AD 665853

AFCRL-68-0011
JANUARY 1968
SPECIAL REPORTS, NO. 70

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

AFCRL Space Science Research During 1967 (Annual Report to COSPAR)

Editor
A. McINTYRE

OFFICE OF AEROSPACE RESEARCH

United States Air Force

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DEPUTY FOR TECHNICAL PLANS AND OPERATIONS

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Abstract

A summary of the space science organization and facilities of Air Force Cambridge Research Laboratories (AFCRL); its international activities in space science; rockets, satellites, and balloons launched; results of experiments associated with the moon, planets, micrometeoroids, solar physics, energetic particles and magnetic fields, upper atmosphere physics, meteorology, geodesy, and terrestrial photography; planned research in 1968; and a space science research related bibliography are included. The definition of space science for the purpose of this report is limited to in-situ observations and measurements using the broad definition of space.

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AFCRL Space Science Research During 1967 (Annual Report to COSPAR)

I. INTRODUCTION

This report has been submitted to the Space Science Board of the National Academy of Sciences/National Research Council for use in preparing the United States Space Science Program Report to COSPAR for the Eleventh Annual Meeting and is limited to AFCRL space science research results which are the product of in-situ measurements attained through the use of either satellites or space probes. For the purpose of continuity, research results not previously reported to COSPAR are included.

The inclusion of AFCRL's space science research in this report was guided by Porter's definition of space science as scientific work based on in-situ observations or measurements in space. As a result, space science research conducted at the Sacramento Peak Observatory and the Prospect Hill Millimeter Wave Antenna, among other space research efforts, was deliberately excluded, although some of the most valuable space research in the world is conducted by AFCRL scientists at these facilities, or in other ground-based programs at AFCRL proper.

More detailed accounts of the space science research results reported herein may be found in the various professional journals or in AFCRL's scientific publications.

(Received for publication 9 January 1968)

2. AFCRL ORGANIZATION FOR SPACE SCIENCE RESEARCH

The Air Force Cambridge Research Laboratories (AFCRL) reports directly to the Office of Aerospace Research (OAR), which is a separate operating agency of the United States Air Force charged with the research mission of the United States Air Force.

The mission of AFCRL is to perform both basic and applied research in the environmental, engineering, and physical sciences. It is currently composed of nine laboratories roughly organized along the lines of the principal scientific discipline in which they most heavily specialize (see Figure 1). Using the definition of Porter*, seven of the nine laboratories of AFCRL are active in space science research.

2.1 Aerospace Instrumentation Laboratory

This laboratory conducts and supports research and assigned development directed toward the collection of environmental data through the use of plastic balloons, rockets, and satellites, and toward the development of techniques for measuring and describing the variability of atmospheric parameters.

2.2 Space Physics Laboratory

This laboratory conducts and supports research and assigned development in solar and planetary atmospheres, particles and fields, stellar sources, and space power techniques.

2.2.1. SACRAMENTO PEAK OBSERVATORY

This observatory conducts an observational program to obtain highly accurate and detailed data on solar phenomena; relates the data to the properties and processes of space and the terrestrial atmosphere; and performs theoretical studies of the physics of the sun.

2.3 Optical Physics Laboratory

This laboratory conducts and supports research and assigned development on the generation, transmission, and detection of optical and infrared radiation and its interaction with the aerospace environment.

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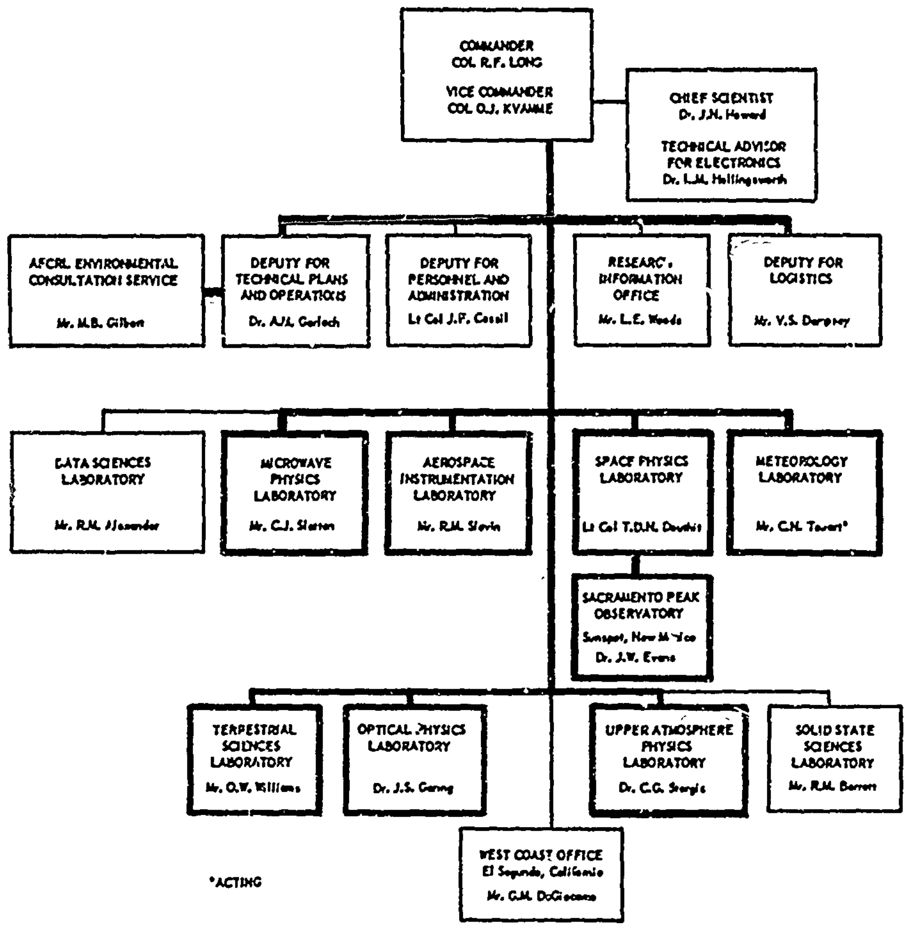
*United States Space Science Program, Report to COSPAR, Tenth Meeting, London, England, July 1967, NAS/NRC, 1967. (Foreword)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Dr. J.N. Howard
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AFCRL ENVIRONMENTAL CONSULTATION SERVICE
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Mr. C.N. Touart*
SACRAMENTO PEAK OBSERVATORY
Sunspot, New Mexico
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SOLID STATE SCIENCES LABORATORY
Mr. R.M. Barrett
WEST COAST OFFICE
El Segundo, California
Mr. G.M. DeGiacomo
*ACTING

Figure 1.

2.4 Upper Atmosphere Physics Laboratory

This laboratory conducts research and assigned development in the fields of aeronomy, ionospheric physics, and ionospheric perturbations.

2.5 Microwave Physics Laboratory

This laboratory conducts and supports research and assigned development in the generation, radiation, transmission, and detection of electromagnetic energy and its interaction with ionized and solid media, primarily at microwave frequencies.

2.6 Meteorology Laboratory

This laboratory conducts research and assigned development in meteorology in the broad definition.

2.7 Terrestrial Sciences Laboratory

This laboratory conducts and supports research and assigned development in the earth sciences, including seismology, geodesy, and gravity; acoustics; selenodesy; and planetary gravitional fields.

2.8 AFCRL Management for Space Science

The Commander is the overall AFCRL Laboratory Director. The Chief Scientist serves in an advisory capacity to the Commander on scientific matters. The Deputy for Technical Plans and Operations is responsible to the Commander for the actual formulation, planning, establishment, review, and management of all research and development programs assigned to AFCRL, including the allocation of available funds, manpower, and facilities. Through the Environmental Consultation Service, technical consultation is provided to Air Force exploratory development laboratories, development divisions (including their contractors), and other Government agencies in need of such technical support. The Deputy for Logistics is responsible to the Commander for the ormulation of current and future logistics plans, and policies and procedures in the areas of materiel, facilities, and field operations, including engineering and fabrication, technical photography, library, and computation service support to the laboratories. Each Laboratory Director reports directly to the Commander, AFCRL, and is responsible for the management of his specific laboratory. The West Coast Office of AFCRL provides scientific consultation and liaison to Air Force activities located primarily in California.

To further clarify the organizational structure of AFCRL, the principal lines of management as related to space science research activities have been emphasized in Figure 1, along with the principal laboratories conducting space science research and assigned exploratory development.

3. AFCRL FACILITIES FOR SPACE SCIENCE RESEARCH

AFCRL's total permanent installations are currently located at 17 different geographical locations, and in terms of land owned, leased, and occupied, covers 944 acres.

At AFCRL, complete in-house facilities are available to design and fabricate most sounding rocket, satellite, and balloon payloads as well as to perform most pre-launch tests; and to decommutate and computer-process telemetry data.

The major sites, or facilities, outside of those located at L. G. Hanscom Field, Bedford, Massachusetts, which are used either partially or fully for the conduct of research in space science include the Sagamore Hill Radio Observatory, Hamilton, Massachusetts which includes two large radio telescopes, one with an 84-ft parabolic dish and one with a 150-ft parabolic dish. The 150-ft dish has been used to receive data from the OV1-5 AFCRL Solar X-ray Monitoring Satellite on an as available basis. It has also been used to conduct ionospheric research by receiving transmissions from the Early-bird and NASA ATS-1 satellites. A Solar Radio Observatory, which monitors solar radio emissions at six frequencies, including the internationally valuable frequencies of 606 and 1415 MHz, is also located at Sagamore Hill along with other lesser antenna facilities.

3.1 Other AFCRL Major Ground-based Facilities

Some of the other AFCRL ground-based facilities used in conjunction with space science research include the Sacramento Peak Observatory, which is one of the largest and most completely instrumented optical solar observatories in the world, and the 29-ft Millimeter Wave Antenna located on Prospect Hill in Waltham, Massachusetts, which is used to conduct solar millimeter wavelength studies at 8.6 millimeters.

AFCRL also operates permanent sites for the launch of high altitude balloons at both Chico, California, and at Holloman Air Force Base, New Mexico.

3.2 Research Aircraft

AFCRL uses about six aircraft in the conduct of space science research. These aircraft include: one KC-135 principally instrumented with a Granger sounder, gamma ray monitor, visible photometer, and infrared spectrometer; one KC-135 equipped with a variety of advanced optical and infrared instruments, including radiometers, interferometers, spectrometers, photometers, cameras, and other associated equipment; one C-130 with an infrared scanner, multiband camera, various types of gravity meters and associated instrumentation; one C-130 with a refractometer, APN-144 Doppler radar, vortex thermometer, and water content measuring device; one C-130 with an aerosol spectrometer, microwave refractometer, spectroradiometer, magnetic recording equipment, and a horizontal path-function meter; and one T-29 to replace a similar aircraft equipped for balloon research which has yet to have its primary instrumentation installed.

4. INTERNATIONAL ACTIVITIES IN SPACE SCIENCE

4.1 Satellite OV3-2

When the satellite recorder on solar-orbiting satellite OV3-2 failed, a command system was installed at Churchill to obtain real-time readouts of the OV3-2 data. In addition, the National Research Council of Canada has been making simultaneous riometer, magnetometer, ionosonde and optical measurements in conjunction with satellite OV3-2 passes in a cooperative Canadian-AFCRL effort to study auroras and auroral effects.

4.2 Satellite ISIS-A

Narcisi and Sagalyn of AFCRL will conduct positive ion composition and positive ion density and temperature experiments, respectively, on the Joint Canadian-United States ISIS-A satellite. The satellite is sponsored by NASA and the DRTE, Ottawa, and will be launched in 1968.

4.3 Micrometeoroid Collections (Sounding Rockets)

Skrivanek of AFCRL was invited to participate in a particle collection experiment on an ESRO Centaur rocket, launched from ESRange on July 31. The experimental payload performed as expected; however, the parachute recovery system malfunctioned, and the rocket was recovered in extremely poor condition. No useable data were obtained from this experiment.

AFCRL also invited guest experimenters from other countries (West Germany, Australia, Japan, England) to participate in the December 13th Aerobee (AE3.268) particle collection experiment. This flight was also unsuccessful.

4.4 Ferdinand Series (Sounding Rockets)

Plans are being made for future flights in the Ferdinand series (Nike-Apache) being launched from Andoya, Norway. An AFCRL 40 to 70 Hz receiver was carried in the Ferdinand 14, 26 June 1966. The Danish Technical Institute was responsible for the integration of the experiments. Launching, tracking, and telemetry were performed by the Norwegian Defense Research Establishment.

4.5 Polar Cap Absorption Event - 1968

An extensive and complex rocket and ground-based operation will take place at Thule, Greenland during September and October 1968 to study, as completely as possible, a polar cap absorption event (PCA). As part of this program twenty-two rockets will be launched to measure the ionosphere before and during the initial and later stages of a PCA event.

4.6 AFCRL ORBIS Cooperative Program

AFCRL conducts a continuing cooperative effort with many countries to study ionospheric irregularities using the AFCRL ORBIS (Orbiting Ionospheric Satellite) series of satellites. Cooperating countries include Portugal, England, Peru, Denmark, France, Sweden, Greece, Italy, Israel, Germany, Spain, Ghana, Kenya, Formosa, India, and the West Indies. New Zealand has also provided data to the program.

5. AFCRL SPACE SCIENCE RESULTS - 1967

5.1 Moon, Planets, and Micrometeoroids

5.1.1 BALLOON-BORNE LUNAR INFRARED

Salisbury of AFCRL continued experiments using a 60-cm balloon-borne telescope, which can automatically acquire and track selected areas on the lunar surface. A circular variable filter spectrometer, with a copper-doped liquid-helium cooled germanium detector, provided spectral data on infrared emission from the lunar surface between 5 and 13.6 microns. The experimental objective is to determine the extent to which molecular vibration features (reststrahlen bands) are present in the lunar infrared emission, and to utilize any such features in a study of the composition of the lunar surface materials.

Of the four flights attempted during 1967 (H67-28, -47, -71, and -83), two yielded spectroscopic data. Preliminary data reduction indicates a rather strong spectral feature at 7 microns, and a much weaker feature at 9 microns. The 7 micron feature may be due to the presence of non-silicate volcanic sublimates on the lunar surface.

5.1.2 MICROMETEOROID COLLECTIONS USING THE X-15 AIRCRAFT

The final series of X-15 micrometeoroid collection experiments were conducted by Skrivanek of AFCRL on 6 and 16 October and 15 November 1967. These particle collections, using a wing tip collection device, were performed between the altitudes of 150,000 ft and 350,000 ft. Based upon calculated particle fall velocities, these altitudes provide an excellent opportunity for the collection of appreciable amounts of extraterrestrial material. Of the three flights conducted in 1967, two provided useful data. Some experimental difficulties were encountered due to contamination originating from the attitude-control rockets on the nose of the X-15. This has slowed the analytical processes somewhat; however, it is anticipated that a technical report will be published within the next year.

5.1.3 MICROMETEOROID COLLECTIONS USING ROCKETS

A new particle collection rocket (AG7.272) was tested for the first time by AFCRL in June 1967, and telemetry signals received indicate that the entire collector performed as expected. This collector, designed for a Niro rocket, was to have been used in a series of rocket launchings from Natal, Brazil in the summer of 1967. Unfortunately, a new water recovery system for this payload was not ready at that time, and the program was postponed for one year.

AFCRL also participated in two successful Luster rocket launches from White Sands Missile Range on 6 June 1967 and on 11 August 1967. The results of these rockets, which were launched during periods of increased meteor shower activity, tend to support the low particle flux values reported by Skrivanek for previous Luster rockets. The low particle fluxes in these instances suggest that either the peak of the shower was missed or that the shower contributed a negligible amount of particles to the steady state condition. In both launches, an inflight shadowing device was utilized for maximum contamination control. The results of the inflight shadowing will be published in the next year.

A new capacitor microphone particle detector was test flown by AFCRL for the first time on 13 December 1967. This system, expected to be 2 to 3 orders of magnitude more sensitive than the present piezoelectric microphone detectors, appeared to function as expected throughout the entire flight (AF3.268). In addition to the increased sensitivity, it also appears that the new microphone detectors are not susceptible to the thermal difficulties reported for the piezoelectric microphones. Additional laboratory testing is presently being performed, and it is expected that these new detectors will be in use within the next year.

5.2 Solar Physics

5.2.1 SATELLITE MONITORING OF SOLAR RADIATION.

The OV5-1 (1967-40E) is the only AFCRL satellite in a program to monitor solar radiation. It was successfully launched from the Eastern Test Range on 28 April 1967 into a 9,484 by 110,350 km elliptical orbit. Excellent data are being received by Yates and within a year significant results should be available. The orbit and instrumentation are such that considerable information on both solar x-rays and solar particle radiation will be available. Because x-ray detectors also respond to charged particles, corrections for the particle background were necessary. For this purpose, the OV5-1 satellite has several particle counters. The satellite instrumentation included the following:

Instruments	Measurements	
GM Tubes (6)	X rays Electrons	2 to 14 A° E > 40 KeV
PM Tube (LE)	Electrons Protons	E > 350 KeV E > 3.8 MeV
PM Tube (HE)	Electrons Protons	E > 3.3 MeV 40 < E < 80 MeV
Solid State Detector	Electrons Protons	E > 700 KeV 12 < E < 19 MeV
Surface Barrier Detector	Protons	1.2 < E < 3.4 MeV
Bremsstrahlung	X rays	20 < E < 100 KeV
PM Tube	Electrons Protons	E > 1.6 MeV E > 18 MeV

The Geiger-Mueller tubes, which provide the main complement of X-ray detectors, are directional. These tubes are so located that at least two sweep by the sun as the satellite spins. Several sun sensors are included in the system to indicate which counters are looking at the sun and when.

For real time readout of the satellite the AFCRL Sagamore Hill site is being used. In addition to the real time effort, data from the satellite is also acquired by the NASA STADAN ground stations. The NASA stations provide an alternate input of data for more sophisticated analyses.

Data analysis is oriented for: (1) a vigorous determination of the quiet-sun solar X-ray background and disturbed-time X-ray fluxes as measured by the OV5-1 sensors; (2) use in studies of solar flare particle producing events to permit evaluation of the 1 to 14 Å solar X-ray measurements as predictors for particle producing flares. The measured X-ray fluxes will be correlated with selected solar and geomagnetic activity parameters such as optical measurements of active regions from ground based observations and the K_p indices. Measurements from the OV5-1 and other sources will also be presented to detail the time morphology of the solar flare events. About one hundred hours of data are being acquired each week. Eight hundred hours of acquired data, in addition to data from certain particle producing flares, will be selected for detailed analysis.

The next step will be accomplished by AFCRL in conjunction with the Air Weather Service (AWS). From the physical data available, conclusions shall be drawn and recommendations made to refine the operations of the AWS Solar Forecast Center. There are several questions of immediate interest. What size should an X-ray flux increase be before it is reported? (If too large, significant events will be missed; if too small, the false alarm rate will be unacceptable.) Which wavelength band of the X-ray spectrum is the most sensitive indicator? What is the maximum acceptable delay in reporting events to the AWS Solar Forecast Center? As these and similar problems are resolved, the results will be disseminated through oral and written reports to the AWS Solar Forecast Center.

Plans are being made for the launch of a satellite with similar instrumentation. This satellite (OV5-6) has a tentative launch toward the end of 1968.

5.3 Particles and Magnetic Fields

5.3.1 PARTICLES

The AFCRL satellite experiments launched during 1966 (OV3-1, OV1-9, OV1-10) continued to operate and data analysis from these is progressing. An analysis of low energy proton data ($.24 < E < 1$ MeV) as a function of the L parameter in the trapping region by Katz, Kuck, and Rothwell showed qualitative agreement with inward radial diffusion conserving the first two adiabatic invariants. The peak flux as a function of L at a particular energy followed the theoretical predictions based on the assumption of equatorial diffusion, even when measured at high latitudes. The spectra became softer with increasing L and the peak flux as a function of L became broader with decreasing particle energy. However, detailed spectral shapes at these small equatorial pitch angles did not agree with the equatorial diffusion predictions.

Observed time variations and spatial dependence of low altitude electrons ($1 < E < 4$ MeV) studied by the AFCRL group suggest that the transport of relativistic electrons across L shells can be qualitatively understood as the interplay of two processes: (a) radial diffusion with conservation of first and second adiabatic invariants, resulting in spectra monotonically decreasing with L, and (b) radial diffusion arising from shell splitting and pitch angle diffusion, consistent with energy spectra independent of L for $L > 4$. Process (a) is dominant during magnetically active periods, and (b) is dominant during quiet periods.

The measurements of 55 MeV trapped proton flux (in nuclear emulsions exposed on recoverable polar orbiting satellites) by Filz of AFCRL in 1966 and 1967 tend to indicate that the fluxes at low altitude are decreasing as expected due to solar cycle atmospheric density increases. Further observations at altitudes of 300 to 400 km are required to confirm this effect.

Currently under study at AFCRL are the time variations of higher energy trapped protons. The full effects of the Starfish burst on naturally trapped protons are still being investigated both experimentally and theoretically. Theoretical calculations indicate that the interaction of the protons with the hydromagnetic shockwave associated with the expanding magnetic bubble created by Starfish may be the most probable cause of the pitch angle redistribution of inner zone protons observed by Filz and Holeman. Because of the sparse amount of proton flux data available, immediately following Starfish, and the complete absence of pre-Starfish data above an L of 1.5 at the equator, it will be difficult to evaluate theoretical calculations.

Two small packages of emulsions with sliding plate time measurement devices were flown on balloons by Fukui of AFCRL at Fort Churchill during the summer of 1967. These will be used as part of a long-term AFCRL study of low energy cosmic ray heavy nuclei to determine solar modulation effects.

The OVI-86 (1967-72A) also carried an AFCRL telescope to study heavy relativistic primaries with E > 540 MeV/nucleon, to determine relative abundances of the various elements as well as rigidity spectra.

5.3.2 AURORAL BAY MAGNETIC-FIELDS EXPERIMENT

The Javelin data (AB19.286, launched May 1966) has been reduced and a paper has been written by Vancour of AFCRL for publication. The results show that during the magnetic disturbance investigated, the sharp magnetometer dips at the beginning of the disturbance were associated with a hard electron spectrum. The flight data shows the decay of this spectrum. The slow magnetometer dip is associated with a general increase in the integral flux of electrons during the flight and with a softer spectrum. The correlation of the electron flux peaks with magnetometer dips and the general agreement between the magnetometer and riometer records indicate that the electron intensity variations were time changes and not spatial. The integral electron flux was of the order of 10^6 cm^{-2} sec^{-1} ster^{-1} for $E \geq 50$ keV. The integral proton flux ($E \geq 0.45$ MeV) was $\sim 3 \times 10^3$ cm^{-2} sec^{-1} ster^{-1}. There may be correlation of proton peaks with similar structure for the electron count rate but the statistics for this conclusion were poor.

5.4 Upper Atmospheric Physics

5.4.1 ION AND NEUTRAL COMPOSITION EXPERIMENTS.

A total of eleven quadrupole mass spectrometer systems were launched on board seven rockets and two satellites in experiments conducted by Narcisi's group at AFCRL (See Appendix A, Table A1). The rocket experiments were concentrated toward obtaining comprehensive measurements in the D and E regions of the ionosphere while the satellite experiments were designed for measurements of neutral and positive ion species between 300 and 1000 km.

The AFCRL rocket program, designated as "PIQSY", was carried out at Eglin during April. The purpose of this program was to study the formation and decay dynamics of the ionospheric D and E regions and to study the effects of transport processes in these regions. Near simultaneous rocket measurements of neutral winds both horizontal and vertical, neutral and charged particle densities, and positive ion composition were performed. Additional measurements were made by a ground-based ionosonde which was operated continuously throughout the series. Four cryogenically-pumped, quadrupole mass spectrometers along with spherical electrostatic probes were flown in Nike-Iroquois rockets before and after sunset and sunrise. The ion composition experiments were completely successful. Generally, the experimental results showed that hydrated protons $H^+ \cdot (H_2O)_n$ dominated the composition below 85 km while NO^+ was the major constituent above 85 km, except in the sunset experiments where metallic ions predominated over a small range near 93 km.

From the experiments around sunset, launched on rockets AA7.168 and AF7.385 at solar zenith angles of 88.5° and 98.6° respectively, it was found that the lower ionosphere decays immediately within the first hour after sunset and only a smaller amount of additional decay occurs through the night. However, the decay was not uniform; below 85 km the hydrated protons decayed by a factor of about 4; from 85 to 120 km the decay in NO^+ varied from a factor of 3 to a small value and from 120 to 150 km the NO^+ density decreased by a factor of 10 to 20. In addition, metal-atomic and silicon ion layers were measured and the silicon layer showed a vertical displacement in the time between rocket launchings. The altitudes and displacement of these layers are presently being correlated with the wind measurements.

The sunrise experiments were launched at solar zenith angles of 102.5° and 90° on rockets AF7.384 and AF7.386 respectively, and showed the effects of Lyman α ionization of nitric oxide and Lyman β ionization of molecular oxygen in the upper E region. In addition, two metal ion layers which consisted mainly of iron and magnesium located near 111 and 118 km showed a striking density increase of a factor of ten at sunrise. It is believed that the increased ionization in these layers was caused mainly by charge transfer between NO^+ and neutral metal atoms. Also noteworthy was the detected enhancement in the hydrated proton density at sunrise. Because all the "hard" radiation is attenuated above the D region at a solar zenith angle of 90°, this indicates that the hydrated protons are created by radiation which is less energetic than Lyman α. The possibility that this arises from ionization of neutral water conglomerates, which may have very low ionization thresholds, has already been advanced. Reaction rate computer programs are presently being applied to all this data to study the physical chemistry.

Another rocket program to study the lower ionosphere was conducted at Ft. Churchill, Canada, in early December. A D-region cryogenically pumped negative ion mass spectrometer was designed, developed and tested at AFCRL during 1967. This instrument was successfully flown on the first attempt to obtain such measurements on 4 December on Niro rocket AF7.387. The payload also contained cylindrical Langmuir probes which were provided by Ulwick. The rocket was launched at a solar zenith angle of 99° and measurements were obtained between 70 and 120 km on ascent and descent. Most of the mass peaks detected were near the threshold of the instrument sensitivity limit; therefore, only mass numbers could be identified and their presence or absence over the altitude range indicated. Some of the more prominent mass numbers detected were 16^-, 35^-, 37^- and 46^-. Masses 35^- and 37^- were present only in the E region.

As a conjunctive experiment with the negative ion experiment a similar payload, including instead a positive ion mass spectrometer, was launched 20 minutes before the negative ion experiment on Niro rocket AG7.880. Measurements were obtained between 55 and 147 km and the descent results mirrored the ascent results. Of particular import was the identification of a significant layer of atomic sulfur ions located near the mesopause and restricted entirely below 85 km. Ion layers of mass 32^+ were detected near the mesopause on all four rockets in the April series. It wasn't until the more sensitive instrument was launched at Ft. Churchill that 34^+ was clearly detected and the ratio $32^+/34^+$ was seen to be identical to the ratio of the relative abundances of the sulfur isotopes. Metallic ions were also measured on this rocket and found layered between 85 km to about 100 km; some that were identified were sodium, magnesium, aluminum, calcium, iron, and nickel. A full analysis of the positive ion and negative ion results has just begun.

A third rocket was fired at Ft. Churchill on 6 December on Niro AF7.388 into a 2-dB daytime absorption event in a continuing program to study disturbed ionospheric phenomena. The payload consisted of a positive ion mass spectrometer and cylindrical Langmuir probes. Positive ion composition measurements were obtained in the E region. These data have not yet been reduced.

The Air Force OV3-5 satellite failed to achieve orbit on 31 January because of the explosion of the fourth stage motor. A similar satellite, OV3-6, was successfully placed into a nearly circular polar orbit at 440 km on 5 December to study the latitudinal variations in the composition and density and the effects of solar flare perturbations on these parameters. Two quadrupole mass spectrometers were mounted 180° apart along the satellite spin axis. One unit was fitted with an accommodation sphere to allow neutral species to reach thermal equilibrium before entering an enclosed ionization chamber. The second unit has an ion source exposed to the ambient atmosphere and can be operated as either a neutral or positive ion detector. Each mass spectrometer has a mass range from 1 to 34 amu which is scanned every five seconds. An on-board tape recorder is used to obtain data over a complete orbit. The satellite has been operational for over a month and a large amount of data has already been acquired. The major constituents of the neutral atmosphere; O, N_2, O_2, and He are being measured. The ion spectra show that the ions present are O^+, N^+, He^+, N_2^+, NO^+, O_2^+, H^+, and O^{++}. Computer programs are presently being organized to reduce the data.

5.4.2 AFCRL CHEMICAL RELEASE EXPERIMENTS

Chemical Release experiments were conducted by Rosenberg's group at AFCRL to measure the horizontal and vertical ionospheric wind components and their horizontal and vertical shears in conjunction with the simultaneous mass spectrometric measurements of densities and ionosonde observations of the electron density profile of the E region. Launches providing this data were made from Eglin AFB, Florida, and included two flights in January (AF7.654 and .656), three flights in April (AG7.622, .623, and AG8.647), and five flights in December (AG7.630, .631, AG8.665, AF7.663 and AF7.659).

An earlier similar experiment has confirmed the theoretical prediction that vertical shear of the vertical neutral wind can control the layering of ionization in the lower E-region.

A statistical analysis has been carried out on a group of 70 vertical profiles of horizontal winds reported by various investigators over the last several years. This analysis has disclosed certain statistical trends in circulation patterns which were reported at the 1967 COSPAR meetings in July. Their mean velocity spectrum was reported at the IUGG meeting in October. Further analysis has disclosed that the 70-trail mean velocity and shear can be well predicted from a simple model of a vector velocity which has a semidiurnal rotation in time and a vertical spatial rotation bet[illegible] 90 and 150 km with a wavelength of about 3 scale heights.

Observa[illegible] of the solar resonance radiation from neutral and ionized barium clouds released in the 130 to 230 km altitude region has led to further determinations of the neutral and transverse and longitudinal ion diffusion coefficients following the techniques of the original work by the Max Planck Institute. Five launches provided this data, one in January (AF7.503) and two in April from Eglin (AG8.650 and .651), and two from Wallops Island (AG8.645 and .646), in October.

The analysis of cloud dimensions of upper atmosphere chemical releases has been improved by the inclusion of the effects of exposure time and transverse wind on the photographic image, allowing more accurate studies of the releases to be made.

The study of the spatial and time variations of various sunlit resonance and emission lines of the neutral and ionized Ba clouds have led to further understanding of the mechanisms of ion formation and decay processes, as well as those of excited state neutral Ba.

Simultaneous studies of radio frequency reflectivity have been somewhat difficult to interpret. Except for early-time reflectivity (prior to pressure equilibration), returns have been limited to frequencies below 10 MHz, although optical estimates of maximum electron density ($10^7/cm^3$) should have given returns as high as 30 MHz. On the other hand, ray tracing studies have shown an extremely high aspect sensitivity to a field-aligned cloud of high asymetry, and it is possible that optimum rf transmitting-receiver locations have not been used. Studies are continuing to correlate optical and rf observations.

Further measurements of temperature in the 130 to 150 km altitude region were made by analysis of A10 fluorescent band spectrum from twilight TMA releases in January from Eglin. The results of these and earlier measurements were reported at the COSPAR meetings in July.

In order to provide improved altitude resolution to temperature measurements in the 90 to 140 km altitude region, a multiple grenade package was combined with a TMA trail into a single payload flown in two launches (AG7.630 and .631) in December 1967 from Eglin. In this technique, the same rockets which released the TMA also released, at 3-km intervals, a series of 18 grenades, which detonated within the visible trail. The expanding spherical shock waves were rendered luminous at their intersection with the trail. Optical instrumentation included high-speed framing cameras and streak cameras. The records from these are being processed, and it is anticipated that a temperature-height profile with 3-km height resolution will be obtained.

The problems of expansion and shock formation following the detonation of a grenade in a chemiluminous trail were considered. Limits on the accuracy of the method have been evaluated, and some suggestions for improvement of the technique have been incorporated into these measurements.

From the spherical expansion of TMA puffs, diffusion coefficients in the 130 to 170 km altitude regions were obtained by Golomb of AFCRL. In twilight, the TMA puffs display the fluorescent radiation of A10. From the vibrational-rotational spectrum of the fluorescence, the temperature of the radiating molecules and, hence, of the ambient atmosphere was determined. Relating the diffusion coefficients and temperature, the atmospheric density was deduced. Since the experiments were carried out at dawn and dusk, and in summer and winter, respectively, some conclusions could be reached about the diurnal and seasonal atmospheric structure variations. These variations appear to be quite small (within + 25%) from dawn to dusk, summer and winter, consistent with the latest U.S. Standard Atmosphere, 1966.

A new technique was also provided to determine atmospheric densities. It is based on the measurement of the radius of the contact surface of a gas released from a supersonic vehicle into the atmosphere. The radius is proportional to the drag coefficient, vehicle velocity, gas thrust, and the atmospheric density. The contact surface radius is rendered visible by virtue of the luminous reaction of nitric oxide with atomic oxygen. The radius is obtained from photographs of nitric oxide trails. This technique is feasible in the 90 to 140 km region, where atomic oxygen is abundant and requires clear skies at night. In preliminary experiments, good results have been obtained in the 110 to 130 km region. The experiment will be repeated in January 1968 at the Ft. Churchill missile range.

5.4.3 ELECTRICAL STRUCTURE EXPERIMENTS

Previously unreported* experiments were successfully flown by Sagalyn and Smiddy of AFCRL on five satellites in 1966. The properties of environmental charged particles as well as the flux, density, and energy distribution of protons and electrons with energies up to 2.5 keV, were investigated over the altitude range 260 km to 120,000 km.

The densities, temperatures, and energies of ambient positive ions and electrons were measured on six rockets (AF7.168, AF7.385, AF6.561, AF7.384, AF7.386, and AF7.550) launched between 13 and 18 April 1967. Positive ion composition was measured simultaneously. The primary objective of these launchings was to study local sunrise and sunset phenomena in the D and E Regions.

Between 24 and 28 October 1967, five rockets (AF7.637 through .641) were launched by Sagalyn of AFCRL from Vega Baja, Puerto Rico. Electron and ion densities and temperatures were the principle measurements. The experiments were conducted as part of an ionospheric investigation coordinated with the Arecibo Backscatter Radar.

An experiment was conducted by Sagalyn of AFCRL to determine the feasibility of measuring spacecraft pitch and yaw angles using the properties of environmental positive ions and the appropriate electrostatic probe configuration. Secondary objectives included measuring the ambient thermal ion distribution along the satellite trajectory, measuring the charged particle distribution in the satellite wake, mapping the charged particle distribution around the spacecraft during controlled maneuvers, and determining the relative motion of the upper air ion drift with respect to the neutral winds and rotation of the earth. The experiment was flown on two vehicles, Gemini X and XII, in August and November 1966.

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*Previously unreported in the AFCRL Annual Reports to COSPAR.

The results of the D-10 experiment flown on Gemini X and XII show that it is possible to measure pitch and yaw angles to within a fraction of a degree. The response time of the AFCRL Ion Attitude System was found to be much more rapid than the inertial guidance system (milliseconds, compared with seconds).

The experiment showed that the use of the ion attitude sensing system could considerably reduce the time required for special maneuvers such as docking, maneuvering, photography, and reentry. On Gemini XII for example, the astronauts were able to reduce the time required to align the inertial platform from 40 minutes to approximately 5 minutes using the ion pitch and yaw sensors as a reference. The yaw-sensing part of the system is particularly valuable because no other existing instrument can directly give spacecraft yaw.

The Gemini results disclosed that there is no significant systematic change in the ion drift motion with latitude over the range ±30° (Gemini spacecraft latitude). This demonstrates that for precision attitude determination, a mean ion drift motion does not have to be taken into account as a correction.

Measurement of the distribution of ionization measured as a function of position around the spacecraft shows that the charge density decreases by over two orders of magnitude in the -180° position (the wake region). These measurements constitute the first precise description of the distribution of charged particles as a function of position about the spacecraft at altitudes where free molecular flow exists.

The flux, energy distribution, and concentration of ions and electrons were investigated by means of two omnidirectional plasma probes flown on the OGO-III satellite by Sagalyn of AFCRL. The measurements cover the energy range from zero to 1 keV over the altitude region 1.1 to 20 earth radii (R_e).

It was found that between 1.1 and 6 R_e, a rapid decrease in charged particle density (energies less than 25 eV) is observed, the rate of decrease being markedly dependent on whether the satellite is on the sunlit side or in the shadow of the earth. The positive ion and electron densities are found to be equal within the experimental error.

Very rapid variations in the ion-electron densities were observed as the satellite went into and out of the shadow of the earth; the variations that occur within the shadow region are consistent with the altitude variations predicted theoretically for the nightside of the earth. It should be noted that the boundaries of the shadow region may be confused by experimenters with what is often called the "Whistler Knee" occurring between 2 and 8 R_e.

The average energy of the "low energy" particles increases rapidly with altitude from a value of approximately 0.2 eV at 1.1 R_e to 5 to 7 R_e where the energy is measured to be 6±2 eV. Above this level, the average particle energy does not vary in any systematic manner with altitude.

In the outer magnetosphere, the ion fluxes in the energy range 25 to 1000 eV vary between 10^6 and $10^8/(cm^2 sec)$. The electron fluxes vary between 10^7 and 5×10^9. A rapid change of flux with distance is usually observed within 1 earth radius of the altitude predicted by the Spreiter-Jones model for the shock boundary.

The most striking variations of charged particles (25 to 1000 eV) with time and altitude, in the outer magnetosphere, have been observed following solar flares and sudden commencements. The results indicate that at such times the shock boundary moves closer to the earth, and rapid decreases of an order of magnitude in the charged particle flux are observed at the boundary.

OV3-1 Satellite Electrical Structure. Two plasma probes were flown by Sagalyn of AFCRL on the OV3-1 satellite launched in April 1966. One of the sensors was designed to measure the flux, energy, density, and temperature of positively charged particles of energies between zero and 2 keV; the second sensor measured similar properties of negatively charged particles. These two experiments constitute a portion of a radiation payload. The principal objective was to study particle injection and loss in the Van Allen radiation belts, study global heat flow mechanisms, and gain new insights into acceleration and deceleration mechanisms of charged particles in the ionosphere and exosphere. The perigee altitude is 360 km, apogee approximately 6000 km, with an inclination of 82°. Analysis of the flight results continues.

The April 1967 rocket launch times for the AFCRL sunrise - sunset rocket studies in the lower ionosphere were selected by Sagalyn so that solar angles would be appropriate to examine the effects of Lyman α in the lower E region and the effects of Lyman β in the upper E region. The objectives also included determination of the dynamics of the formation of the D and E regions around sunrise as well as the decay of ionization at sunset. The charged particle measurements of densities and temperatures together with the simultaneously measured ion composition and wind shears have provided significant new information on the physics of the lower ionosphere (Rockets AF7.168, AF7.385, AF6.561, AF7.384, AF7.386, and AF7.560).

5.4.4 SOLAR SPECTROPHOTOMETRY

A solar EUV spectrophotometer by Hinteregger of AFCRL for wavelengths varying from 250 to 1300 Å (AFCRL experiment on the NASA satellite, OSO-III) operated successfully for about six months after its launch on 8 March 1967. One mode of operation was to scan the wavelength range of 250 to 1300 Å. Another mode of operation was to command the instrument to variously chosen fixed wavelengths. The latter provided data on the absorption characteristics of the upper atmosphere and on the intensity variations of specific solar emission lines allowing the observation of many "EUV-flares" with excellent resolution of their temporal structure. Progressive deterioration of instrumental counting efficiency affected the quality of photometric data from the scanning mode much more seriously than the observations of short-term variations and atmospheric absorption acquired at various fixed wavelengths. Therefore the latter mode of operation was chosen for a progressively larger fraction of the remaining life of the experiment.

A compact type of solar EUV spectrophotometer for wavelengths from 170 to 1700 Å, consisting of six monochromators with a common scanning mechanism, was carried on a solar oriented section of the OGO-IV satellite. After two weeks of successful operation, a malfunction terminated this experiment on 12 August 1967.

In a continuing program of AFCRL rocket observations of EUV fluxes, six monochromators were flown on Aerobee rockets during 1967 (NASA 4.102 to .104, AG3.526, .528, and AH3.530), designed for measurements at wavelengths ranging from 250 to 1260 Å, providing information on long-term variations and reference data for the calibration of the OSO-III satellite instrument. Another Aerobee rocket experiment on 8 August 1967 (AH3.529) successfully repeated previous measurements of the same wavelength region (30 to 130 Å) on 3 November 1965, accomplishing the separation of previously unresolved spectral lines and better data on absolute intensities due to improved laboratory calibration.

5.4.5 ATMOSPHERIC DENSITY

During 1967 the editing and printing of the "U.S. Standard Atmosphere Supplements, 1966" was completed by AFCRL and the book was published by the U. S. Government Printing office. The models in this book are the most comprehensive and realistic that have yet been published but they still have limitations. Thus work is continuing to develop improved atmospheric models for inclusion in future COSPAR International Reference Atmospheres or U. S. publications.

Nine rocket vehicles carrying falling sphere density experiments were launched by Faire of AFCRL during 1967. Five rounds were flown from White Sands Missile Range, New Mexico (WSMR); four on 23 January (ERDA 67-1 through -4) and one on 26 January (ERDA 67-5). Three of the five rounds gave complete density data while two provided usable data during sphere ascent or descent. Four successful flights were made from Eglin AFB, Florida (APGC); two on 13 and 18 April (Nike-Tomahawk and Niro), respectively, one on 17 August (Nike-Javelin) and one on 13 December (APGC-943). Two of these rockets (APGC-943 and Niro) also carried chemical release payloads (TMA) for making simultaneous observations on high altitude winds.

Density, temperature, and pressure results obtained on four flights made at WSMR during the summer of 1964 and 1966 were presented at the COSPAR 8th

International Space Science Symposium held in London during July 1967. The density results show the summer mean density to be in reasonable agreement with the summer Supplemental Model considering the small data sample. Also, the data tend to support the conclusion that the major density variation, in the 35 to 125 km altitude region, is seasonal and that diurnal variations do exist but are smaller than the seasonal variations, at least above 80 km. The temperature profiles obtained are in satisfactory agreement with the 30°N summer model.

The bremsstrahlung emitted by high speed electrons as they are slowed down by collisions with atoms and molecules can be detected and used to measure atmospheric density. The results from the first AFCRL rocket flight utilizing the bremsstrahlung technique were given in last year's COSPAR Annual Report. A second AFCRL bremsstrahlung payload was constructed and flown on 26 August 1967 at Eglin (AF7.378). Due to unknown causes the electron beam failed to exit from the rocket and atmospheric density was not measured; however, background data were obtained.

Two rocket payloads are in the process of being modified to ensure that this type of failure will not be repeated in the two planned flights of the bremsstrahlung experiment for 1968.

According to the classical theory of Rayleigh the amount of light scattered by the atmosphere is proportional to its molecular number density and inversely proportional to the fourth power of the wavelength. This suggests that the particle density of the upper atmosphere can be determined by employing a compatible airborne optical transmitter and receiver. A rocket experiment has been designed which incorporates suitable optical instrumentation to determine particle density up to 140 km using the principle of Rayleigh scattering. A mercury light source emitting strong radiation at short wavelengths is used to illuminate the surrounding atmosphere. Some of the scattered light is detected by an optical system which focusses the light on the cathode of a photomultiplier tube. A test flight was made at Eglin AFB, Florida on 5 September 1967 (AG7.176). Due to a malfunction in the light source good data were obtained only during the last 120 seconds of flight.

Along with the direct density measurements performed from the Snapshot satellite, listed and described in the last annual report to COSPAR by Champion's group at AFCRL, is the successful launch of OV3-6 (ATCOS II) on 4 December 1967. OV3-5 (ATCOS I) failed to achieve orbit due to a fourth stage rocket failure on 31 January 1967.

ATCOS II obtained an approximate circular orbit of 450 km. It's polar inclination will permit observations of density variations over a global range of latitudes. Measurements of density are being performed by means of cold-cathode type ionization gages. An abstract has been submitted for the American Geophysical Union Meetings in April of 1968. Preliminary results will then be presented.

5.4.6 AURORA AND AIRGLOW

Two Aerobee flights were carried out by Silverman of AFCRL in collaboration with Northeastern University as part of a continuing program for the measurement of day airglow and daylit aurora and continued work that has been reported on in previous reports to COSPAR. In both flights Ebert-Fastie scanning spectrophotometers were used, set to scan in the visible region of the spectrum. In one flight photometers designed to measure the 5577A (OI) emissions as a function of height were also included.

One flight (AE 3.582) was launched at 1842 (UT) at Churchill Research Range on July 5, 1967 and reached an approximate apogee of 137 statute miles. Previous flights during a moderate magnetic storm and in the presence of a sporadic-E layer had shown the presence of daylit aurora during the early morning hours. It was felt desirable to test for the existence of aurora at local noon when the discrete auroral zone should be to the north and while the diffuse auroral zone remained at the same geomagnetic latitude. It was further felt desirable to obtain a background result in the absence of magnetic activity. The flight on July 5 was during a period of prolonged magnetic quiet. Preliminary results indicate a basically airglow situation. More complete results will be reported at a later date.

A second flight (AD 3.365) was launched at 1934 UT 19 November 1967 from Natal, Brazil. The purpose of the flight was the measurement of the equatorial day airglow. On this flight the photomultiplier tube of the scanning spectrometer unfortunately failed shortly before tip ejection. Some data were obtained, however, with a 5577 Å (OI) photometer. Analysis of this data is not yet available.

Additional analysis of the N_2^+ bands in order to determine temperatures was carried out for the July 1964 flight from Churchill Research Range. The analysis, now completed and in course of publication, showed a temperature profile with height consistent with other measurements though differing in detail.

The results of previous rocket flights were used for a discussion of the optical environment of spacecraft. Our experimental data were used to estimate the contributions and relative importance of ambient atmospheric light, spacecraft corona, spacecraft scattering, and glare.

A program of measurements of the sky color and intensity during the 12 November 1966 eclipse was carried out from ground sites in Peru, Bolivia, and Brazil and from an aircraft over the Atlantic. This program was carried out with the collaboration and/or cooperation of the Instituto Geofisico del Peru, Lima, Peru; Laboratorio de Fisica Cosmica, La Paz, Bolivia; and Cosmissao Nacional de Ativadades Espaciais, Sao Jose dos Campos, Brazil. Some of the results are in process of publication and others are to be presented shortly at the Eclipse Symposium in Brazil.

Other work included a report on airborne measurements of the latitude dependence of the (OI) night airglow and a report on auroral temperature measurements carried out at Churchill in 1960 using interferometric techniques.

5.4.7 SPECIAL AURORAL AND IONOSPHERIC STUDIES

Plasma frequency probes were flown on satellites OV3-5, which failed to orbit, and OV3-6 by Ulwick of AFCRL. This probe was designed to measure F-region electron density irregularities and electron temperatures with special emphasis on auroral zone measurements. As the frequency is swept from 15 MHz to .1 MHz, two antenna resonance conditions are detected. A parallel resonance (the impedance goes to infinity) always occurs at the plasma frequency while a series resonance condition (impedance going to zero) occurs below the plasma frequency. The series frequency is determined for a given antenna by the plasma frequency and the electron temperature. These resonance frequencies are digitized and stored on the on-board tape recorder. These data are being evaluated to determine electron densities and temperatures.

A Black Brant rocket (AF17.750D) was flown on 6 December 1967 from Churchill into an auroral absorption event (1.5 dB) by AFCRL. This rocket, the third in a series, also served to develop and check out techniques and instrumentation for the more comprehensive program (six rockets) planned for the next year for the investigation of the D region during a polar cap absorption event. The rocket flown into a 1.5 dB auroral absorption event in September 1966 showed an electron profile with a flat maximum of the E-layer peak averaging 3.5×10^5 cm^{-3} between 90 and 110 km. The electron temperatures increased in this same height range from 400 to 1000°K. Ion temperatures were quite scattered with a mean value of about 300°K in this height range. An electron scintillator, which gives the energy flux for electrons of energy greater than 7 keV, showed that the flux remained relatively constant throughout most of the flight at a value of 1 erg/ (cm^2 sec ster). The energy flux of the bremsstrahlung X-rays for different energy intervals were obtained from a proportional counter. A reasonable correlation of the fluctuations in the X-ray energy with the scintillator were observed. The spectral shape of the X-ray counts remained nearly constant during the flight and could be approximated by an exponential energy distribution with an e-folding value of 2 keV between 1 and 10 keV.

Analysis of data from the auroral input-output rocket program is continuing with emphasis on the two rockets fired within 30 seconds of each other into the same aurora on 12 December 1966. Energy spectra and pitch angle distributions of electrons were made by electrostatic analyzers. The incident electron energy flux was found to be constant within a factor of two and the spectral shape could be approximated by an exponential with an e-folding value of 5 keV. The pitch angle distribution measured from 20° to 90° was isotropic within a factor of two. For pitch angles greater than 90° the distribution is energy dependent with the ratio of reflected to incident flux decreasing with increasing energy. Measurements of electron temperatures and hyperthermal electron flux in active auroras show considerably more structure than those from diffuse auroras. The shape of the integral flux spectrum was found to be fairly well preserved in the individual auroral events irrespective of short time variations of the flux and that different auroral events produce different spectral shapes. A good correlation has been found to exist between the flux of hyperthermal electrons and the electron temperature. The maximum of electron density of the E_{sa} layer in dim diffuse auroral regions was about 2×10^5 electrons/cm^3, while in the higher auroral forms (IBC II) the densities were about a factor of 4 higher. The ratio of 5577 (OI) to 3914 A (N_2^+) intensity was found to be independent of altitude up to 190 km with a ratio of 2.

5.4.8 IONOSPHERIC RESEARCH

In order to observe propagation and ionospheric effects on satellite beacon transmissions, a chain of stations has been set up near the 70th and 80th meridian. The effects include propagation parameters such as absorption, ionospheric and tropospheric scintillation, and a study of ionospheric total electron content. Two S-66 beacons as well as the synchronous satellites Canary Bird and ATS-3 are utilized. The AFCRL observation sites under Aarons and Mullen include Thule, Greenland; Sagamore Hill, Massachusetts; and Panama, Canal Zone. Collaborating observatories include the University of the West Indies, Jamaica; the Danish Meteorological Institute station, Narssarssuaq, Greenland; and the Instituto Geofisico del Peru, Huancayo, Peru. The technique is to compare records of the same pass of low orbit satellites or for the same time in the case of synchronous satellites.

Observations of the S-66 satellite have been made at the Sagamore Hill Radio Observatory, Hamilton, Massachusetts and at Narssarssuaq, Greenland during March 1966. These data, recordings of the 40-MHz satellite beacon, have been used to establish the diurnal variation of the ionospheric irregularity structure as shown by scintillation. In scintillation measurements of the 40-MHz transmissions from S-66 taken at Narssarssuaq, Greenland by the Danish Meteorological Institute and at Sagamore Hill, the diurnal pattern for low magnetic indices was obtained. During the daylight hours the scintillation curtain is north of Narssarssuaq with the boundary between 75° to 80° geomagnetic north. After sunset, the boundary moves south of Narssarssuaq. There is evidence that the irregularity layer is both thicker and lower in the auroral zone during the night hours. Comparing similar time periods, it was found that during magnetic storms the boundary of the curtain moves away from the auroral zone in a manner similar to that of the optical and radio aurora. These measurements indicate that the latitudinal variations of the irregularity structure are closely correlated with low energy (few keV) electrons in both their time patterns and their magnetic storm variations.

Differential Faraday rotation measurements taken at three northern hemisphere stations in the spring of 1966 using 40 and 41 MHz signals from Explorer 22 contributed to the study of latitude dependence of total electron content from 5 to 65 degrees north latitude. During the time interval data were available for study, 0700 to 1000 and 1700 to 2000 local mean time, the total electron content generally decreased with increasing latitude, with steeper gradients occurring during the hours nearer midday. Slab thickness values, however, generally increased with latitude, indicating that the height gradient of electron density was considerably less in northern latitudes than at low latitudes.

Total electron content results taken by differential Faraday, using 40 and 41 MHz, and by differential Doppler, 40 and 360 MHz, have been compared for consistency. All these frequencies are available simultaneously from the 1000-km height, near circular orbit satellite, Explorer 22. It was found that, while the detailed shape of small changes in total electron content agree very well, the absolute value of the two curves differ, with the results from the differential Doppler technique being generally higher by amounts up to 25 percent. Neither second order corrections in the Faraday technique nor errors in choosing the mean ionospheric height seem to explain this difference. The importance of this problem is underlined by plans to measure the difference between Faraday-derived and group delay measurements of total electron content from signals transmitted from future geostationary satellites, where the exospheric contribution is expected to be the same order as the current difference between methods observed with the low orbit satellite.

Continuous observations of total electron content are continuing at Sagamore Hill, using signals from Canary Bird and from ATS-3, to study seasonal, diurnal, and anomalous changes.

Two-station spaced aerial data taken from the satellite Explorer 22 by AFCRL during the summer and fall of 1966 have been analyzed to yield height information on sixteen passes. Ten of these yielded heights in the E region while sporadic E (E_s) was measured at a nearby ionosonde. In four records, no scintillation (and, therefore, no height measurement) was observed nor was E_s. In the remaining two, scintillation was observed without E_s. In these two, the measured heights were considerably higher. A dual baseline of 6.4 and 10 km was used. It was found that correlation falls off at 10 km in the N-S direction. In general, daytime heights tended to group around 100 km in the presence of E_s. Nighttime heights tended toward 200 to 300 km in the presence of E_s.

An experiment by Guidice of AFCRL to measure the radiometric temperature of the earth's atmospheric oxygen mantle at a frequency of 60.80 GHz was flown aboard OV1-86 (1967-72A) on 27 July 1967. The purpose of the experiment was to measure the global distribution of the radiometric temperature as a function of latitude, solar illumination, and general underlying geography. If the experiment showed that the radiometric temperature at this frequency was substantially independent of these parameters, the feasibility of the concept of using the 60-GHz radiation from the earth's mantle for accurate local vertical determination would be established.

Because of malfunctions in the vertistat (the gravity-gradient stabilization system), OV1-86 failed to achieve proper orientation. Of the 26 orbits during which the 60-GHz radiometer was activated, only one orbit allowed the radiometer to spend a substantial time viewing the earth. For most of the other orbits the radiometer was pointed away from the earth toward "free space", whose radiometric temperature was found, as expected, to be about 0°K. From the one earth-viewing orbit, the radiometric temperature of the earth's mantle at 60.80 GHz was estimated to be of the order of 235°K (this accuracy is limited since the satellite orientation during the measurement was uncertain). No information concerning the global distribution of temperature was thus acquired.

5.4.9 IONOSPHERIC ELF STUDIES

In order to increase our knowledge of the effect of the ionosphere on ELF radio waves, a program to measure rf noise emitted by power lines at 50 to 60 Hz was initiated by P. Newman at AFCRL.

An OAR research pod carried by a reentry vehicle contained a receiver and loop with an rf range of 40 to 80 Hz. It was launched 7 April 1967, 1119.236 UT from the Western Test Range at Vandenberg AFB, California. It carried the designation SP[illegible]2. The apogee was about 1000 km over Hawaii, and descent was south of W[illegible]sland.

An excellent record was obtained on the Ferdinand 14 flight. A field strength profile was recorded up to apogee at 140 km. A similar profile was obtained on the downward leg, ending 230 seconds after launch, 130 km away. Considerable penetration of the ionosphere by the presumptive power line radiation is indicated. The pod data is less satisfactory. The pod was not separated from the vehicle and the telemetry was poor. There was considerable outage.

5.4.10 ATMOSPHERIC OPTICS

In an AFCRL balloon experiment (H67-31) a set of twelve interference filter photometers, covering a spectral range from 3900 to 9000 Å with about 250 Å bandwidth each, was mounted looking straight. These photometers measured with a field of view of approximately 1.5° the upwelling radiation flux from the atmosphere and reflected from the background terrain. The purpose of this experiment is to measure the terrain background radiance as a function of altitude and to determine its relation to atmospheric spectral contrast attenuation.

The second experiment on the balloon was conducted by the Meteorological Institute of the University of Munich, Germany under contract to AFCRL. This experiment consisted of an eight channel infrared radiometer (3 to 10 microns) with a 10° to 20° field of view which could scan the lower hemisphere from nadir to about 15° above the horizon. From these measurements data on the vertical flux of atmospheric radiation into space can be derived and compared with theoretical results obtained for various atmospheric models.

No useful results were obtained from this first balloon flight experiment. The University of Munich instrumentation malfunctioned at an altitude of about 15000 ft. The data obtained from the AFCRL instrumentation, despite satisfactory operation, are of little use because of an almost solid underlying cloud cover over most of the balloon trajectory.

A balloon flight was conducted by Toolin of AFCRL, to measure the spectral and spatial distribution of natural untraviolet sky radiation to an altitude of 30 km. Its intent was to determine the scattering and absorption of the sky radiation for the particularly sensitive wavelengths between 2000 and 4000 Å. Precise orientation of the measuring equipment involved the use of a balloon-borne biaxial sun pointer. The detection system was an Ebert (one meter) spectrometer, equipped with a solar-blind photomultiplier. This system, after sun acquisition, was programmed to scan from horizon to horizon through the vertical plane defined by the sun.

The balloon (H67-52), 2×10^6 cu ft in volume and fabricated of Stratofilm, was launched at 0037 on 11 July at Holloman. Only 30 minutes of useful information were obtained, principally because a preamplifier became overheated during the early portion of the trajectory and also because of early termination due to high winds in the normal impact area. These data are now being evaluated to gain an improved knowledge of sky light distributions at high altitudes.

In July 1967, a balloon nephelometer program was implemented by AFCRL to determine the polarization and angular light scattering properties of the atmosphere for altitudes up to 30 km. Specifically the objective of the program is to extend our knowledge of the interaction of the visible and near infrared radiation with the atmosphere. The application of such knowledge will permit better quantitative treatment of sky background and atmospheric transmission.

The instrument consists of a source telescope which projects a beam of light having an essentially uniform intensity distribution throughout the volume being measured. Five observation telescopes view the projected beam at scattering angles of approximately 25°, 45°, 90°, 130°, and 155°. The volume defined by the intersection of the source and observation beams contains the air and aerosol sample whose scattering properties are measured. This instrument is the first such device to be built for high altitude balloon investigations. Design, test, and fabrication were completed in September 1967 and the instrumentation launched 4 November 1967 using a two million cubic foot balloon (H67-77).

The five telescopes and xenon light source functioned satisfactorily to about 20 km. A preliminary examination indicates the data acquired to be of good quality. A full analysis of the data is now in process. At the termination of the flight, the impact release provisions failed to function. Accordingly the parachute dragged the instrumentation for about a kilometer so that considerable damage resulted. It is expected that the balloon nephelometer will be refurbished and launched again May 1968.

Rocket borne measurements of the Earth's limb radiance were carried out in late 1965 and 1966 by Walker of AFCRL. The results of these flights have become available in 1967 and have not been previously reported to COSPAR.

Probe AD 3.722 was launched on 25 September 1965 and attained an altitude of 190 km. A malfunction of the attitude-control system prevented the vehicle from attaining the local vertical, and for the entire data-gathering portion of the flight the rocket was tipped at an unfavorable angle. Although some radiance data were obtained, it has not been possible to determine the instrument line-of-sight.

All the AFCRL radiance data obtained during this flight were in the 15μ CO_2 region, except for a few horizon crossings early in the flight in the 10μ window region. The mean radiance observed for 16 horizon crossings at an effective wavelength of 14.76μ was 2.74×10^{-4} W cm^{-2} sr^{-1} μ^{-1}, with an rms deviation of 0.09×10^{-4} W cm^{-2} sr^{-1} μ^{-1}. This corresponds to an equivalent blackbody radiation temperature of 234 ± 2.7°K.

The second of the AFCRL series, AE 3.723, was launched on 29 April 1966. All instruments performed satisfactorily. The rocket reached a peak altitude of 159 km after 213 sec of flight. During this period approximately 90 horizon crossings were recorded in the 15μ region, 80 in the rotational water vapor region, and 50 in the 10μ window. The two stellar-aspect systems observed approximately 30 to 35 stars during each roll, thus providing good vehicle-attitude data. Analysis of the stellar data indicates that the vehicle attitude and motions are determined to within 5 min of arc during each roll maneuver. Infrared radiance data of high quality were obtained throughout the entire flight.

Probe AE 3.724 was launched on 6 December 1966 and attained a peak altitude of 189 km. All instruments operated satisfactorily and about 125 horizon crossings were obtained. The payload had undergone extensive modification to permit radiometric observations in the 9.6μ ozone band and to achieve a higher signal-to-noise radio in the 15μ CO_2 observations.

A number of balloons have been launched on a contractual effort supported by AFCRL with the University of Denver. The principal investigator is Murcray. These balloon flights have had three major objectives: the study of the transmission of solar radiation through the atmosphere at high altitudes and with spectral resolutions of 0.1 cm^{-1} or better; study of the thermal flux of the atmosphere as a function of altitude, spectral region, and direction; and a more precise determination of the solar constant.

The data obtained on these AFCRL-supported flights is still in reduction and analysis.

5.5 Meteorology

5.5.1 METEOROLOGICAL ROCKETS

AFCRL launched a total of 218 meteorological rockets during 1967 of which 140 were for system development purposes and 78 flights were for the development of sensing equipment.

The greatest emphasis at AFCRL was on the refinement of the Loki-class instrumented Dart system. AFCRL procured an initial operational quantity (240) of this type of probe (PWN-8A) for AWS and Navy use. A simultaneous qualification effort brought the higher performance PWN-8B Dart system to operational status. At the year's end, AFCRL initiated the procurement of over 800 PWN-8B's for tri-service operational use. The PWN-8B has a nominal apogee of 200,000 ft when launched from sea level at an elevation angle of 80°. It is relatively insensitive to high surface winds and its cost is less than that of the Arcasonde system (PWN-6A) which it replaces. It uses a Ballute retardation and deceleration device instead of a parachute. A separate transponder payload development effort was well along at the close of the year and first Dart flights were imminent.

Much attention was given to improvement of the mount used for rocket-sonde bead thermistors. A wire mount developed for the Arcasonde bead was flown extensively in March and December and appears to avoid the uncertainty problem inherent in the standard mylar mount. It is being reconfigured for use on the PWN-8B.

The 140-km Viper Dart system underwent two flight test series. Design goals were approached by the year's end, although more development is required for an operational system. The payload is a Robin passive falling sphere intended to measure density and winds from 100 km down to 30 km.

5.5.2 DESIGN CLIMATOLOGY

Continuing the AFCRL endeavors to better describe variability of atmospheric profiles through the mesosphere, "Mean Monthly Atmospheres for 15° North" by A. E. Cole, AFCRL-67-0120, February 1967, were developed. In a parallel endeavor to determine mesoscale variability of these profiles, 12 sets of meteorological rockets were fired along the coast of California. Each set consisted of three Arcas-Robin soundings, launched simultaneously at distances of 100 and 200 km apart. Wind, density, and temperature variability over these distances are now being studied for altitudes between 30 and 70 km.

The possibility that unusually strong wind shear in the stratosphere and mesosphere may cause rockets to become unstable during separation of stages has led to a special study of shears from the Robin sensor, a falling 1- meter sphere. Wind data from parachute borne meteorological rocket sounding systems were avoided since parachutes are suspected of gliding at high altitudes, thus lacking the precision required for determining shear through thin layers. A total of 2315 shears from 64 Robin soundings, especially edited for this study, did not reveal any shears exceeding 0.1 sec^{-1} for 3000-ft layers thickness. The strongest shears occur in the spring and fall during reversal of zonal flow. Another sample of 194 soundings is currently being processed.

A further investigation of the 30 to 60 km altitude region by Sissenwine of AFCRL involved three pairs of specially designed turbulence sensing payloads, released from NIRO rockets (AG7.568 and .661; AG7.662 and .657; AF7.663 and .659). These were flown at Eglin in November and December 1967. Each rocket in the pair emitted smoke trails from 30 to 60 km on both the up and down legs of flight, so that four trails were visible simultaneously for up to 15 minutes. Separation distances between trails range from 40 to 140 km. Several camera sites were utilized in order to record movements of and within these trails photographically. Studies of turbulence and undulence will be provided from analysis of these photographs. One further test is scheduled for early 1968.

The investigations of stratosphere humidity, described in last years report, were completed. Only one additional sounding was obtained. It too indicated a tendency toward an increase of humidity above the tropopause up to about 25 km above which there is a decrease. When the 25 to 30 km gradient is extrapolated upward, it provides water vapor at 80 km in agreement with that speculated to be present when noctilucent clouds are observed.

5.5.3 SATELLITE METEOROLOGY

AFCRL conducts research designed to exploit the utilization of m[illegible]ological satellite data in operations and forecasting. To this end, not only are b[illegible]ic and applied studies conducted utilizing satellite data, but also research is per[illegible]ormed on problems of the characteristics of the atmosphere and its circulation which are fundamental to the effective utilization of satellite data.

Conventional, synoptic-scale techniques are limited to analysis and forecasting of the movement and development of circulation features and a general assessment of the weather. The specifics of the weather are mesoscale processes and can only be estimated with conventional methods. Satellite data provide resolution of features well into the mesoscale range. In order to take advantage of this characteristic of satellite data, it is necessary to understand the behavior of the atmosphere on this smaller scale. Kreitzberg conducted AFCRL Project Stormy Spring in which an augmented network of surface and upper air stations were used in conjunction with satellite and special aircraft observations to investigate the mesoscale structure of cyclones passing over southern New England. From these studies an occlusion model was developed which details the frontal passes as a series of "pre-frontal surges" of cold air aloft alternating with moist air which is lifted from lower levels well ahead of the surface occlusion on the synoptic map. The analyses also disclosed regions of extremely large wind shear at both low and high levels which have sufficient time and space continuity to establish their validity but which would certainly be missed by a conventional upper air network.

Studies of the transport of water vapor have been made by Danielsen of Pennsylvania State University under contract to AFCRL. Utilizing moist-adiabatic trajectories where applicable, he has computed a model of the trajectories followed by air parcels in the vicinity of a developing cyclone.

Satellite data cannot be used quantitatively until more is known of the physical properties of the atmosphere and clouds. In order to reduce photographic cloud data to a quantitative base, the sensing and processing systems both in the satellite and on the ground must be accurately calibrated initially and there must be a capability for in-orbit monitoring of any calibration changes. In addition, the pictures must be "normalized" for solar angle so that an accurate albedo value may be completed. Marggraf at General Dynamics/Convair has just completed the observational and data reduction phase of a study designed to determine the effects of sun angle on cloud-reflectivity. This work includes observation of the physical properties of the clouds such as thickness, drop size, water content, temperature, and optical density. On the same contract, studies have also been made of the effects of the atmosphere, from the surface to 6 km, on the infrared radiation emitted by a variety of ground surfaces such as snow, sand, grass, and so forth in the 8 to 13 micron region. Results of these studies will be available early in 1968.

Infrared experiments were conducted by Valovcin of AFCRL on the infrared characteristics of cirrus clouds in the 8 to 13 micron region as measured by an airborne radiometer. The results show that cirrus clouds can be considered black-body radiators only 1 per cent of the time. Even thick, optically dense cirrus emit at black-body temperatures which occur 3 to 5 km below their visible tops. This implies, of course, that the utilization of satellite infrared measurements to determine cloud-top heights or temperatures where cirrus clouds are present is subject to serious error.

The major in-house satellite meteorology effort at AFCRL is the application of video and infrared satellite data to problems of forecasting in tropical regions.

5.6 Geodosy and Terrestrial Photography

5.6.1 SATELLITE GEODOSY

The technique of position determination of two or more nonintervisible stations by three dimensional triangulation/trilateration, using satellites to carry the necessary beacon equipment, has become a geodetic reality. Various methods of distance and angle measurements are now available for satellite geodesy which show promise of geodetic precision for position determination between stations more than 1000 km apart. USAF interests in satellite geodesy have tended toward techniques of triangulation employing optically visible satellite beacons or reflections as mutually intervisible signals which can be photographed against star backgrounds to determine distance and direction between widely spaced camera sites.

The Air Force has a project for the optical observation of satellites. As a participant in the National Geodetic Satellite Program, the Military Airlift Command's 1381st Geodetic Survey Squadron operates the stellar cameras and the Aeronautical Chart and Information Center reduces the camera plate data and computes geodetic positions and azimuths.

Satellite conditions do not allow for observations of the light beacons aboard ANNA-1B and GEOS-1A, so the USAF camera teams observe passive satellites which can be made optically visible by reflected sunlight or by laser light reflected from prismatic reflectors carried on several orbiting satellites.

The technique of making timed interruptions of traces of sun-illuminated satellites as they cross the field of view of the stellar cameras, as described last year, has been extensively tested between Bermuda and several points in the eastern half of the United States. Forty-five intervisible ties were obtained in Bermuda and these contained enough data to permit adjustment of the Hunter AFB, Georgia; Aberdeen, Maryland; and Hamilton, Bermuda triangle.

During 1967, AFCRL's laser geodesy experiments were concentrated on attempts to make ground-to-satellite range measurements with a controlled pulse ruby laser which has the capability of emitting several pulses during each stimulation period. The timing and spacing of these pulses has been controlled with enough precision to make ranging measurements possible.

On 19 December 1967, a successful measurement was made by transmitting a multiple-pulse from Bedford, Massachusetts to satellite S-66 (Beacon Explorer B) during a daylight pass. Subsequent recomputation of the satellite orbit shows the laser measured range to be in agreement with best tracking radar values to 125 meters.

5.6.2 TERRESTRIAL PHOTOGRAPHY

Dry lakebeds, situated in all of the world's deserts, are useful as emergency aircraft landing sites and as indicators of the hydrologic environment. A factor that has limited their use is the inability to continuously monitor surface changes that occur as a result of rain. A partial solution in monitoring them is through the use of satellite photography. Reflectance changes that indicate soil moisture variation (which in turn affect trafficability) have been observed on Gemini color photographs and Nimbus AVCS (Advanced Vidicon Camera System) imagery by Neal of AFCRL.

An AVCS image taken over northwestern Nevada, shows a variety of lakebed surface conditions ranging from hard, dry clay crusts to soft, dry, friable surfaces. The latter frequently contain moist surfaces with accumulations of salt. Without prior knowledge of surface conditions, it would be difficult to predict the type of surface present on these lakebeds. For example, the gray-level of the hard, dry clay crust at Smith Creek Valley is the same as that of the central salt-core of the Humboldt Salt Marsh. However, it is known that these two lakebeds change little from year to year, so that any pronounced change in the reflectance level would probably indicate a change in moisture, or surface flooding.

Enlarged segments of two Gemini 70-mm color transparencies acquired by AFCRL show Willcox Lake (playa), Arizona, and a reduced-scale conventional photomosaic. The dark sinuous feature observed on Gemini IV had disappeared 3 months later and was not visible on the Gemini V photograph even though contrast was generally greater. The change can be explained by the presence and subsequent evaporation of soil moisture in which a 20 percent reflectance difference occurs.

These studies have shown that both the Nimbus AVCS and Gemini color photos have value in lakebed studies, especially when they can be used together. Future systems with improved resolution are certain to provide more detailed information of our knowledge of planetary environments.

5.7 Other

5.7.1 EARTH BACKGROUND MEASUREMENTS IN THE SPECTRAL REGION FROM 1 TO 4.3 MICRONS

During calendar year 67 successful earth background measurements were made from Satellites OV1-5 (1 to 3 microns), an Agena vehicle (2.6 to 3 microns), and OV1-86 (1 to 4 microns) by Lovett of AFCRL. Satellite OV1-5, with its optical measurement systems, has been operating successfully since April 1965. The instrumentation onboard the Agena vehicle worked successfully for the planned mission period of two weeks. Successful measurements were made over Kodiak, Hawaii, Cook, Guam, and Pretoria stations. Preliminary reduction and analysis of data has been performed on the Kodiak, Cook, and Guam acquisitions. On the acquisition over Cook on orbit 95, instrumentation on OV1-86 (orbit 257) and OV1-5 (orbit 6842) were activated in order to obtain complementary spectral data that would enhance the experiment on the Agena venicle. The OV1-86 pass was within ten minutes and the OV1-5 within 180 minutes of the Agena readout on orbit 95 over Cook. ESSA-digitized mosaics are being provided wherever possible for all interesting acquisitions during the duration of the RM12/15 mission.

The optical instrumentation on OV1-86 has operated very successfully, but due to problems with the stabilization system it was not possible to look at the nadir. Some of the data have been analyzed and looks very promising.

The OV1-5 has been operating successfully since 1 April 1965. AFCRL plans to operate the vehicle instrumentation in conjunction with the OV1-86, as their spectral regions overlap.

The basic instrumentation for all three AFCRL satellite experiments was comprised of interferometers and one- or two-channel radiometers equipped with narrow band filters at 2.2 and 2.7 microns. The resolution of the interferometers is 40 cm^{-1}; the field of view is two degrees for OV1-5 and OV1-86 and .25 degrees for the Agena vehicle. PbS is the principal detector system for the OV1-5, thermal electric cooled PbS for the Agena and thermal electric cooled PbSe for OV1-86.

The principal spectral regions of interest to AFCRL are in the atmospheric windows at 1, 1.5, and 2.2μ and in the absorption bands at 1.87, 2.7, and 4.3μ. The data obtained on OV1-5, OV1-86 and the Agena are in excellent agreement with previous data obtained by AFCRL onboard Gemini 5 and Gemini 7.

5.7.2 REENTRY COMMUNICATIONS STUDIES

A microwave (S-band) transmission experiment was conducted by Poirier and Rotman of AFCRL on a Trailblazer II (AD21.860) launched from Wallops Island on 28 June 1967. This experiment constituted the first successful flight test of electroacoustic probes. The effects on the S-band microwave transmissions with respect to antenna pattern distortion and mismatch, antenna coupling, and pulse distortion were all within the predictable limits for plasma parameters at the stagnation point of the vehicle.

Future AFCRL Trailblazer II flights will be concerned with additional microwave transmission studies, with tests of new plasma diagnostic instruments such as inductance and conductivities probes, and with plasma alleviation techniques, such as rf heating and chemical injectants. These studies are expected to provide additional data on the properties of high-temperature shock-ionized flow fields, as well as of their effects on communication links. The second Trailblazer II rocket is scheduled for launch in May 1968.

5.7.3 ANTENNA VOLTAGE BREAKDOWN STUDIES

An antenna voltage breakdown experiment was conducted by Ellis of AFCRL on a Nike-Cajun (AD6.842) launched from Wallops Island on 2 October 1967. The test showed that the antenna breakdown was regular when the test antennas were exposed to sunlight and statistical in nature when shaded. The probable cause of this effect is solar ultraviolet stimulation of photoelectrons from the rocket's metallic skin, photoionization of the surrounding gases, or a combination of both. It is now apparent that the voltage breakdown of an antenna at moderate power levels can be predicted from either laboratory or wind tunnel measurements.

Appendix A

Rocket, Satellite, and Balloon Launchings in 1967

Table A1. AFCRL Sounding Rocket Launchings and Experiments Carried, 1967

Date (UT)	Time (UT)	Rocket Number or Type	Launching Site	Approx. Altitude (km)	Experiments Carried
1967					
11 Jan	2331	AF7.500	Eglin	--	Barium Diffusion Rates (Chemical Release)
16 Jan	1148	AF7.654	Eglin	217	Ionospheric Wind Variations (Chemical Release - Heated TMA)
16 Jan	2334	AF7.503	Eglin	193	Barium Diffusion Rates (Chemical Release)
17 Jan	0000	AF7.653	Eglin	168	Ionospheric Wind Variations (Chemical Release - Heated TMA)
17 Jan	1900	AG3.526	White Sands	243	Solar Spectrophotometry (EUV Monochromator) Retarding Potential Analyzer
19 Jan	2322	AF7.655	Eglin	112	Atmospheric Turbulence (Chemical Release)
19 Jan	2322	AF7.656	Eglin	--	Atmospheric Turbulence (Chemical Release)
23 Jan	0701	ERDA 67-1	White Sands	89*	Atmospheric Density (7-in. Falling Sphere)
23 Jan	1000	ERDA 67-2	White Sands	209	Atmospheric Density (7-in. Falling Sphere)
23 Jan	1300	ERDA 67-3	White Sands	85*	Atmospheric Density (7-in. Falling Sphere)
23 Jan	1925	ERDA 67-4	White Sands	226	Atmospheric Density (7-in. Falling Sphere)
26 Jan	1845	ERDA 67-5	White Sands	229	Atmospheric Density (7-in. Falling Sphere)
4 Mar	2105	AF7.582	Eglin	196	Atmospheric Density (Expandable Sphere)
6 Mar	0305	AF7.583	Eglin	175	Atmospheric Density (Expandable Sphere)
14 Mar	1714	NASA 4.102DS	Wallops Island	205	Solar Spectrophotometry (EUV Monochromator) Retarding Potential Analyzer
22 Mar	1656	NASA 4.103DS	Wallops Island	229	Solar Spectrophotometry (EUV Monochromator) Retarding Potential Analyzer
13 Apr	0001	AA7.168	Eglin	144	Ion Trap Measurements Ionospheric Formation and Decay (Mass Quadrupole Spectrometer)
13 Apr	0049	AF7.385	Eglin	152	Ion Trap Measurements Ionospheric Formation and Decay (Mass Quadrupole Spectrometer)
13 Apr	0056	AG7.622	Eglin	165	Chemical Release (TMA Trail and Puff Releases)
13 Apr	0057	AG7.623	Eglin	169	Chemical Release (TMA Trail and Puff Releases)
13 Apr	0724	AG8.647	Eglin	176	Atmospheric Density (7-in. Falling Sphere) Chemical Release (TMA)
13 Apr	0722	AF6.561	Eglin	117	Ion Trap Measurements
18 Apr	1025	AF7.384	Eglin	135	Ionospheric Formation and Decay (Mass Quadrupole Spectrometer) Ion Trap Measurements
18 Apr	1025	AF7.624	Eglin	--	Chemical Release (TMA)
18 Apr	1025	AF7.625	Eglin	--	Chemical Release (TMA)
18 Apr	1121	AF7.386	Eglin	138	Ion Trap Measurements Atmospheric Composition (Mass Quadrupole Spectrometer)
18 Apr	1140	AF7.560	Eglin	169	Ion Trap Measurements Atmospheric Density (7-in. Falling Sphere)

*Denotes that the vehicle did not attain predicted altitude.

Table A1. AFCRL Sounding Rocket Launchings and Experiments Carried, 1967 (contd)

Date (UT)	Time (UT)	Rocket Number or Type	Launching Site	Approx. Altitude (km)	Experiments Carried
1967					
20 Apr	0040	AF8.650	Eglin	260	Chemical Release (Barium)
28 Apr	0112	AF8.651	Eglin	254	Chemical Release (Barium)
7 Jun	1320	AG7.372	Eglin	154	Micrometeoroid Particle Collection
28 Jun	1032	AD21.860	Wallops Island	274	Reentry Plasma Sheath Studies at 16,500 fps Antenna Breakdown at S-Band Frequencies
5 Jul	1842	AE3.582	Fort Churchill	219	Day Airglow (Scanning Spectrophotometer)
8 Aug	2045	AH3.529	White Sands	235	Solar Spectrophotometry (EUV Monochromator)
15 Aug	1745	AG3.528	White Sands	243	Solar Spectrophotometry (EUV Monochromator)
17 Aug	0839	APGC-903	Eglin	168	Atmospheric Density (7-in. Falling Sphere Method)
26 Aug	0635	AF7.378	Eglin	177	Atmospheric Density (Bremsstrahlung Method)
5 Sep	0600	AG7.176	Eglin	101	Atmospheric Density (Light-Scatter Method)
30 Sep	1614	NASA 4.104DS	Wallops Island	216	Solar Spectrophotometry (EUV Monochromator)
2 Oct	2000	AD6.842	Wallops Island	107	Antenna Breakdown
4 Oct	0020	AH8.645	Wallops Island	251	3 Barium Releases/3 Frequency RF Beacon
5 Oct	0018	AH8.646	Wallops Island	250	3 Barium Releases/3 Frequency RF Beacon
24 Oct	1714	AG7.637	Vega Baja, P.R.	174	Ionospheric Characteristics (Charged Particle Densities and Temperatures)
24 Oct	2300	AG7.638	Vega Baja, P.R.	173	Ionospheric Characteristics (Charged Particle Densities and Temperatures)
26 Oct	1709	AG7.639	Vega Baja, P.R.	--	Ionospheric Characteristics (Charged Particle Densities and Temperatures)
27 Oct	1714	A67.640	Vega Baja, P.R.	173	Ionospheric Characteristics (Charged Particle Densities and Temperatures)
28 Oct	0915	AG7.641	Vega Baja, P.R.	172	Ionospheric Characteristics (Charged Particle Densities and Temperatures)
7 Nov	1745	AH3.530	White Sands	246	Solar Spectrophotometry (EUV Monochromator) Thermal Electrons (Retarding Potential Analyzer)
15 Nov	1934	AD3.365	Natal	223	Equatorial Day Airglow (Scanning Spectrophotometer)
19 Nov	1008	AG7.314	Natal	119	Research Payload Water Recovery Test
22 Nov	1007	AG7.316	Natal	119	Research Payload Water Recovery Test
29 Nov	2251	AG7.568	Eglin	129	Atmospheric Turbulence (Chemical Trail)
29 Nov	2251	AG7.661	Eglin	129	Atmospheric Turbulence (Chemical Trail)
3 Dec	2253	AG7.662	Eglin	123	Atmospheric Turbulence (Chemical Trail)
3 Dec	2253	AG7.657	Eglin	128	Atmospheric Turbulence (Chemical Trail)
4 Dec	2220	AF7.880	Fort Churchill	146	Positive Ion Species (Mass Quadrupole Spectrometer)
4 Dec	2244	AF7.387	Fort Churchill	120	Positive Ion Species (Mass Quadrupole Spectrometer)

Table A1. AFCRL Sounding Rocket Launchings and Experiments Carried, 1967 (contd)

Date (UT)	Time (UT)	Rocket Number or Type	Launching Site	Approx. Altitude (km)	Experiments Carried
1967					
6 Dec	1825	AF7.388	Fort Churchill	133	Positive Ion Species during Daytime Absorption Event (Mass Quadrupole Spectrometer)
6 Dec	1620	AF17.750D	Fort Churchill	135	Polar Cap Absorption Input-Output Experiments
13 Dec	1259	AF3.268	White Sands	177	Micrometeoroid Particle Collection Capacitor Microphone Particle Detector Test
13 Dec	0840	APGC-943	Eglin	180	Atmospheric Density (7-in. Falling Sphere) TMA Release
13 Dec	0843	AG7.627	Eglin	165	Vaporized TMA Experiment
13 Dec	0922	AG7.630	Eglin	164	TMA Trail/Multiple Point Explosions
14 Dec	0937	AG7.631	Eglin	162	Chemical Release (TMA Trail/Multiple Point Explosions)
14 Dec	0958	AG8.665	Eglin	110	Chemical Release (Diborane and TMA Trails)
16 Dec	2258	AF7.663	Eglin	135	Atmospheric Turbulence (Chemical Trail)
16 Dec	2258	AF7.659	Eglin	137	Atmospheric Turbulence (Chemical Trail)

Table A2. AFCRL Satellite Experiments, 1967

Satellite Scientific Designation	Popular Name	Launch Date	Experiments	Initial Orbital Elements Perigee (km)	Apogee (km)	Period (min)	Inclination (degrees)
--	OV3-5	31 Jan 67 (WTR)	Neutral and Ion Species Electron Density and Temperature Atmospheric Density (Gauge Method)	---	---	---	---
1967-20A	OSO-III	8 Mar 67	Solar EUV Spectrophotometry	540	570	95.8	32.9
1967-40E	OV5-1	28 Apr 67	Solar Radiation Monitor	110,350	9,484	2831.	34.5
1967-72A	OV1-86	27 Jul 67	Earth and Cloud IR Oxygen Mantle Measurements at 60 GHz Cosmic Radiation	606	445	95.1	101.7
1967-73A	OGO-IV	28 Jul 67	Solar EUV Spectrophotometry	412	908	98.	86.0
1967-120A	OV3-6	5 Dec 67	Latitudinal Variation in Neutral and Ion Species (a Mass Spectrometer) Electron Density and temperature (Impedance Probe) Atmospheric Density (3 gauges)	428	458	93.1	90.7

Table A3. AFCRL Balloon Launchings and Experiments Carried, 1967

Balloon Flight No.	Launching Site	Date (UT)	Time (UT)	Float Alt. (Ft)	Experiments Carried
H67-28	Holloman	25 Mar 67	0612	106,000	Lunar Mapping
H67-31	Holloman	7 Apr 67	1428	81,000	Atmospheric Optics
C67-10	Chico	26 Apr 67	1358	113,800	Humidity Distribution Study
H67-40	Holloman	23 May 67	0524	--	Lunar Mapping
H67-42	Holloman	1 Jun 67	1342	102,500	Infrared Studies
H67-47	Holloman	22 Jun 67	0516	102,000	Lunar Mapping
H67-48	Holloman	22 Jun 67	1323	23,000	Solar Constant Measurement
H67-49	Holloman	26 Jun 67	1400	97,000	Infrared Studies
H67-52	Holloman	11 Jul 67	1337	89,000	Atmospheric Optics
C67-24	Chico	7 Aug 67	1404	96,000	Infrared Solar Measure
H67-71	Holloman	17 Oct 67	0204	39,000	Lunar Mapping
H67-73	Holloman	20 Oct 67	1211	103,000	Solar Constant Measurement
H67-77	Holloman	4 Nov 67	0755	93,000	Light Scattering Study
H67-83	Holloman	16 Nov 67	0434	105,000	Infrared Lunar Mapping
H67-85	Holloman	30 Nov 67	Unknown	97,000	Solar Radiation Study
H67-86	Holloman	2 Dec 67	1732	36,000	Dropsonde Study
H67-87	Holloman	2 Dec 67	2000	100,000	Solar Radiation Study
H67-91	Holloman	7 Dec 67	Unknown	97,000	Solar Radiation Study

Appendix B

Rocket, Satellite, and Balloon Launchings Planned for 1968

Table B1. Sounding Rocket Launchings Planned by AFCRL for 1968

Principal Investigator	Experiment	Launch Site	Remarks
J. Sandcock	Auroral Absorption	Fort Churchill	
J. McIsaac	Atmospheric Density (Bremmsstrahlung Method)	Eglin	2 Rockets
D. Golomb	Ionospheric Winds (Chemical Release)	Fort Churchill	4 Rockets
D. Golomb	Atomic Oxygen Variation	Fort Churchill	2 Rockets
A. Jursa	Atmospheric Absorption (Spectrometric Method)	White Sands	2 Rockets
G. Faucher	Atmospheric Density (Expandable Sphere)	Kauai, Hawaii	2 Rockets
H. Hinteregger	Extreme Ultraviolet Monochromator Measurements	White Sands	5 Rockets
R. Walker	Infrared Horizon Studies	Fort Churchill	
R. Vancour	Geomagnetic Fields	Fort Churchill	3 Rockets
R. Hutchinson	Magnetic Field Experiment	Fort Churchill	2 Rockets
A. Faire	Atmospheric Density (7-inch Falling Sphere)	Eglin	2 Rockets
G. Faucher	Atmospheric Density (Expandable Sphere)	Eglin	4 Rockets
R. Narcisi	Atmospheric Composition (Mass Quadrupole Spectrometer)	Eglin	3 Rockets
N.W. Rosenberg	Ionospheric Winds (Chemical Release)	Eglin	15 Rockets
N.W. Rosenberg	Ionospheric Winds (Chemical Release)	White Sands	2 Rockets
N.W. Rosenberg	Barium Diffusion Rates (Chemical Release)	Eglin	
N. Sissenwine	Atmospheric Turbulence	Eglin	2 Rockets
N.W. Rosenberg	Dawn-Dusk Wind Variation	Eglin	3 Rockets
N.W. Rosenberg	Carbon Dioxide in the F-Region	White Sands	
R. Skrivanek	Meteoritic Dust	Fort Churchill	2 Rockets
R. Skrivanek	Micrometeorite Flux	Fort Churchill	
R. Skrivanek	Meteoritic Dust (Water Recoverable Collector)	Natal, Brazil	3 Rockets
R. Sagalyn	Electric Fields and Structures	Fort Churchill	2 Rockets
J. Ulwick	Auroral Input-Output Experiment	Thule, Greenland	2 Rockets
J. Ulwick	Polar Cap Absorption (PCA) Studies	Thule, Greenland	7 Rockets
A. Faire	Atmospheric Density (7-inch Falling Sphere)	Thule, Greenland	5 Rockets
R. Narcisi	Atmospheric Composition (Mass Quadrupole Spectrometer)	Thule, Greenland	8 Rockets
W. Rotman	Reentry Microwave Physics	Wallops Island	
S. Silverman	Aurora and Airglow Measurements	Fort Churchill	
R. Walker	Infrared Horizon (Minute-of-Arc Probe)	Fort Churchill	

Table B2. Planned AFCRL Satellite Experiments, 1968

AFCRL Scientist	Experiment	Satellite	Launching Site
D. Smart	Cosmic Radiation Experiments	OV1-13	WTR
K.S.W. Champion	Atmospheric Density (Accelerometer Method)	OV1-15	WTR
R. Narcisi	Perturbed Neutral and Ionized Atmospheric Structure	OV1-15	WTR
R.C. Sagalyn	Ion Altitude Sensor	OV1-15	WTR
B. Shuman	Geomagnetic Storm Studies	OV2-5	ETR
R. Sagalyn	Charged Particle Plasma Measurements	OV2-5	ETR
J. Mullen	ORBIS High	OV2-5	ETR
R.S.W. Champion	Low Altitude Atmospheric Density (≤160 km)	OV1-16	WTR
H. Hinteregger	Solar Spectrophotometry (EUV Monochromator)	OGO-F	Cape Kennedy
R. Narcisi	Positive Ion Composition (2 Mass Spectrometers)	ISIS-A	Cape Kennedy
R.C. Sagalyn	Positive Ion Density and Temperature	ISIS-A	Cape Kennedy
R.C. Sagalyn	0 to 2 keV Ions and Electrons	INJUN-V	Cape Kennedy
R.C. Sagalyn	0 to 2 keV Ions and Electrons	OGO-E	Cape Kennedy
K. Yates	Solar X-Ray Radiation	TBD	WTR

Table B3. Planned AFCRL Balloon Launchings (to July 1968)

Scientist	Experiment	Launching Site	Remarks
C. Cunniff	Solar Constant Measurement	Chico Holloman	1 Flight 4 Flights
C. Cunniff	Infrared Studies	Chico Holloman	2 Flights 2 Flights
J. Salisbury	Lunar-Planetary Spectra	Holloman	4 Flights
R. Penn	Atmospheric Optics	Holloman	3 Flights
L. Elterman	Infrared Measurements	Chico Holloman	2 Flights 2 Flights
R. Cowne	Met. Sensors & Techniques Dropsonde Studies	Holloman	2 Flights
A. Jursa	Studies of Upper Atmosphere Processes	Holloman	1 Flight

Appendix C

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Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Air Force Cambridge Research Laboratories (CRT) L. G. Hanscom Field Bedford, Massachusetts 01773	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
AFCRL SPACE SCIENCE RESEARCH DURING 1967
(Annual Report to COSPAR)

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Scientific Summary - Special Report (1 Jan 67 - 31 Dec 67)

5. AUTHOR(S) *(First name, middle initial, last name)*
A. McINTYRE, Editor

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1968	51	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) AFCRL-68-0011
b. PROJECT, TASK, WORK UNIT NOS.	
c. DOD ELEMENT	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d. DOD SUBELEMENT	Special Report No. 70

10. DISTRIBUTION STATEMENT
Distribution of this document is unlimited. It may be released to the Clearinghouse, Department of Commerce, for sale to the general public.

11. SUPPLEMENTARY NOTES TECH, OTHER	12. SPONSORING MILITARY ACTIVITY Air Force Cambridge Research Laboratories (CRT) L. G. Hanscom Field Bedford, Massachusetts 01773

13. ABSTRACT A summary of the space science organization and facilities of Air Force Cambridge Research Laboratories (AFCRL); its international activities in space science; rockets, satellites, and balloons launched; results of experiments associated with the moon, planets, micrometeoroids, solar physics, energetic particles and magnetic fields, upper atmosphere physics, meteorology, geodesy, and terrestrial photography; planned research in 1968; and a space science research related bibliography are included. The definition of space science for the purpose of this report is limited to in-situ observations and measurements using the broad definition of space.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Space Science						
Rocket Probes						
Satellites						
Moon						
Meteoroids						
Energetic Particles						
Geomagnetic Fields						
Upper Atmospheric Physics						
Meteorology						
Geodesy						
Terrain Photography						
Atmospheric Density						
Atmospheric Composition						
Ionospheric Physics						
Balloons						
International Activities						
Research Facilities						
Research Organization						
COSPAR						

Unclassified

Security Classification