LORENCE W. FRASER

# HIGH ALTITUDE RESEARCH AT THE APPLIED PHYSICS LABORATORY IN THE 1940s

In an era of orbiting satellites and space shuttles, the pioneer efforts to explore the region above the earth are apt to be forgotten. But, in the years before the space age began in 1957 with the launch of Sputnik, much was learned about the upper atmosphere by direct observation from earth using instruments carried aloft, first by people climbing to the tops of mountains, then by balloons and aircraft, and later by rockets. By the end of World War II, the rocket was no longer an unpredictable erratic device but had become a powerful tool for exploring phenomena in which attainment of altitude was important to surmount the limitations imposed by the earth's atmosphere.

## INTRODUCTION

The earth's atmosphere is reasonably transparent to visible light, to sound waves, and to a wide range of radio waves. But it is quite opaque to cosmic radiation and ultraviolet light. Their effects at sea level are only a slight indication of the nature of the primary cosmic radiation as it initially strikes the top of the atmosphere.

As early as 1943, Erich Regener and Ernst Stuhlinger in Germany planned investigations of the cosmic-ray intensity above the atmosphere and of the solar ultraviolet spectrum, with equipment to be carried on test flights of V-2 military rockets. Such flights were never conducted because of wartime pressures, including Allied air raids on the German rocket base at Peenemunde that also destroyed some of the instruments built for atmospheric research.

The post-World War II period brought intensive efforts within the United States and the Soviet Union to develop high-performance rockets for military purposes. At a less well known level, it was also characterized by the aspirations of scientists to use such rockets as vehicles to carry scientific equipment to high altitudes. In late 1945, the Jet Propulsion Laboratory successfully flew a small sounding rocket, called WAC Corporal, from the newly established White Sands Proving Ground in New Mexico. The rocket, a scaled-down version of the Jet Propulsion Laboratory's military rocket Corporal, reached an altitude of 70 kilometers with a potential payload of 5 kilograms. In some ways, the flight advanced the much earlier plans of Robert Goddard to conduct scientific work with rockets flown to high altitudes for sounding or investigating the upper atmosphere. However, the WAC Corporal was not applied in any significant manner to scientific work.

The first major development in the history of the rocket flight of scientific equipment came a few months later. The U.S. Army Ordnance Department transferred a group of German rocket engineers and a large stock of V-2 rocket components from Peenemunde to the United States. The Army planned to assemble and fire a number of V-2s for the purpose of technical assessment and experience as part of the then embryonic effort of the United States to develop ballistic missiles. The primary purposes of the program were to get a military appraisal of the V-2 as a weapon and to gain field experience in the handling, firing, tracking, and recovery of large missiles. However, in response to the expressed interest of Ernst H. Krause of the Naval Research Laboratory, Col. Holger N. Toftoy and Lt. Col. James G. Bain invited scientists from universities and from government and industrial laboratories to formulate a program for using the payload capacity (1000 kilograms) of the V-2 test flights to conduct scientific investigations.[1]

The nationwide group of scientists and engineers had no official status or authority. However, it was entrusted by Army Ordnance with developing a scientific program, allocating available payload capacity on V-2 test flights, and advising the Department on such other matters as would assure successful execution of the program. This self-constituted group called itself the "V-2 Upper Atmosphere Panel." Its first formal meeting occurred on February 27, 1946. Work on preparing scientific instruments was already under way, and a provisional schedule of launchings was agreed upon.

James Van Allen tells how he became involved in the upper atmosphere research program at APL:[2]

> At that time [1945] I was seeking to return to civilian employment at APL after service as an ordnance and gunnery officer in the U.S. Navy since November 1942. In 1940 and 1941 I had worked at the Department of Terrestrial Magnetism (DTM) of the Carnegie Institution of Washington in helping develop rugged vacuum tubes and photoelectric and radio proximity fuzes for gun-fired projectiles. Merle A. Tuve had established APL in early 1942 and then served as its wartime director. Along with other colleagues in the proximity fuze group at DTM, I was transferred to APL at the time of its creation. At Tuve's request I was commissioned directly from my post at APL into the U.S. Naval Reserve as a lieutenant (junior grade) in November 1942 as one of three individuals to take the first issue of secret radio-proximity fuzed 5″/38 projectiles to the South Pacific Fleet. My functions were to introduce this new type of anti-aircraft ammunition into service in the fleet, to instruct gunnery officers in its use, to observe and report its effectiveness in combat, and later to set up re-batterying facilities in Australia, New Caledonia, Espiritu Santo, Tulagi, Eniwetok, and Manus. After my return to the United States and the end of the war in the Pacific, I had a number of conversations with Tuve on resuming peacetime research. My 1939 Ph.D. from the University of Iowa had been in experimental nuclear physics, and I had continued in this field at DTM as a research fellow of the Carnegie Institution in 1939-40. During this period I had acquired an interest in cosmic-ray research from Scott Forbush and others at DTM. Tuve encouraged me to pursue this interest and invited me to return to APL to conduct research in this field.
>
> Henry H. Porter of APL told me about the Army Ordnance Department's plans for the V-2 firings, and on January 16, 1946, I joined with many other interested scientists at a meeting at the Naval Research Laboratory for a briefing on the possibilities [of using these firings for upper atmosphere research]. One tangible result of this meeting was the formation of an unofficial group of scientists who had a realistic expectation of preparing equipment for flight. I was fortunate enough to be a member of this group, a circumstance that was pivotal to my subsequent career. My gunnery experience and my earlier intensive experience in developing vacuum tubes and associated circuits that survived linear accelerations of up to 20,000 g while being fired from guns led me to think that building electronics and scientific instruments for rocket-borne payloads would be easy—an expectation that later proved to be only partially true.
>
> With Tuve's support I organized [at APL] a high-altitude research group of kindred spirits: Howard E. Tatel, John J. Hopfield, Robert P. Peterson, Lorence W. Fraser, Russell S. Ostrander, Clyde T. Holliday, and, later, J. F. R. Floyd, S. Fred Singer, Gene M. Melton, Alfred V. Gangnes, James F. Jenkins, Jr., Harold E. Clearman, Arthur E. Coyne, J. Vincent Smith, J. W. Blair Barghausen, Frank W. Loomis, Bertman F. Chaffee, and David W. Hamlin. We very quickly developed plans for a comprehensive program of measurements of primary cosmic rays, the ultraviolet spectrum of the sun, and the geomagnetic field in the ionosphere.

## THE V-2 PROGRAM

After an exhaustive survey of the United States in 1945 by Lt. Col. Harold R. Turner, Maj. Herbert Karsch, and others from Army Ordnance, the extensive government reservation of the White Sands area had been selected as a proving ground for high-performance missiles. In October 1945, the Chief of Army Ordnance invited the Secretary of the Navy to join him in using the newly established White Sands Proving Ground as an intermediate land test range for naval guided missiles for the Bureau of Ordnance and for pilotless aircraft for the Bureau of Aeronautics. In March 1946, the bureaus jointly accepted the invitation. V-2 firings commenced in early 1946.

Assembly of the V-2s was carried out by engineers and technicians from the General Electric Co., supervised by L. D. White, and from the German Peenemunde group, under Wernher von Braun. The Naval Research Laboratory supplied the specially designed payload shells (warheads) required for the experimental apparatus and provided complete telemetry equipment, tracking beacons, and command receivers.

Radio control was used in the V-2 for emergency fuel cutoff and to cause aerodynamic instability for missile destruction and for easier recovery of experimental equipment. A group at New Mexico College of Agriculture and Mechanical Arts under George Gardiner performed tracking, telemetry reception, and other valuable services. Master time signals were furnished by the Aberdeen Ballistics Research Laboratory and the Army Signal Corps. Soon V-2 rockets were sending back signals containing previously unattainable information on the physics of the upper atmosphere.

Five research agencies had primary cognizance of experimental equipment in the V-2 flights: the Naval Research Laboratory, General Electric, the Air Materiel Command, Princeton University, and APL.

## THE V-2 LAUNCHINGS

A static V-2 firing was carried out on March 15, 1946, followed by a live firing on April 16, during which the rocket reached an altitude of only 14,000 feet. That V-2 was instrumented by APL with a self-starting and self-recording single Geiger tube cosmic-ray recorder. The instrumentation failed to operate, presumably because of insufficient acceleration to activate the starting switch, which was set to operate at 4 *g*. Two flights by the Naval Research Laboratory followed. On May 10, the APL experiment was repeated but, while the flight itself was successful, the equipment was never recovered from the huge impact crater.

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Explosive charges were then used to achieve warhead blowoff, which was obtained in the third APL flight, on July 30, 1946. While the warhead itself with its steel-drum recorders was never located, the afterbody of the rocket was found in fairly good condition. No tangible scientific results were obtained from those initial flights because of a comprehensive variety of mistakes of omission and commission in the exciting and demanding early learning stages of a new art. Despite that, Van Allen and his team pressed on with their programs, learning rapidly by diagnosis of their failures.

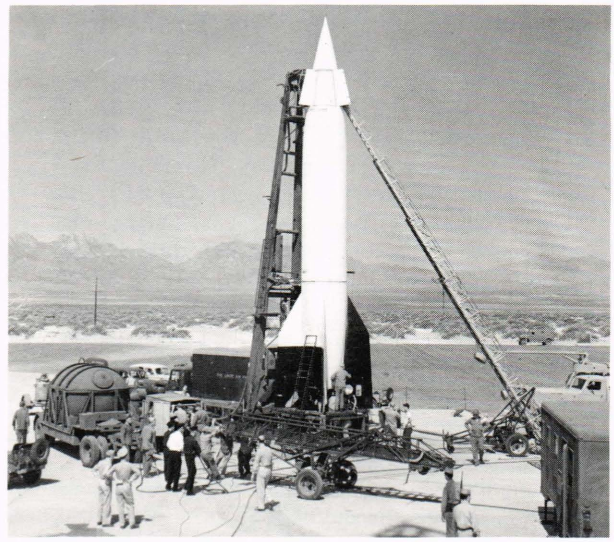
From May 1946 until February 1949, 10 V-2 rockets were instrumented by APL and fired at White Sands. Experiments ranged from preliminary surveys and exploratory measurements of cosmic radiation to investigation of the transition effects of the cosmic radiation in lead, as well as solar spectroscopy and high-altitude photography.

The V-2 firings from White Sands were not without unforeseen incidents. An early V-2 that fell in Juarez, Mexico, almost precipitated an international incident and resulted in the temporary closing of the border. Shortly after it landed, parts of the V-2 were being hawked in the streets of Juarez. Fortunately, APL had not instrumented that rocket.

## THE AEROBEE PROGRAM

Since it was obvious from the inception of the research program that the number of V-2 rockets was limited, a high-performance sounding rocket of relatively modest cost was essential for continuing and expanding the high-altitude research effort. Such a rocket also had to have a much greater load capacity than the WAC Corporal.

At the suggestion of Tuve and Porter, Van Allen undertook a survey of the national situation with respect to suitable vehicles of U.S. manufacture for high-altitude research. On January 15, 1946, he submitted his conclusions to Tuve in a memorandum entitled "Procurement of Liquid Powered Sounding Rockets for High Altitude Studies." A detailed proposal was requested from the Aerojet Engineering Corp. in January, and on February 22, the company submitted a proposal for a high-altitude sounding rocket. The Naval Research Laboratory also expressed an interest in the proposed high-altitude vehicles. On March 1, APL recommended to the Navy's Bureau of Ordnance that it negotiate a contract with Aerojet for the development and manufacture of 20 solid propellant boosters for launching, and acid-aniline-powered sustainer rockets capable of delivering an instrument payload



An early V-2 launching at White Sands Proving Ground using the original German handling equipment.

of 150 pounds to an altitude of over 300,000 feet. Five rockets were assigned to the Naval Research Laboratory and 15 to APL.

The rocket was called Aerobee, a name proposed by Van Allen as signifying "Aero" for Aerojet, the designers and manufacturers, and "bee" for its relationship to the Bumblebee family of APL missiles. The Aerobee was developed largely from June 1946 to November 1947, the time of the first successful firing.

APL prepared the original performance specifications and provided technical guidance for the work of Aerojet throughout development of the rocket. Aerojet engineered the elements of the propulsion system, and the basic design of the aerodynamic features was done by Douglas Aircraft Co., under subcontract to Aerojet. The development was supported by the Navy's Bureau of Ordnance and the Office of Research and Inventions (later the Office of Naval Research). APL participated in working out all the field aspects of the Aerobee, i.e., firing, range safety, windage and trajectory control, handling, telemetering, emergency fuel cutoff equipment, and recovery techniques.

Aerobee was to be an unguided rocket, in contrast to the V-2, which had gyro-controlled jet vanes. In the initial phase of preparing Aerobee launching facilities at White Sands, there was considerable skepticism about the ability of APL to keep the impact of such an uncontrolled rocket within the limits of the proving ground. The skepticism stimulated APL to give considerable thought to that particular phase of Aerobee operations.

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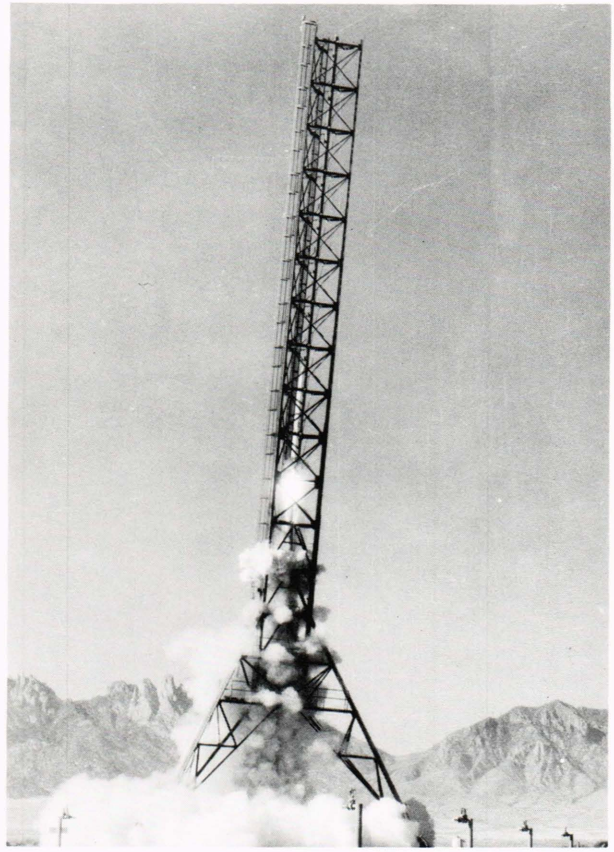
After examining all aspects of the launching problem, Van Allen prepared a detailed draft of a range safety doctrine. First, the Aerobee tower was constructed so as to be tiltable to compensate for wind effects. This was essential as the result of an analysis of the low-altitude winds at White Sands and on the theory of the "weathercocking" tendency of unguided rockets while under powered flight in the presence of crosswinds. A simple system of moving guide wires, developed by J. F. R. Floyd, that visually defined the safe limits of the trajectory was erected at two points near the firing site. The observers at either site were authorized to call for termination of powered flight if the path of the missile deviated from the calculated safe sector defined by the guide wires. A fail-safe radio command receiver, developed by the Physical Science Laboratory of New Mexico College of Agriculture and Mechanical Arts and built by APL, cut off the fuel supply to the Aerobee, thus limiting the trajectory.

During 1946, in preparation for the handling and proof firings of naval missiles, a U.S. Naval Unit was established by the Bureau of Ordnance at White Sands with Comdr. Robert B. McLaughlin and later Capt. W. A. Gorry as Officer-in-Charge. All Aerobee rockets were instrumented by and launched under the direction of APL, with operational aspects of servicing, handling, and launching conducted by service personnel of the Naval Unit.

A launching tower 140 feet high and similar to that used for the WAC Corporal provided 90 feet of guided travel. It was designed and constructed by Aerojet and the Nigg Engineering Corp. under the supervision of APL.

The first fully powered flight of the new two-stage Aerobee took place on November 24, 1947. From then until February 1951, 21 Aerobees were launched. During that period, only one of the Aerobees—the first—exhibited a large enough deviation in trajectory to necessitate termination of flight by fuel cutoff actuated by radio command. (The impending out-of-bounds trajectory, as indicated by the sky screen, was later determined to be the result of a jet condition in the booster nozzle that was easily remedied.) It became clear early that the new rocket performed considerably in excess of the original specification, and Aerobee was established as an important new research vehicle. The success of Aerobee led to its acceptance by the research branches of the U.S. military and the National Aeronautics and Space Administration. It has been used for research in practically all the major fields of upper air physics.



An Aerobee launch at White Sands. (The tower is tiltable to adjust for windage.)

By 1984, 1250 Aerobee rockets, in the original version and in several upgraded versions, had been flown from several different sites for a wide variety of scientific investigations. It has played an important part in the U.S. space program, where it has served as a test bed for checking out satellite experiments.

It is of interest to note that the instrumentation used in the immediate postwar era bears little resemblance to that used today. Circuits contained vacuum tubes, which in turn required substantial filament power and high plate voltages. A typical experiment might require 12-volt storage batteries capable of supplying 100 amperes as primary power for the duration of the flight.

## SHIPBOARD LAUNCHINGS

With the advent of the Aerobee, high-altitude measurements became possible at locations other than White Sands. The simplicity, low cost, and relative ease of handling and firing indicated the possibility of

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INSTRUMENT TEST MARKS END OF ERA IN U.S. ROCKETRY

A prototype of an instrument that will be aboard the Hopkins Ultraviolet Telescope (HUT) was successfully tested in a rocket experiment conducted by a Hopkins team led by Paul Feldman of the Department of Physics and Astronomy on January 17. The instrument, an ultraviolet spectrograph, was carried to an altitude of 100 miles aboard an Aerobee rocket launched from the White Sands Missile Range in New Mexico.

The spectrograph recorded far ultraviolet emissions of "dayglow" in the earth's upper atmosphere. Dayglow is a phenomenon caused by sunlight striking molecules in the upper atmosphere, causing them to fluoresce. By analyzing the spectra of these molecules, Professor Feldman and his colleagues expect to learn more about the chemical components of the upper atmosphere.

The Aerobee launch marked the end of an era in American rocketry, since this was the last scheduled use of these rockets. Aerobees were developed under the direction of James Van Allen, who later achieved fame as the discoverer of the Van Allen radiation belt. The first Aerobee flight was conducted by the University's Applied Physics Laboratory in 1947, and for many years they were the workhorses of high-altitude scientific research. Since 1961, Hopkins scientists in physics and astronomy have used Aerobees 37 times to conduct studies.

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conducting Aerobee launchings from shipboard. Further, the importance of extending certain high-altitude investigations to geographic locations other than White Sands made such a program highly desirable; the scientific objectives of both the cosmic-ray and terrestrial magnetism work were particularly well served by measurements at the geomagnetic equator and in northern latitudes.

In 1949 and 1950, APL conducted four successful Aerobee flights from the USS *Norton Sound*, two off the coast of Peru and two in the Gulf of Alaska. Operations at sea were markedly simplified by R. O. Robinson's development of a notch-excited telemetry antenna. Because of its greatly improved radiation pattern, it obviated the need for support vessels for the receiving system. The new antenna, installed in the Aerobee fin, radiated directly aft instead of to the side, thus permitting the launching ship to carry the receiving equipment for the telemetered data.

## SCIENTIFIC RESULTS OF APL'S COSMIC-RAY RESEARCH IN THE UPPER ATMOSPHERE

A most interesting result of the use of rockets for research was a series of direct measurements of the total intensity of the primary cosmic radiation above the appreciable atmosphere. The upper limit of the atmosphere for cosmic-ray interactions was experimentally located and directly measured for the first time. A smoothed composite curve of single-counter data showed the plateau of counts per second. Previous balloon measurements had never been made at the altitude where this plateau appeared.

Later cosmic-ray experiments using Geiger tube telescopes measured the directional dependence of the cosmic radiation; the burst producing component; the transition effects of the primary cosmic radiation in varying amounts of lead, aluminum, and the atmosphere; and the primary specific ionization (number of ion pairs per unit path length).

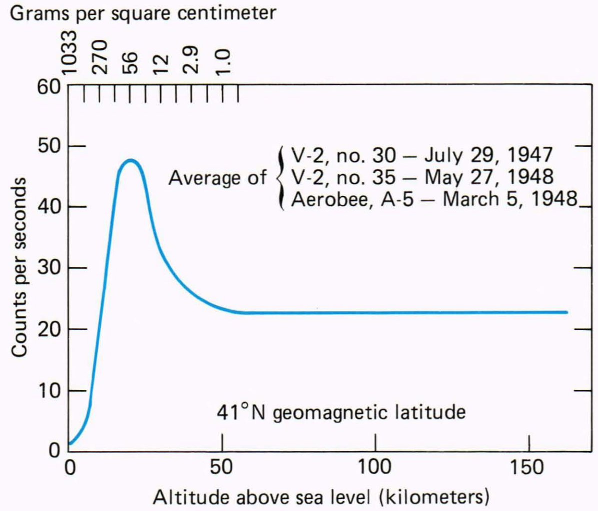
Zenith angle dependence, vertical intensity, and azimuthal asymmetry were determined at the geomagnetic equator by shipboard launchings. Results of these measurements, combined with those of other flights, made it possible to deduce the primary cosmic-ray spectrum.

Supplementing the upper atmosphere work, cosmic-ray experiments were conducted at high latitudes and in B-17 aircraft. During the summer of 1947, cosmic-ray telescopes were carried above the Arctic Circle where cosmic-ray intensity and Auger shower measurements were made.

## GEOMAGNETIC EXPERIMENTS

One of the areas of upper atmosphere research at APL was the investigation of the geomagnetic field in the ionosphere. Ernest Vestine of the Carnegie Institution of Washington, Department of Terrestrial Magnetism, and Allen Maxwell of the Naval Ordnance Laboratory were important collaborators in the high altitude magnetometer program for direct measurement of the magnetic effects of ionospheric currents.

Joint experiments with Aerobees by APL and the Naval Ordnance Laboratory were made at White Sands and, as was already mentioned, at the geomag-




Smoothed composite curve of cosmic-ray data using a single Geiger counter.

netic equator off the coast of Peru from the *Norton Sound*. The results were in good agreement with theory.

The observational work done at APL using rockets fired vertically to altitudes of about 60 kilometers contributed to the 1958 discovery by earth satellites of radiation belts of the earth, which were named after Van Allen.

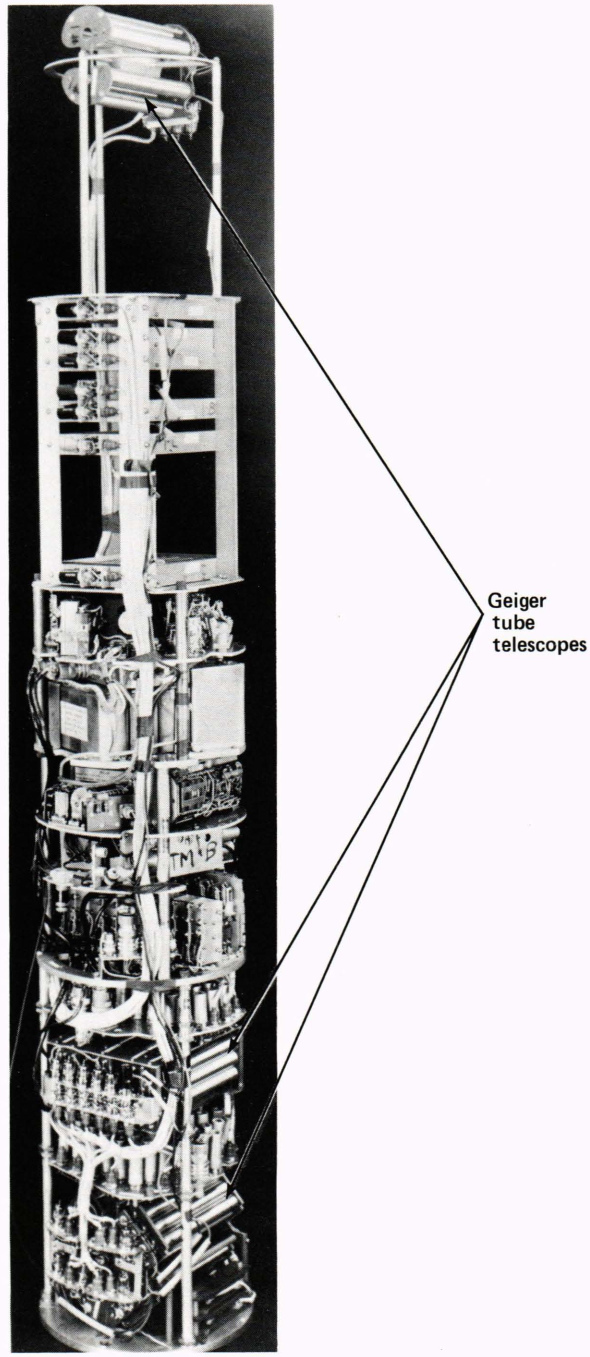
## SOLAR SPECTROSCOPY EXPERIMENTS

The V-2 and Aerobee rockets provided a means of recording the solar spectrum in the ultraviolet region below 2900 angstroms, that is, in the region considered to be in the far ultraviolet. Using gratings ruled to 15,000 lines per inch by the Physics Department of The Johns Hopkins University, ultraviolet spectra of the sun were obtained by J. J. Hopfield down to 2300 angstroms and traces evident as far as 2230 angstroms.

Work in the field of high-altitude spectroscopy was expanded to include measurements of the distribution of ozone with altitude. A spectrometer with quartz optical elements was carried through and above the ozone layer in two Aerobees. The intensity of the dispersed sunlight falling on photomultiplier tubes in each of several wavelength bands was obtained. The observed intensity ratios, in conjunction with available ozone absorption coefficients obtained on the ground, were used to yield the continuous integral distribution of ozone as a function of altitude. The Yerkes Observatory of the University of Chicago and the Astronomy Department of Ohio State University collaborated in the spectrographic work.

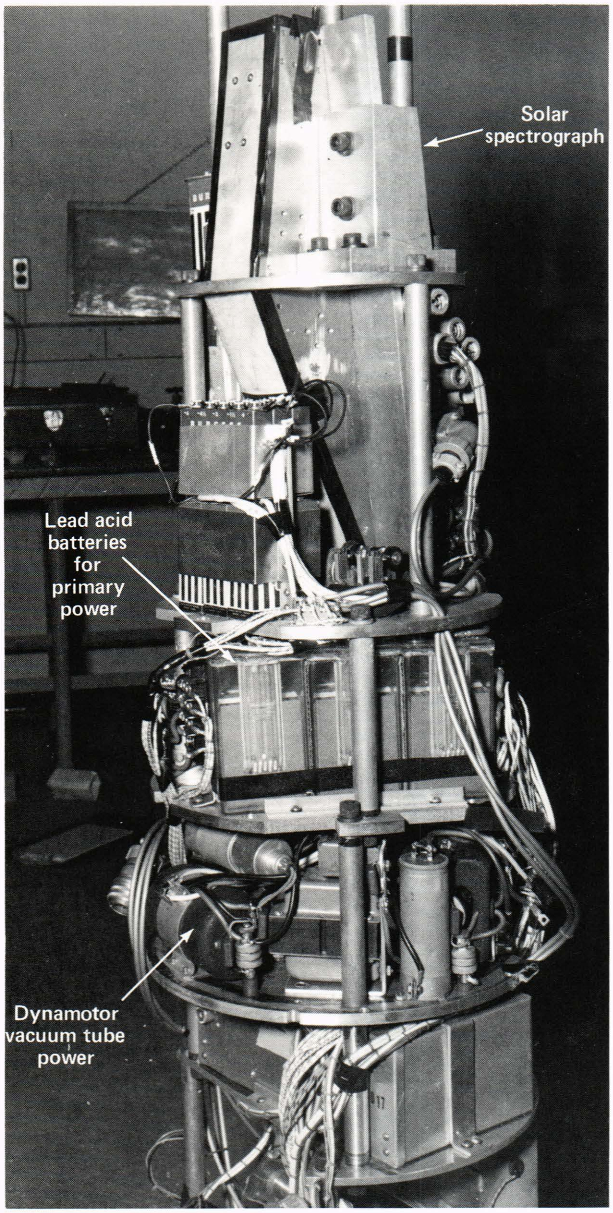
## HIGH ALTITUDE PHOTOGRAPHY

In October 1946, Clyde Holliday of APL placed a DeVry 35-millimeter motion picture camera in a V-2 rocket to obtain the first pictures of the earth at altitude. The camera and exposed film in an armored case were recovered a few hours after the flight. Few news releases ever won the attention of the world-wide media as did the photographs of more than 1,100,000 square miles of the earth's surface from Aerobee and V-2 rockets at nearly 70 miles altitude.

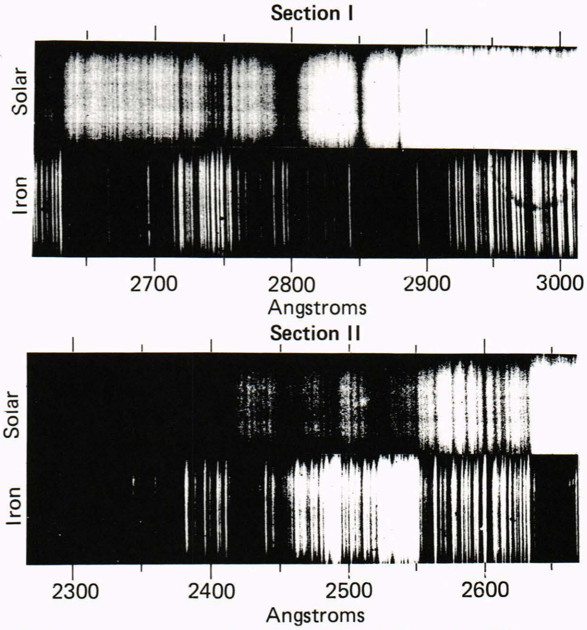



Aerobee cosmic-ray instrumentation (approximately 7 feet in height). Present-day solid state electronics would permit a substantial reduction in weight and volume.

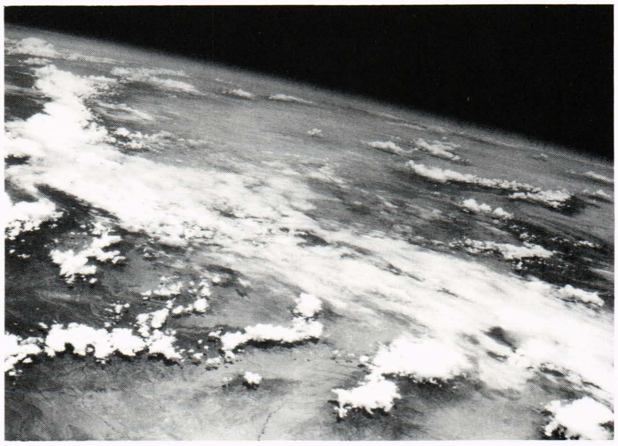
The photographs of the earth from rockets, while spectacular and of great public interest in their display of cloud covers, served a most valuable purpose in providing unquestioned data on the angular motion of the rocket in the upper portions of flight. The principal value of the information was in its support of the experiment's results, where it was essential to know




Solar spectrograph mounted in an Aerobee rocket.




Solar spectrum obtained during a V-2 rocket flight.



A V-2 rocket-eye view from 70 miles altitude.

the orientation of the rocket as it affected the angular distribution of the cosmic radiation. A K-25 serial reconnaissance camera gave 4 × 5 inch infrared photographs that provided complete and unequivocal information on the angular motion.

## A PREDICTION COME TRUE

In 1948, Van Allen made a prediction:[2]

> Popular magazines were filled with conjectures about space flight. By the late 1940s even hardheaded practitioners such as I began to be converted to the realistic prospect for earth-orbiting satellites and spacecraft that could escape from the earth's gravitational field. In July 1948 I wrote a paper entitled "The Use of Rockets in Upper Atmosphere Research" for the August 17-28, 1948, meeting of the Eighth General Assembly of the International Union of Geodesy and Geophysics in Oslo, Norway. After surveying the state of this subject, I concluded:
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> "Then there is always the prospect of pioneering measurements at higher and ever higher altitudes. Serious consideration is being given to the development of a satellite missile which will continuously orbit around the earth at a distance of, say, 1000 km. In the even dimmer future is the prospect of astronomical type flights."
>
> This thought was, of course, not original with me. It had been commonplace among visionaries for many years. Its inclusion in a working scientific paper by a working scientist in the field did, however, give it some significance. My statement was cited with levity by the New Yorker and with restrained contempt by the New York Times. The then Director of the Applied Physics Laboratory, Ralph Gibson, asked me to strike it from the formally published paper on the

grounds that it was excessively conjectural and detracted from the remainder of the paper. After some grumbling I complied.

Within a few years the flight of scientific equipment on satellites of the earth had been accepted as a realistic prospect throughout the interested segment of the scientific community.

Van Allen's comments on the early APL work in high altitude research were as follows:

> The small cadre of investigators was motivated by the exploratory nature of the opportunities and by the great freedom and flexibility of the circumstances, notably free of long-range planning, detailed accountability, and other bureaucratic constraints. It was a period in which the wartime spirit—that most individuals are honorable and that results are what count—carried over into peacetime pursuits. From the perspective of 1983 one may deplore the passing of such an epoch. Those of us who survived this early period of high-altitude rocket investigations were, with few exceptions, the ones who conceived and built the first instruments for satellite flight. Without this preparatory period we would have been ill prepared to conduct investigations with satellites.

Funding for further Aerobees was difficult to procure, and the APL high altitude research program was terminated in the early 1950s. However, a few years later when satellite flights began in earnest, an enormous resurgence of interest arose. Van Allen proceeded with his historic measurements of trapped electrons and ions. APL, in turn, proposed and implemented a satellite navigation system (Transit) that required for its success precise geophysical measurements of the earth's shape, ionospheric signal dispersion, and evaluation of aerodynamic drag at high altitudes. Later forays into space physics have continued the effort that was begun nearly 40 years ago.

## REFERENCES

[1] H. E. Newell, Jr., ed., *Sounding Rockets,* McGraw-Hill, New York (1959).

[2] J. A. Van Allen, *Origins of Magnetosphere Physics,* Smithsonian Institution Press, Washington (1983).

## BIBLIOGRAPHY

S. F. Singer, *Report of Cosmic Ray Observations Made While on Arctic Operation 1947,* JHU/APL TG 36 (1947).

J. A. Van Allen, "The Exploration of the Future," *Explorers J.* **24** (1947).

L. W. Fraser, R. P. Peterson, H. E. Tatel, and J. A. Van Allen, "Methods in Cosmic Ray Measurements in Rockets," *Phys. Rev.* **72**, 173 (1947).

L. W. Fràser and E. H. Siegler, *High Altitude Research Using the V-2 Rocket,* JHU/APL Bumblebee Report No. 81 (1948).

J. A. Van Allen, "The Use of Rockets in Upper Atmospheric Research," 8th General Assembly of the IUGG, Association of Terrestrial Magnetism, Oslo, Norway (Aug 17-28, 1948).

H. E. Tatel and J. A. Van Allen, "Cosmic Ray Bursts in the Upper Atmosphere," *Phys. Rev.* **73**, 87 (1948).

J. A. Van Allen and H. E. Tatel, "The Cosmic Ray Counting Rate of a Single Geiger Counter from Ground Level to 161 Kilometers Altitude," *Phys. Rev.* **73**, 245 (1948).

J. J. Hopfield and H. E. Clearman, Jr., "The Ultraviolet Spectrum of the Sun from V-2 Rockets," *Phys. Rev.* **73**, 877 (1948).

J. A. Van Allen, "Exploratory Cosmic Ray Observations at High Altitudes by Means of Rockets," *Sky and Telescope* **VII** (1948).

J. A. Van Allen, L. W. Fraser, and J. F. R. Floyd, "The Aerobee Sounding Rocket," *Science* **108**, 746 (1948).

L. W. Fraser, *Aerobee High Altitude Sounding Rocket: Design, Construction and Use,* JHU/APL Bumblebee Report No. 95 (1948).

A. V. Gangnes, J. F. Jenkins, Jr., and J. A. Van Allen, "The Cosmic Ray Intensity above the Atmosphere," *Phys. Rev.* **75**, 57 (1949).

S. F. Singer, "The Specific Ionization of the Cosmic Radiation above the Atmosphere," *Phys. Rev.* **76**, 701 (1949).

J. F. Jenkins, Jr., "The Zenith Angle Dependence of Flux of the Hard Cosmic-Ray Component up to 36,000 Feet," *Phys. Rev.* **76**, 992 (1949).

J. A. Van Allen, L. W. Fraser, and R. S. Ostrander, "Nature of the Primary Cosmic Radiation as Revealed by Transition Effects in Lead and Within the Atmosphere," *Bull. Am. Phys. Soc.* **24**, 48 (1949).

S. F. Singer, "The Zenith Angle Dependence of the Cosmic Radiation at $\lambda = 41°$N.," *Phys. Rev.* **77**, 729 (1950).

S. F. Singer, "On the Nature of the Cosmic Radiation near the Pfotzer Maximum at $\lambda = 41°$N.," *Phys. Rev.* **77**, 730 (1950).

J. A. Van Allen and A. V. Gangnes, "The Cosmic Ray Intensity above the Atmosphere at the Geomagnetic Equator," *Phys. Rev.* **78**, 50 (1950).

J. A. Van Allen and S. F. Singer, "On the Primary Cosmic-Ray Spectrum," *Phys. Rev.* **78**, 819 (1950).

J. A. Van Allen and A. V. Gangnes, "On the Azimuthal Asymmetry of Cosmic Ray Intensity above the Atmosphere at the Geomagnetic Equator," *Phys. Rev.* **79**, 51 (1950).

S. F. Singer, "The Primary Specific Ionization and Intensity of the Cosmic Radiation above the Atmosphere at the Geomagnetic Equator," *Phys. Rev.* **80**, 47 (1950).

C. T. Holliday, "Preliminary Report on High Altitude Photography," *Photogr. Engravers* **1**, 16 (1950).

L. W. Fraser and R. S. Ostrander, "Photographic Determination of the Orientation of a Rocket," *Photogr. Engravers* **1**, 105 (1950).

L. W. Fraser, *High Altitude Research at the Applied Physics Laboratory,* JHU/APL Bumblebee Report No. 153 (1951).

S. F. Singer, "On the Density Spectrum and Structure of Extensive Air Showers," *Phys. Rev.* **81**, 579 (1951).

## THE AUTHOR

LORENCE W. FRASER retired from APL in 1973, having been associated with APL since its inception in the early 1940s. He was born in Cleveland in 1908 and received a B.S. degree in metallurgical engineering from Case Western Reserve University in 1930. From 1930 to 1940, he designed instruments for the measurement of X-ray dosage for the Victoreen Instrument Co. in Cleveland.

Joining the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in 1941, he was involved in the pioneer development work on the radio proximity fuze. This work was carried on by APL under the direction of Merle A. Tuve during World War II.

From 1946 to 1951, he worked with Dr. James A. Van Allen in the APL Upper Atmosphere Program and then participated in the development of the Talos Control System. Later, he was a member of the Fleet Systems Department. His avocation is amateur radio, and he has held an operator license since 1923.

Mr. Fraser recalls, "Working with Jim Van Allen in the investigation of upper atmosphere phenomena was a most rewarding experience. Jim's small group of dedicated people was autonomous. It was possible to carry out all aspects of an experiment from concept to published paper without outside direction or controls. Once the work was outlined, Jim left the implementation in the hands of his colleagues, only looking in periodically, not to question particular techniques, but only to monitor progress. Jim's insistence on simple, uncomplicated experiments was an important step in his discovery of the radiation belts named after him."