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MEMORANDUM REPORT
NO. 1614

HARP 250 MC TELEMETRY EXPERIMENTS, JUNE - OCTOBER 1964

By W. H. Mermagen

NOVEMBER 1964

U. S. ARMY MATERIEL COMMAND
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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MEMORANDUM REPORT NO. 1614

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HARP 250 MC TELEMETRY EXPERIMENTS, JUNE-OCTOBER 1964

W. H. Mermagen

Exterior Ballistics Laboratory

A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

FRONTISPIECE - THE 16-INCH GUN AT BARBADOS - A NIGHT FIRING

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1614

WHMermagen/mb
Aberdeen Proving Ground, Md.
November 1964

HARP 250 MC TELEMETRY EXPERIMENTS, JUNE-OCTOBER 1964

ABSTRACT

High Altitude Research Project (HARP) firings were conducted both at Wallops Island, Virginia and Barbados, West Indies during the months of June through October 1964. A substantial number of these firings included high-"g" telemetry experiments. Three telemetry payloads were flown at Wallops in June and July, and three more in October. During the month of July, thirteen telemetry vehicles were flown at Barbados.

The telemetry experiments were highly successful. Five of the six payloads flown at Wallops functioned and four gave data. Nine of the thirteen units fired at Barbados survived the high-"g" launch. Seven of these successfully transmitted data. The results of measurement are presented and include sunseeker data, event monitoring, temperature data, and the performance of magnetometers and pressure gages.

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1. INTRODUCTION

High Altitude Research Project[1,2,3] (HARP) test firings at Wallops Island, Virginia (NASA) and Barbados, West Indies (McGill U.) were continued during the months of June through October 1964. Telemeters which can survive high accelerations had been developed[4] and successfully tested in horizontal gun firings. Previous HARP firings[5] had demonstrated the feasibility of using high-"g" telemeters as beacons over great flight distances. No in-flight data had, as yet, been produced. The June-October firings included telemeters of a more sophisticated design to provide data on vehicle performance and evaluate new types of sensors. The complete firing program at Barbados is described elsewhere[6,7]. This report will present the results of the telemetry program.

Harry Diamond Laboratories (HDL) built the telemeters for the McGill and Ballistic Research Laboratories (BRL) designed vehicles. NASA personnel provided ground receiving support at Wallops Island while the BRL staff designed and manned a mobile ground-receiving station at Barbados.

The Wallops firings consisted of six telemetry payloads. Five of these functioned and four gave data. Thirteen vehicles with telemetry were launched at Barbados. Four of these were damaged or broken up in the gun. Of the remaining nine payloads, seven functioned.

Both the Wallops and the Barbados tests can be considered highly successful from the point of view of telemetry experiments. Data were obtained which will prove useful in the design of future experiments. Several telemeters designed by the Ballistics Measurements Laboratory of BRL were flown at Wallops during October. These units operated at 1750 mc and functioned successfully. The results of these tests are being reported separately by BML.

2. TELEMETRY PROGRAM FOR WALLOPS

The telemeter designed for the 5-inch gun firings at Wallops can perform two functions. Temperature at a point can be measured and simple "yes-no" events can be monitored.

* *Superscript numbers denote references found on page 30.*

There is a considerable interest in payload compartment temperatures and antenna temperatures during flight. The 5-inch vehicle can carry a balloon package to altitude and eject it into the upper atmosphere. Ground radars can track such balloons and give upper-atmosphere wind measurements. The balloon payload is fragile and might be destroyed by excessive payload compartment temperatures. A bead thermistor was located in the payload compartment to provide the needed temperature information.

During firings at Barbados, excessive drifting of the radio frequency (RF) transmitter was observed. It was suggested that this drifting might be due to aerodynamic heating of the nose antenna. Therefore, the telemeters designed for the October shots at Wallops included bead thermistors located at the nose antenna in the hope of obtaining an in-flight temperature history.

The Wallops telemeter was made capable of observing "yes-no" events at the same time as making temperature measurements. This capability was used in the October shots to evaluate a number of inertia switches.

Harry Diamond Laboratories supplied six telemeters for the Wallops program. Figure 1 shows the arrangement of sub-assemblies in the 5-inch vehicle. The telemeter is a two-channel, commutated, FM/FM device. One channel is assigned to the temperature measurement. The other provides an in-flight reference frequency as well as event (yes-no) data. A reference frequency is essential because of subcarrier oscillator frequency shift during flight. The data can be corrected if the change in reference frequency is known. Figure 2 shows the telemeter circuit. Figure 3 is a typical calibration curve for the thermistor. Normally, the entire payload fits in the forward (body) section of the vehicle. The rear (boom) section is available for additional instrumentation.

"Yes-no" events are observed by the destruction of one or more resistors (one resistor per event). The event sets off a squib or small powder charge. The detonation destroys a 1/4-watt resistor placed across the charge. By suitable selection of resistors, the subcarrier can be made to change frequency by any desired amount. Different frequency shifts are assigned to each event and the number of events is limited only by available space.

The RF transmitter operates at 250 mc with more than 0.25 watt of power developed across 50 ohms. The subcarrier oscillator (SCO) operates nominally at 10.5 kc for the temperature channel and 7.5 kc for the event channel. The commutation frequency is nominally 70 cps. Figure 4 illustrates a typical calibration curve for the SCO.

Two types of antenna were used with the 5-inch vehicle. The first, and older version, used the body and boom of the vehicle as half of an asymmetrical dipole. The other half of the dipole was a wire imbedded in the fiberglas nose. The second version used a spike-nose as the other half of the dipole and consisted of a steel sting, a fiberglas insulator, and an aluminum base. Figure 5 shows both types of antenna and a typical radiation pattern. The spike-nose antenna was developed to overcome structural difficulties with the all-fiberglas nose. Both antennas required a tuning coil for optimum impedance matching. There is no isolation between antenna and oscillator and so the RF frequency of the oscillator depends strongly on antenna length.

The battery power supply for the July firings consisted of Mercury cells. Silvercell and NiCad batteries were tried during the October firings. Circuit turn-on was accomplished by inertia switches, several being used in parallel for reliability. Manual turn-on was provided for preshot checkout.

The ground receiving station at Wallops had excellent equipment for receiving and recording telemetry signals. Operating personnel were made available for the telemetry firings. In general, the Wallops telemetry station consists of high-gain antennas (including a 28-db General Bronze antenna), FM receivers, magnetic tape recorders and oscillograph recorders. Magnetic tape recordings were made of video outputs, signal strength, and discriminator outputs for each shot. Oscillograph records were also made for visual display. The tape recordings were played back and the data were reduced at BRL.

3. TELEMETRY PROGRAM FOR BARBADOS

A variety of telemetry vehicles were flown at Barbados during June and July of 1964 and can be distinguished either by the nature of the experiment or by the antenna configuration. For the sake of simplicity, the Barbados telemetry experiments will be discussed in this report under the three varieties of antenna: slotted fin, spike nose, and quadraloop.

3.1 Slotted Fin Antenna Vehicles

Four Martlet-2 vehicles were designed to carry aloft balloon payloads and eject the balloons at predetermined altitudes. The balloon canister was located behind the nose cone with an explosive charge immediately behind the canister. A fuze was installed to set the charge off at an appropriate time and push the canister out of the vehicle. A telemeter was installed to monitor this event. For simplicity of construction and assembly, the telemetry package was located just behind the balloon canister and a slotted antenna was used in one of the fins. A long coaxial cable connected the package to the fin antenna. An insulated wire was run from the nose cone back to the telemeter. This wire was electrically in parallel with a resister in the SCO. Upon balloon ejection, the nose cone would come off and the wire would be broken. A change in subcarrier frequency would be produced. Figure 6 shows the details of this arrangement. Figure 7 is a photograph of the Martlet-2 slotted-fin vehicle.

3.2 Spike Nose Antenna Vehicles

Five Martlet-2 vehicle nose cones were designed for telemetry instrumentation to be carried entirely within the nose cone. As a result, the nose cone had to include the antenna as well as the telemeter. The telemeter could monitor any single event or combination of time-separated events occuring during the flight. The main purpose of the unit was to monitor the release of TMA, (Trimethyl Aluminum - a chemical used for seeding the upper atmosphere) giving the time at which the release valve functioned. A pressure switch was installed in the chamber behind the

TMA drive piston to monitor the pressure of the driving gas. The switch was nominally set to 100 psi and would provide an indication when the pressure in the piston chamber dropped below that value. Figure 8 shows schematically the mechanical details of the TMA monitor. Figure 9 is a photograph of the spike-nose antenna vehicle. The details of the antenna can be seen in Figure 10. This antenna is an asymmetrical dipole and requires a loading coil to match to the impedance of the RF oscillator. The loading coil has a tunable slug for last minute power adjustments in the field. The frequency of the RF oscillator is strongly dependent on the spike antenna dimensions because of the close coupling between oscillator and antenna.

3.3 Quadraloop Antenna Vehicles

Previous HARP experiments have shown that the quadraloop antenna is a very successful design for high-"g" firings[5]. The quadraloop has good impedance matching characteristics as well as a symmetrical radiation pattern. Because the quadraloop antenna is physically quite long (about 17-inches including the mounting bracket) it was used only on the Martlet-3-B rocket vehicles. A number of telemetry experiments were designed for the rocket vehicles using magnetometers, sunseekers and pressure gages as sensors. Four rocket nose cones were built with quadraloop antennas: two carried sunseekers and pressure sensors; two carried magnetometers and pressure sensors.

The magnetometer instrumentation consisted of three mutually perpendicular magnetometers mounted in the rocket nose cone. One of the magnetometers was oriented along the long axis of the rocket. The purpose of the experiment was to demonstrate feasibility, to give in-flight attitude data and to determine if these data were sufficiently accurate for command guidance use. The devices were furnished by Canadian Bristol Aerojet Limited of Winnipeg and were of the second-harmonic, flux-gate variety. A description of their operation is found in Appendix A. Figure 11 shows the physical arrangements of the magnetometers in the rocket nose cone. All the electronic components of the magnetometers were potted internally.

Temperature compensation was not provided for. Each magnetometer was assigned a separate SCO channel. The SCO outputs were mixed to produce a complex signal which in turn modulated the RF oscillator.

The sunseeker instrumentation consisted of a pair of solar cells and amplifiers. The cells are silicon photoconductors. Each is located at the bottom of a rectangular slot with a window at the front end of the slot. Figure 12 shows the physical arrangement of the cells in the rocket nose cone. The sunseeker would demonstrate feasibility, would provide attitude data, and would be evaluated for command guidance capability. Appendix B gives the sunseeker specifications. One channel of the sunseeker provides a positive electrical pulse whenever the sun is within its field of view. The other channel similarly provides a negative pulse. The pulses were made to modulate a 70-kc subcarrier. The interval between successive positive (or negative) pulses corresponds to a single revolution of the vehicle. The interval between a positive and a negative pulse can be related to the solar aspect angle. The data from the sunseeker, then, are angles which the vehicle makes with respect to the solar vector. If the solar vector is known, the orientation of the vehicle is known to within a cone about that vector. Figure 13 is a photograph of the rocket nose cone with sunseeker payload. The opening in the nose cone is the viewing port. Figure 14 shows the rocket with telemetry nose cone.

Each quadraloop antenna vehicle also included a pressure gage for monitoring rocket motor pressures. Figure 15 shows a pressure gage situated so that it senses pressures in the forward section of the rocket motor compartment. A carbon pile gage was developed by HDL and rated at 3,000 psi. The gage had a separate SCO circuit, nominally 40 kc, whose output was mixed with the complex signal resulting from the other SCOs (either sunseeker or magnetometer).

3.4 Circuits for High-"g" Telemetry

The basic subcarrier oscillator circuit used both at Wallops and Barbados is shown in Figure 16. The SCO is a stable multivibrator whose frequency is a function of the signal voltage. The circuit parameters can be altered to provide any frequency from 3 to 70 kc. The radio frequency oscillator (transmitter) circuit is shown in Figure 17. This oscillator is a Hartley type using a minimum of components to insure reliability under high accelerations. Because of the simple design, the operating frequency is not very stable. Instability, if not too great, is not considered important since the signal can be tracked over a long time of flight. A highly stable transmitter is desirable, however, for doppler measurements and ranging but is not considered possible at present considering the state of the art. Both SCO and RFO circuits are described in detail by HDL[8].

Figure 18 shows, in block diagram form, the circuit for the Balloon-eject monitor. R_b represents the insulated wire which runs the length of the vehicle and connects the nose cone to the subcarrier circuit. When the nose cone is ejected, the wire R_b is disconnected from the circuit and the voltage on the SCO drops from 13 VDC to 8 VDC, producing a change in frequency.

Figure 19 is a block diagram of the TMA-release-monitor circuit. The pressure switch changes in resistance suddenly from 1 k-ohms to 100 ohms as the pressure drops below a nominal value of 100 psi. This resistance change drops the SCO input voltage from 13 to 8 VDC, causing a corresponding frequency change.

The magnetometer circuit is represented in Figure 20. The various SCOs were set for a deviation of $\pm$ 7.5% for full scale output. The SCO signals are mixed directly through capacitive filters to form a complex signal modulating the RF oscillator.

A block diagram of the sunseeker circuit is shown in Figure 21. The 70-kc SCO was set for a deviation of $\pm$ 15% for full scale output. The 40-kc pressure gage channel was set to $\pm$ 7.5%.

In all cases, the units were turned on by inertia switches at launch. Switches of several designs were used in parallel for reliability. At least one switch of HDL design[8] and one switch built by Aerodyne Controls were used in each telemeter. An umbilical connection was provided for circuit checkout prior to firing. Each telemeter was powered by a rechargeable Nickel-Cadmium battery pack.

3.5 Ground Station

A ground station for receiving and recording the telemetered signals was set up by BRL near the launch control center. Figure 22 is a schematic of the ground station layout. Figures 23 and 24 are photographs of the instrumentation van and its interior. The station consists of three high-gain helical antennas connected to preamplifier-multicouplers for additional gain. Each preamp-multicoupler fed two FM telemetry receivers. The video output of each receiver was recorded on magnetic tape. The automatic gain control (AGC) levels from the three most sensitive receivers were also recorded on tape to provide signal strength information. One of the video outputs was fed into a tunable subcarrier discriminator. The discriminator output was recorded on tape. A time zero pulse and a 40-kc reference frequency were also recorded. An oscillograph was used in conjunction with the tape recorder to give a graphic display of signal strengths, discriminator data and timing.

4. PRESHOT CHECKOUT AT WALLOPS

Each of the telemeters was turned on at the gun site before firing using its internal power supply. The ground station, some seven miles distant, listened to each transmission and noted RF and SCO frequencies. A sample of each signal was recorded on tape.

The telemeters for the July firings all checked out at close to 255 mc. After about one-half hour of operation the frequency had drifted down to 250 mc, probably because of the instability of the Mercury-cell power supply. All subcarriers were functioning satisfactorily during the preshot checks. The telemeters used in October all checked out close to their designed frequencies.

5. PRESHOT CHECKOUT AT BARBADOS

5.1 Telemeters

Each telemeter was turned on before firing using its own internal power supply. The RF transmitter frequency, subcarrier frequencies, and deviation ratios were measured. Inertia switches were checked for open circuit. Battery voltages were measured. A final tuning for maximum power was made whenever possible. Samples of the subcarrier signals were recorded on tape for each telemeter and sensors calibrations were recorded where possible. Table I summarizes the results of these preshot measurements.

5.2 Ground Station

A number of sensitivity tests were made after the ground station had been assembled and installed. An FM signal generator (AN-URM-70) was used for these tests. Channel 2 had the least sensitivity at -107 dbm. Channel 5 had the greatest sensitivity at -113 dbm, and was assigned the antenna covering the greatest range. These measurements were made with a modulating frequency of 20 kc at a 48-kc deviation. Daily sensitivity checks were made to insure that the system was functioning correctly. The subcarrier discriminator was found to have a sensitivity of -110 dbm for 1:1 signal-to-noise ratio.

6. RESULTS OF FIRINGS AT WALLOPS

Three HDL telemetry payloads were fired at Wallops in July and three more were built and fired by October. The July firings are distinguished by all-fiberglas-nose-antenna vehicles. In October spike-nose-antenna vehicles were flown exclusively. The results of these firings are summarized in Table II.

6.1 Fiberglas-Nose-Antenna Vehicles

Three vehicles were designated shots El-1955, 1956, and 1959 and correspond to HDL numbers 5, 8, and 7 (in order). All three were programmed for temperature measurement only.

Shot El-1955 was fired on 1 July 1964. Signals were received almost immediately. The strong signals showed that the new nose had remained intact. Muzzle velocity was measured at 5,300 feet per second with an acceleration of 46,200 "g". An apogee of 200,000 feet was expected but only 101,000 feet were reached. The transmission was monitored over the entire flight until impact except for an occasional loss of signal. The subcarrier was very erratic and no temperature data were produced.

E1-1956 was shot immediately after 1955 on the same day. The muzzle velocity was repeated at 5,300 fps with an acceleration of 46,200 "g". The vehicle flew satisfactorily but no signals were received from the telemeter. Figure 25 shows that the nose section may have been damaged during launch.

Shot 1959 was launched at reduced breech pressure on the next day. The muzzle velocity dropped to 4,900 fps with an acceleration of 39,200 "g". Signals were picked up at T + 3 seconds and monitored until impact. The strong signals showed that the nose had remained intact. Temperature data were obtained and are presented in Figure 26. An apogee of 155,000 feet was achieved.

6.2 Spike-Nose-Antenna Vehicles

Three spike-nose-antenna vehicles were delivered to Wallops in October and were designated shots E1-1963, 1964 and 1966. Each vehicle was instrumented to measure temperature at the nose-body joint and to carry, in addition, one or more inertia switches so that their functioning could be monitored. All three were fired on October 15th.

Shot E1-1963 carried two HDL-design inertia switches and operated at 235 mc before firing. Its power supply consisted of Silvercell batteries. Signals were picked up immediately after launch at 234.5 mc. The nose had remained intact. The RF drifted slowly during flight to a value of 228.5 mc shortly before impact. Both inertia switches functioned and temperature data were obtained for the first ten seconds of flight. An apogee of 163,500 feet was obtained.

Shot 1964 carried two HDL-design inertia switches and operated at 248 mc before firing. NiCad batteries were used in the power supply. Signals were acquired on launch at a frequency of 247 mc. This frequency drifted to 246 mc by the end of the flight. The nose antenna evidently remained in one piece. The inertia switches functioned but the temperature gage developed an open circuit and no data was received. Shot 1964 reached only 77,000 feet. The AGC record shows a periodic frequency probably produced by a large yawing motion. The resultant increase in drag should account for the low apogee. The NiCad power supply had been installed in the boom (rear) of the vehicle. This increased weight to the rear reduced the static margin and probably contributed to the aerodynamic instability.

Shot E1-1966 had only one HDL inertia switch for test. This unit was powered by the older Mercury-cell battery pack. The preshot frequency was 243 mc. Signals were picked up after launch at 248 mc and were quite strong. Thus, the nose had remained intact. AT T + 29 seconds the signals were abruptly lost and not reacquired until after re-entry. The inertia switch functioned and temperature data were recorded for the first 12 seconds of flight. An apogee of 175,500 feet was realized.

Figure 27 shows the temperature data from shots 1963 and 1966. The upper limit of the thermistors was 400° F and was reached within 12 seconds on both shots. The thermistor probably continued to function at the subsequent higher temperatures but the calibration curve supplied with the device stops at 400° F. On shot 1963 the thermistor was observed to become an open circuit during the latter portion of flight.

7. RESULTS OF FIRINGS AT BARBADOS

Thirteen HDL telemetry payloads were fired at Barbados during July 1964 with considerable success. Each firing was given a code name for identification. The results of firing are given below and are grouped according to the type of antenna used. These results are summarized in Table III.

7.1 Slotted-Fin-Antenna Vehicles

The four slotted-fin-antenna vehicles were given the code names Daphne, Odette, Ethel and Frances. All four were to monitor a balloon ejection event. The telemeter installed in Frances was not operating before launch. Shots Frances and Odette broke up in the gun and, of course, no signals were received. Daphne was launched on 10 July 1964 and the nose cone came off during launch. Daphne achieved a low apogee of 155,000 feet. Ethel was a good shot with an apogee of 346,000 feet. No signals were received from either Daphne or Ethel.

7.2 Spike-Nose-Antenna Vehicles

The five spike-nose-antenna vehicles were given the code names Gloria, Hope, Sharon, Ursula and Victoria. All five telemeters transmitted and data were obtained from four of them.

Shot Gloria was designated to measure the functioning of a fuze. A 150 second fuze and a charge of powder were put in the Martlet-2 body before launch. A successful fuze function would be shown by a change in subcarrier frequency produced by means of a pressure switch. Gloria was launched at 1540 hours on 21 July 1964 and flew successfully to an apogee of 316,000 feet. Telemetry signals were acquired at T + 10.8 seconds at 254 mc and were observed until impact. The radio frequency drifted considerably during flight. The pressure switch functioned at T + 179.4 seconds showing an error of 29.4 seconds or 20% in fuze functioning time. Figure 28 shows the flight data obtained from this shot. The AGC (Automatic Gain Control) record shows the time at which the vehicle turned over on re-entry into the atmosphere. After re-entry a complex AGC frequency was observed. This might indicate that the vehicle had not stabilized after turnover. Finally, the complex signal became sinusoidal and dampened out just before impact. The AGC record also gave time of impact at T + 300.6 seconds. A photograph of the AGC record is given in Figure 29.

Shot Hope was assigned to monitor the release of TMA. The pressure switch was set to 120 psi. The TMA release valve had been preset to actuate at 70 seconds. Hope flew successfully to an apogee of approximately 340,000 feet. Telemetry signals were acquired at T + 2.1 seconds at 259 mc. Signals were weak up to apogee and were, in fact, lost for a short period of the ascent. After apogee, the signal strength increased and the transmission was monitored until impact. The radio frequency drifted considerably (from 259 to 255 mc) during flight. The AGC record yielded the same data as on shot Gloria. Impact was observed at T + 303 seconds. The data from the telemeter showed that the release valve had not functioned since no change in the pressure switch was observed. No TMA trail was observed optically. Figure 30 shows the in-flight data from Hope.

Shot Sharon was similar to Hope in design and purpose. The spike-nose-antenna had been cut back 4-inches and the RF oscillator retuned to 244 mc before launch. This was done to prevent a substantial frequency shift should the antenna break at launch. Sharon flew successfully to an apogee of 350,000 feet and released TMA as programmed. Telemetry signals were acquired at T + 0.13 seconds at 244 mc and were monitored to impact. A 13 second loss of signal occurred during the ascent. The AGC record provided the same valuable data as shots Gloria and Hope. Once again, the signal strength increased after apogee. The subcarrier frequency drifted considerably during flight. No pressure switch data were observed. Impact was observed at T+ 309.4 seconds. Figure 31 gives the AGC and subcarrier data from shot Sharon.

Shot Ursula was similar to Hope and Sharon in design and purpose. Ursula was launched successfully to an apogee of 324,000 feet and released TMA from the muzzle on up. Telemetry signals were received at T + 7 seconds at 261 mc, the upper band edge of the receivers. Four inches had been trimmed off the spike-nose-antenna before firing, and the RF oscillator had been retuned to 251 mc. The RF signal was quite erratic during flight and was tracked to impact at 292.5 seconds. The pressure switch gave data at T + 15 seconds, indicating that the piston driving chamber pressure had dropped below 120 psi. Figure 32 shows the AGC and pressure SCO data taken during the flight.

Shot Victoria was the last Martlet-2 vehicle for TMA release which carried a telemetry payload. Once again, before flight the nose-antenna had been trimmed 4-inches and the oscillator retuned to 252 mc. Victoria was fired successfully and reached an apogee of 275,000 feet. The low apogee indicates that Victoria may have suffered some damage during launch. Telemetry signals were not received until T + 192 seconds and were then located at the upper band edge of the receivers (261+ mc). Thus, the radio frequency had shifted beyond the receiver capability during launch. Impact occurred at T + 308.3 seconds. The subcarrier frequency showed that the switch had functioned earlier in the flight.

7.3 Quadraloop-Antenna Vehicles

The four rocket vehicles with quadraloop telemetry antennas were called Arvida, Escuminac, Chicoutimi, and Fontainbleau. One vehicle broke up in the gun, one was damaged in the gun, and two flew for some time after exiting the gun.

Shot Arvida was a Martlet-3B rocket with magnetometer and pressure sensing telemetry. The magnetometers were not functioning before launch. The rocket motor began burning while the vehicle was being launched and as a result the vehicle was damaged while in the barrel. Muzzle pictures showed that the vehicle flew successfully (no radar track was accomplished) although the antenna was damaged. No telemetry signals were observed.

Shot Escuminac was similar to Arvida with magnetometer and pressure sensing telemetry. Only one magnetometer was functioning before launch. Shot Escuminac broke up in the gun. The nose cone continued to fly, however, with the quadraloop antenna missing. Extremely weak signals were received at T + 8 seconds at 255 mc and were lost at T + 37 seconds. The maximum signal strength observed was -109 dbm. Figure 33 shows the AGC record for Escuminac and indicates that the nose cone was tumbling, as one might well expect.

Shot Chicoutimi carried a telemetry payload of sunseekers and a pressure gage. Chicoutimi flew to an apogee of 115,000 feet. Telemetry signals were acquired immediately but with some noise for the first four seconds. There was a periodic fading of the signal due to the use of only one of the quadraloop antennas for transmission. This periodic fading should correspond to the roll rate of the vehicle and was observed to increase from 3.4 cps to about 4 cps during the flight. Turnover occurred at T + 90 seconds and impact at T + 184.4 seconds. Figure 34 shows the AGC and pressure channel data for Chicoutimi. A pressure pulse was observed at T + 18.5 seconds indicating rocket ignition. The pulse was only 0.25 seconds in duration which shows that the gage failed. The pressure at gage failure was observed to be 2,400 psi. There was substantial interference with the transmission between T + 22 and T + 38 seconds, possibly due to rocket motor buring. Sunseeker data were acquired. Figure 35 shows the roll and attitude data obtained from the sunseeker as well as the roll rate data from the AGC. The data are referenced to the sun vector as would be observed from a perfectly stable flight. These data were obtained from T + 7 to T + 50 seconds and show that the vehicle experienced large amplitude oscillations. The maximum amplitude before rocket ignition was observed to be 10 degrees while after burnout it was a maximum of 25 degrees.

Shot Fontainbleau also carried sunseekers and a pressure gage. Fontainbleau was launched successfully and signals were acquired at T + 0.1 seconds at 238 mc. Telemetry signals were lost at T + 30 seconds, probably due to impact. Unfortunately, Fontainbleau went drastically off course. The sunseeker functioned as planned and showed that the vehicle was undergoing large amplitude oscillations before rocket ignition. No data were obtained from the pressure sensor. Figure 36 shows the AGC signal and the sunseeker signal received from Fontainbleau.

8. DISCUSSION OF RESULTS AT WALLOPS

The Wallops firings were considered very successful from the point of view of telemetry. Five of the six transmitters functioned and four gave in-flight data. The October firings saw an improvement in altitude capability over the July firings.

8.1 Fiberglas-Nose-Antenna Vehicles

The new fiberglas nose-cone design solved the problem of nose breakage experienced in earlier Wallops firings. It seems, however, that some loss of altitude occurred with the fiberglas nose. It has been suggested that the glass may be shredding under aerodynamic heating with a consequent increase in drag.

Shot El-1956 was most probably damaged when it left the gun. The smear photograph (Figure 25) shows deformation at the nose-body joint. Noses have been lost completely in previous firings and still telemetry signals were received. It must be concluded that El-1956 did not transmit, perhaps because of battery failure, inertia switch failure or component failure.

The data received from shot El-1959 is shown in Figure 26. Temperatures in the payload compartment did not exceed 200° F during the flight. These data are useful in planning for balloon shots where high temperatures in the payload compartment might ruin the balloon packages. Since balloon ejection would occur near apogee, the data show that 150° F would be an upper limit for compartment temperatures. These data must be understood in light of the fact that the temperature sensors were packaged in epoxy resin. Higher temperature values would have been observed if the sensor could have been bonded directly to the steel wall of the compartment. These data, of course, apply to a muzzle velocity of 4,900 feet per second. Data are needed at 5,500 feet per second, the conventional operating velocity of the 5-inch system. Figure 26 also shows a temperature rise after T + 150 seconds. The heat imput to the walls of the vehicle becomes negligible after leaving the dense portion of the atmosphere. One would expect the temperature to increase more gradually, then, as the heat distributes itself throughout the vehicle. This is indeed observed in that portion of the data curve near T + 140 seconds. Upon re-entry, however, atmospheric effects again become important and heating of the walls again takes place. Now one would expect a gradual increase in the interior temperature because of the new heat input. This can be seen to have taken place in that part of the data curve past T + 150 seconds.

The erratic subcarrier behavior of shot 1955 cannot be explained satisfactorily. It is possible that a component was damaged during launch or that the thermistor did not survive the gun accelerations.

8.2 Spike-Nose-Antenna Vehicles

The spike-nose antenna performed well and seems to have eliminated the altitude loss observed with the all-fiberglas nose. With breech pressures comparable to the July firings, these vehicles achieved substantially higher altitudes. Nevertheless, the antenna pattern is still unfavorable for maximum signal reception.

The HDL-design switches proved suitable for HARP firings and should give a considerable cost savings if incorporated into future programs. The Silvercell and NiCad power supplies worked well under high "g" conditions and are far superior in electrical characteristics to the current Mercury cells. The last shot, 1966, used the Mercury cells and transmission was lost for most of the flight. Moreover, the radio frequency was quite erratic while the unit was transmitting.

The data from shots 1963 and 1966 (Figure 27) show that substantial temperatures exist at the nose-body joint early in the flight. The upper limit of the thermistor was 400° F. For this reason the data are presented only to the 400° F. The temperature at this point probably did increase far above 400° F. Future experiments will try to extend the range of measurement.

Parachute ejections were tried in some early 5-inch gun experiments. At that time the nose cone was held on with epoxy glue. Smear photographs of those tests show that the nose was still attached to the vehicle at launch and yet extremely low apogees were observed, as though the nose had come off. Perhaps the high nose-body joint temperatures observed in the October firings (where, incidentally, the nose cone was held to the body with steel pins) might help to explain the earlier failures.

The temperature data show that nose antenna suffers temperatures high enough to alter the electrical and mechanical characteristics of the antenna. Since the RF circuit is located at the base of the antenna, it too probably experiences high temperatures. The above high temperatures might account for the continued drifting of both the RF and the subcarrier frequencies during flight. Such drifting in RF has been invariably observed with the spike-nose antenna.

9. DISCUSSION OF RESULTS AT BARBADOS

The telemetry firings at Barbados were highly successful. Of the thirteen telemetry vehicles fired, four were damaged or destroyed on launch. Seven of the remaining nine telemeters functioned successfully. The results of these firings are summarized in Table III.

9.1 Slotted-Fin-Antenna Telemeters

Only shots Daphne and Ethel flew and shot Daphne was missing the nose cone after launch. No transmittions were observed from either shot. The failure can be most probably attributed to the long coaxial cable running from the telemeter container to the slotted-fin-antenna. It is quite likely that this cable was too long for the high accelerations experienced in the gun. The cable could have failed in tension or could have sheared at the body-fin interface.

9.2 Spike-Nose-Antenna Telemeters

All the spike-nose-antenna telemeters transmitted as planned. Data were received from three of the five units and probably from a fourth. The probable fourth piece of data was from shot Victoria. RF transmission was not acquired on Victoria until well after the event occurred, but the SCO frequency indicates that the pressure switch did function.

The close coupling between spike-antenna and RF oscillator was of great advantage. Part of the spike had broken off on shot Gloria and yet the transmitter continued to function but at a different frequency. In other words, the transmitter shifted frequency to accomodate the new antenna dimensions. Had the two circuits (RF and antenna) been isolated, then any change in physical dimensions of the antenna would have resulted in complete loss of transmission. Excessive shift of radio frequency was observed on Hope, Ursula and Victoria. Moreover the frequency was, at times, severely unstable. This is perhaps due to the reduced antenna length but it is felt that aerodynamic heating of the fiberglas insulator might be the dominant factor. Future firings will include temperature sensors to evaluate the effect of aerodynamic heating.

The loss of signal on all the spike-antenna shots during early portions of the flight might be ascribed to the butterfly antenna pattern. However, one would expect this signal loss to be symmetric about the time of apogee and such was not the case.

9.3 Quadraloop-Antenna Telemeters

Three of the four rocket borne telemeters did function although only two of the shots can be considered successful. The magnetometers were found to be unsuitable as designed. They were more sensitive to temperature fluctuations than to magnetic field variations. Only one of the six units was functioning before launch. The failure of the other five might be due to high potting temperatures incurred during assembly.

The sunseekers survived the firings successfully. The deviation ratios for the sunseeker channels were too low with the result that the signals were just barely above the noise. In shot Chicoutimi, the noise finally dominated after T + 45 seconds. Since only one of the quadraloop antennas on each vehicle was active, the radiation pattern was unsymmetric. A periodic loss of signal resulted. If sunseekers are to be used for guidance, then a symmetric radiation pattern is required since the periodic loss of information cannot be tolerated. This periodic modulation of the RF signal did produce some interesting information. The average frequency of this fading during the ascent of shot Chicoutimi was about 3.4 cps which agrees well with the sunseeker data of 3.7 cps. After re-entry, a fundamental fading frequency of 3.9 cps is observed on the AGC channel. The observed increase in spin rate does agree with the idea that the vehicle should spin up on re-entry because of the cant of the fins.

It must be observed that the sunseeker devise actually takes a measurement only once in each revolution of the vehicle. If the vehicle is experiencing pure rolling motion about an axis at some angle to the sun vector, then the data will be quite accurate. But, if the vehicle is also experiencing a pitching and yawing motion of frequency comparable to the roll rate, then the data would be meaningless. An analysis of the Martlet-3B vehicle motion for shot Chicoutimi conditions shows that a pitching and yawing frequency of one cycle per second could exist at 20,000 feet altitude. This frequency decreases with altitude (except for the time of increased velocity due to rocket thrust) so that at 100,000 feet the pitching and yawing frequency is about 0.3 cps. The data would therefore be in error for shot Chicoutimi by as much as 25% during the early flight and would improve in accuracy as the pitching and yawing motion dies out.

The data for Chicoutimi, as shown in Figure 32, suggest that the motion of the vehicle became more unstable after rocket burnout. Unfortunately, as mentioned above, these data are discrete measurements rather than a continuous history of vehicle attitude. At any rate, instability of motion after rocket burnout is not as important as during rocket burning or before ignition. For guidance purposes, however, the stability of motion is important both for timing a second stage ignition and for measuring the attitude by sunseekers.

The little data received from Fontainbleau indicate that the vehicle was quite erratic at the time of rocket ignition. The roll rate was an extremely low 0.5 cps. The sunseeker data are of no real value, since the pitching and yawing frequency was probably of the same order of magnitude as the roll rate. This erratic motion correlates well with the fact that the rocket veered completely off course and flew an entirely new trajectory.

No rocket pressure data were received from either Fontainbleau or Chicoutimi. The pressure gage channel on Chicoutimi showed that the gage did break when the rocket motor began to perform. Thus, an accurate time of rocket ignition was obtained. Signals from Fontainbleau were lost about 15 seconds after the rocket motor probably started and no information is available as to pressure gage performance. It is felt, however, that the pressure sensor for HARP rocket firings needs substantial development.

9.4 Automatic Gain Control (AGC) Data

Perhaps the most significant data produced by the telemetry experiments were the data recovered from the signal strength or AGC measurements. The AGC observations consistently produced accurate impact times which agree quite well with radar observations of impact. Such data are invaluable for extremely high altitude flights, since the MSP-19 radar capability stops at about 350,000 feet. Reacquisition of target by the MPS-19 during the descent portion of the flight has been a matter of approximately 80 per cent success. The telemeter has provided a beacon capability which invariably gives impact times.

A most important piece of information obtained from the AGC record was the time at which the vehicle turned over on re-entry. No prior data have been available as to turnover time and it was expected to occur much later in the trajectory than the current data actually show. These data will be used to correct ballistic trajectories for the Martlet vehicles by taking the increased drag into account. The AGC record also demonstrates the oscillatory motion of the vehicle, particularly after re-entry.

9.5 General Comments

Despite the substantial success of the telemetry instrumentation certain areas need continued development. Improvements and redesign are needed in power supplies, umbilical connections, sensors, transmitters and antennas.

In general, the power supplies were poorly designed. Part of the reason for the poor design stems from the variety of voltages required in each telemeter. For example, the magnetometer payloads required six different supply voltages at various points in the circuit. The power supplies were so designed that they experienced continuous internal drain of current through portions of the circuit. The power supplies had to be constantly on-charge or they would be depleted within sixteen hours.

The SCO inputs called for a bias of +8 volts DC. To prevent loading down the SCOs, the magnetometers and sunseekers had to be biased about

+8 volts DC. SCO redesign shoult take into account that most voltage generating sensors are zero-output devices under zero-input conditions.

The deviation ratios on each telemeter were much too low. For optimum signal-to-noise ratio, the receiving system (300 kc bandwith) required a deviation ratio of 2.5 for a subcarrier frequency of 40 kc. The maximum deviation ratio needed would be 4.0 for a 3-kc subcarrier. Shot Victoria, which had the greatest deviation ratio, measured at only 1.3.

The great frequency shifts experienced with the spike-nose-antenna require that the RF transmitter be designed to operate at 240 mc as a first step in eliminating the possibility of loss of transmission.

10. SUMMARY AND CONCLUSIONS

The telemetry portion of the firing program conducted at Wallops and Barbados during June-October of 1964 was quite successful and demonstrated considerable improvement over the telemetry used in previous HARP firings. Data were received and provided useful information about vehicle performance and some flight parameters.

Signal strength (AGC) data are quite valuable and in themselves would justify the use of telemetry in HARP firings. In the event that the radar would not acquire the vehicle, the AGC data can given an adequate account of the events of the flight. It would be an advantage, then, to have telemeters on board HARP firings even if they acted merely as beacons.

Data sensors, antennas and improved deviation ratios are the areas requiring immediate improvement. For command guidance and range safety abort/destruct systems, continuous transmission during ascent is mandatory. Any loss of signal could seriously disturb the progress of the flight program.

11. ACKNOWLEDGEMENTS

Thanks are due to Dr. Charles H. Murphy of the Ballistic Research Laboratories and Dr. Gerald V. Bull of McGill University for their continued support and direction of this program. The electronic development work was carried out by the Harry Diamond Laboratories, 530 Branch and particular thanks are due to Messrs. Dan Finger and Neil Wilkin. We are indebted to Messrs. Jules Green and Ralph Welsh, Jr. of NASA-Wallops for the telemetry receiving support of the 5-inch program. A final word of thanks to Mr. William Tenly of the Ballistic Research Laboratories for his invaluable assistance in establishing and operating the ground station at Barbados.

W. H. MERMAGEN

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APPENDIX A

Canadian Bristol Aerojet Ltd. provided magnetometers of the "second-harmonic flux-gate" variety for use with the Martlet-3B rockets. The magnetometer produces a voltage proportional to the magnitude of the component of an external magnetic field along the axis of the sensing head.

The sensing head consists of primary coils wound about a saturable core and a set of secondary coils. The primary coils are excited by an oscillator which causes the core to saturate every half cycle. The permeability of the core varies with the strength of the magnetic field. Consequently, a frequency is produced in the secondary coils which is twice the frequency of the primary and whose amplitude is proportional to the strength of the magnetic field along the core axis. This a.c. voltage is rectified by a detector to produce a d.c. voltage proportional to magnetic field strength.

When the earth's magnetic field is the external field, the magnetometer can provide roll rate, pitching frequency, field strength or vehicle aspect when used in conjunction with some other device such as solar cells.

Canadian Bristol cites an accuracy of $\pm$ 2% for the magnetometer when used as an off-the-shelf item. No accuracy figures can be given at present for its use in modified form with the Martlet 3B.

APPENDIX B

Canadian Bristol Aerojet, Ltd. provided sunseekers (Solar Sensors) for use with the Martlet-3B rocket vehicle. The solar cell consists of a silicon, photovoltaic device which produces a voltage whenever visible radiation is incident on it. The cell output voltage is between 150-350 millivolts in direct sunlight. Amplifiers are required to bring the signals up to usable levels. The cell is housed behind a narrow slit which permits a 2° lateral and a 170° transverse field of view.

The sunseeker system consists of two solar cells. The cells are physically so oriented that their fields of view form two sides of an irregular tetrahedron and intersect to form a line outside the missile. We shall call the vector from the missile to the sun the 'solar vector'. Since the altitudes achieved by the vehicle are small with respect to the distance between sun and earth, the 'solar vector' is essentially the vector from the earth to the sun. The position of this vector with respect to the missile axes depends on the attitude of the missile and the time of day (or position of the sun). If the vehicle is made to roll, then the solar vector describes a cone about the long axis of the vehicle. This cone intersects the two sides of the tetrahedron which are the fields of view sequentially in time. If the attitude of the vehicle changes, the intersections occur either closer together or further apart in time. If the solar cells are made to have different outputs, say one positive and the other negative, then the time interval between pulses can be distinguished. One complete revolution of the vehicle corresponds to the time between two positive or two negative pulses, and the attitude of the vehicle can be related to the time between a positive and subsequent negative pulse.

At best, the solar vector can be determined to within a cone about the vehicle. For an absolute determination of attitude, another vector (such as the earth's magnetic vector) must be found independently.

TABLE I

Shot	Telemeter No.	RFO (mc)	SCOs (kc)	Deviation (kc)	Deviation Ratio (Δf/f)
DAPHNE	1	248	34.5	30	0.9
ODETTE	4	250	33.5	30	0.9
ETHEL	2	249	33.1	30	0.9
FRANCES*	3	-	-	-	-
ARVIDA**	3	251	2.6	-	-
			4.7	-	-
			9.3	-	-
			31.8	-	-
ESCUMINAC**	4	248	3.2	-	-
			6.3	-	-
			10.5	-	-
			47.8	-	-
GLORIA	F	252	34.1	30	0.9
HOPE	A	251	35.5	28	0.8
CHICOUTIMI	2	243	45.7	16	0.4
			81.0	-	-
SHARON	E	244	34.8	40	1.2
FONTAINBLEAU	1	237	42.0	16	0.4
			70.0	-	-
URSULA	C	251	34.6	30	0.9
VICTORIA	D	252	43.9	55	1.3

* *This unit was not operating before firing.*

** *Deviation could not be determined because of the complex modulating signal.*

TABLE II

JULY & OCTOBER FIRINGS AT WALLOPS

Shot	Date	Telemetry Experiment	Launch	Apogee (ft)	RF (mc)	Data	Acceleration	Muzzle Velocity (fps)
El-1955	July 1st	Temperature	Good	101,000	251	No	46,200 g	?
El-1956	July 1st	Temperature	Good	130,000	255	No	46,200 g	?
El-1959	July 2nd	Temperature	Good	155,000	254	Yes	39,200 g	5000**
El-1963	Oct 15th	Temperature "g" switches	Good	163,500	234.5	Yes Yes	38,600 g	4270*
El-1964	Oct 15th	Temperature "g" switches	Marginal Stability	77,000	247	No Yes	44,900 g	4460*
El-1966	Oct 15th	Temperature "g" switches	Good	175,500	248	Yes Yes	43,700 g	4440*

**Velocity derived from smear camera records.*

***Velocity derived from doppler records.*

TABLE III

JULY FIRINGS AT BARBADOS

Shot	Day & Time	Telemetry Experiment	Launch	Velocity (fps)*	Apogee (ft)	RF (mc)	Data	Acq Time (sec)	Event Time (sec)	Turnover Time (sec)	Impact Time Telemetry (sec)	Impact Time Radar (sec)
DAPHNE	10th 1015	Balloon	Nose off	5470 F	155,000	-	No	-	-	-	-	300
ODETTE	11th 1655	Balloon	Broke up	-	-	-	No	-	-	-	-	-
ETHEL	12th 1720	Balloon	Good	5480 F	346,000	-	No	-	-	-	-	342
FRANCES	13th 1452	Balloon	Broke up	-	-	-	No	-	-	-	-	-
GLORIA	21st 1540	Fuze	Good	5150 F	316,000	254	Yes	10.8	179.4	234.9	300.6	301
HOPE	21st 2223	TMA Valve	Good	5500 R	339,000	259	Yes	2.1	-	241.2	303.2	303
SHARON	22nd 1900	TMA Press	Good	5500 R	350,000	244	No	0.1	-	249.2	309.4	310
URSULA	25th 2100	TMA Press	Good	5300 R	324,000	261	Yes	6.3	15.0	228.3	292.5	293
VICTORIA	25th 2330	TMA Press	Damage	(?)	275,000	261+	(?)	192.3	(?)	219.0	308.3	307.5
ARVIDA	15th 1715	Magnetom. & Pressure	Antenna damage	3350 F	(?)	-	No No	-	- -	-	-	-
ESCUMINAC	17th 1630	Magnetom. & Pressure	Broke up	-	-	255	No No	7.5	- -	-	36.5	-
CHICOUTIMI	22nd 1506	Sunseek. & Pressure	Good	3000 F	116,000	242	Yes Yes	0.2	** 18.5	90.0	184.4	184
FONTAINBLEAU	24th 1638	Sunseek. & Pressure	Good	2600 F	30,000	238	Yes No	0.1	** -	-	-	-

*F - *Fastax Camera Velocity*
R - *Estimated from Radar Apogee*
***This is not an event, but data throughout the flight.*

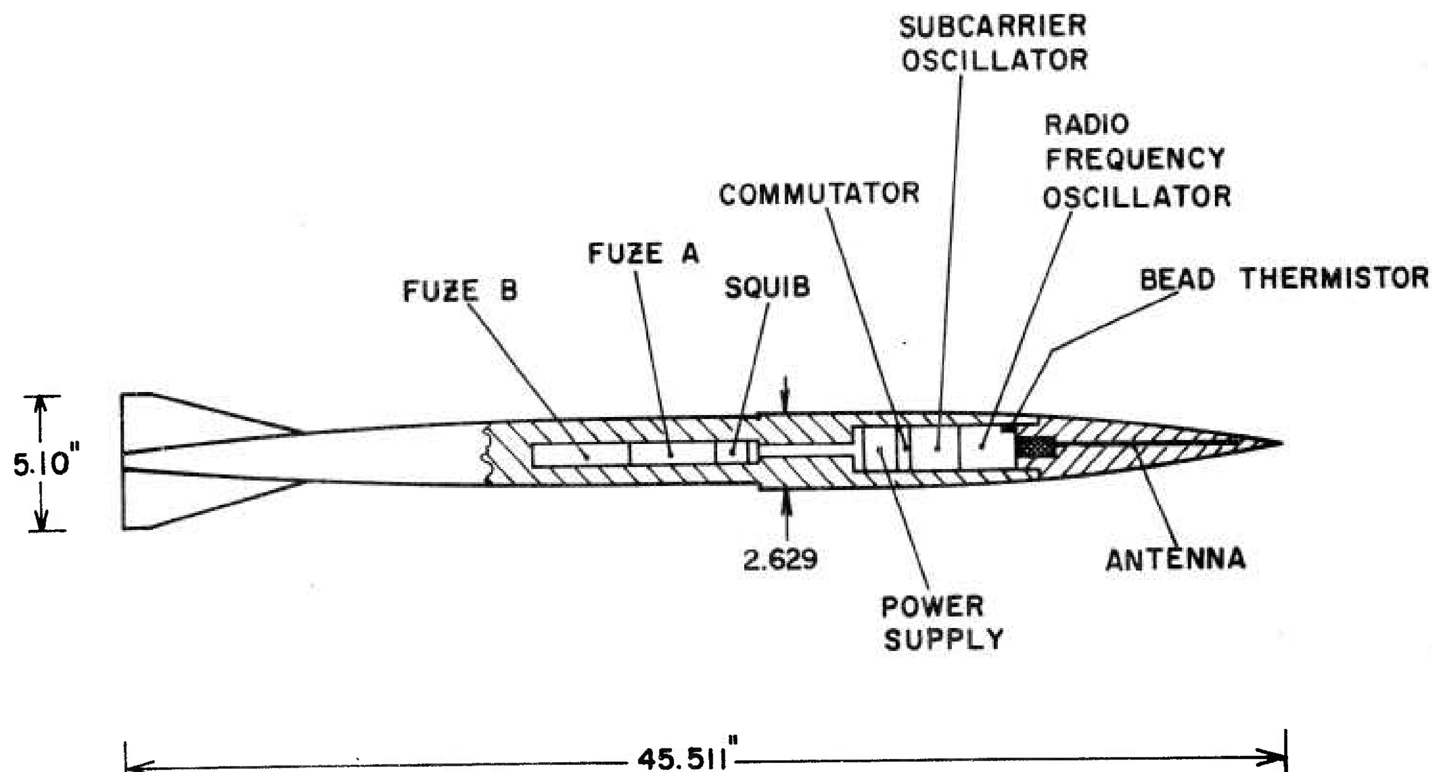


FIG. 1 ARRANGEMENT OF TELEMETRY COMPONENTS IN THE HARP- WALLOPS 5-INCH VEHICLE.

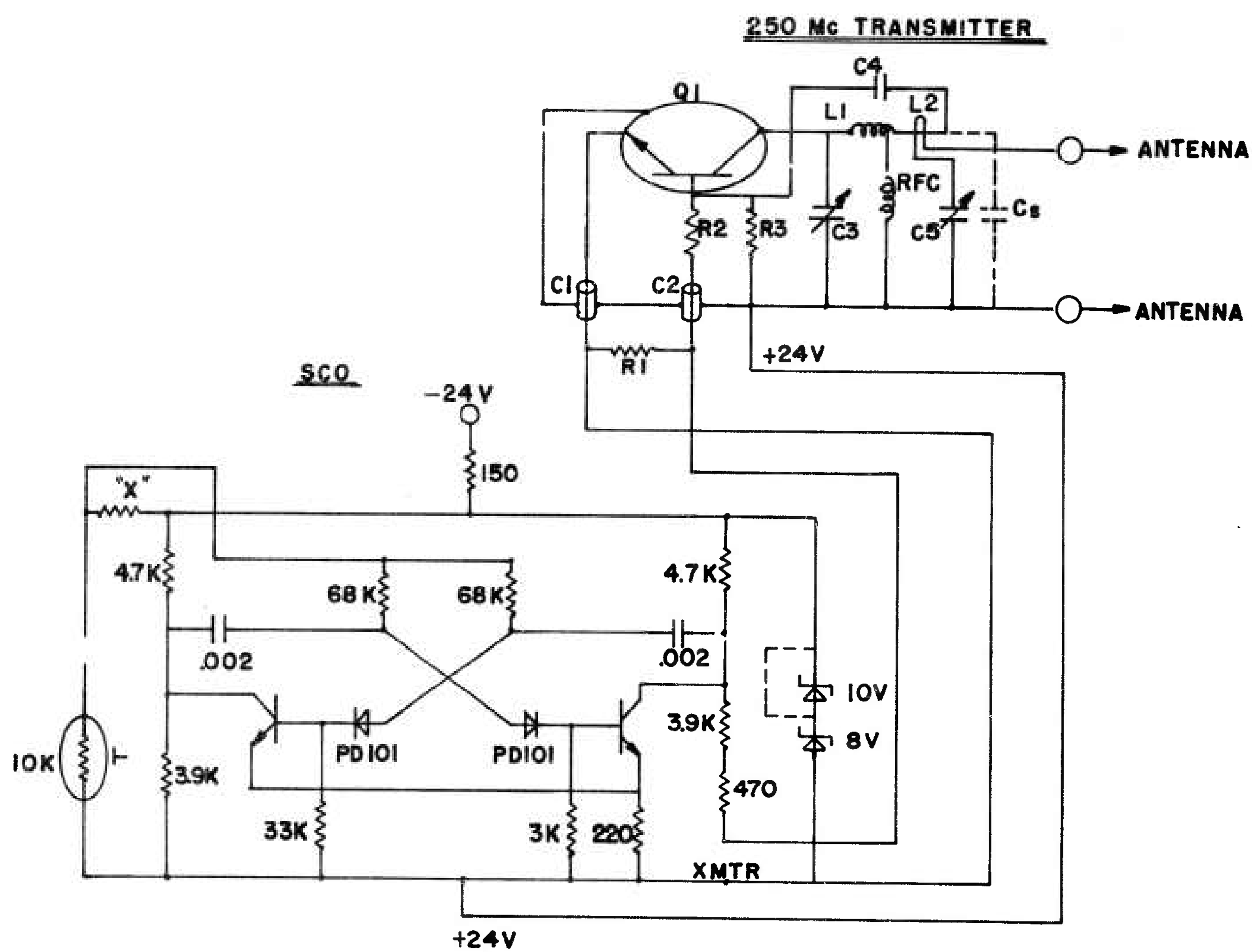


FIG 2. CIRCUIT DIAGRAM OF HDL 5-INCH GUN PROBE TELEMETER

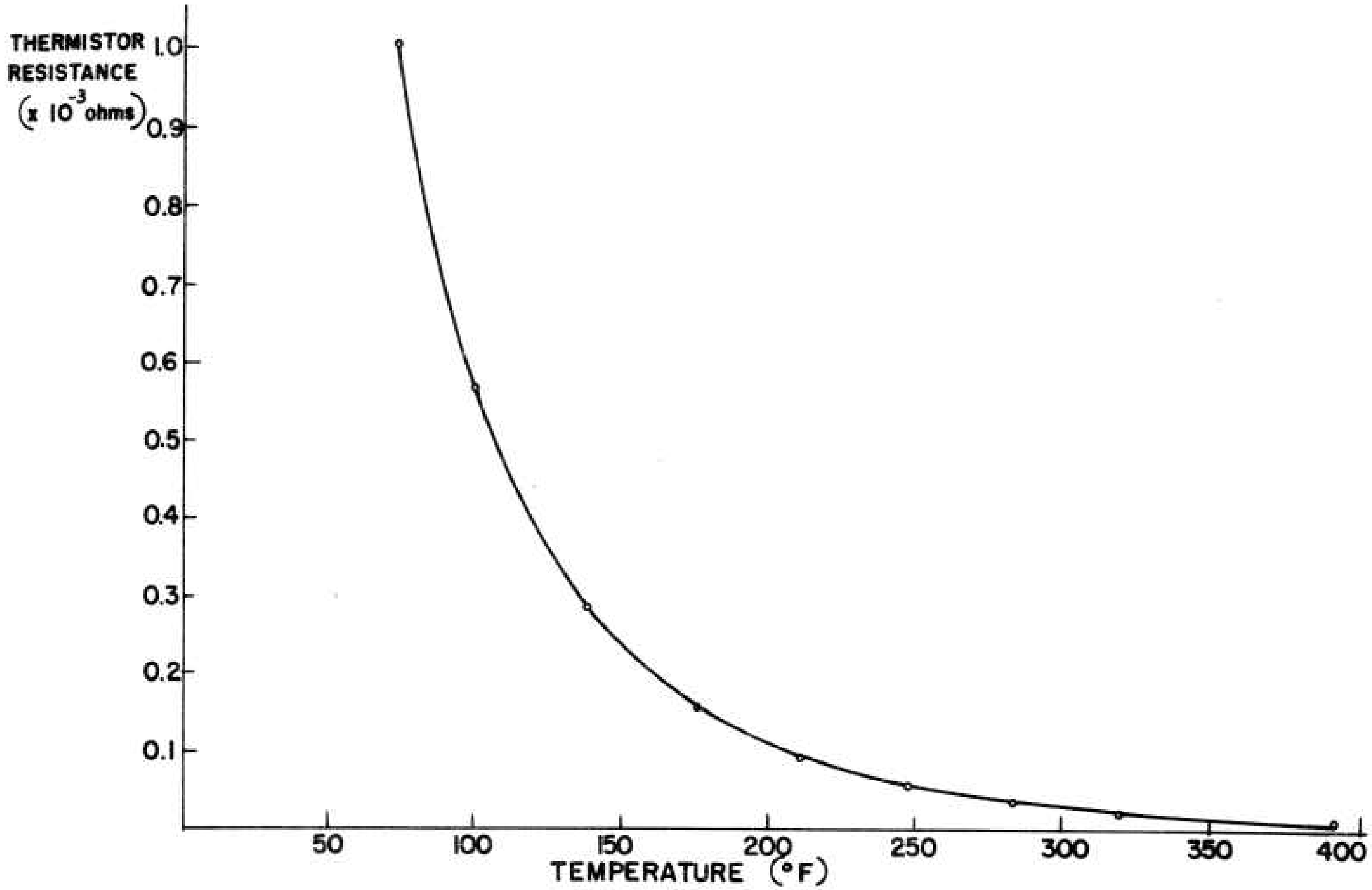


FIG. 3 TYPICAL CALIBRATION CURVE FOR BEAD THERMISTORS

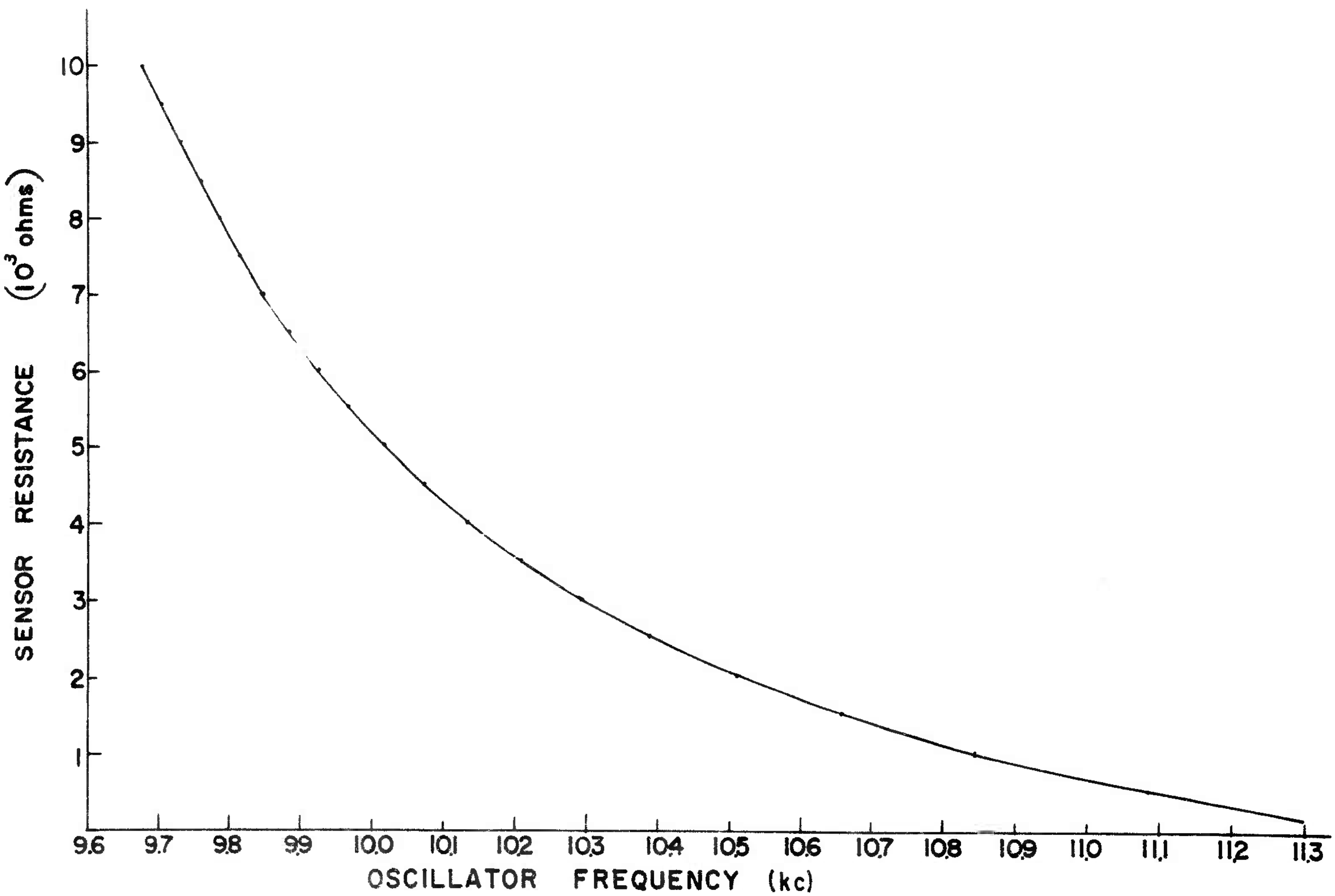


FIG. 4 TYPICAL SUBCARRIER OSCILLATOR CALLIBRATION

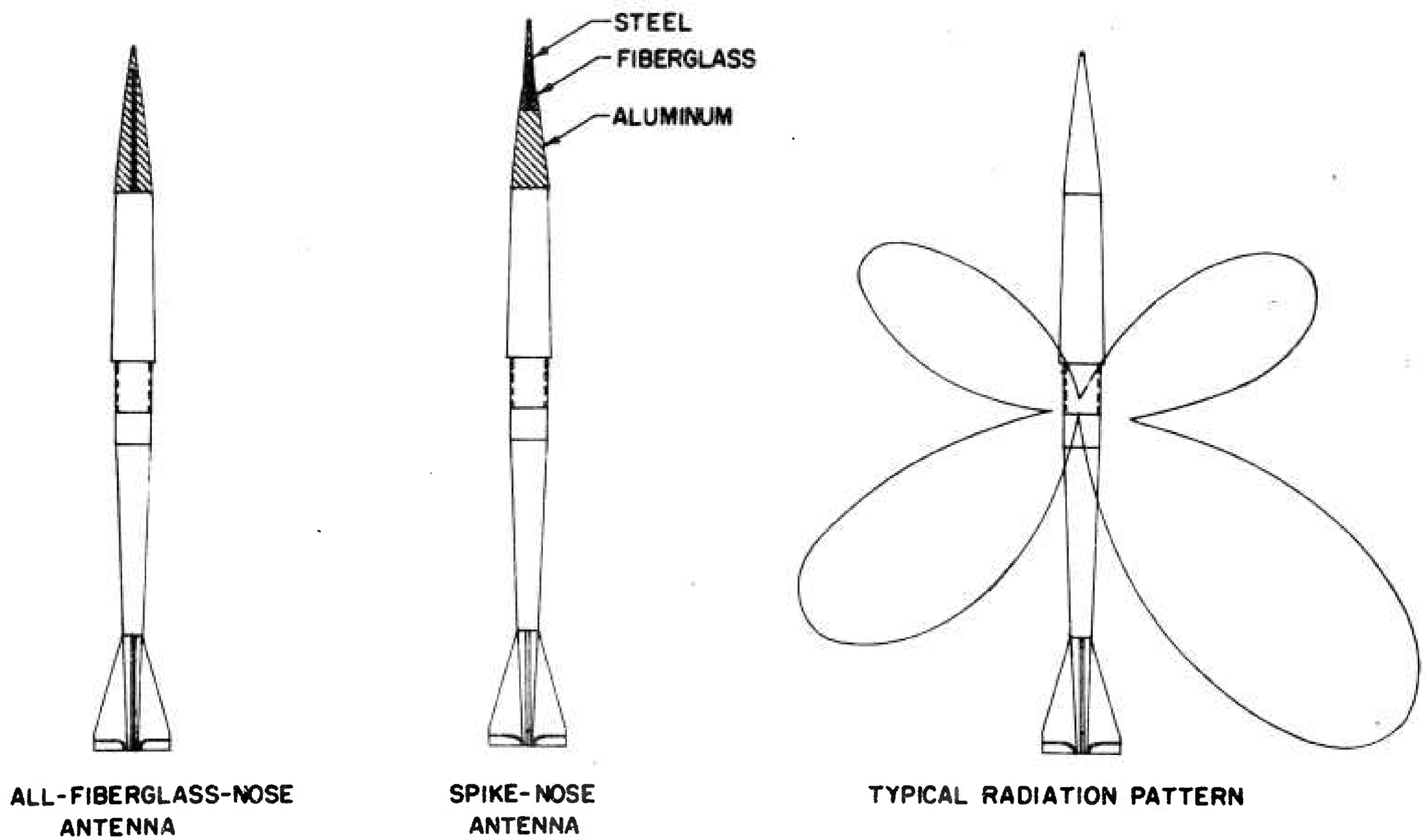


FIG. 5 5-INCH GUN PROBE VEHICLE ANTENNA AND A TYPICAL PATTERN

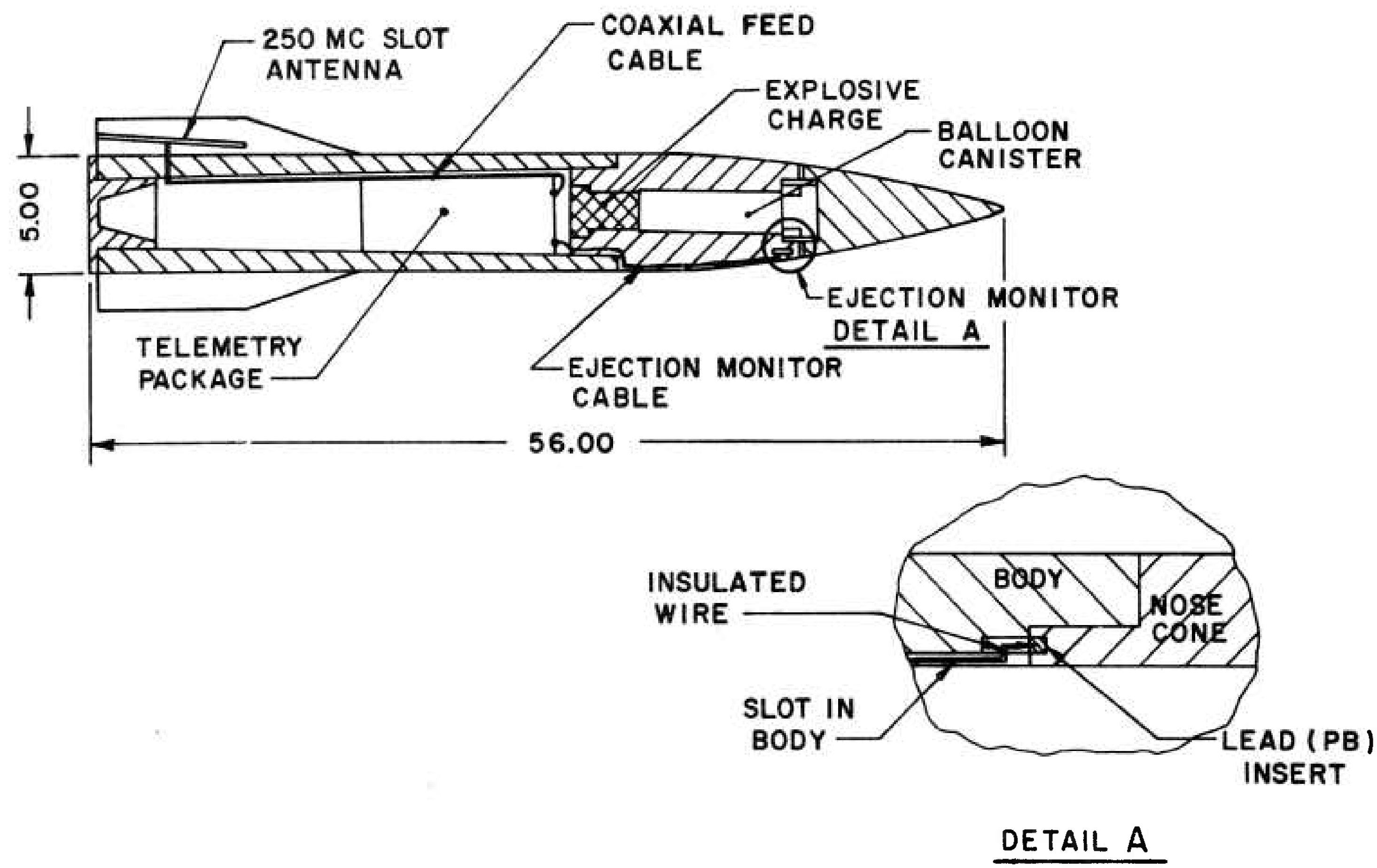


FIG. 6, SECTIONAL DIAGRAM OF THE MARTLET 2 ROBIN BALLOON AND TELEMETRY TO MONITOR EJECTION

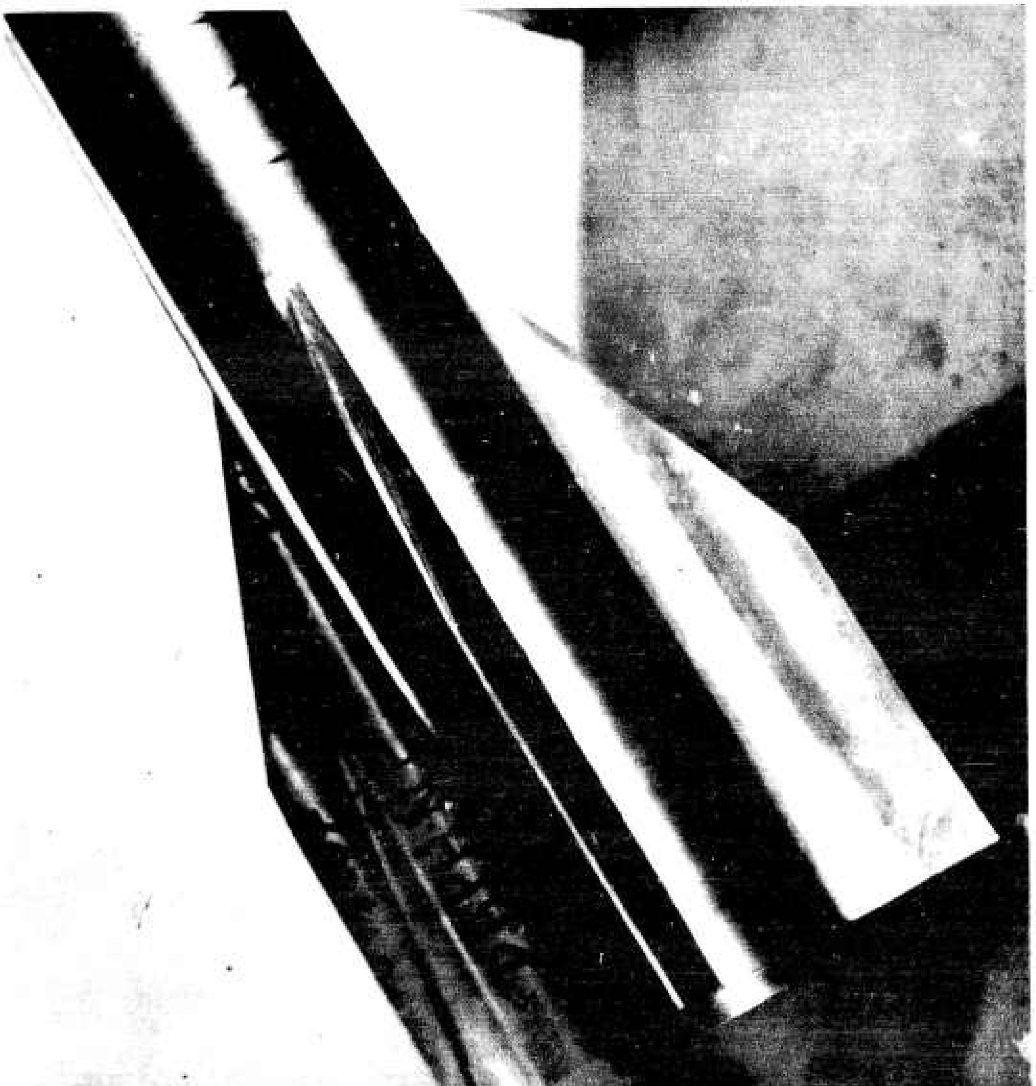


Figure 7. The Martlet-2 Slotted-Fin Antenna

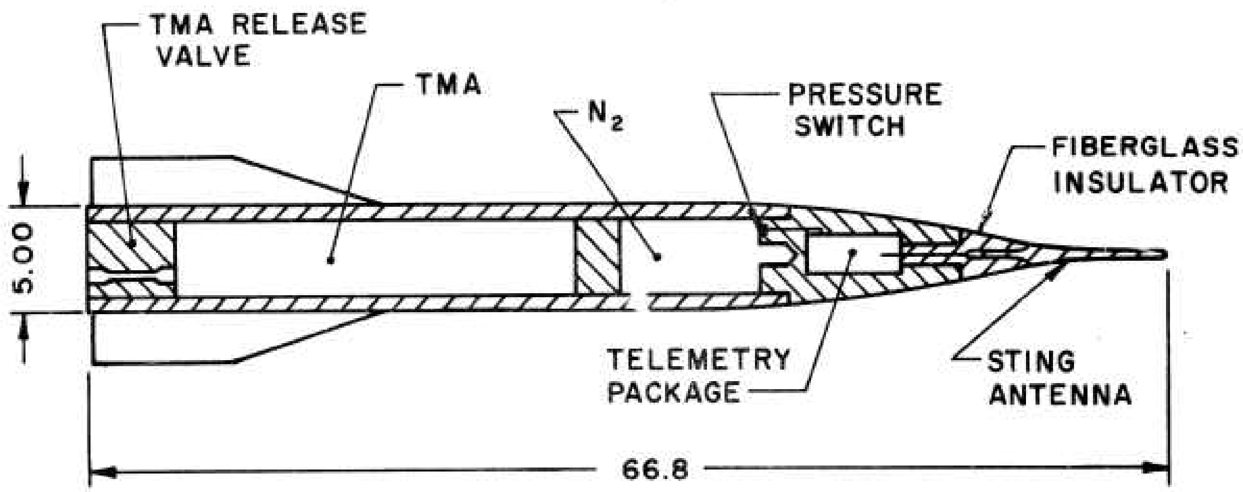


FIG 8, MARTLET 2, TMA AND TELEMETRY MONITOR

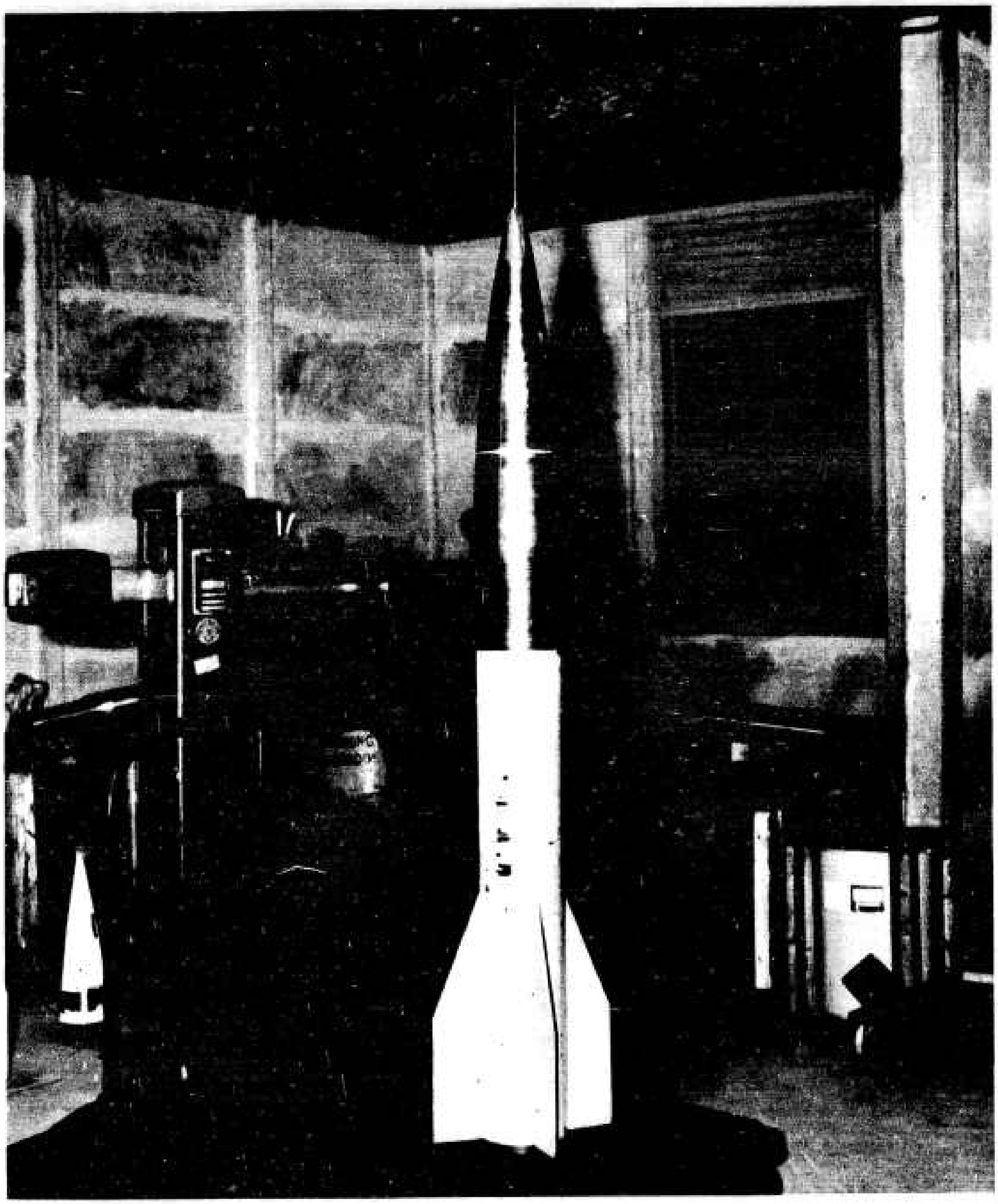
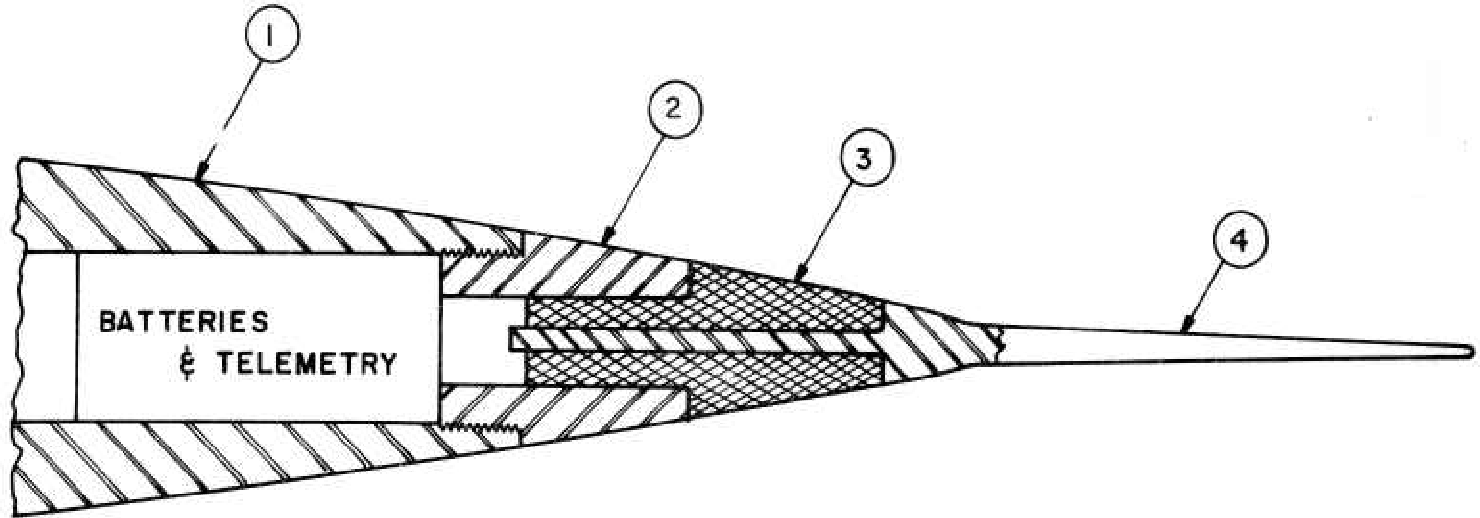


Figure 9. The Martlet-2 Spike-Nose-Antenna Vehicle



1. BODY
2. CONNECTING FITTING
3. FIBERGLASS INSULATOR
4. SPIKE

FIG 10. THE MARTLET 2 SPIKE-NOSE ANTENNA

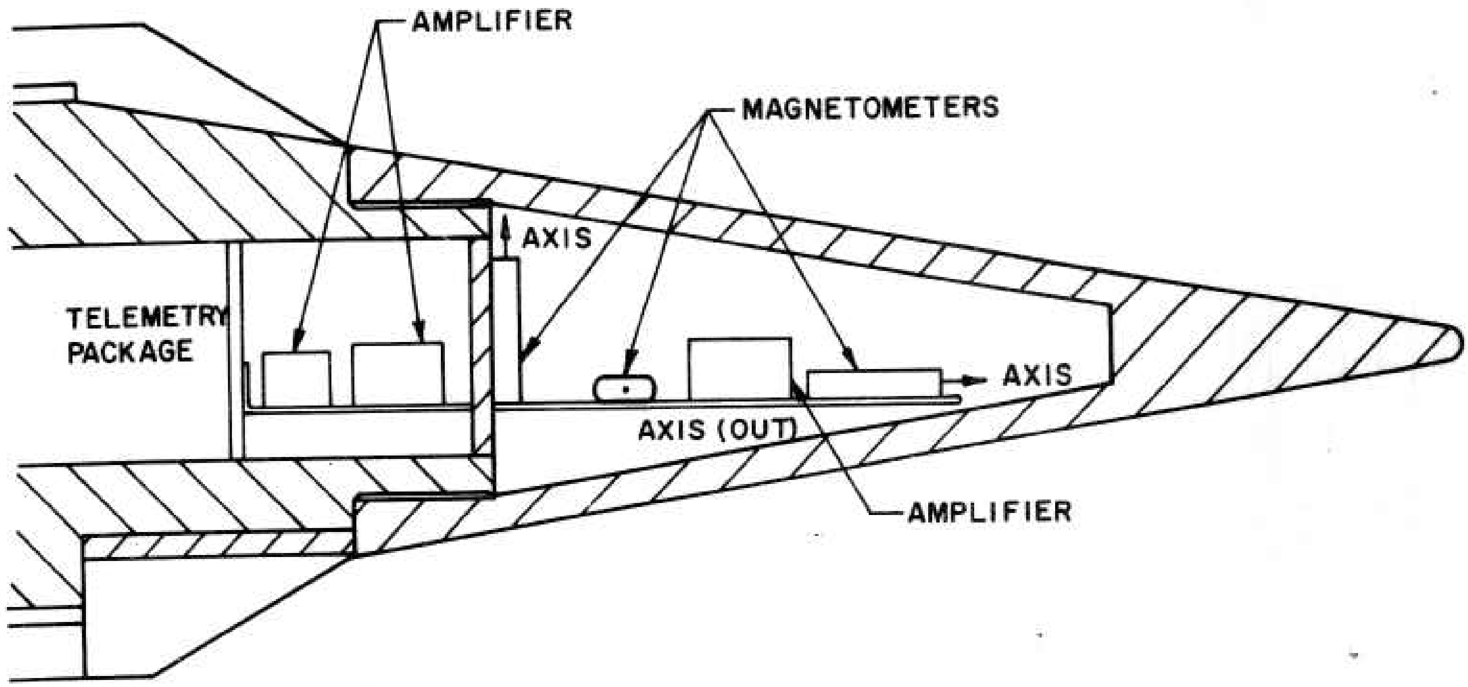


FIG 11, SCHEMATIC SHOWING THE ARRANGEMENT OF MAGNETOMETERS IN THE MARTLET 3B NOSE CONE

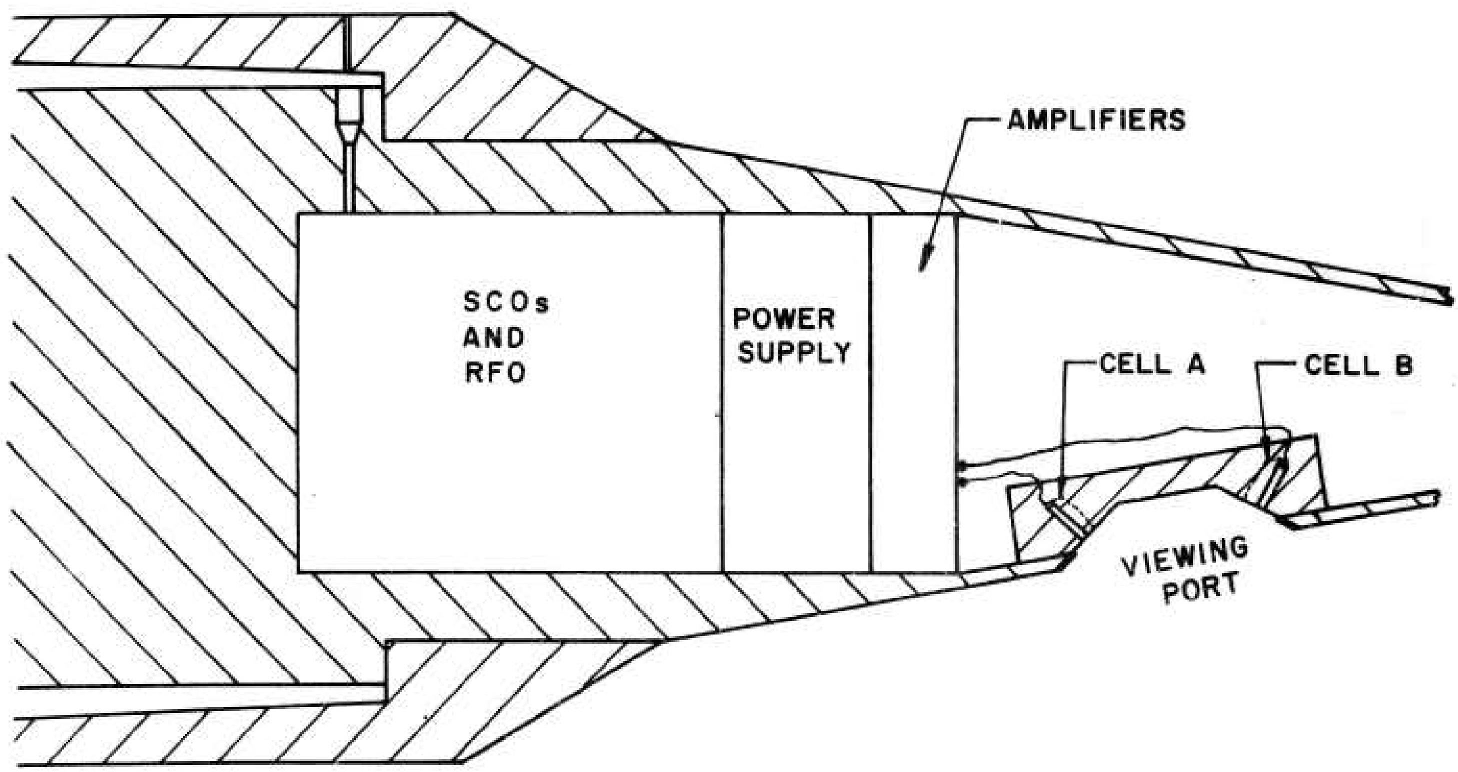


FIG. 12, ARRANGEMENT OF SOLAR CELLS IN THE MARTLET-3B NOSE CONE

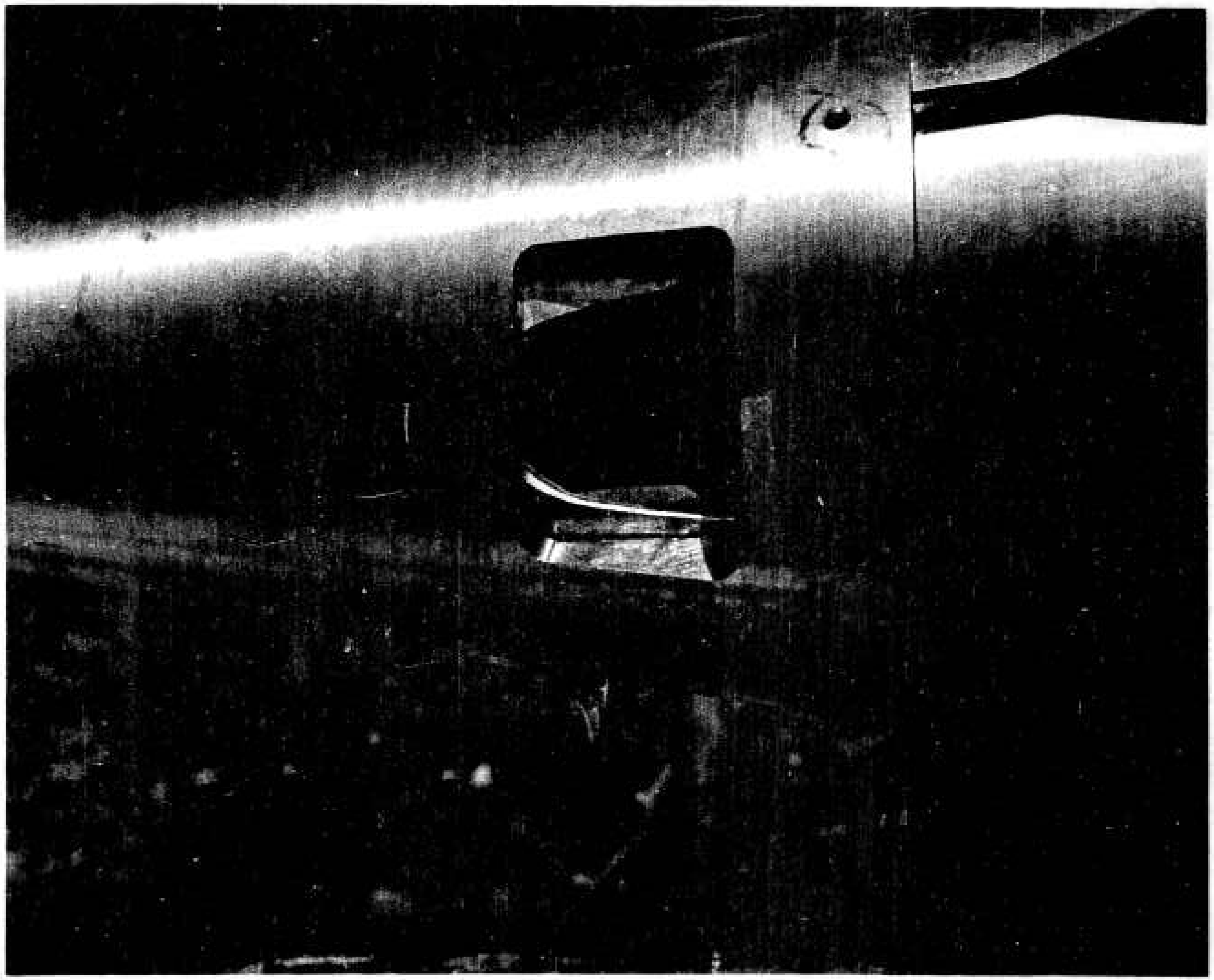


Figure 13. A Close-up of the Sunseeker Viewing Port in the Martlet-3B Rocket.

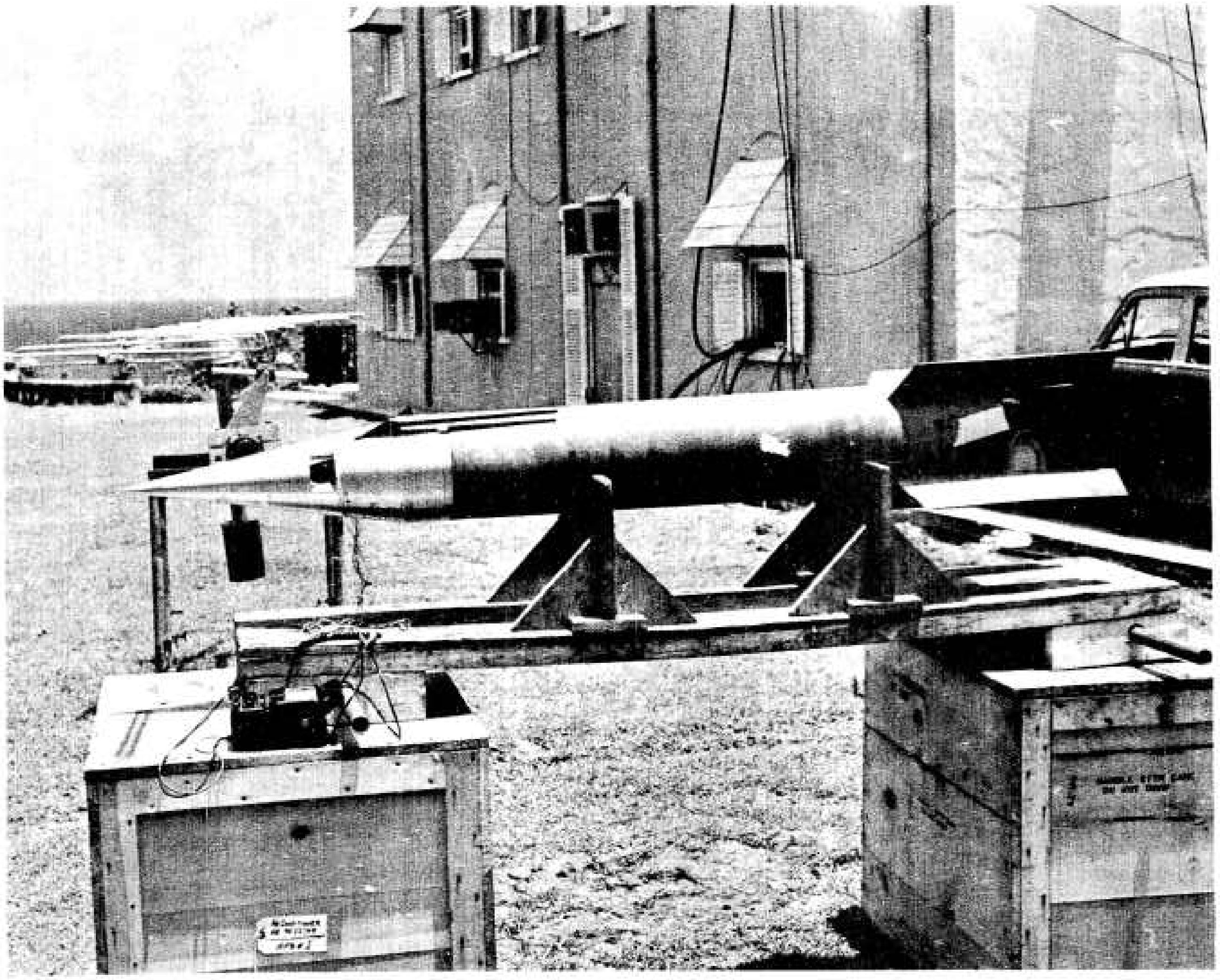


Figure 14. The Martlet-3B Rocket with Sunseeker Payload.

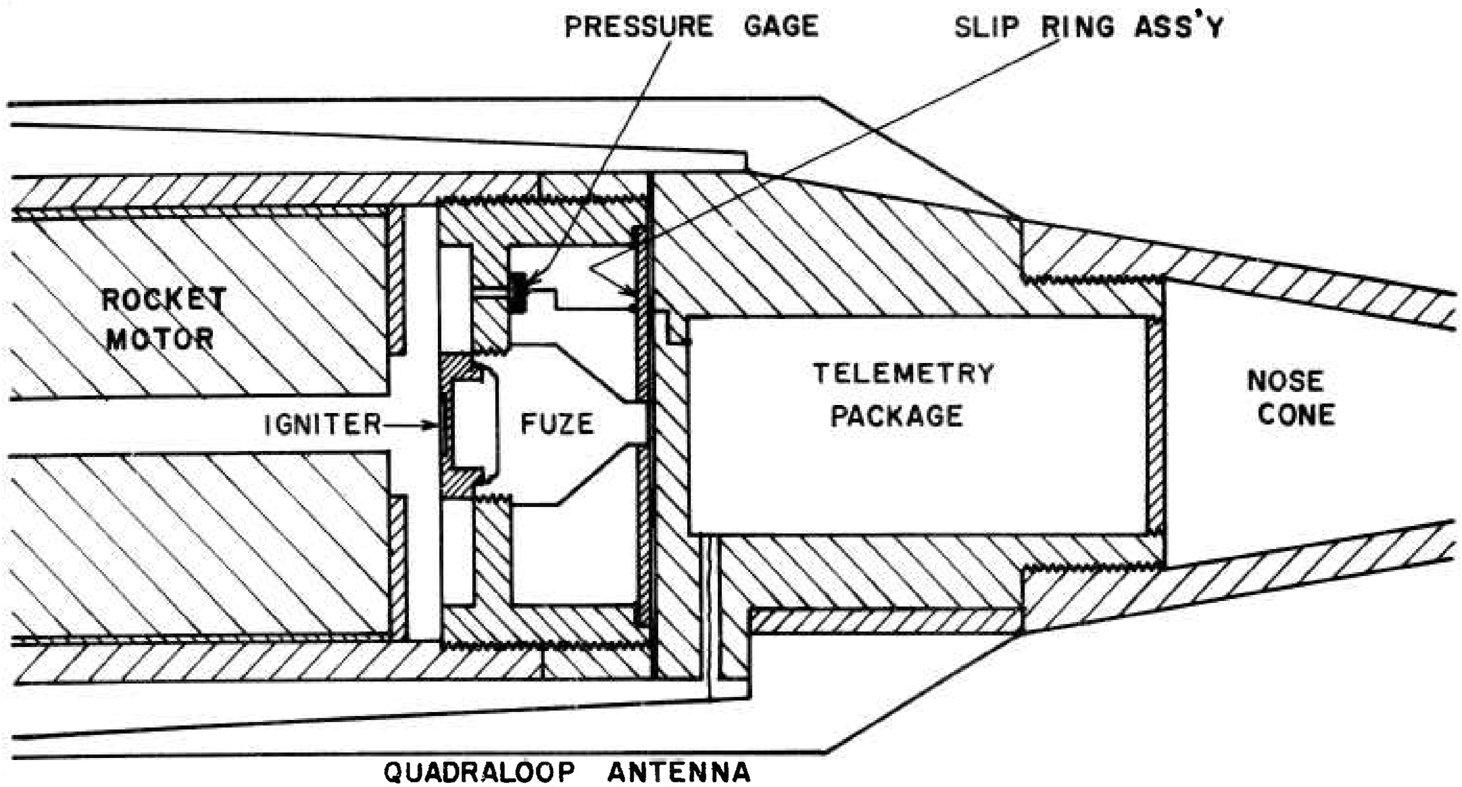


FIG. 15 DIAGRAM OF PRESSURE SENSING ARRANGEMENT FOR THE MARTLET 3B ROCKET

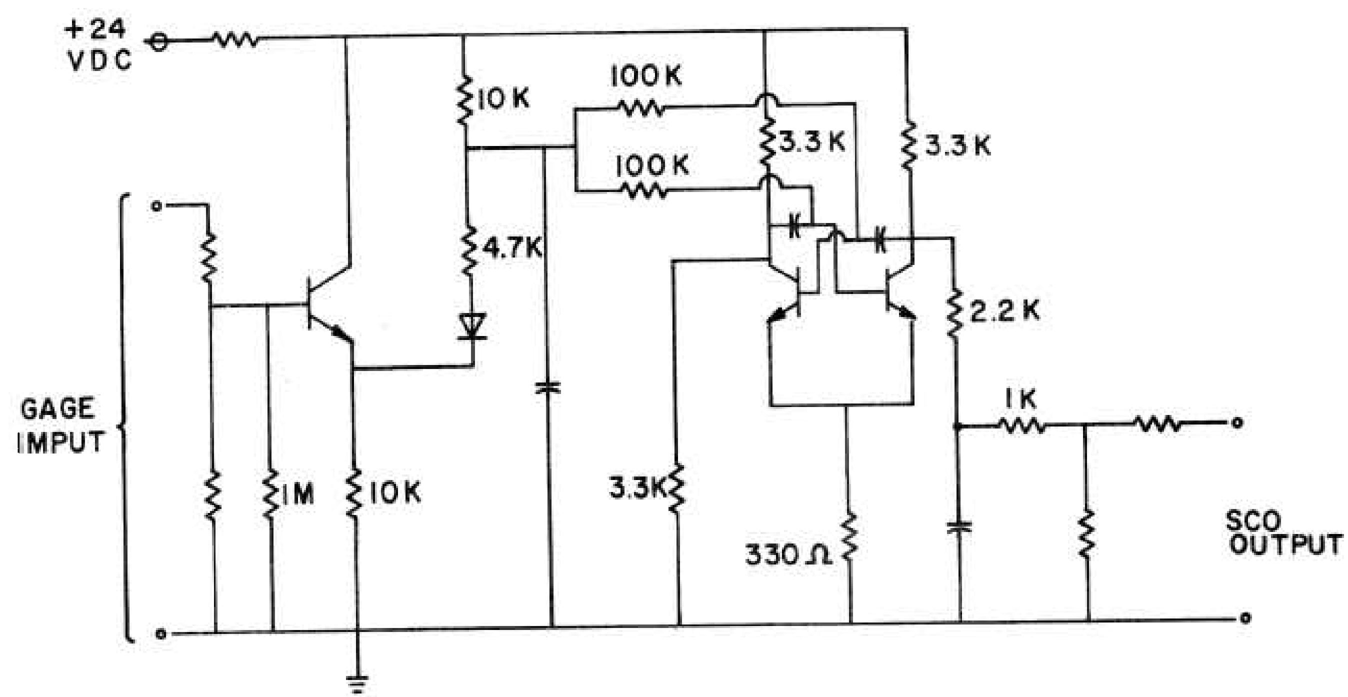


FIG 16, SUBCARRIER OSCILLATOR BASIC CIRCUIT DIAGRAM

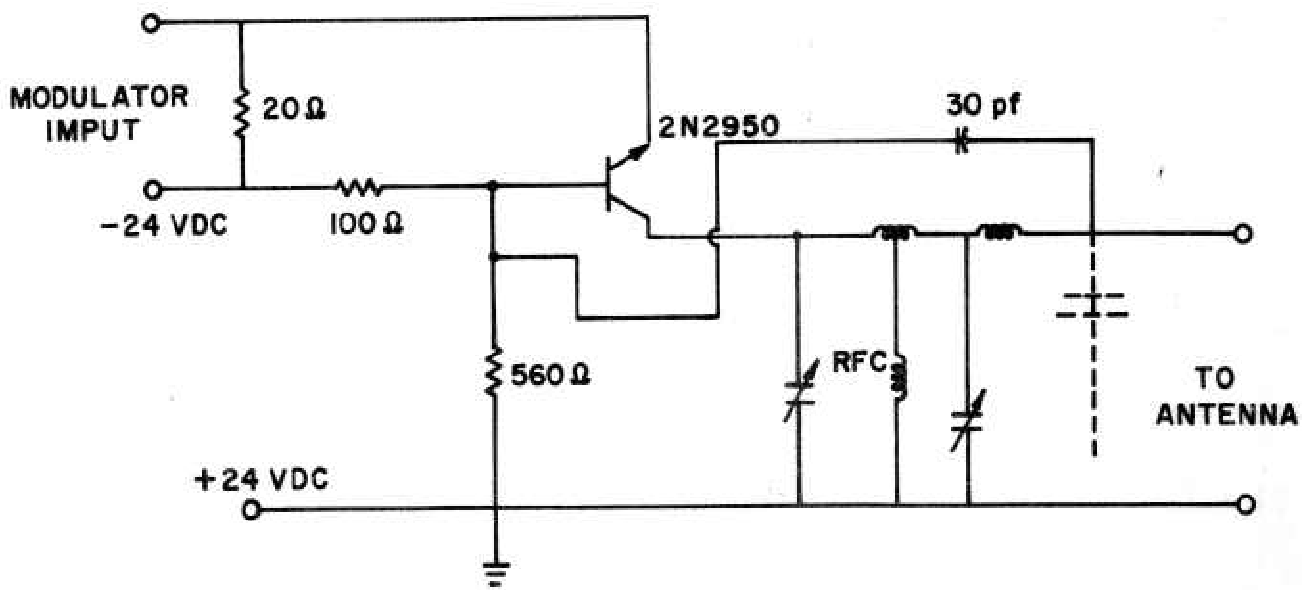
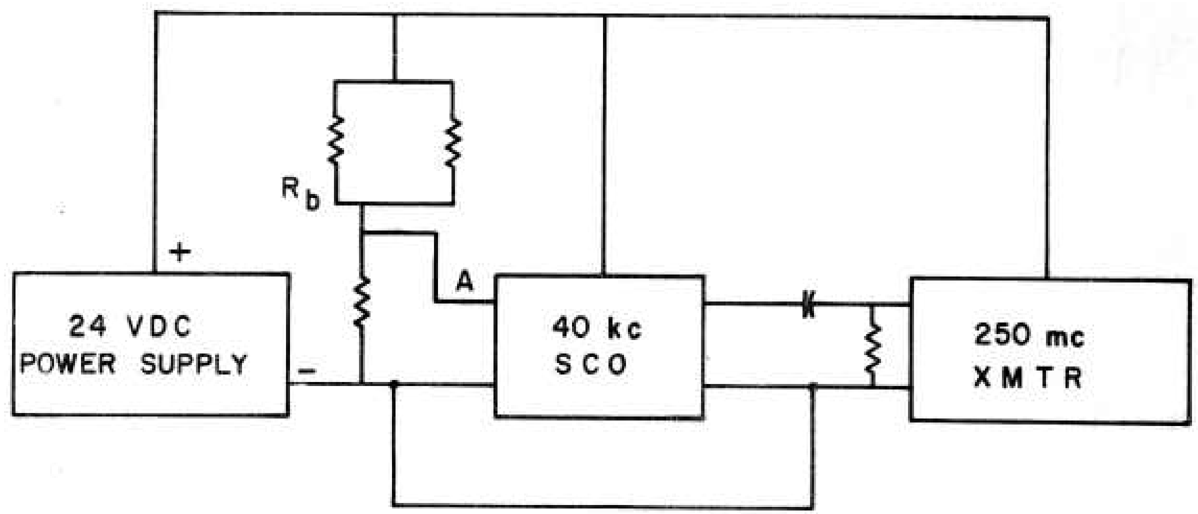
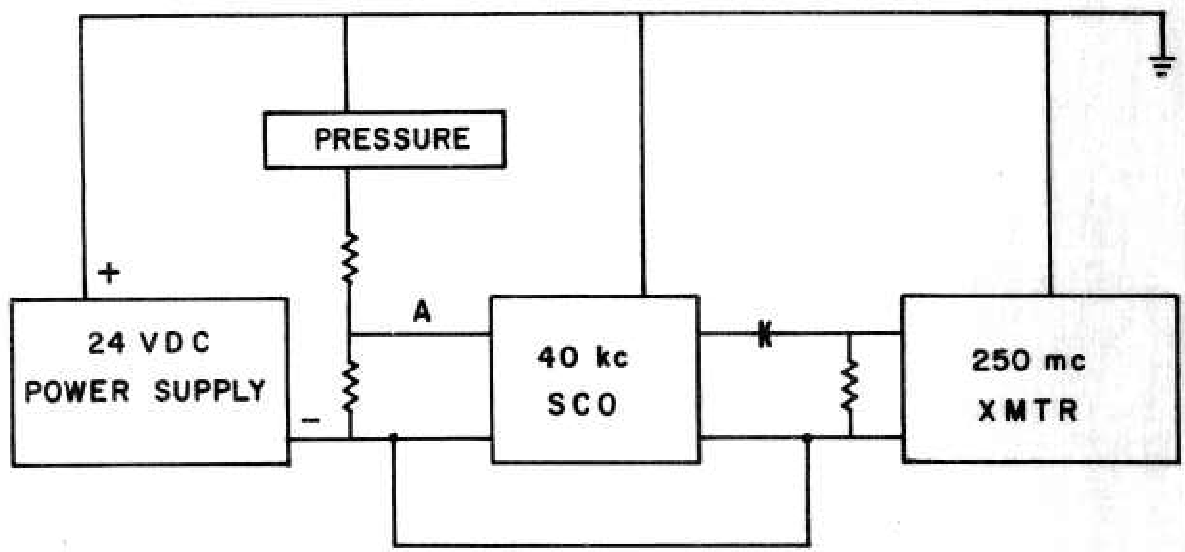


FIG.17, 250mc RADIO FREQUENCY TRANSMITTER



A: WITH R_b IN THE CIRCUIT, A IS AT +13 VDC
WITH R_b BROKEN OR DISCONNECTED, A IS AT +8 VDC

FIG 18, BLOCK DIAGRAM OF THE BALLOON MONITOR CIRCUIT



A: WITH PRESSURE SWITCH CLOSED, A IS AT 13 VOLTS
WITH PRESSURE SWITCH OPEN, A IS AT 8 VOLTS

FIG.19, BLOCK DIAGRAM OF TMA-RELEASE-MONITOR CIRCUITS

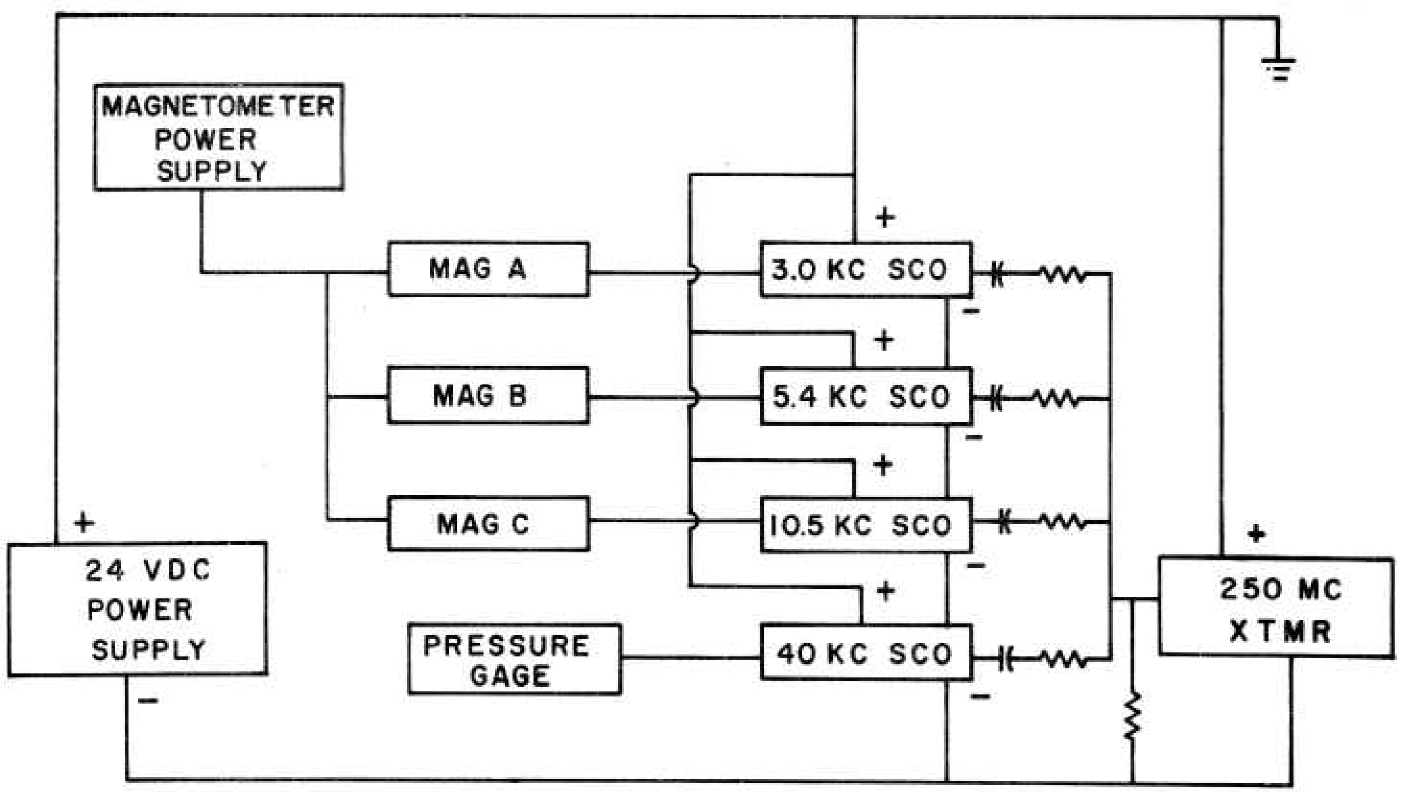


FIG 20, BLOCK DIAGRAM OF MAGNETOMETER AND PRESSURE SENSING CIRCUIT

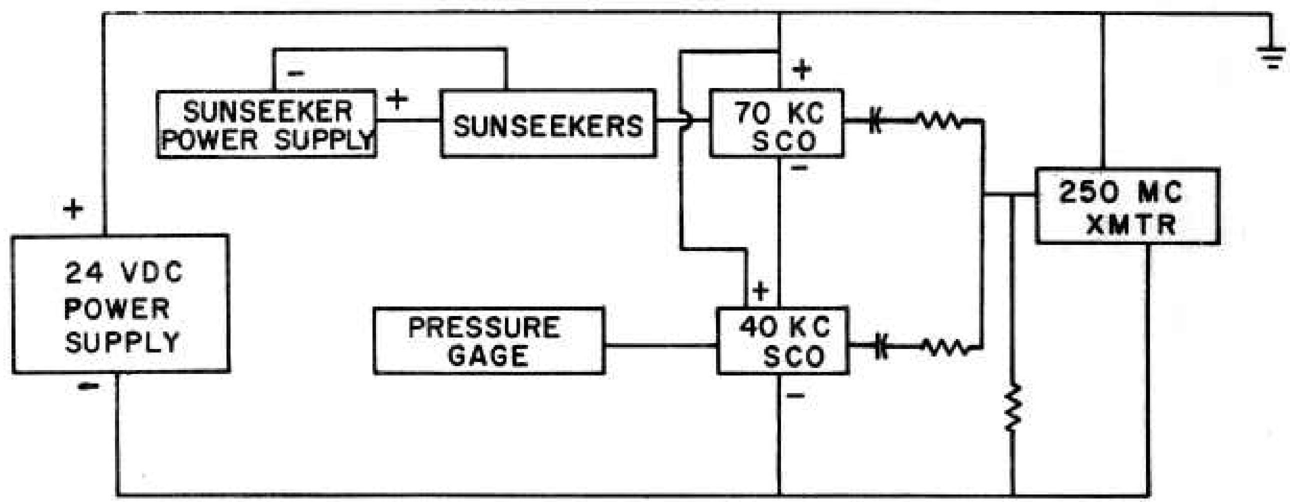


FIG. 21, BLOCK DIAGRAM OF SUNSEEKER AND PRESSURE SENSING CIRCUIT

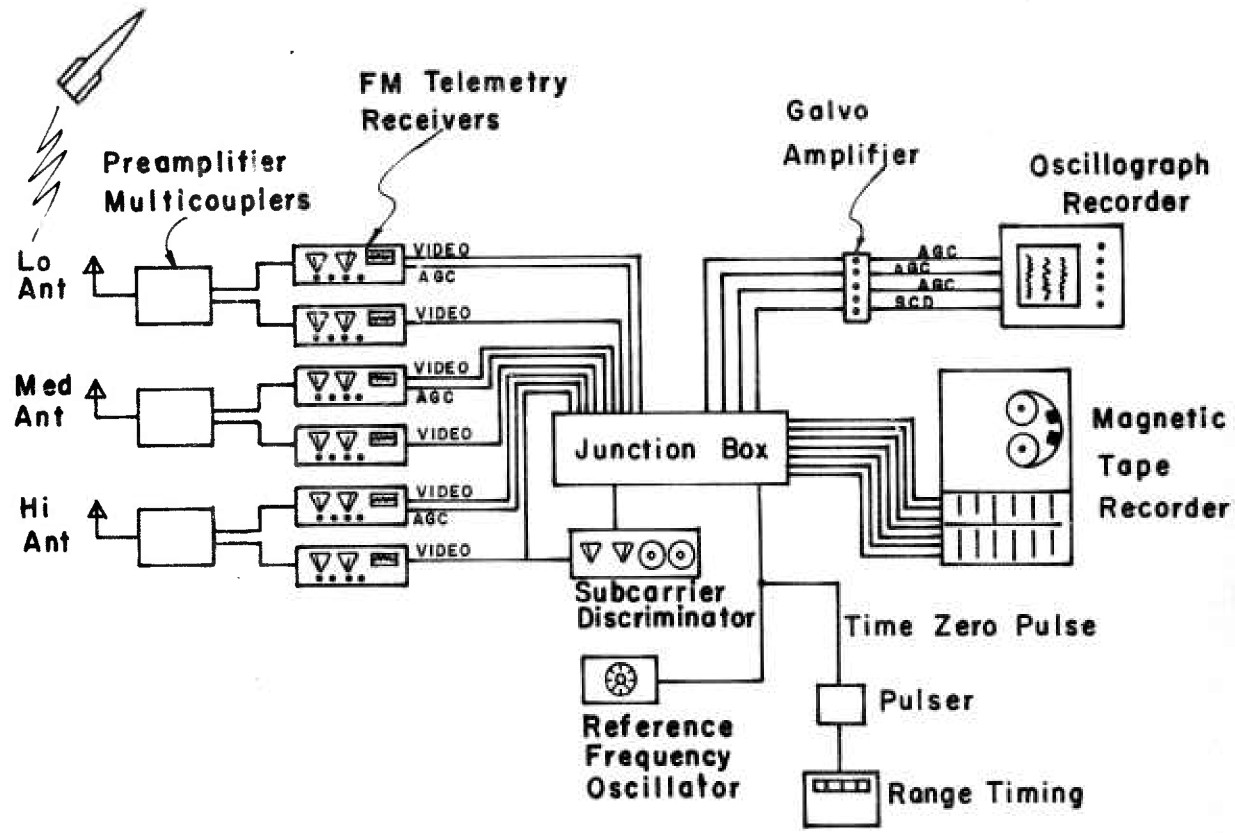


FIG. 22 SCHEMATIC OF GROUND STATION RECEIVING/RECORDING SYSTEM

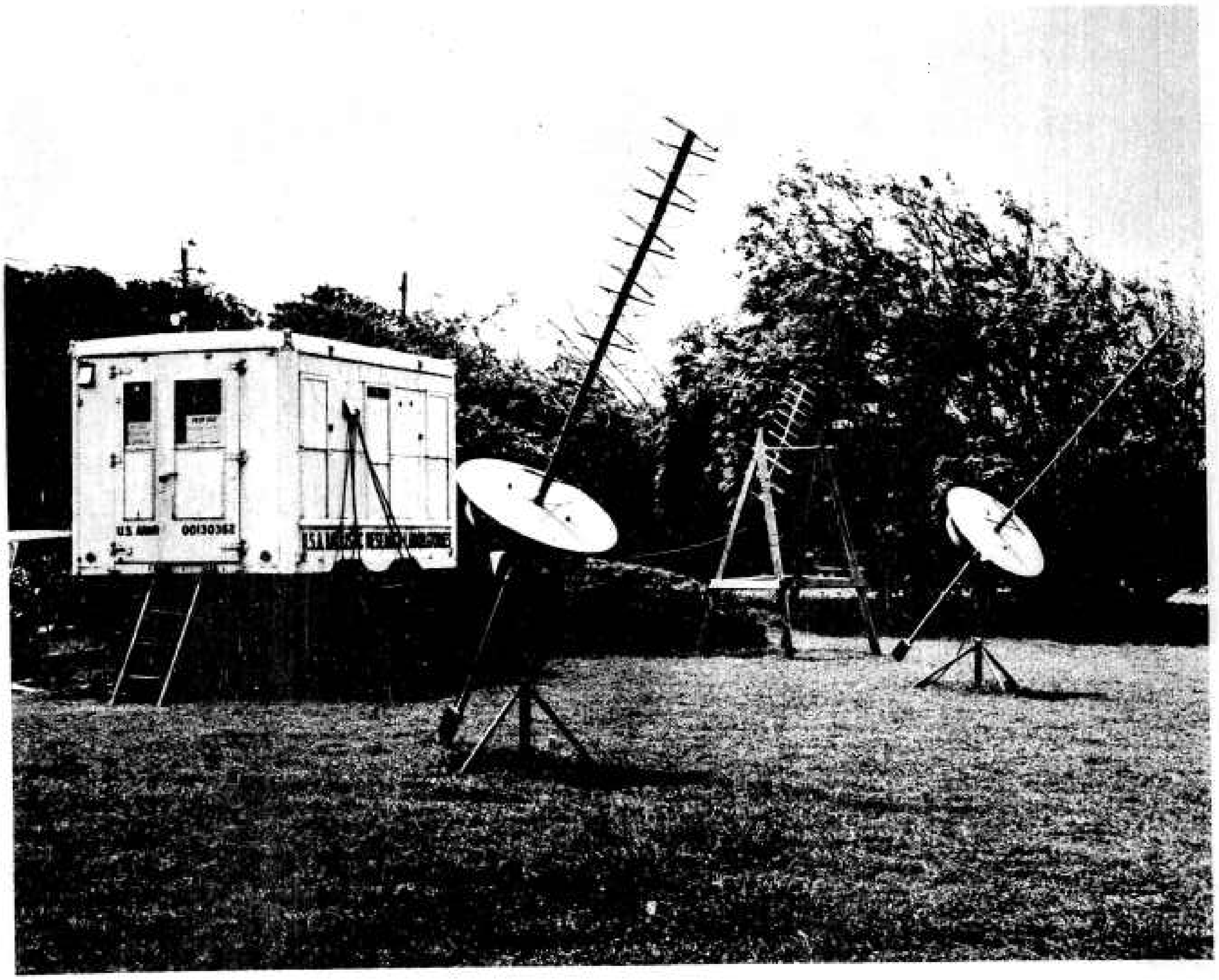


Figure 23. The BRL Ground Receiving Station at Barbados.

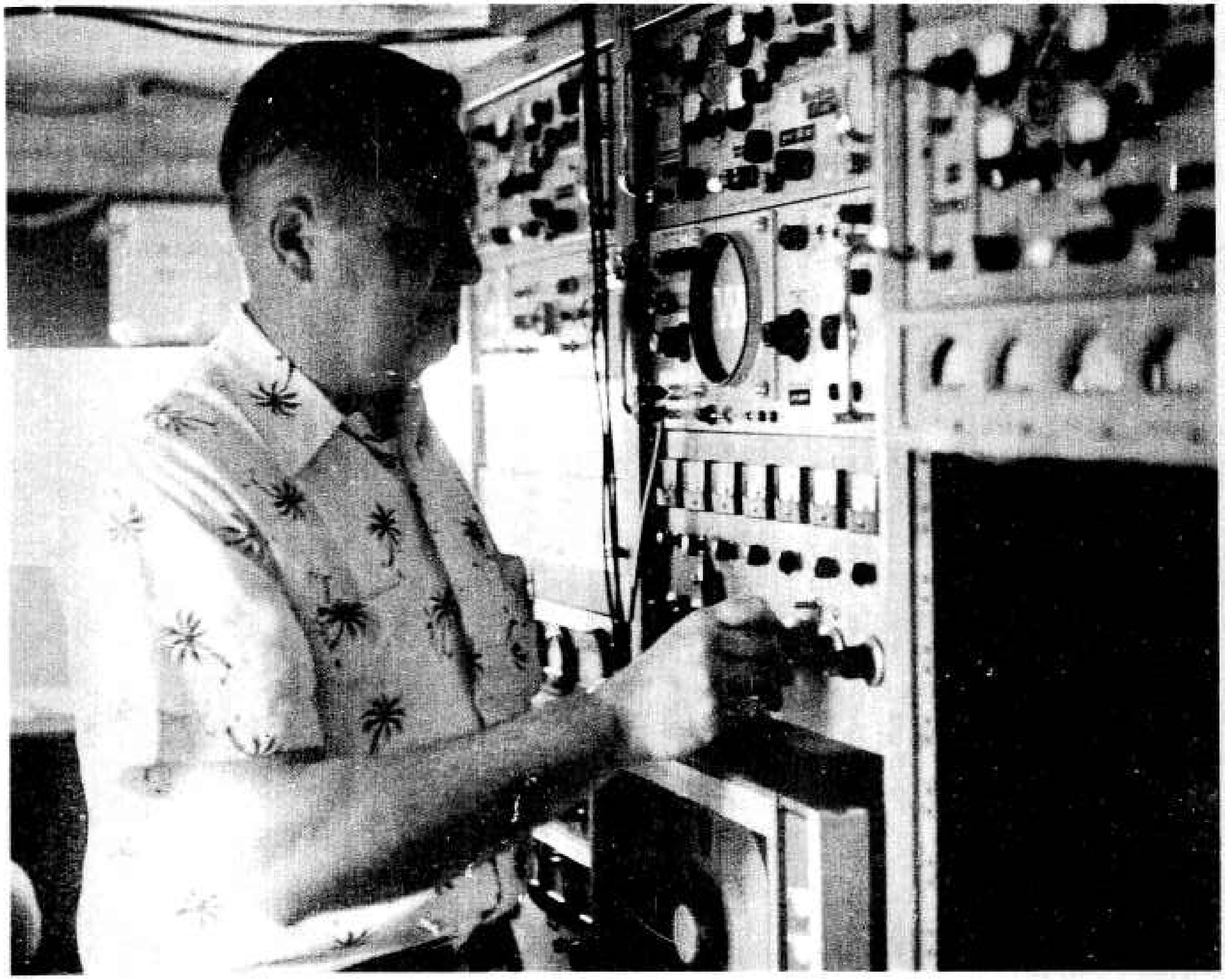


Figure 24. The Interior of the BRL Telemetry Van Showing Receivers, Tape Recorders, etc.

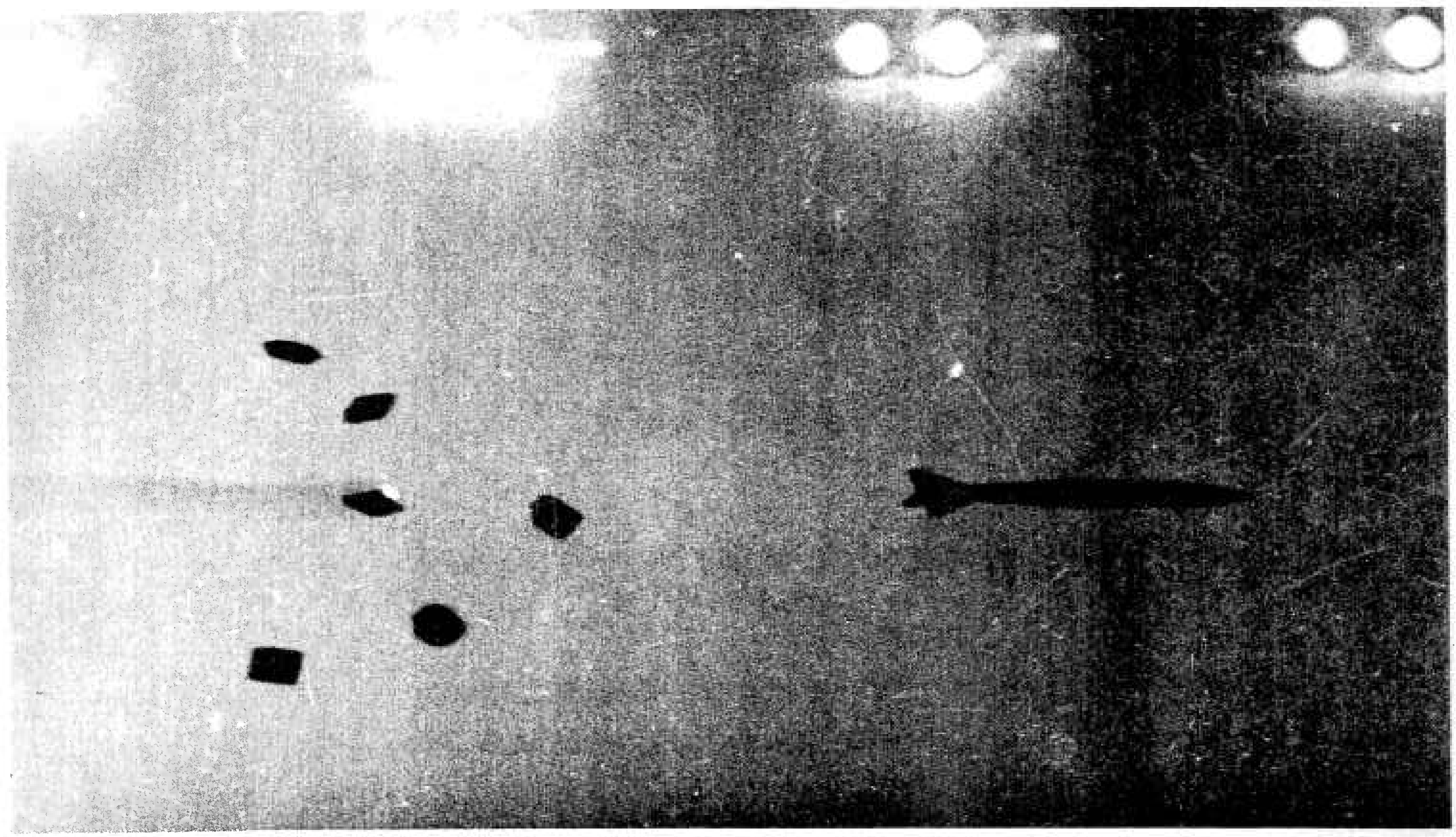


Figure 25. Smear Photograph of Shot E1-1959.

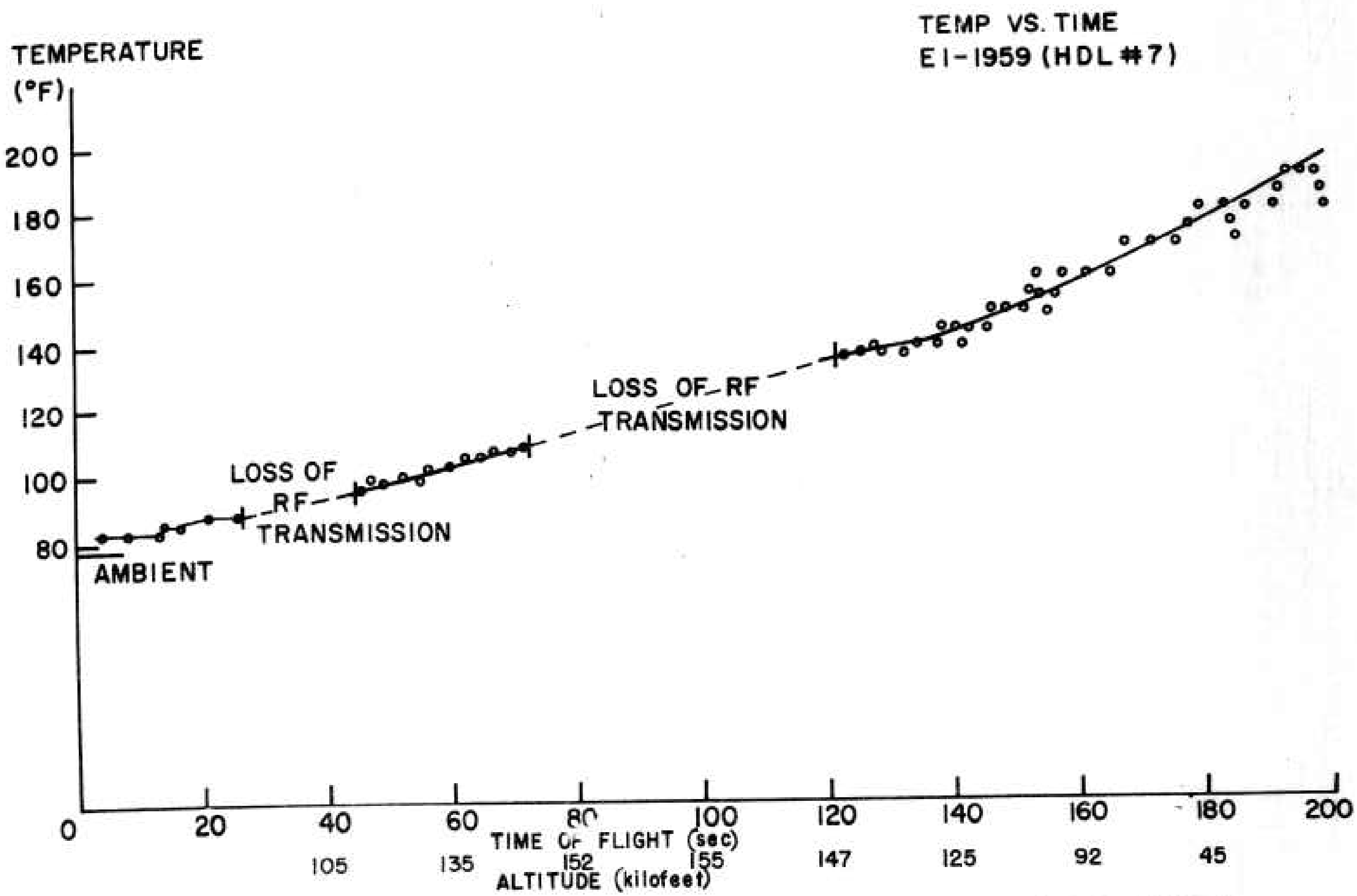


FIG. 26, TEMPERATURE DATA FROM SHOT E1-1959 (MEASURED AT INSIDE WALL OF PAYLOAD COMPARTMENT)

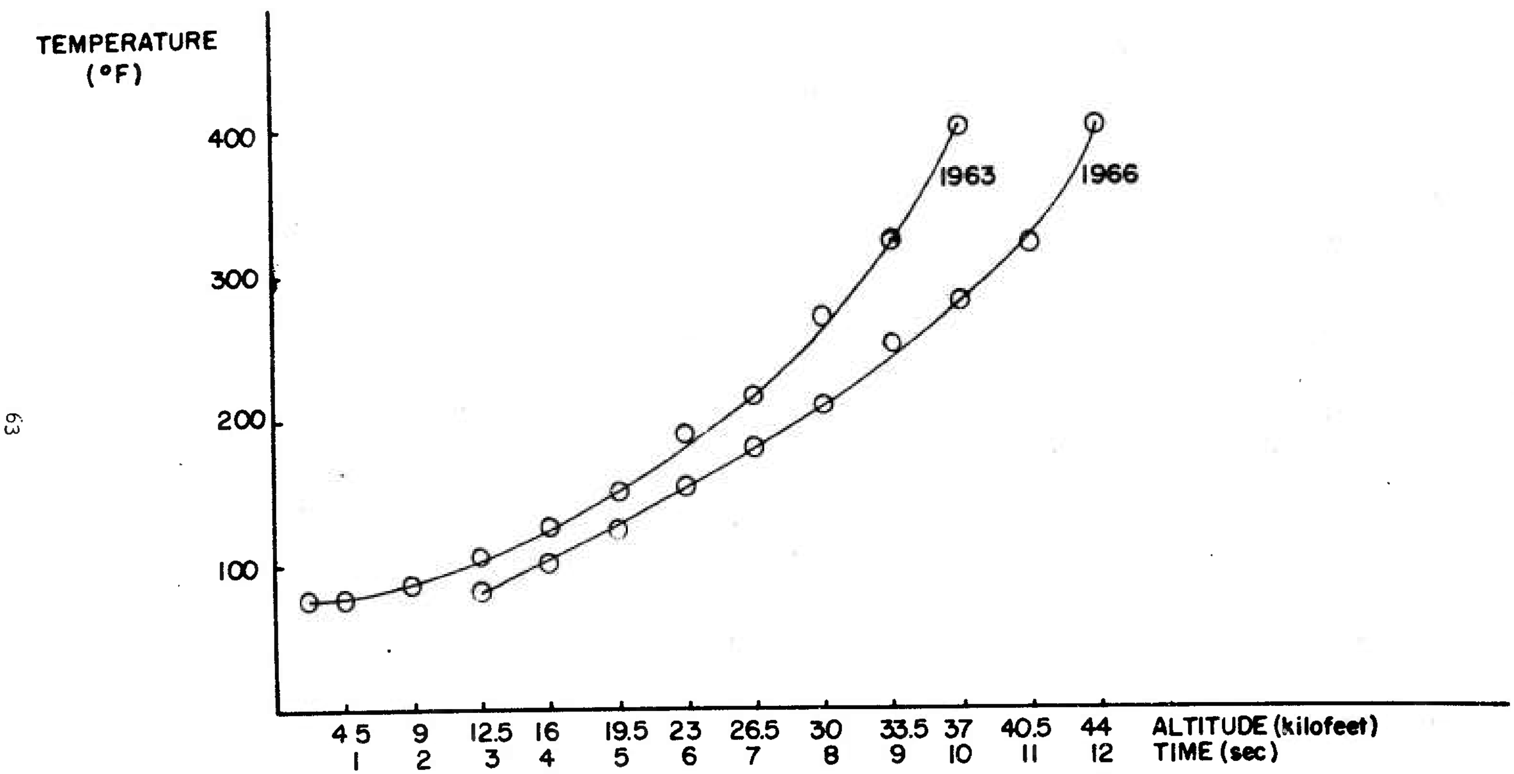


FIGURE 27. TEMPERATURE-TIME DATA FROM SHOTS EI-1963 AND EI-1966 (MEASURED AT NOSE-BODY JOINT)

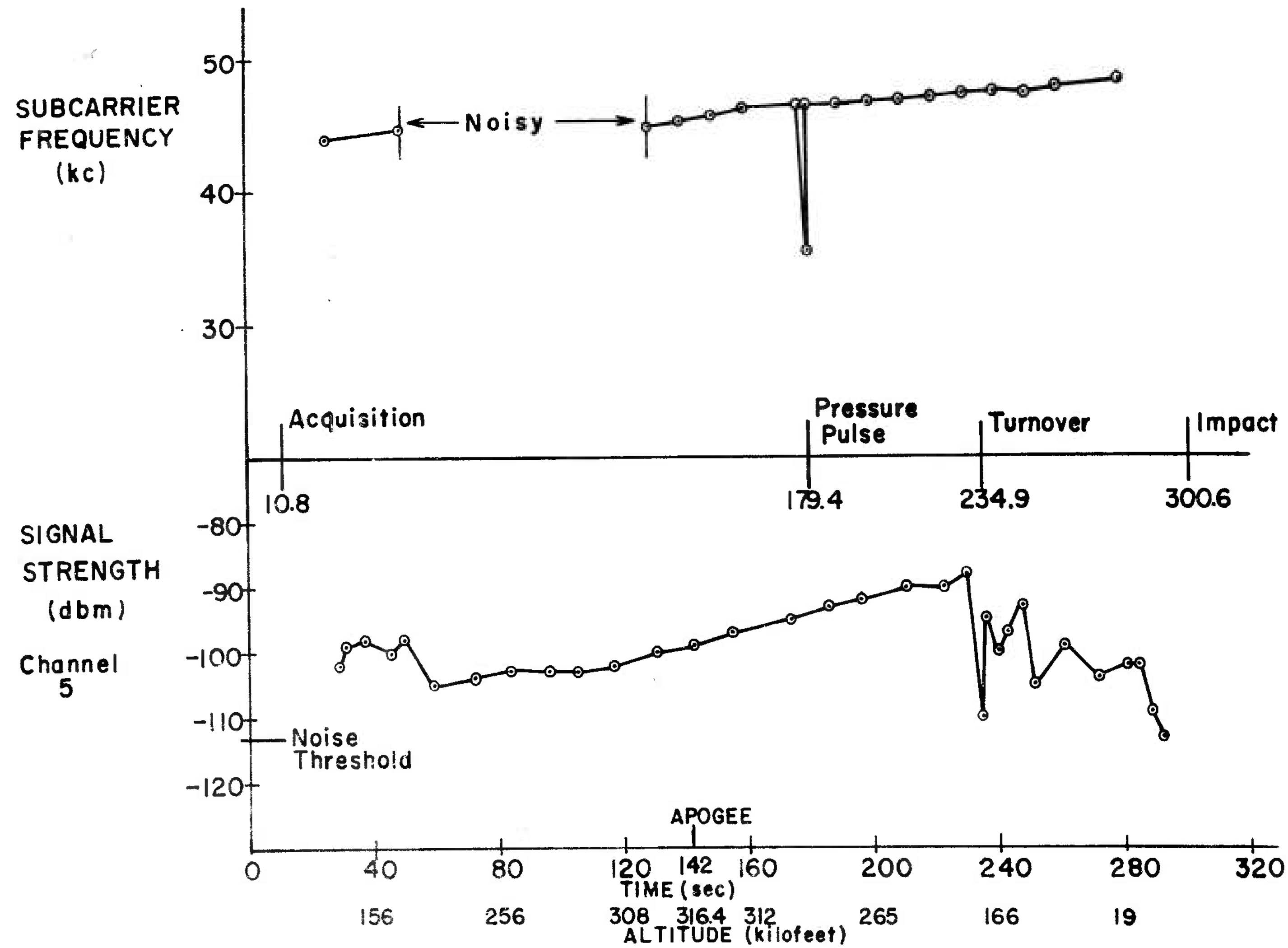


FIG. 28. IN-FLIGHT TELEMETRY DATA FROM SHOT GLORIA

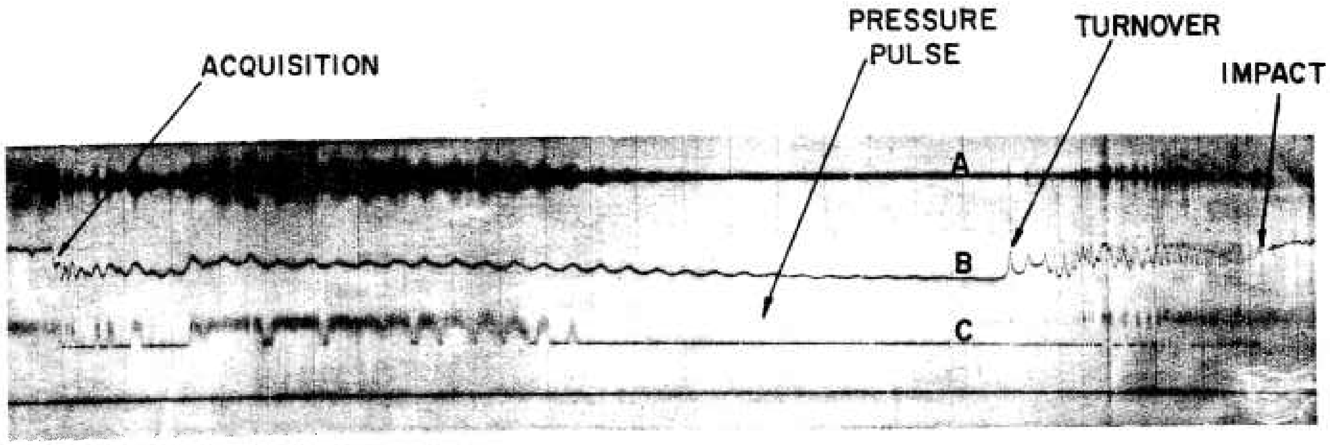


FIGURE 29. THE IN-FLIGHT RECORD OF SHOT GLORIA

A. VIDEO CHANNEL

B. AGC CHANNEL

C. DISCRIMINATOR OUTPUT

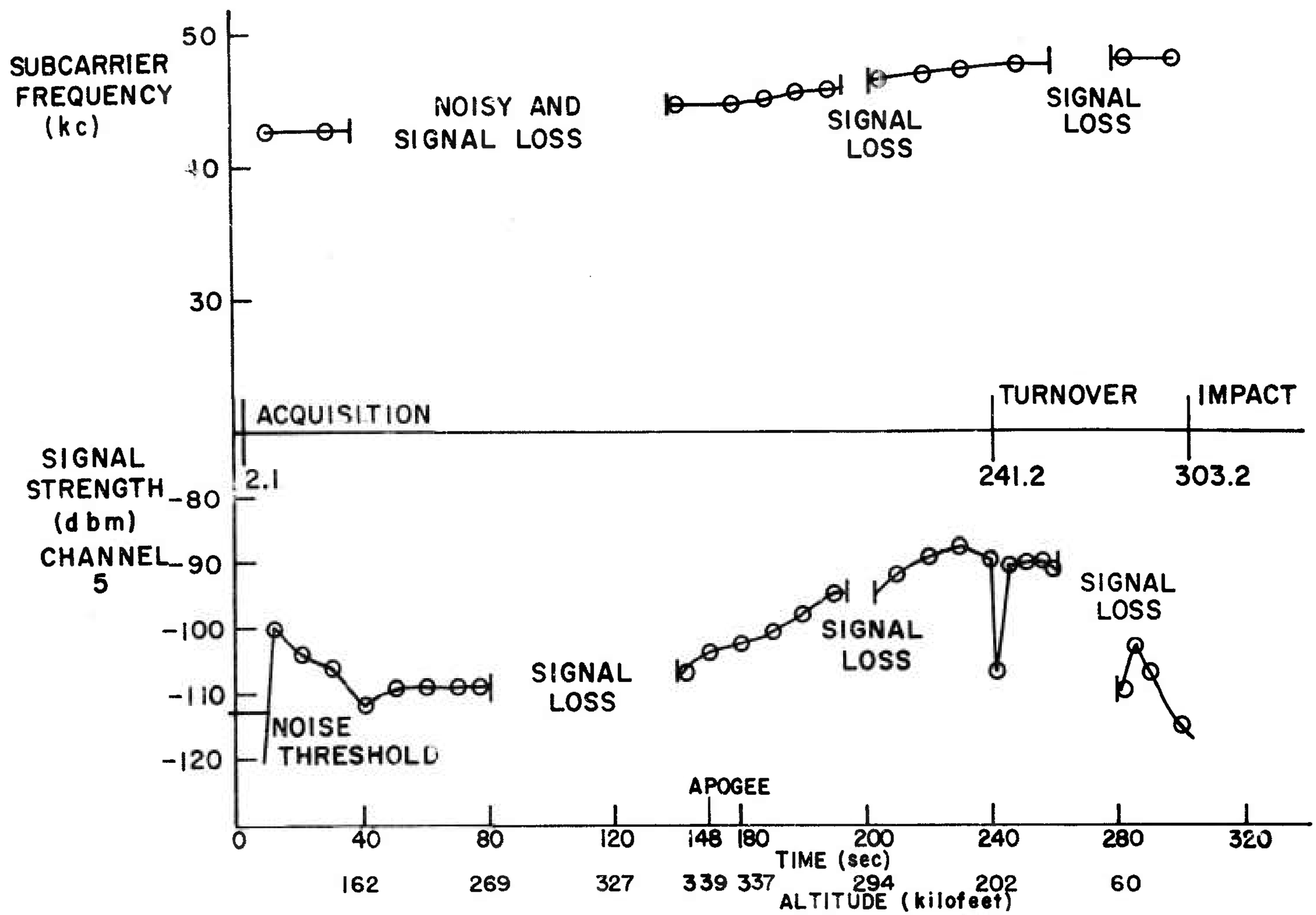


FIG.30 IN-FLIGHT TELEMETRY DATA FROM SHOT HOPE

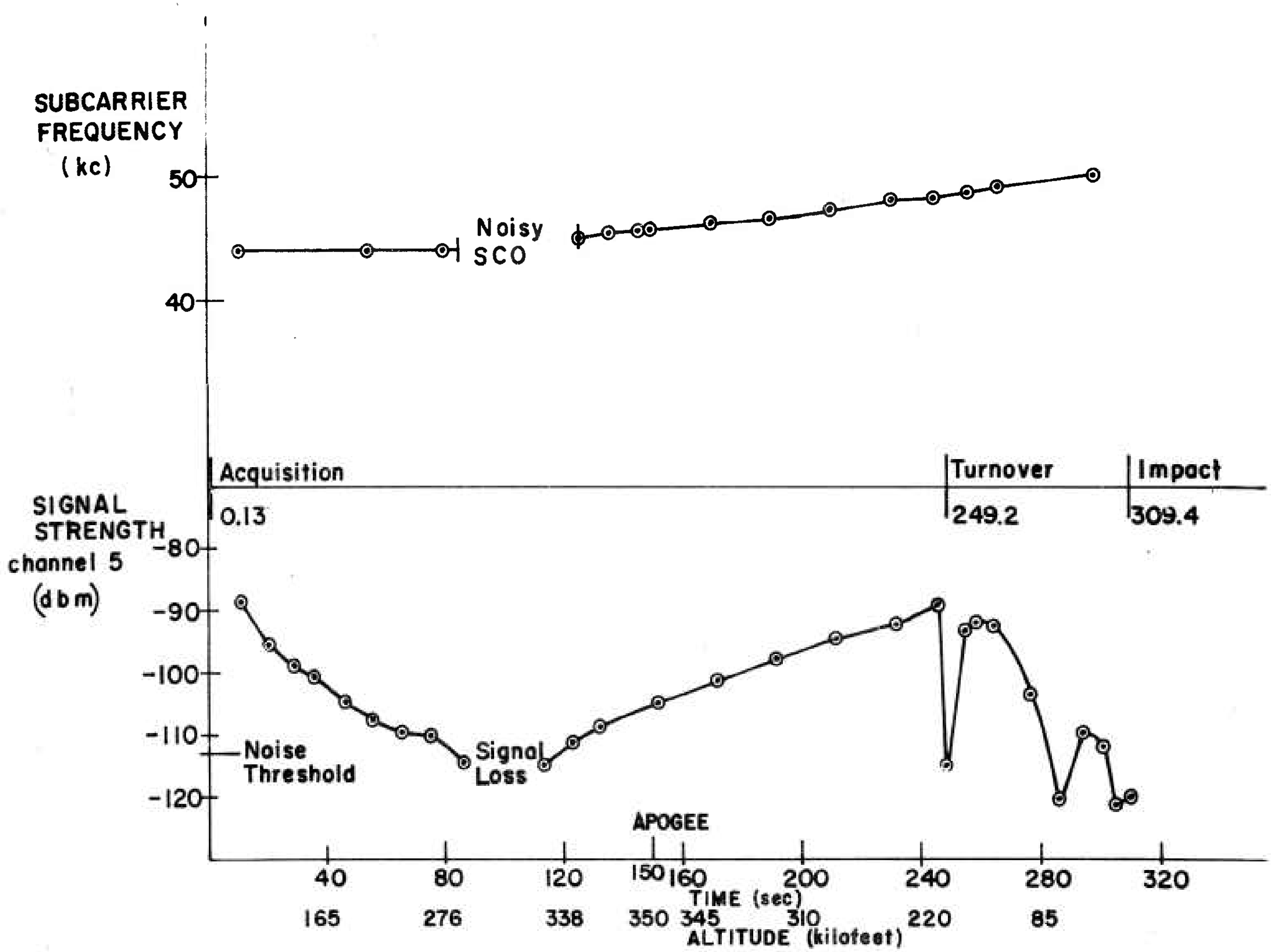


FIG. 31. IN-FLIGHT TELEMETRY DATA FROM SHOT SHARON

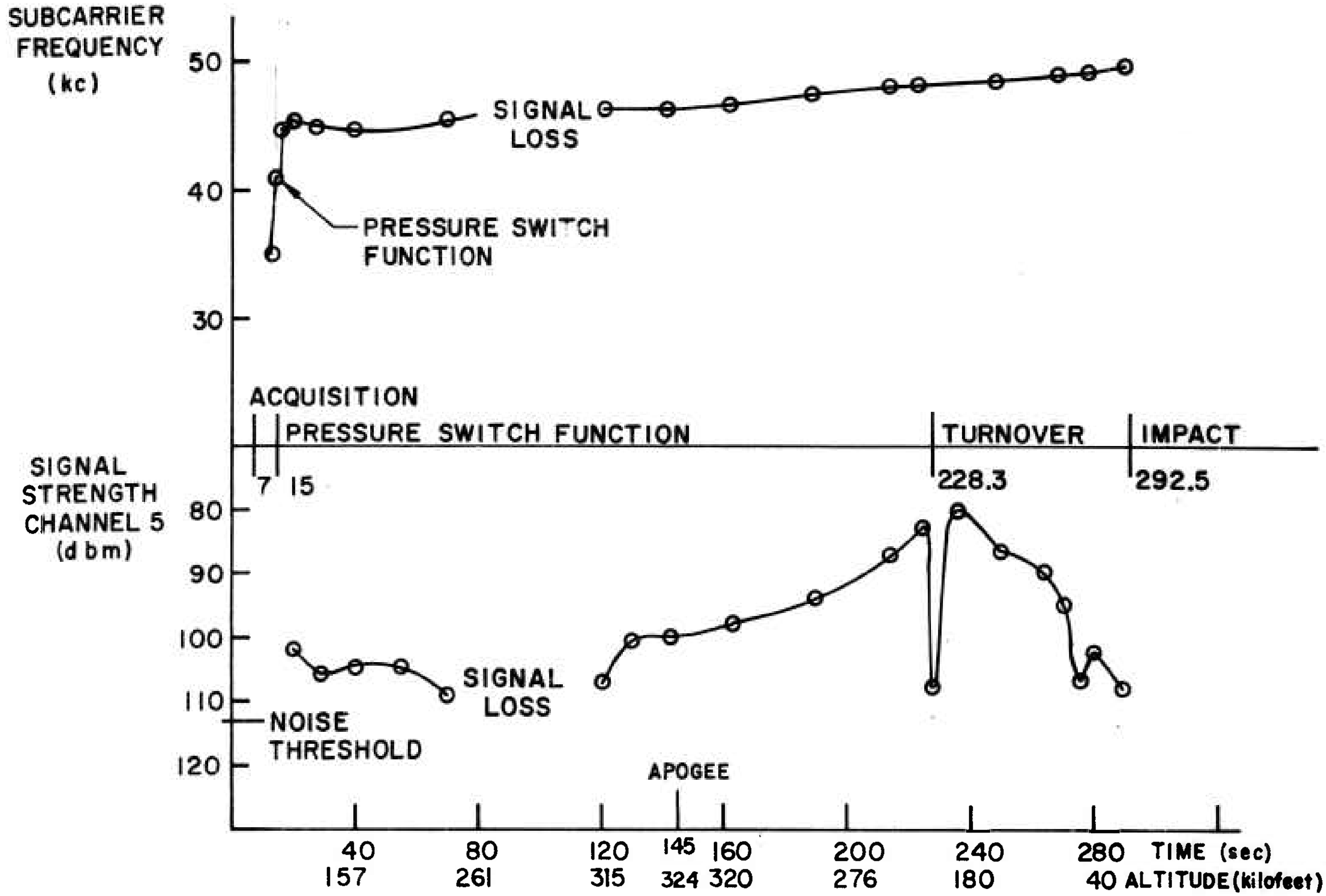


FIG. 32. IN-FLIGHT TELEMETRY DATA FROM SHOT URSULA

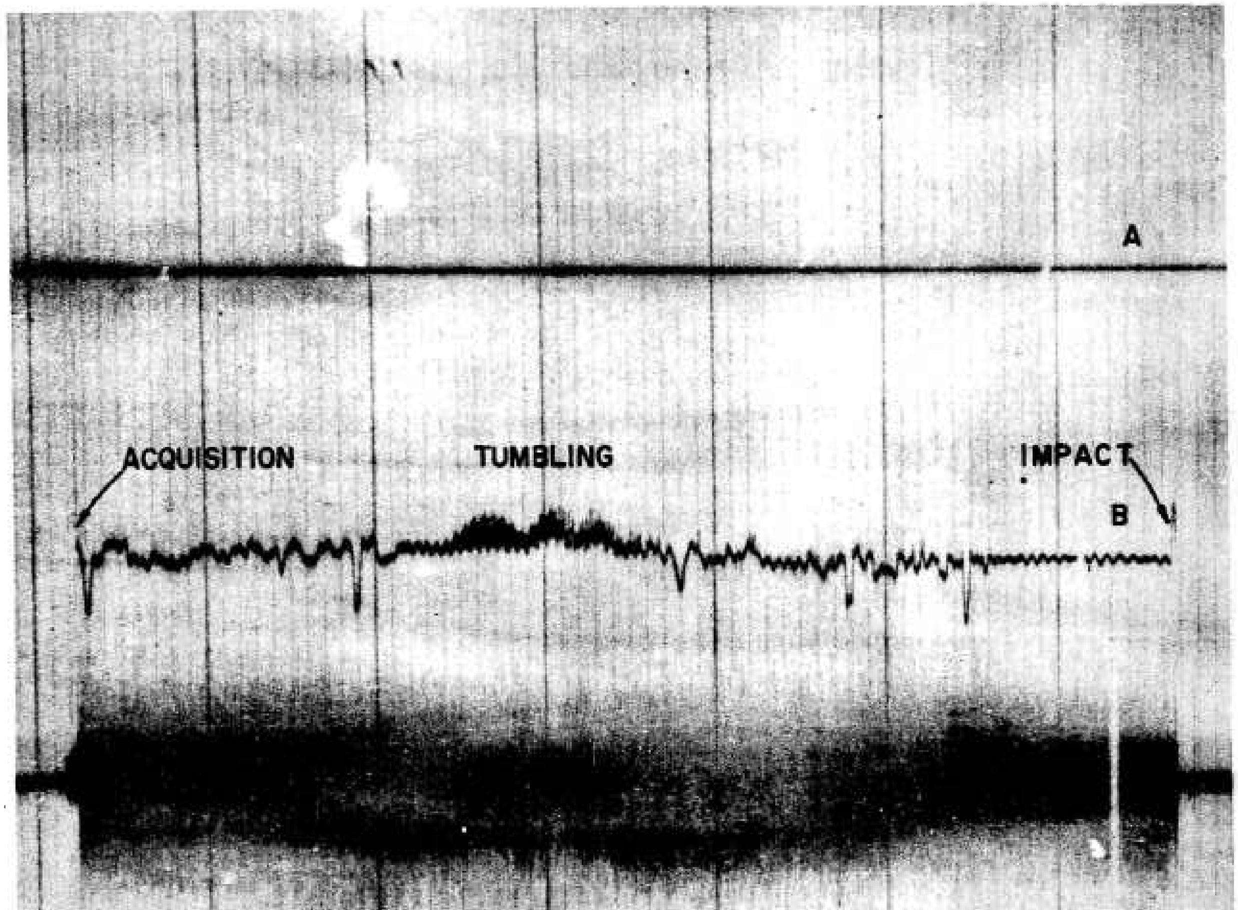


FIGURE 33. THE IN-FLIGHT RECORD OF SHOT ESCUMINAC
A. VIDEO CHANNEL
B. AGC CHANNEL
C. DISCRIMINATOR

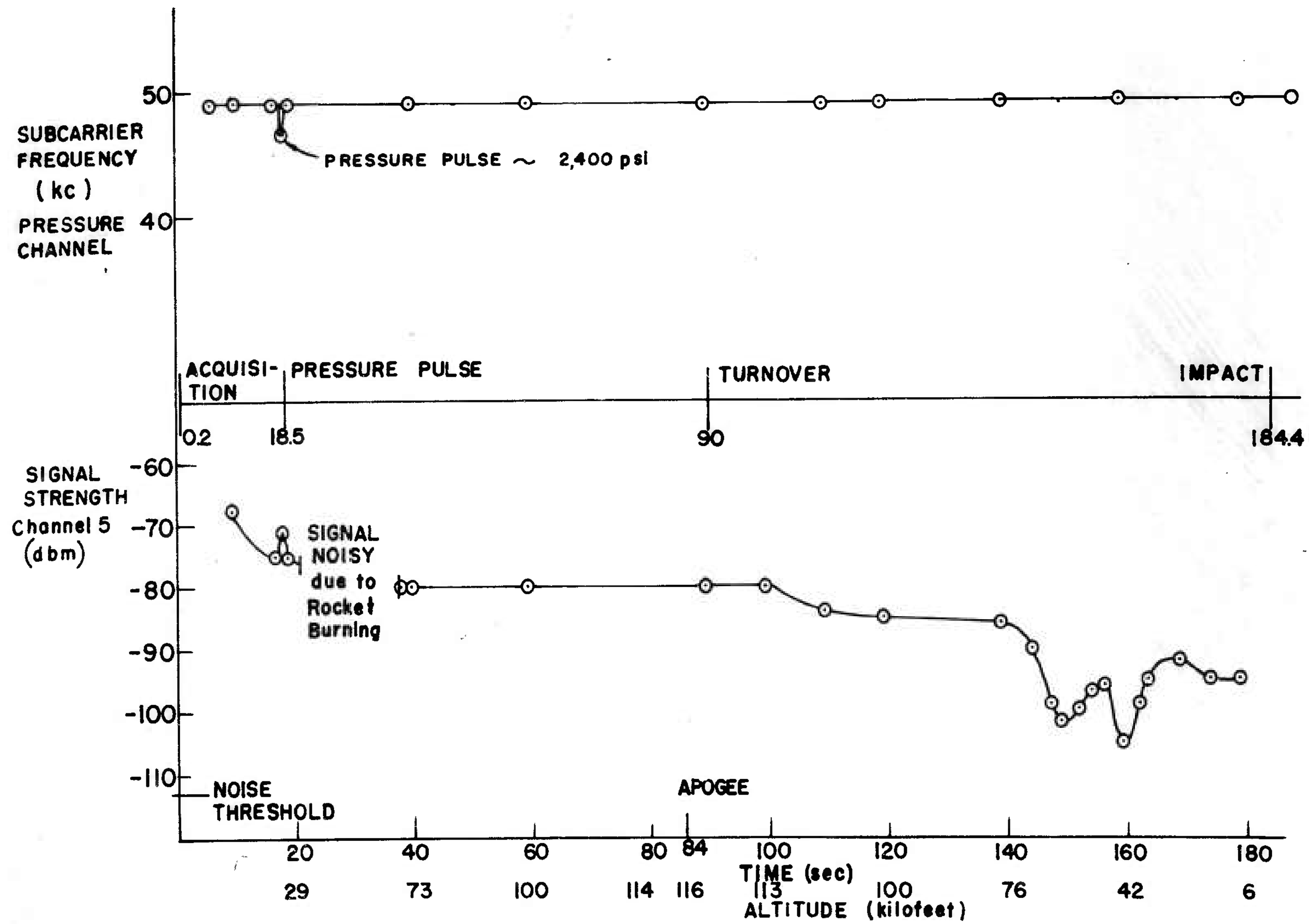


FIG. 34 IN-FLIGHT TELEMETRY DATA FROM SHOT CHICOUTIMI

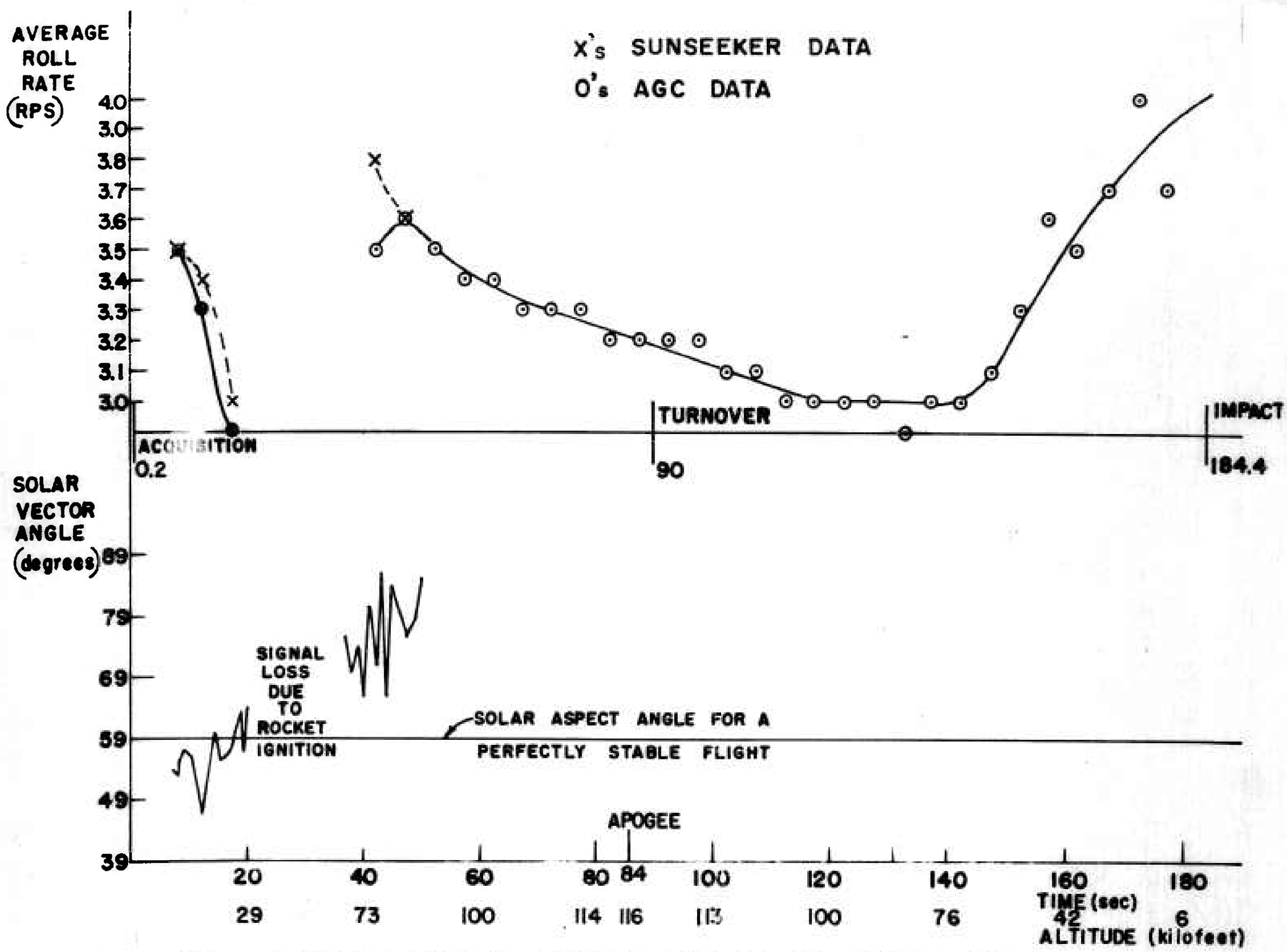


FIG. 35. SOLAR VECTOR ANGLE AND ROLL RATE DATA FROM SHOT CHICOUTIMI

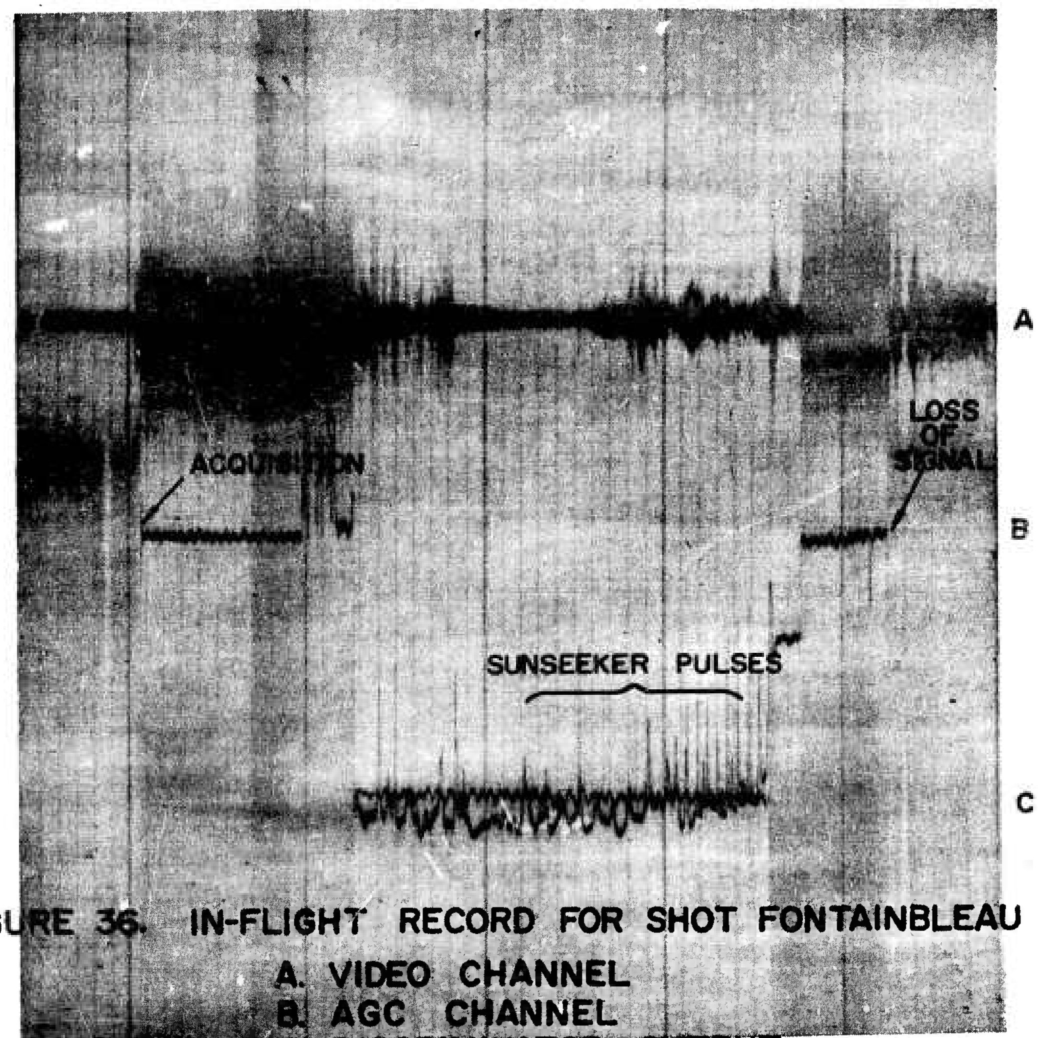


FIGURE 36. IN-FLIGHT RECORD FOR SHOT FONTAINBLEAU

A. VIDEO CHANNEL
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High Altitude Research Project (HARP) firings were conducted both at Wallops Island, Virginia, and Barbados, West Indies during the months of June through October 1964. A substantial number of these firings included high-"g" telemetry experiments. Three telemetry payloads were flown at Wallops in June and July, and three more in October. During the month of July, thirteen telemetry vehicles were flown at Barbados.

The telemetry experiments were highly successful. Five of the six payloads flown at Wallops functioned and four gave data. Nine of the thirteen units fired at Barbados survived the high-"g" launch. Seven of these successfully transmitted data. The results of measurement are presented and include sunseeker data, event monitoring temperature data, and the performance of magnetometers and pressure gages.

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