

**U. S. AERONAUTICS AND SPACE ACTIVITIES,
JANUARY 1 TO DECEMBER 31, 1960**

REPORT TO CONGRESS

FROM

THE PRESIDENT OF THE UNITED STATES

1/21

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THE WHITE HOUSE

TO THE CONGRESS OF THE UNITED STATES:

In accordance with Section 206(b) of the National Aeronautics and Space Act of 1958, I am transmitting herewith the third annual report on the Nation's activities in the fields of aeronautics and space.

As this report testifies, 1960 witnessed a vast expansion of man's knowledge of the earth's atmosphere and of the limitless regions of space beyond. The Vanguard, Explorer, and Pioneer spacecraft have added substantially to our knowledge of the earth's environment and of the sun-earth relationship. Experiments with Projects Echo and COURIER, TIROS I and II, and TRANSIT I and II have shown the promise of spacecraft application in the fields of communications, meteorology, and navigation. Among the outstanding accomplishments in technology were a series of successful recoveries from orbit of capsules from the DISCOVERER satellites and the increasing degree of reliability in stabilizing these satellites in the required orbit.

Significant advances were made in the manned space flight program and in the preparation of a small fleet of powerful launch vehicles to carry out a wide variety of space missions.

Underlying the Nation's aeronautics and space programs was a strong basic and applied research effort which resulted in constantly broadening scientific and technological horizons. Finally, the entire effort has been drawn together in a long-range program of space exploration which offers every promise that in the years to come benefits for all mankind will be extensive.

Summarized within this report are contributions of Federal agencies participating in the space effort.

DWIGHT D. EISENHOWER

THE WHITE HOUSE

January 18, 1961

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U. S. AERONAUTICS AND SPACE ACTIVITIES

SUMMARY

THIRD ANNUAL REPORT

- - 1960 - -

In 1960, the National Aeronautics and Space Administration, which directs the Nation's nonmilitary space effort, moved out of its formative stage, accelerating its space research and development and its fundamental aeronautical research programs. Adding breadth and depth to the near-term objectives, a long-range U.S. plan of space exploration -- which envisions manned expeditions to the moon after 1970 -- was developed and set in motion.

At the year's end, preparations for the first manned suborbital flight in NASA's Project Mercury were nearing the final stages. The agency plans to launch astronauts on both suborbital and orbital flights during 1961. Another very high priority NASA project, Saturn, was progressing satisfactorily as static testing of the clustered 1.5-million-pound-thrust engine went forward.

Among other significant activities, NASA and Department of Defense earth-satellite, space-probe, and sounding-rocket programs moved ahead, along with construction of tracking and data-collection networks.

NASA and the Department of Defense established an Aeronautics and Astronautics Coordinating Board with co-chairmen from the two agencies.

NASA made headway with other elements of its launch vehicle program as the first of a small fleet of standardized units, tailored specifically for space mission, approached the flight-test phase. They will replace interim launch vehicles, evolved or modified from models designed originally either for Department of Defense programs or for Project Vanguard.

NASA's aeronautical program was highlighted by performances of the rocket-powered X-15 experimental airplane which achieved world speed (2,196 mph) and altitude (136,500 feet) records. The agency continued advanced research and development work on VTOL (Vertical Take-Off and Landing) and on STOL (Short Take-Off and Landing) aircraft.

In U.S. field centers and stations, basic research continued in many areas, including: advanced instrumentation and propulsion, combustion, plasmas, cryogenics, special materials, and structures for future airplanes and spacecraft.

Early in the year, NASA established the Office for the United Nations Conference to direct this country's participation in the first International Conference on the Peaceful Uses of Outer Space. Several space projects were carried out jointly with other nations; agreements were made with foreign governments; and discussions were held with various foreign scientists and groups concerning further cooperative space research activities.

To date (December 31, 1960), the United States had successfully launched 31 earth satellites and four deep space probes; of these 16 satellites are still circling the earth and two probes are in orbit around the sun. Data accruing from NASA and Department of Defense (DOD) programs during 1960 added substantially to the growing body of scientific knowledge of space and to the technology of space applications.

U.S. SPACE PROGRAM HIGHLIGHTS

NASA Activities

During the year, NASA launched four satellites into orbit and one space probe.

The NASA space flight program was highlighted by the successes of the Echo I passive communications satellite and of the TIROS I AND TIROS II experimental weather satellites (which pointed the way to operational systems having practical applications) as well as by achievements of Pioneer V, the sun-orbiting spacecraft, and Explorer VIII, an ionosphere-probing earth satellite.

The one-ton, bell-shaped Project Mercury capsule and its escape tower underwent numerous flight tests, culminating in an unmanned, suborbital flight launched by a Redstone on December 19.

The seven Mercury astronauts continued their training schedule, to prepare for the first manned (Redstone) sub-orbital flight and the first manned (Atlas) orbital flight, both planned for 1961. At the same time, construction of the worldwide Mercury Tracking and Ground Instrumentation

Network approached completion. Formal agreements for all NASA tracking stations abroad had either been signed or were near conclusion as 1960 ended.

The NASA Pioneer V space probe achieved the orbit around the sun which NASA scientists had calculated. It transmitted invaluable scientific data on the phenomena of deep space, while establishing the greatest range -- 22,462,740 miles from the earth -- over which radio contact has been maintained with a spacecraft.

NASA's TIROS I, an experimental meteorological satellite, transmitted 22,592 photographs of cloud cover and other weather phenomena after attaining a nearly circular orbit with an altitude averaging approximately 450 miles.

Echo I, the world's first passive communications (or "radio mirror") satellite, also achieved a nearly circular orbit, averaging about 1,000 miles in altitude. The inflatable sphere was used for numerous communications experiments, including two-way telephone conversations, trans-Atlantic signal relays, and transmission of facsimiles, photographs, and music.

Explorer VIII was launched by NASA into an orbit enabling it to carry out the first intensive direct measurement study of the earth's ionosphere. The data are being analyzed and related to earlier information.

Cloud pattern photographs and radiation data from TIROS II, an advanced version of TIROS I, are still being analyzed.

The X-15 rocket-powered airplane (No. 1) -- a joint NASA-Air Force-Navy project -- set a new world's speed record of 2,196 mph, with NASA test pilot Joseph A. Walker at the controls. With Air Force Maj. Robert M. White in the cockpit, the aircraft flew to a record altitude of 136,500 feet.

In March, all administrative and technical responsibilities for the Saturn, the powerful 1.5-million-pound-thrust, clustered-engine launch vehicle, were transferred from the Department of Defense to NASA.

Saturn satisfactorily completed a first series of static tests when the prototype first stage was fired for two minutes and two seconds at Marshall Space Flight Center.

In addition, NASA carried out many upper atmosphere experiments with sounding rockets.

U.S. Satellites and Space Probes, 1960

Name	Launch Date & Lifetime*	Dimensions	Shape	Weight (lbs)	Type	Perigee (Miles)	Apogee (Miles)
Discoverer IX	Feb 4, 1960 (0)	19.2 ft. long; 5 ft. in diameter	Cylindrical	1,700	Satellite	0	0
Discoverer X	Feb 19, 1960 (0)	19.2 ft. long; 5 ft. in diameter	Cylindrical	1,700	Satellite	0	0
MIDAS I	Feb 26, 1960 (0)	22 ft. long; 5 ft. in diameter	Cylindrical	4,500	Satellite	0	0
Pioneer V (1960 Alpha)	Mar 11, 1960 (100,000 years)	26-in. diameter	Spherical	94.8	Planetoid	74,967,000**	92,358,000***
Explorer	Mar 23, 1960 (0)	21 in. long; 7 in. in diameter; surrounded by 9 by 9 by 12 in. solar cell box	Cylindrical	35.3	Satellite	0	0
TIROS I (1960 Beta 2)	Apr 1, 1960 (50-100 years in orbit)	19 in. high; 42 in. in diameter	Cylindrical	270	Satellite	435	468
Transit IB (1960 Gamma 2)	Apr 13, 1960 (16 months)	36-in. diameter	Spherical	265	Satellite	233	479

* (0) Indicates that the satellite or probe did not orbit. Other figures within parentheses are approximate orbital lifetimes of spacecraft still up as of January 1, 1961.

** Perihelion

*** Aphelion

U.S. Satellites and Space Probes, 1960

Name	Launch Date & Lifetime	Dimensions	Shape	Weight (lbs)	Type	Perigee (Miles)	Apogee (Miles)
Discoverer XI (1960 Delta)	Apr 15-26, 1960	19.2 ft. long 5 ft. in diameter	Cylindrical	1,700	Satellite	109	380
Echo	May 13, 1960 (0)	100-ft. diameter	Spherical	136	Satellite	0	0
MIDAS II (1960 Zeta 1)	May 24, 1960 (40 months)	22 ft. long; 5 ft. in diameter	Cylindrical	4,500	Satellite	292	322
Transit IIA (1960 Eta I)	Jun 22, 1960 (50 years)	36-in. diameter	Spherical	223	Satellite	389	665
Solar Radi- ation Satellite (1960 Eta 2)	Jun 22, 1960 (50 years)	20-in. diameter	Spherical	42	Satellite	382	667
Discoverer XII	Jun 29, 1960 (0)	19.2 ft. long; 5 ft. in diameter	Cylindrical	1,700	Satellite	0	0
Discoverer XIII (1960 Theta)	Aug 10, 1960 —Nov 14, 1960	19.2 ft. long; 5 ft. in diameter	Cylindrical	1,700	Satellite	161	436
Echo I (1960 Iota 1)	Aug 12, 1960 (indefinite)	100-ft. diameter	Spherical	136	Satellite	945	1,049
Discoverer XIV (1960 Kappa)	Aug 18, 1960 —Sep 16, 1960	19.2 ft. long; 5 ft. in diameter	Cylindrical	1,700	Satellite	116	502
Courier IA	Aug 18, 1960 (0)	51-in. diameter	Spherical	500	Satellite	0	0

U.S. Satellites and Space Probes, 1960

Name	Launch Date & Lifetime	Dimensions	Shape	Weight (lbs)	Type	Perigee (Miles)	Apogee (Miles)
Discoverer XV (1960 Mu)	Sep 13, 1960 —Oct 18, 1960	19.2 ft. long; 5 ft. in diameter	Cylindrical	1,700	Satellite	130	472
Pioneer	Sep 25, 1960 (0)	39-in. diameter	Spherical	387	Probe	0	0
Courier 1B (1960 Nu 1)	Oct 4, 1960 (several years)	51-in. diameter	Spherical	500	Satellite	501	658
SAMOS I	Oct 11, 1960 (0)	22 ft. long; 5 ft. in diameter	Cylindrical	4,100	Satellite	0	0
Discoverer XVI	Oct 26, 1960 (0)	25 ft. long; 5 ft. in diameter	Cylindrical	2,100	Satellite	0	0
Explorer VIII (1960 Xi 1)	Nov 3, 1960 (10 yrs.)	30 in. long; 30 in. in diameter	Biconical	90.14	Satellite	258	1,423
Discoverer XVII (1960 Omicron)	Nov 12, 1960— Dec 29, 1960	25 ft. long; 5 ft. in diameter	Cylindrical	2,100	Satellite	116	616
TIROS II (1960 Pi 1)	Nov 23, 1960 (50-100 yrs.)	19 in. high; 42 in. in diameter	Cylindrical	280	Satellite	387	453
Transit IIIA	Nov 30, 1960 (0)	36-in. diameter	Spherical	203	Satellite	0	0

U.S. Satellites and Space Probes, 1960

Name	Launch Date & Lifetime	Dimensions	Shape	Weight (lbs)	Type	Perigee (Miles)	Apogee (Miles)
Solar Radiation Satellite	Nov 30, 1960 (0)	20-in. diameter	Spherical	40	Satellite	0	0
Explorer	Dec 4, 1960 (0)	12-ft. diameter	Spherical	14	Satellite	0	0
Discoverer XVIII (1960 Sigma)	Dec 7, 1960 (1 month)	25 ft. long; 5 ft. in diameter	Cylindrical	2,100	Satellite	154	459
Pioneer	Dec 15, 1960 (0)	39-in. diameter	Spherical	388	Probe	0	0
Discoverer XIX (1960 Tau)	Dec 20, 1960 (1 month)	25 ft. long; 5 ft. in diameter	Cylindrical	2,100	Satellite	120	400

Department of Defense Activities

During the year, the Department of Defense continued intensive effort on its DISCOVERER program. For the first time in history, a man-made object was recovered from space after it had orbited the earth, when a DISCOVERER capsule was retrieved from the Pacific Ocean on August 11. Later in the year, three more capsules were recovered in mid-air -- a far more difficult operation -- by aircraft equipped with special slings.

Other important "firsts" included feasibility demonstrations by navigation (TRANSIT) and communications relay (COURIER) satellites.

Twenty-one launch attempts were made, with 12 successfully attaining orbit.

Included among key Defense Department projects were:

- 1) GREB (Galactic Radiation Experiment Background), a solar radiation experiment satellite launched pick-a-back on TRANSIT in a multiple payload experiment;
- 2) NOTUS, a communications system program of which the COURIER launching (above) was a part.
- 3) SHEPHERD, a program to obtain a space surveillance tracking system.
- 4) LONGSIGHT, a project to find and remedy serious short- and long-term gaps in study and research relating to foreseen military needs in space technology.
- 5) SAMOS - a program to determine the capabilities for making observations of the earth from satellites.
- 6) VELA, a project whose objective is a system for detecting nuclear explosions.
- 7) SAINT (Satellite Inspector System) program, intended to develop and demonstrate a rendezvous and inspection satellite.
- 8) LORRAINE, devoted to advanced energy conversion.
- 9) BLUE SCOUT, a project to develop and standardize and economical, versatile, and reliable test vehicle.
- 10) MIDAS, a satellite-borne Missile Defense Alarm System.

11) DYNA-SOAR, a project to construct and test a manned, maneuverable aerospace vehicle that will explore hypersonic flight approaching orbital speeds. To this project NASA is contributing research services.

Summary of Other Government Space-Related Programs

The following space-related work went forward in other Government agencies:

The Atomic Energy Commission continued cooperation with NASA on Project Rover, directed toward attaining nuclear rocket propulsion; and Project SNAP, a series of nuclear-generated auxiliary electric power systems for spacecraft.

The Department of State was active in matters related to the emerging political and legal problems of space. In all activities, which have ranged from participation in United Nations General Assembly meetings to non-governmental scientific meetings, the United States has pursued its national policy of fostering international cooperation in space research and exploration, and in seeking effective international control of outer space activities.

The National Science Foundation forged ahead with its policy of supporting basic research of a pioneering nature. The foundation made a number of grants to nonprofit institutions for the support of research projects proposed by staff scientists of the institutions involved.

The Department of Commerce, through the National Bureau of Standards, the Weather Bureau, and the Coast and Geodetic Survey, participated in many aspects of the space program.

The Space Science Board pursued its endeavors in both domestic and foreign space programs. General study groups were convened to consider specific problems, and a report, entitled "Science in Space" issued in nine separate pamphlets was distributed in the U.S. and abroad. The Board's international activities were carried out mostly through COSPAR (Committee on Space Research).

The Smithsonian Astrophysical Observatory, under a NASA grant, continued its technical direction and related responsibilities of the Baker-Nunn Optical Tracking Network.

The Federal Communications Commission increased its activities, both domestic and international, in the fields

of space communication, radio astronomy, and aeronautics. Progress was made toward implementing the 1959 Geneva Radio Regulations which provide specific frequencies for space communications research and radio astronomy.

The United States Information Agency issued news releases, photographs, pamphlets, magazine reprints, and employed a variety of communications media -- including radio, television, motion pictures, and exhibits -- to disseminate information abroad on space activities of the United States.

International Cooperation in Space

The National Aeronautics and Space Act of 1958 stipulates that NASA should cooperate "with other nations and groups of nations" in aeronautics and space activities "and in the peaceful applications of the results thereof."

In keeping with this policy, NASA requested negotiation of formal agreements with other nations for establishment of U.S. tracking stations abroad; made available to foreign scientists, through COSPAR, data from several U.S. experiments such as Echo I and TIROS II; entered upon joint space projects with scientific organizations of several countries and initiated discussions leading toward more such projects; and established the Office for the United Nations Conference, to serve as a focal point -- with guidance from the Department of State -- for U.S. participation in the First International Conference on the Peaceful Uses of Outer Space.

Summary Evaluation of U.S. Space Goals and Problem Areas

During 1960, the practical benefits of space research -- especially in the fields of meteorology and communications -- came into sharper focus. At the same time, experiments in other areas continued to add to the immense store of significant scientific data. (For example, when Explorer VIII's transmission ended on December 27, it had produced 700 miles of magnetic tape, now being analyzed.)

After consolidating its organization, NASA began implementing its Long Range Plan with the full resources at its command. Beyond the strict research and development aspect, the agency's Committee on Long Range Studies arranged for four studies centering on wide-ranging socioeconomic and political implications of space activities.

The basic problem areas of 1959 -- lack of high-thrust launch vehicles designed specifically for space missions, lack of reliability in space experiments, etc. -- were still in evidence as 1960 ended. But new, standardized launch vehicles had been developed and soon would be operational. Progress was also being made in development of midcourse and terminal guidance equipment and techniques. Research into the performance of materials and fuels in the temperature extremes and stresses of space flight, and development of technology for deep space flight technology were productive.

In sum, despite setbacks to be expected in any new, highly active and complex, research field, the civilian and military space programs of the United States had to their credit many noteworthy scientific achievements as well as a respectable list of sound technical accomplishments. Together with their implications, the year's developments forecast that the U.S. will exercise dynamic and fruitful leadership as men range deeper and deeper into new dimensions of space exploration.

CHAPTER I

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTRODUCTION

The National Aeronautics and Space Administration (NASA) was created by Congress in 1958 to conduct nonmilitary aeronautics and space research and development. (In practice, NASA confines its aeronautics activities to research.) The Space Act states that these activities must be pursued not only for the benefit of the U.S. but for all mankind. The legislation also stipulates that NASA support space-related military research programs as required.

NASA's mission encompasses exploration of the earth's atmosphere, and of the moon, planets, and interplanetary space.

Accomplishments and developments in principal NASA programs during 1960 are summarized below.

EXPERIMENTAL MISSIONS

During the period January 1, 1960, to December 31, 1960, NASA attempted to launch 10 earth satellites and space probes. Five achieved most of their goals and several exceeded their expected performance. These experiments, like those of 1958 and 1959, added to knowledge of the ocean of air in which we live and of the reaches of space beyond. They produced invaluable data on the Great Radiation Region, the earth's magnetic field, micrometeoroid density in space, and on many other phenomena.

All of these launchings were from Cape Canaveral, Fla.

Major Satellite and Space Probe Experiments

...March 11 Pioneer V, a 94.8-pound probe, designed to gather scientific data from deep space and to test communications over interplanetary distances, was launched by a Thor-Able. The probe contained two radio transmitter-receivers, one of five watts, the other of 150 watts, as well as instrumentation to measure: 1) radiation streaming

from the sun; 2) the spatial distribution of energetic particles and medium-energy electrons and protons; 3) the number and density of meteoric dust particles striking the probe; and 4) the strength of magnetic fields.

Four paddle-shaped 14- by 18-inch vanes jut from the globe-shaped payload, each vane studded with 1,200 solar cells which provide power to recharge Pioneer V's nickel-cadmium batteries.

To achieve the desired orbit -- perihelion approaching the sun and near the orbit of Venus -- Pioneer V was launched in a direction opposite to that of the earth's revolution around the sun. With a speed less than the earth's -- and hence with a reduced centrifugal force to offset the sun's gravitational pull -- the probe fell inward toward the sun. (Previous probes had been launched so that their speed was added to that of the earth, and they thus moved outward, away from the sun.)

Pioneer V established the greatest range -- 22,462,740 miles from earth -- over which man has tracked, received telemetry from, and maintained control over an instrumented vehicle. The previous record was set by Pioneer IV, which was tracked to 407,000 miles.

The probe's magnetometer confirmed the existence of an electrical "ring current" circling the earth at an altitude of 40,000 miles, a giant girdle of low-energy charged particles. The newly discovered current, the existence of which has been argued by geophysicists for more than 50 years, is not to be confused with the Great Radiation Region discovered by earlier U.S. satellites.

The probe also: 1) reported an intense zone of disturbed magnetic fields at distances of 40,000 to 60,000 miles; 2) revealed that the boundary of the earth's magnetic field is twice as far from earth as had been previously supposed; 3) made a detailed examination of the interplanetary magnetic field; and 4) reported the first direct observation of pure cosmic rays at altitudes completely free of the earth's atmosphere. The observation was made three million miles in space.

...March 23 an Explorer satellite, equipped to analyze electron and proton radiation energies in the Great Radiation Region over an extended period of time, failed to achieve orbit. Communication with the Juno II launch vehicle was lost after second stage burnout. Probable cause of failure: a malfunction in one of the rockets in the second stage cluster causing angle deviation and a decrease in velocity.

...April 1 TIROS I (Television and Infra-Red* Observation Satellite), a 270-pound, drum-shaped, experimental meteorological satellite, was launched by a Thor-Able. The satellite went into a near-circular orbit with a perigee of 428.7 miles and an apogee of 465.9 miles.

TIROS I made meteorological history, giving scientists an unprecedented opportunity to study the earth's cloud patterns and relate them to the weather. Among the striking phenomena shown for the first time were large-scale cyclones, with spiral bands sometimes covering an area one thousand miles across.

Photographs transmitted by its two television cameras also indicated the presence of jet streams, regions of moist and dry air, thunderstorms, fronts, and other data. Experimental studies of TIROS data have already resulted in improved understanding and increased accuracy in weather forecasting, particularly over large ocean areas.

The satellite's cameras swept the earth's cloud cover between 50 degrees north and south latitudes -- a band extending roughly from Montreal, Canada, to Santa Cruz, Argentina, in the Western Hemisphere, and from Le Havre, France to Southern Africa and from Northern Manchuria to New Zealand in the Eastern Hemisphere. One camera was capable of photographing hundreds of thousands of square miles in one picture -- the area varying with the angle of the lens to the earth. The other instrument, a high-resolution camera, could photograph an area 80 miles on a side within the area covered by the first camera. The high-resolution camera, which provided 10 times the detail of the wide-angle camera, reproduced the structure and texture of clouds within the over-all cloud mass.

About midnight on June 29, after TIROS I had completed 1,302 orbits around the world, attempts to interrogate the satellite ceased. Its effective lifetime, during which it transmitted 22,592 pictures, was at an end.

...May 13 an attempt to launch an Echo passive communications satellite into orbit failed because of an apparent malfunction in the second stage of the new Delta launch vehicle and failure of the third stage to receive the ignition signal.

* The infrared sensor equipment had not been completed by launch time, hence was not included in the payload.

...August 12 Echo I, the world's first successful passive communications or "radio mirror" satellite, was launched by Delta (it was Delta's first successful flight). The 100-foot diameter, inflatable sphere of aluminized Mylar plastic, weighed 136 pounds and contained an additional 30 pounds of subliming chemicals to inflate it.

The sphere went into a nearly circular orbit which was confirmed when word of a sighting was received from a tracking station at Woomera, Australia. Echo's initial apogee was 1,049 miles, perigee 945 miles. During its first orbit, scientists transmitted President Eisenhower's tape-recorded voice from California to New Jersey, via the sphere. Since then, numerous communications experiments have been conducted. Transmissions have included teletype signals, facsimile photographs, two-way telephone conversations using commercial equipment, trans-continental and trans-Atlantic signal relays, and experiments to learn more about the effects of the ionosphere upon radio signals.

Echo I's launching is part of NASA's program to investigate the feasibility of satellites for global communications including worldwide telephone, radio, and television. Such satellites may eventually lead to worldwide "live" TV broadcasts.

...September 25 an attempt to fire a Pioneer space probe into lunar orbit ended when abnormal burning in the second stage of the Atlas-Able rocket vehicle failed to provide necessary velocity.

...November 3 Explorer VIII, a 90-pound satellite equipped to carry out the first intensive direct measurement study of the earth's ionosphere, was launched by a Juno II. The spin-stabilized satellite, shaped like a toy top, went into an initial orbit with an apogee of 1,423 miles, a perigee of 258 miles.

The ionosphere consists of a series of regions of charged particles beginning about 50 miles above the earth's surface and extending for hundreds of miles into space. Here, ultraviolet radiation from the sun acts upon the atoms of the atmosphere, causing them to become ionized; that is, to lose their electrons. The result is plasma, a gaseous substance.

Because radio signals normally bounce back and forth between the earth and the ionosphere, international radio communications are made possible, despite the curvature of the earth. However, the composition of the ionosphere is

constantly changing because of solar storms, auroral displays and other natural phenomena such as sunlight and shadow. These shifts sometimes disrupt communications, cause the radio signals to be absorbed in the ionosphere -- or cause them to streak right through the ionosphere into space.

The satellite has two secondary objectives: 1) to measure the charge accumulation, that is, the static electricity, on the satellite's aluminum surfaces which can be related to the problem of electrical drag; and 2) to measure the number of micrometeoroid impacts.

(Explorer VIII transmissions ceased on December 27. The data sent by this satellite, recorded on 700 miles of magnetic tape, is being analyzed.)

...November 23 TIROS II, a 280-pound advanced version of TIROS I, was launched from AMR by a Delta, flying into an orbit with a 387-mile perigee, a 453-mile apogee. The satellite is equipped with a narrow-angle and wide-angle television camera, each the size of a water glass, plus infrared sensors to measure solar and terrestrial radiation. The radiation experiment will assist research meteorologists in studying general circulation of the atmosphere and in determining many features of atmospheric composition and temperature.

In early December, data from the satellite were still being analyzed. At that time, the narrow-angle camera and infrared sensors were working well, but the wide-angle camera was not providing pictures of as high quality as those produced by TIROS I.

...December 4, the first orbital experiment with the Scout launch vehicle did not achieve objective because the second stage did not ignite. The vehicle was intended to place in orbit a 12-foot-diameter, inflatable satellite to measure density of the atmosphere.

...December 15 an attempt to launch a Pioneer space probe ended with an explosion which destroyed the Atlas-Able rocket vehicle 70 seconds after liftoff at an altitude of about 40,000 feet. Purpose of the experiment was to probe the environment between earth and moon and to develop technology for controlling and maneuvering spacecraft from the earth. Cause of the explosion is under study.

NATIONAL LAUNCH VEHICLE PROGRAM

Standardized Vehicles Come on Line

NASA's launch vehicle program, a key element of the Long-Range Plan, made significant progress in 1960. Through mid-year, most NASA launch vehicles traced their lineage to components developed in either the Department of Defense missile program or in Project Vanguard, the U.S. earth-satellite program for the International Geophysical Year. NASA is now replacing these vehicles with the first of a fleet of standardized units especially designed for space missions. Through continued use of the new vehicles, the agency expects to achieve a high degree of reliability.

Vanguard and the Army-developed Jupiter C have been phased out, the Jupiter-based Juno II and the Thor-Able programs will be completed in 1961. Delta -- launched successfully for the first time this year -- will not be used after 1961. Moving on line to replace them are the four-stage, solid-fueled Scout, capable of launching 150-pound earth satellites, and Thor-Agena B, which has a 1,600-pound earth orbital capacity.

Scout has 105,000 pounds thrust. It was designed for reliability, ease of handling, versatility, and relatively low production cost, i.e., about \$750,000 each. On October 4, the first complete Scout vehicle was launched.

Thor-Agena B is basically the same vehicle as that used in the DISCOVERER satellite program. Agena B is a 15,000-pound-thrust liquid-fuel rocket; Thor has a thrust of 165,000 pounds. In a more powerful class is Atlas-Agena B. With Atlas (360,000-pound thrust at lift-off, 80,000-pound thrust in its sustainer stage), the Agena B will be able to launch 750 pounds to the moon -- including hard-landing pay loads -- and 5,000-pound earth satellites.

More powerful is Atlas-Centaur, the first U.S. launch vehicle to employ a high-energy upper stage, using liquid hydrogen-liquid oxygen (LOX) propellant instead of hydrazine (kerosene) and LOX. The Centaur second stage consists of two rocket engines, each generating 15,000 pounds of thrust. The vehicle's capability: 8,500-pound earth satellites, 1,450-pound lunar orbiters and planetary probes.

The largest U.S. launch vehicle under construction is Saturn whose first stage, eight clustered liquid-fuel engines, will deliver 1.5 million pounds of thrust. Mounted on the cluster in the first (or C-1 version) will be two

Centaur upper stages. The C-1's capacity: 19,000 pounds in earth orbit, 5,000 pounds on a lunar trajectory. Second-generation versions of Saturn are also under consideration. One of these, the three- or four-stage C-2, will carry a second stage with four 200,000-pound thrust, liquid hydrogen-liquid oxygen engines. During the report period, Saturn completed its first series of static tests satisfactorily with a two-minute, two-second firing of the prototype first stage.

Much study was devoted to defining the launch vehicle to follow Saturn. One of a number of possibilities is the Nova concept, which would employ the single-chamber, 1.5-million-pound thrust F-1 engine, now being developed. Under this approach, several F-1 engines would be used in the first stage and hydrogen-oxygen stages would be mounted thereon.

The principal objective of the F-1 is to land a manned spacecraft on the moon and return it to earth.

MANNED SPACE FLIGHT PROGRAM

Project Mercury

Objectives -- Project Mercury, which entails the first U.S. manned suborbital and orbital space flights, is the first step in NASA's long-range manned space flight program. It has two basic objectives: 1) to demonstrate how usefully a man can function in space flight; and 2) to discover the design and operational problems that must be solved to make advanced manned space flight feasible and as safe as possible. (Detailed background, objectives, and evolution of the project were provided in the President's Second Annual Report to Congress on the Nation's Activities in the Fields of Aeronautics and Space.)

Astronaut Training -- The seven Mercury astronauts experienced a wide range of training in 1960 -- from survival tests in the Nevada desert to flight mission simulations in centrifuges.

As the year opened, the seven Mercury astronauts had completed basic and theoretical studies in their training program and had started practical engineering studies. This involved, for example, a transition from theory of propulsion to study of actual propulsion systems.

Astronaut training included astronautics, electronics, trajectories, guidance, rockets, and preparation for scientific observations during orbital flight. They visited numerous industrial and Government facilities engaged in rocket vehicle research and development.

The men acquired intensive training in devices that simulate space flight and capsule environment; practiced escape from a capsule at sea; took courses in star identification and celestial navigation; participated in zero-gravity familiarization flights; and observed unmanned test flights of the capsule.

Mercury Capsule -- The production model of the Mercury flight capsule entered the "shakedown" or qualification stage with the following flights:

...May 9. The capsule, with its rocket-equipped 16-foot escape tower, was mounted on a launch pad at Wallops Station as it would be on the nose of an Atlas. The escape rocket was fired, carrying the capsule to an altitude of 2,540 feet where a drogue parachute was deployed. It stabilized the capsule and dragged out the main parachute which lowered the capsule into the Atlantic.

The capsule-escape tower showed good aerodynamic stability and no tumbling occurred.

...July 29. A launch of a Mercury production capsule by an Atlas ended in failure when a malfunction occurred one minute after lift-off, resulting in destruction of the launch vehicle.

...November 8. An attempt to launch a Mercury capsule on a suborbital flight from Wallops Station, Va., ended when the capsule failed to separate from its Little Joe launch vehicle. The Little Joe, with capsule and escape tower still attached, fell into the Atlantic.

...November 21. An attempt to launch a capsule from Cape Canaveral ended when a signal triggered by the Redstone rocket vehicle's ground connection shut down the engine immediately after ignition. The escape tower rockets ignited almost simultaneously with the Redstone engine shutdown. The escape tower broke loose, shot several thousand feet in the air, and fell back to earth.

...December 19. All capsule systems worked satisfactorily in a suborbital launch of a Mercury capsule from Cape

Canaveral with a Redstone rocket vehicle. The capsule reached an altitude of 135 miles and was recovered from the Atlantic Ocean at a distance of 235 miles.

Capsule Modifications Continue -- Wind tunnel and flight tests of the capsule have demonstrated that aerodynamic heating and air stresses of "loads," during powered flight may be more severe than originally anticipated. As a result, the capsule and escape tower structures have been strengthened and electrical conduits modified to provide more protection against heat. Methods of increasing cabin pressure are being examined to prevent excessive stresses resulting from an abort maneuver.

In addition, beryllium has been substituted for a cobalt alloy in the afterbody section housing the capsule's main parachute, and the entire afterbody skin has been thickened. These measures were taken as a result of the Big Joe flight of September 9, 1959, which indicated a peak temperature of 2,300 degrees Fahrenheit on the afterbody.

Mercury Tracking and Communications Network -- The worldwide Mercury Tracking and Ground Instrumentation Network will become operational in early 1961 in readiness for the first unmanned orbital abort tests, scheduled for the second quarter, and the manned suborbital and orbital flights planned for later in the year.

During 1960, the stations which will cover the manned suborbital flights were readied. Progress was made on the remainder of the network, including the stations aboard ships which will be deployed in the Indian and Atlantic Oceans.

Other Project Mercury Developments -- Progress in other elements of the project included:

...A team of 160 military and civilian medical specialists has been organized to serve with Project Mercury's recovery and tracking forces.

...Department of Defense recovery support for Project Mercury, which is under the direction of the Commander of Destroyer Flotilla 4 at Norfolk, Va., moved ahead with plans to deploy naval vessels, aircraft, helicopters, and amphibious rescue craft to pick up the manned capsule.

...A group of young chimpanzees underwent training at Holloman AFB, N.M., for flights in the Mercury capsule preceding manned flights.

...The U.S. Weather Bureau made plans to furnish meteorological support to the project.

SPECIAL RESEARCH PROJECTS

The X-15 Experimental Airplane

The rocket-powered X-15, a sleek black, stub-winged experimental aircraft, set world speed and altitude records in 1960. A joint NASA-Air Force-Navy project, the X-15 is the latest in a long series of research airplanes the first of which -- the X-1 -- brought about the long-awaited breakthrough to supersonic flight.

The X-15 is expected to be this country's first piloted vehicle to penetrate the fringes of space. After the X-15 will come Dyna-Soar, a manned orbital glider that will be carried into space by a launch vehicle. Dyna-Soar is a joint Air Force-NASA project with NASA furnishing technical assistance.

On August 4, at the Flight Research Center, Edwards AFB, Calif., X-15 No. 1 set a new world's speed record of 2,196 mph -- more than three times the speed of sound (Mach 3.31). NASA test pilot Joseph A. Walker was at the controls.

The flight began at 8:58 a.m. PDT, after the airplane had been released from its mother ship at an altitude of 45,000 feet. Walker opened the two rocket engines to full thrust. In four minutes of powered flight before the fuel burned out at 66,000 feet, the X-15 attained the record speed, as Walker said, "for just the snap of a finger." The previous world record was 2,094 mph.

On August 12, X-15 No. 1, piloted by Air Force Maj. Robert M. White, broke another record by flying to an altitude of 136,500 feet, surpassing the previous world record of 126,200 feet.

The X-15 climbed at Mach 1.9, at an angle of 50 degrees. Fuel in the two engines was exhausted at an altitude of about 120,000 feet but momentum carried the airplane to the record height of 136,500 feet. Then the X-15 nosed down and glided to 60,000 feet at about 1,000 feet per second, during which its stability was tested and found to be good. After a total flight time of 11 minutes, the aircraft glided to a landing on Rogers Dry Lake at Edwards.

Dyna-Soar Support

In support of Dyna-Soar, which is still in the design stage, NASA is carrying out a wide range of research activities in its laboratories and wind tunnel to determine configurations that can best withstand the stresses of space flight.

SPACE SCIENCES PROGRAMS

NASA space science research in 1960 emphasized two major areas: 1) satellite and sounding rocket programs, and 2) lunar, planetary and interplanetary programs. The chief aim is to increase knowledge of the earth and its environment (geophysics), and of the sun, stars, and universe (astronomy).

Principal Accomplishments

Notable NASA space sciences milestones during the year included: 1) the Pioneer V deep space probe (now in orbit around the sun) transmitted its final message to earth from about 22.5 million miles; 2) the agency made available to scientists throughout the world a description of the techniques needed to interpret the telemetering codes of Explorer VII, the 91.5-pound radiation probing satellite launched on October 13, 1959; 3) NASA released results from analyses of data transmitted by Vanguard III (launched September 18, 1959) and Explorer VI (launched August 7, 1959); 4) staff scientists of NASA participated in the First International Space Symposium of the International Committee on Space Research (COSPAR), Nice, France, January 8-16, 1960; 5) the first NERV (Nuclear Emulsion Recovery Vehicle) experiment, designed to study energetic particles in the lower belt of the Great Radiation Region, was successfully launched (September 19, 1960); 6) numerous sounding rockets were launched to determine the composition and pressure of the atmosphere, to investigate winds and wind shears in the upper atmosphere, to determine atmospheric temperatures, and to measure neutrons and other radiations in the upper atmosphere; 7) Aerobee sounding rockets were launched for astronomical studies of ultraviolet radiation from the stars and nebulae; and 8) several small Aerobee rockets were launched, carrying cameras to photograph cloud cover and other weather phenomena.

These experiments have laid the groundwork for coming series of progressively larger and more effective unmanned spacecraft, carrying increasingly elaborate instrumentation

for investigations of the moon, interplanetary space, and later, Venus and Mars.

Coming Experiments

A principal goal of NASA's lunar program is to explore and investigate the moon for information on the history of the earth-moon system and on the origin of planetary bodies in the solar system. First step will be Ranger, a lunar spacecraft that will carry an instrument package designed to survive a crash landing on the moon, where it will record and radio to earth data about the make-up of the lunar surface. In 1961, NASA will begin test-flying Ranger with the Atlas-Agena B launch vehicle.

Beyond Ranger, NASA has let contracts for advanced engineering studies of a soft-landing lunar spacecraft (called Surveyor), which will be the first U.S. spacecraft capable of making a controlled landing on the moon. Later steps to extend unmanned exploration of space to the nearer planets are in the planning stages.

SATELLITE APPLICATIONS

The practical aspects of space exploration -- goal of NASA's satellite applications program -- were clearly demonstrated by two extremely significant experiments during 1960. One, the first of a series of experimental meteorological satellites, demonstrated to the world that weather observation on a global scale is technically sound and economically feasible. The second, also the first of a series of progressively advanced experiments, showed that passive communications satellites can be successfully employed as world-wide teleradio links.

The meteorological satellite, TIROS I, launched on April 1, and its successor, TIROS II, launched on November 23, have given Weather Bureau and other interested scientists, here and abroad, unprecedented opportunities to relate the earth's cloud cover to weather observations from the ground. TIROS I, for example, orbiting at altitudes averaging 450 miles, transmitted nearly 23,000 television pictures of the earth's cloud patterns, of which an estimated 60 percent were useful for analysis. Experimental use of these photographs has already resulted in increased accuracy in analyzing the world's weather patterns, particularly in areas such as those over the oceans where it is difficult to obtain data by orthodox means.

The Echo I passive communications satellite, launched on August 12, achieved equally important results. The 100-foot-diameter, inflatable aluminized plastic sphere, orbiting at an altitude of between 945 and 1,049 miles, has maintained sufficient inflation to permit relay experiments to continue. At dusk when the balloon-shaped satellite is in sunlight and passes overhead it is clearly visible as a star-like body, about as bright as Vega. Hence it has been viewed by hundreds of thousands of observers in both hemispheres.

Among Echo I's notable "firsts" have been: relay of President Eisenhower's tape-recorded voice from California to New Jersey; relay of the first transoceanic radar signal (from Trinidad, B.W.I.F., to Floyd, N.Y.); first relay of a trans-Atlantic wireless-code radio transmission; first relay of wire-photo transmissions; and first relay of a trans-Atlantic voice message. Other transmissions have included relaying of teletype signals, facsimile photographs, two-way telephone conversations using standard commercial equipment, and experiments to learn more about the effects of the ionosphere on radio signals.

While these projects were being carried forward, NASA rounded out planning for other satellites evolved from, or related to, Echo and TIROS. Included are the Nimbus series of weather satellites, and further development of inflatable passive communications satellites, rigidized to give longer lifetimes.

NASA is also continuing to study the potentialities of "active" communications satellites containing radio receivers, transmitters, and antennas, plus batteries, devices for converting sunlight into electricity, or other auxiliary power sources. The active satellite will receive messages from ground stations and either transmit them immediately to distant parts of the earth or store them on magnetic tape for later transmissions upon command signals from a ground station, perhaps on the opposite side of the globe from the originating point.

SOUNDING ROCKETS

NASA employs sounding rockets to supplement earth satellite and space probe investigations. At present, NASA plans to limit its sounding rocket models to 11 and to increase their reliability by frequent firings. These vehicles range from the Aerobee 100, designed to carry 70 pounds to an altitude of about 80 miles, to the Argo D-8, capable of carrying 130 pounds to a distance of 1,300 miles.

During 1960, NASA launched scores of sounding rockets in a broad range of experiments, gathering data about the atmosphere, ionosphere, energetic particles and magnetic and electric fields. In the astronomy area, sounding rocket payloads included experiments for solar spectroscopy and for detection of areas of ultraviolet emission in space.

INTERNATIONAL PROGRAMS

Preparations for International Space Conference

NASA is continuing its preparations for participating in the International Conference for the Peaceful Uses of Outer Space. The Conference, tentatively scheduled for 1961, will be held under the auspices of the United Nations.

First International Space Science Symposium

NASA representatives supported the National Academy of Sciences delegation to the First International Space Science Symposium of the International Committee on Space Research (COSPAR), in Nice, France, January 8-16. NASA's offer to fly foreign experiments in U.S. satellites and spacecraft was reaffirmed.

International Organizations

With the Department of State, NASA also gave informal assurances of cooperation to scientists of 10 European nations which are considering space efforts modeled on the Centre Europeen pour la Recherche Nucleaire (CERN). In addition, NASA scientists took part in the Advisory Group on Aeronautical Research and Development of the North Atlantic Treaty Organization.

International Participation in NASA Experiments

NASA made it possible for foreign scientists to take part in several experiments including Echo I, Explorer VII, and TIROS I and II. For example, the first receipt of a trans-Atlantic transmission from the U.S. using Echo I as a "radio mirror" was reported by the French National Telecommunications Establishment.

The agency continued its policy of making data from its experiments available to the international scientific community.

Agreements were made with the United Kingdom and Canada for United States launchings of satellites prepared by those countries. In addition, NASA and the space organizations of several other nations discussed cooperative sounding rocket experiments.

NASA also awarded study grants to foreign scientists under a program funded by NASA and administered by the National Academy of Sciences, and arranged for foreign scientists, sponsored by their governments, to study space technology at NASA laboratories.

Formal agreements for all NASA tracking and data acquisition stations abroad had either been signed or were in final stages of negotiation as the year ended.

TRACKING AND DATA ACQUISITION

NASA's ground tracking and data acquisition networks must be capable of supporting four basic types of operational missions: 1) vertically fired sounding or research rockets; 2) earth satellites; 3) manned earth satellites; and 4) deep space probes requiring communication over vast reaches of space.

In 1960, NASA began extending its 10-station Minitrack earth satellite network by initiating construction at the following four high-latitude stations: East Grand Forks, Minn.; Fairbanks, Alaska; St. Johns, Newfoundland; and Winkfield, England. The network also underwent a number of modifications and improvements to increase its scope and effectiveness.

The following progress was made with the three-station Deep Space Network:

1) New transmitting equipment at the Deep Space Instrumentation Facilities at Goldstone, Calif., was installed in time for the station to take part in the Echo I experiment.

2) Construction of the receiving station at Woomera, Australia, moved to completion.

3) Site surveys and other ground work for the station at Krugersdorp, Union of South Africa, were completed.

NASA began studies of larger antennas for its deep space stations. The Jet Propulsion Laboratory, Pasadena, Calif.,

which directs the deep space tracking network, has published requirements for a large antenna in the 250-foot class that would increase the Goldstone stations range 10 to 20 times.

Another significant development was the extension to December 31, 1961 of NASA's contract with the University of Manchester, Manchester, England for use of the Jodrell Bank radio telescope in NASA's space program.

ADVANCED RESEARCH PRIMARILY IN SUPPORT OF SPACE ACTIVITIES

Propulsion

NASA plans for coming space missions require the design and development of a family of larger, more powerful launch vehicles, requiring advanced methods of propulsion. The agency is employing several approaches, extending from the development of liquid propellants that hold promise of yielding higher energies and the improvement of solid propellants, to propulsion systems based on several different types and combinations of nuclear and electrical power.

Liquid Propellants -- At present, nearly all major U.S. vehicles (except Scout, a large solid rocket) are fueled with kerosene and liquid oxygen, a relatively low-energy propellant-oxidizer combination. However, NASA is developing liquid-hydrogen and liquid-oxygen engines whose 25 percent greater specific impulse will substantially increase payload and mission capabilities. Such an engine is the XLR-115, which will be employed in a cluster of two as the second stage of the Atlas-Centaur vehicle and will produce 15,000 pounds of thrust. A scaled-up version, the XLR-119 -- producing 17,500 pounds of thrust -- will be used in a cluster of four for the second stage (designated S-IV) of the Saturn C-1. Two XLR-119 engines will be clustered for the second stage of later Centaur vehicles and in the third stage.

NASA's giant Saturn vehicle will use the H-1 rocket engine, a 188,000-pound-thrust unit based on the Thor design -- modified to improve simplicity and reliability. Eight of these kerosene-liquid oxygen engines will be clustered in Saturn's first stage to produce 1.5-million pounds of thrust, quadruple that of the Atlas, the most powerful U.S. rocket today.

A series of Saturn cluster-firing (using an interim 165,000-pound thrust engine in the cluster) tests have been made, starting with two engines, and progressing to the full

eight which have produced approximately 1.3-million pounds of thrust for short periods. Several engine components are being redesigned to withstand higher operating temperatures.

Development of the J-2, a single-chamber, 200,000-pound thrust, liquid hydrogen-liquid oxygen engine, was begun in September. Clustered, these engines will be installed in the second stage of the advanced C-2 version of the Saturn.

During 1960, development continued on the F-1, the 1.5-million-pound-thrust single-chamber engine being considered for Nova, the next generation vehicle beyond Saturn. Work was completed at NASA's Flight Research Center, Edwards, Calif., on a new test stand (2A) to check out the F-1 at full rated capacity. Unfortunately, tests were delayed nine to 14 weeks when a trial run on August 21 damaged the stand. The long-range development plans call for a preliminary flight-rating test of the F-1 engine in February, 1963. It is not yet known whether time lost because of the August accident can be made up and schedules met.

NASA extended development work on a liquid-fluorine liquid-hydrogen rocket engine, theoretically capable of very high performance. The combination is extremely reactive and toxic, however, and imposes severe handling problems. The engine is now in the "breadboard," or laboratory (workable but nonflyable) stage, and test results have been encouraging. A chamber capable of producing 7,000 pounds of thrust has been operated with high performance and no damage to equipment.

NASA has continued investigating the "plug nozzle" concept for rocket engines. In this, the rocket exhaust gases, instead of flaring out from a bell-shaped vent, push into the atmosphere or space from combustors arranged in segments around a central, inverted cone, or plug. The plug deflects the hot gases and permits them to expand in cone fashion, thus providing greater thrust area. Use of small, segmented chambers, instead of the much larger chambers of conventional rockets, has this advantage -- combustor units can be arranged to produce engines of various sizes or thrusts.

Work has also gone forward on other problems directly related to chemical propulsion. Included are studies of propellant-tank insulation materials for cryogenic (extremely cold) propellants, studies of the mechanics of combustion, and investigations of the effects of solar radiation and other space-environment conditions on fuels and oxidizers such as liquid-hydrogen, liquid-oxygen, hydrocarbons, and hydrazine.

Solid-Propellant Rockets -- A number of advantages are inherent in rockets utilizing solid propellants. NASA is expanding work on the technology of this approach to space propulsion. The solid rocket concept is relatively simple. In theory, large powerful models should require less time to develop and should be less expensive to manufacture than their liquid counterparts. They require no pumps, valves, turbines, and other elaborate components or launching crews with long training in multiple specialties. Despite these and other advantages, solid rockets have been little used except for sounding rockets and for comparatively small (3,000 to 5,000-pound-thrust) final stages for such launch vehicles as Thor-Able, Atlas-Able, and Delta.* The limiting factor is that solid propellants have not thus far been developed to ultra-high energy levels.

Several NASA-sponsored studies have indicated the possibility of developing a solid-propellant first stage 30 percent smaller and lighter than a liquid counterpart. During 1960, NASA let three contracts for definitive studies of very large solid-propellant engines to serve as first stages of launch vehicles. Such vehicles could carry added weight in their upper stages and thus greatly increase payload sizes.

Three NASA contractors are working concurrently on six-month studies for two specific vehicles. The first vehicle will be in the one-million-pound gross weight class, about the same as the liquid-fueled Saturn; the second will weigh about seven million pounds. Basic factors to be considered are economy and reliability. Designs will employ existing propellants and materials. Methods of steering these large solid-propellant rockets will also be studied.

During the year, NASA let a number of new contracts to develop high-performance, solid-propellant rocket engines. Work continued on similar, existing projects, including an experimental rocket engine with "layered" construction, an unconventional "nozzleless" rocket, and a sounding rocket combining several advanced design features to increase performance over present units by an estimated 40 percent.

* The one notable exception is Scout, NASA's 36,000-pound, four-stage launch vehicle, which can place a 150-pound payload in a 300-mile orbit.

Nuclear Energy Applications for Space -- The most advanced liquid- and solid-propellant rocket engines are rapidly approaching the performance limit set by the available energy of chemical combustion. Nuclear reactors, on the other hand, are capable of essentially unlimited energy release, so that even first-generation nuclear rocket engines promise twice the performance of the best chemical rockets.

In cooperation with the AEC, NASA is working to develop an operational nuclear rocket (Project Rover) as early as possible. NASA supports the AEC's rocket reactor field tests by developing complementary non-nuclear equipment which can be used in engines and vehicles. NASA is responsible for integrating the reactor into engines and flight vehicles, and for supplying the liquid hydrogen propellant for all phases of the program.

Effort is also continuing on nuclear electric power generating systems, particularly SNAP-8, a joint AEC-NASA project that appears doubly promising because it may be suitable for basic propulsion as well as for auxiliary generating systems.

Now in the research stage are higher power systems to follow SNAP-8. New technologies will be required, based on the use of liquid metal working fluids (coolants) that can operate at higher temperatures than the mercury employed in SNAP-8. Methods must be devised for containing metal vapor, for lubricating rotating parts, and for discharging excessive heat through space radiators. A program of applied research is in progress.

Electric Propulsion -- In April, NASA awarded two contracts for a one-year competitive project to develop a laboratory model of a 30-kw arc-jet engine. This system, for primary propulsion on space missions where long operating lifetimes and high efficiency will be required, employs an electric arc through which a propellant such as liquid hydrogen is passed and heated to several thousand degrees F. The heated propellant then expands as a gas and is ejected through a rocket nozzle. The thrust from this engine, which will be about the size of a standard thermos bottle, is only about a half-pound -- very low, but of extremely high jet velocity and hence, of great efficiency in space where gravitational forces are weak. It will require an auxiliary electric generating plant such as the SNAP-8 nuclear system.

In September, NASA issued a contract for a one-year program to develop a 1-kw arc-jet engine, producing a thrust of about 1/100th of a pound. Operating on principles similar

to those of the larger unit mentioned above, this device would be used for spacecraft attitude-control and stabilization systems. Also under contract study is an experimental ion engine, about 8 inches in diameter and 12 inches long, which it is hoped, will produce 1/100th of a pound of thrust.

ADVANCED RESEARCH
PRIMARILY IN SUPPORT OF AERONAUTICS ACTIVITIES

Typical Advanced Aeronautics Research

Aircraft Aerodynamics -- During 1960, NASA's Langley and Ames Research Centers continued their research across the entire speed range of aircraft, extending from VTOL (Vertical Take-Off and Landing) aircraft that can take off, land, and hover at zero forward speed, to the rocket-launched Dyna-Soar manned orbital glider with which the U.S. Air Force plans to explore velocities between 4,000 and 18,000 mph.

At Ames Research Center, a study was made of flying and performance requirements of VTOL and STOL (Short Take-Off and Landing) aircraft. A valuable tool in this research has been an X-14 deflected aircraft modified to simulate characteristics of various VTOL/STOL aircraft. Fitted with special equipment to vary stability, damping, and control, this X-14 is being used to check out the performance of many types of aircraft during any portion of their flight, from hovering through all transition phases to forward flight at full speed. Studies are augmented by wind tunnel experiments and data from ground-based simulators.

At Langley Research Center, flight studies and wind tunnel tests with tilt-wing VTOL have been continued, to learn more about their flying qualities. Performance has been improved appreciably. Langley has also made studies of a jet-powered turbofan engine that combines vertical or short take-off with high subsonic cruise speeds.

Fluid Mechanics -- At Lewis Research Center, heat transfer experiments are being carried out in a flow tube and in a shock tube, to investigate processes that occur at the molecular level. Other studies involve interactions of ionized gases at very high temperatures or in the presence of strong electric and magnetic fields. Knowledge from this basic research can be applied to problems such as the cooling of hypersonic engines and vehicles, and the drags and pressures on vehicle bodies.

Aeronautical Propulsion Systems -- Research on air-breathing engines at Lewis and Langley continued to be primarily devoted to problems of air inlets. Several basic conclusions have been drawn from wind tunnel studies. For example, a pipe-like, or duct-like, three-dimensional inlet, in which air is compressed internally as it passes through, appears to hold special promise for hypersonic applications. Another design, called the "spike" inlet because of its shape, is also undergoing tests.

Several other studies were carried out to improve performance of jet-engines at speeds and altitudes other than those for which they were designed. It was found that streamlined terminal fairings around the nozzle exit of a jet engine may improve performance at near-sonic speeds with little effect on characteristics at the supersonic speeds for which the engines were designed.

Flight Safety -- As in former years, NASA devoted much attention to problems of flight safety, operations, and environment. Studies were carried out to increase the accuracy of aircraft altimeters over long periods of service, since regulations call for an altimeter to be calibrated for accuracy only once. This is particularly important because a pilot must know his altitude accurately if he is to maintain the necessary vertical separation between his flight path and those of other craft flying on the same airway. To a considerable degree, assigned separation determines how much traffic an airway can accommodate. Other continuing investigations concerned noise sources on supersonic transports, "downwash" effects on VTOL aircraft, "wake" effects of large transport aircraft, measurements of winds and wind shears, and assessments of physiological conditions of pilots under various environmental stresses.

NASA ORGANIZATIONAL CHANGES

NASA's personnel increased from 9,755 to more than 15,600 during the year -- reflecting for the most part, the transfer to the agency of the Development Operations Division of the Army Ballistic Missile Agency, Redstone Arsenal, Huntsville, Ala. On July 1, NASA officially took over the Division's personnel, facilities and 1,200 acres at the Arsenal. President Eisenhower named it in honor of the soldier-statesman General George Catlett Marshall.

To facilitate standardization of launch operations and facilities, the agency created the Launch Operations Directorate (LOD) within the Office of Launch Vehicle Programs. LOD will launch most NASA vehicles, support the

launch operations of the remainder, and provide launch support for several Army vehicles.

NASA also established the following Offices:

...the Office for the United Nations Conference, to direct this country's participation in the First International Conference on the Peaceful Uses of Outer Space.

...the Office of Life Sciences, to operate a research program dealing with 1) survival and performance of man in space; 2) the effect of the space environment on biological organisms, systems and processes; and 3) the search for extraterrestrial life forms.

...the Office of Reliability and Systems Analysis, to supervise a program to evaluate and improve operational reliability of NASA launch vehicles and payloads.

...the joint Atomic Energy Commission-NASA Nuclear Propulsion Office to facilitate the cooperative effort in the development of nuclear rocketry. AEC will have responsibility for development of all reactors and their components, including those for flight missions specified by NASA. NASA will have primary responsibility for research and development of engines and rocket vehicle systems.

LONG RANGE STUDIES

NASA has established a Committee on Long Range Studies pursuant to Subsection (4), of section 102(c) of the National Aeronautics and Space Act of 1958. The committee has awarded contracts to private research organizations to study the wide-ranging socio-economic and political implications of space technology activities.

In October, the American Bar Foundation completed a study entitled "Report to the National Aeronautics and Space Administration on the Law of Outer Space" (see Appendix A).

NASA AND DOD ORGANIZE COORDINATING BOARD

On September 13, 1960, NASA and the Department of Defense announced formation of an Aeronautics and Astronautics Coordinating Board. The Board has co-chairmen, one from NASA and one from DOD. Officials managing aeronautics and space activities in the two agencies make up membership of the board.

DEPARTMENT OF DEFENSE

INTRODUCTION

The Department of Defense (DOD) continues to be primarily interested in applying the new capability for space flight to achieve a more efficient military force for the United States and its allies. Space efforts of the Department are integral to the over-all military program, complementing or supplementing other military activities.

During 1960, the tempo of military space activities increased. Several noteworthy successes were achieved, among them: 1) recovery of capsules from orbit; 2) launching of multiple payloads from one vehicle; and 3) feasibility demonstrations of satellites for accurate all-weather navigation and communications relay.

The military departments cooperate in developing space applications under the close supervision of the Director of Defense Research and Engineering. Military space projects are assigned to appropriate departments after due consideration of their particular interests, responsibilities, or special competence. For example, development of reconnaissance and early warning satellites was assigned to the Air Force, navigational satellites to the Navy, and communication satellites to the Army. Other projects are, or will be, handled in a similar manner. Space activities are closely coordinated between departments concerned. The Air Force is responsible for launching all military satellites.

To insure close working relationships, and to integrate DOD and NASA space activities into a single national effort, a NASA-DOD Aeronautics and Astronautics Coordinating Board was established. The Board is co-chaired by the Deputy Administrator of NASA and the Director of Defense Research and Engineering of DOD. Through the Board membership and six functional area panels, projects and project support are planned, reviewed, defined, and adjusted to eliminate duplications and to augment effort in areas requiring it.

Twenty-one launch attempts were made with 12 successfully attaining orbit.

A brief summary of the major programs follows:

MAJOR PROGRAMS

DISCOVERER

Particularly emphasized was the DISCOVERER satellite program, testing components, propulsion, and guidance systems and techniques to be utilized in various U.S. space projects. Capsule recovery is foremost among techniques being studied. On August 11, the U.S. recovered from the Pacific Ocean a DISCOVERER capsule that had been in orbit about a day. This event marked the first time that any nation had successfully recovered a man-made object after it had orbited the earth. The capsule was donated to the Smithsonian Institution. An American flag taken from the payload was donated to the Eisenhower Memorial Museum, Abilene, Kan.

In later experiments, additional U.S. capsules* were recovered in mid-air by aircraft equipped with slings.

Included in the DISCOVERER Program is the AGENA upper stage vehicle, which is also used as a satellite vehicle for MIDAS, SAMOS, and other programs. AGENA has proven to be a highly reliable vehicle. The propulsion system has never failed. The stabilization system, which makes recovery possible, is the first to maintain an earth-oriented attitude. AGENA has also exhibited accuracy and effectiveness. The latest version, AGENA B, with double the tank capacity and twice the burning time of AGENA A, was successfully tested on DISCOVERER XVII in November. Everything worked according to plan, including ejection of the capsule from AGENA, and mid-air recovery after 50 hours of orbital flight.

TRANSIT

The TRANSIT satellite navigation system, initiated early in 1958, is in the second phase of the program: 1) developing shipboard navigation gear, 2) increasing system reliability, 3) improving accuracy--including research and experiments in the refraction and geodetic areas, 4) simplifying system and shipboard operation, and 5) studying aircraft navigational systems and making preliminary design.

TRANSIT satellites placed in orbit were completely successful. All subsystems operated properly and all four radios transmitted normally. Excellent refraction data and limited data on the shape of the earth were obtained. Position

* Total of three mid-air recoveries to date.

determination experiments from these satellites have proven TRANSIT fixes to be accurate to within one-quarter of a mile.

Plans are under way for an operational, completely passive system to insure reliable, all-weather navigation. Ships anywhere on the globe will be able to receive not only navigational information but also the exact times and the predicted orbits of the satellites. Voyages for ships of all nations can thus become safer and more efficient.

GREB

The Solar Radiation Satellite GREB (Galactic Radiation Experiment Background) launched pick-a-back on TRANSIT, transmits continuous measurements of solar activity in the X-ray and ultra-violet radiation bands. These solar "weather reports," correlated with a host of ground level observations, help to unravel the mysteries of ionospheric behavior and the mechanisms of solar storms.

This satellite system has contributed significantly to scientific knowledge. For example, in August there occurred a solar flare lasting 18 minutes. Just as the flare began, a satellite came within range of a ground receiving station, and six minutes of clear signals depicted the history of the way that ultraviolet and X-ray emission developed. The sequence of events in the early life of a solar storm is extremely rapid. No previous observations provided a continuous record of the first minutes of a solar storm's birth.

MIDAS

The goal of the MIDAS project is development of a reliable, operational satellite-borne missile defense alarm system. MIDAS will place in orbit payloads having infrared detection scanners that can detect the launching of ballistic missiles.

In 1960, the first two research and development MIDAS satellites were launched from the Atlantic Missile Range (AMR). The second launch, which placed an infrared scanning satellite into orbit for the first time, obtained valuable infrared background data relating to the earth's surface.

ARGUS

The ARGUS experiments, in which nuclear explosions were set off in the exosphere, were successfully completed in 1959. However, data are still being analyzed and used in other space

research and air defense programs, for example, VELA (see pp. 27-28). The results continue to shed light on the fundamental nature of the Van Allen belts (Great Radiation Region) and on the earth's magnetic field.

NOTUS

This project, for developing a communications system utilizing satellites to provide long-range radio communications links, was reoriented to emphasize two programs: COURIER and ADVENT.

COURIER demonstrated the feasibility of a delayed repeater satellite to relieve crowded point-to-point communications when the COURIER 1B satellite was successfully launched in October. Vast quantities of information were relayed between the ground stations at Puerto Rico and New Jersey. The COURIER portion of the NOTUS project is now completed.

ADVENT is intended to demonstrate the feasibility of an instantaneous repeater located at a fixed position above the earth, revolving at the same speed as the earth. The project should provide broadband, point-to-point communication and ground-to-aircraft communication. Organization for management was completed and the principal program contractors were selected.

SHEPHERD

The objective of this program is to obtain, at the earliest practicable date, a space surveillance tracking system that can satisfy military and other requirements. Present systems are SPASUR (Space Surveillance System) and SPACETRACK (National Space Surveillance Control Center); both were placed under control of the Commander-in-Chief, Continental Air Defense Command, in November.

SPASUR, a network of radars, can detect and determine the orbit of any objects in space passing over the United States at altitudes up to 1,000 miles, regardless of whether they are sending out signals. As an example of the capability of this system, early in 1960 SPASUR detected an unknown object in orbit around the earth. The orbit was determined and, from this, the object was identified as a part of a previously launched DISCOVERER satellite vehicle that had been "lost" for some time.

The primary functions of SPACETRACK at Bedford, Mass., are to calculate orbital elements of all satellites and to maintain a catalog of these elements and distribute the information to the military services, intelligence agencies and the scientific community. The center was constructed in 1959 and began operation in January 1960. Data are received from many sources, including SPASUR. Information is given out on a cooperative basis. A study was completed of anticipated future requirements in space detection, tracking and cataloging to aid in determining future requirements for an operational military system.

LONGSIGHT

The purpose of Project LONGSIGHT was to find and remedy serious short- and long-term gaps in study and research relating to foreseen military needs in space technology. During the report period, the study was concluded. A sub-project, ORION, continues. It is a study of the feasibility of propelling very large payloads through space by means of a series of nuclear explosions. Early in 1960, after initial engineering feasibility studies, the project was reoriented toward answering basic questions to determine performance. Engineering studies were continued at a level that should give approximate estimates of design parameters. In addition, the Atomic Energy Commission laboratories were requested to aid in design studies of nuclear devices for propulsion vehicles of the ORION type.

SAMOS

Project SAMOS is a research and development program to determine the capabilities for making observations of the earth from satellites. The first SAMOS flight test was in October, when SAMOS I was launched from the Pacific Missile Range (PMR). However, due to equipment malfunction during launch, orbit was not attained. Research and development on essential components is continuing.

VELA

The Department of Defense, in collaboration with AEC, NASA, and the Departments of Commerce and Interior, has developed Project VELA, whose objective is a system for

detecting nuclear explosions, both underground and at high altitudes. VELA is subdivided into three research and development programs:

- 1) VELA Uniform: detection of underground nuclear explosions;
- 2) VELA Sierra: ground-based detection of nuclear tests in space; and
- 3) VELA Hotel: satellite-based detection of nuclear tests in space.

SAINT

The Satellite Inspector System (SAINT) program, intended to develop and demonstrate a rendezvous and inspection satellite, will place inspection payloads in orbit in close proximity to specified targets.

LORRAINE

Research in advanced energy conversion is being highlighted by the establishment of this new project. On a continuing basis, LORRAINE will support advanced program needs within the Department of Defense. Progress continued on energy conversion techniques and energy storage and collection.

BLUE SCOUT

The BLUE SCOUT program is directed toward developing and standardizing an economical, versatile, and reliable test vehicle to improve components, subsystems, and specialized techniques related to military space activities and ballistic missile development.

Available facilities at Cape Canaveral were used to launch two BLUE SCOUT vehicles. On September 21, one achieved a probe altitude estimated at more than 14,000 miles during a seven-hour flight. The second, launched on November 8, blew up after 68 seconds.

PROJECT TRANSFER TO NASA

In March, all administrative and technical responsibilities for Project Saturn were transferred to NASA.*

* See Chapter 1

DYNA-SOAR AEROSPACE SYSTEM DEVELOPMENT*

The Dyna-Soar system development is a joint DOD-NASA program, financed and administered by DOD, to construct and test a manned, maneuverable aerospace vehicle that will explore hypersonic flight up to orbital speeds. The project will establish and confirm the basic technology to develop weapons systems or other vehicles capable of orbit, atmospheric entry, and maneuver to a conventional landing at a pre-selected air base.

After an intensive three-month review of technical features, the program was approved in April. The glider, the launch vehicle, and launch vehicle engines were contracted for.

Studies covering more than 20 areas were completed. A comprehensive wind tunnel test program to develop performance, stability, and control data for a range of Mach 0.3 to Mach 18 was conducted. Structures and materials are being refined and tested at an accelerated rate.

SPACE FLIGHT SUPPORTING RESOURCES

During 1960, 10 NASA and 21 DOD space vehicles were launched from AMR, and from the Vandenberg AFB and Pt. Arguello launch areas of PMR, utilizing the support of the National Missile Ranges. To a substantial extent, these launches were supported by existing facilities and equipment initially provided for missile requirements. In a number of cases, however, facilities have been augmented with equipment to support the newer upper-stage rocket engines.

Construction was begun and is proceeding at AMR to provide a launch capability for the Atlas-Centaur combination and the Saturn vehicle.

* See Chapter 1

CHAPTER III

U. S. ATOMIC ENERGY COMMISSION

INTRODUCTION

During 1960, the Atomic Energy Commission (AEC) expanded its efforts in connection with the National Space Program. Work has continued on Project Rover (an effort to attain nuclear rocket propulsion) and Project SNAP (a series of nuclear-generated auxiliary electric power systems for spacecraft). The Commission's Los Alamos Scientific Laboratory (LASL) is also conducting research on a plasma thermocouple for direct conversion of fission heat.

PROJECT ROVER

Rocket reactor development under the joint AEC-NASA Project Rover is centered at LASL. A vigorous program is under way to develop a first generation reactor suitable for early flight tests. A concurrent effort is directed toward developing lighter, higher-powered reactors.

During 1960, Kiwi-A Prime and Kiwi-A3, the second and third experimental reactors in the Kiwi* series, were successfully tested at the Nevada Test Site. Both reactors used high-pressure hydrogen gas as propellant, but contained modifications and design improvements over the earlier design for increased performance. Fabrication and assembly of Kiwi-B, the first experimental reactor of a flyable design, were initiated during the year. Facility modifications and construction began at the Nevada Test Site in preparation for the first of a series of Kiwi-B tests scheduled for 1961. The new reactor series will involve the use of liquid, rather than gaseous, hydrogen as the coolant-propellant. This is a requirement in a flyable system.

PROJECT SNAP

The SNAP (Systems for Nuclear Auxiliary Power) program has been developing compact, lightweight, long-lived, nuclear

* Kiwi-A was tested in 1959. See Chapter 3, Second Annual Report to Congress from the President of the United States.

electric power packages for use in satellites and space vehicles. Two developmental approaches have been followed: 1) radioisotope-powered systems, and 2) small reactor-powered units.

The radioisotope units are being developed by the Nuclear Division of The Martin Company, Baltimore, Md. The reactor units are being developed by Atomics International, a division of North American Aviation, Inc., Canoga Park, Calif.

The SNAP program also includes the development of techniques, materials, and equipment for advanced heat-to-electricity conversion systems capable of operating in the space environment. The SNAP program has demonstrated compact turboelectric conversion units, using mercury vapor as a working fluid. Furthermore, to convert heat directly to electricity without moving parts, banks of solid state thermoelectric elements have been successfully designed and configured as static generators surrounding the SNAP heat source. Development efforts are being conducted to demonstrate the advantages of high-temperature thermionic conversion systems for space applications, and to provide the long-term reliability essential to operation in space.

Companies participating in the energy conversion portion of the SNAP program, in addition to Martin and Atomics International, are Thompson-Ramo-Wooldridge, Inc., Cleveland, Ohio; Aerojet-General Corp., Azusa, Calif.; Minnesota Mining and Manufacturing Co., St. Paul, Minn.; Thermo-Electron Engineering Corp., Cambridge, Mass.; and Westinghouse Corp., Pittsburgh, Pa.

Radioisotope Space Power Systems

The SNAP-3 generator was developed to demonstrate the feasibility of using radioisotopes as a heat source for a completely static (no moving parts) thermoelectric generator system. The first SNAP-3 unit was delivered to the AEC by The Martin Company in January 1959. Four SNAP-3 units have been fueled and demonstrated in Washington, D.C.; Cleveland and Cincinnati, Ohio; Topsfield, Mass.; San Francisco, Calif.; Baltimore, Md.; Tokyo, Japan; and Buenos Aires, Argentina. SNAP-3 produces four watts from 2,000 curies of Polonium-210 and weighs four pounds. This unit has been subjected to shock, vibration, and acceleration operational tests; fire, explosion, high velocity impact, corrosion, and plasma jet safety tests; and a 10-month life test. Performance has indicated it to be suitable as a low-power generator for space use.

The SNAP-1A thermoelectric generator is being developed to demonstrate the use of higher powered space generators of the SNAP-3 type, fueled with fission waste products. SNAP-1A, designed to produce 125 watts of electrical energy for one year, is fueled with 880,000 curies of Cerium-144. It weighs approximately 200 pounds. Environmental tests of an electrically heated unit have been completed. Safety studies and tests, very similar to those run on SNAP-3, have been conducted, and ground equipment, to assure safe handling in ground operations, has been fabricated. Hot cell tests of a fueled SNAP-1A will be initiated in 1961 when the unit is fueled with the proper quantity of Ce-144 and design tested through its operating performance.

The SNAP isotopic power program also includes studies of a curium fuel technology and nuclear safety, both directly applicable to space power units. The safety effort includes atmospheric entry burn-up tests, launch trajectory studies from Cape Canaveral, and lunar impact studies. Much of this current work is directed to supporting requirements for radioisotope thermoelectric generators for the U.S. Navy navigation satellite (TRANSIT) and the NASA lunar soft landing mission (SURVEYOR).

A thermionic generator is being developed that will produce 7-10 watts and weigh about nine ounces. Electrically heated prototypes have been fabricated and tested for as long as 2,100 hours. These devices use close-spaced, high-vacuum, thermionic diodes developed under the SNAP program by the Thermo-Electron Engineering Corp. A demonstration device fueled with curium-242 will be delivered in 1961.

Reactor Space Power Systems

SNAP-2 -- The SNAP-2 space power system for satellites is based on a small zirconium-hydride-moderated reactor, homogeneously fueled with three kilograms of U-235. The reactor portion of the system weighs approximately 220 pounds and produces three kilowatts of electrical energy at 1,200°F outlet temperature. The turboelectric conversion equipment (consisting of the turbine and a brushless inductor electrical generator) is mounted on a single shaft which also powers the necessary auxiliary pumps for the system. The entire unit is hermetically sealed. The overall weight of SNAP-2 is approximately 600 pounds, exclusive of shielding. The SNAP Experimental Reactor, after completing a one-half year test -- operating at design power and temperature for 50 percent of the time -- was shut down on November 18 for post-operational examination. The SNAP-2 Development System is being installed in a test facility

completed in October at the AEC's site in Los Angeles County. Integrated reactor and power conversion system tests will begin early in 1961.

SNAP-8 -- SNAP-8 is a joint AEC-NASA project to develop a reactor and power conversion system to produce either 30 or 60 electrical kilowatts of usable power. The SNAP-8 reactor is being developed by the AEC as an extension of the SNAP-2 reactor and will use similar components. The reactor weighs approximately 300 pounds, is fueled with 5.2 kilograms of U-235, and will produce 700 thermal kilowatts reactor power at 1,350 F outlet temperature. Reactor tests will prove out the reactor design and configuration. The turboelectric conversion system developed by NASA is designed as a module concept to produce 30 electrical kilowatts. Two of these units can be powered from the SNAP-8 reactor to produce a useful output of 60 electrical kilowatts. The reactor and conversion systems will be combined and tested as a full system in facilities to be constructed at the AEC site in Los Angeles County. This space power plant is expected to weigh approximately 900 pounds, exclusive of shielding.

SNAP-10A -- SNAP-10A is an AEC project originated through Air Force interest for a low-power, lightweight, static, electric power source for space applications. A SNAP-2 reactor core will be utilized with sodium potassium liquid metal coolant. An electromagnetic pump forces the coolant from the reactor core to the thermoelectric elements where the heat is converted directly into electricity. The SNAP-10A system is designed to weigh less than 750 pounds including shielding. SNAP-10A will produce 500 watts of electricity continuously for at least one year in a space environment.

PLASMA - THERMOCOUPLE

The work at LASL on direct conversion of fission heat by thermionic (electron) emission from a nuclear fuel (zirconium carbide-uranium carbide) in a cesium plasma diode continues to show promise. Additional work of this nature is being conducted by several industrial contractors both as "in-house" and government-supported projects. Recent results from a single cell experiment in the LASL Omega West Research Reactor gave a maximum power of about 85 watts, and a maximum current of about 130 amps. The estimated efficiency was about 13 percent, a reasonable efficiency for this early stage of development. Theoretical efficiencies as high as 50-60 percent have been predicted for the future, but only after a prolonged period of development. In another experiment, three-unit cells were combined in electrical series in a triple-cell

assembly and operated in the Omega West Reactor. As expected, the output voltage of approximately nine volts was roughly three times the voltage of each unit cell. Sufficient power was developed to operate a six-volt car fan.

DEPARTMENT OF STATE

INTRODUCTION

Throughout 1960, the United States continued to play a leading role in encouraging international consultation on the opportunities and problems arising from the exploration and use of outer space. Forums of discussion have ranged from the United Nations to non-governmental scientific meetings and from multi-lateral consultation to bilateral negotiation. In all these activities the United States has vigorously pursued its national policy of fostering international cooperation in space research and exploration and in seeking effective international control of outer space activities.

ACTIVITIES WITHIN THE UNITED NATIONS GENERAL ASSEMBLY

The position of the United States on the urgent problem of appropriately controlling the use of outer space was clearly set forth in the President's Address of September 22, 1960, to the General Assembly of the United Nations. The President pointed to the importance of reaching speedy international agreement on measures to "enable future generations to find peaceful and scientific progress, not another fearful dimension in the arms race, as they explore the universe." To this end the President proposed to the members of the General Assembly that:

"1. We agree that celestial bodies are not subject to national appropriation by any claims of sovereignty.

"2. We agree that the nations of the world shall not engage in warlike activities on these bodies.

"3. We agree, subject to appropriate verification, that no nation will put into orbit or station in outer space weapons of mass destruction. All launchings of space craft should be verified in advance by the United Nations.

"4. We press forward with a program of international cooperation for constructive peaceful uses of outer space under the United Nations. Better weather forecasting, improved worldwide communications, and more effective

exploration not only of outer space but of our earth -- these are but a few of the benefits of such cooperation."

In addition, the United States has been engaged since the beginning of the year in negotiating the organization of the United Nations Committee on the Peaceful Uses of Outer Space. This Committee, composed of twenty-four members of the United Nations, was established by the Fourteenth General Assembly and assigned a number of tasks proceeding largely from problems identified by the July 14, 1959 Report of the Ad Hoc Committee on the Peaceful Uses of Outer Space. The Committee's tasks include studying scientific and technical programs in the peaceful uses of outer space that could appropriately be undertaken under United Nations auspices and studying the nature of the legal problems that might arise from the exploration of outer space. The General Assembly also decided to convene before the end of 1961 under the auspices of the United Nations an international conference for the exchange of experience in the peaceful uses of outer space. The Outer Space Committee was requested to work out proposals with regard to the convening of such a conference.

OTHER INTERNATIONAL ACTIVITIES

During 1960 the Department of State has continued its activities related to the emerging political and legal problems of outer space. The Department has also maintained its efforts in support of the technical requirements of the United States outer space effort and in implementing cooperative arrangements with other countries.

Agreements have been substantially completed respecting the worldwide tracking and communications network supporting Project MERCURY, the installation of deep space tracking facilities, and the extension of the Minitrack network.* Arrangements were also made for other facilities needed in connection with governmental programs of outer space research and development.

The Department has worked closely with NASA to facilitate scientific cooperative arrangements and, on an inter-agency basis, the Department has initiated preparations for the Extraordinary Administrative Radio Conference to be held in 1963 to consider further the allocation of frequencies for space communications.

* See Chapter 1.

THE NATIONAL SCIENCE FOUNDATION

INTRODUCTION

One of the principal objectives of the National Science Foundation is to support basic research of a pioneering nature. This is done primarily through grants to nonprofit institutions for the support of research projects proposed by staff scientists of the institutions involved. A substantial part of these efforts is in support of scientific investigations that seek an understanding of the fundamental laws of the physical universe. A limited number of grants have been made and contracts awarded to develop special instrumentation or facilities deemed especially important for improving research in particular fields.

PROGRAMS IN BASIC SCIENCE RELATED TO SPACE

The more basic a research result, the wider its area of potential application. It is therefore difficult to establish exact criteria for determining the relationship of a particular project to science in space. In the case of physics research projects -- for example, nuclear physics, plasma physics, low temperature research, and solid state research -- it is difficult to think of an area of investigation that does not have some application to science or technology in space. In the biological and medical sciences, the Foundation supports a very substantial program of research, much of which will find important application in the space sciences. In constructing the tabulation given in Appendix B, the rule has been to include among the projects active during calendar year 1960:

1. All projects in the Astronomy Program.
2. Only those projects in the Atmospheric Sciences Program which deal with the effects of objects outside the earth's atmosphere (such as the sun) upon the earth's atmosphere, or which employ extra-terrestrial vehicles in the research procedure.
3. Only those projects in the Chemistry Program which deal specifically with the chemistry of free radicals and with the behavior of substances at extremely high or extremely low temperatures.

4. Only those projects in the Earth Sciences Program which deal with meteorites, with geophysical properties affecting the earth as a whole or with properties that are detectable at great distances above the surface, such as the magnetic field.

5. Selected projects from the Engineering Sciences Program dealing directly with materials at high temperature, combustion, gas and plasma dynamics and with high-temperature heat transfer.

6. No projects in the Mathematical Sciences Programs, although the Foundation's support of computers for research will find application in many phases of space science -- orbit computation, aerodynamics, and the like.

7. Only those projects in the Physics Program concerned with primary cosmic ray phenomena.

8. No projects in the Biological and Medical Sciences Program, although as noted, much of the supported research will find application in space science.

In some instances, a project will be listed under one Program even though the name of the project would imply that the research is in the area of another Program. In these cases, it should be assumed that the background, interests, and special techniques of the investigators stem from an area of the Program under which the listing is made.

Several projects in the regular programs in support of basic research warrant special mention.

The National Radio Astronomy Observatory

The location of the Observatory -- Green Bank, W. Va. -- was especially selected because radio noise interference there was at a very low level. The instrumentation includes one 85-foot equatorially mounted radio telescope (now in full operation) and one 140-foot telescope similarly mounted (planned to go into operation in 1962). Both telescopes are or will be useable over the entire range of wavelengths employed in radio astronomy down to 3 centimeters. The Observatory is being constructed and operated under contract by the Associated Universities, Inc. All qualified U. S. astronomers have access to these facilities, with priorities determined by the scientific merit of their respective projects.

The Kitt Peak National Observatory

This new installation was established on Kitt Peak, 40 miles southwest of Tucson, Ariz., after extensive surveys indicated that location offered the most promising site in the southwestern part of the United States for research with very large astronomical telescopes. The instruments now planned include a 36-inch reflector and an 80-inch telescope and a 60-inch solar telescope (scheduled for completion in 1962). The solar telescope will be several times larger than any instrument of its kind now in existence. The Observatory is being constructed under contract by the Association of Universities for Research in Astronomy. All qualified U.S. astronomers will have access to these facilities, with priorities determined by the scientific merit of their respective projects.

The Observatory is also undertaking long-range design studies on a moderately large (aperture of about 50 inches) space telescope. The intention is to design an instrument useful for a wide variety of research problems -- involving spectroscopy, direct photography, and photometry in the ultraviolet region -- and with an optical resolution as close as possible to the theoretical limit determined by the aperture. It is hoped that the telescope might be placed in a twenty-four hour orbit and remain operable for at least a year, perhaps for 10 years. If successful, the telescope would be made available to all qualified U. S. astronomers. No time schedule for completion or launching has been set. It is intended that the work proceed free from the pressure of launching schedules as long as is possible. Close liaison is being maintained with NASA; when it is agreed that a workable instrument can be produced, perhaps five or 10 years hence, vehicles capable of placing it in orbit will probably have been developed.

At present, photographic plates constitute the best method for recording information which a telescope collects from an extended area of the sky (such as that occupied by a galaxy or a star cluster). However, even the fastest photographic emulsions available have a very low efficiency. It is generally found that only one photon in every thousand which strike the plate forms a distinct blackened image. Accordingly, it takes approximately 1,000 times as long to photograph a faint galaxy as theoretically should be necessary.

A number of photoelectric devices giving promise of greatly increased efficiency in the photographic procedure have been developed since 1945. They all depend on the fact that photons, when striking an appropriate photoemissive

surface, will cause one electron to be emitted for approximately every ten photons. Each electron can then be given a high energy by means of accelerating electrodes, so that it subsequently produces a distinct blackened image on a photographic plate.

The purpose of the image tube projects is to develop simple, inexpensive, efficient light amplifiers for astronomical purposes. For certain applications these devices in effect multiply the aperture of an existing telescope by 5 to 10 times.

High Altitude Astronomy

The angular resolution obtainable in astronomical photographs taken from ground-based observatories is limited by the fluctuations in the refraction of the earth's atmosphere which are responsible for the twinkling of the stars and produce the condition known as poor astronomical "seeing." When photographs are taken at night with present telescopes, the angular diameter of a point image (such as a star) is never less than 0.3 seconds of arc.

The most promising means of obtaining better resolution in astronomical photographs is to mount a telescope on a platform at an altitude well above most of the earth's atmosphere. The Princeton investigators have already successfully taken photographs of the sun with a 12-inch reflector suspended from a balloon at an altitude of 80,000 feet.

This program is now being extended; a 36-inch balloon-borne telescope is being designed and constructed for observing objects in the night sky. The technique opens up the prospect of greatly increasing our detailed knowledge of the surface features of the moon, Mars, and similar objects. First flights are currently planned for 1961.

This project is being supported by the Foundation cooperatively with the Office of Naval Research and the National Aeronautics and Space Administration.

Physics Program

Cosmic rays originate in outer space. Some also come from the sun or are influenced by it. The energy spectrum and particle spectrum of these rays are directly related to physical processes occurring in outer space. Directional

studies of cosmic rays at high energies are used to help determine the galactic origin of cosmic ray particles. Information on the particle spectrum bears directly on the origin of the universe and its composition.

Neutron flux studies today are of special interest to physicists because of the information these measurements give on the sun and the magnetic fields between the earth and sun.

Balloon flights, rockets, and satellites are used to get information on the cosmic ray particles in their virgin state before they break up in the earth's atmosphere. These high altitude studies are also tied in with the earth's magnetic field and solar activity. These flights may use emulsions, counters, or ionization chambers. Terrestrial telescopes which are sensitive to air showers are also employed to obtain information on the cosmic source of very high energy particles.

Atmospheric Sciences Program

The atmosphere around us has been receiving increased study for decades. The problems today are not new, but unique facilities, such as satellites, offer a method of obtaining observations and hence of improving research into atmospheric phenomena of interest to both aeronautics and space research. The investigations include such studies as the physics of atmospheric motions; the earth's planetary albedo; the effect of solar activity on atmospheric circulation and distribution of meteorological phenomena in the stratosphere; the variability in the composition of the stratosphere; and tidal oscillations in the stratosphere.

Engineering Sciences Program

The supersonic flight of a high-speed vehicle, or missile, in the upper atmosphere poses a number of engineering problems. The frictional drag quickly heats up the solid surface to temperatures so extreme that not only is the structure of the vehicle endangered but also the flight behavior is changed. The gas layers adjacent to the heated surfaces also become red-hot and the gaseous molecules become stripped of their electrons, ionized, and electrically conducting. Under these extreme conditions the flow behavior becomes drastically altered and extremely complex. To understand these flow patterns, physical measurements and theoretical studies are not only made at high speed of the drag of various shapes, but also the rate of heat loss

by various mechanisms, and the influence of the extent of ionization and the nature of the gaseous medium on the maximum temperatures attained. In fact the properties of a high-temperature, ionized gas are so unusual that it is given a special name -- a plasma -- and is the subject of a large amount of theoretical and experimental study, particularly when the pressure is also low. Other studies seek to explore the thermal conductivities and other properties of substances at the extreme temperatures involved.

DEPARTMENT OF COMMERCE

THE NATIONAL BUREAU OF STANDARDS

While the National Bureau of Standards (NBS) is not specifically charged with a primary responsibility for national aeronautics and space activities, its work contributes to, and must be considered an essential part of, the total national program. Space technology programs are not independent of previous experience in research and engineering, but must draw upon existing knowledge as well as obtain new understanding of the physical phenomena with which they are concerned.

Because NBS is responsible for developing and improving physical standards and for advancing techniques of measurement, its programs have an important bearing on all research programs. The relationship is basic to space exploration, which depends heavily on precision measurement. NBS provides the standards to meet space measurement problems and requirements and to furnish basic data on properties of matter so that scientists and engineers can develop devices that will operate at the great speeds, high temperatures, and other severe conditions encountered in space and in entry of vehicles into the earth's atmosphere.

The report on aeronautics and space activities for calendar year 1959 described NBS programs that were directly related to space technology. During calendar year 1960, these activities continued.

Standards and Measurement Methods

Length -- Demand for closer dimensional tolerances in the production of many components of space devices has placed a premium upon improved measurements of length. Progress can be reported in three aspects of the search for ultraprecision: 1) During the year, techniques were developed to permit a fivefold improvement in accuracy-of-length measurements. For the first time in history, the Bureau calibrated commercial gage blocks to better than one part in five million. 2) Significant progress was achieved in developing gage block materials that are far more stable than the best in current use. 3) These

advances take on added significance in the light of action in October by the 11th General Conference on Weights and Measures which established a new international standard of length. Redefinition of the meter in terms of the wavelength of a specified light emission from the element krypton should foster further increase in accuracy in length measurement.

Frequency and Time Interval -- For several years, NBS has been carrying out intensive research to establish atomic standards for frequency and time measurement. Based on an unchanging property of the atom, such standards would have decided advantages over the present one -- the period of the earth's rotation about the sun. During 1960, two cesium-beam atomic standards for frequency and time-interval measurement were placed in operation, providing NBS and the nation with the world's most precise frequency standard. This makes it possible to refer the national standard of frequency to an atomic resonance with an accuracy better than two parts in 100 billion. Radio broadcasts of standard frequency signals by the Bureau are now monitored by reference to this precise frequency standard.

Work also progressed on an atomic frequency standard for use in a NASA satellite that will check the gravity-dependent frequency shift predicted by Einstein's general theory of relativity. A prototype rubidium vapor standard was constructed and found to be stable to one part in 100 billion over a period of a month. Exposure to radiation, corresponding to that of the Van Allen Radiation Belts (Great Radiation Region), produced no observable change in measurement accuracy. The standard is being miniaturized for the satellite.

Scientists and engineers engaged in rocket testing and in satellite and missile tracking urgently need improvement in the accuracies with which radio signals of standard frequency and time interval can be transmitted to remote locations. Accuracy of NBS radio signals is limited by small, erratic variations caused by changes in the height and density of the ionosphere from which the signals are reflected. To reduce errors (insignificant before the stringent requirements of the Space Age), the Bureau has undertaken an experimental program of broadcasts at a low frequency (60 kc) and at a very low frequency (20 kc).

Temperature -- Today's requirements for high-temperature materials resistant to high speeds, friction, and increasing propulsion efficiencies place a premium on the upward extension of the temperature scale and on techniques for measuring

it. During 1960, NBS continued projects to increase temperature measurement precision and to extend it into extreme high-temperature regions. Recent advances include a photoelectric optical pyrometer that improves calibrations up to 4000°C, and a special type of high-temperature resistance thermometer that greatly improves calibration precision in the 630°-1063°C range. Research on high-temperature sources resulted in a high-current arc that appears promising as a stable and reproducible standard for the region from 10,000° to 20,000°C.

Force -- Measuring large forces precisely has become especially critical in determining the thrusts of powerful, advanced rocket engines that the U. S. is developing. During rocket engine development, relatively small increases in the accuracy of large force measurements will save millions of dollars by reducing the number of test firings. Moving toward this goal, NBS has completed basic designs for dead-weight, force-measuring machines of 300,000-pound and 1,000,000-pound capacity and for a laboratory to house them. By providing improved accuracies, these machines should make it possible to develop better, portable secondary standards that can be utilized in other laboratories.

Pressure -- The extremely low pressures obtained in high-vacuum facilities roughly correspond to pressures encountered many miles above the earth's surface. The need is growing for precise measurement in this pressure range, to assist in space vehicle development as well as in fundamental space research. NBS has established a vacuum standards laboratory to concentrate on evolving standards for extremely low pressures. Initial effort is aimed at generating reproducible pressures to serve as fixed points on a pressure scale. At the same time, progress is being made in establishing high-pressure standards and a well-defined scale for them.

Radio Standards -- Space exploration, communications, guidance and command systems, and miniaturization are subjecting electronic equipment to novel and complex uses and to extreme environments. Consequently, the need for accuracy on the production line becomes increasingly important. To produce uniform and extremely accurate components requires a chain of calibrations leading from the assembly line back to the precise electrical standards maintained by NBS. The Bureau has expanded its program on radio standards research and calibration, seeking improvements in the entire radio and microwave frequency. During 1960, NBS calibration services increased about 45 percent over the

previous year, and new or better standards were established for a number of quantities.

Plasma Physics and Astrophysics -- Many newer fields of technology -- for example, astronautics, ultrasonic aerodynamics, thermonuclear power, and ionospheric communications -- concern a medium whose characteristics are poorly understood: an ionized gas, often at very high temperature, whose particles are continuously interacting. At present, a number of laboratories working in this medium are forced to rely on expensive and inefficient empirical methods because they lack precise measurement techniques and basic data on fundamental properties. To help solve this problem, NBS has unified and strengthened its work in providing standards and measurement methods for plasma and astrophysics data. The Bureau is attempting to develop measurement standards, basic data, theoretical guidance, and interpretative techniques for determining the relevant properties of ionized gases. Investigations involve basic research in atomic cross sections, transition probabilities, reaction rates, statistical mechanics, and theoretical astrophysics. The NBS goal is to provide understanding fundamental to physical interpretation of experiments and observations of the terrestrial, planetary, solar and stellar atmospheres.

Properties of Materials

Requirements of the space program for basic data on properties of materials under extreme environmental conditions and for completely new applications have underscored the role of NBS in this area of research. During 1960, primary emphasis was given to reorganizing and reorienting materials research to make it more responsive to the latest needs for basic data.

The program has been directed toward the preparation and analysis of the extremely pure and precisely described materials required for studies of fundamental properties. Emphasis has been given to techniques of precise determination of composition, structure, and presence of impurities or imperfections, as well as the development of methods of preparation of pure materials and of introducing minute impurities and imperfections into pure materials. Fundamental NBS Programs in chemical kinetics, chemical thermodynamics, and reaction mechanisms also received greater support.

Cryogenic Engineering -- NBS work on properties of materials at extremely low temperatures has been particularly

relevant to space technology because cryogenic fluids are extensively employed for rocket propulsion. During the year, this work was extended (through direct cooperation with NASA and NASA contractors) to: 1) provide fundamental data on liquid hydrogen; 2) undertake studies of cryogenic instrumentation; 3) compile data on low temperature properties of a number of materials; and 4) study cryogenic problems in particular developmental programs so that design principles and materials utilization criteria could be established.

Radio Propagation

The use of passive and active satellite telecommunication systems should revolutionize radio telecommunications within the next few years. The work of the Central Radio Propagation Laboratory (CRPL) of NBS is laying the groundwork to exploit this major technological advance. Much of the basic research of CRPL on upper atmosphere physics and radio propagation through the atmosphere -- as well as research in communication theory, antennas, and components -- will strengthen the entire field of space telecommunications. Development of advanced instrumentation for communication, navigation, and guidance of spacecraft requires more and more knowledge about composition of the atmosphere and interplanetary space, and the refraction, absorption, and scattering of radio waves in these media. CRPL activities supporting space communications are high-lighted below:

Satellite Ionospheric Studies -- Following its detailed observations of ionospheric effects on radio signals from satellites, CRPL has been participating in planning for similar ionospheric experiments to come, including: 1) refraction observations at two or more frequencies, 2) radio beacons, and 3) satellite soundings of the ionosphere from above.

Atmospheric Turbulence -- Extensive CRPL studies of phase stability of radio waves propagated over point-to-point paths have provided information required in the design of guidance systems, as well as basic data on the nature and effect of turbulence in the atmosphere between transmitting and receiving antennas.

Direction Finding -- Using radio stars as a source of radio waves, CRPL has studied the perturbations of radio waves passing through the ionosphere. The fundamental information on the distortion of directional signals by scintillation and refraction effects is aiding in determining

and improving accuracy of radio signals to and from vehicles in and beyond the atmosphere.

Upper Atmosphere Physics -- Broad CRPL studies of the dynamics, composition, and physical characteristics of the ionosphere and upper atmosphere have provided important information for use in designing space communication systems.

Work has progressed on the design and installation of a high-power scatter radar facility to exploit a new technique that provides, for the first time, a practical means of using ground-based equipment to measure electron density variations of the ionosphere out to great distances. Such data could previously be obtained only through expensive satellite and rocket measurements. This electron density variation, or profile, is of great importance to scientists concerned with the dynamic and static structure of the outer atmosphere. Accurate measurement of the profile is an absolute necessity in all missile and satellite activities requiring radio tracking of the vehicle trajectory or orbit.

The highly sensitive scatter radar facility is expected also to provide previously unavailable information on kinetic temperature of heavy ions, identity of ionized constituents, hydromagnetic aspects of coherent irregularities, and the physical processes of absorption of radio energy in the lower ionosphere. This information should aid in overcoming several serious limitations to practical applications of radio propagation through the ionosphere.

WEATHER BUREAU

Several aspects of the United States space program are of great importance in Weather Bureau plans. The Bureau's activities in relation to meteorological satellites center largely in its Meteorological Satellite Laboratory (MSL) which is supported by the National Aeronautics and Space Administration (NASA). The Bureau is participating with other agencies in a meteorological sounding rocket program. Meteorological observation and forecast support is provided by the Bureau to the Pacific Missile Range and NASA's Wallops Station and Project Mercury. International aspects of meteorological satellites are receiving much attention in the Bureau's activities and planning, in coordination with NASA.

TIROS I and Cloud Cover Analysis*

The TIROS I satellite, launched by NASA on April 1, 1960, provided 22,592 pictures of the earth's cloud cover by means of wide-angle and narrow-angle television cameras. The cloud patterns seen by TIROS ranged in size from large cyclones to small cumulus clouds. These pictures are being studied in detail by research meteorologists in the MSL to explore the meteorological significance of the cloud forms.

Among the most striking cloud patterns photographed by TIROS are the large-scale cyclonic vortices (or storms) whose spiral bands are sometimes more than 1,000 miles in diameter. For example, when pictures of several of these vortices were studied in conjunction with conventional meteorological data, Weather Bureau scientists learned the structure of moisture fields, the cloud structure of frontal zones, the relation of spiral cloud bands to the wind flow, and the cloud patterns associated with jet streams. TIROS pictures taken over the oceans have already indicated points in the standard meteorological analyses that could be improved, both in connection with cyclonic vortices and frontal and non-frontal cloud bands of considerable horizontal extent in the tropics and middle latitudes.

Perhaps most important are the contributions that TIROS data are making toward a better understanding of the physical processes associated with cyclonic vortices and widespread cloud areas. A cellular arrangement of cumulus clouds has been found that may be significant in transfer of energy and moisture from ocean surfaces to the atmosphere. Cloud "streets," or long narrow lines of clouds, often observed in TIROS pictures, have been theoretically associated with the wind field. The pictures of cells and streets are being compared with conditions prescribed by theory or prevailing in laboratory experiments.

The satellite pictures are also contributing to detection and study of severe local storms. Very bright cloud images have been observed frequently in TIROS pictures. In several cases, research has verified that pronounced cumulus clouds produced the images. In one instance, an isolated, bright cloud area has been definitely associated with a zone of severe thunderstorms that produced tornadoes a few hours later.

* For other information on TIROS I, TIROS II, and other meteorological activities, see Chapter 1.

Other phenomena revealed in TIROS pictures are cloud and snow cover in mountain regions in various parts of the world, ice on sizeable bodies of water, and sunlight on the oceans.

Judging from studies of TIROS I photographs, it is obvious that satellite pictures add an entirely new dimension to meteorological observations. The ability to view both gross and detailed features of cloud patterns makes it possible to detect and obtain valuable information on the structure of storms and other circulation systems over almost any portion of the globe. Experiments carried on during the life of TIROS I indicate that the information can be used to improve analyses of surface and upper air weather charts in regions where, heretofore, data has been sparse, and to provide detailed cloud information -- now difficult to obtain -- for certain aircraft operations, rocket testing, and other specialized activities.

TIROS II

The second TIROS satellite was launched by NASA on November 23, 1960. In addition to television cloud cameras similar to those carried by TIROS I, the second TIROS payload included instruments for measuring solar and terrestrial radiation. These will assist research meteorologists in studying general circulation of the atmosphere and in determining many features of atmospheric composition and temperature. The radiation experiment and narrow-angle television camera system have worked satisfactorily, but to date the wide-angle camera system has not provided pictures of as high quality as those obtained from TIROS I.

Based on TIROS I results, an increased program for the experimental operational use of the satellite cloud picture data was carried out for the second meteorological satellite. Teams under Weather Bureau leadership were located at readout stations to analyze these cloud pictures promptly and transmit the findings to the Bureau's National Meteorological Center, near Washington, D. C. The data will be used at the NMC and also relayed by facsimile and teletype circuits to military and civilian meteorological centers elsewhere. MSL is employing the Bureau's electronic computer facilities for much of the processing of radiation data obtained from the second TIROS.

In preparing the second TIROS satellite, MSL worked closely with NASA, particularly in calibrating the television cameras and radiation sensors, in developing

systems for data processing, and in training personnel for operational phases of the second TIROS program.

Explorer VII Satellite-Heat Budget Experiment

Explorer VII, launched by NASA on October 13, 1959, contains a heat budget experiment designed by Professor Suomi of the University of Wisconsin. In this experiment, measurements are being made of the energy received by the earth (both atmosphere and ground) from the sun, the solar energy reflected by the earth to space, and the infrared energy emitted by the earth. Measurements of the net heat (heat budget) received from the sun by the earth from day to day will aid in understanding the general circulation of the atmosphere.

To increase data coverage from Explorer VII, MSL arranged early in 1960, to install five additional data receiving stations which operated most of the year. Four are located at Weather Bureau offices; one is operated by the Air Weather Service of the USAF. MSL edited the data received from these stations before sending it to Professor Suomi for processing. The Laboratory also provided assistance to the University of Wisconsin in coding the machine program for processing the data. Some of the data were also processed by the MSL.

Preliminary examination of the heat budget data indicates a logical physical relationship to the weather patterns seen on standard weather maps. When this report was prepared, the Explorer VII heat budget experiment was still operating during daylight. Following the launching of TIROS II, data were to be collected from the Explorer VII satellite for comparison with those obtained by TIROS II. Additional comparisons, made by launching radiation instruments attached to balloons released from U.S. Weather Bureau stations for Explorer VII will be continued for TIROS II.

Studies have been conducted to determine various energy parameters and atmospheric heat transport which are related to general circulation of the atmosphere. As large amounts of Explorer VII and TIROS II heat budget data become available, measurements will be related to computed atmospheric heat transport and energy parameters and, thus, to the general circulation of the atmosphere.

Advanced Meteorological Satellite Experiments

MSL has been working closely with NASA on developing the Nimbus satellite, the first of which is scheduled for launching in 1962. Theoretical studies have been completed and laboratory work is in progress to develop a prototype infrared spectrometer for satellite use. The instrument will assess worldwide temperature distribution in the stratosphere and upper troposphere by measuring radiation emitted in the 15-micron carbon dioxide band. The instrument would also obtain measurements in the 11.1 micron water vapor "window," which can be used to determine the temperature at the earth's surface or cloud tops.

A preliminary engineering feasibility study has been completed on the use of satellite-borne radar to detect precipitation. Further engineering studies are being conducted by MSL in conjunction with the U.S. Army's Diamond Ordnance Fuze Laboratories. Theoretical studies have been completed on a technique for measuring atmosphere ozone from meteorological satellites. The possibility of measuring the height of cloud tops from satellites utilizing pulsed light techniques has also been investigated.

Planning for Operational Meteorological Satellite System

The dramatic success of TIROS I has emphasized the potentialities of meteorological satellites for providing worldwide weather observations. This will not only meet U.S. requirements, but will enhance this country's efforts to employ space for the benefit of all mankind. The Weather Bureau has prepared a preliminary plan for establishing and operating a joint system of meteorological observation satellites for all U.S. Government agencies concerned in weather activities.

Meteorological Rocketsondes

The Weather Bureau is continuing to participate with other Government agencies in the development and utilization of meteorological sounding rockets to extend observations above the maximum altitudes that can be obtained with conventional balloon sounding techniques. A preliminary meteorological rocket network, operated by the Department of Defense and NASA during 1960, is providing meteorological data for research and to determine atmospheric conditions encountered by high altitude vehicles. The Bureau participates in coordinating data analysis and research,

and is making the data available through the Bureau's National Weather Records Center.

Meteorological Support for Space Activities

A team of Weather Bureau meteorologists takes meteorological observations at NASA's Wallops Station. They also prepare forecasts and provide meteorological advice to support operations at the station.

The Weather Bureau provides extensive meteorological support for the Pacific Missile Range through operating weather observing stations in California and the Pacific, some of which were established specifically for range support.

At the request of NASA, the Weather Bureau is providing meteorological forecasting support for Project Mercury. Three meteorological groups are operating at the National Meteorological Center, near Washington, D. C. and at Cape Canaveral and Miami, Florida. Arrangements have been made to acquire meteorological data along the path of the Mercury capsule to be used in forecasting for the project.

By providing climatological data and studies, the Weather Bureau also serves as meteorological consultant to other groups engaged in space activities.

International Activities

The Weather Bureau is participating in international aspects of meteorological satellites. Representing the United States, the Bureau has kept the World Meteorological Organization (WMO) informed about U.S. meteorological satellites. As a result, panels and working groups have been established in the WMO to stimulate progress and to plan and coordinate the international use of meteorological data. In addition, Bureau personnel serve on other international bodies such as the Committee on Space Research (COSPAR) and the International Union of Geodesy and Geophysics (IUGG).

Following the success of TIROS I, Bureau personnel presented several scientific papers at meetings of international committees and scientific bodies. The Bureau has also distributed a limited number of TIROS I pictures and supporting data to weather services and research groups in other countries. All TIROS pictures will be made available to interested international groups early in 1961.

The Weather Bureau is working with NASA on a program of international participation in support of the TIROS II satellite experiment. Several countries have agreed to take special meteorological observations when TIROS II is passing over their country. These observations and satellite data will be exchanged. Later, all TIROS II data will be made available to any group desiring them.

COAST AND GEODETIC SURVEY

Calibration and testing of instruments designed by NASA and its contractors have been carried on at the Fredericksburg (Md.) Magnetic Observatory and Laboratory. The unique facility at the observatory for this work is a set of coils about 18 feet in diameter which provide a working space in which the geomagnetic field at any point on the earth's surface or in interplanetary space can be duplicated. Moreover, special controls permit holding the magnetic field constant -- free from the disturbances of normal, almost continuous, variations of the field, which are occasionally severe enough to be called a "magnetic storm."

Instruments for artificial satellites, and for high altitude rockets (including moon shots) have been tested and calibrated in the Fredericksburg coils to determine not only the performance capability of the magnetic equipment, but also to measure quantitatively the induction effects at very low field intensities of other equipment and of the vehicle itself.

CHAPTER VII

SPACE SCIENCE BOARD

INTRODUCTION

The Space Science Board was established in June 1958 by the President of the National Academy of Sciences to serve as the focus of the Academy's interests in space science. The Board is intended to be advisory and consultative.

Domestically, the Board serves in an advisory capacity to agencies of the Federal Government having executive responsibilities in the field of space science. These agencies are the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the Department of Defense (DOD). Because NASA and NSF have primary responsibility for civilian space science, the relations of the Board to these agencies have been particularly close, and the Board is supported by these two institutions. The Board has provided advice and recommendations on a variety of subjects relating to basic research; it has served to represent the interests of scientists; and it has sought to provide a broad scientific base for current and future U.S. space science efforts by stimulating the scientific community to take an interest in space research.

Internationally, the Board, as the Academy's agent, provides for cooperation with scientists of other countries. The vehicle for such cooperation is the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU). Adherence to this committee is provided by the Academy through the Board's Committee on International Relations, whose chairman serves as the delegate to COSPAR. The Board, its committees, and Academy staff have devoted considerable effort to problems of international cooperation during 1960.

The members of the Board serve as chairmen of fifteen specialized committees covering the various scientific disciplines and fields of activity associated with the country's space science program. The Board and its committees are composed of approximately 150 leading scientific specialists. (Membership of the Board and its committees is given in Appendix A.)

DOMESTIC ACTIVITIES

The Board has devoted a major portion of its time and attention during this year to the longer range objectives of space science. The Board convened its specialized committees in each discipline to consider development of comprehensive program goals for planetary exploration in the 1970's, followed by a similar study of the research programs for the 1960 decade to ascertain what would be required to insure the success of the later planetary program. Comprehensive briefings by NASA personnel supplemented and expanded on previously prepared program documents and recommendations at each committee meeting.

The various committees of the Board have held 20 formal meetings during the year and a large number of informal discussion sessions. The Board itself met in Washington (March) and in Arcadia, Calif. (June). As a result of these deliberations, reviews and plans have been transmitted in formal recommendations for consideration by the appropriate agencies of the Government.

Study Groups

In addition to its regular ad hoc committees, the Board has convened several special study groups to consider specific problems. Six such groups held a total of ten meetings during the period. The following brief descriptions are indicative of topics which the Board has considered to be of importance in the conduct of the space research program.

Project West Ford -- This communications system has been critically reviewed throughout the year by a special study group in order to assess its impact on a number of fields of science, such as atmospheric and ionospheric physics, radio and conventional astronomy, etc. As a result of its study, the Board has made recommendations to the Government concerning the conduct of the experiments and has arranged for presentation and discussion of the technical details internationally. It continues to provide advice and information to project personnel through a small specialized group of scientists.

Planetary Atmospheres -- With the focusing of attention on planetary exploration, the Board recognized the need to bring together the special competences of a number of scientific disciplines. In order to examine the state of current knowledge about the atmospheres of the planets, the Board convened a conference in conjunction with its June meeting. Meteorologists, both theoretical and observational, and planetary astronomers met with upper atmosphere and ionospheric physicists to discuss and assess ways

and means of improving and expanding this information. Proceedings of this conference are scheduled for publication in the Transactions of the American Geophysical Union in early 1961. As a result of this conference a small working group of specialists began work in December to compile a definitive study of the planetary atmospheres; this study will serve as a research guide in the immediate years ahead and will stimulate interest in planetary research, so that the necessary information about planetary environments will be available on a timely basis.

Balloon, Rocket and Ground-based Observations -- The Board has continued to recommend to the Government and to the scientific community that those investigations which can be performed with high altitude balloons, rockets or from the ground should be supported to the maximum extent, considering their value in relation to the more expensive satellite and space probe experiments. Conventional ground-based astronomical studies of the planets carried out by experienced observers supplemented by work with balloon-borne telescopes, can provide much information about planetary atmospheres. Similarly, the use of rockets as geophysical and astronomical tools should not be overlooked. To this end, the Board has established a committee on rocket research under the chairmanship of Dr. William W. Kellogg, which coordinates the several disciplines in the exploitation of this research tool.

Chemical Analysis of Meteorites -- Late in 1959, as a result of continued Board concern for the lack of a coordinated program to collect and analyze meteorites, the Board convened a small group of chemical analysts and curators of meteorite collections under the chairmanship of Professor Harrison Brown. Implementation of the Board recommendations endorsing the findings of this conference has established the California Institute of Technology as a clearinghouse for cataloguing, analyzing and otherwise coordinating and facilitating the chemical analysis of meteorites, as a step toward understanding of the space environment.

Laboratory Astrophysics -- The Board has recognized the ever increasing demand from observational geophysicists and astrophysicists for values of those physical parameters that they need for the interpretation of results, such as collision cross sections for various physical processes, wavelengths, intensities, and transition probabilities in energy ranges like the far ultraviolet that have only now become accessible through observations from outside our atmosphere, and in this connection has noted the excellent work of the National Bureau of Standards. Recommendation for continuance and expansion of such laboratory work to provide the

answers to these needs was forwarded to the Secretary of Commerce and other interested Government agencies.

Nuclear Propulsion -- A small panel, under Board members Professors Donald F. Hornig and Harold C. Urey, has kept the Board informed of the nuclear propulsion programs for space vehicles. As a result of this information, the Board has urged that no reasonable research project aimed at providing some radical and different means of propulsion should be overlooked, because some way must be found to break through the limitation on specific impulse imposed by chemical fuels. Continuing emphasis on current nuclear propulsion investigations has been recommended.

Geodetic Satellite -- On advice from NASA that the scientific satellite planned for the improvement of geodetic data had been canceled, the Board convened a small group of geodesists to conduct a preliminary inquiry into the matter, and formally requested the President's Science Advisory Committee to determine whether or not the program now proposed meets the requirements recommended by informed geodesists.

Biological Contamination -- The Board has continued to emphasize the need for avoidance of biological contamination of the Moon and planets until suitable biological investigations can be conducted. It is also noted that the return of probes to the earth with lunar or planetary samples raises problems of back contamination.

Other Biology -- During 1960, in support of the newly established NASA Office of Life Sciences, the Board has increased its emphasis on the biological sciences with the addition of three committees: Exobiology, Dr. Joshua Lederberg, Chairman; Environmental Biology, Dr. Colin S. Pittendrigh, Chairman; and Man-in-Space, Dr. Christian J. Lambertsen, Chairman.

Auroral Zone Rocket Launching Site -- The value of rocket launching sites in the auroral zone, and the scientific results obtained from rocket launchings at Ft. Churchill during the IGY in particular, provided the basis for the Board recommendation that continued financial support by the U.S. is in the scientific interest.

Space Mathematics -- A special study group of eminent mathematicians has been convened within the National Research Council to examine the problem of space research susceptible of solution by mathematical techniques, for example, data reduction, information theory, orbit computation and satellite prediction information.

Satellite Tracking Requirements -- A special study group has been organized to assess current satellite tracking and orbit results and procedures in relation to scientific requirements. The report of this group is expected to be available early next year.

Radio Frequency Allocations -- In continuance of 1959 activities, the Board has provided advice to NASA, Federal Communications Commission, and other governmental agencies on the requirements for allocation of radio frequency bands to meet special research requirements. It continues to work closely with the responsible government agencies as well as the National Academy of Sciences Committee on Radio Frequency Protection and the relevant committees of the International Radio Scientific Union (URSI).

"Science in Space" -- During the early part of this period, the Board devoted considerable effort to a report on the research possibilities and objectives of space science, called Science in Space. The report was issued in nine separate pamphlets, distributed both domestically and internationally.

World Data Center A, Rockets and Satellites -- During 1960, the operation of the Data Center within the Academy continued to provide a means for international exchange of scientific data resulting from rocket and satellite programs. At the request of COSPAR, the Center will continue to serve the needs of international cooperation in furthering the peaceful exploitation of space research. The Center added some synoptic data from the Meteorological Network to its catalogue and has systematically exchanged data with Centers B (Soviet Union) and C (United Kingdom). The following reports were issued during the period:

Satellite Report Series: Number 10, Determination of Ionospheric Electron Content and Distribution from Satellite Observations; Number 11, Observations of Corpuscular Radiation with Satellite and Space Probes; Number 12, Ionospheric Research with Satellites

Rocket Report Series: Number 6, A Second Compilation of US/IGY Rocket Program Results.

Several additional volumes in each series are being prepared for issue early in 1961.

INTERNATIONAL ACTIVITIES

COSPAR Charter Adopted

COSPAR was established by ICSU in October 1958, and its initial organizing meetings were held in November 1958 and in March 1959. At the third meeting, held in Nice, France, January 8-16, 1960, delegates from 13 countries and from 6 ICSU Unions adopted the present COSPAR Charter. National members present at this meeting included Argentina, Australia, Belgium, Canada, France, Germany (West), India, Japan, Poland, South Africa, United Kingdom, US and USSR.

Results of COSPAR Meeting at Nice

Among the more significant actions taken at the meeting were the following: An International Rocket Interval for 1960 (September 16-22) was established, and rocket experimenters from all countries were urged to perform rocket soundings during the quarterly world meteorological intervals for 1961. Biologists were requested to undertake experiments to develop basic data for quantitative specifications to be used in decontaminating and sterilizing spacecraft. Action was taken to insure collaboration with the International Telecommunications Union in allocating radio frequencies for space research purposes. Recommendations were adopted on the exchange of information on satellite launchings, including pre-launch and post-launch data and orbital elements. The world-wide communication system, known during IGY as AGIWARN, was endorsed for this purpose under the new name SPACEWARN. Plans were developed for an interdisciplinary study of the remarkable geophysical events that occurred during July 1959; a symposium on this subject was held during the IUGG Assembly at Helsinki in August 1960. A preparatory group was organized to develop an international reference atmosphere for the properties of the upper atmosphere, above the present 32 km altitude limit. Resolutions were adopted initiating the publication of a monthly COSPAR Bulletin, an annual compilation of rocket flight summaries and a consolidated list of published sources of information on results of space research. COSPAR formally adopted a resolution noting with satisfaction the resolutions passed by the General Assembly of the United Nations to establish a Committee on the Peaceful Uses of Outer Space and to convene an international scientific conference for the exchange of experience in the peaceful uses of outer space. This resolution also offered the services of COSPAR in any matters within its competence to the United Nations Committee. Subsequently, COSPAR has conferred with the UN Committee and has offered its services in particular for the purpose of organizing the scientific program of the UN conference.

Other COSPAR Accomplishments

A meeting of the Bureau of the Executive Council of COSPAR was held in Stockholm from August 11-13, 1960. The Bureau reviewed the budgets for 1960 and 1961, considered reports on the three working groups of COSPAR and developed plans for the fourth COSPAR meeting scheduled for April 1961.

Rocket Interval -- On behalf of COSPAR, the Space Science Board and its staff helped coordinate the U.S. contribution to the COSPAR Rocket Interval for 1960. Approximately 35 research rockets were launched by U.S. scientists during the period September 16-22, 1960. The greater number of these -- approximately 27 -- were for meteorological purposes. Results of rocket experiments during this period will be reported by the Space Science Board to COSPAR for distribution to the world scientific community and will also be deposited in the World Data Centers established during the IGY. Two major international rocket intervals have been scheduled by COSPAR for 1961. The first, from February 12-18, will be concerned primarily with solar-terrestrial effects related to the total solar eclipse of 15 February and the atmospheric structure during the Northern Hemisphere's winter. Launchings during the second interval, July 16-25 will emphasize atmospheric structure during the Northern Hemisphere's summer. Rocket firings devoted to upper atmosphere and solar observations also will be made during the quarterly meteorological world intervals in January, April, and October, 1961.

The 1959 July Event -- COSPAR has initiated an interdisciplinary study of the remarkable series of geophysical events that occurred during July, 1959. As part of this study, COSPAR was instrumental in organizing a symposium on this subject at the IUGG Assembly held in Helsinki in August, 1960. The Board took an active part in organizing the participation of U.S. scientists.

International Symposium -- In addition to the administrative sessions at the third COSPAR meeting, the dates of January 11-15, 1960, were set aside for the First International Space Science Symposium. This scientific meeting was organized into separate sessions on the following subjects: Earth's Atmosphere, Ionosphere, Cosmic Radiation and Interplanetary Dust, Solar Radiation, The Moon and Planets, Meteorites, and Tracking and Telemetering. About 300 scientists from 20 countries attended; and 101 scientific papers were read by scientists of 12 countries. Forty-seven papers were presented by scientists from the U.S. The full proceedings of the symposium have been published by the North-

Holland Publishing Company. The Space Science Board coordinated U.S. participation and contributions to this symposium, and assisted in planning and publication aspects.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

INTRODUCTION

The Smithsonian Astrophysical Observatory, under a NASA grant, has technical direction of the Baker-Nunn Optical Tracking Network -- a worldwide system of 12 stations equipped with special cameras of great precision and power. The Observatory is also responsible for operating the network and reducing and analyzing the data it obtains.

TRACKING AND DATA SYSTEMS

Baker-Nunn Optical Network

Direction and Operation -- The Baker-Nunn Optical Tracking Network consists of nonmobile precision cameras capable of photographing a very faint object (13th magnitude) to an accuracy of 4 seconds of arc and 2 milliseconds of time. Associated are 110 international volunteer visual Moonwatch stations in 22 countries, which supply additional approximate observations and act as a surveillance system for lost satellites.

Capabilities and Locations -- The network makes it possible to determine precisely the initial trajectories of space probes and the orbits of satellites. It is also useful for geodetic research leading to precise information on the shape of the earth and the relative positions of the continents. The 12 sites of the Baker-Nunn cameras are: Jupiter, Florida; Curacao, Netherlands West Indies; Arequipa, Peru; Villa Dolores, Argentina; Olifantsfontein, Union of South Africa; San Fernando, Spain; Shiraz, Iran; Naini Tal, India; Woomera, Australia; Tokyo, Japan; Maui, Hawaii; and Organ Pass, New Mexico.

Accomplishments -- Approximately 17,200 satellite passages have been photographed by the network as of September 30, 1960, and 17,000 recorded visually by Moonwatch. The current output is approximately 1,200 useful photographs per month. A number of scientific results relating to the upper atmosphere and the gravitational potential of the earth have been derived.

Future -- No new Baker-Nunn Optical Tracking Stations had been planned as this report period ended.

CHAPTER IX

FEDERAL COMMUNICATIONS COMMISSION

INTRODUCTION

The Federal Communications Commission's activities in the fields of space communication, radio astronomy, and aeronautics greatly increased during 1960, mostly because of the many new and unique problems arising from rapid technological and scientific developments in telecommunications. For example, applications for experimental licenses were filed by private enterprise to permit research on civil communication systems employing space satellites, the feasibility of which was demonstrated by the Echo project during 1960.*

These and similar events during the year have served to emphasize the many difficult telecommunication problems that must be solved, especially those anticipating the operational use of such systems. Progress has also been made toward implementing the 1959 Geneva Radio Regulations which provide specific frequencies for space communications research and radio astronomy. Emphasis was also placed on the preparatory work for the forthcoming special International Telecommunications Union (ITU) conference on space, scheduled for late 1963. Two FCC allocation proceedings relating to space communication frequency requirements were instituted during the year; VHF aeronautical frequencies underwent major reallocation to provide more space for Government air traffic control operations. Study was initiated on the technical aspects of sharing between space communication ground terminals and conventional microwave relay communications systems.

SPACE COMMUNICATIONS

Although the Commission is not responsible for any overall space programs or for launch vehicle technology, rapid developments in the space field have created many telecommunication problems. These, by virtue of the obligation under the Communications Act of 1934, as amended, to "...make available, so far as possible, to all of the people of the United States a rapid, efficient, nationwide, and worldwide wire and radio communication service..." involve the FCC to a major extent. The assignment of frequencies for space communication and experimentation directed toward the

* See Chapter 1.

imminent development of a civil communication system employing space satellites are of direct concern to the FCC. During the past year, Project Echo effectively demonstrated the technical feasibility of such a system on an experimental basis. However, the anticipated development and operational use of communications satellites, either active or passive, present a multitude of additional telecommunication problems with which the FCC must cope. Not the least of these is the matter of providing enough suitable frequencies and insuring compatibility between space and surface systems so that the public interest will best be served. Many other regulatory problems will stem from the combined operational use of space satellites and radio.

The solutions to such problems involve both national and international considerations. Accordingly, the Commission is following a policy of close coordination and cooperation with all of the interests involved. There has been increased collaboration between the FCC and NASA at all levels to ensure a common approach to space problems involving both agencies. For example, consultations were recently concluded between the legal staffs on certain questions of jurisdiction. Other interagency activities of the FCC include participation in the following:

- (a) The Telecommunication Coordinating Committee (TCC) of the Department of State -- The TCC has organized an Ad Hoc Working Group under the chairmanship of FCC Commissioner Craven to draft foreign policy recommendations on space communication systems.
- (b) The Telecommunication Planning Committee (TPC), which advises the Office of Civil and Defense Mobilization (OCDM) -- The FCC participates in Panels I and II which are concerned with space matters. FCC representatives participated in a preliminary report accepted by the TPC.
- (c) FCC/OCDM Coordination -- The FCC and the OCDM have joint responsibility for national frequency allocations. Staff work is through joint meetings of FCC representatives with the Interdepartment Radio Advisory Committee (IRAC) and its Subcommittee on Frequency Allocations (SFA).
- (d) The U.S. Committee for Study Groups IV and VIII of the International Radio Consultative Committee (CCIR) of the International Telecommunication Union (ITU) -- The Commission participates in subgroups dealing with matters such as the "preferred characteristics" of operational satellite relay communications systems

and techniques of monitoring, measuring and identifying space vehicle radio transmissions. This is in preparation for the next CCIR Plenary Assembly (New Delhi, 1963).

- (e) Space Science Board (SSB) -- The Commission's Chief Engineer serves as a member of the International Relations Committee of the SSB which is concerned with international basic space research activities, working internationally through the Committee on Space Research (COSPAR).
- (f) The International Radio Scientific Union (URSI) -- The FCC is represented on this group, which is a member of the International Council of Scientific Unions (ICSU).
- (g) National Bureau of Standards -- The FCC maintains scientific liaison with the Central Radio Propagation Laboratory of the National Bureau of Standards through membership on the Interdepartment Council on Radio Propagation and Standards.

International Administrative Radio Conference

The International Administrative Radio Conference held in Geneva in 1959 under the auspices of the ITU led to the adoption of an international table of frequency allocations which, for the first time, provided bands of frequencies for the space and earth-space services. These services were also included in the new international definitions. It should be noted, however, that the bands for space allocated internationally at Geneva are for research purposes only and are useful principally for tracking, control and telemetry functions. Although no bands were allocated internationally for use by operational space satellite relay communication systems, a special ITU Administrative Radio Conference was scheduled tentatively for late 1963 to deal specifically with space problems on the basis of developments as of that time. In that connection, at the request of the Department of State, preparatory work directed toward formulating the U.S. position for that conference has been initiated jointly by the FCC and the Interdepartment Radio Advisory Committee (IRAC).

Domestically, steps have been taken by the FCC toward implementing the 1959 Geneva Radio Regulations nationally, pending the ratification of the Geneva treaty. (Ratification is expected in the first session of the 87th Congress.) It is hoped that basic rule-making actions will be completed in time to meet the May 1, 1961, implementation date. This will

require many amendments to the Commission's Table of Frequency Allocations and corresponding amendments to the Rules governing the various specific radio services administered by the FCC.

As a result of developments in space communications, during 1960 the FCC reopened its proceeding in the general matter of allocating frequencies above 890 mc (Docket 11866). The object was to determine, in the light of all evidence then available, whether the frequency requirements for communications via space satellites would require a modification of the Commission's decision in that proceeding to permit some additional classes of users to establish communications systems utilizing frequencies between 1,000 and 10,000 mc. After a careful analysis of all the evidence, the Commission concluded that its earlier decision need not be modified at that time.

In anticipation of the proposed special administrative conference of ITU tentatively scheduled for 1963, the Commission issued a Notice of Inquiry, Docket 13522; the purpose of this proceeding is to accumulate all available data pertinent to the questions of frequency allocations for communications utilizing space satellites. A court appeal from the Docket 11866 decision has been taken by the American Rocket Society. The first date for comments from the general public in Docket 13522 is March 1, 1961. (Further comments may later be requested by dates stipulated by the FCC.)

It now appears that future allocations to provide adequate frequencies nationally and internationally for space-satellite relay-communication systems will be facilitated by conclusive knowledge of the extent and techniques whereby such systems can operate on a shared basis with other radio services in the spectrum. With a view toward obtaining additional information on this subject, the FCC has been active in stimulating appropriate cooperative studies and experimental programs by both industry and Government organizations.

Need for International Coordination

The need for international coordination in connection with operational space satellite relay communication systems for use internationally was emphasized by visits of foreign space experts during 1960. These groups consulted with Government and industry organizations having an interest in space activities, including the FCC. Space matters of mutual interest were discussed. In view of the fact that no frequencies are allocated internationally for such systems, careful consideration must be given to the interference that might result from

the operations being conducted in this and other countries in accordance with the international table of frequency allocations.

Monitoring of Channels for Space Communications

Another FCC activity during 1960 has been the continued monitoring of channels being used for space communication purposes to prevent their unauthorized use by other stations, and to identify and locate sources of interference. At a number of monitoring stations, special facilities have been installed, including sensitive receivers, high gain directional antennas, and automatic frequency scanning devices. These facilities, which are being further developed, have been employed in handling specific requests to monitor frequencies that have been employed for space vehicle radio transmissions. They have also helped locate interference-free frequencies for such transmissions.

RADIO ASTRONOMY

As pointed out in the previous section on space communications, the International Administrative Radio Conference held in Geneva in 1959 resulted in the adoption of a revised international table of frequency allocations. This table, for the first time in history, included provisions for protecting specific frequencies for radio astronomy use. Among other things, this has the significance of applying to radio astronomy the provisions in the International Radio Regulations regarding the elimination of harmful interference. The groundwork leading to such amendments has already been completed by the FCC and coordinated with the IRAC during 1960. However, until the new Geneva Radio Regulations can be ratified, it is not feasible to incorporate these provisions in the national table of frequency allocations through appropriate amendments to the FCC Rules. Accordingly, the radio astronomy interests in the U.S. are compelled to await ratification of the Geneva Radio Regulations before fully realizing the benefits to radio astronomy contained therein.

The FCC is continuing to study the future needs of the radio astronomy interests in coordination with the OCDM, which is concerned with Government policy, and looks to the National Academy of Sciences for advice in this field.

AERONAUTICS

The FCC prescribes the manner and conditions under which frequencies may be assigned to non-Government licensees for aircraft communications (including telemetry), for aeronautical radio-navigation, and for the control and telemetry in the development of missiles, rockets and satellites.

The higher speeds that result from the commercial use of jet aircraft have created increased demands on communication and aeronautical radio-navigation facilities. Expansion of such facilities has also been necessary to meet the increased volume of air traffic resulting from normal growth in air travel. All of these demands have had to be accommodated within the limited frequency space available.

Flight Safety Requirements

A major reallocation of spectrum space was completed in the band 108-132 mc to provide additional frequencies for air traffic control facilities believed necessary for flight safety. More than 800 aeronautical enroute stations were redeployed to permit the band 126.825-128.825 mc to be made available for exclusive use by air traffic control facilities after July 1, 1960. Frequencies in the band 132.05-134.95 mc also became available for air traffic control after that date. However, the announced requirements of the FAA indicate that the frequencies currently available for operating the air route structure will soon be saturated and a definite shortage will develop by 1963.

Flight-Test Communication Requirements

Because of the continued increase in flight-test communication requirements in connection with the testing of missiles, rockets and satellites, as well as aircraft, by manufacturers, further efforts were made toward assigning adequate frequencies to meet these requirements. Meeting such requirements involves more effective administration in utilizing the limited frequencies available and in exploiting technical advances that will permit greater conservation of frequencies.

UNITED STATES INFORMATION AGENCY

The United States Information Agency (USIA) is responsible for disseminating information abroad on both civilian and military space activities of the United States. In carrying out this function, USIA issues news releases and photographs of individual events, and gives more general treatments of space achievements through distribution of pamphlets, photographs and magazine reprints. Other communications media used frequently include radio, television, motion pictures, and exhibits. Information is obtained from the National Aeronautics and Space Administration, the Department of Defense, the Atomic Energy Commission, and other government agencies participating in the research and development of space and aeronautics.

Instances of worldwide dissemination through USIA facilities are presented herewith, subdivided by the various media employed.

News Releases

During 1960, USIA prepared and distributed more than 250 news and feature stories, totalling more than 100,000 words, on U.S. space activities during 1960. About 175 of these stories covered the activities of NASA; the remaining 75 covered military satellites. All these stories, and many others not tabulated, were transmitted over the regional wireless files (news services directed to USIA offices in the European, Near East and African, Latin American, and Far Eastern areas) and three special wireless files (Eastern Europe, Rio de Janeiro, and Ottawa).

Highlights of NASA coverage were 18 stories on Pioneer V, 20 stories on TIROS I and TIROS II, and 20 stories and orbit timetables on Echo; the latter, distributed in about 150 foreign cities, were especially effective in drawing attention to the United States' increasingly successful space program. Vanguard I and Explorer VII were featured prominently to show their long-term values. The progress of the X-15 experimental rocket-powered airplane was closely covered. Seven "Space Summaries" were prepared and transmitted to the field; these emphasized the U.S. accomplishments in engineering features of its satellites and probes. Detailed summary sheets on individual space

vehicles were obtained from NASA and were distributed to all overseas posts. In addition, special stories were written on the Scout launch vehicle (which is being offered to launch cooperative experiments for foreign nations), Project Mercury, Saturn, and nuclear rocket progress (AEC). Major speeches by outstanding personalities in the space program were also featured.

Publications and Photos

Overseas posts were given quantity reprints of twelve selected articles on space from American magazines such as "Science," "Saturday Evening Post," "Sky and Telescope," "The New York Times," "Science World," "Saturday Review," "Scientific American," and "Johns Hopkins Magazine." The posts also received six "Astrologs" -- a compilation of material from "Missiles and Rockets" magazine. Selected photographs (6,915 prints and 2,441 negatives) on 53 space-related subjects, including captions and brief stories, were sent to 120 overseas posts for distribution to foreign press and publications. Plastic mat pictures totalling 50,731 plastic plates on 21 subjects were also sent to the posts for distribution, as were some 17,000 photo prints and 7,000 negatives on 146 subjects related to space activities.

"America Illustrated," a magazine distributed within Soviet Russia (in exchange for our agreement to distribution of "USSR" here), carried four space stories in its 1960 editions. The subjects were "Weather Satellites," "Dangers of Meteorites in Space Flight," "Education of Young Scientists," and "New Frontiers" (the challenge of space).

Radio and Television

U.S. space activities continued to be a featured theme on Voice of America (VOA) broadcasts during 1960, in the form of newscasts, special events, and scripts, prepared for use abroad both in foreign languages and in English. Newscasts, which constitute about one-half of all VOA services, carried detailed accounts of launchings. Failures were reported briefly and factually; each successful mission was carried as long as the news values justified continued coverage. Successful launchings were invariably the lead stories in a particular day's programming. After the launching of Echo I, over-pass timetables were supplied to the worldwide English and foreign language services for broadcast use. In addition, each announcement of a new

launching included a brief recapitulation of previous successes, showing the steady increase in the number of U.S. satellites aloft, together with a brief mention of the number of Soviet satellites still up. Comparisons were left to the listener, rather than being included in the VOA announcements. Whenever possible, the peaceful purposes of U.S. space launchings were stressed. News roundups also reported all major space launchings and activities, making use of recorded interviews and news conferences, recorded scientific reports in foreign languages, and special trips to launching installations, NASA research and development facilities, universities and laboratories. Launchings covered included Pioneer V, TIROS I, Transit, Polaris, Courier, Discoverer XIII, Echo, and TIROS II. After the launching of Echo I, VOA arranged to have the words of ambassadors and diplomats from 15 nations bounced off the satellite and recorded for later direct broadcasts and other uses in the country of origin of the person concerned.

In preparing scripts on space activities for use in overseas radio stations, 34 special scripts were produced, as well as items to be included in each edition of a weekly science script and another weekly feature entitled "America This Week." A special half hour documentary program "Success In Space -- Twelve Hours to Zero" was a dramatized account of an actual space launching.

For use by television stations overseas, the TV service of USIA gave worldwide distribution (53 posts, including foreign language sound-track users) to the following special space programs: 1) "Architects of Space" -- 15-minute program made at Convair Astronautics; 2) "Project Echo" -- four-minute background story on communications satellite; 3) "Courier Communications Satellite" -- background information distributed to foreign posts in advance of launchings. These were telecast on foreign TV stations at the time of actual launching.

Special programs prepared for TV use by stations in the 20 Latin American Republics included: "Panorama Panamericana" -- a weekly news program in Spanish which covered Echo, the X-15 research airplane, Discoverer, the Astronauts, Courier, Scout, and TIROS; "Challenge of Space" -- four 15-minute programs on space activities in the U.S. Two special 25-minute programs were also prepared and telecast in collaboration with the British Broadcasting Company. They were titled "The American Space Effort" 1) "Non-Inhabited Satellites" 2) "Man in Space".

Motion Pictures

Worldwide distribution of motion pictures was another effective method of telling the story of U.S. space activities to audiences abroad. During 1960, the following films on space subjects were sent in multiple copies to form part of regular USIA public film showings overseas: 1) "Project Mercury," 2) "Exploring by Satellite," 3) "X-15," 4) "Pioneer in Interplanetary Space," 5) "Echo in Space," and 6) "Survey of Astronautics." In addition, newsreel shorts on all major U.S. space events were made available to regular movie theaters abroad.

Exhibits and Libraries

Among the exhibits displayed by USIA overseas, the Pioneer V Space Probe exhibit and the TIROS I model exhibit were standouts. Eight sets of the TIROS I exhibit were sent to as many overseas posts, and are now being exhibited simultaneously. The TIROS exhibit was also shown at the Technical University, Stockholm, Sweden, during the meeting of the 11th International Astronautical Congress. At the Space Development Exhibition of the International Trade Fair in Tokyo (June-July), sponsored by the four large regional newspapers of Japan, a U.S. exhibit made of components supplied by NASA and other U.S. agencies was immensely popular. An exhibit on "Space Unlimited" was reported a "clear-cut favorite" at the Kokura (Japan) Trade Fair where it was displayed between a Soviet exhibit and a Communist China exhibit.

Lecture materials, color-slide transparencies, books and pamphlets on U.S. space subjects have been sent regularly to USIA overseas libraries and Information Centers. In addition, some 350 sets of the National Academy of Sciences' special series of booklets "Science in Space" and about 200 copies of the NASA publication "NASA Industry Program Plans Conference" were supplied to the libraries. A special "Space Lecture" packet was also delivered to libraries and Information Centers abroad where it will be used as lecture material to illustrate the application of experimental data obtained through U.S. space activities to improve meteorology, navigation, and communications for the benefit of the peoples of the world.

APPENDIX A

REPORT TO NASA ON THE LAW OF OUTER SPACE

(October 1960)

(This is an analysis of a 205-page report prepared by the American Bar Foundation under a NASA contract. The report is not a statement of NASA policy but represents a comprehensive compilation of thoughts both in the U. S. and abroad on space law.)

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PREFACE

The American Bar Foundation deems it a privilege to publish as a Foundation volume this "Report to the National Aeronautics and Space Administration on the Law of Outer Space." The document prepared by Professors Leon Lipson of Yale Law School and Nicholas deB. Katzenbach of the University of Chicago Law School, under the guidance of the Advisory Committee, is, we believe, a valuable and scholarly contribution to the ever expanding volume of literature on the subject.

Shortly after the launching of the first artificial satellite in 1957, the American Bar Association, through its Section of International and Comparative Law, formed a Special Committee on Law of Outer Space. David F. Maxwell, Esquire, a past President of the Association, was named its Chairman; its membership included leading authorities in the United States on international law, air law, and space law, as well as certain government officials with responsibilities for legal aspects of space programs. In 1958, the Committee, noting the existence of a growing body of information and scholarly writing on space law, suggested the need of a systematic survey of the literature as a first step toward developing recommendations with regard to a law of outer space. The Committee recommended that the American Bar Foundation undertake that survey.

Early in 1959, the Foundation entered into a contract with the National Aeronautics and Space Administration whereby the Foundation undertook to "conduct research on the law of outer space, including, but not limited to review and analysis of all available space literature and proposals which have been made for the control and administration of Outer space activities." The Board of Directors of the Foundation designated the American Bar Association Section Committee on Law of Outer Space as an Advisory Committee to the project, and appointed Professors Lipson and Katzenbach as Project Reporters in charge of conducting the research.

This Report sets forth the results of the research performed under the contract. Professors Lipson and Katzenbach have been assisted in the task by Roger H. Bernhardt, J. Lani Bader, Eliezer Ereli and Mrs. Sybille Fritzsche, all members of the Foundation staff. The abstracts of the literature and the final Index were largely the work of Messrs. Bader and Bernhardt. Mr. Bader took responsibility for preparing the Tables and Bibliography.

The Board of Directors and staff of the Foundation wish to express their very sincere appreciation to those who have helped in bringing this task to completion, — to the authors for their dedicated service and their scholarly product, to the Advisory Committee for its guidance and helpful suggestions, to the research staff for its diligent service,

and to the National Aeronautics and Space Administration for its encouragement and support.

Attention should be called to the fact that the law of outer space is not only far from being an exact science, but in many of its aspects it is still in a highly controversial state. In view of this fact, no attempt has been made to obtain Committee approval of the Report or its contents. The Committee members do not assume responsibility for any of the positions taken by the Reporters. These responsibilities are assumed by the Reporters themselves. All are agreed, however, upon the high scholarly quality of the Report, and the American Bar Foundation is proud to publish it as a worthy addition to the literature of a new, fascinating and fluid field of the law.

Chicago, Illinois

E. BLYTHE STASON
Administrator

I. ANALYSIS

A. General Problems

1. Introduction

a. Background of Legal Writing

Before the successful orbiting of Sputnik I in October 1957, legal scholars gave relatively little consideration to the problems that would accompany man's entry into outer space. Works on aviation law made occasional mention of the possibility of flight at very high altitudes and of artificial satellites, but only a handful of experts, with interest in aviation, astronautics or international organization, had the vision to see and forecast publicly some of the difficult and important questions that would soon have to be faced by lawyers and statesmen. Among the most notable of these were Cooper, Haley, Schachter, Bornecque, Mandl and Meyer. Since 1957, the streams of legal literature, fed by the general interest in space science and the political and military significance of space activities, have been flowing more abundantly, and considerable interest has been shown by the organized Bar, governments, and universities in many countries.

The great bulk of legal writing has been patterned closely on the ideas put forward by the earlier scholars. While particular proposals, solutions and argumentation have differed, much of the literature revolves around the problems of "sovereignty" posed by Cooper and others in the early literature. Almost all the writers have taken as a starting point universal agreement that national sovereignty extends to "air space". They have posed as central and important questions the following: (1) Does "air space" (or does national sovereignty) extend indefinitely out from the earth's surface? (2) If it does not, at what point does it end? (3) What is the legal status of space beyond air space? (4) May a state acquire sovereignty over artificial or natural bodies in space and, if so, how?

A second area of legal problems explored in the literature virtually from the outset concerns the liability of states conducting space activities for damage to persons and property in other states or elsewhere. The factual hypothesis most commonly put forward is that of a misfired or runaway rocket, and the legal question most often treated is whether liability for unintentional damage depends on a showing of negligence.

A third area of legal problems was identified somewhat later in the literature and even yet has not, perhaps, been thoroughly explored. This is the problem of deciding whether, and how, to limit

the use of space to "peaceful purposes." It entails questions of interpretation of the United Nations Charter and the possibility of various forms of international regulation or control of space activities. In part this problem is related to the question of the meaning and range of sovereignty.

With the advance of space science and technology, and increased public knowledge and discussion of various potential uses of space, legal problems related to particular uses have come to be more fully discussed than before. For example, the allocation of radio frequencies to countries on a geographical formula has not been adaptable to communication with satellites which rapidly move through existing radio-frequency regions; the possibility of using satellites for meteorological purposes has suggested the need for legal rules governing the dissemination of weather information and, eventually, for the control of weather control; the possibility of observing activities on the ground (or elsewhere) from space has raised the question whether such observation could be considered unlawful — a question made sharper by the U-2 incident of May 1, 1960 and Soviet charges of U. S. "aggression" in the Security Council. But, as compared with the literature dealing with problems of sovereignty, discussions of particular legal arrangements to deal with defined space activities are meager.

Finally, crossing all these problems, are the questions how to proceed to develop a law of outer space and how to make that law effective. Here the writers diverge as to the desirability of international agreement, the matters on which agreement should be sought, the likely or desirable forms of agreement, and the role of existing or new international organizations or agencies. Discussion of these problems has been given additional impetus by the progress of space activities in quantity and quality, the increasingly apparent military and economic significance of various activities and the scientific knowledge derived from them, the extent to which lawyers and scientists interested in space problems have organized themselves on national and international lines, and the discussion of both scientific and legal problems in the United Nations.

b. Pertinent Factual Developments

While this is not the place for a narrative of man's activities in space, we ought to take brief note of some of the more important events that have affected the legal literature. At present, the two "space powers" are the Soviet Union and the United States. Their prowess has been stimulated by, and used in, the Cold War. Whether or not outer space can be described today as a theater of potential military action (if we leave to one side the temporary presence of ballistic missiles at very high altitudes), the technical feasibility of some military use of outer space is taken more and more seriously in statements by officials, scientists, engineers, and journalists. In a broader sense of the term "military," the Soviet Union has exploited its space prowess intensively

for Cold-War advantage. Expressions of hope that space could be somewhat divorced from international politics have been disappointed, as they were doomed to be.

From the beginning of man's activity in outer space, and even before it began, the United States has cherished and expressed the hope that outer space could be devoted exclusively to peaceful uses. As early as January, 1957, the United States urged in the United Nations that studies on space disarmament be undertaken without delay. In August, 1957, our Government was joined by Canada, France, and the United Kingdom in proposing a technical committee in the U. N. to study the creation of a system of inspection that could effectively insure that objects would be sent through space for peaceful purposes only. These initiatives, it may be noted, preceded the first successful launchings of artificial satellites. The approach was endorsed by the United Nations General Assembly on November 14, when it adopted Resolution 1148 (XII). Again, in January, 1958, immediately after the launching of Explorer I, President Eisenhower began his correspondence with Bulganin aimed at the solution of the sensitive and difficult disarmament problem connected with space activities.

Official spokesmen have been generally cautious in stating principles of a law of space. Awareness of military potential may have dictated circumspection before the advocacy of rules that might inhibit activities regarded as essential to national security or might at some future time favor one of the space powers over another in ways yet unforeseen. The problem has been made even more complicated by the fact that space technology is in a state of rapid development and it is difficult to arrive today at conclusions one can be confident will long endure. Furthermore, it is difficult to devise a workable formula to segregate military from non-military uses of space technology, except at the extremes like nuclear warheads. This was evidenced by the reluctance of the United Nations Ad Hoc Committee on Peaceful Uses of Outer Space to reach detailed conclusions on the meaning of "peaceful uses" in advance of the discussion and resolution of related issues in disarmament negotiations.

To find a realistic, effective method of insuring that space is used exclusively for peace continues to be a prime and urgent goal of the United States. This might be called the prohibitory, or negative, side of space law. It means that a way has to be found to some form of international agreement or understanding, effectively promoting general stability of expectation that outer space will not be used in ways to threaten the peace. The United States Government has continued to work toward that goal within the framework of the

United Nations, through international agreements and through positive unilateral action aimed at insuring that outer space will be used only for non-aggressive purposes. Although on the international side there is a little progress as yet from which we can take encouragement, the goal remains important and should, by every reasonable means, be pursued.

The positive part of space law is no less important. The United States has taken the view that the family of nations should encourage all activities in outer space with the exception of those whose prohibition shall have been or should be internationally agreed upon. This is sound. The uses of outer space that have been made and are presently contemplated are, in the main, uses in which it is possible for several participants to engage without serious mutual interference. Space holds great promise not only for scientific information, but also for important benefits in communications, transportation, meteorological information, and other inclusive or sharable uses. While particular activities may require regulation—for example, an agreed allocation of radio frequencies—there is no sound reason for the community of nations to tolerate general claims to exclusive uses of any part of this vast, sharable resource.

A second positive side is the fostering of international collaboration on space activities. On December 12, 1958, by Resolution 1348 (XIII), the United Nations General Assembly created an Ad Hoc Committee to examine peaceful uses of outer space and to report to the General Assembly at its next session. The terms of reference laid down in Paragraph 1 of the Resolution were:

- "a. The activities and resources of the United Nations, of its specialized agencies and of other international bodies relating to the peaceful uses of outer space;
- "b. The area of international cooperation and programs in the peaceful uses of outer space which could appropriately be undertaken under United Nations auspices to the benefit of States irrespective of the state of their economic or scientific development, taking into account the following proposals, among others:
 - (i) Continuation on a permanent basis of the outer space research now being carried on within the framework of the International Geophysical Year;
 - (ii) Organization of mutual exchange and dissemination of information on outer space research; and

(iii) Coordination of national research programs for the study of outer space, and the rendering of all possible assistance and help towards their realization;

- "c. The future organizational arrangements to facilitate international cooperation in this field within the framework of the United Nations;
- "d. The nature of legal problems which may arise in the carrying out of programs to explore outer space."

The Resolution proceeded from the premise that international encouragement of space activity can stimulate scientific progress and its application to economically and socially beneficial ends. It can foster the collaboration of scientific and technical workers of many lands—not only the citizens of States now capable of launching objects into outer space, but men of skill and talent throughout the world. It can stimulate international cooperation in the arts of peace.

The Soviet Union, Czechoslovakia, and Poland refused to take part in the deliberations of the Ad Hoc Committee; the United Arab Republic and India took the view that that refusal precluded the Committee from accomplishing any useful function. The Soviet refusal was expressly based upon the "inequality" of representation on the Committee. As if declaring outer space to be within bounds of a Cold-War game, Soviet spokesmen stated that the Committee should have equal representation from the NATO and Warsaw Pact countries.

The Committee met, nonetheless, in May, June, and July, 1959, with thirteen countries represented. It completed a report (Document A/4141, July 14, 1959), to which representatives of all participating countries unanimously adhered. With due allowance for the exigencies of international compromise, the U.N. report was a useful first step towards the basic goal of building a sensible legal framework for activities in space. This report was presented to the U. N. General Assembly; in the meantime a new committee with larger national membership was named in December, 1959. It remains to be seen what action this new committee will take, including any action on the report of the Ad Hoc Committee.

A further fact to be taken into account by both governments and scholars is the strong support from the international scientific community for the broadest possible exchange of scientific data and information derived from space. It would be a fair statement that two most interested professional groups, the military and the scientific, are in agreement that activities in space should not be

hampered by the imposition of a legal system which, for example, would require prior consent of all subjacent states for all activities. Scientists and the military may disagree on the type of information to be disseminated, on techniques of control, and on particular activities that should be fostered or prohibited; but they are united in opposition to a legal regime that would regard space as subject to national sovereignties. It is not, therefore, surprising to find that scholars in all countries have been overwhelmingly in support of the proposition that at some point, defined in terms of location or of function, national sovereignty ceases and something else begins. The U. N. Committee took substantially the same position, with qualifications to be discussed later.

Related to both the negative and positive aspects of space law are the facts that no nation has as yet requested permission from another to fly satellites and space vehicles at very high altitudes "over" the other's territory, and that no nation has as yet protested such overflight as a violation of its sovereignty. Earlier writers had to regard this fact as one for future speculation, noting, for example, Soviet protests at the overflight of United States high-altitude balloons as potentially indicating a certain Soviet view of space activities. To these might be added the protests at the U-2 overflights. Yet no protests were lodged against two satellite launchings that took place at almost the same time as the downing of the U-2: TIROS, a photographic satellite widely supposed to be among other things the forerunner of a reconnaissance satellite, and an early form of MIDAS, a device designed to "sense" the flashes of heat from missile launchings below. Although the evidentiary value of the absence of protest is itself not free from dispute, the present political and factual context would seem to lend an exceptional importance to the absence of protest in this case.

It has been observed that the views of lawyers have been, as they ought to be, influenced by increasing knowledge about space activities and their significance for communication, meteorology, navigation, observation and other uses. Two examples will suffice to make this introductory point. The first has to do with technical aspects of regulation. The range and "bite" of any system of international control of space activities must depend in substantial measure on the technical possibilities of verifying compliance and detecting evasion. To say this is not to deny that the very existence of an agreement may, to an (uncertain and varying) extent, inhibit violation even if the violation be considered undetectable; it is only to point out that one must expect different things from a system of registration, reporting, or inspection depending on the technical means at hand

For the second illustration we may advert again to the protested aerial reconnaissance by the U-2. Assuming, as seems reasonable, that similar reconnaissance is or becomes technically feasible from satellites, would the differences in altitude and in vehicles make the activity politically and legally acceptable to states whose territory is observed? If not, what consequences may or should follow? Can such problems be resolved in terms of the location of the observer, or must they be solved in terms of the nature of the activity? Unfortunately, as this study indicates, problems of this sort are ubiquitous. One cannot avoid the conclusion that, at some time and in some manner, a law of space will have to come to grips with some method of determining and defining what activities in space, if any, are to be discouraged or prohibited. To the extent that facts bear out the desirability of such classification and classification itself is possible technically, then it may be that problems of the general legal status of space are--even "legally"--less important than problems cast in terms of the particular activity under consideration.

2. Problems of Sovereignty

a. Sovereignty over Air Space

Most of the writing on space law regards as the central problem of the subject the determination of the legal status of space; that is, how far "up" or "out" does national sovereignty extend, and what is the status of space beyond these limits if such limits exist?

The starting point of all these discussions is the existing law on sovereignty in "air space". Under the terms of international conventions and most national legislation, national states have complete and exclusive sovereignty in the "air space" above their territories. No writer, whatever his views de lege ferenda, has questioned that all states make this claim on their own behalf and acknowledge it when claimed by others. No government official has suggested any general lack of agreement as to the existence of sovereignty over air space.

Whether existing international agreements and customary law with regard to air space apply of their own force to activities in (outer) space has, therefore, been exhaustively discussed by publicists. Essentially the same question can be put in a number of ways: How far out does "air space" extend? Does "air space" include all space "above" national territory? Is there legally a distinction between "air space" and "space": (or "outer space," "cosmic space," and various other names for what, if anything, lies beyond)? For the great majority of writers who have concluded that "air space" (and "therefore" sovereignty) does not extend indefinitely, two further problems are necessarily raised: Where does "air space" cease? What is the status of space which lies beyond?

From the terms and history of the relevant international agreements which provide that every state "has complete and exclusive sovereignty over the air space above its territory" arguments of interpretation have been put forward by most writers. Identical language is used in the Paris Convention of 1919 and the superseding Chicago Convention of 1944. In each case the phraseology is in terms of "air," "air space" or foreign equivalents literally translated as "atmosphere" and "atmospheric space." Furthermore, the agreements deal with, and refer to, "aircraft," "air navigation" and equivalents, and, in annexes to both the Paris and Chicago Conventions, "aircraft" are defined as machines which can derive support in the atmosphere from reactions of the air. There is general agreement among the writers that the draftsmen of the pertinent sections of the Paris and Chicago Conventions had no thought, at the time, of space vehicles and space travel. All craft, with the exception of the V-2 rocket which in 1944 was in some use, required aerodynamic lift.

While no writer has as yet examined definitively all national statutes regulating flight, those that have been cited employ jurisdictional language closely parallel to that of international conventions. Even if some did not, it would be difficult to infer from the language of such unilateral claims an international acquiescence in a greater vertical sovereignty than that provided for in the multilateral conventions—whatever that may be.

From the use of words such as "air," "atmosphere" and "aircraft," most writers have concluded that the conventions do not apply automatically to activities in space, although the "boundary" (discussed below) between "air space" and "space" is as yet undetermined; that is, although the area in which the agreements do operate is not clearly defined and distinguished from that in which they either do not or may not.

The fact that the ambit of existing conventions acknowledging the sovereignty of subjacent states over air space is overwhelmingly regarded as a limited one leaves the status of space an open question. One cannot on this evidence alone infer an abnegation of sovereignty over space beyond air space. One can say that it is doubtful that states have already agreed to the extension of national sovereignty to higher altitudes.

Commentators have persuasively supported this interpretation by pointing to other evidence to rebut claims to sovereignty at very high altitudes. Most significant in this connection is the fact, already mentioned, that states signatory to the conventions, as well as nonsignatory states whose legislation claims sovereignty over air space, have not as yet protested any launching of objects at high altitudes as violative of their sovereignty. The orbit of

one or another of these objects has at some time taken it to a point in space that is directly above the territory of almost every other state on the earth, in the sense that the object would have been "hit" by the projection of a radial line drawn from the center of the earth through some point on the surface of that state's land mass (or territorial waters). If states regarded those objects as passing through an area subject to their sovereignty, one would have expected protest or objection or, at a minimum, public statement reserving their rights and stating the conditions of their acquiescence to present activities. Initially scholars predicted or anticipated such protests. When they failed to materialize after the first successful orbiting of satellites a number of writers pointed out that the acquiescence might have been implicitly limited by the circumstances of the International Geophysical Year, and that in view of this world-wide scientific effort the acquiescence need not be construed as a general consent or waiver. The pattern of acquiescence has now, however, continued well beyond the IGY and has included a wide variety of objects with varying purposes. This continuing silence seems consistent only with the absence of claims to sovereignty in overlying space at the altitudes at which satellites have orbited and space probes have flown.

This conclusion is bolstered by the attitudes of states participating within the United Nations. In the debates preceding the passage of General Assembly Resolution 1348 (XIII) creating the Ad Hoc Committee on Peaceful Uses of Outer Space, most states took the view that space was distinguishable from air space, and that national sovereignty did not extend indefinitely. The Ad Hoc Committee itself, in its Report and in its public debates, expressed the same opinion, in guarded language. While the Soviet Union did not participate in the Committee, Soviet scholars seem to be in accord on this point, and, by implication from its space activities, the Soviet government seems to proceed from a similar position. In the debates that took place in the Security Council in May, 1960, on the Soviet charges of aggression in the U-2 overflights, several speakers (not from the Soviet bloc) did allude to outer-space activities; but they seemed not so much to be pushing airspace concepts upward as to be pulling outer-space concepts downward.

A number of writers have pointed also to practical arguments in support of the contention that national sovereignty does not extend indefinitely. It has been pointed out that the moon and other bodies in space pass directly "over" the territory of various states, but no states have ever claimed that they have sovereignty over them. Nor, it is urged, could they do so in view of the fact that other states would have as good a claim. Since the notion of bodies in space being at one moment subject to one state's sovereignty and at another moment subject to another state's sovereignty seems incompatible with the idea of comprehensive sovereignty, it has been urged that sovereignty in space must in any case stop short of the moon.

In addition, many scholars have observed that claims to sovereignty over air space historically bore a close relationship to national security and defense. Subsequently regulation by the subjacent state also was conceived to be important in terms of transportation, commerce and safety. Yet, beyond some limit (which is never a precisely definable limit and which varies with particular factors), the fact that an object is located, or an activity is taking place, "above" a certain spot on the surface of the earth has no necessarily close or intimate objective connection with that spot. Some activities in space require line-of-sight connection with a given area on the earth but do not require that the particular line of sight remain within the projected vertical boundaries enclosing that area. Even from the point of view of defense against missiles, if something is dropped or pushed from space to fall on a given area on the earth it is not a necessary incident that the descent be commenced at a point directly "above" that area, and in the majority of cases it would not be so. Similarly, countermeasures designed to protect a given area on the earth from attack that issues from, or passes through, space may for physical reasons have to make contact at some point in space that is not "above" the defended territory. Indeed, the energy cost of arranging for a path "straight up" or "straight down" between an object in outer space and a point on earth would probably be prohibitive under present technology for payloads of considerable weight.

This latter argument points to the lack of utility in extending sovereignty to very high altitudes from the point of view of subjacent states potentially "affected" by an activity. The traditional feature of claims to sovereignty, as distinguished from lesser jurisdictional claims, is simply the legal capacity to forbid virtually any activity within the area claimed unless consent to such activity is expressly given or can be implied from past conduct. It is for this reason that one would have expected protest had any states regarded existing satellites as having violated their air space. Since satellites and space probes pass through space which is "over" several states, a claim to sovereignty at very high altitudes would, in effect, be a claim to a veto power over any space activity whatsoever of which any subjacent state disapproved. There would be no need to assert an "interest" or any adverse effect; the disapproval could be entirely arbitrary.

Such a regime would be undesirable and for political reasons unlikely. In view of the military potential of space, it is highly unlikely that major space powers would acquiesce in a rule which—given the character of orbital trajectories—permitted a veto by another state of activities that they regarded as essential to their national security and defense.

This is not to suggest that minor powers have no interest in curtailing claims to high altitude sovereignty. All people everywhere have an interest in the benefits that space activities can bring to all. The benefits that mankind can gain from space activities, both for scientific knowledge and for a variety of other socially useful and desirable purposes, would be endangered by a rule which permitted a few states, acting arbitrarily, to hold up space progress. Furthermore, states presently having space capabilities are endowed with sufficient territory and adjacent high seas to launch missiles without violating the traditionally understood territorial air space of other states. States with smaller territories hemmed in by other sovereignties will be less fortunate in their capacity to launch missiles or bring them back to earth without a technical violation of some other state's sovereignty, if a "boundary" is conceded to exist below which spacecraft are held to be trespassers on air space. The higher the "boundary," the more difficult the situation potentially will be for such states. Nor is the situation hypothetical, for it is probable that many states will have space capabilities in the future. The present high costs of rocketry lie in experiment and development. Once these costs have been absorbed, the rocket production and launching will not be so dear as to preclude many users.

Not all writers have been persuaded by these arguments; at least one believes that national sovereignty extends outward without limit. But the overwhelming majority of commentators take the view that at some point national sovereignty ceases, and this view appears to have the support of governments.

Three final points should be borne in mind: (1) to say that existing conventions do not of their own force apply in space is not to say that their provisions may not be relevant in many respects to space activities; (2) writers who agree that sovereignty does not extend indefinitely do not agree on where it ceases to exist; (3) general agreement that space beyond the "boundary" is not subject to the sovereignty of the subjacent state does not of itself establish the legal status of space, the terms and conditions on which states can use such space, or the rights and duties of states with respect to one another with regard to activities in space.

b. The Boundary Between Air Space and Space

As we have seen, there is formal agreement that air space is subject to national sovereignty and substantial agreement that what lies in outer space is subject to a different legal regime or regimes. It has seemed to most observers to follow as a matter of inexorable logic that at some altitude sovereignty ceases. A great deal of the writing on space law has been concerned with discovering or proposing the location of this "boundary" and prescribing the upper limits of national sovereignty.

Before examining the various proposals that have been advanced, we may note that the logical existence of such a boundary would not, without further argument, establish the importance of explicit or implicit agreement as to where it is. Though many commentators regard this problem as the most important problem of space law presently facing lawyers and governments, others regard it as having a low priority and little practical importance. These conflicting positions will be discussed after we have examined proposals on the location of the boundary.

It is not always easy to distinguish between boundary suggestions put forward as if reflecting an interpretation of existing conventional law and proposals recommended for future agreement. Since conflicting interpretations of existing law would require some form of agreement for their resolution, it may make relatively little difference whether a writer is talking de lege lata or ferenda. Many proposals have been based upon supposed geophysical or astronomical constants; some on beliefs as to the maximum height attainable by aircraft; some on more than one boundary, or zone, or belt. Many proposals have been withdrawn by writers initially proposing them.

The most frequent approach has been to relate the proposals in some way to the existing conventions. As we noted, these conventions refer to "air" or "atmosphere" and deal with "aircraft" as defined in annexes. National laws also use terms identical with or similar to those included in the Paris and Chicago Conventions. It can be and has been argued, therefore, that under these conventions and laws the use of the terms "air," "air space," "atmosphere," or "atmospheric space," or the expressed purpose of regulating "aircraft," affords a criterion for measuring sovereignty.

One proposal, relating "air" to "aircraft", suggests that claims to sovereignty acknowledged in existing conventions and custom go only to the height to which "aircraft," as defined in the annex to the Chicago Convention, can ascend in the atmosphere while "deriving support from reactions of the air." From this perfectly legitimate interpretation would follow certain difficulties, acknowledged even by its proponents. First, it does not provide a fixed location of the "boundary" in very precise terms. Second, if offered as a proposal for the future it is thwarted by the likely activity of "aircraft" such as the X-15, which use aerodynamic lift at lower altitudes but can with the aid of other devices be flown out of the lift area.

A variation of this proposal is the "von Karman line." As put forward by Haley and others, it accepts the basic concept of aerodynamic lift but argues that such lift need not be the only "support" and that present law could be interpreted as extending sovereignty up to the point where any aerodynamic lift is available.

For an object traveling at 25,000 feet per second, that line is said to be about 275,000 feet from the earth's surface. While this line is thought to have more stability than the proposal first put forward, it would also vary with atmospheric conditions and with design changes and other factors affecting the flight of objects.

A third approach, similar but distinguishable, lays stress upon the word "air" or "atmosphere," rather than "aircraft," and seeks to use a scientific definition of the earth's atmosphere to determine the reach of sovereignty. That interpretation, again a perfectly permissible one, runs into rather more difficulties than the first two suggestions. First, there is no agreed definition among scientists any more than lawyers of the word "atmosphere," whose meaning varies with conditions as well as the purpose of the inquiry. Second, several of the possible definitions would certainly put the limit far above many satellite orbits and missile flight paths, though it may be doubted whether the proponents intended to claim that the satellite flights had trespassed upon national air space. In short, it would be too high and too uncertain.

A number of other proposals, suggesting more or less arbitrary lines based on variations of the reasoning described above, have been put forward. These suggest agreement either interpreting the conventions or fixing the boundary afresh at an altitude roughly related to lift, or drag, or atmosphere.

A somewhat different approach, which takes advantage primarily of the inferred attitudes of states to satellites already orbited but still is capable of doctrinal harmony with existing law, is to set the boundary at that altitude at which unpowered flight is possible; or, with somewhat more precision, at which an unpowered satellite will orbit the earth at least once. This proposal would bestow express legality on previously launched satellites, and it can also be related to many of the definitions of aerodynamic lift and atmosphere. It has the difficulty (among others) that we are not presently certain that a reasonably exact distance for all parts of the earth's surface, all relevant velocities and altitudes, and all possible orbits can be calculated.

Variations of these formulas which take account of some of the uncertainties in expressing an exact boundary are those that add to the area of sovereignty a further contiguous zone, supposedly analogous to that of the high seas, in which subjacent states may exercise jurisdiction but over which they do not have sovereignty. Similar suggestions had played a role briefly in the early debates on air space sovereignty, during the early years of the century. While Cooper's proposal to this effect for outer space was initially approved by others, he has not recently urged its acceptance, and the more recent literature generally ignores it.

A different theory of sovereignty over air space, not related to the words of existing conventions but capable of being related to their purposes, is that which Kelsen proposed in 1944 in connection with the Paris Convention. He viewed the claim to sovereignty, recognized by that Convention, as going as far out as the subjacent state could exercise effective control. He recognized that under this theory there would be not one single boundary but several boundaries, since some states were more technically proficient than others, and that the boundary would keep going up as science added new techniques for controlling space activities. For these reasons the proposal seems unlikely to be acceptable to many states. A variation suggested by Cooper in 1951 (and later withdrawn) called for the extension of state territory "as far as then scientific progress of any state in the international community permits such state to control space above it." This would have eliminated the diversity of boundaries existing at any one time but not the difficulty of determining the uniform boundary or the instability of that boundary once determined.

Still another proposal is that which argues that a state's sovereignty extends as far as its interest extends. In its acknowledgment of a basic purpose behind claims to sovereignty, this view is sound. But it is difficult to define a state's interest, and its interest in some activities would extend to a very high altitude and to others much less. Some activities in which a state was vitally interested would be outside its air space thus defined because the line-of-sight connection would not require a space object to be "overhead"; at the same time a state could use its claim to sovereignty to exclude activities in which it had no legitimate interest whatsoever and which bore no special relationship to its territory.

Finally, proposals have been made for several lines rather than one. We already noted the existence of proposals for a contiguous zone. Knauth, for example, goes much further. Instead of endeavoring simply to distinguish air space from outer space, he proposes several "belts": "airspace," "air-nonair fringe," "orbit-satellite," rocket failure area, "belt in which the Moon orbits." He believes that each belt should be subject to its own legal regime, and that all belts in cis-lunar space should be presently given legal status appropriate to each.

A rough and incomplete tabulation of altitude-boundaries inferred, reported, suggested, or proposed by several of the writers on space law may serve to illustrate the controversy. In generally "ascending" order, they are as follows:

<u>Height</u>	<u>Abstract # or Source</u>	<u>Remarks or Reasons Given</u>
30 miles	616	400 miles for neutrals in wartime.
275,000 feet	636	Objects traveling at 35,000/sec.
52 miles	594	Limit of atmospheric lift.
53 Miles	643	Von Karman line.
60 miles	584	Loss of earth's gravitational effect; air travel becomes impossible.
100 miles	606	
200-300 km.	Source 272	Limit of air-filled space.
150-225 miles	609	
300 km.	599	Limit of area filled with air layers.
250 miles	Neumann	Too little air.
200-300 miles	626	Analogy to 3-mile limit at sea.
300 miles	555, 559	Limit of "contiguous space."
300-500 miles	Source 35	Assumptions as to atmosphere.
310-620 miles	605	Limit of atmosphere.
500 miles	603	
650 miles	Source 62	Limit of atmosphere.
7000 miles	Source 74	Citing Western meteorologists.
Infinity	700; Source 115	

From what has been said it is clear that the difficulties of fixing a stationary boundary by reference to supposed geophysical or astronomical constants are at least formidable, perhaps insuperable. Many proposals have been withdrawn or varied in the light of new scientific information. Whether the physical characteristics of the air, the physical characteristics of flight craft, or other relevant factors can be reasonably expressed with reference to a fixed altitude is a subject of dispute. The measurement of that fixed altitude may be a source of scientific disagreement. If, to avoid these difficulties, an arbitrary limit were to be chosen, it might be difficult to get agreement on a height that was not related either to the purpose of space activities or the language of existing conventions.

Yet disagreement stemming from such difficulties may be exaggerated. Let us examine the area of agreement.

First, it seems clear that the sovereignty over air space acknowledged by the various air conventions and customary law extends at least as far as is required by and for the purposes that those conventions envisage; that is, to the altitude presently used for normal aircraft flight, and so much more of the air space as might reasonably be envisaged as usable for similar purposes. Since the conventions speak of "air space" rather than the objectives of commercial aviation, one cannot delimit a boundary by referring to any existing usage or altitudes achieved at any given time; "air space" may be the area used for "aircraft"—as several scholars have suggested—but that area does not seem more easily defined by this suggestion, nor is it the only permissible interpretation of the conventions or customary law. In any event, we should have no difficulty in concluding that "the" boundary, if it existed, would be somewhere above the altitude now in common use for aviation purposes. The recent U-2 flights, at altitudes of some 12 miles or more, were not formally defended as being beyond traditional "air space" and weather balloons at altitudes of over 100,000 feet have been protested.

On the other hand, the failure of any state to protest as an invasion of its sovereignty any space activities to date strongly supports contentions that "the boundary of sovereignty, if one were to be fixed, should not be placed at higher than, roughly, the probable perigee of durable satellite orbits. This view would be consistent with several of the proposals made by scholars seeking to interpret the existing conventions; aerodynamic lift, von Karman line and some other definitions of atmosphere as related to flight could be brought into approximate harmony with it. Earlier proposals which took atmosphere (in the legal sense) much further into space seem inconsistent with practice since 1957. Arguably, too, a ceiling on national sovereignty at some such point would be consistent with present contentions about effective control (though not with future possibilities). Beyond some such altitude, also most activity is less and less related to any special interest of an "underlying" state. Furthermore, the fact that sovereignty over air space did not extend beyond such an altitude would not mean that states with space capabilities could lawfully do anything they wished "above" this line, or that "underlying" states did not possess some rights with regard to particular activities, analogous to those that coastal states possess beyond territorial waters, based not on sovereignty but on a legitimate interest with regard to the particular activity.

We might provisionally conclude, therefore, with wide support from scholars and from governmental actions, that "the" boundary lay somewhere between these two possibilities: higher than traditional flight (say, twelve miles) and lower than the perigee of past satellites (say a hundred miles). The gap between a twelve-mile floor and a hundred-mile ceiling might seem to leave room enough for the placing of an arbitrary line or even a zone; yet there are grounds to

believe that the gap is unstable and may become meaningless. For one thing, experiments such as the X-15 indicate that it is possible to have a craft that is both an "aircraft" and a "spacecraft." Therefore, the limit of conventional air space in terms of usage or purpose at least potentially may be moving up to, and even above, areas now regarded as beyond national sovereignty. There is somewhat similar evidence that typical "space" uses may move downward toward present conventional air space. For example, power-assisted satellites may come to move continuously at an altitude lower than that in which free flight is now possible, and such satellites may be even more advantageous for some uses than satellites restricted to higher altitudes.

Thus, it seems probable that our provisionally assumed minimum altitude and maximum altitude may be in the process of converging and also possible that they may even cross each other; that is, some typical air activities may at some future time be conducted at altitudes higher than some typical space activities.

It is not an answer to this observation to point out that the extremes may be clear despite fuzziness at the border-line. The present inquiry is not whether the extremes should be treated differently, but whether a borderline should be drawn. With present knowledge of space activities and technology in a relatively infant and rapidly developing state, it is important to examine arguments for and against drawing a "boundary" in precise terms at this time. Is it important? Is it possible? Is it likely to serve any useful purpose?

At the outset it should be noted that while many writers have urged that agreement on the boundary be achieved at the earliest moment possible some of these same writers have recently urged caution and do not seem to attach the same urgency to its resolution. This change of position is not necessarily a change of viewpoint, but may simply reflect new environmental and political factors. Initially it was feared that, without agreement, space activities would be hampered by contentions that sovereignty was being violated. The failure of these protests to develop, and the gradual growth of a customary law which appears to limit claims to sovereignty to relatively low altitudes, are important new developments, which may remove much of the force that once was thought to underlie the argument for a formal boundary agreement.

The strongest arguments for determining with precision the boundary between air space and space seem to be these: (1) That formal agreement would help to preclude states from making unjustified claims in the future to sovereignty in large regions of space "above" their territory on the contention that it is "air space." Some legitimate verbal formulas (for example, definitions of "air" or "atmosphere") would go to one thousand or more miles. Efforts of some

of the most distinguished scholars, wary of our past difficulties in coping with similar claims with regard to the high seas, unoccupied territory and the like, have undoubtedly been directed at this objective. (2) That given certain possible interpretations of existing conventions, there is always the possibility that some states will protest space activities as violative of their sovereignty. Acceptance of such contentions would greatly hamper space activities favored by scientists and military specialists alike, and would permit relatively small states to exercise what could amount to an arbitrary veto over particular activities. (3) That disputes as to the extent of air space could lead to international tensions and serious controversy. (4) That the United States, supporting as it does the Rule of Law in international as in domestic matters, should avoid being put in the position of making unilateral decisions on the interpretation of existing conventions and should urge resolution through international agreement and other cooperative means. (5) That the resolution of this fundamental legal question would help to induce cooperative attitudes toward building law in regard to space and that these attitudes could help to shape desirable technological trends.

Arguments against efforts to resolve the boundary problem by fixing on an agreed altitude can be summed up as follows: (1) That the absence of explicit agreement has not yet led to international tensions and does not appear likely to do so. That an attempt to reach explicit agreement on establishment of an altitude boundary would invite many states to make claims to sovereignty which, in analogous cases such as the high seas, have led to immoderate demands. Pandora's box might be harder to close than to open. (3) That any boundary set might have to be set too high. An altitude beyond that which seems to be the maximum being established by custom (the roughly one hundred mile figure suggested above) would seriously hamper some space activity. A figure of a hundred miles, while less serious in effect, might also hamper at least some future activities. The possibility of getting anything less through agreement would seem to be negligible, primarily because fear of the unknown would lead states to claim as much as they could. On the other hand, future activities at lower altitudes may be acceptable if there is no explicit agreement on the extent of air space. (4) That an agreed altitude once achieved will be next to impossible to reduce. States will not gladly give up sovereignty over territory. (5) That an agreement reached later is likely to fix on a lower altitude than an agreement reached sooner, and that the lower figure would be in the general interest. (6) That an arbitrary line, even if low enough to permit more space activity, might encourage rather than avert disputes because it might provoke technical complaints about violations which at high altitudes would be difficult to verify.

This last point perhaps requires elaboration. It rests on the premise that the boundary question is inextricably tied to the

question, what activities are permissible beyond it; that is, what rules govern space? The claim to sovereignty amounts to a statement that within the specified area only activities permitted by the subjacent state may be carried on, and assumes some intimate connection between that area and the state. The converse is not, of course, true. Beyond the boundary not every activity is legally permissible; but at the moment it is very difficult to specify what activities are permitted and what are not. Drawing the boundary will not help to solve this problem except perhaps to the limited extent of shifting the burden of proof. It has already been pointed out that the higher the altitude of an activity, the less the space "above" national territory bears any special relationship to the underlying area, whether for reasons of defense, transportation, commerce or safety.

Two examples may illustrate. First, artificial satellites launched in geocentric orbits have come much closer to the earth at some points than at others, although in no case interfering with any obvious interests of any subjacent state. In some cases the perigee fell within one or more of the boundaries proposed by publicists, while the apogee fell beyond. It would make little sense to impose one legal regime or status on a satellite at perigee and another on the same satellite at apogee, at least under present technology. This is, of course, an argument only against establishing the line "too high," not against an arbitrary line that would be "low enough"; but, as indicated above, doubts have been raised whether under present conditions of the international political process a boundary could be set "low enough."

Second, in the U-2 incident the Soviet Union charged the United States with "aggression" and accused it of "espionage." It has been frequently stated in the West that the U-2 was violating Soviet air space and that for this reason the Soviet Union could legitimately object to the unpermitted overflight. This would not amount to "aggression." But was the Soviet objection based primarily on the location of the U-2 or on the character of its activity? In the near future satellites may be able to perform equivalent functions from altitudes of (say) two to three hundred miles. Would a boundary set at a hundred miles remove Soviet objections to such activity? True, it would forestall objections based on violation of air space. But it would not of itself establish the legality of the activity if there were other grounds to consider it illegal.

Finally, the U-2 incident has pointed up the need for international agreement on the question of how high sovereignty extends skyward. This question is certain to become more acute in the future as air craft fly at higher altitudes and as space flights, many of them equipped with cameras or other devices, become more common. It is a question full of difficulties and one which demands the full attention and consideration of the United Nations as well as

the individual nations themselves. The Committee hopes that efforts will be pushed to pursue U.N. studies with a view to bringing about agreement.

The foregoing part of this analysis, however, would indicate rather that the U-2 incident underlined the extreme difficulty of an attempt to agree on the permissibility or impermissibility of space activities by reference to an altitude boundary, and lends support to the action of the United Nations Ad Hoc Committee, which at its meeting in 1959, classified the boundary problem among those not susceptible of priority treatment. It did this in part because other members doubted the wisdom of drawing a fixed boundary, in part because other members had doubts as to its feasibility at that time. The Committee also suggested the possibility of using functional rather than spatial criteria to regulate and control activities in space. Were it possible to build up, through understanding, custom and agreement, adequate functional criteria for space activities then the boundary problem would be obviated. Certain activities might be prohibited; others might be permitted under certain restrictions as to time, place, mode and disclosure; all others would remain free. The system establishing these arrangements might be made up of some specific formal agreements and some general understanding, tacit or at least informal, confirmed by practice and doctrine.

c. Sovereignty over Bodies in Space

The entry to outer space raises legal problems with regard to the use and occupation of bodies presently in space, such as the moon and planets, and of the use and occupation of artificial satellites placed in space by one or more states.

Scholars have much discussed whether it is possible for a terrestrial nation-state to acquire sovereignty over all or part of a natural celestial body, and what would be required under existing international law to make such a claim legally valid. Quite understandably, doctrine of terrestrial international law with regard to discovery, contiguity, occupation and annexation of parts of the earth has been applied to this problem. A frequently employed analogy is Antarctica. This analogy has seemed particularly apt because it poses in contemporary context conflicting claims to sovereignty on one of the few yet unoccupied parts of the earth, and because these claims have not been based on occupation or settlement in any clear-cut sense. At present, and for some years past, conflicting claims to sovereignty over parts of Antarctica by a number of states have not been resolved, and claims to bodies in space, or parts of them, would be unlikely to be acknowledged by other states. Several writers have noted that the analogy between Antarctica and space bodies though apt is scarcely a helpful one save, perhaps, as it indicates the unlikelihood that claims to sovereignty would be widely honored by other states. If the present military importance of Antarctica is greater, and that of celestial bodies less, than is commonly supposed, the analogical value of the Antarctic agreement seems all the higher.

There is agreement among several commentators that under existing international law "discovery" of space bodies scarcely provides a basis, factually or legally, sufficient to support claims to sovereignty, and that the same is true of various symbolic acts of occupation such as planting flags, photographing terrain, mapping, or exploration. In themselves it is doubtful if these acts would be sufficient to justify a state that has made claims to sovereignty in excluding others from the bodies involved and preventing other states from carrying out exploration or scientific experiments. At the same time, however, it is noted that acts of this sort are presently the basis for the suspended or frozen claims in Antarctica. As a result the issue is not free from doctrinal doubts.

Extensions of principles of continuity and contiguity via "vectors" which have marked the Antarctic claims of Argentina and other Latin American states have not seemed applicable to space as they have not been widely acknowledged by other states with regard to Antarctica itself. One commentator, however, has expressed the conjecture that only those states "over" which a body passes would have a basis for claiming sovereignty. The moon, for example, passes over the United States but not over Red China, a fact which might exclude the latter's claim in his view.

A number of writers have expressed the view that it is not possible to acquire sovereignty in space by any means, that space bodies are to be regarded as res communis or res extra commercium, like the high seas, and not res nullius capable of appropriation. Such writers see space, and everything in space, as a common resource of all states and mankind, open to all on a basis of equality, and incapable of subjection to the control and sovereignty of a singly earthly state. Some have justified this approach by saying that ours is a "terrestrial" system and that the moon, for example, is not "territory" but a "celestial body" and part of a different "world." Others state the position more in terms of preference, deploring any status that would permit one state to exclude others from parts of space and preferring to regard the whole of space as a sharable resource. Earthly disputes should not, it has been asserted with some wistfulness, be projected into space; sovereignty in space is undesirable.

This latter viewpoint has led to a number of proposals that space be "internationalized," that bodies in space be subjected to United Nations ownership and control, and that exploitation be under United Nations, rather than national, auspices and law. Understandably this is a view that is dominant among the smaller states which presently do not have space capabilities. At the meetings of the United Nations Ad Hoc Committee a suggestion in the United States working paper as to the potential relevance of analogies from the Antarctic experience was deleted on a Latin American objection. It was said that they could not be relevant because they dealt with bases for sovereignty and no one could legitimately claim sovereignty in space.

There is a good deal of merit in, and support for, a regime with regard to celestial bodies which prohibits recognition of claims to exclusive sovereignty by any state. It would be useful for both public and private groups to work towards formulating standards and procedures that will guarantee access by all to these resources on equitable terms and prevent interference by one state with scientific programs of another. To a large extent the resources of natural bodies in space, like the vast reaches of space itself, represent sharable assets of the whole community. Scientific exploration of the moon or Venus under national auspices of any one country does not require, and should not without cause involve, the prohibition of similar exploration by other countries. We may look to similar ventures elsewhere in space. These should not be precluded by claims made on various grounds to sovereignty over such bodies; nor should their acceptability depend on the recognition of such claims.

The present trend of both private and public views is clearly against the permissibility of claims to sovereignty over natural bodies. Soviet writers have taken this view, although at the same time suggesting that it was not the view of the United States and that the Soviet Government would, in such a situation, have to protect its own interests. The American Government has expressed doubts as to whether space bodies are capable of appropriation. The American Bar Association in 1959 passed a resolution "that in the common interest of mankind. . . . celestial bodies should not be subject to exclusive appropriation." The U.N. Ad Hoc Committee took the position that present activities would not be a basis for claims to exclusive sovereignty and expressed the belief that problems involved in such claims would not arise until it became feasible to settle on such bodies and exploit their resources.

Artificial bodies in space raise comparable problems. While generally such bodies seem more analogous to ships on the high seas, or Texas Towers, or lightships, than to natural celestial bodies, problems as to control and exclusion of others nonetheless may arise. Space stations, used to stage further space exploration, raise questions as to co-ordination of activities, control of access by the launching state or by international agencies, access to such satellites by other states or by private groups, and criteria and standards of peaceful possession. Once again it has been observed that it would be unfortunate if a legal regime premised on sovereignty or exclusive jurisdiction by the launching state were to result in needless interference between two national space programs, such as might occur if, for example, experiments by one nation were to create hazards to personnel using another nation's satellite for admittedly legitimate purposes. It would, also, be desirable if standards for cooperative use of space station facilities could be worked out by participants, thus avoiding unnecessary duplication and waste. Once again, the presence or absence of sovereignty does not seem of itself, to provide many answers to important questions which it is not too early to discuss and explore in a preliminary way looking to effective international rules and sanctions.

d. Conflict of Laws

Problems of sovereignty are in some respects related to potential problems of conflict of laws. A considerable amount of conflicts doctrine is premised upon the concept that the national law governing events is that of the territory in which some pertinent act takes place. If space was not subject to the sovereignty of any nation, what national law would govern?

Writers have posed such problems in the traditional terms of territorial jurisdiction based on sovereignty, and have then proceeded to run through the almost endless list of conflicts questions to which a territorial connection is relevant. The fact, however, that the place of a particular act is not subject to the sovereignty of a particular state, or even that it is not ascertainable, does not make the problem insoluble or even particularly difficult. Other principles are available for choice of law.

Problems of national law will, indeed, arise, as will the need to amend various statutory provisions with regard to jurisdiction and venue. By comparison with other problems of space law, these seem either relatively simple or relatively routine. It might, however, be unfortunate if the meaning of terms such as "air space," having special diplomatic and political ramifications, were left to judicial resolution in conflict-of-laws cases in connection with relevant national laws. A more delicate and comprehensive treatment of the conflicts question might require, and be secured by, international agreement.

3. The Legal Status of Space

a. General Observations

If it is assumed that national sovereignty does not prevail in outer space, what is the status of space? To what rules, if any, is it subject, and by whom are they prescribed? A rejection of the contention that subjacent states have sovereignty does not compel us to discern a legal vacuum. For example, as has been observed, there may in some instances be a special and intimate relationship between a particular space activity and a particular subjacent state. Similarly, general principles of law governing the relations of states, such as those contained in the United Nations Charter, would seem to be as relevant to space activities as to other state activities wherever conducted. Again, if space is to be regarded as a place not subject to national sovereignty, there are valid analogies from customary law governing other areas which may well be applicable to activities in space.

As we have reported above in connection with claims to celestial bodies, the majority of the writers discussing the problem of a law for space have urged that space be regarded as res communis

or res extra commercium, like the high seas. In terms of "status" this simply amounts to a denial that it is, under current conventions, subject to the sovereignty of subjacent states or capable of appropriation. Stated positively, it amounts to affirming a community policy of encouraging all non-exclusive, or sharable, uses of space. If space is not subject to or capable of subjection to national sovereignty, then it is "free" to all users on terms of equality. The United Nations Committee, somewhat cautiously, agreed with commentators by stating that "there may have been initiated the recognition or establishment of a generally accepted rule to the effect that, in principle, outer space is, on conditions of equality, freely available for exploration and use by all in accordance with existing or future international law or agreements."

The primary difficulty with saying simply that space is "free" is that it says little more than that it is not subject to unilateral control and regulation by some, or many states claiming sovereignty over portions of it. In many respects the two possibilities—sovereignty of subjacent states vs. freedom, or exclusive use vs. sharable use—are almost polar opposites. In the one instance a state conducting activities in space can do nothing without the consent of subjacent states; in the other it can do anything not forbidden by international law. The second alternative is generally regarded as the more desirable; but, at the same time, it imposes obligations to work out standards and rules not necessarily in the form of explicit conventions, for implementing the policy of the international community in space. It is not enough to say that space is "free". That is a good starting point.

In recommending a legal regime for space some authorities, hoping to make fast a line from the known to the unknown, have suggested the adaptation of the rules that, regardless of their source, are thought to prevail in the law of the air, in the law of the high seas, or in the law of the polar regions or in particular regions of Antarctica. Few, if any, have proposed the literal and indiscriminate adoption of an entire body of supposed rules from any one of these special areas. Many have recognized, as has the U.N. Committee, that space is distinguished by many features, not all of which are now precisely known, that render many of its legal problems probably unique.

As compared with activity on the high seas, for instance, the present use of space exhibits fewer commercial and economic aspects; its military potentiality represents a relatively higher fraction of its present apparent total importance; the users for some time to come will be relatively few and will probably be, for the most part, governmental entities or international organs. This picture may change rapidly, as in the recently accelerated development of communications satellites; indeed, the rapidity of potential change in the uses of space serves by itself to distinguish the field from activities on the high seas. As compared with Antarctica, space represents, of course, a vastly greater area, of less well defined limits, susceptible of exploration—to say

nothing of permanent settlement—only under very different conditions. As compared with conventional air space, the distances and speeds and times involved in the use of outer space are different; the methods of launching and, eventually, of landing are different; the effects of gravity and of radiation are different; the military threat is of a different character and, for the time being, of a different order of magnitude; the commercial and economic possibilities are less well known, though potentially even more extensive, than those of aerial transportation.

The futility of mechanical adoption does not mean that the experience of decades or centuries in these other fields is irrelevant to the control of space. On the contrary, reflection on that experience mutatis mutandis will help to anticipate problems of space and suggest ways of dealing with them. Particular solutions or devices may commend themselves for adaptation; historic failures may enable us to guard against repetition. The law of the sea may afford some hints for the accommodation of inclusive uses like navigation (space flight), fishing (exploitation of mineral or energy resources), and cable-laying (communications) to defensive or exclusive uses like naval maneuvers, protection of customs, and protection of neutrality, and vice versa. Rules of space navigation may draw upon the experience of the law of the sea and of the law of air space. Decisions on the registration of space vehicles, and on the consequences of registration, may be facilitated by a look at the successes and failures of similar efforts in air law and maritime law. Recent experiences in Antarctica may tend to show that in certain circumstances international cooperation and national enterprise are furthered by the conscious and agreed absence from pressing claims to sovereignty.

In general terms the objectives of rules regulating space activities are those which, in addition to their independent validity, are expressed in the Charter of the United Nations. Even were these objectives not expressly stated as binding legal norms, they would be the goals of decent men everywhere, to be pursued at every level of public or private activity, national or international. Articles 1 and 2 oblige those nations that have and will have space capabilities to conduct their programs in a manner consistent with the principles and purposes of the Charter. It is clear that space itself and the knowledge gained from space exploration should not be used for aggressive purposes; that disputes that may arise from space activities should be settled "by peaceful means in such a manner that international peace and security and justice, are not endangered"; that, in short, the mere fact that an activity is conducted in outer space does not release any nation from its existing international obligations to promote, and to cooperate with others in promoting, peace, justice and human dignity for mankind.

The problem is to give more explicit content to these objectives and principles asserted in extremely general terms. How do states assure one another that activities in space are not aggressive; that the

activities of one state will not unreasonably interfere with legitimate activities of another; that activities will not be negligently or haphazardly conducted in such a way as to endanger others; that the benefits of space science will be widely shared to the benefit of all mankind; that such activities will not be incompatible with legitimate interests of states, whether or not subjacent, in which, or on which, the activity has some impact? No state may exclude another from access to space if space is free and open to all. But how does the community of nations lay down meaningful rules to state the terms and conditions upon which states should or should not conduct particular activities? Those are the problems of a realistic law of space.

We have suggested that the international community is on its way to the rejection of a spatial regime in which each of the several states may veto activities in a particular location, and to the adoption of a regime that, in broad terms, permits space activities unless prohibited. That leaves many questions unresolved and is a matter of understandable concern to all states with a potential stake in this vast, sharable resource. A state that believes itself adversely affected by the space activities of another will demand a voice in the conduct or control of those activities, or in the establishment of standards for such conduct or control. This is one of the reasons for the difficulty in drawing the "boundary," for, if all else fails, an affected state may attempt to insist that its sovereignty extends to very great heights, or indefinitely, as a device for claiming a voice in a particular activity. Agreement on a low altitude boundary, if achieved and if adhered to, could forestall this, but the preceding analysis has indicated that such agreement is unlikely and would not correspond to the needs of all or most affected states. Even if a general boundary agreement were contemporaneously or subsequently modified by the extension of contiguous source, the irrelevance of vertical distance to most of the pressing problems would keep alive the concern of affected states over many of the activities that would be taking place.

One obvious device would be a system of international control. But this is difficult to accomplish, and even in its absence it is important to press on with space technology and science, which might be unduly hampered if non-launching states sought to impose unjustified restrictions. Perhaps modest international schemes can be soon adopted. In any event cooperative discussion may help to moderate unilateral decisions by space powers and set up functional criteria in furtherance of the objectives common to all mankind.

b. The Problem of "Peaceful Purposes": Military Uses

In some respects the problems of space resemble the problems of the atom. The interest of mankind in the peaceful uses of atomic energy may be compared to its interest in the peaceful uses of space. Like virtually every atomic activity, virtually every activity in space has a possible military connotation; military and non-military uses are

extraordinarily interdependent. The scientific knowledge relevant to atomic power was, broadly speaking, equally relevant to atomic bombs; the possession of fissionable material for power plants created a possibility of possession for military purposes. A similar interdependence of uses and objectives exists with regard to space activities. Scientific knowledge about cosmic radiation may be useful for radiological warfare; television and radio relay stations may be used to hinder as well as promote communication; geodetic and meteorological observations have the same potential duality of function; and much of the technology relevant to the exploration of space is equally relevant to the launching of intercontinental ballistic missiles or the stationing of weapons in space. This interdependence of military and non-military uses, while extensive, does not of course preclude all comparative characterization in terms of objectives, and such evaluation may become more accurate and reliable as experience and knowledge develop.

Nor are those problems peculiar in kind to space and the atom. A panoramic view of the high seas, seen through time and space, shows a history of efforts to exclude, falling before a sounder policy of encouraging sharable uses and opening this great resource to all, only to have in our time a new crop of unjustifiably extensive claims to exclusive rights. It, too, is a history of interdependence of non-military uses, and of efforts by the community of nations to state norms of use in peace and war which limited unilateral action where unjustified by self-defense or, in earlier times, by legitimate uses of violence.

In modern times, we have seen new aspects of old problems in the controversy that has surrounded matters such as atomic tests in the Pacific, controversies which are obviously close to those involved in comparable space activities. In 1946 the United States, despite the monopoly that it then possessed over atomic knowledge and successful atomic experience, took the position (in the Baruch proposal) that nothing less than definitive, enforceable international control of atomic energy could be counted on to achieve the objectives of the Charter, and that nothing less than foolproof international inspection and enforceable regulation of atomic activities was consistent with either the aspirations of all men for peace and security or the right of self-defense inherent in customary international law and recognized in Article 51. In common with many other nations, the United States has taken the same position with regard to space activities. Without enforceable and effective controls, the United States must beware of unsafeguarded agreements that might not deter violators but at the same time could foreclose us from taking steps necessary to preserve our national existence.

Space power is military power, too, and in the future it may become the decisive element of all military power. Until an appropriate inspection and control system can be created by international agreement, nations can work toward the fullest international cooperation in peaceful uses of space and space technology, as in peaceful uses of atomic energy, only in the shadow of its potential for aggressive military use.

They must, therefore, act within the legal framework of the Charter and of customary international law, imposing positive duties upon states to pursue the paths of peace.

In this connection an important point may be made. Nothing in the Charter prevents the maintenance of an efficient and modern military establishment or declares the mere ability to defend one's self inconsistent with positive obligations toward peaceful settlement of disputes. Article 51 is not an exhaustive statement of the rights of self defense and does not preclude the lawfulness of such devices as contiguous zones for security. There is, thus, no need to rely exclusively upon Article 51 to justify the capacity of the United States, and of its allies, to defend themselves against attack or even the threat of attack by maintaining a sufficient force in being.

One difficulty is that the word "peaceful" is used in various contexts. In the sense of the Charter, and in international law generally, it is employed in contradistinction to "aggressive." It seems to have been used in this sense—which we believe to be a proper one—in various Congressional resolutions dealing with space activities. Thus any use of space which did not itself constitute an attack upon, or threat against, the territorial integrity and independence of another state would be permissible; the high seas, for example, can be used for the maintenance of a naval force-in-being without any violation of international law, and may be employed "peacefully" for maneuvers and testing of weapons. The word "peaceful" has, however, been used in other contexts; for example, it is used in the agreement setting up the International Atomic Energy Agency in the sense of "non-military." And it may have been used in this sense in the efforts, referred to above, to insure that space is used only for "peaceful purposes." A disarmament agreement, which the United States Government has been seeking through the United Nations, implies a system of control that seriously inhibits military usage and limits it in specific ways. By the same token, a United Nations Committee on "peaceful uses" of outer space cannot, without impinging on the terms of reference of its disarmament counterpart, attempt to classify definitely what uses are "peaceful" in the sense of being contrasted to those that raise problems of international control aimed at insuring security.

That the problem is in part a semantic one does not make it less real. For the time being it seems that the only uses of space that are prohibited are those that fall within the prohibition of the Charter, and that until a disarmament agreement dealing with space activities can be arrived at, the United States is justified in using space for non-aggressive military uses consistent with the terms of the Charter. Such use is clearly in accordance with existing international law, and the United States would have no embarrassment in asserting that it is "peaceful." Whether it falls without the jurisdiction of U. N. Committees employing the word "peaceful" in another sense is irrelevant to its characterization in general.

To compare the course of thinking on space law with the early history of international air law may be hazardous for several reasons, one of which is that we cannot now know whether the period from 1956-1960 is best compared to (say) 1901-1910 or 1901-1914. One tentative contrast may be suggested. Both then and now, the security-threat has assumed progressively greater importance in the literature. Both then and now, considerations of security seemed to call into question the desirability of a regime of uncontrolled overflight. The responses, however, may well prove from the vantage-point of tomorrow's historian to have differed significantly. The main response in the first part of the century was to establish the exclusive sovereignty of the underlying state; the main response today is to focus attention on international control or regulation. The reasons for this contrast, if it is accurate, must be found, we submit, only partly in the physical and psychological difficulty of projecting sovereignty far "out"; they lie also in the massive changes that have taken place in the past fifty years in the structure of the international community, the increasing consciousness of interdependence, and the substantial though uneven progress made in the techniques and efficacy of international organization. If conventional aircraft were to be invented only in 1961, and if we could imagine that all the rest of twentieth-century history had been as it was, it is arguable that the international community would not hit upon airspace sovereignty as we actually know it.

Until and unless all space activities can be brought under unified international control, we can safely assume that space programs will continue to be carried on by nation-states individually and perhaps (as with atomic energy) collectively as well; that these programs will increase in scope, intensity and frequency; and that they will develop basic scientific knowledge of great though now unpredictable significance to mankind, and technology which may be employed to a variety of non-military as well as military ends.

The factual interdependence of non-military and military uses of space and space technology complicates the tasks of creating a legal system in line with our basic goal. It cannot but affect the legal doctrine relevant to particular activities and the role and power of international institutions that can now be created; but it does not raise an insuperable obstacle to international cooperation in setting up legal principles and institutions governing many space activities. Experience with regard to similar problems raised by the atom indicates the broad and worthwhile areas in which cooperation can be achieved, as well as the limits imposed by considerations of national security.

The reluctance of some states to assert unequivocally that national sovereignty stops at a relatively low altitude and beyond that point space is "free" lies partly in the fear that the two space powers might act immoderately with regard to each other, or might do things in space which non-space powers regarded as inimical to their interests. Hence, their emphasis on a legal regime which insists that uses of space

be "peaceful," that space powers act "reasonably," that due regard be given to principles of "equality," and so forth. While they do not appear to desire a regime that would allow to each subjacent state an unqualified veto (the effect of unlimited sovereignty in space "over" territory) neither would they wholeheartedly approve a regime that authorized the space powers to decide unilaterally (or even, conceivably, bilaterally) what was permissible. In this connection it is worth recalling that the law of the sea, which many urge as the most appropriate analogy, was worked out over the years by a variety of doctrines adjusting special claims of coastal states to the common interest in free access, navigation, and so forth. We can expect, and perhaps anticipate, similar developments in space.

At the same time, as many have pointed out, the facts of space are in many ways distinguishable from those of other areas; as yet we have relatively little knowledge of the difficulties that may arise and the measures that might best be taken to promote the objectives as to which there seems considerable consensus. Lawyers can contribute significantly to the solution of legal problems arising from known and predictable contingencies; they cannot sensibly recommend in detail rules to deal with contingencies wholly or largely unknown and beyond human experience. With the gradual accumulation of experience and speculation we shall become better able at least tentatively to state the main legal problems in their relationship to facts, on the one hand, and the objectives of the United States and of the international community on the other.

B. Selected Legal Problems Arising from Space Activities

A number of writers have urged that we work towards a code of space law. Others, including governmental representatives, have preferred to take problems one at a time rather than attempt what they regard as a premature codification.

Clearly there is consensus that uses of space should be subject to rules of law, whether or not they now are, and that the objectives of shared benefit for all mankind should be pursued through international cooperation and regulation of some space activities.

From this, however, it does not follow that the time has become to draw up a code of rules for the use of space. The rule of law is neither dependent on, nor assured by, comprehensive codification, which may help or hinder depending on circumstances. At present we know very little about the actual and prospective uses of outer space in all their possible varieties of technical significance, political context, economic utility, and military advantage. In this situation an effort to agree on any comprehensive code might either come to naught, or yield a small set of pious maxims of extreme generality, or produce an unworkable regime that would be all the more dangerous for giving the

temporary illusion of certainty. It should be kept in mind, also, that in the present loose structure of relations among states a multi-lateral convention once agreed upon would be no easy thing to amend when circumstances called for its amendment.

A detailed and comprehensive code, or convention, to govern the use of outer space would seem to be premature and might even be harmful today. The idea can properly be reserved for periodic re-examination in the light of new facts; among other things, the labors of scholars and scientific and legal groups may in time contribute to a state of affairs in which the preparation of such a code could be realistically considered. Meanwhile, it is fitting to take particular problems already raised by activity in outer space or looming in the near future and to discuss the wisdom of various measures, including express international agreement, proposed for dealing with them.

The U. N. Ad Hoc Committee, in 1959, rejected as premature the notion that states should now attempt to codify, directly or indirectly the Law of Space. It pointed out that the law of the sea and air space might provide "fruitful analogies" but that "outer space activities were distinguished by many specific factual conditions, not all of which were now known, that would render many of its legal problems unique." It affirmed the applicability of the Charter to space activities.

In line with this approach, the U.N. Committee listed six general questions as "susceptible of priority treatment." These were (1) Question of Freedom of Outer Space for Exploration and Use; (2) Liability for Injury or Damage Caused by Space Vehicles; (3) Allocation of Radio Frequencies; (4) Avoidance of Interference between Space Vehicles and Aircraft; (5) Identification and Registration of Space Vehicles and Coordination of Launchings; (6) Re-entry and Landing of Space Vehicles. Equally important, it classified as "Other Problems"—that is, not susceptible of priority treatment—the following: (1) Question of Determining Where Outer Space Begins; (2) Protection of Public Health and Safety; Safeguards against Contamination of Outer Space or from Outer Space; (3) Questions relating to Exploration of Celestial Bodies; (4) Avoidance of Interference among Space Vehicles. In each case, the Committee limited itself to identification of the problem and did not, save by indirection, attempt to pronounce the relevant doctrinal standards.

Only a few of these questions have been discussed in any detail in the existing literature. However, it is perhaps useful to review some of the conclusions and recommendations which have been made even if, as with the U. N. Committee, little more has been done than to identify and state the problem.

1. Radio Spectrum Management

Radio-equipped space satellites and projectiles raise new problems relating to the allocation and use of radio frequencies and power specifications. Previous international agreements and custom which allocated frequencies on a geographical basis have been partially outmoded as to outer space. Law relating to international radio spectrum management may have to be amended and adjusted to take account of new conflicts and new capacities made possible by radio broadcasting from objects in space. For example:

(1) Tracing of radio-equipped space vehicles is of scientific importance to space exploration. Typical methods involve identification on wave-lengths that will be known in advance. It is important to the success of scientific experiment to know what wave-lengths may be used without interfering with other space programs or with other normal radio activities. Present arrangements, in part related to informal agreement by cooperating IGY scientists, are obviously ad hoc and of limited capacity. Any large increase in space activities will overburden existing facilities and result in disputes over the propriety of using a particular frequency.

(2) Radio-equipped satellites with self-generating equipment may continue to emit signals almost indefinitely, thus "using up" a frequency for years—perhaps centuries—unless standards, e.g., for automatic cutoff, are recommended, adopted and followed. The allotment of a limited frequency band to each nation engaged in space activity will encourage caution in such uses.

(3) A failure to allocate frequencies for national space programs increases the difficulty of prescribing norms with regard to either intentional or unintentional jamming of communication facilities. Interference by one state with another's space program, or interference by space vehicles with normal communication channels, could lead to retaliation and a serious dispute.

What has been said could be extended but is sufficient to indicate the need for radio spectrum management under legal norms based on informed scientific appraisals and recommendations. The U.N. Committee took note of the problems of radio frequency allocation and termination of transmissions that have outlived their usefulness and called attention to the technical studies to be presented in August, 1959, to the Administrative Radio Conference of the International Telecommunications Union. A detailed analysis of the work of the Conference may be found in Dr. Wenk's study prepared for the Senate Committee on Aeronautical and Space Science.

2. Conservation of Space

There is scientific opinion to the effect that a state with space capabilities could propel into orbit a large quantity of "junk" (for example, radioactive waste) the effect of which would be to preclude much further scientific experimentation and increase the hazards of space travel and the possibility of surprise missile attack. Such a program would overload tracking facilities and could distort communications. Presumably an effort would be made to justify it as a measure of self-defense.

It is important that all nations with space capabilities use them with discretion and reserve in the interest of future scientific and technological programs. As space capabilities increase, the possibility of an iron curtain holding back scientific progress for years to come increases as well. Steps to limit the number of satellites that can be put into orbit and to furnish some assurance that each serves a useful function would be constructive contributions to the law of space. It would be unconscionable to future generations for us unnecessarily to hamper their opportunities.

3. Radio and Television Relay Satellites

It has been predicted that space may be used to establish a world-wide network for point-to-point communication and for broadcasting, through the use of satellites carrying relay equipment. This possibility will raise problems of frequency allocation. In addition it may have repercussions on program content (censorship), use by commercial entities, application of laws regarding defamation, and the allocation of costs among governments and between governments and users. Again the prospect of jamming occurs, both in the form of interference with programs being relayed and in the form of the improper use of relay equipment to interfere with local communications.

Much of the experience and law already familiar in other areas may be applicable to situations in space. But not all the experience has been productive of satisfactory legal norms, and space techniques will make what have usually been bilateral conflicts into multilateral ones. Generally, analogous difficulties have arisen between adjacent states; soon, in respect to this problem, states widely separated on the earth's surface will be brought into direct and immediate contact.

It is common knowledge that the United States has deep-rooted convictions and policies about the importance of free communication among peoples everywhere. The advent of a world-wide network of communications could be a gigantic step forward in bringing the people of the world into contact, which might in turn help promote understanding of one another's culture, ideas, and problems. Therefore, this predictable miracle in communication should be studied and analyzed further with a view to recommending the necessary rules and procedures that will allow it to proceed with a minimum of friction and dispute.

4. Weather Forecasting and Control

A number of problems may arise in the use of space for weather forecasting and, possibly, weather control.

All nations have an interest in accurate weather forecasting. For security reasons, some may be reluctant to acquiesce in foreign national satellites for weather forecasting if these remain exclusively under national control without effective assurances of free and accurate dissemination of all information. Possibilities for resolution of this difficulty include duplicate facilities, bilateral collaboration (A's satellite transmitting to B's read-out station), international controls, and agreements as to the nature and content of information to be disseminated by the operating state.

The possibility of power over some weather conditions raises more difficult problems. Some, however, may be readily resolved; for example, the breaking up of conditions likely to produce local disasters such as hurricanes may be technically feasible without substantial harm done elsewhere. If science enables us to alter climate in important ways, virtually all aspects of life will be dramatically affected and all states will be rightly concerned. It may be difficult to agree on standards where weather-control would have far-reaching effects on crop production, for example. Analogous problems have arisen from efforts to create rainfall through cloud-seeding, and give some evidence of the difficulty of balancing the various interests involved.

Other problems may arise out of the fact that satellites used for forecasting may have a capacity to perform other functions; for example, to observe parts of the earth's surface.

5. Damage to Subjacent States, Aircraft and Vessels: Safety Standards

Space vehicles and space craft must travel for at least some periods within altitudes sometimes used for normal air travel. Recovery of space craft creates at least a possibility of surface damage if the place of recovery is miscalculated. There is also the possibility of misfiring and failure of safety equipment to operate satisfactorily.

The possibility of agreement on safety standards (notification of firings, policing areas of danger on the high seas, safety equipment on missiles to insure harmless destruction in the event of misfire) might usefully be explored with a view to minimizing dangers to non-participants and creating standards of care that would have to be met to avoid entailing state liability. In addition, it may be possible to specify situations where states should be willing to assume absolute liability, regardless of negligence, for certain kinds and amounts of damage arising from space activities. The U. N. Ad Hoc Committee suggested in this connection that early consideration should be given to

agreement on submission to the compulsory jurisdiction of the International Court of Justice in disputes between states as to liability of states for injury or damage caused by space vehicles.

6. Repossession of Space Craft and Repatriation of Space Personnel

Through miscalculation a spacecraft or "ship" may be brought back to earth in a country not intended as the place of landing. What standards shall be applied to determine the duty of the state of landing to return the equipment and repatriate any personnel, without invoking various local statutes? Agreement in advance on these points seems both possible and desirable in the interest of reducing areas of dispute and tension. As the U. N. Committee noted without making a definite recommendation, rules of international law already exist on rights and duties with respect to aircraft and airmen landing on foreign territory through accident, mistake, or distress; these rules may well deserve to be applied in the event of similar landings of space vehicles.

7. Observation Satellites

A number of writers have mentioned the possibility of satellites with relay television cameras capable of observing the earth in considerable detail. The United States project Samos has this objective. It has recently taken on considerable importance because of the U-2 incident of May, 1960 and subsequent developments.

It will be recalled that the Soviet Government characterized the U-2 as "aggression" and strongly objected to its activity--aerial photography--as well as to its intrusion into Soviet air space. Immediately after the Security Council debates, the latest Soviet disarmament proposal included as a first stage of "disarmament" the cessation of aerial reconnaissance, which may be some indication of the importance the Soviet attaches to the preservation of secrecy. The Soviet Union viewed reconnaissance as aggressive on the theory that its purpose was to locate and identify targets. The United States characterized it as essential to self-defense and helping to deter aggression by its capacity to identify in advance activities that might be of an aggressive nature. The polar characterization of the same events indicates some of the difficulties in present doctrine. Reconnaissance might serve either purpose, or both purposes, and various kinds of reconnaissance devices might have different utility for the two purposes.

Possibilities for resolving this difficulty of characterization may exist in setting up and equipping a United Nations Reconnaissance Unit. In Paris after the breakdown of the Summit Conference in May 1960, President Eisenhower stated that he planned "in the near future to submit to the United Nations a proposal for the creation of a United Nations aerial surveillance to detect preparations for attack." No definite proposal, however, was conveyed in the President's address

to the General Assembly in September, where he only referred generally to the possibility of reducing the danger of war by miscalculation "in times of crisis, by the intervention when requested by any nation seeking to prove its own peaceful intention, of an appropriate United Nations surveillance body." One or more observation satellites (Samos, Midas, or other) or systems of observation satellites could be operated as trustee satellites on behalf of the United Nations to which the operating country would turn over all information obtained. Parallel unilateral activity need not be prohibited and might be supported as a check.

8. Coordination of Space Programs

Connected with the problem of conservation, yet independent of it, is the task of coordinating national space programs for various purposes. Objects propelled into space must be tracked by tracking facilities all over the world if their scientific significance and technological performance are to be properly appraised. Phenomena in space precipitated by human agency often require coordinated observation and interpretation from many points on the earth. As we have already pointed out, the more objects in space and the more activities in space, the more difficult this task will be. In addition, as space programs advance in capability and dimension, the likelihood of near-simultaneous firings into related paths will increase. This contingency could lead to the mutual frustration of expensive and important experiments and argues for a common interest in cooperative efforts. It could result in more than the desirable amount of duplication of scientific experiment. One possible solution lies in proposals for advance filing of flight plans and coordination of launch times. It may be premature and unnecessary to spell out "rules of the road" in detail, but it is not too early to take first steps in the direction of creating legal norms and institutions that could avoid the contingencies even now to be foreseen.

C. International Organization for Space Activities and Space Law

Some space activities are already conducted internationally, in the sense that representatives or nationals of more than one state take part in them. Whether existing arrangements, many of them casual and provisional, should be altered, continued, confirmed, or imitated is a matter with which lawyers will have much to do although it is not usually regarded as a "legal" problem.

The forms of international activity in outer space may be determined, and will be affected, by the purposes, overlapping and perhaps in part conflicting, with which the activity is undertaken. Stated from the standpoint of the United States, but indirectly as well from the perspective of a larger community, some of those purposes may be briefly mentioned as follows:

Technical factors may require some type of international cooperation, if only in the form of agreement on the approach to take to

specific problems. The U.N. Ad Hoc Committee listed, in its Report on Paragraph 1(b) of the General Assembly Resolution 1348(XIII), some illustrative topics for international agreement: use of radio frequencies, registration of orbital elements, continuing radio transmission, removal of spent satellites, re-entry and recovery of space vehicles, return of equipment, identification of origin, and contamination. For these activities, and others that might be named, international agreement seems necessary either because no one country has all the necessary technical facilities or possibilities, or because the particular activity is one where the objective depends upon the consistency of all unilateral action, as in the case of "decontamination".

Some forms of international space action can be used, from the point of view of a launching power, to obtain the benefit of scientific, technical, or even financial contributions of other nations, to share with other nations the burdens as well as the benefits of space activities, to give evidence of the peaceful intent of the launching power, to provide training for technical personnel on both (or on all) sides, to channel economic and technological developmental assistance, and to furnish a model for other kinds of international cooperation, for example in connection with disarmament or arms control.

Not all of these objectives are necessarily of equal importance or urgency; not all of them can be directly reflected in forms and methods of organization. Those may perhaps be determined by reference to other objectives, not necessarily less important than the "space-connected" objectives. The number of participants in any international organization set up for space activity can be bilateral, regional (bloc), multilateral, or global. The participating members may be governments or organizations of scientists, engineers, lawyers, etc. The powers of the organization may be weak or strong along a spectrum of relative "supranationality." The organization might be a specialized agency of the United Nations; it might be a committee of technical advisers to the General Assembly or to the Secretary General; it might in some respects resemble existing agencies such as the International Atomic Energy Agency. It need not duplicate the work now being done, or capable of being done, in such quasi-official bodies as COSPAR, or in such other organs as the International Telecommunications Union, the International Civil Aviation Organization, or the World Meteorological Organization.

On the U.S. side, the National Aeronautics and Space Administration is engaged in four basic types of international activity, which one of its officials describes as operational, informational, joint, and personnel exchanges and training.

The operational programs consist of space probe tracking activities, conducted or about to be conducted in 19 countries abroad. Some of the stations are operated by U.S. technicians, some jointly with technicians of the host countries, some by foreign technicians under contract or grant arrangements. Informational programs are an

outgrowth of IGY operations. Launchings of sounding rockets, satellites, and space probes are reported by various means; periodic catalogs of information are made; results of experiments are published and distributed, for example, through world data centers; NASA scientists take part in scientific meetings.

In March, 1959, the U.S. delegate to the meeting of COSPAR at The Hague offered on behalf of NASA a program to include experimental payloads, designed by foreign scientists, in vehicles launched by the United States; to launch satellites designed by foreign scientists, with agreed payloads up to a certain weight in a certain range of orbital altitude; and to invite space experimenters to work on their projects in the U.S. laboratories. A number of projects and plans have grown out of this initiative, and more elaborate joint projects are going forward with the Canadians and the British. NASA makes a small number of grants to foreign scientists (as well as domestic scientists) through the National Academy of Sciences for post-doctoral and senior resident associateships. In addition, NASA is endeavoring to provide laboratory support and guidance for foreign scientists, sent and supported by their governments, to work in U.S. space laboratories.

The scientific section of the 1959 U.N. Committee's report proceeded on the premise "that a principle of open and orderly conduct lies at the root of international cooperation directed towards the peaceful use of outer space." It calls for a rallying point related to the United Nations, small in size but well informed, "a center to which inquiries can be directed at any time, and by which information can be communicated effectively to the appropriate body in much the same way as ICSU meets a similar need for the existing international scientific unions."

The United Nations Ad Hoc Committee as a whole decided "that it would not be appropriate at the present time to establish any autonomous inter-governmental organization for international cooperation in the field of outer space", or "to ask any existing autonomous inter-governmental organization to undertake over-all responsibility in the outer space field." Its other organizational recommendations were on the whole limited to the setting up of study groups; it dealt with the "focal point" recommendations of the scientists by suggesting that "consideration might...be given to provision for a small advisory committee, advisory to the Secretary General, which could include representatives of the appropriate specialized agencies, scientists designated by international scientific organizations, and representatives of member states, as necessary." It noted the possibility of establishing a committee of the U.N. General Assembly, "composed of representatives of member states and having such membership as the Assembly may decide," to study international cooperation, to study legal problems, and to review, "as appropriate," the subject matter covered in the terms of reference of the Ad Hoc Committee.

Whatever organization emerges from these recommendations, even if they are confirmed by the re-constituted U.N. Committee scheduled to meet in 1960, is unlikely to possess formal powers to exert general regulation over national programs or make binding legal norms for space activities. Whether it will be able to make recommendations and suggest standards that may as a matter of optional acceptance be followed by states engaged in national programs remains yet to be seen.

Legal scholars have, in several instances, gone much further than the U.N. Committee in recommending international regulation, coordination, control, operation, or even ownership. Some of the recommendations appear to proceed from a preoccupation with particular difficulties or conflicts, in particular the security threat. Others appear to have proceeded from political objectives, not necessarily "space-connected". Still others appear to be based on a desire to abolish the complexities that make international cooperation difficult and a belief, not always expressed or examined that the maximal "internationalist" solution would be tidy and comprehensive. Here, one might say, the objective is not so much political as anti-political.

The present Report does not contain any recommendations on the form of organization of an international agency for space, or even on the future desirability of such an agency. We would make two points that seem particularly relevant to the present stage of space activity and organization for space:

(a) It is at the level of fact, as it seems to us, that an international agency of some kind, able to draw upon the talents of highly-trained scientists to appraise possibilities and alternatives, can play its most useful role in promoting legal standards for national or other space programs. Such a group could help to mobilize the talents of the international scientific community in making responsible recommendations for the consideration of national states, either as a basis for subsequent formal international agreement or as a consideration that will be relevant to unilateral decisions. It would not thereby supersede national authority and control.

(b) If an international organization, existing or to be established, is to conduct any space operations, as to which we likewise make no recommendation, it may usefully begin by appropriate provisional arrangements with states having space capabilities. Such arrangements might take the form of trust agreements, the operation of vehicles being carried out under terms and conditions roughly comparable to those presently applicable to trust territories; or they might take the form of "guest payloads," prepared by international bodies but launched on their behalf by particular national governments. They might be particularly suited to the operation of space vehicles and space craft for some of the purposes canvassed in subsection B above, and this operation might promote agreement on norms and procedures applicable to purely national space activities. The "provisional" arrangements, like other "provisional" arrangements, might turn out to have unexpected lasting qualities.

International agreement on the problems raised in this report is not a prerequisite to national activity in space, unless the term, "agreement" is interpreted broadly. On the other hand, states should act reasonably and with moderation regardless of the presence or absence of formal legal norms. To the extent that workable formal agreement can be achieved, difficulties and friction may be obviated thereafter; even an unsuccessful attempt to reach such agreement on a well-defined set of practical, impending problems may be helpful in the making of national decisions if it influences states with space capabilities to conduct their space activity in such a way as to avoid major disagreements and reduce international tension. The area of disagreement at the negotiating table may prove to be narrow by comparison with the area of agreement; the number of states taking one position may be shown to be insignificant by comparison with the number taking a different position; the reasons urged in support of one position may be far more persuasive to the international community than those urged for another; that subject matter in which the difference of opinion relates to soluble technical questions may be separable from others. By clarifying and proposing legal arrangements within the modest scope set out in this report, lawyers can contribute, in common with public officials, to fostering a climate in which durable institutional machinery and, eventually, comprehensive codes for space activity can be launched when that appears practical and necessary. In the same spirit, the United States may well be urged to encourage parallel international and national activities whenever security considerations permit.

APPENDIX B

NATIONAL SCIENCE FOUNDATION IN BASIC SCIENCE RELATED TO SPACE

ASTRONOMY

Instrumentation for General Astronomy

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Design of Equipment Consisting of an Automatic Machine for Measuring Astrographic Positions and Magnitudes	To be used to measure photographic plates taken with the Lick Observatory Astrograph.	University of California Vasilevskis	\$341,550	12/57	5 years
Application of the Lallemand-Type Image Converter to the Investigation of the Spectra of Faint Stars	Installation of image tube on caude spectrograph at Lick Observatory.	University of California Walker	8,600	12/58	1 year
Design and Construction of High-Dispersion Nebular Spectrograph	For use with the 36 inch reflector at Lick Observatory, to obtain radial velocities and motions in gaseous nebulae.	University of California Herbig	30,300	12/59	1½ years
24-Inch Photometric Telescope	For use in a wide variety of research programs on stellar photometry.	University of California Whitford	20,000	3/60	2 years
Investigations and Construction of Photoelectric Image Tubes for Research in Astronomy	Light is amplified, which increases the range of telescopes.	Carnegie Institution of Washington Tuve	385,000	5/58	3 years
New Ultraviolet Transmitting Objective Prism	To be used on the 24-36 inch Schmidt telescope of the Warner and Swasey Observatory.	Case Institute of Technology Nassau	10,500	12/58	1½ years
Image Converters for Astronomical Photography.	Purchase and testing of image tubes.	University of Chicago Hiltner	15,000	3/59	2 years

ASTRONOMY

Instrumentation of General Astronomy (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Equipment for Selected Photometric Observations	Construction of automatic data processing equipment for use with photoelectric photometer on large telescope, to increase accuracy and productivity.	University of Chicago Miller	\$ 8,800	6/60	1 year
Development of Two Interferometer Telescopes	For use in seeing tests in site survey in Chile.	University of Chicago Kuiper	6,000	6/60	1 year
High Resolution Spectrograph	To be used with the Coronagraph of the High Altitude Observatory.	University of Colorado Roberts	80,000	12/58	2 years
A Design Study on Very Large Arrays for Radio Astronomy	Design studies on very large antenna arrays for radio astronomy, made at the Radiophysics Laboratory, Sydney, Australia	William C. Erickson (individual)	1,000	6/60	3 mos.
Equipment for New Graduate Program in Astro-Geophysics	Purchase of a microphotometer and other equipment for use of staff and graduate students in new research center for Astro-Geophysics.	High Altitude Observatory Roberts	9,060	12/59	1 year
Studies and Tests for Improvement of Feed Systems for Large Paraboloids	To be used with Radio Telescopes. Principal purpose is to obtain maximum illumination of the primary dish while reducing spillover at the edges.	Jasik Laboratories Jasik	55,000	8/58	2-1/3 years

ASTRONOMY

Instrumentation of General Astronomy (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
An All-Mirror Cassegrain Spectrograph for Astronomical Research	To be used with the Perkins Observatory 69-inch reflector.	Ohio State University Keenan	\$ 30,000	7/56	5 years
Installation of 16/24-inch Schmidt Telescope at Perkins Observatory	To be used for spectral survey, and distribution of variable stars.	Ohio Wesleyan University Slettebak	41,700	12/59	2 years
A Radio Telescope for Millimeter Wavelengths	To make studies of sun, moon, planets.	University of Texas Straiton	20,900	6/60	1 year
The Application of Television Techniques to Astronomy	Primary purpose is to obtain image amplification coupled with low internal noise	Vanderbilt University DeWitt	27,900	6/59	2 years
Modernization of a Long Screw Measuring Engine and its Application to Astrometric Research	Star positions will be recorded automatically, greatly speeding up the measurements.	Yale University Brouwer	27,500	8/58	3 years

ASTRONOMY

Facilities for General Astronomical Research

Project Title	Supplementary Description	Participants	Amount	Grant	Duration
Establishment, Construction and Operation of a National Radio Astronomy Observatory at Green Bank, West Virginia		Associated Universities, Inc. Berkner	\$12,834,000	11/56	5 years
Establishment, Construction and Operation of a National Stellar and Solar Optical Observatory at Kitt Peak, Arizona		Association of Universities for Research in Astronomy, Inc. McMath	10,212,460	12/57	5 years
Preliminary Conceptual Design, and Experimental Studies for Large Aperture Orbital Telescopes		Association of Universities for Research in Astronomy, Inc. A.B. Meinel	412,300	6/59	1½ years
Radio Astronomy H-Line Installation in South America	Development of radio astronomy equipment to be installed and operated in South America. It will establish fruitful relations with South American astronomers.	Carnegie Institution of Washington Tuve	41,000	6/60	1 year
Studies Related to the Establishment of a Large Astrographic Telescope in the Southern Hemisphere	The principal activity is site testing in the Southern Hemisphere. Present activities are centered on the area around Santiago, Chile	Columbia University Schilt	25,300	3/59	2 years

ASTRONOMY

Facilities for General Astronomical Research (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
21-Centimeter Radio Astronomy	A maser receiver is being developed.	Harvard University Bok, Menon and Gold	\$488,100	10/52	8 years
High Altitude Astronomy	Spectroscopic observations are to be made from a manned balloon.	Johns Hopkins University Strong	70,000	12/57	3 years
Transfer of the Perkins Reflector to Flagstaff, Arizona	The move from Ohio to Arizona will ensure more clear nights, and the better quality of the sky will shorten photographic exposure times.	Lowell Observatory Hall	231,300	12/59	1 year
A fixed Paraboloid and Tilttable-Flat Reflector for Radio Astronomy Research	This instrument is designed to combine very large collecting area with relatively low cost. It will be of the transit type.	Ohio State University Kraus	404,350	2/56	5-3/4 years
Relocation of Observatory	Observatory and equipment will be moved to Delphos, Ohio to be used for observations of variable and double stars. It will be available to high school and college students and to the public.	L.C. Peltier (Individual)	1,500	5/60	1 year
A Survey on Suggested Sites in New Zealand as to Their Suitability for Astronomical Research		University of Pennsylvania Wood	26,400	9/60	1 1/2 years

ASTRONOMY

Facilities for General Astronomical Research (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
High Altitude Astronomy	Telescopes are carried to high altitudes by unmanned balloons	Princeton University Schwarzschild	\$1,420,000	5/58	4½ years
Radio Astronomy	Solar observations at low frequencies.	Rensselaer Polytechnic Institute Fleischer	38,000	3/57	3 years
Design of Infrared-Microwave Telescope	Steerable dishes having apertures in the range from 10 feet to perhaps 60 feet and surface tolerances of the order of a fraction of a millimeter are being studied.	University of Texas Johnson	70,000	3/59	3-3/4 years

ASTRONOMY

Solar System Astronomy

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Indirect Flare Detection	Effects of solar activity on radio propagation are monitored.	American Association of Variable Star Observers Bondy	\$ 575	5/59	1 year
Physical and Statistical Studies of Asteroids	Continuation of research programs on motions and light variations of asteroids to gain knowledge of their shapes, sizes and reflectivity.	University of Chicago Kuiper	69,200	7/53	7 years
Solar System Studies	Photometry of moon and asteroids, planetary studies, observations of comet tails.	University of Chicago Kuiper	15,600	6/57	3 years
The Calculation of Minor Planet Orbits	The computing facilities of the University are used to compute orbits of newly discovered minor planets and to improve other orbits, making use of planet positions observed at centers all over the world.	University of Cincinnati Herget	24,850	6/57	3 years
Optical Solar Flare Patrol and Solar Activity Summaries	A photographic solar flare patrol program started under the IGY is being continued. This program makes possible a variety of studies of solar-terrestrial relationships. The High Altitude Observatory collects data from many IGC stations and prepares summaries.	University of Colorado Roberts	26,200	5/59	1 year

ASTRONOMY

Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Research in Solar Magnetic Fields at the Crimean Astrophysical Observatory	Exchange of visits with a Russian astronomer. Visits to Russian observatories. Research in solar magnetic fields.	University of Colorado Zirin	\$ 6,300	8/60	1 year
Solar Activity Related to Ionospheric Phenomena	Photographic patrol of solar surface, and motion picture photography of rapidly changing solar features.	Dartmouth College Dimitroff	7,300	6/57	2-2/3 years
Planetary Emissions at Radio Frequencies	A program on the nature and origin of radio-frequency emissions from the planets, including spectral analysis by simultaneous monitoring of four frequencies, and study of polarization of planetary emissions.	University of Florida Smith	46,500	8/57	5 years
Radio Observations of Jupiter and Saturn from Chile	Since these planets now appear low in the Southern sky for observers in the northern hemisphere, a field station is being operated near Santiago in cooperation with the National Astronomical Observatory of Chile.	University of Florida Carr and Smith	41,000	12/58	2 years
Investigations of the Sun's Spectrum	High resolving power is used.	Georgetown University Kiess and Meggers	52,800	3/58	3 years
Harvard Radio Meteor Project	Reflection of radar pulses from meteor trails adds to the knowledge of ionosphere and yields data for determining orbits of meteors.	Harvard University Whipple	175,000	9/60	1 year

ASTRONOMY

Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Solar Activity Flare Patrol	Reporting of solar flares and prominences.	University of Hawaii Steiger	\$ 8,000	5/59	1½ years
Observations of Asteroids	Observations are used at the Minor Planet Center for computing orbits.	Indiana University Edmondson and Cuffey	45,200	6/54	7 years
Research in Solar Physics	Visual flare patrol, and study of transient solar phenomena with rapid-sequence camera.	Lockheed Aircraft Corporation Moreton	16,300	3/60	1 year
The Reduction of Observations of Magnetic Fields and Motions on the Surface of the Sun	Variation of solar magnetic field with position and time, and correlation of magnetic field with turbulent motion.	University of Massachusetts Howard	8,860	12/59	2 years
The Abundance of Certain Elements in the Solar Atmosphere	Spectrographic observations of the sun, using high dispersion.	University of Michigan Aller	13,600	8/58	3 years
Lyot Photoheliograph Flare Patrol	Photographic patrol of the solar features which are visible in the light of hydrogen alpha.	University of Michigan Mohler	10,600	5/59	1 year
Terrestrial Magnetic Storm and Solar Activity	Correlations between solar and terrestrial phenomena.	University of Michigan Mohler	8,000	9/59	1 year
High Altitude Balloon Monitoring for Cosmic Rays and Solar Terrestrial Phenomena	Equipment is carried to high altitudes by balloons. Recording of cosmic rays, aurorae.	University of Minnesota Ney and Winckler	54,700	6/60	4 months

ASTRONOMY

Solar System Astronomy (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Solar Activity Data	Data are tabulated and published.	National Bureau of Standards (Boulder) Brown	\$ 14,900	5/59	1 year
Rocket Observations of Solar Flare Emissions in Ultraviolet and X-Rays	Instruments are carried by rockets to various heights to measure radiation received at times of solar flares.	U.S. Naval Research Laboratory Friedman	250,000	5/59	1 year
Zodiacal Light in the Tropics	A specially designed Schmidt camera on top of a mountain in Bolivia makes accurate automatic recordings of the Zodiacal light. Observations are studied to learn distribution of interplanetary dust and electrons and its dependence on solar activity.	University of New Mexico Regener	22,900	5/59	2 years
Photometric Atlas of the Solar Spectrum	Extension into the far ultraviolet (3000A to 3650A) and the near infrared.	Ohio State University Mitchell	28,800	9/59	2 years
Indirect Flare Patrol	Effects on radio reception are monitored.	Rensselaer Polytechnic Institute Fleischer	8,000	5/59	1 year
Possible Turbulence in Sun Spots	Determination of the existence of turbulent velocities at varying optical depths in a sunspot, by analysis of sunspot spectrum photographs taken in polarized light.	Ripon College Zei	5,500	6/60	1 year

ASTRONOMY

Solar System Astronomy (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Solar Radio Emission	Comparison of Stanford and Japanese records of solar radio emission and of optical solar images will throw light on the physical conditions in the sun's corona.	Stanford University Bracewell	\$ 11,160	3/60	1 year
An Analysis of Solar Granulation	Theoretical investigation to determine behavior of temperature convection velocity, and rate of heat transport at various depths.	University of Texas Edmonds	9,200	8/58	3 years
Interferometric Study of Coronal Emission	Detailed study of line profiles of the solar corona to be made during solar eclipse of October 12, 1958, using interferometric methods combined with photo-multiplier detection.	University of Wisconsin Mack	24,600	8/57	4 years
Investigation of Planetary Radio Emission	Observations and theory of radio emission from Jupiter and other planets. Simultaneous observations are made at different locations and at different frequencies.	Yale University Smith	75,500	12/57	4 years

ASTRONOMY

Extra-Solar System Astronomy

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Eclipsing Binaries	Observations of variation in brightness of eclipsing binaries to determine sizes and masses.	Amherst College Koch and Linnell	\$ 7,500	12/59	1 year
A Spectrographic Study of Eclipsing Binaries and of Beta Canis Majoris Variables		Brigham Young University McNamara	29,700	4/56	6 years
Photometric Investigations in the Southern Hemisphere, at the Mount Stromlo Observatory, Canberra, Australia	Observations made in Australia of magnitudes, colors, and photometric diameters of southern stars and globular clusters.	University of California Kron	1,800	6/60	1 year
Statistical Studies of Double and Multiple Galaxies	To determine whether individual galaxies are in stable orbits or are separating as the result of an explosion.	University of California Neyman	12,100	6/60	1 year
Operation of the Lallemand-type Image Converter	The image tube will be adapted for direct planetary and stellar photography.	University of California Walker	34,600	6/60	2 years
Evolution of Close Binary Stars	Observational and theoretical studies are being made on spectroscopic binary stars and intrinsic variable stars.	University of California Struve	34,400	6/57	4 years
Computation of Orbits in the Restricted Three-Body Problem	A theoretical investigation of the motion of gases which envelop close binary star systems.	University of California Heney	20,000	3/59	2 years

ASTRONOMY

Extra-Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Application of a Pressure-Scanning Fabry-Perot Interferometer to High Resolution Stellar Spectroscopy		University of California Whitford	\$ 38,200	9/59	2 years
Abundances of the Elements in High Velocity G Dwarf Stars		University of California Wallerstein	5,000	9/59	2 years
A Cooperative Supernova Search	The 48-inch Schmidt telescope at Mt. Palomar and telescopes at the University of Arizona are being used to search for supernovae in selected groups of galaxies. Observations of light variations and spectral characteristics are being made.	California Institute of Technology Zwicky and University of Arizona Carpenter	52,700	7/56	6 years
Determination of the Radial Velocities of a Special Class of Blue Stars		California Institute of Technology Zwicky	3,900	6/59	1 year
Construction of Catalogue of Galaxies and of Clusters of Galaxies		California Institute of Technology Zwicky	25,320	9/60	2 years
Infrared Studies of Faint Red Stars	Experiments are planned to produce faster stable infrared photographic emulsions, and to combine use of fast infrared emulsions with low dispersion objective prisms to study statistical distribution of M-stars near the galactic pole and in young globular clusters.	Case Institute of Technology Blanco	16,900	6/59	2 years

ASTRONOMY

Extra-Solar System Astronomy (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Distribution of A-Type Stars in Selected Galactic Regions		Case Institute of Technology Massau	\$ 5,900	3/58	2 years
Spectroscopic Binaries in the nearest O-Associations	Photometric observations and radial velocity measurements of double stars in the associations of O and B stars in Orion, Cepheus and Scorpio.	University of Chicago Elaauw	12,000	1/56	5 years
Program for Research on Galactic Clusters	Photometric and spectroscopic studies.	University of Chicago Hiltner	12,800	8/58	2 years
Problems of Theoretical Astrophysics	Theoretical investigations of the evolution of young stars, and the nature of the flow of superficial gas streams near binary stars.	University of Chicago Prendergast	11,700	3/59	2 years
Simultaneous Three-Color Photometry of Faint O-F Stars	A three color spectrometer is used to determine reddening and spectral classes.	University of Chicago Stramgren and Weitbrecht	4,100	1/56	4 years
Astrometric Investigations	Observations of positions to obtain orbits of double stars, comets, asteroids, planetary satellites. Determination of luminosities of faint nearby stars.	University of Chicago Van Biesbroeck	33,800	6/54	7 years
Composition, Energy Spectrum, and Intensity of the Primary Cosmic Radiation as a Function of Time	Observations from balloons to study change in cosmic rays during solar flares.	University of Chicago Meyer	75,000	10/60	1 year

ASTRONOMY

Extra-Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Spectroscopic and Photometric Studies of the Structure and Dynamics of External Galaxies		University of Chicago Burbidge and Burbidge	\$ 48,900	2/60	2 years
Studies in Stellar Classification	A reexamination of stellar classification from point of view of stellar populations and evolution.	University of Chicago Morgan	35,700	12/59	4 years
Faint Variable Stars in the Cygnus Cloud of the Milky Way	Photographic methods are used.	Fordham University Miller	19,900	4/56	5 years
Photometric Reduction of Standardized Photographs of Galaxies	Determination of luminosity distribution in representative types of bright galaxies.	Georgetown University Rubin	7,200	6/60	2 years
Intensity Distribution in Galaxies in the Virgo Cluster	Measure of luminosity distribution as a function of distance from the center, leading toward mass distribution, and a better distance scale.	Harvard University Liller, M.H.	4,300	6/60	1 year
Evolutionary Effects on the Continuous Spectra of Stars	Comparison of observations with theoretical spectral energy distribution for white dwarf stars.	Harvard University Liller, W.	2,700	6/60	1 year
Photometric Studies of Bright Galaxies		Harvard University de Vaucouleurs University of Texas	31,200	2/59	2-2/3 years

ASTRONOMY

Extra-Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Theoretical Energy Levels and Transition Probabilities	A new theoretical scheme for describing atomic spectra has been developed.	Harvard University Layzer	39,800	6/58	3 years
Henry Draper Spectral Types for the Southern Polar Cap	Spectral classification of about 4,000 stars.	Harvard University Menzel	6,900	6/59	1½ years
The Dynamical Evolution of Star Clusters		University of Illinois King	8,200	6/58	3 years
The Rotational Velocities of Early Type Stars in Galactic Clusters	Comparison of rotational velocities of stars in clusters with those of single field stars, to learn something about the origin and evolution of clusters.	University of Illinois Meadows	2,770	3/60	1 year
Light Curves, Color Curves-Periods, and Changes in Periods of Short Period Variable Stars in the Globular Cluster Messier 53		Indiana University Cuffey	5,800	6/60	1 year
Analysis of Photoelectric Observations of Cepheids	Photoelectric observations of Cepheid variable stars made in the southern hemisphere to give information on their distances and hence on galactic structure.	Indiana University Irwin	6,900	5/60	1 year

ASTRONOMY

Extra-Solar System Astronomy (cont.)

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Astrophysical Problems	Theoretical studies of stellar atmospheres and interiors.	Indiana University Wrubel	\$ 41,600	6/57	6½ years
Photoelectric Photometry of A and F Stars		Institute for Advanced Study Stromgren	19,800	10/59	2 years
Proper Motion Survey of the Northern Hemisphere	A catalogue of proper motions is being published. Measurements of stars between magnitudes 8.0 and 16 or 17 are being made on 2 sets of homogeneous plates taken 30 years apart.	Lowell Observatory Giclas	78,700	4/56	6½ years
Computations in Radiative Transfer and Theoretical Photometry	Comparison of theory of planetary illumination with observations of the changing brightness of planets with phase.	University of Kansas Horak	9,600	6/60	1 year
The Influence of Chemical Composition on Stellar Evolution		Louisiana State University and University of Illinois Demarque	31,750	6/60	2 years
Research on Variable Stars, Especially in Sagittarius		Maria Mitchell Observatory Hoffleit	10,800	6/60	3 years

ASTRONOMY

Extra-Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
To Detect the Galactic Deuterium Line	Adaptation of the radio receiver to allow detection of the deuterium line and determination of the galactic deuterium-to-hydrogen abundance ratio.	Massachusetts Institute of Technology Wiesner	\$ 60,000	6/60	19 months
General Proper Motion Survey	Measurements of colors and positions of stars with large proper motions to locate blue stars and white dwarfs in the neighborhood of the sun. Two catalogues have been published. A third is in preparation.	University of Minnesota Luyten	59,600	6/52	9 years
Relative Frequencies of G and K Giants with Weak and Strong CN Absorption	Distribution of space velocities is being studied. Continuation of a project started at Louisiana State University.	Mount Holyoke College and Louisiana State University Yoss	9,628	6/58	3 years
Support of Astrometric Research in the Southern Hemisphere		National Academy of Sciences Clemence	25,000	6/60	2 years
Luminosities of Mira Variables and Related Variable Stars	Establishment of luminosity criteria by analysis of high-dispersion spectra.	Ohio State University Keenan	6,300	5/60	2 years
Astronomical Research in the Infrared	Observations of the variations of infrared light during eclipses of eclipsing binary systems.	University of Pennsylvania Blitzstein and Wood	21,300	8/58	2-2/3 years

ASTRONOMY

Extra-Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Determination of the Parallaxes of Dwarf Stars		University of Pittsburgh N. Wagman	\$ 6,000	3/59	4 years
Investigation of Astronomical Data Pertaining to Extinction and Polarization by Non-Spherical Particles	Comparison of predicted and observed polarizations and extinctions at several wavelengths to gain knowledge of interstellar dust particles and the galactic magnetic field.	Rensselaer Polytechnic Institute Meltzer	4,900	6/60	1 year
The Scattering of Light by Small Particles	An analogue method is used employing microwave techniques.	Rensselaer Polytechnic Institute Greenberg	73,900	6/58	3-1/3 years
Astrometric Study of Nearby Stars	Continuation of a program of measurements of stellar positions to determine trigonometric parallaxes and to increase knowledge of masses and luminosities of stars.	Swarthmore College Van de Kamp	70,800	6/56	5½ years
Search for Spectrum Lines in Radio Astronomy	A parametric amplifier is being developed for this purpose. It is to be used on the U. of Michigan 85-foot radio telescope.	University of Toledo Chipman	22,800	6/59	2 years
An Investigation of the Structure of the Galaxy Through the Study of the Nearer Association of OB Stars		Vanderbilt University Hardie	29,300	12/57	3¼ years

ASTRONOMY

Extra-Solar System Astronomy (cont.)

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
An Infrared Survey of a Region in the Scutum Cloud	Spectral classification of M-type stars from infrared objective prism plates.	Vassar College Albers	\$ 2,200	6/60	2 months
Nebular Spectroscopy in the Southern Hemisphere	A fast spectrograph will be built for use at Cordoba, Argentina, to obtain spectra of southern galaxies.	Wesleyan University Page	13,700	12/59	1 year
Determination of Systematic Errors and New Plate Constants of Northern Hyderabad Zone of the Astrographic Catalogue	Continuation of a project started at Georgetown U.	Wesleyan University Eichhorn	6,700	10/59	1 year
Three-Color Studies of Eclipsing Binaries		University of Wisconsin Huffer	5,600	6/59	1 year
Absolute Calibration of the Energy Distribution of Astronomical Radiation Sources		University of Wisconsin Code	16,700	3/58	2 years
Constitution of the Late-Type Stellar Atmospheres and Interiors		Yale University Wildt	7,500	12/57	2 years

ASTRONOMY

General Support of Science in Space

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Space Science Board	This is a consultative and advisory group of scientists. Support is being provided jointly by the National Science Foundation and the National Aeronautics and Space Administration. See text for additional information.	National Academy of Sciences Cornell	\$360,000	8/58	2 years
Support of COSPAR	To further on an international scale the progress of all kinds of scientific basic research carried out with rockets or rocket-propelled vehicles.	National Academy of Sciences Meid	5,000	5/60	1 year

ATMOSPHERIC SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Ionospheric Absorption, Cosmic Noise Method	A chain of cosmic radio noise monitoring stations is operated to map polar blackouts and aurorally associated absorption and to detect solar cosmic ray events.	University of Alaska H. Leinbach Jr.	\$158,000	9/60	2 years
Interdisciplinary Studies in Solar-Upper Atmosphere Relationships	Solar-terrestrial relationships with emphasis on cross-connections among auroral, airglow, ionospheric and geomagnetic phenomena. An effort to define the nature of solar emissions and their influence on geophysical phenomena.	University of Colorado W. O. Roberts	125,000	8/59	3 years
Propagation of Radio Waves in and Above the F-Region	The propagation of radio waves in an ionized atmosphere containing tubular irregularities of electron density will be studied.	Cornell University Henry G. Booker	61,800	12/59	3 years
Origin and Morphology of the Aurora	Statistical, theoretical, and experimental studies of aurora, propagation of solar-auroral particles, analysis of associated magnetic-hydrodynamic boundary problems and solar-terrestrial atmosphere interactions.	Cornell University C. Gartlein	104,300	5/60	3 years

ATMOSPHERIC SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Synoptic Whistler Studies Along the E ⁰⁴ Geomagnetic Meridian	Whistler observations leading to information on electron density and geomagnetic field at distances out to several earth radii are continued. Results are coordinated with those of the Stanford Group to insure maximum utilization of data.	Dartmouth College M.G. Morgan	\$ 46,000	10/60	1 year
Cosmic Ray Neutron Monitor		University of Hawaii W. R. Steiger	6,000	6/60	1 year
High Altitude Balloon Monitoring for Cosmic Rays and Solar-Terrestrial Phenomena		University of Minnesota J Winckler and E. P. Ney	96,000	12/60	8 months
Cosmic Ray Intensity Variations Deep in the Atmosphere	A continuation of cosmic ray monitor observations started during the IGY. Correlations are being made with solar activity during the declining part of the solar cycle.	University of Nebraska R.L. Chasson	54,800	8/60	3 years
Neutron Intensity -- Time Variations of Cosmic Radiation		University of New Hampshire J. Lockwood	4,000	10/60	1 year

ATMOSPHERIC SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Time Variation of Cosmic Radiation	Measurements of time variations of cosmic ray mu-mesons using two large scintillator telescopes installed at Chacaltaya Laboratory, Bolivia. The purpose of the study is to investigate the extent to which the diurnal variation is the result of an extraterrestrial anisotropy of the primary cosmic-ray flux.	University of New Mexico V. H. Regener	\$ 65,200	9/58	4 years
Whistler and Very Low Frequency Observations	Experiments to determine the effect of decreasing solar activity on the characteristics and rate of occurrence of whistlers and VLF emissions. This will provide information on the temporal variations of electron density in the exosphere up to heights of five earth radii from the center of the earth.	Stanford University R. Helliwell	74,600	5/59	1 year

CHEMISTRY

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Preferential Adsorption of Orthohydrogen and of Parahydrogen		University of Arizona D. Chapin	\$ 36,500	3/59	3 years
Chemistry of Free Radicals in Solution		Brandeis University S. G. Cohen	46,800	8/60	3 years
Low Temperature Chemistry		California Institute of Technology G. W. Robinson	45,800	10/59	3 years
Investigation of Thermodynamic and Magnetic Properties Particularly at Low Temperatures		University of California W.F. Giauque	116,500	12/59	1 year
Fast Gas-Phase Reactions		University of California H. Johnston	54,300	2/59	3 years
Investigation of Elementary Gas Phase Radical Reactions		University of California R. K. Brinton	19,600	8/60	3 years
Optical Spectroscopy of High Temperature Molecules		University of California R. G. Brewer	20,100	12/60	2 years
Lifetime and Reactions of Vibrationally Excited Species		Catholic University B. deB. Darwent	36,800	11/59	3 years

CHEMISTRY

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Experimental Investigation on the Properties of Matter at Low Temperatures		University of Chicago L. Meyer	99,200	12/59	2 years
Free Radical Reactions		Columbia University C. Walling	51,700	11/59	3 years
Synthesis and Characterization of Inorganic Polymers		Cornell University A. W. Laubengayer	31,700	10/59	3 years
Low Velocity Positive Ion Scattering in Gases		University of Florida W. H. Cramer	6,400	12/59	1 year
Preparation and Reactions of Free Radicals		Georgetown University F. O. Rice	32,300	9/59	1 year
Unstable Intermediates in Gas Phase Reactions		Harvard University G.B. Kistiakowsky	63,600	9/60	3 years
High Temperature Molecular Spectroscopy		Harvard University W. Klemperer	40,000	9/58	3 years
Photochemical Synthesis of Biochemical Compounds		University of Houston Oro'	14,800	5/60	2 years
Theoretical Studies of Atomic and Molecular Structure		Indiana University H. Shull	121,100	1/61	3 years

CHEMISTRY

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Theoretical Work on the Electronic Structure of Molecules		Iowa State University K. Ruedenberg	\$ 51,500	11/59	2 years
Determination of Zinc and Cadmium in Meteorites		University of Minnesota E.B. Sandell	14,000	9/59	2 years
Effect of High Pressure on Chemical Reactions in the Liquid Phase		State University of New York W.J. le Noble	19,300	8/60	2 years
Flash Photolysis of Hydrides and Oxidizing Agents		Ohio State University A.B. Garrett	27,000	12/60	2 years
Low Temperature Research in Chemistry		Pennsylvania State University J. G. Aston and J. J. Fritz	33,200	9/59	2 years
Deuterium Analysis Using Gas Chromatography		University of Pittsburgh E. McC. Arnett	10,200	6/60	1 year
Stabilities of Molecules, Ions and Radicals		University of Pittsburgh E. McC. Arnett	31,000	8/60	3 years
High Temperature Inorganic Chemistry		Temple University A.V. Grosse	28,400	11/60	1 year
Chemical Studies by Flash Photolysis and High Magnetic Fields		Vanderbilt University T. Martin	38,200	12/60	2 years

CHEMISTRY

<u>Project Title</u>	<u>Supplementary Description</u>	<u>Participants</u>	<u>Amount</u>	<u>Date of Grant</u>	<u>Duration</u>
Kinetic Studies of Homogeneous Unimolecular Reactions		University of Washington E.S. Rabinovitch	\$ 32,000	11/60	2 years
Gas-Solid Interactions at High Temperatures		University of Wisconsin J.L. Margrave	43,300	11/60	2 years
Experimental and Theoretical Approach to Mechanistic Photochemistry		University of Wisconsin H.E. Zimmerman	36,900	5/60	3 years

EARTH SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
The Mineralogical and Chemical Composition of Stony Meteorites	Analyses of stony meteorites including both chondrites and achondrites.	American Museum of Natural History Brian H. Mason	\$ 30,130	8/60	3 years
Nininger Meteorite Collection	Grant to enable Arizona State to acquire the Nininger Meteorite Collection. The collection will be administered for research purposes, not for exhibition.	Arizona State University Crowley	240,000	6/60	1 year
Meteorite Studies	Including chemical, microscopic and other analyses.	University of Chicago Edward Anders	39,800	8/60	3 years
Leads in Basalts and Eclogites	Although these are terrestrial rocks, the studies are related to previous work on lead isotopes in meteorites.	Royal R. Marshall (individual)	17,550	11/58	2 years
Isotopes of Lead and Strontium	Isotopic studies including meteorite analyses.	University of Minnesota P. W. Gast	29,000	7/59	2 years
Construction of a Highly Sensitive Mass Spectrometer for Analyzing Rare Gases in Meteorites		Smithsonian Institution E. Fireman	25,000	12/60	1 year
The Beyer Collection of Tektites from the Philippine Islands	Acquisition of the large tektite collection from Otley Beyer	Smithsonian Institution E. P. Henderson	8,000	12/59	6 months

EARTH SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Tektite Research	To examine many of the major tektite areas of the earth and to look for field evidence of their age and origin.	University of Texas V. Barnes	\$ 36,000	10/59	2 years
Determination of the Tides in the Real Oceans	This is an extension of the recent computer-based solution of the LaPlace tidal equations, which have hitherto defied solution. The work has bearing on tidal forces in general.	Weizmann Institute of Science C.L. Pekeris	238,700	12/60	2 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
High Temperature Phosphate Reinforced Cements	Study of the mechanism of reaction of phosphate bound ceramics and study of the effect of variables upon physical properties of developed binders.	Polytechnic Institute of Brooklyn Bruins	\$ 8,200	4/60	1 year
Experimental and Theoretical Investigations into the Thermodynamic Functions of Substances	Study of transport properties and intermolecular forces in gases at high temperature.	Brown University Kestin and Ross	101,200	10/59	3 years
Basic Studies on Solar Energy	Study of spectral characteristics of materials, study of means of measuring solar energy fluxes, and the establishment of a solar weather station.	University of California Gier and Dunkle	51,000	8/59	2 years
The Effect of Local Air Injection on the Heat Transfer from a Flat Plate	An investigation of the effects of local air injection from a slot on heat transfer through a boundary layer to a flat plate.	University of California Seban	12,400	10/59	1 year
Gaseous Radiation Studies	Investigations of the spectral band absorption and emission of several gases and gas mixtures and initiation of measurements' on non-isothermal and inhomogeneous gases.	University of California Gier and Edwards	27,800	3/60	2 years
Mass Transfer Mechanism	Study of the mechanism of mass transfer, and the related fluid dynamic and physical chemical phenomena.	University of California Wilks, Acrivos, Prausnitz and Petersen	125,000	9/59	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Free-Molecule Transfer Processes at High Speeds	Study of the energy-transfer and momentum transfer processes at solid surfaces exposed to high-speed free-molecule flows.	University of California Knuth	\$ 75,800	9/59	3 years
Stability and Transition in Fluid Flow	Study of circular Couette flow between concentric rotating cylinders with emphasis on spiral turbulence, stability criteria, and nonlinear interaction.	California Institute of Technology Coles	57,000	10/58	3 years
Equilibrium Measurements in Reactive Metal Systems at High Temperatures	Systems to be studied are Zr-Mo binary system and the Zr-Mo-H ternary system. For melting, levitation technique will be used.	Carnegie Institute of Technology McCabe	47,400	2/59	3 years
Transient Boiling Heat Transfer	Study of the controlling mechanisms involved in the transient phenomena accompanying the sudden drop of pressure in a nucleate boiling system.	Case Institute of Technology Bell	18,200	2/60	1 year
Heat, Mass and Momentum Transfer in Rotating Systems	To study in further detail the influence of fluid rotation in a stationary tube.	University of Colorado Kreith	52,400	2/59	3 years
Fundamental Study of a Submerged and Non-Submerged 3-Dimensional Jet Impinging Upon a Normal Plane	An analysis of the mechanics of jet diffusion, shear stresses, and eddy viscosity developed along a surface deflecting a jet.	Colorado State University Research Foundation Smith	28,300	7/59	2 years
Momentum and Energy Transport between Plates of Unequal Roughness		Cornell University McManus	35,700	9/59	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Fluid Dynamics of Ablating Bodies	Theoretical and experimental studies of ablating bodies using salt, sugar, plaster, ice and other materials.	University of Florida Williams	\$ 32,900	9/59	3 years
Potential Distribution in an Ion-Focused Electron Beam	Investigation of the potential distribution within the ion trap of a solid, cylindrical ion-focused electron beam and a study of ion oscillation.	University of Florida Lear	22,000	7/59	2 years
High Temperature Gas Dynamics Project	Group study of properties and flow of dissociating and ionizing gases, boundary layer flow, and magneto-fluid-mechanics.	Harvard University Emmons and Bryson	300,000	8/59	2 years
Studies of Sprays	Investigation of the mechanical interaction of two colliding droplets, and a study of the evaporation and burning mechanisms of sprays.	Harvard University Williams	30,000	4/60	3 years
Thermal Forces in Materials of High Thermal Conductivity	Investigation to obtain experimental data on theories of thermal repulsion.	Georgia Institute of Technology Orr	19,000	1/59	2 years
Heat Transfer in Rarefied Gases	Investigation of heat transfer to gases in the subsonic slip flow region.	Illinois Institute of Technology Peck	9,200	2/60	2 years
Thermal Stresses in Plates and Shells		Illinois Institute of Technology Essenburg	15,700	6/59	2 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Production of Uniform High Intensity Ultrasonic Fields	Study of high intensity ultrasonic fields to produce larger uniform fields, to further reduce variations in focused and unfocused fields, and to find materials more suitable for producing high intensity fields under continuous operation.	University of Illinois Fry and Brunschwig	\$ 44,800	2/59	2 years
Large Antenna Arrays with Randomly Spaced Elements for Radio Astronomy Research	An investigation of the effect of element spacing on the number of elements required in a large antenna array for radio astronomy research.	University of Illinois Lo	18,700	10/60	1 year
Microstructure of Low Pressures Flame Front	A quantitative study of the structure of kinetically simple, low pressure, premixed laminar flames.	Johns Hopkins University Fristrom	12,900	10/59	1 year
Vibrational Characteristics of Sandwich Material	Mathematical and experimental analyses of the vibrational characteristics of curved and flat sandwich plates having various types of edge supports.	Kansas State University Raville and Kirmser	26,900	9/59	2 years
A Study of Phase and Volumetric Behavior at Extremely Low Temperature	Study of phase and volumetric behavior of normally gaseous systems in the temperature range from 20° to 150° R. and up to 100 atmospheres.	University of Kansas Kurata	54,000	7/59	2 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Interdepartmental Research Program on Ionized Plasmas	Study of gaseous electronic processes, plasma statics, magnetohydrodynamics of compressible and incompressible fluids and ionospheric physics.	Massachusetts Institute of Technology Allis	\$500,000	7/59	2 years
Cryogenic Chemistry	Research centered around the stability of organic free radicals (produced by thermal or photochemical means) and the properties of liquid carbon monoxide.	Massachusetts Institute of Technology Reid	19,300	2/59	2 years
Basic Mechanism of Flame Stabilization in a Boundary Layer	Theoretical study of interactions between a flame and a flow field, and theoretical and experimental studies of the structure and propagation of a 2-dimensional laminar flame near a heat sink at reduced pressures.	Massachusetts Institute of Technology Tau-Yi Toong	29,800	1/59	2 years
The Effect of Transverse Vibrations of a Heated Surface on Heat Transfer in Free Convection		University of Michigan Research Institute Clark	30,800	8/59	2 years
Thermodynamic Properties of Light Hydrocarbons at High Pressure and Low Temperatures	Enthalpy-pressure-temperature measurements on hydrocarbons in the single phase region down to a temperature of -200°F . and up to a pressure of 2,000 pounds per square inch.	University of Michigan Research Institute Katz	37,200	7/59	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Theoretical Investigation of Ram Jet Buzz		University of Minnesota Chang	27,800	2/59	2 years
Radiative Heat Transfer Analyses	Analytical study of radiative energy transfer employing solutions of the integral or integro-differential equations which describe this process for simple geometries.	University of Minnesota Eckert	50,000	10/59	3 years
Study of Dissociation Effects in Front of Blunt Aerodynamic Bodies at Hypersonic Air Speeds and Temperatures up to 5000°R		University of Minnesota Herman	26,700	3/60	1 year
Measurement of Prandtl Number and Heat Conductivity of Gases	Experimental investigation of Prandtl Numbers and thermal conductivity of gases in the temperature range above 1000°R, and a study of intermolecular potentials.	University of Minnesota Ibele	51,200	4/60	2 years
Three Topics Selected from the Field of Magneto-Aerodynamics	A study of magnetic boundary layers and magneto-fluid-mechanic shocks.	New York University Ludloff	25,000	3/60	2 years
An Experimental and Analytical Investigation of Boundary Layer Effects	A study of the effects of flame holder boundary layer characteristics on flame stabilization.	North Carolina State College Snyder	25,500	11/59	2 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Radiation Properties of Solids at Low Temperature	An investigation of experimental procedures for the determination of total hemispherical emissivities, total absorptivities, and monochromatic reflectivities.	North Carolina State College Irvine	43,800	9/60	2 years
Turbulent Motion and Mixing		Ohio State University Brodkey	21,200	7/59	2 years
Research on the Radiation Characteristics of High Temperature, Dissociated and Ionized Gas Fields	Investigation of the emission and absorption characteristics of plasma jets.	Oklahoma State University Jovanovic and Haworth	54,100	10/59	2 years
Vapor-Atomicity in Metals	A study of the vapor pressures and bonding effects of multi-component metallic vapors.	University of Oklahoma Cosgarea	38,600	3/60	3 years
Kinetics of Gas-Liquid Reactions		University of Oklahoma Research Institute Perry	18,700	9/59	2 years
Ionosphere Winds and the Statistical Characteristics of Ionospherically Reflected Radio Waves	A study of the diffraction pattern formed at the ground by an ionospherically reflected radio signal, to determine the properties of ionosphere irregularities and their time variation.	Pennsylvania State University Bowhill	64,100	8/60	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Design, Fabrication and Utilization of a High Energy Molecular Beam	Investigation of exchanges of momentum and energy between molecules and between a solid surface and molecules, employing a high energy molecular beam.	Princeton University Drake and Boudart	\$ 98,700	8/59	2 years
Integration of the Transfer of Radiant Energy into the Field of Fluid Dynamics	The integration of the radiant energy expressions in the fluid flow conservation equations of both optically thin and thick media.	Purdue University Goulard	18,600	11/59	1 year
Theoretical and Experimental Study of Some Basic Magneto-Fluid-Mechanics Problems	A study of turbulent channel flow of an electrically conducting fluid in the presence of a magnetic field, a study of the flow around a magnetized sphere moving in an electrically conducting medium, and a study of the influence of electrostrictive forces in polar gases.	Purdue University Lykoudis	24,100	8/60	1 year
Mechanism of Turbulence in Free Surface Flow		Purdue Research Foundation Delleur	21,700	7/59	2 years
Characteristics of Structural Elements at Elevated Temperatures		Purdue University Lo and Ballard	50,000	11/58	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Viscosities of Hydrocarbon mixtures at High Pressures	Correlation for the viscosity of light hydrocarbon mixtures based on corresponding theories of state involving the actual viscosity at one atmosphere, the compressibility factor, the reduced temperature, and the reduced pressure.	Rice Institute Kobayashi	\$ 17,800	4/59	3 years
Thermodynamic Properties of Hydrocarbon and Hydrogen Mixtures	Study of the volumetric behavior of gaseous hydrocarbon mixtures over a range of temperatures between 100° F. and 300° F., and at pressures to 10,000 atmospheres.	Rice Institute Kobayashi and Lenand	13,100	10/58	3 years
Effect of Kinetics on Forced-Convective Heat Transfer to Reacting Gases		Stanford University Mason	25,600	2/59	3 years
Heat Transfer from Impinging Air Jets to a Plane Wall	Experimental and theoretical determination of local heat transfer coefficients, and velocity and temperature profiles for air jets directed at several angles onto a heated isothermal plate.	Stanford University Eustis	53,200	9/59	3 years
Analytical Study of Nonequilibrium Flow	A theoretical investigation of the flow of gases in chemical or vibrational nonequilibrium. The investigation complements an experimental investigation in the field of high temperature gas dynamics.	Stanford University Vincenti, Van Dyke and Karamcheti	93,900	10/60	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
An Investigation of the High Temperature Oxidation Properties of Transition Metals Containing Small Percentages of Alkaline Earth Metals		Syracuse University Keller	\$ 17,300	8/60	1 year
The Kinetics of Reactions Between a Single-Component Gas and a Single-Component Liquid		Syracuse University Gill and Jelinek	20,200	6/59	2 years
Pressure-Volume-Temperature Relations of Gases at Low Pressures	Pressure-volume-temperature behavior of gases at pressures from 0.1 to 2.0 atmospheres and from -40° C to 100° C.	University of Texas McKetta	31,800	7/59	3 years
Thermal Failure of Heaters in Accelerating Nucleate Pool Boiling Systems	Investigation of the effects of acceleration on boiling peak heat flux attainable prior to thermal failure.	University of Washington Costello	9,500	6/60	1 year
Diffusion in an Optical Absorption by III-V Components		University of Washington Wei	32,800	9/59	2 years
A Study of Combustible Mixture Formation With Liquid Fuels	Investigation will use a unique photographic technique utilizing fluorescent dyes which cause the fuel droplets in the spray to fluoresce and become primary sources of light when excited by means of short duration, high intensity light.	University of Wisconsin Myers	57,600	1/59	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
The Direct Conversion of Solar Energy to Power	Investigation of radiation properties of surfaces, photoelectric conversion processes, and thermoelectric conversion processes.	University of Wisconsin Duffie	\$ 22,500	11/59	2 years
Momentum and Mass Transport and Rates of Combustion Reactions in Turbulent Shear Flow		Worcester Polytechnic Institute Shipman	20,800	2/60	2 years
High Pressure Properties of Materials	Study of compressibility, phase equilibria, and solubility of gases in metals at pressures up to 10,000 atmospheres.	Yale University Dodge	41,400	10/58	3 years

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Effect of Ultrasonic Vibrations on Liquid Heat and Mass Transfer	Study of conditions which influence the nature of boundary layers to attempt to correlate resulting heat transfer data with mass transfer data.	University of California Petersen	\$ 12,700	11/58	2 years
Plastic Strength of Structures Under Repeated Loads	Study problems of alternating plasticity and incremental collapse.	University of California Papov	21,800	8/58	2 years
Jet Reactor Concentration and Temperature Fluctuations	Experimental studies to obtain data on concentration fluctuations, temperature fluctuations, and their correlation which will advance understanding of mixing process in jets, hydrodynamics of reacting fluids, combustion phenomena, and turbulent flames.	University of California Prausnitz	11,800	10/58	2 years
Solar Bursts at Meter Wavelengths	Investigation of Faraday rotation in the corona, statistical study of linearly polarized bursts, study of position and polarization of spectral-type IV bursts.	Cornell University Cohen	29,500	11/58	19 months
IGC-1959, Whistlers-East Project	Study of atmospheric, low frequency, radio signals whose origin is attributed to lightning flashes.	Dartmouth College Morgan	39,800	5/59	1 year

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Adsorption of Gases and Vapors at Elevated Temperatures and Pressures	Adsorption of gases like nitrogen, oxygen, carbon dioxide, hydrogen at pressures up to 1,000 pounds per square inch at room and higher temperatures.	State University of Iowa Kammermeyer	\$ 27,700	9/58	2 years
Ignition and Combustion of Fuel Sprays		Massachusetts Institute of Technology Taylor and Rogowski	37,500	10/58	2 years
Oxidation Kinetics in Porous-Walled Tubes	Study of hydrocarbon oxidation kinetics in a reaction vessel whose walls are made of a finely porous material through which an inert gas can be passed to eliminate diffusion of reacting species.	Massachusetts Institute of Technology Satterfield and Reid	11,400	10/58	2 years
Diffusion Coefficients of Gases at High Pressure	Measurement of diffusion coefficients of mixtures of carbon dioxide and argon as a function of pressure up to 1,000 atmospheres by means of radioactive tracer techniques.	Purdue University Bennett	20,000	10/58	2 years
Physical Properties of Liquid Hydrocarbons at elevated Pressure and Temperature	Determination of the viscosity of n-paraffin hydrocarbons in the range of 60°F. to 250°F. and a pressure range of 0 pounds per square inch to 6,000 pounds per square inch.	University of California Vogt	5,900	9/59	1 year

ENGINEERING SCIENCES

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Photographic Study of Unusual Flow Patterns in Turbulent Shear Flow	Use of the tracer-displacement technique to reveal unusual flow patterns at velocities above the critical Reynolds number.	North Carolina State College Beatty and Richardson	\$ 14,000	9/59	1 year
New Experimental Methods in Gasdynamics		Rensselaer Polytechnic Institute Foa	11,000	9/59	1 year

PHYSICS

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Large Air Shower Detector	Continuation of program to measure cosmic ray showers.	University of California P.H. Barrett	\$ 6,200	6/60	1 year
Cooperative Emulsion Flight for High Energy Events	Studies of cosmic Primary Particles. To fly three stacks of sheet emulsion in a balloon at high altitudes to carry out studies in high energy range. Will give information on recent galactic theories of cosmic origins.	University of Chicago M. Koshiba	625,000	5/58	3 years
Primary Cosmic Rays	Cosmic ray studies of particles at high altitudes.	College of Puget Sound M. E. Nelson	15,400	2/58	4 years
Cosmic Ray Shower and Particle Study	To measure energies of mesons entering magnetic spectrometer from the air and observe their interactions in matter.	Cornell University K.I. Greisen	31,800	6/59	1½ years
Asymmetry of Extensive Air Showers		University of Denver M. Iona	12,600	3/55	6 years
Structure of Solar Magnetic Fields	Optical telescopic methods are used to get information about the sun's magnetic fields.	De Pauw University M. Correll	23,100	9/59	3 years
Primary Cosmic Ray Flux and Fragments Produced in Cosmic Ray Stars		Manhattan College G. Kane	10,000	12/58	2 years

PHYSICS

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Elementary Particles Reactions in Photographic Emulsions	Balloon flights on nature of high energy cosmic ray particles and particles from accelerators.	Marquette University A. G. Barkow	\$ 15,600	9/59	2 years
Cosmic Ray Air Shower Research	Deals with galactic origins of very high energies.	Massachusetts Institute of Technology B. Rossi	176,100	10/59	2½ years
Variations in Cosmic Ray Intensities	Information about earth and sun to be obtained by studying correlations of intensities with solar and terrestrial changes.	Nebraska Wesleyan University W.R. French, Jr.	7,300	10/58	2½ years
Heavy Nuclei Component of Cosmic Radiation		New Mexico College R. E. McDaniel	9,400	11/59	2 years
Cosmic Ray Neutron Monitor in Alaska		New York University S.A. Korff	34,600	4/59	2 years
Emulsion Investigations of Primary Cosmic Rays		Ohio University C.A. Randall	17,500	6/57	4 years
Decay of Cosmic Ray Particles at Sea Level		Rutgers University E. Boldt	14,100	10/59	2 years
Heavy Primaries in Cosmic Radiation		St. Bonaventure University Z. O'Friel	14,000	2/57	5 years

PHYSICS

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Primary Cosmic Rays and Scattering of Heavy Ions by Nuclei		Seattle Pacific College D.D. Kerlee	\$ 25,700	12/59	2 years
Cosmic Ray Neutrons Near the Earth's Surface		University of South Carolina R.D. Edge	13,500	8/59	2 years
Emulsion Studies of Cosmic Radiation		Southern Illinois University O.E. Young	9,800	7/60	2 years
Primary Cosmic Radiation		Washington University M.W. Friedlander	53,300	8/60	3 years

PHYSICS

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Time Variations of Neutron, IGY Hard and Soft Cosmic Ray Components		University of California W. B. Fretter	\$ 5,000	5/59	1 year
Primary Cosmic Radiation	IGY Balloon flights to measure proton and alpha particle intensity during a solar flare.	University of Chicago P. Meyer	20,100	5/59	1 year
Low Energy Primary Cosmic Rays at Thule	Continuation of IGY to study cosmic rays of low energy that come in through a "magnetic window". Measurements are to be continued through a solar cycle.	The Franklin Institute M.A. Pomerantz	10,600	5/59	1 year
Cosmic Ray Studies at High Altitudes	Six or eight long-duration high altitude balloon flights near the north magnetic pole to study radiations of low energy from the sun, the daily variation of cos- mic ray intensity, etc.	State University of Iowa K. A. Anderson	40,400	5/59	1 year
Cosmic Ray Telescope at Thule	A cosmic ray telescope is being operated at Thule, Greenland, to measure solar variation, cosmic ray storms and Forbush decreases, solar flare increases, annual variation of cosmic radiation.	University of Maryland W. Webber	6,400	4/59	1 year

PHYSICS

Project Title	Supplementary Description	Participants	Amount	Date of Grant	Duration
Continuous Balloon Monitoring of Cosmic Rays and Solar Phenomena	Balloon flights to maintain aloft at all times instruments for recording cosmic ray events and variation of total intensity of cosmic rays with solar phenomena.	University of Minnesota E. P. Ney J. R. Winckler	350,000	5/59	1 year
Cosmic Ray Monitoring	A monitoring station will be operated to the next sunspot minimum.	University of Nebraska R. L. Chasson	17,200	5/59	1 year
Forbush-Type Decreases in Cosmic Rays	Solar effects on neutron flux.	University of New Hampshire J. A. Lockwood	3,200	4/59	16 months

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