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THE UNITED STATES SOUNDING ROCKET PROGRAM

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THE UNITED STATES SOUNDING ROCKET PROGRAM

July 1971

Sounding Rocket Division
Goddard Space Flight Center
Greenbelt, Maryland

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I INTRODUCTION

Space research by means of sounding rockets is today some twenty-five years old. Since rockets were first equipped with scientific instruments to probe the upper air and space, they have accounted for or contributed to discoveries of major scientific and practical significance.

Basically a sounding rocket is a relatively small vehicle which carries scientific instruments to altitudes of 50 miles and over in nearly verticle trajectories. It may use liquid or solid propellant and it may have one or more stages. It does not contain a guidance system but rather is fin stabilized and during powered flight it weathercocks into the wind.

In 1961 there were 70 some sounding rocket launches. The average payload was 50 lb. and the altitude less than 100 miles. This past year the number of launches has more than doubled and the average payload weight has tripled. In addition the experiments and instrumentation have become most sophisticated; for example pointing accuracies of better than one arc minute are available for astronomy.

Sounding rocket research has been an important cornerstone of the NASA International Cooperative Programs. NASA provides Sounding Rocket flight opportunities for scientists and agencies of other countries. During the past decade, twenty countries have joined NASA in cooperative projects resulting in the launching of more than 500 rockets from ranges in the United States and abroad.

Unique Capabilities of Sounding Rockets

The sounding rocket has a unique and useful place in space research. Some of these capabilities are shown in Figure 1.

Past Accomplishments

Sounding Rockets provided the first means of directly examining the portion of the spectrum consisting of wavelengths shorter than 3000 Å. Up to then measurements had been limited by the opaque nature of the Earth's atmosphere. Observations of the solar ultraviolet spectrum by means of a spectrograph were made in 1946 and one of the earliest triumphs of rocket solar astronomy was the discovery of solar X-rays originating in the million degree corona.

Over the years, knowledge of the solar spectrum has steadily increased as the observable limit has been extended from approximately 2200 Å in the early measurements, through the line-emission region, and into X-ray wavelengths. By 1950 the solar spectrum had been broadly mapped and the outlines of the mechanisms by which solar ionizing radiations produce and control the ionosphere were discernable. In recent years, satellites too have monitored the various emission levels, but the principal characteristeics of the emissions, so important to our understanding of the Sun and the upper atmosphere, were identified from rocket data.

Some of the contributions of Sounding Rocket research that were singled out by the Space Science Board of the National Academy of Sciences in 1969 are shown in Figure 2.

II THE U.S. SOUNDING ROCKET PROGRAM

A. NASA Program

1. Disciplines Under Investigation

The NASA Sounding Rocket Program is principally in the fields of Solar Physics, Galactic Astronomy, Fields and Particles, Ionospheric Physics, Aeronomy and Meteorology. Specifically included in the program are rockets to map the parameters of the earth's atmosphere between 19 and 100 NM (40 - 200 km); to study pressure, temperature, and density of the ionosphere; to measure ionosphere electric currents; and to study auroras and airglow. The interrelations of these parameters and their dependence on solar heating, solar flares, geomagnetic storms, trapped radiation fluctuations, and meteor streams are also being investigated through sounding rockets to supplement the knowledge obtained from balloons and satellites. Special situations occur where simultaneous vertical measurements are required at a number of locations or where data from vertical cross-sections are required to supplement data from horizontal cross-sections. The development of attitude stabilization systems, particularly

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

1. Disciplines Under Investigation (con't)

for the Aerobee, makes the Sounding Rocket Program uniquely suitable for conducting exploratory astronomical observations in the X-ray, ultraviolet, and radio regions of the electromagnetic spectrum which are not visible from the earth's surface.

2. Vehicles

Through the development of vehicles and subsystems necessary to satisfy experimenter requirements, NASA has, over the years, evolved a family of sounding rocket vehicles that provides the range of capabilities necessary to cover the majority of the desired sounding rocket missions.

The NASA Sounding Rocket vehicle family provides experimenters with the capability of economically placing 10 to 1000 pound payloads at altitudes up to 1500 KM. When necessary, provisions can be made for payload recovery or highly accurate payload pointing.

Configuration drawings of the basic family of NASA Sounding Rocket vehicles are presented in Figure 3, while Figure 4 provides their performance capabilities. Table I provides a general data

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

2. Vehicles (con't)

summary for each of the NASA vehicles. For convenience, the vehicles in Figure 3 are grouped into three basic categories. The basis for these categories is derived from their principal uses and their payload/altitude capabilities. The categories are: (I) Meteorological and upper atmosphere research, (II) Astronomy and solar physics, and (III) Upper ionosphere and radio astronomy. It should be noted, however, that specific rockets are by no means limited to any given category.

With reference to Figures 3 and 4, category I would include the single stage and boosted Arcas, the recently developed Astrobee D, the Nike Cajun, the Nike Apache, and the Single Stage Tomahawk. Category II would include the Black Brant IIIB, the Aerobee 150, the Aerobee 170, the Nike Tomahawk, the Black Brant VC, and the Aerobee 350. Work is underway to provide the solid fueled Astrobee F to supplement these capabilities. Category III includes the Black Brant IV, the Javelin, and the Astrobee 1500.

The performance as shown in Figure 4 is provided for an 85 degree sea level launch as a function of gross payload weight.

A. NASA Program (con't)

2. Vehicles (con't)

Performance different from that shown in Figure 4 would result from changes in payload geometry, protrusions such as antennas, and variation in launch elevation. It would be impossible to summarize these effects for all the rockets shown without providing individual curves for each vehicle; however, the effect of launch elevation angle on apogee of two of the rockets is shown in Figures 5 and 6.

Gross payload weight includes, as necessary, the weight of the nose cone, any cylindrical extensions, telemetry, Attitude Control System (ACS), recovery package, and, of course, the experiment itself. An example of the breakdown of payload weight is given in Figure 7.

For many experiments the time available above a specific altitude is of particular importance. Figure 8 provides data on the experiment time available for a series of the rockets. This time--referred to as "time above altitude"--varies widely with payload weight and elevation angle. Although complete data is not provided, the figure does give some idea of the wide range of capability available within NASA's Sounding Rocket family.

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

2. Vehicles (con't)

The impact range of a given rocket and its dispersion about the predicted impact point are important since they cay be the limiting factor in the ability to launch a particular vehicle from a specific range. For example, at the present time vehicles like the Nike Tomahawk, Black Brant IV, Javelin and Astrobee 1500 are prohibited from being launched at the White Sands Missile Range (WSMR). For convenience, the nominal impact range (note that this range is a function of launch angle and payload weight) and the approximate 1 sigma dispersion about the predicted impact point are included in Table I.

A desirable feature of the rocket program is the capability of launching rockets from remote locations. This capability is largely dependent on mobility of the launcher systems. Four types of launchers are used for NASA Sounding Rockets. They are the (1) tube launcher, (2) zero length launcher, (3) rail launcher, and (4) tower launcher. The first three are easily transportable. Although the fourth, the tower launcher, is normally a permanent fixture at an established rocket launching range, there is a portable launch tower available for the Aerobee 150. The tower launcher is utilized by the higher

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

2. Vehicles (con't)

performing Category II vehicles to minimize impact dispersions. Table I shows the types of launchers adaptable to each rocket.

The rockets are spun to reduce vehicle dispersion and to maintain gyroscopic stability after the vehicle leaves the atmosphere. A factor which strongly influences the spin rate is the vehicle dynamics. Except in the case of the second stage of the Astrobee 1500 which uses roll jets, spin-up is induced aerodynamically by "canting" the fins or placing wedges on the trailing edge of fixed fins. Table I also shows the nominal burnout spin rate.

Where experimental requirements dictate a lower spin rate the package can be despun to thc desired rate after the payload leaves the atmosphere.

The payload diameter (also shown in Table I) indicates the nominal payload size. Bulbous payloads are flown on some of the rockets. For example, the Nike Apache and Nike Cajun have flown payloads up 22.86 centimeters in diameter. It is planned to fly the Astrobee F (under development) with payloads ranging up to 56 centimeters. These larger payloads, of course, reduce the apogee altitude accordingly.

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

2. Vehicles (con't)

Thermal environment is an important consideration in the design of a sounding rocket system for a specific mission. This is especially true in the higher performance vehicles where the effects of aerodynamic heating can be critical to either the instrumentation mechanism or the structural integrity of the vehicle itself.

Thermal protection can easily be developed when required. Fortunately, the effect on vehicle performance of the additional weight of thermal protection systems is usually negligible.

Within the United States a large number of government agencies are flying, or have flown, Sounding Rockets. In many cases these agencies have designed rockets to their own specific requirements utilizing surplus military boosters. Members of this class of Sounding Rockets are too numerous to mention individually and some have seen only limited use. Typical of these are the Navy's water launched Hydra series and air launched SPAROAIR series.

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

2. Vehicles (con't)

The primary agencies launching Sounding Rockets today are: National Aeronautics and Space Administration (NASA), Air Force Cambridge Research Laboratory (ARCRL), Naval Research Laboratory (NRL), Atomic Energy Commission (AEC Sandia), Kitt Peak Observatory, and the Defense Atomic Support Agency (DASA).

3. Attitude Control

One of the most noteworthy aspects of the Sounding Rocket Program over the past decade is the advent of the pointed and stabilized rocket and/or rocket payload. It has transformed Sounding Rockets to the role of a stabilized, oriented spacecraft capable of conducting sophisticated scientific experiments, unencumbered by the major effects of the earth's atmosphere, gravity, or environment during the coasting or free fall portions of the rocket trajectory.

It is the belief of NASA that in the pointed and stabilized rocket program it has a very cost and scientifically effective tool which compliments and augments its scientific satellite programs.

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

3. Attitude Control (con't)

The rocket borne experiment's major disadvantage of limited experimental time is at the same time one of its major advantages since it allows simple, rapid, and inexpensive recovery of the payload. Rapid laboratory recalibration of the spacecraft instruments and the use of photographic techniques for experimentation and attitude verification are relatively simple matters with the rocket payload. The reuse of the scientific instruments, control systems, and support instrumentation on future flights add significantly to the cost effectiveness of what is already a relatively inexpensive "ride in space."

In the past two years there has been an increasing demand to cross reference or calibrate an orbiting observatory by flying a pointed payload using the same or similar instruments to those in the observatory. By observing identical targets or phenomena at identical or appropriate times a verification of satellite performance can be obtained.

Controlled rocket programs are conducted in the United States by a number of agencies. Prominent among these are the National Aeronautics and Space Administration, The Naval

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

3. Attitude Control (con't)

Research Laboratory, Air Force Cambridge Research Laboratory, Kitt Peak National Observatory (AURA) and Sandia Corp. (under Atomic Energy Commission sponsorship). These agencies use a number of different control systems, some of which are manufactured or developed and serviced by commercial firms in the U.S. and some of which are strictly built within the using agency. Table II lists some of the more prominently used systems and attempts to define briefly their characteristics and estimated performance.

In the United States program, there has been little or no attempt to control the rocket or payload during the boost phase of flight. This is due primarily to the desire to keep the vehicle and control system cost, complexity and weight to a minimum. All of the control systems listed below initiate control after the rocket or payload is essentially free of aerodynamic effects. In the case of the gyro referenced systems, a reference is maintained or "remembered" from the ground up, and, upon initiation of control, the vehicle or payload is aligned to the gyro reference. Fine guidance optical error sensors are used to either up-date or replace the gyro reference to effect greater accuracy and/or

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

3. Attitude Control (con't)

stability. In the case of the strictly solar pointing systems, it is the general practice to utilize coarse solar sensors to drive the payload into the acquisition field of view of the fine solar sensor. If a magnetometer is used for control of the third axis, then no gyroscopes are required.

All of the control systems that are now operational in the U.S. have on thing in common. They use cold gas reaction jets to control and stabilize the vehicle operating in an on-off mode. Most systems vary the duration and frequency of the on-off jet commands in proportion to the magnitude of the error signal from the position and rate sensors. The error sensors and logic implementation utilized in the U.S. systems varies significantly, due primarily to the original mission and precision for which the system was designed or developed. Most of the systems have evolved special purpose adaptions to handle missions for which they were not capable of performing in their original design configurations. Often, the special purpose adaptions come into common use due to the fact that they have created a new capability for conducting different types of scientific investigations. A recent example of this was the Solar Eclipse Mission of March 1970.

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

3. Attitude Control (con't)

In order to observe the totally eclipsed sun with high stability (± several arc seconds of jitter) and accuracy, a star pointing STRAP III control system was equipped with a solar crescent error sensor and a pair of low drift rate, high resolution rate integrating gyroscopes. The system was launched just prior to totality and maneuvered to the partially eclipsed sun position on its standard wide angle gyroscopes. Control in two axes was then switched to the solar crescent sensor and the vehicle was aligned in a precise manner with respect to the solar crescent. Just before totality, the system switched control to the aforementioned rate integrating gyros and maintained the required precise pointing and stability throughout totality and third contact was observed before reentry of the rocket payload. Since the eclipse mission, the trimodal system described above has been used on four occasions to stabilize on X-ray sources and dim stellar fields. A system called STRAP IV with multi-target maneuvering capability under rate integrating gyro control is presently under development at the Goddard Sounding Rocket Laboratories to enable two axis fine stabilization on X-ray sources. In short much of the NASA work with sounding rocket control and stabilization has been evolutionary in nature with the demand for more control capability forcing system changes and improvements.

None of the U.S. systems is at present a precision three-axis control system of the type that is required for some of the X-ray pointing and star field astronomy experiments on the horizon. All of the U.S. systems have only two axes of fine pointing capability with much coarser pointing accuracy in the third axis. There is a need for a three axis fine pointing system with capability of using two stellar error sensors to update (in three axes) a low drift rate inertial reference. The first sensor could be used to correct in pitch and yaw and the second sensor could provide the roll correction. This would allow simultaneous observations of different positions on the celestial sphere without requiring a trackable source. Preliminary design studies and some component evaluation is in progress at present. The present work on this system is attempting to define the cost/complexity tradoffs vs. accuracy and performance. Actual system design will begin in the second half of 1971. It is believed that pointing accuracies of about one arc minute can be obtained at reasonable cost and

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

3. Attitude Control (con't)

complexity. By use of fluidic proportional thrusters rather than the on-off controllers used in present systems, it is believed that sub arc second stability on target can be obtained.

4. Recovery Systems

The NASA Sounding Rocket Program is currently utilizing three recovery systems to support Nike Apache, Nike Cajun, Aerobee 150, Aerobee 170, and Aerobee 350 operational vehicles. Two additional systems are nearing operational status to support the requirements of the Black Brant IIIB and Black Brant VC vehicles. With the exception of the Aerobee 150/170 system these systems are available in one configuration only--a two stage land recovery system. The Aerobee 150/170 system is available as a two stage land recovery system or a two stage water recovery system. In addition, the Aerobee 150/170 systems are available with a shaped charge vehicle severance system or a squib operated mechanical system.

In general, NASA sounding rocket land recovery systems provide for severance of the payload prior to atmospheric re-entry at the conclusion of the experiment portion of the flight. Where the requirements of the experiment dictate, separation of the payload prior to the start of the experiment is provided. The recovery body is allowed to fall freely to approximately 20,000 feet at which time a barometric sensing system initiates deployment of the first stage decelerator. The first stage decelerator stablilizes the recovery body and reduces the dynamic pressure to a safe level for deployment of the main parachute. A chemical reefing line cutter actuates twelve seconds after first stage deployment. This releases the first stage and extracts the final stage parachute. Water recovery system operation is similar to land recovery. A flotation bag is located on a tow line between the parachute and the body. It is extracted by deployment of the main parachute. The inflation system is mechanically actuated and the bag inflates during the final descent phase and is fully inflated at water impact. Figure 9 shows the sequence of operation. The basic characteristics of the various recovery systems are summarized in Table III.

The normal mounting location of the recovery system on all operational vehicles is at the base of the payload. However, at

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

4. Recovery Systems (con't)

the present time consideration is being given to revised versions of the Aerobee 150/170 system and the Black Brant VC system for mounting at the base of the nose cone. This involves separation of the vehicle severance system from the recovery system. Specialized versions of the Aerobee 150/170 system have also been used for vehicle recovery.

Expansion of the recovery capabilities to support anticipated needs of the scientific community include upgrading the Aerobee 150/170 system to support a recoverable weight of 750 pounds, upgrading the Aerobee 350 system to support a recoverable weight of 1000 pounds, incorporate a water recovery capability in the Black Brant VC, and establish a land and water recovery capability for the Nike Tomahawk vehicle.

5. T/M - Instrumentation

Experiment data can be recovered from Sounding Rockets by means of various telemetry systems. There are three principle types of telemetry system currently being used on NASA Sounding

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

5. T/M – Instrumentation (con't)

Rockets. They are FM/FM, PPM (Pulse Position Modulation), and PCM (Pulse Code Modulation). A summary comparison of the three systems is presented in Table IV.

More than one telemetry system can be and usually is flown on a single rocket. A small rocket with few measurement requirements might fly one FM/FM system with only 10 channels. A large vehicle with very extensive measurement requirements might fly, for example, one PPM system, one PCM system, and two FM/FM systems for a total of several hundred data channels and a total sampling rate of around 80KC. A typical measurement plan is shown in Table V.

As can be seen from Table IV the size, weight, and power requirements of the 3 systems are roughly the same. The input signal levels and the input impedance are all the same except for the optional ±2.5 volt range on FM/FM. Sampling rates are higher on PPM (20K version) and PCM than on a typical FM/FM system, but a non-typical FM/FM system could have about 20KC also.

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

5. T/M - Instrumentation (con't)

There are two primary differences between FM/FM and the digital systems. The first is the system accuracy. An order of magnitude increase in accuracy is accomplished in going from FM/FM to PPM or PCM because of the digital nature of these systems. The second difference is in the data reduction techniques used for the FM/FM system vs. the digital systems. The digital systems data is directly usable by digital computer and thus data reduction is automated. The FM/FM system data is normally reduced by hand from paper records. There are digitization systems which will provide digital computer tapes from FM/FM data but they are not widely used. Normally an experimenter who wants automated data reduction will use a PPM or PCM system.

A brief description of each type of system and a discussion of the data reduction processes used follows.

(1) FM/FM

A carrier frequency on the order of 240 MHz is frequency modulated by the subcarriers which are themselves frequency

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

5. T/M - Instrumentation (con't)

(1) FM/FM (con't)

modulated by the transducer voltage. A typical flight will have about a dozen subcarriers, although it is possible to have up to 18. The subcarrier frequency responses vary from about 60 Hz to about 6000 Hz. The total information rate for an FM/FM system is typically about 10 KHz. Figure 10 is a simplified block diagram of the system.

(2) PPM (PULSE POSITION MODULATION)

The sounding rocket PPM telemetry, shown in Figure 11, is a 16-channel system with a total sampling rate of 5 KC, 10 KC, or 20 KC, the frequency being prewired into the flight premodulator. Transducer signals are compared by the premodulator to a ramp and position-modulated pulses are generated thereby. The reference pulses, which start the ramp for each channel, are not transmitted directly because so doing would limit the available data bandwidth. Instead, the information contained in the reference pulse and also the frame pulse which indicates the beginning of the 16 samples, are combined into a synchronization signal referred to as the Triple Pulse. This Triple Pulse is used by the ground station Servo Clock to reconstruct the frame and reference signals.

The PPM format out of the Servo Clock is used to drive all real-time displays, but the data is not stored in its PPM format (except on the backup video tape). It is instead converted to paralleled binary data (9-bit) for storage on a digital tape. This tape is used for all post-flight data reduction. Recording the data in binary form eliminates the inaccuracies which are inherent in analog (video) recordings due to tape deck wow and flutter.

(3) PCM (PULSE CODE MODULATION)

The sounding rocket PCM telemetry, shown in block form in Figure 12, is a 16-channel system with a total sampling rate of 20 KC and a bit rate of 200 KC. The first two channels are used for the Frame Sync Code and the Sub-frame Counter. Each channel is transmitted (in serial

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

5. T/M - Instrumentation (con't)

(3) PCM (PULSE CODE MODULATION)

Bi-Phase code) as 9-bit data plus a single parity bit. The PCM Encoder uses a fast (9-bit) A/D converter to generate the binary data values. By transmitting data in binary code, PCM avoids the slight inaccuracy which is inherent in PPM due to small drifts in clock frequency, and small variations in bias and slope of the ramps used to generate PPM data.

PCM is by far the most accurate of the 3 types of telemetry in use at this time.

On the ground, the Serial Bi-Phase signal is recognized by a Bit Synchronizer which is very insensitive to noise in the T/M signal. The clean pulse output of the Bit Synchronizer is fed into a Frame Synchronizer which produces a frame pulse based on the Frame Sync Code contained in channel 1 and part of channel 2. The subframe decommutator uses the subframe count in the low order 5 bits of channel 2 to allow the real-time displays to display not only main data channels, but also, where applicable, a particular subchannel. There can be up to 32 subchannels in each of the 14 data

II The U.S. Sounding Rocket Program (con't)

A. NASA Program (con't)

5. T/M - Instrumentation (con't)

(3) PCM (PULSE CODE MODULATION) (con't)

channels, thus, the system is basically a 448 channel system, although if used as such, the perchannel sampling rate would only be about 45 samples per second.

As in the case of PPM, the PCM signal is stored in parallel binary (9-bit) format with a video tape provided only as a backup.

6. Sounding Rocket Telemetry Antennas

Nearly all Sounding Rocket Telemetry Antennas that are presently used can be classed as two types, i.e., flush and nonflush mounting types. Aerodynamic considerations make the flush mount antenna admirable, but they usually have radiation characteristics which have an undesirable null fore and aft of the missile along the longitudinal axis. In addition to the undesirable radiation patterns, flush mount antennas usually tie into the vehicle structure and are often called upon to carry the structural integrity of the scientific payload. For these reasons, flush mount antennas are not widely used. Many variations of nonflush antennas are available and each is a design compromise directed toward suitable configurations which satisfy aft radiation coverage requirements, and the achievement of aerodynamic objectives.

One of the most widely used nonflush antennas is a basic element called the "Quadraloop." Its name is derived from the geometric configuration quarter-of-a-loop. It is basically a shorted quarter wave transmission line which is dielectrically loaded to achieve physical shortness. The elements are always employed in pairs and are mounted diametrically opposite on the missile. One element is always fed 180° out-of-phase with respect to the other element when the wavelength to rocket diameter ratio is greater than one. In cases where the wavelength to vehicle diameter ratio is less than one, perturbations in aft radiation coverage is experienced. In this case, other types of element phasing must be considered.

Another very common nonflush antenna is a Sweep-Back Radiator which is nothing more than a quarter wave rod canted back an angle of 45° to 60° with respect to the axis of the vehicle. In general, there are four of these elements in quadrature with each being fed progressively 90° out-of-phase to give a circular polarization component. It should be noted that in cases where circular polarization is used, the sense of circular wave rotation must be in the proper direction, to avoid cross-polarization (i.e. 10 db decrease in signal). In most sounding rocket antenna work the right circular polarization is the most conventional. It is defined as a clockwise rotating field looking aft of the vehicle. (The 3 db gain achieved in using) right circular polarization on sounding rocket vehicles is sometimes weighted against the increased drag experienced by the addition of two more radiators. With only two diametrically opposite elements, linear polarization is experienced. If right circular polarization is used on the ground in a receiving mode, cross-polarization will not be experienced. In nearly all instances circular polarized receiving antennas are used for the reception of scientific data from the sounding rocket.

While all the goals of an ideal multipurpose antenna have not been reached, new improvements in vehicle antenna design are continuing and being tested for increased performance.

II The U.S. Sounding Rocket Program (con't)

B. The NRL Program

Sounding Rocket research at the Naval Research Laboratories in Washington is conducted by the Space Science Division. Under Dr. R. Tousey, the Rocket Spectroscopy Branch makes spectroscopic and other investigations from rockets and satellites as well as from the earth's surface of the optical radiations from the sun and other celestial bodies, the night and day airglows, and the aurora. The relations between the experimental results and the physical processes that take place in the atmospheres of the sun and earth are studied.

A tabulation of recent and projected firings which is indicative of the types of rocket research being conducted is shown in Table VI.

C. The AFCRL Program

The Air Force Cambridge Research Laboratories at Bedford, Massachusetts has conducted rocket research since 1946. Over 800 large research rockets and a similar number of smaller meteorological rockets have been launched. During the past three years, AFCRL launched a total of 166 research rockets with most of these being launched from Eglin AFB, Florida (57), Ft. Churchill, Canada (54), White Sands Missile Range (14), and Wallops Island (13). In addition ten were launched from Brazil, nine from Puerto Rico and seven from Kauai, Hawaii.

C. The AFCRL Program (con't)

Rockets are used to examine all aspects of the earth's upper atmosphere and near-space environment - atmospheric winds, temperatures and densities; the electrical structure of the ionosphere; solar ultraviolet radiation; atmospheric composition; the earth's radiation belts; cosmic ray activity; and airglow and the aurora. The kinds of rockets most frequently used by AFCRL are the Nike Iroquois (NIRO), the Nike Cajun, the Black Brant, and Aerobee.

D. The Kitt Peak Program

The Kitt Peak National Observatory located in Arizona has conducted research in the planetary sciences with rockets since 1963. To date over 20 rockets have been flown. This program started at a time when pointing systems adequate for astronomy had not yet been developed and has played an active roll in the development of such systems. Significant studies have been conducted in Daytime Airglow, UV spectra of Venus, Jupiter and Mars, UV spectra of about 30 hot stars in the Orion region, Solar X-rays and Zodiacal Light.

The increasing participation and interest in the Kitt Peak rocket program taken by astronomers and others at various American universities has led to a desire to increase the number of sounding rocket flights.

D. The Kitt Peak Program (con't)

Projected plans include the following objectives:

(1) The measurement of the solar energy flux

(2) Measurements of hydrogen/deuterium ratio in planetary atmospheres

(3) Measurements of the carbon resonance line at 1657A° in Venus.

E. Launch Sites

The location of sounding-rocket ranges has been determined mainly by logistic and safety requirements. In some cases, such as that of the auroral site at Fort Churchill, ranges have been constructed specifically to undertake research on special scientific problems. A number of scientific problems involving coordinated launchings of sounding rockets from several sites have been carried out, beginning during the International Geophysical Year. During IGY, World Days were set aside for coordinated launchings of sounding rockets. Through COSPAR's Working Group II Panel on Synoptic Sounding Rockets, synoptic scientific investigations have been proposed and worldwide cooperative flights have been undertaken. It has been from studies of this nature that the advantages derived from the simultaneous or coordinated sounding-rocket investigations at various geographical sites have been established. It is now possible to investigate problems in meteorology and aeronomy by means of simultaneous or consecutive flights (from several launching sites). The study of solar-terrestrial relations and the effects of latitude variations are typical examples.

The distribution of sounding-rocket sites has become all the more important in the correlation of observations obtained from satellites with observations of phenomena which vary with altitude. The capacity for undertaking such comparisons depends on the geographical distribution of sounding rocket launching facilities and the state of development of these facilities. (See Table VII)

III INTERNATIONAL PROGRAMS

The purpose of the Sounding Rocket Program as related to International Cooperative Programs is to stimulate scientific interest and technical competence in other countries. In order to stimulate interest NASA provides Sounding Rocket flight opportunities for the participation of scientists and agencies of other countries in the tasks of increasing man's understanding and use of his spatial environment, and to support operating requirements for launching and observation of Sounding Rocket flights.

III International Programs (con't)

During the past decade, twenty countries have joined with NASA in cooperative projects resulting in the launching of more than 500 rockets from ranges in the United States and abroad. In all cases, the scientific data are shared and the results published in the open literature. The basic components of a Sounding Rocket Program are the scientific payload, the Sounding Rocket, the launching facilities and services, and the ground equipment for command, telemetry and tracking. Division of responsibilities in International Cooperative Projects with Brazil, Norway, India and other countries has varied to reflect the respective interests and capabilities of the cooperating parties in the specific project.

In most cases, foreign scientists propose experiments of their own development to NASA. If we have an interest in the scientific results, we then design cooperative project arrangements in which NASA provides the Sounding Rockets and the cooperative agency provides both the scientific payload and range services. As an example, in 1966 and 1968, Indian scientists built payloads to measure the magnetic and electrical properites of the equatorial electrojet. NASA provided four Nike-Apache rockets and the Indian launch team at Thumba conducted the launch operations.

Another variant has involved payloads jointly instrumented by U.S. and foreign scientists. For instance, NASA Norwegian and Danish scientists, during the period 1961 - 1967, conducted a variety of polar ionospheric studies from Norway's Andoya range using jointly developed payloads. More than twenty rockets of various types were used in these campaigns, with the Norwegians purchasing some and NASA contributing others.

In another type of relationship, for example, NASA scientists initiated an X-ray astronomy program in 1966 requiring a launch from the Brazilian equatorial range in to the South Atlantic Anomaly. In this case, NASA provided both the scientific payload and the Aerobee Sounding Rocket, while Brazilian space authorities prepared and operated the launching range.

The development of Sounding Rockets by other countries has in several cases made it possible to fly U.S. payloads on foreign Sounding Rockets or to coordinate U.S. and foreign Sounding Rocket Launchings. Nations which have developed or are developing their own rockets include France, the United Kingdom, Canada, Mexico, Brazil, Argentina, India, Pakistan, Japan and Australia.

During 1970 new Cooperative Sounding Rocket agreements were signed with Australia, India, Spain and Sweden. At year's end, negotiations with the French were nearing completion for cooperative upper atmosphere studies to be launched from an equatorial site in Kourou, French Guiana. Canada and the U.S. reached agreement for continued access by the U.S. to the Canadian Churchill Research Range for Sounding Rocket and other scientific activities. Under previous agreements, launchings during 1970 took place in Argentina, Australia, Brazil, Germany, India, Norway, Pakistan, Spain and Sweden.

During 1971, under previous or new Cooperative Agreements, Sounding Rocket launches will be conducted from Spain, Sweden, Norway, India, Canada, French Guiana and off the east coast of Kenya from the San Marco Platform.

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UNIQUE CAPABILITIES

- ONLY MEANS OF OBTAINING DIRECT MEASUREMENTS IN THE ALTITUDE RANGE OF 40 TO 200 KM.
- EXPERIMENT SIZING, QUALIFICATION, CALIBRATION
- PAYLOAD RECOVERY
- LOGISTIC FLEXIBILITY
- SHORT LEAD TIME AND LOW COST
- APPLICABILITY TO GRADUATE SCHOOL RESEARCH

Figure 1.

SOME SCIENTIFIC RESULTS OF ROCKET RESEARCH

- THREE NEW BRANCHES OF ASTRONOMY - ULTRAVIOLET, X - RAY AND GAMMA - RAY ASTRONOMY - ATTRIBUTED TO SOUNDING ROCKETS.
- MAIN FEATURES OF EARTH'S UPPER ATMOSPHERE CHARACTERIZED BY SOUNDING ROCKETS.
- GEOCORONA FIRST RECOGNIZED AND DEFINED BY SOUNDING ROCKETS.
- ALMOST ALL OUR KNOWLEDGE OF IONOSPHERIC CHEMISTRY STEMS FROM ROCKET SOUNDINGS.
- EXISTENCE OF ELECTRICAL CURRENTS IN IONOSPHERE AND ELECTROJETS DETECTED BY SOUNDING ROCKETS.
- ROCKET MEASUREMENTS HAVE PROVIDED MOST ACCURATE DESCRIPTION OF PARTICLE FLUXES IN AURORAS.
- ALMOST ALL IMPORTANT SPACE ASTRONOMY RESULTS OBTAINED FROM ROCKETS.

Figure 2.

NASA SOUNDING ROCKET VEHICLES

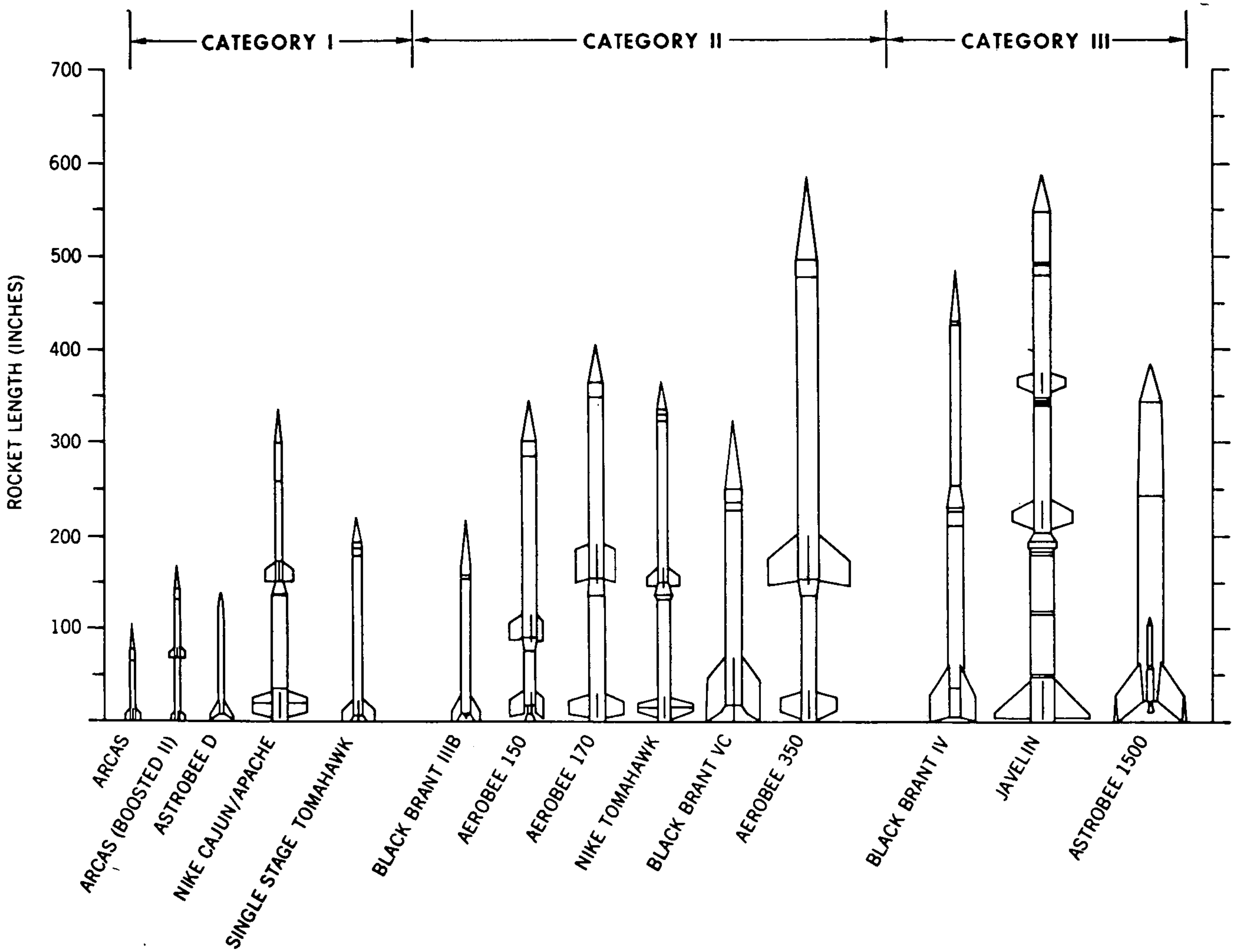

Figure 3.

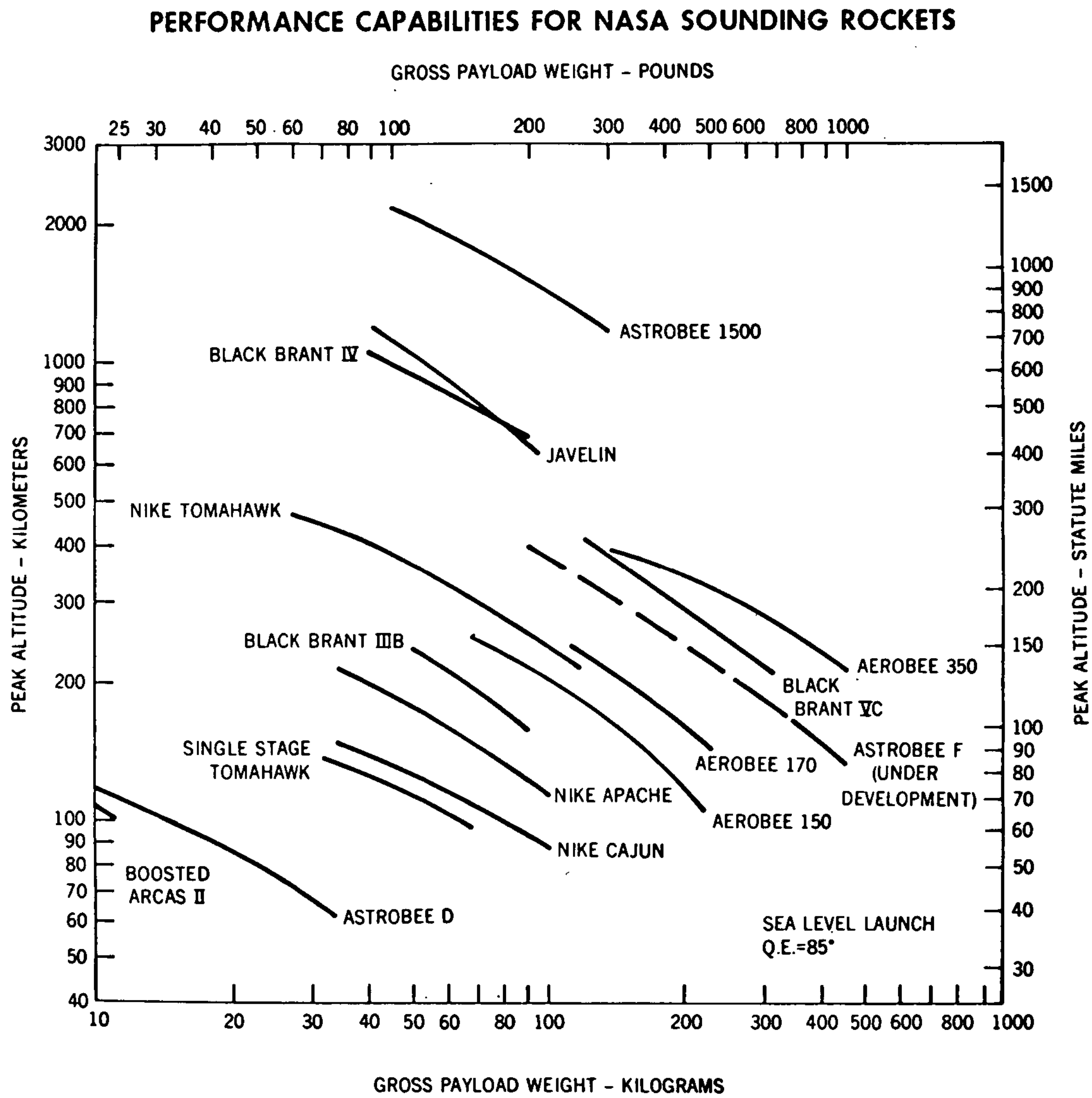
PERFORMANCE CAPABILITIES FOR NASA SOUNDING ROCKETS
GROSS PAYLOAD WEIGHT - POUNDS
25 30 40 50 60 80 100 200 300 400 500 600 800 1000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
1500
1000
900
800
700
600
500
400
300
200
150
100
90
80
70
60
50
40
30
PEAK ALTITUDE - KILOMETERS
PEAK ALTITUDE - STATUTE MILES
ASTROBEE 1500
BLACK BRANT IV
JAVELIN
NIKE TOMAHAWK
BLACK BRANT IIIB
SINGLE STAGE TOMAHAWK
NIKE APACHE
NIKE CAJUN
AEROBEE 170
AEROBEE 150
AEROBEE 350
BLACK BRANT VC
ASTROBEE F (UNDER DEVELOPMENT)
BOOSTED ARCAS II
ASTROBEE D
SEA LEVEL LAUNCH
Q.E.=85°
10 20 30 40 50 60 80 100 200 300 400 500 600 800 1000
GROSS PAYLOAD WEIGHT - KILOGRAMS

Figure 4.

APOGEE ALTITUDE VS LAUNCH ELEVATION ANGLE

NIKE TOMAHAWK
PAYLOAD LENGTH = 310 cm.
SEA LEVEL LAUNCH

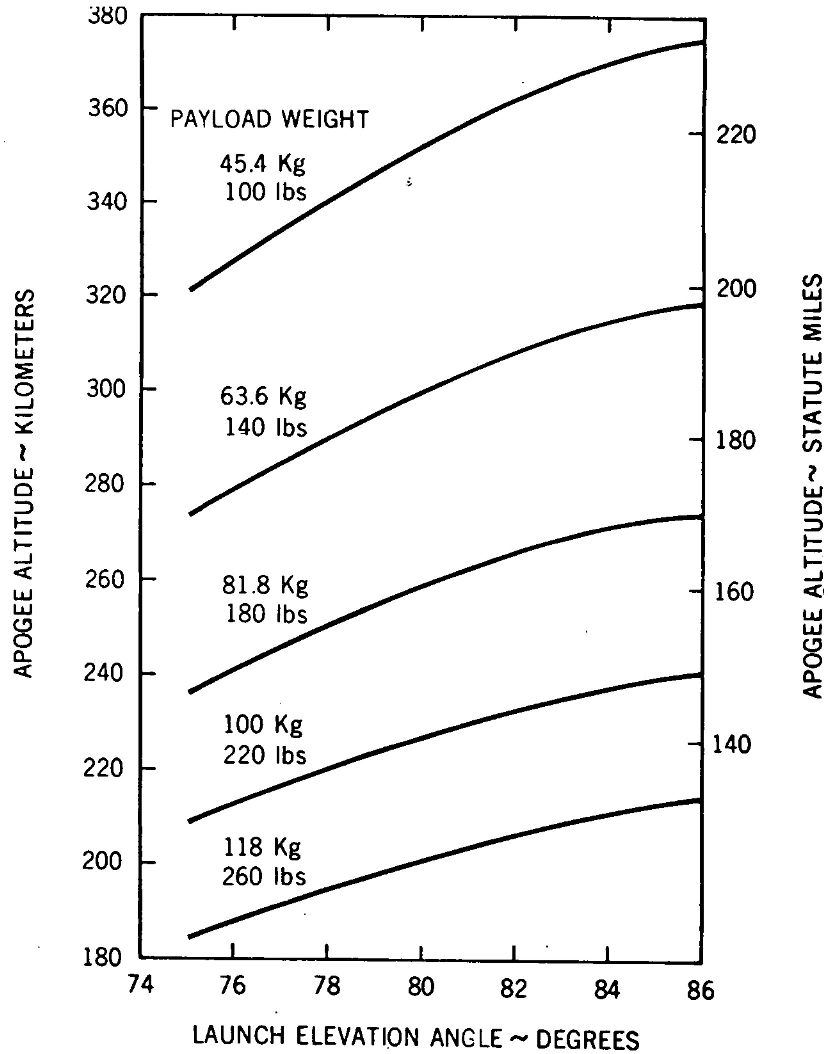

Figure 5.

APOGEE ALTITUDE VS RANGE AT APOGEE

NIKE APACHE WITH 18° NOSE CONE
LAUNCH ALT-1216 METERS (3996 FT.)

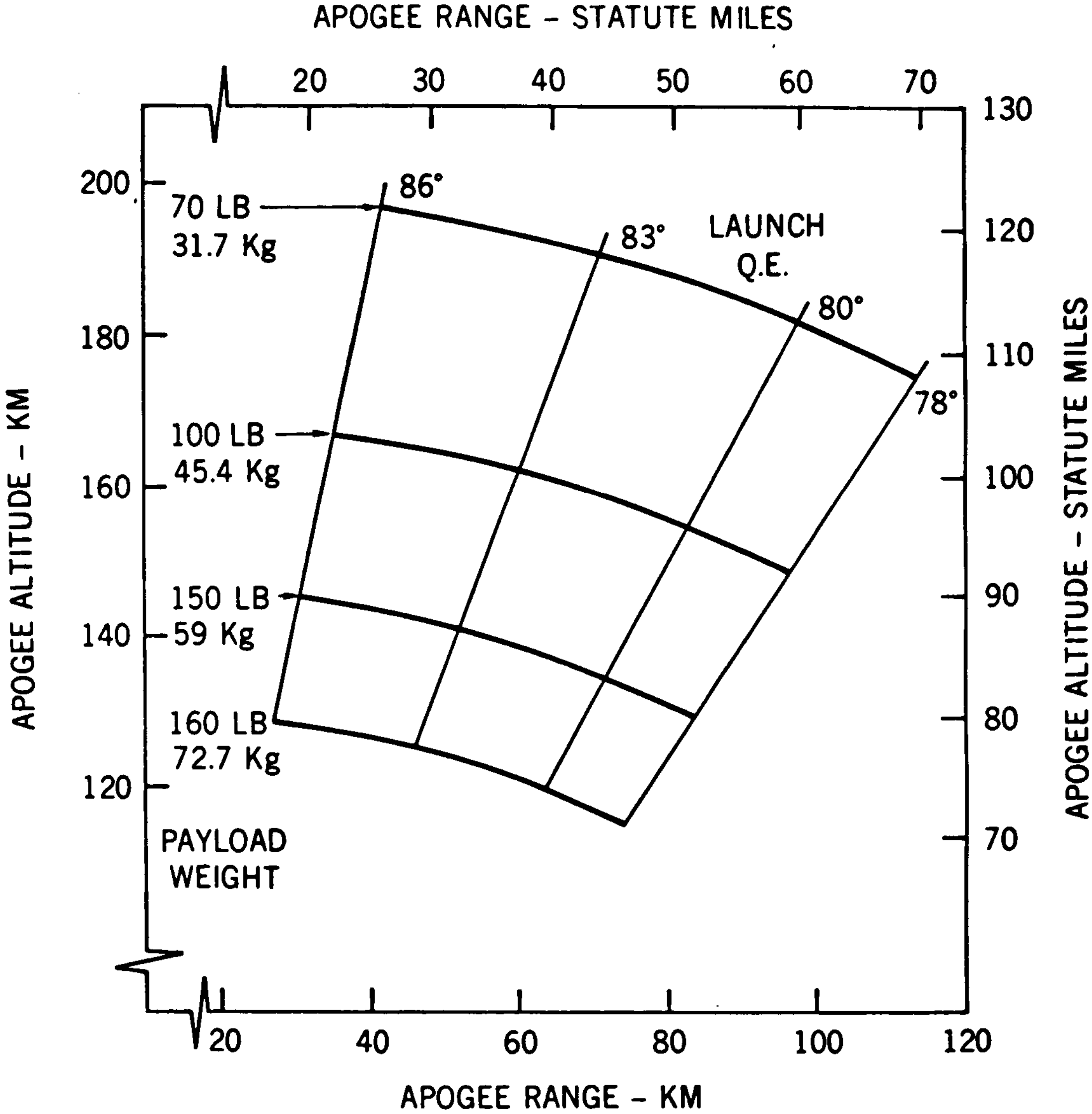

Figure 6.

TYPICAL SOUNDING ROCKET PAYLOAD HOUSINGS

(NOT TO SCALE)

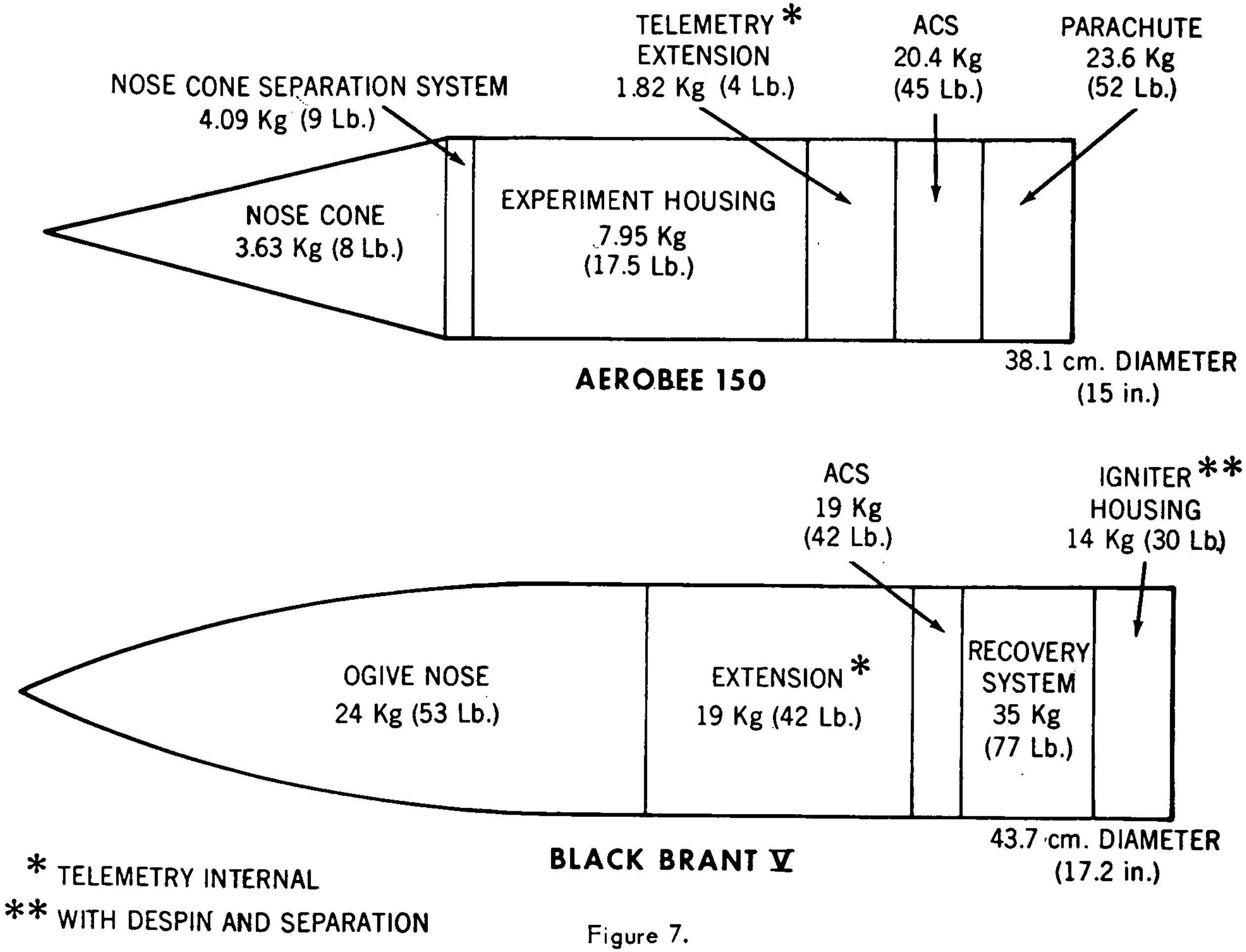

Figure 7.

TIME ABOVE REFERENCE ALTITUDE VS APOGEE ALTITUDE

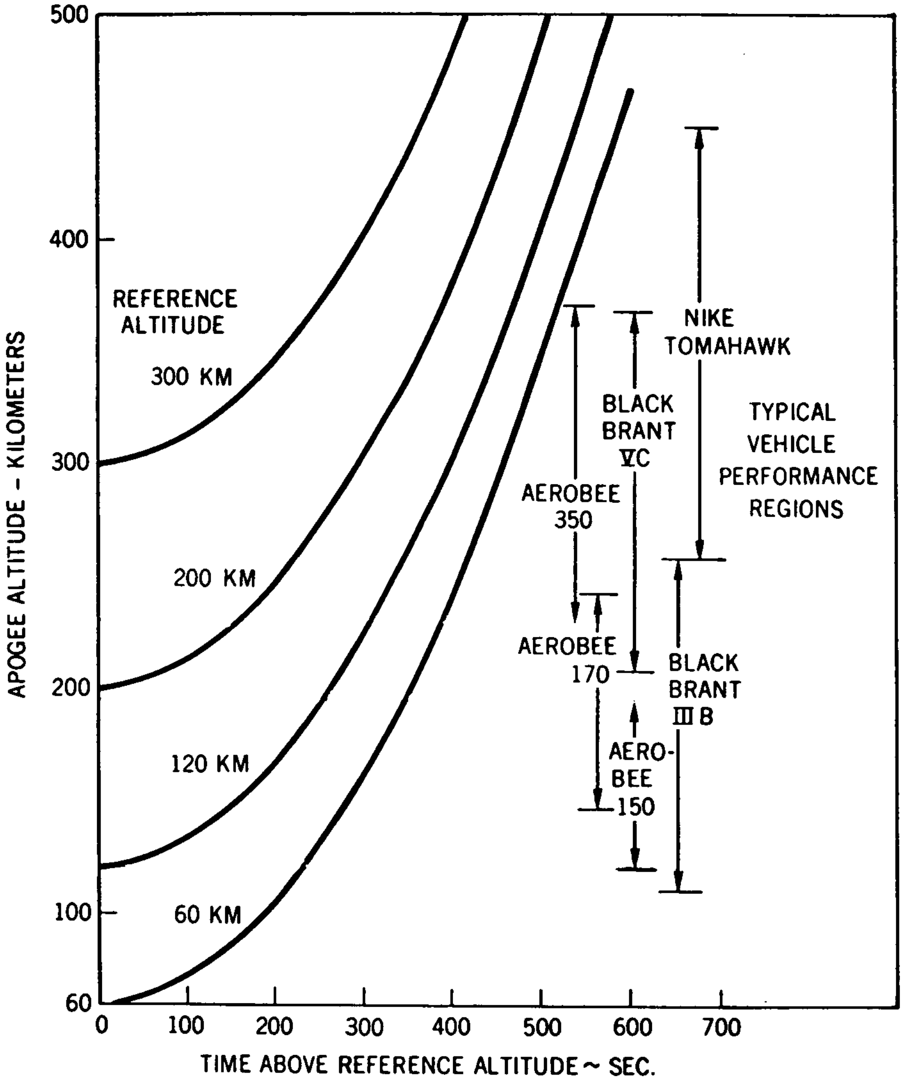

Figure 8.

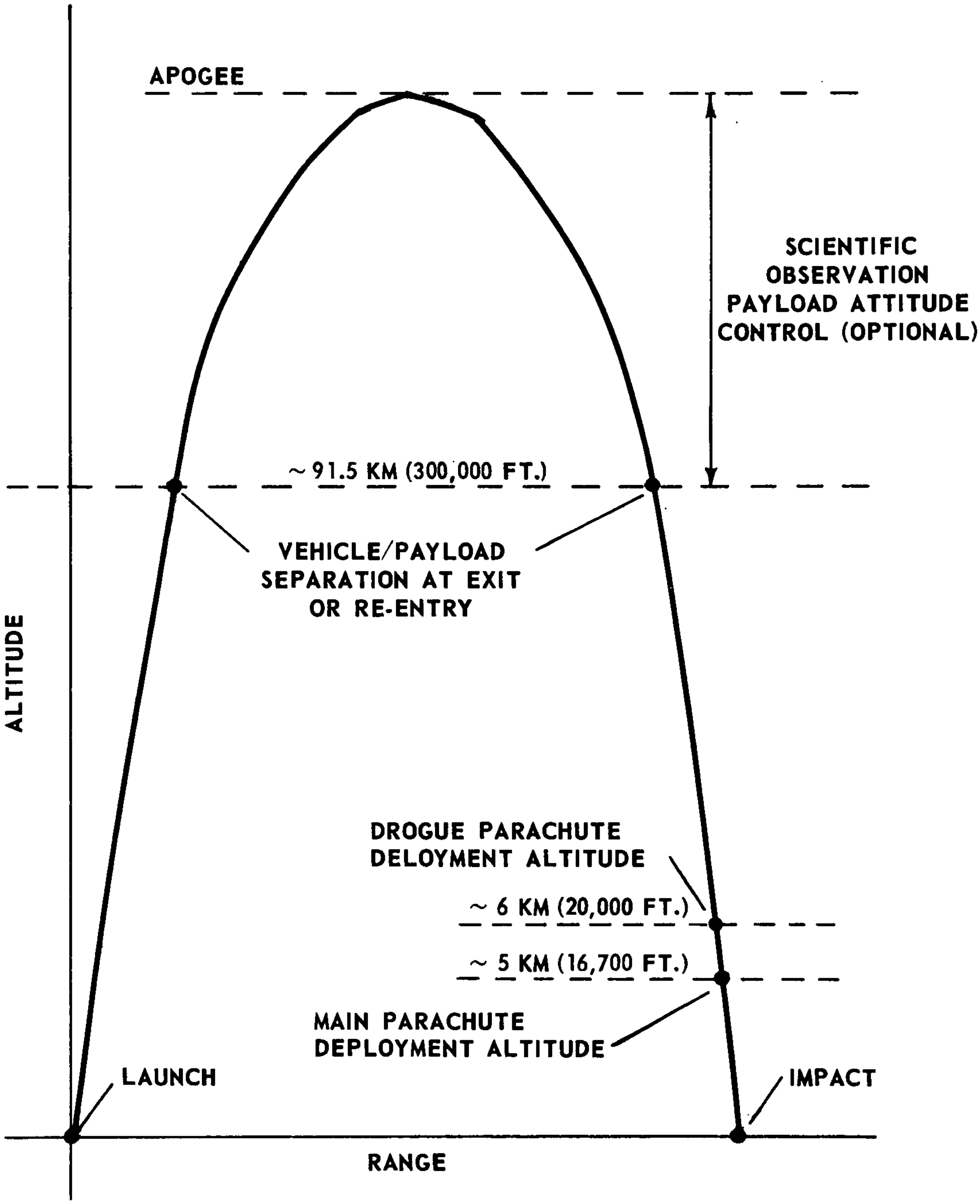

Figure 9. Typical Recovery Mission Profile

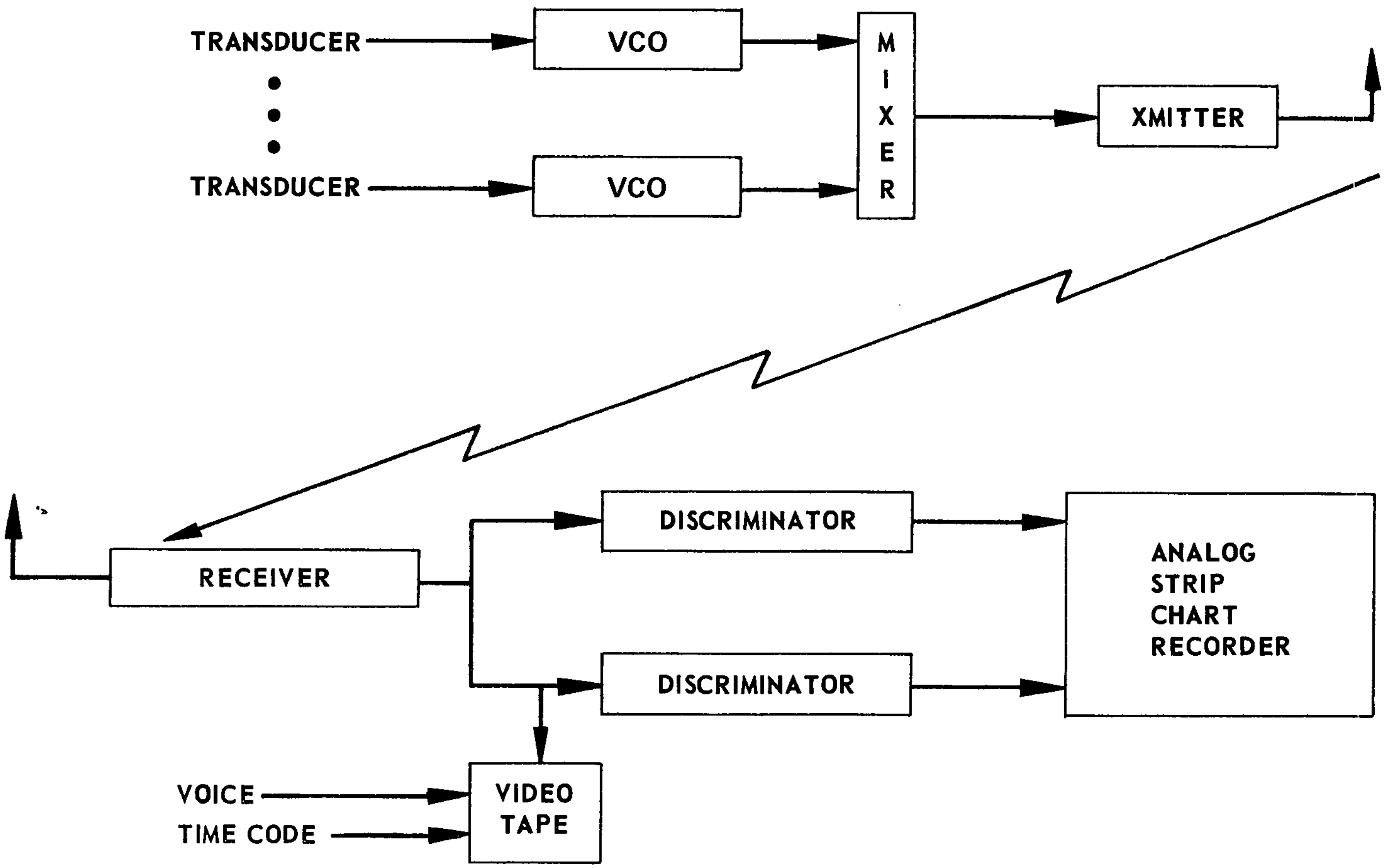

Figure 10. FM/FM System

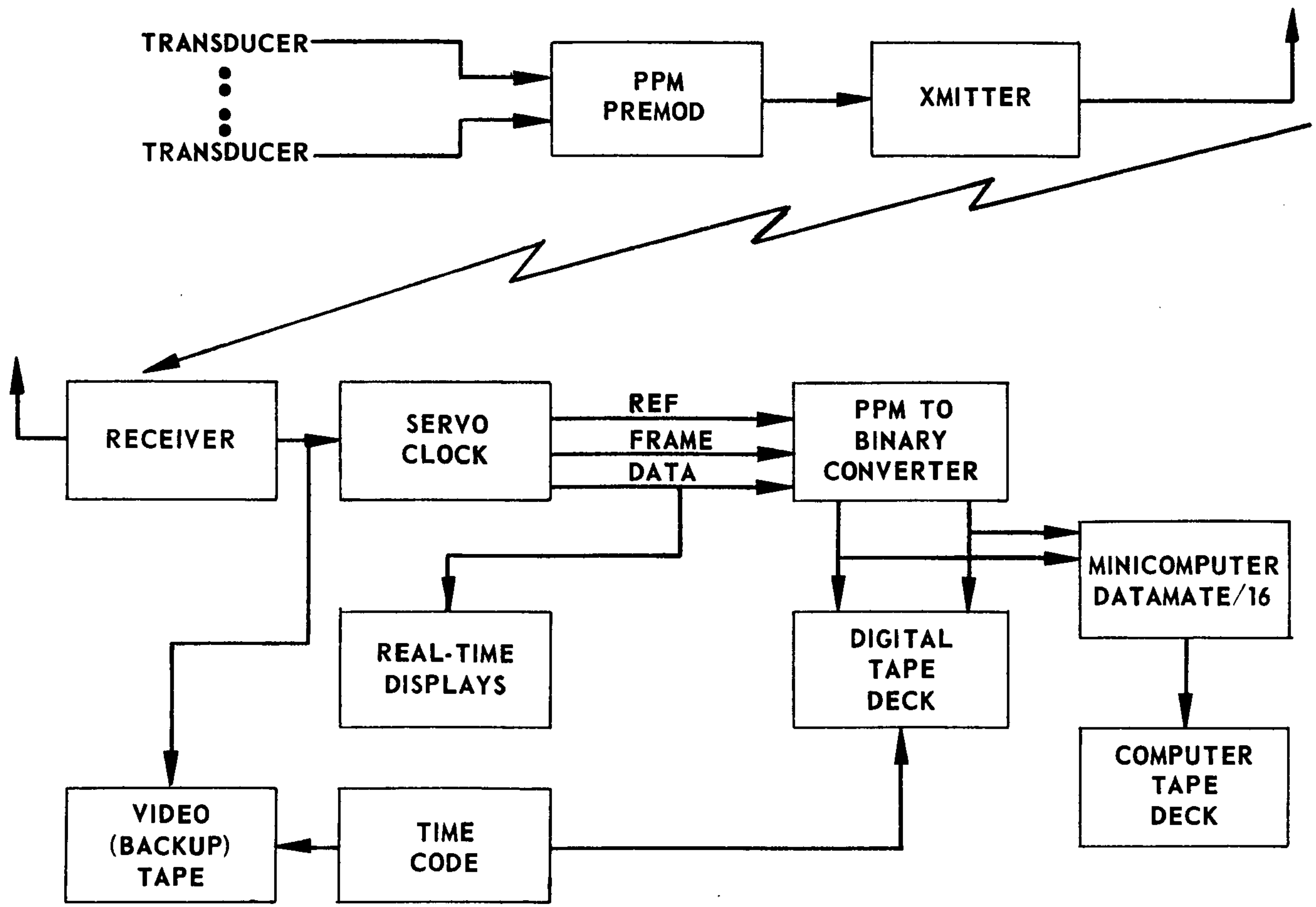

Figure 11. PPM System

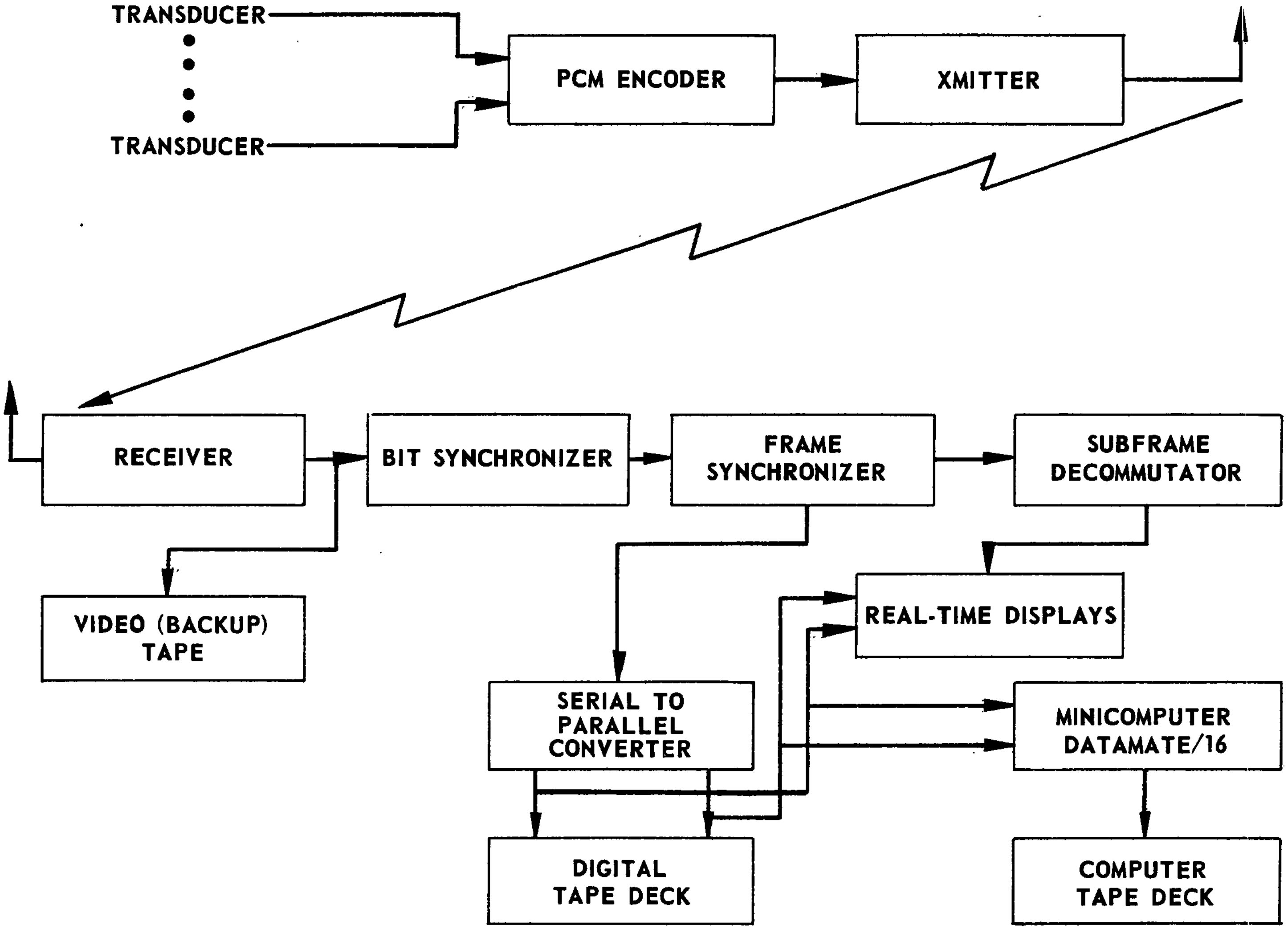

Figure 12. PCM System

Table I

NASA SOUNDING ROCKET DATA

* UNDER DEVELOPMENT
** TO BE ESTABLISHED
1 LENGTH VARIES WITH PAYLOAD LENGTH, AVERAGE VALUE GIVEN
2 IMPACT RANGE VARIES WITH LAUNCH ELEVATION ANGLE AVERAGE VALUE GIVEN
3 DISPERSION VARIES WITH LAUNCH RANGES, APPROXIMATE VALUE GIVEN

ROCKET	PAYLOAD DIA CM INCHES	VEHICLE NOMINAL[1] LENGTH CM INCHES	NOMINAL PAYLOAD WEIGHT KILOGRAMS POUNDS		SYSTEMS AVAILABLE			NO. FINS PER STAGE	NO STAGES	BOOSTER TYPE	NOMINAL B.O. SPIN RATE	NOMINAL[2] IMPACT RANGE KILOMETERS ST. MILES	1 SIGMA[3] DISPERSION RADIUS KILOMETERS ST. MILES	RANGE USE		LAUNCHER TYPE AVAILABLE			
			LIGHT	HEAVY	ACS	DESPIN	RECOVERY							WSMR	WI	TUBE	RAIL	ZERO LENGTH	TOWER
ARCAS	11.43 4.5	231 90.9	2.3 5	9 20			X	4	1	–	20	60 35	12.9 8	X	X	X	X		
ARCAS BOOSTED II	11.43 4.5	408 160.7	5.5 12	9 20			X	4	2	ARCAS	12	115 70	19.5 12	X	X	X	X		
ASTROBEE D	15.24 6	350 138	4.6 10	34 75				3	1	–	12	80 50	**	X	X		X		
NIKE CAJUN	16.51 6.5	839 330	34 75	100.2 225		X	X	4	2	NIKE	7	120 75	21 13	X	X		X	X	
NIKE APACHE	16.51 6.5	839 330	34 75	100.2 225		X	X	4	2	NIKE	7	120 75	21 13	X	X		X	X	
S S TOMAHAWK	22.86 9	562 221	27 60	118 260		X		4	1	–		80 50	27 17	X	X		X	X	
BLACK BRANT IIIB	25.9 10.2	550 217	50 110	90 198	(1 AXIS CONTROL)	X	X	3	1	–	7	120 75	**	X	X		X		
AEROBEE 150	38.1 15	966 380	68 150	227 500	X	X	X	3 or 4	2	VAM 17 VAM 20	2.2	80 50	16 10	X	X		X		X
AEROBEE 170	38.1 15	1160 457	113.5 250	227 500	X	X	X	4	2	NIKE	2.2	80 50	16 10	X	X		X		X
NIKE TOMAHAWK	22.86 9	930 366	27 60	118 260		X	*	4	2	NIKE	7	120 75	40 25		X		X	X	
BLACK BRANT VC	43.7 17.2	813 320	140 308	280 608	X	X	*	4	1	–	0.4	80 50	**	X	X		X		X
AEROBEE 350	55.9 22	1500 590	138 300	454 1000	X	X	X	4	1	NIKE	2.4	80 50	22.5 14	X	X				X
ASTROBEE F *	38.1 15	1119 440	91 200	454 1000	X	X	X	4	1	–	2.4	80 50	**	X	X		X		X
BLACK BRANT IV	25.9 10.2	1133 446	40 88	90 198		X		3	2	BLACK BRANT	0.4	400 250	194 120		X		X		
JAVELIN	48.3 19	1485 584.5	41 90	95.5 210		X		4	4	HONEST JOHN (1) NIKE (2) NIKE (3)	8.5	560 350	240 149		X			X	
ASTROBEE 1500	52 20.5	1016 404	45 100	136 300		X		4	2	JUNIOR +(2) RECRUITS	5	1600 1000	464 288		X				

Table II
CHARACTERISTICS OF SOUNDING ROCKET ATTITUDE CONTROL SYSTEMS

	CONTROL SYSTEM	COGNIZANT AGENCY (MANUFACTURER)	OPERATIONAL MODE	ROCKET AVAILABILITY	FINE GUIDANCE ERROR SENSOR (FGES)	APPROX. LENGTH & WEIGHT (Exclusive of FGES)	EXPECTED POINTING ACCURACY	LIMIT CYCLE NOISE AND FREQUENCY (Typical)	NOTES
1.	STRAP III	NASA-GSFC (Ball Bros. Res. Corp)	3 axis, gyro referenced, cold gas jet controlled, inertially programmed system with capability for fine pointing and stabilization in two axes by use of optical fine guidance error sensor. Can also be used for scanning missions. Has programmable multitarget capability (up to 10 targets)	1. Aerobee 150/170 2. Aerobee 350 3. STRYPI IV 4. Black Brant V	1. ITT FGES III (Startracker) 2. BBRC Celestial Error Sensor 3. GSFC Dual Reticle Startracker 4. GSFC Solar Sensor	1. Aerobee 150/170-10" long-63 lb. 2. Aerobee 350-13" long-115 lb. (including separation & gas supply)	±3 degrees on coarse gyros ±1 arc minute on FGES	±¼ degrees @ 1/10° sec. (coarse gyros) ±10 arc seconds @ 15 arc sec./sec. (FGES)	Honeywell GG-87 inertial grade rate integrating gyros can be substituted for FGES to obtain better stability or offset pointing capability. Limit cycle & accuracy depend primarily on signal-to-noise ratio obtained from FGES. System is separable from rocket on all but Aerobee 150/170 where residual rocket pressurization gas is used to point complete rocket and payload.
2.	MARK II	Space General	Same as System 1.	1. Aerobee 150/170 2. Veronique (French) 3. Skylark (British)	1. ITT FGES III (Startracker) 2. Solar Sensor (BBRC SS-100)	1. Aerobee 150/170 15" long-75 lbs. 2. Skylark 30" long-105 lbs.	Same as System 1.	Same as System 1.	Same as System 1.
3.	SPCS-1	Kitt Peak National OBS'Y-AURA (Ball Bros. Res. Corp)	3 axis separable, cold gas controlled pointing control using gyro reference to perform a roll-pitch maneuver to one stellar or planetary target. Control in pitch & yaw then switches to Startracker to effect fine two axis pointing.	1. Aerobee 150/170	1. BBRC Astral Tracking Unit	Aerobee 150/170-15 inch body extension plus pneumatics in nose cone – total wt. 100	Roll: ±10 degrees drift during flight Pitch Yaw: ±30 arc seconds	Pitch & yaw: ±15 arc seconds @ 30 arc seconds/sec. Roll: ±5 degrees @ 2 arc min. per second.	Separate parachute recovery system available for pneumatic section in nose cone. System requires experiment to initially face aft due to packaging of pneumatic in nose cone.
4.	SPARCS	NASA-AMES Res. Ctr. (Lockheed Missiles & Space Co.)	Despin & Coarse stabilization on sun achieved with error signals from coarse solar cells and a two axis magnetometer. Final stabilization and fine pointing in pitch & yaw is controlled by a fine solar sensor with roll remaining under magnetometer control.	1. Aerobee 150/170 2. Aerobee 350 3. Black Brant V	1. Lockheed Sun Sensor 2. Intermediate Sun Sensor (Exotech) 3. Solar Experiment Alignment Sensor (Exotech, Inc.)	Aerobee 150/170-6 inches long-35 lbs. Black Brant V-6 inches long 45 lbs.	Pitch-yaw: 15 arc seconds Roll: ±2 degrees	Pitch & yaw: ±½ arc sec. @ 10 arc sec/sec. Roll: 1/5 degree stability.	System is separable in all cases with integral cold gas supply. Has adjustable solar raster scan and roll angle adjustment capability. Also can offset point to different portions of the solar disk.
5.	SPCS-2	Ball-Bros. Res. Corp.	Despin and coarse stabilization on sun achieved with coarse solar cells & rate gyros. Final stabilization and pointing in pitch & yaw controlled by fine solar sensor. Roll axis rate controlled by rate gyro.	1. Aerobee 150/170 2. Nike Tomahawk	1. BBRC SS-100 Solar Sensor	Aerobee 150/170-7.5" body extension plus pneumatics in nose cone – 66 lbs. total.	Pitch & yaw: 15 arc seconds Roll: rate controlled to 3 arc min/sec.	Pitch & yaw: ±2.5 arc sec. @ 30 arc sec./sec. Roll: rate controlled to 3 arc min./sec.	Same as System 3
6.	SPT	Space Vector Corp.	Two axis (rocket continues to roll) gyro referenced system using one or two jets firing normal to the longitudinal axis of the rocket or payload in a programmed direction.	1. Nike Tomahawk 2. Nike Javelin 3. Black Brant V	Can be used with an Electro Optics Solar Sensor to correct gyro reference for solar pointing mission.	Nike Tomahawk-15 inches long 21 lbs.	Better than 3 degrees	Pitch & yaw: ±1 degree @ 1/3 cps. Roll: Spinning	
7.	MARK III	Space General	3 axis cold gas jet solar pointing system using one strapped down 2 axis free gyro for roll control and to establish the acquisition plane. Coarse solar cells and fine sun sensor complete the solar capture and stabilization sequence.	1. Aerobee 150/170	BBRC SS-100 Solar Sensor	Aerobee 150/170 6" long 52 lbs.	Pitch & yaw: ±1 arc minute Roll: ±3 degrees	Pitch & yaw: ±arc seconds @ 15 arc sec./sec. Roll: ±¼ deg @ 1/10°/sec.	Points entire rocket at sun using residual rocket pressurization gas. Has provision for offset pointing on solar disk and raster scan program. Uses much of System 2 hardware.

Table III

NASA SOUNDING ROCKET RECOVERY SYSTEMS

SYSTEM IDENTIFICATION	TYPE	RECOVERY BODY WEIGHT	RECOVERY SYSTEM WEIGHT	TYPICAL ATTITUDE CONTROL SYSTEM WEIGHT	NET AVAILABLE FOR EXPERIMENT HOUSING, TELEM-ETRY, ETC.	TYPICAL TELEMETRY SYSTEM WEIGHT	VEHICLE SEPARATION SYSTEM	FIRST STAGE DECELERATOR DEPLOYMENT SYSTEM	MAIN PARACHUTE DEPLOYMENT SYSTEM	PARACHUTE CHARACTERISTICS: 1ST STAGE TYPE	PARACHUTE CHARACTERISTICS: MAIN PARACHUTE TYPE	PARACHUTE CHARACTERISTICS: SEA LEVEL RATE OF DESCENT
CAPACHE	Two Stage Land	150 lbs	27 lbs.	--	123 lbs.	25 lbs.	Shaped Charge	Shaped Charge	Chemical Reefing Line Cutter	4.29 Ft Dia Flat Circular Ribbon	14.84 Ft Dia Flat Circular	27 Ft/Sec
AEROBEE 150/170	Two Stage Land	500 lbs.	55 lbs.	50 lbs.	395 lbs.	40 lbs.	Shaped Charge or Mechanical	Shaped Charge	Chemical Reefing Line Cutter	8.4 Ft Dia Conical Ribbon	24 Ft Dia Flat Circular	35 Ft/Sec
AEROBEE 150/170	Two Stage Water	300 lbs.	70 lbs.	50 lbs.	380 lbs.	40 lbs.	Shaped Charge or Mechanical	Shaped Charge	Chemical Reefing Line Cutter	8.4 Ft Dia Conical Ribbon	24 Ft Dia Flat Circular	35 Ft/Sec
AEROBEE 350	Two Stage Land	736 lbs.	105 lbs.	116 lbs.	515 lbs.	65 lbs.	Shaped Charge	Pyrotechnic Valve	Shaped Charge	Inflatable Balloon with Drag Skirt	35 Ft Dia Ex-tended Skirt	30 Ft/Sec
BLACK BRANT IIIB	Two Stage Land	280 lbs.	47 lbs.	53 lbs.	180 lbs.	40 lbs.	Manacle Ring	Drogue Gun	Chemical Reefing Line Cutter	6.0 Ft Dia Conical Ribbon	20 Ft Dia Flat Circular	33 Ft/Sec
BLACK BRANT VC	Two Stage Land	600 lbs.	77 lbs.	43 lbs.	480 lbs.	60 lbs.	Manacle Ring	Drogue Gun	Chemical Reefing Line Cutter	8.5 Ft Dia Conical Ribbon	28 Ft Dia Flat Circular	33 Ft/Sec

NOTES:
1. When no Attitude Control System is required the weight available for the experiment, housings and telemetry may be increased accordingly.
2. Two telemetry links are assumed for the Aerobee 350. All other vehicles assume one telemetry link.
3. Despin systems are part of the vehicle except for the Aerobee 350 where it is part of the Attitude Control System.

Table IV

Summary Comparison of the Three Types of Telemetry

Item	FM/FM	PPM	PPM
(1) Number of Channels	13 typical (can be up to 18)	16	16
(2) Total frequency response	10KC (Typical)	5, 10 & 20 KC	20KC
(3) System accuracy	2%	.35%	.2%
(4) Sampling technique	Continuous	Discrete	Discrete
(5) Input signal level(s)	0 - 5v or -2.5v to 2.5v	0 - 5v	0 - 5v
(6) Input impedance	1 Megohm	1 Megohm	1 Megohm
(7) Power*	35 watt	26 watt	36 watt
(8) Size*	37 in ^{2}	50 in ^{2}	50 in ^{2}
(9) Weight*	3.5 lb	4.0 lb	4.0 lb

*These parameters include the modulator, calibrator, and transmitter.

Table V

TELEMETRY SYSTEMS AND CHANNEL ALLOCATIONS FOR NASA 17.09 UG

T/M System 1; 20 KC PPM/FM (232.9 MHz carrier)

Channel		Allocation
1		Triple Pulse
2		Lithium Polarimeter
3		Lithium Polarimeter
4		Lithium Polarimeter
5		Lithium Polarimeter
6		Lithium Polarimeter
7		Lithium Polarimeter
8		Lithium Polarimeter
9		Lithium Polarimeter
10		Lithium Polarimeter
11		Lithium Polarimeter
12		Lithium Polarimeter
13		Lithium Polarimeter
*14	Chamber Pressure I (0-600psi)	Lithium Polarimeter
*15	Chamber Pressure II (0-600psi)	Lithium Polarimeter

* Channel switch at T + 60 seconds

Table V (con't)

T/M System 2, 20 KC PPM/FM (240.2 MHz Carrier) (Con't)

	Channel		Allocation	
	1		Triple Pulse	
	2		Lithium Polarimeter	(Analog)
	3		"	"
	4		"	"
	5		Bragg Polarimeter	"
	6		"	"
	7		"	"
	8		"	"
*	9	Chamber Pressure III (0-600psi)	4 Frame Sync	(Digital)
*	10	Chamber Pressure IV (0-60psi)	Lithium Polarimeter	"
*	11	Attack Angle - Pitch	"	"
*	12	Attack Angle - Yaw	"	"
*	13	Fuel Line Pressure	"	"
*	14	Injector Pressure	"	"
*	15	He Bottle (0-4000psi)	Bragg Polarimeter	"
*	16	He Regulator (0-600psi)	"	"

---

* Channel Switch occurs at T + 60 sec.

Table V (con't)

TM System #3; FM/FM (244.3 MHz Carrier)

IRIG Band	IRIG Freq. (KHz)	Frequency Response (Hz)	Allocation
3	0.73	11	Spare
4	0.93	14	Magnetometer
5	1.30	20	ACS Roll Position
6	1.70	25	ACS Pitch Gyro/Tracker Position
7	2.30	35	ACS Yaw Gyro/Tracker Position
8	3.00	45	ACS Roll Rate
9	3.90	60	ACS Pitch Rate
10	5.40	80	ACS Yaw Rate
11	7.35	110	ACS Roll Valves Monitor
12	10.50	160	ACS Pitch Valves Monitor
13	14.50	220	ACS Yaw Valves Monitor
14	22.00	330	Accelerometer 1 (± 5 g)
15	30.00	450	Accelerometer 2 (±20 g)
16	40.00	600	Commutator No. 1a
17	52.50	790	Commutator No. 1b
18	70.00	1050	Commutator No. 2a

Table V (con't)

T/M System #4; FM/FM (258.5 MHz Carrier)

IRIG Band	IRIG Freq. (KHz)	Frequency Response (Hz)	Allocation
11	7.35	110	PFJ 4
12	10.5	160	Position Gauge 4
13	14.5	220	Position Gauge 3
14	22.0	330	Position Gauge 2
15	30.0	450	Position Gauge 1
16	40.0	600	Thrust Accel. X-Axis
17	52.5	790	Thrust Accel. Y-Axis
18	70.0	1050	Thrust Accel. Z-Axis

Table V (con't)
Commutator, No. 1a, Segment Allocations Telemetry System 3,
Channel 16 (40.0 KHz), 2.5 RPS, Non-IRIG

Segment	Allocation
1	Calibration (Signal Ground)
2	Calibration (+2.5 VDC)
3	+ 5 VDC Reg. Monitor
4	+ 12 VDC Reg. Monitor
5	- 6 VDC Reg. Monitor
6	Temperature Monitor
7	Magnetometer Bias Monitor
8	Magnetometer
9	Temperature #4 (Exp. Housing Skin)
10	+ 28 VDC Reg. Monitor 1
11	+ 28 VDC Reg. Monitor 2
12	+ 28 VDC Reg. Monitor 3
13	+ 28 VDC Raw Monitor 1
14	+ 28 VDC Raw Monitor 2
15	Camera 1 Monitor
16	Camera 2 Monitor
17	Bragg Anti. No. 1 Monitor
18	Bragg Anti. No. 2 Monitor
19	HV Sig. Monitor
20	Lithium Anti. Monitor
21	A Program Monitor
22	B Program Monitor
23	HV Anti Monitor
24	Nose Tip Temperature Monitor
25	Star Tracker Temperature Monitor No. 1 (Trkr. Skin)
26	Star Tracker Temperature Monitor No. 2 (Trkr. Mount)
27	X-Late Maneuver Pressure Monitor
28	Temperature #5 (Exp. Housing Skin)
29	+ 5 VDC (Sync)
30	+ 5 VDC (Sync)

Table V (con't)
Commutator, No. 1b, Segment Allocations Telemetry System 3, Channel 17 (15.5 KHz), 2.5 RPS, Non-IRIG

Segment	Allocation
1	Calibration (Signal Ground)
2	Calibration (+ 2.5 VDC)
3	ACS Pitch RIG Temperature Monitor
4	ACS Yaw RIG Temperature Monitor
5	ACS Tank Temperature Monitor
6	ACS Tank Pressure Monitor
7	ACS Med. Pressure Monitor
8	ACS ±15 V Monitor
9	ACS ± 26 V Monitor
10	ACS Star Magnitude Monitor
11	ACS Tracker HV Monitor
12	ACS Despin Monitor
13	Temperature #6 (Instru. Skin)
14	ACS Mode Monitor
15	ACS Low Pressure Monitor
16	ACS Pitch Tracker (lo/hi) T/M
17	ACS Yaw Tracker (lo/hi) T/M
18	ACS Gimbal Error T/M
19	Aerobee Chute Man. Pressure
20	Aerobee A-Firing Monitor
21	Aerobee A-Arming Monitor
22	Aerobee B-Firing Monitor
23	Aerobee B-Arming Monitor
24	Temperature #7 (Instru. Skin)
25	Aerobee Chute Separation Monitor T/M
26	Aerobee Air Reservoir Pressure T/M
27	Aerobee Event Monitor A T/M
28	Aerobee Event Monitor B T/M
29	+ 5 VDC (Sync)
30	+ 5 VDC (Sync)

Table V (con't)

Commutator, No. 2a, Segment Allocations Telemetry System 3, Channel 18 (70.0 KHz), 2.5 RPS, Non-IRIG

Segment	Allocation
1	Calibration (Signal Ground)
2	Calibration (+ 2.5 VDC)
3	+ 28 V Experiment Buss No. 1 Monitor
4	+ 28 V Experiment Buss No. 2 Monitor
5	+ 28 V Instrumentation Buss Monitor
6	+ 28 V PPM Buss Monitor
7	+ 28 V Bragg Door Buss No. 1 Monitor
8	+ 28 V Bragg Door Buss No. 2 Monitor
9	+ 15 V Experiment Buss Monitor
10	+ 9.3 V Experiment Buss Monitor
11	Tip Eject Loop Monitor
12	Tracker Eject Loop Monitor
13	Tip Eject Squib Current Monitor
14	Tracker Eject Squib Current Monitor
15	Separation Loop Monitor #1
16	T/M Second Motion Fuel
17	Second Motion Oxidizer
18	Separation Loop Monitor #2
19	Injector Pressure
20	Injector Pressure
21	Bragg Door 1 Monitor Switches
22	Bragg Door 2 Monitor Switches
23	Bragg Door 3 Monitor Switches
24	Bragg Door 4 Monitor Switches
25	Bragg Door 1 Position Monitor
26	Bragg Door 2 Position Monitor
27	Bragg Door 3 Position Monitor
28	Bragg Door 4 Position Monitor
29	+ 5 VDC (Sync)
30	+ 5 VDC (Sync)

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Table VI
ROCKET EXPERIMENTS

Date	Vehicle	Experiment	Project Scientist	Remarks
8/6/69	Aerobee	Solar Radiation	Garrett	
9/21/69	Aerobee	Stellar UV	Patterson	UV stellar photograph, cosmic x-ray background observed.
10/13/69	Aerobee	Ion Composition	Young	Magnetoglow of He^{+} 304 Å discovered.
11/4/69	Aerobee	Solar Physics	Tousey	Obtained flare spectra in great detail.
11/8/69	Black Brant VB	Infrared Astronomy	McNutt	
1/24/70	Aerobee	Solar Infrared	Feldman	
2/28/70	Aerobee	Cosmic X-Ray Astronomy	Fritz	Obtained x-ray coverage of almost entire overhead sky; several x-ray sources and background measured. Discovered x -ray emission from Perseus A.
3/7/70	Aerobee	Solar Eclipse	Brueckner	Obtained XUV flash spectra.

Table VI (con't)

ROCKET EXPERIMENTS (con't)

Date	Vehicle	Experiment	Project Scientist	Remarks
3/7/70	Aerobee	Coronograph	Koomen	Good white-light photographs of the outer corona. Good XUV photograph and spectroheliograms of the solar disk and inner corona.
3/13/70	Aerobee	Stellar UV	Carruthers	Discovered H_2 between earth and ξ Persel.
5/25/70	Aerobee	X-Ray Scan	Byram	Recorded x-ray intensity which indicates infrared background glow close to 3°K.
8/13/70	Aerobee	Stellar UV Photometry	Carruthers	First use of far UV electronographic recording of star-field photography.
10/21/70	Super Chief	(Diagnostic Test)	Arritt	Performance good.
	Blue Scout Jr.	Galactic UV	Carruthers	

Table VI (con't)
ROCKET EXPERIMENTS (con't)

Vehicle	Experiment	Project Scientist
Black Brant VB	Infrared Astronomy	McNutt
Aerobee	Slow Scan Centaurus A	Byram
Aerobee	X-Ray Sky Map	Fritz
Aerobee	UV Spectrograph	Carruthers
Aerobee	Coronagraph & UV Instrumentation	Koomen
Super-Chief	X-Ray Astronomy	Chubb/Byram
Aerobee	Solar X-Ray Bragg Spectrometer	Kreplin
Aerobee	Ion Composition	Young
Aerobee	Lyman- α Profile	Garrett
Aerobee	Far UV Imaging of M31	Carruthers

Table VII

LAUNCH SITES

Site	Coordinates
Argentina	
Chamical	(30.5°S, 66°W)
Australia	
Woomera	(31°S, 137°E)
Brazil	
Natal	(5°S, 35°W)
Canada	
Fort Churchill	(58.8°N, 94.3°W)
France	-
French Guiana	(5°N, 53°W)
India	
Thumba	(8.5 N, 77 E)
White Sands, N. M.	(32.5°N, 106.5°W)
Cape Kennedy, Fla.	(28.2°N, 80.6°W)
Wallops Island, Va.	(37.8°N, 75.5°W)
Eglin AFB, Fla.	(30.4°N, 86.7°W)
Point Mugu, Calif.	(34.1°N, 119.1°W)
Hawaii, Kauai	(21.9°N, 156.6°W)

Site	Coordinates
Italy	
Sardinia	(39.6°N, 9.5°E)
Norway	
Andoya	(69.3°N, 16°E)
Netherlands	
Dutch Guiana, Surinam	(5°N,55°W)
Pakistan	
Sonmiani	(26°N, 67°E)
Sweden	
Sweden	
Kronogard	(66°N, 18°E)
Kiruna	(68°N, 21°E)
United States	
Kwajalein, Marshall Islands	(08.8°N, 167.7°E)
Tonopah, Nevada	(38.0°N, 116°30'W)
McMurdo Sound, Antarctica	(77.9°S, 116.6°E)
Pt. Barrow, Alaska	(71.3°N, 156.8°W)
Keweenaw Peninsula, Mich.	(37.5°N, 87.7°W)