METEOROLOGICAL ROCKET TELEMETRY IN THE 1680 MEGACYCLE BAND

WILLIAM A. DREWS and W. T. WALTON

Abstract A summary of the present state of design and a review of hardware currently in use and under development for meteorological rocket payloads is given. Important design parameters are discussed and the constraints imposed by existing ground support equipment are described.

Introduction It is important to mention at the outset that progress in meteorological rocket telemetry in the 1680 megacycle band has been directed and restricted by two major constraints: first, by the fact that the performance specifications must be tailored to features of existing ground support equipment which is standard for upper atmosphere measurements; and, second, by a low-cost requirement which exists because of the expendable nature of the instrument. The existing ground support equipments. are Rawin Set AN/GMD-1 and Rawin Set AN/GMD-2. A comparable equipment Radiotheodolite WBRT-57 to the best of the author's knowledge, is not being used for sounding rocket support.

Important features of the Rawin sets which dictate telemetry design criteria are:

Antenna beamwidth	7 degrees
Antenna gain	29 db
Receiver noise figure	18 db
Antenna tracking rate	6 degrees/second
Data encoding form	Pulse rate (0-200 pps)
Data channels	Single

Cost considerations, which limit the employment of sophisticated assemblies that are highly reliable, stem from several views: recovery of the instrument is economically and operationally impractical; hundreds, and in ensuing years, thousands, of upper atmosphere soundings with these expendable instruments will be made annually; and, the instrument cost should preferably be comparable to vehicle costs. Since current vehicles range in price from about $400 to $1,200 one considers an allowable current payload price to be in the range of $150 to $400, depending upon its complexity. As consumed quantities increase, current price ranges can be expected to decrease markedly. Fortunately, for the class of rocket systems considered here, prudent trade-off can be made between system reliability and system cost, for the decision at stake does not directly involve considerations of the safety of humans or the successor a military mission but only the gathering of scientific data.

Telemetry Design Considerations

A. Influence of Ground Support Equipment

With reference to the importance of the ground support equipment stated earlier, a brief explanation of the nature of the influence of certain performance parameters is in order. Figure 1 provides an over-all concept of a typical meteorological rocket sounding operation.

From this, the importance of the relatively narrow beamwidth of the tracking antenna and the relatively slow angular tracking rate may be judged. Moreover, the impact of telemetry antenna radiation pattern design becomes evident when one considers the two tracking situations; i.e., first, a relatively high speed ascending vehicle phase wherein antenna pattern in the tail aspect is of concern and is influenced by the presence of the rocket motor; and, second, a low velocity descending phase accompanied by an oscillating motion of the parachute and instrument wherein the antenna pattern is no longer influenced by the presence of the rocket motor.

Current meteorological rocket systems are designed to reach an altitude and deploy a payload in the vicinity of 200,000 feet. From figure 1 and considering the displacement of the descent system by winds, distances between ground receivers and telemetering transmitters may easily reach 150 miles and vertical angles of the tracking antenna may vary from 90 degrees to near zero. Again antenna pattern design is influenced but, more importantly, the gain and noise figure of the ground receiving system establishes the required performance of the telemetry transmitter in terms of the radiated power.

Data format of the telemetering instrument is restricted to that for which the Rawin set and the recording system are designed. The latter are designed to detect and record modulation wherein the intelligence is encoded as a varying pulse rate whose limiting values are between approximately 10 and 200 pulses per second.

Finally, the ability of the Rawin sets to accept only one information channel restricts modulation in the telemetering instrument to a single channel with serial sampling being employed when multiple data sources are installed.

All current meteorological rocket instruments generally contain the same functional modules. These are transmitter, data encoder of the blocking oscillator type, commutator or timer, and power supply. For transponding instruments, a receiver of the super regenerative type is added to the functional modules.

B. Gross Weight

Since payload weight reflects directly into rocket performance and cost, other things being equal, minimization of weight becomes an important consideration at the outset of any design. As a general rule of thumb, at least for one rocket which has encountered extensive use, a loss of 10,000 feet in apogee altitude occurs for each added pound of payload weight. Because a large portion of the weight of a meteorological rocket telemetry payload will be incurred by structural parts and power supplies, these two must receive early consideration in any design.

C. Space and Geometry

Circular cross sections of small diameter and of streamlined shape are highly desirable because of a need, from the rocket performance standpoint, to reduce drag on the vehicle. The resulting preferred geometry is that of a slim body of revolution which gradually tapers to a point. Typical of present payload enclosures are the bodies shown in figure 2. These shapes tend to present packaging problems because a serious loss in diameter utilization occurs for a large fraction of the available length.

D. Cross-Talk, Interference, and Noise

Because of the requirement for relatively high packing density, undesirable signals and other effects on circuits can easily occur and consideration of these possibilities becomes an early criteria for layout work. Since adequate shielding adds space and weight, careful location and arrangement of parts and subassemblies should substitute for shielding, where possible, as a means of reducing internal interference problems.

E. 1680 Megacycle Transmitters

Historical development and quantity production, with resulting low cost, of weather balloon telemetering instruments in the meteorological band between 1660 and 1700 megacycles has established the selection of RF sources for meteorological rocket transmitters. Integral-cavity oscillators which employ pencil triodes have been used for the purpose to date. Types 5794A, 6562, 7533, and 4048V3 are the type numbers generally in use. The choice is a natural one for a number of reasons: they are a complete integral source; their RF power output (600 milliwatts) is adequate for the purpose; they are small and of a desired cylindrical shape (1 inch diameter and 2 inches long); their power requirement of 120 volts at 34 milliamperes for the plate and 6 volts at 160 milliamperes for the filament results in a simple power pack; and, most importantly, their cost is low ($6.00) because of the quantity production for weather balloons. Experience has shown that these devices are sufficiently rugged to withstand the rigors of shock, vibration, and acceleration imposed by meteorological sounding rockets. While this type of source will obviously suffer instability and drift in frequency, this has not been a problem of serious concern because of the wide frequency band allotted to the meteorological community.

Research effort is in progress by at least one leading manufacturer to develop a solid state RF source for use in meteorological instruments. This product would again be an integral package and, in comparable quantity production, will probably compete with the present cost of triode types. At least one advantage of the solid state source would be the solution of some power supply problems for meteorological rocket payloads. The general approach being used to date for solid state sources of this type is the employment of a relatively low frequency transistor oscillator followed by multipliers which employ varactor diodes as active elements. Achievable RF power is, of course, currently limited by the state of the art in solid state components. One difficulty with these devices is the generation of spurious radiations at harmonic frequencies of the basic oscillator. One manufacturer advertises a device capable of delivering 250 milliwatts of power at 1680 megacycles when supplied from a 16 volt energy source.

F. Antennas

One of the most difficult problems facing the telemetry designer for meteorological rockets is the choice of optimum antennas. Constraining factors in this connection are: avoidance of vehicle drag during rocket ascent; achievement of small size; avoidance of bulky and expensive impedance matching devices;.attainment of acceptable radiation patterns; and, maintenance of low cost.

As mentioned earlier, drag forces induced by extending surfaces become a serious detriment to the realization of optimum vehicle performance. Hence antenna configurations which impose such drawbacks should be avoided. Fortunately, at the transmitter frequency of interest, designs can be achieved which realize the desirable features of small size, efficient coupling, zero drag force, and acceptable cost. Radiation patterns of desirable characteristics are somewhat more of a problem, however. This stems from the general system in current use for obtaining meteorological data by sounding rocket techniques as shown in figure 1. Measurements of the atmospheric parameters of interest in this system are made from rocket apogee downward; that is, under descending conditions.

The telemetry antenna radiation pattern should exhibit very broad angle coverage under these conditions to allow for a rather severe oscillatory motion of the Parachute which normally occurs for a long period following its ejection from the rocket. The instrument’s motion, when suspended from the parachute, is complex and includes residual roll resulting from the rocket motion prior to ejection. Complicating this situation is the fact that Rawin set antennas are linearly polarized in the vertical plane. Thus oscillatory motion of a parachute supported instrument, whose antenna pattern is directional, can lead to severe loss of data. A further complication stems from the desire to maintain track of the instrument during its ascent on the rocket. Maintaining track during ascent is preferred because current Rawin sets have narrow beam widths and do not possess automatic area scan features. If track is lost during ascent, much valuable data is lost during the early part of the descent phase while the Rawin set is being manually manipulated to acquire the telemetry signal.

In summary of the forementioned problems, it becomes evident that omnidirectional radiation of a circularly polarized wave offers the optimum solution. Practically, of course, compromises must be made. Typical of some antenna designs which have been made for the purpose are linearly polarized slotted cylinders, quarter-wavelength stubs, dipoles, and circularly polarized slotted cylinders. Figure 3 illustrates several existing designs.

In general, the radiation patterns achieved by all types leaves something to be desired. The rocket tail aspect pattern appears to offer no serious problem insofar as allowing the Rawin sets to maintain track during ascent is concerned. However, during descent of the instrument., frequent dropout of signal occurs with a resultant loss of data. Experience has shown that parachutes do not damp quickly at high altitude and severe oscillation will continue from say, an initial altitude of 200,000 feet down to the region of 150,000 feet. A better than average record of telemetered data which illustrates the problem is shown in figure 4. It is seen here that useful and reliable data was not consistently recorded until about two and one-half minutes following payload ejection. During this particular flight, a peak altitude of 2203,000 was reached by the payload but consistent data was not obtained above 180,000 feet.

G. Transponding Instruments

The foregoing design considerations, except for weight and geometry aspects, have dealt only with transmitting type telemetering instruments. An alternate instrument, which is sometimes used, is a transponding type wherein the ground equipment, Rawin Set AN/GMD-2, transmits a modulated carrier in the 400-406 megacycle band to the rocket payload. In this case, the instrumented payload must be able to receive the ground based signal, detect the modulation, and repeat the modulation back to the Rawin set. The modulation is a range measuring signal of fixed frequency at 81.94 kilocycles. Phase comparison of outgoing and received modulation of a fixed frequency is used as a ranging method by the Rawin set.

The employment of a receiver in the instrument, of course, adds to the problem of space and weight conservation and to the problem of antenna selection. Added power requirements also complicate the design. The design approach used to date for transponding instruments has been to employ a receiver of the super regenerative detector type.

H. Ascending Telemetering Instruments

One technique used in the acquisition of meteorological data is the "Pitot-tube method." In this method, the impact pressure existing at the leading surface of a high speed vehicle is measured and, from this data, atmospheric density is deduced. In this application, contrary to instruments mentioned earlier, the telemetering requirement is to obtain data during ascent of the vehicle rather than during descent of a parachute. Transponding type instrument designs have been employed to date for these payloads. The transmitter and receiver sections are functionally identical to those employed for descending payloads. The treatment of antennas and the package configuration in these applications are the basic differences.

The problem here is to provide good antenna pattern distribution when viewed from the tail aspect of the ascending vehicle. In this respect, the designer must allow for rocket motions of pitch, yaw, and roll, and additionally for the change in the flight angle as the vehicle ascends on a ballistic trajectory. Flight angle is defined as the angle between the earth vertical and the longitudinal axis of the rocket. Some knowledge of the vehicle behavior in these respects is therefore a prerequisite of the antenna designer. In the systems under consideration here, solutions to date have been the employment of swept-back turnstile configurations for both transmitting and receiving. Antennas are stowed within the payload body during early portions of a flight where drag would be a problem and later are erected to provide an optimum pattern and gain. Fortunately, distances between ground equipment and payload are small enough, during the stowed phase, that track can be maintained and data reception can be obtained.

I. Power Supplies

From a weight, geometry, and cost standpoint, power packs for telemetry operation have been a troublesome problem. Low cost water-activated types, as are used in weather balloon instruments, have been found to be unacceptable. This is because of their relatively large size and because of self-heating. For applications wherein only transmitters are used in the instrument, solutions have been found to the problem by employing a package of dry batteries of the zinc-manganese-dioxide type and mercury cells for low current drain circuits. A useful operating life of at least three hours is usually obtained from these packs provided the batteries have been properly stored. Shelf life characteristics of the dry type battery are the most serious drawback. Experience indicates, however, that good performance can be obtained if batteries are stored at sub-freezing temperature. The rather long desired operating life of three hours, compared with a usual data collection time of only about one hour, stems from frequent launch delays which occur after the instrument is loaded into the rocket and energized. The nominal energy sources required for such instruments are:

120 volts at 34 milliamperes
6.3 volts at 160 milliamperes
1.5 volts at 15 microamperes

The nominal 1.5 volt source can be derived from a mercury cell and is often employed as a source for a blocking type oscillator. Its relatively stable voltage, at very low drain and over wide temperature range, makes the mercury cell particularly attractive for this purpose.

For transponding instruments, the practice has been to employ silverzinc cells to provide a nominal 6.0 volt pack. The battery is used to directly supply all filaments and a DC to DC solid-state converter which provides at its output the required plate supply voltage for both receiver and transmitter, nominally 120 volts. As with dry type battery packs, cell size is selected to provide about three hours of operating life. A design problem with this type of power supply is transients, generated by the DC to DC converter. These tend to permeate the entire electronic circuitry and become particularly troublesome in blocking type oscillators. The latter serve to encode the measured data in the instrument as a variable pulse rate and their output pulses represent the data value. The difficulty stems from a tendency for the pulse rate to synchronize with the converter switching transients and results in false data being transmitted. The employment of a separate battery for exciting the blocking oscillators has been found to be the most economical solution to at least some of the transient problem; by-pass filtering and shielding solves the remainder.

Rechargeable batteries of the silver-zinc and nickel-cadmium types have been employed by some designers for meteorological rocket payload s. In general, however, the expendable dry types and the primary type wet cells have been found to be more economical, both from the size and the cost standpoints.

Current Models of Instruments

In figures 5 through 12 are shown photographs of meteorological rocket telemetering instruments for use in the 1680 megacycle band. The instrument depicted in figure 5 was developed by the U. S. Army Signal Corps and is of the transponding type. Figure 6 is also a transponding type and was developed by the U. S. Air Force Cambridge Research Laboratories. Figure 1 depicts an instrument of the transmitter only type and was developed at the White Sands Missile Range. Figures 8 and 9 represent transmitting only and transponding type instruments, respectively, and are the product of Atlantic Research Corporation. Figures 10 and 11 depict a transponding type instrument which is designed for data collection during rocket ascent. Development of this device was sponsored by the U. S . Navy Pacific Missile Range. Figure 12 illustrates a telemetering instrument developed by Metro Physics Incorporated for a booster-dart meteorological rocket.

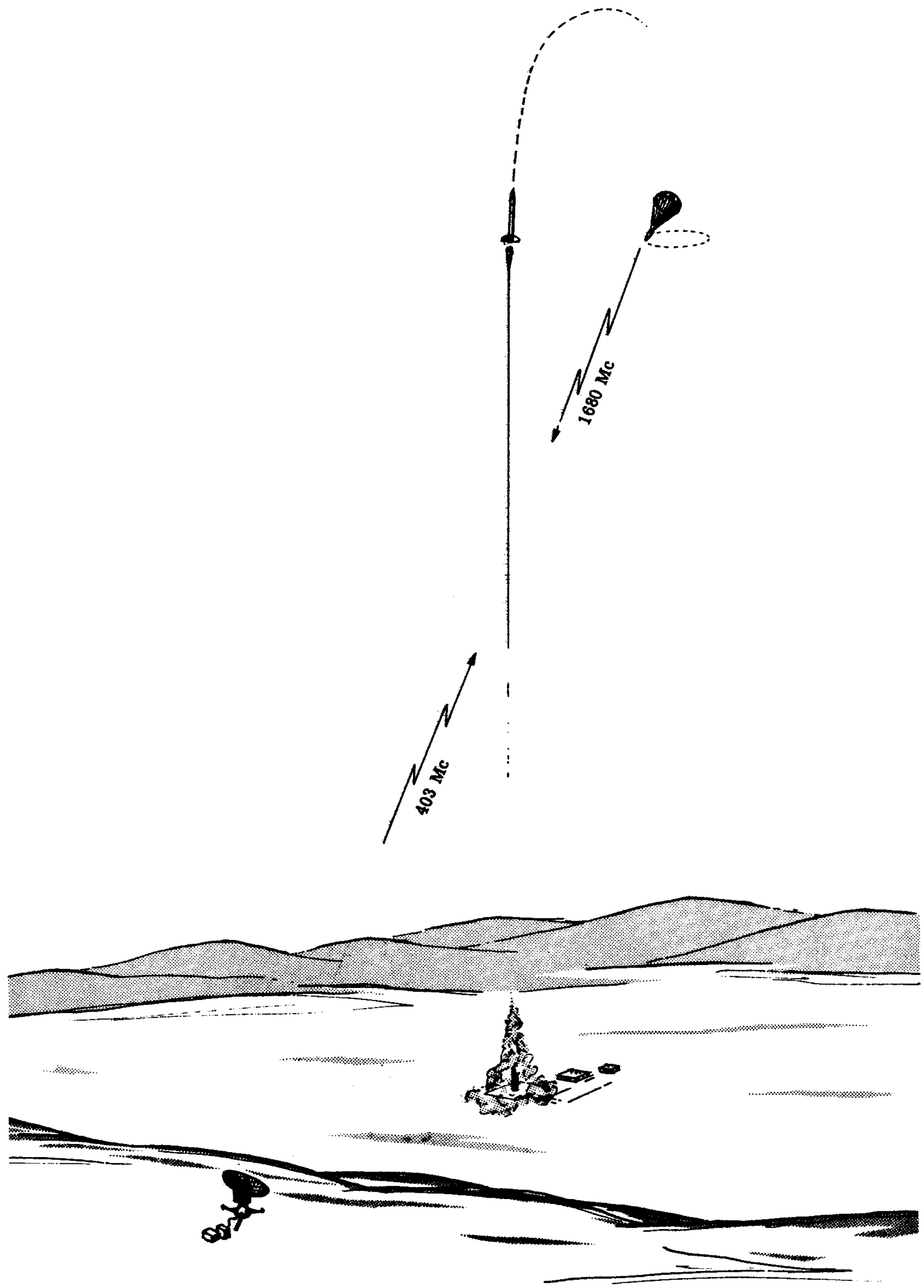

FIGURE 1. TYPICAL METEOROLOGICAL ROCKET SOUNDING OPERATIONS.

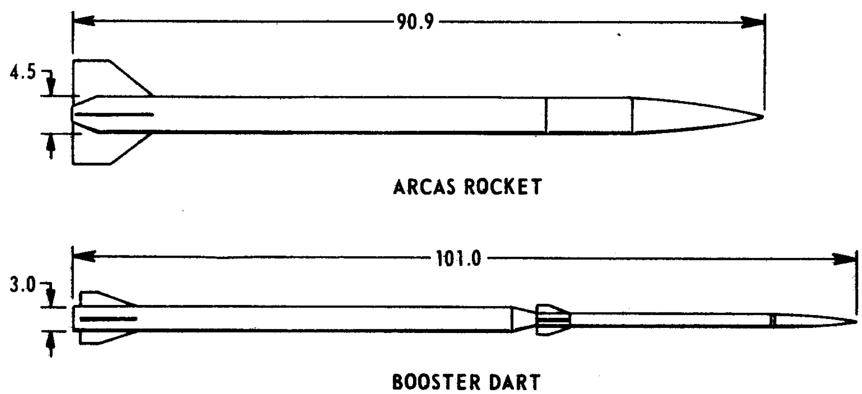

FIGURE 2. CURRENT METEOROLOGICAL ROCKET SYSTEMS.

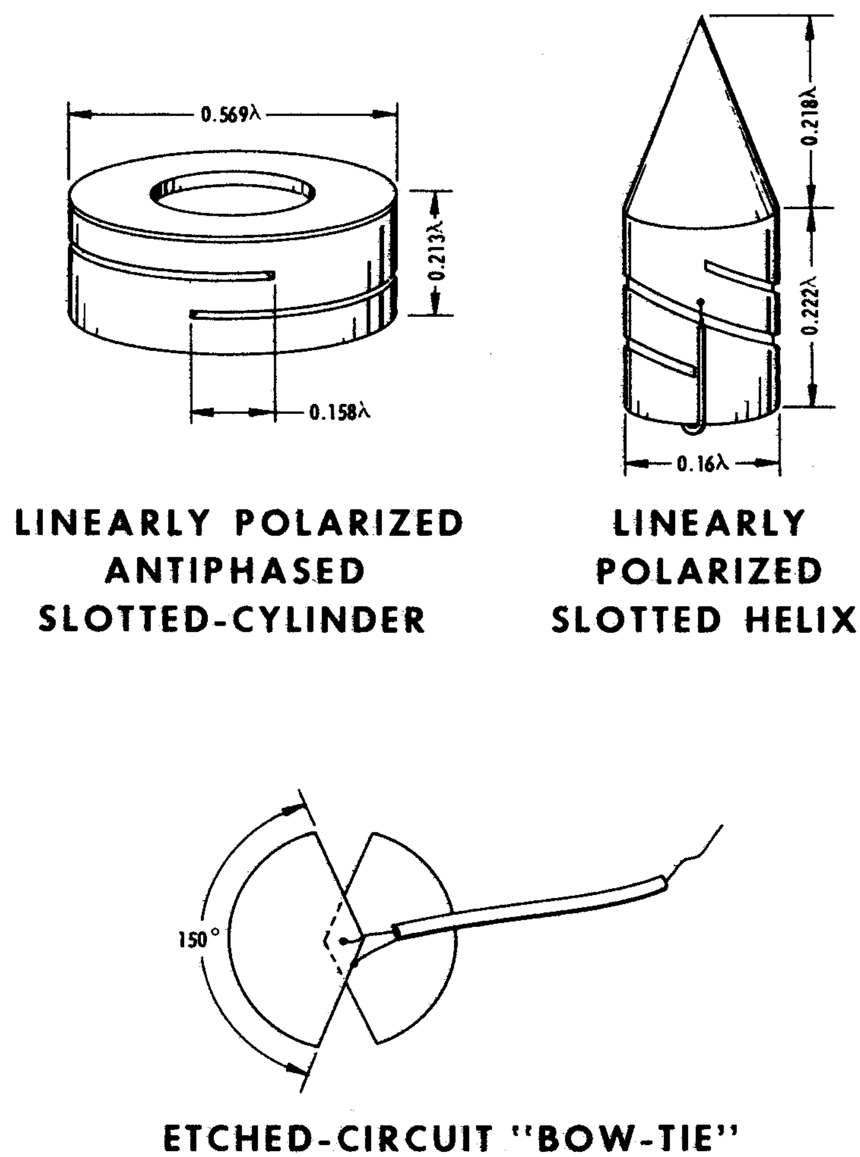

FIGURE 3. EXAMPLES OF CURRENT 1680 Mc METEOROLOGICAL ROCKET ANTENNA.

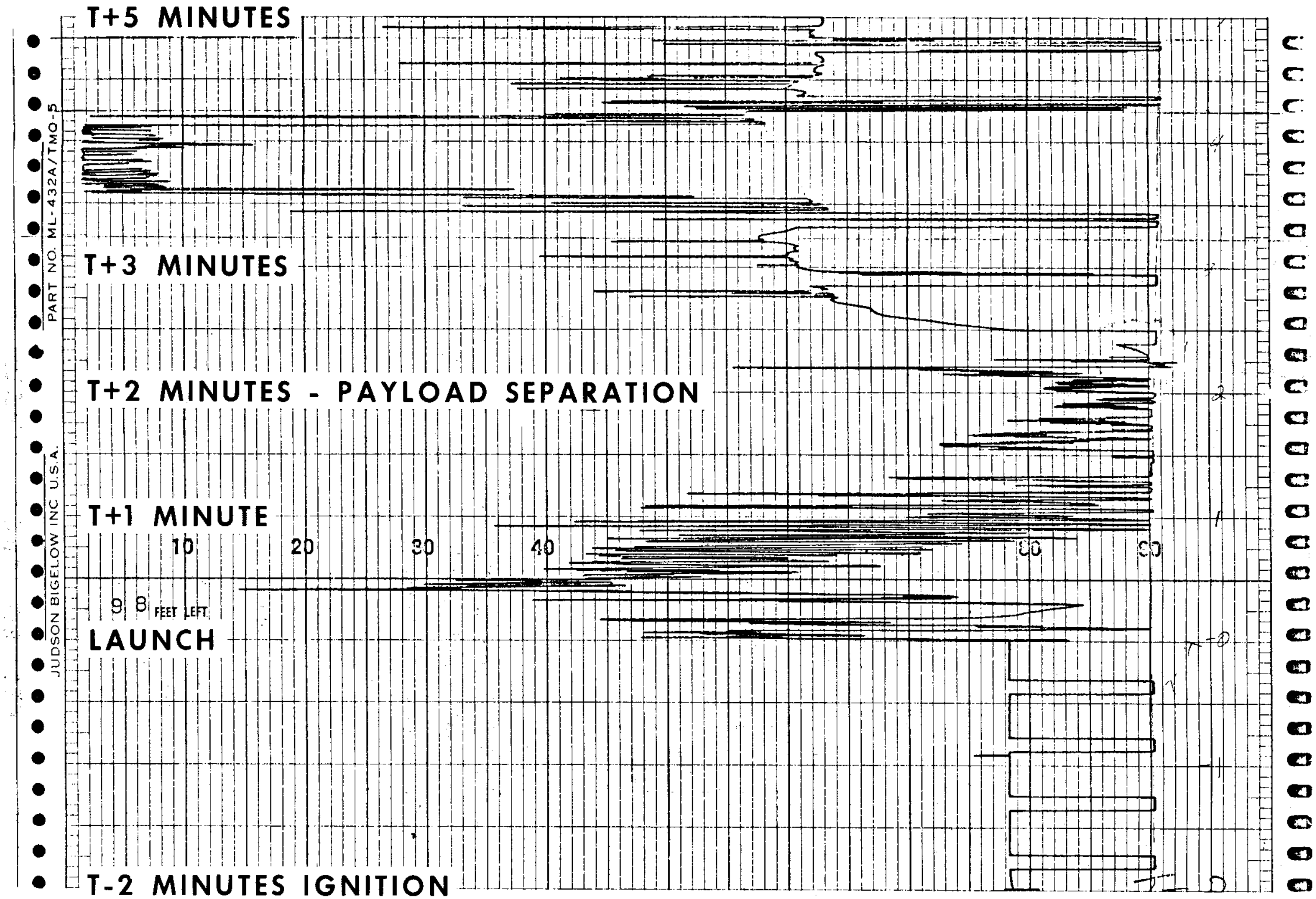

FIGURE 4. RECORDED METEOROLOGICAL ROCKET DATA COURTESY US ARMY WHITE SANDS MISSILE RANGE.

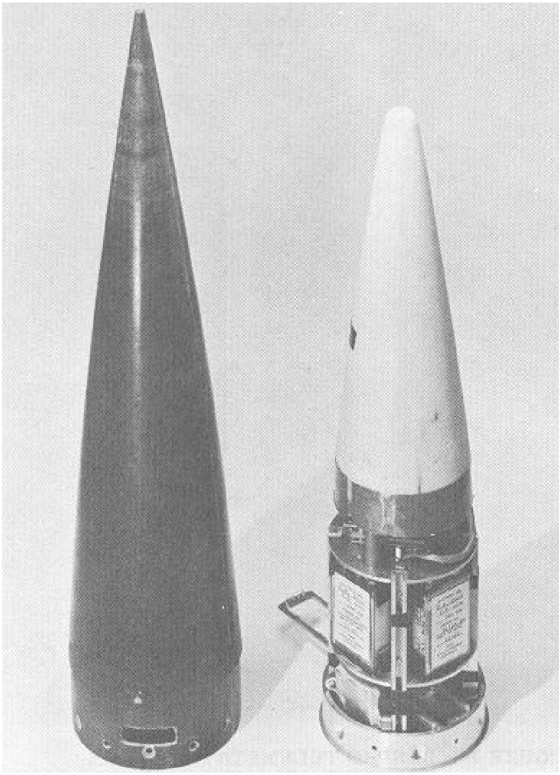

FIGURE 5. RADIOSONDE SET AN/DMQ-6 COURTESY ATLANTIC RESEARCH CORP. CONTRACT DA-36-039-SC-84542.

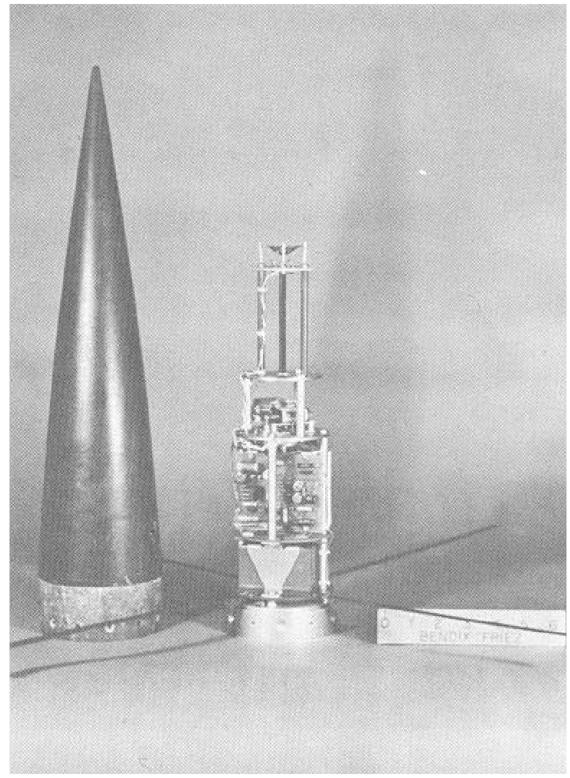

FIGURE 6. AN/DMQ-9 COURTESY ATLANTIC RESEARCH CORPORATION

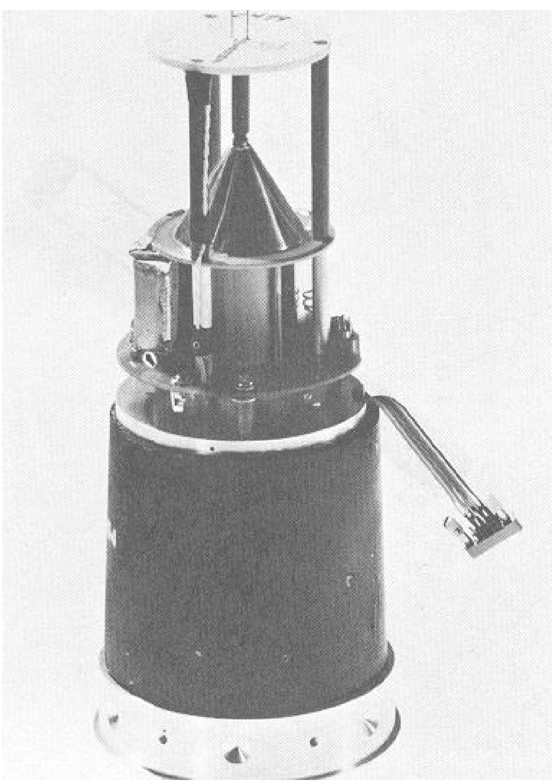

FIGURE 7. DELTA MODEL METEOROLOGICAL ROCKET TELEMETRY US ARMY PHOTOGRAPH WHITE SANDS MISSILE RANGE.

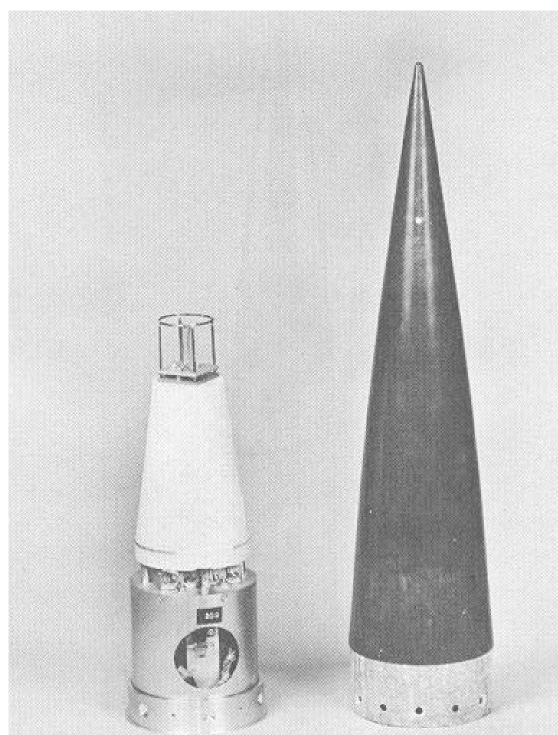

FIGURE 8. ARCASONDE 1A COURTESY ATLANTIC RESEARCH CORPORATION.

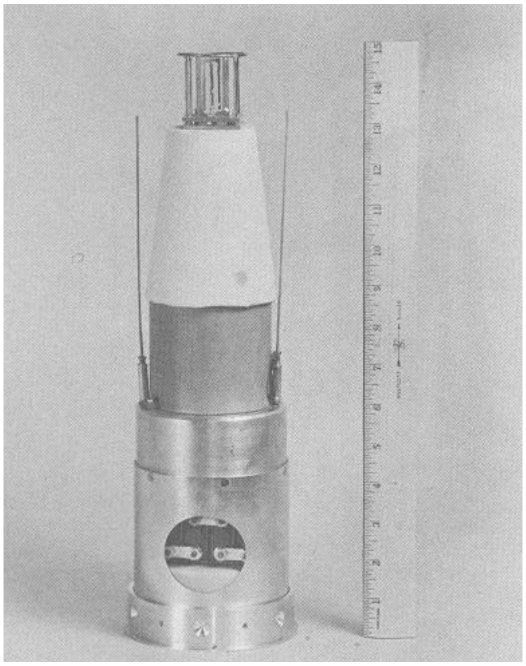

FIGURE 9. ARCASONDE 2A COURTESY ATLANTIC RESEARCH CORPORATION.

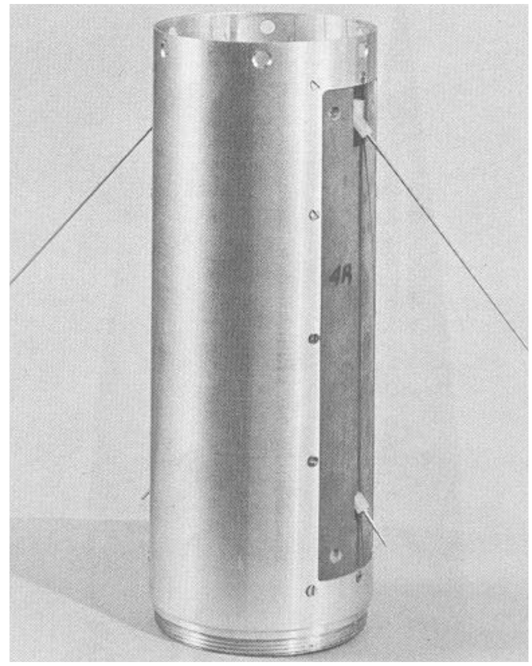

FIGURE 10. DENPRO TELEMETRY PACKAGE COURTESY ATLANTIC RESEARCH CORP. CONTRACT N123(61756)-32883A (PMR).

FIGURE 11. DENPRO PAYLOAD COURTESY ATLANTIC RESEARCH CORP. CONTRACT N123(61756)-32883A (PMR).

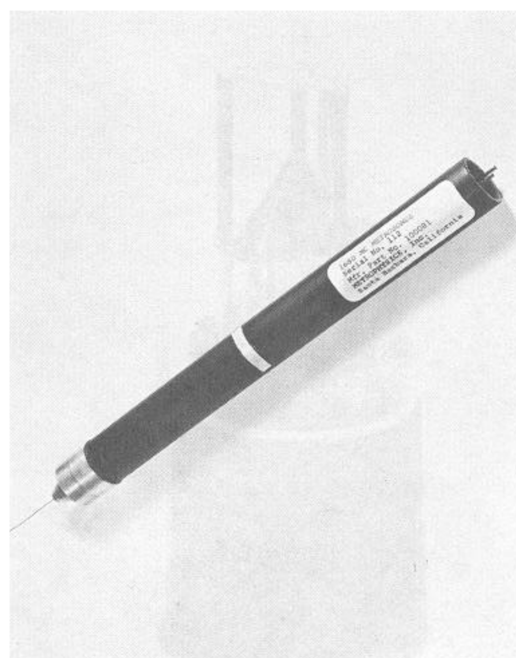

FIG. 12 METROSONDE BOOSTER - DART TELEMETRY COURTESY METRO PHYSICS INCORPORATED.