U.S. THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SECOND SEMIANNUAL REPORT TO THE CONGRESS

April 1, 1959 —
September 30, 1959

1520 H Street, N.W.
Washington 25, D. C.

TO THE CONGRESS OF THE UNITED STATES:

Pursuant to the provisions of the National Aeronautics and Space Act of 1958, I transmit herewith for the information of the Congress the second semiannual report of the National Aeronautics and Space Administration, covering the period April 1, 1959 through September 30, 1959.

DWIGHT D. EISENHOWER

THE WHITE HOUSE,

MARCH 17, 1960

Letter of Transmittal

MARCH 14, 1960

Office of the Administrator

The President
The White House

Dear Mr. President: This, the Second Semiannual Report of the National Aeronautics and Space Administration, covers the period April 1, 1959, through September 30, 1959. It is submitted to you for transmittal to the Congress in accordance with the National Aeronautics and Space Act of 1958, section 206 (a).

NASA's operational achievements during the second six months of its existence were substantial.

Seven astronauts for the Project Mercury manned space flight program were selected and began intensive training.

An Atlas booster propelled a Mercury capsule model to an altitude of 100 miles and a range of 1300 miles, a flight that culminated in a successful test of capsule instruments, stability, and heat shielding.

Two monkeys, Able and Baker, survived a space flight at speeds as great as 10,000 mph and to a peak altitude of 300 miles. The monkeys were part of a biomedical experiment carried in a Jupiter nose cone in a flight conducted by the Army under NASA sponsorship.

The X-15 rocket-powered research airplane completed successful glide-flight tests and made its first powered-flight test during the report period.

Explorer VI, the so-called "paddlewheel" satellite, was successfully launched into orbit. Later, it relayed a crude photograph of the earth's cloud cover and transmitted valuable data on radiation, micrometeoroids, radio waves, and the earth's magnetic field.

Also successful was Vanguard III -- last of the Vanguard satellite series -- which has provided data on the earth's magnetic field, solar X-rays, and micrometeoroids.

NASA made significant progress in developing general-purpose medium- and high-thrust rocket vehicles, with emphasis upon reliability. These include Scout and Delta, "work-horse" vehicles to launch small-to-medium payloads (about 250 pounds) into earth orbits, and smaller payloads on space missions. On a larger scale is Centaur, designed for missions of many types, which will use an Atlas booster to loft heavy payloads -- placing 8,000 pounds in a 300-mile earth orbit, 2,300 pounds in deep space, and 730 pounds on the moon.

During the report period, NASA strengthened its ties with other government agencies and private organizations that contribute to the National Space Program. The program is constantly being reviewed to cope with problems as they evolve and to turn to good account advances that have been coming rapidly on the frontiers of aeronautics and space science and technology.

While NASA's operational activities continue to grow, its fundamental mission remains unchanged. As embodied in the National Aeronautics and Space Act of 1958, it is to direct all U.S. nonmilitary aeronautical and space research and development "for the benefit of all mankind." In the latter regard, NASA increased its efforts in the international field and made preliminary arrangements with several nations for cooperative space ventures.

After the period covered by this report closed, several important developments took place:

In October, you proposed the transfer to NASA of the Development Operations Division of the Army Ballistic Missile Agency at Redstone Arsenal, Huntsville, Ala., along with Saturn, the 1.5-million-pound-thrust clustered rocket engine under development by the Division. Unless Congress disapproves, this transfer will be effective 60 days from formal notification of Congress on January 14, 1960. The budgetary transfer would be completed on July 1, 1960; it would include 4,300 employees of the Division and 815 supporting personnel. NASA would then assume responsibility for 1,200 acres at the Arsenal, including Division facilities.

In November, NASA was assigned sole responsibility for developing high-thrust space vehicle boosters, regardless of their ultimate exploitation for civilian or military missions. With this action, NASA assumed direction and control of the Nation's nonmilitary space program in all its aspects, remaining at the same time, "fully responsive" to the Department of Defense in defense-related technology.

On December 11, NASA cancelled its development program for the Vega launch vehicle which was based on use of the Atlas as a booster and a modified version of Vanguard as the second stage. Vega would have been capable of propelling a 4,800-pound vehicle in a 300-mile earth orbit or of firing 1,000 pounds to the moon. Development of Vega was cancelled to avoid duplication, and to increase reliability by keeping the types of rocket vehicles in the program to the minimum.

Among high-thrust developments are the Saturn vehicle, a cluster of boosters designed to deliver 1.5-million pounds of thrust, and the F-1 single-chamber rocket engine, which will also be capable of 1.5 million pounds of thrust. The F-1 ultimately will be clustered to form a multi-million pound thrust booster.

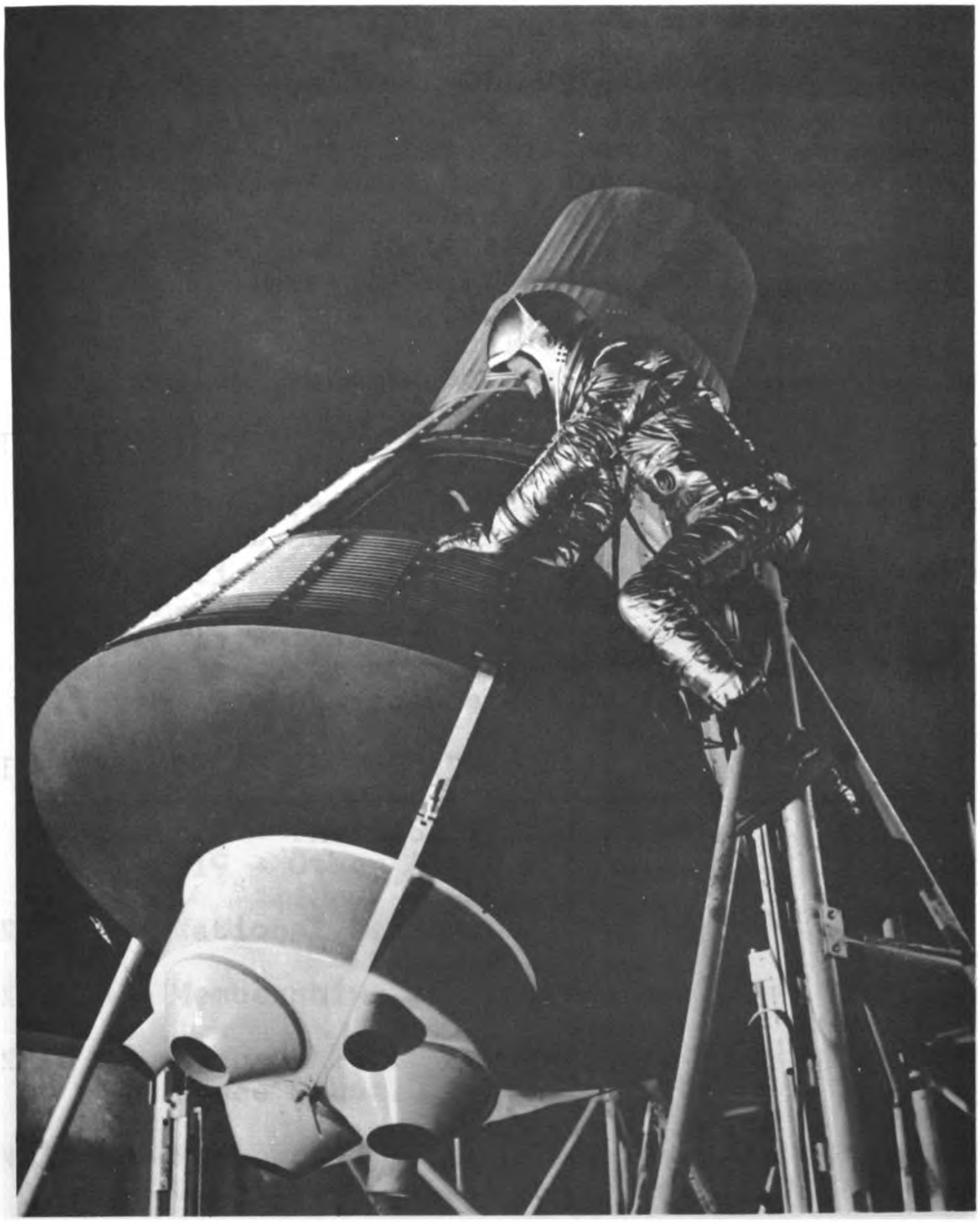
Recently the first U. S. rocket engine fueled with liquid hydrogen -- the powerful XLR-115, with 30 percent greater thrust than present engines using kerosene and liquid oxygen -- was successfully test fired at full thrust. It will be used to power the Centaur space vehicle which will be mounted on a modified Atlas. The XLR-115 will later power an upper stage of Saturn.

To speed development of rocket vehicles, NASA reorganized its headquarters in late 1959. It created an Office of Launch Vehicle Programs to which the Huntsville group will report directly. Other NASA divisions under the new organization include: the Office of Space Flight Programs, which is charged with mission-planning, payload design and development, and in-flight research and operation; the Office of Advanced Research Programs; and the Office of Business Administration.

I believe that this report portrays a record of solid accomplishment, evidencing a firm base upon which the National Aeronautics and Space Program will continue to progress and gain momentum.

Sincerely,

T. Keith Glennan
Administrator



Wearing a full pressure suit of the type being developed for use in the NASA Project Mercury program, an engineer inspects a full-scale model of the Project Mercury capsule being constructed by McDonnell Aircraft Co., St. Louis, Mo. At lower left is the mounting for retrorockets which, when fired in the direction of the capsule's flight, will retard its speed so that it will reenter the earth's atmosphere for recovery. (See *Project Mercury.*)

CONTENTS

PAGE

CONTENTS

SECTION I

INTRODUCTION AND HIGHLIGHTS

INTRODUCTION

FRAMEWORK OF PROGRESS

The Second Semiannual Report of the National Aeronautics and Space Administration gives an accounting of NASA activities from April 1 to September 30, 1959. During this period, the agency continued developing its organization. NASA moved forward with an operational space flight program, sustained by broadened research and development in space sciences and technology. Of perhaps equal importance, NASA was able in the light of experience to set more positive goals, immediate and future, than had been possible during earlier stages of the National Space Program.

The mission of NASA is to direct the government's nonmilitary activities in aeronautics and space research and development, and to cooperate with and support Department of Defense activities in these fields. (In aeronautics, NASA restricts its work to research.) Fundamentally, the goal of the national program is exploration of space to extend knowledge of the solar system and the universe, to make possible manned flight to the moon and to the planets nearest the earth, and to utilize and disseminate the information we gain about the space environment for the peaceful benefit of all mankind.

Already it has been proven that space technology is feasible for such promising applications as weather surveillance and long-range telecommunications. Other developments, such as microminiaturization of electronic components for space vehicles, are beginning to enrich the economy as they are adapted for use in industrial equipment.

In 1960 and in the years immediately ahead, NASA will heavily stress the development of launching vehicles with greatly increased weight-lifting capacity and reliability. Effort will also be concentrated on developing midcourse and terminal guidance equipment and techniques. A substantial program of scientific research will be carried out through use of earth satellites and spacecraft. Meanwhile, there will be increasing emphasis on lunar missions of many types, important steps toward developing the vehicles, instrumentation, and measurement techniques that eventually will enable man to explore the planets and interplanetary space.

Associated tracking and telemetry systems -- essential and integral to space-flight programs -- are being developed in parallel to the four types of missions that require them: sounding rockets, space probes, and manned and unmanned earth satellites.

During NASA's second half-year, noteworthy progress was made in the fields of space vehicle development; manned space flight; space sciences; and advanced space research and aeronautics research, basic and applied, that supply the knowledge upon which the technology of flight within and beyond the earth's atmosphere can build.

In addition, the period was marked by growing NASA activities with foreign governments and organizations and with international groups interested in space research and development as it applies to human well-being. NASA entered discussions with other nations to obtain permission to operate tracking stations abroad. Arrangements for a joint U.S.-Canada ionosphere-sounding project were made. NASA officials took active part in proceedings of the Ad Hoc Committee on the Peaceful Uses of Outer Space of the United Nations, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions, the International Telecommunications Union, NATO's Advanced Group for Aeronautical Research and Development (AGARD), and with a number of individual members of the European scientific community.

SPACE FLIGHT PROGRAMS

Manned Space Flight Program

The first stage of this undertaking is Project Mercury, which is designed to place a man in orbit around the earth, to recover him, and to study human capabilities under the stresses of acceleration, weightlessness, deceleration, and landing.

Space Sciences Program

This program is devoted to gathering data by satellite, space probe and sounding rocket, in the fields of geophysics and astrophysics. Under intense study are the properties and behavior of the earth's atmosphere, ionosphere, magnetic field, auroras, and other phenomena. Other experiments concern cosmic rays, radiation zones and solar winds thousands of miles from earth. Still other studies deal with phenomena at interstellar distances.

Satellite Applications Program

Here the goal is to apply space technology to practical, beneficial activities. As the program advances, it is expected to improve weather forecasting, make navigation for air and sea travel more exact and timely, and provide worldwide television and telephone services.

Lunar and Interplanetary Programs

Initial steps involve probes past and around the moon, then "hard" and "soft" lunar landings by unmanned instrumented satellites, followed by manned lunar expeditions. Probes to Mars and Venus, with the ultimate goal of manned exploration of the planets, will be launched on the appropriate astronomical dates, as the technology permits.

National Space Vehicle Program

As of September 30, this program was concentrated on a series of vehicles -- Scout, Delta, Vega*, Centaur, Saturn -- and the F-1 1.5-million-pound-thrust, single-chamber rocket engine -- each capable of carrying a larger payload and performing a more complex mission than its predecessors. The objective is to attain maximum capability with minimum research and development. Each vehicle type will be utilized in numerous and varied space experiments to achieve high reliability.

ADVANCED RESEARCH PROGRAMS

Extensive, step-by-step research is required to develop the technology needed for building the advanced vehicles planned for NASA missions. Research is directed toward answering such questions as: What type of structure is required to withstand the stresses of launching and the heating encountered on reentering the atmosphere? How can we transmit and receive information through ionized layers of the atmosphere? How will we go about making landings on the moon? How can we protect the vehicle from micrometeoroid damage? What is the most efficient propulsion for missions of long duration? How can we best guide and navigate the vehicle during the various stages of the mission? What is the best way to provide power for operating the electronic equipment and life-support systems?

The advanced space research program centers upon coming generations of space vehicles, manned and unmanned; the problems of launching large boosters; guidance and navigation during space missions; micrometeoroid damage to vehicles; space propulsion for long missions (1,000 days or more); rendezvous techniques; and lunar and planetary landings. Reentry into the earth's atmosphere by a variety of vehicles is under study along with the technology of space platforms, including ways of erecting and resupplying them.

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* Cancelled December 11, 1959

The aeronautical research program involves the development of concepts and experimental verification of those concepts for advanced vehicles operating solely within the atmosphere. Research is conducted on aircraft through a wide range of velocities -- from hovering to near-orbital speeds. Under study are problems of flight efficiency, aerodynamic stability and control, propulsion, structure, and operations of such aircraft.

NASA HIGHLIGHTS*
(April 1 - September 30, 1959)

April 2. -- SEVEN PROJECT MERCURY ASTRONAUTS SELECTED. This followed intensive screening of candidates through intelligence, physiological, psychological, physical, and stress tests.

April 13. -- PROJECT TIROS TRANSFERRED TO NASA from Department of Defense. Project Tiros is a further step in the meteorological satellite program in which Vanguard II was the first experiment.

April 13. -- VANGUARD LAUNCH FAILS due to second stage malfunction. Payload instrumentation was designed to gather and transmit information on the earth's upper atmosphere and magnetic field.

April 29. -- NASA AWARDS CONTRACT FOR DELTA VEHICLE. Douglas Aircraft Co. will act as prime contractor for design, fabrication, test, and launch of 12 vehicles intended to place a variety of satellites and probes into space.

May 28. -- TWO MONKEYS SURVIVE A SPACE RIDE at speeds as great as 10,000 mph and altitudes as high as 300 miles, an experiment in which NASA participated with the military services. The monkeys were part of a biological payload in an Army Jupiter nose cone. Valuable physiological and psychological data relating to space flight were obtained.

June 4.-- SIX-STAGE ROCKET REENTRY TEST SUCCEEDS at Wallops Island. Reentry speed was 16,000 mph. Significant data on space-vehicle reentry physics were obtained.

June 8. -- X-15 PASSES GLIDE-FLIGHT TEST (from B-52 aircraft). Launching, aerodynamic control, and landing characteristics were satisfactory.

June 22. -- RADIATION BALANCE SATELLITE EXPERIMENT FAILS. A pressure regulator in the Vanguard booster second stage did not function, permitting pressure to build up and blow the rocket apart.

July 1. -- NASA AWARDS CONTRACT FOR SOLID-FUEL ROCKET ENGINE WITH VERY HIGH PERCENTAGE OF PROPELLANT BY WEIGHT, marking a significant advance in propulsion technology. Grand Central Rocket Company will build the prototype, which can utilize existing propellants.

* Details are in later chapters.

July 1. -- CENTAUR ROCKET PROGRAM TRANSFERRED TO NASA from the Advanced Research Projects Agency (ARPA) of the Department of Defense.

July 8. -- JUPITER DROPPED FROM MERCURY PROGRAM. Boosters for this program will be a combination of eight solid-rocket engines used for "Little Joe," the Atlas for "Big Joe" tests, the Redstone for training flights downrange, and the Atlas for orbital flights.

July 9. -- ION-ROCKET ENGINE PROTOTYPE operated at Lewis Research Center. Spacecraft powered by electrical engines will be capable of long-duration flights into far regions of space.

July 16. -- JUNO II ROCKET CARRYING EXPLORER SATELLITE DESTROYED in flight. AMR safety officer destroyed the rocket 5 1/2 seconds after lift-off when it veered toward mainland.

July 20. -- NASA AWARDS CONTRACT FOR MERCURY NETWORK, ground telemetry and radar tracking stations, to Western Electric Co., Inc. Stations will maintain almost constant communication with the pilot and gather information on capsule and astronaut behavior and reactions.

July 22. -- INTERNATIONAL PROJECT MERCURY RANGE NEGOTIATIONS begun to permit operation of tracking stations abroad.

July 24. -- MODIFIED U.S. NAVY MARK IV PRESSURE SUIT SELECTED for astronauts. The suit is made by B. F. Goodrich Co.

August 7. -- EXPLORER VI PLACED IN ORBIT by a Thor-Able III booster. The "Paddlewheel" satellite carried instruments to gather and transmit information on radiation, meteoroids, radio waves, and earth's magnetic field, and to relay a photograph of earth's cloud cover.

August 14. -- TWELVE-FOOT INFLATABLE SATELLITE LAUNCHING FAILS because of premature fuel exhaustion in JUNO II booster and malfunction of attitude control system for upper stages.

August 14. -- EXPLORER VI TRANSMITS CRUDE IMAGE OF EARTH'S SURFACE (North Central Pacific Ocean) and cloud cover. Area photographed was some 20,000 miles from the satellite camera.

August 17. -- NIKE-ASP SODIUM VAPOR ROCKET EXPERIMENT SUCCEEDS. Perfect flight and precise timing of sodium vapor release resulted in measurement of wind velocities as high as 600 miles per hour in upper atmosphere, between 50 and 150 miles above the earth. Orange-yellow sodium vapor cloud, ejected over coastal Virginia, was seen from Maine to Florida and as far west as Ohio.

August 18. -- SECOND SODIUM VAPOR ROCKET EXPERIMENT FAILS when Nike-Asp rocket malfunctions.

August 21. -- FIRST "LITTLE JOE" LAUNCHING OF MERCURY CAPSULE ABORTS because escape mechanism fired prematurely.

September 9. -- "BIG JOE" EXPERIMENT SUCCEEDS. Atlas launched from AMR carried boilerplate Mercury capsule 100 miles above earth. Capsule was recovered in the Atlantic Ocean north of Puerto Rico. Capsule instruments, stability, and heat shield met performance specifications.

September 17. -- X-15 COMPLETES FIRST POWERED FREE FLIGHT. Launching of the X-15 from the B-52 mother craft, and its propulsion, control, and landing characteristics were generally satisfactory.

September 18. -- VANGUARD III SATELLITE PLACED IN ORBIT. Satellite is instrumented to gather and transmit data on earth's magnetic field, solar X-rays, and micrometeoroids. Success of Vanguard III completed Vanguard experiments, the Nation's first scientific satellite program.

September 24. -- ATLAS-ABLE VEHICLE FOR LUNAR ORBIT SHOT EXPLODES during ground test at AMR. The vehicle, which would have fired a 375-pound payload into a lunar orbit, was to be first U.S. attempt to employ midcourse and terminal guidance.

SECTION II

THE NASA SPACE FLIGHT PROGRAM

Progress, April 1 -- September 30, 1959

OPERATIONAL MISSIONS

LAUNCHINGS

April Vanguard Fails

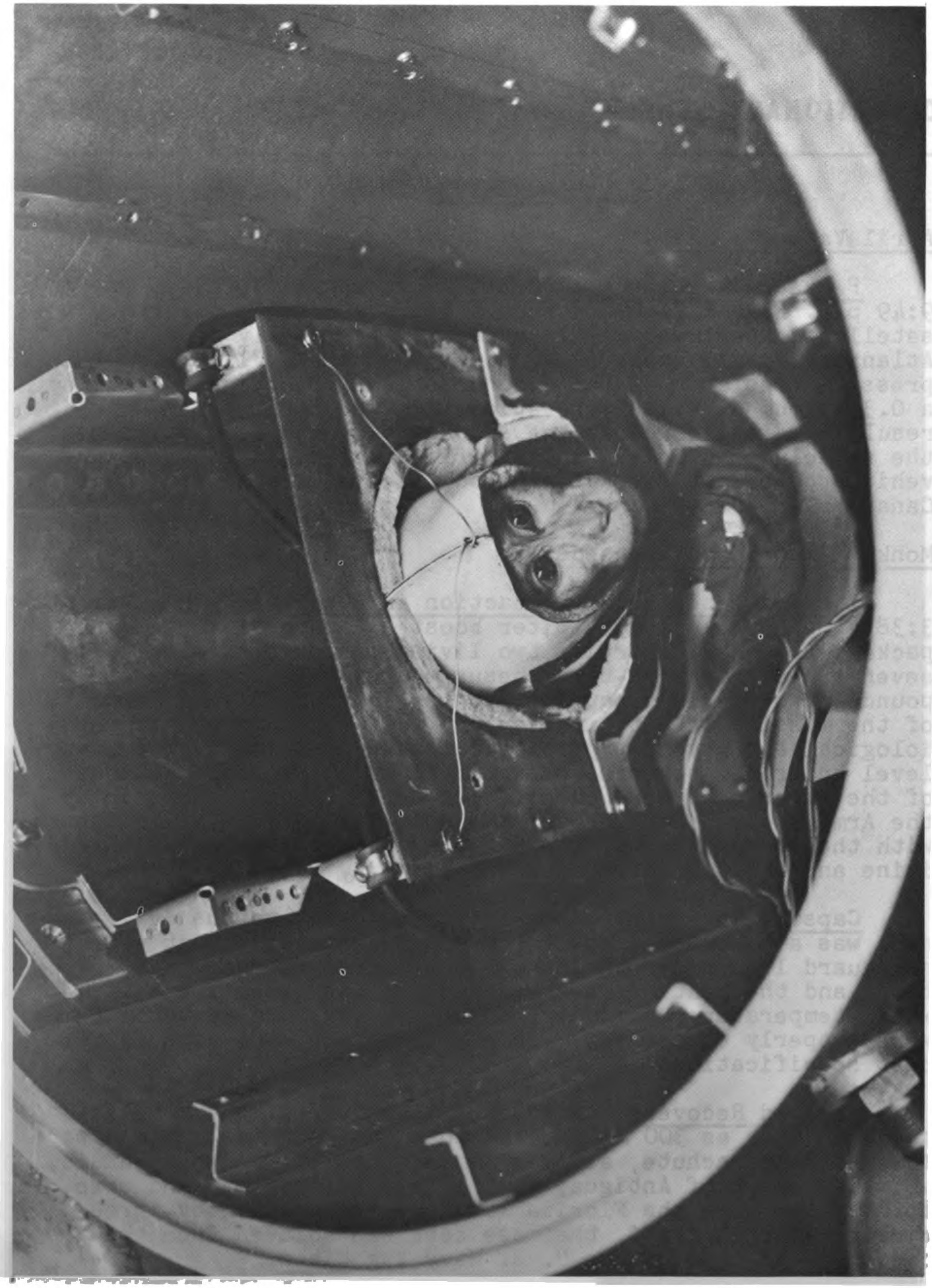
Pressure Regulator at Fault -- On April 13, 1959, at 9:49 p.m. EST, a Vanguard rocket bearing a twofold earth satellite experiment was launched unsuccessfully from the Atlantic Missile Range (AMR), Cape Canaveral, Fla. A fuel pressure regulator in the second stage malfunctioned, causing a 0.3-second delay in separation from the first stage. The resulting disturbance in the second-stage nozzle flow caused the vehicle to tumble. After a flight of eight minutes, the vehicle came down several hundred miles downrange from Cape Canaveral.

Monkey Experiment Succeeds

Mission Tests Primate Reaction in Space -- On May 28, at 3:38 a.m. EDT, an Army Jupiter booster launched a nose cone package from AMR, carrying two living passengers -- Able, a seven-pound, American-born rhesus monkey, and Baker, a one-pound South American squirrel monkey, both females. Purposes of the mission were to recover the nose cone and obtain physiological and psycho-physiological data on animals of primate level under the stresses of space flight. Medical portions of the experiment were carried out under NASA sponsorship by the Army Medical Service and the Army Ballistic Missile Agency, with the cooperation of the U.S. Naval School of Aviation Medicine and the U.S. Air Force School of Aviation Medicine.

Capsule Environment Controlled -- Basic to the dual mission was a capsule (a sealed, pressurized cabin) that would safeguard life under the stresses of acceleration, deceleration, and the heat of reentry, and provide an environment in which temperature, humidity, oxygen supply, and carbon dioxide were properly controlled. In every respect, the capsule met test specifications.

Payload Recovered -- After a 15-minute flight at altitudes as high as 300 miles, the nose cone and its payload were lowered by parachute, as programmed, into the South Atlantic, 40 miles north of Antigua, West Indies Federation, and some 1,500 miles from the Florida launching site. Ninety-three minutes after liftoff, the nose cone was hoisted from the ocean by the crew of the U. S. Navy tug Kiowa.



A Rhesus Monkey Displays its Helmet During a Pre-Space Flight Test

Extensive Physiological Data Obtained -- Electrodes planted just beneath the skin of the animals reported flight effects upon heart action, temperature, respiration, and muscular reactions. Because of an electronic failure, Able's electrocardiograph channel did not record during flight, but 12 other electronic channels did report data.

Other Biological Experiments -- Besides the two monkeys, the scientific payload contained experiments to test the effects of cosmic rays, acceleration, deceleration, weightlessness, and other factors upon low-order living organisms. Among the experiments were corn and mustard seeds, onion tissue, fruit fly pupae, sea urchin sperm and eggs (some fertilized before and some during flight), and human whole blood.

June Vanguard Fails

Pressure Regulator Again at Fault -- A Vanguard rocket, carrying a 22.5-pound satellite to measure the radiation balance of the earth and its atmosphere and the flux of solar energy, was launched from AMR, June 22, at 4:16 p.m. EDT. The satellite failed to orbit because, as in the April 13 experiment, a pressure regulator in the second stage malfunctioned. The malfunction permitted pressure to build up to the point where the pressure tank split apart.

Explorer Booster Vehicle Destroyed

Guidance Power Supply Malfunctions -- On July 16, at 12:37 p.m. EDT, NASA, with the U.S. Army as agent, attempted to launch a 91.5-pound Explorer satellite from AMR with a Juno II rocket. The range safety officer destroyed the vehicle 5.5 seconds after liftoff when it veered sharply toward the mainland. Failure of the guidance-system power supply caused the malfunction.

Explorer VI Succeeds

Launching According to Plan -- The 142-pound Explorer VI earth satellite was launched from AMR by a Thor-Able III rocket on August 7, 1959, at 10:23 a.m. EDT. NASA funded and managed the project, with the U.S. Air Force as agent. The launching went smoothly; the vehicle performed so nearly according to plan that it was unnecessary to fire a reserve rocket installed in the satellite to provide additional thrust.

Achieves Highest Orbit -- Explorer VI went into a highly elongated, elliptical orbit, with a perigee of 156 miles, an apogee of 26,357 miles, and a period of 12 1/2 hours. At apogee, the satellite is so far from the earth that it is noticeably affected by the moon's gravitational field. As a result of this perturbation, the perigee altitude is also affected, and will grow gradually lower until air drag will eventually cause the satellite to burn up. Explorer VI will probably remain in orbit more than a year.

Batteries Charged by Sun -- Batteries for Explorer VI are charged by the sun. Four large vanes, each studded with 2,000 solar cells (1,000 cells on either side) were to extend from the side of the satellite, giving it the appearance of a paddlewheel. During the launch phase, one of the solar cell vanes failed to extend completely and the battery-charging system produced only 65 percent of the programmed power. This meant that the 378-mc digital transmitter could not be operated to the extent planned. However, the other transmitters functioned satisfactorily.

Contains Complex Package -- Explorer VI is a complex scientific package, containing 14 experimental devices, including: a scanning device to relay a crude representation of the earth's cloud cover; three devices to measure particles of different energy ranges in the layers of the Great Radiation Region;* a detector to determine the number and approximate energy of micrometeoroids striking the satellite; four experiments to study behavior of radio waves in space; and two instruments to study the earth's magnetic field. The solar cells recharge the chemical batteries which power three radio transmitters and two receivers.

Reveals Radiation Data -- Explorer VI, which contains far more elaborate instrumentation for radiation detection than its predecessors, has reported much new information on the Great Radiation Region. It has indicated the existence of previously undetected particles of higher energy than those discovered by earlier satellites. Some 1,000 miles above the surface of the earth at lower latitudes, the radiation appears to be composed chiefly of protons having energies above 75 million electron volts (mev). The region also contains electrons with energies of 13 mev or higher. The high-energy particles extend over a band about 300 miles thick.

Confirms Outer Radiation -- The satellite confirmed existence of radiation detected earlier. However, energies reported by Explorer VI were only 1/10 to 1/20,000 as intense as those reported by previous satellites and probes. Explorer VI discovered pockets of radiation that kept appearing and disappearing, probably as a result of solar disturbances. The main concentration of particles is believed to consist of electrons that stream continually from the sun and are trapped in the earth's magnetic field. Early Explorer VI data indicate that the Great Radiation Region may consist of a single

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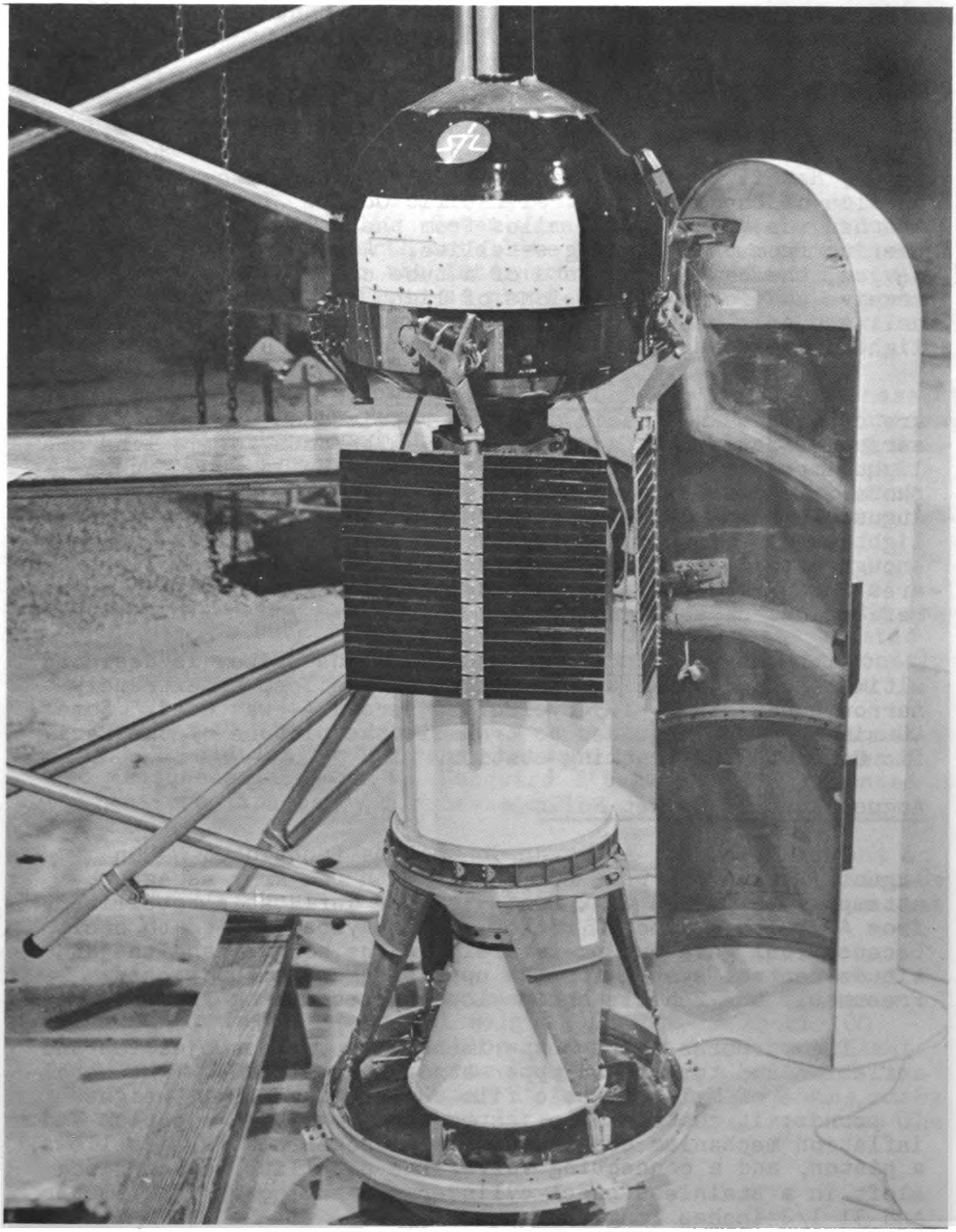
* Belts of high-energy charged particles, trapped in the earth's magnetic field, first reported by James A. Van Allen, of the State University of Iowa.



Explorer VI, launched into orbit on August 7, is shown with paddles down and locked while it is fitted to the fairing which protected it during the first and second stages of flight.

wide zone or region with characteristics that vary in different sections, rather than two "doughnuts" of trapped radiation indicated by earlier experiments.

Cloud Picture Transmitted -- On August 14, while the satellite was passing over Mexico at an altitude of about 17,000 miles, it transmitted to a ground station at South Point, Hawaii, a crude picture of a sunlit, crescent-shaped portion of the North Central Pacific Ocean. The area photographed was about 20,000 miles from the telescope-like camera peering from the spinning satellite. A two-pound scanning device, the camera consists of a tube containing a mirror to receive and focus impressions of light on a sensitive photocell and an electronic circuit and counter to transform the light impressions into coded electrical impulses.

Converted into Radio Signals* -- The electrical impulses are converted into radio signals, received on earth as a series of dots on a facsimile unit. The dots form a line of light impressions; these lines gradually build up a crude photo image of the area scanned. The picture transmitted on August 14 shows blurry white lines with some dark and some light areas. Although not clearly defined, the image has enough detail to indicate correspondence between the light areas and what are either clouds over the North Pacific or reflections of sunlight from the water.

Ultra-Narrow Bandwidth -- Because the system is designed ultimately to transmit over millions of miles, an extremely narrow bandwidth -- 1.5 cycles per second -- was used. Some 40 minutes were required to transmit the picture of the Pacific Ocean to the tracking station.

August Juno II Rocket Fails

Fuel Gave Out; Attitude Control Malfunctioned -- On August 14, at 7:31 p.m. EST, NASA, with the Army as agent, attempted to launch a 12-foot diameter inflatable satellite from AMR with a Juno II rocket. The payload failed to orbit because fuel gave out prematurely in the booster and the attitude-control system for the upper stages malfunctioned. Presumably the vehicle and payload burned during reentry.

The purposes of the experiment were to test ejection and inflation and to measure upper-atmosphere density. The satellite, made of Mylar plastic film and aluminum foil, weighed 10 pounds; it contained no instrumentation. The ejection and inflation mechanism consisted of a nitrogen bottle, a bellows, a piston, and a connecting valve. The satellite was carried aloft in a stainless steel cylinder, seven inches in diameter and 31 1/2 inches long.

* The satellite stopped transmitting on October 6, 1959, probably because of an electronic failure.

Last Vanguard Succeeds -- Program Completed

Attains Planned Orbit -- Injection of Vanguard III into orbit at 1:29 a.m. EDT on September 18 marked the end of launching activities in the Nation's first scientific earth satellite program.

The rocket vehicle that launched Vanguard III was the last of a series of 14. Seven were launchers designed to place a scientific earth satellite into orbit as part of the U. S. contribution to the International Geophysical Year (IGY). Other vehicles were fired as proof-test units without upper stages. An earlier vehicle was presented to the Smithsonian Institution.

Rich Vanguard Heritage -- Although the launching phase of Project Vanguard has been completed, the personnel, techniques, and hardware developed during the program are continuing to contribute substantially to the U.S. space effort. Vanguard constituted an entire system of space technology, including vehicles and instrumented payloads, a world-wide tracking network, and a scientific research program.

Vanguard III Payload -- Vanguard III is a magnesium sphere 20 inches in diameter, with a 26-inch tapered tube attached. The tube is made of glass-fiber-reinforced plastic (six inches in diameter at the base, tapering to 2.6 inches), and carries a proton magnetometer at its tip.

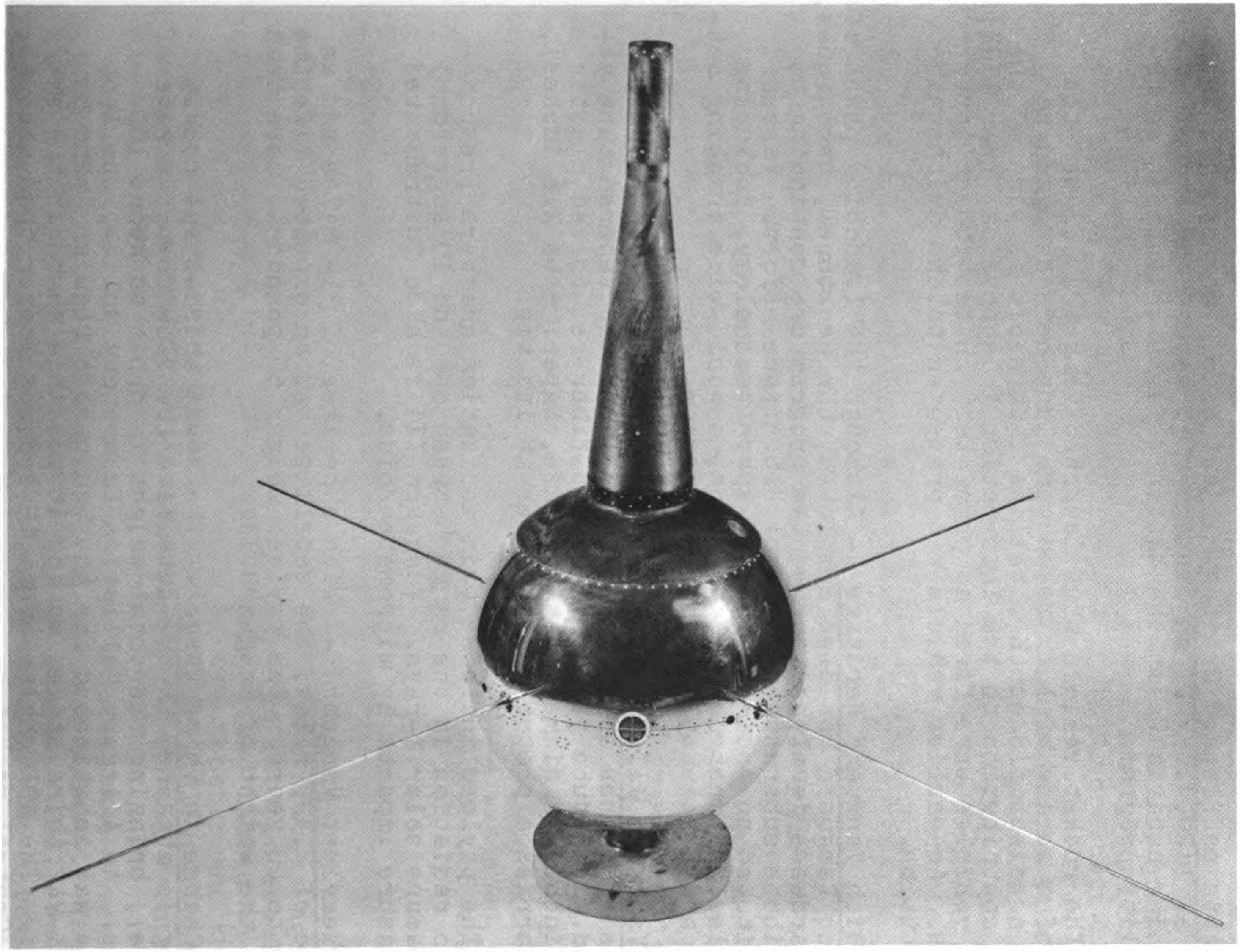
The payload includes twin ionization chambers (responding to radiation in the range between one and 10 angstroms) to measure solar X-rays. Vanguard III is also instrumented to measure impacts by micrometeoroids.

Heaviest Vanguard -- With a perigee of 319 miles and an apogee of 2,329 miles, the satellite has an expected lifetime of 30 to 40 years. The payload weighs 50 pounds -- more than twice the weight of Vanguard II.

Change in Third Stage -- The spent third-stage rocket casing is attached to the satellite (to slow down the rate of tumble), bringing the total weight in orbit to about 100 pounds. An Allegany Ballistics Laboratory solid-propellant engine was substituted for the Vanguard's regular Grand Central X-242 third stage, making it possible to boost the extra weight. The ABL engine burns 10 seconds longer than does the Grand Central rocket.

Sounding Rockets

Six-stage Vehicles Fired from Wallops Station -- NASA and the Advanced Research Projects Agency (ARPA) of the Department of Defense are conducting joint research in reentry



Vanguard III, put into orbit on September 18, is a 20-inch sphere topped by a 26-inch long tapered tube. A magnetometer at the end of the tube measures the earth's magnetic field. The Vanguard is also instrumented to transmit information on solar X-rays and environmental conditions in space. Vanguard III completed the Vanguard Program.

physics with six-stage rockets fired from NASA's Wallops Station, Wallops Island, Va.

The six stages of the vehicle are Honest John, Nike, and Lance boosters, a Thiokol T-40 and a Thiokol T-55 rocket engine, and a spherical NASA-developed rocket engine as the last stage.

To simulate a space vehicle's reentry into the friction-inducing atmosphere, the first three stages lift the vehicle to a peak altitude of about 200 miles and, after a coasting period following third-stage burn-out, the last three stages are fired and the vehicle is propelled earthward at speeds up to Mach 22* (about 16,000 mph).

Data are obtained by means of optical devices, radar, and telemetry. Atmospheric friction at downward-leg speeds causes the final stage to be consumed in flames.

On March 3, the sixth stage of one of these vehicles malfunctioned. Why it failed has not been determined. On June 4, a six-stager was fired successfully.

Research Centered at Wallops Island -- More than 3,000 multi-stage, research rockets of all types have been fired from Wallops Island since 1945 when the National Advisory Committee for Aeronautics established a center there for research into transonic and low supersonic speeds. A number of these rocket designs have been utilized as the basis for components of sounding rockets used under space flight conditions.

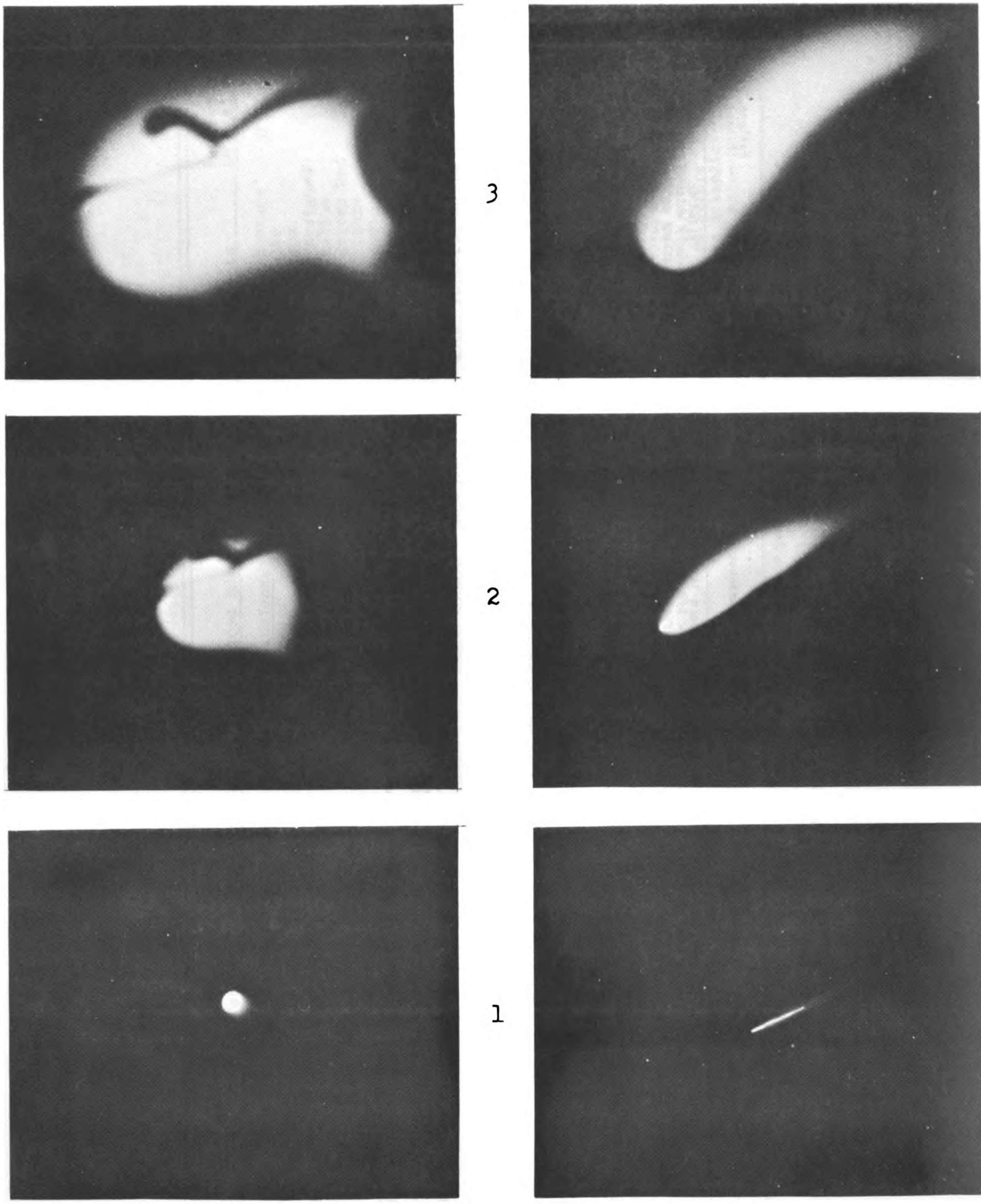
Sodium Vapor Cloud Experiments -- Two recent experiments involved the ejection of sodium vapor trails to obtain geophysical data on wind velocity.

The first of two Nike-Asp sounding rockets was fired at 5:18 a.m. EDT on August 17. Its 75-pound payload included 10 pounds of sodium pellets mixed with thermite compound. The sodium-thermite mixture was burned to create a sodium vapor trail from an altitude of 50 miles to the peak rocket altitude of 150 miles.

The vast orange-yellow cloud was visible over a large area of the Eastern Seaboard. Drifting inland, it was seen as far south as Vero Beach, Fla., as far north as Pittsburgh, Pa., and as far west as Dayton, Ohio. Scientists photographed the cloud and are now studying data to aid in future studies of wind velocity and direction, and diffusion phenomena in the upper atmosphere. Results indicated that winds with velocities as high as 600 miles per hour sometimes exist at an altitude of 150 miles.

* Mach 1 is equal to the speed of sound.

The second experiment, launched August 18 at 8:34 p.m. EDT, failed because a fin of the second stage Asp was damaged during launching. The vehicle became aerodynamically unstable and broke apart in flight.



As viewed from field photography station

As viewed from Wallops Island, Va.

Sequence in Emission of Sodium Vapor Cloud by Nike-Asp Sounding Rocket on August 17, 1959

TABLE 1

NASA Satellites, Lunar Probes, and Space Probes

April 1 - September 30, 1959

(Official Statistics Prepared by the National Aeronautics and Space Administration)

Name, By, Type, Orbit Weight, Payload Weight	Lifetime	Launching Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
Vanguard United States Two Satellites Total weight of scientific payloads: 23.3 pounds.	April 13, 1959-0	Vanguard SLV 5 (Same as TV 3)	Dimensions: Vanguard 3A -- 13-inch ball with a 17 1/2 by 2 1/2 inch cylinder extending from it. Vanguard 3B -- a 30-inch inflatable sphere containing no instrumentation to be tracked optically. Experiments: Vanguard 3A contained a precise magnetometer to be used to map Earth's magnetic field. Vanguard 3B was to measure drag in space. Composition: 3A was made of fiberglass and phenolic resins. 3B was laminated aluminum foil and plastic sheet. Transmitters: For 3A -- 108 mc at 10 mw for tracking and 108.03 mc at 80 mw for telemetry on ground command. Power supply: silver zinc batteries. Antennas: four spring-lock rods.	Second stage failed to operate properly which caused a tumbling motion. Payload and third stage fell into Atlantic Ocean several hundred miles off Cape Canaveral. Total flight time: about 500 seconds.	0	0

Notes: All distances are statute miles above surface of the Earth. Except where indicated, this chart does not include descriptions and weights of spent rocket casings, etc., that have gone into orbits or flight trajectoryies along with payloads.

Statistics on Explorer VI and Vanguard III are subject to updating after study of their data is completed.

Name, By, Type, Orbit Weight, Payload Weight	Lifetime	Launching Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
VANGUARD (SLV-6) Satellite (sphere) Total weight in flight and scientific instrumentations: 22.5 pounds.	June 22,1959 - 0	Standard Vanguard SLV	Dimensions: 20 inches in diameter Experiments: measurements of solar-earth heating process which generates weather. Shell Composition: Magnesium alloy. Antennas: four metal rods. Transmitters: a) 108 mc at 10 mw; b) 108.03 mc at 100 mw. Power Supply: Mercury batteries.	A faulty 2nd stage pressure valve caused failure. A regulator designed to control helium flow which drives 2nd stage propellants into engine, did not respond to command. Pressure then built up within helium reservoir which ruptured about 40 seconds after 2nd stage ignition. Without sufficient pressure on the propellants, 2nd stage engine ran roughly. Helium tank burst when vehicle was at 40 to 50 miles altitude. The rocket rolled over in a ballistic trajectory at an altitude of about 90 miles. 3rd stage ignited before plunging into Atlantic Ocean some 300 miles northeast of AMR.	0	0

Name, By, Type, Orbit Weight, Payload Weight	Lifetime	Launching Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
EXPLORER United States Satellite (Two truncated cones joined at bases.) Total weight in flight and scientific payload: 91.5 pounds	July 16, 1959 - 0	Juno II (Am-16) Same as Pioneer III	Dimensions: 28 inches high, 30 inches diameter. Experiments: Measurements of: 1) Earth's radiation balance; 2) Lyman-Alpha x-rays; 3) heavy primary cosmic rays; 4) Micrometeorites; 5) Cosmic rays; and 6) Satellite temperature; 7) Erosion study of exposed solar (silicon) cell on outside of satellite Transmitters: a) 20 mc at 650 mw; b) 108 mc at 15 mw Power Supply: a) solar energy; b) chemical batteries Transmitter lifetime: a) cutoff after one year; b) two months	Vehicle was destroyed by range safety officer after 5½ seconds when it tilted sharply due to failure of power supply to guidance system.	0	0

Name, By, Type, Orbit Weight, Payload Weight	Lifetime	Launching Vehicle	Payload Instrumentation	Test Results	Perigee (miles)	Apogee (miles)
EXPLORER VI United States Satellite (Paddlewheel; spheroid-shaped with flattened bottom plus four solar vanes or paddles.) Scientific payload and total weight in orbit: 142 pounds	August 7, 1959 - over one year.	Thor-Able III Stages: 1st: Thor (liquid) minus guidance. 2nd: Modified Vanguard second step (liquid) 3rd: X 248 solid rocket made for Vanguard program. Gross takeoff weight: 105,000 pounds plus. Height: 90 feet.	Dimensions: 26 inches in diameter and 29 inches deep with four solar vanes 18 inches by 18 inches square. Experiments: 1) Measurement of 3 specific radiation levels of Earth radiation belt; 2) TV-like scanning device to relay cloud cover picture; 3) Solar cells (8,000 in all; 1,000 on each side of four paddles) to create voltage to recharge the satellite's chemical batteries in flight (electronic gear in satellite includes 3 transmitters and 2 receivers); 4) Micrometeorite detector; 5) Two types of magnetometer to map Earth's magnetic field; 6) Four experiments to study behavior of radio waves, all aimed at learning more about deep space communications. Antennas: Two dipole aluminum rods. Transmitters: a) 108.06 mc at 500 mw; b) 108.09 mc at 500 mw; c) Ultra-high frequency (undisclosed). Power Supply: Nickel-cadmium batteries rechargeable by 8,000 solar cells mounted on 20x22 inch vanes jutting from satellite's equator.	Experiment successful. Data being analyzed as of August 16 1959. Details will be published when available. *Period: 12½ hours; speed (Perigee) 23,031 mph; speed (apogee) 3,126 mph. Inclination to Equator: 46.9 degrees. *August 16, 1959	156	26,357

Name, By, Type, Orbit Weight, Payload Weight	Lifetime	Launching Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
BEACON United States Satellite (cylinder) Scientific instrumentation in third stage rocket casing 25.8 pounds, including 10-pound inflatable sphere which is ejected to fly into orbit free of payload case. Total weight in orbit including spent third stage: 84 pounds	August 14, 1959 - 0	Modified Juno II (AM-19B) Stages: Three 1st: Jupiter (liquid) 2nd: 11 clustered Sergeants: (solid) 3rd: Three clustered Sergeants (solid) Gross takeoff weight 121,000 pounds	Dimensions: 7 inches by 31½ inches. (Inflatable sphere is 12 feet in diameter when inflated.) Experiments: Inflatable satellite of Mylar plastic film and aluminum foil. Satellite itself contains no instrumentation. Ejection and inflation mechanism consists of nitrogen bottle, a bellows, a piston and a connecting valve. Shell Composition: Stainless steel. Transmitter: 108.03 mc at 50 mw. (In rocket casing). Power Supply: 12 mercury batteries.	Payload failed to achieve orbit due to premature fuel depletion in booster and malfunction in attitude control system for upper stages. Time to third stage burnout (normally time of injection into orbit): 11.07 minutes.	0	0

Name, By, Type, Orbit Weight, Payload Weight	Lifetime	Launching Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
VANGUARD III (SLV-7) United States Satellite (sphere from which tapered tube extends) Scientific payload of 50 pounds and attached third-stage together weigh about 100 pounds.	Sept. 18, 1959-- Estimated 30-40 years	Vanguard Satellite Launching Vehicle 7. Stages: three 1st: liquid (G.E.) 2nd: liquid (Aero-jet) 3rd: solid (ABL) Gross takeoff weight: approx. 22,600 pounds. Height: 72 feet. Diameter (base): 45 inches	Dimensons: 20-inch sphere from which a 26-inch tapered tube extends. Experiments: Measurements of earth's magnetic field, solar X-rays, and environmental conditions in space. Shell Composition: highly polished silicon-monoxide-coated magnesium. Antennas: Four metal rods. Transmitters: a) 108.00 mc at 30 mw, tracking and X-ray and environmental; b) 108.03 mc at 80 mw for magnetometer and command. Power supply: chemical batteries. Transmitter lifetime: Programmed for about 90 days.	To be announced at a later date	319	2,329

CHAPTER 4

NATIONAL SPACE VEHICLE PROGRAM

GOALS: GREATER RELIABILITY, LARGER PAYLOADS

NASA vehicle development emphasizes simplicity and reliability. To date, vehicles used in the scientific space program have evolved from types designed for ballistic missile service. The variety has been too large to provide the reliability that comes from firing individual types repeatedly. To achieve greater reliability, NASA has designed its vehicle development program to insure that the required payload and performance capabilities will be provided by a minimum number of vehicle types. The new vehicles will permit space experiments with payloads weighing several thousand pounds.

Vehicles Involved

As of September 30, the program was concentrated on developing Scout, Delta, Vega, and Centaur.

Scout and Delta are to be "work-horse" vehicles for launching small-to-medium payloads in the near future.

Development of Scout is nearing completion. The first firing of this vehicle is scheduled for mid 1960.

Construction of Delta is on schedule.

Centaur, a general-purpose vehicle, is being developed for later and more advanced experiments. Designed for great reliability, Centaur will propel heavy payloads on many types of space missions, including high and low earth-satellite orbits, and lunar and planetary probes.

Design and fabrication of Centaur were carried forward during the report period, as the second-stage engine underwent full-duration tests.

Scout

Scientific experiments planned for the next five years require highly versatile, reliable, and inexpensive vehicles that can be used to conduct a wide range of experiments. These include a variety of scientific payloads designed for 300-500 mile orbits, as well as for space probes, high-velocity reentry tests, and advanced heating and ablation studies.

To meet these requirements, Scout was designed from the reliable, multi-staged, solid-propellant rocket systems that Langley Research Center has developed during the past decade for aerodynamic and reentry experiments at high velocities.

Vehicle -- The Scout vehicle comprises four technically advanced solid-rocket stages. The guidance system incorporates gyroscopic stabilization and a built-in, pre-set program which will permit a variety of trajectories. Controls consist of jet vanes and aerodynamic surfaces for the first stage, peroxide reaction jets for the second and third stages, and spin-stabilization for the fourth stage. Scout will be capable of launching payloads of about 200 pounds in circular west-east orbits at altitudes of 300 miles, and of launching probes with 100-pound payloads to altitudes of 6,000 miles. Scout may also be utilized for high-velocity reentry tests.

Because Scout engines use solid propellants, they are easier and simpler to handle than are liquid-fuel rockets. The components are also simpler, as are launching and handling techniques. As a result, the vehicle does not require a great launching complex such as that at Cape Canaveral; it can be fired from a number of sites, including NASA's Wallops Station. This circumstance should reduce handling and launching costs substantially.

Scout Status -- The four major areas of Scout development are: propulsion, guidance and control, airframe, and launcher. Development and procurement contracts for components were awarded early in 1959. By the end of this report period, most of these had been fabricated and were in process of qualification testing.

Propulsion -- The Scout first stage, being developed by the Aerojet-General Corp., Sacramento, Calif., is a 23,000-pound rocket having a thrust of about 115,000 pounds. As of September 30, the first eight flight motors had been completed and five had been shipped to Wallops Island where they were fired.

The second-stage engine, an 8,900-pound rocket having a thrust of 56,000 pounds, is being developed by the Redstone Division of the Thiokol Chemical Co., Huntsville, Ala. Basically a Sergeant rocket, the engine is fueled with an improved propellant and has a larger nozzle cone for high-altitude performance. A small contract for a second-stage backup engine, using the same rocket hardware, was let in early 1959 to the Aerojet-General Corporation.

The third-stage engine, a 2,200-pound rocket having a thrust of 13,600 pounds -- a scale-up of the existing fourth stage -- is being developed by the Allegany Ballistic Laboratory, Cumberland, Md. Although difficulties with chamber insulation and fabrication caused several early failures, by October the third stage had been successful in five of eight test firings. The third-stage rocket is constructed of reinforced plastic -- basically fiberglass with epoxy resin binder.

The fourth-stage engine, developed by the Allegany Ballistic Laboratory, is a 500-pound rocket with a thrust of 3,100 pounds. Because this stage was adapted from the Vanguard upper-stage rocket, no development tests are required. Like the third stage, this unit is constructed of fiberglass and epoxy resin.

Guidance and Control -- Guidance for Scout is being developed by the Missile Development Laboratory of the Minneapolis-Honeywell Regulator Co., Los Angeles, Calif. The two hydrogen-peroxide stabilization systems for the vehicle are being developed by Walter Kidde Co., Inc., of Belleville, N.J. The systems have been fabricated; reaction-chamber operating problems are being investigated.

Airframe -- The contract for the Scout airframe calls for integrating the rockets, guidance and control systems, and payloads. The task is being carried out by the Vought Astronautics Division of Chance-Vought Aircraft Corp., Dallas, Tex. Minor engineering problems have been solved and components for flight vehicles have been shipped to the launching site at Wallops Island.

Launcher -- The Scout launcher, fabricated by the Vought Astronautics Division of Chance-Vought, is being erected on a pad at Wallops Island. A complete launcher assembly with a mockup vehicle at the company's plant indicated no problems.

Modified Scout Vehicle -- The Air Force has started a development program (designated 609A) based on combinations of Scout stages for military and scientific applications. Coordination of the efforts of NASA and the Air Force Ballistic Missile Division, Los Angeles, Calif., includes a NASA-Air Force committee to define responsibilities and to make basic decisions. Aeronutronic,a division of Ford Motor Co., Glendale, Calif., was chosen to coordinate Air Force vehicle systems.

Development and procurement of modified Scout vehicles for the 609A are being carried out by NASA for the Air Force. About 10 vehicles are to be purchased for the Air Force. Flights will be from AMR. An auxiliary system for spin-stabilizing the terminal stage will be developed.

Delta

The Delta vehicle will be capable of placing 100-300 pounds into circular orbits of 1,040 miles and into elliptical orbits of between 156 and 46,100 miles. It will also be able to reach the moon with 65-pound payloads.

Vehicle -- The three-stage Delta vehicle is a modified Thor-Able. A modified Thor operational missile forms the first stage, in which an adapter section replaces the Thor warhead. This section, which supports the second stage during first-stage burning, opens into four petals to allow the second stage to separate after it is ignited.

The second stage is an improved version of the Vanguard second stage. Radio guidance and an attitude-control system for coasting flight have been added, and a steel thrust chamber replaces the aluminum Vanguard unit.

The third stage, a spin-stabilized modification of the Vanguard solid-propellant motor, carries the payload.

Progress -- All major elements of the Delta vehicle are on schedule. Four sets of hardware for a series of launchings were delivered to Langley Research Center on schedule. Object of these experiments is to test the third-stage of the Delta system and a 100-foot inflatable sphere -- a communications satellite experiment -- by firing them to an altitude of 250 statute miles. Clustered, operational solid rockets will be used as boosters for the tests.

Missions and Schedules -- Delta will be used to launch the 100-foot sphere for communications experiments (Project Echo), a meteorological satellite (TIROS II), radiation and spectroscopy experiments, a deep space probe, and several atmospheric and ionospheric experiments. The first Delta launching is scheduled for early 1960, with other firings continuing through 1962. Launchings will be divided between the Atlantic Missile Range and the Pacific Missile Range.

Vega*

The cancelled Vega would have been a general-purpose space vehicle, drawing largely on existing components.

Centaur

The Centaur general-purpose vehicle being developed by NASA will place a communications satellite in an equatorial orbit at an altitude (approximately 22,300 miles) that will

* The Vega project included both a two-stage and a three-stage booster. The first stage was an Atlas. The second stage, an engine originally used as the primary booster for Vanguard, was being modified to permit in-flight stopping and restarting. The third stage was to utilize the 6,000-pound-thrust, storable-propellant engine under development by the Jet Propulsion Laboratory.

permit the satellite to remain fixed over one spot on the earth's surface. The vehicle will be employed also for earth-satellite and lunar and planetary scientific missions.

Vehicle -- Centaur's first stage is an Atlas-D missile, modified by replacing the tapered forward part of the liquid oxygen tank with a cylinder of the same diameter as the aft portion of the Atlas. An adapter attached to the upper end of the Atlas holds the second stage.

The second stage and the payload are protected by a nose cone that will be jettisoned early in flight, as soon as aerodynamic heating is no longer critical. The second stage is powered by a two-barrel, turbopump-fed, rocket engine, with liquid hydrogen and liquid oxygen as propellants. The use of high-energy hydrogen fuel accounts for the high load-carrying capacity of Centaur.

Progress -- Atlas boosters for all Centaur vehicles have been purchased by NASA from the Air Force Ballistic Missiles Division. Design and fabrication of the second-stage vehicle are under way.

The inertial guidance system for the Centaur is progressing on schedule.

In September a heavy, nonflying simulator of the tankage for Centaur was completed and installed for testing at the Point Loma test site in California.

Missions and Schedules -- The first Centaur firing is scheduled for mid-1961. The first six missions will have progressively more difficult orbits, culminating in a 24-hour stationary orbit. The first three Centaurs may carry small scientific and engineering payloads in addition to vehicle instrumentation.

CHAPTER 5

MANNED SPACE FLIGHT

PROJECT MERCURY

Program Plans and Objectives

Project Mercury is the first phase of the U.S. manned space flight effort. Its primary objective is to determine man's capabilities in a space environment. Because of the project's far-reaching significance, NASA designated Mercury as one of its top-priority goals for the period 1959-1961. Planning is completed. Well under way are Mercury capsule development, booster adaptation, development and installation of the tracking network, and construction of the launching complex. Seven Mercury astronauts have been selected and are in training.

Before the first U.S. astronaut orbits the earth, he will have been intensively trained and conditioned, and the capsule will have been exhaustively tested.

Testing and evaluation include capsule ballistic flights over short distances, instrumented ballistic and orbital flights, and animal passenger flights.

Preliminary analyses and experimental investigations are in progress to acquire information needed to determine what steps should follow Project Mercury in the manned space flight program.

Capsule

The Mercury capsule, which will be launched by an Atlas booster, will have a nickel-cobalt outer shell and a titanium inner shell, separated by insulation against heat, cold, and noise. The astronaut, clad in a pressure suit, will recline on a contour couch that will permit him to withstand much of the stress of launching and reentry accelerations. The capsule will be fitted with communications and navigation devices, equipment to provide oxygen and remove carbon dioxide, attitude control jets, an ablation heat shield against severe reentry heating, three solid-fuel retrograde rockets to reduce the speed of the capsule in orbit in order to initiate its descent, and main and emergency parachutes for landing.

A ballistic or nonlifting reentry configuration was chosen for the capsule, based upon existing and proven technology. At launch, the capsule will be topped by a pylon-like arrangement containing an escape rocket system. If the booster malfunctions at any time from pad to staging, an escape rocket can be triggered to carry the capsule away from the booster. Parachute release and capsule recovery will then take place.

Inside the capsule there will be instruments to inform the pilot of his equipment performance and capsule attitude. Communications equipment will transmit this and other information on the capsule and the astronaut to ground stations of the Mercury tracking network.

Flight Plan

The Mercury capsule will be boosted into orbit by an Atlas launched from AMR in a direction slightly north of east. During three earth circuits, the capsule will travel at a speed of about 18,000 mph and at an altitude of about 100 miles over Africa, Australia, Mexico, and the United States.

Near the California coast, retro-rockets will be fired either by the astronaut or by radio command from the ground, slowing the capsule by 350 mph, so that in about one-quarter of a circuit it will land in the Atlantic Ocean, near the Bahama Islands.

After the capsule has been retarded by aerodynamic drag, the parachute will open at 10,000 feet to slow to a landing speed of 30 feet per second. After impact in the water, the parachute will be detached automatically and the capsule will float. Military aircraft and ships concentrated in the landing area will search for and recover the capsule and its astronaut passenger. The capsule is expected to stay aloft 4 1/2 hours.

A worldwide system of tracking and control stations will be in communication with the Mercury capsule almost continuously.

Early Mercury Developments*

NASA formally organized Project Mercury on October 5, 1958. A Space Task Group, reporting directly to the Office of Space Flight Development, NASA Headquarters, Washington, D.C., was organized to direct the project.**

* Early developments were reported in detail in the NASA's First Semiannual Report to the Congress, pp. 8 through 11.

** The group now reports to the Director, Goddard Space Flight Center, Greenbelt, Md.

On October 27, 1958, a Special Committee on Life Sciences was established to determine qualifications and attributes required of America's first man in space and to give advice on other human aspects of Project Mercury. Using criteria provided by the committee, NASA thoroughly screened Navy, Air Force, and Marine test pilots who volunteered for the project, and seven astronauts were selected on April 2, 1959.

In January 1959, McDonnell Aircraft Corp., St. Louis, Mo., was selected from among 12 firms that had submitted bids to design, develop, and build the Mercury capsule. Subsequently, NASA arranged to procure existing rocket vehicles or boosters for test flights and eventual orbital flight.

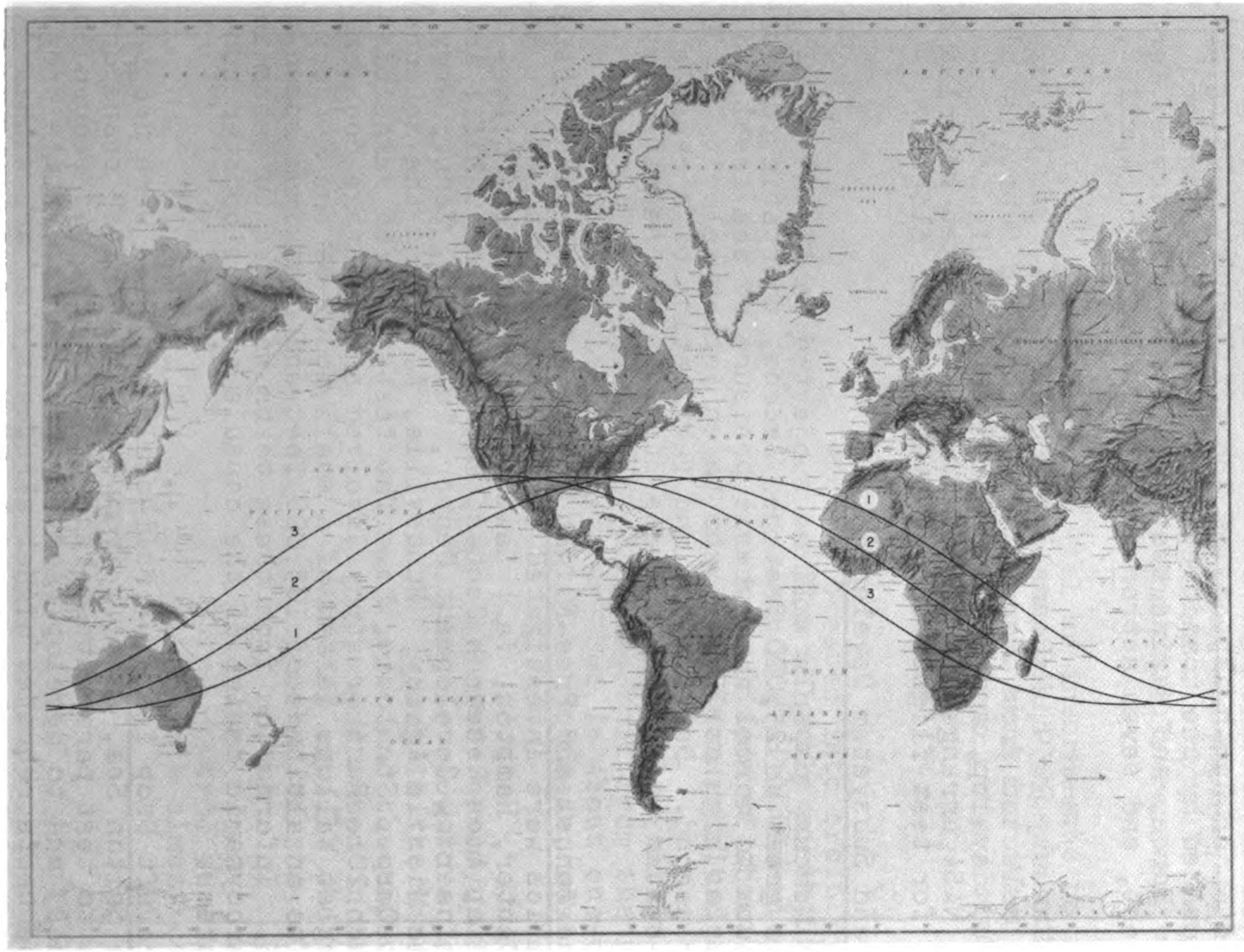
Capsule and Subsystem Development

The Mercury capsule will be subjected to flight velocities as great as 25,000 feet per second, to static pressures from vacuum to normal atmospheric pressure at sea level, to temperatures as high as 3000°F, and to an impact velocity of 30 feet per second. Development and fabrication of a capsule and sub-system to withstand these stresses are nearing completion.

Wind Tunnel and Free-Flight Tests -- Capsule and booster aerodynamics were investigated in wind tunnels at Langley Research Center, Hampton, Va.; Lewis Research Center, Cleveland, Ohio; Ames Research Center, Moffett Field, Calif.; Arnold Engineering Development Center, Tullahoma, Tenn.; Army Ballistic Missile Agency, Huntsville, Ala.; and the McDonnell Aircraft Corp., St. Louis, Mo. The tests covered velocities up to Mach 20. Further study involved a four-stage booster launching at Wallops Island of a small model of the Mercury capsule to an altitude of 105,000 feet and a maximum speed of Mach 9.5. Information from these tests was used to determine final aerodynamic design of the capsule and its booster control systems.

Aircraft Drop Tests -- Full-scale capsules were dropped into the Salton Sea, Calif., from C-130 "Hercules" transport aircraft to test parachutes, recovery systems, and sequencing techniques, and to develop recovery procedures. Since drogue parachute tests required higher airspeeds than are within C-130 capabilities, they were made by using F-104 "Starfighter" interceptor aircraft. These tests were held at Edwards Research Center, Edwards, Calif. Rocket-launched tests, placing even greater requirements on the drogue parachute system, were conducted at Eglin Air Force Base, Valparaiso, Fla.

Information from the aircraft drop tests resulted in decisions to utilize a ring-sail main parachute and to discard a proposed jettisonable beryllium heat sink. Developmental



Mercury Capsule Orbital Paths

tests have been completed. Tests with production hardware have begun. These are being conducted by the Air Force-Navy Joint Parachute Facility, El Centro, Calif., following initial tests at Edwards Air Force Base.

Launch Pad Escape Test -- While the booster is on the pad, a Grand Central rocket is mounted on a pylon frame above the capsule. At a signal from the pilot, the ground control center, or a booster-abort sensing system, this rocket will fire and hurl the capsule away from the booster, allowing the reserve parachute to deploy if the main parachute fails. The escape system was tested at Wallops Station where boilerplate models of the capsule were fired to an altitude of approximately 2,000 feet. There will be further tests.

Flotation Tests -- If everything goes according to plan, the capsule will land on water. Models were subjected to flotation tests at Langley Research Center to assure that the capsule will float upright, regardless of how it strikes the water. Tests included the effects of wave action, pilot exit, and parachute swinging. The capsule floats upright because most of its weight is concentrated near the large end (heat shield) and air bags are used to stabilize it in the water.

Impact Studies -- The main parachute will have slowed the capsule's descent to 30 feet per second at the moment of impact. The problem of impact (particularly if the capsule strikes the ground instead of water) extends to structure, instrumentation, and astronaut. External and internal cushioning are being studied.

Little Joe Flight Tests -- Little Joe is the name given to a fin-stabilized, clustered, eight-rocket booster (four solid-fuel Sergeant* and four solid-fuel Recruit engines) designed to test the Mercury capsule in ballistic flight. While Little Joe can boost the capsule to only one-fifth of orbital velocity, the system provides an economical means of testing the escape system over a wide range of dynamic pressures; of checking capsule stability, controls, and recovery systems; and of studying the behavior of primates during weightlessness. On August 21, 1959, shortly before the first scheduled launching at Wallops Station, a malfunction in the electrical system prematurely fired the escape rocket mounted on the capsule model. This occurred while the batteries were being charged. Charging had not been sufficient to set off the main parachute ejection mechanism; consequently, the main parachute did not deploy. The capsule hit the ocean with great force and sank. The booster remained on its launcher, undamaged.

* Modified

As this reporting period closed, a second Little Joe vehicle was scheduled for launching.*

Big Joe Flight Test -- A launch termed Big Joe was considered one of the important tests of the Mercury development program. On September 9, 1959, at 3:19 a.m. EDT, an Atlas boosted a full-scale instrumented boilerplate model of the Mercury capsule to near-orbital speed and to an altitude of about 100 miles. The purpose was to test reentry capabilities, chiefly performance of the heat shield, flight characteristics of the capsule and its instruments, and capsule recovery. The capsule was picked up by a Navy destroyer in the Atlantic Ocean north of Puerto Rico.

Results were gratifying. The capsule proved stable and its instruments operated properly. The ablation heat shield successfully survived the fierce heat of reentry, and capsule temperatures and reentry decelerations were within levels of human tolerance. The Mercury capsule also stood up well to vibration and structural loads caused by the severe noise levels and frequencies encountered during the test.

Instruments for the actual Mercury capsule will be designed along lines similar to those carried by the boilerplate capsule model launched in the Big Joe test.

The Big Joe capsule was built by the Lewis Research Center, Cleveland, Ohio. Capsule instruments were provided by Electrical Mechanical Research, Inc., St. Petersburg, Fla.; General Electric Co., Schenectady, N. Y.; and Minneapolis-Honeywell Regulator Co., Minneapolis, Minn. Radioplane Division, Northrop Corp., Los Angeles, Calif., furnished the landing system components. Lewis Research Center designed, laboratory-tested, and installed the attitude control system for Big Joe. This system oriented and stabilized the capsule during flight.

Retrorockets -- Development of the cluster of three solid retrorockets in the capsule is assigned to the Thiokol Chemical Corp., Elkton, Md.

Additional Test Facilities Planned -- Lewis Research Center is adapting a facility for simulating high altitudes to use as a low-pressure chamber to approximate conditions approaching those in space. The facility will be employed to evaluate capsule-booster separation techniques, and to determine the effect of the escape rocket exhaust on the capsule.

* Little Joe was successfully fired October 4.

Capsule Production

The McDonnell Aircraft Corp., Mercury capsule contractor, modified the full-scale mock-up completed in March to incorporate changes that were suggested by the astronauts, and other modifications that resulted from developmental tests. The contractor had completed the detailed design of the capsule and its components and had started production by the end of September.

Capsule Qualification Program

Certain developmental tests, such as the previously noted launch-pad abort and the Little Joe and Big Joe missions, will be repeated to qualify the McDonnell capsule for flight. In addition, Redstone rockets will be used to check capsule systems at speeds up to 6,000 feet per second and to familiarize the astronaut-pilot with all phases of the capsule. Atlas boosters are also programmed to test capsule reentry at peak simulated abort acceleration. A number of unmanned missions will precede man's orbital flight. Chimpanzees will be sent on some of the qualification flights so that the environmental system, and primate reflexes and other behavior patterns can be checked under space-flight conditions.

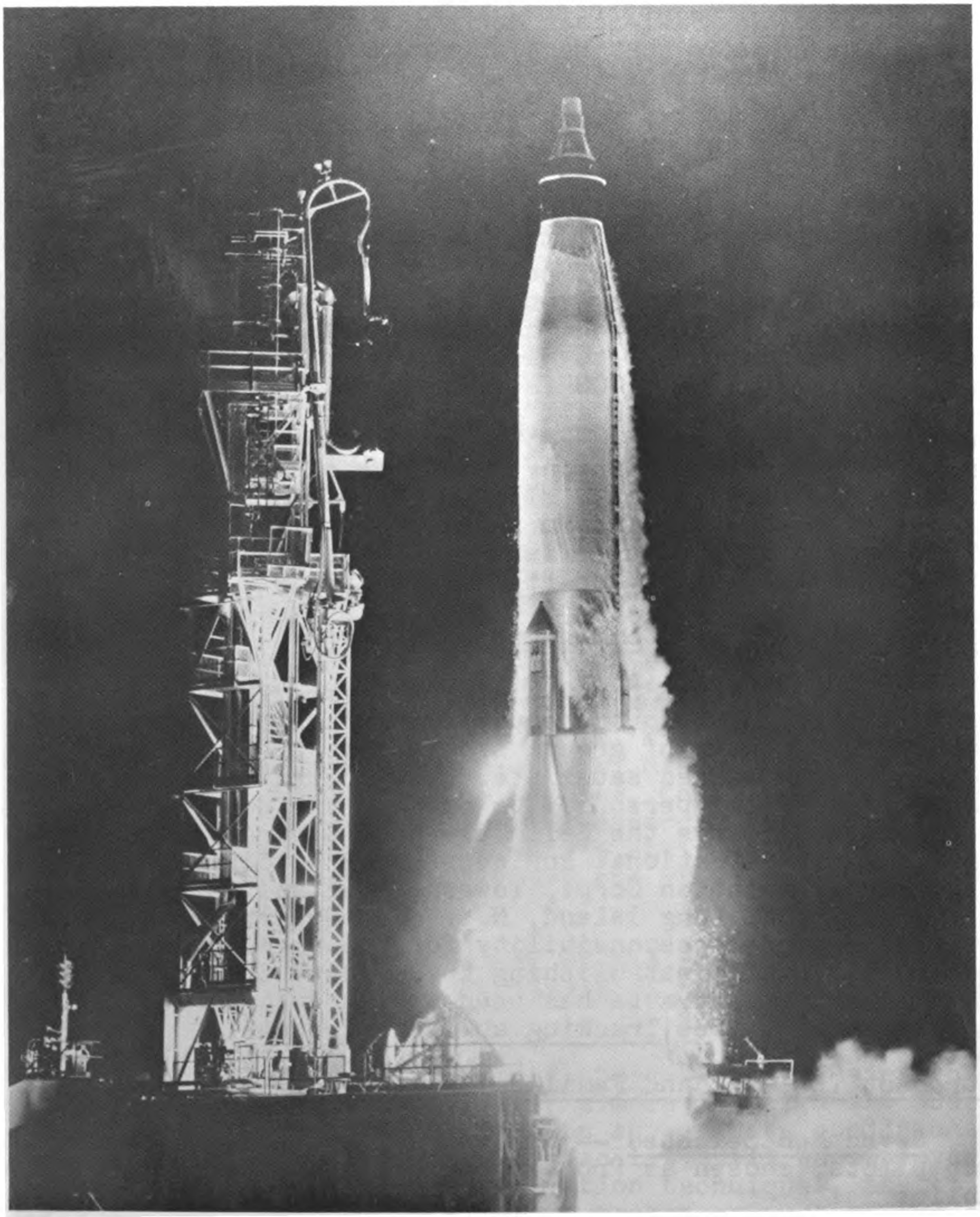
Mercury Tracking and Communications Network

Western Electric Corp., Inc., New York, N.Y., was chosen as the prime contractor to equip and manage construction of a worldwide network of ground stations to track and monitor flights of the manned satellite. The company is also in charge of training personnel to operate the network. Associated contractors are the Bell Telephone Laboratories, Whippany, N.J.; International Business Machines Corp., New York, N.Y.; Bendix Aviation Corp., Towson, Md.; and Burns and Roe, Inc., Hempstead, Long Island, N.Y. The Department of Defense has been assigned responsibility for the recovery operations. Responsibility for establishing the Mercury tracking network and monitoring contracts has been assigned to the Langley Research Center. (See Tracking and Data Systems.)

Astronaut Training and Familiarization Program

Seven Men Selected -- On April 9, names of the seven test pilots, chosen as Project Mercury astronauts, were made public:

Lt. Malcolm S. Carpenter, USN, Garden Grove, Calif.
Capt. Leroy G. Cooper, Jr., USAF, Carbondale, Colo.
Lt. Col. John H. Glenn, USMC, New Concord, Ohio
Capt. Virgil I. Grissom, USAF, Mitchell, Ind.
LCDR Walter M. Schirra, Jr., USN, Hackensack, N.J.
LCDR Alan B. Shepard, Jr., USN, East Derry, N.H.
Capt. Donald K. Slayton, USAF, Sparta, Wis.



Launching of the "Big Joe" Mercury Test, September 9, 1959

Astronaut Engineering and Familiarization Activities -- On April 27, the astronauts reported for full-time duty with the NASA Space Task Group at Langley Field, Va. Each is specializing in and contributing to a different aspect of the Mercury project -- communications and navigation, control system, cockpit layout, life-support system, tracking and recovery, Redstone booster, or Atlas booster. Each man is responsible for determining, within his particular area, whether the Mercury system is suitable for manned operation.

In addition to their specialty assignments, the pilots as a group attend lectures on rocket propulsion, space mechanics, gyroscope theory, stable platforms, space navigation, communications, meteorology, astronomy, and physics of the upper atmosphere. They also receive status briefings from the NASA Mercury Project engineers and visit the various contractor and service facilities. Individually, the pilots visit the sub-contractors within their own specialty areas. During these visits, they are briefed on the Mercury systems and on advanced programs that are under study and development.

Flight Simulators and Training Facilities -- It is essential to provide the astronauts experience with every conceivable characteristic of space flight that can be simulated in the air or on the ground. Dynamic and static simulators developed for this training are:

1. Langley Analog Computer. This computer, in conjunction with a fixed-base simulator, gives practice in controlling the vehicle with the manual control system during simulated orbit, retrofire, and reentry. An instrument panel for pilot training contains the actual capsule flight instruments which are driven by an analog computer.

2. Langley MB-3 Flight Simulator. Similar to the analog computer, the MB-3 simulator also includes an instructor's console.

3. Procedures Trainers. The procedures trainer of the Langley Space Task Group is a mock-up of the interior of the actual capsule and, in conjunction with the MB-3 simulator, familiarizes the pilot with operating procedures in normal and emergency missions. A second procedural trainer will be used at Cape Canaveral to provide additional training in range-network and launching procedures.

4. ACEL Environmental System Trainer. A complete life-support system will be placed in the decompression chamber at the Navy Air Crew Equipment Laboratory, Philadelphia, Pa. The trainer will serve the dual purpose of qualifying the environmental control system and familiarizing the pilots with the system's characteristics.

5. Human Centrifuge Facilities. Centrifuge facilities at the Air Force Wright Air Development Center, Dayton, Ohio, and at the Naval Air Development Center, Johnsville, Pa., provide familiarization with high acceleration and also give the pilot practice in controlling capsule attitude during simulated orbital flight and reentry.

6. Air-Bearing Attitude Simulator. A pivoting support couch mounted on a single low-friction bearing will be used to familiarize the pilots with the orbital dynamics of the capsule under influence of the reaction-control jets. This simulator is limited to 45° rotation in pitch and roll.

7. Gimballed Attitude Simulator. This simulator, located in the Altitude Wind Tunnel at the Lewis Research Center, possesses complete angular freedom in pitch, yaw, and roll, and will give the pilots practice in controlling a capsule under conditions of severe angular rotation.

8. Capsule Egress Trainer. A special egress capsule will be used to train the astronauts to get out of the capsule under varied ocean conditions.

9. Zero-g Flights. Flights in specially-equipped C-131 and F-100F aircraft provide the experience of weightlessness for periods of from 15 seconds to one minute. The astronauts experienced zero gravity for 15 seconds during a C-131 flight.

10. Zero-g Water Tank. A water tank mounted on bearings determines pilot disorientation under partially simulated zero-g conditions.

Pressure Suit Selected

A modified U.S. Navy Mark IV pressure suit has been selected as the closest approach to the type of life-support garment which the astronauts will wear in orbital and Redstone-boosted suborbital flights. The suit is made by the B. F. Goodrich Co., Akron, Ohio. Factors in the decision were comfort, mobility, compactness, reliability, resistance to temperature, pressure, impermeability, ease of donning and removing, and noise reduction. The suit will serve as a back-up safety feature; it will automatically inflate should the capsule pressure system fail. A coating of silver spray will act as an additional heat buffer and radiation shield.

THE X-15 RESEARCH AIRPLANE

Objectives

The X-15 research airplane is a "near-space" vehicle that will fly to altitudes of 250,000 feet or more, an early step in the transition from flight within the atmosphere to flight in space. The X-15 does not take off from the ground under its own power, but is drop-launched from a B-52 mother ship.

Principal objectives of the X-15 program are to: 1) determine intensity of aerodynamic heating and its effect on the structure; 2) obtain stability and control data in the very thin air of the upper atmosphere; and 3) observe the effects of weightlessness on the pilot.

Responsibilities

The X-15 is a joint Air Force-Navy-NASA project, with the two services providing contract funds and with NASA furnishing technical direction and having responsibility for the research flight test program.

Development

The initial proposal for the airplane was made by NASA in May 1954; it was accepted by the services two months later. In December 1954, North American Aviation Inc., Los Angeles, Calif., was awarded a contract to build three experimental aircraft. In October 1958, the first X-15 was completed on schedule and delivered for ground testing to Edwards Air Force Base, Calif.

Test Flights

The X-15 completed its first glide flight on June 8, 1959, and its first powered flight on September 17, 1959. During both flights, the X-15 showed generally satisfactory launching, aerodynamic control, and landing characteristics.

Launchings from the B-52 were made at a speed of Mach 0.8 at an altitude of about 38,000 feet. In the powered flight, a maximum speed of Mach 2 and an altitude of 50,000 feet were reached. Power was from two (interim) XLR-11 rocket engines that produce a total of approximately 13,000 pounds of thrust.

A series of captive flights preceded the X-15 free flights. The captive flights demonstrated that the X-15 - B-52 combination was aerodynamically compatible and that the X-15 subsystems operated well.

Pilot landing techniques for the X-15 were perfected by ground simulation. These techniques were verified by the generally satisfactory approaches and landings performed by the X-15.

The demonstration flights of the X-15 by the contractor will follow detailed flight-test demonstrations agreed upon by the Air Force, NASA, and North American Aviation. After the completion of systems and structural integrity demonstration by the contractor, the X-15 will be turned over to NASA for flights by NASA, Air Force, and Navy pilots.

Operational Flight and Space Research Programs

The first operational X-15 flights will investigate weightlessness, low dynamic pressure, exit-entry dynamics, and the maximum speed potential. Other flights will be made to study flying qualities, critical stability and control areas, aerodynamic and reaction-control qualities, and approach and landing characteristics.

Future X-15 research will investigate effects of the space environment on the pilot such as weightlessness, whole-body radiation, etc. Much of the effort will be directed toward obtaining data on heating at hypersonic speeds that may subject the X-15 structure to temperatures as high as 1200°F.

X-15 Research Plane Immediately upon Release from B-52 Mother Plane on First Powered Free Flight September 17, 1959

CHAPTER 6

SPACE SCIENCES RESEARCH

RECENT RESULTS

The discovery of greatest significance in the space sciences area during this report period was that the Great Radiation Region is much more complex in structure and behavior than had been supposed. A new region of high-energy protons was discovered and sufficient additional measurements were obtained to show that the entire region varies considerably in intensity of radiation and geographical distribution over relatively short periods of time. The new proton layer was detected by Explorer VI; it is some 310 miles thick and extends about 20 degrees on either side of the geomagnetic equator, centered at an altitude of about 1,250 miles. Further measurements will be required to determine the details of this proton layer.

Explorer VI reported that energies in the entire radiation region were from 10 to 20,000 times less intense than those detected by previous satellites and probes. Among phenomena discovered were pockets of radiation that faded in and out, probably as a result of solar disturbances. It now appears that the Great Radiation Region may be a very extensive area of energetic particles instead of the two rather distinct bands indicated by earlier experiments. The outer part of the region appears to be made up of electrons that stream from the sun and are trapped in the earth's magnetic field.

Preliminary magnetometer data from Explorer VI and Vanguard III give promise that it will be possible to map the earth's external magnetic field extensively.

Micrometeoroid experiments aboard the satellites are yielding a better understanding of the nature, energies, and densities of these microscopic particles of cosmic dust.

Preliminary results of the August 17 Nike-Asp sounding rocket experiment were that even though the atmosphere is very tenuous at an altitude of 150 miles, wind velocity is as high as 600 mph. Further experiments of this type are planned to obtain more information about phenomena and structure of the upper atmosphere.

RESEARCH PROGRAMS

Fields Under Investigation

Space sciences research may be divided into these principal areas: 1) Atmospheres, 2) Ionospheres, 3) Energetic Particles, 4) Electric and Magnetic Fields, 5) Gravity Fields, 6) Astronomy, and 7) Lunar Science.

Atmospheres -- The composition of the earth's atmosphere is being investigated intensively with sounding rockets and satellites. Particular emphasis is on obtaining and understanding daily, geographical, and seasonal variations, and on learning more about the relationship between surface meteorology and the structure and behavior of the upper atmosphere.

Instrument design and construction, payload plans and specifications, and developmental work are proceeding satisfactorily for an atmospheric structure satellite that will determine atmospheric composition and the daily, geographical, and seasonal variations that occur in composition and behavior. Improved sounding rocket instrumentation is being developed at the Goddard Space Flight Center, and the rocket program for investigating the upper atmosphere is under way. The program is under the management and technical direction of the Goddard Space Flight Center; participants include the University of Michigan and the Geophysics Corporation of America.

Ionospheres -- The ionosphere is a region of electrically charged (ionized) air beginning about 35 miles above the surface of the earth. It includes several layers (D, E, F_1, and F_2) that vary in height and ionization with the season and time of day. Ionization of the air molecules into ions and electrons is caused by ultraviolet rays. Electrons exert tremendous effect upon radio waves by reflecting some of them over great distances, thus making long-range radio communications possible. The objective in this program is to study the origin of these charged particles (electrons and ions) and how they vary with altitude, time of day, and latitude. Mass spectrometers are used to determine the ions that are present, and specialized instruments, such as Langmuir probes (for determining electron content) and electric-field meters, are used in rockets and satellites. Radio frequency propagation experiments are also used, such as the very low radio frequency propagation experiment in Explorer VI.

Research studies, instrument development, and payload design and assembly for three satellites intended for ionospheric measurements are under way at the Goddard Space Flight Center, the Army Ballistic Missile Agency, the Defence Telecommunications Establishment in Canada, the Central Radio Propagation Laboratory of the National Bureau of Standards at

Boulder, Colo., the Geophysics Corporation of America, Stanford University, the University of Illinois, the University of Auckland, and Pennsylvania State University. The satellites, in order of launching, will be: 1) Ionospheric Properties, 2) Ionosphere Beacon, and 3) Ionosphere Topside Sounder. The sounding rocket program in ionospheric studies is under way at the Goddard Space Flight Center; successful experiments have already extended our knowledge of electron densities in the ionosphere and served for valuable tests and calibrations of instruments to be used in the satellites.

Energetic Particles -- Energetic particles are electrically charged particles, mostly electrons and protons, that are moving at very high velocities and thus possess great amounts of energy. Included are the particles forming the Great Radiation Region surrounding the earth, cosmic rays, and the particles involved in the auroras of the Northern and Southern Hemispheres. The program in this area is designed to determine the nature, energy, and distribution in space of these particles, and the nature of their interactions with the magnetic field and the atmosphere of the earth.

The immediate program includes two satellites for detailed investigations of the nature and intensities of the particles in the Radiation Region and of the changes which occur at different times and geographical positions. Instrumentation work, payload planning and assembly, and engineering are proceeding on schedule for these satellites at the Goddard Space Flight Center, the Army Ballistic Missile Agency, Space Technology Laboratories, Inc., the University of Chicago, State University of Iowa, the University of Minnesota, the University of New Mexico, New York University, and the University of North Carolina.

The sounding rocket program for investigations of energetic particles is being developed along several lines at the Goddard Space Flight Center, including investigations of auroral particles and cosmic rays and nuclear emulsion recovery experiments. (Energetic particles leave a record of their passage in a photographic film that can be interpreted in terms of their nature, number, and energy. In this type of investigation, film must be recovered after the rocket flight.)

Electric and Magnetic Fields -- The magnetic field of the earth is of great importance to navigation and to studies of the ionosphere and of energetic particles phenomena. The strength and the direction of the earth's field undergo a variety of changes from gradual ones over periods of several years to abrupt changes and disturbances lasting for hours or days. Solar phenomena appear to be responsible for most, if not all, of the abrupt changes. The reasons for the slow, gradual changes are not well understood. The program in this area includes satellite and sounding rocket investigations with instruments designed to measure the strength and the variations of the earth's magnetic field, and to study the causes and phenomena of the sudden magnetic disturbances. Special types of magnetometers, such as the proton-precessional and the alkali-vapor instruments, have already been developed for rocket and satellite use.

Development and construction of magnetometers for inclusion in satellites, space and lunar probes, and sounding rocket experiments are proceeding at the Goddard Space Flight Center and the University of New Hampshire. An intensive program of sounding rocket measurements with magnetometers will result in numerous launches in 1960. A Thor-Delta vehicle is scheduled as a lunar probe to carry a magnetometer to measure the earth's magnetic field to the moon and to determine the lunar field more accurately than the measurements the Russians reported.

Gravity Fields -- In this program, study plans have been completed and a satellite has been scheduled for launching into an 800-1,000 mile orbit to obtain precise geodetic data over a long period of time. The satellite will contain a flashing light of very high intensity so that very precise optical tracking may be employed.

Preliminary design studies of the flashing-light system have been completed by Edgerton, Germeshausen and Grier, Inc. The Goddard Space Flight Center has made a preliminary design analysis of the entire geodetic satellite system and has prepared definitive engineering specifications for the complete structure and all functional components. It is expected that construction of the satellite will be started shortly under Goddard direction.

Astronomy -- Six scientific projects were established in Observational Astronomy and Solar Physics Programs: Gamma Ray Astronomy; Relativity Investigations; Orbiting Astronomical Observatories; Radio Astronomy; Solar Probes; and Solar Observatory. Through 22 research and development contracts, universities, industrial organizations, and government agencies began the design and testing of experimental techniques destined to help unlock many of the secrets of the universe, and to answer such questions as: How are stars born? What causes the gigantic storms observable on the sun? Is there life on Venus or Mars? Do nearby stars have planets? Is the universe growing old or standing still in time?

Construction progressed at the Massachusetts Institute of Technology (MIT) and at ABMA, Huntsville, Ala., on a satellite gamma-ray telescope to be flown in 1960 as part of a Gamma Ray Astronomy Project. Appreciable engineering was done by the Ball Brothers Research Corp., Boulder, Colo., and at Goddard Space Flight Center on an Orbiting Solar Observatory, a 300-pound satellite designed to study the sun in the ultraviolet and X-ray regions of the spectrum.

Payload construction has been nearly completed by Cooper Development Corp., Aerojet-General Corp., and Keithley Instrument Co. for a series of rockets to be launched from Wallops Island early in 1960 in a Solar Rockets Project. Component studies for 4000-pound orbiting astronomical observatories were started by NASA in conjunction with the Applied Physics Laboratory of Johns Hopkins University, the Smithsonian Astrophysical Observatory, the University of Michigan, the University of Wisconsin, Princeton University, and the University of Arizona. Preliminary engineering specifications for the necessary stabilized platform system were prepared by NASA's Ames Research Center.

These observatories are being designed to be adaptable to provide information on subjects as diverse as solar-terrestrial relationships, and the structure and composition of planetary atmospheres and surfaces, and thus to contribute to knowledge of the origin and evolution of stars, galaxies, and the universe.

Under a Relativity Investigations Project, the National Bureau of Standards, MIT, and Hughes Aircraft Co. proceeded with the development of an accurate atomic clock to be flown in a satellite as a test of Einstein's relativity theory. A clock on the ground will be compared with a similar clock in the satellite. According to theory, the clock in the satellite should run faster.

The Canadian Defence Telecommunications Board in Ottawa and the University of Michigan started design and construction on rocket and satellite experiments for measuring solar, planetary, and cosmic radio noise as part of an orbiting radio astronomy project.

Lunar Science -- The NASA program of lunar explorations includes a variety of missions such as probes and satellites, instrumented soft landings, instrumented circumnavigations with return to earth, and, eventually, manned versions of both these missions. The booster vehicles used will, as they become progressively larger, be capable of handling greater payloads. The series includes Atlas-Able, Thor-Delta, Atlas, Centaur, Saturn, and eventually an even larger vehicle.

The scientific objectives of the lunar missions, simply stated, are to determine in as much detail as possible, the environment surrounding the moon and the structure and composition of the lunar surface and subsurface. Such information will not only have great scientific value but will also be absolutely essential in developing the technology that some day will enable man to set foot on the moon.

During this report period, contracts leading to advanced lunar science experimentation were let to a number of universities, government and industrial institutions (see Appendices L and M). Instrumentation for vehicles scheduled in a second-generation lunar flights project is being developed by the California Institute of Technology, Columbia University, La Coste and Romberg, the University of Chicago, Geotechnics and Resources, Inc., Massachusetts Institute of Technology and Goddard Space Flight Center. Contract specifications drawn up for developing payloads to be used in lunar soft-landing missions consist of X-ray fluorescence spectrometers, a mechanical complex to obtain surface samples, temperature and gravity measuring devices, advanced plasma-probe equipment, and magnetometers, seismographs, and mass spectrometers.

CHAPTER 7

SATELLITE APPLICATIONS

METEOROLOGICAL SATELLITE PROGRAM

Weather in all its varieties is produced by elements and processes and their results, interacting in the earth's atmosphere -- including cloud cover, storminess, precipitation, temperature variation, heat balance, wind direction, and water vapor distribution. NASA has established a Meteorological Satellite Program to determine the effectiveness of weather satellites to observe and report to ground stations worldwide weather patterns as they generate and develop. Evolving from this should be far-reaching improvements in weather prediction.

Execution of the Meteorological Satellite Program is the responsibility of Goddard Space Flight Center. Payload development and fabrication is carried out by contractors. For example, the TIROS (see below) payload is being built at R.C.A. Astro-Electronics Products Division, Hightstown, N.J., with the U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., technically monitoring satellite development.

Military participation and coordination are through the Joint Meteorological Satellite Advisory Committee, having representation from the three military services, ARPA, Weather Bureau, and NASA.

Workable weather satellites will require development of: 1) stabilized satellites in polar orbits, with altitudes of 500 to 1,000 miles, and "stationary" satellites for equatorial orbits at altitudes of 22,300 miles; 2) on-board detection equipment, including television, infrared detectors, radar, and spectroscope; and 3) adequate data-storage, handling, and communications equipment, and techniques.

The long-range objective is to develop operating principles for a system of instrumented orbiting satellites that would be linked with a communications network so that global meteorological data can be transmitted swiftly to the National Meteorological Center of the Weather Bureau, Suitland, Md.

Earth satellites promise to be highly valuable to meteorology in general and to weather forecasting in particular. Although weather satellites will not solve all meteorological problems, they should supply a tremendous amount of data which cannot be obtained by present means. Weather experts have envisioned benefits that include early warnings of hurricanes and other violent phenomena, to safeguard life and property; safer, more dependable transportation; more assurance in crop planning, control, and protection; and greater certainty in industrial planning for weather-dependent products, outdoor work, and heating and cooling loads. Eventually, perhaps, it may be possible to achieve some degree of weather modification and control. By no means the least dividend would be international goodwill returned to the U.S. for providing current global meteorological data to other nations.

Meteorological satellite data could be processed to meet special military requirements.

NASA is moving forward with a series of meteorological satellite experiments. At this writing, two have been at least partially successful (see Operational Missions). They were:

Vanguard II, which included scanning photocells to record cloud cover, and

Explorer VI, which carried a TV-scanning device to relay crude cloud-cover pictures.

A gross radiation-balance experiment was part of the scientific payload of the "Heavy IGY" satellite* aborted at launch on July 16.

On April 13, 1959, the meteorological satellite, Project TIROS, initiated by DOD, was transferred to NASA by agreement between DOD and NASA. The first TIROS experiment will carry two television cameras to take clearer, more comprehensive pictures of cloud cover than could the photographic devices in Vanguard II and Explorer VI. A later version of TIROS (TIROS II) will include both scanning and non-scanning infrared radiation detectors to report detailed radiation information and the gross radiation picture.

Further in the future, meteorological satellites will be equipped with refined versions of existing sensors and with experimental radar and spectroscopic devices.

As a parallel to this program, NASA is supporting substantial research to develop techniques for utilizing satellite data. Data from rocket probes, aircraft reconnaissance, and regular meteorological-observation sources are being used to simulate types of information that satellites will gather and report. The work is centered in the Meteorological Satellite Section of the U. S. Weather Bureau.

* Three months later, this satellite was launched successfully.

GEODETIC SATELLITE PROGRAM

This NASA program will develop specialized geodetic satellites, and conduct extensive ground observations and analyses leading to use of these satellites as precise tools for mapping, geodetic, and other geophysical investigations. After analysis by NASA personnel and by Edgerton, Germeshausen & Grier, Inc., a preliminary design for a geodetic satellite has been prepared.

A sphere 36 inches in diameter, weighing about 150 pounds, the satellite will be equipped with: 1) a flashing-light system of high intensity, powered by solar cells and radiating the equivalent of 32,000 lumen-seconds (a measure of the luminous energy emitted) as a point source in flashes of one millisecond duration; 2) telemetry pulses synchronized with the light flashes; 3) a stable oscillator for programming the light flashes and transmitting clock pulses (all to an accuracy of one millisecond); 4) optical corner-cube reflectors for use with ground-based searchlights; 5) radio-beacon transmitters for tracking; and 6) a command receiver for triggering light flashes of twice normal intensity when desired. Under consideration is the addition of a ranging transponder for direct distance measurements.

Engineering studies have been made of a number of technical problems, primarily in the flashing-light system and associated power supply. They show that a satellite of this type is feasible at the present stage of technology. The flashing-light system should have an active lifetime of more than a year; the corner-cube reflectors and the radio-beacon transmitters should operate almost indefinitely. Thus, over a long period of time, the satellite should be useful as a precise optical reference point for geodetic and geophysical studies.

By photographing the light flashes against the stellar background, the satellite's position will be determined to about 50-100 feet -- at an altitude of 1,000 miles. Three separate techniques may be used with a satellite of this type to obtain geodetic data: 1) observing the flashing light simultaneously from a number of ground stations; 2) using the satellite orbit as in interpolation device to connect non-simultaneous observations from ground stations; 3) using purely dynamical methods, based on analysis of the perturbations (disturbances) of the orbit. By the same methods, the size and shape of the earth may be measured more precisely, and geophysical data -- now unobtainable -- can be gained about orbital irregularities of satellites caused by influences exerted by the earth and by the sun, and by the planets and other sources in space.

COMMUNICATIONS SATELLITES

Project Echo

The purpose of Project Echo is to test the feasibility of passive reflecting satellites as global teleradio-transmission links.

NASA's Langley Research Center has designed and constructed several 100-foot-diameter inflatable spheres of aluminized Mylar plastic, to reflect electromagnetic waves beamed from transmitters on the ground. Folded and enclosed in a metal container, 26 1/2 inches in diameter, one of these spheres will be launched by a Delta vehicle and placed in orbit at an altitude of about 1,000 miles. On entering orbit, the container will separate from the third stage and open, and the sphere will inflate.

Plans call for communications to be established via the satellite between the Jet Propulsion Laboratory's facility at Goldstone, Calif., and the Bell Telephone Laboratories, Holmdel, N.J. The Naval Research Laboratory will participate in the experiment. The Project Echo satellite will afford industrial and private scientific research organizations opportunities for communications and related experiments of their own.

The satellite will also be used to investigate propagation phenomena such as polarization, Faraday rotation, and signal fading. An understanding of such inconsistencies in the transmission path will lead to better communications systems.

Goddard Space Flight Center is managing the program.

Preliminary to attempting to place one of the Mylar spheres in orbit, tests of the ejection and inflation of the spheres are to be conducted using short-range high-altitude rockets launched from NASA's Wallops Station.

CHAPTER 8

SOUNDING ROCKET DEVELOPMENT

WORK ON TWO PROTOTYPES UNDER WAY

NASA space science investigations require a family of sounding rockets to carry scientific payloads of numerous types to different altitudes. Prototype rockets of a projected series are "Arcon" and "Iris." Initially, they were projects of the Naval Research Laboratory (NRL) and the Navy Bureau of Ordnance. Transfer from the Navy to NASA was arranged in January 1959, after a transfer of personnel working on them. Now directed by NASA's Goddard Space Flight Center, Arcon and Iris development is being carried out under contract by the Atlantic Research Corporation, Springfield, Va.

Arcon

Six inches in diameter and eight feet, six inches long, the Arcon rocket weighs 220 pounds, and uses a fast, end-burning solid propellant. A stabilizing fin section and a 40-pound, instrumented payload are attached to form a vehicle 11 feet long, weighing 254 pounds. The Arcon vehicle was designed to lift its payload to an altitude of 70 miles. NASA development, consisting of improvements in chamber insulation and propellant-charge design, was completed in September 1959.

After ground-firing tests, two successful Arcon launchings were made in June. In a third test, the rocket blew up in the launcher, apparently because the propellant was faulty. In August, three more Arcon vehicles were flight-tested; two of them malfunctioned, due to aerodynamic factors, as the rockets neared burnout. Payloads failed to reach planned altitudes because drag forces proved greater than anticipated.

Further development will be needed to increase the rocket's power.

Iris

Substantially larger than Arcon, the Iris rocket is also being developed by Atlantic Research Corp. Designed to propel a 100-pound payload to an altitude of 185 miles, the rocket is approximately 13 feet long, one foot in diameter, weighs 1,140 pounds, and uses the same propellant as Arcon. A stabilizing fin section and a 100-pound payload are attached, resulting in a 1,290-pound vehicle, 20 feet long.

Launched from a tower, the rocket will be given extra initial thrust by a small clustered booster. NASA development includes the increase of engine reliability by improving the propellant charge and chamber insulation. Goddard Space Flight Center participates in aerodynamic design, supplies payloads, and will conduct flight tests at Wallops Island.

Iris rocket firing tests revealed two basic problems. The internal chamber insulation eroded excessively and nozzle components did not withstand the hot exhaust for the required 50-second burning time. After a number of firing tests, the difficulties were overcome; a complete flight engine will begin ground tests in January 1960. First Iris flights are scheduled for spring.

CHAPTER 9

INTERNATIONAL COOPERATION

TRACKING NETWORK NEGOTIATIONS*

In July NASA began discussions -- with the assistance of the State Department -- toward acquiring sites for eight Project Mercury tracking stations abroad. Preliminary site surveys have been made.

SPACE RESEARCH ARRANGEMENTS

Discussions with the United Kingdom regarding cooperative space research programs are in an advanced stage. It is expected that the United Kingdom will provide several instrumented satellites for launching by U.S. vehicles. This country may furnish two or three vehicles for the cooperative program which will probably extend over two to three years. Selection of scientific experiments will be subject to joint agreement. No exchange of funds is involved.

Other negotiations with the Canadian Defence Research Board have resulted in arrangements in a satellite project for "top-side" sounding of the ionosphere. Thus far, ionosphere sounding has been conducted from the ground; this would be the first instance of sounding from above. Laboratories in the participating countries will develop suitable instrumentation for the experiment by joint agreement. Again, no exchange of funds is planned.

In addition, NASA recently initiated several small grants or contracts for tracking and data analysis services in the United Kingdom, West Germany, and Japan.

Several grants were made to foreign scientists under a NASA-sponsored, post-doctoral Resident Research Associates Program administered by the National Academy of Sciences. These are for basic space-connected research in the United States and afford recipients opportunities to take part in NASA's scientific programs.

In September, Dr. Hugh L. Dryden, the Deputy Administrator of NASA, participated in discussions with various scientists and officials of the European scientific community. The purpose was to inform NASA of space-connected interests and

* See also Tracking and Data Systems.

activities in those countries and to indicate NASA's willingness to discuss possibilities of cooperative space research programs.

After the United Nations Ad Hoc Committee on Peaceful Uses of Outer Space had been organized, December 13, 1958, Dr. Dryden was appointed a U. S. Alternate Representative on the committee. He participated in the activities of its Technical Subcommittee during the period of this report.

The report of the Ad Hoc Committee recommended that "as the first technical area in which immediate international action is required, attention be called to the (committee's) conclusions regarding allocation of radio frequencies for space activities."

NASA helped formulate requirements upon which the U. S. position on the allocation of radio frequencies for space activities were based. These recommendations were presented to the International Telecommunication Union, in Geneva.

In September, the Deputy Administrator represented NASA as the U. S. delegate to the General Assembly (meeting in Aachen, Germany) of NATO's Advanced Group for Aeronautical Research and Development (AGARD). Several NASA scientists presented papers before AGARD's Technical Panels.

Through the National Academy of Sciences, NASA has continued to endorse and support the activities of the Committee on Space Research (COSPAR) of the International Council of Scientific Unions. During the March 1959 meeting of COSPAR at The Hague, the U. S. delegate was authorized to offer on NASA's behalf the following program to:

1. Include mutually-agreed experimental payloads designed by scientists of other countries in vehicles launched the U.S.;

2. Launch one or more satellites, designed by foreign scientists, with agreed payloads up to 300 pounds in an orbit of 200 to 2,000 miles altitude;

3. Invite the experimenters to work on their projects in U.S. laboratories.

Several preliminary inquiries prompted by this offer and by the discussions held abroad by the Deputy Administrator in September have been forwarded to NASA and are under consideration for further discussion.

NASA is supporting preparations for the First Annual Space Science Symposium, sponsored by COSPAR, scheduled to be held in France in January 1960. Its purpose is to present and discuss scientific results obtained by rockets, satellites, and space probes during and after the International Geophysical Year.

CHAPTER 10

TRACKING AND DATA SYSTEMS

RADAR, OPTICAL TRACKING, AND TELEMETRY

Tracking and data-analyzing stations on the earth's surface are all-important in acquiring and reducing to usable form the scientific information about space that satellites and probes collect and transmit. These stations employ radar, optical tracking, and telemetry.

Systems in Operation

The NASA tracking network includes installations throughout the Free World. As of September 30, nine stations of the Minitrack Network (established for the International Geophysical Year), 12 Baker-Nunn optical stations, and the Goldstone, Calif., Deep Space Station were in active service. In force also are arrangements for NASA to use, as projects require, stations operated by other government agencies and private organizations.

Expansion

Plans for augmented tracking and data facilities -- outlined in the NASA's *First Semiannual Report to the Congress* -- have been developed in detail. Diplomatic negotiations, site surveys, and construction are in progress. The Minitrack and Deep Space networks have been expanded, and a 16-station Mercury network is being created.

Mercury Stations

Special Requirements of Manned Satellite -- Project Mercury tracking and ground-instrumentation stations will provide complete radio tracking, communications (including voice), and data acquisition during launching, flight, and recovery of the Mercury capsule. (See *Project Mercury*.)

Mercury stations are being built to meet new problems of tracking and communications. Emphasis is on pilot safety, particularly during launching and recovery. Existing Minitrack stations cannot accurately determine the orbit of a satellite until it has completed several passes. Thus they would not be adequate for the manned Mercury capsule, which will return to earth after only three circuits.

Over-all Planning -- Sixteen Mercury stations will be established between Latitudes 35° North and 35° South, in the projected path of the manned capsule. Most of them will be housed in temporary structures so that they may be shifted for other NASA projects. For most ground communications, existing military links and commercial facilities (leased) will be utilized. The Space Task Group, Goddard Space Flight Center, will direct all Mercury stations. Langley Research Center is charged with establishing the stations and monitoring contracts.

Range Contractors Chosen -- On July 13, NASA selected the Defense Projects Division of the Western Electric Co., New York, N.Y., to equip and manage construction of the Mercury network and to supervise personnel training. Four companies, associated with Western Electric as major subcontractors, have these responsibilities: Bell Telephone Laboratories, Whippany, N.J., system engineering, engineering consultations, and command and control; International Business Machines, New York, N.Y., computer programming, simulation, and computers; Bendix Aviation Corp., Towson, Md., installation of radar, ground-to-air communications, telemetry and site equipment; and Burns and Roe, Inc., Hempstead, L.I., N.Y., site preparation, site facilities, construction, and logistic support. The prime contractor will also be responsible for over-all logistics and ground communications.

*Site Surveys in Progress -- Mercury stations are proposed for Cape Canaveral, Fla.; Bermuda; another island in the Atlantic; Northwest, Southwest, and Southeast Africa; three locations in the South Pacific; Kauai, Hawaii; Point Arguello, Calif.; White Sands, N.M.; Corpus Christi, Tex.; Eglin Air Force Base, Valparaiso, Fla.; a ship in the mid-Atlantic Ocean; and a ship in the Indian Ocean.

At the end of this report period, preliminary site surveys have been completed for almost all projected stations.

Agreements and Understandings -- Agreements on the use of military sites and equipment within the United States are being effected. Surplus radars from Department of Defense sources are being modified for the Mercury network. Diplomatic agreements for foreign sites are being drafted.

Minitrack Network

Description and Capabilities -- Minitrack stations, which use radio for tracking satellites and which receive, record, and transmit telemetry data to a computing center in Washington, D.C., are suitable for general-purpose radio observations of experimental and scientific unmanned earth

* See also International Cooperation.

satellites where several hours delay in orbital determination is permissable.

Operating Stations -- Nine stations operational as of September 30 are at: Blossom Point, Maryland; Antigua, West Indies Federation; San Diego, Calif.; Quito, Ecuador; Lima, Peru; Antofagasta, Chile; Santiago, Chile; Woomera, Australia; and Esselen Park, Union of South Africa.* These stations, plus another in Havana, Cuba, were established for satellite tracking during the IGY. The Havana station has been transferred to Fort Myer, Fla., and will be operational soon at its new location. The Grand Turk Island station, also established for IGY, has been eliminated.

Coverage To Be Broadened -- To increase effectiveness of the network by extending high-latitude coverage, four new stations will be established. Two will be at Fairbanks, Alaska, and East Grand Forks, Minn. Two others will be in high-latitude locations abroad. Plans were made to move the center, which receives, interprets, and publishes the station data, to the Goddard Space Flight Center from the old Vanguard Center in Washington, D.C. Construction has started on the Fort Myer station and on three of the four high-latitude stations.

Automatic Data Read-Out System -- A recently designed automatic data read-out system will not only speed data collection but will enable simultaneous tracking of more satellites than is possible with present equipment.

New Tracking Frequency -- A new tracking frequency of 136-137 mc was assigned nationally to the tracking stations. A NASA representative at the International Telecommunications Union Conference is seeking approval for use of this and other frequency bands internationally. The present 108-mc tracking frequency was assigned for the IGY. Specification for the frequency change-over, requiring new antenna and other equipment, are largely completed. This equipment will incorporate many improvements.

Twenty-four Hour Operation -- During the last six months, tracking stations were operating 24 hours a day, with the exception of a three-hour lapse at one station when a circuit broke down.

* Operation and support of stations outside of the United States is largely by local personnel and organizations, with NASA retaining responsibility for management and direction of the system.

Deep Space Stations

Locations -- An ideal deep space network would consist of three stations near the equator, separated from one another by 120° of longitude. Such locations would provide complete 24-hour coverage of space vehicles which are at heights of 4,000 miles or more from the earth. The network planned by the NASA will consist of stations located in Goldstone, California; the South Pacific Ocean; and South Africa. These locations were chosen for reasons of economy and utility and will give coverage closely approaching ideal station locations. When completed the network will be utilized for all space probe vehicles and for some satellite programs. Its 85-foot tracking antennas will be capable of picking up faint signals from distances of millions of miles.

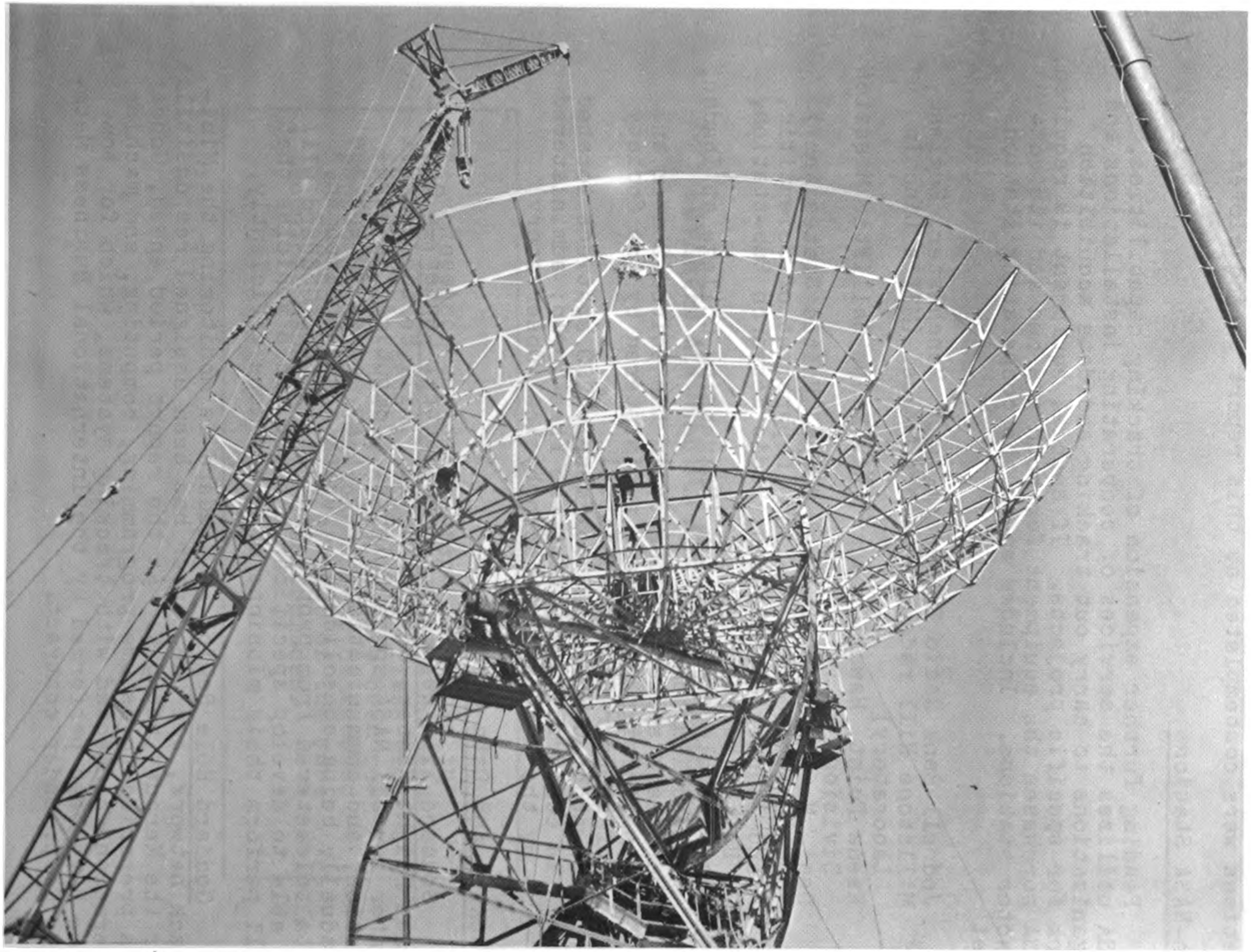
Progress -- Goldstone is now being equipped with transmitting as well as receiving antennas and equipment. Other stations may receive transmitting equipment later. Construction of the receiving antenna for the South Pacific site has been completed. In addition, the Department of Defense has agreed to transfer to NASA an 85-foot "dish" antenna for installation at the South African site. Agreements relative to the South African and South Pacific sites are being drafted. A site-survey team has visited South Africa.

Baker-Nunn Optical Network

Direction and Operation -- The Baker-Nunn Optical Tracking Network is under the technical direction of the Smithsonian Astrophysical Observatory, which is also responsible for operation and data reduction. This work is being done under a NASA grant. The network consists of non-mobile precision cameras capable of photographing a very faint object (13th magnitude) against a star background.

Capabilities and Locations -- The network makes it possible to define the orbits of satellites precisely; it may also be used for determining initial trajectories of space probes. The 12 sites of Baker-Nunn cameras are Hobe Sound, Fla.; Curacao, Netherlands West Indies; Arequipa, Peru; Villa Dolores, Argentina; Olifantsfontein, Union of South Africa; Cadiz, Spain; Shiraz, Iran; Naini-Tal, India; Woomera, Australia; Mitaka, Japan; Haleakala, Hawaii; and White Sands, N.M.

Accomplishments -- Approximately 4,200 satellite transit photographs had been taken by the network as of September, 30, 1959. The current output of the network is approximately 600 useful photographs per month.



The 85-foot "Dish" of the Goldstone Deep Space Transmitter,
Goldstone, California

Expansion Not Contemplated -- No new Baker-Nunn optical stations were contemplated as this report period closed.

Non-NASA Stations

Pending further expansion of tracking capabilities, NASA utilizes the services of cooperating installations and organizations to carry out tracking and data acquisition work for specific projects. If special equipment is required, NASA purchases the equipment for both its own and its contractor stations. Included among the cooperating stations are:

- Jodrell Bank Radio Telescope, near Manchester, England
- Millstone Hill radar, Westford, Mass. (MIT's Lincoln Laboratory)
- Kaena Point, Hawaii, radar (Air Force Ballistic Missiles Division)
- Deal, N. J., radar (Signal Corps, United States Army)
- Singapore telemetry station (Department of Scientific and Industrial Research, Radio Research Sub-station, United Kingdom)
- Nigeria telemetry station (University College at Ibadan, United Kingdom)
- Phototrack stations (located in the United States and some foreign countries; administered by the Society of Photographic Scientists)
- Moonwatch stations (approximately 200 stations located in countries throughout the Free World; administered by the Smithsonian Astrophysical Observatory)

Tracking and Data Center

Goddard Will Be Space Flight Control Center -- Goddard Space Flight Center, Greenbelt, Md., will be the control center for all NASA space flights. Computing, data reduction, and communications facilities and equipment are gradually being consolidated. Using space-environment data telemetered from probes and satellites, Goddard will be able to develop specifications for space vehicles that will perform their missions more and more efficiently.

Goddard Role Begins -- Goddard is monitoring the Minitrack network, and the center has been assigned responsibility for the Mercury network. As the report period ended, Goddard was preparing to assume programming, computing, and machine operations connected with tracking systems, which for some time have been performed by the International Business Machines Corp. under contract.

SECTION III

ADVANCED AERONAUTICS AND SPACE RESEARCH

Research and development described in the following section are part of a continuing effort. Because this is the first time that many of these activities have been reported since NASA was organized, background and explanatory details of some of the more technical aspects have been included.

CHAPTER 11

PROPULSION AND POWER GENERATION

SPACE PROPULSION

Tomorrow's space flight poses many problems that today's research must solve. To the forefront of these is the problem of propulsion. Space propulsion systems for future use that are under intensive NASA research include chemical, nuclear, and electrical rockets. Chemical and nuclear rockets can yield enormous thrusts, but both are limited in jet velocities. Electrical rockets yield very small thrusts but can attain almost unlimited jet velocities.

High-thrust systems will always be needed for raising payloads from the earth's surface to an earth orbit. On long-distance missions from an earth orbit to other planets, only low-thrust systems are required; these will have distinct advantages because they can be made small, compact, and light in weight, and can be provided with long-lived energy sources.

For such missions in space -- where gravity forces are small -- NASA is developing electrical rocket propulsion systems capable of high jet velocities. These systems may depend on nuclear electric power generation (see Nuclear Energy Applications for Space) and could furnish low thrust over long periods for: 1) attitude orientation and stabilization; 2) position control or orbital correction of satellites; 3) final-stage propulsion for high-altitude satellites, or for lunar or interplanetary vehicles after they have been fired beyond the earth's atmosphere; and 4) vernier rockets to control the velocities and trajectories of lunar or interplanetary vehicles.

Electric-rocket research at Lewis Research Center, Cleveland, Ohio, includes investigation of basic physical processes, applying this fundamental knowledge to feasible electric-propulsion engines, and testing prototype electric-rocket engines. Three general types of electric rockets are being investigated: 1) the ion rocket, in which ionized propellant (an ion is an atom from which an electron has been removed) is ejected rearward by electrostatic fields to produce thrust; 2) the plasma rocket, in which plasma propellant (a mixture of ions and electrons) is ejected rearward by electromagnetic fields to produce thrust; and 3) the electrothermal rocket (in which propellant gas is heated electrically so that hot gases expanding rearward produce thrust).

Ion Rockets

When an atom is electrically balanced, its net charge is zero. If one of its electrons is removed, it is no longer neutral but is positively charged. Ionization, the process of removing an electron, may be produced in several ways. One of NASA's research objectives is to find the most efficient way. Several projects in this field have shown substantial progress in the past six months at Lewis. An experimental ion-rocket engine has been operated for a total of 50 hours without component failure. So far, the engine has not been operated at maximum design conditions, but valuable information has been derived from the tests.

Another ion rocket of different design is now undergoing test, and preliminary data show satisfactory operation. Analysis indicates that a prototype ion rocket would be capable of lifting a communications satellite from a 300-mile orbit to the 22,300-mile altitude required to keep the satellite above a given point on the equator, a technique of great importance for the so-called "stationary" communications satellites.

Plasma Rockets and Electrothermal Rockets

Research is continuing at Lewis on a number of types of plasma and electrothermal rockets. In general, the investigations are exploratory. Difficulties in measuring plasma density, velocity, and other properties have hampered the investigations, but progress is being made.

Development of Electrical Propulsion Systems

Current NASA plans call for exploring the potentialities of: 1) an ion-propulsion system in which the electric power will be supplied by the SNAP-8 unit, which will be used for experimental flight tests; 2) an arc-plasmajet propulsion system for SNAP-8 which could be used to boost a satellite payload from a low to a high-altitude orbit; and 3) a small arc-plasmajet for use with a solar-electric power supply to orient and stabilize the satellite and control its orbital position. In coming months NASA will request proposals from private industry for this applied research and for component development. (For details of SNAP-8, see Nuclear Energy Applications for Space.)

Electric-Rocket Test Facilities

Experimental evaluation of ion and plasma rockets for space propulsion requires vacuum tanks in which conditions approaching those of space can be simulated. Cryopumping (that is, pumping at extremely low temperatures) the propellant is the most economical means of achieving the low pressures needed. This technique condenses the propellant on surfaces cooled with liquid nitrogen; the tank must be large to provide adequate surfaces.

NASA has procured five electric-rocket tanks for research at Lewis. The tanks are five feet in diameter, approximately 17 feet long, and contain liquid-nitrogen-cooled baffles for condensing the electric rocket propellant. Two 32-inch oil diffusion pumps and associated mechanical pumps are provided for initial evacuation of the tank and for pumping out non-condensable gases that leak into the tank.

LIQUID-PROPELLANT-ROCKET ENGINE PROGRAM

Requirements of future NASA vehicles using liquid-chemical propulsion must be anticipated well in advance. The NASA program in this area is directed toward achieving highly reliable engines, but with types and sizes held to the minimum that can meet requirements for vehicle performance.

The F-1 1.5-Million-Pound-Thrust Single-Chamber Rocket Engine

Since January 1959, the F-1 single-chamber rocket engine, capable of producing 1.5-million pounds of thrust, has been under development at the Rocketdyne Division of North American Aviation, Inc. The engine will be clustered to form boosters for a vehicle capable of orbiting 150,000 pounds around the earth.

Facilities -- Because the engine is so large, provision of suitable test facilities is a difficult problem. The development program is based on utilizing the rocket engine test stands at Edwards AFB, and one such stand is now being modified.

Propellants are needed in great quantities for the test program, and local facilities for manufacturing liquid oxygen will soon be inadequate. A new oxygen-generating plant in the vicinity of Edwards AFB is being planned by NASA, and will be contracted through Goddard Space Flight Center. Associated storage and distribution systems will be at the test complex.

Until the stands at Edwards are completed, the Rocketdyne test facility is being utilized. The Rocketdyne stand can sustain test runs of only a few seconds at thrusts no greater than one million pounds. During early development, this limitation is not serious because most tests are on engine-starting. However, difficulty in obtaining steel during the nationwide steel strike, along with other shortages, are delaying construction of the new Edwards test facilities. As a result, tests of the engine to full thrust and full deviation have also been delayed. Meanwhile, engine problems that can be studied with the facilities available are being investigated.

Development Progress -- During this report period, attention was focused on designing, fabricating, and testing the thrust chamber to achieve safe and reliable starts, and as much thrust as the stand can take. Operating difficulties with the thrust chamber at start-up were encountered when pressure oscillations were generated in the burning gases -- a phenomenon common to most large rocket engines under development, and a severe hazard to the equipment. After corrective work, the engine operated well under the limiting conditions of the test stand. However, more development is required before combustion-driven pressure oscillations can be brought under satisfactory control.

Other components of the 1.5-million-pound-thrust engine are still in design and fabrication stages. Two engine-system studies have been completed by Rocketdyne. One study concerned a number of methods to control the thrust direction of the engine. Swiveling the thrust chamber in a small arc was recommended. The second study sought efficient means of pressurizing the propellants in the storage tanks. An inert gas pressurant, heated in a turbine exhaust heat exchanger, was recommended.

CHEMICAL ROCKETS

Chief aims of NASA research on chemical, liquid-fueled rockets are to: 1) learn more about using high-energy propellants, such as hydrogen (with oxygen or fluorine as the oxidant) in space vehicles; and 2) study basic factors that affect component performance -- for example, combustion efficiency, pump efficiency, and engine cooling.

Hydrogen-Fluorine Rocket Engine

Liquid fluorine and liquid hydrogen in combination give promise of the highest performance of any known chemical propellant system. Because the bulk density of this combination is greater than that of hydrogen and oxygen, it does not require tanks as large as those for hydrogen-oxygen stages. The use of fluorine is complicated by the hazards of fluorine fires and by the high toxicity of fluorine and the products from its burning. Still undefined characteristics of liquid fluorine must be assessed to determine the feasibility of the propellant combination in a vehicle stage.

Accomplishments -- Operating characteristics of hydrogen and fluorine in rocket chambers are being determined by Bell Aircraft Co., Niagara Falls, N.Y., over a wide range of fuel and oxidizer mixture ratios. The feasibility of cooling a chamber regeneratively has been successfully demonstrated. Performance was found to be better than that of hydrogen and oxygen under similar conditions.

In September 1959, a fluorine seal-bearing and pump system was successfully tested with liquid fluorine for several prolonged cycles of operation. A bi-propellant valve, utilizing fluorine and hydrogen, was also operated successfully.

Separate thrust-chamber and turbopump tests demonstrated that a pump-fed hydrogen-fluorine engine should be feasible at the present stage of technology.

Combustion Research

Combustion chambers designed for the use of hydrogen with oxygen, and hydrogen with fluorine, were tested at Lewis Research Center under a number of conditions. High combustion efficiency was achieved. Heat-transfer measurements indicated that hydrogen is feasible for regenerative cooling. It was demonstrated that as the chamber output (or total heat release) was increased, unstable combustion also increased; this could lead to dangerous oscillations. Investigations are continuing.

Combustion efficiency was measured under many pressures, temperatures, and propellant injection velocities, and in combustion chambers of different shapes. Combustion was found to occur primarily between propellants in a gaseous rather than in a liquid state -- in other words, the propellant-vaporization rate controls the rate of combustion.

Rocket Engine Exhaust Nozzles

Extensive experiments with hydrocarbon and oxygen propellant combinations at Lewis have shown how internal flow and energy losses are affected by the shape, length, area ratio, expansion ration, and other features of nozzle design. The larger the exhaust-nozzle area, the greater the efficiency at high altitudes.

Pump Cavitation Investigations

Work is going forward on pumps that will be capable of operating efficiently and without damage in extensive vapor formations. Under investigation are small, lightweight units that can pump boiling fluid. Liquid-hydrogen pumps have been operated under these conditions. Slight tank-pressure surges were sufficient to start these pumps even at the boiling condition. Methods of starting pumps under such conditions and at very nearly zero gravity are being investigated. Pumps operated in water and in liquid nitrogen (which behaves much like liquid oxygen) indicated similar results, but regions of unstable operation with vapor pulses and reversals of flow were observed.

High-Pressure Hydrogen Pump Investigations

Investigations at Lewis and at Plum Brook have demonstrated that high-speed centrifugal pumps with newly designed radial blading can meet high-pressure pumping requirements for liquid hydrogen. The new blade design controls internal flow much better than could earlier radial blades. Extremely high system pressures may require multistage axial-flow pumps. A pump of this type has performed well with water and is now being tested with liquid hydrogen.

Turbodrive Investigations

High-energy rocket turbodrive systems are being investigated at the Lewis cold-air facility and at Plum Brook's cold-hydrogen facility. Work is also aimed at improving procedures and controls used in designing these units.

Rocket-Engine Ignition

Two methods proved successful in igniting hydrogen-oxygen rocket engines: 1) electrical (spark plugs), and 2) chemical (short flow bursts of spontaneously combustible chemicals with the hydrogen and oxygen in the combustion chamber). The chemical system started with great reliability. Studies will be continued at altitude conditions, using improved lightweight flow systems.

Flow Systems Components and Ground Handling

Research is in progress on individual components of hydrogen-oxygen vehicle systems (lines, valves, controls, regulators, and related equipment) and on the flow system. Analytical and experimental research is also under way on problems related to purging, loading, venting, and topping liquid-hydrogen-and-oxygen propellant systems. One facility for carrying out this research has been completed at Lewis Research Center; a second is under construction; and initial flow studies of a simulated liquid hydrogen-oxygen vehicle have begun. Program aims are to obtain basic answers to flow-systems problems and to assist the Centaur project.

Investigation of Liquid-Hydrogen-Oxygen Gas-Generator Systems

Experimental and theoretical studies are in progress on problems of starting, operating, and controlling gas-generator systems using liquid hydrogen-oxygen propellants. A gas-generator system facility has been built and operated. Several gas-generator systems have proved highly efficient in initial performance tests.

Other studies are in progress on pressurizing hydrogen-oxygen fuel tanks and on using plastic bags to keep the liquid hydrogen from being contaminated and cooled by the pressurizing gases.

Zero-Gravity Experiments -- Vehicles in space will be weightless (or at zero gravity) for extended periods. Thus, fuels will not flow from the tanks; they will slosh about when attitude or direction is changed, and they will vaporize when the sun heats the exposed tanks. Experiments in airplanes that can attain zero gravity conditions for short periods are aimed at studying the effects of this phenomenon on attitude control, rocket motor restart, and fuel boil-off.

SOLID-PROPELLANT ROCKET PROGRAM

The Solid-Propellant Rocket Program of NASA is establishing the technical groundwork upon which to build the next logical major advance in the technology of space engines. In progress at various contractors facilities are feasiblity studies aimed at exploiting the reliability, simplicity, and economy of solid-propellant engines.

Heavy emphasis is placed on evolving advanced solid rockets of superior performance for use as stages of space vehicles. Also being sought are better methods to angle, modulate, and terminate thrust. The use of solid propellant engines as powerful first-stage boosters is also under study.

Advantages

Solid rockets have several inherent advantages: they can be stored for extended periods, and they are simple to operate because their components are uncomplicated. Since firing procedures are simple, launching crews do not require elaborate training. As a rule, solid rockets may be developed in shorter times with less expense than comparable liquid rockets. Other assets: solid rockets can be readily fabricated in a wide range of sizes and they can be shipped with propellant already loaded.

Solid rockets have two outstanding merits that can be put to use in space-vehicle boosters. First, upper-stage rockets, in which the propellant represents well over 90 percent of the total weight of the stage, can be built from present materials. Second, thrust levels can be varied easily, and it is feasible to develop thrusts of 1,000,000 pounds or more by scaling up the dimensions of current designs which generate between 100,000 and 500,000 pounds of thrust.

Disadvantages

However, at the present stage of development, the utility of solid rockets is limited by cumbersome and inefficient thrust-level control during burning. Thrust-direction controls and thrust cut-off techniques also need to be improved.

Goals

NASA solid-rocket projects are seeking to remedy these and other limitations. Advanced space rocket propellants will be investigated and developed as new ingredients and materials become available from Department of Defense programs. Work in progress falls into five categories: 1) high-performance rocket motors; 2) steering and velocity control techniques; 3) thrust modulation, termination, and re-ignition; 4) materials and manufacturing techniques; and 5) high-impulse propellants.

High-Performance Rocket Motors

During the report period, three contracts were signed: one to develop a prototype high-performance engine suitable as an upper stage, and two for independent studies of the potential usefulness of large, solid-propellant, first-stage engines.

Upper Stage Rockets -- On July 1, 1959, a contract was awarded to Grand Central Rocket Co., Redlands, Calif., to develop a prototype rocket motor that will contain a very high proportion of propellant to inert parts weight. The motor will weigh about 500 pounds and will utilize propellants now available.

Large Boosters -- Under contract to NASA, the Aeronutronic Division of the Ford Motor Co., Glendale, Calif., and Lockheed Aircraft Corp., Sunnyvale, Calif., are investigating possible dimensions, thrust levels, and burning times for large future rockets as well as the potentials of very large clustered boosters.

Work so far indicates that solid rockets possess many characteristics needed in very large boosters. The optimum initial thrust to total vehicle weight ratio seems to be about 3 to 1. Solid engines can easily operate at this ratio; liquid engines are limited to lower ratios because they require fuel-feeding machinery that is too large to achieve higher ratios economically. The ratio for Atlas is less than 2 to 1; that for Vanguard was only about 1.2 to 1; while that for the solid rocket Scout is 3.1 to 1.

For even the largest applications, a booster burning-time of between 0.5 minute and 1.0 minute is preferable to the two or three minutes common for today's large liquid boosters. The velocity loss caused by gravity is less during a shorter burning time, which more than compensates for the greater drag forces resulting from higher accelerations. Solid rockets are more amenable to short burning times than are liquid rockets, due again to the size of the liquid-fuel pumping systems.

Steering and Velocity Control

Solid rockets can be made more efficient and less complex if such guidance and control features as angle of thrust, roll control, and velocity adjustment can be separated from the rocket and incorporated in an auxiliary system. Relatively small auxiliary rockets could be utilized to steer vehicles, and, after the main stage burns out, they could be used to adjust vehicle speed. Control rockets can exert sufficient thrust in excess of control force requirements to "carry" much of their own weight. NASA will let a contract in early 1960 to develop a prototype steering and velocity control system that can be applied later to a specific vehicle stage.

Thrust Modulation, Termination, and Re-ignition

Thrust cutoff is a standard feature of many military rockets, but restart and control of thrust level are largely unexplored. NASA has received several proposals in this field; one contract was awarded to study thrust modulation. NASA's Jet Propulsion Laboratory is also investigating thrust termination and restart.

Acoustica Associates, Inc., Plainview, N.Y., and Los Angeles, Calif., has a NASA research contract to determine if the thrust level of a solid rocket can be varied by acoustical energy (sound waves). Awarded on July 1, 1959, the contract will run for about nine months. Experience with combustion instability in solid rockets indicates that the burning rate can be radically affected by energy waves generated in the combustion chamber. If the investigation is successful, a variable sonic energy generator -- a whistle or siren of special design -- will be located in a rocket chamber to control burning rates.

Program aims are to: 1) show feasibility of sonic control; and 2) learn how much thrust-level variation is possible. First, small propellant strands will be burned in strong soundwave fields to study gross effects; then, the degree of soundwave control possible in 20-pound rocket motors will be studied.

Materials and Manufacturing Techniques

Several factors could limit the use of solid-propellant rockets. For example, nozzle materials must resist temperatures of more than 6000°F. Also, if solid rockets are to be utilized as multi-hundred-thousand-pound boosters, new means of making and transporting them must be found.

In June 1959, NASA awarded a contract to the ARDE-Portland Corporation, Newark, N.J., and Portland, Me., to investigate properties of several unique materials that are resistant to both elevated temperatures and gas erosion. The materials are metallic carbides and new compositions which can be fused to improve their basic properties. As the report period closed, the materials were being fabricated and the rocket for evaluating them was being designed. First tests will be late in 1959. Other materials proposed to NASA for nozzle fabrication may also be tested in the equipment procured under this contract.

To simplify handling, logistics, and quality-control of very large solid rockets, NASA is investigating the "building block" system of fabricating the engine in segments that can be assembled at the launching site. Each segment would be a separate solid charge, weighing from 10,000 to 100,000 pounds; rockets of varying thrust could be assembled. Obviously this method makes for simpler quality control and, thus, for greater economy.

High-Impulse Solid Propellants

NASA research on high-impulse propellants is aimed at developing superior fuels for space flight -- propellants having ultra-high impulse and/or characteristics that permit long-term storage in space -- and at determining engineering problems involved in designing rockets to use these fuels. Under NASA contract, Callery Chemical Co., Callery, Pa., is studying the thermodynamics and kinetics of a radically different fuel system. Most details of the work are classified. However, small-scale test rockets have been successfully fired and the basic soundness of the thermochemistry and thermodynamics of the system has been verified.

A major aspect of this work will be evaluation and application of materials from the advanced propellant chemistry program of the Advanced Research Projects Agency of Department of Defense. NASA will apply these materials to space flight.

6000-POUND THRUST STORABLE-PROPELLANT ROCKET ENGINE

NASA is developing a 6000-pound-thrust rocket that will utilize hydrazine and nitrogen tetroxide propellants fed to the engine under pressure. These propellants lessen the problems of long storage in space because they remain in the liquid state at space temperatures. Moreover, use of a pressurized rather than a turbo-pump-fed system will reduce the weight of the vehicle and simplify development in general. It will be useful for vehicles whose missions require extended periods of storage in space before renewal of thrust.

The project was originally undertaken in 1958 for the Army Ordnance Missile Command by the Jet Propulsion Laboratory, California Institute of Technology. Development of the engine was transferred to NASA in November 1958.

Progress -- The feasibility of using hydrazine fuel (a mono-propellant*) to cool the rocket nozzle has been successfully demonstrated in recent months. Several methods of fabricating the nozzle and its coolant passage were explored and two successful chambers were designed. In order to meet flight schedules, the chamber easiest to fabricate was selected for early engine flights although it was heavier than the other type.

Extensive combustion chamber design work and testing has been in progress to obtain high performance.

Facilities were constructed at JPL for ground-testing the engine in a simulated space environment. The facility consists of a test stand and a device attached to the discharge of the rocket nozzle to diffuse the exhaust and simulate discharge pressures encountered at high altitudes. Preliminary tests indicated that the rocket chamber had to be put under higher pressure than normal in order to start the system. Model tests provided information to improve this difficult starting condition.

A static-test unit of the propulsion system, including tanks, lines, valves and engine, was fabricated and shipped in September to the JPL test group at Air Force Edwards Test Station.

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* A rocket propellant, usually liquid, consisting of a single substance containing both fuel and oxidant, either combined or mixed together.

SECOND-STAGE CENTAUR ENGINE

The 15,000-pound-thrust rocket engine being developed as the second stage of the Centaur vehicle will utilize hydrogen and oxygen fuels. The engine will also be used in an upper stage in the Saturn vehicle. Formerly sponsored by ARPA, Centaur was transferred to NASA on July 1, 1959. The Air Force Special Projects Office of the Ballistic Missile Division is administering the contract with Pratt & Whitney under NASA direction.

This will be the first U.S. engine to utilize a truly high-energy fuel combination. Such propellants will greatly increase payload capabilities of existing and planned booster stages. For example, a hydrogen-oxygen stage would lift double the payload possible with conventional propellants. Even greater increases could be achieved by using more than one hydrogen-oxygen stage.

By late September, a first version of the flight-weight engine was nearly ready for testing at the contractor's plant.

NUCLEAR ENERGY APPLICATIONS FOR SPACE

The two principal types of nuclear systems considered suitable for propelling heavy payloads in space are: 1) the nuclear heat-transfer rocket and 2) the electrical-propulsion system that will use a nuclear reactor to generate electricity for power.

Nuclear Heat-Transfer Rockets

In a nuclear heat-transfer rocket system, hydrogen is heated to elevated temperatures in a reactor and expelled as rocket exhaust, producing about 700 to 1000 pounds of engine-thrust per pound of hydrogen flowing per second. This high specific impulse could send large payloads on extended missions, provided the engine is not too heavy.

This type of rocket will probably be applied earliest as upper stages of chemical rocket launch vehicles. Current aims are to accumulate information for developing a reactor flight test system that would be launched by chemical rockets. In this program, NASA is working with the Atomic Energy Commission (AEC).

Studies indicate that heat-transfer rockets evolved from the reactors being developed by AEC's Los Alamos Scientific Laboratory can be used to propel vehicles from an earth orbit to the moon or to some of the nearer planets. Such a nuclear rocket could also be used as the upper stage of a chemical-booster system.

In the joint Nuclear Rocket Development Program, NASA is supporting AEC's Rover Reactor Test Program by developing technology for non-nuclear components such as the pump, turbine, gas generator, and rocket nozzle. NASA is also conducting design studies of nuclear rocket engine and vehicle systems. Los Alamos is conducting reactor feasibility investigations, and studying critical problems associated with attaining stable operation of the reactor system at high temperatures.

Lewis Research Center and Los Alamos are investigating various phases of more advanced concepts embodying features such as lighter weight and higher temperatures. Basic research in heat transfer and cryogenics is being accelerated. For example, NASA scientists are studying the heat-transfer characteristics of gas flowing through tubes -- operated at high temperatures -- which simulate the flow passages in nuclear reactors. For these experiments the tubes are heated by electricity (instead of nuclear fission) to temperatures higher than 5000°F.

Hydrogen Turbopump Systems -- NASA is developing liquid hydrogen feed turbopump systems for Project Rover, supplying the hydrogen that is required in all testing, and developing other non-nuclear components needed for the tests. Among these components is an axial-flow, liquid-hydrogen pump being developed under contract by the Rocketdyne Division of North American Aviation, Inc. Because nuclear rockets will require large hydrogen flows, this pump was designed to have greater capacity than existing hydrogen pumps. In addition, NASA is supporting the development of a turbine that will be used to drive this pump. Lewis Research Center is also doing research on such an 8-stage hydrogen pump drive turbine to supply design data required by industry.

In addition, NASA is investigating methods of controlling the flow systems of nuclear rockets. Starting characteristics of three hydrogen-flow systems have been analyzed at Lewis. One system is now being tested, under contract, by the Aerojet-General Corp.

Effects of Radiation on Nuclear-Rocket Materials -- Many of the components of a nuclear rocket will be at extremely low temperatures because of contact with the liquid hydrogen. Very little is now known about the ability of materials to self-anneal the effects of nuclear radiation at these low temperatures. For this work, contract negotiations are under way with the Lockheed Aircraft Corporation, Georgia Division. Lockheed will design, fabricate, and install test equipment in the NASA Plum Brook Reactor Facility, Sandusky, Ohio.

Research and development is in progress on radiation shielding, and on operation of jet nozzles and liquid-hydrogen tanks under simulated space conditions.

Nuclear Reactor Electric Generating Systems -- For nuclear reactor electric-generating systems, NASA is developing both the equipment to convert reactor heat to electrical power and the over-all operational electric generating systems. AEC is developing the reactor and working to assure the nuclear safety of the system.

Two types of conversion equipment appear promising for high-power systems: 1) thermionic emitters, and 2) space turbo-generators. Thermionic emitters are much like the vacuum tubes in radio sets. Essentially, they consist of a heated electron-emitting surface and a collector. The turbo-generator is similar to the steam powerplants used in ordinary substations. However, achieving light weight in space payloads requires that the turbine be of a type that can use vaporized metal as the working fluid and operate at extremely high temperatures.

Thus space turbogenerators differ three ways from turbogenerators used on the ground: 1) the working fluid is a boiled and condensed (liquid) metal -- mercury, rubidium, potassium, or sodium, 2) operating temperatures are higher, and 3) waste heat removed during condensation is radiated into space so that the vapor leaving the turbine will be condensed into a liquid and pumped into the boiler.

NASA's work in this area is aimed at developing: 1) the SNAP-8 system ("System for Nuclear Auxiliary Power") in cooperation with the AEC; 2) the technology required for reactor systems of light weights, high power (several hundred kilowatts), and long life; and 3) eventually, reactor-thermionic emitters.

Significant auxiliary power and propulsive missions can be accomplished with a 30-kw power supply. Accordingly, NASA submitted to the AEC a request to develop the SNAP-8 reactor, which will be the first in the SNAP series powerful enough to generate electricity for propulsion, in addition to serving as a source of electricity for payload instrumentation. NASA has requested proposals from private industry for the conversion equipment and integration of this equipment and the reactor into an operational system.

Looking beyond SNAP-8, researchers are developing design data for lightweight, long-lived units capable of delivering more than 100 kw.

Effects of Space Environment on Reactor Materials -- In the extreme conditions of the space environment -- such as hard vacuum, zero gravity, and very low temperatures -- materials may sometimes behave in unusual or unexpected ways. There is much still to be learned about even the most common materials; problems are even more severe with relatively new and untried materials such as those used in nuclear reactors. How, for example, will molten and varpoized metal "coolants" used to pipe heat from the nuclear reactor to the power generator -- at temperatures that may reach 2000°F. -- react with other metals and materials of which the piping, turbines, and pumps are made? And how will the zero gravity and hard vacuum of space affect the pressure and flow of these heat-exchanging metals, the pumps that circulate them, and the electric power generators? Research is in progress in these areas.

NASA contractors are also studying the materials that may be used in space to dissipate the waste heat of the system. In hard vacuum, many materials -- for example, oxide coatings used to increase the radiation capability -- may vaporize.

Still another test that materials must be able to withstand in space is the impact of meteoroids which, though small, may strike with terrific force. NASA is conducting experiments aimed at determining the effect of meteoroid damage on various radiator materials, to find out the thicknesses required. In this connection, the Goddard, Langley, and Lewis centers are designing and instrumenting satellites to record meteoroid penetrations of thin-walled shells of large area. Because the radiator will be the heaviest component of the space electric system, these data are essential if lightweight systems are to become feasible.

In designing such systems, a critical problem is to determine the extent to which molten, boiling, and condensing metals corrode pipes, turbines, and pumps. Present knowledge about liquid-metal corrosion, while generally good, is almost nil at the extreme temperatures needed in operating high-powered space systems. NASA is therefore initiating a broad program to determine the corrosion characteristics of materials at high temperatures, along with the liquified and vaporized materials that will be used as coolants in space electric systems. The Lewis Research Center, AEC's Oak Ridge National Laboratory, and the Naval Research Laboratory are among those involved in such research. Proposals have also been invited from private industry for a large portion of this work.

AUXILIARY POWER UNITS

It is obvious that any space vehicle must have aboard some source of electricity to power transmitters, receivers, research instruments, environmental control systems, and the like. It is equally obvious that the more compact and lightweight these power sources are, the better.

At present, reliance is on electro chemical and solar batteries, which are relatively bulky and make up a substantial part of payload weight. The cost of vehicles and launchings is very high per pound of payload. Today's vehicles, such as Explorer VI, can carry power units that develop only a few tens of watts of electricity. Use of batteries, chemical energy, and fuel cells, appears limited to short missions, such as those of early manned satellites which will require power for a few days, at most.

Thus, if best advantage is to be taken of the larger payload weights that our advanced vehicles will provide, lightweight power units must be developed to produce hundreds of watts, or even several kilowatts. It is also imperative that these power sources be capable of trouble-free operation over extended periods -- on deep space missions, for example, that may last a year or more. These long voyages into interplanetary space will depend upon use of solar or nuclear energy sources. Solar energy appears practical for most extended missions where the power required is a few kilowatts or less. For the very large power needs -- 30 kw or more -- the nuclear reactor systems (see Nuclear Energy Applications for Space) will almost certainly be used.

3-kw Solar Auxiliary Power Unit

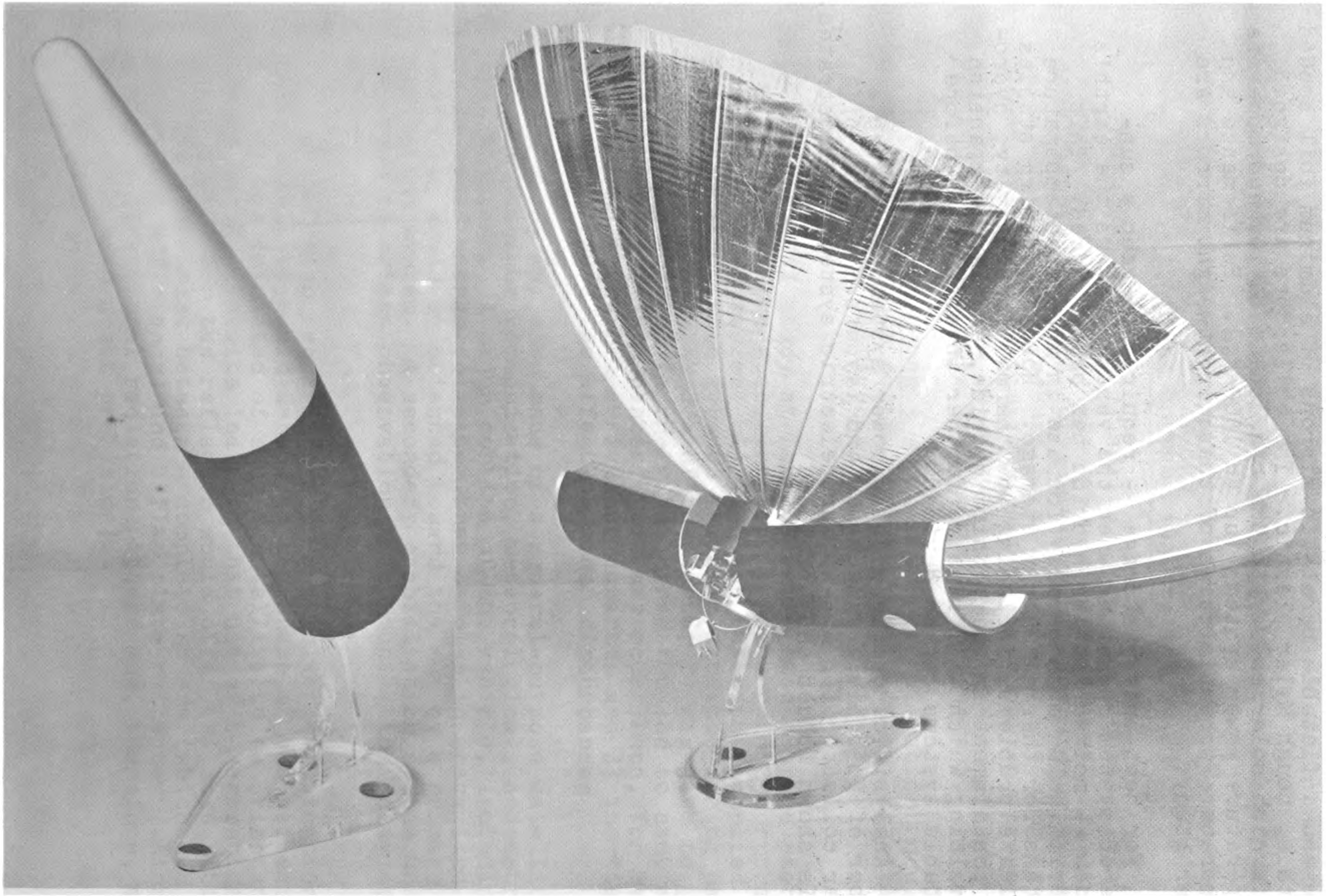
During this report period, plans were made by NASA Headquarters to request proposals for the development of a 3-kw solar auxiliary power unit (called Sunflower-I) for use in satellites or space vehicles. Sunflower-I will weigh approximately 1000 pounds. It will include a large solar collector, at least 300 square feet in area, to collect solar radiation for conversion into electric power by thermal or direct processes. The solar collector will be folded in the nose of the space vehicle until it enters orbit, at which time the collector will automatically unfold and be oriented and stabilized to face the sun.

The power supply will contain an energy-storage system so that power can be generated while the satellite is behind the earth's dark side.

During the coming months, NASA will start developing the Sunflower-I system.

Research on Solar Collector Systems

Research at Langley Research Center has been conducted on using solar energy to provide electrical power for space vehicles. System and component studies are continuing, with particular emphasis on: 1) the energy concentrator or mirror; 2) the thermal energy storage unit; and 3) the stabilization and orientation system of the collector.



Launch Configuration　　　　Orbiting Configuration

Umbrella Type Solar Collector

Experimental work with collectors is emphasizing umbrella-like and inflatable parabolic mirrors of aluminum foil bonded to thin, tough Mylar plastic. The collectors are designed to furnish solar energy to the converters of low and moderate temperature power systems (up to 1500°F.). Performance and temperature potentialities of these lightweight mirrors are under study.

For heat-energy storage -- required to keep a sun-powered system operating when the vehicle enters the earth's shadow -- molten lithium hydride has been studied. This material holds much promise for use in moderate-temperature systems for thermal energy storage. However, design studies indicate problems, including low thermal conductivity, hydrogen containment in the lithium hydride, and large expansion on melting which will require further investigation before suitable systems can be devised.

Analysis of complete solar power systems indicates a number of possible arrangements and layouts. A model of a solar collector for a 4-kw turboelectric system is illustrated. It is shown folded and unfolded.

CHAPTER 12

CONTROL AND GUIDANCE OF SPACECRAFT

ATTITUDE CONTROL AND STABILIZATION

Research studies of attitude control and stabilization systems for spacecraft involve: 1) spelling out system requirements, 2) developing methods of determining and maintaining attitude reference in space, and 3) devising techniques of providing control forces. In addition, procedures have to be developed to evaluate control system performance and reliability in a simulated space environment.

System Requirements -- To match stabilization requirements with attitude control system capabilities, possible methods must be compared with mission requirements for accuracy, weight, power, simplicity, and reliability.

An initial study at Langley for a manned space station indicated that the stabilization system should incorporate the following features: 1) attitude reference supplied by a solar seeker, with gyro to maintain attitude during periods of darkness in the shadow of the earth; 2) gas jets to get the vehicle pointed in the right direction and to damp major perturbations (disturbances) that may occur when, for example, a space ferry vehicle arrives or departs; and 3) inertia wheels to reduce the effect of minor disturbances

A study was also made of a general-purpose satellite for simultaneous communication, meteorological, and astronomical missions. A major portion of the vehicle, including a large solar energy collector that unfolds in space like an umbrella, would be oriented toward the sun by a primary stabilization system. A secondary stabilization system would be employed to orient observation or communication relay equipment.

Orientation requirements of a passive communication relay satellite would depend on the shape of the reflector. A study was initiated of such a satellite to be oriented toward earth. Results indicate that use of a segment of a large sphere for the reflector would offer the most satisfactory compromise between a complete sphere (which has low reflecting efficiency) and a flat plate reflector (which has a highly directional radiation pattern and, therefore, must be pointed with great precision).

Attitude Reference-Sensors -- Sensing devices that can provide attitude reference -- that is, determine the position and direction of a vehicle in space -- by detecting radiation from the earth, moon, and sun are being investigated. Two different types of horizon scanners have been designed, both of which are compact, lightweight, rugged, and require only small amounts of power. One type is sensitive to light waves and is limited to daytime use; it is intended primarily for vertical probes. The other, for day or night use, employs heat-sensitive detectors and a system of rotating mirrors: it will operate at altitudes of some 3,000 miles from the earth. This unit can be packaged within a 3x5-inch cylindrical container.

A solar sensor comprised of two pairs of silicon cells, with each pair connected across both branches of the circuit, has been designed and tested. The sensor was able to detect radiation over a wide angle (±120 degrees) and showed high sensitivity when properly aimed; accordingly, a means for automatically adjusting the pointing action of the sensor has been devised.

Attitude Control -- NASA's Jet Propulsion Laboratory is developing equipment suitable for pointing one vehicle reference point toward the sun and simultaneously aiming a directional antenna toward the earth.

Preliminary studies of means for pointing an earth satellite with respect to the fixed stars have been started at the Ames Research Center. Data gathered from these studies will be used to define requirements of a contract for an astronomical satellite of extreme stability and long lifetime.

Control Forces -- A study is in progress on ways of controlling a satellite in orbit. One promising approach involves a principle roughly similar to that of a gyroscope. By accelerating the rotor of an electric motor in one direction, an equal and opposite force is applied to the vehicle on which the motor is mounted. Such devices, called inertia wheels, can supply relatively large force and oppose disturbances to the satellite, enabling it to stay on course. Bench tests and analytical studies of several systems for both orbiting and non-orbiting flight have been made.

In a detailed system and hardware study of reaction jets that are turned on and off in short bursts to control space-craft, a switching sequence was developed that resulted in good control with a minimum expenditure of jet fuel.

Inertial Simulator -- One especially useful research tool for developing and evaluating complete space vehicle control systems is the zero-damping simulator (a number of which are in use) -- which is a delicately balanced platform, supported on a spherical air bearing, free to rotate in any direction. Because the platform floats on a film of air, there is virtually no friction between the platform and its mount. The platform can be adjusted to simulate characteristics of the vehicle under study. Also, the complete guidance and control system of the vehicle -- including its reaction controls -- can be mounted on the platform, put through simulated flight tests, and adjusted to achieve the best possible performance.

A control system for one of the Project Mercury vehicles for manned space flight was tested on such a test rig. Later, the same control system was used during a successful test flight of the Mercury capsule at Cape Canaveral.

Expansion of Entry Corridor Width

The entry path, or "corridor," by which a spacecraft may enter the earth's atmosphere is very narrow. If entry is made too low, the vehicle will strike the atmosphere at such a steep angle that the impact will cause deceleration stress too severe for a human occupant. If reentry is made at an angle that is too flat, the vehicle may bypass the earth because there will not be enough aerodynamic drag to bring about deceleration.

For a manned spacecraft entering the atmosphere, guidance must be extremely accurate to avoid excessive deceleration or aerodynamic heating. An analytical method has been developed to provide quantitative information about the entry corridor above the earth's atmosphere through which spaceships must be guided. The method has also been applied to determine the corridor width, heating, and associated guidance accuracy requirements for entering the atmosphere of other planets. The results showed the entry corridor widths to be extremely small -- only about 7 miles wide for ballistic (zero-lift) entry and about 30 to 40 miles if lift is used.

Studies have been directed toward widening the entry corridors. Recent results have shown that by changing the angle of attack of the vehicle, and thus varying the lift, the corridor can be widened to more than 100 miles for entry at very high speeds. However, it is not certain how much of this increased corridor width can be utilized, because the amount of heat to which the vehicle is subjected is increased when lift is used. Studies are continuing.

A study of the drag of the earth's atmosphere as a braking force to allow the recapture of a returning space vehicle was completed. This method of return, which would eliminate the need of retrorockets for braking, would greatly decrease the rocket power requirements of such a vehicle. Very little corrective power is needed to guide the vehicle to the proper minimum altitude on its first pass through the atmosphere.

In an investigation of a high-drag, low-lift vehicle (known to keep heating down to acceptable levels, but not very maneuverable), good control was obtained by using the limited lift over a considerable distance -- between 1,000 and 2,000 miles; by this means the vehicle could be brought down to within 10 to 20 miles of a desired destination. These results were obtained with either automatic or manual control, and with either a ground-controlled approach or the use of onboard guidance equipment.

Still another study of this problem considered a vehicle having lifting capability and using a gliding, rather than a ballistic, entry. It was found that by carefully controlling the amount of lift applied, the allowable range of entry conditions could be increased without raising aerodynamic heating beyond reasonable bounds. This study is being extended to higher entry speeds.

Studies are being conducted to define desirable types of trajectories based on power, guidance, and communication requirements. A study of the major perturbations of lunar trajectories was completed. Effects of eccentricity of the moon's orbit, oblateness of the earth, and solar attraction were considered. It was found that not compensating for the earth's oblateness could cause an error of one moon radius (about 1,000 miles) in the vicinity of the moon; the other effects resulted in errors of only a few hundred miles.

Two studies of interplanetary trajectories were started: 1) A small digital computer was employed to study the power requirements to keep a vehicle on course during the middle portion of a Mars-probe mission, considering the effects of the two nearest planets. 2) A complete digital program was set up to investigate flight anywhere in the solar system, taking account of all the important perturbing effects. A specific objective of this program is to study midcourse guidance systems. Several such systems are being considered, and one is now being set up on a digital computer.

Feedback Control Systems Research -- Research to design automatic control systems giving the desired vehicle response and stability is in progress. This is primarily analytical work, using mathematical models of aircraft, missiles, and space vehicles.

Areas in which significant progress has been made in the last six months are: 1) physical size of the power actuator (control surface servo for aircraft; jets, inertia wheels, rockets, etc., for spacecraft) and its effect on controller design; 2) effects of extreme variations in aerodynamic pressures, speed, and altitude throughout a given flight. (Flight tests to confirm results are under way); 3) errors on a radar seeker resulting from deflections of the radar signal as it passes through the radome (special nose enclosure) on a guided missile. These errors, heretofore, have caused large target-miss distances, particularly at high altitudes. A technique has been developed which, when incorporated into the vehicle guidance system, substantially reduces the miss distance.

Flight Simulation Techniques -- Control, guidance, and navigation of flight vehicles have been studied at Ames Research Center both with a human pilot and with automatic controls. Flight simulation techniques were used to study 1) dynamic problems of piloted airplanes; 2) pilot's ability to control airplanes and reentry vehicles under varying flight conditions; 3) guidance of missiles and manned automatic interceptors; and 4) methods for analyzing the stability of orbiting vehicles.

In recent studies at Ames of various airplane piloting tasks, actual flight results were compared with results obtained with fixed and moving flight simulators. Motion stimuli, to make pilot operation more realistic, were found to be desirable or mandatory in systems with abrupt response to control inputs and in studies of instrument presentations in maneuvering flight. In studies of more "conventional" behavior, however, the fixed simulator with adequate instrument presentation still appears to be a useful device for training pilots and evaluating systems.

Tests made on the simulator with the human pilot represented by a linear mathematical model showed that in tracking tasks, performance similar to that of a human pilot could be attained by the model, implying that the linear model is a fairly good approximation of a human pilot. Results of the study showed that the pilot-model was the same for cases where the "best" control-system dynamics were provided in association with poor airplane dynamics, and for cases where good airplane dynamics were provided.

Another investigation was made in flight to determine pilot reactions and ability to control unstable airplanes; even slight instabilities were unacceptable when the pilot was distracted by duties other than simply flying the airplane.

Rocket Engine Thrust Control, Stability, and Throttling -- In general, when the thrust of a rocket engine is reduced (as may be required, for example, in landing a manned vehicle on the moon) violent oscillations occur in fuel feed and combustion. The problem of reducing these oscillations has been attacked at the Lewis Research Center in two ways: by directly testing engines with controls derived from theory, and by studying the contribution of each component of the rocket engine to instability. Specifically, fast-acting regulators were used to control a 5,000-pound-thrust hydrogen-fluorine engine over a range from full thrust to one-tenth thrust, and to start and stop the engine reliably without harming it. This work is now being extended to hydrogen-oxygen engines.

The more basic approach -- studying the contributions of all components -- should make the work applicable to many varieties of rocket motors. Studies of the dynamic contributions of combustion in a hydrogen-oxygen and an ammonia-oxygen engine have been made or are in progress, and a theory for the combustion dynamics has been evolved. Studies have also been made of the pipes from tanks to the thrust chamber; results have been used to verify a general theory useful in engine design. The pumps that force the propellant fluids into the rocket thrust chamber are now under study. Fast-acting flow-control valves that tend to suppress unstable oscillation have been developed from theory and tested; they show low pressure loss, accurate regulation, and fast enough action to suppress some, but not all, types of unstable engine oscillation. Work on faster valves is continuing.

Thrust Direction Control and Vehicle Dynamics -- A space vehicle can be guided properly only if the thrust direction of its rockets can be controlled. This can be accomplished by swiveling the main rocket motors. However, the structure of some of the larger vehicles has proven so flexible that the swivel-action control motors bend the entire vehicles, causing it to whip, thereby limiting the thrust direction control and threatening the structure. This problem becomes more difficult with increased vehicle size and length.

Two vehicle dynamics test stands for studying thrust direction control on large flexible booster vehicles are now being completed at Lewis.

Course Correction Control -- As a vehicle proceeds through space, its navigational system gradually reveals errors in the flight path that could not be detected early in the flight. The control must then issue commands to the propulsion system to correct the flight path with a minimum consumption of propellant. Studies have been made at Lewis, which will permit design of an automatic mechanism to make these needed corrections. The amount of propellant that must be stored on board for course correction was worked out during the same study. This work is being extended to other types of navigational systems.

Zero-Control in Fluid Systems and Fluid-Containing Vehicles -- Vehicles in space will be weightless, or at "zero gravity," for long periods of time. Consequently, fuels will not flow from tanks, fluids will slosh about when the attitude or direction of the course is changed, and the accumulation of solar heat from exposed tanks will be affected.

Accordingly, the Lewis Research Center has conducted experiments with airplanes which can be flown in a "free fall" for 30 seconds to 1 minute, thereby achieving zero gravity. Experiments are being planned on attitude control of a vehicle containing liquid, an experiment concerned with the ability of a rocket motor to start, and an experiment on how to expel "boil off" gas from a fuel tank without expelling some liquid.

CENTAUR GUIDANCE SYSTEM

Development of inertial guidance systems for the Centaur rocket vehicle, the first U.S. multi-stage vehicle with active guidance throughout powered flight from lift-off to injection, is under way. The guidance system will permit coasting periods followed by engine restart, to satisfy the orbit requirements of 24-hour satellites and lunar and deep space missions.

Guidance for Centaur is being developed by Minneapolis-Honeywell as a subcontractor of Convair. The system employs a four-gimbal platform with three-axis stabilization and a digital computer developed by Librascope, Inc. It is light enough -- 150 pounds -- for inclusion in the upper stage.

Terminal Guidance -- A promising technique resulting from the study of planetary terminal guidance is based on sighting the planet against the star background to determine angle of approach, and measuring the apparent diameter of the planet to determine distance.

CHAPTER 13

MATERIALS AND STRUCTURES

MATERIALS RESEARCH

Man's progress has always been closely related to the materials that have helped him conquer his environment. Particularly in the United States, almost every scientific advance has depended in large part upon new or improved materials. For example, aircraft of increased speed and performance could be constructed only after suitable materials had been developed to meet increasingly stringent requirements. Introduction of various types of jet engines created a need for materials that could operate at ever higher temperatures. The use of nuclear fission as a heat source called for materials that could stand not only high temperatures but atomic radiation as well.

Space flight has introduced many new areas of special interest to NASA. These include: 1) propulsion devices for aircraft, missiles, and spacecraft; 2) devices to generate electric power for space vehicles; 3) heat sources other than combustion (for example, nuclear reactors and solar collectors); 4) structures of missiles and spacecraft; and 5) space itself (environmental characteristics such as hard vacuum, radiation, and meteoroids).

Materials for Special Environmental Conditions

Much of NASA's research is directed toward finding materials that will be suitable for special and demanding conditions of space flight. Under investigation are such diverse areas as ablation; properties of metals and ceramics at high temperatures; oxidation-resistant coatings for promising metals; deterioration of plastics and other nonmetallic materials under ultraviolet radiation, in vacuum, and at high and low temperatures; permeability of such materials to air; and the use of foaming plastics for structures collapsed on earth and erected in space.

Other Areas of Material Research

Other principal areas of NASA materials research include: physics and chemistry of solids (effects of strain on the properties and stability of materials, studies of imperfections, etc.); materials for use at very high temperatures (superalloys and refractory materials); oxidation of materials such as molybdenum, tungsten, tantalum, and columbium, which have high melting points; materials having light weight and high strength; materials for use at cryogenic (very low) temperatures; materials to resist surface attack (corrosion, erosion, and evaporation); and special-purpose materials such as energy converting materials, nuclear fuel elements, bearing materials, elastomers, and lubricants.

Today, the science of metallurgy recognizes that the physical properties of a metal -- strength, creep resistance, and ductility, -- depend on its internal structure and on the way its atoms are arranged. Studies of the atomic arrangements, of the forces between atoms, and of atomic movement have led to greater understanding of material failure, and of such phenomena as fatigue and creep. Basic investigations of the behavior of materials have led to new concepts for making them stronger and using them more intelligently.

Fiber Metallurgy - Study of "Whiskers"

Typical of the work in this area is a study of fiber metallurgy, conducted at Lewis Research Center, to increase the strength of metals. In solid state physics it has long been known that the metals commonly used today are far weaker than they could and should be according to theory. The reasons are many, but research has shown that weakness is principally due to imperfections in the crystal structure of the metals.

When metals or ceramics are made so that they have little or no crystal structure imperfection, they often show almost incredible strength.

Metal "whiskers," so called because of their appearance, apparently hold the key to this problem. Microscopic metal fibers (diameter of 1/10,000 inch or less), which grow out of bits of metal under heavy electronic bombardment, have a tensile strength of as much as 2 million pounds per square inch (psi) in comparison with a maximum of 350,000 psi for modern steels in bulk.

If the full strength of whiskers could be utilized in a practical engineering material, that material would be so strong that most structural components could be greatly reduced in size and weight and still maintain their structural integrity. Rocket and other space components could be lightened, and payloads could be increased significantly.

It is most difficult to experiment with fibers as short or as fine as actual whiskers. Whiskers are not available commercially. Some of the great strength of whiskers is derived from their fine diameter. For example, the finer wire is drawn, the greater its strength per unit area. Therefore, research on fine wires is proceeding so that as much progress as possible in this general field can be made until whiskers become available in greater quantity.

The first experiments of this nature utilized strong wires. Fundamental studies using tungsten wires embedded in copper have shown that, when the fibers run continuously from one end of a specimen to another, the composites exhibit a strength proportional to the number of fibers present in the specimen and the strength of these fibers. Thus copper, having a strength of 30,000 pounds per square inch, was strengthened to more than 120,000 pounds per square inch by adding 35 volume percent of tungsten fibers (having a strength of 300,000 pounds per square inch). This shows: 1) that it is possible to strengthen relatively weak metal by simply adding a much stronger fiber to the metal and 2) that by adding more fiber, the strength can be increased proportionately.

Another important finding has been that the same strengths have been achieved in tungsten-copper composites reinforced with very short lengths of fibers that do not extend from one end of the specimen to the other. It follows that if very short but phenomenally strong whiskers could replace the wire filaments in such a structure without damage to the whisker strength, the end product would have unusually high strength. Work to date indicates that this can be done.

Materials for Cryogenic Fuel Storage During Space Missions

Use of cryogenic (literally, very low temperature) propellants, such as liquid hydrogen and fluorine, poses problems in designing tanks to contain them. Liquid hydrogen is very cold and liquid fluorine has high chemical reactivity. Liquid hydrogen will be used as a propellant for both nuclear and high-energy chemical rockets and liquid fluorine may be used in combination with hydrogen for some chemical rocket applications. Research programs are therefore under way at the Lewis Research Center to investigate the design of reliable tanks of minimum weight for cryogenic fuels.

Little is known about properties of high-strength materials at very low temperatures. Consequently tensile tests are being made on sheet metal specimens at the temperature of liquid hydrogen (-423°F). To determine how well tensile properties can be used to predict material performance in fuel tanks and similar containers under stress, small-scale pressure vessels filled with liquid hydrogen are also being tested to compare actual with predicted strengths.

The tensile test program centers on materials that are relatively insensitive to notches at low temperatures -- principally austenitic stainless steel, and alloys based on nickel, aluminum, and titanium.

Investigation of Thermally Insulated Liquid Hydrogen Tanks -- Hydrogen tanks for rocket vehicles must be thermally insulated, but conventional vacuum jackets are too heavy. Needed is a lightweight vacuum-jacketed tank or a low-density thermal insulation. Experimental and theoretical research is aimed primarily at materials and ways of sealing. Problem areas include: 1) attaching insulation to tank walls; 2) sealing insulation to prevent air condensation; and 3) protecting insulation from erosion and heating. Results to date show that several lightweight insulating materials, such as foamed-in-place plastics, have considerable promise for use with liquid hydrogen tankage. The research will also be valuable for nuclear-rocket-propelled spacecraft.

Tensile tests with specimens immersed in liquid fluorine are in progress to determine the compatibility of highly stressed tank materials with fluorine.

Analytical and experimental investigations of stresses in the area of junctions of surfaces have been started, to aid in designing lightweight tanks. In addition, ways of reinforcing openings in thin-walled pressure vessels are being studied.

Solid Propellant Casing Material Studies -- To reduce weight of large solid-propellant vehicle cases, very strong materials must be used; however, the ultimate strength obtained from tensile specimens of the materials used is not necessarily an indication of the strength of the material in a pressure vessel under stress in two directions at once. Consequently, in welding ultra-high-strength steels, small cracks are almost impossible to avoid. Difficulties also arise from other flaws in sheet steel. Vehicle cases, welded and then heat-treated to increase strength, often fail catastrophically from these small cracks or flaws. Failures can occur at loads of only a fraction of the design stresses.

A research program is under way at Lewis to determine why these sheet steels fracture or crack as a result of heat treatment. A special device was developed to simulate effects of cracks in sheet steel specimens. Many commercial steel types were evaluated and the data were immediately made available to the Large Solid Propellant Rocket Motor Committee of the Materials Advisory Board of the National Academy of Sciences.

None of the commercial compositions in which there were cracks or flaws were free from embrittlement when heat treated for very high strength; however, the degree of embrittlement varied with both steel type and heat treatment. Results of the investigation permitted selection of optimum heat treatments for given steel types, and information was developed that greatly improved the steel used in one of the large ballistic missiles.

Future studies will be directed to improve steel and design vehicle cases that will not fail even if small cracks and flaws occur.

Cryogenic Tank Insulation Studies -- The tanks of rockets and spacecraft using liquid hydrogen fuel will require insulation because, otherwise, heat would rapidly flow into the hydrogen during the atmospheric part of their flights. Types and amounts of insulation will depend on specific vehicles and flight programs. However, some requirements for insulation are universal -- i.e., light weight, low thermal conductivity, impermeability to air, resistance to wind erosion, and capability of withstanding aerodynamic heating at launching.

The Lewis Research Center is investigating insulation of types that are non-vacuum, non-metallic, bonded to the outside of the tank, and surface-sealed against air penetration into the insulation. Recent results of this program show that:

1. The best of the materials studied are corkboard and insulation-filled, glass-cloth honeycomb having continuous-surface layers on both faces (sandwich construction).

2. Epoxy resin fiberglass can be used to bond the insulation to the cryogenic propellant tank.

3. Corkboard has the lowest over-all thermal conductivity of the materials studied, about 40 percent lower than those for the best insulation-filled honeycomb sandwich materials.

4. The external surface can be sealed effectively with 0.001-inch thick Mylar sheet bonded to the insulation.

STRUCTURES RESEARCH

Designing vehicles for high-speed atmospheric or space flight is a continuing challenge to NASA's structural engineers. Spacecraft must operate in many differing environments, some of great severity. For example, hypersonic aircraft, and spacecraft entering the atmosphere, encounter aerodynamic heating during which temperatures of 3000°F and higher are not uncommon.

Many problems remain to be solved even in lower speed ranges. Much must be learned about fatigue problems of a number of materials subjected to jet noise, unsteady aerodynamics, and "buffeting" at transonic speeds.

Much NASA research in these areas is based on pioneering by its predecessor agency, NACA, and many new projects have been started. Highlights of typical NASA research follow:

Turbulence Intensities at High Altitudes

Under direction and coordination of Langley Research Center, atmospheric turbulence is being measured, at diverse operational altitudes and weather conditions, in the Western United States, England, Western Europe, Turkey, Japan, and elsewhere. Data collected and analyzed so far indicate that turbulence decreases markedly at high altitudes. However, strong local effects, such as those caused by mountains and very high altitude winds (jet streams), may result in fairly widespread turbulent areas at altitudes as high as 55,000 feet.

Landing Loads for High-Speed Aircraft and Spacecraft

Analytical studies were also made of factors that must be taken into account in the prediction of landing loads for future aircraft of very high Mach numbers. Particular attention has been centered on early landings of the X-15 airplane.

Experimental landing mats and membranes (coverings) for use on unprepared fields were tested on the Langley Landing Loads Track Facility to provide information for the Army Corps of Engineers. For the Navy, Langley investigated the loads that can be expected when landing brakes are applied, and loads that might affect landing gear designed for aircraft coming down on a new non-skid material developed for aircraft carrier decks.

Extremely high-speed aircraft, and spacecraft entering the atmosphere, encounter severe frictional heating. If conventional pneumatic tires are used, they must be retracted into cooled storage compartments, which add to bulk, weight, and complexity of the craft. To avoid this, metal skids for main gears and all-metal wheels for nose gears are being considered. Information on sliding friction and wear rates of materials for use as skids is being sought, and research is under way on how skids are affected by landings on concrete, asphalt, and dirt.

Skid materials tested included steel, tungsten, nickel, titanium, copper, Inconel-X, columbium, molybdenum and two types of cermets (ceramic-metal materials). Skidding resistance varied from a low of 20 percent of the vertical load (for tungsten carbide) to a high of more than 50 percent of the vertical load (for copper).

Two kinds of all-metal wheels were tested. One, made from wire brush, withstood test conditions but had a very high rolling resistance -- about 20 percent of the vertical load. The other, a wheel with a spring-steel rim, had a very low rolling resistance, but failed during the tests. After being altered and strengthened, it will be tested again.

Erectable Structures for Space Vehicles

To accomplish space missions now being planned, some payloads will need to be quite large and yet very light in weight. Mounting such ungainly structures on booster rockets involves many difficulties. At Langley, ways are being studied to pack a large structure in a small package, and then -- after it has been lifted into space -- to expel and erect it.

Expansion of the structures by inflation, spinning, or other mechanical means, using the simplest possible equipment, is being considered. Recent work at Langley has centered mainly on automatically erecting parabolic reflectors (antennas for television and radio communications) and solar collectors (to produce auxiliary electric power for manned or unmanned space vehicles). Several such structures have been fabricated and tested in ground facilities. Other experiments have been made on the use of foamed-in-place plastics to inflate structures of this general type and hold them rigid.

Tests on a small solar collector of the umbrella type indicate that its thermal efficiency is almost half as great as that of much heavier glass or metal collectors. Models of similar antennas and collectors will be tested in vertical and orbital flights before they are incorporated in actual space vehicles.

Soft Landings on Gas-filled Bags

Gas-filled bags of different shapes and configurations have been considered for bringing a vehicle to a vertical soft landing on the moon, earth, or nearby planets. An analytical method has been developed at Langley for calculating deceleration characteristics at descent velocities up to the sonic speed of the gas enclosed in the bag. It has been found highly desirable to control the rate of gas leakage from the bag during impact.

Strength Analysis of Structural Elements -- Many different shapes and proportions are being proposed for aeronautical and spacecraft design. Many of the data on structure acquired in the past now apply only at lower speeds and with simpler configurations than those of great interest today. It follows that many old structural problems must therefore be reevaluated, and that data and methods of analysis must be developed for new structural approaches.

Use of corrugated sheet is important in very hot structures that must withstand severe temperature differences. The shear*-carrying capability of corrugated sheet was evaluated experimentally, and charts to aid in the design of shear beams of high strength-weight ratio were prepared.

Large aircraft and most missiles and boosters have thin-walled, cylindrical shells. Although much study has been devoted to predicting the strength of cylinders, little is known of their behavior under the various loads and pressures, internal and external, that booster tanks undergo. NASA and several universities, working under NASA contract, have therefore undertaken a theoretical and experimental attack on this problem. Research at the Langley Research Center has included an experimental investigation of the strength of large-scale, carefully constructed circular cylinders under compression, bending, and internal pressure.

Structures for Manned Reentry Vehicles -- The structural design of manned spacecraft that will reenter the atmosphere can be approached in two ways: 1) refractory materials can be used to withstand the very high temperatures of aerodynamic heating; or 2) standard materials can be used, providing they are kept at a safely low temperature by a thermal protective system.

Research in progress includes both approaches. A generalized study has been made to learn conditions under which various structural approaches -- hot, insulated, or insulated and cooled -- are most efficient. Another study is under way to learn more about how heat transfer occurs in sandwich panels of the type that might be used for heat shields or primary structure. Work is also continuing to develop better test facilities for experiments at high temperatures.

Regardless of approach, refractory metals such as molybdenum, niobium, and tungsten are likely to be used either in the primary structure or in heat shields. An evaluation of structural components built of refractory metals was therefore initiated. The first phase, now nearing completion, dealt with molybdenum alloy. Working with material suppliers and fabricators, a number of resistance-welded sandwich specimens were made and coated to protect the molybdenum from oxidation. Tests of the welded and coated specimens at temperatures to 3000°F showed that maximum strength corresponds closely to the strength of molybdenum itself. Tests of the coating, using both simple and sandwich specimens, indicated that oxidation failures usually occur at the edges of the thin sheet. The contractor is now working to correct coating techniques. Molybdenum structures appear feasible for reentry vehicles; success of the program has encouraged additional research by both industry and Government on structures of refractory metals.

* "Shear" is the load across a beam near its support.

Structural Dynamics -- A flexible structure is much harder to control in flight than one that is rigid. Since large rocket vehicles are inherently more flexible than small ones, the problem is becoming more and more acute. Three aspects are involved: the inherent stability of the vehicle; the way it behaves when disturbed by winds, gusts, and other external forces; and the ease and degree of control, especially during launching. Specific studies on the Scout vehicle indicate that the fin area should be increased and that the internal control system must be improved.

Tests have also been made on cylindrical and spherical tanks, using various baffle arrangements to study and control the detrimental effects that fuel sloshing has on flight; experimental and analytical studies are also under way on helicopter rotor systems to reduce flapping of rotor blades.

Panel Flutter -- In an effort to eliminate panel flutter in the X-15 airplane, all movable portions of the lower vertical stabilizer were tested in the 9x6-foot Thermal Structures Tunnel at Langley. Various models are being tested in several facilities to establish conditions under which the present structure and proposed modifications will be free of flutter.

Panel flutter tests were also conducted at transonic and supersonic speeds to determine the behavior of buckled curved panels with longitudinal stringers.

Other flutter studies included helium tunnel tests of various wings in the relatively unexplored Mach number region around 7 and tests in the transonic region to assess the importance of wing thickness on flutter.

Cryogenic Propellant Storage in Space -- Nuclear or chemical rocket propulsion systems for future space vehicles will utilize hydrogen as a propellant. The oxidant for high-energy chemical rockets may be either oxygen or fluorine. Since all of these propellants are cryogenic, special care will be required to keep down losses from vaporization during long space missions. An analytical study at Lewis calculated vaporization losses for hydrogen and oxygen tanks of various arrangements and with different shielding devices. Multiple, reflective foils were utilized as heat barriers between adjacent vehicle components at different temperature levels; such foils were also tested as possible shields between the tanks and the sun.

CHAPTER 14

FLUID MECHANICS

IMPORTANCE TO AIRCRAFT AND SPACECRAFT DEVELOPMENT

Fluid mechanics is the study of reactions between fluids and solids immersed in them. (In the science of aerodynamics, air is considered a fluid.) Research in this broad field applies to many aspects of aeronautics and space flight, some of which are: 1) heating problems associated with the reentry of space vehicles; 2) stability and behavior of the viscous boundary layer (the layer of low-energy air immediately adjacent to the surface of a body); 3) behavior of plasmas (fluids that become ionized due to very high temperatures or electromagnetic radiation); 4) flow processes in nuclear reactors; 5) properties of gases at high temperatures; and 6) flow around bodies traveling at hypersonic speeds and in air of very low density.

Problem of Atmospheric Reentry

One of the biggest reentry problems is to keep vehicles entering the atmosphere from burning up; to do this, the nature of the flow around such bodies at hypersonic speeds must first be known. NASA scientists have made theoretical analyses to: 1) indicate shock wave positions and pressure distributions about blunt-nosed, slender bodies such as rockets and missiles, and show the general characteristics of air flowing by at hypersonic speeds; and 2) to determine the heat transfer conditions at the stagnation point of a body.

The next major step is to devise ways of keeping the body from taking in too much heat. Research has centered on three methods: 1) ablation cooling, in which a surface coating of material -- for example certain plastics -- melts and vaporizes, protecting the surface beneath it; 2) internal cooling; and 3) transpiration cooling, in which a fluid "sweats" through the skin of the body.

Boundary Layer and Transition

The nature and effects of this aerodynamic heating, especially at high speeds, depend significantly on whether the flow in the boundary layer is smooth or turbulent. Turbulent flow produces higher skin friction, and hence more heat. For years, means have been sought to learn more about how and why the airflow around a body becomes turbulant. An important research tool in these studies is the wind tunnel. In this device, the aircraft model stands still in a moving stream of air and experiences the same aerodynamic forces that would be exerted on an aircraft in flight through relatively still air.

According to theory, the airflow would remain smooth longer if the surface of the body around which it passes were cooled. However, wind tunnel experiments have led to contradictory results. To obtain more conclusive data, the wind tunnel experiments were augmented by studies using shock tubes -- devices in which a gas under high pressure is suddenly released in a tube to create a shock wave -- rather than the continuous flow of a wind tunnel. These shock tube studies also showed no correlation with theory; that is, the use of surface cooling did not affect transition significantly.

If closer examination of the existing information on transition mechanism in internal flows supports these findings, research will have to be considerably reoriented to obtain more data.

Heat Transfer and Skin Friction

Blunting Effects with Supersonic Flow -- An investigation was made of the effect of blunting (use of blunt rather than streamlined shapes) on turbulent heat transfer at supersonic speeds on wings and tail surfaces of high-speed vehicles. A flat plate with different degrees of bluntness was studied because it approximates the shape of a wing and is easy to construct and maintain. Experimentally determined distributions of heat transfer and surface pressure were obtained at a Mach number of 4.7. These data, which are being correlated with predictions based on the local flow conditions over the plate, show that blunting reduces heat transfer significantly. A second phase of this investigation, namely the effect of the degree of wing sweepback on turbulent heat transfer, will be undertaken soon.

Gases Emitted to Reduce Skin Friction -- NASA scientists have been investigating still another approach to the aerodynamic heating problem -- the use of gas emitted from the surface of the vehicle body to reduce the heat generated by skin friction. A test was made using a porous cone through which several gases -- helium (a very light gas), air, and freon-12 (a heavy gas) -- were injected. Skin friction was measured at Mach numbers of 0.3 to 4.7. The gas injection substantially reduced skin friction, but it was found that the Mach number also showed a marked effect on the relative reduction -- an effect not previously defined or predicted by existing theories. These experimental skin-friction data have provided information useful in determining the insulating effects resulting from surface gas emitted from ablating surfaces employed on high-speed reentry vehicles.

Effects of Surface Roughness on Friction -- The range of supersonic bombers and transports could be appreciably increased if smoother air flow could be obtained over wing and fuselage surfaces. So far no great progress has been made in this direction because present manufacturing techniques leave surface irregularities, and the surfaces are further roughened by dents, scratches, and the like as the aircraft is in service. An experimental study of this problem in a NASA supersonic pressure tunnel has improved understanding of how surface roughness triggers the transition from smooth to turbulent flow at supersonic speeds. Results were also correlated to give a method of predicting how rough a surface could be and still have smooth flow at Mach numbers up to 2 or 3. An extension of this program to hypersonic speeds is in progress.

Effects of Chemical Reactions on Heat Transfer -- The objective of another study was to determine the effects of measurable homogeneous and heterogeneous chemical reaction rates on laminar heat transfer at hypersonic speeds, with and without fluid injection. (Homogeneous reactions are those reactions which occur among various constituents of the gas, whereas heterogeneous reactions are those that occur between gas constituents and the surface.) Procedures are sought for calculating heat transfer to vehicles reentering the atmosphere at orbital or escape velocities.

Ballistic Models Used to Measure Aerodynamic Heating -- At Ames Hypervelocity Ballistic Range, models are used to measure aerodynamic heating at flight speeds of from 7,000 to 15,000 miles per hour. A number of gases are being tested to investigate heating in the earth's atmosphere at these speeds, and the heating expected from the atmospheres of several other planets. Special telemetering instrumentation was developed to measure the surface temperatures of the models in free flight.

Tests to date have consisted of measurements of stagnation-point temperature at a launch velocity of 7,500 miles per hour in air, argon, and carbon dioxide. Results agree well with theoretical predictions. Similar tests are planned for higher speeds. Studies will also be made to determine the separate contributions of radiation and convection* to aerodynamic heating.

The Problem of Hot Spots -- Studies of "hot spots" on spacecraft and missiles are continuing. These hot spots are caused by intense local aerodynamic heating produced by the shape of the vehicle in combination with particular flight conditions such as Mach number, altitude, and flight attitude. Investigations are being made both in rocket-powered models and in hypersonic, heated wind tunnels. The problem has not yet been reduced to an engineering computation but it has

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* The transfer of heat by the automatic circulation of a fluid (liquid or gas) due to differences in temperature or density.

shown that the designer must carefully take into account areas where shock waves intersect leading edges of wings, sharp corners exist, or protuberances occur in high-speed air streams.

Cooling of Hypersonic Vehicles

Ablation Cooling -- The process of ablation, in which a cooling material melts and/or vaporizes, has been found excellent for shielding ballistic missiles and spacecraft from heat generated during atmospheric reentry. During the past year, understanding of ablation greatly increased. A theoretical method has been developed that permits heat shield requirements to be calculated for the real case of rapidly varying heat-transfer rates. With this method, data obtained in ground-simulation facilities can also be evaluated. Excellent agreement between the theory and experiment has verified the soundness of the use of ablating materials for cooling and, in turn, has stimulated research into improved materials.

For materials that melt before they vaporize, the presence of a liquid layer alters the process appreciably. The liquid layer is subject to strong forces of deceleration as a vehicle enters the atmosphere. Analysis shows that this can cause the liquid layer to reverse its flow direction along the body. Consequently, layer thickness varies and eventually the liquid accumulating at different points may alter air flow and heat transfer around the body.

Transpiration Cooling -- Further tests are planned in which the local heat transfer on surfaces cooled by transpiration will be measured for both smooth and turbulent boundary layers. The local Mach number at the edge of the boundary layer will range from 0 to 5. In addition to its application to transpiration and ablation cooling processes, the heat-transfer information will be used for comparison with available skin-friction data to determine the analogy between heat transfer and skin friction with transpiration.

Recent work has revealed that as much as 80 percent of the convective heat transferred to a blunt body, rotating as it moves through the atmosphere at high speed, can be eliminated by expelling a small amount of gas through a porous region in the nose. Skin friction can be reduced as much as 65 percent by the same means. The study also shows that a limited region downstream of the transpiration zone on the surface also benefits by reduced skin friction and heat transferred to the surface.

The results of these studies can be applied to the planning of future ballistic, reentry, and high-speed glider vehicles for which frictional heating is a major design problem. The information can be applied to rocket-nozzle design as well.

Internal Cooling -- As heat comes through the skin of a vehicle, it may be absorbed by a metal "coolant" that melts at relatively low temperatures. The liquid metal is then set into motion by the deceleration force and carries heat to other parts of the body where it can be absorbed. This internal-cooling method depends on the body shape because different shapes decelerate at different rates. Accordingly, a theoretical analysis of the flow and heat transfer of fluids driven by body forces (such as deceleration) inside two-and three-dimensional bodies was undertaken to determine the best body shapes for internal cooling. This analysis will aid in determining the feasibility of using this cooling method in various reentry missions (such as ballistic and glide reentries) and determining the best body shape for a given mission with given heat transfer requirements.

A number of studies are under way to provide both empirical information on, and understanding of, these processes which, in theory, should substantially reduce both skin friction and heat transfer.

Supersonic and Hypersonic Flow

Today's supersonic and hypersonic wind tunnels pose a number of new problems for the engineer. One of these involves the physical properties of the air passing through the tunnel. As temperatures in wind tunnels become higher, changes take place in the physical properties of the air, and these changes must be studied and taken into account. For example, the relatively simple methods used in the past in designing test nozzles and estimating speeds become inaccurate.

The "ideal gas" described in Boyle's law, in which pressure and volume are always in inverse proportion, does not exist at high temperatures. Measurements must be made on real (non-ideal) gases that do not behave exactly according to the rule.

NASA scientists are studying real gases at extremely high temperatures and pressures (more than 4,000°F. and up to 1,000 atmospheres of pressure). The results of their calculations permit the rapid calibration of real (non-ideal) hypersonic nozzle flows by the techniques that were used in the past for ideal nozzle flows. For air (in chemical equilibrium), the change in nozzle contour for a fixed Mach number that is caused by non-ideal or real gas effects has been found to be significant, and the difference between the actual contour and the ideal contour can be determined only by carrying out complete nozzle calculations.

Further studies are being made for air that is not in chemical equilibrium, under conditions common to very high temperature arc-gun tunnels. This research contributes directly to the development of improved tunnels for missile and spacecraft design.

Magnetogasdynamics

This is a relatively new branch of fluid mechanics which deals with the motion of electrically-conducting fluids in the presence of electric and magnetic fields. When a body moves at hypersonic speeds, a strong shockwave around the body heats the air to temperatures so high that it becomes ionized -- that is, it will conduct electricity. Ionization can be increased by introducing, for example, a gas of a kind that ionizes more readily than air. Applying electromagnetic fields to the ionized air and gas alters the flow and heat transfer about the body of a vehicle. Theoretical studies are under way on the flow of an electrically conducting gas about two- and three-dimensional blunt bodies for various types of magnetic fields.

Another project in this field is a study of the interaction of crossed electric and magnetic fields with a viscous, incompressible, electrically conducting fluid (for example, brine, mercury) flowing in a channel approximately as wide as the fields are long. Immediate goals are to eliminate unevenness in the flow and thus to improve the over-all efficiency of magnetogasdynamic pumps. It has been found both theoretically and experimentally that performance can be significantly improved by properly shaping the magnetic field at the ends of the channel.

Plasma Accelerators -- Devices for accelerating gases to high velocities are important for wind tunnel systems, since they aid in simulating conditions that will be encountered by space vehicles. Work in this area at Langley Research Center has included studies of various techniques for producing and accelerating plasma (ionized gas). Models of plasma accelerators have been operated, producing velocities as high as 100,000 mph.

During the report period, a system was also developed for producing highly ionized gases by using a cyanogen-oxygen flame to which alkali metal is added. The plasma produced simulates the electron density encountered by the nose of a ballistic missile reentering the atmosphere. The highly ionized flame was employed for laboratory study of radio blackout (loss of radio signals) from high-speed missiles when they are surrounded by hot ionized air.

New Possibilities -- A significant finding during the period in the new and still almost uncharted field of magnetogasdynamics was that electrodes made of lanthanum hexaboride can be operated in a nitrogen atmosphere without being reduced in efficiency. This opens up new possibilities, since it offers a means of accelerating relatively dense ionized gases.

The generation and study of high-temperature ionized plasmas is of importance in various thermonuclear (fusion) and space-propulsion devices. NASA has undertaken research to heat plasmas as high as 500,000°F. or more by using high-frequency magnetic fields. Present efforts involve a small (2-inch) discharge tube, but NASA is designing larger devices to employ greater radio-frequency power -- initially 15 kw and later 200 kw.

CHAPTER 15

SPACECRAFT AERODYNAMICS

PRESENT RESEARCH SCOPE

In recent months, NASA research on spacecraft aerodynamics has been mainly concerned with entry vehicles and problems related to them. An extremely wide variety of configurations is under investigation, including: 1) zero-lift ballistic types (ranging from blunt vehicles like those used in Project Mercury to less blunt devices having higher impact speeds for advanced ballistic missile applications); 2) low-to-moderate lift capsules (such as might be appropriate for satellite or lunar missions); and 3) wing and body configurations having lift-drag ratios as high as 2.5.

Entry Vehicle Problems

The main problems in this area involve: 1) handling reentry aerodynamic heating; 2) reducing reentry deceleration forces; 3) providing aerodynamic stability and control; and 4) providing lift when needed for greater maneuverability and flexibility of operation. Another important and closely related problem is determination of the most favorable modes of operating some of these configurations during entry.

The nature and importance of each problem varies with the configuration and the mission. For example, research data and flight experience indicate that aerodynamic heating of blunt-nose ballistic missiles and satellites can be handled straightforwardly by advanced ablation techniques. With entry vehicles of higher speeds, such as those returning from lunar or interplanetary flights, similar techniques might also apply, but more research is needed.

During entry, zero-lift ballistic capsules have little or no maneuverability for steering to a desired landing area or for correcting small guidance errors before entry. Both Langley and Ames have extensive research programs under way to study the relative advantages and disadvantages of using lift to provide greater maneuverability and to reduce deceleration forces. A number of wind-tunnel test programs are in progress to test ways of increasing lift by simple modifications. Some involve adding flaps to compact ballistic capsules, designed to have small amounts of basic lift, or to more slender bodies having somewhat greater lift. Still more lift can be obtained from rigid, high sweptwing-and-body configurations, from inflatable-wing gliders, and from flexible kite-like structures.

Generally speaking, however, increased lift intensifies the heating problem. Many configurations, some of them rather novel, are being tested in high-speed, high-temperature wind tunnels, in ballistic ranges, and in other laboratory facilities to determine lift, drag, stability, and control characteristics.

Stability investigations have included specialized tests to determine the dynamic response to flight disturbances. Some of the configurations being investigated have the potential of landing at conventional airports; they have been tested in low-speed wind tunnels and free-flight facilities. Many spacecraft concepts employ parachutes for recovery, and all NASA research centers have made important contributions in advancing the technology of parachutes and other specialized drag-deceleration devices.

Booster Stage Separation

Space vehicles use stage or step rockets -- three or more propulsion units stacked one on top of another, or in clusters -- as the most efficient way of lifting a payload. As each stage uses up its propellant, it must be separated from the remaining stages so that it will not be carried along as dead weight.

A key problem is how to separate the used stages without knocking the upper stages off course. In earlier, relatively simple, staged rockets, it was possible to force the separation with an explosive device such as a powder charge. However, the more refined, high-payload systems now in use require that the propulsion unit of the upper stage be brought to full thrust before separation; it is then flown off the lower stage.

Starting the upper stage before separation takes place requires that there be ports between the two stages, large enough to allow the rocket exhaust gases to escape without introducing extraneous forces. At Lewis Research Center, this problem has been simulated in an altitude chamber; the effects of size, location and shape of the ports and adjacent areas have been determined. This study indicated some of the ways in which these factors influence and interact with each other.

Experiments have also been conducted in various transonic and supersonic wind tunnels at the Ames, Langley, and Lewis Research Centers to determine: 1) the magnitude of the aerodynamic forces and interactions that occur in the junction region as the stages separate; and 2) the general aerodynamic characteristic of each stage in several representative booster configurations. The actual dynamic separation of the two stages is simulated in some of the tests. Results indicate that the airflow around the upper stages as they separate can possibly introduce extraneous forces. Under some conditions, fluctuating loads that cannot be calculated readily will disturb the upper stages and introduce unknowns into the final trajectory.

Vehicle Base Heating

A major problem in rocket vehicle launching is the recirculation of hot exhaust gas around the base of the vehicle, heating it to very high temperatures and, in some cases, even setting the engine compartment on fire. The problem has grown more complex with the increasing use of clustered rockets. At Lewis and Langley both single and clustered jets are being used to learn more about base heating and how to control it.

At Lewis, jet gas recirculation was observed in the 8x6-ft. supersonic wind tunnel, employing four-jet and eight-jet cluster configurations up to Mach 2. Measurements defining the jet flow recirculation patterns confirmed that base heating is indeed a more severe problem with clustered jets than with a single jet. Preliminary observations were made to determine the effectiveness of techniques for alleviating the base heating problem.

Similar measurements were made using a single jet to velocities as high as Mach 3 in an effort to consolidate and generalize previous data and to extend single-jet research to higher Mach numbers and altitudes.

Booster Recovery Systems

Since rockets are complicated and extremely expensive devices, considerable thought has been given to the possibility of recovering boosters after they have been fired, making whatever repairs or replacements are necessary, and using them again.

The chief problem, of course, is to return the booster to the ground in as nearly an undamaged condition as possible. The problem is being attacked from several angles. One of these is the use of lift to reduce the aerodynamic forces and to permit a relatively precise point landing near the launching area. Winged boosters powered by air-breathing engines are being considered for the first stage. Use of parachutes or residual propellants for braking during reentry or landing are also being investigated.

Wind Loads on Vehicles in Launch Position

When a rocket vehicle is in launch position and a strong ground wind is blowing, the vehicle is under a relatively steady load in the direction of the wind, but may oscillate in the crosswind direction. Work is in progress at Ames and Langley to learn more about these crosswind oscillatory loads, on which there is at present little experimental data. For large bodies there is not even a satisfactory theory to use as a basis for estimates. Therefore, models have been constructed and are being instrumented for use in the Ames 12-ft. pressure wind tunnel to develop empirical relations that will provide estimates of wind-induced stresses in cylindrical structures.

CHAPTER 16

AIRCRAFT AERODYNAMICS

CONTINUED IMPORTANCE OF RESEARCH

For years to come, the chief means of rapid passenger and cargo transport will continue to be aircraft flying through the earth's atmosphere and powered by air-breathing engines. Research aimed toward swifter, safer, and more efficient aircraft continues to be an important activity of the Langley and Ames Research Centers.

Subsonic aerodynamic phenomena are relatively well understood; existing knowledge is usually applied to solve special problems arising from new aircraft concepts and from continued economic pressure to make existing aircraft faster, safer, and more efficient. At supersonic (1,000 - 3,500 mph) and hypersonic (above 3,600 mph) speeds, aerodynamic knowledge diminishes as the speed increases. It must also be taken into account that the swifter aircraft will encounter problems in lower speed ranges that may profoundly affect over-all design.

Subsonic Speed Types

Langley and Ames are studying a wide variety of V/STOL (Vertical and/or Short Takeoff and Landing) aircraft, including helicopters and ground-cushion machines.

Work on helicopters has included determining and specifying control-response characteristics needed to permit flight in all kinds of weather. A Langley variable stability helicopter used to simulate unconventional configurations has paved the way to successful transition flights of new military research airplanes, called "test beds." Recent Ames helicopter rotor tests have shown several possible ways to delay blade stalling and thus enable higher forward speeds.

Years of Langley effort on propeller-driven, tilt-wing, and deflected-slipstream aircraft have provided a research background for the family of tilt-wing aircraft now under flight evaluation by the military services. NASA pilots and engineers participated in early evaluation of the flying qualities of these vehicles. Langley will soon flight test a representative tilt-wing configuration (Vertol 76).

Ames full-scale wind-tunnel tests have resulted in modfications providing more satisfactory flight characteristics for a tilt-rotor (Bell XV-3), a deflected-slipstream (Ryan O2), and a tilt-duct (Doak 16) VTOL aircraft. These are to be included in the NASA program to evaluate the flying qualities of various VTOL types.

The ground-cushion machine is a unique new vehicle that hovers a few feet above ground or water. It is supported by the lift of a jet of air directed downward. Lifts of from six to 10 times the design thrust have been obtained near the ground or water. Probably of equal importance, knowledge has been gained on how to reduce adverse ground effects associated with many VTOL designs.

Transonic-Supersonic Speeds

Supersonic aircraft design has always been compromised by conflicting requirements of subsonic flight associated with taking off, landing, and cruising. Recently Langley proposed a new type of aircraft incorporating the principle of wing variable sweep to obtain optimum subsonic as well as supersonic characteristics. After extensive wind tunnel tests, an aerodynamic configuration has been developed that provides large changes in wing sweep with relatively small changes in stability. This was obtained by sweeping back the outboard wing panels only, without any changes in fore and aft wing position. Performance studies indicated that an aircraft designed with this feature could have excellent short field take-off and landing characteristics, long subsonic range, extended loiter capability (ability to fly in a given vicinity at relatively low speeds for long periods of time), and efficient high-altitude supersonic cruising.

In recent months experimental studies were made to develop optimum supersonic cruise airplane designs. A swept-wing transport was developed for flight at Mach 2, utilizing results of local flow studies to improve the wing-fuselage-nacelle combination. This program achieved the highest experimental lift-drag ratio (which is indicative of the aircraft's range and efficiency) for a complete configuration yet attained at Mach 2.

To reduce interference effects, recent experimental studies were conducted at Mach numbers from 2 to 4, using various shapes and designs of wings and fuselages, and changing engine placement. These studies have provided valuable aerodynamic data to improve design; the combination of these elements into an integrated configuration has increased lift-drag ratio by 10 to 20 percent over the highest ratios previously attained.

As noted previously, the ratio of lift to drag is the primary aerodynamic factor governing range and aircraft efficiency; it is composed of three basic elements -- wave or pressure drag, produced at supersonic speeds by the shock-wave pattern over the aircraft (about 15 percent), skin friction drag (about 35 percent) and drag due to lift (the remainder).

Until recently, the skin-friction drag of an aerodynamically smooth surface was considered to be at an irreducible minimum. However, recent experiments at supersonic speeds have shown important reductions in turbulent skin friction when small amounts of air were injected into the boundary layer. The source of injected air would be the so-called "bleed" air available from the air inlets. This air-injection technique may also help reduce surface temperatures at supersonic speeds.

In the field of drag resulting from lift, new insight has recently been gained in regard to the use of wing camber* and twist as a possible way of reducing such drag. After analysis and correlation of theory with experiment, marked improvements in lift-drag ratio have been measured experimentally for twisted and cambered wings in the moderate supersonic speed range, pointing the way to efficiency as high as, or higher than, that of present-day subsonic jet aircraft. Incorporating these advances into practical configurations would improve performance in military aircraft, as well as help usher in the era of supersonic transports.

Hypersonic Speeds

Exploratory research programs are in progress to define the problem areas and establish the general feasibility of air-breathing craft capable of sustained cruising at hypersonic speeds. Indications are that within the next few years development of airplanes with cruising speeds of about Mach 6 could be seriously considered. At higher speeds, however, aerodynamic heating -- especially in the interior of the engine -- presents grave problems from a materials standpoint, and it remains questionable that sustained cruising at Mach 8 to 12 can become practicable.

AIR-BREATHING ENGINES

Research on air-breathing engines at Lewis Research Center has been primarily devoted to problems of supersonic inlets for turbojets and ramjets. The inlet investigation, conducted in the 8x6-ft. and 10 x 10-ft. supersonic wind tunnels, includes both basic inlet research, and special

* The curvature of the median line from the leading edge to the trailing edge of the wing or airfoil.

inlet research and evaluation requested by the military services.

Two basic experiments were conducted in the 10x10-ft. tunnel to estimate accurately preliminary aircraft design performance: 1) the aerodynamic drag of a full-scale inlet boundary layer diverter plate,* measured at Mach numbers of from 2.0 to 3.5; and 2) a rectangular Mach 3.0 inlet was installed beneath a supersonic aircraft configuration with drag measured for various inlet locations. These measurements defined the extent of aerodynamic drag for an inlet-engine package located beneath the aircraft, and the effect of the fuselage on inlet performance.

At the request of the Air Force, the inlet system of the Northrop Corporation Radioplane Division Q4B target drone was installed and evaluated in the 8x6-ft. tunnel. Design performance of this vehicle is anticipated after modifications derived from the tunnel tests are incorporated on the inlet.

Inlet tests for the Talos missile were made in the 10x10-ft. tunnel at request of the Navy. Design performance was checked and the modifications needed were suggested to the contractor for continued missile flight testing.

Work on air-breathing engines at Ames has also been largely devoted to the study of engine inlets. The effect of engine location on the performance, stability, and control of low-aspect-ratio** missiles was studied, and an arrangement was found that reduced the total drag by 25 percent.

A difficulty with missile inlets is that, at the speeds involved, the temperature is so high that it affects the chemical and physical properties of the air. A number of investigations under way are directed toward these problems. Studies of the external and internal characteristics of air-induction systems have shown that pressure can be appreciably increased by removing a small amount of the boundary layer. Theoretical studies have given results applicable to pressure calculations which will greatly reduce the amount of experimentation required.

At Langley Research Center, previous research on air-breathing propulsion systems has been limited to speeds below

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* A device placed between the jet inlet and an adjacent surface to redirect low-energy air around the jet.

** The ratio of the span to the width of a wing or airfoil structure.

Mach 4 for possible application to long-range manned aircraft, missiles, and boosters for space vehicles. Analytical and experimental programs on air inlets, diffusers, and exhaust nozzles are now in progress to investigate feasibility of promising aerodynamic arrangements and to establish the performance that can be achieved at hypersonic speeds in these complex internal-flow systems.

A preliminary wind-tunnel investigation of an internal compression, two-dimensional inlet at Mach 7 was completed, to determine performance level on a simplified model and to discover the associated flow problems. Relatively high pressure recovery, with small losses, was achieved. Detrimental viscous effects, more serious at this high Mach number than at lower speeds, were reduced by bleeding low energy flow or boundary layer air through the side walls.

More detailed investigations of air inlets and exhaust nozzles, with and without temperature simulation, are in progress, and analyses have shown that reasonably short and practical shapes are feasible. In addition, nozzles have been designed to provide a substantial lift force at no loss in thrust, and to aid in obtaining lift-to-drag ratios required for long-range vehicles.

CHAPTER 17

OPERATIONS AND ENVIRONMENT

EMPHASIS ON PROBLEMS OF ADVANCED AIRCRAFT

Problems of flight within the atmosphere have grown more complex with each advance in aircraft design and speed, and with each innovation in the development of high-speed transports, helicopters, vertical take-off and landing (VTOL) and short take-off and landing (STOL) craft. Prime attention is focussed on determining means to insure the safety of vehicles and crews, and upon learning more about the environmental and special conditions under which they must operate. Work on flight problems is going forward at Ames, Langley, Lewis, and at flight research centers.

Operating Statistics

In a long-range cooperative effort with major airlines of the United States and with some foreign operators, NASA installs instruments that record the accelerations, air-speeds, and altitudes of airplanes during entire flights from take-off to landing. Samplings will be made over a period of about two years. Records are returned to Langley for evaluation and analysis. Pointing up development problems that arise when new equipment is introduced, the records show potential sources of structural fatigue not considered in design, and flight practices not in keeping with the design of the airplane. Information already passed on to the airlines and manufacturers has brought about corrections to maintain and improve the safety record of U.S. airlines.

Aircraft Flying and Handling Qualities

NASA is studying problems connected with flying high-performance aircraft and has helped establish performance capability requirements. Special flying techniques have been developed for landing these aircraft with or without power. Effects of crosswinds on take-off capabilities of jet transports have also been investigated.

As noted previously (see Aircraft Aerodynamics), NASA is studying and improving the handling qualities of helicopters to achieve all-weather operational capability. Work on experimental VTOL vehicles is being pushed to improve stability and handling.

An experimental flight study of sonic booms to determine the effects of Mach number, airplane size, flight altitude, and climb angle on ground pressures was conducted by Langley with F8U-3 and B-58 airplanes. Ground pressures and the response of simple buildings were measured. The data so obtained will be used in operational studies to evaluate means of lessening structural damage by means of flight planning and programming for supersonic transports. It has been found that ground pressure can be reduced significantly by increasing the airplane's climb angle.

Since sonic boom intensity on the ground is related to the airplane's altitude, proper flight planning is necessary. The airplane must climb at subsonic speeds as high as possible before accelerating to supersonic flight for the remainder of its climb and for cruising. This technique, while not a cure-all, will help alleviate the critical sonic boom problem for supersonic transports.

Studies of Aircraft Landing Problems

Landing Speeds -- A NASA study of factors influencing choice of landing speeds or affecting the safety and precision of the landing approach has disclosed that pilots limit landing speed primarily because of loss of control of flight path angle and attitude. Contributing elements include, among others, poor engine-thrust response and reductions in stability and control at low speeds.

In landings where throttling the engine becomes an important means for attitude control, the dynamic engine responses of a number of jet-propelled airplanes were investigated. Flight studies were also made to show how a continuously controllable thrust reverser affects the landing approach characteristics of a jet-powered aircraft. Thrust reversal results showed: 1) reduced landing approach speeds for steep approach angles; 2) a widened selection of approach angles; and 3) improved glide path control and more accurately controlled touchdown points.

Runways -- Rough taxiways or runways impose significant stresses on aircraft and can make for serious control difficulty during take-off and landing. In many cases, the necessity of operating from unprepared fields has important military bearing.

For several years, Langley has been conducting an organized study of ground bumps, airplane behavior, and the influence of factors such as speed and airplane weight. Progress has been made in determining how rough runways may be -- or how smooth they must be -- for civilian and military aircraft of different types.

Flight Safety

Thrust Reversal -- Investigation in the Ames 12-foot pressure wind tunnel, using a scale model typical of current jet transports, indicated that reverse thrust can be employed effectively to brake high-speed descents from operational altitudes. Applying reverse thrust under cruise conditions would also more than double the drag and initial rate of descent without lessening the pilot's control or causing the airplane to be buffeted.

Noise

Suppression -- Noise from jet engines is created by the high velocity of jet exhaust gases and by the rapid rotation of compressor blades (compressor whine). Jet-exhaust sound suppressors developed by NASA are being flight-tested to determine over-all effects on aircraft performance.

Several methods for reducing compressor whine are being studied. Preliminary studies are also under way to study noise problems expected when advanced types of supersonic transports begin operating.

Generation -- Studies of turbulence and noise associated with a jet (an exhaust pipe) make it possible to predict the noise field of any jet. The method applies equally to small subsonic jets or to large rockets. Studies of low-turbulence, low-noise nozzles have greatly increased knowledge of noise-suppression techniques.

Boundary Layer Noise -- A turbulent boundary layer near the surface of any vehicle moving through the atmosphere produces fluctuating noise at the vehicle surfaces. The magnitude of these pressures depends on characteristics of the boundary layer and velocity of the vehicle. At transport aircraft velocities, pressures transmitted through the skin of the aircraft can result in high interior noise levels. At the extremely high speeds of ballistic missiles, noise pressures become great enough to cause structural damage and can result in malfunctions of delicate control and electronic equipment.

Basic studies of boundary layer turbulence and noise are being conducted over the entire range from transport flight speeds to ballistic missile reentry speeds. Methods for predicting noise levels and their effects are being developed.

Rocket Noise -- Noise fields around rocket engines have been measured, with particular attention to launching manned space vehicles. Results indicate that data from small-scale tests can be correlated with those for very large engines.

Future Supersonic Transports

The delta-wing configuration used for supersonic airplanes requires greater pilot attention than do older types because of poor lateral-directional characteristics. Thus, during landing, a considerable speed margin above stall is needed to allow for airspeed fluctuations. To determine minimum acceptable characteristics in landing approach, tests were conducted, using a variable-stability airplane, to investigate ranges of damping and bank-to-sideslip ratios of present craft and of those projected for the future. Results were obtained for both normal operation and also for failure of stability equipment -- such as power boost and automatic control dampers -- to limit airplane motions. Pilots agreed with theoretical findings previously made, that greater damping is required with increased bank-to-sideslip ratio. From the standpoint of control, an investigation using both fixed and moving simulators and airplanes, disclosed that roll damping and roll-control power boosting were necessary to establish a standard for satisfactory roll performance.

Studies of Spacecraft Landing Problems

A healthy, trained parachutist can normally land without serious injury by using the shock-absorbing power of his bent knees. If, however, he parachutes in a rigid container (such as a capsule coming from space or ejected from a hypersonic vehicle), there must be some shock-absorbing medium to take the place of the man's springing legs. Similarly, delicate instruments landed by parachute from missiles or spacecraft must be protected from landing shock. A Langley program seeks to determine the effectiveness of several methods of shock absorption that can be used for bringing capsules down softly, on land and in water, using airfilled bags, springlike structures, and crushable material as shock absorbers.

When a vehicle makes an emergency landing, it may come in much faster than the planned rate of descent. The pilot must be safeguarded against such a possibility. Work is in progress on blocks of crushable materials to cushion the pilot and absorb landing shock. The material has been subjected to many tests, and results show that its use definitely increases the pilot's chance of surviving a crash landing.

Hard Surface Landing of a Winged Space Vehicle

An investigation has been made of landing stresses undergone by a winged space vehicle having a main-skid, nose-wheel (X-15 type) landing gear employing the plastic-deformation properties of a metal to absorb the landing shock. Simple aluminum cantilever elements were incorporated into the gear struts in place of shock absorbers, and deformed in bending during landing impact. Data on loads were obtained with an airplane on a runway surface at the monorail facility of Langley's Hydrodynamics Division. Many variations of landings were tried, using different approaches and sinking speeds and different cargo weights. An alternate nose-skid gear and an alternate nose-wheel gear position were also investigated. A few landings on smooth water were also made, using a nose-skid main-skid gear.

For a common landing gear configuration with the main gear near the wing trailing edge and the nose gear far forward, severe loading occurs at initial nose gear contact. A maximum nose wheel impact load of approximately 5.5g was experienced with plastic-deformation struts at a landing trim of 13 degrees, a gross load of 5,000 pounds, and a sinking speed of five feet per second.

Inflated-Sphere Soft-Landing Techniques

NASA plans call for instrument packages to be dropped "softly" on the surface of the moon and planets. One technique under study is to enclose the package in a gas-inflated plastic sphere. Analysis indicates that vacuum tubes and other delicate equipment so enclosed can withstand impact velocities as high as 600 to 1,000 feet per second, and that payloads as large as 70 percent of the total mass of the landing vehicle can be accommodated.

Pilot Performance

The role of piloted-flight simulators in aeronautics and space research is on the increase. Experimental vehicles, such as the X-15, VTOL aircraft, boost gliders, and manned satellites, are simulated with electro-mechanical trainers in which the flight motions and other characteristics of these vehicles are investigated with pilots at the controls.

Effects of normal (head-to-foot) and longitudinal (front-to-back) gravity fields on the pilot's ability to control a vehicle when it plunges into the atmosphere are being studied, using the centrifuge at the Aviation Medical Acceleration Laboratory, Naval Air Development Center, Johnsville, Pa. (see Project Mercury). The centrifuge is also being employed for the X-15 program and other NASA research.

Simulators

Side-Located Controllers -- Tests have shown that side-located controllers which move about two axes and govern the vertical and horizontal motion of the flight vehicle are superior to conventional center-located control sticks for use by pilots in high-performance flight vehicles. The characteristics of a number of side-located flight controllers having three degrees of freedom are being tested in ground-based cockpit simulators at Langley. The better configurations, on the basis of pilot performance and ease of operations, are to be tested in flight. Such tests may lead to better pilot control of hypersonic and high acceleration vehicles.

Weightlessness Simulator -- A device under development at Langley to simulate weightlessness consists primarily of a rotating water tank in which an animal or human subject can be wholly immersed. The chief purpose is to deprive the subject of the same orientation cues that he would be missing in a weightless state. Objective and physiological measurements will be made. The device is currently undergoing shakedown tests with immersed subjects.

Pitch-roll Motion Simulator -- This device, also at Langley, supplies the pilot with cues that simulate the angular motion of a vehicle in flight. The device has undergone preliminary testing and is currently being set up to simulate the motions of the Mercury satellite vehicle through its retro and reentry maneuvers. It will be used to learn more about how the pilot will respond to angular motions in carrying out these maneuvers in actual flight. It will also aid in designing and/or improving controllers, instruments, and related equipment to perform maneuvers adequately.

Full-View Visual Presentation System -- A third simulator at Langley is a device developed to examine, without danger, a pilot's ability to perform terminal maneuvers visually with reentering winged satellites or other low lift-to-drag ratio aircraft. The device is currently under design and construction.

VTOL Simulation

A Sikorsky AO3S-1 (Commercial S-51 model) helicopter has been modified electronically to simulate VTOL aircraft during the hover stage. Control power and damping can be varied with this experimental craft and the best set of combinations for each VTOL vehicle can be determined. To date, three types of VTOL aircraft have been simulated. Manufacturers have been informed of suggested changes in control power and damping and NASA and company pilots have been trained in the flying characteristics of each vehicle before flying the actual aircraft.

Simulation of Satellite Vehicles

To determine how well pilots can control the motions and trajectories of several proposed satellite designs during return to earth, simulated flights were made using a fixed cockpit simulator.* Stability and control characteristics of the vehicles were documented and displayed to the pilot on instrumentation similar to the types that will probably be

* A device that simulates instrument readings, but not the motion of the simulated craft.

used. Tests were made on the pilot's ability to control: 1) high-drag capsules (including the Mercury capsule); 2) high-drag, variable-lift winged vehicles; and 3) glide capsules.

To reproduce vehicle accelerations during atmospheric entry, further tests were made using a cockpit mounted on the arm of the 50-foot Navy centrifuge noted earlier. The completed tests indicated that pilots can withstand reentry stresses.

Navigation Simulator

Methods of navigating satellite vehicles during reentry and descent to a designated point on the earth's surface were tested, using a simulated piloted vehicle and ground-control center (a cockpit electronically connected to analog computer equipment). Methods of navigation included: 1) ground control (voice) approach methods; 2) on-board computer with visual display to pilot; and 3) automatic hovering control. All three methods were found satisfactory.

Environment

Winds -- Programs are under way to study high-altitude winds by means of rocket smoke trails and to study the detailed nature of cloud turbulence by flying a specially instrumented airplane through clouds. More studies will be required to obtain definite answers, but the recent data obtained will permit research studies of the trends in missile and aircraft behaviors and the modification of current analyses used in the design of flight vehicles.

SECTION IV

ORGANIZATION AND SUPPORTING ACTIVITIES

THE NASA ORGANIZATION

STRUCTURE AND FUNCTIONS

General Plan of Organization

The National Aeronautics and Space Administration is organized around three major program activities -- Space Flight Development, Aeronautical and Space Research, and Business Administration.* Planning and executive direction of NASA programs are vested in Headquarters; program execution and administration are delegated to field research and space flight centers. In addition to the immediate Office of the Administrator, consisting of the Administrator, Deputy Administrator, and Associate Administrator, and their respective assistants, the chief elements of NASA organization are as follows:

Headquarters

Staff Offices provide staff assistance within their areas of responsibilities. NASA staff offices include: 1) Assistant Administrator for Congressional Relations; 2) Program Planning and Evaluation; 3) General Counsel; 4) Public Information; 5) International Programs; and 6) Inventions and Contributions Board.

Research Advisory Committees** assist the Administrator in directing research activity towards scientific and technical problems requiring additional research emphasis. There are 13 such committees in the following areas: 1) Fluid Mechanics; 2) Aircraft Aerodynamics; 3) Spacecraft Aerodynamics; 4) Control, Guidance, and Navigation; 5) Chemical Energy Processes; 6) Nuclear Energy Processes; 7) Mechanical

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* Effective January 1, 1960, NASA's program direction activities were assigned as follows: Office of Advanced Research Programs (directing advanced aeronautical and space research), Office of Space Flight Programs (directing mission planning, payload design and development, and in-flight research and operation), Office of Launch Vehicle Programs (directing booster development and space vehicle launchings) and Office of Business Administration (with functions as in this report).

** Membership of NASA Research Advisory Committees is listed in Appendix G, NASA's First Semiannual Report to Congress -- October 1, 1958 to March 31, 1959.

Power Plant Systems; 8) Electrical Power Plant Systems; 9) Structural Loads; 10) Structural Design; 11) Structural Dynamics; 12) Materials; and 13) Aircraft Operating Problems.

Program Direction Offices are under the supervision and coordination of the Associate Administrator. These three offices plan and direct NASA programs:

1. The Office of Space Flight Development is concerned with all aspects of space exploration including: design and procurement of vehicles and payloads; launching and monitoring of satellites, space probes, and manned space vehicles; and accumulation and interpretation of data. The office directs and coordinates the activities of the Goddard Space Flight Center, Greenbelt, Md.; Jet Propulsion Laboratory, Pasadena, Calif., operated by a NASA contractor; Wallops Station, Wallops Island, Va.; and NASA installations at the Atlantic Missile Range, Cape Canaveral, Fla., and the Pacific Missile Range, Point Arguello, Calif.

2. The Office of Aeronautical and Space Research directs and coordinates the activities of Langley Research Center, Hampton, Va.; Lewis Research Center, Cleveland, Ohio; Ames Research Center, Moffett Field, Calif.; and Flight Research Center, Edwards, Calif. The office conducts a program of basic and applied research in support of aeronautics and space science and technology. It contracts with laboratories of industry and of educational and non-profit institutions for supplementary research.

3. The Office of Business Administration manages and directs administrative and management support activities of NASA as described by the names of its major divisions; Budget and Fiscal, Procurement and Supply, Personnel, Security, Technical Information, Audit, and Administrative Services. It also provides management analysis, safety, and facilities coordination services.

Field Installations

Execution of NASA in-house research and development programs is accomplished at nine Government-owned and operated facilities and one Government-owned, but contractor-operated, installation.

Research Centers -- Chief areas of research include aerodynamics and flight mechanics; propulsion systems; structural materials; and operating problems. In addition to their work in advancing the frontiers of knowledge in aeronautics and space sciences, the centers conduct research for the military in support of new weapons systems. NASA research centers and their functions, and brief summaries of activities during the reporting period are shown below.

1. The Langley Research Center, Hampton, Va., is responsible for research, both basic and applied, in aeronautical and space flight fields. The work of this center is primarily centered upon research in aerodynamics, fluid mechanics, stability and control, vibration and flutter, and loads, structures, and materials.

During the period of this report, Langley performed research and development on such projects as inflation techniques for inflatable satellites, design of vehicles for space flight, Vertical Take-Off (VTOL) and Short Take-Off and Landing (STOL) aircraft, ground cushion machines, multi-staged solid fuel rocket systems, and the Mercury Program. In Project Mercury, Langley is responsible for establishing tracking stations and monitoring contracts for the Mercury range. During the period, Langley Research Center participated in studies and tests relative to Mercury noise vibration and fatigue studies, control of capsule in flight, pilot safety during early flight, free flight tests of models, water and land impact, floating of the capsule, wind tunnel tests, and fabrication of the capsule for the Little Joe tests.

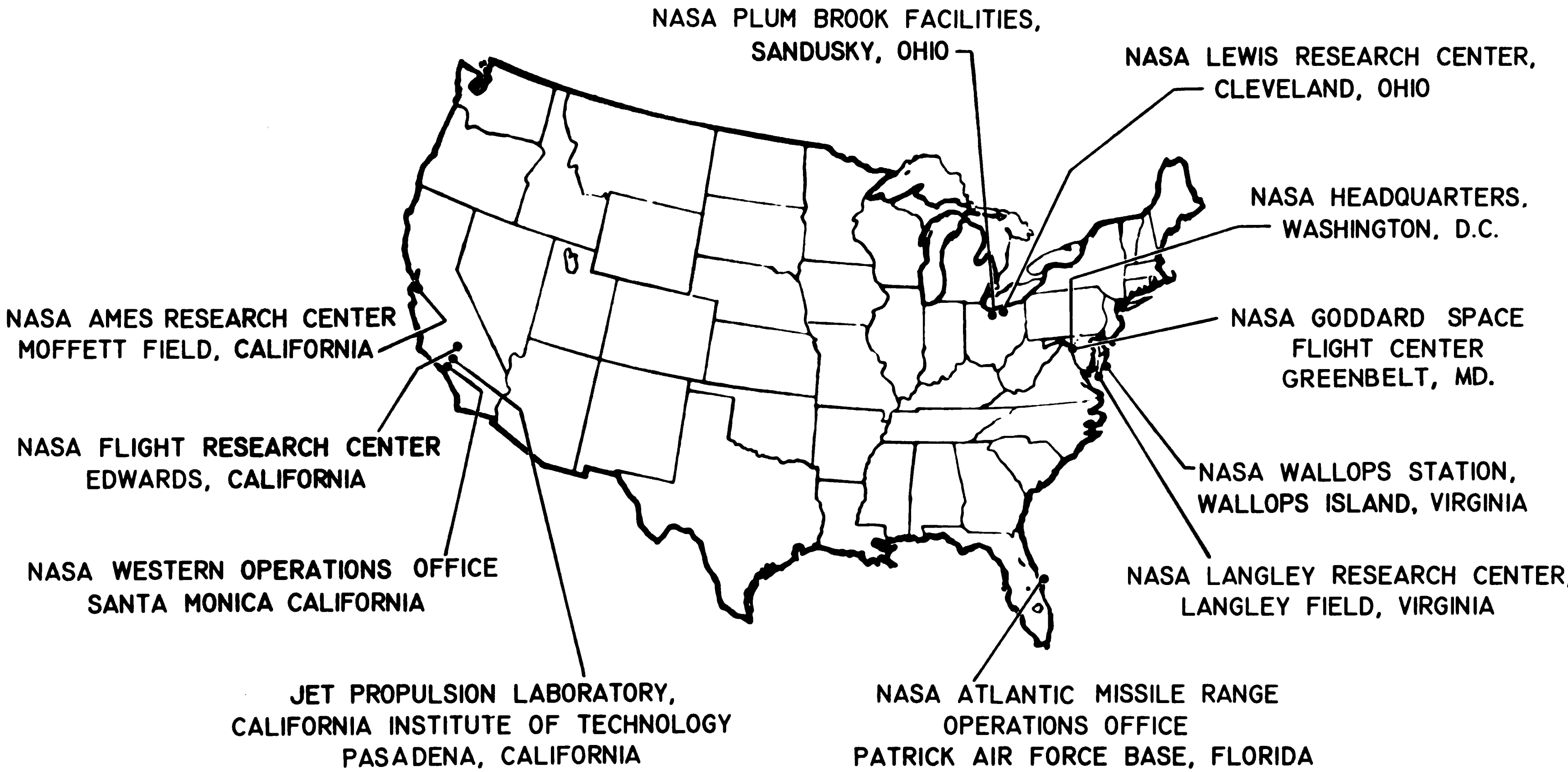
2. The Ames Research Center, Moffett Field, Calif., is responsible for research, both basic and applied, primarily in the fields of aerodynamics, fluid mechanics, and loads relating to aeronautical and space flight problems. This Center also performs selected research studies relating to fluid mechanics, stability and control and vibration and flutter.

Among research and development projects in which Ames was engaged in during the period were: orbital attitude stabilization of the meteorological satellite (Project Nimbus); attitude control systems, optical error sensors, and power supplies for an orbiting astronomical observatory; the defining of the dynamic instability of the Mercury capsule; problems of space vehicles -- particularly reentry; high speed aerodynamics especially in supersonic and hypersonic speed ranges; VTOL and STOL aircraft; missile and supersonic bomber (B-70) problems; and impact studies.

3. The Lewis Research Center, Cleveland, Ohio, is responsible for research, both basic and applied, primarily in the areas of aeronautical and space propulsion, including electric and nuclear propulsion systems. It is responsible for operating the Plum Brook research reactor facility at Sandusky, Ohio, and for nuclear and rocket systems research. The center is also engaged in research activities relating to high temperature materials and rocket fuels.

Accomplishments of Lewis during the period of this report included developing a nickel-base, high-temperature alloy superior for some applications to other available alloys,

NASA FACILITIES



developing and demonstrating an experimental ion-rocket engine, fabricating the instrumented pressurized portion of the "Big Joe" Mercury capsule, and modifying an existing high-altitude facility for laboratory evaluation of Mercury systems in a simulated space environment.

4. The Flight Research Center, Edwards, Calif., was formerly called the High Speed Flight Station. It is primarily responsible for aircraft flight research involving problems of stability and control, handling qualities, performance, loads, propulsion aerodynamics, and aerodynamic heating. The center is responsible for the operation and testing of the X-15 research airplane which made its first powered flight on September 17. The center's contribution to Project Mercury included an investigation of human capability for controlling multi-staged rocket-boosted vehicles under the acceleration stress of launching, and drogue parachute tests.

Space Flight Development Installations -- In addition to its existing research centers, NASA has established four field installations whose work relates primarily to space flight and space sciences and its applications.

1. The Goddard Space Flight Center, Greenbelt, Md., is the first major installation in the United States devoted entirely to the investigation and exploration of space. In addition to modern laboratories, buildings, equipment, and supporting facilities being constructed at Greenbelt, the Center has launching and operational facilities at the Atlantic Missile Range, Cape Canaveral, Fla.; the Pacific Missile Range, Point Arguello, Calif.; Wallops Station, Wallops Island, Va.; and Fort Churchill, Canada. It also operates the world-wide network of Minitrack stations. The center's three areas of research and development are: (a) manned satellites such as Project Mercury; (b) space sciences and satellite applications such as investigating rocket astronomy, ionospheres, payload systems, and tracking and data systems; and (c) booster development such as the Delta launching vehicle. Goddard has the bulk of responsibility for earth satellite programs and Project Mercury. Among activities it managed during the report period were the Pioneer VI and Vanguard III experiments.

2. The Jet Propulsion Laboratory (JPL), Pasadena, Calif., is a Government-owned facility operated under contract by the California Institute of Technology. About half of JPL's total work is for the Army and Air Force.* JPL concentrates its efforts in civilian space technology on research and development in lunar and interplanetary programs. During the report

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* During the reporting period, JPL was at work on the Sergeant, an Army solid fuel missile, and was engaged in wind tunnel research for the Army and Air Force.

period, it provided technical direction and contract monitoring for NASA's deep space tracking network, began construction of transmission facilities for its Goldstone, Calif., deep space receiving station, and conducted research and development in the fields of physics, gas dynamics, propulsion, materials, and electronics.

3. Wallops Station, Wallops Island, Va., is a facility for ground-launched rocket-propelled airplanes, missiles, and spacecraft instrumented to transmit information on flight characteristics to ground telemetering stations which analyze the information. Water landing, parachute deployment, escape system, reentry heating and ionospheric tests are conducted at the station. Among activities carried out at the station during the last six months were Mercury escape system tests; four and six-stage rocket launchings; and sounding rocket launchings (including two with sodium flares). "Little Joe" Mercury tests are conducted at Wallops Station.

4. The Atlantic Missile Range Operations Office, Cape Canaveral, Fla., is maintained to coordinate the schedule and use of test and range facilities at AMR for NASA programs.

Western Operations Office, Santa Monica, Calif. -- The Western Operations Office provides administrative and management support for the rapidly expanding NASA research and development activities west of Denver, Colo. In addition, it provides liaison with industry, scientific institutions, and universities in the Far West.

Significant Organizational Changes*

Associate Administrator Appointed -- Richard E. Horner was appointed Associate Administrator of NASA on June 1, 1959. The Associate Administrator assists the Administrator and the Deputy Administrator in the over-all management of NASA operations by directing and coordinating the activities of the Office of Space Flight Development, Office of Aeronautical and Space Research, and Office of Business Administration.

Western Operations Office Established -- The Western Operations Office was established on August 25, 1959, after a reorganization and expansion of the functions of NASA's Western Coordination Office. Administrative and management functions were added to the liaison function previously performed by the Western Coordination Office.

* In October 1959, the President announced his intention to transfer the Development Operations Division, Army Ballistic Missiles Agency, Huntsville, Alabama, to NASA. The President's transfer plan will be forwarded to Congress in January.

High Speed Test Flight Operations Consolidated -- During September, NASA took action to consolidate high-speed test-flight operations performed by the Langley, Lewis, and Ames Research Centers, and by the High Speed Flight Station. Chief reason for the realignment is economy resulting from centralization. The High Speed Flight Station, Edwards, Calif., was chosen as the center for such work because of its natural lake bed and relative remoteness from both built-up areas and congested airlanes. The station was later renamed Flight Research Center.

Beltsville Center Renamed -- The Beltsville Space Flight Center was renamed Goddard Space Flight Center in honor of the late rocket pioneer Dr. Robert H. Goddard. The Center was assigned a Greenbelt, Md., address.

Pilotless Aircraft Research Station Renamed -- The Pilotless Aircraft Research Station, Wallops Island, Va., was renamed Wallops Station.

PERSONNEL

Personnel Strength

On September 30, 1959, NASA had 9,348 civilian staff members as compared to 8,685 on March 31, 1959. Staffing plans call for a total NASA civilian strength of 9,988 by July 1960.* The increased number of personnel are required largely for support of the manned space program which begins with Project Mercury. Distribution of personnel between various organization elements is shown in Table 1 below.

Functional Description of Staffing

Of the 9,348 personnel, 27-1/2 percent were research scientists, 8 percent support personnel such as mathematicians and engineers, 8.8 percent technicians; 39.7 percent skilled, semi-skilled, and unskilled laborers; and 16 percent professional, administrative, and clerical personnel. In addition 2600 employees of the Jet Propulsion Laboratory, California Institute of Technology, are under contract to NASA. General Schedule (GS) employees totaled 5,431; Wage Board (WB), 3,713; and Excepted, Statutory, When-Actually-Employed (WAE) and Alien, 204. NASA employed 11 alien scientists on September 30. The Civil Service Commission has authorized hiring of 50.

* This figure does not include the personnel of the Development Operations Division.

ORGANIZATIONAL CHART
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SEPTEMBER 30, 1959

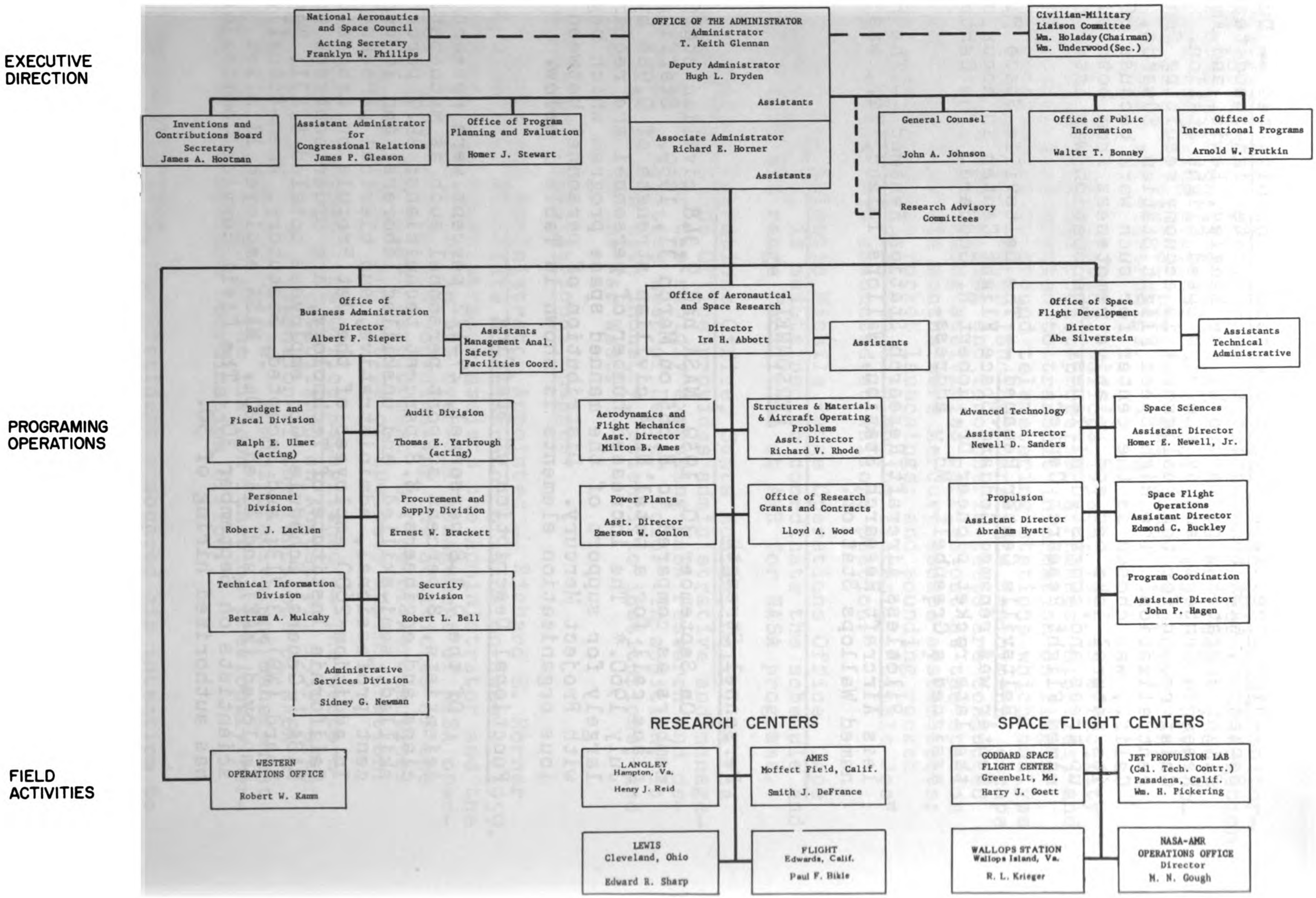

TABLE 2

Distribution of NASA Personnel

	Oct. 1, 1958		Mar. 31, 1959		Sept. 30, 1959	
	Civilian	Military	Civilian	Military	Civilian	Military
Langley*	3368	20	3587	13	3877	11
Ames**	1413	21	1434	16	1434	18
Lewis***	2713	25	2711	30	2788	24
Goddard****	—	—	296	—	467	6
Flight*****	292	8	303	4	336	2
Total, Field	7786	74	8331	63	8902	61
Headquarters	180	—	354	1	446	5
TOTAL	7966	74	8685	64	9348	66

* Langley Research Center, Hampton, Va.
** Ames Research Center, Moffett Field, Calif.
*** Lewis Research Center, Cleveland, Ohio
**** Goddard Space Flight Center, Greenbelt, Md. (includes field units of Wallops Station)
***** Flight Research Center, Edwards, Calif. (prior to September 22, 1959, the High Speed Flight Station)

TABLE 3

Appointments of Key Personnel April 1 - Sept. 30, 1959

	Headquarters	Date
Richard E. Horner	Associate Administrator	June 1, 1959
Ira H. Abbott	Director of Aeronautical and Space Research	July 1, 1959
Milton B. Ames, Jr.	Assistant Director of Research (Aerodynamics and Fluid Mechanics)	May 17, 1959
Emerson W. Conlon	Assistant Director of Research (Power Plants)	July 7, 1959
John P. Hagen	Assistant Director (of Space Flight Development) for Program Coordination	April 20, 1959
Arnold W. Frutkin	Director, Office of International Programs	Sept. 14, 1959
	Field Establishments	
Harry J. Goett	Director, Goddard Space Flight Center	Sept. 1, 1959
Paul F. Bikle	Director, Flight Research Center	Sept. 15, 1959
Robert W. Kamm	Director, Western Operations Office	Aug. 31, 1959

Professional Activity

During the period March-September 1959, NASA scientists presented numerous reports on aeronautical and space sciences and applications at meetings of scientific and technical societies and contributed numerous articles to professional and scientific journals. In addition, they submitted a total of 76 descriptions of inventions to Headquarters (compared to 21 in the period Sept. 1958-March 1959, for patent applications.

Recruiting

Recruiting efforts encompassed the nation and included such measures as visits to universities,* classified ads in newspapers and scientific journals, preparation of an article entitled "NASA Careers -- A Study in Space and Aeronautical Sciences" for the "College Placement Journal," and publication of two recruiting pamphlets -- "Careers in Space" which described employment opportunities at Goddard Space Flight Center and "Career Countdown" which encouraged scientists to apply for employment at the various NASA research centers.

RELATIONS WITH OTHER GOVERNMENT ORGANIZATIONS

Civilian Space Technology a Part of Broad National Program

Civilian space technology is an integral part of the overall scientific and technological revolution which is the keystone of the age we live in. Because the realm of civilian space technology is so overwhelmingly interwoven with other technologies and with military and political considerations, NASA must work with a number of other organizations.

Coordinating Groups

National Aeronautics and Space Council -- The Administrator of NASA participates in the meetings of this council which is chaired by the President of the United States. Its statutory membership and functions are described in Section 201 of Public Law 85-568, the National Aeronautics and Space Act of 1958. (See Appendix A.)

Civilian-Military Liaison Committee -- Established by the Act, this committee serves as a channel for exchange of information between NASA and the Department of Defense.

* NASA recruiting teams visit over 120 colleges and universities throughout the United States to talk to individuals who will be ready for employment in the near future.

Government Agencies

Names of agencies and fields in which activities are coordinated are given below.

Atomic Energy Commission -- Developing nuclear power plants for space vehicles.

Civil Aeronautics Board -- Technical advice and accident investigation.

Department of Commerce (including Coast and Geodetic Survey, National Bureau of Standards, and Weather Bureau) -- Industrial research and development; geophysical measurements and investigations; and research in atmosphere circulation, solar interaction, and other atmospheric phenomena.

Department of Defense -- Major activities relating to the space program have been transferred from the Department of Defense to NASA since October 1, 1958. In addition to those activities transferred during the prior semiannual period, the CENTAUR and the Tiros Meteorological Satellite projects were transferred during this period. Defense and NASA worked together to effect the smooth transition of these activities from DOD to NASA. Also, NASA and the Department of Defense have been coordinating development of a national tracking program, a national space vehicle program, and military aircraft and missiles.

Department of State -- International scientific relations, including the granting of sites for Minitrack installations and installations for monitoring the Mercury capsule.

Federal Aviation Agency -- Aeronautical development.

Federal Communications Commission -- Assignment of radio frequencies for monitoring and tracking satellites.

National Academy of Sciences and the Space Science Board of the National Research Council -- NASA participation in the International Geophysical Year (IGY). The Academy provides NASA with the results of research arising from its research grants, chiefly to university scientists and engineers. NASA assists the researchers by providing full-scale facilities for applying the results of research. The Space Science Board assists in providing working relations between space science activities and other scientific activities of the Federal Government. The board also assists in developing international space and science cooperation.

National Science Foundation (NSF) -- Aeronautical and space sciences research. Primary program coordination is by the Director, NSF, and the NASA Administrator through the

National Aeronautics and Space Council of which both are members. Technical coordination is through the Space Science Board which is jointly supported by NSF and NASA. Coordination at the working level is by the headquarters staffs of NSF and NASA.

Office of Civil and Defense Mobilization -- Development of plans for essential operation in case of war.

Smithsonian Institution -- Optical satellite tracking.

United States Coast Guard (Treasury Department) -- Aeronautics and flight safety.

United States Information Agency -- Distribution of scientific information abroad.

CHAPTER 19

OTHER ACTIVITIES

PROCUREMENT AND CONTRACTING

Decentralization and Aid to Small Business

Salient feature of the NASA procurement and contracting organization is a system of decentralized operation under central policy direction and review by NASA headquarters. With the exception of grants and contracts for basic and applied research (see Research Grants and Contracts) which are made at Headquarters, the great bulk of contracts are awarded and administered by the NASA field installation responsible for technical direction and supervision of the project. The Headquarters procurement staff is primarily responsible for planning, developing, and issuing procurement regulations and procedures, reviewing and approving major contracts, and assuring compliance with NASA policies and regulations.

NASA Procurement and Contracting Authority and Regulations

NASA purchases and contracts are made under authority of the National Aeronautics and Space Act of 1958 and in accordance with Title 10, Chapter 137, of the United States Code. As NASA and the Department of Defense are governed by the same procurement statute and to a considerable extent deal with the same segment of industry, NASA's policy is to prescribe, when practicable, procurement regulations that are consistent with policies and procedures contained in the Armed Services Procurement Regulations (ASPR).

Procurement Regulations Being Published

In accordance with an agreement between NASA and the General Services Administration, the NASA Procurement Regulations are being published in Chapter 18, Title 41, of the U.S. Code. Regulations promulgated include: administrative requirements in reviewing and approving contracts; procedures in negotiating and awarding contracts for research and development; administration of patent provisions included in NASA contracts; small business policy and program; establishment of a Board of Contract Appeals, and procedures for adjudicating appeals from contractors; and procedures for judging contractor claims for extraordinary equitable relief.

Both Advertising and Negotiations Used in Contracting

NASA usually procures supplies, equipment, services, and construction through formal advertisement for competitive bids and awards of fixed-price contracts to lowest bidders. It usually negotiates contracts for research and development because definitive specifications for research and development work can seldom be developed. Even in negotiation, NASA policy is to encourage widest possible competition by asking all qualified firms to submit detailed proposals describing their technical programs and presenting cost data.

Small Business Program

The Administrator has declared that it is in the interest of the civilian space program that the number of firms engaged in research and development work for NASA be expanded and that there be an increase in the extent of participation in such work by competent small business firms. Procurement instructions have been issued requiring that all proposed purchases and contracts in excess of $2500 be screened by small business specialists at each major purchasing office prior to issuance of bid invitations or requests for proposals, to determine suitability for small business participation or set-aside. NASA contracting officers and small business specialists examine the larger R&D procurements to determine possible subcontracting opportunities for small business firms. Between April 1 and September 30, 1959, about $16,187,000 in purchase orders and contracts went to small business firms -- approximately 35 percent of total obligations arising from purchases and contracts awarded to business firms directly by NASA.

Procurement Agreements with Other Agencies

Many NASA research and development contracts are carried out by firms that also hold military contracts. To avoid duplication of effort, and to use most effectively the resources of NASA and the Department of Defense, formal working arrangements in contract administration have been established between NASA and the military departments. Among other things, these agreements provide that the military department with plant jurisdiction over the particular contractor involved will, upon request, provide NASA with contract administration, audit, and other field services as required.

Major Procurement Contracts

Major procurement contracts awarded during the report period were for Delta, Vega, and the Mercury tracking network. These and other principal active contracts are listed in Appendix M.

Delta -- In April 1959, NASA awarded a $24 million contract to Douglas Aircraft Company, Inc., Los Angeles, Calif., for design, construction, testing, and launching of Delta. The contract calls for delivery of a dozen vehicles during the two years from date of signing.

Vega -- NASA awarded a $33.5 million contract to the Convair Astronautics Division of General Dynamics Corporation, Pomona, Calif., for this booster vehicle in May 1959.

Mercury Tracking Network -- In July 1959, NASA awarded a letter contract to Western Electric Corporation, New York, N. Y., for construction of world-wide tracking and ground-instrumentation stations to be used in Project Mercury. (For details, see Tracking and Data Systems.)

Research Grants and Contracts

NASA is working on some of the most advanced frontiers of science. Universities and other research organizations are encouraged to contribute to NASA programs.

The Research Grants and Contracts Program encompasses all NASA-sponsored research within educational and other non-profit institutions and basic research in industrial organizations. Research is both supporting -- for example, problems of manned space flight, space propulsion technology, investigations of satellite applications, and investigation of the space environment, and fundamental -- for example, theoretical or experimental physical sciences, the cosmological sciences, life sciences, engineering sciences, and socio-economic studies.

Research grants and contracts are based on proposals, generally unsolicited, submitted by organizations desiring to enter the program. Research grants are made only to universities or nonprofit institutions. Research contracts are negotiated with universities, nonprofit institutions, and industrial organizations.

NASA awarded 51 research grants and contracts totalling $4,385,196 during the report period. Research grants and contracts in effect during the period are shown in Appendix L.

TABLE 4

Financial Statement as of September 30, 1959

Appropriations and Transfers for the Fiscal Years 1959 and 1960

	Salaries and expenses	Research and development	Construction and equipment
Approved, Fiscal Year 1959:			
Appropriations to National Advisory Committee for Aeronautics: Independent Offices Appropriation Act, 1959; Public Law 85-844	$78,100,000	------------	$23,000,000
Appropriations to National Aeronautics and Space Administration: Supplemental Appropriation Act, 1959; Public Law 85-766..	5,000,000	$50,000,000	25,000,000
Second Supplemental Appropriation Act, 1959; Public Law 86-30....................	3,186,300	------------	------------
Transfers from the Department of Defense (72 Stat. 433)...........................	------------	154,619,532	------------
Total appropriations and transfers, fiscal year 1959..................	86,286,300	204,619,532	48,000,000
Approved, Fiscal Year 1960:			
Appropriations to National Aeronautics and Space Administration: Supplemental Appropriation Act, 1960; Public Law 86-213..	$91,400,000	$335,350,000	$73,825,000

Status of 1959 Funds as of September 30, 1959

	Allotments	Obligations	Expenditures
Salaries and expenses......................	$86,286,300	$85,491,719	$83,532,931
Research and development:			
Aeronautical and space research........	$12,282,151	$12,142,034	$9,588,589
Scientific investigations in space.....	73,781,148	72,900,459	30,412,742
Satellite applications.................	4,589,000	4,000,329	793,982
Manned space flight....................	48,294,233	47,277,712	17,448,486
Vehicle systems technology.............	1,310,000	810,000	----------
Space propulsion technology............	20,449,000	18,006,306	11,221,686
Vehicle development....................	40,766,000	40,380,322	6,967,732
Supporting activities..................	3,148,000	3,072,487	1,830,311
Total research and development.......	204,619,532	198,589,649	78,263,528
Construction and equipment.................	$48,000,000	$25,024,275	$5,987,701

Status of 1960 Funds as of September 30, 1959

	Allotments	Obligations	Expenditures
Salaries and expenses......................	$91,400,000	$20,898,622	$13,778,210
Research and development:			
Aeronautical and space research........	$27,551,000	$5,238,557	$775,851
Scientific investigations in space.....	47,820,000	12,487,795	55,458
Satellite applications.................	10,850,000	1,792,870	7,486
Manned space flight....................	90,116,000	4,074,000	----------
Vehicle systems technology.............	8,587,000	252,000	----------
Space propulsion technology............	45,287,000	86,150	----------
Vehicle development....................	86,900,000	16,575,000	30
Supporting activities..................	14,709,000	5,057,074	458,586
Bureau of the Budget reserve...........	3,530,000	----------	----------
Total research and development.......	335,350,000	45,563,446	1,297,411
Construction and equipment.................	$73,825,000	$4,001,800	----------

PATENTS

Patent Provisions Cited in Act

NASA's rights to inventions made by contractors in the performance of NASA contracts are delineated in Section 305 of the National Aeronautics and Space Act of 1958. That section provides that inventions made in the performance of work under NASA contracts shall be the exclusive property of the United States whenever the Administrator makes certain statutory determinations concerning the conditions under which the invention was made, unless the Administrator, under regulations prescribed by him, waives all or any part of the rights of the United States to such inventions.

Patent Regulations Published

NASA's procurement patent regulations were published in the Federal Register of May 5, 1959 (24 F.R. 3574-3579). They contain the patent clauses which must be used in NASA contracts and rules and instructions for their use.

Establishment of Patent Counsel at Research Centers

Langley Research Center, Hampton, Va., and Lewis Research Center, Cleveland, Ohio, now provide counsel to prepare patent applications and to advise on matters pertaining to patents and inventions. The counsel is under the administrative jurisdiction of the research center directors but is responsible for professional performance to the General Counsel, NASA Headquarters, Washington, D. C.

Before NASA was established, the Department of the Navy prepared and processed applications for patents on inventions of NACA personnel at the Lewis and Langley Research Centers.

Waiver Regulations Revised

NASA patent waiver regulations were first published in the Federal Register, March 5, 1959 (24 F.R. 1644-1649). On May 18, 1959, thirty-five representatives of industry and Government attended a public hearing on the regulations. Waiver regulations were reviewed and revised. Final waiver regulations are scheduled to be published in the Federal Register late in October. The waiver regulations set forth the policy concerning the granting of waivers and the procedure by which contractors may request the Administrator to waive rights in inventions made under NASA contracts.

Review of Patent Applications

Section 305(c) of the National Aeronautics and Space Act provides for review by the Administrator of patent applications having significant utility in aeronautical and space activities. Under section 305(d) and (e) the Administrator has the prerogative of requesting that any patent having such significance be issued to him on behalf of the United States. During the period, the Commissioner of Patents transmitted to NASA 644 copies of patent applications under the foregoing provisions. Review of these applications indicated that none involved inventions made under NASA contracts, and the Administrator advised the Commissioner of Patents that he would not request that any of these patents be issued to him. This experience disclosed that many of the patent applications transmitted to the Administrator were obviously unsuitable for NASA. Administrative arrangements made with the Commissioner of Patents have reduced the number of applications transmitted to NASA.

Patent Infringement

Section 203(b)(3) of the National Aeronautics and Space Act authorizes NASA to acquire by purchase or lease such interest in patents as it deems necessary. Of three patent infringement claims received during this report period, NASA is investigating one and negotiating settlement of another. A third claim has been withdrawn.

Waiver of Rights in a Contractor's Inventions Is Granted

The first petition for waiver of rights to inventions made under a NASA contract was received in July from a contractor under a contract originated by the Air Force and transferred to NASA. The contractor's request for waiver of rights in forty inventions listed in his petition was granted.

NASA Authorizes 30 Employee Patent Applications

Of the 76 inventions disclosed by employees to the Office of the Assistant General Counsel for Patents during the period, 30 patent applications were authorized. As of September 30, the Office had prepared 12 patent applications.

Contributions Awards

Section 306 of the National Aeronautics and Space Act of 1958 provides for the granting of monetary awards for scientific and technical contributions having significant value in the conduct of aeronautical and space activities. The Inventions and Contributions Board established under the provision of Section 305 of the Act, in addition to its duties relating to the waiver of rights in inventions, reviews and evaluates scientific and technical contributions proposed to the Administration and recommends to the Administrator the granting of awards when appropriate.

During the reporting period, 521 proposed contributions were evaluated.

CONSTRUCTION

Rapid advances in aeronautical and space technology have brought modification and expansion of laboratory facilities to meet research and development requirements. NASA construction expenditures from April 1 through September 30, 1959, totaled $16,795,292. Of this, the bulk was for new research and development facilities. NASA construction activities, as of September 30, included:

Goddard Space Flight Center.

Status of major construction is as follows:

Facility	Percent Complete
Space Projects Building	50
Research Project Laboratory	28
Central Flight Control & Range Operations Building	1

When completed, the Space Projects Building will have a gross area of 59,000 square feet, of which 35,000 square feet will be usable floor space. The Research Projects Building will have a gross area of 73,000 square feet and 41,000 square feet of net usable area. Flight Control and Range Operations Building will have a gross area of 103,000 square feet and net usable area of 66,000 square feet. The differences between gross and net are areas used for lobbies, corridors, service enclosures, and fan lofts, and other mechanical equipment devoted to building operation.

Jet Propulsion Laboratory (JPL).

In addition to a number of projects for the expansion and modernization of existing facilities, JPL has constructed a charged-particle accelerator to simulate effects of interplanetary plasmas, and a low-density gas dynamics facility to study ionization, reaction kinetics, plasmas, and atmospheres similar to those believed to exist on Mars and Venus.

Langley Research Center.

In addition to a number of modifications of existing facilities, the center was purchasing new high-speed electronic analytical and computing equipment to increase the scope and effectiveness of existing programs.

Planned or in progress during the period were construction of a new high-temperature structural dynamics facility, tracking facilities, and a 110-kv cable tie to meet increased demands on the electrical system.

Wallops Station.

Facilities were being expanded to handle larger rocket launchings and otherwise to contribute to greatly expanded space science needs. The nature of the terrain makes beach erosion on the island a major problem, and control projects were under way.

Lewis Research Center.

A number of laboratories for testing missiles and rockets were being constructed. Among these were facilities for testing high-energy rocket engines, hypersonic missiles propulsion, electric rockets, and turbopumps. Existing facilities were being modified.

Ames Research Center.

Ames was constructing two major facilities: one for mass transfer cooling and the other a 12x12-inch hypervelocity helium wind tunnel.

Flight Research Center.

Facilities were being constructed for terminal guidance, computing, and testing for the 1.5-million-pound single-chamber rocket engine. Modifications of existing buildings to house these facilities were under way.

Atlantic Missile Range.

Launching facilities for the Saturn and other advanced space vehicles were under construction. Modifications of other facilities to meet current payload requirements were in progress. Modifications of a building to house the instruments for the Mercury control center were begun.

Various Locations.

Mercury Tracking Network -- Surveys had been completed for station sites in all but one foreign nation, and preliminary engineering plans have been developed for five stations. Site preparation was in progress in Bermuda and Canton Island.

Minitrack Network -- Procurement of equipment for the frequency changeover from 108 mc to 136 mc was underway. Work had started on the four new stations to be completed in calendar year 1960.

Deep Space Network -- Expansion of the Goldstone, Calif., tracking station, from a receiving to a two-way station, was in progress. Construction of antenna equipment and buildings had started. When completed, the Goldstone facility will include an 85-foot diameter tracking antenna and 960-megacycle receiver and an 85-foot diameter transmitting antenna and a 10-kilowatt transmitter which can operate from 890 mc. to 3,000 mc. The transmitter is being built at a site seven airline miles from the receiver. First anticipated use of the Goldstone transmitter-receiver station is as part of Project Echo, to study the feasibility of passive communications satellites.

Examples of New Research Facilities Completed

Typical of the space age facilities completed or being constructed at NASA installations are the following:

Plum Brook Pilot Turbopump Facility -- When completed, the Pilot Turbopump Facility, operated by Lewis Research Center, will comprise a hydrogen pump building, a hydrogen turbine building, a gas generator facility, and a contract building containing data acquisition systems for the other buildings. Already in limited operation, the facility is used to obtain information about performance of turbines in gaseous hydrogen, nitrogen and air and of pumps in liquid hydrogen and nitrogen. It is large enough to obtain results that may be applied not only in designing turbopumps for chemical rocket motors but also in designing facilities to study turbopumps for nuclear-powered vehicles having extremely high rates of propellant flow.

In the control building are two large tanks, one containing the data acquisition systems and the other containing the controls and other instrumentation needed for conducting tests at the facility. The turbine building houses a research turbine driving a dynamometer. Hydrogen is supplied to the turbine from portable, high-pressure tanks. The turbine may also be powered by either a gaseous-nitrogen or high-pressure air system. Control and turbine buildings were in full operation when this report period began.

The pump building houses a cryogenic pump test rig, driven by an air turbine. Six thousand-gallon storage vessels for liquid hydrogen beside the building provide either a closed-loop test system or an open-end system, pumping from an inlet to a receiver tank. Other equipment, such as oxygen tanks and gas-generator equipment, is moved into the area on trucks. The pump building became fully operational in September 1959. Work has begun on a gas-generator facility, scheduled for completion in March 1960.

Scheduled projects include tests of: 1) a series of single-stage axial-flow hydrogen pumps; 2) a series of single-stage turbines operated with gaseous nitrogen and hydrogen; 3) a high-pressure-hydrogen centrifugal pump model of the type to be used in a hydrogen-oxygen booster vehicle; 4) a bleed turbine model of a hydrogen-oxygen booster; and 5) a gas-generator for a hydrogen-oxygen booster.

Langley Hypersonic Physics Test Group -- The Langley Research Center hypersonic test area is employed largely for studies of materials and their capabilities of withstanding high temperatures and other environmental factors. Much effort is devoted to the design of space vehicles. Of urgent concern in development of space vehicles are the effects of micrometeor impacts, of radiation, and of extreme temperatures on the strength and permanence of materials. The area is also utilized for rocketry investigations. Main facilities are:

1. 500-kw, DC Arc-Jet Test Tunnel can provide air temperatures up to about 10,000°F. Placed in full operation in August 1959, it has been used principally to develop design and working techniques for the 2000-kw, DC Arc-Jet Test Tunnel scheduled for completion in December 1960. Studies have been directed toward determining satisfactory materials for electrodes, nozzle, and other equipment and optimum spacecraft design; and developing operational techniques for maintaining arc stability. As the 2000-kw tunnel construction advances, the smaller jet tunnel will be phased into other types of high-temperature research.

2. Chemical Physics Laboratory includes a furnace to permit tests at temperatures as high as 5000°F. and equipment for studying kinetics and surface phenomena such as ablation. The laboratory started full-scale operation in June 1959.

3. Impact and Projectile Range is devoted to study of the effects of micrometeoroid impacts on materials for use in space vehicles and payloads. It includes a test chamber 100 feet long in which pressures between two atmospheres and a low vacuum can be attained. Means are provided to speed simulated micrometeoroids to impact velocities of more than 20,000 feet per second. Now in partial use, the range should be in full operation by January 1960.

4. A group of facilities for studying rocket-engine ignition systems, destruct systems, and other devices required for the research programs. The

group, which went into full operation in June 1959, includes:

(a) Propellant Processing Laboratory which can make up, cast, and cure fuel batches weighing up to 125 pounds.

(b) Rocket Assembly Building which contains, among other equipment, special lathes to machine the propellant grain.

(c) Rocket Test Unit which consists of two test cells (one for solid-fuel rockets and one for liquid-fuel rockets) that provide thrusts as high as 60,000 pounds.

Lewis Electric Rocket Research Facility -- Facilities for electric rocket research must simulate conditions existing in space, particularly very low pressures. An electric-rocket test facility consisting of four cylindrical tanks is being installed. The first was successfully operated in June 1959 when an ion engine prototype was test run. Vacuum pumps, connected to the bottom of the tank, evacuated air that came in from unavoidable minute leaks and kept the interior pressure at about one millionth of atmospheric pressure when the ion rocket was not operating. The tank interior was maintained at about one-thousandth of atmospheric pressure during ion engine operation.

Since vacuum pumps cannot fully remove electric-rocket exhaust gases, special means were devised to maintain the vacuum during operation. These consist essentially of providing a large, very-low-temperature surface area on which the gases are frozen. After operations cease, the temperature rises, and the gas vaporizes and is pumped out.

The vacuum-tube power supplies are capable of supplying voltages up to 40 kv and currents up to one ampere, enough to test ion rockets with as much as 0.1 pound of thrust.

A second tank facility, similar to the first, was given its final checkout in September. Most power equipment to operate ion rockets inside the tank had been received by September 30. Installation of the two remaining tanks is scheduled for October and November 1959. Three of the tanks are about five feet in diameter and 16 feet long. The fourth is about three and one-half feet in diameter and seven feet long. In addition to testing small-scale ion engines and their components, scientists will use this facility to obtain additional data needed in designing large facilities for research on full-scale electric rockets.

INFORMATION

Policy

Information policy of the National Aeronautics and Space Administration is delineated in Public Law 85-568 as follows: "The Administration, in order to carry out the purpose of this act shall....provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." NASA accomplishes this objective by a broad technical and public information program.

Technical Information

NASA disseminates its technical information through: 1) talks by its scientists before professional societies, 2) articles and reports in scientific and technical journals, and 3) NASA technical publications which are available to organizations and individuals in the aeronautical, space, and other scientific fields. In addition, unclassified NASA publications may be purchased by the general public.

Technical Publications -- NASA technical publications include:

1. Technical Reports -- Unclassified presentations that completely cover a project or investigations and are of apparent permanent reference value.

2. Technical Notes -- Unclassified presentations that cover completed phases of projects or investigations and other presentations that have transitory value.

3. Technical Translations -- Significant foreign language technical documents that have been translated into English for the use of NASA's technical staff and for general distribution.

4. Technical Memorandums -- Publications containing security-classified and other information necessitating controlled distribution.

Publications Distribution -- During the report period, NASA distributed 194 unclassified technical publications and 135 security classified publications to authorized addressees on appropriate mailing lists. In addition, NASA handled 14,360 letters requesting specific publications.

Announcements List Available Publications -- New NASA publications, newly-declassified NASA publications, and British and AGARD (NATO Advanced Group for Aeronautics Research and Development) documents for which NASA is depository and distributor are listed in NASA "Technical Publications Announcements" issued at intervals of two to four weeks. The announcements are distributed to private industry, Government agencies, libraries, and universities.

NASA Library Holdings Increase -- Widening technical activity and consequent need for additional technical reference material have increased NASA acquisition of books periodicals, and reports for its Headquarters Library. The library is open to the public.

Financial Support for Non-NASA Bibliographic Projects -- NASA provides financial support for the "Monthly Index of Russian Accessions", prepared by the Library of Congress, for the "Abstracts of Aviation Medicine," prepared under the direction of the Aero-Space Medical Association, and for several other non-NASA bibliographies with aerospace implications.

NASA Issues Index of NACA Technical Publications -- National Advisory Committee for Aeronautics technical publications, issued or made available through declassifications during the 15 months preceding the establishment of NASA, are listed in a subject Index produced by NASA in July. The Index was distributed through the NASA technical publications mailing lists. Additional copies are available upon request from the Office of Technical Information.

ASTIA Services Provided NASA Contractors -- NASA has completed arrangements to provide its contractors with the same technical information services that are furnished to Department of Defense contractors by the Armed Services Technical Information Agency (ASTIA). Copies of all NASA technical publications go to ASTIA for announcement purposes. DOD contractors may secure NASA publications direct from NASA or ASTIA.

Public Information

Press Releases and Conferences -- NASA regularly prepared and issued news releases, fact sheets, photographs, and film clips on its current activities. During major space experiments, NASA maintained a 24-hour information service for newspaper, wire service, magazine, television, radio, and newsreel media and arranged press conferences at which officials and scientists explained the experiments. Between April 1 and September 30, 1959, press conferences were held on the Jupiter Biomedical Experiment, the Mercury Astronaut Team, the Astronaut Program, the launching of Explorer VI, the image of the earth's surface and cloud cover radioed back by Explorer VI, and Vanguard III. The Vanguard III press conference consisted of a panel discussion by scientists from

NASA, the Naval Research Laboratory, and the International Geophysical Year team, followed by questions from the floor.

Publications and Speeches -- Information about NASA and space activities disseminated through press releases and conferences was supplemented by NASA publications and by speeches of NASA officials. Booklets prepared and published by NASA between April 1 and September 30, 1959 included "The Challenge of Space," "Space, the New Frontier," an aid to recruitment of scientists titled "Careers in Space," two aids to contractors titled "Patents and Progress" and "Selling to NASA -- A Guide to Procurement," a periodically revised space probe and satellite statistical chart, "Highlights of NASA's First Year (October 1, 1958 - September 30, 1959)," "The NASA Space Sciences Program," and "The National Aeronautics and Space Administration First Semiannual Report to the Congress -- October 1, 1958 - March 31, 1959." NASA scientists and administrative officials presented many talks before professional, technical, and civic groups and contributed technical and non-technical articles to periodicals, newspapers, and yearbooks.

Motion Pictures -- NASA completed two films -- "United States Space Explorations, 1958" and "Time and Space" -- during the reporting period. "Time and Space," an extremely popular film about Pioneer IV, the Nation's first artificial planetoid, had been seen by an estimated 17 million people by September 30. It has been shown on a TV network, at the Venice Film Festival, and at meetings of civic, business, and scientific societies. For having achieved the honor of selection for showing at the Venice Film Festival, "Time and Space" was awarded the coveted "Certificate of Participation."

Research Center Tours -- NASA arranged many tours of its research centers for the press, scientists, industrial representatives, and visiting scientists and officials from other countries. In this way, first-hand information was presented about U.S. civilian-oriented aeronautical and space activities. A particularly effective tour was that of the 63 news media representatives who toured Langley Research Center, on July 7. They visited areas of Langley engaged in the Mercury program and were briefed on the program by engineers of the Space Task Group.

Langley Inspection Plans -- NASA is continuing the practice of annual inspections of its work-in-progress which its predecessor, the National Advisory Committee for Aeronautics, inaugurated. By the close of the report period, NASA had completed arrangements for the first inspection wholly prepared under NASA auspices, to be held at Langley Research Center.

APPENDIX A

PUBLIC LAW 85-568
85th Congress, H. R. 12575
July 29, 1958

AN ACT

To provide for research into problems of flight within and outside the earth's atmosphere, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

National Aeronautics and Space Act of 1958.

TITLE I—SHORT TITLE, DECLARATION OF POLICY, AND DEFINITIONS

SHORT TITLE

SEC. 101. This Act may be cited as the "National Aeronautics and Space Act of 1958".

DECLARATION OF POLICY AND PURPOSE

SEC. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201 (e). 72 Stat. 426.

72 Stat. 427.

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).

DEFINITIONS

SEC. 103. As used in this Act—

(1) the term "aeronautical and space activities" means (A) research into, and the solution of, problems of flight within and outside the earth's atmosphere, (B) the development, construction, testing, and operation for research purposes of aeronautical and space vehicles, and (C) such other activities as may be required for the exploration of space; and

(2) the term "aeronautical and space vehicles" means aircraft, missiles, satellites, and other space vehicles, manned and unmanned. together with related equipment, devices, components, and parts.

TITLE II—COORDINATION OF AERONAUTICAL AND SPACE ACTIVITIES

NATIONAL AERONAUTICS AND SPACE COUNCIL

Establishment. SEC. 201. (a) There is hereby established the National Aeronautics and Space Council (hereinafter called the "Council") which shall be composed of—

(1) the President (who shall preside over meetings of the Council);

72 Stat. 427.
72 Stat. 428.

(2) the Secretary of State;

(3) the Secretary of Defense;

(4) the Administrator of the National Aeronautics and Space Administration;

(5) the Chairman of the Atomic Energy Commission;

(6) not more than one additional member appointed by the President from the departments and agencies of the Federal Government; and

(7) not more than three other members appointed by the President, solely on the basis of established records of distinguished achievement, from among individuals in private life who are eminent in science, engineering, technology, education, administration, or public affairs.

Alternate. (b) Each member of the Council from a department or agency of the Federal Government may designate another officer of his department or agency to serve on the Council as his alternate in his unavoidable absence.

(c) Each member of the Council appointed or designated under paragraphs (6) and (7) of subsection (a), and each alternate member designated under subsection (b), shall be appointed or designated to serve as such by and with the advice and consent of the Senate, unless at the time of such appointment or designation he holds an office in the Federal Government to which he was appointed by and with the advice and consent of the Senate.

(d) It shall be the function of the Council to advise the President with respect to the performance of the duties prescribed in subsection (e) of this section.

(e) In conformity with the provisions of section 102 of this Act, it shall be the duty of the President to— Duties of President.

(1) survey all significant aeronautical and space activities, including the policies, plans, programs, and accomplishments of all agencies of the United States engaged in such activities;

(2) develop a comprehensive program of aeronautical and space activities to be conducted by agencies of the United States;

(3) designate and fix responsibility for the direction of major aeronautical and space activities;

(4) provide for effective cooperation between the National Aeronautics and Space Administration and the Department of Defense in all such activities, and specify which of such activities may be carried on concurrently by both such agencies notwithstanding the assignment of primary responsibility therefor to one or the other of such agencies; and

(5) resolve differences arising among departments and agencies of the United States with respect to aeronautical and space activities under this Act, including differences as to whether a particular project is an aeronautical and space activity.

(f) The Council may employ a staff to be headed by a civilian executive secretary who shall be appointed by the President by and with the advice and consent of the Senate and shall receive compensation at the rate of $20,000 a year. The executive secretary, subject to the direction of the Council, is authorized to appoint and fix the compensation of such personnel, including not more than three persons who may be appointed without regard to the civil service laws or the Classification Act of 1949 and compensated at the rate of not more than $19,000 a year, as may be necessary to perform such duties as may be prescribed by the Council in connection with the performance of its functions. Each appointment under this subsection shall be subject to the same security requirements as those established for personnel of the National Aeronautics and Space Administration appointed under section 203 (b) (2) of this Act. Employees. Compensation. 63 Stat. 954. 5 USC 1071 note. Security check.

(g) Members of the Council appointed from private life under subsection (a) (7) may be compensated at a rate not to exceed $100 per diem, and may be paid travel expenses and per diem in lieu of subsistence in accordance with the provisions of section 5 of the Administrative Expenses Act of 1946 (5 U. S. C. 73b-2) relating to persons serving without compensation. Per diem. ~~72 Stat. 428.~~ 72 Stat. 429. 69 Stat. 394.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEC. 202. (a) There is hereby established the National Aeronautics and Space Administration (hereinafter called the "Administration"). The Administration shall be headed by an Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate, and shall receive compensation at the rate of $22,500 per annum. Under the supervision and direction of the President, the Administrator shall be responsible for the exercise of all powers and the discharge of all duties of the Administration, and shall have authority and control over all personnel and activities thereof. Administrator.

(b) There shall be in the Administration a Deputy Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate, shall receive compensation at the rate of $21,500 per annum, and shall perform such duties and exercise Deputy Administrator.

such powers as the Administrator may prescribe. The Deputy Administrator shall act for, and exercise the powers of, the Administrator during his absence or disability.

Restriction. (c) The Administrator and the Deputy Administrator shall not engage in any other business, vocation, or employment while serving as such.

FUNCTIONS OF THE ADMINISTRATION

SEC. 203. (a) The Administration, in order to carry out the purpose of this Act, shall—

(1) plan, direct, and conduct aeronautical and space activities;

(2) arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations; and

(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

(b) In the performance of its functions the Administration is authorized—

Rules and regulations. (1) to make, promulgate, issue, rescind, and amend rules and regulations governing the manner of its operations and the exercise of the powers vested in it by law;

Employees. (2) to appoint and fix the compensation of such officers and employees as may be necessary to carry out such functions. Such officers and employees shall be appointed in accordance with the civil-service laws and their compensation fixed in accordance with the Classification Act of 1949, except that (A) to the extent the Administrator deems such action necessary to the discharge of his responsibilities, he may appoint and fix the compensation (up to a limit of $19,000 a year, or up to a limit of $21,000 a year for a maximum of ten positions) of not more than two hundred and sixty of the scientific, engineering, and administrative personnel of the Administration without regard to such laws, and (B) to the extent the Administrator deems such action necessary to recruit specially qualified scientific and engineering talent, he may establish the entrance grade for scientific and engineering personnel without previous service in the Federal Government at a level up to two grades higher than the grade provided for such personnel under the General Schedule established by the Classification Act of 1949, and fix their compensation accordingly;

63 Stat. 954.
5 USC 1071 note.
72 Stat. 429.
72 Stat. 430.

Acquisition of property. (3) to acquire (by purchase, lease, condemnation, or otherwise), construct, improve, repair, operate, and maintain laboratories, research and testing sites and facilities, aeronautical and space vehicles, quarters and related accommodations for employees and dependents of employees of the Administration, and such other real and personal property (including patents), or any interest therein, as the Administration deems necessary within and outside the continental United States; to lease to others such real and personal property; to sell and otherwise dispose of real and personal property (including patents and rights thereunder) in accordance with the provisions of the Federal Property and Administrative Services Act of 1949, as amended (40 U. S. C. 471 et seq.); and to provide by contract or otherwise for cafeterias and other necessary facilities for the welfare of employees of the Administration at its installations and purchase and maintain equipment therefor;

63 Stat. 377.

(4) to accept unconditional gifts or donations of services, money, or property, real, personal, or mixed, tangible or intangible; Gifts.

(5) without regard to section 3648 of the Revised Statutes, as amended (31 U. S. C. 529), to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or with any State, Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution. To the maximum extent practicable and consistent with the accomplishment of the purpose of this Act, such contracts, leases, agreements, and other transactions shall be allocated by the Administrator in a manner which will enable small-business concerns to participate equitably and proportionately in the conduct of the work of the Administration; Contracts, etc. 60 Stat. 809.

(6) to use, with their consent, the services, equipment, personnel, and facilities of Federal and other agencies with or without reimbursement, and on a similar basis to cooperate with other public and private agencies and instrumentalities in the use of services, equipment, and facilities. Each department and agency of the Federal Government shall cooperate fully with the Administration in making its services, equipment, personnel, and facilities available to the Administration, and any such department or agency is authorized, notwithstanding any other provision of law, to transfer to or to receive from the Administration, without reimbursement, aeronautical and space vehicles, and supplies and equipment other than administrative supplies or equipment; Agency cooperation.

(7) to appoint such advisory committees as may be appropriate for purposes of consultation and advice to the Administration in the performance of its functions; Advisory committees.

(8) to establish within the Administration such offices and procedures as may be appropriate to provide for the greatest possible coordination of its activities under this Act with related scientific and other activities being carried on by other public and private agencies and organizations; Coordination.

72 Stat. 430. 72 Stat. 431.

(9) to obtain services as authorized by section 15 of the Act of August 2, 1946 (5 U. S. C. 55a), at rates not to exceed $100 per diem for individuals; 60 Stat. 810.

(10) when determined by the Administrator to be necessary, and subject to such security investigations as he may determine to be appropriate, to employ aliens without regard to statutory provisions prohibiting payment of compensation to aliens; Employment. Aliens.

(11) to employ retired commissioned officers of the armed forces of the United States and compensate them at the rate established for the positions occupied by them within the Administration, subject only to the limitations in pay set forth in section 212 of the Act of June 30, 1932, as amended (5 U. S. C. 59a); Retired officers. 68 Stat. 18.

(12) with the approval of the President, to enter into cooperative agreements under which members of the Army, Navy, Air Force, and Marine Corps may be detailed by the appropriate Secretary for services in the performance of functions under this Act to the same extent as that to which they might be lawfully assigned in the Department of Defense; and Agreements.

(13) (A) to consider, ascertain, adjust, determine, settle, and pay, on behalf of the United States, in full satisfaction thereof, any claim for $5,000 or less against the United States for bodily injury, death, or damage to or loss of real or personal property Claims.

resulting from the conduct of the Administration's functions as specified in subsection (a) of this section, where such claim is presented to the Administration in writing within two years after the accident or incident out of which the claim arises; and

Report to Congress.

(B) if the Administration considers that a claim in excess of $5,000 is meritorious and would otherwise be covered by this paragraph, to report the facts and circumstances thereof to the Congress for its consideration.

CIVILIAN-MILITARY LIAISON COMMITTEE

SEC. 204. (a) There shall be a Civilian-Military Liaison Committee consisting of—

(1) a Chairman, who shall be the head thereof and who shall be appointed by the President, shall serve at the pleasure of the President, and shall receive compensation (in the manner provided in subsection (d)) at the rate of $20,000 per annum;

(2) one or more representatives from the Department of Defense, and one or more representatives from each of the Departments of the Army, Navy, and Air Force, to be assigned by the Secretary of Defense to serve on the Committee without additional compensation; and

(3) representatives from the Administration, to be assigned by the Administrator to serve on the Committee without additional compensation, equal in number to the number of representatives assigned to serve on the Committee under paragraph (2).

(b) The Administration and the Department of Defense, through the Liaison Committee, shall advise and consult with each other on all matters within their respective jurisdictions relating to aeronautical and space activities and shall keep each other fully and currently informed with respect to such activities.

(c) If the Secretary of Defense concludes that any request, action, proposed action, or failure to act on the part of the Administrator is adverse to the responsibilities of the Department of Defense, or the Administrator concludes that any request, action, proposed action, or failure to act on the part of the Department of Defense is adverse to the responsibilities of the Administration, and the Administrator and

72 Stat. 431.

the Secretary of Defense are unable to reach an agreement with re-

72 Stat. 432.

spect thereto, either the Administrator or the Secretary of Defense may refer the matter to the President for his decision (which shall be final) as provided in section 201 (e).

Chairman.

(d) Notwithstanding the provisions of any other law, any active or retired officer of the Army, Navy, or Air Force may serve as Chairman of the Liaison Committee without prejudice to his active or retired status as such officer. The compensation received by any such officer for his service as Chairman of the Liaison Committee shall be equal to the amount (if any) by which the compensation fixed by subsection (a) (1) for such Chairman exceeds his pay and allowances (including special and incentive pays) as an active officer, or his retired pay.

INTERNATIONAL COOPERATION

SEC. 205. The Administration, under the foreign policy guidance of the President, may engage in a program of international cooperation in work done pursuant to this Act, and in the peaceful application of the results thereof, pursuant to agreements made by the President with the advice and consent of the Senate.

REPORTS TO THE CONGRESS

SEC. 206. (a) The Administration shall submit to the President for transmittal to the Congress, semiannually and at such other times as it deems desirable, a report of its activities and accomplishments.

(b) The President shall transmit to the Congress in January of each year a report, which shall include (1) a comprehensive description of the programed activities and the accomplishments of all agencies of the United States in the field of aeronautics and space activities during the preceding calendar year, and (2) an evaluation of such activities and accomplishments in terms of the attainment of, or the failure to attain, the objectives described in section 102 (c) of this Act.

(c) Any report made under this section shall contain such recommendations for additional legislation as the Administrator or the President may consider necessary or desirable for the attainment of the objectives described in section 102 (c) of this Act.

(d) No information which has been classified for reasons of national security shall be included in any report made under this section, unless such information has been declassified by, or pursuant to authorization given by, the President.

TITLE III—MISCELLANEOUS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

SEC. 301. (a) The National Advisory Committee for Aeronautics, on the effective date of this section, shall cease to exist. On such date all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of that organization, shall be transferred to the Administration.

Termination. Transfer of functions.

(b) Section 2302 of title 10 of the United States Code is amended by striking out "or the Executive Secretary of the National Advisory Committee for Aeronautics." and inserting in lieu thereof "or the Administrator of the National Aeronautics and Space Administration."; and section 2303 of such title 10 is amended by striking out "The National Advisory Committee for Aeronautics." and inserting in lieu thereof "The National Aeronautics and Space Administration."

Definitions. 70A Stat. 127.

(c) The first section of the Act of August 26, 1950 (5 U. S. C. 22–1), is amended by striking out "the Director, National Advisory Committee for Aeronautics" and inserting in lieu thereof "the Administrator of the National Aeronautics and Space Administration", and by striking out "or National Advisory Committee for Aeronautics" and inserting in lieu thereof "or National Aeronautics and Space Administration".

64 Stat. 476. 72 Stat. 432. 72 Stat. 433.

(d) The Unitary Wind Tunnel Plan Act of 1949 (50 U. S. C. 511–515) is amended (1) by striking out "The National Advisory Committee for Aeronautics (hereinafter referred to as the 'Committee')" and inserting in lieu thereof "The Administrator of the National Aeronautics and Space Administration (hereinafter referred to as the 'Administrator')"; (2) by striking out "Committee" or "Committee's" wherever they appear and inserting in lieu thereof "Administrator" and "Administrator's", respectively; and (3) by striking out "its" wherever it appears and inserting in lieu thereof "his".

63 Stat. 936.

(e) This section shall take effect ninety days after the date of the enactment of this Act, or on any earlier date on which the Administrator shall determine, and announce by proclamation published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this Act.

Effective date. Publication in F.R.

TRANSFER OF RELATED FUNCTIONS

SEC. 302. (a) Subject to the provisions of this section, the President, for a period of four years after the date of enactment of this Act, may transfer to the Administration any functions (including powers, duties, activities, facilities, and parts of functions) of any other department or agency of the United States, or of any officer or organizational entity thereof, which relate primarily to the functions, powers, and duties of the Administration as prescribed by section 203 of this Act. In connection with any such transfer, the President may, under this section or other applicable authority, provide for appropriate transfers of records, property, civilian personnel, and funds.

Reports to Congress.

(b) Whenever any such transfer is made before January 1, 1959, the President shall transmit to the Speaker of the House of Representatives and the President pro tempore of the Senate a full and complete report concerning the nature and effect of such transfer.

(c) After December 31, 1958, no transfer shall be made under this section until (1) a full and complete report concerning the nature and effect of such proposed transfer has been transmitted by the President to the Congress, and (2) the first period of sixty calendar days of regular session of the Congress following the date of receipt of such report by the Congress has expired without the adoption by the Congress of a concurrent resolution stating that the Congress does not favor such transfer.

ACCESS TO INFORMATION

SEC. 303. Information obtained or developed by the Administrator in the performance of his functions under this Act shall be made available for public inspection, except (A) information authorized or required by Federal statute to be withheld, and (B) information classified to protect the national security: *Provided*, That nothing in this Act shall authorize the withholding of information by the Administrator from the duly authorized committees of the Congress.

SECURITY

Requirements.

SEC. 304. (a) The Administrator shall establish such security requirements, restrictions, and safeguards as he deems necessary in the interest of the national security.

72 Stat. 433.
72 Stat. 434.

The Administrator may arrange with the Civil Service Commission for the conduct of such security or other personnel investigations of the Administration's officers, employees, and consultants, and its contractors and subcontractors and their officers and employees, actual or prospective, as he deems appropriate; and if any such investigation develops any data reflecting that the individual who is the subject thereof is of questionable loyalty the matter shall be referred to the Federal Bureau of Investigation for the conduct of a full field investigation, the results of which shall be furnished to the Administrator.

Referral to F.B.I.

Access to AEC restricted data.

(b) The Atomic Energy Commission may authorize any of its employees, or employees of any contractor, prospective contractor, licensee, or prospective licensee of the Atomic Energy Commission or any other person authorized to have access to Restricted Data by the Atomic Energy Commission under subsection 145 b. of the Atomic Energy Act of 1954 (42 U. S. C. 2165 (b)), to permit any member, officer, or employee of the Council, or the Administrator, or any officer, employee, member of an advisory committee, contractor, subcontractor, or officer or employee of a contractor or subcontractor of the Administration, to have access to Restricted Data relating to aeronautical and space activities which is required in the performance of his duties and so certified by the Council or the Administrator, as the case may be,

68 Stat. 942.

but only if (1) the Council or Administrator or designee thereof has determined, in accordance with the established personnel security procedures and standards of the Council or Administration, that permitting such individual to have access to such Restricted Data will not endanger the common defense and security, and (2) the Council or Administrator or designee thereof finds that the established personnel and other security procedures and standards of the Council or Administration are adequate and in reasonable conformity to the standards established by the Atomic Energy Commission under section 145 of the Atomic Energy Act of 1954 (42 U. S. C. 2165). Any individual granted access to such Restricted Data pursuant to this subsection may exchange such Data with any individual who (A) is an officer or employee of the Department of Defense, or any department or agency thereof, or a member of the armed forces, or a contractor or subcontractor of any such department, agency, or armed force, or an officer or employee of any such contractor or subcontractor, and (B) has been authorized to have access to Restricted Data under the provisions of section 143 of the Atomic Energy Act of 1954 (42 U. S. C. 2163).

68 Stat. 942.

(c) Chapter 37 of title 18 of the United States Code (entitled Espionage and Censorship) is amended by—

Espionage and Censorship.
62 Stat. 736-738; 65 Stat. 719.
18 USC 791-798.

(1) adding at the end thereof the following new section:

"§ 799. Violation of regulations of National Aeronautics and Space Administration

Violation.

"Whoever willfully shall violate, attempt to violate, or conspire to violate any regulation or order promulgated by the Administrator of the National Aeronautics and Space Administration for the protection or security of any laboratory, station, base or other facility, or part thereof, or any aircraft, missile, spacecraft, or similar vehicle, or part thereof, or other property or equipment in the custody of the Administration, or any real or personal property or equipment in the custody of any contractor under any contract with the Administration or any subcontractor of any such contractor, shall be fined not more than $5,000, or imprisoned not more than one year, or both."

Penalty.

(2) adding at the end of the sectional analysis thereof the following new item:

"799. Violation of regulations of National Aeronautics and Space Administration."

72 Stat. 434.
72 Stat. 435.

(d) Section 1114 of title 18 of the United States Code is amended by inserting immediately before "while engaged in the performance of his official duties" the following: "or any officer or employee of the National Aeronautics and Space Administration directed to guard and protect property of the United States under the administration and control of the National Aeronautics and Space Administration,".

Protection of U.S. officers and employees.
62 Stat. 756.

(e) The Administrator may direct such of the officers and employees of the Administration as he deems necessary in the public interest to carry firearms while in the conduct of their official duties. The Administrator may also authorize such of those employees of the contractors and subcontractors of the Administration engaged in the protection of property owned by the United States and located at facilities owned by or contracted to the United States as he deems necessary in the public interest, to carry firearms while in the conduct of their official duties.

Permission to use firearms.

PROPERTY RIGHTS IN INVENTIONS

SEC. 305. (a) Whenever any invention is made in the performance of any work under any contract of the Administration, and the Administrator determines that—

(1) the person who made the invention was employed or assigned to perform research, development, or exploration work and the invention is related to the work he was employed or

assigned to perform, or that it was within the scope of his employment duties, whether or not it was made during working hours, or with a contribution by the Government of the use of Government facilities, equipment, materials, allocated funds, information proprietary to the Government, or services of Government employees during working hours; or

(2) the person who made the invention was not employed or assigned to perform research, development, or exploration work, but the invention is nevertheless related to the contract, or to the work or duties he was employed or assigned to perform, and was made during working hours, or with a contribution from the Government of the sort referred to in clause (1),

such invention shall be the exclusive property of the United States, and if such invention is patentable a patent therefor shall be issued to the United States upon application made by the Administrator, unless the Administrator waives all or any part of the rights of the United States to such invention in conformity with the provisions of subsection (f) of this section.

Contract provision.

(b) Each contract entered into by the Administrator with any party for the performance of any work shall contain effective provisions under which such party shall furnish promptly to the Administrator a written report containing full and complete technical information concerning any invention, discovery, improvement, or innovation which may be made in the performance of any such work.

Patent application.

(c) No patent may be issued to any applicant other than the Administrator for any invention which appears to the Commissioner of Patents to have significant utility in the conduct of aeronautical and space activities unless the applicant files with the Commissioner, with the application or within thirty days after request therefor by the Commissioner, a written statement executed under oath setting forth the full facts concerning the circumstances under which such invention was made and stating the relationship (if any) of such invention to the performance of any work under any contract of the Administration. Copies of each such statement and the application to which it relates shall be transmitted forthwith by the Commissioner to the Administrator.

72 Stat. 435.
72 Stat. 436.

Board of Patent Interferences.

(d) Upon any application as to which any such statement has been transmitted to the Administrator, the Commissioner may, if the invention is patentable, issue a patent to the applicant unless the Administrator, within ninety days after receipt of such application and statement, requests that such patent be issued to him on behalf of the United States. If, within such time, the Administrator files such a request with the Commissioner, the Commissioner shall transmit notice thereof to the applicant, and shall issue such patent to the Administrator unless the applicant within thirty days after receipt of such notice requests a hearing before a Board of Patent Interferences on the question whether the Administrator is entitled under this section to receive such patent. The Board may hear and determine, in accordance with rules and procedures established for interference cases, the question so presented, and its determination shall be subject to appeal by the applicant or by the Administrator to the Court of Customs and Patent Appeals in accordance with procedures governing appeals from decisions of the Board of Patent Interferences in other proceedings.

(e) Whenever any patent has been issued to any applicant in conformity with subsection (d), and the Administrator thereafter has reason to believe that the statement filed by the applicant in connection therewith contained any false representation of any material fact, the Administrator within five years after the date of issuance of such patent may file with the Commissioner a request for the transfer to the Administrator of title to such patent on the records of the Commissioner. Notice of any such request shall be transmitted by the Commissioner to the owner of record of such patent, and title to such patent shall be so transferred to the Administrator unless within thirty days after receipt of such notice such owner of record requests a hearing before a Board of Patent Interferences on the question whether any such false representation was contained in such statement. Such question shall be heard and determined, and determination thereof shall be subject to review, in the manner prescribed by subsection (d) for questions arising thereunder. No request made by the Administrator under this subsection for the transfer of title to any patent, and no prosecution for the violation of any criminal statute, shall be barred by any failure of the Administrator to make a request under subsection (d) for the issuance of such patent to him, or by any notice previously given by the Administrator stating that he had no objection to the issuance of such patent to the applicant therefor.

(f) Under such regulations in conformity with this subsection as the Administrator shall prescribe, he may waive all or any part of the rights of the United States under this section with respect to any invention or class of inventions made or which may be made by any person or class of persons in the performance of any work required by any contract of the Administration if the Administrator determines that the interests of the United States will be served thereby. Any such waiver may be made upon such terms and under such conditions as the Administrator shall determine to be required for the protection of the interests of the United States. Each such waiver made with respect to any invention shall be subject to the reservation by the Administrator of an irrevocable, nonexclusive, nontransferrable, royalty-free license for the practice of such invention throughout the world by or on behalf of the United States or any foreign government pursuant to any treaty or agreement with the United States. Each proposal for any waiver under this subsection shall be referred to an Inventions and Contributions Board which shall be established by the Administrator within the Administration. Such Board shall accord to each interested party an opportunity for hearing, and shall transmit to the Administrator its findings of fact with respect to such proposal and its recommendations for action to be taken with respect thereto.

Waiver.

Inventions and Contributions Board.

(g) The Administrator shall determine, and promulgate regulations specifying, the terms and conditions upon which licenses will be granted by the Administration for the practice by any person (other than an agency of the United States) of any invention for which the Administrator holds a patent on behalf of the United States.

License regulations.

72 Stat. 436.
72 Stat. 437.

(h) The Administrator is authorized to take all suitable and necessary steps to protect any invention or discovery to which he has title, and to require that contractors or persons who retain title to inventions or discoveries under this section protect the inventions or discoveries to which the Administration has or may acquire a license of use.

Protection of title.

(i) The Administration shall be considered a defense agency of the United States for the purpose of chapter 17 of title 35 of the United States Code.

Defense agency.
66 Stat. 805-808.

(j) As used in this section—

Definitions.

(1) the term "person" means any individual, partnership, corporation, association, institution, or other entity;

(2) the term "contract" means any actual or proposed contract, agreement, understanding, or other arrangement, and includes any assignment, substitution of parties, or subcontract executed or entered into thereunder; and

(3) the term "made", when used in relation to any invention, means the conception or first actual reduction to practice of such invention.

CONTRIBUTIONS AWARDS

SEC. 306. (a) Subject to the provisions of this section, the Administrator is authorized, upon his own initiative or upon application of any person, to make a monetary award, in such amount and upon such terms as he shall determine to be warranted, to any person (as defined by section 305) for any scientific or technical contribution to the Administration which is determined by the Administrator to have significant value in the conduct of aeronautical and space activities. Each application made for any such award shall be referred to the Inventions and Contributions Board established under section 305 of this Act. Such Board shall accord to each such applicant an opportunity for hearing upon such application, and shall transmit to the Administrator its recommendation as to the terms of the award, if any, to be made to such applicant for such contribution. In determining the terms and conditions of any award the Administrator shall take into account—

(1) the value of the contribution to the United States;

(2) the aggregate amount of any sums which have been expended by the applicant for the development of such contribution;

(3) the amount of any compensation (other than salary received for services rendered as an officer or employee of the Government) previously received by the applicant for or on account of the use of such contribution by the United States; and

(4) such other factors as the Administrator shall determine to be material.

(b) If more than one applicant under subsection (a) claims an interest in the same contribution, the Administrator shall ascertain and determine the respective interests of such applicants, and shall apportion any award to be made with respect to such contribution among such applicants in such proportions as he shall determine to be equitable. No award may be made under subsection (a) with respect to any contribution—

(1) unless the applicant surrenders, by such means as the Administrator shall determine to be effective, all claims which such applicant may have to receive any compensation (other than the
72 Stat. 437. award made under this section) for the use of such contribution or
72 Stat. 438. any element thereof at any time by or on behalf of the United States, or by or on behalf of any foreign government pursuant to any treaty or agreement with the United States, within the United States or at any other place;

(2) in any amount exceeding $100,000, unless the Administrator has transmitted to the appropriate committees of the Congress a full and complete report concerning the amount and terms of, and the basis for, such proposed award, and thirty calendar days of regular session of the Congress have expired after receipt of such report by such committees.

APPROPRIATIONS

SEC. 307. (a) There are hereby authorized to be appropriated such sums as may be necessary to carry out this Act, except that nothing in this Act shall authorize the appropriation of any amount for (1) the acquisition or condemnation of any real property, or (2) any other item of a capital nature (such as plant or facility acquisition, construction, or expansion) which exceeds $250,000. Sums appropriated pursuant to this subsection for the construction of facilities, or for research and development activities, shall remain available until expended.

(b) Any funds appropriated for the construction of facilities may be used for emergency repairs of existing facilities when such existing facilities are made inoperative by major breakdown, accident, or other circumstances and such repairs are deemed by the Administrator to be of greater urgency than the construction of new facilities.

Approved July 29, 1958.

APPENDIX B

MEMBERSHIPS OF CONGRESSIONAL COMMITTEES
(As of September 30, 1959)

Senate Committee on Aeronautical and Space Sciences

DEMOCRATS	REPUBLICANS
Lyndon B. Johnson, Tex., Chairman	Styles Bridges, N.H.
Richard B. Russell, Ga.	Alexander Wiley, Wis.
Warren G. Magnuson, Wash.	Margaret Chase Smith, Maine
Clinton P. Anderson, N. Mex.	Thomas E. Martin, Iowa
Robert S. Kerr, Okla.	Clifford P. Case, N.J.
Stuart Symington, Mo.	
John Stennis, Miss.	
Stephen M. Young, Ohio	
Thomas A. Dodd, Conn.	
Howard W. Cannon, Nev.	

House Committee on Science and Astronautics

DEMOCRATS	REPUBLICANS
Overton Brooks, La., Chairman	Joseph W. Martin, Jr., Mass.
John W. McCormack, Mass.	James G. Fulton, Pa.
George P. Miller, Calif.	Gordon L. McDonough, Calif.
Olin E. Teague, Tex.	J. Edgar Chenoweth, Colo.
Victor L. Anfuso, N.Y.	Frank C. Osmers, Jr., Wis.
B. F. Sisk, Calif.	William K. Van Pelt, Wis.
Erwin Mitchell, Ga.	A. D. Baumhart, Jr., Ohio
James M. Quigley, Pa.	Perkins Bass, N. H.
David M. Hall, N.C.	R. Walter Riehlman, N.Y.
Leonard G. Wolf, Iowa	
Joseph E. Karth, Minn.	
Ken Hechler, W. Va.	
Emilio Q. Daddario, Conn.	
Walter H. Moeller, Ohio	
David S. King, Utah	
J. Edward Roush, Ind.	

APPENDIX C

MEMBERSHIP OF NATIONAL AERONAUTICS AND SPACE COUNCIL

(As of September 30, 1959)

President Dwight D. Eisenhower, Chairman

Christian A. Herter
Secretary of State

Neil McElroy
Secretary of Defense

John A. McCone
Chairman, Atomic Energy Commission

T. Keith Glennan
Administrator, National Aeronautics and Space Administration

Dr. Detlev W. Bronk
President, National Academy of Sciences

Dr. Alan T. Waterman
Director, National Science Foundation

Dr. John T. Rettaliata
President, Illinois Institute of Technology, Chicago, Ill.

William A. M. Burden*
General Partner, William A. M. Burden and Co., Investment Bankers, New York, N. Y.

Acting Secretary

Franklyn W. Phillips

* Resigned October 5.

APPENDIX D

MEMBERSHIP OF THE CIVILIAN-MILITARY LIAISON COMMITTEE

(As of September 30, 1959)

William M. Holaday, Chairman

William J. Underwood, Assistant to the Chairman and Secretary

NASA MEMBERS

Dr. Hugh L. Dryden, Deputy Administrator
Abe Silverstein, Director of Space Flight Development
Homer J. Stewart, Director of Program Planning and Evaluation
Ira H. Abbott, Director of Aeronautical and Space Research

NASA ALTERNATES

DeMarquis D. Wyatt, Technical Assistant to the Director of Space Flight Development
Abraham Hyatt, Assistant Director for Propulsion

DEPARTMENT OF DEFENSE MEMBERS

Roy W. Johnson, OSD, Director, Advanced Research Projects Agency
Maj. Gen. W. W. Dick, Jr., Army, Director of Special Weapons, Office, Chief of Research and Development, Dept. of Army
Vice Adm. R. B. Pirie, Navy, Deputy Chief of Naval Operations (Air)
Brig. Gen. Homer A. Boushey, Air Force, Director of Advanced Technology, Office, Deputy Chief of Staff, Development

DOD ALTERNATES

John B. Macauley, OSD, Deputy Director, Office, Defense Research and Engineering
Colonel Charles G. Patterson, Deputy Director of Special Weapons, Office, Chief of Research and Development, Department of the Army
Rear Admiral K. S. Masterson, Director Guided Missiles, Office, Chief of Naval Operations
Colonel John R. Martin, Jr., Air Force, Deputy Director of Advanced Technology, Office, Deputy Chief of Staff, Development

APPENDIX E

MEMBERSHIP OF LUNAR SCIENCE GROUP

Robert Jastrow, Goddard Space Flight Center, NASA, Chairman

Harrison Brown, California Institute of Technology, Pasadena, Calif.

Maurice Ewing, Columbia University, New York, New York

Thomas Gold, Cornell University, Ithaca, New York

A. R. Hibbs, Jet Propulsion Laboratory, Pasadena, Calif.

Joshua Lederberg, Stanford University, Department of Genetics, Stanford, Calif.

Gordon MacDonald, University of California, Institute of Geophysics, Los Angeles, Calif.

Frank Press, California Institute of Technology, Pasadena, Calif.

Bruno Rossi, Massachusetts Institute of Technology, Cambridge, Mass.

Ernest Stuhlinger, Army Ballistic Missile Agency, Huntsville, Ala.

Harold Urey, Scripps Institute of Oceanography, University of California, La Jolla, Calif.

APPENDIX F

MEMBERSHIP OF SPECIAL COMMITTEE ON LIFE SCIENCES

(As of September 30, 1959)

Dr. W. Randolph Lovelace II, Chairman
Director of the Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico

Boyd C. Myers II, Secretary
National Aeronautics and Space Administration

MEMBERS

Lt. Commander John H. Ebersole (MC)
U.S. Naval Hospital (Staff) National Naval Medical Center, Bethesda, Maryland

Brig. Gen. Donald D. Flickinger,
Surgeon and Assistant Deputy Commander for Research Headquarters, Air Research and Development Command, Andrews Air Force Base, Washington, D. C.

Col. Robert H. Holmes (MC)
Forensic and Aviation Pathology Branch
Armed Forces Institute of Pathology
Washington, D. C.

Dr. Wright H. Langham
Los Alamos Scientific Laboratory, University of California

Dr. Robert B. Livingston
Director of Basic Research in Mental Health and Neurological Diseases, National Institutes of Health, Bethesda, Md.

Dr. Orr Reynolds
Director of Science, Office of the Assistant Secretary of Defense for Research and Engineering, Washington, D. C.

APPENDIX G

MEMBERSHIP OF JOINT (AEC-DOD-NASA) COMMITTEE ON HAZARDS OF SPACE NUCLEAR SYSTEMS

Mr. Robert E. English, Lewis Research Center, NASA, Chairman

Dr. Wright Langham, Los Alamos Scientific Laboratory, University of California

Dr. Nathan W. Snyder, Advanced Research Projects Agency, Department of Defense

Mr. Spurgeon Keeny, Office of the Special Assistant to the President for Science and Technology

APPENDIX H

MEMBERSHIP OF COMMITTEE ON LONG RANGE STUDIES

(As of September 30, 1959)

John A. Johnson, NASA, General Counsel, Chairman

Arnold W. Frutkin, NASA Director of International Programs

Homer J. Stewart, NASA Director of Program Planning and Evaluation

Wesley J. Hjornevik, NASA Assistant to the Administrator

Jack Oppenheimer, NASA, Executive Secretary

APPENDIX I

MEMBERSHIP OF INVENTIONS AND CONTRIBUTIONS BOARD

(As of September 30, 1959)

Robert E. Littell, Assistant to the Director of Aeronautical and Space Research, Chairman

Paul G. Dembling, Assistant General Counsel, Vice Chairman

Elliott Mitchell, Chief of Solid Rocket Development, Office of Space Flight Development, Member

J. Allen Crocker, Chief of Guidance and Control, Office of Space Flight Development, Member

C. Guy Ferguson, Assistant Classification and Organization Officer, Office of Director of Personnel, Member

APPENDIX J

MEMBERSHIP OF NASA-DOD SPACE SCIENCE COMMITTEE

Dr. Homer E. Newell, Jr., Chairman
NASA

Dr. J. F. Clark
NASA

Dr. Richard W. Davies
Jet Propulsion Laboratory
Pasadena 3, Calif.

Dr. James B. Edson
Office, Assistant Chief of Staff, Intelligence
Department of the Army,
Washington 25, D. C.

Dr. Herbert Friedman
Naval Research Laboratory
Washington 25, D. C.

Dr. John T. Holloway
Office of the Director of Defense Research and Engineering
Washington 25, D. C.

Dr. Geoffrey Keller
National Science Foundation
Washington 25, D. C.

Dr. Ward C. Low
Advanced Research Projects Agency
Washington 25, D. C.

Mr. W. J. O'Sullivan, Jr.
Langley Research Center
Hampton, Va.

Mr. John W. Townsend, Jr.
Goddard Space Flight Center
Washington 25, D. C.

Dr. Heinrich J. Weigand
Technical Advisor,
Department of the Air Force
Washington 25, D. C.

APPENDIX K

DISTRIBUTION OF RESEARCH GRANTS AND CONTRACTS

STATE	NO.	AMOUNT
Michigan	15	$1,007,000
California	19	969,000
New York	12	800,000
D. C.	12	797,000
Texas	2	606,000
Illinois	8	559,000
Ohio	6	552,000
Connecticut	5	400,000
Colorado	4	316,000
Iowa	2	314,000
Massachusetts	5	299,000
New Jersey	2	209,000
Indiana	1	200,000
Minnesota	3	166,000
Wisconsin	2	122,000
Maryland	3	101,000
Pennsylvania	4	77,000
Florida	1	64,000
North Carolina	1	63,000
New Hampshire	1	46,000
Virginia	1	34,000
New Mexico	1	32,000
Arizona	1	25,000
Utah	1	15,000
Washington	1	5,000
Overseas	2	184,000

APPENDIX L

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS
April 1, 1959 to September 30, 1959

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
PHYSICAL SCIENCES Physics				
NAw 6553	CALIFORNIA INSTITUTE OF TECHNOLOGY Investigation of wave motion in conducting fluids including the construction of facilities for work on and preliminary studies of magnetohydrodynamic processes.	H. W. Liepmann	12 mos	$37,895
NASw-13	UNIVERSITY OF VIRGINIA Experimental investigation of ionization phenomena by high velocity molecular beams incuding the design, construction, and preliminary testing of the apparatus having highest possible beam intensity with minimum beam energy and minimum spread in beam energy.	R. A. Lowry and G. H. Miller	12 mos	34,200
NsG 12-59	NEW YORK UNIVERSITY Theoretical investigation of molecular states, including computation of hybrid and exchange integrals, calculation of matrix elements, and preliminary calculations of potential curves for upper atmosphere constituents.	R. C. Sahni	12 mos	49,525
NsG 1-59	YALE UNIVERSITY Investigation of molecular beam frequency standards and atomic collision cross-sections.	V. W. Hughes	12 mos	110,000
NsG 5-59	UNIVERSITY OF MARYLAND Investigation of the forces between atoms, molecules, and ions at small separate distances for use in the evaluation of properties of gases at very high temperatures.	E. A. Mason and J. T. Vanderslice	36 mos	59,426

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
PHYSICAL SCIENCES				
Physics				
NsG 11-59	CALIFORNIA INSTITUTE OF TECHNOLOGY Study of the fundamental parameters of fatigue failure including considerations of the effect of fatigue stressing on precipitation and of the relationship between temperature and frequency effects.	S. R. Valluri and E. E. Sechler	12 mos	17,965
NsG 6-59	RICE INSTITUTE Research on the physics of solid materials, including the study of the basic laws governing the behavior of solids at high temperatures.	Franz Brotzen	36 mos	500,000
NsG 22-59	UNIVERSITY OF MICHIGAN Theoretical investigation of discontinuities in three-dimensional magnetohydrodynamics.	Rudi S. B. Ong	36 mos	13,000
NsG 40-60	CALIFORNIA INSTITUTE OF TECHNOLOGY Investigations of rarified gas flows.	H. W. Liepmann	36 mos	120,050
Chemistry				
NAw-6552	JOHNS HOPKINS UNIVERSITY Experimental investigation of heterogeneous reactions in boundary layer flows, including the construction and calibration of an annular porous palladium wall reactor apparatus.	Eric Weger	12 mos	13,252
NAw-6558	STANFORD UNIVERSITY Investigation of the production by controlled progressive growth from the melt of metallurgical structures containing uniformly dispersed stable particles.	R. A. Huggins	12 mos	31,474

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
PHYSICAL SCIENCES Chemistry				
NASw-10	UNIVERSITY OF CALIFORNIA Investigation of the ductile characteristics of some model ceramic systems over temperature ranges where plastic deformation is possible.	J. A. Pask	12 mos	16,000
NsG 9-59	NEW YORK UNIVERSITY Investigation of the feasibility of the production of breathing oxygen from space minerals.	E. R. Kaiser	12 mos	14,405
NASw-71	BATTELLE MEMORIAL INSTITUTE Investigation of radiation effects of a reactor fuel material for nuclear rockets.	W. H. Goldthwaite	7 mos	24,500
NASw-76	ARMOUR RESEARCH FOUNDATION Experimental investigation of the physical and chemical properties of a range of mixtures of fluorine and ozone to determine the feasibility of using ozone-fluorine mixtures for rocket engine oxidants	L. C. Kinney	12 mos	55,000
NASw-111	STANFORD RESEARCH INSTITUTE An investigation of the use of a reactive metal anode such as lithium and sodium to achieve a high energy battery.	J. E. Chilton	14 mos	45,041
NASw-77	ARMOUR RESEARCH FOUNDATION Investigation of surface recombination rates and kinetics of atomic oxygen on specific catalytic surfaces using a paramagnetic resonance techniques.	S. A. Marshall and D. S. Hacker	12 mos	34,908

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purposes	Individual	Duration	Amount
PHYSICAL SCIENCES				
Chemistry				
NsG 42-60	JOHNS HOPKINS UNIVERSITY Investigation of the kinetics and mass transfer steps associated with a heterogeneous reaction occurring on the surface of a porous material under boundary layer flow.	Eric Weger	24 mos	28,562
	STANFORD UNIVERSITY Investigation of a technique for the production of metallurgical structures containing uniformly dispersed stable particles.	R. A. Huggins and D. A. Stevenson	12 mos	31,000
COSMOLOGICAL SCIENCES				
Planetary Sciences				
NsG 4-59	UNIVERSITY OF MICHIGAN Theoretical investigation of the use of radar to map interplanetary surfaces and to determine conductivity permittivity and permeability of planetary surface materials.	K. M. Siegel	36 mos	126,000
Astrophysics				
NsG 15-59	UNIVERSITY OF COLORADO Hs-191 National Bureau of Standards-supporting services for NsG 15-59 Research on Zodiacal Light.	G. Newkirk, Jr.	24 mos	36,225 5,195
NsG 21-59	BOSTON UNIVERSITY Investigation of the nature and origin of tektites.	Gerald S. Hawkins	12 mos	9,667

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
COSMOLOGICAL SCIENCES				
Astronomy				
HS-149	YALE UNIVERSITY Summer institute in dynamical astronomy.	Dirk Brouwer	1 mo	22,050
NsG 8-59	YALE UNIVERSITY Investigation to determine the solar parallax utilizing absorption line techniques.	A. E. Lilley and Dirk Brouwer	24 mos	113,660
NsG 29-60	YALE UNIVERSITY Research on problems of satellite and planetary motion.	Dirk Brouwer	36 mos	149,580
NsG 43-60	UNIVERSITY OF CINCINNATI Fundamental research in celestial mechanics.	P. Herget	36 mos	178,000
ENGINEERING SCIENCES				
Energetics				
NAw 6551	OHIO STATE UNIVERSITY Investigation of parameters affecting the initiation of detonation in gaseous mixtures including determination of the effects of internal geometry in a tube upon the detonation induction distance for several combustible mixtures at initial pressures of 1 to 25 atm.	R. Edse	12 mos	28,889
NsG 10-59	UNIVERSITY OF CALIFORNIA Investigation of wave development during detonation of a gaseous mixture and determination of the composition profile of the wave to obtain data necessary to provide accelerating wave.	A. K. Oppenheim	36 mos	118,800

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES				
Energetics				
NsG 44-60	OHIO STATE UNIVERSITY Investigation of parameters affecting the initiation of detonation in gaseous mixtures.	R. Edse and L. E. Bollinger	24 mos	105,625
Electromagnetics				
NsG 2-59	UNIVERSITY OF MICHIGAN Research on information and communication theory pertinent to the very low signal-to-noise ratios that are encountered inspace communication and telemetry.	M. S. Nichols	36 mos	30,000
Fluid Mechanics				
NAw 6549	POLYTECHNIC INSTITUTE OF BROOKLYN Analytical investigation of convective heat transfer through three-dimensional non-steady boundary layers with and without fluid injection.	T. P. Torda	12 mos	15,100
NAw 6550	UNIVERSITY OF MICHIGAN Investigation of cavitation-erosion phenomena with liquid metals including construction and initial calibration of a continuous flow fluid tunnel and associated equipment.	F. G. Hammitt	12 mos	24,370
S59-53	NATIONAL BUREAU OF STANDARDS Investigation of the mechanics of transition from laminar to turbulent flow in boundary layers of subsonic and supersonic flows.		12 mos	50,000

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES Fluid Mechanics				
NAw 6554	STANFORD UNIVERSITY Investigation of convection heat transfer in annular passages with and without asymmetric heating and eccentricity, including construction and initial testing of the sectionally heated flat duct and the variable diameter-ratio annulus apparatus.	W. M. Kays and W. C. Reynolds	12 mos	32,160
NASw-3	UNIVERSITY OF MINNESOTA Analytical and theoretical investigation of Prandtl number and thermal conductivity of air at high temperatures, including the measurement of recovery factor to approximately 2000° F and evaluation of methods for determining thermal conductivity of air at higher temperatures.	E. R. G. Eckert	12 mos	30,514
NsG 3-59	RICE INSTITUTE Investigation of the performance and flow condition in the test section of maximum Mach number windtunnels, including studies of temperature distribution, degree of ionization in the free-stream, boundary layer effects and nozzle shape.	A. J. Chapman and H Beckman	36 mos	105,550
HS-82	FRANKLIN INSTITUTE Research on gas-lubricated bearings (NR 097-343b).		6 mos	15,000
HS-118	NORTHWESTERN UNIVERSITY Symposium on Magnetohydrodynamics.	A. B. Cambel		1,676

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES Fluid Mechanics				
NsG 13-59	UNIVERSITY OF ILLINOIS Investigation of the flow and heat transfer conditions within separated flow regions.	H. H. Korst	12 mos	23,057
NsG 20-59	UNIVERSITY OF MICHIGAN An experimental and theoretical study of the flow about right circular cones at angles of attack up to 90° and at Mach numbers above 3.	Hans P. Liepman	12 mos	31,000
NsG 31-60	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Experimental investigation of the effect of sound impingement upon shear flows.	Erick Mollo-Christensen	29 mos	74,350
NTF 64	NATIONAL BUREAU OF STANDARDS Investigation of boundary layer transition.	G. B. Shubauer	12 mos	70,000
NsG 39-60	UNIVERSITY OF MICHIGAN Investigation of cavitation-erosion phenomena.	F. G. Hammitt	24 mos	93,710
NsG 41-60	NATIONAL ACADEMY OF SCIENCES-NATIONAL RES. COUNCIL Joint support of International Union of Theoretical and Applied Mechanics symposium of magneto-fluid dynamics.		1 mo	10,000
	UNIVERSITY OF CALIFORNIA Second international symposium on rarified gas dynamics in 1960.	F. S. Sherman	1 mo	6,500

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES				
Materials Technology				
NASw-2	CATHOLIC UNIVERSITY OF AMERICA Experimental investigation of the flow and fracture of high-strength materials including a study of fracture strength for various strain rates and testing temperatures and the relation of fracture strength to strength levels, metal structure and carbon content of the material.	E. P. Klier	12 mos	27,500
NASw-5	UNIVERSITY OF MICHIGAN Investigation of the effects of trace elements on structure, high temperature strength, and fabricability of high temperatures and refractory alloys.	J. W. Freeman	12 mos	50,000
HS 34	NATIONAL BUREAU OF STANDARDS Investigation of the effect of surface reaction on fatigue failure.		7½ mos	18,417
NASw 8	DENVER UNIVERSITY Investigation of the scavenging action of selected rare earth metals with tungsten and molybdenum alloys, including an investigation of the effects of the rare earth metals on dispersion strengthening of the tungsten and molybdenum alloys at high temperatures.	J. P. Nachman	12 mos	49,815
HS 35	NATIONAL BUREAU OF STANDARDS Investigation of crosslinking of transparent polymers by radiant energy.	G. M. Kline	7 mos	17,500
NsG 26-59	STANFORD RESEARCH INSTITUTE International symposium on high temperature technology.	Nevin K. Hiester	1 mo	4,000
NASw 72	MARLIN ROCKWELL CORPORATION Investigation of methods for reducing the amount of end fiber in bearing components and of the effect of the reduction on the life of bearings and bearing balls.	A. S. Irwin	12 mos	39,521

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES				
Materials Technology				
NASw 74	T. R. FINN AND COMPANY Investigation of techniques for the fabrication and coating of Columbia, Molybdenum, Tantalum, Tungsten, Beryllium and their alloys.	C. W. Brunstetter	12 mos	99,134
NASw 101	BATTELLE MEMORIAL INSTITUTE Investigation of the influence of impurity elements, structure and prestrain on the tensile transition temperature of chromium.	R. I. Jaffee	12 mos	35,630
NsG 38-60	RENSSELAER POLYTECHNIC INSTITUTE Investigation of the mechanism of strengthening a metal matrix by a finely dispersed insolube second phase.	F. V. Lenel	24 mos	60,190
Mechanics				
NAw 6556	UNIVERSITY OF WASHINGTON Investigation of the stability (snap through) of conical shells subjected to lateral loads.	E. Dill	12 mos	4,644
S59-60	NATIONAL BUREAU OF STANDARDS Investigation of creep deflection of structures including an investigation of torsional creep of tubes at elevated temperatures.		12 mos	25,400
NAw 6557	UNIVERSITY OF MICHIGAN Investigation of the use of differential analyzer representations in studying a structural dynamics of plates, rings, stiffened cylindrical shells and beams.	R. M. Howe	12 mos	18,630

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES				
Mechanics				
NAw 6559	UNIVERSITY OF MICHIGAN Investigation of the vibration and flutter of buckled panels of finite aspect ratio.	E. J. Masur and J. Eisley	12 mos	19,570
NASw-14	PENNSYLVANIA STATE UNIVERSITY Theoretical investigation of stress penetration waves and impact damage in plates.	Norman Davids	12 mos	15,450
NASw-39	IOWA STATE COLLEGE Thermal stresses in circular disc.	Glenn Murphy	3½ mos	2,900
NsG 16-59	UNIVERSITY OF FLORIDA Investigation of the theory of the general instability of stiffened cylindrical shells	Wm. A. Nash	36 mos	64,330
NsG 18-59	CALIFORNIA INSTITUTE OF TECHNOLOGY Investigation of cylindrical and conical shells with large radius to thickness ratios.	E. E. Sechler	36 mos	108,000
NsG 17-59	NEW YORK UNIVERSITY Investigation of the axial and bending general instability of stiffened circular cylinders.	George Gerard	36 mos	120,000
NsG 27-59	UNIVERSITY OF MICHIGAN Investigation of the natural vibration characteristics of twisted rotating blades in combined bending and torsion.	G. Isakson	12 mos	16,822

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
ENGINEERING SCIENCES				
	System Analysis and Control			
NAw 6555	STANFORD UNIVERSITY Investigation of third order nonlinear control systems, including studies of the operation of quasi optimum control systems and of the effects of imperfections in the systems on their operations.	I. Flugge-Lotz	15 mos	15,500
NsG 14-59	RENSSELAER POLYTECHNIC INSTITUTE Investigation of the synthesis of high order non-linear control systems with time input including consideration of type input, multiple nonlinear system, form and accuracy of the synthesis.	Chi Neng Shen	36 mos	84,384
NsG 28-59	PURDUE UNIVERSITY Investigation of linear and nonlinear control theory having applications to missiles and satellites.	R. Oldenburger	36 mos	200,262
NsG 36-60	CASE INSTITUTE OF TECHNOLOGY Investigation of the use of hybrid numerical circuits in closed-loop control systems.	H. W. Mergler	36 mos	178,040
SOCIO-ECONOMIC STUDIES				
NASw-91	RAND CORPORATION Investigation to identify national objectives of non-military space activities, suggest the magnitude and scope of effort required to attain these objectives and determine balance of emphasis of the program.		1 mo	26,878

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
SOCIO-ECONOMIC STUDIES				
NASw 105	UNIVERSITY OF UTAH Predicting success in scientific laboratories from biographical information.	C. W. Taylor	15 mos	14,940
NASw 96	BROOKINGS INSTITUTION Design of a comprehensive and long term program of research and study regarding the social, economic, political, legal and international implications of the use of space for peaceful and scientific purposes.		12 mos	96,000
SCIENTIFIC INVESTIGATION IN SPACE Sounding Rockets				
NASw 4	UNIVERSITY OF MICHIGAN Investigation for development of rocket instrumentation packages for measuring the properties of the upper atmosphere.	L. M. Jones	12 mos	175,000
NASw 31	NEW YORK UNIVERSITY Investigation of the neutrons produced by cosmic radiation at high altitudes, including the instrumentation of two Aerobee-Hi rockets to be flown by the NASA	S. A. Korff and R. C. Haymes	24 mos	98,000
NsG 32-60	UNIVERSITY OF ROCHESTER Investigation of far ultra-violet and soft x-ray astronomy.	Malcolm P. Savedoff	12 mos	25,000
NsG 33-60	UNIVERSITY OF NEW HAMPSHIRE Further investigation of the equatorial electrojet.	L. J. Cahill, Jr.	18 mos	45,600

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
SCIENTIFIC INVESTIGATION IN SPACE				
Sounding Rockets				
NASw 115	UNIVERSITY OF MICHIGAN Rocket grenade instrumentation program.	H. F. Allen	24 mos	300,000
Earth Satellites				
NASw 24	UNIVERSITY OF CHICAGO Design and building of an instrument to measure the composition and energy spectrum of the primary cosmic radiation.	John Simpson	13 mos	300,280
NASw 33	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Preliminary investigation of the satellite gravitational redshift experiment, including performance comparisons of cesium frequency standards and comparison at cesium units with the NBS rubidium clock.	J. R. Zacharias	6 mos	50,000
NASw 17	STATE UNIVERSITY OF IOWA Space probe instrumentation to determine the components of the great radiation belt and the analysis of radiation observations made with satellites.	James A. Van Allen	16 mos	311,420
NASw 37-59	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Designing, constructing and testing a high-energy gamma ray detector capable of being carried in a satellite.	W. L. Krausbaer	6½ mos	68,000
NASw 54	UNIVERSITY OF MICHIGAN Preliminary investigation of instrumentation suitable for measuring the intensity of radio noise levels above the ionosphere and to measure the dynamic spectra of solar radio bursts.	F. T. Haddock	12 mos	81,600

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purpose	Individual	Duration	Amount
SCIENTIFIC INVESTIGATION IN SPACE Earth Satellites				
NASw 55	UNIVERSITY OF MICHIGAN Preliminary investigation of techniques and instrumentation for measurement of the ultra-violet solar emission spectrum.	Leo Goldberg	12 mos	76,000
NAWs 56	UNIVERSITY OF MINNESOTA Development and construction of instrumentation to measure directly in space the flux and specific ionization of cosmic rays and radiation belt particles, including installation of such instrumentation in three space vehicles.	J. R. Winckler	15 mos	74,951
NASw 59	UNIVERSITY OF NORTH CAROLINA Development and use of a precision coincidence telescope for study of primary cosmic radiation.	E. D. Palmatier	18 mos	63,140
NASw 66	UNIVERSITY OF WISCONSIN Stellar spectra-photometry in the far ultra-violet, including preliminary design studies of a satellite-borne telescope and consideration of data recovery and processing problems.	A. D. Code	12 mos	62,641
HS 168	PENNSYLVANIA STATE UNIVERSITY Investigation of ionospheric properties from satellite frequency observations at spaced locations.	W. J. Ross	12 mos	37,169
NsG 7-59	SMITHSONIAN INSTITUTION Scientific and engineering study for instrumenting an orbiting telescope.	F. L. Whipple	3 mos	99,935
NsG 24-59	UNIVERSITY OF ILLINOIS Investigation of the ionosphere using signals from earth satellites.	S. W. Swenson, Jr.	12 mos	64,800

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purposes	Individual	Duration	Amount
SCIENTIFIC INVESTIGATION IN SPACE				
Earth Satellites				
NsG 25-59	UNIVERSITY OF ARIZONA Investigation of telemetry, coding and data processing requirements for the orbiting observatories project.	E. L. Morrison	12 mos	24,917
NsG 30-60	STANFORD UNIVERSITY Investigation of ionospheric electron content and long range radio propagation.	O. K. Garriott	12 mos	91,620
NASw 89	UNIVERSITY OF COLORADO Study of solar ultra-violet radiation.	W. A. Rense	12 mos	110,600
NASw 107	UNIVERSITY OF ROCHESTER Investigation of solid state photodetectors.	R. E. Hopkins	12 mos	123,000
NASw 99	UNIVERSITY OF NEW MEXICO Investigation of high-energy gamma-radiation in the primary cosmic radiation by satellite measurements.	C. P. Leavitt	12 mos	31,760
NASw 80	STANFORD RESEARCH INSTITUTE Investigation of electronic, ionic, and atomic impact phenomena.	C. J. Cook	12 mos	48,000
Lunar Probes				
NASw 81	CALIFORNIA INSTITUTE OF TECHNOLOGY Investigation of the moon with a lunar seismograph station.	H. Benioff and F. Press	48 mos	125,000
NASw 82	COLUMBIA UNIVERSITY (Lamount Lab) Investigation of a lunar seismograph system.	M. Ewing and M. E. J. Oliver	48 mos	125,000

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Purposes	Individual	Duration	Amount
SCIENTIFIC INVESTIGATION IN SPACE				
Lunar Probes				
NsG 37-60	UNIVERSITY OF CHICAGO Ground based lunar studies	C. P. Kuiper	13 mos	67,630
Deep Space Probes				
NsG 19-59	YALE UNIVERSITY Investigation of the feasibility of remote detection of bacteria by automatic observation of changes in exposed culture media.	Wolf Vishniac	12 mos	4,485
NsG 23-59	PENNSYLVANIA STATE UNIVERSITY Investigation of the helium contents of meteorites.	Carl A. Bauer	12 mos	10,042
NASw 75	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Investigation of plasma densities and motions within the solar system.	B. Rossi	12 mos	97,200
SATELLITE APPLICATIONS INVESTIGATIONS				
NASw 65	UNIVERSITY OF WISCONSIN Preparation of machine programs for automatic reduction and analysis of data from meteorological satellites.	V. E. Suomi	12 mos	59,050

ACTIVE NASA RESEARCH GRANTS AND CONTRACTS (Continued)

Grant or Contract No.	Organization and Pruposes	Individual	Duration	Amount
SPACE OPERATIONS TECHNOLOGY				
Manned Space Flight				
NASw 70	UNIVERSITY OF MINNESOTA Initiate prototype development for a photosynthetic gas exchanger and a non CO_2 waste stabilizer for use in space vehicles.	A. H. Brown, H. S. Isbin & H. M. Tsuchiya	12 mos	60,000
SUPPORTING ACTIVITIES				
Tracking and Data Acquisition				
NsG 45-60	UNIVERSITY OF HEIDELBERG Operation of telemetry receiving station for composite radiation satellite, payload 16.	O. Hazel		5,435
NASw 68	UNIVERSITY OF MANCHESTER Tracking data from space probes.		12½ mos	179,200
NASw 88	GEORGE WASHINGTON UNIVERSITY A study of and reduction of data from telemetry records.		12½ mos	32,475

APPENDIX M

OUTSTANDING NASA R&D CONTRACTS WITH OBLIGATIONS OF $100,000 AND OVER AS OF SEPTEMBER 30, 1959*

ACTIVITY: NASA HEADQUARTERS

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 and 1960
Aeronautical & Space Research Support of JPL Plant.........	NASW-6 (HS-41) (HS-323)	Conduct of Research (see also "Lunar and planetary exploration", "Communications", "Vehicle systems technology", "Liquid Rockets", "Vega", and "Supporting Activities.")	JPL (California Tech)	$8,160,000
Scientific Investigations in Space Sounding Rockets.............	NASW-69 (HS-26-207)	Twenty ASPAN rockets	Cooper Development Co.	$140,000
	NASW-25 (HS-43)	Develop instrumentation (See also "Scientific satellites")	Itek Corporation	$160,000
	NASW-58 (HS-71)	Twelve Javelin rockets (ARGO D-4)	Aerolab Development Co. Ordnance (Army)	$240,000
	NASW-36 (HS-156) (HS-25-27-28)	Five Aerobee-Jr. vehicles Five Aerobee-Hi vehicles Seven Spaerobee kits	Aerojet General Corp.	$660,000
	NTF-2 (HS-71)	Twelve X-248A6 rockets	Ordnance (Navy)	$140,000
	NTF-3 (HS-71)	Twelve Honest John and Twenty-four Nike rockets	Ordnance (Army)	$160,000

*Excludes Research Grants and Contracts which are listed in Appendix L

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
Scientific Investigations in Space				
Scientific satellites........	NTF-12 (HS-1) (HS-46-304-325-332-357)	Radiation payload for Juno II, 19a (see also "Lunar and planetary explorations")	AOMC (Army)	$900,000
	NTF-17 (HS-6-194-361)	1 earth satellite (including 1 Thor-Able booster and 1 Thor to be used in "Delta" program) (see also "Lunar and planetary explorations")	BMD (ARDC-Air Force)	$9,150,000
	NTF-61 (HS-21-301-333)	Five Juno II boosters	AOMC (Army)	$10,020,000
	NASW-20 (HS-20)	Alterations to buildings 5-7 Bellevue Annex	Alton Engineering Co.	$140,000
	NASW-25 (HS-43)	Develop instrumentation (see also "Sounding rockets")	Itek Corporation	$450,000
	NTF-33 (HS-48)	Research on rubidium frequency standards	Bureau of Standards (Commerce)	$270,000
	NTF-40 (HS-120)	Reimbursement for special activities	AOMC (Army)	$100,000
	NASW-62 (HS-148)	Design and construction ammonia beam maser and associated dividing circuitry	Hughes Aircraft Co.	$200,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	NTF-52 (HS-175)	R&D in specified areas (see also "Lunar and planetary exploration" and "Vehicle systems technology")	ABMA (Army)	$100,000
	NTF-53 (HS-178)	Radio beacons for satellite	AOMC (Army)	$561,000
	NASW-98 (HS-226)	Electron density by Langmuir technique	Geophysical Corp. of America	$110,000
	NTF-11 (HS-234)	Astronautical detectors .05 to 120A	NRL (ONR)	$100,000
	NTF-15 (HS-4) (HS-305)	Continuation of inflatable sphere program	AOMC (Army)	$100,000
Scientific Investigations in Space				
Lunar and planetary exploration................	NTF-12 (HS-1) (HS-46)	Lunar probe projects (see also "Scientific satellites)	AOMC (Army)	$2,610,000
	NTF-13 (HS-2)	Lunar probe projects	BMD (ARDC-Air Force)	$2,140,000
	NTF-14 (HS-3)	Lunar probe projects	NOTS (ONR-Navy)	$200,000
	NTF-17 (HS-6) (HS-194-300-334-361-368-373)	One lunar orbiter and one deep space probe (see also "Scientific satellites")	BMD (ARDC-Air Force)	$17,530,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	NTF-35 (HS-66)	Conduct R&D on television for space vehicles	NOTS (ONR-Navy)	$100,000
	NASW-6 (HS-41)	Deep-space study	JPL (California Tech.)	$1,300,000
	NASW-6 (HS-129 & HS-201)	Vega-space vehicle and related payloads (see also "Vega")	JPL (California Tech.)	$5,000,000
	NTF-71 (HS-40)	Construction of addition to building No. 125 at JPL	Corps of Engineers (Army)	$130,000
	NTF-55 (HS-219)	Studies on soft lunar landings	AOMC (Army)	$150,000
	NTF-6 (HS-246)	Measure natural radio-activity of the moon	NRL (ONR)	$150,000
Satellite Applications Meteorology.................	NTF-19 (HS-11) (HS-209)	Meteorological analysis	U. S. Weather Bureau (Commerce)	$140,000
	NTF-41 (HS-126)	Project Tiros	Signal Corps. (Army)	$540,000
	NTF-67 (HS-262)	Modification of facilities at Kaena Point, Hawaii and operation for three months following successful launch-ing	Air Force (BMD)	$280,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
Satellite Applications Communications..............	NTF-15 (HS-4)	100 ft. inflatable sphere	AOMC (Army)	$2,150,000
	NASW-38 (HS-80) (HS-366)	Third stage hardware Delta space vehicle (see also "Delta")	Douglas Aircraft Co.	$140,000
	NASW-6 (HS-177)	Transmitter for the passive communications satellite program	JPL (California Tech.)	$130,000
	NASW-6 (HS-340)	Purchase of items for the launching of communications satellite in March 1960	JPL (California Tech.)	$280,000
	NASW-110 (HS-216-282)	Assembly and operation of a transmitting and receiving facility	Western Electric Co.	$170,000
Manned Space Flight	NTF-66 (HS-183)	Provide one Jupiter - launched recoverable animal payload	Office of Surgeon General (Army)	$150,000
	NASW-95 (HS-215)	Design, develop and fabricate a prototype of a closed ecological system	General Dynamics Corp. Electric Boat Div.	$120,000
Vehicle Systems Technology	NTF-52 (HS-175)	R&D in specified areas (see also "Scientific satellites" and "Lunar and planetary exploration")	ABMA (Army)	$810,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	NASW-6	Conduct of research (see also "Support of JPL plant")	JPL (California Tech.)	$250,000
Space Propulsion Technology Solid rockets................	NASW-29 (HS-72)	Exploratory R&D on propellants	Callary Chemical Co.	$170,000
	NASW-51 (HS-123)	Demonstrate feasibility of unique design of rocket engines	Grand Central Rocket Corp.	$180,000
Space Propulsion Technology Liquid rockets...............	NTF-20 (HS-13)	"State-or-art" work on rocket engines	WADC (ARDC-Air Force)	$430,000
	NASW-6 (HS-58)	Develop 6,000 lb. thrust storable propellant system	JPL (California Tech.)	$2,000,000
	NASW-16 (HS-10) (HS-356)	1,500,000 lb. thrust rocket engine	Rocketdyne Division of North American Aviation, Inc.	$10,000,000
	NASW-28 (HS-76) (HS-197) (HS-347)	Feasibility of liquid fluorine-liquid hydrogen in a rocket engine	Bell Aircraft Corp.	$1,070,000
	NASW-40 (HS-127)	Investigate feasibility of plug nozzle rocket thrust chamber	General Electric Co.	$390,000
Space Propulsion Technology Nuclear systems technology	NTF-21 (HS-15)	Rover program	A.E.C.	$1,870,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	NASW-104 (HS-192)	Investigation of spectral and total emissivity and reflectivity	Pratt and Whitney	$100,000
Vehicle Development Delta........................	NASW-38 (HS-80) (HS-241)	Delta space vehicle (see also "Communications")	Douglas Aircraft Co.	$6,900,000
	NTF-1 (HS-162)	Eleven THOR missiles	BMD (Air Force)	$5,870,000
	NTF-70 (HS-185)	Sixteen X248A5 Delta rocket motors (see also "Communications")	Bureau of Ordnance (Navy)	$140,000
	NTF-65 (HS-324)	Operation of computers and post-flight analysis of data for seven Delta launchings	BMD (Air Force)	$130,000
Vehicle Development Vega........................	NASW-6 (HS-129) (HS-309)	Vega space-vehicle and related payloads	JPL (California Tech.)	$6,400,000
	NASW-30 (HS-103) (HS-274) (HS-363)	Development of liquid propellant rocket engine	General Electric Co.	$4,120,000
	NTF-4 (HS-252)	Eight modified ATLAS vehicles (including spares)	BMD (Air Force)	$7,500,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	NASW-45 (HS-164) (HS-360)	Eight Vega second-stage vehicles, 1 Vega for captive firing tests and design, develop, test and fabricate nose cone fairings	Convair Astronautics Division	$7,000,000
Vehicle Development Centaur....................	NTF-57 (HS-302-362)	Provide for work on Centaur for the fiscal year 1960	ARDC (Air Force)	$13,000,000
Supporting Activities				
	NASW-11 (HS-17)	Operations of Minitrack stations in South America and Cuba for 18 months beginning 1/1/59	Bendix Radio Corporation	$860,000
	(HS-22)	Photo reduction equipment	Smithsonian Astrophysics Laboratory	$140,000
	(HS-32-330-331)	Tracking and data reduction services	Smithsonian Institute	$880,000
	NTF-38 (HS-115)	Procurement test equipment for telemetry stations	NRL (ONR-Navy)	$440,000
	NASW-6 (HS-135)	R&D on improved tracking and receiving equipment	JPL (California Tech.)	$300,000
	NTF-72 (HS-335)	Support of Fort Churchill through September 1959	Research & Development (Army)	$400,000
		ACTIVITY: LANGLEY RESEARCH CENTER		
Aeronautical and Space Research Support of NASA Plant	NASI-218	S/M modification of gov't airplane	Butler Aviation	$150,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
Satellite Applications Communications	NAS5-53	Aerojet junior rocket motors	Aerojet General Corp.	$150,000
Manned Space Flight	NAS5-57	Destruct system, design of transport vehicles and launcher and one (1) control study	North American Aviation	$1,090,000
Vehicle Development Scout......................	NAS1-249	Scout IV vehicles and launcher and umbilical cords	Chance Vought Aircraft, Inc.	$990,000
	NAS5-61	Second-stage reaction control system	Minneapolis-Honeywell Regulator Co.	$150,000
	NAS5-53	Fabrication and static firing of jupiter rockets	Aerojet General Corp.	$150,000
Supporting Activities	NASI-229	Tracking facilities ground instrumentation for Project Mercury	Massachusetts Institute of Technology	$900,000
Vehicle Development Anticipated Reimbursements - Scout...................	NAS5-61	S/M for study of and fabrication of standard Scout guidance and control system	Minneapolis-Honeywell Regulator Co.	$140,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
		ACTIVITY: LEWIS RESEARCH CENTER		
Manned Space Flight				
	NAS3-305	Furnishing Six Automatic Flight Control Systems	Minneapolis-Honeywell	$150,000
	NAS3-335	Furnishing two Telemetering Systems for Prototype Man-for-Space Capsule	Electro Mechanical Research, Inc.	$120,000
Space Propulsion Technology				
Liquid rockets...............	NAS3-262	Propellant tank assemblies	Douglas Aircraft Co.	$110,000
	NAS3-234	Furnishing six Rocket Thrust chambers and necessary tooling	Solar Aircraft Co.	$330,000
Scientific Investigations in Space				
Sounding Rockets.............	HS-47	Partial support of Space Sciences Division (Townsend) (see also "Scientific Satellites")	NRL (ONR - Navy)	$1,860,000
	GS-1	Research & Development Services in connection with the tenancy of elements of the GSFC at NRL	NRL (ONR - Navy)	$1,550,000
Scientific Satellites........	HS-47	Partial support of Space Sciences Division (Townsend) (see also "Sounding Rockets")	NRL (ONR - Navy)	$2,000,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	GS-1	Research & Development Services in connection with the tenancy of elements of the GSFC at NRL	NRL (ONR - Navy)	$1,420,000
Scientific Investigations in Space				
Lunar and planetary exploration.................	GS-1	Research & Development Services in connection with the tenancy of elements of the GSFC at NRL	NRL (ONR - Navy)	$720,000
Vanguard Program............	HS-23	Support of the Vanguard Program, Goddard Space Flight Center	NRL (ONR - Navy)	$20,050,000
		Personal services and related costs, travel and contractual services		$1,700,000
Satellite Applications				
Meteorology..................	GS-1	Research & Development Services in connection with the tenancy of elements of the GSFC at NRL	NRL (ONR - Navy)	$770,000
	GS-48 NTF-67	Project TIROS read out facility at Kaena Point, Hawaii	Air Force Ballistics Missile Division	$150,000
Manned Space Flight				
	S-1507(G)	Test of drogue chute	Air Force Cambridge Research Center	$140,000

GRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	HS-44	Redstone boosters	AOMC (Army)	$1,050,000
	HS-36	Atlas boosters	BMD (Air Force)	$1,000,000
	HS-36	Ten Atlas d booster	BMD (Air Force)	$10,260,000
	S-1013(G)	Seven XM-45 rockets (see also "Earth Satellites")	ABMA (Chief of Ordnance, Army)	$120,000
	NAS5-55	Twenty-four XM-19E1 rockets	Thiokol, Inc.	$110,000
	L-55,931(G)	Sixteen TX-33-20 rockets, 12TX-33-22 rockets (see also "Earth Satellites")	ABM (Chief of Ordnance, Army)	$2,190,000
	HS-44	Part of 8 Redstone boosters	AOMC (Army)	$8,910,000
	HS-54	Two Jupiter boosters	AOMC (Army)	$2,740,000
	S-1202	Five Pressure suits	Commander, Hdqrs. Air Material Command	$120,000
	NAS5-63	Ablation heat shields	Cincinnati-Testing & Research Lab.	$120,000
	NAS5-59	Twelve capsule systems, 12 ablation and 6 beryllium heat shield, 6 escape and 6 retro-rocket systems, 9 release mechanisms, a mock-up of the capsule system	McDonnell Aircraft Corp.	$20,090,000
Vehicle Development Scout........................	S-1000(G)	Eight X-248 rockets	Bureau of Ordnance (Navy)	$100,000

PROGRAM	CONTRACT NUMBER	PURPOSE	CONTRACTOR	APPROXIMATE OBLIGATIONS TOTAL, 1959 AND 1960
	S-1010(G)	Eight X-254 rockets	Bureau of Ordnance (Navy)	$1,120,000
	NAS5-53	Eight Jupiter seniors	Aerojet Gen. Corp.	$1,020,000
		Nine Transtainers	Aerojet Gen. Corp.	$170,000
	L-55,931(G)	Eight TX-33-20 rockets (see also "Manned space flight")	ABM (Chief of Ordnance, Army)	$620,000
	NAS5-61	Attitude control system	Minneapolis-Honeywell Regulator Co.	$770,000
Supporting Activities				
	GS-1	Research & Development Services in connection with the tenancy of elements at the GSFC at NRL	NRL (ONR - Navy)	$1,280,000
	NASW-19 (GS-2)	Two earth satellite radio tracking & receiving stations	University of Chile	$240,000
	GS-4	Operation of Minitrack Stations for 1960 by Bendix	Bendix Radio, Div. of Aviation Corp.	$2,010,000
	GS-7	Operation of satellite radio tracking & receiving station Peru	Instituto Geofisico De Huancayo	$110,000

APPENDIX N

RESEARCH PUBLICATIONS

REPORTS

1342. A Variational Theorem for Creep with Applications to Plates and Columns. By J. Lyell Sanders, Jr., Harvey G. McComb, Jr., and Floyd R. Schlechte, NACA

1343. A Phenomenological Relation Between Stress, Strain Rate, and Temperature for Metals at Elevated Temperatures. By Elbridge Z. Stowell, NACA

1344. A Simplified Method for Approximating the Transient Motion in Angles of Attack and Sideslip During a Constant Rolling Maneuver. By Leonard Sternfield,NACA

1345. The Response of an Airplane to Random Atmospheric Disturbances. By Franklin W. Diederich, NACA

1346. Differential Equations of Motion for Combined Flapwise Bending, Chordwise Bending, and Torsion of Twisted Nonuniform Rotor Blades. By John C. Houbolt and George W. Brooks, NACA

1347. Ditching Investigations of Dynamic Models and Effects of Design Parameters on Ditching Characteristics. By Lloyd J. Fisher and Edward L. Hoffman, NACA

1348. Ground Simulator Studies of the Effects of Valve Friction, Stick Friction, Flexibility, and Backlash on Power Control System Quality. By B. Porter Brown, NACA

1349. A Low-Speed Experimental Investigation of the Effect of a Sandpaper Type of Roughness on Boundary-Layer Transition. By Albert E. von Doenhoff and Elmer A. Horton, NACA

1350. Methods for Obtaining Desired Helicopter Stability Characteristics and Procedures for Stability Predictions. By F. B. Gustafson and Robert J. Tapscott,NACA

1351. Theory of Self-Excited Mechanical Oscillations of Helicopter Rotors with Hinged Blades. By Robert P. Coleman and Arnold M. Feingold, NACA

1352. Effect of Fuel Variables on Carbon Formation in Turbojet-Engine Combustors. By Edmund R. Jonash, Jerrold D. Wear, and William P. Cook, NACA

1353. An Experimental Investigation of Sting-Support Effects on Drag and a Comparison with Jet Effects at Transonic Speeds. By Maurice S. Cahn, NACA

1354. Effect of Chord Size on Weight and Cooling Characteristics of Air-Cooled Turbine Blades. By Jack B. Esgar, Eugene F. Schum, and Arthur N. Curren, NACA

1355. A Theoretical and Experimental Study of Planing Surfaces Including Effects of Cross Section and Plan Form. By Charles L. Shuford, Jr., NACA

1356. Investigation of Separated Flows in Supersonic and Subsonic Streams with Emphasis on the Effect of Transition. By Dean R. Chapman, Donald M. Kuehn, and Howard K. Larson, NACA

1357. Experimental Determination of Effects of Frequency and Amplitude on the Lateral Stability Derivatives for a Delta, a Swept, and an Unswept Wing Oscillating in Yaw. By Lewis R. Fisher, NACA

1358. On Flow of Electrically Conducting Fluids Over a Flat Plate in the Presence of a Transverse Magnetic Field. By Vernon J. Rossow, NACA

1359. Thin Airfoil Theory Based on Approximate Solution of the Transonic Flow Equation. By John R. Spreiter and Alberta Y. Alksne, NACA

1360. Growth of Disturbances in a Flame-Generated Shear Region. By Perry L. Blackshear, Jr., NACA

1361. Approximate Analysis of Effects of Large Deflections and Initial Twist on Torsional Stiffness of a Cantilever Plate Subjected to Thermal Stresses. By Richard R. Heldenfels and Louis F. Vosteen, NACA

1362. Theoretical Combustion Performance of Several High-Energy Fuels for Ramjet Engines. By Leonard K. Tower, Roland Breitwieser, and Benson E. Gammon, NACA

1363. Origin and Prevention of Crash Fires in Turbojet Aircraft. By I. Irving Pinkel, Solomon Weiss, G. Merritt Preston, and Gerard J. Pesman, NACA

1364. Measurement of Static Pressure on Aircraft. By William Gracey, NACA

1365. A Correlation of Results of a Flight Investigation With Results of an Analytical Study of Effects of Wing Flexibility on Wing Strains Due to Gusts. By C. C. Shufflebarger, Chester B. Payne, and George L. Cahen, NACA

1366. The Mechanism of Thermal-Gradient Mass Transfer in the Sodium Hydroxide-Nickel System. By Charles E. May, NACA

1367. Calculated and Measured Stresses in Simple Panels Subject to Intense Random Acoustic Loading Including the Near Noise Field of a Turbojet Engine. By Leslie W. Lassiter and Robert W. Hess, NACA

1368. Systematic Two-Dimensional Cascade Tests of NACA 65-Series Compressor Blades at Low Speeds. By James C. Emery, L. Joseph Herrig, John R. Erwin, and A. Richard Felix, NACA

1369. Blowing-Type Boundary-Layer Control as Applied to the Trailing-Edge Flaps of a 35° Swept-Wing Airplane. By Mark W. Kelly, Seth B. Anderson, and Robert C. Innis, NACA

1370. Area-Suction Boundary-Layer Control as Applied to the Trailing-Edge Flaps of a 35° Swept-Wing Airplane. By Woodrow L. Cook, Seth B. Anderson, and George E. Cooper, NACA

1371. Investigation of Some Wake Vortex Characteristics of an Inclined Ogive-Cylinder Body at Mach Number 2. By Leland H. Jorgensen and Edward W. Perkins, NACA

1372. A Method of Computing the Transient Temperature of Thick Walls From Arbitrary Variation of Adiabatic-Wall Temperature and Heat-Transfer Coefficient. By P. R. Hill, NACA

1373. Theoretical Analysis of Total-Pressure Loss and Airflow Distribution for Tubular Turbojet Combustors with Constant Annulus and Liner Cross-Sectional Areas. By Charles C. Graves and Jack S. Grobman, NACA

1374. The Similarity Rules for Second-Order Subsonic and Supersonic Flow. By Milton D. Van Dyke, NACA

1375. A Wind-Tunnel Investigation of the Aerodynamic Characteristics of a Full-Scale Supersonic-Type Three-Blade Propeller at Mach Numbers to 0.96. By Albert J. Evans and George Liner, NACA

1376. Elliptic Cones Alone and With Wings at Supersonic Speeds. By Leland H. Jorgensen, NACA

1377. Measurements of Free-Space Oscillating Pressures Near Propellers at Flight Mach Numbers to 0.72. By Max C. Kurbjun and Arthur W. Vogeley, NACA

1378. A Method for Simulating the Atmospheric Entry of Long-Range Ballistic Missiles. By A. J. Eggers, Jr., NACA

1379. Compressible Laminar Boundary Layer Over a Yawed Infinite Cylinder With Heat Transfer and Arbitrary Prandtl Number. By Eli Reshotko and Ivan E. Beckwith, NACA

1380. An Analysis of Pressure Studies and Experimental and Theoretical Downwash and Sidewash Behind Five Pointed-Tip Wings at Supersonic Speeds. By William B. Boatwright, NACA

1381. A Study of the Motion and Aerodynamic Heating of Ballistic Missiles Entering the Earth's Atmosphere at High Supersonic Speeds. By H. Julian Allen and A. J. Eggers, Jr., NACA

1382. A Comparative Analysis of the Performance of Long-Range Hypervelocity Vehicles. By Alfred J. Eggers, Jr., H. Julian Allen, and Stanford E. Neice, NACA

1383. Survey of Hydrogen Combustion Properties. By Isadore L. Drell and Frank E. Belles, NACA

1384. A Summary of Preliminary Investigations Into the Characteristics of Combustion Screech in Ducted Burners. By Lewis Laboratory Staff, NACA

1385. Drag Minimization for Wings and Bodies in Supersonic Flow. By Max A. Heaslet and Franklyn B. Fuller, NACA

1386. Investigation of the Drag of Various Axially Symmetric Nose Shapes of Fineness Ratio 3 for Mach Numbers from 1.24 to 7.4. By Edward W. Perkins, Leland H. Jorgensen, and Simon C. Sommer, NACA

1387. Full-Scale Investigation of Several Jet-Engine Noise-Reduction Nozzles. By Willard D. Coles and Edmund E. Callaghan, NACA

1388. NACA Research on Slurry Fuels. By M. L. Pinns, W. T. Olson, H. C. Barnett, and R. Breitwieser, NACA

1389. Characteristics of the Langley 8-Foot Transonic Tunnel With Slotted Test Section. By Ray H. Wright, Virgil S. Ritchie, and Albin O. Pearson, NACA.

1390. Incompressible Flutter Characteristics of Representative Aircraft Wings. By C. H. Wilts, California Institute of Technology.

1391. Investigation of a Nonlinear Control System. By I. Flügge-Lotz, C. F. Taylor, and H. E. Lindberg, Stanford University.

1392. Boron and Zirconium From Crucible Refractories in a Complex Heat-Resistant Alloy. By R. F. Decker, John P. Rowe, and J. W. Freeman, University of Michigan.

TECHNICAL NOTES

D-1 A Study of the Acoustic Fatigue Characteristics of Some Flat and Curved Aluminum Panels Exposed to Random and Discrete Noise. By Robert W. Hess, Robert W. Herr, and William H. Mayes.

D-2. Approximate Composition and Thermodynamic Properties of Nonionized Nitrogen-Oxygen Mixtures. By Richard A. Hord.

D-3. An Examination of Methods of Buffeting Analysis Based on Experiments with Wings of Varying Stiffness. By A. Gerald Rainey and Thomas A. Byrdsong.

D-4. Influence of Shaft Deflection and Surface Roughness on Load-Carrying Capacity of Plain Journal Bearings. By F. H. Raven and R. L. Wehe.

D-5. Investigation of Methods for Computing Flutter Characteristics of Supersonic Delta Wings and Comparison with Experimental Data. By C. H. Wilts.

D-6. Vacuum-Induction, Vacuum-Arc, and Air-Induction Melting of a Complex Heat-Resistant Alloy. By R. F. Decker, John P. Rowe, and J. W. Freeman.

D-8. Laminar Skin-Friction and Heat-Transfer Parameters for a Flat Plate at Hypersonic Speeds in Terms of Free-Stream Flow Properties. By James F. Schmidt.

D-9. Experimental Investigation of Air Film Cooling Applied to an Adiabatic Wall by Means of an Axially Discharging Slot. By S. Stephen Papell and Arthur M. Trout.

D-10. On Series Expansions in Magnetic Reynolds Number. By Vernon J. Rossow.

D-11. Measured and Predicted Section Wave Drag Coefficients at a Mach Number of 1.8 for a Delta Wing with Two Airfoil Sections. By Frederick C. Grant.

D-12. Solutions of the Laminar Compressible Boundary-Layer Equations with Transpiration which are Applicable to the Stagnation Regions of Axisymmetric Blunt Bodies. By John T. Howe and William A. Mersman.

D-13. Effectiveness of an All-Movable Horizontal Tail on an Unswept-Wing and Body Combination for Mach Numbers from 0.60 to 1.40. By Louis S. Stivers, Jr.

D-14. Transonic Aerodynamic Characteristics of Several Bodies Having Elliptical Cross Sections and Various Plan Forms. By Robert A. Taylor.

D-15. Experimental Investigation at Transonic Speeds of Pressure Distributions Over Wedge and Circular-Arc Airfoil Sections and Evaluation of Perforated-Wall Interference. By Earl D. Knechtel.

D-16. Low-Speed Wind-Tunnel Investigation of Blowing Boundary-Layer Control on Leading-and Trailing-Edge Flaps of a Full-Scale, Low-Aspect-Ratio, 42° Swept-Wing Airplane Configuration. By Ralph L. Maki and Demo J. Giulianetti.

D-17. Wind-Tunnel Investigation of Effect of Ratio of Wing Chord to Propeller Diameter with Addition of Slats on the Aerodynamic Characteristics of Tilt-Wing VTOL Configurations in the Transition Speed Range. By Robert T. Taylor.

D-18. Two Techniques for Detecting Boundary-Layer Transition in Flight at Supersonic Speeds and at Altitudes above 20,000 Feet. By John G. McTigue, John D. Overton, and Gilbert Petty, Jr.

D-19. Consideration of Some Aerodynamic Characteristics During Take-Off and Landing of Jet Airplanes. By John M. Riebe.

D-20. The Analysis and Design of Continuous and Sampled-Data Feedback Control Systems with a Saturation Type Nonlinearity. By Stanley Francis Schmidt.

D-21. Near-Field and Far-Field Noise Surveys of Solid-Fuel Rocket Engines for a Range of Nozzle Exit Pressures. By William H. Mayes, Wade E. Lanford, and Harvey H. Hubbard.

D-22. Measurements of Ground-Reaction Forces and Vertical Accelerations at the Center of Gravity of a Transport Airplane Taxiing Over Obstacles. By James H. McKay.

D-24. Calculation of Supersonic Flow Past Bodies Supporting Shock Waves Shaped Like Elliptic Cones. By Benjamin R. Briggs.

D-25. Large-Scale Wind-Tunnel Tests of an Airplane Model with an Unswept, Aspect-Ratio-10 Wing, Four Propellors, and Blowing Flaps. By James A. Weiberg and V. Robert Page.

D-26. Moving-Cockpit Simulator Investigation of the Minimum Tolerable Longitidinal Maneuvering Stability. By B. Porter Brown and Harold I. Johnson.

D-27. Shielding Stagnation Surfaces of Finite Catalytic Activity by Air Injection in Hypersonic Flight. By Paul M. Chung.

D-28. A Combined Water-Bromotrifluoromethane Crash-Fire Protection System for a T-56 Turbopropeller Engine. By John A. Campbell and Arthur M. Busch.

D-29. Summary of VGH and V-G Data Obtained from Piston-Engine Transport Airplanes from 1947 to 1958. By Walter G. Walker and Martin R. Copp.

D-31. A Dynamic Model Investigation of the Effect of a Sharp-Edge Vertical Gust on Blade Periodic Flapping Angles and Bending Moments of a Two-Blade Rotor. By John Locke McCarty, George W. Brocks, and Domenic J. Maglieri.

D-32. A Limited Flight and Wind-Tunnel Investigation of Paddle Spoilers as Lateral Controls. By Robert G. Mungall, Harold I. Johnson, and William L. Alford.

D-33. Free Fall and Evaporation of JP-4 Fuel Droplets in a Quiet Atmosphere. By Herman H. Lowell.

D-34. Airplane and Engine Responses to Abrupt Throttle Steps as Determined from Flight Tests of Eight Jet-Propelled Airplanes. By Maurice D. White and Bernard A. Schlaff.

D-36. Analysis of Acceleration, Airspeed, and Gust-Velocity Data from a Four-Engine Turboprop Transport Operating over the Eastern United States. By Martin R. Copp and Mary W. Fetner.

D-38. Effect of Chordwise Heat Conduction on the Torsional Stiffness of a Diamond-Shaped Wing Subjected to a Constant Heat Input. By Robert G. Thomson and J. Lyell Sanders, Jr.

D-39. Effects of Water-Landing Impact on an Orbital Capsule from the Standpoint of Occupant Protection. By Howard G. Hatch, Jr.

D-41. An Approximate Analysis of Unsteady Vaporization Near the Stagnation Point of Blunt Bodies. By Leonard Roberts.

D-43. An Evaluation of Linearized Vortex Theory as Applied to Single and Multiple Rotors Hovering in and out of Ground Effect. By Harry H. Heyson.

D-48. Ground Measurements of the Shock-Wave Noise from Airplanes in Level Flight at Mach Numbers to 1.4 and at Altitudes to 45,000 Feet. By Domenic J. Maglieri, Harvey H. Hubbard, and Donald L. Lansing.

D-50. Wind-Tunnel Investigation of the Aerodynamic Characteristics of a Model Representative of a Supersonic Fighter-Class Airplane with an External-Flow Jet-Augmented Flap in Low-Speed Flight. By William A. Newson, Jr.

D-54. Shock-Tube Heat-Transfer Measurements on Inner Surface of a Cylinder (Simulating a Flat Plate) for Stagnation-Temperature Range 4,100° to 8,300° R. By Jim J. Jones.

D-56. An Investigation to Determine Conditions Under Which Downwash from VTOL Aircraft will Start Surface Erosion from Various Types of Terrain. By Richard E. Kuhn.

D-59. Investigation of Vibration Characteristics of Circular-Arc Monocoque Beams. By Wilbur B. Fichter and Eldon E. Kordes.

D-60. Jet-Engine Exhaust Noise from Slot Nozzles. By Willard D. Coles.

D-63. Field Experiments on Treatment of Fluorine Spills with Water or Soda Ash. By R. James Rollbuhler, George R. Kinney, and Lorenz C. Leopold.

D-65. Propellant Vaporization as a Criterion for Rocket-Engine Design; Experimental Effect of Chamber Diameter on Liquid Oxygen - Heptane Performance. By Marcus F. Heidmann.

D-66. Analysis of Effects of Rocket-Engine Design Parameters on Regenerative-Cooling Capabilities of Several Propellants. By Arthur N. Curren, Harold G. Price, Jr., and Howard W. Douglass.

D-70. Gravity Torque on an Orbiting Vehicle. By Brian F. Doolin.

D-71. An Approximate Method for Calculating Surface Pressures on Curved Profile Blunt Plates in Hypersonic Flow. By Marcus O. Creager.

D-73. Comparison of Calculated and Measured Stall Boundaries of a Helicopter Rotor at Advance Ratios from 0.3 to 0.4. By John L. McCloud, III and George B. McCullough.

D-79. High-Temperature Tensile Properties of Wrought Sintered Tungsten. By Paul F. Sikora and Robert W. Hall.

D-83. Mixing of Wakes in a Turbulent Shear Flow. By Salamon Eskinaza.

D-85. Analysis of Computed Flow Parameters for a Set of Sudden Stalls in Low-Speed Two-Dimensional Flow. By William T. Evans and Kenneth W. Mort.

D-87. Effects of Chemical Dissociation and Molecular Vibrations on Steady One-Dimensional Flow. By Steve P. Heims.

D-92. Measured and Theoretical Flow Fields Behind a Rectangular and a Triangular Wing Up to High Angles of Attack at a Mach Number of 2.46. By Frank J. Centolanzi.

D-95. Theoretical Analysis of the Creep Collapse of Columns. By Floyd R. Schlechte.

D-97. A Note on the Calculation of Helicopter Performance at High Tip-Speed Ratios. By Alfred Gessow.

D-98. Optimum Proportions of Truss-Core and Web-Core Sandwich Plates Loaded in Compression. By Melvin S. Anderson.

D-108. Relationship of Polymer Structure to Thermal Deterioration of Adhesive Bonds in Metal Joints. By J. M. Black and R. F. Blomquist.

D-109. Effects of Creep Stress on Particulate Aluminum-Copper Alloys. By E. E. Underwood and O. K. Manning.

D-110. Method for Predicting Off-Design Performance of Axial Flow Compressor Blade Rows. By George K. Serovy and E. W. Anderson.

D-111. Fatigue Strengths of Aircraft Materials. Axial-Load Fatigue Tests on Edge-Notched Sheet Specimens of 2024-T3 and 7075-T6 Aluminum Alloys and of SAE 4130 Steel with Notch Radii of 0.004 and 0.070 Inch. By H. J. Grover, W. S. Hyler, and L. R. Jackson.

D-112. Experimental Investigation of the Pressure Fluctuations on a Flat Plate and a Cylinder in the Slipstream of a Hovering Rotor. By John W. McKee.

D-128. The Flame Stability Effect of Gases Ejected into a Stream from a Bluff-Body Flameholder. By Edgar L. Wong.

D-150. Approximate Solutions to Optimum Climbing Trajectory for a Rocket-Powered Aircraft. By Angelo Miele and James O. Cappellari, Jr.

D-151. Combined Operations with and without Afterburning for Minimum Fuel Consumption in Level Flight. By Angelo Miele and Carlos R. Cavoti.

D-152. Approximate Solutions to Optimum Flight Trajectories for a Turbojet-Powered Aircraft. By Angelo Miele and James O. Cappellari, Jr.

D-155. Minimal Maneuvers of High-Performance Aircraft in a Vertical Plane. By Angelo Miele.

D-157. Experimental Pressure Distributions over Blunt Two-and Three-Dimensional Bodies Having Similar Cross Sections at a Mach Number of 4.95. By Jerome D. Julius.

D-162. Handbook of Structural Stability. Part VII - Strength of Thin-Wing Construction. By George Gerard and Herbert Becker.

D-163. Handbook of Structural Stability. Supplement to Part III - Buckling of Curved Plates and Shells. By George Gerard.

D-195. Evolution of Amplified Waves Leading to Transition in a Boundary Layer with Zero Pressure Gradient. By P. S. Klebanoff and K. D. Tidstrom.

TECHNICAL MEMORANDUMS

10-1-58E. Turbulent Heat-Transfer Coefficients in the Vicinity of Surface Protuberances. By Richard J. Wisniewski.

10-5-58E. Structural Design and Preliminary Evaluation of a Lightweight, Brazed, Air-Cooled Turbine Assembly. By William C. Morgan and Andre J. Meyer, Jr.

10-6-58E. A Three-Dimensional Flow Expander as a Device to Increase the Mach Number in a Supersonic Wind Tunnel. By Reino J. Salmi.

10-9-58E. Heat-Transfer and Friction Measurements with Variable Properties for Airflow Normal to Finned and Unfinned Tube Banks. By Robert G. Ragsdale.

10-10-58L. Effect of Nose Length, Fuselage Length, and Nose Fineness Ratio on the Longitudinal Aerodynamic Characteristics of Two Complete Models at High Subsonic Speeds. By Kenneth W. Goodson.

10-20-58L. Basic Pressure Measurements at Transonic Speeds on a Thin 45° Sweptback Highly Tapered Wing with Systematic Spanwise Twist Variations. By John P. Mugler, Jr.

11-3-58L. Force-Test Investigation of the Stability and Control Characteristics of a $\frac{1}{4}$ - Scale Model of a Tilt-Wing Vertical-Take-Off-And-Landing Aircraft. By William A. Newsom, Jr., and Louis P. Tosti.

11-4-58L. Flight Investigation of the Stability and Control Characteristics of a $\frac{1}{4}$ - Scale Model of a Tilt-Wing Vertical-Take-Off-And-Landing Aircraft. By Louis P. Tosti.

11-5-58L. Analytical and Experimental Determination of the Coupled Natural Frequencies and Mode Shapes of a Dynamic Model of a Single-Rotor Helicopter. By Milton A. Silveira and George W. Brooks.

11-21-58W. Effect of Rest Periods on Fatigue of High-Purity Aluminum. By J. W. Berry, J. Lemaitre, and S.R.Valluri.

11-26-58E. Compairson of Calculated and Experimental Total Pressure Loss and Airflow Distribution in Tubular Turbojet Combustors with Tapered Liners. By Jack S. Grobman

11-27-58E. Performance of Typical Rear-Stage Axial-Flow Compressor Rotor Blade Row at Three Different Blade Setting Angles. By Marvin I. Kussoy and Daniel Bachkin.

11-30-58A. Experimental Wind-Tunnel Investigation of the Transonic Damping-In-Pitch Characteristics of Two Wing-Body Combinations. By Horace F. Emerson and Robert C. Robinson.

12-1-58W. Heat Transfer in the Turbulent Incompressible Boundary Layer. I - Constant Wall Temperature. By W. C. Reynolds, W. M. Kays, and S. J. Kline.

12-2-58W. Heat Transfer in the Turbulent Incompressible Boundary Layer. II - Step Wall-Temperature Distribution. By W. C. Reynolds, W. M. Kays, and S. J. Kline.

12-3-58A. Large-Scale Wind-Tunnel Tests of an Airplane Model with an Unswept, Aspect-Ratio-10 Wing, Two Propellers, and Blowing Flaps. By Roy N. Griffin, Jr., and Curt A. Holzhauser, James A. Weiberg.

12-3-58L An Analysis of Flight-Test Measurements of the Wing Structural Deformations in Rough Air of a Large Flixible Swept-Wing Airplane. By Harold N. Murrow.

12-3-58W Heat Transfer in the Turbulent Incompressible Boundary Layer. III-Arbitrary Wall Temperature and Heat Flux. By W.C. Reynolds, W.M. Kays, and S.J. Kine.

12-4-58A Three-Dimensional Orbits of Earth Satellites, Including Effects of Earth Oblateness and Atmospheric Rotation. By Jack N. Nielsen, Frederick K. Goodwin, and W.A. Mersman.

12-4-58W Heat Transfer in the Turbulent Incompressible Boundary Layer. IV-Effect of Location of Transition and Prediction of Heat Transfer in a Known Transition Region. By. W.C. Reynolds, W.M. Kays, and S.J. Kline.

12-4-58L Preliminary Measurements of the Noise Characteristics of Some Jet-Augmented-Flap Configurations. By Domenic J. Maglieri, and Harvey H. Hubbard.

12-5-58W Interaction Effects Produced by Jet Exhausting Laterally Near Base of Ogive-Cylinder Model in Supersonic Main Stream. By P.W. Vinson, J.L. Amick, and H.P. Liepman.

12-8-58E NASA Reactor Facility Hazards Summary. Vol. I By Lewis Research Center.

12-10-58E NASA Reactor Facility Hazards Summary. Vol. II By Lewis Research Center.

12-13-58E The Thermal Stability of Unsymmetrical Dimethylhydrazine. By Adolph E. Spakowski.

12-14-58W Structure of Weak Shock Waves in a Monatomic Gas. By L. Talbot and F.S. Sherman.

12-15-58L Free-Flight Investigation of a Rocket-Propelled Model to Determine the Aerodynamic Heating on a Thin, Unswept, Untapered, Multispar, Aluminum-Alloy Wing at Mach Numbers Up to 2.22. By Emily W. Stephens.

12-20-58L Investigation of the Maximum Spin-Up Coefficients of Friction Obtained During Tests of a Landing Gear Having a Static-Load Rating of 20,000 Pounds. By Sidney A. Batterson.

12-21-58E Experimental Investigation of Coaxial Jet Mixing of Two Subsonic Streams at Various Temperature, Mach Number, and Diameter Ratios for Three Configurations. By Richard R. Burley and Lively Bryant.

12-23-58E A Study of Oxidation of Hydrogen Based on Flashback of Hydrogen-Oxygen-Nitrogen Burner Flames. By Burton D. Fine.

12-24-58E Computer Program for Solving Nine-Group Diffusion Equations for Cylindrical Reactors. By James W. Miser, Robert E. Hyland, and Daniel Fieno.

12-25-58A Boundary-Layer-Transition Measurements on Hemispheres of Various Surface Roughnesses in a Wind Tunnel at Mach Numbers from 2.48 to 3.55. By Angelo Bandettini and Walter E. Isler.

12-26-58A The Effect of Leading-Edge Sweep and Surface Inclination on the Hypersonic Flow Field Over a Blunt Flat Plate. By Marcus O. Creager.

12-28-58L Basic Pressure Measurements at Transonic Speeds on a Thin 45° Sweptback Highly Tapered Wing with Systematic Spanwise Twist Variations. By John P. Mugler, Jr.

12-29-58A Effects of Large Wing-Tip Masses on Oscillatory Stability of Wing Bending Coupled with Airplane Pitch. By Donald T. Higdon.

12-29-58E Propellant Vaporization as a Criterion for Rocket-Engine Design; Experimental Performance, Vaporization, and Heat-Transfer Rates with Various Propellant Combinations. By Bruce J. Clark, Martin Hersch, and Richard J. Priem.

12-30-58L A Weight Comparison of Several Attitude Controls for Satellites. By James J. Adams and Robert G. Chilton.

1-2-59L A Method for Computing Turbulent Heat Transfer in the Presence of a Streamwise Pressure Gradient for Bodies in High-Speed Flow. By Nathaniel B. Cohen.

1-3-59L Measurements of Local Heat Transfer and Pressure on Six 2-Inch-Diameter Blunt Bodies at a Mach Number of 4.95 and at Reynolds Numbers per Foot Up to 80×10^6. By Morton Cooper and Edward E. Mayo.

1-5-59E Estimated Performance of Radial-Flow Exit Nozzles for Air in Chemical Equilibrium. By Gerald W. Englert and Fred D. Kochendorfer.

1-5-59L The Effect of Beam Loading on Water Impact Loads and Motions. By John S. Mixson.

1-6-59E Analytical Investigation of the Significance of Turbine-Inlet Temperature in High-Energy Rocket Turbodrive Applications. By Harold E. Rohlik.

1-6-59L Investigation of Spherical-Wave-Initiated Flow Fields Around Bodies. By Donald R. McFarland.

1-7-59L A Wind-Tunnel Investigation of Rotor Behavior Under Extreme Operating Conditions with a Description of Blade Oscillations Attributed to Pitch-Lag Coupling. By John W. McKee, and Rodger L. Naeseth.

1-9-59E Experimental Investigation of Expanded Duct Sections and Screens for Reducing Flow Distortions at Subsonic Flows. By Bruce G. Chiccine and Kaleel L. Abdalla.

1-9-59L Hydrodynamic Impact-Load Alleviation with a Penetrating Hydro-Ski. By Philip M. Edge, Jr.

1-10-59A Two-Dimensional, Supersonic, Linearized Flow with Heat Addition. By Harvard Lomax.

1-10-59E Pressure Drag of Axisymmetric Cowls Having Large Initial Lip Angles at Mach Numbers from 1.90 to 4.90. By Nick E. Samanich.

1-10-59L A Hydrogen Peroxide Hot-Jet Simulator for Wind-Tunnel Tests of Turbojet-Exit Models. By Jack F. Runckel and John M. Swihart.

1-11-59E Experimental Investigation of Aerodynamic Effects of External Combustion in Airstream Below Two-Dimensional Supersonic Wing at Mach 2.5 and 3.0 By Robert G. Dorsch, John S. Serafini, Edward A. Fletcher and I. Irving Pinkel.

1-15-59L Effects of Fuselage Nose Length and a Canopy on the Low-Speed Oscillatory Yawing Derivatives of a Swept-Wing Airplane Model with a Fuselage of Circular Cross Section. By James L. Williams and Joseph R. DiCamillo.

1-15-59E Combustion of Various Highly Reactive Fuels in a 3.84- By 10-Inch Mach 2 Wind Tunnel. By Harrison Allen, Jr., and Edward A. Fletcher.

1-16-59A A Numerical Method for Calculating the Wave Drag of a Configuration from the Second Derivative of the Area Distribution of a Series of Equivalent Bodies for Revolution. By Lionel L. Levy, Jr., and Kenneth K. Yoshikawa.

1-16-59L Semiempirical Procedure for Estimating Lift and Drag Characteristics of Propeller-Wing-Flap Configurations for Vertical-And Short-Take-Off-And-Landing Airplanes. By Richard E. Kuhn.

1-17-59L Analysis of Acceleration, Airspeed, and Gust-Velocity Data from a Four-Engine Transport Airplane Operating Over a Northwestern United States-Alaska Route. By Jerome N. Engel, and Martin R. Copp.

1-18-59A Subsonic Wing Loadings on a 45° Sweptback-Wing and Body Combination at High Angles of Attack. By John A Axelson and Jack F. Haacker.

1-19-59A Finishing and Inspection of Model Surfaces for Boundary Layer-Transition Tests. By Max E. Wilkins and John F. Darsow.

1-19-59E Summary of Statistical Icing Cloud Data Measured Over United States and North Atlantic, Pacific, and Arctic Oceans During Routine Aircraft Operations. By Porter J. Perkins.

1-20-59A Boundary-Layer Transition on Hollow Cylinders in Supersonic Free Flight as Affected by Mach Number and a Screwthread Type of Surface Roughness. By Carlton S. James.

1-20-59L Measurements of Total Hemispherical Emissivity of Several Stably Oxidized Metals and Some Refractory Oxide Coatings. By William R. Wade.

1-21-59A Experimental Investigation of the Pressure Rise Required for the Incipient Separation of Turbulent Boundary Layers in Two-Dimensional Supersonic Flow. By Donald M. Kuehn.

1-22-59A Pressure Distributions at Transonic Speeds for Bumpy and Indented Midsections of a Basic Parabolic-Arc Body. By Robert A. Taylor.

1-22-59L Low-Subsonic Static Stability and Damping Derivatives at Angles of Attack from 0° to 90° for a Model with a Low-Aspect-Ratio Unswept Wing and Two Different Fuselage Forebodies. By Peter C. Boisseau.

1-23-59A Low-Speed Wind Tunnel Investigation of Blowing Boundary-Layer Control on Leading-and-Trailing-Edge Flaps of a Large-Scale, Low-Aspect-Ratio, 45° Swept-Wing Airplane Configuration. By Ralph L. Maki.

1-23-59L Maximum Mean Lift Coefficient Characteristics at Low Tip Mach Numbers of a Hovering Helicopter Rotor Having an NACA 64_1A012 Airfoil Section. By Robert D. Powell, Jr.

1-25-59L Effect of Convex Longitudinal Curvature on the Planing Characteristics of a Surface Without Dead Rise. By Elmo J. Mottard.

1-26-59E Application of Gas Analysis to Combustor Research. By R.R. Hibbard and Albert Evans.

1-26-59L Flight Investigation of the Surface Pressure Distribution and Flow Field Around An Elliptical Spinner. By Lovic P. Thomas, III.

1-27-59E Reactor Design and Operating Criteris for Fluorine Disposal By Reaction with Charcoal. By Harold W. Schmidt.

1-27-59L Low-Speed Wind-Tunnel Investigation to Determine the Aerodynamic Characteristics of a Rectangular Wing Equipped with a Full-Span and an Inboard Half-Span Jet-Augmented Flap Deflected 55°. By Thomas G. Gainer.

1-29-59A A Pilot Opinion Study of Lateral Control Requirements for Fighter-Type Aircraft. By Brent Y. Creer, John D. Stewart, Robert B. Merrick, and Fred J. Drinkwater, III.

1-29-59E Evaluation of Transpiration-Cooled Turbine Blades with Shells of "Poroloy" Wire Cloth. By Hadley T. Richards.

1-30-59L Effects of Cross-Sectional Shape, Solidity, and Distribution of Heat-Transfer Coefficient on the Torsional Stiffness of Thin Wings Subjected to Aerodynamic Heating. By Robert G. Thomson.

1-31-59L Parasite-Drag Measurements of Five Helicopter Rotor Hubs. By Gary B. Churchill and Robert D. Harrington.

2-1-59H Residual Fuel Expulsion From a Simulated 50,000-Round-Thrust Liquid-Propellant Rocket Engine Having a Continuous Rocket-Type Igniter. By Wesley E. Messing.

2-1-59L Application of the Method of Stein and Sanders to the Calculation of Vibration Characteristics of a 45° Delta-Wing Specimen. By John M. Hedgepeth and Paul G. Waner, Jr.

2-2-59L Evaluation of the Levy Method as Applied to Vibrations of a 45° Delta Wing. By Edwin T. Kruszewski and Paul G. Waner, Jr.

2-4-59L Experimental Influence Coefficients and Vibration Modes of a Multispar 60° Delta Wing. By Deene J. Weidman and Eldon E. Kordes.

2-5-59E An Equation for the Mean Velocity Distribution of Boundary Layers. By V. A. Sandborn.

2-5-59L Free-Flight Test of a Technique for Inflating a NASA 12-Foot-Diameter Sphere at High Altitudes. By Alan B. Kehlet and Herbert G. Patterson.

2-5-59W Heat Transfer in a Liquid Metal Flowing Turbulently Through a Channel with a Step Function Boundary Temperature. By H. F. Poppendiek.

2-6-69L A Technique Utilizing Free-Flying Radio-Controlled Models to Study the Incipient-And-Developed-Spin Characteristics of Airplanes. By Charles E. Libbey and Sanger M. Burk, Jr.

2-7-59L Low-Speed Yawed-Rolling Characteristics of a Pair of 56-Inch-Diameter, 32-Ply-Rating, Type VII Aircraft Tires. By Wilbur E. Thompson and Walter B. Horne.

2-7-59L An Investigation of the Effect of a Highly Favorable Pressure Gradient on Boundary-Layer Transition as Caused by Various Types of Roughnesses on a 10-Foot-Diameter Hemisphere at Subsonic Speeds. By John B. Peterson, Jr., and Elmer A. Horton.

2-9-59L An Experimental Study at a Mach Number of 3 of the Effect of Turbulence Level and Sandpaper-Type Roughness on Transition on a Flat Plate. By Robert A. Jones.

2-10-59L A Generalized Hydrodynamic-Impact Theory for the Loads and Motions of Deeply Immersed Prismatic Bodies. By Melvin F. Markey.

2-11-59E Effect of Stator and Rotor Aspect Ratio on Transonic-Turbine Performance. By Robert Y. Wong and Daniel E. Monroe.

2-11-59L An Investigation of the Performance of Various Reaction Control Devices. By Paul A. Hunter.

2-12-59A The Effects of Target and Missile Characteristics on Theoretical Minimum Miss Distance for a Beam-Rider Guidance System in the Presence of Noise. By Elwood C. Stewart, Frank Druding and Togo Nishiura.

2-12-59L Compression Tests on Circular Cylinders Stiffened Longitudinally by Closely Spaced Z-Section Stringers. By James P. Peterson and Marvin B. Dow.

2-13-59A The Synthesis of Optemum Homing Missile Guidance Systems with Ststistical Inputs. By Elwood C. Stewart and Gerald L. Smith.

2-13-59E Experimental Evaluation of Cermet Turbine Stator Blades for Use at Elevated Gas Temperatures. By Patrick T. Chiarito and James R. Johnston.

2-13-59L External Interference Effects of Flow Through Static-Pressure Orifices of an Airspeed Head at Several Supersonic Mach Numbers and Angles of Attack. By Norman S, Silsby.

2-15-59L Ground Simulator Studies of a Nonlinear Linkage in a Power Control System. By Arthur Assadourian.

2-16-59L Effect of Adsorbed Nitrogen on the Therminonic Emmission from Lanthanum Hexaboride. By Arlen F. Carter and George P. Wood.

2-17-59L Some Effects of Yaw Damping on Airplane Motions and Vertical-Tail Loads in Turbulent Air. By Jack Funk and T.V. Cooney.

2-17-59W The Use of Stanton Tube for Skin-Friction Measurements. By S.S. Abarbanel, R.J. Hakkinen, and L. Trilling.

2-18-59L Evaluation of Several Approximate Methods for Calculating the Symmetrical Bending-Moment Response of Flexible Airplanes to Isotropic Atmospheric Turbulence. By Floyd V. Bennet and Robert T. Yntema.

2-18-59W The Interaction of an Oblique Shock Wave with a Laminar Boundary Layer. By R.J. Hallinen, I. Greber, L. Trilling, and S.S. Abarbanel.

2-19-59L Flight Investigation of an Automatic Throttle Control in Landing Approaches. By Lindsay J. Lina, Robert A. Champine, and Garland J. Morris.

2-20-59A Full-Scale Wind-Tunnel Investigation of a Jet Flap in Conjunction with a Plain Flap with Blowing Boundary-Layer Control on a 35° Sweptback-Wing Airplane. By Kiyoshi Aoyagi and David H. Hickey.

2-20-59E A 20,000-Kilowatt Nuclear Turbolelctric Power Supply for Manned Space Vehicles. By Robert E. English, Henry O. Slone, and Daniel T. Bernatowicz.

2-20-59L Tables for the Rapid Estimation of Downwash and Sidewash Behind Wings Performing Various Motions at Supersonic Speeds. By Percy J. Bobbitt.

2-21-59L Study of Taxiing Problems Associated with Runway Roughness. By Benjamin Milwitzky.

2-22-59L Some Static, Oscillatory, and Free-Body Tests of Blunt Bodies at Low Subsonic Speeds. By Jacob H. Lichtenstein, Lewis R. Fisher, Stanley H. Scher, and George F. Lawrence.

2-23-59E A Numerical Method for Obtaining Monoenergetic Neutron Flux Distributions and Transmissions in Multiple-Region Slabs. By Harold Schneider.

2-23-59L Tire-to-Surface Friction Especially Under Wet Conditions. By Richard H. Sawyer, Sidney A. Batterson, and Eziaslav N. Harrin.

2-23-59W Exploratory Study of Ventilated Flows About Yawed Surface-Piercing Struts. By John P. Breslin and Richard Skalak.

2-24-59A The Effect of Moment-of-Area-Rule Modifications on the Drag, Lift, and Pitching-Moment Characteristics of an Unswept Aspect-Ratio-6 Wing and Body Combination. By Robert R. Dickey.

2-24-59L Basic Pressure Measurements at Transonic Speeds on a Thin 45° Sweptback Highly Tapered Wing with Systematic Spanwise Twist Variations. Wing with Quadratic Spanwise Twist Variation. By John P. Mugler, Jr.

2-24-59W Theoretical Determination of Lifetime of Compressed Plates at Elevated Temperatures. By George Herrmann and Hu-Nan Chu.

2-25-59A Numerical Solution of the Flow of a Perfect Gas Over a Circular Cylinder at Infinite Mach Number. By Frank M. Hamaker.

2-25-59E Halogen-Containing Gases as Boundary Lubricants for Corrosion-Resistant Alloys at 1200°F. By Donald H. Buckley and Robert L. Johnson.

2-25-59L Several Methods for Reducing the Drag of Transport Configurations at High Subsonic Speeds. By Richard T. Whitcomb and Atwood R. Heath, Jr.

2-26-59A Some Finite Difference Solutions of the Laminar Compressible Boundary Layer Showing the Effects of Upstream Transpiration Cooling. By John. T. Moore.

2-27-59A Low-Speed Tests of Semispan-Wing Models at Angles of Attack from 0° to 180°. By David Koenig.

2-27-59E Details of Exact Low Prandtl Number Boundary-Layer Solutions for Forced and for Free Convection. By E.M. Sparrow and J.L. Gregg.

2-28-59L Comparison of Measured Flapwise Structural Bending Moments on a Teetering Rotor Blade with Results Calculated from the Measured Pressure Distribution. By Alton P. Mayo.

3-1-59H Flight Studies of Problems Pertinent to Low-Speed Operation of Jet Transports. By Jack Fischel, Stanley P. Butchart, Glenn H. Robinson, and Robert A. Tremant.

3-2-59A Study of the Oscillatory Motion of Manned Vehicles Entering the Earth's Atmosphere. By Simon C. Sommer and Murray Tobak.

3-2-59E Lubricating Properties of Lead-Monoxide-Base Coatings of Various Compositions at Temperatures to 1250° F. By Harold E. Sliney.

3-2-59H Flight Studies of Problems Pertinent to High-Speed Operation of Jet Transports. By Stanley P. Butchart, Jack Fischel, Robert A. Tremant, and Glenn H. Robinson.

3-3-59E Performance of Two Boron-Modified S-816 Alloys in a Turbojet Engine Operated at 1650°F. By William J. Waters, Robert A. Signorelli, and James R. Johnston.

3-3-59L Wind-Tunnel Investigation of the Effect of Angle of Attack and Flapping-Hinge Offset on Periodic Bending Moments and Flapping of a Small Rotor. By John Locke McCarty, George W. Brooks, and Domenic Maglieri.

3-3-59W Study of Plastic Deformation in Binary Aluminum Alloys by Internal-Friction Methods. By. E.C. Olson, R.E. Maringer, L.L. Marsh, and G.K. Manning.

3-4-59L The Shock-Wave Noise Problem of Supersonic Airdraft in Steady Flight. By Domenic J. Maglieri and Harry W. Carlson.

3-5-59E Stability of Ceramics in Hydrogen Between 4000° and 4500° F. By Charles E. May, Donald Koneval and George C. Fryburg.

3-5-59L Noise Problems Associated with Ground Operations of Jet Aircraft. By Harvey H. Hubbard.

3-6-59A Use of Flight Simulators for Pilot-Control Problems. By George A. Rathert, Jr., Brent Y. Creer, and Joseph G. Douvillier, Jr.

3-6-59E Preliminary Study of a Piston Pump for Cryogenic Fluids. By Arnold E. Biermann and Robert C. Kohl.

3-6-59L A Five-Stage Solid-Fuel Sounding-Rocket System. By Andrew G. Swanson.

3-7-59A Pitch-Up Problem - A Criterion and Method of Evaluation. By Melvin Sadoff.

3-7-59L Influence of Large Positive Dihedral on Heat Transfer to Leading Edges of Highly Swept Wings at Very High Mach Numbers. By Morton Cooper and P. Calvin Stainback.

3-8-59L Wind-Tunnel Investigation of a Small-Scale Sweptback-Wing Jet-Transport Model Equipped with an External-Flow Jet Augmented Double Slotted Flap. By Joseph L. Johnson, Jr.

3-9-59A A Wind-Tunnel Investigation of the Stall-Flutter Characteristics of a Supersonic-Type Propeller at Positive and Negative Thrust. By Vernon L. Rogallo and Paul F. Yaggy.

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3-10-59E Optimization of Parametric Constants for Creep-Rupture Data by Means of Least Squares. By S.S. Manson and A. Mendelson.

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3-16-59W Effect of Cascade Parameters on Rotating Stall. By A.H. Stenning, B.S. Seidel, and Y. Senoo.

3-17-59E Analysis and Evaluation of Supersonic Underwing Heat Addition. By Roger W. Luidens and Richard J. Flaherty.

3-17-59L The Fluorescent-Oil Film Method and Other Techniques for Boundary-Layer Flow Visualization. By Donald L. Loving and S. Katzoff.

3-17-59W Space-Time Correlations and Spectra of Wall Pressure in a Turbulend Boundary Layer. By W.W. Millmarth.

4-1-59L Effect of Horizontal-Tail Chord on the Calculated Subsonic Span Loads and Stability Derivatives of Isolated Unswept Tail Assemblies in Sideslip and Steady Roll. By Katherine W. Booth.

4-3-59L Formulas Pertinent to the Calculation of Flow-Field Effects at Supersonic Speeds Due to Wing Thickness. By Kenneth Margolis and Miriam H. Elliott.

4-6-59E Investigation of a 4.5-Inch-Mean-Diameter Two-Stage Axial-Flow Turbine Suitable For Auxiliary Power Drives. By Robert Y. Wong and Daniel E. Monroe.

4-7-59E Engine Operating Conditions that Cause Thermal-Fatigue Cracks in Turbojet-Engine Buckets. By James R. Johnston, John W. Weeton, and Robert A. Signorelli.

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4-13-59W Interactions Between Ground-State Nitrogen Atoms and Molecules. By Joseph T. Vanderslice, Edward A. Mason, and Ellis R. Lippincott.

4-14-59A Samples-Data Techniques Applied to a Digital Controller for an Altitude Autopilot. By Stanley F. Schmidt and Eleanor V. Harper.

4-14-59E Preliminary Development of Electrodes for An Electric-Arc Wind Tunnel. By Charles E. Shepard and Donald R. Boldman.

4-15-59L Charts of the Induced Velocities Near a Lifting Rotor. By Joseph W. Jewel, Jr., and Harry H. Heyson.

4-17-59L Airplane Measurements of Atmospheric Turbulence at Altitudes Between 20,000 and 55,000 Feet For Four Geographic Areas. By Thomas L. Coleman and May T. Meadows.

4-18-59A Predicted Static Aeroelastic Effects on Wings with Supersonic Leading Edges and Streamwise Tips. By Stuart C. Brown.

4-18-59L Noise Survey Under Static Conditions of a Turbine-Driven Transonic Propeller with an Advance Ratio of 4.0. By Mac C. Kurbjun.

4-19-59A Supersonic and Moment-Of-Area Rules Combined for Rapid Zero-Lift Wave-Drag Calculations. By Lionel L. Levy, Jr.

4-19-59L Flight Performance of a Transonic Turbine-Driven Propeller Designed for Minimum Noise. By Thomas C. O'Bryan and Jerome B. Hammack.

4-21-59E Analysis of Flow-System Starting Dynamics of Turbo-pump-Fed Liquid-Propellant Rocket. By Richard P. Krebs and Clint E. Hart.

4-21-59L Investigation of the Characteristics of an Accelera-tion-Type Take-Off Indicator in a Large Jet Airplane. By Joseph J. Kolnick and Emanuel Rind.

4-22-59W Heat Transfer From a Horizontal Cylinder Rotating in Oil. By R. A. Seban and H. A. Johnson.

4-23-59L Analytical Investigation of a Flicker-Type Roll Control for a Mach Number 6 Missile with Aerodynamic Controls Over an Altitude Range of 82,000 to 282,000 Feet. By Reginald R. Lundstrom and Ruth I. Whitman.

4-26-59A Flight Measurements of the Effect of a Controllable Thrust Reverser on the Flight Characteristics of a Single-Engine Jet Airplane. By Seth B. Anderson, George E. Cooper, and Alan E. Faye, Jr.

4-27-59E Heat Transfer from Cylinders in Transition from Slip Flow to Free-Molecule Flow. By Ronald J. Cybulski and Lionel V. Baldwin.

4-30-59L Transonic Aerodynamic Characteristics of Two Wedge Airfoil Sections Including Unsteady Flow Studies. By Patrick J. Johnston.

5-1-59L Low-Speed Investigation of Blowing from Nacelles Mounted Inboard and on the Upper Surface of an Aspect-Ratio-7.0 35° Swept Wing with Fuselage and Various Tail Arrangements. By Thomas R. Turner, Edwin E. Davenport, and John M. Riebe.

5-3-59L Investigation of the Structural Behavior and Maximum Bending Strength of Six Multiweb Beams with Three Types of Webs. By James P. Peterson and Walter E. Bruce, Jr.

5-4-59E Source Distribution Method for Unsteady One-Dimensional Flows with Small Mass. Momentum, and Heat Addition and Small Area Variation. By Harold Mirels.

5-4-59L Charts and Tables for Estimating the Stability of the Compressible Laminar Boundary Layer with Heat Transfer and Arbitrary Pressure Gradient. By Neal Tetervin.

5-5-59L Effect of Artificial Pitch Damping on the Longitudinal and Rolling Stability of Aircraft with Negative Static Margins. By Martin T. Moul and Lawrence W. Brown.

5-5-59W Effect of Contraction on Turbulence and Temperature Fluctuations Generated by Warm Grid. By Robert R. Mills, Jr., and Stanley Corrsin.

5-7-59L Flight Investigation of Effects of Transition, Landing Approaches, Partial-Power Vertical Descents, and Droop-Stop Pounding on the Bending and Torsional Moments Encountered by a Helicopter Rotor Blade. By LeRoy H. Ludi.

5-8-59L Fluid-Dynamic Properties of Some Simple Sharp-and Blunt-Nosed Shapes at Mach Numbers from 16 to 24 in Helium Flow. By Arthur Henderson, Jr., and Patrick J. Johnston.

5-9-59L Hydrodynamic Characteristics of Two Low-Drag Supercavitating Hydrofoils. By John R. McGehee and Virgil E. Johnson, Jr.

5-10-59L Review of Aircraft Altitude Errors Due to Static-Pressure Source and Description of Nose-Boom Installations for Aerodynamic Compensation of Error. By William Gracey and Virgil S. Ritchie.

5-12-59A Surface Pressure Distribution at Hypersonic Speeds for Blunt Delta Wings at Angle of Attack. By Marcus O. Creager.

5-12-59E Analytical Investigation of the Effect of Turbopump Design on Gross-Weight Characteristics of a Hydrogen-Propelled Nuclear Rocket. By Haorld E. Rohlik and James E. Crouse.

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5-14-59E Experimental Altitude Performance of JP-4 Fuel and Liquid-Oxygen Rocket Engine with an Area Ratio of 48. By Anthony Fortini, Charles D. Hendrix, and Vearl N. Huff.

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5-20-59L Low-Subsonic Measurements of the Static and Oscillatory Lateral Stability Derivatives of a Sweptback-Wing Airplane Configuration at Angles of Attack From -10° to 90°. By Donald E. Hewes.

5-21-59E Theoretical Performance of Liquid Hydrogen with Liquid Oxygen as a Rocket Propellant. By Sanford Gordon and Bonnie J. McBride.

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5-24-59L A Simple Method for Determining Heat Transfer, Skin Friction, and Boundary-Layer Thickness for Hypersonic Laminar Boundary-Layer Flows in a Pressure Gradient. By Mitchel H. Betram and William V. Feller.

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5-25-59 1958 NASA/USAF Space Probes (Able-1) FINAL REPORT
Vol. 1 - Summary
Vol. 2 - Payload and Experiments
Vol. 3 - Vehicles, Trajectories, and Flight Histories
By Space Technology Laboratories, Inc.

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5-26-59L Modified Matrix Method for Calculating Steady-State Span Loading on Flexible Wings in Subsonic Flight. By Patrick A. Gainer and William S. Aiken, Jr.

6-1-59L Chordwise Pressure Distributions Over Several NACA 16-Series Airfoils at Transonic Mach Numbers up to 1.25. By Charles L. Ladson.

6-2-59L Compressive Strength of Stainless-Steel Sandwiches at Elevated Temperatures. By Eldon E. Mathauser and Richard A. Pride.

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APPENDIX O

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