GEOPHYSICAL EXPLORATIONS IN AEROSPACE DURING 1961

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TABLE of CONTENTS

A - INTRODUCTION

The mission of the Air Force Cambridge Research Laboratories includes obtaining environmental data in the earth's upper atmosphere and near space. The analyzed data yield "models" which are of critical importance to designers of present and future weapon systems. A natural extension of this activity is the development of prediction techniques which are important in the deployment of such weapon systems.

This report summarizes the environmental research effort conducted by the AFCRL during 1961. Research vehicles used in this program fall into three classes: sensors mounted on low-cost research rockets, sensors mounted "piggy-back" on test vehicles such as Atlas missiles and Agena satellites, and sensors flown on high-altitude research balloons.

B - SUMMARY of the 1961 AFCRL AEROSPACE ENVIRONMENTAL RESEARCH PROGRAM

In order to keep this summary as brief as possible, experiments have been grouped and preliminary results condensed. More extensive information is available from the AFCRL on each of the items reported.

1. Upper Atmosphere Chemical Release

The 1960 research rocket program consisted of twenty-seven chemical payloads fired to aid in the definition of upper atmosphere processes. Analysis of the resulting experimental data has been substantially completed in 1961 and the following results are expected to appear shortly in scientific publications:

a. Wind and Shear Measurements. Ten separate chemical releases in the altitude region 80 to 120 km over a two-month period showed a consistent pattern of wind motion and wind shears in the Eglin AFB area. Optical tracking of atmospheric neutral species and ionosonde tracking of electrons showed similar velocities and directions at a given time.

b. Turbulence and Diffusion Measurements. Measurement of turbulence by radio-frequency scattering from electrons and by optical scattering from neutral gases showed similar sizes of eddies in those regions where transport processes are dominated by turbulence. Several previous mathematical theories for determining the geophysical conditions for turbulence have been confirmed and others have been modified as a result of this work. Diffusion coefficients have also been deduced and interpreted from the experimental data obtained.

c. Electron Decay Processes. Measurement of electron decay processes from the artificial electron clouds has been continued. Relative effects of attachment, recombination and diffusion at various altitudes are being assessed on the basis of the experimental data.

d. Shock Wave and Expansion Characteristics. Observation and analysis of early-time gas expansion prior to pressure equilibration in both the radio-frequency and optical regions have been carried forward, confirming a theoretical model proposed by Brode.

e. Electron Removal. A single attempt at electron removal in the E region yielded inconclusive results. An ionospheric anomaly was recorded, but it may have been a sporadic natural effect.

f. Chemiluminescence. Chemiluminescence, apparently due to aluminum-vapor reaction with ambient oxygen, was observed but has not yet been fully interpreted.

Applications of these studies to observed missile-trail phenomena and nuclear phenomena have been carried out and are continuing. A field program is scheduled for the Summer of 1962 to provide experimental data which may answer presently unresolved aspects of the research studies in progress.

2. Density, Pressure, Temperature and Composition

a. The first direct measurement of atmospheric density between 70 and 130 miles was made on 23 February by AFCRL at Eglin AFB. The experiment employed a 9-foot inflatable spherical balloon released from a two-stage Nike-Cajun rocket. Density was determined from measurements of the aerodynamic drag force experienced by the free-floating balloon. Data from linear accelerometers were telemetered to ground receiving and tracking stations.

The balloon was ejected seventy-six seconds after the rocket firing. It coasted to an altitude of approximately 100 miles on the same trajectory as the spent rocket. It then fell back toward the earth transmitting signals which permitted density calculations.

This experiment was an extension of an earlier measurement in which a 7-inch aluminum sphere, equipped with bobbin accelerometers, was used to probe the atmosphere up to 60 miles to determine ambient density. For higher altitudes, the larger sphere is employed to decrease mass-to-area ratio. The drag deceleration is therefore made large enough for accelerometers to measure drag effects over small finite intervals, providing a sensitive direct determination of ambient density.

The 9-foot sphere (balloon) was made of 1-mil Mylar. An inflatable nylon-Mylar strut located at the balloon's center supported the accelerometers, transmitter and associated electronics. The balloon itself was inflated with methyl alcohol while the strut, requiring much higher pressure, was inflated with Freon-113.

A density value calculated from this flight was 1.46×10^{-9} slugs/ft^3 at 107 km.

b. The second experiment in this series designed to measure density by drag acceleration of the 9-foot inflatable sphere was successfully conducted on 7 December at Eglin AFB using an Aerobee rocket.

Flight records indicate that the sphere was ejected eighty seconds after launch. The rocket was fired shortly after sunset when the sky had darkened and the earth's shadow extended to about 90 km. The sphere was seen for approximately five minutes and attained a maximum altitude of approximately 230 km. Telemetry data were recorded for fifteen minutes. MATTS, DOETS, radar and optical tracking were employed to provide an accurate flight trajectory.

Data from the Aerobee flight are now being analyzed and a scientific report will be published shortly. Results of the earlier Nike-Cajun flight are presented in GRD Research Note No. 63.

c. Another type of density experiment was successfully flown on Discoverer XXV launched on 16 June. Eight good real-time data acquisitions were made. Variation in atmospheric pressure between 1.0×10^{-8} and 1.5×10^{-8} mm Hg was derived from data from a typical orbit, with the corresponding densities therefore lying between 2×10^{-15} and 3×10^{-15} gm/cm^3. For comparison, the density given by the 1959 ARDC Model Atmosphere is 9×10^{-15} gm/cm^3, and that proposed for the revised extension to the U. S. Standard Atmosphere is 6×10^{-15}. Since the data were collected at 0400 local time, it is not unreasonable that this essentially nighttime density is lower than the mean values given by the model atmospheres.

d. In January an Aerobee rocket instrumented with a time-of-flight mass spectrometer was launched from Eglin AFB. The flight package also contained magnetometers for aspect information. The mass spectrometer swept the mass range from 0 to 100 atomic mass units at a 5 cps rate. Two continuous telemetry channels presented a high and low gain of the mass spectrum. A third continuous telemetry channel presented one magnetometer output and a sun-cell output, while a fourth commutated channel telemetered another magnetometer output as well as rocket functions such as tip ejection, timing functions, oxidizer valve monitor, etc. A fifth channel was used to telemeter the pressure output from an ion-getter pump which ran continuously on the ground and during the flight. All instrumentation performed properly. Before tip ejection, the mass spectrometer under high vacuum telemetered the background gas spectrum in the tube; however, at tip ejection a very high-pressure surge occurred, causing a high-voltage arc which resulted in the malfunction of the high-voltage power supply. Examination of the records indicated that the rocket malfunctioned by going into a flat roll shortly after launch. As a result, tip ejection occurred at too low an altitude—at an ambient pressure of almost a millimeter of mercury.

Although no information was obtained on the composition of the atmosphere, two important subsidiary objectives were accomplished—instrumentation and satisfactory operation of an ion-getter pump on a rocket system, and operation of a time-of-flight mass spectrometer during rocket flight.

e. In August two time-of-flight mass-spectrometer systems were used in five balloon flights at Faribault, Minnesota, for continuous sampling of the atmosphere from ground level to approximately 100,000 feet. These mass-spectrometer systems were unique. A servo-controlled leak mechanism was used to maintain the pressure inside the spectrometer at about 10^{-5} mm to within plus or minus 5%, over an ambient pressure range of 750 mm to 10 mm. A flushing system was used to reduce the long times necessary for the diffusion process to occur in the sampling tube before a true sample of the atmosphere could be obtained on the high-pressure side of the leak. This system consisted of a pressure-tight intake tube from the ambient atmosphere to the leak valve, a tube from the leak valve to a tiny axial fan and motor in a pressure-tight container, and an exhaust tube from the fan to the atmosphere—roughly 180° from the intake tube. With the axial fan running, ambient air was continually flushed across the leak.

Response times for true samples were therefore of the order of a few seconds instead of hours.

The spectrometer was housed in a pressure-tight gondola with a 3-foot intake tube to eliminate balloon and gondola perturbations. Six masses (He, H_2O, N_2, O_2, A, CO_2), a pressure monitor, a temperature monitor, and two calibrating voltages were sampled by a commutator moving at a rate of one segment per second and telemetered by an FM-AM system.

Data were obtained on one flight during ascent and descent and on another flight during ascent only. All other flights failed; however, the mass-spectrometer systems performed well in all cases. The failures were due to antenna and transmitter problems for one and one-half flights; balloon failures occurred on the remaining two flights.

Analysis of the data indicated a temperature drift in the mass-spectrometer circuits. Since corrections for temperature are not straightforward, data accuracy is undetermined. These flights are to be repeated with better temperature regulation.

3. Solar Ultraviolet and Extreme Ultraviolet Radiation

a. A normal-incidence spectrograph with a 40 cm concave grating was flown in an Aerobee rocket at sunrise on 12 October at the White Sands Missile Range. This was the second successful flight in a series of rocket-borne experiments designed to obtain data concerning atmospheric composition through observation of the effect of atmospheric absorption in the ultraviolet spectrum of the sun.

Seven good spectrograms were obtained in the altitude interval 85 to 122 km. The spectrograms show excellent continuity with data obtained from a similar rocket-borne experiment in 1958 which covered the altitude interval 62 to 87 km. The October experiment will provide information on the distribution of molecular oxygen in the upper atmosphere, since O_2 is the overwhelmingly predominant absorber in the altitude interval 85 to 122 km in the spectral region investigated.

Publication of the results is dependent upon completion of necessary laboratory experiments related to the rocket experiment.

b. A telemetering grazing-incidence monochromator with a biaxial pointing control was flown on an Aerobee rocket on 23 August. This highly successful flight provided data on solar radiation between 250 and 1300A^o and solar UV attenuation in the atmosphere between 120 and 225 km. Higher spectral resolution was obtained than in previous flights, yielding useful data for solar-spectrum analysis as well as for terrestrial aeronomy. Preliminary reports of the results of this experiment were presented by Dr. Hinteregger to the IAU Symposium at Cloudcroft, New Mexico, in August. Formal publications are in preparation.

4. Electromagnetic Propagation

On 14 March a Nike-Cajun rocket was launched at Eglin AFB with an experiment designed to determine the voltage-breakdown characteristics at high altitudes of a VHF slot antenna and an X-band slot antenna.

The instrumentation consisted of an X-band transmitter and antenna, a VHF transmitter and antenna, X-band and VHF detectors, standard FM-FM telemetry, common power supply, and pressure and temperature sensors. No data were obtained from the X-band experiment due to failure of the transmitter shortly after launch.

Temperatures at the tip of the nose cone reached maximums of 700°F during exit and 500°F during re-entry. External skin temperatures varied between approximately 130°F and 330°F during most of the flight, exhibiting a wide margin of safety between design temperatures and those actually experienced.

The breakdown data obtained on the VHF slot antenna were inconclusive. Although theory and laboratory experiments predict a breakdown altitude region of 120,000 to 240,000 feet, with a definite minimum value of initial power at 180,000 feet, the flight data show a leveling-off to a more or less constant value at all altitudes above 120,000 feet, indicating the possibility of breakdown in the final VHF amplifier rather than at the antenna.

5. Vehicles and Auxiliary Instrumentation

a. Work has been underway in the past year to modify the Iris rocket from the cruciform fin used by NASA to a triform so that it will adapt to the tower at Eglin AFB. Because the Iris diameter is 3 inches smaller than the tower bore, pads are required to insure proper rail-riding qualities. These devices are removed from the vehicle at tower exit by specially curved members. An inert Iris motor with its regular booster was launched on 30 October at Eglin to test the pad-removal scheme. No difficulty was encountered.

b. On 8 December an Astrobee-1500 was launched from the Pacific Missile Range. The vehicle was instrumented with structural and propulsion monitors. In addition to these vehicle monitors, three sets of seven geodetic flares were carried and successfully ignited at altitude. Ground photographs of the flares were taken at several sites on the continent and on Hawaii and Johnston Island. Using star backgrounds for precise positioning, it is anticipated that the final data reduction will increase the accuracy of the geodetic tie of the islands to the mainland. (See item 13.) This vehicle was supplied by Aerojet-General Corporation with flight instrumentation by AFCRL.

c. A significant advance in the area of aspect determination with reasonable accuracy at low cost was accomplished. By proper utilization of information from magnetic field sensors coupled with solar sensors, the angular position of the vehicle can be determined. This type of information is sought by experimenters who require aspect data to interpret data derived from their primary sensors.

d. During early December, water-recovery systems for the Aerobee and Nike-Cajun were successfully drop-tested from aircraft at Eglin AFB. Rocket flights employing the water-recovery technique will be used in calendar year 1963.

e. The AN/DPN-41 tracking beacon was modified and additional electronic circuitry developed to permit commands to be given to rocket payloads.

The system, in some cases, eliminates the need for a separate command receiver. The technique used is to change the repetition rate of the interrogating radar when the command is required. The system was successfully flown on an Aerobee rocket.

f. A new model was developed of a quadraloop antenna which is much smaller and lighter in weight than previous designs. Of particular importance is improvement in the aerodynamic characteristics which makes the antenna usable on the smaller higher-performance rockets such as Cajun and Exos. The design was made possible by the development of a new dielectric material called Flurosint.

g. A sub-miniature C-band beacon was developed for use with small research probes such as Nike-Cajun and Exos. The beacon operates in conjunction with the AN/FPS-16 range positioning radar and is capable of determining rocket position to a greater degree of accuracy than the equivalent S-band systems presently used. Prior to this design, the use of C band was not feasible due to the size and weight of these beacons.

6. Ion and Electron Densities and Vehicle Charge-up

a. Two spherical electrostatic analyzers (plasma probes) were flown successfully on Discoverer 1115 launched 13 October. This experiment was designed to measure the concentration and energy distribution of charged particles (ions, electrons) along the satellite trajectory. In addition, ion and electron temperatures and the potential of the vehicle with respect to the ambient were also measured.

The experiment worked completely during the period power was applied. Unfortunately the unregulated B^+ voltage was lost during the first pass over the tracking station at Kodiak, Alaska. However, a total of six minutes of real-time data readout was obtained covering a lateral distance of 15,000 km.

Analysis of the results has begun and all analog records have been examined. The analyses show that both the electron and ion densities varied by over a factor of two during data acquisition. Electron and ion concentrations, with an average value of 7×10^5 per cm^3 for each sign, agree within a factor of 20%.

The satellite potential was found to be negative. The current voltage curves examined show the charge-up potential with respect to ambient to be about -3 volts.

Only one complete analysis of the ion and electron temperatures has been carried out. Ion temperature of approximately 1400°K was found to be about 40% less than the electron temperature.

These results represent the first simultaneous direct measurement of ion and electron properties from a satellite. The results will provide information on the physical state of the upper ionosphere, including the extent to which thermal equilibrium exists in these regions, the nature of horizontal inhomogeneities in charge density along the satellite trajectory, and the extent to which the satellite charge, and therefore drag, is influenced by changes in the ambient ion and electron content. From the energy distribution data, crude mass-discrimination estimates will also be obtained.

b. A similar experiment was flown successfully on Blue Scout vehicle D-5 launched around local midnight on 12 April. A maximum density of 3×10^5 ions/cm^3 was observed at 325 km and a minimum at peak altitude (2000 km) of 2×10^4 ions/cm^3. The computed scale height at the peak of the F_2 region was 90 km, with the scale height increasing above this level. Assuming an average mass of 18 atomic mass units, the ion temperature in this region is 1700°K. The ascent and descent values are in agreement within experimental error. The vehicle potential varied between -1 and -4 volts with an average value near -3 volts. As yet unexplained, small scale variations in ion density were observed above the F_2 maximum. Reduction and analysis of these data continue.

The same type of experiment was flown on Pods 03 and 08 (launched 22 November and 19 December). Both experiments were successful; however, data analysis has just begun and results are not yet available.

c. Two retarding potential analyzers with plane-parallel geometry were flown on the MIDAS IV vehicle. Unfortunately meaningful data were obtained from only one acquisition somewhere in the North Pacific. The results, if true, are highly significant and should be confirmed as soon as possible. From the data it can be concluded that in a nearly polar orbit at a geocentric distance of about 1.5 earth radii on 12 July, flux densities were measured of 10^9 cm^{-2} sec^{-1} of charged particles with energies of the order of 10 ev, with highly anisotropic velocity distributions and a pronounced north-south asymmetry along the geomagnetic field lines.

d. The radio-frequency impedance probe for the measurement of electron density in the ionosphere was flown successfully on a number of vehicles in 1961. This probe is being developed for DASA. In March two probes at 3 and 7.2 Mc were successfully flown on a Sparrowbee-300 rocket at Eglin AFB. Electron density profiles were obtained for both ascent and descent from 90 to 320 km through the peak of the F-layer. The results were reported at a URSI meeting in Austin, Texas, in October. A Nike-Cajun rocket was fired on the same field trip, and although the second stage failed to ignite, a useful measurement of a dipole antenna in free space was accomplished. This measurement was very important for the calibration of our measuring apparatus on the ground.

A Blue Scout rocket (D-5) launched from Cape Canaveral in April carried two impedance probes. Successful measurements were obtained of the nighttime electron density from fourth-stage burnout to peak altitude of 1875 km on ascent and from 1875 to 175 km on descent on both the 3 Mc and 7.2 Mc probes. These results were also presented at the URSI meeting in Austin, Texas, and are now being prepared for publication.

The impedance probe was successfully flown on two Discoverer satellites—XXXIV and XXXVI—in November and December. On Discoverer XXXIV a 7.2 Mc impedance probe was flown. Real-time readouts were obtained at the recording stations from sixty-one orbits from which local electron densities will be calculated. In addition, the data were recorded on magnetic tape in the satellite for complete earth orbits. Twenty-one orbits are available and are now being analyzed. This represents the first continuous measurement of electron density around the earth. Results are to be presented at the COSPAR meetings in Washington in May 1962 and published as part of the proceedings. On Discoverer XXXVI a 12 Mc impedance probe was successfully flown and real-time measurements obtained at a number of recording stations.

The impedance probe was also flown successfully in a pod released from an Atlas missile for the measurement of electron density in a missile trail. Both the standing-wave impedance probe and a new probe, a sweep-frequency impedance probe, yielded good data. This was the first direct measurement of electron densities in a missile trail. The preliminary results have been reported in a classified paper at an ARPA meeting on 15 February 1962 and will be published as part of the proceedings of that meeting.

7. Galactic Radio Noise

This experiment has been a part of the experimental payload on three Discoverer satellites—XXVI (7 July), XXIX (30 August), and XXXI (17 September). The results from Discoverer XXVI indicate a radiation background higher in intensity than had been anticipated from an extrapolation of ground-based observations. Since the radiometers were saturated for better than 90% of the time information was being received, leakage of ground-radiated energies through the ionosphere at frequencies below the F_2 critical frequency is suggested.

To clarify the interpretation of these results, a new experiment was planned for Discoverer XXIX. The payload for Discoverer XXIX consisted of two radiometric systems of the total-power superheterodyne type which operated at center frequencies of 6.950 Mc and 6.975 Mc, each with a 10 kc bandwidth. The units were adjusted with different gains so that information on the type of interference which saturated the equipment on Discoverer XXVI could be obtained. Broad band signals incident on the antenna system would cause the output of both units to fluctuate uniformly in time but with different amplitudes, since the gains of the two units were not identical. Discrete frequency emission from terrestrial transmitters, however, would cause a non-time-correlated output in each channel.

Due to a design malfunction in the main Discoverer XXIX power supply, the project equipment operated successfully for only one orbit. The information gained from this one orbit, however, substantiates the concept that leakage through the terrestrial ionosphere at 7 Mc is larger than had been anticipated. The results from this single orbit show quite clearly the discrete frequency character of the majority of the signals received.

The Discoverer XXXI experimental package also contained two discrete frequency radiometric systems—one at 6.975 Mc and one at 7.000 Mc—each with a bandwidth of 10 kc. Here data were obtained for over one hundred orbits and the results from Discoverer XXIX were substantiated on the whole. However, at certain times the terrestrial interference level drops to the point where the cosmic background does become evident. Analysis of this flight has not been completed. There are reasonable indications, however, that signals from the ground-based equipment did penetrate the ionosphere on several very low-angle passes. The frequency of these transmissions—7 Mc—was from four to five times lower than the line-of-sight critical frequency.

In summary, the results obtained to date from the Discoverer satellites seem to indicate considerably lower attenuation through the earth's ionosphere than had been predicted. In addition, several objectives of the program for determining the ambient radio environment of cosmic radio noise have been partially met.

8. Micrometeorites

Several types of experiments were conducted during 1961 to obtain information on extra-terrestrial particulate matter. The experiments were flown on rocket and satellite vehicles as well as on two "piggyback" pods.

a. Blue Scout vehicle D-5 was successfully launched on 12 April. This vehicle carried two experiments—one grid detector and one membrane detector. No impacts sufficient to damage either unit were recorded.

b. On 21 April an artificial meteor of known mass and composition was successfully produced by accelerating a small stainless-steel pellet by means of an air-cavity charge attached to the nose of a high-speed re-entry rocket (Trailblazer I). The particle was fired downward at an altitude of 195 km and entered the atmosphere at a velocity of 10 km/sec. The primary purpose of the experiment was to determine the efficiency with which the kinetic energy of a meteoroid is transformed to luminous energy in the photographic region. The results of the experiment will be published sometime in 1962 in the open literature as well as in a GRD research note.

c. On 6 June an Aerobee-150 rocket was successfully launched with a payload designed to collect, and to determine penetration of, extra-terrestrial particulate matter between 88 km and 168 km altitude. The total experiment, including the special nose cone for trapping and recovering micrometeorites, was conceived and designed by scientists and engineers of AFCRL. The nose cone consisted of a pod-like arrangement made up of individual petals or leaves. At an altitude of 47 miles, these leaves opened like a blossoming flower. The nose cone was carried to a maximum altitude of 102 miles over the desert at White Sands, New Mexico. The leaves closed again when the rocket descended to 65 miles. The nose cone remained opened for a total of about four minutes.

Several types of plastic detectors were used in the cone. In some instances the micrometeorites passed through the plastic detectors and in other instances either became embedded in the plastic or formed small craters. Most of the evidence of micrometeorite impact was apparent only through microscopic examination. Only a few micrometeorites themselves were collected since, for the most part, they vaporized on contact with the detecting surfaces. Some of these extra-terrestrial particles, however, were collected intact. Of particular interest to AFCRL scientists are the residual bits of meteorite material lining the walls of the craters. These residual materials will be analyzed by physical, chemical and radioactive techniques.

The preliminary results of this experiment are available in GRD Research Note No. 71.

d. A Nike-Cajun was instrumented with acoustic detectors to check the reliability of early rocket data as well as the reliability of the acoustic devices themselves. This rocket was successfully fired from Eglin AFB on 23 June. The telemetry data from the range were received very recently and therefore no results are yet available.

e. Several detectors were flown on satellites and pods in an attempt to acquire additional data as to the flux and size of extra-terrestrial particulate matter. The detectors were of three types—acoustic, wire grid and membrane. Data were received from ten of the detectors.

f. SAMOS II (1961 Alpha I), launched in January, carried five detectors—three acoustic and two wire grid. Preliminary analysis indicated there were about one hundred and fifty-seven impacts of particles 3 microns in diameter and larger on the acoustic detectors and eight impacts on the grid detectors. Theoretically the smallest meteoritic particle required to break the grid wire is 10 microns. The flux of particles on the acoustic units was 2×10^{-1} per m^2/sec and on the grids 8×10^{-4} per m^2/sec.

g. MIDAS 1201 was injected into orbit on 12 July. During the portion of the one orbit from which data were received, no impacts were recorded on the membrane detector.

h. Pods 03 and 08 were launched from the Atlantic Missile Range on Atlas missiles on 22 November and 19 December, respectively. Each pod carried an acoustic and a membrane detector. Instrumentation operated properly; data have not yet been received for reduction and analysis.

9. Cosmic Radiation

During calendar year 1961 a number of cosmic radiation experiments were flown on Air Force vehicles with varying degrees of success. Among these flights were:

a. Discoverer XXV. This vehicle was launched on 16 June and carried a set of three mutually perpendicular Geiger tubes which were sensitive to

$$\text{protons of } E > 13 \text{ Mev,}$$
$$\text{electrons of } E > 0.25 \text{ Mev,}$$

and gamma rays with low efficiency. The purpose of this experiment was to provide information on cosmic rays near the earth as a function of latitude and longitude. The vehicle telemetered in real time only; however, because of both telemetry and temperature problems, the useful data return was limited. The data from the acquisition point near New Boston, New Hampshire, did, however, give an indication of "dumping" of the outer Van Allen belt.

b. Discoverer XXVII. This satellite was successfully orbited on 30 August and carried a proportional-counter cosmic-ray telescope. The experiment consisted of a center tube surrounded by a ring of six other Geiger counters. This type of instrument was previously flown on Explorer satellites. By utilizing triple-coincidence among three counters in a line, the instrument is sensitive to

$$\text{protons of } E > 65 \text{ Mev,}$$
$$\text{electrons of } E > 13 \text{ Mev,}$$

but is not sensitive to gamma or X-rays. The purpose of this experiment was to provide information on cosmic radiation near the earth as a function of latitude, longitude and time. The vehicle carried a tape recorder to provide continuous data coverage over an orbit, but unfortunately the failure of the timing markers resulted in an inability to determine where in the orbit the data were recorded.

Since twenty complete orbits of data were telemetered back, we hope eventually to be able to correlate the time of group-vehicle functions with the position of the vehicle and thus make the data meaningful in terms of geophysical parameters.

c. Discoverer XXXI. This vehicle was launched on 17 September and carried a biaxial solid-state detector telescope—one telescope oriented vertically and one oriented horizontally. Each telescope consisted of two threshold detectors. This instrument was uniquely and exclusively sensitive to protons of energy from 0.5 to 5 Mev and 5 to 10 Mev. Since a solid-state detector gives a current pulse proportional to the energy lost in the depletion region, and the energy loss per unit path length of an ionizing particle is a function of the square of the charge, alpha particles of energy from 2 to 20 Mev could also be recognized.

By utilizing the stabilized Discoverer vehicle, this instrument provided directional information in addition to latitude, longitude and time variations of energetic protons near the earth. This vehicle also carried a tape recorder which functioned properly during the entire flight. Seventy orbits of excellent data were obtained which show protons of several Mev present in the "horns" of the Van Allen belt. Data from the first twenty orbits show a very pronounced directional effect. Complete analysis of the data is in progress.

d. Discoverer XXXVI. This vehicle was launched on 12 December and instrumented with a solid-state range-energy telescope detector. The purpose of the experiment was to determine the differential energy spectra of protons between 8 and 140 Mev. Although the launch was successful, the instrument telemetry link (on which the tape recorder "read out" its stored data) was extremely noisy and failed after nine orbits. Only two useful orbits of data were obtained. Analysis of these data is in progress.

e. MIDAS III. This vehicle, launched on 12 July, carried a high-energy proton spectrometer and a Geiger-counter experiment to determine various parameters of the inner Van Allen radiation belt at the MIDAS altitudes.

The high-energy proton spectrometer (HEP-1) consisted of two scintillators biased so as to be threshold detectors of

protons of $E \gg 60$ Mev, and
protons of $E \gg 120$ Mev.

Two Cerenkov detectors were utilized as threshold detectors of

protons of $E \gg 250$ Mev, and
protons of $E \gg 500$ Mev.

The HEP package also contained an independent telemetry transmitter.

The Geiger-counter experiment was flown to determine time, latitude and longitude variations in the Van Allen radiation. The Geiger counter was shielded so as to be sensitive to

$$\text{protons of } E > 50 \text{ Mev},$$
$$\text{electrons of } E > 1 \text{ Mev},$$

and gamma rays with low efficiency.

Data from the Geiger-counter experiment were limited to twenty minutes, after which time the vehicle telemetry failed. However, the HEP-1 experiment with its independent telemetry system provided data for many days. The two Cerenkov counters ($>$ 250 Mev) failed to provide meaningful data due to noise generated by proton bombardment of the very high-gain photomultiplier tubes, but the two scintillators provided excellent data on the radiation environment at 1830 nautical miles.

The measured maximum proton flux at the magnetic equator of 2×10^5 protons/cm^2/sec is fully an order of magnitude greater than that predicted by Van Allen's estimates.

f. MIDAS IV. All geophysical experiments, except the HEP-2 instruments, were removed from MIDAS IV to accommodate Project West Ford. The launch was on 21 October.

The Cerenkov counters were removed from the HEP-2 instruments and an additional scintillator and Geiger counter were substituted. The sensitivity ranges of the three threshold detectors were

$$\text{protons of } E > 46 \text{ Mev},$$
$$\text{protons of } E > 76 \text{ Mev},$$
$$\text{protons of } E > 128 \text{ Mev};$$

and a Geiger counter sensitive to

$$\text{protons of } E > 46 \text{ Mev},$$
$$\text{protons of } E > 76 \text{ Mev}.$$
(or equivalent energy electrons)

By comparison of the Geiger counter and scintillator counting rates, it was determined that any electron contribution to the counting rate at the equator is small, while it is the most significant contribution at the higher latitudes.

The data from this flight are still being analyzed. Results confirm the measurements taken on MIDAS III and, in addition, show that:

(1) Proton flux is much more dependent upon altitude than previously expected.

(2) A time dependency is present which appears to be correlated with solar flares.

g. Five radiation experiments were carried on Atlas Pod 08 launched from Cape Canaveral on 19 December. The experiments and the energy and cosmic radiation parameter to be measured were:

CRM-2B	-	proton spectra between 1 and 50 Mev, and alpha particles between 10 and 40 Mev;
NU-3	-	thermal and epithermal neutron density;
HEP-2	-	high-energy proton spectrometer;
MEE	-	electron spectra between 50 and 500 Kev;
MEP	-	proton spectra between 10 and 70 Mev.

Preliminary results show all experiments operated correctly, and data are now being analyzed.

h. Since Discoverer XVIII, six additional blocks of emulsions have been successfully orbited and recovered. These had apogees between 300 and 570 km and exposure periods of one to four days. The emulsion units have been studied for the nucleonic component of the cosmic radiation and the flux of trapped protons residing in this altitude interval. As an index for the nucleonic components, stars have been tallied per unit volume of emulsion. These measurements show that the star intensity increases rapidly with altitude, and even at the lowest altitude of 306 km, the star production rate is double that anticipated from the knowledge of the galactic contributions at balloon elevations and Viking rocket altitudes. The increment in star production at the higher elevations is attributed to the interaction of the more energetic trapped protons with the emulsion nuclei. Studies have also been made of the protons that terminate their range in the emulsions—the so-called proton "ender" tracks. Their termination frequency increases exponentially with altitude in the region 300 to 700 km. The rapid increase in the frequency of the proton "enders" is again an indication that the fringes of the inner Van Allen belt are being sampled by the Discoverer capsule. It would appear from these studies that at anomalous points along the polar orbit, the Van Allen zones dip down to elevations as low as 300 km. Attempts have also been made to study the neutron activation of bismuth samples which were subjected to the same exposures on Discoverer capsules. No appreciable counts over background have been found. It will probably require a major solar flare to activate the bismuth sufficiently to yield positive scientific results.

Similarly exposed and recovered lead samples are being analyzed. None thus far has produced as much tritium as was experienced with samples taken from Discoverer XVII or XVIII.

10. <u>Cyrogenic Whole-air Sampling</u>

The second field test of the rocket sampler was carried out at White Sands, New Mexico, on 26 September. The experiment, carried aloft by an Aerobee rocket, was only a partial success due to a booster failure and the premature opening of the sampling system at too low an altitude (approximately 35 km).

However, the sampler functioned properly and was recovered intact, yielding a stratospheric air sample of considerable scientific value. Analysis of the gaseous constituents is in progress.

A third flight test of the rocket sampler using an Aerobee-Hi vehicle is scheduled for April 1962.

11. Missile-borne Radiometry

The instruments flown on Atlas Pods 03 and 08 were designed to measure the infrared spectrum of the missile exhaust plume in the spectral region from 2.4 to 4.6 microns utilizing a standard Ebert-type grating spectrometer. At the completion of each scan, standard voltage steps were introduced into the output as an internal calibration to check the performance of the telemetering system, and also to provide voltage references by which to measure the amplitude of the spectrum, thereby allowing one to identify absolute spectral radiance of the source. Voltage steps were also introduced to monitor the temperature of the chopper mechanism and the detector.

Both pods were successfully fired and data were gathered throughout the entire flights. The telemetry was noisier on Pod 08 and tended to break up more often, but over 75 spectra were obtained on both firings. The results show the expected strong CO_2 and water-vapor absorption bands at 2.7 and 4.3 microns on both pod flights. The data from Pod 08, in addition, show an unexpected very strong absorption band at about 3.4 microns which has not yet been explained or positively identified. Investigations are being made into the possibility that fuel additives in this particular missile, or the nature of the ablating engine nozzle, may be the cause.

12. Lunar X-ray Analysis

a. Theoretical investigations predict that the bombardment of lunar surface materials by solar radiation will produce secondary X-rays of sufficient intensity to be detected and analyzed from the vicinity of the earth. Analysis of these X-rays will indicate the elemental composition of the lunar surface materials.

b. Instrumentation consisting of three large-area Geiger counters, sensitive in different regions of the X-ray spectrum, was flown aboard an Aerobee-Hi from White Sands, New Mexico, in October. Despite a partial instrumentation failure, this rocket succeeded in detecting X-ray emission from the moon.

13. Geodetics

On 8 December an Astrobee-1500 sounding rocket containing a geodetic payload was launched from Point Arguello, California. Three "poppy" pyrotechnic flare canisters, each containing seven flare cartridges and associated timers, power supplies and telemetry, made up the geodetic package. The flares, with a peak brightness of 62-million candlepower, were programmed to eject in groups of seven at eight, fifteen and twenty-two minutes after launch as the rocket followed a westerly trajectory toward Hawaii. The first and third bursts ejected while the rocket was at about 900 nautical miles altitude; the middle burst, ejected at apogee, was at 1400 miles — 900 miles from the launch site.

The flares were photographed, together with the star background, by a wide variety of scientific cameras and telescopes located throughout the eastern Pacific. The plates, containing a record of both flare and star images, are being reduced to obtain highly accurate positional information of the camera sites. Utilizing the very precisely known location of the stars and the well-surveyed coordinates of selected camera sites, it is possible to compute the spatial coordinates of the flares to within plus or minus one second of arc. From this information and the star coordinates of the other sites, it is then possible to compute the location of the other sites very accurately in terms of the survey systems of the control stations.

AFCRL-developed geodetic stellar cameras used for control were located in Sitka, Alaska; Spokane, Washington; Lincoln, California; and El Centro, California. Other AFCRL cameras were located on Mauna Loa and on Kaena Point in the Hawaiian chain. The Navy Hydrographic Office, cooperating in the experiment, had an AFCRL-type camera at Johnston Island and a stabilized aerial camera aboard a telemetry ship beneath the predicted apogee point. An Air Force Baker-Nunn satellite-tracking camera observed from Edwards AFB, and two Smithsonian Astrophysical Observatory cameras of the same type observed from Organ Pass, New Mexico, and Maui, Hawaii. Also participating were NASA satellite-tracking cameras at Goldstone, California, and cameras operated by the Philco Corporation in the Point Arguello area. Four astronomical observatories — Lick and Leuschner in California, Naval Observatory and Lowell in Arizona — used their telescopes to record the event. Photomultiplier devices were set to record the time of flare burst. Edgerton, Germeshausen and Grier operated one of the photomultiplier detectors in Hawaii and the others, developed by AFCRL for the geodetic stellar-camera systems, were operated by the Air Photographic and Charting Service.

It appears from a preliminary analysis of the plates that twelve to fifteen observations were successfully made of the flares. There were also several visual sightings. It is expected that the reduction of data from the plates will show the feasibility of this novel surveying technique and will result in a greatly refined position for Johnston Island.

14. Horizon Scanner

The AFCRL horizon-scanner experiment on Atlas Pod 03 consisted of a General Dynamics/Convair-developed filter radiometer and optics designed to measure the infrared horizon gradient of the atmosphere. A 1 x 1 mm PbSe cell cooled to -196°C was used as the detector. The spectral regions covered by the instrument were:

a. Narrow band centered at 2.7 microns;

b. 3-4 microns;

c. Narrow band centered at 4.3 microns;

d. 4.5 - 5.5 microns;

e. 5.5 - 6.5 microns.

The small hatch located on the large door blew off prematurely, initiating data recording at T+50 seconds. Furthermore, a problem exists in data reduction. A complete reduction of the data requiring missile altitude, the angle made with the local horizon, roll angle and angle with respect to local earth tangent such that the instrument scan angle can be located, may not be possible.

A quick look at the data recorded indicates that the spectrum from 4.5 to 5.5 microns represents the steepest radiation gradient when scanning across the horizon.

15. Geomagnetism

Due to the unavailability of Fort Churchill as a launch area during calendar year 1961, the high-altitude rocket flights scheduled for geomagnetic experiments were postponed until 1962. These will consist of several Javelin flights during magnetically disturbed conditions. Rubidium-vapor magnetometers will be used in an effort to detect hydromagnetic waves in the ionosphere at these times. Meanwhile, the analysis of a prior magnetometer flight over New Mexico has been completed and exhibits an anomaly of the order of 80 gamma on the ascent portion between the altitudes of 85 and 165 km. Further, a power-spectrum analysis of the proton precession signal obtained up to an altitude of 240 km at Fort Churchill in November 1960 indicated that what appeared to have been a wave motion superimposed on the signal was, in fact, only Gaussian noise.

16. Satellite Meteorology

During the past year, research in this area has resulted in a practical and comprehensive classification system for the interpretation of clouds as seen in television pictures obtained from satellites. The system is based on the form, pattern, texture and brightness of the patterns, shapes and images. Analysis of the photographic data over the tropical Pacific Ocean has revealed important circulation features never indicated by routine observations. These observations support the hypothesis that a cold trough regularly lies across the tropical Pacific at 30,000 feet, oriented WSW-ENE. At times this trough spirals completely around the globe and appears again at about 60°N. Satellite radiation data are being compared with those collected by high-flying aircraft making simultaneous passes along the sub-orbital path. AFCRL contractors have established the feasibility of using digital-computer techniques to produce rectified and scaled reproductions of satellite photographs.

17. Meteorological Rockets

On 9 May a concentrated program of meteorological soundings was conducted by Eglin AFB for AFCRL. The purpose of this program was to determine the direction, speed and diurnal variations of winds at altitudes from 15 to 45 miles above the earth. In addition, it was hoped to determine the variation of the density and temperature of the atmosphere over these altitudes.

Twenty-four ARCAS-ROBIN sounding rockets were fired at the rate of one each hour for twenty-four hours to altitudes averaging 240,000 feet. Of the twenty-four shots, twenty-three were successful. ARCAS is a solid-propellant rocket 4 1/2 inches in diameter; ROBIN is a 39-inch-diameter superpressure balloon. Within the balloon is an aluminized Mylar corner reflector for tracking. A fluid vaporizes to inflate the balloon when the balloon is ejected from the nose cone.

The path of the descending spherical balloon gives a vertical profile of wind speed and direction. Density of the atmosphere can also be calculated from mass, fall velocity and drag computation. Pressure and temperature can be obtained by assuming the perfect-gas law. Thus a fairly complete meteorological profile of the atmosphere from apogee down to 90,000 feet can be constructed. (At the lower point, the balloon reaches equilibrium pressure with the atmosphere and collapses.)

Under the ARCAS-ROBIN program, two hundred shots were made. Data are being reduced for these shots by the University of Dayton under AFCRL contract. An error analysis of collected data and development of a simplified method of data reduction by station weather personnel are being carried out by the Dayton contractor.

Analysis of the data collected between 30 and 70 km over North America by this technique has shown that this layer is generally in the same circulation regime as that of the lower stratosphere. However, in wintertime the characteristics of the thermal field are such that there are considerable variations in the location and intensity of circulation features throughout the layer. Local variations in winds of over 100 m/sec have been observed to occur over a period of only three to five days. These variations can be attributed to specific changes in the large-scale circulation patterns.