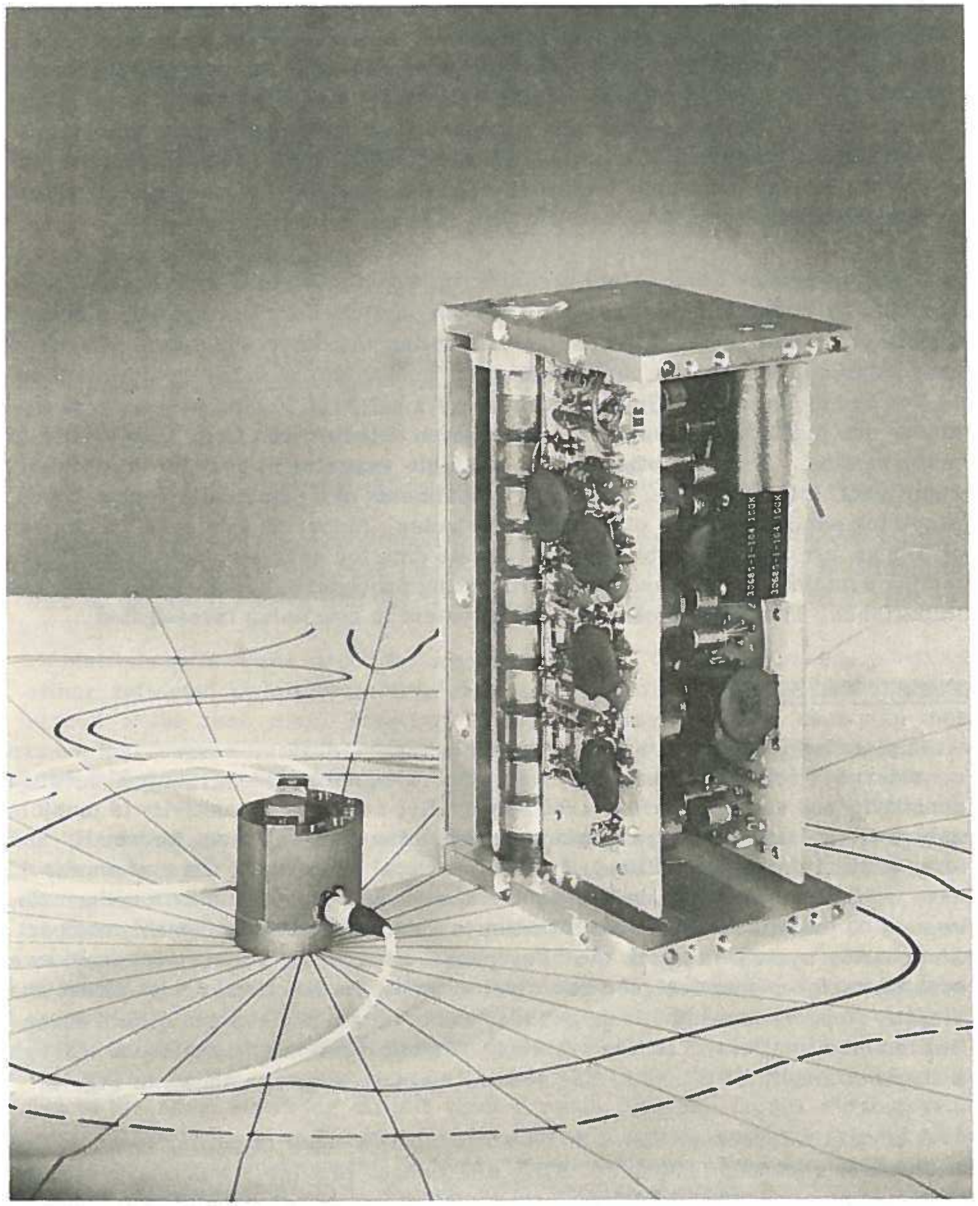

Plate I — The rocket-borne acoustic micrometeorite detector. The crystal microphone appears at the left. The large unit at the right is the electronic system for processing signals prior to transmission. In use, the crystal face of the microphone is in contact with the rocket nose cone.

Systems of the first group have in common a crystal microphone sensor which responds to the elastic waves [7]. Systems of the second group are more varied: (a) fine wire grids and thin-walled pressurized vessels evaluate puncturing hazards [8], (b) resistive films establish the cumulative effects of impacts through rate of erosion, (c) a mechanically resonant plate measures energy transferred by the impact through the amplitude of its vibration [9], (d) a photomultiplier measures energy converted to heat through the intensity of a hot spot produced by a particle striking a thin metallic film [10].

The discrepancy which exists in comparing results obtained with these systems undoubtedly is due to a real nonuniformity in particle distribution; but, a second significant factor is the difficulty in calibrating the devices because of lack of knowledge concerning the complex impact mechanism at meteoroid velocities, 11 km/sec to 72 km/sec. In the region above a height of 200 km, where measurements are made from satellites, and a given detector can have a useful life of many months, the data obtained from a single experiment may be statistically significant. Below 200 km, however, experiments are principally rocket-borne, providing sampling times of only a few minutes. Since, in this case, a number of firings are necessary to collect adequate data for analysis, a "standard" detecting system, with an associated calibrating procedure, becomes of paramount importance. The development of such a system is now being investigated.

## PRESENT SYSTEM

In planning a standard, micrometeorite detecting system, several factors are considered. From a measurement viewpoint, a compromise is required between sensitivity and sensing surface area. Generally, maximum sensitivity is feasible only with isolated sensing surfaces, which, of necessity, must be small, and offer lower impact probability. From a practical viewpoint, the system should have certain features. It should require a minimum of communication channels, be easy to install, require little attention in the field, and be reasonably compact. An acoustic system in which the microphone utilizes the rocket nose cone as a sensing surface, was designed as a first attempt. Its functions are to detect and classify impacts according to magnitude, and to obtain environmental data essential for modifications of future systems. The information is transmitted through a single commutated channel. The system's components are shown in Fig. 1.

A crystal microphone and a three-stage narrow-band amplifier tuned to the mechanical resonant frequency of the microphone provide the primary signals which are processed prior to transmission. High operating frequencies are chosen to minimize interference from rocket noise sources radiating at the lower end of the frequency spectrum. Both 100 kc/s and 50 kc/s units were built to evaluate the effectiveness of this approach.

At its highest level, the signal is processed by two detectors: one, with a short time constant, extracts the impact-induced pulse envelope; the other, with a time constant sufficiently long for its output to be unaffected by individual pulses,



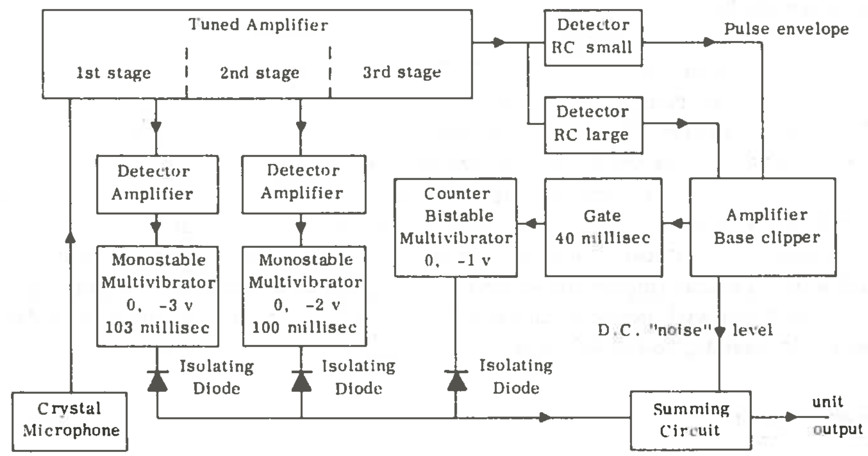


Fig. 1 Functional components of acoustic micrometeorite detector

produces a d-c voltage proportional to noise. False counts due to low-level noise are prevented by a signal base clipper, the clipping level of which is determined both by an initial setting and the d-c voltage from the detector.

Multiple pulses can occur for a single impact if the initial pressure wave is either reflected by discontinuities or not sufficiently attenuated in a complete circuit of the nose cone. A gating circuit eliminates multiple counts in these cases by responding to the first pulse and blocking the passage of subsequent signals for a predetermined period.

The output of the counter, basically a bistable multivibrator, alternates between values of "0" volts and -1 volt. Impact magnitude data is achieved by monitoring the signal levels after one and two stages of amplification. When the signal at these amplifier outputs exceeds a given threshold, one or both monostable multivibrators are excited. The duration of their excited states, represented by an output of -2 volts and -3 volts, as indicated, is adjusted to correspond to a commutator cycle. The -3 volt multivibrator's excited period is set slightly higher to insure that when it returns to its quiescent, or "0" volt state, the -2 volt multivibrator will have done so as well. All three multivibrator outputs are fed to the same summing circuit input through isolating diodes which prevent mutual interference and allow only the largest negative output to appear. The d-c level proportional to noise is fed to the second input of the summing circuit, and the transmitted signal is the sum of the two input signals.

A partially assembled 50 kc/s system and the associated microphone are shown on the front cover of the Bulletin. The system is connected by a latching relay to a self-contained nonrechargeable mercury battery of capacity sufficient for operation through several countdowns. In the final assembly the components are coated with a shock-absorbing resin and the unit is filled with a temperature-insulating potting compound. The electronic package, 6.3 × 8.5 × 14 cm, weighs 830 gm.

## CALIBRATION

Since facilities are not yet available for calibrating at meteoroid velocities, an arbitrary but reproducible calibrating technique was partly developed. The reference, a selected small polystyrene sphere, is dropped from a height of a few centimeters. The height is kept small to avoid deformation of materials during impact. The impact response, observed after two stages of amplification, is related to an equivalent electrical signal at the amplifier input. Sensitivity levels are subsequently determined in terms of electrical signals from a calibrator. Until a mechanical impact simulator is completed, the sphere-dropping phase of the calibration will continue to be used in determining the acoustic coupling between microphone and nose cone.

## FIRST FLIGHT

On April 5, 1963, two units were flown on a Black Brant rocket from Fort Churchill. The microphones were mounted diametrically opposite each other inside the nose cone's largest single section which provided a sensing surface of 1.3 $m^2$. In terms of incident momentum, threshold sensitivities effective over this area were $9 \times 10^{-3}$ gm cm/sec for the 100 kc/s, and $3.6 \times 10^{-2}$ gm cm/sec for the 50 kc/s system. These thresholds correspond to particle masses of $3 \times 10^{-9}$ gm and $1.2 \times 10^{-8}$ gm, respectively, at the reference velocity of 30 km/sec. Both units functioned throughout the six-minute flight. Preliminary analysis indicates no impact for particles larger than $6 \times 10^{-8}$ gm.

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# BLACK BRANT ROCKETS FIRED APRIL 5-6, 1963

- J.H. Craven -

On the night of April 5-6 two Black Brant rockets, sponsored by the National Research Council's Associate Committee on Space Research, were launched into the aurora over Fort Churchill, Manitoba, after months of preparation on the part of both the National Research Council and the universities associated with the Council in investigating the upper atmosphere by means of rockets [1].

In one rocket (Plate I), the University of Saskatchewan sent aloft three cylindrical packages which were ejected from the rocket after about a minute of flight. These packages each carried a probe antenna which was used to measure the fine structure of the electron density in the space near the rocket, but sufficiently far away to avoid any influence due to the rocket itself. The packages also contained telemetry transmitters to relay the information to the ground. In the other rocket, a smaller package designed to measure the potential gradient was ejected in a similar manner.

Both rockets carried magnetometers developed by the University of Alberta, which were specially designed to measure the fine details of the earth's magnetic field by filtering out the large steady component.

Within the Council several different groups were involved. The Cosmic Ray Section of the Division of Pure Physics was responsible for equipment designed to measure cosmic ray activity at high altitudes, with particular reference to its orientation with respect to the earth's magnetic field.

The Upper Atmosphere Research Section of the Radio and Electrical Engineering Division contributed three different configurations of plasma probes to measure the distribution of charged particles along the rocket's path continuously, and to obtain a comparison of the behaviour of these probes [2]. In addition, sensitive microphones were fastened to the surface of one of the nose cones to detect micrometeorite impacts [3].

The Space Electronics Section of this Division was primarily responsible for the integration of all the different electronics systems into a compact and smooth-working system, to ensure that different operations were started or stopped at specific times, and that all the information gathered by the rocket and its ejected packages was transmitted to the ground to be recorded for future processing and assessment [4]. In addition, this Section installed in the rockets other devices designed to convey knowledge of the rocket's attitude and motion, and tested the operation of experimental devices for possible use in future rocket flights.

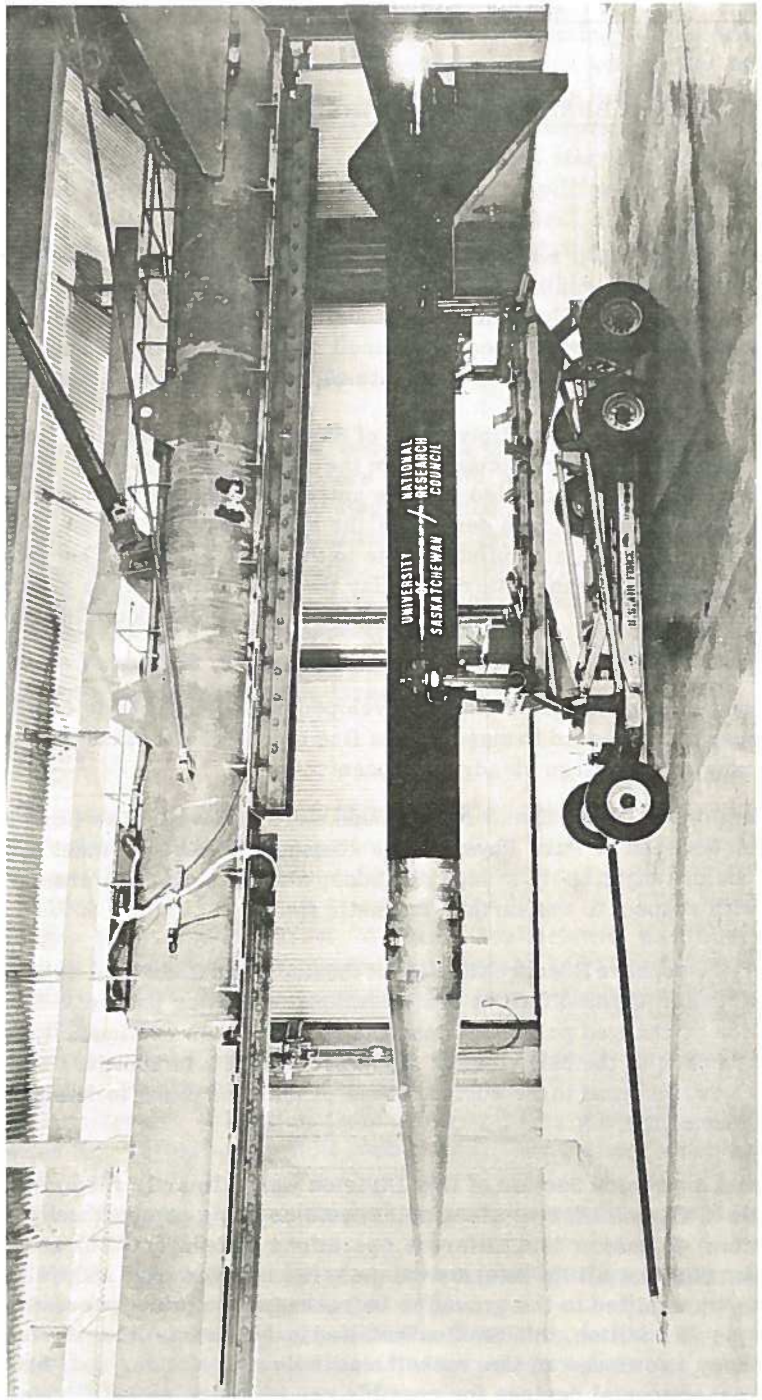


Plate I — Rocket AD-I-23 ready for mounting on launcher

Churchill Research Range Photo



ROCKET AA-I-26

The first rocket fired was that designated "AA-I-26" and generally referred to as the "NRC rocket", since the major experiments carried were of NRC origin, involving cosmic ray, plasma probe, and micrometeorite equipment. Lift-off took place at approximately 10:03 pm on April 5, into almost ideal auroral conditions, with visual aurora, radio absorption, and spectral emission all present. The flight lasted about six minutes and the rocket attained an altitude of 470,000 feet (90 miles), with performance very close to that expected (Fig. 1).

The cosmic ray packages operated satisfactorily and a large amount of data were received. This has been re-recorded in a more suitable form for the Cosmic Ray Section, and they are carrying out further reduction. Attitude information on this rocket is inadequate, so that correlation of cosmic ray intensity with respect to the angle of the earth's field may be difficult. The magnetometers intended to provide this information failed to function. It is believed that a faulty relay caused this failure. Some temperature measurements were also lost from the same cause.

The plasma probe experiment consisted of four Langmuir probes on the nose cone, two fixed and two extendible, designed to measure electron density, temperature, and spatial structure of the aurora. Checkout revealed a short-circuited cable in one of the extendible probes, but as conditions were so close to ideal it was decided to fire the rocket without repairing this probe. The extendible probes, timed to be released at a height of 70 km, operated at about 35 km. Despite the severe aerodynamic stresses sustained, they apparently survived. All three of the operating probes gave good data throughout the flight. It is hoped that from the data from the plasma probes and telemetry signal strength records, some rough indication of attitude may be deduced. At the moment only roll rate has been inferred.

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

The ejection of the University of Saskatchewan potential gradient package was accomplished successfully at the desired time. The telemetry signal received on the ground indicated that the transmitter was functioning after ejection. Signal strength records show a rapid fluctuation for a few seconds after ejection, and also later on at a time consistent with the package's re-entry into the atmosphere. This is attributed to flutter of the thin, flat, monopole antenna by aerodynamic forces. The signal strength received at the ground was some 10 db below that expected, and as a result some difficulty was experienced in getting any useful information from the signals.

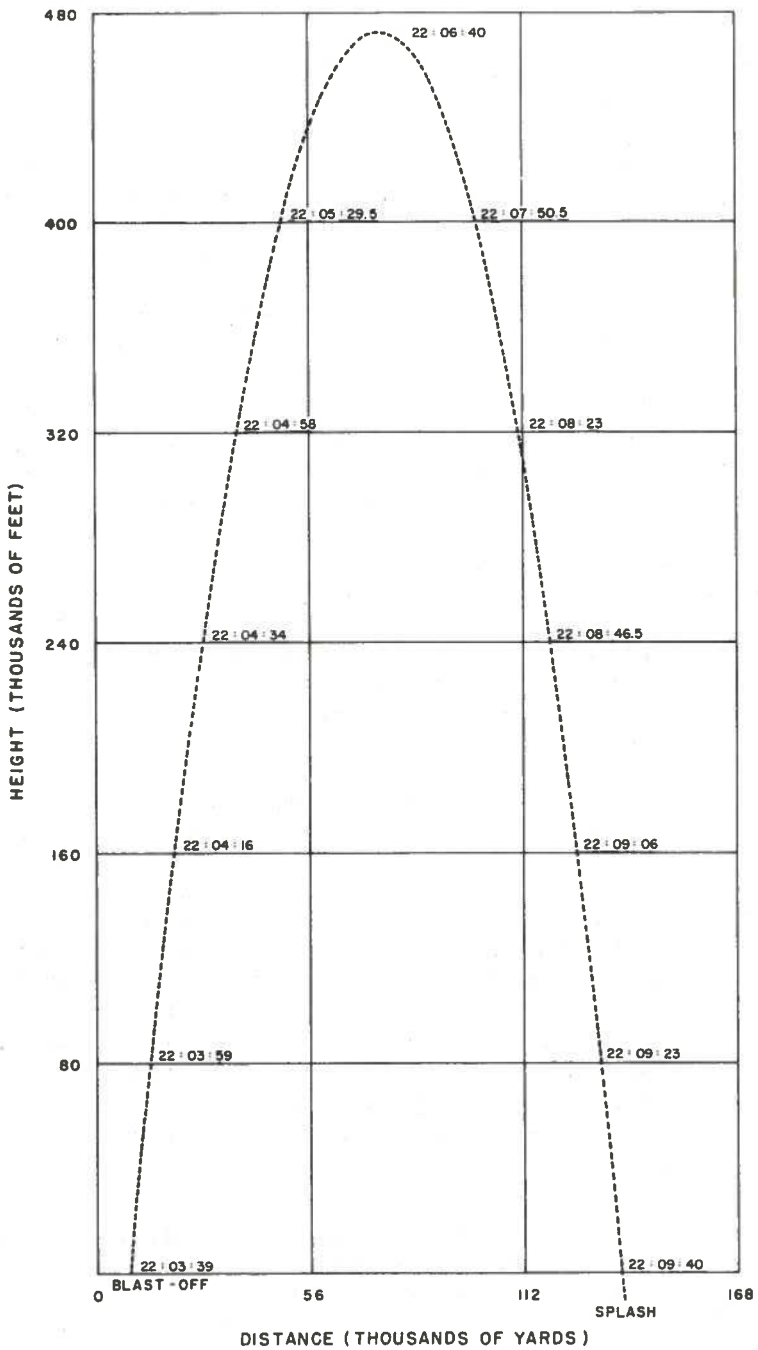


**Fig. 1 Trajectory of AA-I-26 rocket from radar plot**



Measurements of the accelerations to which the packages within the rocket were subjected were obtained from three mutually perpendicular accelerometers. Values were of the order expected, so that it appears that no excessive stresses were applied to the payload.

As a possible aid to visual and photographic tracking of rockets, a light was installed on this vehicle. The light was designed to be extended from the side of the rocket when the denser atmosphere had been left behind. A monitor was provided to give an indication of the operation of the light. Results showed that the light was extended at the correct time, and that it remained lighted until about 95 seconds after lift-off. Failure was probably due to burn-out of the bulb. No photographic results were obtained from ground stations at Belcher and O'Day (about 35 miles to the south) owing to poor visibility.

The rocket was equipped with a beacon transponder to facilitate radar tracking. The beacon operated perfectly and the radar plot was continuous from lift-off to splash. This meant that the position of the rocket was known at all times in the flight.

The pressure in the sealed nose cone was maintained during the flight. The monitoring circuit indicated this satisfactory condition, which was confirmed by the proper operation of the telemetry equipment.

ROCKET AD-I-23

The second rocket was designated "AD-I-23", but was generally referred to as the "University of Saskatchewan rocket", since the major experiment was the ejection of the electron density packages designed by the University. As the result of excellent teamwork by all concerned, this rocket followed the first one off the same launcher in less than 3½ hours, so that it lifted off at 1:25 am on April 6. The time of flight and altitude attained were very similar to those of the first rocket. By this time the auroral conditions had subsided to a lower level.

The three electron density packages were ejected at the correct times and all three transmitters were picked up by the ground receivers. Here again, as with the potential gradient package, there was a pronounced flutter of the received signals for a few seconds after ejection, and again at a time about expected re-entry into the atmosphere. Here too the received signal was some 10 db below the expected level.

An interesting possibility came to light when an attempt was made to explain a sudden reduction in the telemetry signal from the rocket coincident with the ejection of the packages, and, over a period of several seconds, the return of the power to the expected level in three distinct steps. Investigation of the records leads to the conclusion that a cloud of charged particles was formed by detonation of the explosive bolts which released the packages. A voltage breakdown of the telemetry antennas in this plasma was extinguished on each of the blades, in succession, as the charged cloud dispersed.

A planar Langmuir probe was carried on the rocket. The probe performed very well throughout the entire flight and yielded good data.

The University of Alberta magnetometers installed on the rocket functioned correctly and the low-frequency output corroborated the measurements made by the normal Schonstedt magnetometers. Recordings of the high-frequency output have been sent to the University of Alberta for analysis.

The photometer designed to measure the light of the aurora operated as expected, but owing to the slow roll rate of the rocket (35-second period) it did not yield a significant number of good scans. Additional information on rocket attitude was given by the photometer, as it gave a distinctive output when the side of the rocket on which it was mounted faced the moon.

All engineering monitoring circuits functioned properly with measurements of temperature, pressure, vibration, and acceleration being recorded continuously throughout the flight. Attitude determination by the Schonstedt magnetometers was complete through the flight.

The beacon transponder failed to operate for the first minute after lift-off. However, when it did function properly the radar was able to pick it up and plot the trajectory through apogee to splash.

The extendible light operated at the correct time and remained lighted until splash. Poor visibility prevented any photographic record being made.

## FUTURE FIRINGS

Preparations are under way for the firing of a further group of rockets in the fall. These rockets will have different combinations of scientific experiments and will also incorporate some improvements which experience has shown to be desirable.

## References


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2. A.G. McNamara, L.R. McNarry. Plasma probes for auroral rocket research. Bulletin, vol. 11, no. 3, p. 1
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# A CONTROL CONSOLE FOR CHECK-OUT OF SOUNDING ROCKETS

- D.H. O'Hara and A.K. Scrivens -

The Radio and Electrical Engineering Division provides engineering assistance to scientific groups in the field of space research. An important phase of this program has been the launching of high-altitude sounding rockets from the Fort Churchill Research Range. Once the nose cone with its instrumentation is attached to the rocket engine, the only direct access to these instruments is through an umbilical cable. Operations such as turning the equipment on or off, charging batteries, direct monitoring of supply voltages and transducer outputs, and calibrating the telemetry package are carried out through this cable from the control console described below, and shown in Plate I. Because of the variety of rocket experiments which may be launched over a short period of time, and for reasons of economy, it is preferable to have a single or, at the most, a few control consoles, rather than a separate and unique control console for each experimental rocket. Such an approach is possible using program boards similar to those used for computers. In the system adopted, each switch relay or pilot light in the console is connected to a terminal in the program board (Plate II). In this way the complete console can be wired to perform the desired functions for each experimental rocket. When another rocket is to be controlled, a complete rewiring for that rocket can be made quickly by substituting a different prewired program board.

This extreme flexibility does have a penalty. Since each program board has several hundred interconnections, errors arise frequently, and it is difficult and time-consuming to locate and correct them. For this reason, additional equipment is needed to check the wiring of the control console quickly and accurately. A multi-element matrix of display lamps (see front cover of Bulletin) is used to assist in the wiring and checking of the program boards. Similarly, the control console and the umbilical cable can be checked out by the use of such a lamp display matrix which can be arranged to simulate all the normal rocket electrical functions. The equipments are described in the following sections.

## CONSOLE EQUIPMENT

The equipment incorporated in the console is listed below:

1) 37-position voltage monitor with digital read-out
2) 36 lighted pushbutton switches
3) 4 power supplies

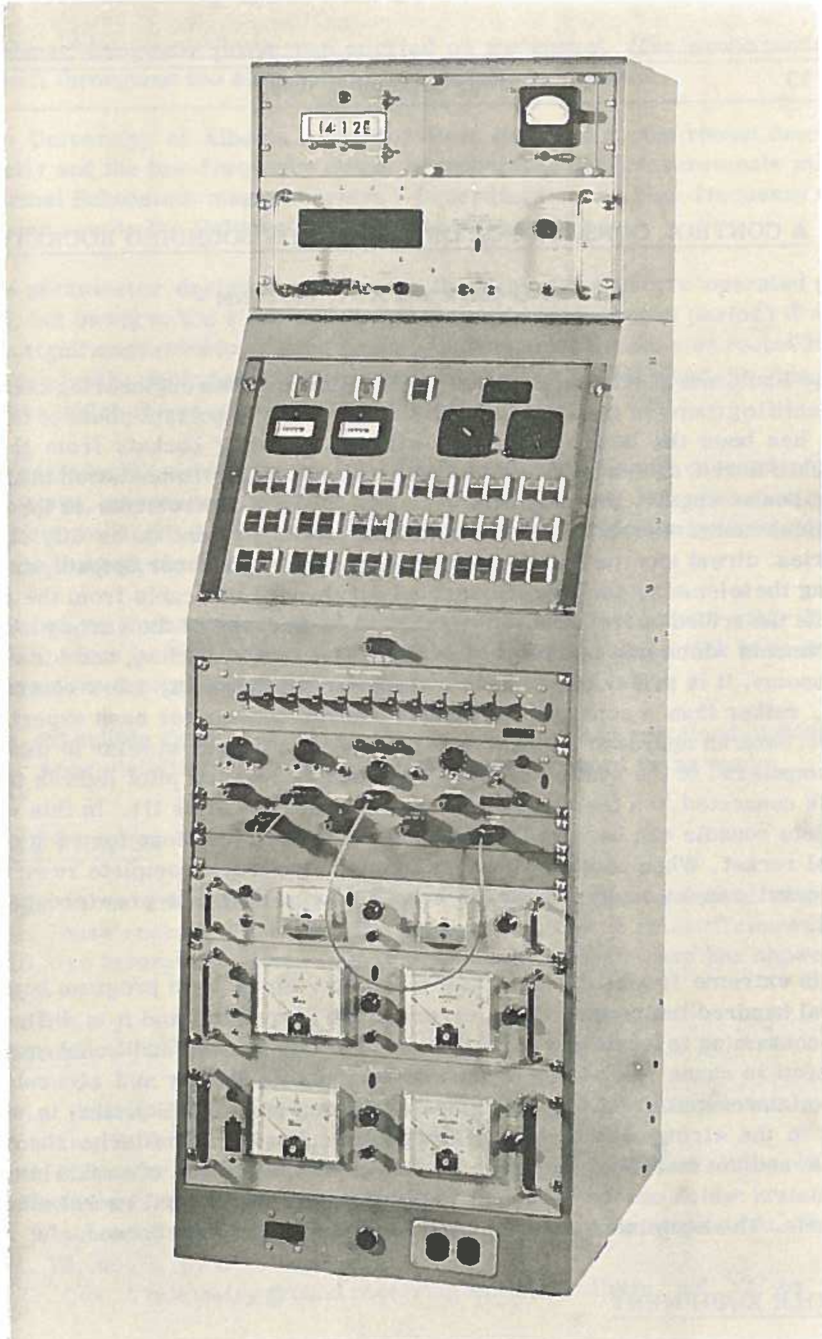

Plate I — Control console for check-out of sounding rockets

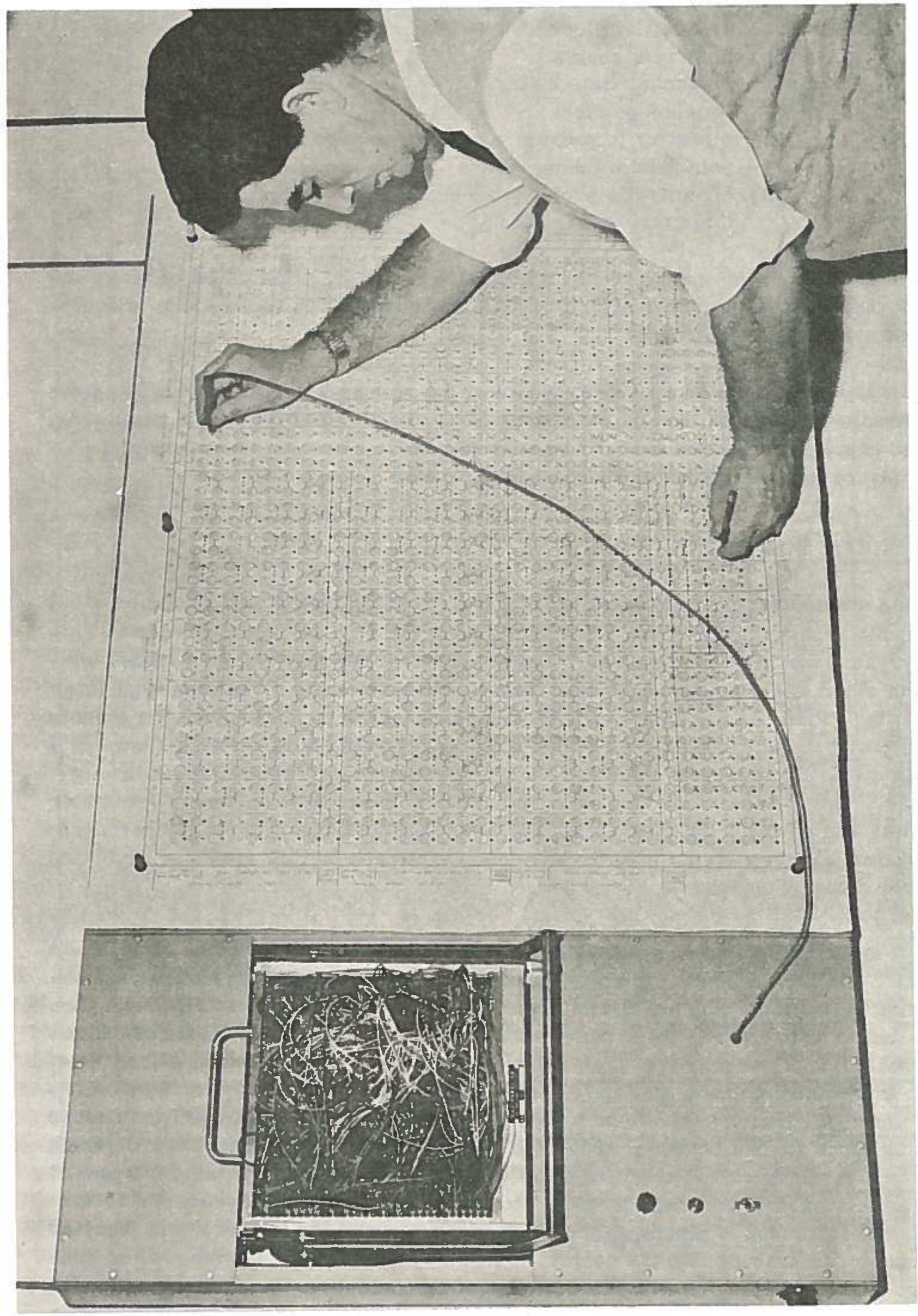

Plate II — Connections in program board (at left) are being checked against wiring diagram. Positions connected by jumpers on program board are indicated by lighted lamps behind wiring diagram.

4) 12 3PDT relays
5) 2 normally closed time-delay relays
6) 8 current shunts
7) 2 running-time meters
8) time-to-go clock
9) circuitry to provide a reverse voltage for polarized latching relays
10) circuitry to provide reference levels for telemetry calibration.

In addition to the main 100-pin umbilical connector, a selection of plugs and jack terminations on the console provides an additional 98 connections to equipment external to the console.

Of the 36 pushbutton switches, 14 are of the momentary-action type, 12 of the alternate-action type, and the remaining 10 may be of either type. The pushbutton head is a lighted screen which is readily removed. These screens accept a $\frac{7}{8}$" × $\frac{5}{8}$" insert upon which switch functions are written.

## PROGRAM BOARD AND CHECK-OUT

As stated above, every terminal of the console equipment and of the external plugs is brought to one of the 1280 terminals in the 40 × 32 program matrix. This program system is of rugged high-quality construction and has gold-plated contacts rated at 5 amperes, with less than 4 milliohms contact resistance. A large drawing (Plate II) has been made of the electrical terminations of the console equipment at the program board. On this drawing each termination is shown as a split circle. The upper portion has the termination co-ordinates written in; e.g., "A30", and the lower portion is blank. In this lower portion the programmer writes the co-ordinate of the terminal to which this point is to be jumpered. In addition, all console equipment is shown schematically on this drawing. A portion of the drawing appears in Fig. 1.

It is difficult to check point-to-point connections through the maze of wires on a 10" × 11" board, with typically upwards of 600 terminations, and at best the check is doubtful. The method of checking described here essentially magnifies the board and removes the encumbrance of the tangle of wires. On the check-out panel (Plate II) the wired program board is in its receiver on the left, and a copy of the layout drawing is on the right. Each terminal at the program board is wired to a prefocused lamp mounted behind a sheet of clear plastic, the spacing between lamps being equal to that between circles on the drawing of the program board. Each lamp represents a terminal at the board. Immediately below each lamp is a socket which accepts a probe that energizes the lamp. All lamps have a common return. When the drawing is placed on the sheet of plastic and the test probe is inserted through the drawing into the socket, this lamp lights. If the corresponding contact on the receiver is connected to any other contact on the receiver, through the wired program board, a lamp behind the drawing, corresponding to this jumper



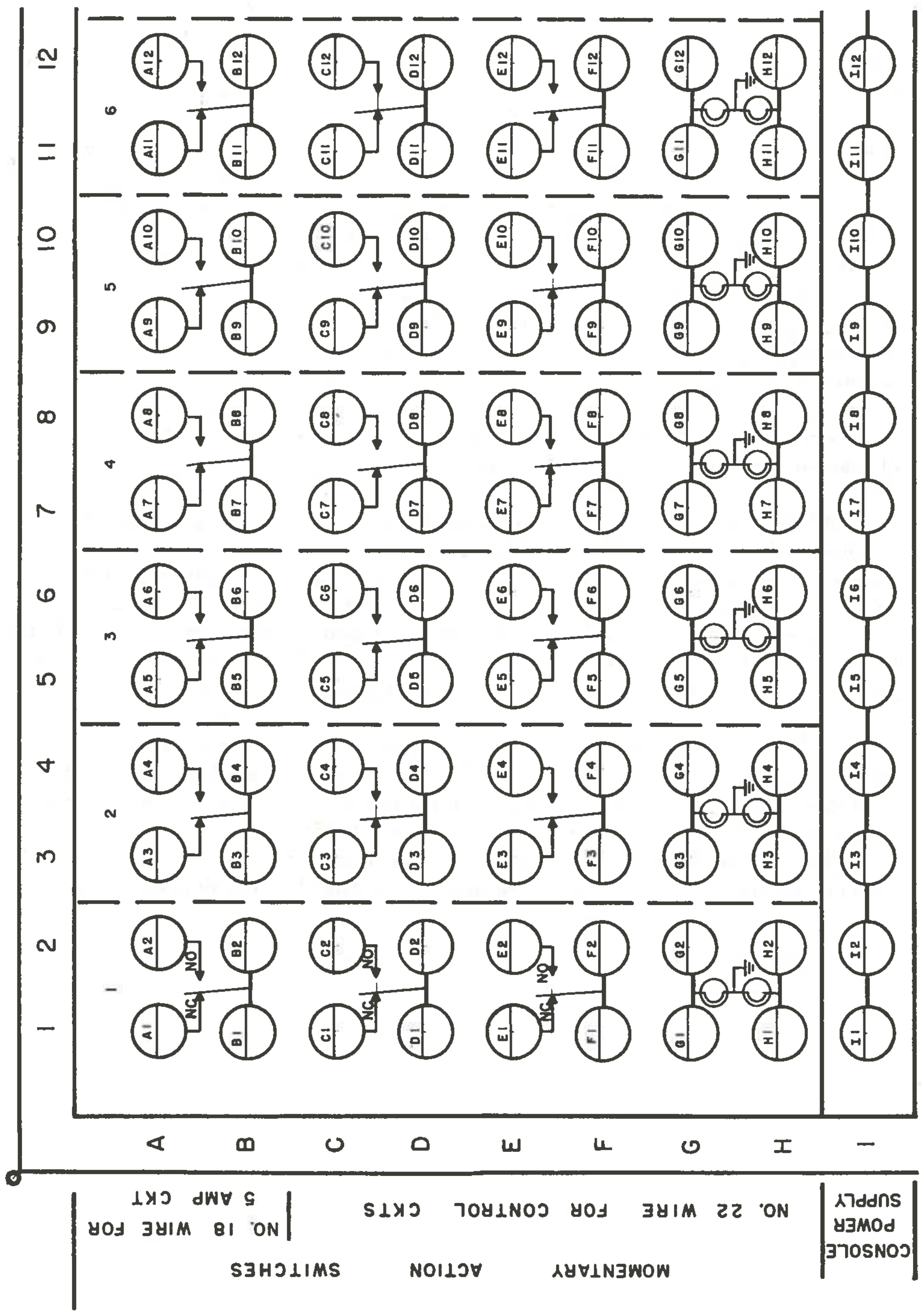


Fig. 1 A portion of the layout diagram

termination, lights. A systematic check with the wandering probe assures a one-to-one correspondence between the wired program board and the layout drawing. One further feature of this method of checking is the ease with which a wired program board can be modified. Changes to the board can be checked as they are made, confirming immediately that the correct jumper has been removed or inserted.

Although the above test procedure checks that the wired program board duplicates the detailed layout, errors in the design of the layout, or errors in layout of this design on the drawing may exist, still undetected. A special test box connected to the umbilical cable provides a quick visual check that the umbilical line is performing its correct function. Basically this box connects each umbilical wire through a lamp to a common bus. Thus, as each power source in the console is connected to its umbilical line, two lamps are lighted, the lamp corresponding to the line which is feeding power from the console and its ground return. By energizing external power lines and relay control lines one at a time, unambiguous check-out of these lines can be carried out.

Umbilical lines used for monitoring must be checked out in a slightly different manner. These lines are used to measure voltages from the rocket electrical system at the console and therefore do not have a console supply associated with them. In order to energize the test box lamp, a voltage is introduced on the pole of the selector switch in the console. As each monitor position is selected, the lamp in the line which this position monitors is energized. One further check is required; this is, to make sure the console supplies have the correct polarity.

Though initially designed for rocket use, this console is readily adaptable to a variety of switching and monitoring functions. In its present form the console is considered too large to be easily portable. A modified console now under construction combines the equipment into functional groups in portable units that can be mounted in standard racks. When these new units are interconnected, they will provide greater capacity and will be more versatile than the present console.



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# JANUARY 1964 ROCKET FIRINGS

- S.G. Jones -

## DESCRIPTION OF PAYLOADS

Three payloads of scientific instrumentation were prepared for launching in Black Brant II vehicles (with II-A modified fins) from the Churchill Research Range early in January 1964. The purpose of the launchings was to allow the study of various phenomena in the upper atmosphere, especially those associated with visual auroral formations. A number of experiments were included in each rocket payload, together with a standard telemetry package and facilities for monitoring batteries, experimental package performance, temperatures, accelerations, and vehicle orientation. Table I lists the scientific experiments included in the payload of each rocket. Coordination of the planning, construction (except for experimental packages), provision of telemetry and other auxiliary equipment, and testing of the payloads, as well as liaison with the range and coordination of launch activities, were the responsibility of the Space Electronics Section of the Radio and Electrical Engineering Division.

## LAUNCHINGS

Visual auroral formations along the rocket trajectory were a pre-requisite for a launching. This implied launching at night under clear skies during a lunar dark period. Because of Range safety considerations, the wind speed near the surface must be below about 15 knots, with higher limits at greater altitudes. The winter period provides the longest nights, but the weather at Churchill is severe and the rocket motor must not be allowed to get too cold. The recent installation on the universal launcher of a clamshell-type heat shield which encloses the entire rocket in a stream of warm air, allows the rocket to be held in the elevated position for long periods while awaiting the development of visual auroral formations in the desired down-range area. Evidently, this installation has made winter auroral launchings a practical proposition, since each rocket was launched on the first night with suitable weather conditions after the vehicle was placed on the launcher. A period of four minutes elapsed from the time the Project Scientist judged auroral conditions to be suitable until lift-off.

TABLE I — SCIENTIFIC EXPERIMENTS FOR JANUARY FIRINGS

| AA-II-25 | AA-II-41 | AD-II-42 |
|---|---|---|
| Plasma Probes* 6, as follows:<br>1 annular<br>2 $\frac{1}{4}$" spheres on 3" fixed stub<br>1 planar<br>2 3" spheres, extended at T +40 seconds | Plasma Probes* 4, as follows:<br>1 planar<br>2 3" spheres, extended at T+40 seconds<br>1 $\frac{1}{4}$" sphere on 3" stub, on ejected package | Electric Field Probes (from U of S)<br>1 ejected at T+50 seconds<br>1 ejected at T+65 seconds<br><br>Electron Density Probe (from U of S)<br>1 for ejection at T+65 seconds (removed at Range because of uncertainties concerning similar size package on AA-II-41) |
| Cosmic Ray Detectors†<br>Standard package — 5 detectors<br>Total energy package — 2 detectors<br>Pitch angle unit — 7 detectors | Cosmic Ray Detectors†<br>Pitch angle unit — 7 detectors<br><br>Neutron Detector (from UAC)<br>To count neutrons, γ-rays, charged particles | Plasma Probe*<br>1 planar<br><br>Heat Transfer Experiment‡<br>3 sensors |
| Micrometeorite Detector*<br>1 microphone | Micrometeorite Detector*<br>1 microphone | Micrometeorite Detectors*<br>2 microphones |
| Photometer*<br>1 photomultiplier | Photometer*<br>1 photomultiplier | Photometer*<br>1 photomultiplier |

* From Upper Atmosphere Research Section, Radio and Electrical Engineering Division, NRC
† From Cosmic Ray Section, Pure Physics Division, NRC
‡ From Aerodynamics Section, National Aeronautical Establishment, NRC
UAC Physics Department, University of Alberta, Calgary
U of S Institute of Upper Atmospheric Physics, University of Saskatchewan, Saskatoon



TABLE II — JANUARY 1964 FIRINGS — PRELIMINARY ASSESSMENT OF THE FLIGHTS

| ITEM | AA-II-25 | AA-II-41 | AD-II-42 |
|---|---|---|---|
| CRR OR No./Test No. | 116/210 | 117/207 | 118/211 |
| Time of launch and date | 00:04:39 on Jan. 14 | 23:21:56 on Jan. 8 | 01:21:02 on Jan. 17 |
| Time of flight (approx.) | 375 sec | 337 sec | 267 sec |
| Apogee altitude (approx.) | 155 km | 95 km | 75 km |
| Time to apogee (approx.) | 192 sec | 136 sec | 121 sec |
| Tracking, beacon return | complete trajectory | to 12 km | complete trajectory |
| Tracking, radar return | to 17 km | to 66 km | complete trajectory |
| Telemetry from rocket | for complete flight | for complete flight | for complete flight |
| Telemetry subcommutator | normal | intermittent | normal |
| Vehicle performance | normal | not normal, low apogee | not normal, low apogee |
| Plasma probe(s) | 4 to 5 of 6 normal | 1 of 4 probably normal | 1 of 1 normal |
| Cosmic ray detectors | 10 of 14 normal | low counts, but apparently normal | —— |
| Neutron detector | —— | normal | —— |
| Micrometeorite | normal | noisy vehicle, results uncertain | noisy vehicle, results uncertain |
| Ejected package(s) | —— | failed | 2 of 2 normal |
| Light beacon | normal, but not seen | probably burned out prematurely | probably burned out prematurely |
| Photometer | normal | failed | no output — failed |
| Heat transfer experiment | —— | —— | normal |

## PRELIMINARY ASSESSMENT OF THE FLIGHTS

The three rockets, AA-II-41, AA-II-25, and AD-II-42 were launched on January 8, 14, and 17, respectively, with varying degrees of over-all success. In each launch, nose cone preparation and the countdown checks proceeded much as expected, and without any serious difficulties. For rockets AA-II-41 and AD-II-42, vehicle performance was not normal. Apogee altitudes of about 95 and 75 kilometers, respectively, were attained instead of the expected 135 kilometers, and some type of vehicle failure is suspected. In rocket AA-II-41, axial accelerometer data shows that severe vibration could have occurred during the last one-third of motor burn time. This may have caused premature release of the package designed for ejection at 40 seconds after lift-off. There is uncertainty about what actually happened because of interruptions in monitor signals from time to time. Various hypotheses are being tested to account for the difficulties, but it seems likely that some mechanical damage occurred in the forward body section of the payload. Preliminary indications are that at least one of the four experimenters obtained useful data during the flight of AA-II-41. Payload performance in the flight of AD-II-42 apparently was normal, but because of the low altitude achieved, the scientific value of the data will be less than would have been the case if normal altitude had been attained. Rocket AA-II-25 reached record altitude of about 155 kilometers, and its flight appears to have been in all respects normal. Most of the experimental packages appear to have operated satisfactorily.

Table II gives a preliminary assessment of the flights. Most of the data have been received from the Range, and playback records are being produced for data analysis. Detailed results of the scientific and engineering measurements will be published as analyses are completed.



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# ENGINEERING DATA FROM JANUARY 1964 ROCKET LAUNCHINGS

- S.G. Jones -

The Radio and Electrical Engineering Division provides engineering assistance to the high-altitude rocket sounding program of the Associate Committee on Space Research of the National Research Council. It is responsible for technical coordination, which includes the planning, preparation, and testing of rocket payloads, provision of telemetry and other items of instrumentation common to a number of rockets, arrangements for launching the Black Brant rockets (Plate I) at Churchill Research Range, and processing of the data into a format usable by the experimenter. This arrangement makes it possible for relatively small groups at various universities and at the National Research Council to participate in the rocket sounding program, whereas they might otherwise be unable to do so because of insufficient resources.

In the previous issue of the Bulletin, a brief outline of the scientific instrumentation contained in the three payloads and a preliminary assessment of the results were presented. In addition to the experimental packages, each payload contains equipment for telemetering data from the rocket to the ground, for monitoring and controlling the experimental packages and power sources, for aiding the tracking and providing data on the motions and orientation of the rocket, and for monitoring the environmental conditions in which the instrumentation is operating. In what follows, a brief summary of the engineering data obtained in the January 1964 launchings is presented.

## ROCKET TRAJECTORIES AND MOTIONS

An accurate knowledge of the position and motions of each rocket throughout its flight is required by the experimenters in order to relate their data to the place and conditions of measurement. The position of the rocket is determined by radar, aided by a transponder beacon supplied by the Range, which was carried in each payload to enhance the return from the rocket. The radar data is recorded by the Range in two ways: (1) radar range, elevation, and azimuth data were recorded in digital form on magnetic tape using an Austin Data Recorder (ADR), for later processing by digital computer at a data centre in the United States; and (2) during flight, the radar polar coordinates were converted to rectangular (altitude, northings, and eastings) by an analog computer, and recorded by large pen recorders, called "plotting boards". These plots, altitude against ground range and the ground track (northings against eastings), are convenient for immediate viewing, but the coordinates are only crudely related to time as indicated by the periodic lifting of the recorder pen. Because the reduction of ADR data takes

Plate I — Black Brant IIA rocket on universal launcher at Churchill Research Range in preparation for elevation and launching. The clamshell heat shield, part of which appears above the boom from which the rocket is suspended, is used to keep the rocket warm while oriented vertically, awaiting suitable auroral conditions. Three types of plasma probes and a pair of telemetry antennas can be seen on the nose cone. (Churchill Research Range photo)



several months to reach the experimenter, a data link to allow the ADR data to be transmitted from the radar site to the launch site for recording on the magnetic tape record along with the telemetry data was suggested to the Range. We offered to supply the transmitter and subcarrier oscillators, and proposed that the Range provide the antennas and receiver. The Range agreed, and the link was put into operation during the January launchings. So successful was the system that the Range wished to have it remain as a permanent addition to their facilities for use by all experimenters.

The availability of accurate data through the ADR data link made it possible to decode sufficient points manually to produce accurate trajectory plots for rockets AA-II-25 and AD-II-42 within a few weeks of the launchings. Failure of the beacon, due to loss of battery power in AA-II-41 at about 40,000 feet of altitude, made it necessary to obtain an estimated trajectory for this rocket using the plotting board data of the radar which tracked the rocket echo to 220,000 feet and the time of impact. The trajectory plots are shown in Fig. 1.

Only rocket AA-II-25 performed as anticipated. It followed a smooth trajectory and reached an altitude of 508,000 feet. Rockets AA-II-41 and AD-II-42 reached altitudes of 315,000 and 243,000 feet, respectively. Fig. 2 shows the vertical velocity characteristics of the early portions of the flights. All vehicles behaved normally until after burnout. Shortly thereafter, rocket 25 experienced normal deceleration of some 1.2 g, gradually falling toward 1 g. Rocket 41 experienced a deceleration of about 3 g for some 25 seconds, and rocket 42 experienced a deceleration of about 6 g for some 15 seconds, after which they approached a free-fall phase. Additional light is shed on this abnormal behaviour by consideration of the angular motions of the vehicles.

Data from two mutually perpendicular magnetometer probes mounted transversely to the longitudinal axis of the rockets, and the received signal strength recordings, were available to provide information on angular motions. Just after burnout, rocket 25 had a spin period of 2.3 seconds, which did not change appreciably during the flight. From T + 60 to T + 300 seconds its motion was a regular precession with a half-cone angle of 29.5°, which caused the apparent spin period to vary between 2.24 and 2.4 seconds at the precession period of 145 seconds. The angular momentum vector was inclined 14° to the magnetic field direction. Rocket 41 had an abrupt decrease in spin period, from about 3 seconds to 1 second, just after burnout. Five seconds later a d-c component in the magnetometer output suggested pitching without spin or coning synchronized with spin. Further substantial changes in the angular motion took place until T + 44 seconds, when the rocket settled into a uniform angular motion which was very close to a flat spin of period 1.8 seconds, with the angular momentum vector inclined about 20° to the magnetic field vector. The angular motions of rocket 42 were very similar to those of rocket 41, and also culminated in motion very close to a flat

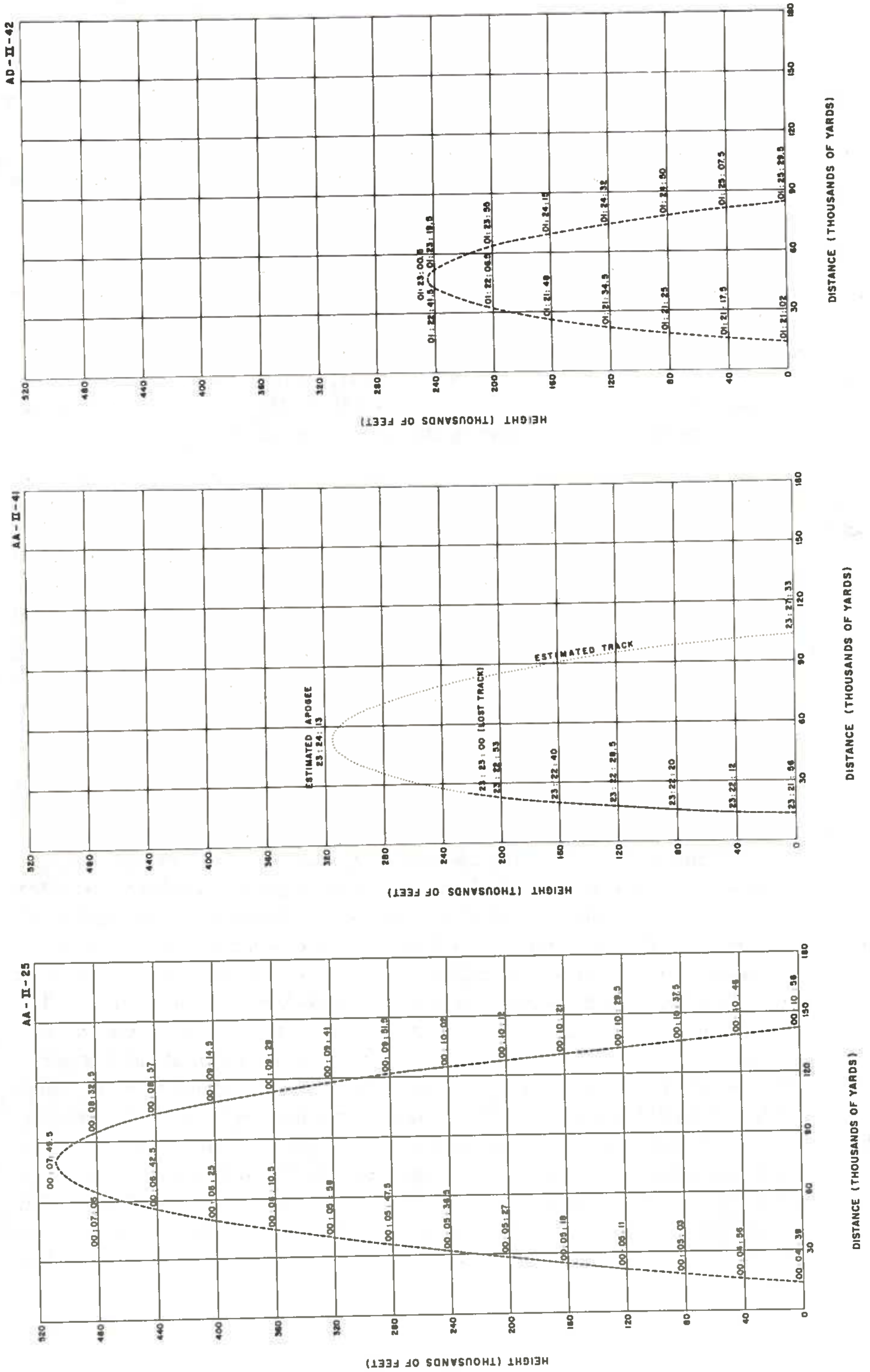


Fig. 1 Trajectories of rockets launched January 1964



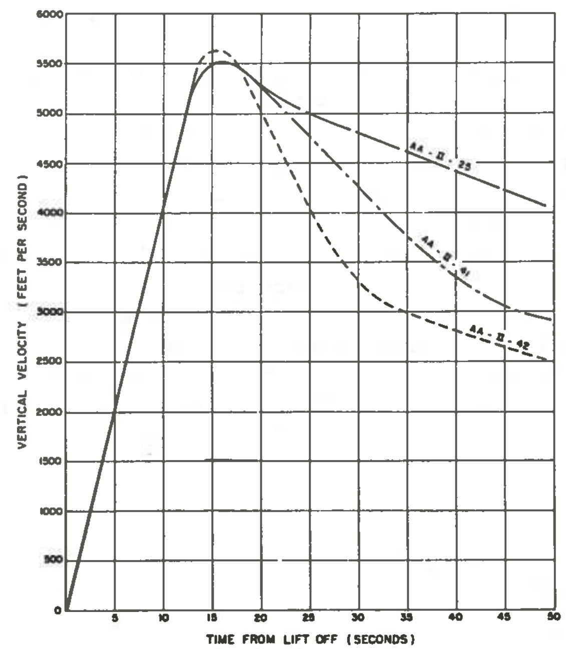


**Fig. 2 Vertical velocity during early part of rocket flights**

spin of period 3.8 seconds. Evidently these abnormal angular motions resulted from an unstable condition just after burnout, and explain the high drag noted previously for rockets 41 and 42. Qualitative confirmation of these tumbling motions was given by the indications of the axial accelerometers, but some quantitative discrepancies remain to be resolved.

Received signal strengths on circular, vertical, and horizontal polarizations from the ejected Electric Field Probe packages were recorded to aid estimation of the motion and orientation of the packages.

In case of failure of the radars to track the vehicle, signals from a pair of altitude (pressure-sensitive) switches can be used to provide an estimated trajectory. On rocket 25, one altitude switch was used to gate a photometer on and off, and the precision with which switching times were known suffered. However, an estimate based on these times gave an apogee which was only 5% less than that indicated by the radar.

A light beacon, consisting of an automobile headlight bulb extended from the rocket at an altitude of about 150,000 feet was flown on each rocket. On rocket 42, the bulb failed prior to extension, owing to being switched on prematurely. According to verbal reports from visual observers and parallactic camera operators, the light beacons were neither seen nor detected in the photographs, despite the presence of monitor signals indicating normal illumination of the bulb to re-entry in rocket 25, and premature illumination between altitudes of 90 and 150 thousand feet in rocket 41.

## TEMPERATURE MEASUREMENTS

Because a knowledge of environmental temperatures is important in the design of payload instrumentation, temperature sensors were fitted whenever telemetry space was available. Nine sensors were flown in rocket 25, four in rocket 41, and nine in rocket 42. Fig. 3 shows temperature data obtained in rocket 25. Temperatures measured on the inner surface of the nose cone casting rose rapidly to about 400°F. (The station numbers in the legend refer to the distance in inches from the nose tip.) The gradual fall after the initial rise at station 81 is due to heat conduction to the instrumentation mounting structure and forward body casting at the base of the cone (station 86). The H-frame and H-frame extension refer to the instrumentation mounting structure within the cone, and the tops of these correspond to stations 59 and 39, respectively. The air temperature sensor at the top of the H-frame was not completely shielded from radiation heat transfer

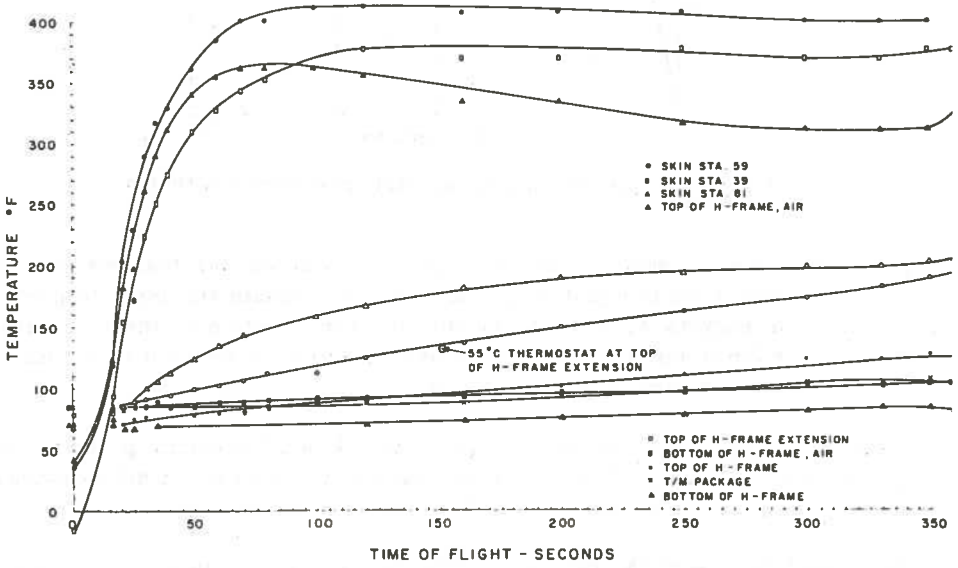


Fig. 3 Temperature data from Rocket AA-II-25

and hence probably indicates a temperature which is higher than the actual air temperature. The temperature environment for most of the instrumentation increased less than 40°F from the approximately 80°F launch temperature. In rockets 41 and 42 for which performance was abnormal, maximum skin temperatures of about 400°F were also observed, but these were reached much earlier in the flights than was the case in rocket 25. Increases in temperature in the vicinity of the instrumentation were also much higher, being some 80° to 100°F compared with the 40°F rise observed in rocket 25.



## PAYLOAD VIBRATION AND ACCELERATIONS

Data from a vibration accelerometer requires a wide-band telemetry channel, and this was available only in rocket 42. The transducer was mounted at the top of the H-frame, with its sensitive axis normal to the longitudinal axis of the rocket, and was set for a maximum vibration level, before clipping, of 5 g vector. The predominant component during motor burning was at 25 c/s, and varied in amplitude between 0.25 and 1.5 g at a 2 to 3 c/s rate, but at times was much higher in amplitude. It reached the 4 to 5 g level on four occasions, and possibly 10 g for 0.2 seconds during the first second of flight. Also present was a high-frequency component at levels up to 1 g, whose frequency decreased from about 300 c/s at lift-off to about 200 c/s at T + 19 seconds. During the remainder of the flight, several lateral disturbances were indicated which varied in amplitude from 1.5 g to 5 g, and low-frequency vibrations at 1 to 2 c/s at amplitudes up to 2 g.

Three mutually perpendicular linear accelerometers were mounted near the top of the H-frame in each of the rockets. The transducer, mounted with its sensitive axis along the longitudinal (Z) axis of the rocket, had a range -3 to +20 g, and measured the acceleration due to motor thrust, the subsequent deceleration due to drag, and in abnormal flights such as rockets 41 and 42, accelerations due to angular motion about axes normal to the Z axis. The transverse (X axis and Y axis) accelerometers had ranges of ±10 g in rockets 25 and 41, and ±5 g in rocket 42. The typical Z axis record shows a sudden jump of +9 g at lift-off, and gradual increase to a peak of +15 g at T + 13 seconds, a smooth fall to zero at T + 17 seconds, and a drag peak of -2 g at T + 18 seconds which rapidly approaches the free-fall condition. This was obtained on all rockets, except, that on rocket 41, indications of severe vibrations were superimposed during the last one-third of motor burn time, and during the mid-flight flat-spin phase a steady acceleration of -2 g was recorded. Rocket 42 showed a -1 g offset during its mid-flight flat-spin phase, and a fluctuation at the onset of the flat spin. The transverse accelerometers on rocket 25 remained at zero throughout the flight until re-entry; on rocket 41 they indicated 5 g acceleration during the final 25% of burn time, and up to 4 g in the period T + 25 to T + 40 seconds; and on rocket 42 they showed off-scale (i.e., > 5 g) from T + 19 to T + 26 seconds, and oscillations at the onset of the flat-spin phase. As so often happens, the sensitive transducers (±5 g) were installed on the one rocket for which the ±10 g units would have been desirable.

## TELEMETRY SYSTEMS PERFORMANCE

Taking the broad view, telemetry systems performance was satisfactory, since no significant loss of experimental data can be attributed to rocket telemetry difficulties. This does not imply that operation was always exactly as planned. On rocket 41, momentary interruptions of the telemetry system output and intermittent operation of the subcommutator, due to power supply malfunction believed to be associated with some mechanical damage suffered in the rear portion of the payload, made it difficult or impossible to decipher some monitor signals just when they were needed most to help explain the cause and nature of the disruptions. A quadraloop antenna system not previously flown in Black Brant II rockets gave satisfactory performance, but the back-up transistorized transmitter, carried on the chance that the quadraloop system would not perform satisfactorily, failed for the period T + 70 to T + 160 seconds, probably owing to power supply problems associated with the abnormal flight of vehicle 41. The fail-safe feature of the in-flight calibrator of the telemetry system shut itself down in rockets 41 and 42 when difficulties which might have led to the loss of wanted signals threatened, again probably because of abnormal vehicle performance.

## PERFORMANCE OF AUXILIARY DEVICES

Electronic timers were employed in the rocket to program events at stated times after launch, with action provided by electrically triggered pyrotechnic devices. The timer in rocket 25 operated on time, and the two timers in rocket 42 each operated about two seconds late. In rocket 41, the picture is not clear because of the intermittent monitor signals mentioned previously. It appears likely that premature firing of the squibs occurred, and that the timer-squib firing circuit was susceptible to the momentary power supply failures which were encountered in this rocket. Future rockets will employ mechanical timers which are not subject to this defect.

There is some evidence to suggest that the release device for the Electron Density type package in rocket 41 may have failed as a result of the severe vibration and lateral acceleration which occurred prior to burnout. It is virtually certain that this package was ejected prematurely, and it is assumed that the mechanical damage sustained within the rocket resulted from this cause. A similar package in rocket 42 was replaced by ballast rather than chance a recurrence of this misfortune. The release devices on the Electric Field Probe ejected packages performed as expected, despite the severe lateral accelerations sustained by rocket 42.

## CONCLUSIONS

Vehicle malfunction in two of the three rockets was disappointing, not only because it led to failures in the payloads, but also because the scientific value of the measurements obtained was less than would have been the case had the vehicles all attained the expected altitude. Yet satisfaction can be taken from the considerable portions of the payloads which withstood the adverse forces and conditions and performed satisfactorily. Useful scientific data were obtained from each of the rockets with abnormal vehicle performance, and in rocket 25 where vehicle performance was normal, good scientific data were obtained and payload performance was very satisfactory.



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# FOUR SOUNDING ROCKETS FIRED AT FORT CHURCHILL APRIL 1964

- A. Staniforth -

The Radio and Electrical Engineering Division is engaged in a rocket sounding program, working with various research groups from Canadian universities and physicists within the National Research Council. The Division is concerned with all aspects of planning, fabricating, and checkout of the nose cone payloads, and provides general engineering assistance to the experimenters as well. The completed nose cone is then shipped to the Churchill Research Range where it is given a final checkout, and is launched by a coordinated effort of the NRC team, the scientists, and the Range personnel. The checkout equipment and control console are shown in Plate I.

In addition, the Division operates a telemetry ground station with facilities for processing and recording of the data on paper charts. The Churchill Range records the telemetry data on magnetic tape as it is received from the rocket in the form of frequency-modulated subcarriers. At the NRC ground station in Ottawa the information is separated through channel selectors and discriminators, and then recorded on paper charts at a speed appropriate to the data rate.

Between April 6 and April 17 four Black Brant rockets were fired successfully. Three rockets were standard BB II vehicles purchased from CARDE and the payloads were planned, assembled, and checked out by the Division. The fourth rocket consisted of a BB II motor, with a BB V nose cone and fin assembly designed by Canadian Bristol Aerojet Ltd. (CBA). The payload was fabricated and checked out by CBA in cooperation with the Division. The experiments included in the payload of each of the rockets are listed in Table I, and in Table II a summary of the results of the flights is shown. The completed nose cone instrumentation of AD-II-36 is shown in Figs. 1 and 2.

The Churchill Research Range is equipped with an indoor launcher having a roof that slides back to allow for vertical elevation, and a heated clamshell shroud. However, this equipment was inoperative, and all four rockets were fired from the CARDE outside launcher in zero degree weather. The range provided a temporary plywood shelter for horizontal checkout, and a polyethylene sleeve around the entire rocket for use in the vertical position. Two aircraft engine heaters were used to blow hot air around the rocket inside the plastic shroud. This system allowed the rocket to be held in a vertical position as close to firing as T - 90 seconds

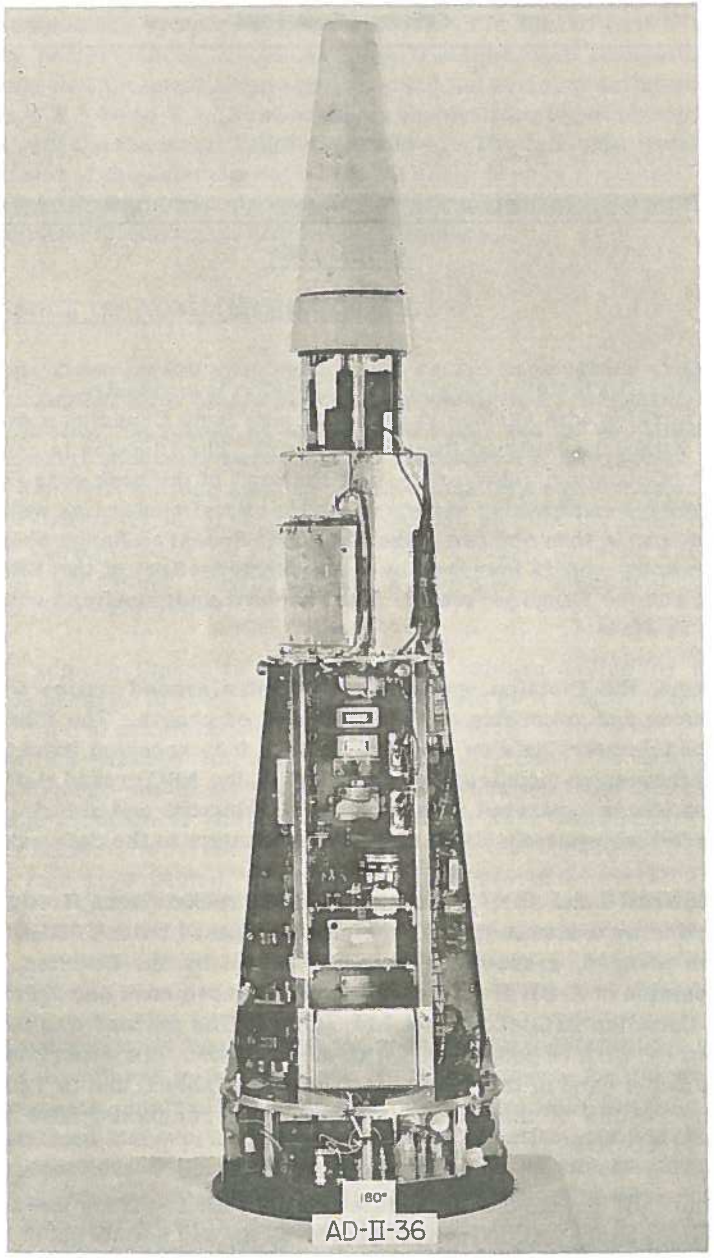


Fig. 1 Forward section of nose cone payload (top to bottom) neutron detector, scientific experiments and performance monitors, telemetry package

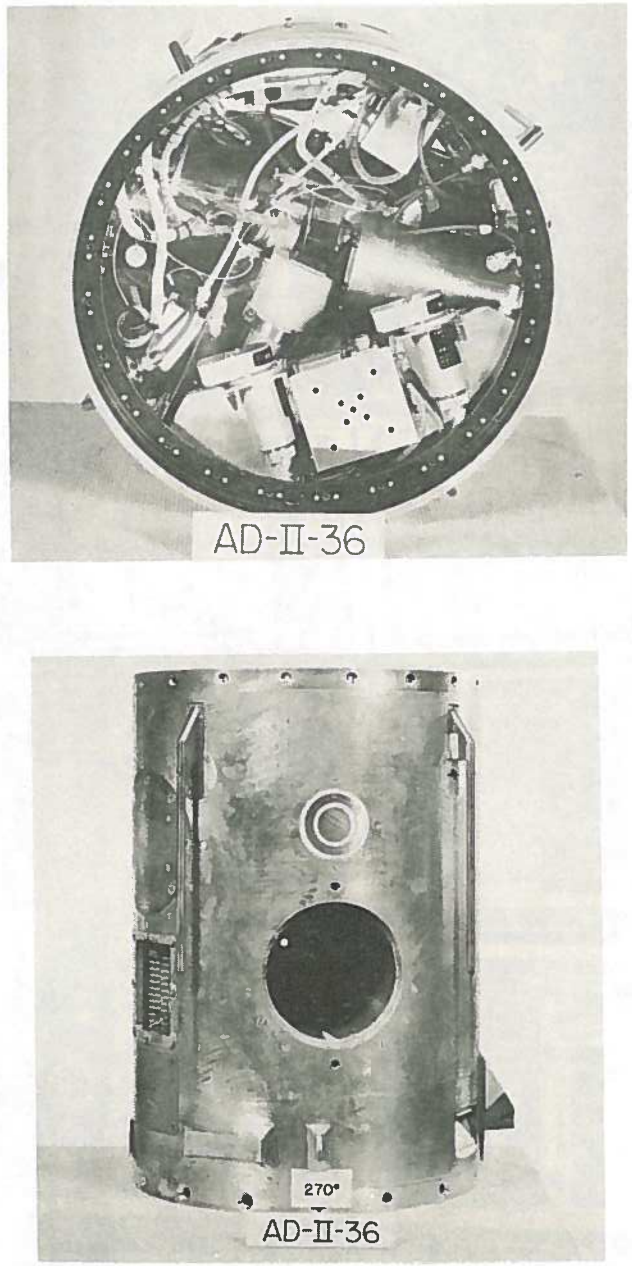


Fig. 2 Aft section of nose cone payload (top view) scientific experiments (side view) telemetry antennas, plasma probe, and ejection chute for electron density package

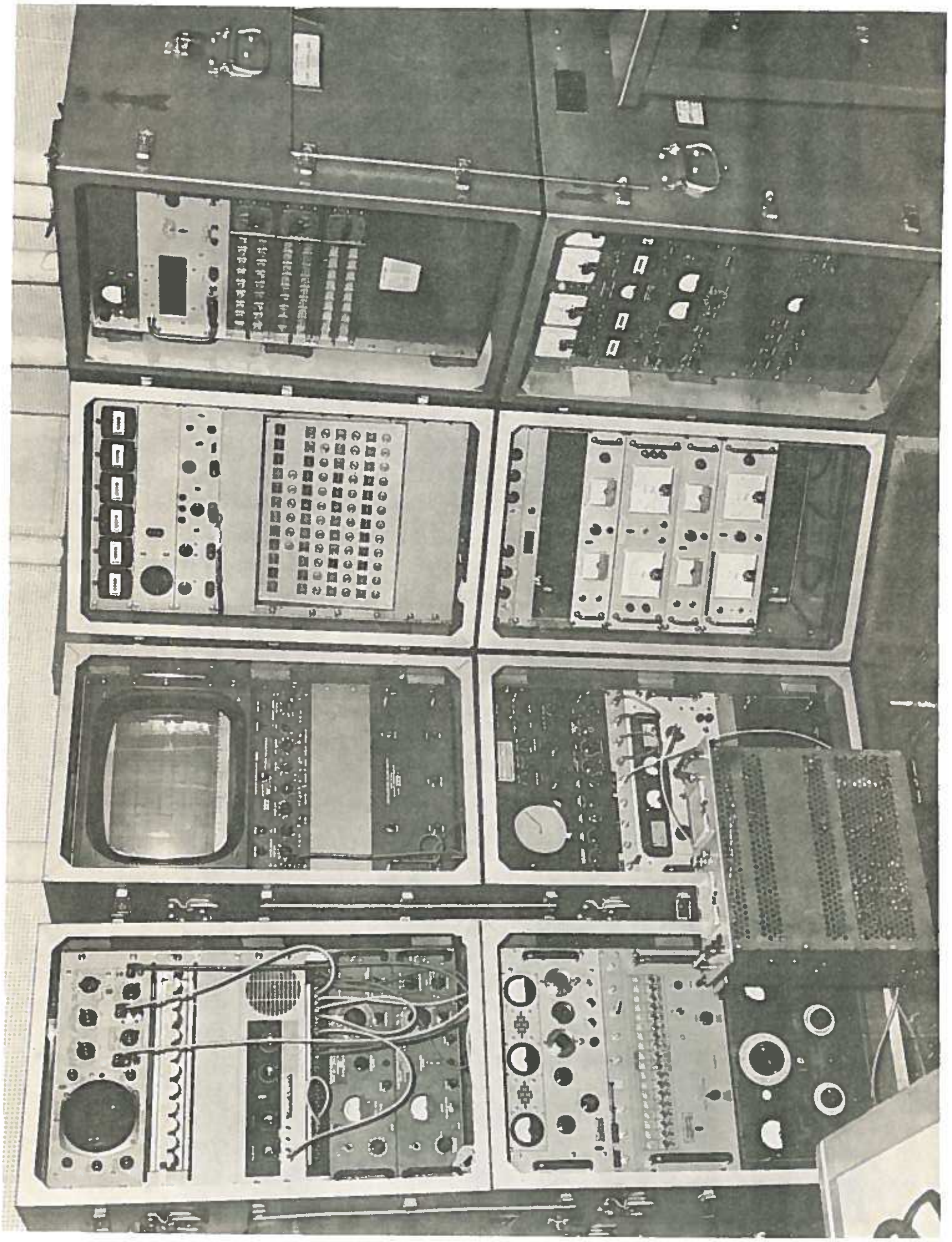

**Plate I** — Check-out equipment (left) and control console (right), as set up in blockhouse, for Black Brant II payload. The apparatus is mounted and operated in transit cases to facilitate shipment between Ottawa and the Range.

Churchill Research Range Photo



for several hours awaiting the auroral conditions desired by the Project Scientist. The three rockets, AA-II-43, AD-II-44, and AD-II-36 were fired at night in solunar darkness, clear sky, and with aurora in the trajectory of the rockets. The fourth rocket, AF-VA-35/03, was fired into a clear sky in daylight, since it was mainly a performance test vehicle requiring good visual observation conditions during the early part of the flight.

Most of the scientific measurements made in sounding rockets are important above 40 or 50 km, whereas most of the important environmental measurements are made below this height. In order to utilize the telemetry channels more effectively, the vehicle accelerations and vibrations were recorded to T + 30 seconds and scientific experiment signals thereafter. In rocket AD-II-44, two channels which monitored an electron density package were transferred to other measurements when the package was ejected at T + 57 seconds. These signal transfer and package ejection systems were initiated accurately by mechanical timers and all operated satisfactorily.

In three nose cones there were four packages and one pair of Langmuir probes. Two of the packages, instrumented for measuring electron density, were ejected by a 150-pound spring after a restraining $\frac{1}{8}$" diameter cable was severed by a Holex Pyrotechnic operated cutter. The other two packages, electric field probes, were ejected by a 15-pound spring after a restraining bronze wire was cut by a bellows actuator (squib-operated). The Langmuir probes were released by a bellows actuator operating a ball-groove device and were extended two feet from the rocket. These operations were timed to occur at about 250,000 feet.

The orientation of the rocket relative to the magnetic field was measured with two aspect magnetometers, their axes mutually at 90° and at right angles to the vehicle longitudinal axis. In rocket AF-VA-35/03 solar aspect sensors were used to obtain the orientation relative to a second reference line, thus defining the rocket aspect relative to the earth with only one ambiguity. The coning motion and roll rate of each of the rockets are indicated in Table II. This data applies only after T + 50 seconds when the aerodynamic forces become negligible and the motions become relatively steady-state. Rocket AF-VA-35/03 went through a high wind shear at about 40,000 feet, which caused it to develop a spin-yaw resonance condition resulting in a flat spin. This did no damage to the vehicle, but reduced the apogee by about 100,000 feet as a result of the increased drag.

Each rocket contained a Type-DPN-41 radar beacon to enable the radars to track the complete trajectory. This information is important for two reasons:

a) Range safety — an approximate location of the impact is required as a check on the prediction calculations.

b) For most scientific measurements an altitude-time record is required.

The trajectories of the four rockets are shown in Fig. 3 and summarized in Table II. It can be seen from Table II that the beacon track is necessary for re-

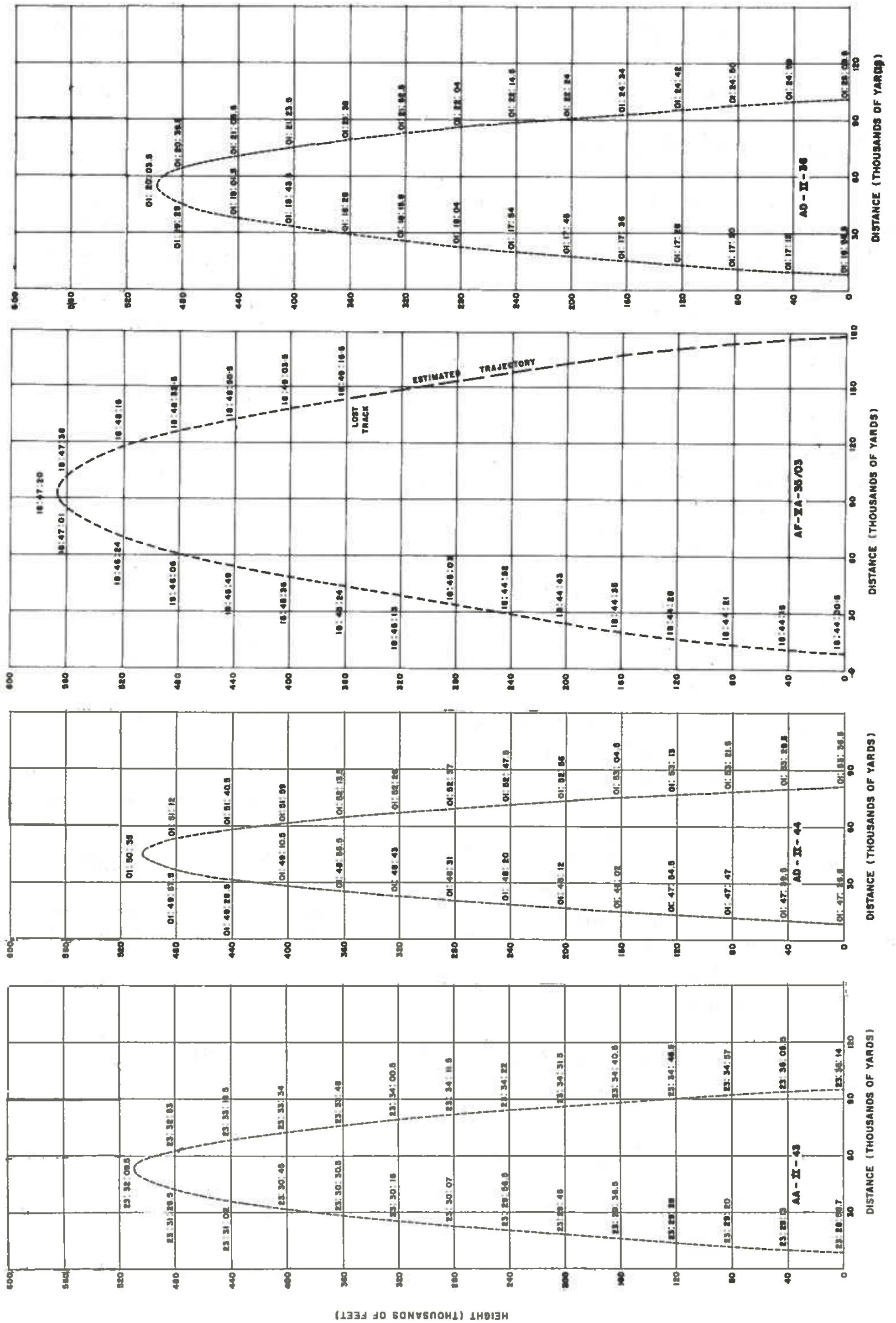


Fig. 3 Trajectories of four rockets fired April 1964



liable trajectory information, the skin track being only fragmentary. Even though the beacon became inoperative just after reaching apogee, a fairly reliable trajectory of AF-VA-35/03 was obtained by assuming a ballistic flight and calculating a best fit curve.

As a back-up for the radar in obtaining trajectories, each nose cone was fitted with altitude switches set to close at 50,000 feet. Using this data and assuming a ballistic flight above 50,000 feet, calculations of apogee resulted in an error of about 10%. However, if an empirical constant is used for "g", the calculations produce an apogee which is within 1% of the radar apogee providing the rocket is "well-behaved". In the case of rocket AF-VA-35/03, which developed a high drag attitude, these calculations resulted in large errors. A cosmic ray altimeter, with a "Pfotzer maximum" reference altitude of 72,000 feet, gave results which were accurate to about 1% in two rockets, AD-II-44 and AF-VA-35/03. This would indicate that the error in the calculations caused by drag is negligible above about 75,000 feet.

All the instrumentation must be designed and mounted in the nose cone to operate throughout the changing environment of a rocket flight. A record of the low-frequency accelerations encountered during the first 25 seconds of flight of rocket AD-II-44 is shown in Fig. 4. After this time, they are negligible until re-entry into the atmosphere near the end of flight. Calibration pulses of amplitude 5 g are used at 10-second intervals.

To study higher-frequency accelerations, vibration measurements in each payload near the point of attachment to the rocket were recorded on two channels. The channel frequency response was 2 c/s to 800 c/s. In rocket AA-II-43, at T + 7 seconds, an impulse initiated a vibration of 110 c/s which built up to ±10 g and lasted until T + 13 seconds. A record of these oscillations is shown in Fig. 5. In rocket AD-II-36 and in rocket AF-VA-35/03 the vibrations at no time exceeded 1 g.

The preparation and assembly of an instrumented nose cone for high-altitude sounding rockets requires a great deal of careful planning and liaison between the various scientific groups. In addition, it should be emphasized that after the rocket is fired, a considerable amount of work remains in the reduction, processing, and analyzing of the data. It is also the responsibility of the Division to distribute the reduced data to interested groups.

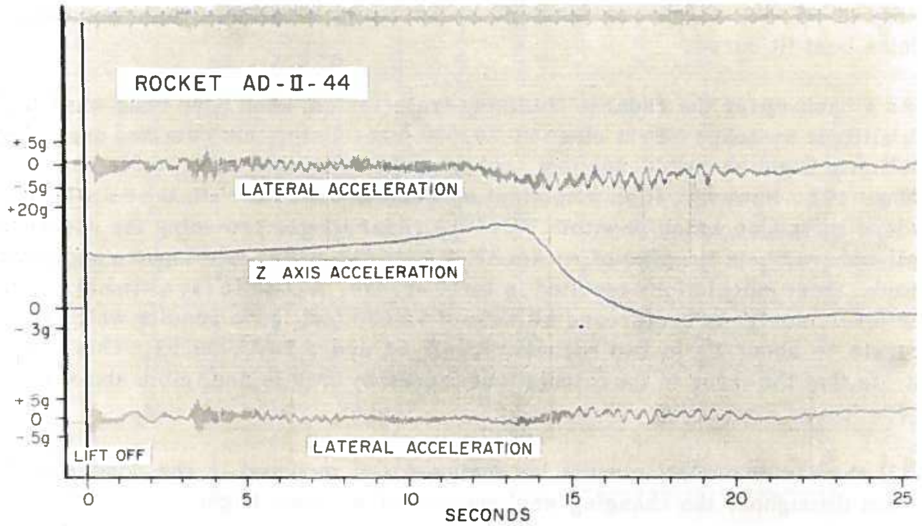


Fig. 4 Mutually perpendicular low-frequency accelerations on a Black Brant II rocket in normal flight

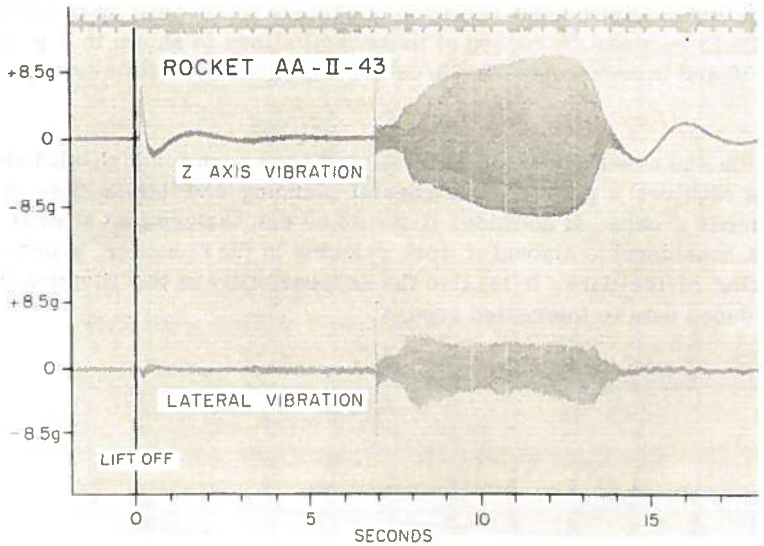


Fig. 5 Vibrations on a Black Brant II payload



TABLE I

NOSE CONE PAYLOADS — APRIL 1964

| | AA-II-43 | AD-II-44 | AF-VA-35/03 | AD-II-36 |
|---|---|---|---|---|
| (conical section) | Langmuir probe<br>Symmetrical plasma probe<br>Accelerometers — 3 axes<br>Vibration — 2 axes<br>Magnetometers — 2 axes<br>Micrometeorite<br>Radar beacon<br>Cosmic ray altimeter | Neutron detector<br>X-ray detector<br>Accelerometers — 3 axes<br>Vibration — 2 axes<br>Magnetometers — 2 axes<br>Micrometeorite<br>Radar beacon<br>Cosmic ray altimeter | Plasma probe<br>6 Accelerometers — 3 axes<br>Vibration — 2 axes<br>Magnetometers — 3 axes<br>Radar beacon<br>Cosmic ray altimeter | Neutron detector<br>Accelerometers — 3 axes<br>Vibration — 2 axes<br>Magnetometers — 2 axes<br>Micrometeorite<br>Radar beacon |
| (cylindrical section) | 2 Langmuir probes extended 2 ft.<br>Planar plasma probe<br>Photometer<br>Cosmic ray pitch angle<br>Cosmic ray total energy<br>Cosmic ray std. pkg.<br>Altitude switches | Electric field probe ejected<br>Electron density pkg. ejected<br>Photometer<br>Cosmic ray pitch angle<br>Plasma probe<br>Altitude switches | Solar aspect sensor<br>Motor pressure<br>Altitude pressure switches<br>Temperatures | Electric field probe ejected<br>Electron density pkg. ejected<br>Photometer<br>X-ray detector<br>Plasma probe |

TABLE II — NRC BLACK BRANT FIRINGS — APRIL 1964

| Item | AA-II-43 | AD-II-44 | AF-VA-35/03 | AD-II-36 |
|---|---|---|---|---|
| OR No./Test No. | 130/272 | 131/273 | 134/281 | 133/283 |
| Time of launch | Apr.6, 23:28:59 | Apr. 9, 01:47:27 | Apr. 16, 18:44:00 | Apr. 17, 01:16:56 |
| Time of flight | 376 sec. | 373 sec. | 428 sec. | 373 sec. |
| Apogee altitude | 509,000 ft. | 504,000 ft. | 565,000 ft. | 499,000 ft. |
| Time to apogee | 196 sec. | 193 sec. | 195 sec. | 190 sec. |
| Tracking, beacon | Complete trajectory | Complete trajectory | Lift-off to 310 sec. | Complete trajectory |
| Tracking, skin | From 464,000 ft. to impact | From 3,000 ft. to impact | — | CNY (inoperative) |
| Telemetry from rocket | Normal, complete flight | Normal, complete flight | Normal, complete flight | Normal, complete flight |
| TLM subcommutator | Normal | Normal | — | Normal |
| Vehicle performance | Excellent | Excellent | Disturbance at 8 sec. Apogee reduced 20 miles | Excellent, as predicted |
| Package ejection | Normal | Normal | — | Normal |
| Signal transfer | Normal | Normal | Normal | Normal |
| Magnetometers | Both normal | #1 Latch Rly CNY (inoperative) #2 Operation normal | All normal | Both normal |
| Vibration | Normal | CNY (inoperative) | — | Normal |



TABLE II — cont'd

| Item | AA-II-43 | AD-II-44 | AF-VA-35/03 | AD-II-36 |
|---|---|---|---|---|
| Accelerometers | Normal | Normal | Normal | Normal |
| Plasma probes | 4 of 6 normal | 2 of 2 normal | 1 of 1 normal | 1 of 1 normal to 110 sec. |
| Cosmic ray dectectors | Pkg. operated satisfactorily | Pkg. operated satisfactorily | — | — |
| Neutron detector | — | Satisfactory | — | First part of flight only |
| Micrometeorite | Electronics normal, noise level high | Satisfactory | — | Satisfactory |
| Photometer | Normal | Normal | — | Normal |
| X-ray detector | — | Appears satisfactory | — | Satisfactory |
| Electron density package | — | Low-level signal | — | Doubtful |
| EFP package | — | Normal | — | Normal |
| Solar aspect sensor | — | — | Normal | — |
| Roll rate | 0.40 c/s | 0.55 c/s | Flat spin | 0.62 c/s |
| Cone half-angle | 7.5° CWLF | 41° | | 19° CCWLF |
| Cone period | 160 sec. | 90 sec. | | 100 sec. |
| Angle of cone axis to H | 11° | 23° | | 7° |

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