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NASA SOUNDING ROCKETS, 1958–1968

A Historical Summary

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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William R. Corliss

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FOREWORD

To explore the upper atmosphere man first used kites, then balloons, then aircraft. For many years balloons were the most effective means of obtaining direct measurements in the stratosphere. But they were limited in altitude, so scientists had to probe the ionosphere and other portions of the atmosphere beyond the stratosphere by indirect means.

Sounding rockets provided the first means to carry instruments to the outermost reaches of the Earth's atmosphere. They were, indeed, our first space vehicles. As Mr. Corliss relates in this history, in this day of satellites and deep space probes, sounding rockets remain as important to space science as ever, furnishing our most powerful means for obtaining vertical profiles of atmospheric properties. NASA continues to depend on sounding rockets for research in aeronomy, meteorology, ionospheric physics, exploratory astronomy, and other disciplines.

Those of us who were privileged to take part in the early upper atmosphere rocket program, who recall with considerable nostalgia watching V-2s, Vikings, and Wac Corporals carry our instruments into the sky, are pleased to see some of the record of those pioneering days preserved. Out of that early work has come the more flexible, more capable sounding rockets of today, and a facility in their use that permits a broad involvement of university, Government, and other researchers. As Mr. Corliss suggests, this most valuable feature is a major reason why sounding rocket research continues to flourish.

HOMER E. NEWELL
Associate Administrator

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PREFACE

This monograph represents a first attempt at sketching the evolution and history of NASA sounding rockets. If it seems to be a Goddard Space Flight Center story, that is because NASA's sounding rocket program has been directed from that Center. The study is complicated by the great abundance of different vehicles, different governmental and private organizations, and by the many hundreds of NASA launchings since 1958. The author will be very happy to hear of any errors, omissions, or misconceptions. Original measurements were in the English system.

The author wishes to acknowledge the help of the following people in preparing this short history of sounding rockets: Alfred Rosenthal, Goddard Historian and monitor of this project, and Karl R. Medrow, Eleanor C. Pressly, George E. MacVeigh, Jon Busse, and Norman Peterson, all of the Goddard Sounding Rocket Branch. In addition, William R. Witt, of the Goddard International Programs Office, and Lloyd E. Jones, Jr., Headquarters Office of International Affairs, have helped relate NASA's extensive cooperative programs. At the Goddard Library, C. DeMoss and staff helped materially in researching this monograph. Joseph Robbins, Wallops Station Historical Monitor, and E. C. Draley, at Langley Research Center, provided information about the early NACA work at Wallops. R. Cargill Hall, Jet Propulsion Laboratory Historian, submitted valuable information on the early days at Guggenheim Aeronautical Laboratory, California Institute of Technology. John R. Holtz, at NASA Headquarters, contributed considerable information on sounding rocket development trends and overall NASA philosophy. In addition to the above individuals, Joseph A. Shortal, Eugene M. Emme, Frank W. Anderson, Jr., John E. Naugle, Leonard Jaffe, and J. Allen Crocker also reviewed the Comment Edition.

WILLIAM R. CORLISS

Glenarm, Md.
May 1, 1971

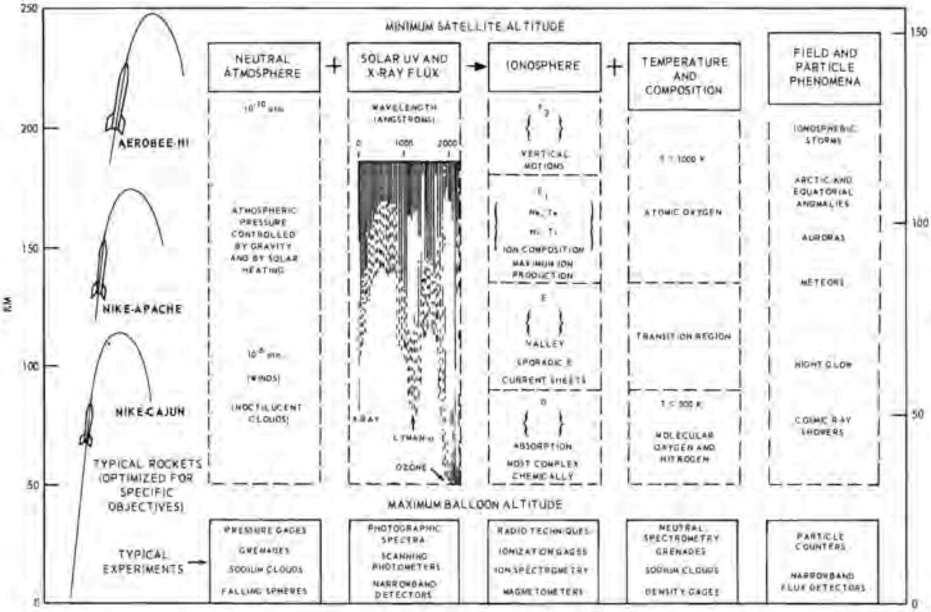
I

IMPORTANCE OF SOUNDING ROCKETS IN SPACE SCIENCE

When the first Sputnik began beeping back scientific data from outer space in 1957, it seemed that the 12-year reign of the sounding rocket as the chief space research vehicle was over. Scientific satellites can stay above the atmosphere for months, even years. A satellite gives the Earth-confined experimenter data from its orbital track all the way around the world. The sounding rocket can offer the experimenter only a few minutes at high altitudes above the launch site.

Certainly satellites are superior in terms of staying power and geographical coverage—if that is what the experimenter wants. Often this is not what he wants; often he wishes to make measurements in regions of the atmosphere that are too thick and dense for satellites to orbit and yet too high for balloons to reach. Sometimes he does not wish to wait two or three years for the design, development, and launch of a scientific satellite. All three research vehicles—sounding rocket, balloon, and satellite—have their own roles to play and regimes to explore in space research. Far from being the "Model T's" of the Space Age, as they were once called, sounding rockets are more popular than ever with the scientists who use them.

The sounding rocket offers a scientist a vehicle that will carry his instruments (a few kilograms to a few hundred kilograms worth) to almost any altitude he desires between a few kilometers and a few thousand kilometers. Besides affording the opportunity of making measurements on the way up and back down through the atmosphere (a "vertical profile"), the sounding rocket can provide several minutes of observation time above the Earth's atmosphere, that layer of gas that insulates scientific instruments from much of the radiation, plasma, and micrometeoroid flux pervading outer space. Thus many sounding rockets are true spacecraft, albeit ephemeral ones. Just a few minutes above the atmosphere has been sufficient to make many fundamental discoveries about the nature of the Sun, the stars, and our celestial environment. And, of course, rockets remain our best



Some basic space research problems requiring the use of sounding rockets. Only sounding rockets can explore successfully the region between maximum balloon and minimum satellite altitudes.

vehicles of all for exploring that region of the atmosphere above balloon altitudes (about 40 km, or 25 mi) and below satellite orbits (about 160 km, or 100 mi).

The payload and altitude capabilities are not the only features that attract experimenters to sounding rockets.

Some Advantages of Sounding Rockets

- *Simplicity:* Sounding rockets are usually much simpler than satellites, with far fewer interfaces to match. Launch facilities are also less elaborate.
- *Informality:* Most sounding rocket payloads consist of one experiment or one group of closely related experiments. The payload is the "property" of only one experimenter; and there need be no formal, time-consuming reviews to ensure compatibility with other experimenters.
- *Low cost:* Small sounding rockets can be bought for less than \$10 000; the biggest for \$150 000 to \$200 000. Satellites, in contrast, are multimillion-dollar vehicles. Sounding rockets are cheap enough to try new ideas on. Indeed, many experiments

destined for satellites get their first rides on sounding rockets. By virtue of their low cost, hundreds of sounding rockets are launched worldwide each year for research purposes plus many more for weather studies.

- *Recoverability:* Payloads, such as film packs and even small animals, can often be recovered for study or reflight.
- *Geographic flexibility:* Sounding rockets can be launched almost anywhere, making them ideal for studying eclipses, solar flares, polar-cap absorption events, the equatorial electrojet, and other localized phenomena.
- *Temporal flexibility:* Experiments and rockets can be prepared in just a few weeks to take advantage of scientific targets of opportunity. Or they can be kept in readiness for firing during solar flares and, as has been done on occasion, during the passage of a scientific satellite to obtain vertical-profile and orbital data at the same time.

Some Disadvantages of Sounding Rockets

- *Restricted time of observation:* Sounding rockets are essentially "quick-look" vehicles.
- *Localized coverage:* Unlike satellites, sounding rockets do not see the geographical "big picture."
- *Payload limitations:* Some experiments, such as large telescopes, are just too big for sounding rockets.
- *Lack of glamour:* This used to be a factor right after Sputnik, but the advantages of sounding rocket research have overcome this subjective problem.

That the advantages of sounding rocket research greatly outweigh the disadvantages is obvious from the fact that NASA alone launches over 150 each year—launches by other U.S. agencies double this figure—with no slackening in demand as bigger satellites have become available.

Although sounding rockets perform much rather routine work of a synoptic nature in the upper atmosphere, they are also often first into space with new research tools. In this sense they are in the vanguard of space research and have marked up many "firsts." The discovery of cosmic X-ray sources by Herbert Friedman[1] and his group at the Naval Research Laboratory (NRL) is typical. Rockets were also the first to measure the

[1] H. Friedman, E. T. Byram, and T. A. Chubb, "Distribution and Variability of Cosmic X-Ray Sources," *Science*, CLVI (Apr. 21, 1967), 374.

details of the extreme ultraviolet and X-ray spectrum of the Sun.[2] The dust layers in the upper atmosphere were also first sampled by sounding rockets.[3] These are just a few solid scientific accomplishments of the "lowly" and unglamorous sounding rocket; more will be introduced as the history of these remarkably versatile vehicles unfolds.

[2]Homer E. Newell, Jr., "Rocket-Sonde," paper presented at the AIAA Sounding Rocket Vehicle Technology Specialist Conference, Williamsburg, Va., NASA N67-23480 (Feb. 28, 1967), p. 9.

[3]M. Dubin, "IGY Micrometeorite Measurements," in H. Kallmann-Bijl, ed., *Space Research* (New York, 1960), pp. 1042-1058.

II

DEVELOPMENT OF SCIENTIFIC ROCKETS PRIOR TO THE V-2

All rocket histories are replete with the well-worn stories of the Chinese rockets of the 13th century, Sir William Congreve's war rockets of the early 1800s, and the whole plethora of more recent weaponry. While most rocket development aimed at attaching bombs or other lethal apparatus to the rocket, a few scientists swam against the current and dreamed of sending instruments into the high regions of the atmosphere.

The scientific urge to explore the atmosphere was a strong one. Torricelli carried his barometer up a mountain in the 1640s; in 1749 kites carrying thermometers were flown in Glasgow; by 1893 huge box kites had taken instruments over 3000 m (10 000 ft). Balloons were not neglected by science, either. Unmanned, instrument-carrying balloons had reached 16 150 m (53 000 ft) by 1893. Balloons, in fact, were essential in unraveling the mystery of cosmic radiation during the first decades of this century. It was only logical to convert rocket warheads into instrument capsules, too.

Claude Ruggieri, apparently an Italian living in Paris, rocketed small animals into space as early as 1806. The payloads were recovered by parachute. By 1830, Ruggieri's rockets were able to lift a full-grown ram.[4] Little else remotely resembling science was done with rockets until 1906, when Alfred Maul, a German engineer, employed rockets to take cameras to high altitudes. Maul's 1912-model rocket carried a photographic plate 203.2 by 254.0 mm (8 by 10 in.) in size and was stabilized by a gyroscope. All in all, these were a rather precocious run of experiments.

In his classic 1919 paper, *A Method of Reaching Extreme Altitudes,* Robert H. Goddard suggested that rockets might well be used for upper atmosphere research.[5] It was not until July 17, 1929, however, that

[4]Willy Ley relates that Ruggieri was preparing to launch a human volunteer into space when the police stopped him. *Rockets, Missiles and Space Travel,* rev. ed. (New York, 1958), p. 85.

[5]Goddard repeated his suggestion in 1920 in "The Possibilities of the Rocket in Weather Forecasting," *Proceedings of the National Academy of Sciences,* VI (1920), 493.

Dr. Robert H. Goddard (second from right) and his colleagues holding a liquid-propellant rocket in 1932 at their New Mexico workshop.

Goddard placed scientific instruments on his rockets. On this flight—the last test at Auburn, Mass., before officials forced Goddard and his noisy contraptions to New Mexico—an aneroid barometer and a thermometer were attached to the rocket to measure ambient conditions. A camera focused on both instruments was tripped when the rocket parachute was released. Although the scientific content of this experiment was not high and certainly not the main purpose of the flight, this was the first instrumented rocket. Unfortunately, it attained an altitude of only 52.1 m (171 ft).[6]

Goddard's work began to attract attention, notably that of Charles A. Lindbergh, who recommended that the Guggenheims help finance Goddard's venture. The real military potential of the rocket was foreseen in such prophetic articles as R. MacMechen's "Rockets, the New Monsters of Doom," in 1931.[7] But the great scientific utility of this remarkable vehicle was not neglected either; also in 1931, W. J. Humphreys published his article "Mining the Sky for Scientific Knowledge."[8] Both MacMechen and Humphreys harangued a deaf audience. Except for Goddard, a few amateurs, the German army, and the Russians, rockets were mere toys.

[6]Esther C. Goddard and G. Edward Pendray, eds., *Robert H. Goddard, Rocket Development, Liquid-Fuel Rocket Research, 1929-1942* (Englewood Cliffs, 1961), p. xxv.

[7]R. MacMechen, *Liberty,* VIII (Sept. 19, 1931), 16.

[8]W. J. Humphreys, *Scientific American,* CXLIV (Jan. 1931), 22.

One notable exception was John A. Fleming, Head of the Carnegie Institution's Department of Terrestrial Magnetism. On January 27, 1932, Fleming testified before the House Foreign Affairs Committee that thought was being given to using Goddard's rockets for research during the Second Polar Year beginning August 1, 1932.[9] Unfortunately, the depression killed such marginal proposals and, for many scientists, the whole Polar Year program.

If the instruments on Goddard's July 17, 1929, flight are classified merely as engineering devices, the honor of launching the first true sounding rockets belongs to Russia. In 1933, a Russian named Tikhonoravov apparently launched an instrumented, liquid-fueled sounding rocket.[10] In 1935, another Russian rocket designed by F. A. Tsander reached an altitude of 11 km (8 mi) carrying instruments for upper atmosphere research.[11]

As the world moved toward World War II in the early and middle 1930s, two developments occurred that profoundly affected the history of sounding rockets. First, the German military rocket program began in 1930 under the Bureau of Ordnance. Second, rocket work at the Guggenheim Aeronautical Laboratory, California Institute of Technology (GALCIT), was begun in 1936.

The German work, of course, is important because it culminated in the V-2 (discussed in the next chapter). Actually, work leading to the V-2 was begun long before Hitler came to power. Called the A-4 (for *Aggregate 4*) by the engineers, the V-2 was only one of a long series of rockets developed during the years between 1930 and 1944 by the German army. It is interesting to note in passing that Walter R. Dornberger, one of the key German rocket men, refers to the A-2 as a "sounding rocket."[12] The A-2 was first launched just before Christmas in 1934 from the island of Birkum in the North Sea. With a motor of 299.4-kg (660-lb) thrust, the A-2 reached an altitude of about 980 m (6500 ft). No information about its scientific instrumentation–if any–is known. Later, the A-4s (V-2s) occasionally carried instruments on test flights, but these were aimed at measuring the performance and environment of the rocket.

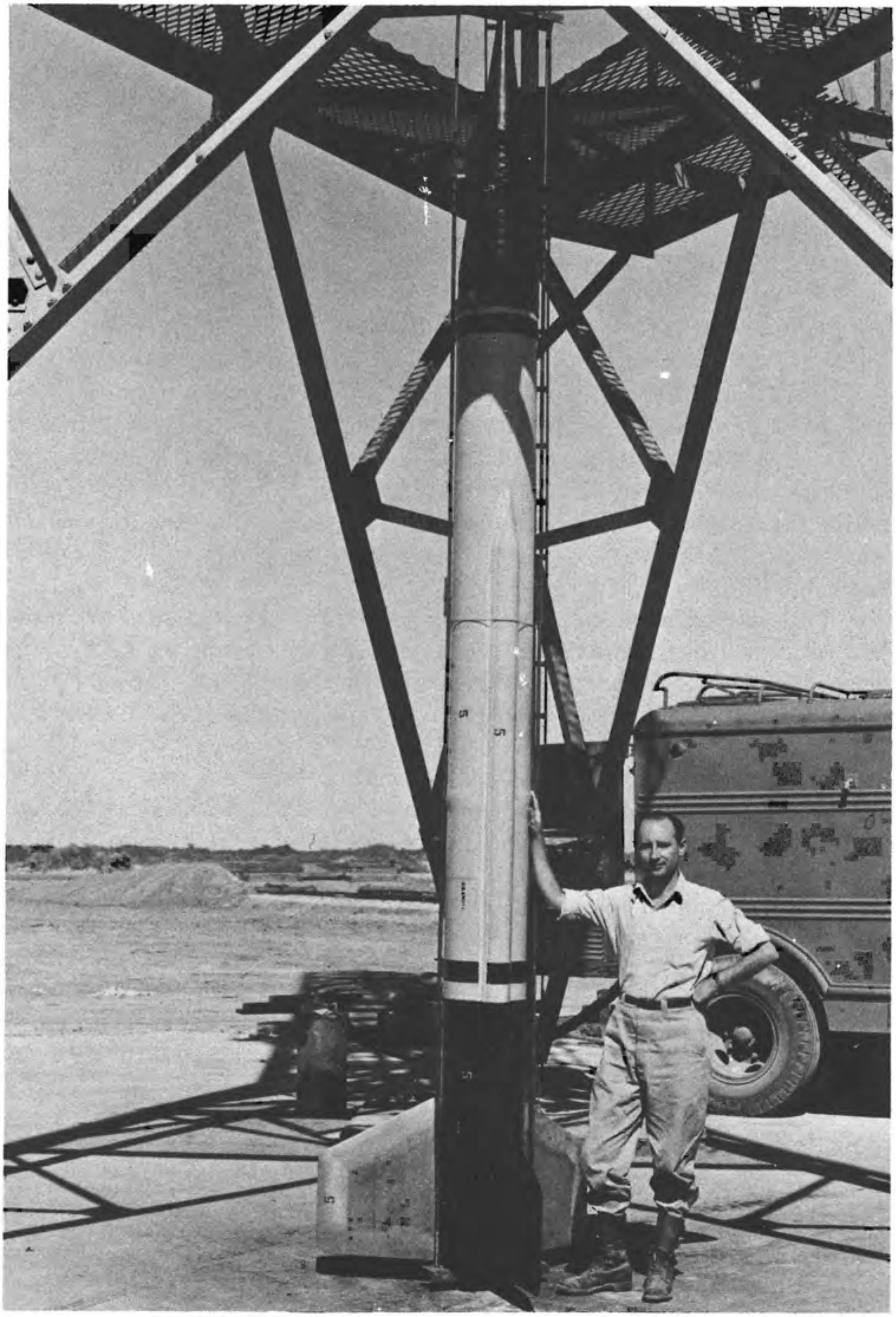
GALCIT was created in 1926, but it specialized at first in aeronautics under the leadership of Theodore von Kármán. A decade later GALCIT was

[9]Walter Sullivan, *Assault on the Unknown* (New York, 1960), p. 16.

[10]Frederick I. Ordway, III, and Ronald C. Wakeford, *International Missile and Spacecraft Guide* (New York, 1960), p. 4.

[11]*Ibid.*, p. 4. Just what instruments were carried and what results were obtained were never revealed in publications reaching the West.

[12]Walter R. Dornberger, "The German V-2," *Technology and Culture*, IV (Fall 1963), 397.



Frank J. Malina (a former JPL Director) and the Wac Corporal at White Sands, circa 1946. The solid-propellant booster is not shown.

stimulated to look at rockets by Frank Malina. On February 14, 1936, for example, Malina noted:

> If we could develop a rocket to go up and come down safely we would be able to get much data useful to the weather men and also for cosmic ray study.[13]

Malina and others carried out rocket research that ultimately led to the well-known Jet-Assisted Take Off (JATO) units used during World War II. More important to our story, though, Army Ordnance also asked GALCIT to develop missiles for field use in January 1944.[14] The Private, Corporal, and Sergeant missiles evolved from this work. It was a scaled-down version of the Corporal missile, called the Wac Corporal, that became this country's first rocket designed specifically for sounding the upper atmosphere. The Wac Corporal work commenced in December 1944, when the Army Signal Corps notified Army Ordnance that it needed a high-altitude sounding rocket "to carry 25 pounds [11.3 kg] of meteorological instruments to 100 000 ft [30 480 m] or more."[15] The Wac Corporal (named that because it was a "small" Corporal) led directly to the famous Aerobee sounding rocket. In Chapter IV, following the V-2 story, the JPL developments leading to the Aerobees are discussed further.

While the Army's GALCIT worked on solid-propellant JATO units, a parallel series of developments was taking place across country. Reaction Motors, Inc., a company founded by experimenters from the American Rocket Society, began designing and developing liquid-propellant JATO units for the Navy. The Navy work was to lead to the Viking sounding rocket and its descendants. The Navy Viking program actually began before the end of World War II. So even as Germany was building and firing V-2s, two different foundations for future sounding rocket technology were being built in this country.

[13] R. Cargill Hall, *A Selective Chronology, GALCIT-JPL Developments, 1926-1950*, JPL Report (Sept. 8, 1967), p. 4. See also E. M. Emme, *The History of Rocket Technology* (Detroit, 1964).

[14] The stimulating document in this instance was the Nov. 20, 1943, memo by von Kármán entitled "Memorandum on the Possibility of Long-Range Rocket Projectiles." Project ORDCIT commenced in January 1944 as a result of a letter to von Kármán from Major General G. M. Barnes, Office of Chief of Ordnance, U.S. Army.

[15] *Ibid.*, 27.

III

THE V-2 AT WHITE SANDS

The V-2 is most famous for the havoc it wrought in England during the closing phases of World War II. This missile, standing some 14 m (46 ft) high and capable of carrying 907 kg (1 ton) of explosives almost 322 km (200 mi), also was to have an impressive scientific history. It is the purpose of this chapter to describe the importance of the V-2 to sounding rocket technology—the peacetime V-2—rather than recount once more the days at Peenemuende.[16]

In retrospect, the V-2 had three important effects on the history of American sounding rockets.

1. Knowledge that the Germans were working on large rockets during the war stimulated the formation of the ORDCIT project, which ultimately led to the Wac Corporal.
2. German V-2 technology (in terms of captured hardware and engineers) was later applied directly to such American sounding rockets as the Viking.
3. The capture of V-2 rocket components and their subsequent assembly into operable rockets gave American scientists an early opportunity to develop rocket research techniques as well as make some fundamental scientific discoveries at high altitudes.

In short, the V-2 was a windfall and a great stimulus for both American and Russian science and rocket technology.

The Germans themselves did not overlook the scientific potential of the V-2, but pure science was naturally of low priority as the Third Reich faltered. According to Rosen,[17] plans did exist for a program of scientific firings of the V-2 from an island near Peenemuende. Instruments for these

[16] Two important works dealing with the early days of the V-2 are: Ley, *Rockets, Missiles and Space Travel;* and Walter Dornberger, *V-2* (New York, 1954).

[17] Milton W. Rosen, *The Viking Rocket Story* (New York, 1955), p. 19.

flights had been designed by Professor Regener. The plans were never carried out, although the high-altitude capabilities of the V-2 were demonstrated when a Peenemuende test shot reached 172.2 km (107 mi).

As the war drew to a close, both the Americans and Russians were anxious to lay their hands on V-2 hardware and engineers. In the end, the Americans had captured most of the development engineers, while the Russians whisked away a large contingent of production personnel into Russia. More pertinent to a sounding rocket history, though, is the fact that the American Army was first to capture the underground V-2 factory near Niedersachswerfen. It had already been decided that this part of Germany would be occupied by the Russians; but, by the time the military formalities necessary for the transfer had been arranged, the Americans had packed up and removed 300 boxcars full of V-2 parts and equipment. Eventually most of these parts were assembled into complete rockets and fired from White Sands.

One of the American scientists who went to Europe to interrogate German scientists was Ernst H. Krause, of the Naval Research Laboratory. Krause returned greatly impressed with German missilery but unaware of the captured V-2s. When Milton Rosen, one of his NRL staff, proposed building an American research rocket, Krause was most sympathetic. Consequently, on December 17, 1945, the NRL Rocket-Sonde Research Branch was constituted officially. Research groups to study cosmic rays, the atmosphere, the ionosphere, and spectroscopy were created. And, of course, plans were started to develop a new sounding rocket to carry the scientific instruments.

Scientists and engineers in the NRL Rocket-Sonde Research Branch had scarcely begun their work when, on January 7, 1946, they learned from Lt. Col. J. G. Bain, Army Ordnance Department, of the capture of enough parts to build perhaps 100 V-2s. Plans for a new Navy sounding rocket were set aside in favor of exploiting the unexpected acquisition of V-2s described by Col. Bain. The Army had already drawn up plans for firing the V-2s from White Sands to gain military experience but had not implemented a scientific research program. Col. Bain was delighted to find that NRL had already organized a group to these ends. NRL, which had the scientific knowhow but no rockets, was equally pleased and quickly accepted Col. Bain's invitation to join the V-2 project.[18]

Nine days after Col. Bain's NRL visit, about 50 interested scientists and engineers from more than a dozen organizations met at NRL to plan the exploitation of the V-2s. On that date, January 16, 1946, a "V-2 Upper

[18]M. A. Garstens, H. E. Newell, Jr., and J. W. Siry, *Upper Atmosphere Research Report No. 1*, NRL-2955 (Oct. 1, 1946), pp. 1-3.

Atmosphere Research Panel" was created.[19] This panel, with various name changes to reflect the exhaustion of the supply of captured V-2s and the advent of satellites, helped guide sounding rocket research for almost a decade.

Most of the V-2 instrumentation built between 1946 and 1952 came from NRL, the Applied Physics Laboratory, the Army Signal Corps, and the U.S. Air Force. The Army Ordnance Department, which had overall responsibility for the V-2 program, assigned the job of assembling the V-2s and their payloads to General Electric. Actually the General Electric V-2 work was done under the auspices of the Hermes program, a more general missile research and development effort initiated with GE on November 15, 1944. The major scene of action was, of course, the Army's White Sands Proving Ground, which with foresight the Army had established on July 9, 1945.

As Army and GE engineers sorted out the captured German parts, they discovered to their consternation that at best only two complete V-2s could be assembled from the original components. Gyros were in especially short supply and 140 more had to be built by American industry. So it went, down the list of components; despite the 300 boxcars of parts, many repairs were required and industry had to turn to and manufacture a great variety of missing pieces. For example, entirely new scientific "warheads" had to be made because the captured military versions were too heavy and (obviously) had no access doors that would allow experimenters to get at their instruments. The Naval Gun Factory was chosen to fabricate new payload structures.

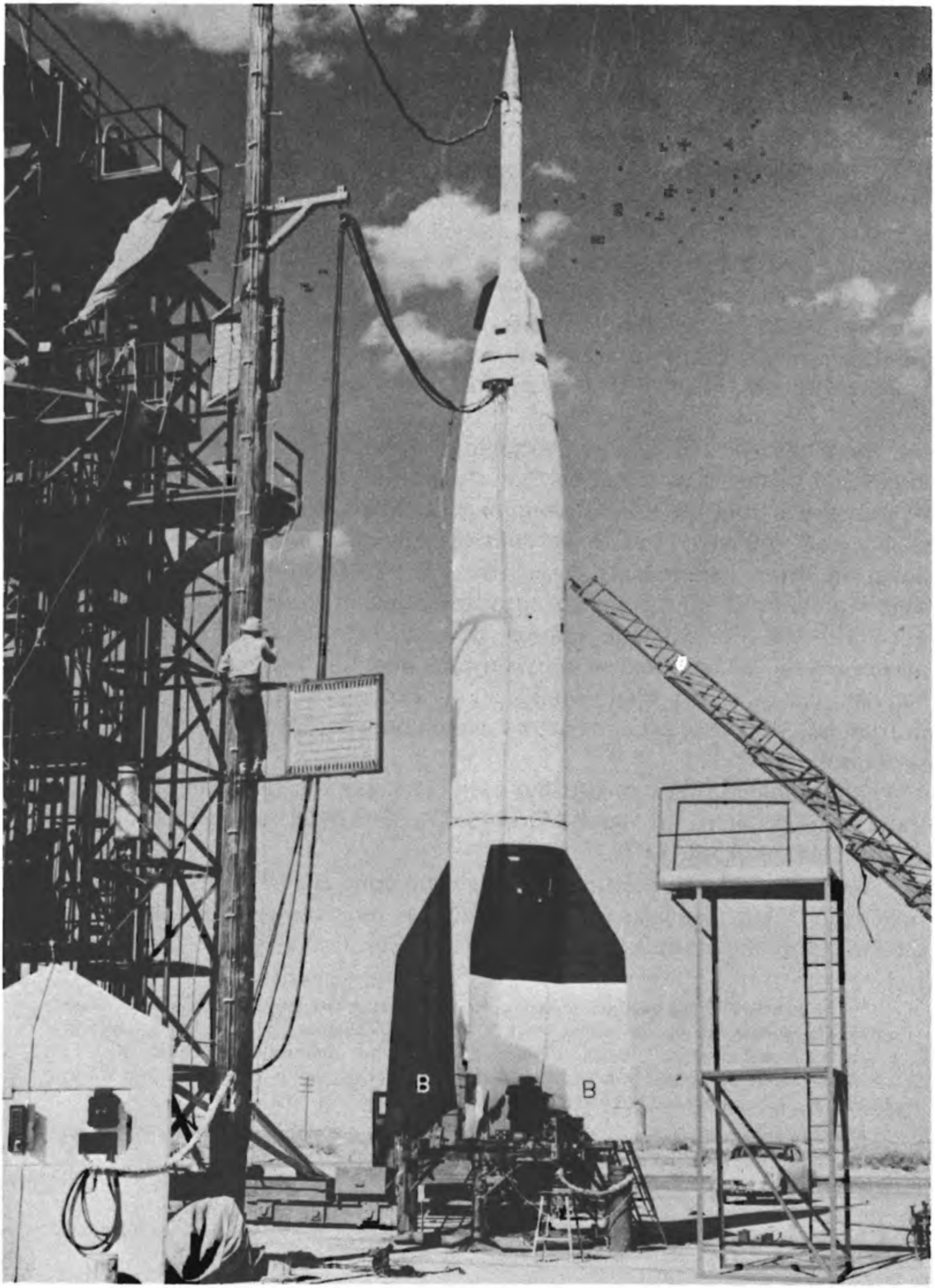
All problems were eventually overcome and the first American V-2 static firing occurred on March 15, 1946. The first flight came a month later at 2:47 P.M. on April 16.[20]

From April 16 to the final V-2 flight on June 28, 1951, 67 V-2s were fired from White Sands as part of the Hermes program. Among these were six Project Bumper shots, employing a Wac Corporal atop a V-2.[21] Seven

[19]The membership was confined to people actually working with the V-2s. Membership varied with time. On October 1, 1946, the members were E. H. Krause (Chairman), NRL; G. K. Megerian and C. F. Green, General Electric; J. Brinster, Princeton; W. G. Dow, University of Michigan; M. J. E. Golay, Army Signal Corps; M. D. O'Day, Watson Laboratories; N. Smith, NBS; J. A. Van Allen, Applied Physics Laboratory; and F. L. Whipple, Harvard.

[20]A list of White Sands firings can be found in Ley, *Rockets, Missiles and Space Travel,* p. 458. Additional details can be found in General Electric Report R52A0510, *Final Report, Project Hermes, V-2 Missile Program* (Sept. 1952).

[21]Two other Bumper shots took place at the Long Range Proving Ground (predecessor of Cape Kennedy) in Florida. Additional V-2 military flights were made at various sites, including a shipboard launch (Project Sandy).



A Bumper-Wac on the launch pad at White Sands in the late 1940s. The first stage was a V-2; the second, a Wac Corporal.

others were associated with Project Blossom, an upper-air research project that involved the parachute recovery of canisters carrying fruit flies and seeds exposed to cosmic rays during flight. Bumper and Blossom were also part of the Hermes program. The most spectacular Bumper flight occurred on February 24, 1949, when the second-stage Wac Corporal reached the record altitude of about 400 km (250 mi).

Almost half the V-2s launched from White Sands were officially classified as failures. Even though most rockets left the launch pad, many did not go far; some exploded; still others behaved so erratically that the scientific experiments were compromised. In fact, as the V-2 firing program drew to a close, it was generally felt among scientists that the rocket was too unreliable to warrant risking months of work in preparing an experiment. Nevertheless, the V-2s took the first solar ultraviolet spectrograms above the Earth's ozone layer. They captured spectacular photographs of Earth from high altitudes; they brought back air samples and cosmic-ray measurements. Although valuable atmospheric data were obtained, it is more honest to regard the series of flights as scientific test vehicles upon which new instrument and telemetering techniques were perfected. Experimenters learned how to build compact, rugged, reliable equipment, while rocket engineers found how to give the instruments a smooth, clean ride. Advances were also made in instrument pointing and recovery. This was technology rather than science, it is true, but experience with the V-2s provided just what American scientists and engineers needed to build sounding rockets tailored specifically to space research.

IV

DEVELOPMENT OF THE FIRST SOUNDING ROCKETS

THE WAC CORPORAL

The V-2 was a remarkable weapon–it was a decade ahead of Allied rocket technology. It was also the "workhorse" of the early American rocket research program. But in the late 1940s, as the captured German components began to deteriorate and the V-2s in consequence became less reliable, scientists turned their interest toward the Aerobee, the Viking, and several other small rockets that had been developed especially for high-altitude sounding.

The first true sounding rocket–built for no other purpose than upper air research–was the GALCIT-JPL Wac Corporal, mentioned earlier in Chapter II. Begun as a meteorological rocket to meet Army Signal Corps requirements, the Wac Corporal was about 5 m (16 ft) long, had an Aerojet liquid-propellant motor, weighed about 320 kg (700 lb) at launch, and could carry about 11 kg (25 lb) of payload to 64 km (40 mi). This performance could hardly match the 900-kg (1-ton) V-2 payloads, but the Wac Corporal was cheap to make and easy to use.

Wac Corporal studies commenced in December 1944 at the ORDCIT project.[22] Rather than test the results of their studies out on a full-scale Wac Corporal, JPL engineers first built a one-fifth-scale model called the Baby Wac. Live tests of the Baby Wac were carried out at the GALCIT Goldstone Range, July 3 to 5, 1945. The choices of three fins and the rocket "booster" were confirmed.[23]

[22]F. J. Malina and H. J. Stewart, "Considerations of the Feasibility of Developing a 100,000 ft. Altitude Rocket (The 'Wac Corporal')," *JPL Memorandum 4-4* (Jan. 16, 1945).

[23]Many liquid-propellant sounding rockets, such as the Aerobee, employ solid-propellant boosters that propel the rocket clear of the launch tower. "Research and Development at the Jet Propulsion Laboratory, GALCIT," *Journal of the British Interplanetary Society*, VI (Sept. 1946), 52.

The first Wac Corporal was launched from White Sands on September 26, 1945, well before the first V-2s were fired in the United States. Thus, the Wac Corporal is often designated as the first true sounding rocket, despite the fact that other rockets had previously carried scientific instruments and despite the fact that it was the direct progeny of the military Corporal missile. Radar tracking showed that the first Wac Corporal reached an altitude of 70 km (43.5 mi), about twice the distance originally planned. This increase was ascribed to design improvements and the substitution of the more powerful Tiny Tim solid-propellant booster for that originally selected.

Although the Wac Corporal payloads were rather small, the rocket could be produced quickly and in quantity. There is no doubt that it would have been used extensively in the middle and late 1940s had not the windfall V-2s become available. As it turned out, the major contribution of the Wac Corporal to sounding rocket technology was its role in the evolution of the famous Aerobee series.

THE AEROBEES

From an agency standpoint, the Aerobee is a hybrid resulting from Navy development funds and Army technology (the Wac Corporal). In 1946, the scientific drawbacks of the V-2 were generally well known, as was the fact that the extant Wac Corporal was too small for much of the anticipated space research. The Aerobee program had its genesis when Merle A. Tuve and Henry H. Porter, of the Applied Physics Laboratory (APL) of the Johns Hopkins University, suggested to James A. Van Allen that he survey the rockets available for scientific research within the United States.[24] An important event during Van Allen's survey was the visit to APL by Rolf Sabersky of Aerojet Engineering Corp., the manufacturers (along with Douglas Aircraft Co.) of the Wac Corporal, in early January 1946.

Van Allen's conclusions were submitted to Tuve (then Director of APL) on January 15 in a memo entitled "Liquid Powered Sounding Rockets for High Atmospheric Studies." Essentially, Van Allen's conclusions were that no fully satisfactory sounding rockets existed and that APL should act as an agent for the Navy Bureau of Ordnance in the development and procurement of new scientific sounding rockets. Also on January 15, APL directed a letter to Aerojet requesting a detailed proposal for the delivery of 20 sounding

[24] James A. Van Allen, John W. Townsend, Jr., and Eleanor C. Pressly, "The Aerobee Rocket," in Homer E. Newell, Jr., ed., *Sounding Rockets* (New York, 1959), p. 55.

rockets capable of carrying 68 kg (150 lb) to 60 960 m (200 000 ft). Following a conference at APL on February 2, Aerojet submitted a letter proposal on February 22 bearing the lengthy title: "Proposal to Develop Sounding Rockets Capable of Attaining Altitudes in Excess of 600 000 Feet [182 880 m] and Carry a Payload from 300 to 1500 Pounds [136 to 680 kg], This to Include Liquid Rocket Motor and Fuel Development and Also to Develop Efficient High Thrust Launching Rockets."

Meanwhile the Naval Research Laboratory, which had provided many experiments for the V-2s, was consulted. On March 1, 1946, Van Allen recommended that the Navy Bureau of Ordnance negotiate a contract with Aerojet for the procurement of 20 liquid-propellant sounding rockets, 15 of which would go to APL and 5 to NRL. The contract was formally awarded to Aerojet on May 17 for 20 XASR-1 sounding rockets.[25] The rocket performance stipulated was the delivery of 68 kg (150 lb) of payload to over 91 440 m (300 000 ft)–obviously, the Aerobee would have to be considerably larger than the Wac Corporal. At APL, which was assigned the task of technical direction by the Navy, James A. Van Allen took charge of the Aerobee program.[26]

The Aerobee industrial team was essentially the same as that which built the Wac Corporal. Aerojet Engineering[27] was the prime contractor while Douglas Aircraft Co. performed aerodynamic engineering and some manufacturing. The original Aerobee was about 6 m (19 ft) long and weighed roughly 725 kg (1600 lb). It featured the same propellants as the Wac Corporal (furfuryl alcohol and red fuming nitric acid) and a 1.8-m (6-ft) solid-propellant booster that accelerated the basic vehicle to about 300 m/sec (1000 ft/sec) before dropping off.

The first Aerobee test took place at White Sands on September 25, 1947, when a dummy Aerobee was launched with a live booster to check out stage separation. Two similar tests followed in October. Then, on November 24, 1947, the first full-scale Aerobee was launched. Although the flight had to be terminated after 35 seconds because of excessive yaw, so many subsequent flights were successful that the rocket was soon renowned for its reliability–particularly in comparison with the V-2. Orders for more

[25]The APL rockets were given the name "Aerobee" by Van Allen, a combination of the name of the prime contractor, Aerojet, and the name of APL's series of Navy missiles, the Bumblebees. The five NRL rockets were originally called "Venus," but eventually the name "Aerobee" was applied to all rockets in this long series of sounding rockets.

[26]For details, see *Aerobee High-Altitude Sounding Rocket Design, Construction and Use*, Johns Hopkins University, Bumblebee Series Report 95 (1948).

[27]Another link between the Aerobee and Wac Corporal lies in the fact that von Kármán and other JPL personnel helped found Aerojet Engineering.

An Aerobee 150 sounding rocket.

Aerobees from Government agencies began to arrive at Aerojet. Aerojet has made various versions of the Aerobee ever since.

Some 40 of the original Aerobee design (XASR-1) were fired before this sounding rocket was supplanted by an improved model termed the "Aerobee-Hi" and, after further improvements, the Aerobee 150.[28] There were actually two Aerobee-Hi's: the Air Force version (Air Force-Hi) and the Navy version (Navy-Hi) as well as some interim and "standard" models.[29] The Aerobee-Hi's were born when the Navy and Air Force were approached by Aerojet in 1952 on the subject of an improved Aerobee—a rocket capable of lifting 68 kg (150 lb) to about 240 km (150 mi). Aerojet

[28] See Appendix A for a listing of all major models of the Aerobee series. As might be expected in such a long program, there have been a great many changes over and above major model changes. Appendix B summarizes NASA firings from 1959 through 1968.

[29] John W. Townsend, Jr., Eleanor Pressly, Robert M. Slavin, and Louis Kraft, Jr., "The Aerobee-Hi Rocket," in Homer E. Newell, Jr., ed., *Sounding Rockets,* p. 74.

received an Air Force contract in 1952 and another from the Navy in 1953. The fundamental difference between the Aerobee-Hi and the original Aerobee—whose thrust had been upgraded from 1179 to about 1800 kg (from 2600 to about 4000 lb)—was the propellant capacity. Beyond this, the Air Force and Navy each had its own modifications of the basic vehicle.[30] The first Air Force-Hi rose from Holloman Air Development Command in New Mexico on April 21, 1955. It carried a payload of 97.5 kg (215 lb) to 198.0 km (123 mi). The first Navy launch occurred at White Sands on August 25, 1955, but the test rocket attained scarcely more than 3-km (2-mi) altitude when the main Aerobee engine failed to ignite. Despite the initial difficulties the Navy experienced, the Aerobee-Hi soon proved as reliable as its predecessor and replaced the original Aerobee as the "workhorse" of space research.[31]

THE VIKING

Back in December 1945 when the NRL Rocket-Sonde Research Branch was taking its first steps, the engineers in this embryonic organization had planned to build their own research rockets. The availability of the V-2s only delayed these plans. At the beginning of their search for the best rocket, NRL engineers C. H. Smith and Milton Rosen set a performance goal of 227 kg (500 lb) of payload at roughly 160 km (100 mi). They reasoned that some experimenters might be satisfied with the 45-kg (100-lb) payloads of the Aerobees then under development but that others needed something closer to the V-2 ton-size payloads. The rocket design finally selected was therefore much larger than the Aerobees on the drawing boards and understandably bore considerable resemblance to the V-2. Originally, this big rocket was called the Neptune; the name it is now remembered by is the Viking.[32]

While the Aerobee received its technical direction from APL (the Laboratory was supported largely by Navy funds), NRL took charge of the Viking. The Navy was the key Government agency in sounding rocket development, although the Army and Air Force did play their roles, as mentioned in connection with the Wac Corporal and Aerobee-Hi. The two major contractors on the Viking were Glenn L. Martin Co., which won the competition for the prime contract in August 1946, and Reaction Motors,

[30]For a description of the differences, see *Upper Atmosphere Research Report No. XXIV*, NRL-4576 (Sept. 8, 1955).

[31]For details see J. W. Townsend and R. M. Slavin, "Aerobee-Hi Development Program," *Jet Propulsion*, XXVII (Mar. 1957), 263.

[32]The name was changed when it was discovered that the Navy already had an aircraft called the Neptune.

A Navy Viking rocket on the launch pad at White Sands, circa 1949.

Inc., which built the rocket engine under a separate contract from the Navy's Bureau of Aeronautics.[33] Program direction at NRL was originally by C. H. Smith, under E. H. Krause; but in the fall of 1947, both Krause and Smith left to work on another project. Their places were taken by Homer E. Newell, Jr., and Milton W. Rosen, respectively.[34]

The original Martin contract called for 10 Vikings. Altogether, 14 were built, with the last 2 assigned to tests in the Vanguard Earth-satellite program. There were many minor variations from vehicle to vehicle, but two major varieties are recognized: the type 7 and the type 9 Vikings. All rockets of type 7 were about 15 m (49 ft) high and weighed about 4500 kg

[33]Milton W. Rosen, *The Viking Rocket Story.*

[34]Homer E. Newell, Jr., "Viking," in Homer E. Newell, Jr., ed., *Sounding Rockets,* pp. 235-242.

(almost 5 tons) loaded. In contrast, the type 9 Viking was shorter (about 13 m (42 ft)) and much squatter; it was 50 percent heavier and could carry 450 kg (1000 lb) to 254 km (158 mi). In fact, the type 9 Viking looked less like a sounding rocket and more like a military missile. At one time, thought was actually given to converting the Viking to a submarine-launched missile.

Viking 1 was fired from White Sands on May 3, 1949; the 12th, the last of the sounding rockets, left its launch pad on February 4, 1955. Two particularly interesting launches were *Viking 4,* which was fired from the deck of the U.S.S. *Norton Sound* in the Pacific (Project Reach) and *Viking 8,* which broke away from its moorings during a supposed static test firing on June 6, 1952. It landed on the desert 8 km (5 mi) away.

The Vikings transported a great many experiments into the upper atmosphere and above—254.3 km (158 mi) up for *Viking 11* on May 24, 1954. They also took impressive high-altitude photographs of the Earth. But the Viking was too expensive and required too many ground personnel and facilities to make a practical sounding rocket. The most significant contributions from the Viking program were in technology. The Viking pioneered the gimbaled engine and paved the way for the Vanguard program with its first-stage powerplant.

NIKE-DEACON AND NIKE-CAJUN

When the V-2 series terminated in 1952, the Aerobees had taken over most of the research workload. In the background, however, the military services were developing a great variety of missiles and pilotless aircraft, many of which could be combined to make passable sounding rockets. Most of these missiles were rather small solid-propellant rockets, but they had the advantage of being highly reliable, available, and, when they became obsolete, very cheap. Typical of the missile-based research rockets are those using Nike boosters, such as the Nike-Cajun.

The Deacon was a member of a family of solid rocket motors named after ecclesiastical dignitaries; viz, the Curate and Vicar motors. The development of this series began near the end of World War II under the National Defense Research Council.[35] When work on the solid-propellant Deacon at Allegany Ballistics Laboratory, Cumberland, Md., terminated with the end of the war, some 300 propellant grains became "surplus." The National Advisory Committee for Aeronautics (NACA) purchased these propellant grains and, working with Allegany, assembled them into what is now known as the Deacon rocket motor.

[35]W. J. O'Sullivan, "Deacon and Cajun," in Newell, ed., *Sounding Rockets,* p. 96.

NACA did not want the Deacon motors for sounding rockets but rather for propelling aerodynamic models at its Wallops Island Test Station.[36] The first models using the Deacon were fired out over the Atlantic in April 1947. The Deacon motor was also employed during Operation Pogo to fire metalized parachutes to high altitudes for radar tracking. The Navy Terrapin sounding rocket also used the Deacon motor. Deacons were also carried to high altitudes by balloons prior to firing in the well-known "rockoon" program.

In 1956, studies at PARD indicated that the Deacon's performance could be substantially improved by substituting new propellants while still retaining the Deacon's convenient configuration and size. NACA contracted with Thiokol Chemical Corp., Elkton, Md., for the development and construction of this new motor.[37] The name Cajun was applied to the motor by Joseph G. Thibodaux, head of the PARD rocket section and from New Orleans. The first Cajun firing occurred at Wallops Island on June 20, 1956.

In size, the Deacon and Cajun were no competitors to even the smallish Wac Corporal. The Cajun was just under 264 cm (104 in.) long and weighed 75.3 kg (166 lb) before firing. The Deacon's dimensions were similar.

When the Deacon and Cajun rockets were combined with the solid-propellant booster of the Nike I guided missile, two very capable sounding rockets evolved: the Nike-Deacon (called DAN for Deacon and Nike) and Nike-Cajun (CAN). DAN could take a 23-kg (50-lb) payload to 111 km (69 mi), while the higher performance CAN could carry the same payload to 167 km (104 mi).[38]

The original mating of the Nike and Deacon was carried out by NACA PARD personnel in 1953 as an in-house project with later financial support from the Air Force Cambridge Research Laboratories (AFCRL). The objective of the NACA work was again the acceleration of model rockets and aircraft to high Mach numbers. The first of these firings took place on November 19, 1953, at Wallops Island.

[36]This work was done under the Pilotless Aircraft Research Division (PARD) of the Langley Research Center. PARD employed rocket-propelled and gun-propelled models to attain the high velocities necessary to NACA's exploration of the supersonic flight regime. See R. S. Watson, *Flight Investigation of 6.25-inch-diameter Deacon Rocket and 10-inch-scale Model Rocket,* NACA RM L8H26 (Mar. 25, 1949). For general treatment see J. A. Shortal's *History of Wallops Station,* Comment Edition (Wallops Station, 1969), which describes the substantial rocket experience NACA (and later NASA) gained from the supersonic, rocket-propelled vehicle work at Wallops.

[37]Other contenders for the Cajun contract were ABL and the Grand Central Rocket Co. Grand Central lost the competition but went on to build its proposed motor anyway. This motor was eventually employed in the Asp sounding rocket.

[38]L. M. Jones, W. H. Hansen, and F. F. Fischbach, "Nike-Cajun and Nike-Deacon," in Newell, ed., *Sounding Rockets,* p. 190.

The Nike-Deacon began its sounding rocket career in 1954 at a meeting of the Upper Atmosphere Rocket Research Panel. Panel Chairman James A. Van Allen asked the NASA representative, William J. O'Sullivan, from Langley Research Center, if one of the PARD vehicles might not be less expensive and more easily launched than the Aerobee. O'Sullivan recommended the Nike-Deacon. Subsequently the Aeronautical Engineering Department of the University of Michigan, which was developing upper atmosphere instrumentation for AFCRL, was funded by AFCRL to convert the PARD Nike-Deacon into a sounding rocket. The new rocket was launched from Wallops Island for the first time on April 8, 1955.[39]

It was only logical next to combine the Nike booster with the improved version of the Deacon, the Cajun. The same NACA-Michigan-Thiokol group made the modifications. The first launch of the combined Nike and Cajun took place at Wallops Island on July 6, 1956.[40]

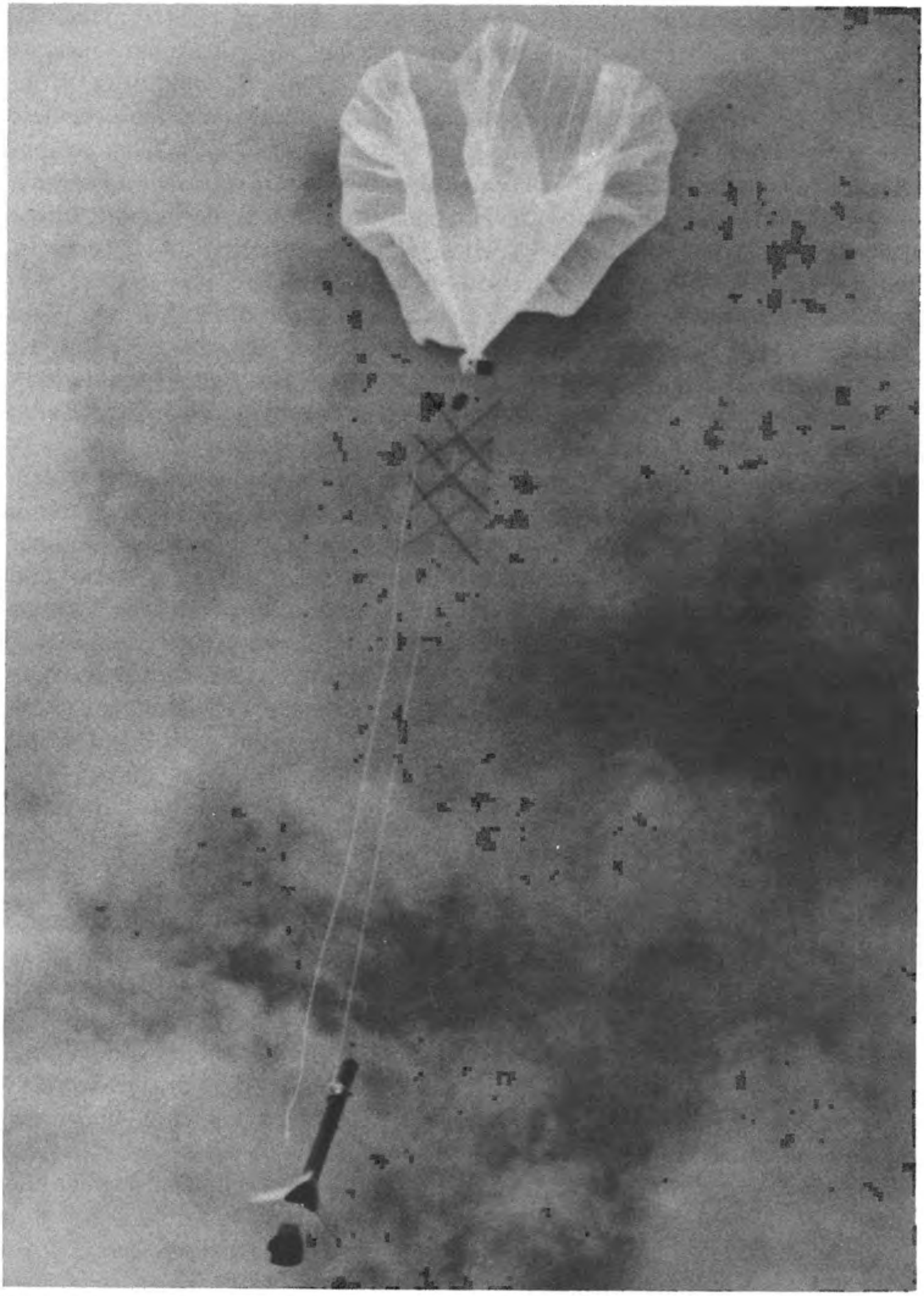
The Nike-Cajun quickly superseded the Nike-Deacon and was widely used during the International Geophysical Year (IGY). It also found application in the Weather Bureau's Project Hugo–a long-range weather research program. The Nike-Deacons and Nike-Cajuns were cheap and reliable, the basic rocket motors having been developed and well tested during their military and NACA careers. Further, they were simple and easy to use–scientists could take them wherever targets of opportunity existed. The University of Michigan group, for example, fired five Nike-Cajuns from the U.S.S. *Rushmore* in 1956. Many launchings in various parts of the world followed.

THE ROCKOONS

Rockoons have been mentioned several times in the preceding pages, particularly in connection with the Deacon rocket. The Deacons were used on most rockoons, but a rockoon is actually the combination of any balloon with any rocket. The rockoon concept seems to have been originated by Lt. M. L. (Lee) Lewis during a conversation with S. F. Singer and George Halvorson during the Aerobee firing cruise of the U.S.S. *Norton Sound* in March 1949. The basic idea is to lift a small sounding rocket high above the dense atmosphere with a large balloon in the Skyhook class. Once enough altitude is attained, the rocket is fired by radio signal straight up through the

[39] R. H. Heitkotter, *Flight Investigation of the Performance of a Two-stage Solid-propellant Nike-Deacon (DAN) Meteorological Sounding Rocket*, NACA TN 3739 (July 1956).

[40] J. F. Royall, Jr., and B. J. Garland, *Characteristics of the Nike-Cajun (CAN) Rocket System and Flight Investigation of Its Performance*, NACA RM L57D26 (1957).



A Navy rockoon just after a shipboard launch. A Deacon rocket is suspended below the balloon.

balloon. The rocket will reach much higher altitudes than it could from the ground. The rockoon has turned out to be a simple, cheap way of getting high-altitude data without special facilities. Many rockoons employing Deacon, Loki, and Hawk rockets were fired between 1952 and 1960. Once satellites and high-altitude sounding rockets became available in adequate numbers, the use of rockoons declined.

James A. Van Allen first put rockoons to practical use when he and his group from the University of Iowa fired several from the Coast Guard Cutter *East Wind* during its cruise off Greenland in August and September 1952.[41] Van Allen was looking for high-altitude radiation near the magnetic poles and needed a vehicle that could reach well over 80 km (50 mi) with an 11-kg (25-lb) payload and yet still be launched easily from a small ship. The rockoon was the answer. With his rockoons, Van Allen detected considerable soft radiation at high altitudes–much more than scientists expected. This was one of the first hints that radiation might be trapped by the Earth's magnetic field. One drawback to the rockoon was that it had to be fired before high-altitude winds carried it out of radio range.

Project Farside was an attempt to reach extreme altitudes with the rockoon concept. Using a four-stage solid-propellant rocket hung below a 106 188-m^3 (3 750 000-ft^3) balloon, altitudes approaching 6437 km (4000 mi) were reached during the fall of 1957. Farside was an Air Force Office of Scientific Research project, using various instruments provided by the University of Maryland. Six rockets were built by Aeronutronic Systems, Inc. Bad telemetry precluded the discovery of the Van Allen belts during the Farside shots near Eniwetok.

ROCKAIRE

If balloons were so useful in stretching rocket performance, why not try high-altitude aircraft? Thus, the "rockaire" concept was born. Actually the rockaire concept was first suggested by Hermann Oberth in his 1929 classic *Wege zur Raumschiffahrt.* The Air Force studied the idea on and off from 1947 on. The Navy did the same and finally tried the idea out on August 16, 1955, using a Navy F2H2 aircraft off Wallops Island. An altitude of 54 864 m (180 000 ft) was reached with a 69.9-mm (2.75-in.) folded-fin aerial rocket (FFAR) of Korean vintage.[42] The Air Force launched theirs in 1956.[43] In general, however, the rockaire concept never achieved the popularity of the rockoon. Apparently no important scientific rocket

[41] James A. Van Allen, "Balloon-Launched Rockets for High-Altitude Research," in Homer E. Newell, Jr., ed., *Sounding Rockets,* p. 143.

[42] Malcolm D. Ross, "Aircraft Launched Rockets," in Newell, ed., *Sounding Rockets,* p. 165.

[43] R. M. Slavin, "The Air Force Rockaire Program," *Jet Propulsion,* XXVII (Mar. 1957), 279.

research was carried out with rockaires, in contrast to the hundreds of rockoons fired during the 1950s.

SUMMARY

To summarize the period from 1945 through the beginning of the International Geophysical Year (IGY), on July 1, 1957, the development of sounding rocket technology may be characterized by the following:

- Captured V-2s provided an immediate source of high-altitude vehicles and test beds upon which to perfect scientific techniques.
- The Wac Corporals and especially their direct descendants, the many varieties of Aerobees, quickly became the "workhorses" of space research.
- The Aerobees were supplemented by other military-derived vehicles, such as the Nike-Cajuns.
- The Viking, conceived as a high-altitude research vehicle, acquainted the United States with the technology of big liquid-propellant rockets.

The period 1945-57, then, was primarily a period of perfecting both rocket and instrument techniques. No spectacular new scientific discoveries came during the 1945-57 period, although the discipline of geophysics was extended from 32 to 40 km (20 to 25 mi) and there were some solid achievements in aeronomy. It was still a time of preparation. True, Van Allen's discovery of soft radiation at high altitudes was interesting, and solar research had been greatly stimulated by the first ultraviolet spectrograms of the Sun. Hundreds of sounding rockets had begun to sketch out the complex, ever-changing upper atmosphere and ionosphere; rocket pictures of the Earth's weather showed the practical potential of high-altitude vehicles. Nevertheless there was nothing that might be labeled a "scientific breakthrough," like the later discoveries of the Van Allen belts, the magnetosphere, etc.

V

THE USE OF SOUNDING ROCKETS DURING THE IGY

The International Geophysical Year (IGY) began on July 1, 1957, and lasted 18 months. This period saw the greatest concerted, systematic application of sounding rockets to upper atmosphere and space research yet attempted. The United States alone fired over 200. Other countries employed hundreds more. The first Russian and United States satellites were also orbited during the IGY, and the first Pioneer space probes were launched in the direction of the Moon. The Van Allen belts, the magnetosphere, and the solar plasma were all discovered by satellites and space probes. However, the technology they employed was primarily developed on sounding rockets. In fact, the early name for the U.S. IGY satellite was the LPR (Long Playing Rocket). And, of course, the scientific firsts of the satellites and probes had to dovetail with the immense quantity of data collected by sounding rockets from the upper atmosphere and the fringes of outer space. Satellites helped complete a picture that sounding rockets had begun to draw in 1945.

Preparations for the IGY officially began during October 1951, when the International Council of Scientific Unions, following a suggestion of Lloyd Berkner, decided to hold a Third International Polar Year.[44] This international effort was to be a larger version of the two previous Polar Years in 1882 and 1932, which had been primarily concerned with accurately locating meridians. In October 1952, the official name was changed to the better known IGY.

Within the United States, the IGY effort was led by the U.S. National Committee for the IGY (USNC-IGY) established by the National Academy of Sciences in February 1953. Funds were supplied by the National Science Foundation. Under the USNC-IGY a Technical Panel on Rocketry (TPR) was organized with F. L. Whipple of the Smithsonian Astrophysical

[44]Eugene M. Emme, *Aeronautics and Astronautics, 1915-1960* (Washington, 1961), p. 68.

Observatory as Chairman. Homer E. Newell, Jr., from NRL was Vice Chairman (later Chairman). The TPR needed a group of scientists and engineers familiar with sounding rockets to handle the actual schedules and launchings. This group, known as the Special Committee for the International Geophysical Year (Working Group on Rocket Operations) (SCIGY), evolved from the Upper Atmosphere Rocket Research Panel (UARRP) mentioned in Chapter IV. SCIGY membership [45] was as follows:

Homer E. Newell, Jr., NRL (Chairman)
John W. Townsend, NRL (Executive Secretary)
Warren W. Berning, Ballistics Research Laboratory
Leslie M. Jones, University of Michigan
Frank B. McDonald, State University of Iowa
William G. Stroud, Signal Corps Engineering Laboratory
P. R. Wyckoff, AFCRL
Robert W. Slavin, AFCRL (replaced Wyckoff)
Kinsey A. Anderson, State University of Iowa (replaced McDonald)
Nelson W. Spencer, University of Michigan (added 1956)
John Hanessian, Jr., USNC-IGY (Recording Secretary)
Pembroke J. Hart, USNC-IGY (Recording Secretary)

SCIGY began work as a UARRP committee in 1953. In February 1955, SCIGY was formally adopted by the TPR and thence became the key technical advisory group on IGY sounding rocket programs.

An interesting and pertinent feature of the TPR and SCIGY is the strong representation of NRL scientists and engineers. These NRL personnel, who figured so strongly in the IGY rocket program, eventually transferred almost to a man to NASA when it was created in 1958. Newell, Townsend, McDonald, Stroud, and Spencer went to Goddard Space Flight Center to build the space science and sounding rocket programs there.

The IGY sounding rocket program was so extensive that it is best summarized by a table (Table 1[46]). Nearly half of the IGY rockets were launched from Fort Churchill, in the Canadian province of Manitoba. On the Arctic barrens, the Fort Churchill site was built by the United States for the IGY at the invitation of the Canadian Government. The facility was built in five months by 550 men of the 87th Task Force, U.S. Army Corps of Engineers, using a design and special equipment provided by Aerojet. The Aerojet Aerobees, being liquid-propellant rockets, could not be fired at that

[45] Jack R. Siewert, *The United States IGY Upper Atmosphere Rocket Operations,* Final Report of The Special Committee for the IGY (Working Group on Rocket Operations), Mar. 1959, p. 9.

[46] Frederick I. Ordway, III, and Ronald C. Wakeford, *International Missile and Spacecraft Guide,* p. 204.

TABLE 1. *U.S. IGY Sounding Rocket Firings*

Launch site	Rockets used	Number
Fort Churchill (Manitoba, Canada)	Aerobees, Loki-Darts, Nike-Cajuns	95
Antarctic	Rockoons	40
San Nicolas Island (off California)	Asps, Nike-Deacons, Rockoons	31
Arctic	Rockoons	18
White Sands	Aerobees, Nike-Cajuns	9
Guam	Aerobees, Nike-Cajuns	9
Danger Island (Pacific)	Nike-Asps	8
Total		210

time without special ground facilities. Thus, Fort Churchill and White Sands saw most of the IGY Aerobee firings, while solid-propellant rockets were launched from shipboard, rockoons, and many remote sites.

In Table 2, the breakdown of the IGY rocket program[47] shows the Fort Churchill site receiving the great bulk of the funds allocated by the National Science Foundation, with most of this fraction going to the Aerobee program. Project 10.1, the Rockoon and DAN program, included the ship firings in the Arctic and Antarctic noted in Table 1. Also under this program,

TABLE 2. *Breakdown of IGY Sounding Rocket Projects*

Project		Agency[a]	Budget
10.1	Rockoon/DAN program	SUI	$ 338 300
10.2	Aerobee program, White Sands	NRL	90 000
10.3	DAN program, Southern California	NRL	154 000
10.4	Aerobee program, Holloman	GRD	0
10.5	Aerobee program, Fort Churchill	NRL	1 020 064
10.6	Aerobee program, Fort Churchill	GRD	248 936
10.7	Aerobee program, Fort Churchill	SRDL	213 889
10.14	Nike-Cajun program, Fort Churchill	BRL	90 000
10.16	Meteorological support, Fort Churchill	SRDL	12 000
10.17	Antarctic rocket data reduction	GRD	0
10.18	Rocket measurements at Guam	SRDL	244 500
10.19	Contract support	NRL	90 800
10.20	Alphatron-sphere experiment	Mich.	75 500
10.21	Pacific solar eclipse expedition	NRL	50 000
	Total		$2 627 989

[a]SUI = State University of Iowa; NRL = Naval Research Laboratory; GRD = USAF Geophysics Research Directorate; SRDL = U.S. Army Signal Research & Development Laboratory; BRL = Ballistics Research Laboratory, Mich. = University of Michigan.

[47]Siewert, *The United States IGY Upper Atmosphere Rocket Operations*, p. 5.

Van Allen and his group from the State University of Iowa extended the polar rockoon experiments that they had pursued since 1952.

Another interesting program was 10.21, conducted by NRL during the total solar eclipse of October 12, 1958. Eight Nike-Asps were fired from Puka Puka Island in the South Pacific before and during totality. Solar X-rays and the Lyman-alpha line of hydrogen were measured by photometers in the payloads. This was the first of many rocket-equipped eclipse expeditions that were sent to various climes between 1957 and 1969.

The mainstays of the U.S. IGY rocket stable were the Aerobee-Hi, which was modified and improved to create what is now termed the Aerobee 150;[48] the Nike-Cajuns; the Nike-Deacons; and two new missile-derived rockets, the Loki-Dart and the Nike-Asp. The Loki was a JPL/Army Ordnance development, while the Asp was a Navy rocket built for high atmosphere work, mainly in connection with nuclear weapons tests. Both the Lokis and Asps were manufactured by the Cooper Development Corp., Monrovia, Calif.[49]

Two brand new Aerobees were added to the series during the IGY: the Aerobee 100 and the Aerobee 300. The Aerobee 100 (also called the Aerobee Junior) was shorter (7.8 m; 25.7 ft) and lighter (655.6 kg; 1445 lb) than the standard Aerobee 150. From a performance standpoint, the Aerobee 100 could reach 160 km (100 mi) with about 18 kg (40 lb) of payload. The most interesting feature of the Aerobee 100 program was that it was not Government sponsored. The development of the new design and the manufacture of 20 rockets were carried out with Aerojet capital. In the manufacturer's words, it was a "do it yourself" rocket. NRL, the Air Force, and NASA (after it was formed) eventually purchased all 20 vehicles. The first was fired by NRL at White Sands on February 18, 1958. Only the final vehicle in the series, launched on September 21, 1961, failed.

The Aerobee 300 is in reality an Aerobee 150 with a motor from the Sparrow missile for an upper stage. For this reason, it is often called a "Spaerobee." Standing about 10 m (33 ft) high, and weighing roughly 940 kg (2075 lb), an Aerobee 300 can reach 480 km (300 mi) with a 23-kg (50-lb) payload. It was developed with Navy funds under the technical direction of NRL. The first of the new 300s was fired from Fort Churchill on October 25, 1958; it was an Air Force rocket instrumented by AFCRL. It reached an altitude of 418.4 km (260 mi).

One other important sounding rocket to make its debut during the IGY was the Arcas (stands for All-Purpose Rocket for Collecting Atmospheric

[48] Whenever a "standard Aerobee" is mentioned, an Aerobee-Hi or its derivative, an Aerobee 150, is usually meant.

[49] C. M. Zimney, "The Asp, a Single-Stage Solid-Propellant Sounding Rocket," *Jet Propulsion,* XXVII (Mar. 1957), 274.

Soundings).[50] The Arcas was a small meteorological rocket capable of reaching 64 km (40 mi) with 5.4 kg (12 lb). Developed jointly by the Army and Navy, Arcas was built by the Atlantic Research Corp. and needed only a simple launch tube. It was cheap–only \$2000 apiece–and 2000 or so are currently fired each year. The first flight of Arcas was at Wallops Island in July 1959. The Arcas was not used in any of the IGY programs, but NASA has since fired several dozen, particularly in its international programs.

The results of the IGY sounding rocket program came not only from American rockets but from other types developed and flown by foreign countries, often in worldwide synchronized experiments. Knowledge was extended in almost every area of geophysics, although as mentioned previously, real scientific breakthroughs had to wait for the first scientific satellites in late 1957 and early 1958. Some of the more significant results from rocket research during the IGY are summarized in the remainder of this chapter.[51] Examination of the results will show that the new data extended rather than revolutionized geophysical thinking.

Meteorology. High-altitude wind patterns were measured. Very high speed westerly winds were measured over Fort Churchill.

Atmospheric physics. Pressure, density, and other parameters measured by sounding rockets were used in preparing the 1962 U.S. standard atmosphere. Vertical distribution of ozone measured up to 70 km (44 mi). Mass spectrometer measurements above Fort Churchill detected N, O, H_2O, NO, O_2, and CO_2 between 85 and 241 km (53 and 150 mi). The night airglow at 6300 Å was shown to originate above 140 km (87 mi). Hydroxyl radiation was observed between 50 and 80 km (31 and 50 mi). The 5577-Å oxygen green line was found to be strongest between 90 and 100 km (56 and 62 mi). Sodium vapor released just below the *E* region of the ionosphere was seen to fluoresce brightly in sunlight. In the auroral zone, soft radiation many times more intense than the primary cosmic radiation was discovered above 40 km (25 mi).

Ionospheric physics. Electron densities were measured directly up to 389 km (242 mi); and the *E* and F_2 regions were mapped in greater detail than possible before. Rockets discovered that atmospheric ionization remains dense during the daytime from the *E* region to as high as measurements were made.

Fields and particles. The Earth's magnetic field decreases according to the inverse cube, as expected. (Note that IGY rockets did not reach the magnetosphere.) Measurements of the primary cosmic radiation were

[50] W. C. Roberts, R. C. Webster, and W. D. Charles, *Arcas and Metroc Sounding Rockets–A Status Report,* ARS paper 2340-62 (1962).

[51] Homer E. Newell, Jr., "The Use of Rockets for Geophysical and Solar Research," in Newell, ed., *Sounding Rockets,* pp. 37-43.

extended geographically and to higher altitudes, laying the groundwork for the discovery of the Van Allen belts by *Explorer I.*

Solar physics. The known ultraviolet spectrum of the Sun was extended from 2900 Å to 977 Å. Solar hydrogen Lyman-alpha and beta lines were measured. The X-ray spectrum and its variability were examined, showing a maximum near 40 Å, where kinetic temperatures appear to be about 700 000 K (1 260 000° F).

Astronomy. Some limited micrometeoroid influx data were obtained. Discrete Lyman-alpha radiation sources were found in the sky.

VI

GENESIS OF THE GODDARD SPACE FLIGHT CENTER SOUNDING ROCKET PROGRAM

The IGY had proven the efficacy of the sounding rocket as a research vehicle; it had also been the stimulus for the development of better rockets, better auxiliary equipment and procedures, as well as smaller and more rugged instrumentation. Something else born out of the IGY was the scientific satellite.

On one hand, the scientific satellite seemed to be a direct competitor of the sounding rocket. A satellite could stay in orbit for months, even years, continually sending back data about its environment. In comparison, sounding rockets were quick-look vehicles that now seemed rather obsolete, like propeller aircraft did after the jets came along. On the other hand, the Sputniks and Explorers brought the beginning of the so-called Space Age; and more money became available for space research than IGY scientists had ever dared hope for. Further, the satellites brought about the formation of NASA and the centralization of space research, formerly dispersed throughout the country, including sounding rocket research. These events, at least, were beneficial to sounding rocket technology.

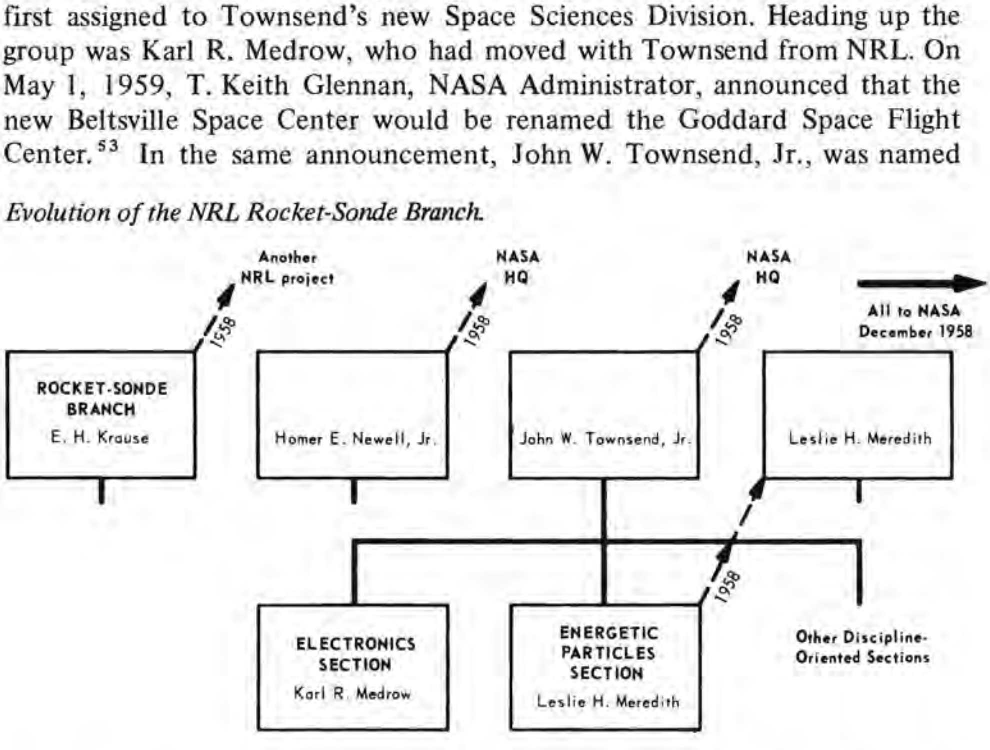
Although the satellite was a more romantic and exciting vehicle to use for experimentation, it soon became apparent that there would not be enough satellites to go around for at least several years after Sputnik. On top of that, there were obviously some things that satellites could not do that sounding rockets could; for example, gather data below 160 km (100 mi) altitude and make direct measurements within the atmosphere along a vertical flight profile. Sounding rockets were not dead, but they certainly did not have the glamour of the satellites and deep space probes.

NASA, created on October 1, 1958, was the logical organization to organize the nation's sounding rocket research program, but it had no staff experienced in this field. Where were cadres of experienced sounding rocket people to be found? Within the Government, the Naval Research Laboratory (NRL), the Air Force Cambridge Research Laboratories (AFCRL), the Jet Propulsion Laboratory (JPL), and the Army Ballistic Missile Agency (ABMA) were the best bets. It was a foregone conclusion that NRL's Vanguard group–150 strong–were to become part of NASA, as they did on November 16, 1958. As it turned out, NRL also provided the great bulk of NASA's sounding rocket knowhow when, on December 28, 1958, John W. Townsend, Jr., was transferred to NASA along with 46 NRL scientists and engineers in his Rocket-Sonde Branch.[52]

Together, the NRL Vanguard and sounding rocket personnel formed the nucleus of professionals for NASA's new Beltsville Space Center just north of Washington. Another NRL scientist who had been most active in sounding rocket research, Homer E. Newell, Jr., transferred to NASA Headquarters.

In the new Beltsville organization, NRL's sounding rocket group was first assigned to Townsend's new Space Sciences Division. Heading up the group was Karl R. Medrow, who had moved with Townsend from NRL. On May 1, 1959, T. Keith Glennan, NASA Administrator, announced that the new Beltsville Space Center would be renamed the Goddard Space Flight Center.[53] In the same announcement, John W. Townsend, Jr., was named

Evolution of the NRL Rocket-Sonde Branch.



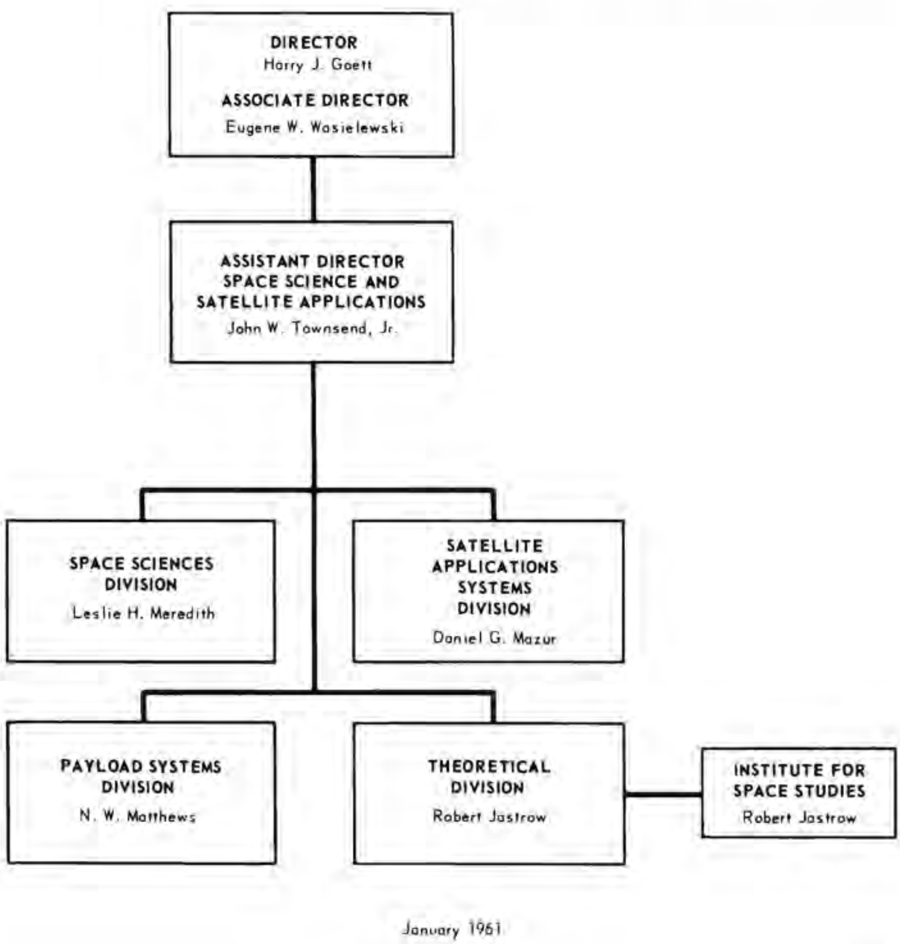
[52] Robert L. Rosholt, *An Administrative History of NASA, 1958-1963,* NASA SP-4101 (Washington, 1966), p. 47.

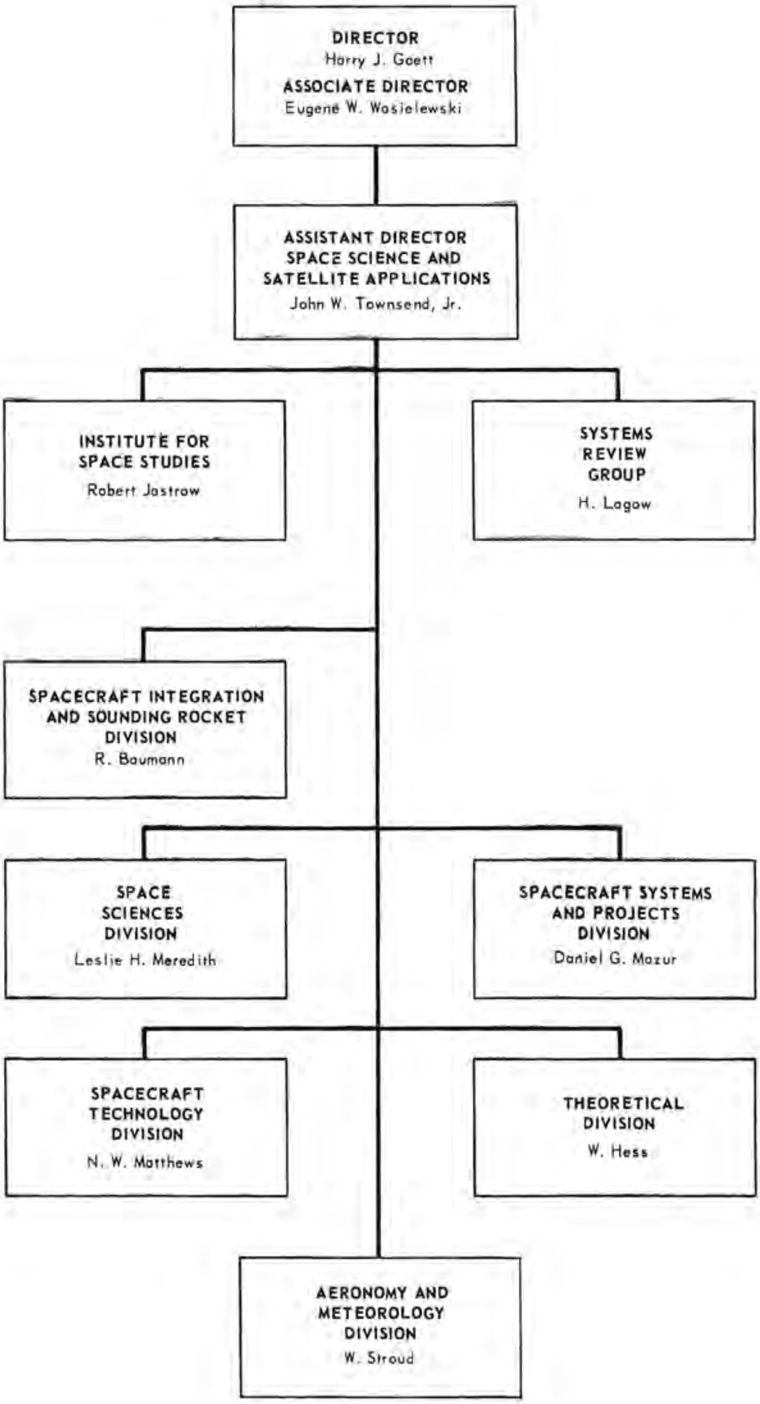
[53] Alfred Rosenthal, *Venture into Space,* NASA SP-4301 (Washington, 1968), p. 29. Goddard Space Flight Center is located at Greenbelt, Md., although the present Sounding Rocket Branch remains at Beltsville, Md., a few miles west.

Assistant Director for Space Science and Satellite Applications. Within Townsend's organization the position of Chief of the Space Sciences Division was assigned to Leslie H. Meredith, also a transferee from NRL. Karl Medrow remained as Chief of the Sounding Rocket Branch. The Townsend-Meredith-Medrow line of authority remained intact until 1962. (See Chapter VII.)

The structure of Goddard's Sounding Rocket Branch has not changed significantly since the group transferred from NRL. When Karl Medrow took charge of NASA's sounding rocket effort right after Christmas 1958, he set as a primary goal the establishment of competence in four areas: vehicles, mechanical engineering, instruments, and performance. Essentially, this was

Evolution of top management structure at Goddard. (Only that portion pertinent to sounding rockets is shown.)





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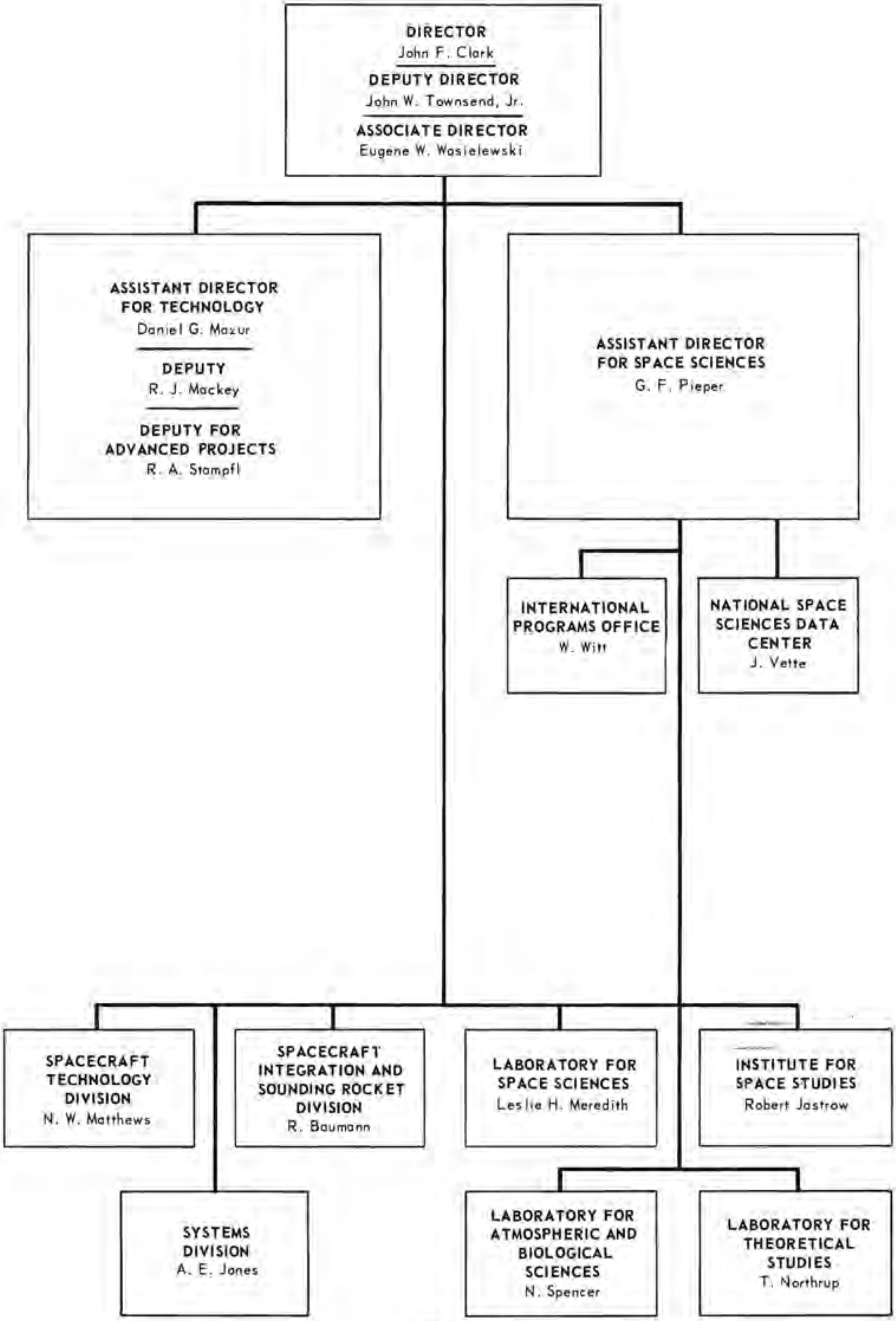

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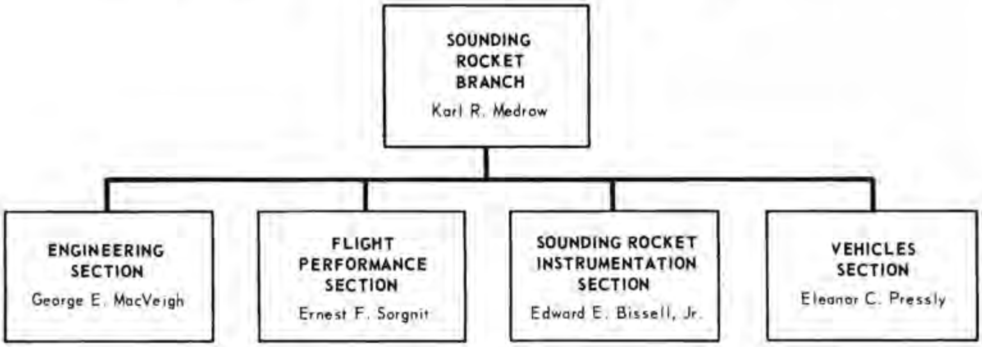
the same approach he employed at NRL.[54] In fact, the individuals heading up the four sections corresponding to Medrow's areas of competence transferred from NRL with Medrow; and, with a single exception, still head their respective sections: Eleanor C. Pressly, Vehicles; Francis J. Hartz, Engineering; Edward E. Bissell, Jr., Instruments; and Ernest F. Sorgnit, Performance. The single exception was Francis (Dutch) J. Hartz, who left NASA in 1959[55] and was replaced by George E. MacVeigh.



The Goddard Sounding Rocket Branch in 1968. The basic structure of the organization has remained unchanged since the move from NRL. The major personnel change between 1958 and 1968 was the replacement of Hartz by MacVeigh.

The original group of NRL transferees was augmented in the beginning by other engineers lured to Goddard from other Government agencies. In the case of sounding rockets, the Naval Ordnance Laboratory was the second source after NRL. Starting with the 47 NRL people, the Goddard Sounding Rocket Branch roughly doubled in the first decade of NASA's existence.

It is important to point out here that the Sounding Rocket Branch at Goddard provided vehicles and launch services and did no experimentation itself. Rather it served various "customers" in the universities, within NASA itself, in industry, and in other Government agencies. Only about one-third of the Branch's launches were specifically for NASA experimenters. This is in contrast to the group's role at NRL where almost all the "science" was in-house.[56] The "standard procedure" was for prospective experimenters to approach the Office of Space Science and Applications at NASA Headquarters with a proposal to fly an experiment on a sounding rocket. On occasion, these proposals were solicited by NASA for specific series of flights; for

[54]Personal interview with Karl R. Medrow, Dec. 11, 1968.

[55]Hartz eventually returned to Goddard.

[56]Personal interview with Eleanor C. Pressly, Dec. 3, 1968.

example, a series of rockets to be flown during an eclipse. If the proposal was sound and had good scientific promise, NASA Headquarters funded the experimenter and, in addition, transferred the necessary funds to Goddard for the vehicle and launch services.[57]

An essential adjunct to the Goddard role was the availability of Wallops Station, which in 1958 became part of NASA along with Langley, Ames, and Lewis Research Centers and the other NACA facilities. Wallops served as a major launch and test site for the sounding rockets procured and instrumented under Goddard's management. For years, many rockets from other Government agencies were launched from Wallops, such as the Army Air Force MX-570 missile as far back as July 4, 1945.

The "tools" that the Goddard Sounding Rocket Branch had available to carry out its task were the rockets described in the preceding chapter: the Aerobees 100, 150, and 300; the Nike-Cajun; the Arcas; and various combinations of the Nike, Asp, and other solid-propellant military rockets. Of course, balloons and aircraft could be used to improve rocket performance as they did in the rockoon and rockaire concepts. But sounding rocket performance had improved so much–in payload and altitude–that rockoons and rockaires were used hardly at all after 1959. There was still a need, however, for better rocket performance and, in particular, lower cost, better reliability, and improved logistics–that is, ease of transport and launching simplicity. Experimenters needed better pointing control for their instruments and bigger capacity telemetry systems. And because NASA was specifically charged in the Space Act of 1958 with fostering international cooperative programs where possible, it would be helpful to have vehicles that could be exported without concern for military antecedents.

During the first year of the existence of Goddard's Sounding Rocket Branch, several sounding rockets, whose development predated NASA, came into the "stable" of vehicles readily available to NASA. Chief among these were the Javelin and Journeyman, both in the so-called Argo series. The Argo series was developed by the Aerolab Development Co. under the sponsorship of NACA/NASA, with support from the Air Force Special Weapons Center, the Naval Bureau of Ordnance, and the Allegany Ballistics Laboratory.

The Argo vehicles were derived from a family of NACA/NASA hypersonic test vehicles, after the fashion of the Nike-Deacon and Nike-Cajun. Aerolab has designed a long series of Argo rockets, including the Argo E-20, designed to lift 4.5 kg (10 lb) to 24 384 m (80 000 ft); but only the Jason (Argo E-5), the Javelin (Argo D-4), and the Journeyman (Argo

[57]See William R. Corliss, *Scientific Satellites,* NASA SP-133 (Washington, 1968), pp. 408-410, for a review of NASA's experiment selection procedures.

D-8) have seen significant use. NASA never employed the Jason, but it is the rocket that the Air Force employed to measure high-altitude nuclear radiation during the Argus experiments in the late summer of 1958, when nuclear weapons were exploded at high altitudes. NASA has used the Javelin to some extent, as indicated by the flight history in Appendix C. The Journeyman helped NASA gather radiation data prior to the Mercury flights and has also seen some Air Force use. In general, the Argos are rather large by sounding rocket standards. They were all put together from off-the-shelf military hardware, often following vehicle adaptations by Langley Research Center. (See Appendix A for rocket details.) NASA use of the Argo series has been minimal.

The development of the Iris sounding rocket had begun at NRL prior to the transfer of its Rocket-Sonde group to NASA. Iris was built by the Atlantic Research Corp. for the Naval Bureau of Ordnance, with NRL monitoring the design, the production, and the payload.[58] The development of the rocket was completed by NASA, with the first NASA firing taking place at Wallops Island on July 22, 1960. In contrast to the monsters in the Argo series, Iris is a small, two-stage, solid-propellant rocket capable of lifting 45 kg (100 lb) to about 320 km (200 mi). NASA has not used the Iris rocket since 1962.

During 1959, its first year of operation, Goddard's Sounding Rocket Branch (with the help of other agencies) fired only 16 rockets, 12 from Wallops Island and 4 from Fort Churchill. Six of these firings were tests of the Arcon rocket at Wallops Island; all of these were classified as failures. (NASA never used the Arcon again.) There also were five Nike-Asp (or Aspan) launches during 1959, all from Wallops Island. Four of the five were successfully launched and two released payloads of sodium at high altitudes for studies of the upper atmosphere. Four Aerobee 150s were fired from Fort Churchill in a series of ionosphere experiments in collaboration with Canada's Defence Research Telecommunications Establishment; three of these were successful.[59]

An interesting scientific use of rockets appeared in 1959, when, on October 28, 1959, NASA launched a 30-m (100-ft) inflatable sphere into a suborbital trajectory from Wallops Island as part of Project Shotput. Project Shotput used a Sergeant-Delta launch vehicle to test payloads for the Echo passive communications satellite project.[60] A second suborbital shot was

[58] J. W. Townsend, Jr., and F. J. Hartz, *Arcon and Iris Rocket Report No. 1*, NRL-5073 (1958).

[59] Full data on these flights as well as all other NASA sounding rocket flights may be found in J. A. Sterhardt and W. E. Weaver, *NASA Sounding Rocket Program, Summary of Sounding Rocket Flights*, X-721-66-515 (Greenbelt, 1966) and X-721-68-283 (Greenbelt, 1968).

[60] The first successful Echo satellite was launched August 12, 1960, from Wallops Island.

made on January 16, 1960. It is a matter of semantics whether the Shotput launches should be considered sounding rockets; certainly useful scientific data were obtained from the suborbital vehicles. Further, other suborbital tests of a similar nature followed–the Shotput tests of the Italian San Marco satellite from Wallops Island in 1962, for example. The Shotput tests must really be considered as extensions of the NASA philosophy of testing scientific instruments on sounding rockets before committing them to satellites.

To summarize, the year 1959 was a year of transition and preparation for future programs at Goddard. The Sounding Rocket Branch was developing programs that would launch a total of 60 sounding rockets in 1960 (about four times the 1959 total). The shift from serving in-house experimenters (the NRL approach) to that of providing rockets for scientists the world over was a major perturbation. In fact, 1959 was only the beginning of perturbation. The year 1959 was only the beginning of a service to science here and abroad that has remained fairly constant despite the recent ups and downs of the overall NASA budget.

VII

SOUNDING ROCKETS DURING THE HEYDAY OF SCIENTIFIC SATELLITES

PREDILECTIONS FOR SATELLITES

During the five-year period 1960-1964, "getting an experiment on a satellite" was the thing to do in space science.[61] Space funds were concentrated on satellites and space probes until the $10-20 million in NASA's annual sounding rocket budget was less than 10 percent of that allocated to the Explorers, Orbiting Observatories, Mariners, Rangers, and other space vehicles. One sounding rocket proponent put it this way:

> . . . the IGY also saw the beginning of satellite era, itself a product of the rocket's prior success, and the satellites sapped the strength which would otherwise have gone into rocket studies.[62]

Even the name "sounding rocket" had an archaic ring to it.[63] Thus the Goddard Sounding Rocket Branch entered the 1960-1964 period at a psychological disadvantage.

Despite the swing of many experimenters to satellites, many scientists felt more comfortable with sounding rockets and, as pointed out earlier, some atmospheric and ionospheric research just cannot be done with satellites. Further, NASA recommended that new instruments destined for satellite flight first prove themselves on sounding rockets wherever feasible. The demand for sounding rockets also rose because scientists newly attracted to space research found it much easier to get space on sounding rockets–the

[61] Personal interview with Eleanor C. Pressly, Nov. 27, 1968.

[62] Colin O. Hines, "Sounding Rocket Resurgence," *Astronautics and Aeronautics,* IV (Jan. 1966), p. 8.

[63] Jon Busse, at Goddard Space Flight Center, has suggested that the name "near-space probe" or "research rocket" might be more appropriate.

satellites, with their limited space, being in effect preempted by the proven "big names" in space research. For these reasons NASA's sounding rocket program accelerated during the early 1960s despite the lack of glamour. Goddard managed 60 sounding rockets in 1960 and exceeded the 100 mark in 1964 and thereafter.

ORGANIZATION OF U.S. SOUNDING ROCKET ACTIVITIES

The Goddard Sounding Rocket Branch, beginning with roughly 50 transferees from NRL and other agencies, could not handle the greater workload alone. Rockets in the NASA "stable" had to be procured and fired at locations around the world; new rockets had to be developed and old ones improved; and there was continuous negotiation with the experimenters from sister agencies, the universities, and foreign countries. To meet the demand, Goddard approximately doubled the manpower of its Sounding Rocket Branch between 1959 and 1965. In addition, onsite contractors, such as Fairchild-Hiller, provided personnel who worked hand in hand with NASA employees. Of course, much of the vehicle engineering and all of the production were done by contractors all over the country. NASA's general philosophy was to keep roughly 20 percent of the scientific and engineering work in-house to maintain Goddard's competence in the area.[64] Such competence is obviously essential in dealing with experimenters and contractors in a complex technical field.

Many other Government agencies conducted their own sounding rocket research programs, particularly the Navy (NRL) and the Air Force (AFCRL). The Environmental Science Services Administration (ESSA) employed meteorological rockets to help gather synoptic weather data. The Atomic Energy Commission, too, was interested in the upper atmosphere because of its responsibility for monitoring radioactivity and detecting nuclear explosions.

Generally these agencies procured their own sounding rockets and provided their own launch services for firings within the United States; from Fort Churchill, Canada; and from vessels in international waters. The Naval Research Laboratory was an exception where NASA provided some rockets, launch services, and funds to develop some of the experiments almost in the same way it does for an in-house or university experimenter. Experimenters in other agencies could and did approach NASA for rockets and funds. Occasionally the Air Force, which maintained a vigorous sounding rocket program at the Air Force Cambridge Research Laboratories, requested and received launch support services available only from NASA. NASA's Wallops

[64] Medrow interview, Dec. 11, 1968.

Island launch facility was used by the Air Force and other agencies. Of course, these were reciprocal relationships because NASA on occasion used the facilities of the Western Test Range (formerly the Pacific Missile Range) for sounding rocket launches. A perusal of the NASA launches in Appendix B bears this out. The Air Force has also been instrumental in developing rockets, such as the Black Brant series (Chapter VIII) that NASA ultimately adopted.

Who coordinates all of the rocket research taking place around the country? There is the natural desire not to duplicate research work. This is augmented by congressional pressure to define agency missions precisely and reduce overlap. The Rocket Research Panel, established as the Joint Atmosphere Rocket Research Panel, partially solved this interagency coordination problem. This panel was formed when NASA and DOD established the Aeronautics and Astronautics Coordinating Board (AACB) on September 14, 1960. The Rocket Research Panel, however, ceased functioning in the early 1960s. The only remaining nationwide forum for sounding rocket research was the White Sands Scheduling Committee, which dealt only with Aerobee launches. NASA interfaces with other agencies in the sounding rocket area have thus become informal ones—with the following exception.

Whenever another agency wished to launch a sounding rocket from a foreign country, as was sometimes the case when eclipses occurred, or when a phenomenon was localized (viz, the auroras), NASA acted as their agent in all dealings with the country involved.[65] Space research has been promoted as a nonmilitary enterprise by the United States ever since NASA was created; indeed, the desire to keep the space program nonmilitary was one of the main reasons why NASA was formed as a separate agency instead of placing space research under the Air Force.[66] The civilian mien of NASA sounding rocket work has usually made it relatively easy for NASA to secure launching privileges in foreign countries where a military agency might be unwelcome.

The procedure an experimenter follows for obtaining space on a sounding rocket was similar—up to a point—whether he was a U.S. citizen or foreign national:

1. The experimenter submitted a proposal for his experiment to the Physics and Astronomy Programs Directorate at NASA Headquarters. The proposal may have been a response to a general

[65]Personal interview with William R. Witt on Dec. 11, 1968. In the case of DOD, this policy was spelled out in the so-called York Memorandum.

[66]The U.S. Air Force did, of course, carry out scientific experiments from many of its own spacecraft.

solicitation of the scientific community or just "a good idea" on the part of the experimenter.

2. Technical evaluation was carried out by the pertinent science program branch chief at NASA Headquarters to determine the scientific value of the experiment, etc., as discussed in Chapter VI.
3. The Goddard Sounding Rocket Branch determined its ability to provide the requested support.
4. A go-ahead was given and Headquarters provided the funds for the experimenter and the Sounding Rocket Branch.

NASA'S INTERNATIONAL PROGRAMS

A similar procedure was followed if a foreign country was involved. In addition, a draft of a Memorandum of Understanding[67] was prepared by NASA Headquarters (Office of International Affairs), which stipulated what each side would provide. Typically the foreign country supplied the launch crew and launch services, the site, transportation, and the experiment. NASA, in turn, supplied the rocket, knowhow, some instrumentation, launch services, the support equipment, and sometimes part of the experiment. In the beginning of the space program, some countries just wanted to "do something in space" without sufficient background and preparation. Education and the development of research competence, therefore, have been two of Goddard's main functions in the sounding rocket program.

Once the Memorandum of Understanding[68] was signed by both countries, each country appointed a Project Manager, who worked together directly. Work then began, often with a simple payload. As the country's scientific competence increased, more complex experiments were undertaken.

During the period 1960-1964, NASA negotiated Memoranda of Understanding and initiated 13 cooperative programs with the following foreign countries: Argentina, Australia, Canada, France, Germany, India, Italy, Japan, New Zealand, Norway/Denmark, Pakistan, Sweden, and the United Kingdom. The international flights that resulted are summarized in Table 3.[69]

[67]See Appendix D for a typical Memorandum of Understanding. Actually, it was an agreement between NASA and a designated civilian agency in the other country.

[68]When NASA initiated a foreign program, as it sometimes did to obtain geographically propitious sites for eclipse observations or a spot on the magnetic equator, it negotiated a Letter of Agreement with the country involved rather than a Memorandum of Understanding.

[69]The bulk of the information in this table was extracted from the booklet "International Programs," prepared by the NASA Headquarters Office of International Affairs.

TABLE 3. *Cooperative International Programs, 1960-1964*

Country	Location	Date(s)	Details
Argentina	Chamical	Dec. 1964	National University of Tucuman flew ionosphere experiments on 2 NASA Nike-Cajuns.
Australia	Woomera	Sept. 1961-Nov. 1961	Goddard flew ultraviolet astronomy experiments on 4 Skylarks.
	Wallops I.	Apr. 1963-May 1963	Australia launched 2 Aerobee 150As in radio noise experiments.
Canada	Fort Churchill	Continuous	79 NASA launches during period.
	Wallops I.	June 1962-Dec. 1962	Canada launched 6 Black Brant IIIs from Wallops in vehicle tests, while Fort Churchill was inoperative due to fire.
France	Wallops I.	Oct. 1963	France launched 2 Aerobee 150s with ionosphere payloads.
	Hammaguir, Algeria	Apr. 1964	NASA and France jointly studied ionosphere using French Dragon and Centaur rockets.
Germany	White Sands	Nov. 1964	Germany participated in launch of an Aerobee 150 with experiment designed to collect extraterrestrial dust (part of the Luster program).
India	Thumba	Jan. 1964	University of New Hampshire flew 4 Nike-Apaches to investigate equatorial electrojet. (Thumba is on the geomagnetic equator.)
	Thumba	Nov. 1963-Nov. 1964	India's Physical Research Laboratory at Ahmedabad used 7 Nike-Apaches in sodium-vapor experiments.
Italy	Sardinia	Jan. 1961-Dec. 1962	Italian Space Commission launched 8 Nike-Cajuns and Nike-Asps with sodium-vapor experiments.
	Sardinia	May 1963	3 Nike-Apaches fired by NASA with sodium-vapor experiments aboard.
Japan	Wallops I.	Apr. 1962-Oct. 1964	Japanese Radio Research Laboratories and Goddard cooperated in ionospheric studies; 3 Nike-Cajuns, 2 Aerobee 150s, and 1 Javelin launched by Japan.

TABLE 3. *Cooperative International Programs, 1960-1964*–Concluded

Country	Location	Date(s)	Details
New Zealand	Birdling's Flat, N.Z.	May 1963-Dec. 1964	University of Canterbury carried out experiments in upper atmosphere and ionosphere with 3 Arcas rockets.
Norway/Denmark	Wallops I.	Dec. 1961-Apr. 1963	Norway participated with Goddard in launching 3 Nike-Cajuns and 1 Nike-Apache in ionosphere studies.
	Andoya, Norway	Aug. 1962-Mar. 1964	Goddard participated with Norway in a series of 3 Nike-Cajun and 4 Nike-Apache launches with varied instrumentation.
Pakistan	Sonmiani Beach	June 1962-Dec. 1964	Cooperative sodium-vapor experiments using 3 Nike-Cajuns and 4 Nike-Apaches.
Sweden[a]	Jokkmokk	Aug. 1961	Sweden used an Arcas to measure winds in vicinity of noctilucent clouds.
	Kronogard	Aug. 1962-Aug. 1964	Series of noctilucent clouds studied using 8 Nike-Cajuns and 8 Nike-Apaches.
	White Sands	Oct. 1963-Dec. 1963	Sweden fired 3 boosted Arcas rockets with ionospheric payloads.
	Wallops I.	Mar. 1964	Sodium/lithium vapor experiments with a boosted Arcas.
United Kingdom	Wallops I.	July 1964-Nov. 1964	Cooperative British-American experiments in ionospheric physics and radio propagation with 2 Nike-Apaches.
	White Sands	Nov. 1964	Collection of extraterrestrial dust particles with an Aerobee 150 (part of Project Luster).

[a]C. B. Tackett, *Sweden Operations–1962,* NASA TM-X-55174 (1965).

Aside from Canada, which has worked hand in hand with the United States ever since the IGY in the construction, maintenance, and use of the Fort Churchill launch site, Italy was the first country to request and receive sounding rocket support from the United States. Between January 1961 and December 1962, eight Nike-Cajun and Nike-Asps were fired from Sardinia; scientists measured upper atmosphere winds by photographing sodium vapor released from the rockets. In this case, NASA worked directly with the Italian Space Commission.

Most of the countries listed were scientifically and industrially advanced. Some, such as Canada and Australia, had their own rocket programs long before NASA was created. In these cases, the cooperative programs have been primarily concerned with NASA acquiring access to desired launch sites outside the United States or with the foreign countries wanting to employ U.S. sites. With less advanced countries such as Pakistan, NASA's role in helping to develop local technological capabilities has been more significant. For example, NASA began working with the Pakistan Space and Upper Atmosphere Research Committee in 1962, when Nike-Cajuns were used to launch sodium-vapor payloads from Sonmiani Beach, Pakistan. More sophisticated payloads followed.

NASA's international sounding rocket programs, like its cooperative satellite programs, have been highly successful as agents of good will and stimuli to space science around the world.

SOUNDING ROCKET STATISTICS

From the scant 16 sounding rockets fired during 1959, the number launched by Goddard's Sounding Rocket Branch steadily increased to 152 in 1964. Appendix C indicates that the most popular of these rockets in the early years was the Nike-Cajun, a rocket which had been improved only in minor ways since its introduction in 1956. The chief additions to the "stable" were the Aerobee 150A and 300A, the Astrobee 1500, the British Skylark, and the Javelin.

The Aerobee 150A is essentially an Aerobee 150 with four tail fins rather than three. Likewise, the Aerobee 300A is an Aerobee 300 which uses a 150A second stage rather than the older three-fin 150. All rockets in the NASA "stable" show such evolutionary improvements, most of which never get recognized by a change in rocket designation.

The British Skylark sounding rocket was first employed by NASA in 1961 when four were fired from Woomera, Australia, in a program of southern hemisphere stellar photography. No Skylarks have been used by NASA since. The Skylark (originally named the Gassiot High Altitude

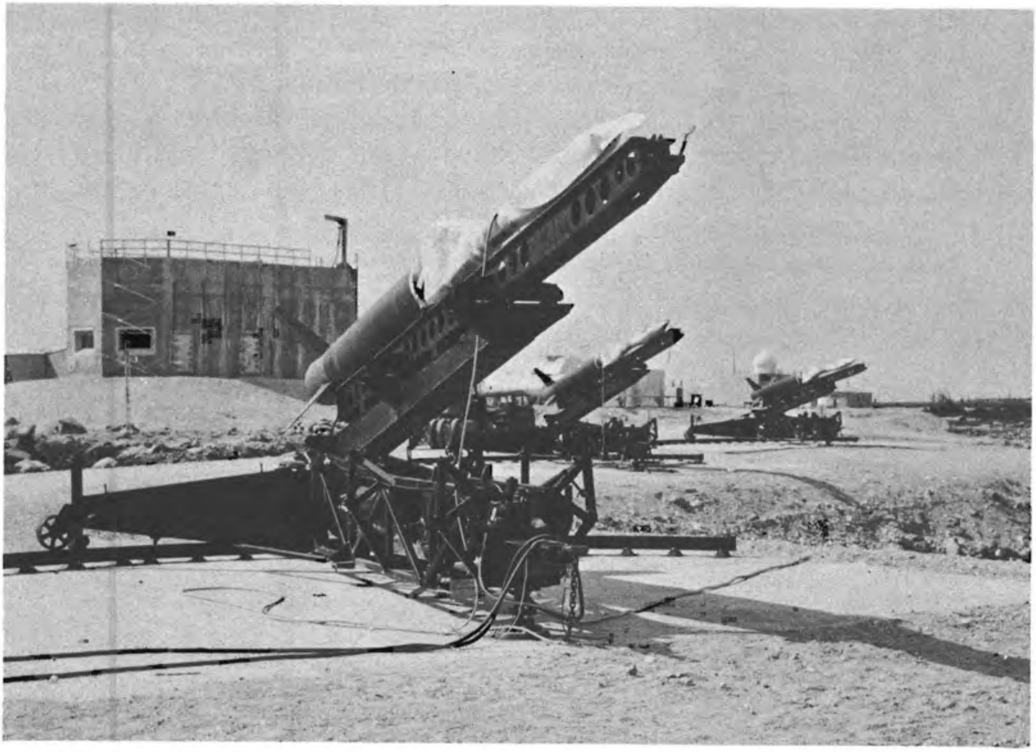
The Astrobee 1500, one of NASA's larger sounding rockets.

Vehicle) was produced by the Royal Aircraft Establishment and was introduced during the IGY.

The Astrobee 1500 was first used by NASA in 1962. It was intended to be a replacement for the large Argo D-8 Journeyman rocket, which NASA used for big payloads and high altitudes. A replacement was necessary because the Journeyman first stage, the Sergeant motor, was becoming increasingly hard to get. Built by Aerojet, the Astrobee 1500 consisted of an Aerojet 100 (Aerojet Junior) first stage augmented by two Thiokol Recruits, plus an Alcor second stage. Like the Journeyman, the Astrobee 1500 has been used only sparingly in NASA's programs, it being unnecessarily big and expensive for most purposes.

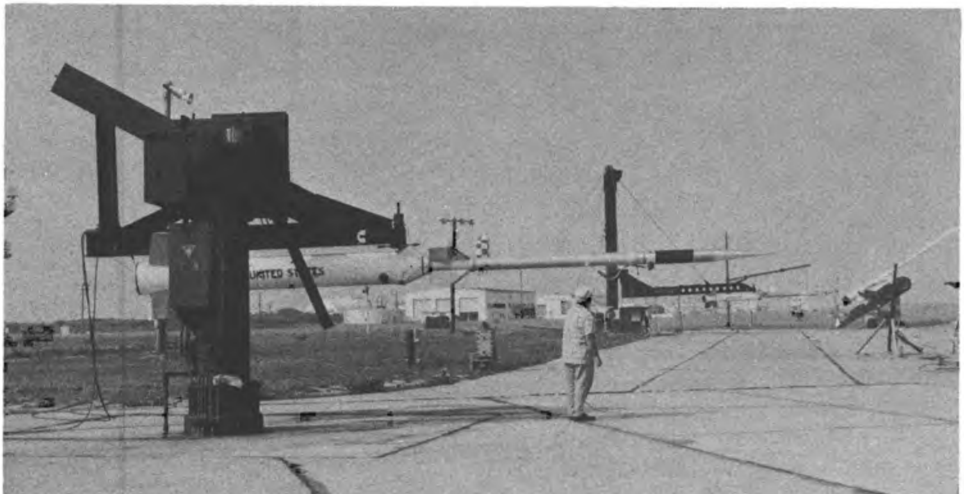
THE NIKE-APACHE AND AEROBEE 350

The most popular sounding rocket introduced during the 1960-1964 period was the two-stage, solid-propellant Nike-Apache, which was similar to the Nike-Cajun in most respects. The primary difference was the propellant



Nike-Apaches ready for launch from Fort Churchill, Manitoba, Canada.

A Nike-Apache on the so-called "universal" launcher at Wallops Station.



and the phenolic lining of the Apache steel nozzle. The Cajun did not have this lining, and the direct exposure of its steel can to high exhaust temperatures was considered undesirable. The Marquardt Asp[70] was tried as a replacement for the Cajun but did not prove satisfactory. NASA eventually adopted the Apache, which had already been developed by Thiokol in Elkton, Md. The Nike-Apache has been fired in large numbers since 1962.

An Aerobee tower launch at Wallops Island.

[70]The Asp was originally developed by the Cooper Development Corp., which was subsequently bought out by Marquardt Corp.

Late in 1961 Aerojet submitted a proposal to NASA for the development of a new member of the liquid-fueled Aerobee series, the Aerobee 350. Goddard let the development contract to Aerojet in 1962 and assigned John H. Lane as Project Manager at Goddard. The 350 was a large Aerobee, consisting of a Nike booster plus a cluster of four Aerobee 150 engines with another 150 as the upper stage. It could launch 227 kg (500 lb) to about 340 km (210 mi) and was designed specifically to give instruments a "soft ride." The Aerobee 350 also incorporated a sophisticated attitude-control system that could select several astronomical targets during flight.[71] The first test of the first "all-Goddard" rocket took place on December 11, 1964, at Wallops Island, when the booster stage was tested successfully with a dummy second stage. The purpose of the test was to check compatibility between the new rocket and the Aerobee launch tower at Wallops. The first complete system test of the Aerobee 350 was successful at Wallops Island on June 18, 1965.

SUBSYSTEMS AND GROUND SUPPORT

When experimenters first began using the captured V-2s in 1946, they discovered to their consternation that a V-2 usually rolled and tumbled so much after its engines ceased operating that instrument pointing was impossible. As specialized research rockets, such as the Aerobees, were introduced, instrument-pointing equipment was developed to aid the scientists. A typical development of the 1950s was the Sunfollower, designed by the University of Colorado. When NASA commenced sounding rocket operations in 1959, it had no choice but to make the experimenters themselves responsible for pointing their experiments. This meant that the experimenters had to go to the University of Colorado or Ball Brothers Corp., a manufacturer in Boulder, for their equipment. In 1962 NASA began its own development of rocket attitude-control devices. Some stellar pointing control work, involving high-precision pointing, was done at Goddard and Space-General, a new subsidiary of Aerojet. Much of the NASA work on solar pointing was carried out at Ames Research Center during the 1965-1968 period. Ames developed a solar pointing system that employed gas jets and a magnetic system for rocket stabilization, the Solar Pointing Aerobee Rocket Control System (SPARCS). This equipment was used for sunspot and solar limb studies.

[71] C. B. Tackett, "Aerobee 350 Rocket Instrumentation," NASA TM-X-63156 (1968); also J. H. Lane and C. P. Chalfant, "Development of the Aerobee 350 Sounding Rocket," AIAA Sounding Rocket Vehicle Technology Specialist Conference (New York, 1967), p. 43.

One of the drawbacks of the Aerobee series of sounding rockets has been their requirement for a special launch tower and other ground facilities. Such equipment was permanently installed at Fort Churchill, Wallops Island, and White Sands. But there were research programs where Aerobee launches from other locations were desirable. To increase the versatility of the Aerobees, Goddard engineers modified a launch tower that was originally used in 1949 for Aerobee launches from the U.S.S. *Norton Sound.* Before NASA acquired this structure it had been modified and used by the Naval Ordnance Test Station (China Lake) for six Aerobee launches from the Bahamas in 1963 and 1964. Goddard modifications to the tower involved shortening the tower and making the entire assembly and associated ground support equipment fully mobile. The result was called the mobile Aerobee launch facility (MALF). MALF was first employed by NASA outside the United States when Aerobee 150s were fired from Natal, Brazil, in 1966 and 1967.[72]

The mobile launch facility used for Aerobee launches. Shown in Brazil, 1966-1967.

An extremely important facet of sounding rocket performance has been reliability. During the early Aerobee work, for example, failure rates were occasionally as high as 20 percent, whereas NASA experienced an overall Aerobee failure rate of only about 10 percent from 1959 through 1964.

[72]Jon R. Busse, "Mobile Aerobee Launch Facility," AIAA Sounding Rocket Vehicle Technology Specialist Conference (New York, 1967), p. 507.

After 1964, the failure rate dropped even lower. The reason for such high performance cannot be assigned to any one specific improvement of many made during the Aerobee's 20-year history. Rather, the increase in Aerobee performance has been the consequence of many cumulative small improvements.[73] Indeed, there have been no really new inventions in sounding rocket technology. The entire technology history is one of slowly improving the state of the art.

RESEARCH TRENDS

The sounding rocket compendium, Appendix B, lists each NASA rocket flight. Obviously there are too many to discuss individually, but some general statements can be made regarding the Goddard program during the five-year period 1960-1964. Table 4 is conclusive in showing that sounding rockets find their greatest application in atmospheric and ionospheric physics. Noteworthy, too, is the fact that few biological experiments were flown during the five years covered in this chapter.[74]

When one examines the 1960-1964 record according to the agency conducting the experiment, Goddard scientists have accounted for almost half of the launches (Table 5). As we shall see in the next chapter, however, university and international flights have become more important with the maturation of the program.

TABLE 4. *Types of Sounding Rocket Experiments, 1960-1964*

Discipline	Flights
Aeronomy	147
Biology	2
Energetic particles	35
Fields	15
Astronomy	29
Ionospheric physics	81
Meteorology	77
Radio astronomy	2
Solar physics	14
Special projects	21
Test and support	30
Total	453

TABLE 5. *Agencies Conducting Experiments, 1960-1964*

Agency	Flights
Goddard	219
Other NASA centers	26
Universities	73
Department of Defense	14
Other Government agencies	7
Industry	75
International	39
Total	453

[73] Pressly interview, Nov. 27, 1968.

[74] This observation holds for scientific satellites, too. NASA has been criticized on occasion for not pursuing more space biological research.

Of the 453 sounding rockets launched during the 1960-1964 period, 265, or 59 percent, began their flights from Wallops Island, making Wallops the undisputed center for sounding rocket research. In the late 1940s and during the 1950s, White Sands was the site of most sounding rocket launches; however, during the period covered by this chapter, only 37 NASA rockets (about 8 percent) were fired there. Of course, the Air Force and other Government agencies with their own rocket programs still use White Sands extensively. During 1960-1964, Goddard fired 79 rockets from Fort Churchill (not counted as international flights); 4 from the Pacific Missile Range; 5 from Eglin Air Force Base, Fla.; and 8 from Ascension Island, which is in the South Atlantic near the end of the Eastern Test Range. In addition to these terra firma launches, six Nike Apaches were launched from the U.S.N.S. *Croatan* in late 1964. The launches occurred in the Atlantic off Wallops Island and in some cases were synchronized with similar launches from shore.

It is difficult to single out any one flight or series of flights for special mention.[75] Several flights involved the feature of payload recovery. The nuclear emulsion recovery vehicle (NERV) and biological satellite (BIOS) flights fall into this interesting class. The first NERV was launched from Point Arguello, part of the Pacific Missile Range, on September 19, 1960, to measure the characteristics of the inner Van Allen belt and determine the effect of the radiation upon mold spores. The flight was completely successful with the capsule being recovered some three hours later nearly 1930 km (1200 mi) away. The two BIOS capsules were also launched from Point Arguello by Journeyman rockets. Launched in November 1961, the BIOS capsules contained nuclear emulsions, biological specimens, and in addition, equipment to collect interplanetary matter.[76] Unfortunately, the BIOS capsules were not recovered. Also of special interest was the series of six Nike-Apache flights attempted from Fort Churchill during the solar eclipse of July 20, 1963. Launched within a three-hour period, the rockets were intended to measure the eclipse's effect on the ionosphere. The first two rockets failed, but the remaining four were successful.

The international phase of the NASA sounding rocket program gathered considerable momentum during the 1960-1964 period, with Goddard launching a total of 48 rockets involving seven countries. (See Table 3.)

[75]For the description of a specific typical flight, see W. P. Fortney, *Instrumentation and Flight Report for Aerobee 150 Flights 4.122 CG and 4.123 CG,* NASA TM-X-55493 (1965).

[76]A number of sounding rocket flights during the 1950s carried so-called "Venus Flytrap Experiments," which were designed to collect micrometeoroid samples at high altitudes. The Project Luster flights in the late 1960s had the same purpose and were more ambitious.

Although the title of this chapter infers that sounding rockets might have been left behind in the dust as space scientists flocked to the new scientific satellites, the rate of sounding rocket launches increased steadily during the 1960-1964 period. Satellites got most of the scientific "firsts" during these five years; but sounding rocket research expanded many times in the disciplines of atmospheric and ionospheric physics, the areas where satellites are of limited usefulness. Sounding rockets were also training aids for experimenters and their equipment. As the middle of the decade approached, more and more scientists began to appreciate the positive advantages of sounding rocket research over satellite research: lack of formality, short lead times, low costs, and more design freedom. The Model T stigma began to disappear from sounding rocket research.

The remainder of this chapter summarizes rocket research results, 1960-1964, in various disciplines.[77]

Meteorology. Some 3500 small rockets (Arcas and Lokis) and a few dozen larger rockets fired from a wide geographical area helped refine our knowledge of winds, temperatures, and other weather-pertinent features of the upper atmosphere. The small rockets were launched by various agencies as part of the cooperative Meteorological Rocket Network. It was learned, for example, that there were consistent exceptions to the supposed steady decline of temperature with altitude in the mesosphere and that circulation systems of the lower mesosphere changed their behaviors abruptly at higher altitudes.

Atmospheric physics. The temperature of the mesopause was variable, generally having its maximum value at high latitudes in the summer with the minimum in the winter. Noctilucent clouds were often associated with the low temperatures in the summer. Strong shear zones were found between 70 and 120 km (44 and 75 mi), apparently arising from internal "gravity waves." The bright auroras were excited by energetic electrons, while the more diffuse and extensive auroras were proton excited. Apparently the Van Allen belts were not the source of the aurora-exciting particles.

Ionospheric physics. The solar spectral regions responsible for ionization were determined throughout the ionosphere. The *F*-region electrons were produced by a wide range of wavelengths. At the magnetic equator, the sporadic *E* layer arose from an acoustic wave generated by a two-stream instability associated with the electrojet. A great deal of data on electron

[77]Extensive details may be found in a series of NASA special publications covering the significant achievements in space from 1958 through 1964: *Space Astronomy*, NASA SP-91; *Ionospheres and Radio Physics*, NASA SP-95; *Satellite Meteorology*, NASA SP-96; *Particles and Fields*, NASA SP-97; *Planetary Atmospheres*, NASA SP-98; and *Solar Physics*, NASA SP-100. All were published in 1966. These reports form the basis for the summary.

temperatures, densities, ionosphere fine structure and irregularities was collected.

Fields and particles. Although the Van Allen belts were discovered by satellites, sounding rockets helped identify the particles and their energies in the inner and outer belts with emulsions and particle spectrometers.

Solar physics. From the beginning, satellites have taken much of the research burden from sounding rockets; viz, the OSOs, the NRL Solrad series, etc. Consequently, sounding rockets have been relegated to testing out instruments destined for future satellites, such as spectrographs and coronagraphs.

Astronomy. In the absence of satellites specifically devoted to astronomy, sounding rockets made the major discovery of discrete X-ray sources outside the solar system. Ten such sources had been found by the end of 1964.

VIII
SOUNDING ROCKET RESURGENCE, 1965-1968

In the January 1966 issue of *Astronautics and Aeronautics*, Colin O. Hines presented an article entitled "Sounding Rocket Resurgence." From this article came the title of this chapter. Eleanor C. Pressly, of Goddard's Sounding Rocket Branch, feels that the word "resurgence" is perhaps not indicative of exactly what happened in the middle 1960s.[78] Most experimenters, she stated, never "left" sounding rockets. Indeed, a study of the number of NASA sounding rockets launched each year (Appendix C) shows a steady increase to about 160 firings per annum, with no significant decreases in recent years despite reductions in the overall NASA budget. The word "resurgence," then, really applies to the reawakening of the scientific community to the value of sounding rockets as research vehicles. The stock of sounding rockets began to rise noticeably in 1965.

Even more indicative of the enhancement of scientists' regard for sounding rockets may be found in the 1969 recommendations of the National Academy of Sciences on the subject of sounding rockets in space research.[79] Specifically, the Committee on Rocket Research of the Space Science Board suggested that NASA increase its annual expenditures to $27 million by 1971 (an increase of 36 percent over fiscal year 1969) with an annual increase of 12 percent thereafter.

Some of the reasons for this enhancement of the sounding rocket mystique have already been mentioned: the fact that only sounding rockets can make direct measurements between 32 and 160 km (20 and 100 mi), their convenience and lack of formality, the short experiment lead times, the low cost, and the greater design freedom. Some additional and more subtle reasons are noteworthy. First, much space research is carried out with the

[78] Pressly interview, Nov. 27, 1968.

[79] Committee on Rocket Research, Space Science Board, *Sounding Rockets: Their Role in Space Research* (Washington, 1969).

help of graduate students in the universities. These students cannot afford to wait around two to five years while a satellite is built, the experiment integrated, and the vehicle launched. The sounding rocket cycle–six months to a year–is much better attuned to graduate research. A second factor concerns the so-called bits-per-buck philosophy, which proponents of scientific satellites often raise when comparing satellites to sounding rockets. It is true that a single satellite of the Observatory class can telemeter back a greater volume of data than all of the sounding rockets NASA launches in a single year. Much of these data are uninteresting, however, and go unanalyzed. When something "interesting" happens in space research, say, the eruption of a solar big flare or the detonation of a high-altitude nuclear weapon, a satellite with the proper instruments may not be in orbit or it may be in the wrong place. Sounding rockets, in contrast, can be launched quickly from almost any spot on Earth. In short, sounding rockets have much greater versatility as to what they measure, when they measure it, and where.

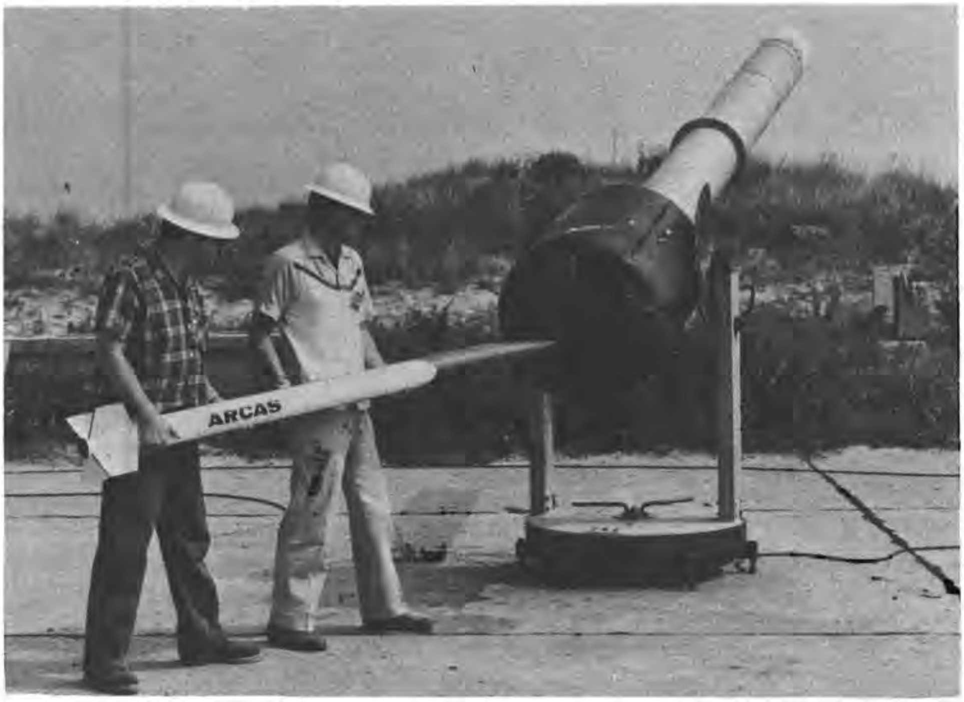
Appendix E portrays the trends in rocket research by scientific discipline. Manifestly, aeronomy, meteorology, and ionospheric physics depend heavily upon rockets because satellites and balloons cannot compete as instrument carriers between 32 and 161 km (20 and 100 mi). The resurgence of sounding rockets is most marked in the discipline of energetic particles. The years 1961, 1962, and 1963 saw an average of only one payload per year; but in 1964, 16 energetic particle payloads were launched by rocket. This increased rate has been maintained since then. The best explanations for the three-year decline and subsequent resurgence must be those we have listed and, in addition, a focusing of attention on the low-altitude auroral zones.

Another discipline that has waxed strong recently with sounding rocket vehicles is galactic astronomy. Some of this heavy use of sounding rockets is attributable to the long delays in launching a successful Orbiting Astronomical Observatory (OAO), but undoubtedly some astronomers are attracted by the simplicity and short cycle time of rockets over the OAO-class spacecraft.

In the context of payload simplicity, there was initially a trend in the early part of the 1965-1968 period toward multidisciplinary sounding rockets–a movement that paralleled the trend away from simple Explorer satellites to multidisciplinary observatories. Some of the bigger rockets, such as the Aerobee 350, had ample room for several experiments. But this trend was actually a regression, in a sense, back to the multidisciplinary V-2s with all the attendant problems of matching interfaces between experiments.

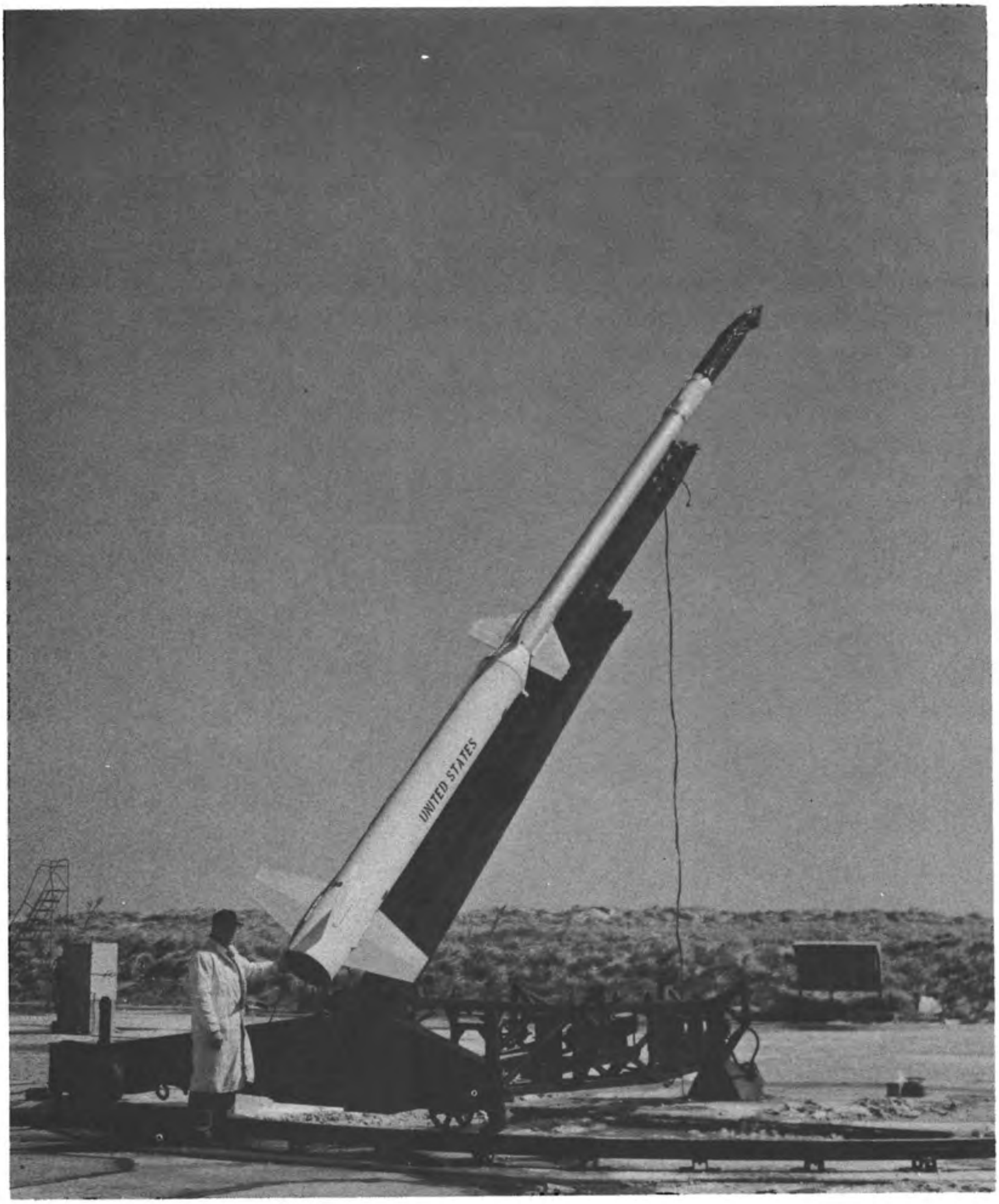
In the preceding chapter, the Aerobee 350 and its development were described. As indicated in Appendix C, this rocket was first tested in 1965 and 1966. The Aerobee 350, however, was not used operationally until the end of 1969.

During 1965 Goddard began using the Arcas sounding rocket, a vehicle first used back in 1958 by the Navy and in 1959 by Langley Research Center and Wallops. The Arcas was an inexpensive rocket, costing only about $2000 per round. Perhaps 2000 were fired each year, mainly for meteorological purposes. It was also a good rocket for launching small payloads to moderate altitudes–5.4 kg (12 lb) to 64 km (40 mi), nominal performance, and employed no special launch equipment. It was therefore eminently suited for NASA's international programs. The Arcas was put into service in Norway, New Zealand, and other countries during the 1965-1968 period. The rockets were purchased directly from the Atlantic Research Corp.



The Arcas tube-launched meteorological rocket.

The Nike-Tomahawk also saw considerable operational use by NASA beginning in 1965. Originally developed by the Thiokol Chemical Corp. for Sandia Corp., the acting agent for the AEC, the Nike-Tomahawk carried a larger payload to higher altitudes than the Nike-Apache.



A Nike-Tomahawk at Wallops Station.

The most interesting addition to the NASA "stable" during the 1965-1968 period was the Black Brant IV, a rocket built by Bristol Aerospace, Ltd., in Winnipeg. There was some controversy within Goddard regarding the desirability of purchasing a rocket from a foreign country when many American manufacturers build a large variety of sounding rockets. According to Karl Medrow, Chief of Goddard's Sounding Rocket Branch,[80] the Black Brant had three positive features that led to its selection:

1. The Black Brants were operational with performance that no American manufacturer could match with off-the-shelf vehicles. (Note: NASA paid only for a propellant change in the Black Brant to improve performance. The U.S. Air Force also contributed financially to the development of the Black Brant series.)
2. The Black Brant used no military hardware and could thus be fired from foreign countries.
3. The Black Brant represented the cheapest way to get the job done.

By the end of 1968, NASA had fired two Black Brant IVs: one with a Canadian payload from Wallops Island on May 7, 1968, and a second from Brazil with a radiation payload provided by the Manned Spacecraft Center, on June 11, 1968.

Appendixes C and E summarize the launch activities of the Goddard Sounding Rocket Branch by rocket vehicle and discipline during the 1965-1968 period. NASA sounding rocket funding is recapitulated in Appendix F. The trends in these areas were covered earlier in this chapter. At this point, some of the more important domestic and international programs are related.

Almost 700 sounding rockets were managed by Goddard Space Flight Center in the four-year period 1965-1968. (See Appendix B for listing.) Most were launched from Wallops Island, Fort Churchill, and White Sands. The instrumentation reflected the emphasis on aeronomy, meteorology, and ionospheric physics portrayed in Appendix E—that is, pitot tubes, grenade experiments, ion probes, etc. While these programs formed the basic fabric of the sounding rocket program, there was also a long series of firings from the U.S.N.S. *Croatan* during 1965, three major eclipse expeditions,[81] and a continuation of the highly successful international program.

The 1965 shipboard firings were part of NASA's contribution to the International Year of the Quiet Sun (IQSY). A total of 77 Nike-Cajuns, Nike-Apaches, and small Arcas meteorological rockets were launched from Wallops' mobile range facility on the U.S.N.S. *Croatan,* while it steamed along the west coast of South America between March 8 and April 22, 1965.[82] The experiments were aimed at determining the states of the upper

[80] Medrow interview, Dec. 11, 1968.

[81] E. E. Bissell, *Report on United States-New Zealand Solar Eclipse Project,* NASA TM-X-55519 (1966).

[82] *Astronautics and Aeronautics, 1965,* NASA SP-4006 (1966), pp. 110, 121, 163, 195.

atmosphere and ionosphere during solar sunspot minimum, particularly the so-called "equatorial electrojet." The instrumentation was provided by the Universities of Michigan and New Hampshire, Goddard Space Flight Center, and others.

The U.S.N.S. Croatan, *the Wallops mobile range facility, used during the IQSY firings along the west coast of South America during 1965.*

A much shorter series of launches continued Project Luster, an effort by NASA's Ames Research Center to collect samples of dust and micrometeoroids in the upper atmosphere. The first Luster payload was launched from White Sands on November 16, 1964, on an Aerobee 150 with the intent of collecting meteoric debris during the Leonid meteor showers. Further flights occurred on November 16, 1965 (an Aerobee 150), November 18, 1965 (a Nike-Apache), and October 22, 1966 (an Aerobee 150)–all from White Sands. The samples collected from altitudes of 160 km (100 mi) were distributed in the United States and Europe.[83] During Project Luster, the Goddard Sounding Rocket Branch provided rockets and launch services, while Ames Research Center was responsible for the payloads. This is the typical relationship between the Sounding Rocket Branch and any experimenter, whether from Government, university, industry, or a foreign country.

Ames Research Center has also been involved in the development of attitude-control equipment for sounding rockets, notably SPARCS, as mentioned in Chapter VII. The first flight test of SPARCS took place on December 10, 1967, when an Aerobee 150 was fired from White Sands. The test was partially successful.

Cooperative sounding rocket programs with foreign countries expanded considerably during the 1965-1968 period. Close to half of NASA's sounding rocket launches occurred on foreign soil–particularly at polar and equatorial sites essential to studies of auroral and equatorial electrojet phenomena. Several new countries–Brazil, Greece, Israel, the Netherlands, and Spain–concluded agreements with the United States, and ongoing programs with other countries increased in size. Because of the importance of these international flights to NASA's mission, they are all listed in Table 6.[84]

The remainder of the chapter summarizes rocket research results, 1965-1968, in various disciplines.[85]

Atmospheric physics and meteorological research. Using a new ionized barium technique, electric fields were measured for the first time in the upper atmosphere. They seemed to be about 100 times stronger than at lower altitudes. The vertical profile of neutral helium was measured up to 1000 km (620 mi).

[83] *Ibid.*, pp. 518, 521. Also *Astronautics and Aeronautics, 1966,* NASA SP-4007 (1967), p. 326. See Table 6 for countries involved.

[84] The bulk of the information in this table was extracted from the booklet "International Programs," prepared by the NASA Headquarters Office of International Affairs.

[85] The detailed achievements of NASA space science programs during the 1965-1966 period may be found in *Space Science 1965,* NASA SP-136 (1967), and *Space Science, 1966,* NASA SP-155 (1967).

TABLE 6. *Cooperative International Programs, 1965-1968*

Country	Location	Date(s)	Details
Argentina	Tartagal	Nov. 1966	Argentine scientists studied upper atmosphere during eclipse of Nov. 12, 1966, with 12 Arcas rockets.
	Wallops I.	Nov. 1966	3 tests of the Argentine-built Orion rockets.
	Chamical	Sept. 1967	National University of Tucuman studied ionosphere with 2 Nike-Apaches.
	Chamical	Apr. 1966-Apr. 1968	As part of the Experimental Inter-American Meteorological Rocket Network (EXAMETNET), Argentina launched 38 Arcas rockets and boosted Darts.
	Mar Chiquita	May 1968-Dec. 1968	EXAMETNET operations moved; 19 more Arcas rockets and boosted Darts fired.
Brazil	Wallops I.	Aug. 1965	Brazilian and Goddard scientists launched a Nike-Apache to study effect of cosmic rays on ionosphere.
	Natal[a]	Dec. 1965	As above; 2 Nike-Apaches.
	Natal	Jan. 1966-Dec. 1968	EXAMETNET operations (see Argentina); included the launching of 52 Arcas rockets and boosted Darts.
	Natal	May 1966-Mar. 1968	Brazilian and Goddard scientists employed grenades to study upper atmosphere; 25 Nike-Cajuns used.
	Cassino	Nov. 1966	17 sounding rockets of various types launched by U.S. and Brazilian experimenters during the total solar eclipse on Nov. 12, 1966.
	Natal	Dec. 1966	Using an Aerobee 150, Catholic University experimenters identified new X-ray sources in the southern hemisphere.
	Natal	Mar. 1967	Variety of experiments prepared by the University of New Hampshire launched on a Nike-Tomahawk.
	Natal	June 1967	In a tripartite agreement, German scientists used 2 Javelins in a variety of experiments and tests of equipment for the German Research Satellite.

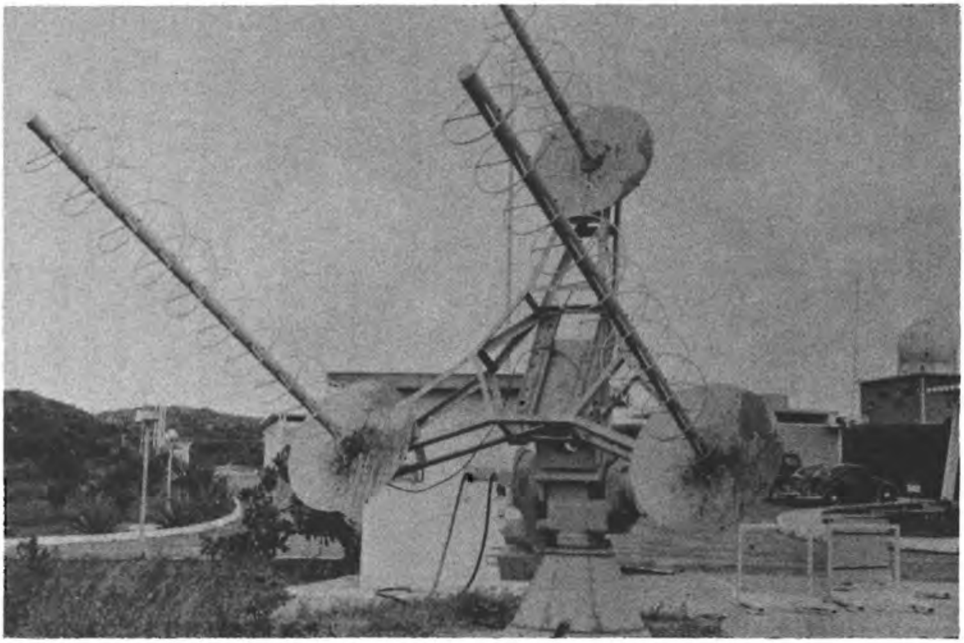
	Natal	Nov. 1967	Air Force Cambridge Research Laboratories launched 1 Aerobee 150 and 2 Nike-Iroquois rockets in airglow and micrometeoroid experiments.
	Natal	June 1968-Dec. 1968	Using 3 Black Brant IVs, Goddard and the Manned Spacecraft Center made radiation belt measurements.
	Natal	1968	Air Force Cambridge Research Laboratories measured meteoroid flux with recoverable payloads on 4 Nike-Iroquois rockets.
Canada	Fort Churchill	Continuous	127 NASA launches during period.
	Resolute Bay	Oct. 1967-Dec. 1968	Canadian and Goddard scientists fired 12 boosted Arcas rockets in studies of particle absorption and ionosphere in polar regions.
	Wallops I.	May 1968	With a Black Brant IV, Canadian engineers tested satellite instrumentation and measured radio noise.
France	Wallops I.	Sept. 1965	Electron density and VLF field strength measured with Aerobee 150 payload.
	White Sands	Nov. 1965, June 1967	French experimenters provided part of Project Luster payloads (Aerobee 150s).
Germany	White Sands	Nov. 1965, Oct. 1966, June-Aug. 1967	German scientists collected dust samples as part of Project Luster (4 Aerobee 150s).
	Wallops I.	Aug. 1966	German researchers measured electron density using a Nike-Apache.
	Wallops I.	Sept. 1966	A Javelin and Nike-Tomahawk were used in experiments dealing with cometary physics, the magnetosphere, and the interplanetary plasma.
	Fort Churchill	Nov. 1966	German scientists tested instrumentation for German Research Satellite and performed various experiments using a Nike-Apache.
	Kiruna, Sweden	Apr. 1967-Apr. 1968	Same as Wallops Island location for Sept. 1966, using 10 Nike-Apaches.
	Natal, Brazil	June 1967	Same as Fort Churchill location for Nov. 1966, using 2 Javelins.

[a]Natal, Brazil, was especially desirable as a sounding rocket launch site because it is within sounding rocket range of the South Atlantic anomaly.

TABLE 6. *Cooperative International Programs, 1965-1968*—Concluded

Country	Location	Date(s)	Details
	Kiruna, Sweden	Dec. 1967	Same as above, using 1 Nike-Apache.
	Thumba, India	Mar. 1968	Germany and India cooperated in barium ion cloud experiment with 4 Nike-Apaches.
	Kiruna, Sweden	June 1968	Micrometeoroid detection experiments, using 2 Nike-Apaches.
Greece	NASA ship off Greece	May 1966	Goddard scientists studied ionosphere during total solar eclipse.
India	Thumba	1964-1966	30 boosted Darts fired in meteorological program supporting the Indian Ocean Expedition.
	Thumba	Mar. 1966-Dec. 1968	Long series of various experiments prepared by the Physical Research Laboratory at Ahmedabad launched by 15 Nike-Apaches.
	Thumba	1968	New Delhi National Physical Laboratory measured electron/ion densities, Lyman-alpha radiation, and X-rays with a Nike-Apache payload.
	Thumba	Mar. 1968	Goddard payloads on 2 boosted Arcas rockets investigated electron density in equatorial ionosphere.
Israel	White Sands	Nov. 1965, Oct. 1966, June-Aug. 1967	University of Tel Aviv participated in Project Luster Aerobee firings to gather samples of extraterrestrial dust.
Japan	Wallops I.	Apr. 1962-Oct. 1964	Goddard and Japanese Radio Research Laboratories measured electron temperature and density using 3 Nike-Cajuns, 2 Aerobee 150s, and 1 Javelin.
	Wallops I.	Apr. 1967	Japanese scientists fired 10 boosted Arcas rockets and 10 Japanese MT-135 rockets in a series of meteorological experiments.
The Netherlands	Coronie, Surinam	Sept. 1965	4 Nike-Apaches fired in sodium-vapor experiments.
	White Sands	Oct. 1967	An Aerobee 150 launched by the Laboratory for Space Research to investigate spatial distribution of solar X-ray sources.

New Zealand	Karikari Peninsula	May 1965	Goddard and the University of Canterbury used 7 boosted Arcas rockets (one a test vehicle) to measure electron density and ionospheric absorption.
Norway/Denmark	Andoya	Mar. 1965-Mar. 1967	Goddard and Norwegian scientists cooperated in a series of ionospheric physics and energetic particles experiments. Vehicles: 3 Nike-Cajuns, 12 Nike-Apaches, 2 boosted Arcas rockets.
	Andoya	Mar. 1966	Goddard and Norwegian cooperative experiment using an ion spectrometer launched by a Nike-Apache.
	Wallops I.	1968	Same as above, using a Nike-Apache.
	Andoya	Aug. 1967-1968	Polar ionosphere and radiation instrument launched on 4 Sidewinder-Arcas rockets by Goddard and Norway.
	Andoya	Sept. 1967	6 Nike-Tomahawks fired to compare techniques for measuring electric fields.
	Andoya	1968	Near-simultaneous launches of barium payloads and instruments to measure particles, and magnetic and electric fields. 5 Nike-Tomahawks used.
Pakistan	Sonmiani Beach	1964-1967	32 boosted Darts launched as meteorological support for Indian Ocean Expedition.
	Sonmiani Beach	Apr. 1965-Nov. 1967	Pakistani and British scientists combined to make meteorological experiments using grenades released from 2 Nike-Cajuns and 4 Nike-Apaches.
	Sonmiani Beach	Feb. 1966	Cooperative experiment; sodium-vapor payloads on 2 Nike-Apaches.
Spain	Huelva	Oct. 1966-1968	National Aerospace Institute used boosted Darts to make meteorological measurements.
Sweden	Andoya	Mar. 1965	2 boosted Arcas rockets and 2 Nike-Apaches launched in auroral and ionospheric physics experiments.
	White Sands	Nov. 1965	Swedish scientists participated in Project Luster.
United Kingdom	White Sands	Nov. 1964, Nov. 1965, Oct. 1966	British scientists participated in Project Luster.
	Sonmiani Beach	Apr. 1965-Nov. 1967	Nike-Cajun and Nike-Apache launched in conjunction with Pakistan. Grenades released by 2 Nike-Cajuns and 4 Nike-Apaches.



Antenna in front of range buildings at Natal, Brazil.

Static test stand for small experimental rocket motors at Thumba Space Sciences and Technology Center India.

Arcas being loaded into launch tube, Thumba, India.

Ionospheric physics. The eclipse expeditions revealed the collapse of the lower ionosphere as the Moon cut off solar radiation. The effects of the Lyman-alpha solar line on the *D*-region during the eclipse led to a better understanding of the mechanisms creating the ionosphere. The electron temperature in the ionosphere was found to drop more than 15 percent at 190 km (118 mi) during totality.

Solar physics. Improved instrument-pointing equipment led to high-resolution ultraviolet and X-ray pictures of the Sun's surface. During the eclipse expeditions, the Moon was employed as part of the experiment to help pinpoint sources of radiation on the Sun's surface.

Astronomy. Many new X-ray sources were found. Two classes of X-ray sources were differentiated. One was associated with optical emissions; the other was not. Ultraviolet astronomy also made progress as many spectrograms of stars in the 1000-2000 Å region were taken. Lines of carbon, silicon, and nitrogen were observed. The effect of absorption on the Lyman-alpha line due to interstellar hydrogen was observed, but the results conflicted with those from radio astronomy. Collection of interplanetary dust during Project Luster indicated that the dust particles were complex, irregular, and highly vesicular. They might have been the remnants of disintegrated comets.

IX

A SUMMARY OF SOUNDING ROCKET DEVELOPMENT

Sounding rockets have been operational on a regular basis since 1945 when the first Wac Corporal flew successfully. Since then, they have become an ever more useful tool of space science. NASA launches roughly 150 sounding rockets a year; collectively other U.S. agencies match that figure. Thousands of small meteorological rockets are also used each year. Looking at the unfolding of sounding rocket technology within NASA, developments may be summarized as follows:

- NASA has concentrated all sounding rocket development and procurement at Goddard Space Flight Center. The basic Goddard sounding rocket organization was transferred from the Naval Research Laboratory in December 1958 and has remained essentially unchanged since that time.
- Goddard has not had to develop a new "stable" of sounding rockets. Utilizing the Aerobees, Nike-Cajuns, and other off-the-shelf rockets (many originally developed by PARD), NASA has been able to meet most needs of the scientific community. New vehicle developments that have been considered essential to its mission have been the Aerobee 170, Aerobee 350, Nike-Apache, Nike-Tomahawk, Javelin, and Black Brant. Except for the Black Brants, these rockets were primarily modifications or new combinations of existing hardware.
- The development of accurate attitude-control devices has greatly increased the effectiveness of sounding rockets in space astronomy and solar physics.
- With the coming of scientific satellites, sounding rockets temporarily seemed obsolete for space research. But their intrinsic simplicity and low cost, their short lead times, and the informality of sounding rocket research have effectively erased that stigma.

- NASA's cooperative international sounding rocket programs have expanded greatly over the past decade, involving some 19 countries. Such programs have helped enhance U.S. prestige all over the world.
- Satellites are more spectacular and have made many major discoveries in space science, but sounding rockets have not been accorded their fair share of credit for new discoveries and the elucidation of recognized phenomena in space science.

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APPENDIX A
SHORT DESCRIPTIONS OF MAJOR SOUNDING ROCKETS

During the preparation of this brief history, the writer had to organize a card file of major sounding rockets in self-defense. It seemed as though almost every permutation and combination of extant rocket stages had been used at one time or another. Furthermore, various names had been applied to the same vehicle. To aid the reader, this glossary of major sounding rockets has been prepared.

Aerobee Hawk: See Aerobee 75.

Aerobee-Hi: See Aerobee 150.

Aerobee Junior: See Aerobee 100.

Aerobee 75: (Aerobee Hawk) Developed by Aerojet for the Army Signal Engineering Laboratory. First flight in 1958. Theoretically could lift 45 kg (100 lb) to 120 km (75 mi). Abandoned.

Aerobee 90: Combination of Hawk and Sparrow missiles. Designed to lift 18 kg (40 lb) to 125 km (78 mi). All other Aerobees had liquid main stages. A "paper" rocket.

Aerobee 100: (Aerobee Junior) Developed by Aerojet on company funds. Twenty fired between 1947 and 1961. Could lift 18 kg (40 lb) to 160 km (100 mi).

Aerobee 150: (Aerobee-Hi) The Aerobee 150 was actually an improved Aerobee-Hi, but differences were slight. This became the so-called "standard Aerobee." Developed by Aerojet. First used in 1955. Navy and Air Force versions existed. Many slightly different models. Could lift 68 kg (15 lb) to 275 km (170 mi).

Aerobee 150A: Similar to Aerobee 150 except it had four rather than three stabilizing fins. First flight in 1960.

Aerobee 170: An Aerobee 150A with a Nike solid-propellant booster.

Aerobee 300: (Spaerobee) Aerobee 150 plus a Sparrow third stage. Developed by Aerojet with Navy funds under technical direction of NRL. First used in 1958. Could lift 23 kg (50 lb) to 480 km (300 mi).

Aerobee 300A: An Aerobee 300 with the Aerobee 150 stage replaced by an Aerobee 150A.

Aerobee 350: Main stage employed four clustered Aerobee 150 stages; the upper stage was another Aerobee 150. A Nike booster was used. Developed by Space-General (Aerojet) for Goddard. A large rocket, it could lift 227 kg (500 lb) to 340 km (210 mi).

Arcas: (*A*ll-*P*urpose *R*ocket for *C*ollecting *A*tmospheric *S*oundings) Developed by the Atlantic Research Corp. for the Office of Naval Research (ONR) with the support of the Navy Bureau of Aeronautics and the Air Force Cambridge Research Laboratories. Primarily a meteorological rocket, the Arcas used a launching tube. First firing in July 1959. Designed to lift 5.4 kg (12 lb) to 64 km (40 mi). Two versions of the boosted Arcas exist. Also used with Sidewinder missile.

Archer: A small solid-propellant rocket developed by the Atlantic Research Corp. Introduced in 1962 for the IQSY. Could lift 18 kg (40 lb) to 160 km (100 mi).

Arcon: Similar to the Deacon and Cajun. Developed by the Atlantic Research Corp. for NRL. First used in 1958. Designed to lift 18 kg (40 lb) to 113 km (70 mi).

Argo series: All of the rockets in this series were adaptations by the Aerolab Development Co. of Langley-designed vehicles. The Argos are all relatively large rockets. An Argo glossary follows.

Argo A-1: (Percheron) Modified Sergeant plus 2 Recruits. Used on occasion by Langley Research Center. Could lift 180 kg (400 lb) to 177 km (110 mi).

Argo D-4: (Javelin) Honest John plus 2 Nike-Ajax plus X-248. First NASA use in 1959. Could lift 45 kg (100 lb) to 800 km (500 mi).

Argo D-8: (Journeyman) Modified Sergeant plus Lance plus Lance plus X-248. A NASA development. First NASA use in 1960. Could lift 68 kg (150 lb) to 1600 km (1000 mi).

Argo E-5: (Jason) Honest John plus Nike plus Nike plus Recruit plus T-55. First used in 1958, Air Force used in Project Jason during the Argus high-altitude nuclear tests.

Arrow: A version of the Loki solid-propellant motor.

Asp: (*A*tmospheric *S*ounding *P*rojectile) Developed by Cooper Development Corp. for the Naval Radiological Defense Laboratory. Flight test in 1956. Could lift 13.6 kg (30 lb) to 40 km (25 mi).

Aspan: (Nike-Asp) Rail-launched vehicle consisting of an Asp plus a Nike booster. Product of the Cooper Development Corp. Could lift 27 kg (60 lb) to 260 km (160 mi). Also an improved version, the Aspan 300.

Astrobee 200: Similar to the Aerobee 150, with a higher acceleration regime. Developed by Aerojet for the Air Force Cambridge Research Laboratories. Designed to lift 57 kg (125 lb) to 320 km (200 mi).

Astrobee 250: Developed by Aerojet. Designed to lift 227 kg (500 lb) to 345 km (215 mi).

Astrobee 500: Developed by Aerojet for the Air Force Cambridge Research Laboratories. Could lift 18 kg (40 lb) to 800 km (500 mi).

Astrobee 1500: A large sounding rocket originally developed by Aerojet for the Air Force. Consisted of an Aerobee 100 (Aerobee Junior) augmented by two Recruits plus an Alcor second stage. Replacement for the Journeyman. First launch attempt by NASA on April 8, 1963, at Wallops Island was a failure. Used sparingly by NASA for heavy payloads and very high altitudes. Could lift 34 kg (75 lb) to 2414 km (1500 mi).

Black Brant: A series of sounding rockets developed by Bristol Aerospace Ltd., Winnipeg, primarily for the U.S. Air Force. The important models are:
Black Brant III: 39.5 kg (88 lb) to 184 km (114 mi)
Black Brant IV: 38.5 kg (85 lb) to 926 km (575 mi)

Black Brant VA: 136 kg (300 lb) to 185 km (115 mi)

Black Brant VB: 136 kg (300 lb) to 386 km (240 mi)

Marshall Space Flight Center used Black Brants in Apollo research. Goddard financed some recent Black Brant development and added the Black Brant IV to its "stable." The first Black Brant firing in November 1961 at Wallops was unsuccessful.

Boa: A Marquardt sounding rocket consisting of an Honest John plus Nike plus Nike. Could lift 227 kg (500 lb) to 108 km (67 mi).

Cajun-Dart: A small rocket developed by Space Data Corp. under contract to Marshall Space Flight Center. First tests at Eglin Air Force Base in August 1964. 80- to 96-km (50- to 60-mi) range. Used at Cape Kennedy as a chaff rocket.

CAN: See Nike-Cajun.

DAN: See Nike-Deacon.

Deacon: A rocket motor developed by Allegany Ballistics Laboratory for the Navy Bureau of Ordnance as one of a series of missile solid-propellant motors (Curate, Vicar, etc.). First fired at Wallops Island in April 1947. NACA used extensively for firing aerodynamic models. Later used in Terrapin rocket, on many rockoon flights, and by NASA in the Nike-Deacon sounding rockets. Superseded by the Cajun. Used alone, it could lift 9 kg (20 lb) to 80 km (50 mi).

Deacon-Arrow: A small rocket developed by Sandia Corp. for use in nuclear weapons tests. Could lift 9 kg (20 lb) to 77 km (48 mi).

Exos: A development of the Air Force Cambridge Research Laboratories, assisted by NACA and the University of Michigan. Consisted of an Honest John plus Nike-Ajax plus Recruit. First fired from Wallops Island on June 26, 1958. Could lift 18 kg (40 lb) to 480 km (300 mi).

Farside: A type of rockoon developed by Aeronutronics Systems, Inc. The rocket consisted of 4 Recruits plus 1 Recruit plus 4 Asps plus 1 Asp. Fired from a General Mills balloon at about 30 km (19 mi), it was used to probe at very high altitudes. Could lift 1.8 kg (4 lb) to 6437 km (4000 mi). Project Farside fired six rockets in the fall of 1957.

Hasp: (*H*igh *A*ltitude *S*ounding *P*rojectile) This small rocket was a converted Loki missile modified by the Naval Ordnance Laboratory. Hasps were fired from 127-mm (5-in.) guns. Could lift 2.7 kg (6 lb) to 29 km (18 mi).

Hawk: (Loki II) A modified Loki II developed by JPL for Army Ordnance and manufactured by Cooper Development Corp. Used extensively during the IGY from the ground and from rockoons. Could lift 3.6 kg (8 lb) to 121 km (75 mi).

Iris: Development of this Atlantic Research Corp. small sounding rocket began with NRL as the contract monitor but was completed by NASA. First NASA firing at Wallops Island on July 22, 1960. Rarely used today. Could lift 45 kg (100 lb) to 320 km (200 mi).

Jaguar: An air-launched rocket developed by the Air Force Special Weapons Command. Consisted of 3 Recruits plus 1 Recruit plus a one-fifth-scale Sergeant. Fired from a B-47 in the late 1950s to explore the Van Allen belt. Could lift 15.9 kg (35 lb) to about 800 km (500 mi).

Jason: (Argo E-5) Copy of a five-stage PARD research vehicle made by Aerolab for the Air Force (AFSWC) for use in the Jason program, which measured the trapped radiation from the Argus nuclear tests in the latter half of 1958.

Launched from Cape Kennedy, Wallops, and Puerto Rico. Consisted of an Honest John plus Nike plus Nike plus Recruit plus a T-55 as the fifth stage. NASA also planned to employ this rocket but never did.

Javelin: See Argo D-4.

Journeyman: See Argo D-8.

Loki: A missile motor developed by JPL for Army Ordnance and manufactured by Cooper Development Corp. Originally an antiaircraft rocket, the Loki was used extensively on rockoons during the IGY. The Loki II was the Hawk. Naval Ordnance Laboratory converted the Loki II into the Hasp. JPL fired the first Loki on June 22, 1951. Loki I could lift 3.6 kg (8 lb) to 92 km (57 mi).

Nike-Apache: A small rocket almost identical to the Nike-Cajun, with which it was interchangeable depending on the payload and altitude desired. The Apache motor was manufactured by Thiokol. One of the most commonly used rockets in the NASA "stable." First test firing from Wallops Island on May 25, 1961. Could lift 45.4 kg (100 lb) to 160 km (100 mi).

Nike-Asp: See Aspan.

Nike-Cajun: (CAN) Developed by NACA in conjunction with the University of Michigan, sponsored by the Air Force Cambridge Research Laboratories. Many launches during the IGY. Still used by NASA in large numbers. First tested at Wallops Island on July 6, 1956. Could lift 34 kg (75 lb) to 160 km (100 mi).

Nike-Deacon: (DAN) The predecessor of the Nike-Cajun. A cooperative development effort between NACA and the University of Michigan, with the sponsorship of the Air Force. Used by NACA in 1954 for aerodynamic tests. Used widely during the IGY. First firing at Wallops Island on November 19, 1953. Could lift 27.2 kg (60 lb) to 97 km (60 mi).

Nike-Genie: A development of Sandia Corp. Could lift 74.8 kg (165 lb) to 50 km (31 mi).

Nike-Iroquois: An Air Force sounding rocket. Iroquois stage manufactured by Thiokol. Could lift 19.9 kg (44 lb) to 217 km (135 mi).

Nike-Javelin: An Air Force sounding rocket.

Nike-Nike: See Python.

Nike-Recruit: First launched December 21, 1956.

Nike-Tomahawk: Developed by Sandia Corp. for nuclear weapons work. Could lift 45.4 kg (100 lb) to 322 km (200 mi). NASA has used the Nike-Tomahawk for research purposes since 1965.

Oriole: A Dart boosted by a Loki I. Development by the Army Signal Corps with the University of Maryland. First fired from shipboard off Virginia in September 1957. Could lift 1.6 kg (3.6 lb) to about 130 km (80 mi).

Pegasus: A large sounding rocket developed by Lockheed Missiles & Space Co. Consisted of a modified Sergeant plus 3 Recruits plus 1 Recruit. Could lift 90.7 kg (200 lb) to 1770 km (1100 mi).

Phoenix: A small two-stage sounding rocket developed for the Air Force by the Rocket Power Co. Instrumented by the University of Maryland. Could lift 9 kg (20 lb) to 274 km (170 mi).

Purr-kee: A boosted Dart used by the Naval Ordnance Laboratory in meteorological research. Manufactured by American Machine & Foundry.

Python: (Nike-Nike) A Marquardt rocket. Could lift 113.4 kg (250 lb) to 30 km (18 mi).

Ram A: A rocket employed by NACA-Langley for accelerating aerodynamic models. Consisted of: (stage 1) a Castor plus 2 Recruits; (stage 2) a Skat; (stage 3) a Skat; and (stage 4) a Recruit. Could lift 34 kg (75 lb) to 1271 km (790 mi).

Robin: An Arcas rocket modified to carry balloons for radar-tracking experiments. Built by Atlantic Research Corp. for the Air Force and Navy.

Rockaire: A generic term applied to aircraft-launched rockets. First tested by the Navy on August 16, 1955, when a small 69.9-mm (2.75-in.) rocket attained 54 864 m (180 000 ft) altitude off Wallops Island. Rarely used for scientific research.

Rockoon: A generic term for balloon-launched rockets. (See Chapter IV for development history.) Deacons and Lokis (Hawks) were launched from several types of balloons before and during the IGY. Rockoons could lift 11.3 kg (25 lb) to approximately 113 km (70 mi). Project Farside employed the rockoon concept. Rarely used today.

Roksonde: A family of small boosted Darts used to eject chaff at high altitudes. Manufactured by Marquardt Corp. (formerly Cooper Development Corp.). Models 100 and 200. The Roksonde 100 used a Loki booster.

Sergeant-Delta: A large rocket used by NASA in Project Shotput in preparation for launching the Echo satellites. Consisted of a Sergeant plus 2 strapped-on Recruits plus a Delta X-248 second stage.

Sidewinder-Arcas: An Arcas rocket boosted by the Navy Sidewinder missile motor.

Sidewinder-Raven: The British Raven rocket boosted by a Navy Sidewinder missile.

Spaerobee: See Aerobee 300.

Sparrow-Arcas: An Arcas rocket boosted by a Sparrow missile motor.

Strongarm: A large five-stage rocket developed by the Army Ballistics Research Laboratory with the cooperation of the University of Michigan. Consisted of an Honest John plus Nike plus Nike plus modified Recruit plus a scaled-down Sergeant. Fired first from Wallops Island on November 10, 1959. Could lift 6.8 kg (15 lb) to 1600 km (1000 mi).

Terasca: A small sounding rocket developed by the Naval Ordnance Test Station, China Lake. Consisted of a Terrier plus Asroc plus Cajun. Could lift 11.3 kg (25 lb) to 158 km (98 mi).

Terrapin: A small Navy sounding rocket. Originally developed for the University of Maryland by Republic Aviation and Allegany Ballistics Laboratory with National Security Agency funding. Modified Deacon first stage with Thiokol T-55 second stage. First fired from Wallops Island on September 21, 1956. Could lift 2.7 to 4 kg (6 to 9 lb) to 129 km (80 mi).

Tic: A Sandia Corp. sounding rocket used in nuclear weapons tests. Consisted of the Lacrosse missile motor plus a Recruit. Could lift 49.9 kg (110 lb) to 160 km (100 mi).

Tomahawk: A Sandia Corp. sounding rocket. Could lift 20.4 kg (45 lb) to about 160 km (100 mi).

V-2: The large German military V-2s were modified for sounding rocket use after World War II. (See Chapter III for historical details.) First U.S. flight at White Sands on April 16, 1946. Could lift 1134 kg (2500 lb) to 184 km (114 mi). Used in Project Bumper and many military test flights.

Viking: A large sounding rocket developed by the Martin Co. for the Naval Research Laboratory. (See Chapter IV for historical details.) Two types. Type-7: nominal performance: 227 kg (500 lb) to 217 km (135 mi); Type-9: nominal performance, 454 kg (1000 lb) to 254 km (158 mi). First firing at White Sands on May 3, 1949.

Wac Corporal: A small sounding rocket developed by JPL for Army Ordnance. Originally developed for meteorological use, the Wac Corporal was the first practical sounding rocket. Built by Aerojet and Douglas, it led directly to the famous Aerobee series. First launched at White Sands on September 26, 1945; it could lift 11.3 kg (25 lb) to 64 km (40 mi). The Wac Corporal was never used to any degree because of the availability of surplus V-2s.

Wasp: (*W*eather *A*tmospheric *S*ounding *P*rojectile) Developed for the Office of Naval Research by the Cooper Development Corp., the Wasp was fired from 127-mm (5-in.) guns. A small rocket used primarily for chaff ejection at high altitudes. First used in February 1956. Could lift 2.7 kg (6 lb) to 35 km (22 mi).

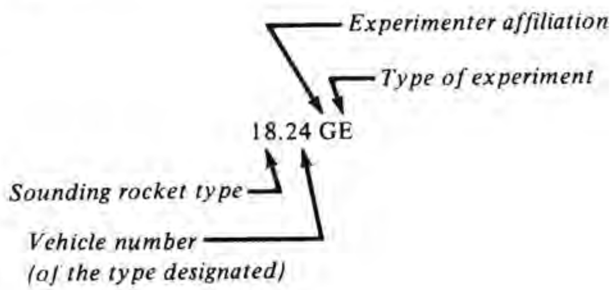
X-17: A sounding rocket developed by Lockheed Missiles & Space Co. Consisted of a modified Sergeant plus 3 Recruits plus 1 Recruit. Originally developed for the Air Force for warhead reentry tests.

APPENDIX B

COMPENDIUM OF NASA SOUNDING ROCKET FIRINGS, 1959-1968

The following tables present key information for all NASA sounding rocket flights.

Key to sounding rocket nomenclature



Sounding rocket type code

1. Aerobee 100
2. Arcon
3. Nike-Asp
4. Aerobee 150/150A
5. Iris
6. Aerobee 300
7. Jason (Argo E-5)
8. Javelin (Argo D-4)
9. Skylark
10. Nike-Cajun
11. Journeyman (Argo D-8)
12. Special projects
13. Aerobee 170
14. Nike-Apache
15. Arcas
16. Astrobee 1500

17.	Aerobee 350
18.	Nike-Tomahawk
19.	Black Brant IV

Experimenter affiliation code

A	Government agency other than NASA or the Department of Defense
C	Industrial
D	Department of Defense
G	Goddard Space Flight Center
I	International
N	NASA center other than Goddard Space Flight Center
U	College or university

Experiment code

A	Aeronomy
B	Biology
E	Particles and fields
G	Galactic astronomy
I	Ionospheric physics
M	Meteorology
P	Special projects
R	Radio astronomy
S	Solar physics
T	Test and support

Firing site abbreviations

ARG	Chamical, Argentina
ASC	Ascension Island, South Atlantic
AUS	Woomera, Australia
BRAZ	Natal, Brazil
BRAZ-A	Rio Grande Beach, Brazil
EGL	Eglin Air Force Base, Fla.
FC	Fort Churchill, Canada
IND	Thumba, India
ITALY	Sardinia, Italy
NOR	Andoya, Norway
NZ	Karikari, New Zealand
PAK	Karachi, Pakistan
PB	Point Barrow, Alaska
PMR	Pacific Missile Range, Calif.
RB	Resolute Bay, Canada
SUR	Coronie, Surinam
SWE	Kronogard, Sweden
WI	Wallops Island, Va.
WS	White Sands, N. Mex.

Affiliation abbreviations

AFCRL	Air Force Cambridge Research Laboratories
AIL	Airborne Instruments Laboratory

AS&E	American Science and Engineering
BRL	Ballistic Research Laboratories
BuStds	National Bureau of Standards
CRPL	Central Radio Propagation Laboratory (National Bureau of Standards)
DRTE	Canadian Defence Research Telecommunications Establishment
ESSA	Environmental Science Services Administration
GCA	Geophysics Corporation of America
GSFC	Goddard Space Flight Center
JHU	Johns Hopkins University
JPL	Jet Propulsion Laboratory
LaRC	NASA Langley Research Center
LeRC	NASA Lewis Research Center
MSC	NASA Manned Spacecraft Center
NCAR	National Center for Atmospheric Research
NOTS	Naval Ordnance Test Station
NRL	Naval Research Laboratory
NYU	New York University
SCAS	Southwest Center for Advanced Studies

NASA Sounding Rocket Flights–Aeronomy

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1959					
3.13 CA	Aug. 17	WI	S	GCA/Dubin	Sodium vapor	S
3.14 CA	Aug. 19	WI	X	GCA/Dubin	Sodium vapor	X
3.15 CA	Nov. 18	WI	S	GCA/Dubin	Sodium vapor	S
3.16 CA	Nov. 19	WI	S	GCA/Dubin	Sodium vapor	X
3.17 CA	Nov. 20	WI	S	GCA/Dubin	Sodium vapor	X
	1960					
4.09 GA	Apr. 29	WI	S	GSFC/Horowitz	Atmospheric composition	S
3.23 CA	May 24	WI	X	GCA/Dubin	Sodium vapor	X
3.24 CA	May 25	WI	S	GCA/Dubin	Sodium vapor	S
10.03 GA	June 16	WI	P	GSFC/Nordberg	Grenade	X
10.04 GA	July 9	WI	S	GSFC/Nordberg	Grenade	S
10.01 GA	July 14	WI	S	GSFC/Nordberg	Grenade	X
10.05 CA	Sept. 20	WI	S	GSFC/Nordberg	Grenade	X
10.09 UA	Nov. 2	WI	S	U. Mich./Dubin	Atmospheric composition	X
8.04 CA	Nov. 10	WI	S	Lockheed/Dubin	Ionosphere	P
4.14 GA	Nov. 15	WI	S	GSFC/Taylor	Atmospheric composition	S
10.10 UA	Nov. 16	WI	S	U. Mich./Dubin	Atmospheric composition	S
10.11 CA	Dec. 9	WI	X	GCA/Dubin	Sodium vapor	X
10.12 CA	Dec. 9	WI	S	GCA/Dubin	Sodium vapor	S
8.05 CA	Dec. 10	WI	S	GCA/Dubin	Sodium vapor	S
10.06 GA	Dec. 14	WI	S	GSFC/Nordberg	Grenade	S

	1961					
10.07 GA	Feb. 14	WI	S	GSFC/Nordberg	Grenade	S
10.08 GA	Feb. 17	WI	P	GSFC/Nordberg	Grenade	S
10.33 GA	Apr. 5	WI	S	GSFC/Nordberg	Grenade	P
3.05 CA	Apr. 19	WI	S	GCA/Dubin	Sodium vapor	S
3.06 CA	Apr. 21	WI	S	GCA/Dubin	Sodium vapor	S
3.07 CA	Apr. 21	WI	X	GCA/Dubin	Sodium vapor	X
3.08 CA	Apr. 21	WI	S	GCA/Dubin	Sodium vapor	S
10.34 GA	Apr. 27	WI	X	GSFC/Smith	Grenade	X
10.02 GA	May 5	WI	S	GSFC/Smith	Grenade	S
10.28 GA	May 6	WI	S	GSFC/Smith	Grenade	S
10.29 GA	May 9	WI	S	GSFC/Smith	Grenade	P
10.50 UA	June 6	WI	S	U. Mich/Dubin	Atmospheric structure	S
10.56 UA	June 9	WI	S	U. Mich./Dubin	Atmospheric composition	X
10.30 GA	July 13	WI	S	GSFC/Smith	Grenade	S
10.31 GA	July 14	WI	S	GSFC/Smith	Grenade	S
10.32 GA	July 20	WI	S	GSFC/Smith	Grenade	S
10.35 GA	July 21	WI	S	GSFC/Smith	Grenade	X
10.57 UA	July 26	WI	S	U. Mich./Dubin	Atmospheric composition	X
8.06 CA	Sept. 13	WI	S	GCA/Smith	Sodium vapor	S
8.22 CA	Sept. 13	WI	S	GCA/Smith	Sodium vapor	S
3.09 CA	Sept. 16	WI	X	GCA/Smith	Sodium vapor	X
3.18 CA	Sept. 16	WI	S	GCA/Smith	Sodium vapor	S
10.36 GA	Sept. 16	WI	P	GSFC/Smith	Grenade	P
10.37 GA	Sept. 17	WI	S	GSFC/Smith	Grenade	X
3.19 CA	Sept. 17	WI	S	GCA/Smith	Sodium vapor	S
1.08 GA	Sept. 23	FC	S	Varian/Martin	Atmospheric structure	S
1.09 GA	Sept. 30	FC	S	Varian/Martin	Atmospheric structure	S
8.23 GA	Oct. 10	WI	S	GSFC/Taylor	Ionosphere	S
1.10 GA	Oct. 15	FC	S	Varian/Martin	Atmospheric structure	S
1.07 GA	Oct. 17	FC	S	Varian/Martin	Atmospheric structure	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Aeronomy–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
1.11 GA	Nov. 2	FC	S	Varian/Martin	Atmospheric structure	S
1.12 GA	Nov. 5	FC	S	Varian/Martin	Atmospheric structure	S
10.72 NA	Nov. 18	WI	S	LaRC/Hord	Airglow	S
10.64 GA	Dec. 21	WI	S	U. Mich./Spencer	Atmospheric structure	S
	1962					
10.90 UA	Feb. 20	WI	S	U. Mich./Dubin	Atmospheric composition	S
10.100 CA	Mar. 1	WI	S	GCA/Smith	Sodium vapor	S
10.38 GA	Mar. 2	WI	S	GSFC/Smith	Grenade	S
10.101 CA	Mar. 2	WI	S	GCA/Smith	Sodium vapor	S
10.39 GA	Mar. 2	WI	S	GSFC/Smith	Grenade	S
4.18 GA	Mar. 19	WI	X	U. Mich./Spencer	Atmospheric structure	X
10.102 CA	Mar. 23	WI	S	GCA/Smith	Sodium vapor	S
10.40 GA	Mar. 23	WI	S	GSFC/Smith	Grenade	S
10.103 CA	Mar. 27	WI	S	GCA/Smith	Sodium vapor	S
10.41 GA	Mar. 28	WI	S	GSFC/Smith	Grenade	S
10.79 NA	Apr. 5	WI	S	LeRC/Potter	Ozone	S
10.42 GA	Apr. 17	WI	S	GSFC/Smith	Grenade	S
3.20 CA	Apr. 17	WI	S	GCA/Smith	Sodium vapor	S
5.04 GA	May 3	WI	P	GSFC/Taylor	Atmospheric structure	S
10.91 UA	May 18	WI	S	U. Mich./Dubin	Atmospheric composition	S
14.19 UA	June 6	WI	S	U. Mich./Spencer	Atmospheric structure	S
10.43 GA	June 7	WI	S	GSFC/Smith	Grenade	S
3.21 CA	June 7	WI	S	GCA/Smith	Sodium vapor	S
3.22 CA	June 7	WI	X	GCA/Smith	Sodium vapor	X
Rehbar 1 (Nike-Cajun)	June 7	PAK	S	GSFC/Mustafa	Sodium vapor	X

10.44 GA	June 8	WI	S	GSFC/Smith	Grenade	S
Rehbar 2 (Nike-Cajun)	June 11	PAK	S	GSFC/Mustafa	Sodium vapor	X
K63-1 (Nike-Cajun)	Aug. 7	SWE	S	GSFC/Witt	Air sample	S
K-62-3 (Nike-Cajun)	Aug. 11	SWE	S	GSFC/Witt	Air sample	S
K-62-4 (Nike-Cajun)	Aug. 11	SWE	S	GSFC/Witt	Air sample	P
14.30 CA	Aug. 23	WI	P	Lockheed/Depew	Atmospheric structure	X
K-62-5 (Nike-Cajun)	Aug. 31	SWE	S	GSFC/Witt	Air sample	X
1.13 NA	Sept. 6	WS	S	JPL/Barth	Ultraviolet airglow	S
14.16 CA	Nov. 7	WI	S	GCA/Smith	Sodium	S
10.65 GA	Nov. 16	FC	X	GSFC/Smith	Grenade	X
1.14 NA	Nov. 20	WS	X	JPL/Barth	Ultraviolet airglow	X
6.06 GA	Nov. 20	WI	S	GSFC/Brace	Thermosphere probe	S
14.17 CA	Nov. 30	WI	S	GCA/Smith	Sodium vapor	S
14.20 UA	Dec. 1	WI	S	U. Mich./Spencer	Atmospheric structure	S
10.45 GA	Dec. 1	WI	S	GSFC/Smith	Grenade	S
10.68 GA	Dec. 1	FC	S	GSFC/Smith	Grenade	X
14.45 AA	Dec. 1	EGL	S	AFCRL/Dubin	Sodium vapor	X
14.46 AA	Dec. 3	EGL	S	AFCRL/Dubin	Sodium vapor	P
10.46 GA	Dec. 4	WI	S	GSFC/Smith	Grenade	X
10.67 GA	Dec. 4	FC	S	GSFC/Smith	Grenade	S
14.18 CA	Dec. 5	WI	S	GCA/Smith	Sodium vapor	P
10.47 GA	Dec. 6	WI	S	GSFC/Smith	Grenade	S
10.66 GA	Dec. 6	FC	S	GSFC/Smith	Grenade	S
4.74 UA	Dec. 13	WI	X	JHU/Dubin	Airglow	X
	1963					
10.80 NA	Jan. 17	WI	S	LeRC/Potter	Ozone	S
4.73 UA	Jan. 29	WI	X	JHU/Dubin	Airglow	X

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Aeronomy–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
3.11 CA	Feb. 18	WI	X	GCA/Smith	Sodium vapor	X
14.35 CA	Feb. 20	WI	S	GCA/Smith	Sodium vapor	S
10.48 GA	Feb. 20	WI	S	GSFC/Smith	Grenade	S
10.58 GA	Feb. 20	FC	S	GSFC/Smith	Grenade	S
14.39 CA	Feb. 21	WI	S	GCA/Smith	Sodium vapor	S
10.53 GA	Feb. 28	WI	S	GSFC/Smith	Grenade	S
10.59 GA	Feb. 28	FC	S	GSFC/Smith	Grenade	S
10.54 GA	Mar. 9	WI	S	GSFC/Smith	Grenade	S
10.60 GA	Mar. 9	FC	S	GSFC/Smith	Grenade	S
14.08 UA	Mar. 28	WI	S	U. Mich./Dubin	Atmospheric composition	S
14.09 UA	Mar. 28	WI	S	U. Mich./Dubin	Atmospheric composition	X
6.07 GA	Apr. 18	WI	S	U. Mich./Brace	Thermosphere probe	S
4.98 UA	May 7	WI	S	JHU/Dubin	Airglow	S
14.110 CA	May 8	WI	S	Lockheed/Bordeau	Massenfilter	X
10.77 IA	May 16	PAK	S	GSFC/Pakistan	Sodium vapor	X
14.140 DA	May 18	EGL	S	ARCRL-Ga. Tech.	Sodium vapor	S
14.141 DA	May 18	EGL	S	AFCRL-Ga. Tech.	Sodium vapor	S
14.137 IA	May 20	ITALY	S	Italy	Sodium vapor	S
14.138 IA	May 21	ITALY	S	Italy	Sodium vapor	S
14.139 IA	May 21	ITALY	S	Italy	Sodium vapor	S
14.13 CA	May 22	FC	S	GCA/Dubin	Sodium vapor	S
14.14 CA	May 22	FC	S	GCA/Dubin	Sodium vapor	S
10.130 DA	May 22	EGL	S	AFCRL-Ga. Tech.	Sodium vapor	S
14.14 CA	May 23	FC	S	GCA/Dubin	Sodium vapor	S
14.40 CA	May 24	WI	S	GCA/Dubin	Sodium vapor	S
14.41 CA	May 24	WI	S	GCA/Dubin	Sodium vapor	X
14.42 CA	May 25	WI	S	GCA/Dubin	Sodium vapor	S

4.75 UA	July 20	FC	X	JHU/Dubin	Airglow	X
K63-1 (Nike-Cajun)	July 27	SWE	S	SWE/Witt	Grenade	S
K63-2 (Nike-Cajun)	July 29	SWE	S	SWE/Witt	Grenade	S
K63-3 (Nike-Cajun)	Aug. 1	SWE	S	SWE/Witt	Grenade	S
10.75 UA	Aug. 2	WI	S	U. Mich./Holtz	Atmospheric density	S
K63-4 (Nike-Cajun)	Aug. 7	SWE	S	SWE/Witt	Grenade	S
10.92 NA	Sept. 25	WI	S	LaRC	Chemical release	
10.93 NA	Sept. 25	WI	S	LaRC	Chemical release	S
14.102 NA	Oct. 9	WI	S	LeRC/Potter	Chemical release	S
14.103 NA	Oct. 10	WI	S	LeRC/Potter	Chemical release	S
4.76 UA	Nov. 12	WI	S	JHU/Dubin	Airglow	S
4.85 NA	Nov. 18	WI	S	JPL/Barth	Airglow	S
14.128 IA	Nov. 21	IND	S	India/Dubin	Sodium vapor	P
14.10 UA	Nov. 26	WI	S	U. Mich./Dubin	Atmospheric composition	S
10.131 UA	Nov. 26	WI	S	U. Mich./Dubin	Atmospheric density	S
10.55 GA	Dec. 7	WI	S	GSFC/Smith	Grenade	S
14.21 UA	Dec. 7	WI	S	U. Mich./Theon	Atmospheric structure	S
	1964					
14.129 IA	Jan. 8	IND	S	India/Dubin	Sodium vapor	S
14.130 IA	Jan. 12	IND	S	India/Dubin	Sodium vapor	S
14.38 CA	Jan. 15	WI	X	GCA/Smith	Sodium vapor	X
14.106 CA	Jan. 15	WI	P	GCA/Smith	Sodium vapor	S
14.125 CA	Jan. 16	WI	S	GCA/Smith	Sodium vapor	S
14.126 CA	Jan. 16	WI	S	GCA/Smith	Sodium vapor	S
8.31 DA	Jan. 17	WI	S	NRL/Dubin	Composition; airglow	S
10.61 GA	Jan. 24	WI	S	GSFC/Smith	Grenade	S
10.86 GA	Jan. 24	FC	X	GSFC/Smith	Grenade	X

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Aeronomy–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
6.09 GA	Jan. 29	WI	S	GSFC/Brace	Thermosphere probe	S
10.71 GA	Jan. 29	WI	S	GSFC/Smith	Grenade	S
10.89 GA	Jan. 29	FC	S	GSFC/Smith	Grenade	S
10.81 GA	Jan. 29	ASC	S	GSFC/Smith	Grenade	S
14.22 UA	Feb. 4	ASC	S	U. Mich./Smith	Atmospheric structure	S
10.62 GA	Feb. 4	WI	S	GSFC/Smith	Grenade	S
10.87 GA	Feb. 5	FC	S	GSFC/Smith	Grenade	S
10.63 GA	Feb. 5	WI	S	GSFC/Smith	Grenade	S
10.136 GA	Feb. 13	WI	S	GSFC/Smith	Grenade	S
10.82 GA	Feb. 13	ASC	S	GSFC/Smith	Grenade	S
10.88 GA	Feb. 13	FC	S	GSFC/Smith	Grenade	S
4.124 UA	Feb. 27	FC	P	JHU/Dubin	Aurora	S
10.137 GA	Mar. 7	WI	S	GSFC/Smith	Grenade	S
14.134 IA	Apr. 9	PAK	S	Pakistan	Sodium vapor	X
4.86 NA	Apr. 14	WS	X	JPL	Airglow	X
14.24 UA	Apr. 15	ASC	S	U. Mich./Smith	Atmospheric structure	S
14.23 UA	Apr. 15	ASC	S	U. Mich./Smith	Atmospheric structure	S
10.142 UA	Apr. 17	WI	S	U. Mich./Dubin	Atmospheric density	S
10.73 GA	Apr. 18	FC	S	GSFC/Smith	Grenade	S
10.83 GA	Apr. 18	WI	S	GSFC/Smith	Grenade	S
4.113 GA-GI	Apr. 21	WS	X	GSFC/Aikin	Astrochemistry; ionosphere	X
14.54 DA	May 28	WS	X	AFCRL/Smith	Air sampling	X
14.49 CA	July 15	WI	S	GCA/Smith	Sodium vapor	S
14.50 CA	July 15	WI	S	GCA/Smith	Sodium vapor	S
14.51 CA	July 15	WI	S	GCA/Smith	Sodium vapor	S
14.52 CA	July 15	WI	S	GCA/Smith	Sodium vapor	S
6.10 GA	July 28	FC	S	GSFC/Brace	Thermosphere probe	S

10.114 GA	Aug. 5	ASC	S	GSFC/Smith	Grenade	X
14.55 DA	Aug. 6	SWE	S	AFCRL/Smith	Air sampling	X
10.138 GA	Aug. 7	SWE	S	GSFC/Smith	Grenade	S
10.78 GA	Aug. 7	WI	S	GSFC/Smith	Grenade	S
10.104 GA	Aug. 8	FC	S	GSFC/Smith	Grenade	S
14.56 DA	Aug. 12	SWE	S	AFCRL/Smith	Air sampling	S
10.139 GA	Aug. 12	SWE	S	GSFC/Smith	Grenade	X
10.84 GA	Aug. 12	WI	S	GSFC/Smith	Grenade	S
10.105 GA	Aug. 12	FC	S	GSFC/Smith	Grenade	S
14.57 DA	Aug. 16	SWE	S	AFCRL/Smith	Air sampling	S
10.140 GA	Aug. 16	SWE	S	GSFC/Smith	Grenade	S
10.85 GA	Aug. 16	WI	S	GSFC/Smith	Grenade	S
10.115 GA	Aug. 16	ASC	S	GSFC/Smith	Grenade	S
10.116 GA	Aug. 16	ASC	S	GSFC/Smith	Grenade	S
14.58 DA	Aug. 17	SWE	S	AFCRL/Smith	Air sampling	S
10.141 GA	Aug. 17	SWE	S	GSFC/Smith	Grenade	S
10.106 GA	Aug. 18	FC	S	GSFC/Smith	Grenade	S
10.113 GA	Aug. 18	WI	S	GSFC/Smith	Grenade	S
4.115 NA	Sept. 18	WI	S	JPL/Barth	Dayglow	S
14.195 CA	Oct. 7	WI	S	GCA/Dubin	Luminescent clouds; ionosphere	S
8.03 CA	Oct. 8	WI	S	Lockheed/Dubin	Ion composition	S
14.194 CA	Oct. 8	WI	S	GCA/Dubin	Luminescent clouds; ionosphere	S
14.197 CA	Nov. 1	FC	S	GCA/Dubin	Luminescent clouds; ionosphere	S
10.132 GA	Nov. 3	WI	S	GSFC/Smith	Grenade	X
10.107 GA	Nov. 5	WI	S	GSFC/Smith	Grenade	S
8.34 UA	Nov. 5	WI	S	JHU/Dubin	Airglow	S
10.133 GA	Nov. 6	WI	S	GSFC/Smith	Grenade	S
14.131 IA	Nov. 6	IND	S	India	Sodium vapor	S
10.134 GA	Nov. 6	WI	S	GSFC/Smith	Grenade	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights—Aeronomy—Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
10.135 GA	Nov. 6	WI	S	GSFC/Smith	Grenade	S
14.204 IA	Nov. 9	IND	S	India	Sodium vapor	S
14.205 IA	Nov. 10	IND	S	India	Sodium vapor	S
14.114 CA	Nov. 10	Ship	S	GCA/Smith	Sodium vapor	S
14.53 CA	Nov. 10	WI	S	GCA/Smith	Sodium vapor	S
14.115 CA	Nov. 11	Ship	S	GCA/Smith	Sodium vapor	S
14.112 CA	Nov. 11	WI	S	GCA/Smith	Sodium vapor	S
14.116 CA	Nov. 12	Ship	S	GCA/Smith	Sodium vapor	S
14.113 CA	Nov. 12	WI	S	GCA/Smith	Sodium vapor	X
4.45 GA	Nov. 16	WI	S	GSFC/Brace	Thermosphere probe	S
4.118 NA	Nov. 16	WS	S	GSFC/Ames	Micrometeoroids	X
14.233 UA	Nov. 17	Ship	S	U. Mich./Dubin	Atmospheric density	S
10.153 UA	Nov. 17	Ship	S	U. Mich./Dubin	Atmospheric density	S
14.29 UA	Nov. 19	Ship	X	U. Mich./Smith	Pitot probe	X
10.117 GA	Nov. 19	WI	S	GSFC/Smith	Grenade	S
14.135 IA	Nov. 30	PAK	S	Pakistan	Sodium vapor	S
14.136 IA	Dec. 1	PAK	S	Pakistan	Sodium vapor	S
4.83 GA	Dec. 1	WS	S	GSFC/Hennes	Ultraviolet airglow	S
4.132 GA-GI	Dec. 16	WS	S	GSFC/Berg	Micrometeoroids	S
4.125 UA	Dec. 17	WS	S	JHU/Dubin	Airglow	S
	1965					
14.142 NA	Jan. 7	WI	S	LeRC/Potter	Airglow	P
4.111 NA	Jan. 13	WI	S	JPL/Dubin	Airglow	S
10.124 GA	Jan. 27	PB	S	GSFC/Smith	Grenade	S
10.121 GA	Jan. 27	FC	S	GSFC/Smith	Grenade	S

10.118 GA	Jan. 27	WI	S	GSFC/Smith	Grenade	S
10.125 GA	Feb. 4	PB	S	GSFC/Smith	Grenade	S
10.119 GA	Feb. 4	WI	S	GSFC/Smith	Grenade	S
10.122 GA	Feb. 4	FC	S	GSFC/Smith	Grenade	S
10.126 GA	Feb. 8	PB	S	GSFC/Smith	Grenade	S
10.120 GA	Feb. 8	WI	S	GSFC/Smith	Grenade	S
10.123 GA	Feb. 8	FC	S	GSFC/Smith	Grenade	S
14.11 UA	Feb. 18	FC	S	U. Mich./Dubin	Composition	S
4.129 UA	Feb. 19	FC	S	JHU/Dubin	Auroral studies	S
14.95 UA	Feb. 19	FC	S	U. Mich./Dubin	Composition	S
10.155 UA	Feb. 26	Ship	S	U. Mich./Dubin	Air density	X
14.196 CA	Feb. 28	FC	S	GCA/Dubin	Ionospheres; luminescent cloud	S
14.198 CA	Feb. 28	FC	X	GCA/Dubin	Ionospheres; luminescent cloud	X
14.199 CA	Feb. 28	FC	X	GCA/Dubin	Ionospheres; luminescent cloud	X
14.200 CA	Feb. 28	FC	X	GCA/Dubin	Ionospheres; luminescent cloud	X
14.253 IA	Mar. 1	NOR	S	Sweden	Discharge of TNT	S
Ferdinand IX (Nike-Apache)	Mar. 3	NOR	P	Norway/Kane	Auroral absorption	X
14.254 IA	Mar. 5	NOR	S	Sweden	Luminescent cloud	S
14.64 UA	Mar. 8	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.65 UA	Mar. 9	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.98 UA	Mar. 11	Ship	S	U. Mich./Dubin	Composition	S
10.156 UA	Mar. 11	Ship	S	U. Mich./Dubin	Air density	S
14.99 UA	Mar. 11	Ship	S	U. Mich./Dubin	Composition	S
Ferdinand X (Nike-Apache)	Mar. 15	NOR	P	Norway/Kane	Auroral absorption	X
14.62 UA	Mar. 18	WI	S	SCAS/Horowitz	Composition	P
12.05 GA (Nike-Tomahawk)	Mar. 19	WI	S	GSFC/Brace	Thermosphere probe	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Aeronomy–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
6.11 GA	Mar. 20	WI	S	GSFC/Brace	Thermosphere probe	S
Ferdinand XI (Nike-Apache)	Mar. 22	NOR	P	Norway/Kane	Auroral absorption	X
14.132 NA	Apr. 1	WI	S	LeRC/Potter	Airglow	S
14.66 UA	Apr. 4	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.26 UA	Apr. 6	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.63 UA	Apr. 9	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.67 UA	Apr. 13	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.27 UA	Apr. 13	Ship	S	U. Mich./Smith	Atmospheric structure	S
14.101 UA	Apr. 13	Ship	S	U. Mich./Dubin	Composition	X
4.127 UA	Apr. 15	WS	S	U. Minn./Dubin	Composition	S
14.100 UA	Apr. 15	Ship	S	U. Mich./Dubin	Composition	X
14.25 UA	Apr. 15	Ship	S	U. Mich./Smith	Atmospheric structure	S
10.171 NA	Apr. 23	WI	S	LaRC/Tolefson	Chemiluminescent cloud	S
14.255 NA	Apr. 23	WI	S	LaRC/Tolefson	Chemiluminescent cloud	S
10.150 GA	Apr. 28	PB	S	GSFC/Smith	Grenade	X
10.94 IA	Apr. 29	PAK	S	Pakistan	Grenade	S
10.95 IA	Apr. 30	PAK	S	Pakistan	Grenade	X
10.127 GA	May 3	WI	S	GSFC/Smith	Grenade	X
14.47 UA	May 22	ASC	S	U. Mich./Smith	Pitot probe	S
14.48 UA	May 22	ASC	S	U. Mich./Smith	Pitot probe	S
14.201 CA	June 23	WI	S	GCA/Dubin	Ionosphere; luminescent clouds	S
4.112 NA	June 29	WS	S	JPL/Dubin	Airglow	S
4.128 UA	July 15	WS	S	U. Minn./Dubin	Composition	S
10.154 UA	Aug. 7	WI	S	U. Mich./Dubin	Air density	S
10.157 UA	Aug. 8	WI	S	U. Mich./Dubin	Air density	S

10.144 UA	Aug. 11	WS	S	Dudley Obs./Dubin	Micrometeoroids	X
14.133 NA	Aug. 19	WI	S	LeRC	Airglow	X
8.11 UA	Aug. 25	WI	S	U. Pitt./Dubin	Helium ionization	S
14.224 IA	Sept. 18	SUR	S	Netherlands/Dubin	Sodium vapor	S
14.225 IA	Sept. 21	SUR	S	Netherlands/Dubin	Sodium vapor	S
14.226 IA	Sept. 24	SUR	S	Netherlands/Dubin	Sodium vapor	S
14.227 IA	Sept. 27	SUR	S	Netherlands/Dubin	Sodium vapor	S
4.150 GA-GI-GB	Sept. 28	WS	S	GSFC/Berg	Micrometeoroids; ionosphere	S
14.202 CA	Oct. 5	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.203 CA	Oct. 6	FC	X	GCA/Dubin	Ionosphere; luminescent clouds	X
4.142 NA	Oct. 19	WI	S	U. Colo./Dubin	1965F comet spectra	X
4.164 UA	Oct. 21	WI	S	JHU/Dubin	1965F comet spectra	S
18.03 GA	Nov. 9	FC	S	GSFC/Brace	Thermosphere probe	S
18.02 GA	Nov. 10	FC	S	GSFC/Brace	Thermosphere probe	S
4.119 NA	Nov. 16	WS	S	Ames/Dubin	Micrometeoroids	S
14.78 UA	Nov. 18	WS	S	Dudley Obs./Dubin	Micrometeoroids	S
	1966					
10.158 UA	Jan. 25	WI	S	U. Mich./Dubin	Air density	S
10.159 UA	Feb. 3	WI	S	U. Mich./Dubin	Air density	S
10.143 UA	Feb. 4	WI	S	U. Mich./Dubin	Air density	S
4.162 UA	Feb. 20	FC	S	JHU/Dubin	Auroral physics	P
14.211 IA	Feb. 25	PAK	S	Pakistan/Dubin	Sodium vapor	S
14.212 IA	Feb. 26	PAK	S	Pakistan/Dubin	Sodium vapor	X
8.25 GA-GI	Mar. 2	WI	S	GSFC/Smith	Geoprobe	S
14.257 IA	Mar. 24	IND	S	India	Sodium vapor	X
14.258 IA	Mar. 25	IND	S	India	Sodium vapor	X
4.143 UA	Apr. 14	WS	S	U. Colo./Dubin	Dayglow	S
4.165 UA	Apr. 21	WS	S	JHU/Dubin	Planetary ultraviolet	P
14.96 UA	July 11	FC	S	U. Mich./Dubin	Atmospheric composition	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Aeronomy–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
8.12 UA	July 12	WI	S	U. Pitt./Dubin	Atmospheric composition	S
8.32 DA	Aug. 15	WI	S	NRL/Dubin	Atmospheric composition	S
14.170 UA	Aug. 16	WS	S	Dudley Obs./Dubin	Micrometeoroid	P
18.05 GA	Aug. 26	WI	S	GSFC/Brace	Thermosphere probe	S
18.06 GA	Aug. 26	WI	S	GSFC/Brace	Thermosphere probe	S
18.22 GA	Aug. 28	WI	S	GSFC/Brace	Thermosphere probe	S
14.278 CA-CI	Sept. 14	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.279 CA-CI	Sept. 14	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	P
14.280 CA-CI	Sept. 16	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.281 CA-CI	Sept. 16	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.282 CA-CI	Sept. 16	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
8.27 IA	Sept. 24	WI	S	Germany/Adamson	Barium release	S
18.26 IA	Sept. 25	WI	S	Germany/Adamson	Barium release	S
4.161 NA	Oct. 22	WS	S	Ames/Dubin	Micrometeoroids	S
4.195 GA-GI	Oct. 25	WS	S	GSFC/Berg	Micrometeoroids	S
14.77 CA-CI	Nov. 12	BRAZ-A	S	GCA/Dubin	Eclipse	S
14.299 UA	Nov. 18	WS	S	Dudley Obs./Dubin	Micrometeoroids	X
4.181 UA	Nov. 30	WS	S	U. Minn./Dubin	Atmospheric composition	S
4.180 UA	Dec. 2	WS	S	U. Minn./Dubin	Atmospheric composition	S
	1967					
4.163 UA	Feb. 17	FC	S	JHU/Dubin	Auroral spectra	S
14.161 IA	Mar. 6	IND	S	India/Dubin	Luminescent clouds	X

14.162 IA	Mar. 9	IND	S	India/Dubin	Luminescent clouds	X
14.163 IA-II	Mar. 12	IND	S	India/Dubin	Ionosphere; luminescent clouds	P
14.206 IA-II	Mar. 12	IND	S	India/Dubin	Ionosphere; luminescent clouds	S
14.267 IA-II	Mar. 13	IND	S	India/Dubin	Ionosphere; luminescent clouds	P
14.283 CA	Mar. 31	WI	S	GCA/Dubin	Luminescent clouds	X
8.43 UA	May 17	WI	S	U. Pitt./Dubin	Atmospheric composition	S
14.300 UA	May 31	WS	X	Dudley Obs./Dubin	Micrometeoroids	X
4.222 NA	June 6	WS	S	Ames/Dubin	Micrometeoroids	S
4.179 UA	June 21	WS	S	U. Minn./Dubin	Atmospheric composition	S
4.212 UA	July 20	WS	S	U. Minn./Dubin	Atmospheric composition	S
4.211 UA	July 20	WS	S	U. Minn./Dubin	Atmospheric composition	S
15.16 DA	Aug. 2	PMR	S	NOTS/Horowitz	Ozone distribution	X
14.343 GT-UA	Aug. 5	WS	S	GSFC/Wood	Recovery system test	X
4.207 UA	Aug. 8	WS	S	U. Mich./Dubin	Composition	S
4.223 NA	Aug. 11	WS	S	Ames/Dubin	Micrometeoroids	S
15.17 DA	Aug. 21	PMR	S	NOTS/Horowitz	Ozone distribution	S
15.35 DA	Sept. 14	Hawaii	S	NOTS/Horowitz	Ozone distribution	X
15.36 DA	Sept. 17	Hawaii	S	NOTS/Horowitz	Ozone distribution	S
18.50 GA	Sept. 18	WI	S	GSFC/Brace	Thermosphere probe	S
15.37 DA	Sept. 19	Hawaii	S	NOTS/Horowitz	Ozone distribution	S
15.38 DA	Oct. 13	Hawaii	S	NOTS/Horowitz	Ozone distribution	S
15.39 DA	Oct. 19	Hawaii	S	NOTS/Horowitz	Ozone distribution	S
15.40 DA	Oct. 22	Hawaii	S	NOTS/Horowitz	Ozone distribution	S
15.41 DA	Oct. 25	Hawaii	S	NOTS/Horowitz	Ozone distribution	S
18.66 UA	Dec. 5	FC	S	U. Alaska/Dubin	Auroral studies	S
4.197 UA	Dec. 5	WS	S	JHU/Dubin	Planetary atmospheres	S
14.347 UA	Dec. 12	WI	S	U. Colo./Dubin	Atmospheric composition	S
	1968					
14.259 IA	Feb. 2	IND	S	India/Dubin	Luminescent clouds	S
4.217 UA	Feb. 9	FC	S	JHU/Dubin	Auroral physics	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Aeronomy–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
14.284 CA	Feb. 21	WI	S	GCA/Dubin	Aeronomy; luminescent clouds	P
14.208 CA	Feb. 22	WI	S	GCA/Dubin	Luminescent clouds; ionosphere	S
18.67 UA	Feb. 23	FC	S	U. Alaska/Dubin	Auroral studies	S
14.350 CA	Feb. 27	WI	S	GCA/Dubin	Aeronomy; luminescent clouds	P
18.68 UA	Feb. 28	FC	S	U. Alaska/Dubin	Auroral studies	S
18.53 GA	Mar. 17	PB	S	GSFC/Spencer	Thermosphere probe	S
18.49 GA	Mar. 17	PB	P	GSFC/Spencer	Thermosphere probe	P
18.51 GA	Mar. 17	PB	S	GSFC/Spencer	Thermosphere probe	S
8.40 UA	Apr. 9	WI	S	U. Pitt./Dubin	Composition	S
4.238 UA	Apr. 23	WS	S	U. Colo./Dubin	Airglow	S
14.335 UA	June 10	WS	S	Dudley Obs./Dubin	Micrometeoroids	S
14.355 IA	June 11	SWE	S	Germany	Micrometeoroids	S
14.354 IA	June 12	SWE	S	Germany	Micrometeoroids	S
14.349 UA	July 24	WI	S	U. Colo./Dubin	Atmospheric composition	S
10.253 UA	July 24	WI	S	U. Mich./Dubin	Air density	P
14.348 UA	July 24	WI	S	U. Colo./Dubin	Atmospheric composition	S
10.254 UA	July 24	WI	S	U. Mich./Dubin	Air density	P
18.31 UA	July 31	WI	S	JHU/Dubin	Airglow	S
4.224 NA	Aug. 1	FC	S	Ames/Dubin	Micrometeoroids	P
18.51 GA	Aug. 8	WI	S	GSFC/Brace	Thermosphere probe	S
18.56 GA	Aug. 9	WI	S	GSFC/Brace	Thermosphere probe	S
14.336 UA	Aug. 12	WS	S	Dudley Obs./Dubin	Micrometeoroids	S
14.301 UA	Aug. 20	WS	S	Dudley Obs./Dubin	Micrometeoroids	S
4.241 UA	Oct. 1	WS	S	U. Colo.	Ultraviolet dayglow	S

18.69 UA	Oct. 16	WI	S	U. Mich./Dubin	Atmospheric composition	S
14.351 UA	Dec. 4	WS	S	Dudley Obs./Dubin	Micrometeoroids	S
8.51	Dec. 10	FC	S	U. Pitt./Dubin	Composition	X
14.352 UA	Dec. 14	WS	S	Dudley Obs./Dubin	Micrometeoroids	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Particles and Fields

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1960					
10.17 GE	June 6	FC	S	GSFC/Fichtel	Solar beam experiment (SBE)	S
8.07 GE	June 30	WI	X	GSFC/Heppner	Magnetic fields	X
10.18 GE	July 22	FC	S	GSFC/Fichtel	SBE	S
4.16 UE	Aug. 23	WI	S	NYU/Meredith	Cosmic rays	S
10.19 GE	Sept. 3	FC	S	GSFC/Fichtel	SBE	S
10.20 GE	Sept. 3	FC	S	GSFC/Fichtel	SBE	S
11.01 GE	Sept. 19	PMR	S	GSFC/Naugle	NERV I	S
10.21 GE	Sept. 27	FC	S	GSFC/Fichtel	SBE	S
10.22 GE	Nov. 11	FC	S	GSFC/Fichtel	SBE	S
10.23 GE	Nov. 11	FC	S	GSFC/Fichtel	SBE	P
10.24 GE	Nov. 12	FC	S	GSFC/Fichtel	SBE	S
10.15 GE	Nov. 12	FC	S	GSFC/Fichtel	SBE	S
10.16 GE	Nov. 13	FC	S	GSFC/Fichtel	SBE	S
10.13 GE	Nov. 16	FC	S	GSFC/Fichtel	SBE	S
10.14 GE	Nov. 17	FC	S	GSFC/Fichtel	SBE	S
10.26 GE	Nov. 18	FC	S	GSFC/Fichtel	SBE	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Particles and Fields–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
10.27 GE	Nov. 18	FC	S	GSFC/Fichtel	SBE	S
8.08 GE	Dec. 12	WI	S	GSFC/Heppner	Magnetic fields	S
	1961					
14.03 UE	July 14	WI	S	U. N.H./Heppner	Magnetic fields	S
14.04 UE	July 14	WI	S	U. N.H./Heppner	Magnetic fields	S
14.05 UE	July 20	WI	S	U. N.H./Heppner	Magnetic fields	S
10.76 GE	Dec. 10	FC	S	GSFC/Fichtel	Cosmic rays	S
	1963					
11.06 UE	Feb. 12	PMR	S	U. Minn./Cline	Electron spectrometry	S
4.91 GE	Sept. 4	FC	S	GSFC/Fichtel	Cosmic rays	S
14.06 UE	Sept. 9	WI	S	U. N.H./Schardt	Electrojet	S
	1964					
14.150 UE	Jan. 15	WI	P	Rice/Schardt	Auroral observations	X
14.79 UE	Jan. 25	IND	S	U. N.H./Schardt	Equatorial electrojet	S
14.80 UE	Jan. 27	IND	S	U. N.H./Schardt	Equatorial electrojet	S
14.81 UE	Jan. 29	IND	S	U. N.H./Schardt	Equatorial electrojet	S
14.82 UE	Jan. 31	IND	S	U. N.H./Schardt	Equatorial electrojet	S
14.43 GE	Feb. 20	FC	S	GSFC/Evans	Aurora	P
14.44 GE	Feb. 29	FC	S	GSFC/Evans	Aurora	P
14.151 UE	Mar. 18	FC	S	Rice/Schardt	Aurora	S
14.152 UE	Mar. 20	FC	S	Rice/Schardt	Aurora	S

14.153 UE	Mar. 23	FC	S	Rice/Schardt	Aurora	S
14.118 GE	Mar. 24	FC	S	GSFC/Evans	Aurora	S
14.120 GE	Mar. 25	FC	S	GSFC/Evans	Aurora	X
14.119 GE	Mar. 26	FC	S	GSFC/Evans	Aurora	P
14.121 UE	Apr. 11	FC	S	Alaska/Schardt	Aurora	S
14.122 UE	Apr. 15	FC	S	Alaska/Schardt	Aurora	X
14.123 UE	Apr. 22	FC	S	Alaska/Schardt	Aurora	S
14.155 GE	June 10	WI	S	GSFC/Davis	Magnetic fields	S
14.156 GE	June 25	WI	S	GSFC/Davis	Magnetic fields	S
14.157 GE	June 26	WI	S	GSFC/Davis	Magnetic fields	S
14.154 UE	July 9	WI	S	Rice/Schardt	Airglow	S
4.107 GE	July 23	FC	S	GSFC/Fichtel	Cosmic rays	P
4.108 GE	July 25	FC	S	GSFC/Fichtel	Cosmic rays	S
14.158 GE	Oct. 7	WI	X	GSFC/Davis	Magnetic fields	X
14.159 GE	Oct. 8	WI	S	GSFC/Davis	Magnetic fields	S
14.60 UE	Dec. 7	WI	S	U. N.H./Schardt	Energetic particles	X
	1965					
14.61 UE	Feb. 3	WI	S	U. N.H./Schardt	Energetic particles	S
14.160 GE	Mar. 8	Ship	S	GSFC/Davis	Magnetic fields	S
14.85 UE	Mar. 9	Ship	S	U. N.H./Opp	Magnetic fields	S
14.83 UE	Mar. 10	Ship	S	U. N.H./Opp	Magnetic fields	S
14.07 UE	Mar. 12	Ship	S	U. N.H./Opp	Magnetic fields	S
14.84 UE	Mar. 12	Ship	S	U. N.H./Opp	Magnetic fields	S
14.171 GE	Mar. 16	Ship	S	GSFC/Davis	Geomagnetism	S
14.172 GE	Mar. 18	Ship	S	GSFC/Davis	Geomagnetism	S
14.174 GE	Mar. 24	Ship	S	GSFC/Davis	Geomagnetism	S
14.173 GE	Mar. 26	Ship	S	GSFC/Davis	Geomagnetism	S
14.175 GE	Mar. 27	Ship	S	GSFC/Davis	Geomagnetism	S
14.70 GE	Mar. 29	Ship	S	GSFC/Davis	Geomagnetism	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Particles and Fields–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
14.185 UE	Apr. 2	Ship	S	U. N.H./Schardt	Energetic particles	P
14.207 UE	Apr. 3	FC	S	Rice/Schardt	Aurora	S
14.184 UE	Apr. 5	Ship	S	U. N.H./Schardt	Energetic particles	P
14.186 UE	Apr. 13	Ship	S	U. N.H./Schardt	Energetic particles	P
11.07 UE	Apr. 14	WI	S	U. Minn./Opp	Energetic particles	X
4.140 GE	June 17	FC	S	GSFC/Fichtel	Energetic particles	S
4.141 GE	June 23	FC	S	GSFC/Fichtel	Energetic particles	S
14.234 UE	Sept. 16	FC	X	U. Cal./Schardt	Energetic particles	X
14.235 UE	Sept. 17	FC	S	U. Cal./Schardt	Energetic particles	S
14.237 UE	Sept. 20	FC	X	U. Cal./Schardt	Energetic particles	X
14.236 UE	Sept. 20	FC	S	U. Cal./Schardt	Energetic particles	S
14.238 UE	Nov. 17	FC	S	Alaska/Opp	Aurora	S
14.239 UE	Nov. 20	FC	S	Alaska/Opp	Aurora	S
14.124 UE	Nov. 24	FC	S	Alaska/Opp	Aurora	S
14.242 UE	Nov. 24	WI	S	Rice/Opp	Magnetic fields	S
	1966					
14.188 GE	Feb. 10	FC	S	GSFC/Evans	Auroral physics	S
14.243 UE	Feb. 17	WI	S	Rice/Opp	Magnetic fields	S
14.189 GE	Feb. 18	FC	S	GSFC/Evans	Auroral physics	S
14.190 GE	Mar. 14	FC	S	GSFC/Evans	Auroral physics	S
18.07 GE	Mar. 23	FC	S	GSFC/Heppner	Magnetic fields	S
18.08 GE	Apr. 14	FC	S	GSFC/Heppner	Magnetic fields	S
14.59 IE-II	July 7	IND	S	India	Magnetic fields; ionosphere	
14.218 GE	July 20	FC	S	GSFC/Fichtel	Solar particle intensity composition experiment (SPICE)	X

14.183 UE	Aug. 24	FC	S	U. N.H./Opp	Particles and fields	S
18.18 UE	Sept. 1	FC	S	U. Cal./Schardt	Auroral radiation	S
14.219 GE	Sept. 2	FC	S	GSFC/Guss	SPICE	S
14.220 GE	Sept. 2	FC	S	GSFC/Guss	SPICE	S
14.221 GE	Sept. 3	FC	S	GSFC/Guss	SPICE	S
18.20 UE	Sept. 6	FC	S	U. Cal./Schardt	Auroral radiation	S
18.21 UE	Sept. 6	FC	S	U. Cal./Schardt	Auroral radiation	S
18.19 UE	Sept. 17	FC	S	U. Cal./Schardt	Auroral radiation	S
18.04 GE	Nov. 8	WI	S	GSFC/Aggson	Fields	S
14.287 IE	Nov. 11	FC	S	Germany/Franta	Energetic particles	S
18.27 UE	Nov. 20	WI	S	U. N.H./Opp	Energetic particles	S
	1967					
18.23 GE	Jan. 28	FC	S	GSFC/Evans	Auroral studies	P
8.41 UE	Feb. 9	FC	S	Rice/Opp	Auroral studies	S
18.24 GE	Mar. 9	FC	S	GSFC/Evans	Auroral studies	S
8.47 UE	Mar. 18	FC	S	Rice/Opp	Auroral studies	S
18.28 UE	Mar. 27	BRAZ	S	U. N.H./Opp	Energetic particles	S
18.09 GE	Mar. 31	WI	S	GSFC/Wescott	Magnetic fields	S
14.328 IE	Apr. 7	SWE	S	Germany	Magnetic fields	S
14.329 IE	Apr. 8	SWE	S	Germany	Magnetic fields	S
14.330 IE	Apr. 9	SWE	S	Germany	Magnetic fields	S
14.331 IE	Apr. 10	SWE	S	Germany	Magnetic fields	S
14.332 IE	Apr. 11	SWE	S	Germany	Magnetic fields	S
18.29 UE	June 6	FC	S	U. N.H./Opp	Cosmic-ray intensities	S
14.297 CE	June 13	WI	S	AS&E/Schardt	Energetic particles	S
8.49 IE	June 16	BRAZ	S	Germany/Franta	Energetic particles	S
8.50 IE	June 17	BRAZ	S	Germany/Franta	Energetic particles	S
18.43 GE	Aug. 31	NOR	S	GSFC/Heppner	Magnetic fields	S
18.46 GE	Aug. 31	NOR	S	GSFC/Heppner	Magnetic fields	S
18.44 GE	Sept. 2	NOR	S	GSFC/Heppner	Magnetic fields	S
18.47 GE	Sept. 2	NOR	S	GSFC/Heppner	Magnetic fields	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Particles and Fields–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
18.45 GE	Sept. 12	NOR	S	GSFC/Heppner	Magnetic fields	S
18.48 GE	Sept. 12	NOR	S	GSFC/Heppner	Magnetic fields	X
18.34 UE	Nov. 24	FC	S	U. Cal./Schardt	Auroral studies	X
14.288 IE	Dec. 5	SWE	S	Germany/Franta	Energetic particles	S
	1968					
18.13 UE	Jan. 23	FC	S	U. Alaska/Opp	Particles and fields	P
18.38 UE	Feb. 6	FC	S	U. N.H./Opp	Electric field; auroral studies	S
14.276 GE	Feb. 22	FC	S	GSFC/Evans	Auroral studies	S
18.61 GE	Feb. 22	FC	P	GSFC/Evans	Auroral studies	X
18.35 UE	Feb. 23	FC	S	U. Cal./Schardt	Auroral studies	S
8.48 UE	Mar. 2	FC	S	Rice/Opp	Auroral studies	S
18.37 UE	Mar. 2	FC	S	U. Cal./Schardt	Auroral studies	P
4.198 GE	Mar. 16	WS	S	GSFC/Boldt	Energetic cosmic rays	S
18.36 UE	Mar. 18	FC	S	U. Cal./Schardt	Auroral studies	S
18.63 UE	Mar. 21	FC	S	U. Md./Opp	Auroral studies	S
14.375 IE-II	Mar. 28	IND	S	Germany	Magnetic fields; ionosphere	S
14.376 IE-II	Mar. 30	IND	S	Germany	Magnetic fields; ionosphere	S
14.377 IE-II	Mar. 31	IND	S	Germany	Magnetic fields; ionosphere	S
14.378 IE	Mar. 31	IND	S	Germany	Magnetic fields	S
14.277 GE	Apr. 4	FC	S	GSFC/Evans	Auroral particles	P
18.60 GE	Apr. 4	FC	S	GSFC/Evans	Auroral particles	S
18.39 UE	Apr. 24	FC	S	U. N.H./Opp	Energetic particles	S
18.33 CE	Apr. 25	FC	S	TRW/Opp	Energetic particles	S
18.40 UE	Apr. 25	FC	S	U. N.H./Opp	Energetic particles	S

18.41 UE	Apr. 30	FC	X	U. N.H./Opp	Energetic particles	X
18.42 UE	May 3	FC	S	U. N.H./Opp	Energetic particles	S
14.222 GE	June 10	FC	S	GSFC/Bertsch	SPICE	X
14.223 GE	June 10	FC	S	GSFC/Bertsch	SPICE	X
19.01 NE	June 11	BRAZ	S	MSC/Holtz	Radiation	S
14.320 UE	Aug. 7	WI	S	Rice/Opp	Particles and fields	S
18.75 GE	Sept. 20	NOR	S	GSFC/Wescott	Magnetic fields	S
18.58 IE	Sept. 20	NOR	S	Norway	Particles and fields	P
18.76 GE	Sept. 21	NOR	S	GSFC/Wescott	Magnetic fields	S
18.77 GE	Sept. 23	NOR	S	GSFC/Wescott	Magnetic fields	S
18.59 IE	Oct. 1	NOR	S	Norway	Particles and fields	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Ionospheric Physics

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1959					
4.08 GI	Sept. 11	FC	S	GSFC/Jackson	Ionosphere	S
4.07 GI	Sept. 14	FC	S	GSFC/Jackson	Ionosphere	S
4.02 II	Sept. 17	FC	S	DRTE/Jackson	Ionosphere	S
4.03 II	Sept. 20	FC	P	DRTE/Jackson	Ionosphere	X
	1960					
6.01 UI	Mar. 16	FC	S	U. Mich./Bourdeau	Ionosphere	S
3.10 UI	Mar. 17	FC	X	U. Mich./Bourdeau	Ionosphere	X
6.02 UI	June 15	FC	S	U. Mich./Bourdeau	Ionosphere	S
6.03 UI	Aug. 3	WI	S	U. Mich./Bourdeau	Ionosphere	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Ionospheric Physics–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
3.12 CI	Aug. 22	WI	X	GCA/Bourdeau	Langmuir probe	X
1.01 GI	Nov. 23	FC	S	GSFC/Whipple	Ionosphere	S
1.02 GI	Nov. 27	FC	S	GSFC/Whipple	Ionosphere	S
10.25 CI	Dec. 8	WI	S	GCA/Bourdeau	Langmuir probe	S
	1961					
6.04 UI	Mar. 26	WI	S	U. Mich./Bourdeau	Ionosphere	S
8.10 GI	Apr. 27	WI	S	GSFC/Jackson	Ionosphere	P
8.09 GI	June 13	WI	S	GSFC/Jackson	Ionosphere	X
8.13 II	June 15	WI	S	DRTE/Jackson	Antenna test	S
8.15 AI	June 24	WI	S	CRPL-AIL/Jackson	Ionosphere	S
10.51 CI	Aug. 18	WI	S	GCA/Wright	Langmuir probe	S
8.17 AI	Oct. 14	WI	S	GSFC/Jackson	Ionosphere	S
10.52 CI	Oct. 27	WI	S	GCA/Bourdeau	Langmuir probe	S
10.74 GI	Dec. 21	WI	S	GSFC/Kane	Ionosphere	S
6.05 UI	Dec. 22	WI	S	U. Mich./Wright	Ionosphere	S
	1962					
8.16 AI	Feb. 7	WI	S	GSFC/Jackson	Ionosphere	X
10.110 GI	Apr. 26	WI	S	GSFC/Serbu	Electron temperature	S
8.21 GI	May 3	WI	S	GSFC/Serbu	ELF electron trap	X
10.112 GI	May 16	WI	S	GSFC/Serbu	Electron temperature	S
10.111 GI	May 17	WI	S	GSFC/Serbu	Electron temperature	S
14.12 GI	June 15	WI	S	GSFC/Kane	Ionosphere	S
14.31 GI	Oct. 16	WI	S	GSFC/Bauer	Ionosphere	S

10.99 CI	Nov. 7	WI	S	GCA/Bourdeau	Ionosphere	S
4.79 II	Nov. 16	WI	X	Australia/Cartwright	Ionosphere	X
10.108 CI	Nov. 30	WI	S	GCA/Bourdeau	Ionosphere	S
14.32 GI	Dec. 1	WI	S	GSFC/Bauer	Ionosphere	S
10.109 CI	Dec. 5	WI	S	GCA/Bourdeau	Ionosphere	S
4.80 II	Dec. 11	WI	X	Australia/Cartwright	Ionosphere	X
Ferdinand III (Nike-Cajun)	Dec. 11	NOR	S	GSFC/Kane	Ionosphere	S
	1963					
14.86 CI	Feb. 27	WI	S	GCA/Bourdeau	Ionosphere	S
14.107 GI	Mar. 8	WI	S	GSFC/Whipple	Ionosphere	P
14.87 CI	Mar. 28	WI	P	GCA/Bordeau	Ionosphere	S
4.58 UI	Apr. 3	WI	S	Stanford/Bourdeau	Ionosphere	S
14.108 GI	Apr. 9	WI	S	GSFC/Kane	*D*-region	S
4.96 II	Apr. 12	WI	S	Australia/Cartwright	VLF receiver	S
4.44 GI	Apr. 23	WI	S	GSFC/Bauer	Electron density	S
4.97 II	May 9	WI	S	Australia/Cartwright	VLF	S
8.14 GI	July 2	WI	S	GSFC/Bauer	Ionosphere	S
4.59 UI	July 10	WI	S	Stanford/Bourdeau	Ionosphere	S
14.88 CI	July 14	FC	P	GCA/Bourdeau	Ionosphere	P
14.89 CI	July 20	FC	X	GCA/Bourdeau	Eclipse ionosphere	X
14.90 CI	July 20	FC	X	GCA/Bourdeau	Eclipse ionosphere	X
14.91 CI	July 20	FC	S	GCA/Bourdeau	Eclipse ionosphere	S
14.92 CI	July 20	FC	S	GCA/Bourdeau	Eclipse ionosphere	S
14.93 CI	July 20	FC	S	GCA/Bourdeau	Eclipse ionosphere	S
14.94 CI	July 20	FC	S	GCA/Bourdeau	Eclipse ionosphere	S
6.08 GI	July 20	WI	S	U. Mich./Brace	Thermosphere probe	S
Ferdinand V (Nike-Cajun)	Sept. 1	NOR	S	GSFC/Kane	Ionosphere	X
Ferdinand IV (Nike-Apache)	Sept. 12	NOR	S	GSFC/Kane	Ionosphere	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Ionospheric Physics–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
4.65 GI	Sept. 25	WI	S	GSFC/Hirao	Ionosphere	S
4.64 GI	Sept. 28	WI	S	GSFC/Hirao	Ionosphere	S
8.18 GI	Sept. 29	WI	S	GSFC/Bauer	Ionosphere	S
14.36 DI	Oct. 7	FC	S	BRL/Bourdeau	Ionosphere	P
4.93 II	Oct. 17	WI	S	France/Shea	Ionosphere	S
4.94 II	Oct. 31	WI	S	France/Shea	Ionosphere	S
14.37 GI	Dec. 13	WS	P	GSFC/Whipple	Ionosphere	P
	1964					
Ferdinand VI (Nike-Apache)	Mar. 12	NOR	S	GSFC/Kane	Ionosphere	S
Ferdinand VII (Nike-Apache)	Mar. 15	NOR	S	GSFC/Kane	Ionosphere	S
Ferdinand VIII (Nike-Apache)	Mar. 19	NOR	S	GSFC/Kane	Ionosphere	S
12.03 GT-GI	Apr. 15	WI	S	GSFC/Guidotti	Rocket test; ionosphere	S
14.143 UI	Apr. 16	WI	S	U. Ill./Schardt	Ionosphere	S
4.113 GA-GI	Apr. 21	WS	X	GSFC/Aikin	Astrochemistry; ionosphere	X
14.33 GI	June 3	WI	S	GSFC/Bauer	Ionosphere	P
14.144 UI	July 15	WI	S	U. Ill./Schardt	Ionosphere	S
14.145 UI	July 15	WI	S	U. Ill./Schardt	Ionosphere	S
14.146 UI	July 15	WI	S	U. Ill./Schardt	Ionosphere	S
14.127 GI	July 16	WI	S	GSFC/Stone	Ionosphere	S
14.34 GI	Aug. 26	WI	S	GSFC/Bauer	Ionosphere	S
8.24 GI-II	Oct. 19	WI	S	GSFC/Serbu	Ionosphere	P
14.104 DI	Nov. 5	FC	S	BRL/Bourdeau	Ionosphere	S

8.19 DI	Nov. 5	FC	S	BRL/Bourdeau	Ionosphere	S
14.105 DI	Nov. 7	FC	S	BRL/Bourdeau	Ionosphere	S
8.20 DI	Nov. 7	FC	S	BRL/Bourdeau	Ionosphere	S
14.147 UI	Nov. 10	WI	S	U. Ill./Schardt	IQSY ionosphere	S
14.149 UI	Nov. 19	WI	S	U. Ill./Schardt	IQSY ionosphere	S
14.148 UI	Nov. 19	Ship	S	U. Ill./Schardt	IQSY ionosphere	S
14.117 GI	Nov. 23	WI	S	GSFC/Bauer	Ionosphere	S
ION 1 64-1 (Nike-Cajun)	Dec. 1	ARG	S	Argentina/Bauer	Ionosphere	S
ION 1 64-2 (Nike-Cajun)	Dec. 4	ARG	S	Argentina/Bauer	Ionosphere	S
4.132 GA-GI	Dec. 16	WS	S	GSFC/Berg	Micrometeoroids	S
14.209 GI	Dec. 16	WS	S	GSFC/Aikin	Ionosphere	S
	1965					
8.28 UI	Jan. 13	WI	S	Penn State/Schmerling	Mother-daughter ionosphere	X
15.03 II	Mar. 1	NOR	S	Sweden	Ionosphere	S
15.04 II	Mar. 2	NOR	S	Sweden	Ionosphere	S
15.01 GI	Mar. 16	NOR	S	GSFC/Kane	Ionosphere	X
14.177 GI	Mar. 16	Ship	S	GSFC/Blumle	Ionosphere	S
14.178 GI	Mar. 18	Ship	S	GSFC/Blumle	Ionosphere	S
14.176 GI	Mar. 18	Ship	S	GSFC/Davis	Geomagnetism	S
14.179 GI	Mar. 18	Ship	S	GSFC/Blumle	Ionosphere	S
14.228 UI	Mar. 20	Ship	S	U. Ill./Schmerling	Ionosphere	S
15.02 GI	Mar. 23	NOR	S	GSFC/Kane	Ionosphere	S
14.229 UI	Mar. 23	Ship	S	U. Ill./Schmerling	Ionosphere	X
14.180 GI	Mar. 24	Ship	S	GSFC/Blumle	Ionosphere	S
14.181 GI	Mar. 26	Ship	S	GSFC/Blumle	Ionosphere	S
14.182 GI	Mar. 27	Ship	S	GSFC/Blumle	Ionosphere	S
14.230 UI	Apr. 5	Ship	S	U. Ill./Schmerling	Ionosphere	S
14.231 UI	Apr. 9	Ship	S	U. Ill./Schmerling	Ionosphere	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Ionospheric Physics–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
14.232 UI	Apr. 12	Ship	S	U. Ill./Schmerling	Ionosphere	S
8.29 UI	May 19	WI	S	Penn State/Schmerling	Mother-daughter ionosphere	S
15.18 GI	May 25	NZ	S	GSFC/Kane	*D*-region ionosphere	S
8.37 GI	May 26	WI	X	GSFC/Maier	Ionosphere	X
15.05 GI	May 30	NZ	S	GSFC/Kane, Aikin	Eclipse ionosphere	S
15.06 GI	May 30	NZ	S	GSFC/Kane, Aikin	Eclipse ionosphere	S
15.07 GI	May 30	NZ	S	GSFC/Kane, Aikin	Eclipse ionosphere	S
15.08 GI	May 30	NZ	S	GSFC/Kane, Aikin	Eclipse ionosphere	S
15.09 GI	May 30	NZ	S	GSFC/Kane, Aikin	Eclipse ionosphere	S
15.10 GI	May 30	NZ	S	GSFC/Kane, Aikin	Eclipse ionosphere	S
14.245 UI	June 14	WI	S	U. Ill./Schmerling	Ionosphere	S
14.246 UI	June 17	WI	S	U. Ill./Schmerling	Ionosphere	S
14.215 AI	June 18	WI	S	BuStds/Schmerling	Ionosphere	X
14.210 GI	Aug. 24	WI	S	GSFC/Bourdeau	Ionosphere	S
14.213 UI	Sept. 1	WI	S	SCAS/Schmerling	Ionosphere	S
14.214 UI	Sept. 3	WI	S	SCAS/Schmerling	Ionosphere	X
14.244 UI	Sept. 15	WI	S	U. Ill./Schardt	IQSY ionosphere	S
4.138 II	Sept. 17	WI	S	France/Stevens	VLF experiment	S
8.36 GI	Sept. 23	WI	S	GSFC/Maier	Ionosphere	S
4.139 II	Sept. 25	WI	S	France/Stevens	VLF experiment	S
4.150 GA-GI-GB	Sept. 28	WS	S	GSFC/Berg	Micrometeoroid; ionosphere; micro-organisms	S
8.30 UI	Oct. 5	WI	S	Penn State/Schmerling	Mother-daughter ionosphere	S
8.42 UI	Oct. 10	WI	X	Penn State/Schmerling	Mother-daughter ionosphere	X

Ferdinand XII (Nike-Apache)	Nov. 20	NOR	S	Norway/Kane	Ionosphere	S
15.20 GI-II	Dec. 2	NOR	S	Norway/Kane	Ionosphere	X
15.19 GI	Dec. 6	NOR	S	GSFC/Kane	*D*-region ionosphere	S
14.247 UI	Dec. 15	WI	S	U. Ill./Schmerling	Ionosphere radio and physics	S
14.68 II	Dec. 15	BRAZ	S	Brazil/Blumle	Ionosphere	S
14.69 II	Dec. 18	BRAZ	S	Brazil/Blumle	Ionosphere	S
	1966					
14.248 UI	Jan. 10	WI	S	U. Ill./Schmerling	Ionosphere	P
8.25 GA-GI	Mar. 2	WI	S	GSFC/Smith	Geoprobe	S
14.109 GI	Mar. 21	NOR	S	GSFC/Kane	Ionosphere	S
14.216 AI	Apr. 6	WI	S	BuStds/Schmerling	Ionosphere	P
14.76 UI	Apr. 8	WI	S	SCAS/Opp	Ionosphere	S
15.25 GI	May 15	Greece	X	GSFC/Aikin	Ionosphere	X
15.26 GI	May 20	Greece	S	GSFC/Aikin	Eclipse ionosphere	S
15.27 GI	May 20	Greece	S	GSFC/Aikin	Eclipse ionosphere	S
15.28 GI	May 20	Greece	S	GSFC/Aikin	Eclipse ionosphere	S
15.29 GI	May 20	Greece	S	GSFC/Aikin	Eclipse ionosphere	S
15.30 GI	May 20	Greece	S	GSFC/Aikin	Eclipse ionosphere	S
15.31 GI	May 21	Greece	S	GSFC/Aikin	Ionosphere	S
14.270 UI	June 14	WI	S	U. Ill./Schmerling	Ionosphere	S
Ferdinand XIII (Nike-Apache)	June 26	NOR	S	Norway/Kane	Ionosphere	S
14.59 IE-II	July 7	IND	S	India	Magnetic fields; ionosphere	S
14.166 II	July 14	WI	S	Germany/Bauer	Ionosphere	S
14.271 UI	Aug. 24	WI	S	U. Ill./Schmerling	Ionosphere	S
14.272 UI	Aug. 25	WI	S	U. Ill./Schmerling	Ionosphere	P
15.12 GI	Aug. 29	WS	S	GSFC/Pederson	Ion density	P
15.11 GI	Aug. 29	WS	S	GSFC/Pederson	Ion density	P
14.278 CA-CI	Sept. 14	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Ionospheric Physics–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
14.279 CA-CI	Sept. 14	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	P
14.280 CA-CI	Sept. 16	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.281 CA-CI	Sept. 16	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.282 CA-CI	Sept. 16	FC	S	GCA/Dubin	Ionosphere; luminescent clouds	S
14.164 UI	Sept. 16	WI	S	U. Md./Schmerling	Ionosphere	S
8.38 GI	Oct. 6	WI	S	GSFC/Maier	Ionosphere	S
4.195 GA-GI	Oct. 25	WS	S	GSFC/Berg	Micrometeoroids	S
10.181 AI	Oct. 25	WS	S	ESSA/Schmerling	Ionosphere	S
14.77 CA-CI	Nov. 12	BRAZ-A	S	GCA/Dubin	Eclipse ionosphere; luminescent clouds	S
14.274 UI	Nov. 12	BRAZ-A	S	U. Ill./Schmerling	Eclipse ionosphere	S
14.302 UI	Nov. 12	BRAZ-A	S	U. Ill./Schmerling	Eclipse ionosphere	S
14.304 UI	Nov. 12	BRAZ-A	S	U. Ill./Schmerling	Eclipse ionosphere	S
14.303 UI	Nov. 12	BRAZ-A	S	U. Ill./Schmerling	Eclipse ionosphere	S
	1967					
14.275 UI	Jan. 31	WI	S	U. Ill./Schmerling	Ionosphere	S
Ferdinand XIV (Nike-Apache)	Mar. 3	NOR	S	Norway/Kane	Ionosphere	S
14.163 IA-II	Mar. 12	IND	S	India/Dubin	Ionosphere; luminescent clouds	P
14.206 IA-II	Mar. 12	IND	S	India/Dubin	Ionosphere; luminescent clouds	S

14.267 IA-II	Mar. 13	IND	S	India/Dubin	Ionosphere; luminescent clouds	P
Ferdinand XV (Nike-Apache)	Mar. 14	NOR	S	Norway/Kane	Ionosphere	S
14.256 II	Mar. 16	WI	S	India/Schmerling	Ionosphere	S
18.12 UI	Mar. 30	WI	S	U. Md./Schmerling	Ionosphere	S
8.39 GI	Apr. 12	FC	S	GSFC/Maier	Ionosphere	S
14.268 UI	May 5	FC	S	SCAS/Schmerling	Ionosphere	S
8.26 UI	June 21	WI	S	SCAS/Schmerling	Ionosphere	P
14.273 UI	Aug. 8	WI	S	U. Ill./Schmerling	Ionosphere	S
15.21 II	Aug. 25	NOR	S	Norway/Kane	Ionosphere	P
14.308 UI	Sept. 7	PB	S	U. Ill./Schmerling	Ionosphere	S
14.305 UI	Sept. 8	PB	S	U. Ill./Schmerling	Ionosphere	X
14.309 UI	Sept. 8	PB	X	U. Ill./Schmerling	Ionosphere	X
8.45 UI	Sept. 21	WI	S	U. Iowa/Schmerling	Ionosphere	S
15.22 II	Oct. 9	NOR	S	Norway/Kane	Ionosphere	S
15.23 II	Oct. 13	NOR	S	Norway/Kane	Ionosphere	S
15.32 GI	Oct. 24	RB	P	GSFC/Kane	Ionosphere	X
15.33 GI	Oct. 24	RB	P	GSFC/Kane	Ionosphere	P
14.298 UI	Nov. 16	WI	S	U. Md./Schmerling	Ionosphere	S
8.35 UI	Dec. 8	FC	S	SCAS/Schmerling	Ionosphere	S
	1968					
10.273 GI	Jan. 16	WI	S	GSFC/Somayajulu	Lower ionosphere	S
10.275 GI	Jan. 16	WI	S	GSFC/Somayajulu	Lower ionosphere	S
15.58 GI	Mar. 8	IND	S	GSFC/Kane	Lower ionosphere	S
15.59 GI	Mar. 8	IND	S	GSFC/Kane	Lower ionosphere	S
18.10 GI	Mar. 15	WI	S	GSFC/Herman	Ionosphere	S
14.375 IE-II	Mar. 28	IND	S	Germany	Magnetic fields; ionosphere	S
14.376 IE-II	Mar. 30	IND	S	Germany	Magnetic fields; ionosphere	S
14.377 IE-II	Mar. 31	IND	S	Germany	Magnetic fields; ionosphere	S
16.04 UI	Apr. 20	WI	S	U. Minn./Schmerling	Ionosphere	X

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Ionospheric Physics–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
19.04 II	May 7	WI	S	Canada	Ionosphere	S
8.46 UI	May 25	FC	S	U. Iowa/Schmerling	Ionosphere	S
14.358 UI	July 24	WI	S	U. Ill./Schmerling	Ionosphere	S
14.359 UI	July 24	WI	S	U. Ill./Schmerling	Ionosphere	S
14.360 UI	July 24	WI	S	U. Ill./Schmerling	Ionosphere	P
14.361 UI	July 24	WI	S	U. Ill./Schmerling	Ionosphere	S
15.52 GI	Aug. 2	RB	S	GSFC/Kane	*D*-region ionosphere	S
15.34 GI	Aug. 2	RB	S	GSFC/Kane	*D*-region ionosphere	S
14.369 GI	Aug. 21	WI	S	GSFC/Aikin	Ionosphere	S
14.368 GI	Aug. 21	WI	S	GSFC/Aikin	Ionosphere	S
14.370 GI	Aug. 21	WI	S	GSFC/Aikin	Ionosphere	S
18.30 UI	Aug. 21	WI	S	U. Md./Schmerling	Ionosphere	P
15.43 II	Oct. 24	SWE	S	Sweden	Ionosphere	S
14.379 GI	Nov. 7	WI	S	GSFC/Goldberg	Ion concentration	P
14.311 GI	Nov. 19	WI	S	GSFC/Aikin	Ionosphere	P

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Solar Physics

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1960					
3.01 GS	Mar. 1	WI	S	GSFC/Hallam	Solar studies	X
3.02 GS	Mar. 3	WI	S	GSFC/Hallam	Solar studies	X

3.03 GS	Apr. 27	WI	X	GSFC/Hallam	Solar studies	X
3.04 GS	May 25	WI	X	GSFC/Hallam	Solar studies	X
	1961					
4.25 GS	Sept. 30	WI	S	GSFC/Behring	Solar studies	S
	1962					
4.23 US	July 24	WI	S	U. Colo./Lindsay	Sunfollower	P
4.21 US	Nov. 27	WS	S	Harvard/Lindsay	Solar studies	X
	1963					
4.61 AS	June 20	WS	S	NRL/Packer	Coronagraph	P
4.62 AS	June 28	WS	S	NRL/Packer	Coronagraph	P
4.77 GS	July 20	WS	S	GSFC/Wolff	Solar studies	X
4.22 US	Sept. 6	WS	S	Harvard/Lindsay	Solar studies	S
4.78 GS	Oct. 1	WS	S	GSFC/Hallam	Solar studies	P
4.33 GS	Oct. 15	WS	S	GSFC/Muney	X-ray	S
	1964					
4.116 GS	Oct. 30	WS	S	GSFC/Muney	Solar studies	S
	1965					
4.63 GS	Mar. 17	WS	S	GSFC/Muney	Solar studies	S
4.49 GS	Apr. 12	WS	S	GSFC/Fredga	Solar studies	S
4.146 DS	Oct. 20	WS	S	NRL/Smith	1965F comet solar studies	P
4.53 GS	Oct. 26	WS	S	GSFC/Fredga	Solar studies	X
4.145 GS	Dec. 2	WS	S	GSFC/Fredga	Solar studies	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Solar Physics–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1966					
4.99 DS	Mar. 2	WI	S	AFCRL/Smith	Solar studies	S
4.100 DS	Mar. 3	WI	S	AFCRL/Smith	Solar studies	P
4.24 US	Apr. 14	WS	S	U. Colo./Dubin	Solar studies	P
4.189 DS	Apr. 28	WS	S	NRL/Smith	Solar studies	S
4.95 GS	May 20	WS	S	GSFC/Underwood	Solar X-ray	S
4.92 GS	May 20	WS	S	GSFC/Neupert	Solar spectra	S
4.101 DS	Aug. 26	WI	S	AFCRL/Schmerling	Solar studies	S
4.153 GS	Nov. 12	WS	S	GSFC/Underwood	Eclipse solar studies	S
4.191 DS	Nov. 12	WS	S	NRL/Smith	Eclipse solar studies	S
	1967					
16.05 US	Feb. 25	WI	S	Harvard/Smith	Solar physics	X
4.102 DS	Mar. 14	WI	S	AFCRL/Schmerling	Monochromatic extreme ultraviolet	P
4.103 DS	Mar. 22	WI	S	AFCRL/Schmerling	Monochromatic extreme ultraviolet	S
4.168 CS	Apr. 5	WS	S	Lockheed/Weldon	Solar physics	S
4.117 GS	Apr. 24	WS	S	GSFC/Neupert	Solar X-ray	S
4.192 DS	May 9	WS	S	NRL/Smith	Solar studies	S
4.104 DS	Sept. 30	WI	S	AFCRL/Schmerling	Monochromatic extreme ultraviolet	P
4.152 GS	Oct. 3	WS	S	GSFC/Underwood	Solar X-ray and ultra-violet	S
4.243 DS	Oct. 5	WS	S	NRL/Holtz	Solar studies	S
4.239 US	Oct. 19	WS	S	U. Colo./Glaser	Solar studies	S

	1968					
4.169 CS	Feb. 19	WS	S	Lockheed/Glaser	Solar physics	S
4.209 CS	Mar. 15	WS	S	AS&E/Glaser	Solar physics	P
4.244 DS	Apr. 27	WS	S	NRL/Glaser	Solar physics	S
4.245 DS	Apr. 29	WS	S	NRL/Glaser	Solar physics	S
4.230 GS	May 20	WS	S	GSFC/Fredga	Solar physics	S
4.134 DS	June 8	WS	S	NRL/Glaser	Solar physics	X
4.263 CS	June 8	WS	S	AS&E/Glaser	Solar physics	S
4.246 DS	Sept. 22	WS	S	NRL/Glaser	Solar corona	S
4.185 US	Sept. 24	WS	S	Harvard/Glaser	Solar studies	X
4.231 GS	Sept. 30	WS	S	GSFC/Behring	Solar extreme ultra-violet	S
4.248 CS	Oct. 16	WS	S	Lockheed/Glaser	Solar studies	S
4.240 US	Nov. 21	WS	S	U. Colo./Glaser	Solar physics	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Galactic Astronomy

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1960					
4.04 GG	Apr. 27	WI	P	GSFC/Kupperian	Stellar fluxes	P
4.05 GG	May 27	WI	S	GSFC/Boggess	Stellar fluxes	P
4.06 GG	June 24	WI	S	GSFC/Boggess	Stellar fluxes	S
4.11 GG	Nov. 22	WI	S	GSFC/Stecher	Stellar spectra	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Galactic Astronomy–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1961					
4.34 GG	Mar. 31	WI	P	GSFC/Boggess	Stellar fluxes	P
9.01 GG	Sept. 18	AUS	S	GSFC/Boggess	Stellar photometry	S
9.02 GG	Oct. 4	AUS	S	GSFC/Boggess	Stellar photometry	S
9.03 GG	Nov. 1	AUS	S	GSFC/Boggess	Stellar photometry	P
9.04 GG	Nov. 20	AUS	S	GSFC/Boggess	Stellar photometry	S
	1962					
4.35 GG	Feb. 7	WI	X	GSFC/Stecher	Stellar spectra	X
4.36 GG	Sept. 22	WI	S	GSFC/Stecher	Stellar photometry	X
4.69 CG	Sept. 30	WI	S	Lockheed/Dubin	Night sky mapping	S
4.54 UG	Oct. 30	WI	S	U. Wis./Kupperian	Stellar studies	S
	1963					
4.70 CG	Mar. 16	WI	S	Lockheed/Depew	Stellar spectra	S
4.30 GG	Mar. 28	WS	S	GSFC/Boggess	Stellar spectra	S
4.37 GG	July 19	WI	S	GSFC/Stecher	Stellar spectra	S
4.29 GG	July 23	WI	S	GSFC/Stecher	Stellar spectra	S
4.31 GG	Oct. 10	WS	X	GSFC/Boggess	Stellar spectra	X
	1964					
4.15 GG	Apr. 3	WS	S	GSFC/Boggess	Stellar spectra	X
4.81 GG	Apr. 10	WS	X	GSFC/Boggess	Stellar spectra	X

4.82 GG	Aug. 11	WS	S	GSFC/Boggess	Stellar spectra	X
4.126 GG	Aug. 22	WS	P	GSFC/Boggess	Stellar spectra	S
4.122 CG	Aug. 29	WS	S	AS&E/Roman	Stellar studies	S
4.55 UG	Sept. 2	WI	S	U. Wis./Kupperian	Stellar studies	S
4.120 CG	Oct. 2	WS	S	Lockheed/Roman	Stellar X-ray	S
4.123 CG	Oct. 27	WS	S	AS&E/Roman	Stellar studies	S
4.52 UG	Nov. 3	WS	P	Princeton	Stellar spectra	P
4.109 GG	Nov. 7	WS	S	GSFC/Stecher	Stellar spectra	S
4.110 GG	Nov. 14	WS	S	GSFC/Stecher	Stellar spectra	S
	1965					
4.133 UG	Mar. 6	WS	S	Princeton/Kupperian	Stellar spectra	X
4.56 GG	Mar. 13	WS	S	GSFC/Boggess	Stellar spectra	X
4.57 GG	Mar. 19	WS	S	GSFC/Boggess	Stellar studies	S
4.114 GG	Apr. 24	WS	X	GSFC/Boggess	Stellar studies	X
4.89 GG	May 5	WI	S	GSFC/Boggess	Stellar studies	X
4.17 UG	June 2	WS	S	Princeton/Kupperian	Stellar spectra	P
4.147 CG	Sept. 22	WS	S	AS&E/Roman	Celestial X-ray	S
4.121 CG	Oct. 1	WS	S	Lockheed/Roman	Stellar X-ray	S
4.151 UG	Oct. 13	WS	S	Princeton/Kupperian	Stellar spectra	S
4.155 GG	Nov. 30	WS	S	GSFC/Scolnik	Stellar spectra	S
	1966					
4.90 GG	Jan. 18	WI	S	GSFC/Wright	Stellar spectra	X
4.50 UG	Feb. 2	WS	S	Princeton/Kupperian	Stellar spectra	S
4.148 CG	Mar. 8	WS	S	AS&E/Roman	Stellar X-ray	S
4.171 UG	May 18	WI	S	U. Wis./Roman	Stellar studies	P
4.51 UG	May 24	WS	P	Princeton/Kupperian	Stellar spectra	P
4.159 GG	July 16	WS	S	GSFC/Stecher	Stellar spectra	S
4.144 DG	July 19	WS	P	NRL/Roman	Stellar spectra	X
4.176 UG	Sept. 20	WS	S	Princeton/Kupperian	Stellar spectra	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Galactic Astronomy–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
4.149 CG	Oct. 12	WS	S	AS&E/Roman	X-ray astronomy	S
4.154 GG	Nov. 21	WS	S	GSFC/Stecher	Stellar spectra	S
4.182 UG	Dec. 13	BRAZ	S	Catholic U./Roman	X-ray astronomy	S
	1967					
4.160 GG	Mar. 3	WS	S	GSFC/Stecher	Stellar spectra	S
4.84 UG	Mar. 3	WS	S	Cornell/Roman	Stellar infrared	S
4.194 DG	Mar. 17	WS	S	NRL/Roman	Stellar spectra	S
4.204 GG	Apr. 1	WS	P	GSFC/Stecher	Stellar spectra	P
4.186 UG	Apr. 7	WS	S	Princeton/Kupperian	Stellar spectra	P
4.157 GG	May 5	WS	S	GSFC/Evans	Stellar spectra	P
4.203 UG	May 5	WS	S	Princeton/Roman	Stellar spectra	X
4.210 GG	June 2	WS	S	GSFC/Smith	Stellar spectra	S
4.190 UG	July 8	WS	S	MIT/Roman	X-ray spectra	S
4.172 UG	Aug. 4	WS	S	U. Wis./Roman	Stellar ultraviolet	S
4.187 CG	Aug. 26	WS	S	Lockheed/Roman	Stellar X-ray	S
4.158 GG	Oct. 27	WS	S	GSFC/Evans	Stellar spectra	P
4.226 UG	Nov. 1	WS	S	Princeton/Roman	Stellar spectra	S
4.229 DG	Nov. 4	WS	S	NRL/Roman	Stellar spectra	P
4.228 CG	Nov. 20	WS	S	AS&E/Roman	Stellar X-ray	X
4.219 GG	Dec. 6	WS	S	GSFC/Smith	Stellar ultraviolet	P
	1968					
4.205 GG	Jan. 26	WS	S	GSFC/Stecher	Stellar spectra	P
4.261 CG	Feb. 2	WS	S	AS&E/Roman	Stellar X-ray	X

4.220 GG	Feb. 2	WS	S	GSFC/Stecher	Stellar spectra	S
4.177 UG	Mar. 1	WS	S	Cornell/Roman	Infrared radiation	S
4.255 GG	Mar. 22	WS	S	GSFC/Smith	Stellar spectra	S
14.241 IG	Apr. 22	IND	S	India-Japan	X-ray astronomy	X
14.260 IG	Apr. 24	IND	S	India-Japan	X-ray astronomy	X
4.227 UG	May 3	WS	S	Princeton/Roman	Stellar spectra	S
4.196 UG	May 3	WS	X	Colo. Rad. Lab./Thaddeus	X-ray astronomy	X
4.221 GG	May 17	WS	S	GSFC/Kondo	Stellar spectra	S
4.173 UG	May 25	WS	S	U. Wis./Roman	Stellar spectra	X
4.236 UG	July 27	WS	S	Colo. Rad. Lab./Roman	Stellar X-ray	S
4.225 UG	July 27	WS	S	MIT/Roman	Stellar X-ray	S
4.174 UG	Sept. 21	WS	S	U. Wis./Roman	Stellar spectra	S
4.265 DG	Oct. 10	WS	S	NRL/Roman	Stellar spectra	X
12.13 GT-GG	Oct. 26	WS	S	GSFC/Busse	Rocket test	S
14.261 IG	Nov. 7	IND	S	India	X-ray astronomy	S
4.268 UG	Nov. 15	WS	S	Princeton/Roman	Stellar spectra	S
4.264 CG	Dec. 6	WS	S	AS&E/Roman	X-ray astronomy	S
4.178 UG	Dec. 20	WS	S	Cornell/Roman	Infrared radiation	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Radio Astronomy

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1962					
11.02 UR	Sept. 22	WI	S	U. Mich./Coates	Radio astronomy	S
	1964					
8.33 GR	Oct. 23	WI	S	GSFC/Stone	Radio astronomy	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Radio Astronomy–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1965					
11.03 UR	June 30	WI	S	U. Mich./Roman	Radio astronomy	S
14.75 GR	Sept. 9	WI	S	GSFC/Stone	Radio propagation	S
	1966					
8.44 GR	May 20	WI	S	GSFC/Stone	Radio astronomy	S
	1967					
16.03 GR	Aug. 30	WI	S	GSFC/Stone	Radio astronomy	X
	1968					
14.346 GR	Mar. 28	WI	S	GSFC/Stone	Radio astronomy	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Biology

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1961					
11.04 GB	Nov. 15	PMR	S	GSFC/Campbell	BIOS I	X
11.05 GB	Nov. 18	PMR	P	GSFC/Campbell	BIOS I	X

	1965					
4.150 GA-GI-GB	Sept. 28	WS	S	GSFC/Berg	Micrometeoroids; ionosphere; micro-organisms	S
	1967					
4.213 NB	Dec. 5	WI	S	Wallops/Belleville	Gravity preference	S
	1968					
4.214 NB	June 24	WI	S	Wallops/Belleville	Gravity preference	S
4.215 NB	Nov. 21	WI	S	Wallops/Belleville	Gravity preference	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Special Projects

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1960					
1.03 GP	Sept. 15	FC	S	GSFC/Baumann	Arctic meteorological photographic probe (AMPP)	S
1.05 GP	Sept. 24	FC	S	GSFC/Baumann	AMPP	P
4.43 GP	Oct. 5	FC	S	NRL/Baumann	AMPP	S
	1961					
4.38 NP	Feb. 5	WI	S	LeRC/Gold	Hydrogen 0 *g*	P
4.39 NP	Apr. 21	WI	S	LeRC/Gold	Hydrogen 0 *g*	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Test and Support–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
3.28 GT	Aug. 9	WI	S	GSFC/Sorgnit	Rocket test	S
5.02 GT	Oct. 18	WI	S	GSFC/Sorgnit	Rocket test	S
3.29 GT	Nov. 3	WI	S	GSFC/Sorgnit	Rocket test	S
	1961					
3.36 GT	Jan. 17	WI	S	GSFC/Sorgnit	Rocket test	S
5.03 GT	Jan. 19	WI	X	GSFC/Sorgnit	Rocket test	P
10.49 GT	Mar. 15	WI	S	GSFC/Sorgnit	Cajun fin test	S
4.19 GT	Apr. 14	WI	S	GSFC/Russell	Attitude control	P
12.01 GT	May 2	WI	S	U. Mich./Spencer	Cone test	S
14.01 GT	May 25	WI	S	GSFC/Sorgnit	Rocket test	S
4.20 GT	June 26	WI	S	GSFC/Russell	Attitude control	P
14.02 GT	Aug. 16	WI	S	GSFC/Sorgnit	Rocket test	S
	1962					
4.68 GT	Jan. 13	WI	S	GSFC/Russell	Attitude control	S
10.69 GT	Mar. 1	WI	X	GSFC/Donn	Water test	S
10.70 GT	Mar. 2	WI	S	GSFC/Donn	Water test	S
4.48 GT	May 25	WI	S	GSFC/Pressly	Sea recovery	S
4.60 GT	Aug. 8	WI	P	GSFC/Russell	Attitude control	P
Ferdinand II (Nike-Cajun)	Dec. 14	NOR	S	Norway	NASA–telemetry only	S
	1963					
16.01 GT	Apr. 8	WI	X	GSFC/Sorgnit	Flight test	X
4.87 GT	June 17	WS	S	GSFC/Russell	Attitude control	S
14.111 GT	Oct. 31	WI	S	GSFC/Williams	Vibration test	S

	1964					
4.88 GT	Jan. 28	WS	S	GSFC/Russell	Attitude control	S
14.28 GT	Feb. 12	WI	S	GSFC/Sorgnit	Rocket fin test	S
12.03 GT-GI	Apr. 15	WI	S	GSFC/Guidotti	Rocket test; ionosphere	S
4.13 GP-GT	Sept. 26	WI	S	GSFC/Busse	Rocket test; other	S
16.02 GT	Oct. 21	WI	S	GSFC/Sorgnit	Rocket test	S
12.02 GT	Dec. 11	WI	S	GSFC/Lane	Rocket test	S
	1965					
17.01 GT	June 18	WI	S	GSFC/Lane	Rocket test	S
	1966					
17.02 GT	Aug. 17	WI	S	GSFC/Lane	Rocket test	S
12.06 GT	Sept. 20	WS	S	GSFC/Busse	Booster test	S
	1967					
15.55 GT	Apr. 20	WI	P	GSFC/Hudgins	Tone ranging test	S
14.343 GT-UA	Aug. 5	WS	S	GSFC/Wood	Recovery system test	X
12.07 GT	Sept. 12	WS	P	GSFC/Busse	Aerobee rail launch test	P
12.09 GT	Oct. 3	WI	X	GSFC/Wood	Arcas booster test	S
4.201 NT	Dec. 10	WS	S	Ames/Holtz	SPARCS test	P
	1968					
12.08 GT	Feb. 5	WI	S	GSFC/Sorgnit	Rocket test	S
4.202 NT	Mar. 19	WS	S	Ames/Holtz	SPARCS test	S
12.10 GT	Apr. 17	WI	S	GSFC/Wood	Rocket test	S
14.363 GT	June 4	WS	S	GSFC/Wood	Recovery system test	S
12.16 GT	Sept. 20	WI	P	GSFC/Pedolsky	Launch tube test	S
12.13 GT-UG	Oct. 26	WS	S	GSFC/Busse	Rocket test	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Meteorology

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
	1965					
14.71 CM	June 23	WI	S	GCA/Smith	Luminescent clouds	S
14.72 CM	June 23	WI	S	GCA/Smith	Luminescent clouds	S
14.73 CM	June 23	WI	S	GCA/Smith	Luminescent clouds	S
14.74 CM	June 23	WI	S	GCA/Smith	Luminescent clouds	S
10.128 GM	July 23	WI	S	GSFC/Smith	Grenade	S
10.151 GM	Aug. 7	PB	S	GSFC/Smith	Grenade	S
10.96 GM	Aug. 7	FC	S	GSFC/Smith	Grenade	S
10.162 GM	Aug. 7	PB	S	GSFC/Smith	Grenade	S
10.165 GM	Aug. 7	FC	S	GSFC/Smith	Grenade	S
10.168 GM	Aug. 7	WI	S	GSFC/Smith	Grenade	S
10.169 GM	Aug. 8	WI	S	GSFC/Smith	Grenade	S
10.166 GM	Aug. 8	FC	S	GSFC/Smith	Grenade	S
10.163 GM	Aug. 8	PB	S	GSFC/Smith	Grenade	S
10.167 GM	Aug. 8	FC	S	GSFC/Smith	Grenade	S
10.170 GM	Aug. 8	WI	S	GSFC/Smith	Grenade	S
10.164 FM	Aug. 9	PB	S	GSFC/Smith	Grenade	S
10.152 GM	Oct. 13	PB	S	GSFC/Smith	Grenade	S
10.97 GM	Oct. 13	FC	S	GSFC/Smith	Grenade	S
10.129 GM	Oct. 13	WI	S	GSFC/Smith	Grenade	S
10.177 GM	Oct. 19	PB	S	GSFC/Smith	Grenade	S
10.98 GM	Oct. 19	FC	S	GSFC/Smith	Grenade	S
10.174 GM	Oct. 19	WI	S	GSFC/Smith	Grenade	S
10.178 GM	Oct. 23	PB	S	GSFC/Smith	Grenade	S
10.175 GM	Oct. 23	WI	S	GSFC/Smith	Grenade	S
10.172 GM	Oct. 23	FC	S	GSFC/Smith	Grenade	S

10.176 GM	Oct. 27	WI	S	GSFC/Smith	Grenade	S
10.179 GM	Oct. 27	PB	S	GSFC/Smith	Grenade	S
10.173 GM	Oct. 27	FC	S	GSFC/Smith	Grenade	S
14.168 UM	Nov. 9	FC	S	U. Mich./Smith	Atmospheric structure	S
14.169 UM	Nov. 10	FC	X	U. Mich./Smith	Atmospheric structure	X
	1966					
14.262 CM	Jan. 17	WI	S	GCA/Smith	Sodium vapor	S
14.263 CM	Jan. 18	WI	S	GCA/Smith	Luminescent clouds	S
14.264 CM	Jan. 18	WI	S	GCA/Smith	Luminescent clouds	S
14.265 CM	Jan. 18	WI	S	GCA/Smith	Luminescent clouds	S
14.266 CM	Jan. 18	WI	S	GCA/Smith	Sodium vapor	S
10.185 GM	Jan. 24	FC	S	GSFC/Smith	Grenade	S
10.182 GM	Feb. 1	PB	S	GSFC/Smith	Grenade	P
10.147 GM	Feb. 1	WI	S	GSFC/Smith	Grenade	S
10.186 GM	Feb. 2	FC	S	GSFC/Smith	Grenade	S
10.187 GM	Feb. 10	FC	S	GSFC/Smith	Grenade	S
10.148 GM	Feb. 10	WI	S	GSFC/Smith	Grenade	S
10.183 GM	Feb. 10	PB	S	GSFC/Smith	Grenade	S
10.145 GM	Feb. 10	FC	S	GSFC/Smith	Grenade	S
10.149 GM	Feb. 10	WI	S	GSFC/Smith	Grenade	S
10.184 GM	Feb. 10	PB	S	GSFC/Smith	Grenade	S
14.251 UM	Feb. 27	ASC	S	U. Mich./Smith	Atmospheric structure	S
14.252 UM	Feb. 28	ASC	X	U. Mich./Smith	Atmospheric structure	X
10.180 IM	Mar. 24	PAK	S	Great Britain-Pakistan	Grenade	S
14.165 IM	Mar. 27	PAK	S	Great Britain-Pakistan	Grenade	S
14.249 IM	Apr. 26	PAK	S	Great Britain-Pakistan	Grenade; chemical release	P
10.190 GM	May 1	PB	S	GSFC/Smith	Grenade	S
10.188 GM	May 2	WI	S	GSFC/Smith	Grenade	S
10.194 GM	May 2	BRAZ	S	GSFC/Smith	Grenade	S
10.192 GM	May 2	FC	S	GSFC/Smith	Grenade	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Meteorology–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
10.191 GM	May 3	PB	S	GSFC/Smith	Grenade	S
10.193 GM	May 4	FC	S	GSFC/Smith	Grenade	S
10.189 GM	May 4	WI	S	GSFC/Smith	Grenade	S
10.195 GM	May 4	BRAZ	S	GSFC/Smith	Grenade	S
10.198 GM	June 17	FC	S	GSFC/Smith	Grenade	S
10.196 GM	June 17	PB	S	GSFC/Smith	Grenade	S
10.199 GM	June 23	FC	S	GSFC/Smith	Grenade	S
10.197 GM	June 23	PB	S	GSFC/Smith	Grenade	S
14.291 CM	July 17	WI	S	GCA/Smith	Luminescent clouds	S
14.292 CM	July 17	WI	S	GCA/Smith	Luminescent clouds	S
14.293 CM	July 17	WI	S	GCA/Smith	Luminescent clouds	S
14.294 CM	July 17	WI	S	GCA/Smith	Luminescent clouds	S
14.295 CM	July 17	WI	S	GCA/Smith	Luminescent clouds	S
14.296 GM	Aug. 7	WI	P	GSFC/Smith	Grenade	S
10.204 GM	Aug. 7	BRAZ	S	GSFC/Smith	Grenade	S
10.202 GM	Aug. 7	FC	S	GSFC/Smith	Grenade	S
14.289 UM	Aug. 7	FC	S	U. Mich./Smith	Atmospheric structure	S
10.203 GM	Aug. 7	FC	S	GSFC/Smith	Grenade	S
10.206 GM	Aug. 7	WI	S	GSFC/Smith	Grenade	S
10.205 GM	Aug. 7	BRAZ	S	GSFC/Smith	Grenade	S
10.200 GM	Aug. 14	PB	S	GSFC/Smith	Grenade	S
10.201 GM	Aug. 15	PB	S	GSFC/Smith	Grenade	S
14.285 UM	Aug. 26	WI	S	U. Mich./Smith	Atmospheric structure	S
14.286 UM	Aug. 28	WI	S	U. Mich./Smith	Atmospheric structure	S
4.156 GM	Aug. 29	WS	S	GSFC/Heath	Airglow; electron temperature and density	S
10.146 GM	Sept. 30	WI	S	GSFC/Smith	Grenade	S

14.217 GM	Sept. 30	WI	S	GSFC/Smith	Grenade	S
10.209 GM	Oct. 1	WI	S	GSFC/Smith	Grenade	S
10.211 GM	Oct. 1	BRAZ	S	GSFC/Smith	Grenade	S
10.210 GM	Oct. 1	WI	S	GSFC/Smith	Grenade	S
10.212 GM	Oct. 1	BRAZ	S	GSFC/Smith	Grenade	S
10.213 GM	Oct. 2	BRAZ	S	GSFC/Smith	Grenade	S
10.214 GM	Oct. 2	BRAZ	S	GSFC/Smith	Grenade	S
10.215 GM	Oct. 2	BRAZ	S	GSFC/Smith	Grenade	S
10.160 GM	Dec. 9	WS	S	GSFC/Hilsenrath	Ozone	P
	1967					
10.207 GM	Jan. 31	WI	S	GSFC/Smith	Grenade	S
14.319 UM	Jan. 31	FC	S	U. Mich./Smith	Atmospheric structure	S
14.310 CM	Jan. 31	FC	S	GCA/Smith	Luminescent clouds	S
10.216 GM	Jan. 31	PB	S	GSFC/Smith	Grenade	S
14.315 UM	Feb. 1	FC	X	U. Mich./Smith	Atmospheric structure	X
14.311 CM	Feb. 1	FC	S	GCA/Smith	Luminescent clouds	S
10.217 GM	Feb. 1	PB	S	GSFC/Smith	Grenade	S
14.317 UM	Feb. 1	FC	S	U. Mich./Smith	Atmospheric structure	S
14.312 CM	Feb. 1	FC	S	GCA/Smith	Luminescent clouds	S
10.218 GM	Feb. 1	PB	S	GSFC/Smith	Grenade	S
14.318 UM	Feb. 1	FC	S	U. Mich./Smith	Atmospheric structure	S
14.313 CM	Feb. 1	FC	S	GCA/Smith	Luminescent clouds	S
10.219 GM	Feb. 1	PB	S	GSFC/Smith	Grenade	S
14.316 UM	Feb. 1	FC	S	U. Mich./Smith	Atmospheric structure	S
14.323 CM	Feb. 1	FC	S	GCA/Smith	Luminescent clouds	S
10.220 GM	Feb. 1	PB	S	GSFC/Smith	Grenade	S
14.314 CM	Feb. 1	FC	S	GCA/Smith	Luminescent clouds	S
14.322 UM	Feb. 1	FC	S	U. Mich./Smith	Atmospheric structure	S
10.221 GM	Feb. 1	PB	S	GSFC/Smith	Grenade	S
10.222 GM	Feb. 3	WI	S	GSFC/Smith	Grenade	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Meteorology–Continued

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
10.208 GM	Mar. 31	WI	S	GSFC/Smith	Grenade	S
10.226 GM	Apr. 4	PB	S	GSFC/Smith	Grenade	S
10.227 GM	Apr. 10	PB	S	GSFC/Smith	Grenade	S
10.223 GM	Apr. 11	WI	S	GSFC/Smith	Grenade	S
10.228 GM	Apr. 18	PB	S	GSFC/Smith	Grenade	S
10.224 GM	Apr. 20	WI	S	GSFC/Smith	Grenade	P
10.225 GM	Apr. 29	WI	S	GSFC/Smith	Grenade	S
10.229 GM	Apr. 30	PB	S	GSFC/Smith	Grenade	S
10.232 GM	May 4	WI	S	GSFC/Smith	Grenade	S
10.230 GM	May 9	PB	S	GSFC/Smith	Grenade	S
10.233 GM	May 11	WI	S	GSFC/Smith	Grenade	S
10.161 GM	May 11	WI	S	GSFC/Hilsenrath	Ozone	X
10.231 GM	May 15	PB	S	GSFC/Smith	Grenade	S
10.238 GM	June 24	BRAZ	S	GSFC/Smith	Grenade	S
10.237 GM	June 24	BRAZ	S	GSFC/Smith	Grenade	S
10.239 GM	June 25	BRAZ	S	GSFC/Smith	Grenade	S
14.337 CM	July 23	WI	S	GCA/Smith	Luminescent clouds	S
14.97 UM	Aug. 3	PB	S	U. Mich./Smith	Atmospheric structure	S
14.290 UM	Aug. 5	PB	S	U. Mich./Smith	Atmospheric structure	S
14.338 CM	Aug. 9	WI	S	GCA/Smith	Luminescent clouds	S
14.339 CM	Aug. 9	WI	S	GCA/Smith	Luminescent clouds	S
14.340 CM	Aug. 9	WI	S	GCA/Smith	Luminescent clouds	S
14.342 CM	Aug. 9	WI	S	GCA/Smith	Luminescent clouds	S
14.341 CM	Aug. 9	WI	S	GCA/Smith	Luminescent clouds	S
10.240 GM	Aug. 21	BRAZ	X	GSFC/Smith	Grenade	X
10.241 GM	Aug. 26	BRAZ	S	GSFC/Smith	Grenade	S
10.242 GM	Aug. 26	BRAZ	S	GSFC/Smith	Grenade	S

10.243 GM	Aug. 28	BRAZ	S	GSFC/Smith	Grenade	S
14.334 UM	Sept. 18	WI	X	U. Mich./Smith	Atmospheric structure	X
10.248 GM	Oct. 14	BRAZ	S	GSFC/Smith	Grenade	S
10.244 GM	Oct. 15	BRAZ	S	GSFC/Smith	Grenade	S
10.245 GM	Oct. 15	BRAZ	S	GSFC/Smith	Grenade	S
14.250 IM	Nov. 29	PAK	S	Great Britain-Pakistan	Grenade; luminescent clouds	S
10.249 GM	Dec. 12	WI	S	GSFC/Smith	Grenade	S
10.246 GM	Dec. 18	BRAZ	S	GSFC/Smith	Grenade	S
10.247 GM	Dec. 19	BRAZ	S	GSFC/Smith	Grenade	S
10.250 GM	Dec. 19	BRAZ	S	GSFC/Smith	Grenade	S
	1968					
18.62 GM	Jan. 22	WI	S	GSFC/Heath	Airglow	P
10.264 GM	Feb. 1	WI	S	GSFC/Smith	Grenade	S
10.259 GM	Feb. 1	FC	S	GSFC/Smith	Grenade	S
10.255 GM	Feb. 1	PB	X	GSFC/Smith	Grenade	X
10.260 GM	Feb. 1	FC	S	GSFC/Smith	Grenade	S
10.261 GM	Feb. 1	FC	S	GSFC/Smith	Grenade	P
10.262 GM	Feb. 1	FC	S	GSFC/Smith	Grenade	S
10.263 GM	Feb. 5	FC	S	GSFC/Smith	Grenade	S
10.234 GM	Feb. 7	WS	S	GSFC/Rast	Ozone parachute system test	S
14.364 CM	Feb. 22	WI	S	GCA/Smith	Luminescent clouds	S
14.365 CM	Feb. 22	WI	S	GCA/Smith	Luminescent clouds	S
14.336 CM	Feb. 22	WI	S	GCA/Smith	Luminescent clouds	S
14.367 CM	Feb. 22	WI	S	GCA/Smith	Luminescent clouds	S
14.344 UM	Mar. 17	PR	S	U. Mich./Smith	Atmospheric structure	S
14.345 UM	Mar. 17	PR	S	U. Mich./Smith	Atmospheric structure	S
14.333 UM	Mar. 18	PR	S	U. Mich./Smith	Atmospheric structure	S
10.270 GM	Mar. 24	BRAZ	S	GSFC/Smith	Grenade	S

[a]S = successful; P = partially successful; X = unsuccessful.

NASA Sounding Rocket Flights–Meteorology–Concluded

NASA rocket	Date	Firing site	Rocket performance[a]	Affiliation/ experimenter	Purpose	Overall flight result[a]
10.271 GM	Mar. 25	BRAZ	S	GSFC/Smith	Grenade	S
10.272 GM	Mar. 25	BRAZ	S	GSFC/Smith	Grenade	S
12.11 GM	Apr. 8	WI	X	GSFC/Smith	Rocket test	X
14.356 UM	Apr. 23	FC	X	U. Mich./Smith	Atmospheric structure	X
10.258 GM	July 24	WI	S	GSFC/Smith	Grenade	S
10.265 GM	July 24	WI	S	GSFC/Smith	Grenade	S
10.266 GM	July 24	WI	S	GSFC/Smith	Grenade	S
14.187 UM	Aug. 8	WI	S	U. Mich./Smith	Atmospheric structure	P
14.357 UM	Aug. 9	WI	S	U. Mich./Smith	Atmospheric structure	S
10.281 GM	Sept. 27	FC	S	GSFC/Smith	Grenade	S
10.287 GM	Oct. 15	PB	S	GSFC/Smith	Grenade	S
10.288 GM	Oct. 15	PB	S	GSFC/Smith	Grenade	S
10.251 GM	Oct. 16	WI	S	GSFC/Smith	Grenade	S
10.252 GM	Oct. 16	FC	S	GSFC/Smith	Grenade	S
10.293 GM	Nov. 19	WI	S	GSFC/Smith	Grenade	S
14.386 UM	Nov. 19	WI	S	U. Mich./Smith	Atmospheric structure	S
10.283 GM	Nov. 20	FC	S	GSFC/Smith	Grenade	S
10.284 GM	Nov. 20	FC	S	GSFC/Smith	Grenade	S
10.289 GM	Nov. 22	PB	S	GSFC/Smith	Grenade	S
10.290 GM	Nov. 22	PB	S	GSFC/Smith	Grenade	S
10.294 GM	Dec. 12	WI	S	GSFC/Smith	Grenade	S
10.295 GM	Dec. 12	WI	S	GSFC/Smith	Grenade	S
10.285 GM	Dec. 13	FC	S	GSFC/Smith	Grenade	S
10.291 GM	Dec. 13	PB	S	GSFC/Smith	Grenade	S
10.286 GM	Dec. 13	FC	S	GSFC/Smith	Grenade	S
10.292 GM	Dec. 13	PB	S	GSFC/Smith	Grenade	S

[a]S = successful; P = partially successful; X = unsuccessful.

APPENDIX C
TRENDS
IN VEHICLE USAGE, 1959-1968

Vehicle	Year										10-year total
	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	
Aerobee 100	0	4	8	2	0	0	0	0	0	0	14
Aerobee 150	4	1	0	3	12	22	23	24	31	35	155
Aerobee 150A	0	10	8	17	18	4	6	5	4	2	74
Aerobee 300/300A	0	3	2	1	2	2	1	0	0	0	11
Aerobee 350	0	0	0	0	0	0	1	1	0	0	2
Arcas	0	0	0	0	0	0	13	9	16	6	44
Arcon	6	0	0	0	0	0	0	0	0	0	6
Astrobee 1500	0	0	0	0	1	1	0	0	2	1	5
Black Brant IV	0	0	0	0	0	0	0	0	0	2	2
Iris	0	2	1	1	0	0	0	0	0	0	4
Javelin	1	5	8	2	2	7	7	6	9	4	51
Journeyman	0	1	2	1	1	0	2	0	0	0	7
Nike-Apache	0	0	5	11	36	76	92	57	48	50	375
Nike-Asp	5	10	8	3	1	0	0	0	0	0	27
Nike-Cajun	0	24	23	37	20	38	43	43	35	38	301
Nike-Tomahawk	0	0	0	0	0	0	3	12	15	30	60
Skylark	0	0	4	0	0	0	0	0	0	0	4
Miscellaneous	0	0	1	0	0	2	0	1	2	6	12
Total	16	60	70	78	93	152	191	158	162	174	1154

Note.–These data do not include the much larger quantities of small meteorological rockets fired all over the world by various agencies, including NASA.

APPENDIX D
A TYPICAL MEMORANDUM OF AGREEMENT

MEMORANDUM OF UNDERSTANDING
BETWEEN THE
COMISSAO NACIONAL DE ATIVIDADES ESPACIAIS
AND THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The Comissao Nacional de Atividades Espaciais (CNAE) of the United States of Brazil and the National Aeronautics and Space Administration (NASA) of the United States of America reaffirm their desire to conduct space research projects of mutual interest for peaceful scientific purposes.

Accordingly, CNAE and NASA agree to conduct a series of scientific sounding rocket flights from the Barreira do Inferno range near Natal, Brazil, to sample the radiation dose rates in the vicinity of the South Atlantic Anomaly. The unique aspects of the South Atlantic Anomaly Region allow these data to be obtained by launching an electron energy spectrometer and other radiation detection instruments to an approximate altitude of 550 statute miles by means of a Black Brant IV sounding rocket. The data returned will allow scientists to examine the dynamics of the inner radiation belts, and will be useful in safeguarding astronauts conducting low altitude, low inclination, Earth orbital missions.

To carry out this project, CNAE and NASA agree to use their best efforts as follows:

1. *NASA Responsibilities:*

a. Provide training at facilities in Brazil for a mutually agreed number of CNAE personnel in payload preparation and handling; Black Brant IV assembly, prelaunching preparation, and launching techniques; and maintenance and operation of the data recording equipment. Training is to include a live launching from the Barreira do Inferno range.

b. Provide and transport to Brazil three Black Brant IV rockets and flight-qualified payloads.

c. Provide on loan and transport to and from Brazil project support and vehicle handling equipment.

d. Install launcher rails on the NASA Javelin launcher currently on loan at the Barreira do Inferno range.

e. Assume primary responsibility for assembly, preparation, preflight checkout, and launching of the first Black Brant vehicle and payload.

f. Provide appropriate technical assistance to carry out the project.

g. Provide and install a teletypewriter circuit between the Barreira do Inferno range and an appropriate NASA facility.

2. *CNAE Responsibilities:*

a. Provide a mutually agreed number of personnel to train in payload preparation and handling; Black Brant IV assembly, prelaunching preparation, and launching techniques; and in the maintenance and operation of the data recording equipment.

b. Assist with customs clearance and provide transportation within Brazil for the project support equipment, rockets, and payloads required for this program.

c. Provide storage for rockets, payloads, and project support equipment for the duration of the project.

d. Assist in the installation of launcher rails, teletypewriter equipment, and other project equipment.

e. Maintain and operate the teletypewriter equipment at the Barreira do Inferno range.

f. Prepare and operate the launching range and associated facilities, including the special data recording equipment provided for this program.

g. Assist, on a training basis, in vehicle and payload assembly, preparation, preflight checkout, and launch of the first Black Brant IV rocket and payload.

h. Assemble, prepare, conduct preflight checkouts and launch the follow-on rockets and payloads according to a mutually agreed schedule.

i. Provide photographic coverage of the preparation and launch of each vehicle.

j. Provide quick look telemetry and radar information as soon as possible after each follow-on flight.

k. Provide radar and telemetry data for each flight.

Each agency will bear the cost of discharging its respective responsibilities, including personnel, travel and subsistence costs.

Each agency agrees to designate a Project Manager to be responsible for coordinating the agreed functions and responsibilities of each agency with the other in the implementation of this agreement. Copies of all correspondence between project managers will be forwarded to the NASA Office of International Affairs, and, if desired, to a comparable office in CNAE.

The raw data obtained will be available both to CNAE and NASA. First publication rights will reside with the principal experimenter for one year after launch. Following a period of one year, records or copies of reduced data will be deposited with the National Space Sciences Data Center and listed with the appropriate World Data Center. Such records will then be made available to interested scientists, upon reasonable request, by the World Data Center or other selected depository. Results of the experiment will be made available to the scientific community in general through publication in appropriate journals or other established channels.

Each agency may release public information regarding its own portion of the project, as desired, and insofar as the participation of the other agency is concerned, after suitable coordination.

In the event of damage arising from activities under this cooperative agreement, under the principles of the Treaty Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, and international law; CNAE and NASA agree to consult promptly.

For the Comissao Nacional de Atividades Espaciais	For the National Aeronautics and Space Administration

Dates

APPENDIX E
TRENDS IN USE
BY DISCIPLINE, 1959-1968

Discipline	Year										10-year total
	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	
Aeronomy	5	10	21	30	35	51	45	31	28	31	287
Biology	0	0	2	0	0	0	0	0	1	2	5
Energetic particles	0	16	1	0	2	16	15	14	11	21	96
Fields	0	2	3	0	1	9	13	5	12	12	57
Galactic astronomy	0	4	5	4	5	11	10	11	16	19	85
Ionospheric physics	4	8	10	14	27	22	46	25	20	21	197
Meteorology	0	5	13	14	11	34	53	59	57	48	294
Radio astronomy	0	0	0	1	0	1	2	1	1	1	7
Solar physics	0	4	1	2	6	1	5	9	10	12	50
Test and miscellaneous	7	11	14	13	6	7	2	3	6	7	76
Total	16	60	70	78	93	152	191	158	162	174	1154

APPENDIX F
FINANCIAL SUMMARY, 1958-1970

1963 and prior	$38 304 000
1964	16 740 000
1965	16 674 000
1966	19 256 000
1967	19 928 000
1968	19 856 000
1969	12 234 000
1970	18 500 000 (plan)
Total	161 492 000

Source: NASA Headquarters, Physics and Astronomy Office.

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