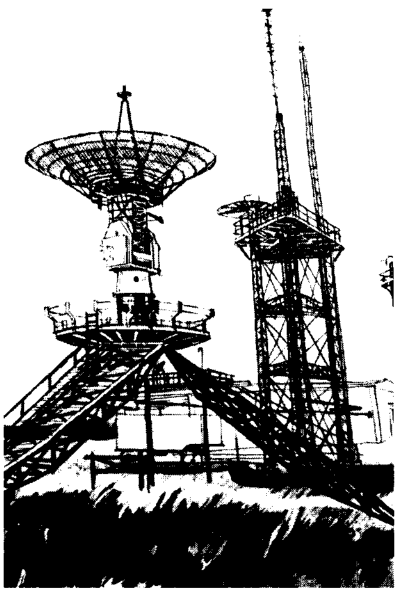
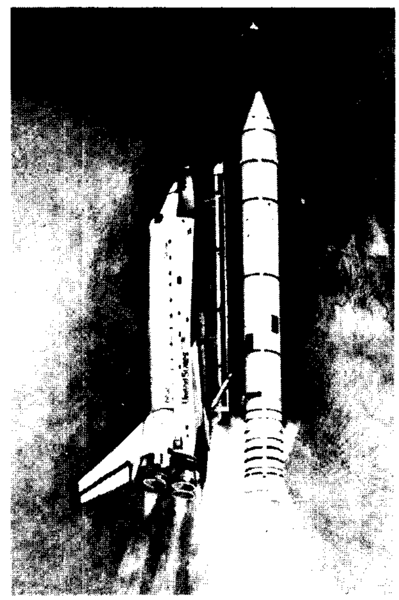
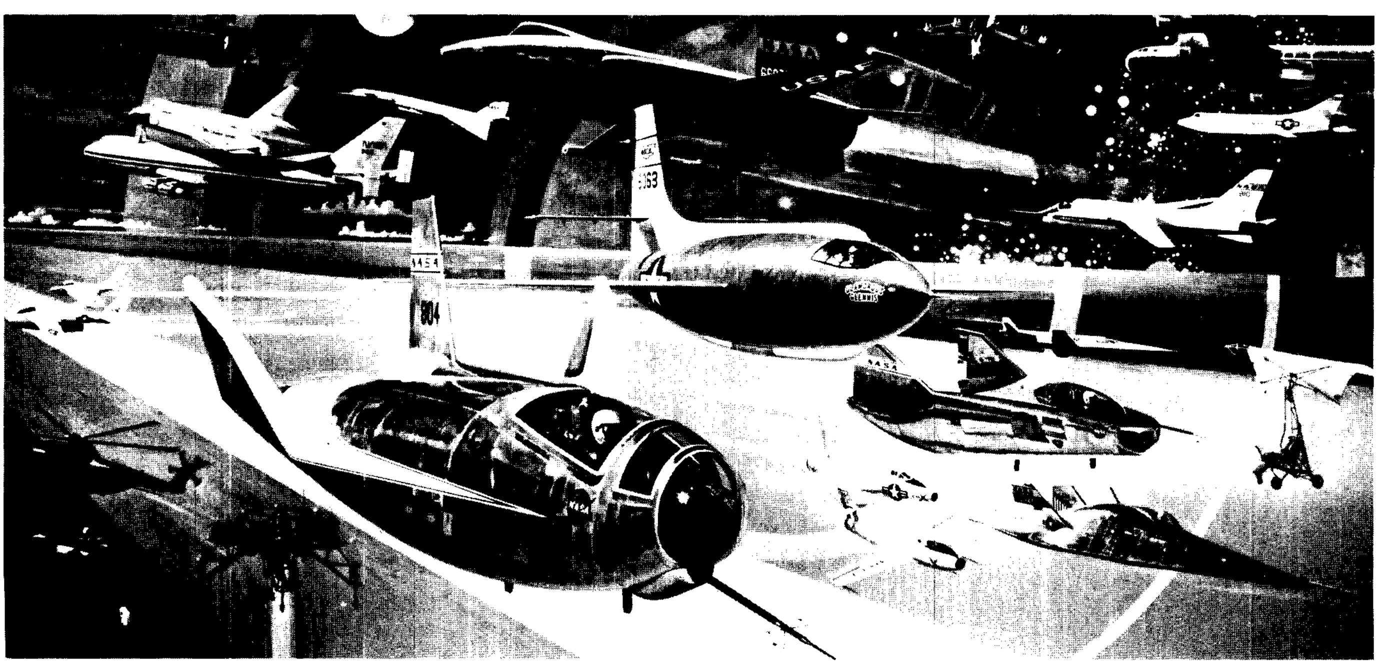
NASA
National Aeronautics and
Space Administration

25 Press Kit
25th Anniversary 1958-1983
October 1983

# Our First Quarter Century of Achievement ... Just the Beginning







**RELEASE NO: 83-132** September 1983

NOTE TO EDITORS:

NASA is observing its 25th anniversary. The space agency opened for business on Oct. 1, 1958.

The information attached summarizes what has been achieved in these 25 years. It was prepared as an aid to broadcasters, writers and editors who need historical, statistical and chronological material.

Those needing further information may call or write: NASA Headquarters, Code LFD-10, News and Information Branch, Washington, D. C. 20546; 202/755-8370. Photographs to illustrate any of this material may be obtained by calling or writing: NASA Headquarters, Code LFD-10, Photo and Motion Pictures, Washington, D. C. 20546; 202/755-8366.

Mary G. Fitzpatrick

Mary G. Fitzpatrick
Acting Chief, News and Information Branch
Public Affairs Division

Cover Art

Top row, left to right: "Command Destruct Center," 1967, Artist Paul Calle, left; "View from Mimas," 1981, features on a Saturnian satellite, by Artist Ron Miller, center; "Plumes," STS-4 launch, Artist Chet Jezierski,right; aeronautical research mural, Artist Bob McCall, 1977, on display at the Visitors Center at Dryden Flight Research Facility, Edwards, Calif.

# CONTENTS

NASA News

National Aeronautics and
Space Administration

Washington, D.C. 20546
AC 202 755-8370

For Release:

1958-1983

# OUR FIRST QUARTER CENTURY OF ACHIEVEMENT--JUST THE BEGINNING

By

James M. Beggs
NASA Administrator

(Editor's Note: These comments on the National Aeronautics and Space Administration's 25 years were prepared by Mr. Beggs for the October issue of NASA Activities, which is published monthly by NASA for the information of the Agency's employees.)

"We celebrate 25 years of reaching for excellence and achieving it in space and aeronautics. The nation's investment in our work has produced a steady stream of new technological discoveries which have benefited everyone on earth. And the returns on this investment will be even greater in the future as we continue our work." James M. Beggs

## OUR FIRST QUARTER CENTURY OF ACHIEVEMENT--JUST THE BEGINNING

By

James M. Beggs
NASA Administrator

We did not get to our present position of leadership in space by accident.

We got there because we had the imagination to dream great dreams and the national will to fulfill them.

We got there because the partnership of government, industry and our universities, built up over the years, created a scientific and high technology base second to none.

We got there for the good common sense reason that we have learned to build on our achievements as we go along -- and to learn from our experience. As Shakespeare wrote: "Experience is by industry achieved and perfected by the swift course of time."

We have had our struggles and our successes in the program over the swift course of NASA's 25-year lifetime. And they have been open for all the world to see, beginning with the launch of our first satellite, Explorer 1. They range from the succession of planetary explorers -- the Mariners, the Pioneers, the Vikings and the Voyagers; through the Mercury, Gemini and Apollo programs to the development of the Shuttle.

All would never have been possible had we not built on past experience. And, largely because we have done so, we became the leaders.

With the Shuttle, we are making dramatic and timely progress in learning to live and work in space. It is a truly impressive vehicle, and as time goes on, we are finding that its performance surpasses even the expectation of its designers.

But the Shuttle allows us to stay in space for only a short time. And while we can extend that time to about a month, we cannot extend it to long-duration, long-endurance space flight.

To do work of long duration, to do all the things we have always dreamed of doing beyond low earth orbit, we will need a space station.

I believe that a Space Station is, indeed, an idea whose time has come. Sooner or later, this country is going to take the next logical step in space and will build one.

And the sooner we do so, the better it will be for us, because a space station is essential if we are to maintain our preeminence.

I see a Space Station as an essential stepping stone to the future. With it, and with the use of an orbital transfer vehicle, which we will ultimately develop to move us to geosynchronous orbit, we will be able to operate routinely some 22,000 miles above the earth. And from there, perhaps we will begin to realize Wernher von Braun's great dream of going back to the moon to build a base, and from that base, mounting a manned expedition to Mars.

I believe that we will be able to accomplish all of these things within the next 25 years so that when NASA celebrates its Golden Anniversary in the year 2008, we will look back on our first quarter century of achievement as just the beginning.

25th Anniversary
1958-1983

# Space Flight

# SPACE FLIGHT

by
Victor Seigel

On American Independence Day, July 4, 1982, NASA astronauts Thomas K. Mattingly II and Henry W. Hartsfield Jr., landed their Space Shuttle orbiter Columbia on a concrete airstrip at Edwards Air Force Base, Calif. Their nearly flawless eight-day earth-orbital mission successfully concluded the orbital flight tests of NASA's Space Transportation System (STS), which was then declared operational. President Reagan, who was at Edwards to greet the returning Columbia and its crew, likened the flight to the historic "golden spike" that inaugurated transcontinental railroading.

Declaring STS operational on Independence Day was symbolic because the system literally frees people to perform economically in space a host of beneficial activities that until recently were considered impracticable. Now the world's first operating spaceline, STS, is designed to provide regular trips for people and cargo between the ground and earth orbit. It can also serve as a platform in space from which to launch and retrieve spacecraft, conduct experiments, make observations and assemble large structures such as space stations, multi-purpose space platforms, solar-powered electric-generating facilities and huge erectable communications antennas that can lead to another quantum jump in world communications.

Like an airline, STS has flight vehicles and ground facilities. It includes two operational spaceports: one at Kennedy Space Center, Fla., and the other being readied at Vandenberg Air Force Base, Calif. Most of the components of its primary vehicle, the Space Shuttle, can be flown repeatedly.

The Shuttle orbiter provides airline-like comfort for as many as seven people, including crew and passengers, as they live and work in space. It enables them to dress in ordinary clothing, breathe earth-like air and eat meals, almost as they do on earth.

For cargo, the orbiter has a spacious payload bay 18.3 meters (60 feet) long and 4.6 m (15 ft.) in diameter. The bay can carry satellites for launch from the orbiters; a complete manned laboratory such as Spacelab, built by the European Space Agency; equipment for conducting a large variety of scientific and technological experiments and processes; and a Canadian-built Remote Manipulator System to deploy or retrieve satellites or move cargo around the bay. The total weight of the orbiter's payload will be as high as 29,500 kilograms (65,000 pounds).

In a typical mission, the Shuttle is launched by its two solid-rocket boosters and the orbiter's main engines. The spent boosters later separate and parachute into the ocean where they are recovered for reuse. The external fuel tank is jettisoned just before orbit, reenters the atmosphere and breaks up over a remote area. The orbiter conducts its mission in space. After atmosphere entry, the delta-winged orbiter is piloted like a glider to a dead-stick landing on an airstrip. It is refurbished and reused.

The Space Shuttle represents a revolutionary departure from the single-service cone-shaped bodies of Mercury, Gemini and Apollo. The cone-shaped design was chosen because it provided the highest ratio of payload to weight; the blunt ends generated maximum lift and drag during reëntry and flight through the atmosphere; and they permitted use of available ballistic missile experience.

The heat shields of these craft were made of a material that was destroyed as it protected the craft from the reentry inferno. In contrast, the Shuttle orbiter is covered by tiles designed both to protect the craft from heating and to last from flight to flight. This sweeping change, involving perfecting the tiles and bonding them to the craft, was among the new technological frontiers that had to be crossed in Shuttle development.

Organized in 1958, Mercury was America's pioneering manned space flight program. Even today, with the accumulated experience of 25 years, engineers and scientists recognize that manned space flights can never be considered routine and that unexpected hazards can occur. At the time of Mercury, however, the known and unknown problems of space appeared to be formidable.

Because space has no appreciable atmosphere, one side of a spacecraft can bake in the sun's heat while the dark side freezes in subzero cold. Tiny micrometeoroids, speeding through space at thousands of kilometers per hour, can pierce a spaceship's hull or an astronaut's pressure suit. Radiation can be lethal to people and degrade materials. The high vacuum of space can kill an exposed astrounaut within 30 seconds.

Apparent weightlessness in space can upset delicate biological processes and impair vital organs. It causes liquids to crawl upwards in their containers and escaped liquid to drift about in a cabin, posing hazards to people and equipment.

Yet, in just 25 years, advances in technology and life sciences have, for the most part, enabled America to cope effectively with the problems of manned space flight. America rapidly forged ahead, from the first hesitant steps in Mercury to the nearly normal accommodations afforded by the Space Shuttle.

The Mercury program of one-man spacecraft demonstrated that man can live, eat, work and sleep in space. It also showed that man can augment data acquired from automatic equipment and can make observations from space. In 1961, shortly after the first Mercury suborbital flight, President Kennedy proposed to Congress the bold new initiative that came to be known as Apollo: "...I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth."

The space flights in the two-man Gemini spacecraft in 1965 and 1966 provided mastery of technology and skills that were crucial to Apollo: maneuvers in space, rendezvous and docking with another vehicle in space, extravehicular activities (EVA), (EVA) and demonstration that man could function effectively in space for as long as two weeks with no lasting harmful aftereffects. In addition, photographs and other data acquired during Gemini's orbital missions provided a wealth of information related to earth's geography, environment and resources and to astronomy.

Even as Gemini was advancing manned space flight technology, a series of manned spacecraft were reconnoitering the moon for Apollo. Ranger provided the world's first lunar close-ups, revealing features not visible to earth observatories, before it crashed as planned on the moon. Lunar Orbiters provided detailed lunar topography that contributed to selection of Apollo landing sites. It also provided tracking, gravity and lunar environmental information. Surveyors, which landed softly on the moon, demonstrated that their landings raised no dust cloud, showed that the moon's bearing strength could support the weight of the Apollo landing craft, provided panoramas of the surrounding moonscape, and showed also that liftoff from the moon would not be periled by a dust cloud. Meanwhile, unmanned Explorer and Pegasus meteoroid-study earth satellites furnished data that contributed to Apollo design.

One of humanity's greatest achievements may well be the comparatively brief period of time in which skills were established; people, materials, and equipment organized; and vehicles and facilities built that resulted at 10:56 p.m. EDT, July 20, 1969, in the following message from Neil A. Armstrong as he stepped from his Apollo lunar module, Eagle, the moon's ancient untrodden surface:

"That's one small step for a man; one giant leap for mankind."

The United States referred to Apollo as a triumph of humanity. For the moment, the triumph gave humanity a new dimension of pride, of togetherness and of confidence that it could achieve other worthwhile but difficult objectives.

Apollo became a scientific mission that vastly expanded knowledge about the moon and earth. Six Apollo expeditions explored the moon, the last in December 1972. Astronauts worked effectively, even drove a vehicle about the lunar surface. They set up experimental equipment that would keep sending data long after they left. They brought back a large variety of lunar samples, countless pictures and other data that would be studied by hundreds scientists in the United States and abroad for years to come.

Skylab was America's first space station. The Skylab workshop, where three American astronauts lived and worked for long periods, was a modified empty third stage of the Saturn V launch vehicle that sent Apollo to the moon. Attached to the stage were an airlock enabling the crew to enter and leave the workshop, a multiple docking adapter for parking the Apollo command/service module that was used to travel between Skylab and earth, and the Apollo telescope mount, an astronomical observatory to study the sun. Apollo was launched by a Saturn IB, the vehicle used in early Apollo earth-orbital tests. Skylab and its first crew were launched in May 1973. Three separate Skylab missions, lasting 28, 59 and 84 days, were conducted until February 1974 when the last crew returned to earth.

Skylab provided a treasure trove of earth survey and solar pictures. It conducted a large variety of tests of industrial and biological processes for manufacturing products in space that would either be unique or of higher quality or produced in greater quantity than possible on earth. Studies of astronaut blood and other samples accumulated and returned to earth advanced knowledge about human biochemical changes in space and, indirectly, human life processes on earth. In Skylab, the astronauts clearly established that with proper equipment, nutrition and exercise, man could work for prolonged periods about as effectively in space as on earth and suffer no lasting harmful aftereffects upon return to earth.

Perhaps the most significant result of Skylab may be the knowledge that people can repair, adjust and install new equipment in space. This ability was quickly demonstrated when the first crew made repairs and installations which saved Skylab from a total loss. Their success supports the plans of Shuttle astronauts to repair satellites and assemble large structures in space.

Skylab was followed in July 1975 by the Apollo Soyuz Test Project (ASTP). ASTP, the world's first international manned space mission, employed the reliable Apollo command/service modules and the Soviet Soyuz.

It tested compatible docking systems as a possible lead to an international space rescue capability and future international manned space missions. It also conducted a large variety of experiments in earth survey, astronomy, life sciences and industrial and pharmaceutical processing.

Apollo-Soyuz ended America's era of expendable manned spacecraft. Six years later, American astronauts returned to space with the revolutionary Space Shuttle, vastly expanding America's capabilities to use space for the benefit of all mankind.

Highlights of individual missions follow.

**Mercury**

Mercury was organized Oct. 5, 1958, to orbit a manned spacecraft, investigate human reaction to and abilities in space, and to return the Mercury spacecraft and its occupant safely to earth.

Late in 1958, the NASA Special Committee on Life Sciences established qualifications for the first Americans to fly into space: a degree or equivalent in physical science or engineering, graduation from a military pilot test school, 1,500 hours of flying time including a substantial amount in high performance jets. NASA initially screened the records of 473 military service officers and on April 9, 1959, announced the Mercury astronauts: M. Scott Carpenter, L. Gordon Cooper, John H. Glenn Jr., Virgil I. Grissom, Walter M. Schirra Jr., Alan B. Shepard Jr. and Donald K. Slayton.

Little Joe was a series of tests between 1959 and 1961 of the Mercury spacecraft in ballistic flight. Tested under various dynamic pressures were its escape system, stability, controls and recovery of the spacecraft and biological effects of acceleration and deceleration forces and weightlessness on rhesus monkeys.

In Little Joe, Mercury was boosted to about one fifth of orbital velocity. In contrast, on Sept. 9, 1959, Big Joe using the Atlas launch vehicle that would launch Mercury, boosted an instrumented boilerplate model of Mercury to near orbital velocity to test entry into the atmosphere, the heat shield, flight characteristics and recovery. Results were so gratifying that no further tests were planned.

On July 29, 1960, MA-1, an unmanned suborbital flight designed to check structural integrity under maximum heating conditions exploded after lift off. Investigations delayed Mercury for about six months. On Nov. 8, 1960, Little Joe 5 failed when booster, tower, and capsule did not separate as planned. In the MR-1 test of Nov. 7, 1960, the Redstone booster ignited and shut down. The escape tower then took off from the spacecraft. On Dec. 19, 1960, NASA launched MR-1A. Both the Redstone and the Mercury spacecraft operated superbly. MR-2, with chimpanzee Ham as passenger, went higher and farther than planned on Jan. 31, 1961, and both the spacecraft and its passenger were recovered in excellent condition. The Mercury Atlas MA-2 unmanned flight test on Feb. 21, 1961, met every expectation. Little Joe 5A, March 18, 1961, did not go as planned but the Mercury-Redstone Booster-Development flight of March 24, 1961, indicated that all major booster problems were eliminated.

On April 12, 1961, the Soviet Union launched Vostok with Maj. Yuri A. Gagarin aboard into earth orbit. After one orbit, he returned to earth. Gagarin made history as the first human in orbit.

On April 25, 1961, NASA launched the unmanned MA-3. The flight was aborted, but the escape system operated perfectly, enabling the spacecraft to be recovered. On April 28, 1961, Little Joe 5B demonstrated the ability of the Mercury escape system to function under the worst conditions a Mercury-Atlas launch would impose.

On May 5, 1961, Astronaut Shepard became America's first man in space. He rode his Freedom 7 Mercury spacecraft on a 15-minute suborbital flight. From launch to landing, everything went as planned.

On July 21, 1961, Astronaut Grissom and his Liberty Bell 7 completed the second Mercury-Redstone suborbital flight. After landing, the hatch cover on his spacecraft blew off, water poured in, and Grissom had to abandon ship. Liberty Bell 7 was lost.

On Sept. 13, 1961, an unmanned Mercury was launched by Atlas into a one-orbit flight test. The test demonstrated that a man could be safely orbited and returned to earth. On Nov. 29, 1961, NASA launched Enos, a chimpanzee into earth orbit.

Astronaut John Glenn was launched into earth orbit Feb. 20, 1962. He and his Friendship 7 spacecraft gave Americans their first manned orbital flight, three orbits in nearly five hours. He took pictures and performed attitude-control and other chores during the flight. Glenn and Friendship 7 achieved the primary objective of Mercury.

On May 24, 1962, Carpenter in Aurora 7 flew another three-orbit mission. His spacecraft was modified and the flight emphasized scientific rather than engineering experiments. He drifted for 77 minutes to conserve fuel and evaluate the effects of drifting on himself and the spacecraft. He overshot his landing point in the Pacific by 250 miles because of a yaw error but was picked up in about three hours. His craft was recovered later.

Launched Oct. 3, 1962, in Sigma 7, Walter Schirra contributed to developing techniques applicable to extended space flight. In nearly every respect, from launch to recovery, his was a textbook mission.

L. Gordon Cooper's Faith 7 launched May 15, 1963, spent more than a day in space, the longest Mercury flight. He conducted earth photography and other scientific experiments. Cooper slept during rest periods, answering the question about whether sleep was possible during space flight.

## Gemini

Gemini markedly advanced the technological and experiential frontiers of manned space flight and vastly increased knowledge about space, earth and human biology. It demonstrated that pilots can maneuver a spacecraft; that properly equipped and clothed, they could live and work outside of their craft; that they could rendezvous and dock with another vehicle; that they could control their craft during descent from orbit; and that they could function effectively for flights up to two weeks in duration. It provided mastery of crucial technology and skills needed for Apollo, the moon-landing mission.

The photographs that the Gemini astronauts took of earth provided a wealth of information related to geography, resources and environment and demonstrated the value of a future earth survey system aided by satellites. Study of Gemini astronauts before, during and after flight and the medical electronic equipment developed for Gemini contributed to advances in instruments used for health care such as those that detect, measure and monitor life processes.

Gemini also contributed to astronomy and to studies of magnetic fields, radiation and micrometeorids around earth.

Gemini was a three-part spacecraft — the reentry module where the crew lived and worked and the only part that returned to earth; the middle part was the adapter retrograde section that contained the retrorockets fired by the astronauts to leave orbit; the third was the adapter equipment section, containing additional equipment and flaring out to mate with the Titan launch vehicle. The Gemini launch vehicle was a modified Air Force Titan II.

When the astronauts were ready for return to earth, they jettisoned the equipment section, fired the retrorockets of the retrograde section to slow down and descend from orbit, and then jettisoned the retrograded section.

Gemini 1, an unmanned test mission, lifted off on April 8, 1964, to determine performance and structural integrity of Gemini-Titan II. After three orbits, all experiment objectives were achieved. No recovery was planned. The vehicle entered the atmosphere April 12.

Gemini 2 was an unmanned suborbital test. Delayed by being struck by lightning, hurricane warnings and a misfire of its launch vehicle, it finally lifted off on Jan. 19, 1965. It proved that the heat shield could protect Gemini under maximum heating during reentry and performed so well that it cleared the way for a manned launch.

Gemini 3, launched March 23, 1965 was named Molly Brown by its commander, Virgil I. Grissom. He and his pilot, John W. Young, conducted the first manual maneuvers, changing not only the shape but also the plane of their orbit, a first for American spaceflight.

James A. McDivitt and Edward H. White II were the crew of Gemini 4 which circled earth from June 3 - 7, 1965. White accomplished the first American (EVA) extra-vehicular activity or spacewalk.

Gemini 5, launched Aug. 21, 1965, circled the earth for eight days, a new world record. It demonstrated that the crew of L. Gordon Cooper Jr. and Charles Conrad Jr., and spacecraft were capable of prolonged functioning in space. No lasting harmful effects of apparent weightlessness were detected.

Gemini 7, launched Dec. 4, 1965, confirmed in a 14-day flight that no lasting harm results from weightlessness. This broke the record of Gemini 5 for the longest manned flight. The crew was Frank Borman and James A. Lovell Jr.

Gemini 6, with Walter M. Schirra Jr. and Thomas P. Stafford, was launched Dec. 15, 1966, for its one-day flight. The launch was originally scheduled for Oct. 25, but was delayed because of problems with the launch vehicle. Gemini 6 successfully rendezvoused with Gemini 7, completing its primary mission, the world's first rendezvous of two vehicles in space and conducted other experiments.

Gemini 8, with Neil A. Armstrong and David R. Scott at the controls, completed the world's first docking in space. However, after docked-vehicle maneuvers, the joined vehicles began an inexplicable spin.

Armstrong undocked from Agena, but the Gemini spin continued. Finally, he fired the reentry rockets. This stopped the spin and cut the mission short. An emergency landing was made off Okinawa. Ground controllers identified the problem as an attitude-control thruster stuck in the firing position.

Gemini 9, June 3 to 6, 1966, manned by Thomas P. Stafford and Eugene A. Cernan, performed a number of maneuvers with a target stage. It did not dock because the shroud covering the target's docking apparatus had failed to separate. Cernan made a two-hour spacewalk.

Gemini 10, launched July 18, 1966, manned by John W. Young and Michael Collins, docked with an Agena target vehicle and later rendezvoused with the Gemini 8 target vehicle that was still in orbit. It used the Agena's power to drive the joined vehicles to a higher altitude and to the Gemini 8 target vehicle. Gemini 10 flew in a formation with Agena while the two craft were linked by a tether. Collins did a stand-up EVA in the open hatch of Gemini and later used a handheld maneuvering unit to propel himself around. He landed on the Agena and retrieved a micrometeroroid experiment. Gemini 10 returned to earth July 21.

Gemini 11, Sept. 12 to 15, 1966, with Charles Conrad Jr. and Richard F. Gordon Jr., accomplished the world's first rendezvous and docking in the first orbit.

Using Agena rocket power, it soared to an apogee of 1,372 kilometers, an altitude record for manned space fight. Gordon spent about two hours in a stand-up EVA and about a half hour floating and working outside of his craft.

Gemini 12, Nov. 11 to 15, 1966, was manned by James A. Lovell Jr. and Edwin E. Aldrin Jr. Thoroughly trained in a simulated space environment on earth and helped by the latest advances in hand and footholds, Aldrin completed about 20 assigned EVA tasks in approximately two hours. His total EVA time including stand-up EVA and a walk in space was about 5 1/2 hours.

Even as Gemini progressed, unmanned lunar spacecraft called Ranger, Surveyor and Lunar Orbiter were scouting the moonscape for the Apollo landing. They helped determine the bearing strength and detailed topography of the moon and provided other data needed to plan moon landings.

Three successful Ranger flights — Ranger 7, launched July 28, 1964; Ranger 8, Feb. 17, 1965; and Ranger 9, March 21, 1965 — provided lunar photography that was as much as 2,000 times as detailed as the best telescopic pictures. They showed that the seemingly smooth lunar plains were pockmarked with craters and that although the moon had no water, it was subject to erosion. Scientists attributed the latter to micrometeoroid bobmardment. So impressed was the International Astronomical Union with Ranger 7 pictures that it renamed the dry Sea of Clouds area that Ranger photographed Mare Cognitum — Known Sea.

Lunar Orbiters helped identify suitable landing sites for Apollo and gave ground trackers experience which they would need for Apollo. They photographed nearly the entire lunar surface including the part that is always turned away from earth. They also furnished data about radiation and meteoroids in the moon's vicinity. They were deliberately crashed on the moon when they finished their mission so that they would not collide with Apollo or other future spacecraft.

Lunar Orbiter 1, launched Aug. 10, 1966, was the first spacecraft to be placed in lunar orbit. It was also the first to photograph the earth from the moon. Lunar Orbiter 2 was launched Nov. 6, 1966; Lunar Orbiter 3, Feb. 5, 1967; Lunar Orbiter 4, May 4, 1967; and Lunar Orbiter 5, Aug. 1, 1967. All were successful.

Surveyor 1, launched May 30, 1966, soft landed in the dry Ocean of Storms. It found the bearing strength of the lunar surface was more than adequate to support the Apollo landing craft. This contradicted a theory that the lunar landing craft might sink into an ocean of dust. Surveyor also telecast many pictures to earth.

Surveyor 3, launched April 17, 1967, landed in another area of the Ocean of Storms. Armed with a shovel, it dug a trench and found that bearing strength increased with depth. It also sent pictures.

Surveyor 5, launched Sept. 8, 1967, landed in the dry Sea of Tranquility. Its alpha scattering device, probing the chemical composition of the surface, revealed a similarity to basalt on earth.

Surveyor 6, launched Nov. 7, 1967, landed in the moon's Central Bay. In an extemely significant experiment, NASA engineers remotely fired Surveyor's vernier rockets to launch it briefly above the surface. Surveyor's launch raised no dust cloud and resulted in only shallow cratering. Surveyor 6 also sent thousands of pictures and many hours of alpha scattering data.

Surveyor 7, Jan. 7, 1968, landed in a highland area of the moon, near the Crater Tycho. Its alpha scattering device showed that the highlands soil contained less iron than plains soil. It photographed laser beams from earth, a significant communications test.

Builders of Apollo needed information about micrometeoroids for design purposes. The first satellite intended specifically for meteoroid studies was Explorer 16, launched Dec. 16, 1962. Its instrumentation was built around the spent upper stage of the Scout launch vehicle. Similar meteroid Explorers were Explorer 23, launched Nov. 6, 1964, and Explorer 46, launched Aug. 13, 1972. They tested abilities of various kinds of structures to resist micrometeoroid punctures and reported on penetration frequencies.

Three Pegasus satellites, which were so huge that they could be seen in the night sky by the unaided eye on earth, were launched on Feb. 16, May 25 and July 30, 1965. At launch, Pegasus consisted of the Saturn IB launch vehicle, predecessor of the uprated Saturn IB used in Apollo manned earth orbital flights; boilerplate Apollo command and service modules; and the Apollo launch escape system. The launch escape system was jettisoned during launch as part of an Apollo test. Data on Saturn IB performance during launch contributed to development of Saturn IB and to Saturn V, which would launch Apollo to the moon.

After separating in orbit from the boilerplate command and service module, Pegasus unfolded 96-foot long wings designed to expose a broad range of thicknesses to micrometeoroids. One result of Pegasus data was discovery of lower meteoroid density than expected, enabling planners to reduce Apollo weight by about 1,000 pounds.

Pegasus consisted of the spent second stage instrument unit and adapter section of Saturn IB and the wing structure.

## Apollo

For centuries, humanity had fantasized about the moon. Apollo turned fantasy into reality. Americans walked on the moon's ancient untrodden surface. They unveiled secrets that had eluded humanity since it first began to think about the moon.

The first Apollo expedition landed on the moon a little more than eight years after the national commitment was made. In 1961, American astronauts were still flying the one-man Mercury spacecraft. The lunar landing reflected giant steps forward.

Within a year after a lunar landing commitment had been made, development of the powerful boosters — Saturn IB, needed for earth orbital tests, and Saturn V, needed for the lunar launch was in progress. The lunar orbit rendezvous procedure called for Apollo to be launched from earth into lunar orbit and a landing craft to be detached to carry two humans to the lunar surface. Later, the pair would rocket their craft from the moon and rendezvous and dock with the orbiting parent craft. The landing craft was called the lunar module. The craft in which the crew would ride to the moon and back was the command module. A third section was the service module containing the main propulsion system and supplies of water and air. It would remain attached to the command module. Only the command module returned to earth. The service module would be jettisoned just before reentry.

Apollo progressed rapidly. By 1965, Saturn IB had successfully completed its six-launch program in which it not only demonstrated the practicability of the clustered-engine concept and a liquid-hydrogen second stage, but also tested a boilerplate Apollo spacecraft and launched three Pegasus satellites. Tests with the uprated Saturn IB and Apollo command and service modules were completed in 1966. Then Apollo command and service modules were considered ready for manned earth orbital flight tests.

On Jan. 27, 1967, as astronauts Virgil I. Grissom, Edward H. White II and Roger B. Chaffee were conducting a countdown toward a simulated launch in the Apollo command module on the launch pad at Cape Kennedy , Fla., when tragedy struck. Fire broke out in the spacecraft. In the approximately five minutes it took for rescuers to open the hatch from the outside, the three astronauts had died from asphyxiation. It was the first fatal accident of the space program. A stunned nation mourned.

The Apollo command module was redesigned and rebuilt. Among the changes were a different hatch, reworked wiring and noncombustible materials.

On Nov. 9, 1967, NASA launched the unmanned Saturn V/Apollo 4 into orbit. This test of the launch vehicle and Apollo's ability to reenter the atmosphere at lunar-return speed (about 25,000 mph) provided provided satisfactory results.

On Jan. 22, 1968, in Apollo 5, a Saturn IB launched the unmanned lunar module into earth orbit. Lunar module ascent and descent engines were fired twice in orbit.

Saturn V/Apollo 6 was launched in another unmanned test on April 4, 1968. Saturn V exhibited some unwanted characteristics such as oscillations called POGO but was considered safe for manned space flight.

The wisdom of this decision was confirmed with the earth orbital mission of Walter M. Schirra, Donn Eisele and Walter Cunningham on Oct. 11-22, 1968. The three-man Apollo spacecraft completed a successful earth-orbital mission of 11 days.

On Dec. 21, 1968, Frank Borman, James A. Lovell Jr. and William Anders flew Apollo 8 to the moon, 10 times around the moon and returned safely to earth. Never before had people traveled so far, so fast or looked so closely at another celestial body. They were the first to view the backside of the moon which cannot be seen from earth. They returned a wealth of lunar pictures and verified the suitability of the lunar landing sites. Apollo 8 demonstrated that the Apollo command and service modules operated as they were supposed to. The crew and their Apollo command module returned safely to earth Dec. 27.

Apollo 9, March 3-13, 1969, provided the first manned orbital flight test of the lunar module. This was the first manned flight of the complete Apollo spacecraft. Astronauts James A. McDivitt, David R. Scott and Russell L. Schweickart, after separating their command/service module from the Saturn V third stage, turned around and docked with the lunar module. They pulled it clear of the third stage. Later, McDivitt and Schweikart entered the lunar module, separated it from the comand module, conducted a variety of maneuvers near and far from the command module, including simulated lunar descent and ascent, and finally rejoined the command module. Schweikart also conducted the first Apollo space walk. Call signs used for communication while the command/service modules and lunar module were separated were Gumdrop and Spider, respectively.

Apollo 10, May 18-26, 1969, conducted America's second manned circumlunar flight. Thomas P. Stafford and Eugene A. Cernan separated the lunar module, Snoopy, from the command module, Charlie Brown. John W. Young continued to pilot Charlie Brown around the moon. Stafford and Cernan conducted what has been called a dress rehearsal for the lunar landing. They maneuvered Snoopy to practice rendezvous and docking, descent to as low as nine miles above the moon, and ascent.

"That's one small step for a man; one giant leap for mankind." These were the words of Neil A. Armstrong, commander of Apollo 11, as he set foot on the moon at 10:56 p.m. EDT, July 20, 1969. He and his lunar module pilot, Edwin E. Aldrin, Jr. had landed Eagle on the moon at 4:18 p.m. EDT, July 20, while Michael Collins orbited overhead in Columbia. Their flight began on July 16 and they returned home to a cheering world on July 24. History had been made. Armstrong and Aldrin had landed, worked on and explored a part of the moon's dry Sea of Tranquility and returned safely to earth.

Apollo 12, Nov. 14-24, 1969, was devoted to extensive exploration of another part of the moon — the dry Ocean of Storms. The surface and subsurface material that Charles Conrad Jr. and Alan L. Bean took home from the moon was different from that brought back in Apollo 11. Among the items brought back were parts of the Surveyor 3 unmanned lander. In addition, Conrad and Bean set up a sophisticated set of experiments called the Apollo Lunar Surface Experiments Package. Among its instruments, which would keep sending information to earth long after the Apollo expedition left, were a seismometer, magnetometer and other geophysical equipment. It was nuclear-electric powered. The lunar module's code name was Intrepid. Richard F. Gordon Jr. orbited overhead and conducted experiments in the command module Yankee Clipper.

Apollo 13, April 11-17, 1970, was a sobering reminder that the problems and dangers of space exploration are frequently beyond anticipation. Although carefully checked beforehand, the oxygen tank of the Apollo 13 service module ruptured while Apollo was enroute to the moon. Without the service module, the command module did not have the water, oxygen and propulsive power needed for a safe return.

Both the crew — James A. Lovell Jr., Fred W. Haise Jr. and John L. Swigert Jr. — and ground controllers recognized that the unused lunar module could provide what they needed to get home. The crew lived in the module as the combined craft continued on its trajectory around the moon. They used the lunar module rockets to correct their course and align their craft properly for safe entry into earth's atmosphere, and abandoned the lunar module only when the command module was on course for a proper atmosphere entry. The crew and craft returned safely.

Apollo 14, Jan. 31-Feb. 9, 1971, was modified to prevent a recurrence of the Apollo 13 problem. Alan B. Shepard and Edgar D. Mitchell landed their lunar module Antares at Fra Mauro upland or foothill region different from the lunar plain which Apollo 11 and 12 had explored. Stuart A. Roosa conducted experiments from the command/service module Kitty Hawk. The work of Mitchell and Shepard was facilitated by use of a Modularized Equipment Transporter, a cart-like device. They set up another Apollo Lunar Surface Experiments Package, collected rock and dust samples from various places as they surveyed the area around Fra Mauro and conducted other scientific tasks.

The first motor trip on the moon was on the Apollo 15 flight. On July 31, 1971, David R. Scott and James B. Irwin removed their folded Lunar Roving Vehicle from their lunar module Falcon and unfolded and set it up for business. In three surface EVAs, they drove far and wide around the Hadley-Apennine region of the moon. They took photographs and rock samples, drove a core tube into the soil, set up the Apollo Lunar Surface Experiment Package and a laser reflector, and did other tasks. The Lunar Roving Vehicle camera telecast Falcon's blast-off from the moon, which in the space vacuum was evidenced as a shower of colorful sparks. After their return to the orbiting Endeavour, piloted by Alfred M. Worden Jr., a small subsatellite instrumented to study the moon for a year was launched. Enroute to earth, Worden conducted the first EVA in deep space as he retrieved film from a camera in the service module.

The Descartes area of the moon was explored by John W. Young and Charles M. Duke Jr. as part of the Apollo 16 mission, April 16-27, 1972. The biggest surprise of the landing mission was that the Cayley Plain which from orbit looked smooth to undulating, suggesting past volcanic flow and igneous rock, was made up of breccias which are composed of rock fragments welded together by intense heat. Young and Duke, who landed in Orion used a Lunar Roving Vehicle and set up an Apollo Lunar Surface Experiment Package as did the Apollo 15 expedition. Thomas K. Mattingly II operated a battery of cameras and other experiments as he orbited overhead in Casper. Enroute to earth, Mattingly went outside the spacecraft to retrieve film from the service module.

Apollo 17, Dec. 7-19, 1972, was the last and most productive of the lunar missions. Eugene A. Cernan and Harrison H. Schmitt Jr. landed on the Taurus-Littrow area of the moon in Challenger while Ronald E. Evans orbited in America. Using the Lunar Roving Vehicle, they traveled farther, spent more time and collected a heavier total of rock samples than in any previous mission. Their total mission and lunar orbit times were the longest of all. Because this was the last lunar expedition, man's last close view of the moon for years to come, the crew sought to see and collect all the data, material and photographs that they could.

The landing of Apollo 17 marked the end of an era. Knowledge about the moon and with it, earth, was expanded vastly by Apollo. Man's ability to perform useful tasks in an alien environment was demonstrated.

Hundreds of scientists in the United States and abroad participated in studying the lunar samples, photographs and other data brought back by Apollo expeditions. The interest in Apollo and in the Apollo astronauts transcended world boundaries. The United States, for its part, took the position that Apollo was a triumph of humanity even though the deeds were performed by Americans.

The technology of Apollo has contributed to many fields such as development of instruments to detect, measure or monitor life processes or to improve production or promote safety in industry.

The greatest achievement of Apollo may be the relatively short time in which skills were established, machines and facilities built, and people and equipment organized on a vast scale to extend the limits of human activities beyond this planet to the moon.

The end of the Apollo era coincided with new views about how to achieve excellence in American life, a change in public priorities. Americans became more concerned with programs that would result in immediate tangible benefits.

## Skylab

Responding to the new American priorities, NASA's next project in 1970 was Skylab, America's first experimental manned space station. The goals of skylab were to:

* Evaluate systems and techniques for acquiring information about earth's resources and environment.
* Increase knowledge of the sun and solar-terrestrial relationships.
* Increase knowledge about effects of prolonged space flight and with it biomedical knowledge.
* Test industrial processes to which space vacuum and so-called space weightlessness can contribute.

Skylab used existing technology and hardware from the Apollo program. The Skylab workshop where the astronauts lived and worked was an empty third stage of Saturn V that launched Apollo to the moon. It was modified as a two-story building, one with a laboratory and the other with living quarters. Attached to the workshop were an airlock module, a multiple docking adapter and an Apollo Telescope Mount. Saturn V placed this stage in orbit. Then, a Saturn IB, like those used in Apollo earth-orbital tests, orbited an Apollo command/service module with a crew of three. The astronauts docked with the workshop, entered it and set up housekeeping and went to work. When the mission was completed, the astronauts returned to their Apollo command/ service module, undocked and pulled away from the workshop, and returned to earth.

Skylab was about the size of an average three-bedroom house. It was the largest object America had placed in orbit.

Saturn V launched the orbital workshop on May 14, 1973. Soon after launch, telemetry told ground controllers that the meteroid shield, needed for protection against both meteroids and solar heat, had been ripped off during launch. In flying off, the shield tore off one solar panel and jammed the other, leaving the workshop without most of its electrical power and with the prospect of baking in the sun.

Engineers worked to devise a makeshift deployable shield and special tools for freeing the solar panel and other vital tasks. The first Skylab crew — Charles Conrad Jr., Joseph P. Kerwin and Paul J. Weitz, carried these and other supplies into space when they were launched on May 25, 1973. After docking, the crew entered the workshop and deployed the shield. The temperature inside began to fall and in about 11 days had reached a comfortable 75 degrees Fahrenheit.

On June 7, Conrad and Kerwin in a four-hour operation succeeded in freeing the solar panel. The surge of power began to charge eight batteries and provide about 3,000 watts of desperately needed electricity.

In addition, the crew fixed a number of other malfunctioning instruments. Among them were a jammed gear mechanism for driving an ultraviolet telescope, a balky tape recorder, a battery not producing power because of a stuck contact in its regulator (Conrad hit it with a hammer, a classic fixit technique) and non-operating valves in the cooling system. Thus, human intelligence and ability to meet unanticipated situations enabled Skylab to fulfill its mission.

Conrad, Kerwin and Weitz worked for 28 days on this space mission. They obtained thousands of earth survey and solar pictures, exceeding the wildest expectations of solar physicists, representatives of industry, agriculture, and weather services and city planners, ecologists, fisherman, prospectors and others concerned with earth's resources and environment. The crew's ability to work in space was much greater than anticipated.

The second Skylab crew — Alan L. Bean, Owen K. Garriott and Jack R. Lousma — more than doubled the time in space of the first crew. During a 59-day mission beginning July 28, 1973, they obtained 77,600 telescope images of the sun's corona whose study vastly increased knowledge about solar processes. They also obtained 14,400 earth-survey pictures which were subsequently used in 116 investigations, both in the United States and abroad, in nearly every field of earth sciences. They formed crystals and metallic spheres more perfect and alloys stronger than those made on earth. They conducted experiments with spiders (Arabella and Anita) and found that, after a period of adaptation, spider webs spun in space resembled those on earth.

They observed a mystifying development with Mummichug minnows. Those brought aboard swam at first in a disoriented manner. Those hatched from eggs brought aboard swam normally.

Blood and other samples the crew brought back with them added to knowledge about biochemical changes in space and contributed to medical knowldge of life processes on earth. Doctors discovered that exercise could stabilze or slow down deleterious effects of weightlessness.

The astronauts also performed engineering work aboard their craft such as installing a new parasol over the first one and plugging in a new assembly of gyroscopes to keep Skylab steady.

In the final Skylab mission, Gerald P. Carr, Edward G. Gibson and William R. Pogue spent 84 days between launch on Nov. 16, 1973, and landing Feb. 8, 1974. They spent more time on major medical experiments than either of the two other crews, contributing to knowledge of the human body as well as to planning for future long duration missions. The record of Skylab indicated that with proper exercise and diet, there may be no limit to how long humans can make their home in space. With proper hand and footholds and tools, there is also no apparent limit on the work that one can do in space.

In addition to the longest flight time, the Skylab 4 astronauts spent more than 22 hours in EVA, another new record.

Skylab clearly demonstrated that man can function effectively without harmful after effects for prolonged periods in space. It produced an unprecedented wealth of data in such diverse fields as study of the sun, medicine, industrial processes in space and earth surveys.

It was originally hoped that another group of astronauts using the Space Shuttle would visit Skylab in the future, retrieve a time capsule bag to learn about reaction of articles to long term space exposure, and perhaps drive Skylab to a higher and longer term orbit. However, solar activity increased atmospheric density at Skylab's altitude, causing drag on the craft and decay of its orbit. On July 11, 1979, Skylab was destroyed by reentry into the atmosphere.

## Apollo Soyuz Test Project

In July 1975, three American astronauts and two Russian cosmonauts docked their two spacecraft in earth orbit, exchanged visits, and conducted joint and independent scientific and technical experiments. The principal goal of this mission, termed the Apollo Soyuz Test Project (ASTP), was to test compatible rendezvous and docking systems for manned spacecraft. The systems worked, opening the way for international space rescue, if necessary, and for future international manned space missions.

Both Apollo and Soyuz were launched on July 15, 1975. Soyuz, with cosmonauts Aleksey A. Leonov and Valeriy N. Kubasov aboard, was launched from the Baikonur Cosmodrome near Tyuratam in the Kazakh Soviet Socialist Republic at 8:20 a.m. EDT. Apollo, with astronauts Thomas P. Stafford, Vance D. Brand and Donald K. Slayton aboard, was launched by a Saturn IB from Kennedy Space Center, Fl., at 3:50 p.m. EDT. The world's first international manned space flight rendezvous and docking were completed at 12:12 p.m. EDT, July 17. The world's first international handshake in space, between Stafford and Leonov, took place at 3:19 p.m. EDT.

Apollo and Soyuz docked twice during the mission. Final undocking was at 11:26 a.m. EDT, July 19. The Soyuz Descent Vehicle landed in Kazakhstan at 6:51 a.m. EDT, July 21. The Apollo Command Module landed at 5:18 p.m. EDT, July 24, in the Pacific Ocean, as planned, where the craft and crew were picked up by a waiting recovery force.

Apollo-Soyuz involved 28 separate scientific and technical experiments. Areas covered were astronomy, earth observations, life sciences, and a variety of applications including such tests as crystal growth and electrophoresis in space.

## SPACE TRANSPORTATION SYSTEM

With the completion of the Apollo-Soyuz flight, the era of one-mission manned spacecraft closed. NASA knew that to gain maximum benefit from space, it would need spacecraft that like airliners could repeatedly take off and land on earth.

With the Space Transportation System (STS), NASA inaugurated a new epoch in transportation between earth and space. STS enables us to do economically many useful things in space that not too long ago were considered impractical. It opens space to reasonably healthy men and women of all nations. (In May 1983, a NASA Task Force for the Study of Private Citizens on the Shuttle recommended that space flights be opened to private citizens.)

Like an airline, the Space Shuttle is intended to provide regularly scheduled travel for people and cargo between earth and earth orbit. STS has launch facilities at Kennedy Space Center, Fla., and Vandenberg Air Force Base, Calif. During its first six flights, STS used the landing facilities at Edwards Air Force Base, Calif., and White Sands Missile Range, N. M.

The Space Shuttle is the primary vehicle of the system. Most of the Shuttle major units — the orbiter and the solid rocket boosters — are reusable.

The orbiter provides as many as seven people with airline-like comfort as they live and work in space. The passengers and crew can dress in ordinary clothing. They breathe air like, but much cleaner than, earth's. They are provided with nutritious meals.

The orbiter has a spacious cargo bay 18.3 meters (60 feet) long and 4.6 m (15 ft.) in diameter. The orbiter is designed to carry as much as 29,500 kg (65,000 lb.) of cargo into space. The bay can accommodate unmanned applications or scientific spacecraft for launch from the bay or a fully equipped manned laboratory designed for use in space. It also accommodates Getaway Specials, the popular name for items flown in the STS Small Self-Contained Payload Program. The program gives any person or organization in the world an opportunity to purchase, at a comparatively moderate price, space for a chosen payload to be flown in space.

The manned laboratory, called Spacelab, was designed and built by the European Space Agency. Another Shuttle device built by another country is the Canadian Remote Manipulator System, an arm-like mechanism in the cargo bay operated from the Shuttle flight deck to deploy objects into orbit or retrieve them.

In a typical mission, the orbiter's main engine and the solid rocket boosters ignite simultaneously, lifting the Shuttle from the launch pad. At a predetermined altitude, the spent boosters separate and parachute into the ocean where they are recovered. The external fuel tank is jettisoned just before the orbiter reachers orbital velocity. The tank enters the atmosphere and breaks up over a remote ocean area. After completing its mission in space, the orbiter uses its maneuvering rockets to slow down and reenter the atmosphere. Once past reentry and in the atmosphere, it behaves like an airplane. Gliding to earth it lands. Computer-driven controls backed up by crew skills enable the orbiter to make virtually pinpoint landings.

The orbiter's maximum altitude is about 1,000 kilometers (600 miles). To send payloads to higher orbits it uses the Air Force Inertial Upper Stage (such as used for TDRS in STS-6) or for lighter payloads, the Payload Assist Module (such as used for SBS-3 and Anik C-3 in STS-5).

The first orbiter, Enterprise, was employed for the crucial deadstick approach and landing tests at Edwards Air Force Base, Calif. Conducted in 1977, the tests involved the Enterprise being carried on the back of a 747 aircraft to an altitude of about 6700 m (22,000 ft.) where it was released and guided to a landing. Edward's extremely long and wide runways along with the flat dry lakebed surrounding them made it a suitable spot for such tests. Six of the first seven Shuttle missions into space also landed at Edwards; one landed at White Sands Missile Range, N. M.

The test program was cautious. Before being flown free, Enterprise was carried five times to altitudes of 7,620 m (25,000 ft.) to check performance, stability, control and safety of the two-aircraft combination. In three captive flights, two NASA astronauts aboard Enterprise helped verify the most favorable separation techniques, refine crew procedures and evaluate Enterprise's systems. Finally, five free flights in which Enterprise was released and successfully landed from the carrier aircraft by the crew were accomplished. Crewman chosen by NASA for the approach and landing tests were Fred W. Haise Jr., Joe H. Engle, Gordon Fullerton and Richard H. Truly.

There are no plans to prepare Enterprise for space flight. It has been used in various public exhibitions such as a tour of United States and European cities and the U.S. aerospace exhibit at the Paris Air Show in 1983. It will be used for fit checks at Vandenberg Air Force Base which is building Shuttle launch, landing and supporting facilities.

Development of the Shuttle meant advancement in new technological frontiers. Among the pacing items were the three hydrogen-fueled main engines of the Shuttle. As part of the orbiter, they had to be built for repeated use. They had to be throttleable. Moreover, their specific impulse had to be much higher than any yet made. Specific impulse is the thrust gained from a pound of propellant in a second. It is comparable to the miles per gallon measure of a motorist.

Another pacing item was the array of more than 30,000 individual tiles that replaced the typical heat shields used in Mercury, Gemini and Apollo. The tiles were supposed to last from flight to flight not be burned away like the heat shield. They were supposed to be flexible enough to avoid cracking and to bond securely to the metal of the orbiter. The tiles were made of a material that could be red hot on one side and cool enough to touch with one's bare hand on the other.

Perfecting these highly advanced items to assure success of the Shuttle from the first flight onward took time. By 1981, however, NASA was ready for the first manned Shuttle flight into space.

A new era in space, promising countless benefits for people everywhere, opened at 1:21 p.m. EST, April 14, 1981. At that time, the orbiter Columbia crewed by astronauts John W. Young and Robert L. Crippen made a perfect landing at Edwards Air Force Base, Calif., after a nearly flawless space voyage.

STS-1 was planned as a short flight in the interest of safety. Its major objectives were safe ascent, orbital flight and landing. Launched April 12, 1981, STS-1 was the first of four planned orbital-flight tests.

Although brief, STS-1 was a record-breaking flight. It was the first time an American manned spacecraft had been orbited without prior tests. It was the first launch of a true aerospace craft — a craft with wings and landing gear that would go into and return from orbit. It was the first time a spacecraft and its boosters (the two solid rockets that helped launch Columbia) were recovered for reuse. It was the first airplane-like landing of a craft from space.

While in space and during descent to earth, Young and Crippen found Columbia easy to control. They tested various systems, including the computers and opening and closing of the cargo bay doors. (Opening the doors is critical to deploy the radiators that keep heat from building up in the crew compartment. It is also critical to launch and retrieval of spacecraft and for conducting experiments. Closing them is vital to a safe return to earth.) The crew wore ordinary coveralls while in orbit.

The launch of Columbia again, for STS-2 on Nov. 12, 1981, made it the first vehicle used for more one space mission. In space, the crew — Joe H. Engle and Richard H. Truly — tested the Canadian-built Remote Manipulator System. This is the huge mechanical arm used to deploy spacecraft from the payload bay, retrieve spacecraft and do other freight-handling work in the bay. STS-2 also conducted experiments which demonstrated that it could be a stable platform for conducting earth surveys, tested advanced instruments and techniques for earth survey from space and gathered data about earth's resources and environment.

The STS-2 mission was cut short by failure of one of three fuel cells that convert hydrogen and oxygen into drinking water and electrical power. Mission safety rules for STS-2 required that if one its fuel cells malfunctioned, the mission had to be ended. The crew landed Columbia at Edwards on Nov. 14, 1981.

Preliminary inspection of Columbia indicated it came through STS-2 in even better condition than STS-1. No tiles were lost and only about a dozen were damaged and needed to be replaced. The improvement is attributed largely to a shock-absorbing water spray system installed on the launch pad and to improved bonding of tiles in the most vulnerable areas.

In its busiest and longest flight to date, Columbia was put through exacting tests and gathered a rich lode of useful space science, medical and materials-processing data. Launched March 22, 1982, Astronauts Jack R. Lousma and C. Gordon Fullerton worked in space for eight days. They landed Columbia at an alternate landing site — White Sands Missile Range, N. M. — because heavy rains had drenched the dry lake bed at Edwards Air Force Base, the primary landing field.

While in space, they pointed different parts of Columbia to the sun for prolonged periods in thermal tests, repeatedly turned the orbital maneuvering engines on and off, and operated the Remote Manipulator System. They solved or adjusted to such comparatively minor problems as space adjustment syndrome (space sickness), a balky toilet, temperature control and radio static.

STS-4, the fourth Columbia mission, and the last orbital-flight test was marked by an on-time launch, nearly flawless completion of mission objectives and a perfect pinpoint landing on a concrete runway at Edward Air Force Base. Landing on the runway rather than the dry lakebed as before meant that the landing had to be precise.

Thomas K. Mattingly and Henry W. Hartsfield Jr., were the crew. Their eight-day flight which began June 27, 1982, was likened by President Reagan to the "golden spike" that opened transcontinental railroading. Columbia's nearly flawless performance resulted in certification of the Space Transportation System as operational.

On STS-4, Columbia carried the first commercial, Getaway Special and military experiments. In addition, Mattingly and Hartsfield participated in two medical experiments. The experiments were winning entries of the Shuttle Student Involvement Project of NASA and the National Science Teachers Association.

The Space Transportation System literally opened for business with the STS-5 flight of Columbia, Nov. 11-16, 1982. This first operational flight also marked the first launch of satellites from Columbia, the commercial communications satellites SBS-3 and Canada's Anik C-3. This was also the first with a crew of four: Vance D. Brand, commander; Robert V. Overmyer, pilot; and Joseph P. Allen and William P. Lenoir, mission specialists. Mission specialists are qualified in satellite deployment, payload support, extravehicular activities (EVA) and the operation of the Remote Manipulator System. The latter was not planned for use on this flight, and mechanical failures in both space suits cancelled the planned space walks of Allen and Lenoir. In addition to its primary mission of launching the commercial communications satellites, STS-5 conducted three Shuttle Student Involvement Projects and one Getaway Special experiment.

Challenger's inaugural flight in the Space Transportation System was STS-6. Challenger is the second of NASA's planned fleet of four orbiters that will also include Atlantis and Discovery.

Paul J. Weitz was commander of STS-6; Karol J. Bobko, pilot; and Story Musgrave and Donald K. Peterson, mission specialists.

Musgrave and Peterson carried out the first EVAs since Skylab in 1974. Moving about and working in Challenger's open cargo bay, they practiced techniques for future missions.

STS-6 launched NASA's first Tracking and Data Relay Satellite (TDRS), which is part of a system that will vastly augment ground communication with earth-orbiting spacecraft and enable NASA to close most of its ground stations. The Inertial Upper Stage failed, however, to place TDRS in the required orbit. NASA ground controllers over a period of many weeks steadily nudged TDRS into the required orbit using surplus gas in the satellite's stabilization system.

STS-6 continued experiments in electrophoresis and in production of monodisperse latex microspheres which have important applications in the pharmaceutical and medical fields. It also carried three Getaway Specials involving artificial snow crystals, packaged seeds and metals research.

The crew of the STS-7 (Challenger) mission of June 18-24, 1983, used the Remote Manipulator System to release a spacecraft called the Shuttle Pallet Satellite (SPAS) into orbit and to retrieve it. They practiced this five times before finally stowing SPAS in the cargo bay. While the satellite was in orbit, the astronauts flew Challenger around, above and below it and as far as 1,000 feet away. During these maneuvers, cameras on both craft telecast spectacular pictures of each other against backdrops of black space and blue earth.

In addition to this important first, STS-7 featured two others: the first five-person crew and first American woman in space. STS-7 crew members were Robert L. Crippen, commander; Frederick H. Hauck, pilot; and John M. Fabian, Sally K. Ride and Norman E. Thagard, mission specialists.

SPAS was built by Messerschmitt-Bolkow-Blohm of the Federal Republic of Germany. It carried experiments from NASA, West Germany and the European Space Agency.

STS-7 also launched two communications satellites: Canada's Anik C-2 and Indonesia's Palapa B. In addition, a number of experiments were carried out on Challenger. Among them were the OSTA-2 materials-processing experiment package of NASA and West Germany; a NASA Monodisperse Latex Reactor for producing microspheres that can be used in medical research and industry; a McDonnell-Douglas Continuous Flow Electrophoresis System for producing pharmaceuticals and medical research products by separating biological materials; and seven Getaway Specials covering such areas as crystal growth, soldering, germination of sunflower seeds and behavior of members of an ant colony.

STS-7 was a nearly flawless mission. Bad weather at Kennedy Space Center, Fla., prevented Challenger from making its planned landing there. Instead, Challenger was rerouted to Edwards Air Force Base where it made a pinpoint landing.

25th Anniversary
1958-1983



# *Space Science*

# SPACE SCIENCE

by
Victor Seigel

NASA's space science programs have contributed significantly to a new golden age of discovery. They have substantially advanced the frontiers of knowledge about our home planet, the relationships of sun and earth and celestial phenomena.

This section opens with a brief summary highlighting new knowledge gained. More detailed presentations on knowledge acquired by analyzing data from each spacecraft follow. It should be noted that an important part of the process of discovery involves correlating data acquired by spacecraft near and far from earth, by ground and airborne observatories, by balloons and by sounding rockets launched from a large variety of locations and by laboratory experiments and theory development.

NASA satellites discovered the existence of the Van Allen Radiation Region around earth.

They demonstrated that earth's magentic field is not shaped like iron filings around a bar magnet but like a vast cosmic teardrop. It is literally blown into this shape by the solar wind, a hot electrified gas constantly speeding out from the sun.

Satellites also contributed to understanding of interaction of solar activity with the magnetic field to produce periodic radio black-outs, trip circuit breakers of electric transformers, cause magnetic compasses to become erratic, and generate auroras.

NASA satellites demonstrated that earth's tenuous upper atmosphere is not as stable and quiescent as previously believed. It swells by day and contracts at night. Its volume and density wax and wane with such solar events as solar flares, the 11-year solar cycle, and the 27-day solar-rotation period.

NASA spacecraft confirmed existence of the solar wind. They discovered that the solar wind streams outward along the sun's magnetic field lines. Analyzing magnetic field and solar wind data from spacecraft near and far, scientists have redrawn the picture of interplanetary space. The solar wind and solar magnetic field are now visualized as forming a vast heliosphere encompassing space billions of kilometers outward from the sun.

Satellites have dramatically altered our conception of the universe. Our atmosphere blocks most of the electromagnetic radiations that can tell us about the nature of celestial objects. Satellite observatories viewing the heavens from above our appreciable atmosphere open a window on the universe.

Astronomers had theorized that only a small fraction of the electromagnetic radiation emitted by stars consisted of X-rays. X-rays are generated by high energy processes; i.e., among the most violent events. A sparse emission of X-rays would indicate that our universe was comparatively peaceful and slowly evolving. However, NASA satellites revealed a skyful of X-ray sources. This revolutionized the concept of the universe to one whose dynamics and evolution are governed by dramatic and enormously powerful processes. Our study of the universe draws us toward the answers to fundamental questions about the very nature of matter, life and the destiny of the stars.

Arguably, the most dramatic discoveries have resulted from observations of other planets and, if present, their satellites.The observations accentuated the uniqueness of our planet, its resources and its environment. It is a place where a variety of suitable conditions combined to create and sustain life.

Our nearest neighbor, the moon, is a radically different world. Apollo expeditions, unmanned spacecraft, and telescope observations show it to be pockmarked with huge meteorite craters partially filled with basalts from ancient lava flows. Its surface is wracked with excessive heat by day and cold by night. It is bombarded by solar radiation because it has neither an intrinsic atmosphere nor magnetic field to ward off the radiation. It has no signs of life nor even evidence that life processes have begun.

In times past, some people speculated that Venus was a twin of earth. Venus' density, gravity and size are nearly the same as earth's. The white clouds enveloping the planet were likened to water-based clouds of earth.

Spacecraft gave starkly different views. The beautiful white clouds are composed primarily of corrosive sulphuric acid droplets. Venus' atmosphere, 97 percent of which is carbon dioxide, has a crushing surface pressure about 100 times earth's at sea level. Its surface temperature is 482 C (900 F), hot enough to melt lead or zinc. Water has disappeared from the hot planet. Spacecraft confirmed that Venus' oven-like surface temperature is due to a greenhouse effect in which Venus' mostly carbon-dioxide atmosphere admits sunlight but traps outgoing heat radiation.

Mars, the planet of fabled canals, was found to have no canals but rather an extensive alluvial system from a period much earlier in its history when water perhaps flowed freely. It has an atmosphere, only about 1/100 the density of earth's, made up mostly of carbon dioxide. Examinations of its soil reveal no signs of life. The planet's water is locked in its north polar ice cap and in a subsurface tundra. The tenuous atmosphere would turn any escaping liquid water promptly into vapor. Mars surface is drier than driest deserts on earth.

Studies of Mars and Venus suggest that once they had rivers and seas and that their atmospheres and temperatures were benign. They cannot determine whether life developed during these benign periods.

Spacecraft could detect no intrinsic magnetic fields around Mars or Venus. Surprisingly, a faint magnetic field was discovered around Mercury. This discovery raised questions about theories of magnetic field origin which call for rapid rotation and liquid metal interior. Mercury rotates slowly. Its surface is pocked with ancient craters, much like the moon's, and it is airless except for wisps of noble gases.

Spacecraft close-range observations of the giant planets Jupiter and Saturn revealed they have no solid surfaces. Beneath their deep turbulent clouds, the planets are composed mostly of liquid hydrogen. They have vast magnetic fields that apparently emanate from their rapid rotations and metallic liquid hydrogen in their interiors. The temperatures and pressures that are responsible for metallic liquid hydrogen are impossible to duplicate on earth. Like earth's, their magnetic fields are blown by the solar wind into vast teardrop shapes. Like earth's, their magnetic fields have trapped atomic particles creating regions of concentrated radiation far larger and more intense than earth's.

Spacecraft data led to discovery of many small satellites around Jupiter and Saturn and a ring around Jupiter. With this ring discovery and the discovery by a NASA airborne observatory of rings around Uranus, only Neptune of the giant outer planets is not known to be ringed.

The satellites of Jupiter and Saturn appear as points of light in earth telescopes. Spacecraft sweeping nearby the planets telecast close-ups not only of the planets but also of their satellites. With these telecasts, for the first time, people saw the surfaces of many of these satellites.

Jupiter has four large Galilean satellites, named for their discoverer, the Italian 17th- century astronomer Galileo, and a dozen smaller ones. One of the four, Ganymede, is the largest satellite in the solar system and is larger than the planets Mercury or Pluto. Its surface shows signs of progessive change before it froze solid more than 3 billion years ago. Another, Callisto, shows scars made by ancient meteorite bombardments. Its surface appears to have changed little in four billion years. Callisto, like Ganymede, has a surface mix of rock and water ice and is larger than the planets Mercury or Pluto. Europa, about the size of earth's moon, has an ice-covered surface that is the smoothest seen on any celestial body. All three satellites are made up of substantial quantities of water ice.

Until viewed close-up, astronomers had believed that Io, the remaining Galilean satellite, was dry, dead and rocky like our moon. Spacecraft confirmed that Io was rocky and waterless and had active volcanoes.

Spacecraft confirmed that water ice makes up most of Saturn's rings and all or a large part of Saturn's satellites. The major exception is the outermost satellite, Phoebe, which close-up pictures suggest is a captured outer solar system asteriod.

Earth telescopes show vast gaps in Saturn's rings. Spacecraft close-ups reveal that the gaps are filled with many additional very thin ringlets.

Saturn's satellite Titan, larger than Mercury or Pluto, was once considered the largest satellite in the solar system. Spacecraft close-up measurements showed it was slightly smaller than Ganymede.

However, Titan is of interest because it is the only satellite in the solar system with a substantial atmosphere. Spacecraft studies indicate that the atmosphere is more than 8 percent nitrogen with methane, ethane, acetylene, ethylene, hydrogen, cyanide and other organic compounds making up the rest. Its atmospheric surface pressure is about 1.6 earth's sea-level pressure. Its atmosphere resembles that which earth is presumed to have had in primeval times. A smog apparently caused by chemical reaction of sunlight on methane in Titan's atmosphere envelops the satellite.

Spacecraft further determined that Titan is composed of about equal amounts of rock and water. Scientists observed that with suitable temperature Titan's environment could trigger pre-life chemistry. Some speculated that the smog-generated greenhouse effect could have accumulated enough heat over the last few billion years to raise the temperature to satisfactory levels. However, Voyager 2 took Titan's surface temperature and found it was a chilling 95 Kelvin (-288 Fahrenheit), far too cold for water to liquefy or for significant progress in pre-life chemistry. Additional information is presented in the discussions that follow on each type of spacecraft. Together, they provide but a glimpse of the infinite opportunities for the advancement of knowledge offered by the exploration of space.

## Explorers Investigate Space Near and Far

Since Feb. 1, 1958, when two organizations that later became part of NASA launched Explorer 1, NASA has launched more than 60 Explorers. Explorer satellites are comparatively small and vary in size and shape. They carry a limited number of experiments into the most suitable orbits.

The Explorer designation has been assigned not only to small satellites conducting space science missions but also to those whose primary mission is in either satellite applications or technological research. Explorers devoted principally to space science programs are described in this section.

### Astronomy Explorers

NASA's launch of Explorer 11 on April 27, 1961, was the first step of its long range program to probe the universe's secrets that are veiled by earth's atmosphere. Designed to monitor gamma rays, the satellite's data appeared to contradict the steady state theory of constant destruction and creation of matter.

NASA and the U.S. Navy launched Explorers 30 and 37 on Nov. 19, 1965, and March 5, 1968, respectively. The satellites monitored solar X- and ultraviolet rays during periods of declining and increasing solar activity.

Perhaps the longest satellites ever launched were NASA's Radio Astronomy Explorers 38 and 49. The tiny bodies of these satellites were each crossed with two antennas that were about three times as long as the Washington Monument is high. The antennas were unreeled to form a vast "X" in space where they received natural radio signals that do not ordinarily reach earth, thus filling a gap in our radio astronomy knowledge.

Explorer 38, launched on American Independence Day, 1968, surprised astronomers by reporting that earth sporadically emits natural radio waves. Until then, the only planet known to emit radio waves was Jupiter.

Earth was so noisy that it drowned out many other sources. However, Explorer 38 was also able to report that the sun emitted more low frequency radio signals than scientists anticipated.

Earth's radio noise prompted NASA to make Explorer 49, the second Radio Astronomy Explorer, into a lunar-anchored satellite. After the June 10, 1973, launch, Explorer 49 was maneuvered into lunar orbit, far enough away to prevent radio interference from earth.

Explorer 42, launched Dec. 12, 1970, was the first of a new category of NASA spacecraft called Small Astronomy Satellites (SAS). Designed to pick up X-rays, it gathered more data in a day than sounding rockets accumulated in the nine previous years of X-ray astronomy. Astronomers used its data to prepare a comprehensive X-ray sky map and X-ray catalog. Data from Explorer 42 suggested that superclusters of galaxies may be bound together by tenuous gases whose total mass is greater than that of the optically visible galaxies. This would provide a significant percentage of the mass needed to support the theory that our expanding universe will eventually contract.

Explorer 42 was the first NASA satellite launched by a foreign nation. Italy launched Explorer 42 from its floating San Marco platform in the Indian Ocean off the coast of Africa, near Kenya. Because Explorer 42 was launched on Kenya's independence day, it was also named "Uhuru" which is Swahili for "freedom."

On Nov. 15, 1972, Italy launched NASA's Explorer 48, the second SAS, from its San Marco platform. Explorer 48 continued the expansion of knowledge about gamma ray sources first begun by Explorer 11. It provided data that could be interpreted as suppporting the theory that the universe is composed of regions of matter and antimatter.

Explorer 53, the third SAS, was launched from San Marco on May 7, 1975. It discovered many additional X-ray sources, including one identified as a quasistellar object (quasar) only 783 million light years away. This is the closest quasar yet discovered.

Many new discoveries were made by the International Ultraviolet Explorer (IUE), launched Jan. 26. 1978. IUE is a joint project of NASA, the United Kingdom and the European Space Agency.

IUE data supported a theory that a black hole with the mass of a thousand solar systems existed at the center of our Milky Way galaxy and revealed that our galaxy had a halo of hot gases. The data provided evidence that so-called twin quasars were actually a double image of the same object. Light waves from the quasar are bent around a massive elliptical galaxy which acts as a gravitational lens to produce the double image picked up by ground observatories.

## Atmosphere Explorers

Atmosphere Explorers have confirmed or redrawn our conceptions of earth's tenuous upper atmosphere. The first, Explorer 8, was launched Nov. 3, 1960. It confirmed that temperatures of electrons in the upper ionosphere are higher by day than by night. It discovered that oxygen predominates in the ionosphere up to an altitude of about 650 miles where helium predominates. A secondary experiment indicated that micrometeoroid quantities varied inversely with size.

Air Density Explorers 9, 24 and 39 were launched Feb. 16, 1961; Nov. 21, 1964; and Aug. 8, 1968, respectively. These were essentially 3.7 meter (12 foot) balloons of aluminum foil and plastic laminate that were inflated in orbit. Air drag on the satellite indicated air density. The satellites revealed that atmospheric density varied from day to night, with the 27-day rotation period of the sun, with the 11-year solar cycle, and with violent eruptions on the sun.

Explorer 25 was launched on the same Scout booster that orbited Explorer 24, the first multiple launch by a single vehicle. Explorer 40 was launched with the same Scout vehicle as Explorer 39. They demonstrated a correlation between air density and solar radiation. Explorers 25 and 40 were called Injuns and University Explorers because they were built by the University of Iowa.

Explorers 17 and 32, launched April 2, 1963, and May 25, 1966, gathered information about the composition of neutral atoms and molecules. Explorer 17 confirmed Explorer 8 indications of a belt of neutral helium in the upper atmosphere.

In radio-echo soundings of the ionosphere, radio signals at different frequencies were transmitted from the ground. The reflected frequency discloses electron density; the return time indicated the altitude or distance at which the density was encountered. Ground-based sounding cannot provide information about the upper ionosphere because electron density increases up to a certain altitude and then tapers off. In addition, many areas of earth are too remote or inaccessible for ground-based radio sounding. These problems were solved by using satellites as topside sounders. They beamed radio waves into the ionosphere from altitudes far above the region of maximum electron density.

NASA topside sounders were Explorer 20, launched Aug. 25, 1964, and Explorer 31, launched Nov. 28, 1965. Scientists correlated data from these satellites with data from the Canadian topside sounders Alouette 1 and 2. Explorer 22, an ionosphere beacon launched Oct. 10, 1964, also measured electron density in the ionosphere. Explorer 22 was built with quartz reflectors for the first major experiment in laser tracking.

The thermosphere, a region of the upper atmosphere, was believed to be relatively stable until Explorers 51, 54 and 55 were launched. These satellites were equipped with onboard propulsion systems that enabled them to dip deep into the atmosphere and pull out again, taking measurements and providing extensive data about the upper thermosphere. They found that the thermosphere behaved unpredictably with winds 10 times stronger than normally found at earth's surface. They discovered abrupt and constantly changing wind shears. Their data contributed significantly to knowledge about energy transfer mechanisms and photochemical processes (such as those that create the ozone layer) in the atmosphere. Launch dates for the three Explorers were Dec. 16, 1973; Oct 6, 1975; and Nov. 19, 1975.

The Solar Mesosphere Explorer, launched Oct. 6, 1981, provided comprehensive data on how solar radiation creates and destroys ozone in the mesosphere, an atmospheric layer below the thermosphere and above the stratosphere. The University of Colorado designed and built the Solar Mesosphere Explorer and operated it for a year after launch.

## Geophysical Explorers

NASA's first successful satellite launch was Explorer 6, orbited Aug. 7, 1959. Explorer 6 added to information about the Van Allen Region and micrometeoroids. It also telecast a crude image of the north Pacific Ocean.

Explorer 7, launched Oct. 13, 1959, provided data revealing that the Van Allen Region fluctuated in volume intensity and suggested a relationship of the region with solar activity. It indicated that variations in solar activity may also be related to the abundance of cosmic radiation in earth's vicinity, magnetic storms and ionospheric disturbances.

Explorer 10, launched on March 25, 1961, to gather magnetic field data, was the first spacecraft to obtain information that suggested that the interplanetary magnetic field may actually be an extension of the sun's field carried outward by the solar wind.

With Explorer 12, launched Aug. 15, 1961, scientists were able to arrive at many conclusions about space: the Van Allen Region is a single system of charged particles rather than several belts; earth's magnetic field has a distinct boundary; the solar wind compresses the earth's magnetic field on the sun's side and blows it out on the other; and geomagnetic storms that cause radio blackouts and power outages may result from solar flares.

On Oct. 2, 1962, NASA launched Explorer 14 to monitor the Van Allen Radiation Region during a period of declining solar activity. Scientists in the meantime discovered that the United States project Starfish, involving a high altitude nuclear burst in July 1962 had created another artificial radiation belt. Explorer 14 was joined by Explorer 15 on Oct. 27 to help monitor this belt. The two satellites' data helped ease scientific anxiety by indicating that atomic particles making up the belt were rapidly decaying.

NASA launched Explorer 26 on Dec. 21, 1964 and its data increased understanding of how atomic particles traveling toward earth from outer space are trapped by earth's magnetic field and how they spiral inward, along earth magnetic field lines in the northern and southern latitudes, interacting with the atmosphere to generate auroras.

Explorer 45, launched Nov. 15, 1971, further investigated the relationships of geomagnetic storms, particles radiation and auroras. It was the second satellite launched by an Italian crew from the San Marco platform off Kenya in the Indian Ocean.

NASA's Interplanetary Monitoring Platforms, or IMP Explorers, added significantly to knowledge about how earth's magnetic field and the Van Allen Radiation Region fluctuate during the 11-year cycle. IMP Explorer 18 confirmed that earth's magnetic field was shaped like a giant cosmic tear drop. It discovered a shockwave ahead of the earth's field. The shockwave is caused by impact of the speeding solar wind with the earth's field. Between the shockwave and the magnetopause, or magnetic field boundary, Explorer 18 discovered a turbulent region of magnetic fields and atomic particles.

IMP Explorer 33 was the first satellite to provide evidence that the geomagnetic field on earth's night side extends beyond the moon. IMP Explorer 35, a lunar-anchored (lunar orbiting) IMP, gathered data about micrometeoroids, magnetic fields, the solar wind, and radiation at lunar altitudes. Its instruments revealed the moon to be what one scientist termed a "cold nonmagnetic nonconducting sphere."

| **IMP Explorers** | **Launch Dates** |
|---|---|
| Explorer 18 | Nov. 26, 1963 |
| Explorer 21 | Oct. 3, 1964 |
| Explorer 28 | May 29, 1965 |
| Explorer 33 | July 1, 1966 |
| Explorer 34 | May 24, 1967 |
| Explorer 35 | July 19, 1967 |
| Explorer 41 | June 21, 1969 |
| Explorer 43 | May 13, 1971 |
| Explorer 47 | Sept. 22, 1972 |
| Explorer 50 | Oct. 25, 1973 |

A two-satellite Dynamic Explorer project, launched simultaneously on Aug. 3, 1981, significantly contributed to data on coupling of energy, electric currents, electric fields, and plasmas (hot electrified gases) between earth's magnetic field, the ionosphere, and the rest of the atmosphere. Among their discoveries were nitrogen ions in the geomagnetosphere. They also confirmed existence of the polar wind which is an upward flow of ions from the polar ionosphere.

The Dynamic Explorers complemented studies of the three International Sun-Earth Explorers (ISEE), a joint project of NASA and the European Space Agency. ISEE 1 and 2 were launched into earth orbit on Oct. 22, 1977. ISEE 3 was placed in a heliocentric orbit near the sun-earth libration point.

The ISEE program focussed on solar-terrestrial relationships as a contribution to the International Magnetospheric Study. The three spacecraft obtained a treasure trove of new information on the dynamics of the geomagnetosphere, the transfer of energy from the solar wind, and energization of plasma in the geomagnetotail. For example, ISEE 1 found ions from our ionosphere accelerated in the goemagnetotail to fairly high energies. Previously, scientists thought these high energy particles originated from the solar wind.

In 1982, when its mission was completed with fuel to spare and all instruments in working condition, ISEE 3 was put through a series of complex maneuvers to explore the earth's magnetotail through December 1983, to fly across and study the wake of Comet Giacobini-Zinner in September 1985, and observe from comparatively close range the effects of the solar wind on Halley's Comet in late 1985 and early in 1986. ISEE 3 will be the first spacecraft to fly through a comet's tail and to survey earth's long magnetotail.

**Astronomical Observatories**

Man's view of the universe is narrowly circumscribed by the atmosphere which blocks or distorts most kinds of electromagnetic radiations from space. Analyses of these radiations (radio, infrared, visible light, ultraviolet, X-rays and gamma rays) give important new information about the phenomena in our universe.

The small Astronomical Explorers indicated the great potential for acquiring new knowledge by placing instruments above earth's obscuring atmosphere. Consequently, NASA orbited a series of large astronomical observatories bearing a great variety of instruments which have significantly widened our window on the universe.

The first successful large scale observatory was Orbiting Astronomical Observatory 2, nicknamed Stargazer, which was launched Dec. 7, 1968. In its first 30 days, OAO 2 collected more than 20 times the celestial ultraviolet data acquired in the previous 15 years of sounding rocket launches.

Among the volumes of data provided by OAO 2 are the following discoveries:

* Stars that are many times as massive as our sun are hotter and consume their hydrogen fuel faster than estimated on the basis of ground observations. OAO 2 data contributed to resolving a disparity between observations made from the ground and theories of stellar evolution.

* Another stellar theory was brought into question. According to this theory, intensity of celestial objects should be less in ultraviolet light than in visible light. However, several galaxies that looked dim in visible observations from earth were bright in ultraviolet observations by Stargazer.

* Diffuse dust nebulae are regarded by many astronomers as the location for the formation of stars.

* Stargazer was able to observe Nova Serpentis in 1970 for 60 days after its outburst. It confirmed that mass loss by the nova was consistent with theory.

* Stargazer observations of the Comet Tago-Sato-Kosaka supported the theory that hydrogen is a major constituent of comets. It detected a hydrogen cloud as large as the sun around the comet. Because of our atmosphere, this hydrogen cloud could not be detected by ground observatories.

* Looking toward earth, Stargazer reported that the hydrogen in earth's outer atmosphere is thicker and covers a larger volume than previous measurements indicated.

Launched Aug. 21, 1972, OAO 3 was named for the famed Polish astronomer Copernicus. The satellite provided much new data on star temperatures, chemical compositions and other properties. It continued studies of the outer atmospheres of earth, Mars, Jupiter and Saturn. It gathered data on the black hole candidate Cygnus X-1, so named because it is the first X-ray source discovered in the constellation Cygnus.

Much of its data supported the hypothesis that Cygnus X-1 is a black hole. A black hole is a one-time massive star that has collapsed to such density that it does not permit even light or other electromagnetic radiations to escape it. Scientists can study Cygnus X-1 because it is part of a binary star system and has a visible companion. In addition, according to theory, a substantial part of the matter dragged into a black hole is transformed into X-rays and gamma rays that are radiated into space before they reach the point of no return.

Among other observations of Copernicus:

* Interstellar dust clouds have fewer heavy elements than our sun. This supported the contention that the sun and planets coalesced from the debris of an ancient supernova.

* Larger amounts of hydrogen molecules than expected were found in interstellar dust clouds.

* Surprisingly large amounts of deuterium (an element with the same atomic number and the same position in the Table of Elements as hydrogen but with twice the mass) were also detected in interstellar dust clouds.

The latter two findings suggest that star formation may be common. The discovery regarding deuterium contradicted a theory that most deuterium, a basic element for atomic fusion in stars, has been exhausted.

## High Energy Astronomy Observatories

Three High Energy Astronomy Observatories portray a universe in constant turbulence with components repeatedly torn apart and recombined by violent events.

HEAO 1, launched Aug. 12, 1977, also discovered a new black hole candidate near the constellation Scorpius, bringing the total to four. Other black hole candidates are in or near the Constellations Cygnus, Circinus and Hercules. Another major result of HEAO 1 was the superhot superbubble of gas 1,200 light years in diameter and about 6,000 light years from earth. Centered in the constellation Cygnus, the bubble has enough gas to create 10,000 suns. HEAO 1 raised the catalog of X-ray sources from 350 to about 1,500.

The Einstein observatory, nicknamed for the famous mathematician, is HEAO 2, launched Nov. 13, 1978. Einstein was equipped with more sensitive instruments than HEAO 1. Thus, it was able to discern that the X-ray background observed by HEAO 1 was not coming from diffuse hot plasmas but from quasars. Einstein also provided the first pictures of an X-ray burster which is apparently located at the center of a globular cluster called Terzan 2. The bursters are frequently associated with clusters of old stars. They are usually explained in terms of gases interacting violently with neutron stars or black holes, emitting very short bursts of X-rays.

Among other data from Einstein are X-ray spectra of supernova remnants. The data support the theory that our system was formed from debris of an ancient supernova.

HEAOs 1 and 2 X-ray measurements related principally to atomic interactions and plasma processes associated with stellar phenomena. HEAO 3, launched Sept. 20, 1979, scanned the universe for cosmic ray particles and gamma radiation. The events that HEAO 3 measures result from nuclear reactions in the hearts of stellar objects and the elements they create.

HEAO 3 has observed in the Milky Way's central region gamma rays that apparently emanate from the annihilation of electrons and positrons (the antimatter equivalent of electrons). It has also discovered an object emitting energy in the form of gamma rays equivalent to 50,000 times the sun's total output. The object is 15,000 light years from earth and appears to be undergoing processes on a comparatively small scale that are believed to occur in quasars on a large scale.

The Netherlands Astronomical Satellite (NAS), launched Aug. 30, 1974, was a small X-ray and ultraviolet orbiting observatory. Among discoveries from its data are X-ray bursters, sources that emit bursts of X-rays for seconds at a time. NAS was a cooperative program of NASA and the Netherlands.

## Infrared Astronomy Satellite (IRAS)

Launched on Jan. 25, 1983, Infrared Astronomy Satellite revealed many infrared sources in the Large Magellanic Cloud, 155,000 light years from earth, that are not visible from earth, helping scientists compile the first catalog of infrared sky sources.

Because all objects, even cool dark ones that may be the black cinders of dead stars, radiate infrared light, IRAS may discover many other invisible objects. It has revealed stars being born in thick opaque clouds of gas.

IRAS is a joint project of NASA, the Netherlands and United Kingdom. In April 1983, IRAS detected a new comet which came within 3 million miles of earth in May, the closest comet approach in 200 years. It most recently discovered a possible new solar system near the star Vega.

## Orbiting Solar Observatories (OSO)

Orbiting Solar Observatories using X-ray and ultraviolet sensors acquired a rich harvest of solar data during the 11-year solar cycle when solar activity went from low to high and then back to low. They photographed for the first time the birth of a solar flare, a great outburst of matter and energy from the sun. When directed toward earth, solar flares can cause black-outs of communications and electricity, magnetic compasses to spin crazily, and enhance displays of the northern and southern lights. OSOs discovered evidence of gamma radiation resulting from solar flares, indicating nuclear reaction in the flares.

OSO 1 showed a correlation between fluctuations in temperatures of earth's upper atmosphere and variations in solar ultraviolet ray emissions. OSO 3 revealed that the center of our galaxy was the source of intense gamma radiation, which, when confirmed by HEAO 3, led to speculation that matter and antimatter were annihilating each other, leaving energy in the form of gamma rays. OSO 5 data revealed that earth's upper atmosphere may contain as much as 10 times the amount of deuterium (a form of hydrogen with twice its mass) previously estimated.

OSOs discovered and provided information on solar poles where there were cooler and thinner gases than in the rest of the corona. Later, they discovered comparable phenomena on other areas of the sun and scientists named them solar holes. OSO observed and reported on the dramatic coronal transient, a solar explosion hurling out hundreds of thousands of tons of material in huge loops at millions of kilometers per hour.

OSOs and their launch dates are as follows:

| | | | |
|---|---|---|---|
| OSO 1 | March 7, 1962 | OSO 5 | Jan. 22, 1969 |
| OSO 2 | Feb. 3, 1965 | OSO 6 | Aug. 9, 1969 |
| OSO 3 | March 8, 1967 | OSO 7 | Sept. 29, 1971 |
| OSO 4 | Oct. 18, 1967 | OSO 8 | June 21, 1975 |

## Solar Maximum Mission

Infinitesimal (.001) reductions in solar energy output that may be related to unusually harsh winters and cool summers on earth were discovered by the Solar Maximum Mission (SMM) satellite. SMM was launched Feb. 14, 1980, to study the sun during the high part of the solar cycle. SMM also made the first clear observations of neutrons traveling from the sun to the earth after a flare and confirmed that fusion, the basic process that powers the sun, occurs in the solar corona during a flare. A malfunction in January 1981 cut SMM's life short. SMM is scheduled for repair on a future Shuttle mission.

## Orbiting Geophysical Observatories (OGO)

A half dozen Orbiting Geophysical Observatories' have provided more than a million hours of scientific data from about 130 different experiments relating to earth's space environment and sun-earth interrelationships. They significantly contributed to understanding of the chemistry of earth's atmosphere, of earth's magnetic field and of how solar particles penetrate and become trapped in the magnetosphere.

They provided the first evidence of a region of low energy electrons enveloping the high energy Van Allen Radiation Region, first observation of daylight auroras, first global map of airflow distribution, and much other knowledge about magnetic fields, particle radiation, earth's ionosphere, the shockwave between the geomagnetic field and solar wind that was discovered by Explorer 18, and the hydrogen cloud enveloping earth.

Beyond earth, they completed the first sky survey of hydrogen, discovered neutral hydrogen around the sun, found several strong sources of hydrogen in the Milky Way, and in April 1970, detected a cloud of hydrogen 10 times the size of the sun around comet Bennett. The existence of large amounts of hydrogen around comets was first discovered around comet Tago-Sato-Kosaka in January 1970 by Orbiting Astronomical Observatory 2 "Stargazer." The large amounts of hydrogen around comets that were observed by OAO and OGO clearly establish that hydrogen is a major constituent of comets.

OGOs and their launch dates:

| | |
|---|---|
| OGO 1 | Sept. 4, 1961 |
| OGO 2 | Oct. 14, 1965 |
| OGO 3 | June 7, 1966 |
| OGO 4 | July 28, 1967 |
| OGO 5 | March 4, 1968 |
| OGO 6 | June 5, 1965 |

## Vanguard Satellites

The U.S. Navy launched Vanguard 1 on March 17, 1958. Vanguard 1 provided information leading in 1959 to identification of the slight but geologically significant distribution called the "pear shape" of the earth.

Vanguard 2, launched Feb. 17, 1959, transmitted the world's first picture of cloud cover from a satellite. A Vanguard 2 wobble caused by an inadvertent bump from its launch vehicle resulted in less than satisfactory picture quality.

Vanguard 3 was launched Sept. 18, 1959. It contributed extensive data about earth's magnetic field, the Van Allen Radiation Region, and micrometeoroids.

## Biosatellite Experiments

The Biosatellite program was designed to study the effects of the condition popularly termed "weightlessness" alone and in conjunction with a known source of radiation. The program was temporarily set back by failure of Biosatellite 1, launched Dec. 14, 1966, when the craft could not be brought back to earth as planned because of retrorocket failure.

Biosatellite 2, launched Sept. 7, 1967, carried microorganisms, frog eggs, plants and insects on an approximately 45-hour space flight. Among the wealth of scientific results harvested from this experiment were the following:

* Weightlessness appears to spur growth of wheat seedlings;

* Young, actively growing, rapidly dividing cells are more severely affected by radiation than mature, slowly growing, less actively dividing cells;

* Plant orientation is disturbed by weightlessness;

* While weightlessness appears to accelerate radiation-induced mutations and other cell damage, it also appears to slow the growth and metabolism of injured cells — the slower growth would provide more time to repair damage;

* Bacteria appear to multiply more rapidly in weightlessness than on earth — Viruses failed, however, to reproduce as well as they do on earth;

* Gravity affects plants much more than previously realized — plant life on the orbiting Biosatellite 2 reacted more than animal life;

Biosatellite 3 was launched June 28, 1969, to gather data on how prolonged space flight affects bodily processes in primates. It contained a small monkey. Planned for 30 days, it was cut short on July 7 when the monkey became ill. After the capsule was recovered the monkey died. An autopsy showed death due to loss of body fluids. The experiment confirmed that replacement of body fluids that people lose during flight in space is vital to their well-being.

## Interplanetary Spacecraft

Data about the environment of interplanetary space have been provided by interplanetary spacecraft and by planetary spacecraft before and frequently after completion of their primary missions.

Mariner 2, which confirmed that, beneath its bright cloud cover, Venus was a dry lifeless inferno, also confirmed the existence of the solar wind as a predominant feature of interplanetary space. Pioneer 10, which provided the first close-up of Jupiter, returned data indicating that the Gegenschein — a faint glare in earth's sky directly opposite the sun — and the zodiacal light are due to the sunlight reflecting from small particles in interplanetary space rather than in earths' atmosphere. The zodiacal light is a faint cone of light extending upward from the horizon in the direction of the zodiac, or ecliptic. Pioneer 10 also showed that the heliosphere extends beyond Jupiter.

This section will, however, cover only those craft launched to circle the sun but not to visit a planet. Scientists correlate data from craft in various points in space with data from planetary spacecraft and scientific earth satellites to increase understanding of the sun and solar system.

## Helios Spacecraft

Helios 1 and 2, a cooperative project of NASA and the Federal Republic of Germany, were designed to survive and function at distances closer to the sun than any other spacecraft.

From perihelions lower than 45 million kilometers (28 million miles) on opposite sides of the sun, they added to knowledge about the solar corona, magnetic field, wind and radiation and about micrometeoroids and other phenomena in this vicinity of space. Helios is named for the sun god of ancient Greece. The craft were launched on Dec. 10, 1974, and Jan. 15, 1976.

## Interplanetary Pioneers

Sun-orbiting Pioneers have contributed volumes of data about the solar wind, solar magnetic field, cosmic radiation, micrometeoroids, and other phenomena of interplanetary space. Pioneer 4, launched March 3, 1959, was the first United States spacecraft to go into solar orbit. It yielded excellent radiation data. Pioneer 5, launched March 11, 1960, confirmed the existence of interplanetary magnetic fields and helped explain how solar flares trigger magnetic storms and the northern and southern lights (aurorae) on earth. The satellite also showed that the Forbush decrease of intergalactic cosmic rays near earth after a solar flare was the same in interplanetary space, and thus does not depend upon an earth-related phenomenon, such as the geomagnetic field.

Pioneers 6 through 9, launched Dec. 16, 1965; Aug. 17, 1966; Dec. 13, 1967; and Nov. 8, 1968, supplied volumes of data on the solar wind, magnetic and electrical fields, and cosmic rays in interplanetary space. Pioneer 7 detected effects of earth's magnetic field more than 3 million miles outward from the night side of earth. Pioneer 6 to 9 data also drew a new picture of the sun as the dominant phenomenon of interplanetary space. They found that the solar wind continues well beyond the orbit of Mars. (Pioneer 10, the first Jupiter explorer, continued to report its existence as it crossed the orbit of Pluto.) Analyses of their data indicated that the solar wind is an extension of the solar corona, the sun's atmosphere. They revealed that the wind draws out the sun's magnetic field to form what were previously called interplanetary magnetic fields but now is referred to as the heliosphere. They showed that the combination of the solar wind's outward pull and the rotation of the sun caused the lines of forces of the magnetic field to be twisted like streams of water from a whirling lawn sprinkler.

Pioneer data showed that solar cosmic rays spiral around the lines of force of the sun's magnetic field. This indicates they travel through space in well defined streams.

Planetary spacecraft that made close-range observations of other planets during flybys, from orbit and from the surface have significantly enhanced knowledge about the other planets in the solar system. They have demonstrated the uniqueness of our own planet. They have provided among other things excellent studies of how, after a presumably common origin, celestial bodies react to different environmental conditions. They suggest earth's past and future and possibly how to improve earth's environment.

### Mariner Spacecraft

Mariner 2 was America's first successful planetary spacecraft. Launched Aug. 27, 1962, it flew past and made close-up observations of Venus on Dec. 14, 1962. Its data supported earth-based microwave scans that suggested a surface temperature as high as 800 Fahrenheit, hot enough to melt lead on both day and night sides. It detected no openings in the dense clouds enveloping Venus. Its data indicated no intrinsic Venusian magnetic field nor increase in radiation. This suggested that Venus has no radiation belt like the Van Allen Radiation Region around earth. The data are consistent because the Van Allen Radiation Region is attributed to the capture of energetic particles by earth's magnetic field. Mariner 2 also confirmed the predominance of the solar wind as a feature of interplanetary space and the ubiquity of interplanetary magnetic fields which, scientists now realize are an extension of the sun's magnetic field dragged out into space by the solar wind.

### Mariner

Speeding by Mars on July 14, 1965, Mariner 4, launched Nov. 28, 1964, gave the world its first close look at that planet's surface. The pictures were surprising: a heavily cratered moon-like surface that looked like it may not have changed much in billions of years. Because the pictures, covered about 1 percent of Mars, they permitted no conclusions until other spacecraft viewed additional areas of the planet. The pictures covered some areas crossed by the supposed Martian canals but showed no readily apparent straight-line features that could be interpreted as artificial. Among other data from Mariner 4 were indications that the surface atmospheric pressure on Mars was less than 10 millibars. Earth's sea level air pressure is about 1000 millibars. Humans would need a pressure suit on Mars. Mariner 4 also gave additional information about Mars, size, gravity and path around the sun. Mariner 4 detected neither a Martian magnetic field nor radiation belt but revealed a Martian ionosphere.

Mariner 5 was launched June 14, 1967, to refine and supplement data about Venus obtained from Mariner 2 and other observations. It contained improved instrumentation and in October 1967, flew within 2,500 miles of Venus as compared to the 21,645-mile closest approach of Mariner 2. Among conclusions drawn after this flyby were:

* Venus' atmosphere is at least 80 percent carbon dioxide.
* Venus' atmosphere is about 100 times denser than earth's.
* Venus' surface temperature may be as high as 800 F.
* The solar wind is diverted around Venus by the planet's ionosphere. (Earth's magnetic field diverts the solar wind around our planet.)
* The Venusian exosphere, like earth's, is made up largely of hydrogen.
* Venus has no detectable magnetic field nor radiation belt.

Mariners 6 and 7 were launched on Feb. 25 and March 27, 1969, respectively, and flew as close as 2,000 miles to Mars on July 31 and Aug. 5, 1969, respectively. Mariner 6 flew past the planet along its equator. Mariner 7 overlapped part of the Mariner 6 ground track and then sped south over the south polar ice cap. They took pictures of Mars and studied it with infrared and ultraviolet sensors. Their pictures show not only cratered but also smooth and chaotic surfaces.

The chaotic region, about the size of Alaska, is characterized by short ridges, slumped valleys, and other irregularities that resemble the after effects of a landslide or quake. Nowhere on earth is a comparable feature so vast.

Launched May 30, 1971, Mariner 9 went into Martian orbit on Nov. 13, 1971, the first spacecraft placed into orbit around another planet. It orbited and studied Mars and the planet's two tiny satellites, Deimos and Phobos, until Oct. 27, 1972. It arrived at a discouraging time when a dust storm enveloped most of the planet. Even the dust storm, however, provided information of value such as atmospheric circulation pattern and the fact that only on Mars were dust storms of such magnitude observed. When the storm cleared, Mariner 9 was able to photograph Martian geography in remarkable detail. Its photographs show Martian volcanic mountains, including one larger than any on earth; canyons including one that would stretch across the United States from the Atlantic to the Pacific Ocean; and signs that rivers and possibly seas may have existed on Mars.

Mars' two small satellites, Deimos and Phobos, appear as points of light in ground observatory telescopes. Mariner 9 swept close to both, providing pictures that showed them to be irregularly shaped and heavily cratered.

## Mariner 10

Mariner 10, launched Nov. 3, 1973, flew by Venus on Feb. 5, 1974 and in a solar orbit, swept nearby and gathered information about Mercury on three separate occasions: March 29 and Sept. 21, 1974 and March 16, 1975. These first close-ups of Mercury reveal an ancient surface bearing the scars of huge meteorites that crashed into it billions of years ago. They show unique large scarps (cliffs) that appear to have been caused by crustal compression when the planet's interior cooled. A Mercurian magnetic field, about a hundredth the magnitude of earth's, and an atmosphere, about a trillionth the density of earth's, were detected. The Mercurian atmosphere is made up of argon, neon and helium. Data suggest a heavy iron-rich core making up about half the planet's volume. (Earth's core is about 25 percent of its volume.) Mariner 10 reported that Mercury's surface temperatures were 510 C (950 F) on the sunlit side and -210 C (-350 F) on the night side.

Mariner 10 was the first picture-taking spacecraft to view Venus. Its optical cameras however failed to find an opening in the clouds that shroud the planet.

Mariner 10's ultraviolet cameras revealed that Venus' topmost clouds circled the planet 60 times faster than the Venus rotates.

They also confirmed a long-held theory about earth's weather that solar heat causes air to rise in the tropical area, flow to the poles, cool, fall and then return to the tropics where the process is repeated. No such process could be discerned on earth as earth's rapid rotation, variable atmospheric water content, sizable axial tilt and mixing of continental and ocean air masses produce strong air currents obscuring the equatorial — polar flow. Venus has practically no water vapor, rotates slowly, has no axial tilt, and no mixing of continental and ocean air masses (no oceans) to obscure this flow.

**Pioneers 10 and 11**

Pioneer 10, launched March 3, 1972, was the first spacecraft to cross the Asteroid Belt, first to make close range observations of the Jupiter system, and the first to go beyond the outermost planets. In December 1973, it swept nearby Jupiter, finding no solid surface under the thick and deep clouds enveloping the planet. Thus, the world learned that Jupiter is a planet of liquid hydrogen. It explored the huge Jupiter magnetosphere, made close-up pictures of the Great Red Spot and other atmospheric features, and observed and measured at relatively close range Jupiter's large Galilean satellites — Io, Europa, Ganymede and Callisto.

Passing Jupiter, Pioneer 10 continued to map the heliosphere, the giant solar magnetic field drawn out from the sun by the solar wind. Pioneer 10 found that the heliosphere, like the magnetospheres of earth and Jupiter, behaves like a cosmic jellyfish, altering its shape in response to rises and falls in solar activity. It also reported that the speed of the solar wind does not decrease with distance from the sun. On June 13, 1983, Pioneer 10 crossed the orbit of Neptune which will be the planet farthest out from the sun for the next 17 years. This is because Pluto, although farthest on average, has an extremely elliptical orbit that crosses and goes inside of Neptune's.

Pioneer 10 is searching for the limits, or outer boundary, of the heliosphere. Together with Pioneer 11, it is also searching for a mysterious massive object beyond the known planets. Scientists hypothesize the existence of the object because of unexplained irregularities in the orbits of Uranus and Neptune. Pluto's mass is insufficient to cause these irregularities.

Considering the possibility, however remote, that Pioneer 10 may encounter intelligent extraterrestrials, NASA equipped Pioneer 10 with a plaque. The plaque has diagrams, sketches and binary numbers indicating where, when and by whom Pioneer 10 was launched.

Launched April 6, 1973, Pioneer 11 swept as close to Jupiter as 42,000 kilometers, compared to the 129,000-km closest approach of Pioneer 10, on Dec. 4, 1973. It provided additional detailed data and pictures on Jupiter and its satellites, including the first look at Jupiter's north and south poles which cannot be seen from earth. This view was possible as Pioneer 11 was guided so that Jovian gravity actually threw the craft out of the plane of the ecliptic in which the planets lie. From above this plane, Pioneer 11 was able to confirm that the heliosphere extends outward in all directions from the sun and is broken into northern and southern hemispheres by a bobbing sheet of electric current.

Pioneer 11 swept nearby Saturn on Sept. 1, 1979, demonstrating a safe flight path for the more sophisticated Voyagers to follow through the rings. It provided the first close-up observations of Saturn, its rings, satellites, magnetic field, radiation belts and stormy atmosphere. It showed areas, smaller but resembling the Great Red Spot on Jupiter, in Saturn's clouds.

It found no solid surface on Saturn but discovered at least one additional satellite and ring. Its data suggested that Saturn's rings, are icy in composition with little or no rock or metal and that Saturn's three largest satellites — Titan, Rhea and Iapetus — are composed in large part of ice.

## Viking

Viking made the world's most extensive study of Mars. The project used two spacecraft, each of which had an orbiter and lander.

Viking 1, launched Aug. 20, 1975, went into Martian orbit on July 19, 1976, and put its lander on the surface July 20, 1976. The orbiter stopped transmitting Aug. 7, 1980; the lander, late in November 1982.

Viking 2, launched Sept. 9, 1975, went into Martian orbit on Aug. 7, 1976. Its lander touched down on Sept. 3, 1976. The orbiter reported until July 24, 1978; the lander, April 12, 1980. They returned a wealth of photographs and other data, mapping about 97 percent of Mars. Their success generated so much public enthusiasm that about $50,000 was raised in 1980 to prolong the project. Late in 1980, the Viking 1 lander was renamed Mutch Memorial Station in memory of Dr. Thomas A. Mutch, former Viking Lander Imaging Team leader and former NASA Associate Administrator for Space Science. He disappeared while mountain-climbing in the Himalayas.

Among significant Viking discoveries —

* The Martian atmosphere, although too thin for most living things on earth to survive (about a 1/100 as dense as earth's), contains all components necessary to sustain life: nitrogen, carbon, oxygen and water vapor.
* The Martian surface resembles deserts on earth but is drier than earth's driest desert. However, considerable quantities of water are locked in the north polar ice cap and in the form of subsurface permafrost.
* Mars' northern and southern hemispheres are very different climatically. Global dust storms originate in the southern hemisphere while water vapor is comparatively abundant only in the far north during its summer.
* Lander analyses of Martian soil gave puzzling results that neither proved nor disproved the presence of past or present life. However, their failure to detect organic molecules reduced support for the presence of life forms.
* No canals or artifacts of any kind were found on Mars. However, evidence was found that in the past Mars' atmosphere was much thicker, its temperature was warmer and it had water on its surface.
* While volcanic mountains — at least one of which is bigger than any on earth — were found on Mars, the planet is seismically much less active than earth.

## Voyager

Just as the solar system has an entourage of planets and other bodies, the giant planets Jupiter and Saturn have their own entourages of rings and satellites. NASA's sophisticated Voyagers 1 and 2 provided a wealth of information including discoveries and answers to questions that have eluded astronomers since the birth of civilization.

After leaving Jupiter, Voyager 1 continued to pull ahead of its partner, reaching Saturn in November 1980. Voyager 2 flew by Saturn in August 1981.

Voyager's discoveries were numerous. They included: a ring of rocky debris around Jupiter, an ionized torus of sulphur around Jupiter, vast thunderstorms, sometimes big enough to engulf earth, on Jupiter and Saturn.

In addition, it discovered many additional small satellites, the natures of the Galilean satellites and Saturn's largest satellites, discoveries about Saturn's rings such as structure, width, unusual braiding, spoke patterns, ringlet formations, additional rings and numerous ringlets filling most of what appear from earth to be gaps in Saturn's rings.

Voyager's close looks at the Galilean satellites showed Io is the most volcanic object in the solar system; Europa has the smoothest surface; Ganymede had some tectonic activity before it froze solid about 3 billion years ago; and Callisto's crater-pocked surface is as ancient as that of the moon or Mercury. Ganymede and Callisto are composed of about equal parts of water ice and rock; Europa has substantial quantities of water; while Io is a waterless moon.

Voyager's findings indicate that Saturn's rings and satellites are for the most part composed of water ice. The exceptions are the giant satellite Titan which is half rock and the outermost satellite Phoebe which is mostly rock. Voyager photographs of Phoebe show that it resembles asteroids. It may be a captured outer solar system asteroid.

Voyager measurements toppled Titan from its position as the solar system's largest satellite. They found Jupiter's Ganymede to be slightly larger. Both are bigger than either of the planets Mercury or Pluto.

Voyager confirmed that neither Jupiter nor Saturn have solid surfaces. Their data indicated that while Jupiter's radiant heat may originate from gravitational contraction or release of heat accumulated during its formation, Saturn's comes from gravitational separation of helium and hydrogen in Saturn's interior. Both planets radiate about 2½ times more heat than they receive from the sun.

Voyager 2 discovered that nitrogen makes up about 82 percent of Titan's atmosphere. (Nitrogen is 78 percent of earth's atmosphere.) The other known ingredients of Titan's atmosphere are methane, ethane, acetylene, ethylene, hydrogen, cyanide and other organic compounds. Titan's atmosphere is believed to be similar to earth's in primeval times. Titan's composition reflects an abundance of water. An orange-colored smog, thought to result from chemical reaction of solar radiation on the methane in Titan's atmosphere, envelops the satellite, preventing direct observation of its surface. Voyager found Titan's surface air pressure to be 1.6 that of times earth's sea level pressure.

Some scientists speculated that the smog in Titan's atmosphere could have created a greenhouse effect that over the last few billion years warmed the planet enough for organic chemicals to evolve toward prelife forms. Voyager 2 measurements show that Titan's surface temperature is 95 Kelvin (-288 F), too cold for water to liquefy or for significant progress in prelife chemistry.

Around this temperature, methane could exist as a liquid, vapor or solid, just as water does on earth. On Titan then, methane rain or snow may fall from methane clouds. Methane rivers may flow through icy methane channels and methane oceans may fill icy basins.

A rare planetary alignment when Voyager 2 was launched will enable it to sweep near Uranus in January 1986 and Neptune in August 1980. If still functioning, it will provide the world with its first close-ups of these planets.

Voyagers 1 and 2 will eventually leave our solar system, like Pioneer 10. Each carries a record called "Sounds of Earth" with electronically imprinted words, photographs and diagrams telling about earth. The "Sounds" include greetings in sixty languages, music from different cultures and eras and sounds of the wind, surf, animals and other earth phenomena.

**Pioneer-Venus Mission**

The Pioneer-Venus mission included an orbiter, launched May 20, 1978 and placed into Venusian orbit on Dec. 4, 1978, and a multiprobe bus, launched Aug. 8, 1978, separated about three weeks before entry into Venus' atmosphere into four probes and the bus. The five entered Venus' atmosphere at widely separated locations on Dec. 9, 1978 and returned information as they descended to the surface. Although none was designed to survive landing, one probe transmitted data for an hour afterward.

Orbiter radar data provided a topographic map of about 90 percent of Venus. Most of Venus is a gently rolling plain. There are two prominent plateaus: one as large as Australia, the other as large as the upper half of Africa. There is a volcanic structure larger than earth's Hawaii-Midway chain — earth's largest — and a mountain that towers higher over Venus' great plain than earth's Mount Everest over sea level.

Other data indicated two major volcanic areas that vent the planet's internal heat. This makes Venus the third solar system body — the others are earth and the Jupiter satellite Io — with significant volcanic activity.

Orbiter and probe data refined information about Venus' atmosphere. They showed that the temperature at Venus' surface is 482 C (900 F) and air pressure on Venus is about 100 times greater than earth's sea level pressure.

The composition of Venus' lower atmosphere is 96 percent carbon dioxide, 3 percent nitrogen and 1 percent other gases, including extremely small parts of sulphur dioxide and water vapor. Venus' clouds are composed of three distinct layers, all of which consist mostly of corrosive sulphuric acid droplets.

Pioneer-Venus confirmed that the greenhouse effect is responsible for Venus' inferno-like surface temperatures it also supported information about atmospheric properties and the absence of an intrinsic magnetic field observed by previous spacecraft. It discovered an excess of primordial gases, compared with Mars and earth, that seem to conflict with theories of planetary evolution.

According to these theories, the gases should be less abundant on a planet that formed closer to the sun than on one that formed farther away.

**Sounding Rockets, Aircraft, Balloons and Ground Observatories**

NASA sounding rockets, high flying airborne observatories, ground observatories and balloons have contributed volumes of data to NASA scientific programs in the past 25 years. NASA has launched thousands of sounding rockets, many in cooperation with other countries, from ranges in the United States and abroad. Among sounding rocket contributions is their ability to explore areas of space too high for balloons and too low for satellites. NASA's fleet of sounding rockets includes Aerobees, Arcas, Argo D-4 (Javelin), Aries, Astrobees, Black Brants, Nike-Apache, Nike-Cajun, Nike-Hawk, Nike-Malemute, Super-Loki and Terrier-Malemute. The most familiar experiments are those involving the release of a chemical that colors the skies.

Observations of the chemical drift provide information on upper atmospheric winds or magnetic field structure. Sounding rockets are also employed in astronomical studies and to test instruments for future use in satellites and other spacecraft.

NASA balloon experiments are designed to study the atmosphere and to make astronomical studies. They are frequently conducted in association with other countries. Among recent balloon studies are those in conjunction with the Solar Mesosphere Explorer to investigate depletion of the ozone layer in our atmosphere. NASA launches its balloons from the National Balloon Facility, Palestine, Texas.

NASA airborne observatories have participated in observations of solar eclipses and other astronomical phenomena, atmospheric studies and geologic and oceanographic observations. Among their most dramatic discoveries were the unexpectedly high ratio of oxygen in earth's upper atmosphere by the Galileo airborne observatory in 1969 and the five faint rings around Uranus by the Kuiper airborne observatory in 1977.

NASA also supports ground observatories. In 1976, ground observatories discovered a satellite circling Pluto and ascertained that methane ice covered the planet's surface. With these observations, astronomers were able to increase their accuracy in measuring Pluto's mass. Their calculations resulted in a substantial reduction of estimates of Pluto's mass and indirectly increased support for the theory that a massive solar system object existed beyond Pluto. The reason is Pluto's mass, as currently estimated, is far less than adequate to produce the perturbations in the orbits of Uranus and Neptune that inadvertently led to the search for and discovery of Pluto.

In 1982, ground observatories reported that Pluto has an atmosphere of gaseous methane. The atmosphere may be the result of Pluto being closer to the sun as its elliptical orbit has carried it inside of the orbit of Neptune.

In 1983, ground observatories discovered a quasar 12 billion light years away, the most distant object discovered. The search that resulted in this discovery started 10 years ago using antennas of NASA's deep space tracking and data acquisition network and observatories in the United Kingdom and Australia.

NASA's Project SETI, Search for Extraterrestrial Intelligence, was begun in 1960. It not only searches for radio signals that could be from intelligent creatures but also does radio astronomy mapping of the sky and studies man-made radio interference that could affect space tracking, data acquisition, and communication.

Airborne and ground observatories, and sounding rockets, and balloons are frequently used jointly, such as in solar eclipse observations. Scientists want to study the solar corona normally masked by bright sunlight. They want to study changes in the atmosphere, magnetic field and other phenomena over all areas of earth on the ground track of the solar eclipse caused by the sudden cut-off and re-emergence of sunlight.

25th Anniversary
1958-1983



# Space Applications

# SPACE APPLICATIONS

By
Victor Seigel

NASA's space applications program, in which satellite technology is directly applied to benefit people, has been a driving force for human progress. Its value is incalculable and steadily growing.

Individuals and organizations of more than 100 nations are employing pictures and other data from Landsat in a diverse number of areas. Among these are agriculture, forestry, land use management, cartography, geology, hydrology, hydroelectric siting and irrigation planning, environmental protection, flood-damage assessment, prospecting for minerals and hydrocarbons, coastal zone management, urban planning, beach-erosion forecasting, siting of offshore facilities and snow-mass mapping and spring run off prediction. With Landsat, the whole earth can be rapidly and repeatedly surveyed at minimal cost. Landsat helps us to discover, inventory, and manage our renewable and nonrenewable resources, alerts us to environmental dangers, and keeps us abreast of natural and manmade changes on earth's surface.

Landsat is now an operational system managed by the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce, but NASA continues its research and development activities to advance the system's capabilities.

Information from weather satellites has been incorporated into operational weather data since launch of NASA's Tiros 1, the world's first meteorological satellite.

NASA continues to develop ground stations and develop and launch weather satellites as a partner with NOAA which establishes requirements for and operates the satellite system.

NASA has expanded weather satellite system capabilities from the original cloud pictures to acquisition of vertical temperature and moisture profiles of the atmosphere, sea- and land — surface temperatures, cloud-top temperatures, rainfall and moisture patterns, sea ice data, solar radiation, heat balance and other information related to weather and climate. With such information, scientists may be able to develop a numerical model for weather to contribute both to long term (3- to 14-day) forecasts and climatology. This benefit would be added to the many that weather satellites have already given the world such as increased accuracy of day-to-day forecasts; alerting coastal populations to approaching hurricanes, thus saving countless lives and millions of dollars of property annually; and informing shippers about the locations of the shifting Gulf Stream, enabling them to ride or avoid it and thus save fuel.

In addition, the NASA-developed Automatic Picture Transmission (APT) system, a relatively low cost way of acquiring pictures and other data from NASA-NOAA weather satellites, is being employed in about 135 countries.

NASA's Syncom and other communications satellites laid the groundwork for INTELSAT, the global commercial communications satellite system in which more than a hundred nations participate, and scores of domestic systems.

NASA technology and demonstrations have contributed to a vast increase in commercial communications service. The first was global TV, which gave people front-row seats to historic events. Among others are the linking of airliners on transoceanic flights with ground terminals and direct broadcast of satellites to rooftop antennas rather than through huge ground stations.

NASA has also shown the potential of communications satellite systems for improving education and health care for persons in remote and isolated areas. By greatly multiplying the number of long distance communications channels available, communications satellites literally revolutionized communications, creating a host of benefits.

An international project in which NASA is participating is SARSAT. Still experimental, SARSAT is demonstrating the use of satellites to speed help to downed airplanes and sinking ships. SARSAT is already credited with saving many lives.

NASA is employing advanced space technology to make precise measurements of movements of tectonic plates into which the rigid outer shell of the earth is divided. Such movements lead in time to earthquakes and volcanic eruptions along the edges of the plates. NASA is observing plate movements along the plate boundary known as the San Andreas Fault in California and, in cooperative programs with other nations, other earthquake prone areas. The measurements may contribute to an earthquake-forecasting system that could save countless lives annually.

NASA's National Geodetic Satellite Program, now completed, has resulted in improved maps and knowledge of earth's structure. It has contributed to surface and air navigation and to the launch, guidance and pinpoint landing of spacecraft such as the Space Shuttle.

NASA's ocean survey satellites provided more geodetic and geophysical knowledge about the oceans than were accumulated in all the years of ship measurements. The data ranged from sea surface to water depth and geologic information, contributing to models for forecasting ocean conditions, to ocean navigation and minerology, and to meteorology.

NASA's small magnetic field satellites swiftly, economically and comprehensively provided global data on earth's magnetic field. The U.S. Geologic Survey used the data to update its charts and maps which are employed by navigators and geologists. Among other things, the data led to forecasts that earth's magnetic field may reverse itself much sooner than expected.

Another small NASA satellite provided the first global vertical profiles of stratospheric aerosols and ozone. Its study of plumes from five volcanic eruptions during the 1979, 1980 and 1981 time period indicated that none would significantly affect world climate.

NASA's Applications Satellite programs are global in character. People and organizations of many nations have participated in them. The programs have contributed not only to substantial advances in knowledge and human progress but also to increased understanding among nations.

## Landsat

A remarkable achievement of our space program is the capability it has provided for keeping a current inventory of our resources, monitoring the quality of our environment and maintaining up-to-date maps depicting natural and manmade surface features at minimal cost. Steady advances in such a capability have already been achieved through NASA's Landsat program.

The advantages of a satellite system like Landsat over aerial and surface surveys, which continue to supplement satellite observations, are significant. Landsat can make repeated observations of an area, revealing changes. It can acquire data from areas where it would be too hazardous or inordinately expensive to do so by other means. It can also reveal large scale features that are overlooked when viewed at lower altitudes.

NASA launched Landsat 1 (originally Earth Resources Technology Satellite, or ERTS 1) on July 23, 1972. It launched Landsat 2 on Jan. 22, 1975; Landsat 3, March 5, 1978; and Landsat 4, July 16, 1982.

Among the areas to which Landsat contributes are agriculture, cartography, water management, flood damage assessment, environmental monitoring, rangeland management, urban planning and geology.

Landsat rapidly provides conventional and near infrared pictures of urban areas, states or regions for land-use planners; surveys rangelands to monitor availability of forage for livestock and to track the animals; observes water levels in reservoirs and snow cover in mountains to help forecast water availability for hydroelectric, agricultural and home use.

It also reports on faults and other geologic formations that hint at mineral, oil, gas or coal accumulations; quickly inventories many fields of different crops in California's Imperial Valley; and describes offshore currents to help control beach erosion and locate offshore facilities. The above are a few examples of hundreds of tests and demonstrations of Landsat potential.

The most notable of these tests and demonstrations are the three-year Large Area Crop Inventory Experiment (LACIE) completed in 1978 and the six-year Agricultural and Resource Surveys through Aerospace Remote Sensing (AGRISTARS) begun in 1980.

LACIE demonstrated that global crop production forecasts of wheat could be achieved better and faster with a satellite system than with other practices. LACIE participants were NASA, the Department of Agriculture, and the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce.

AGRISTARS is testing and developing the use of satellite-acquired data to augment or replace existing techniques for compiling information about earth's resources. AGRISTARS includes the three agencies plus the Department of the Interior.

Landsat is a global project. For example, LACIE involved study of wheat fields in Argentina, Australia, Brazil, Canada, India, the People's Republic of China, the Union of Soviet Socialist Republics and the United States. Hundreds of scientists in many nations have worked at interpreting and maximizing benefits from Landsat data. More than 100 nations use Landsat data. More than a dozen have built ground stations to acquire and process Landsat data directly. Users of Landsat information include individuals, research laboratories, universities, domestic and foreign governmental agencies, and industrial and commercial concerns.

In November 1979, NOAA was designated as manager of all civilian remote sensing activities and directed to pursue eventual commercialization of the Landsat system. NASA continues research and development aimed at advancing Landsat capabilities. On Jan. 31, 1983, NASA turned Landsat 4, the latest and most advanced of the series, over to NOAA.

Satellite communications give people front-row seats to historic events regardless of where they occur. They have reduced long distance costs and made available a host of new communications services. They have left an indelible mark on the world and forever changed world information patterns.

In 1960, millions throughout the world began to view a bright star moving across the night sky. This moving star not only dramatized America's space program but also was the harbinger of the communications revolution that would change the world.

The star that started it all was Echo 1 which NASA launched Aug. 12, 1960. Echo 1 was a 100-foot sphere made of aluminum-coated polyester film. Radio signals sent from one ground station were reflected off of its shiny surface to another ground station.

Shortly after Echo 1 achieved orbit, a message from President Eisenhower was beamed via the satellite from NASA's Goldstone, Calif., station to the Bell Telephone Laboratories, Holmdel, N. J., station. On Aug. 18, the Bell Telephone Laboratories announced that it had made the first transAtlantic wireless code transmission via Echo 1 from Holmdel to a station at Issyles-Moulineaux, France.

Success with Echo 1 led to development of Echo 2, a 135-foot-diameter sphere with a tougher (more rigid) skin than Echo 1, on Jan. 25, 1964. Many communications experiments were carried out with Echos 1 and 2. In addition, the satellites were used as reference points in geodetic observations. The technology of inflatable spheres established in Echo was also applied to Pageos, a geodetic satellite, and to a number of atmosphere Explorer satellites.

Echo 1 was followed by a series of rapid developments in communications satellites. On July 10, 1962, NASA launched the solar-powered Telstar 1, built by the American Telephone and Telegraph Co. Telstar was an active-repeater satellite, meaning it received, amplified and retransmitted radio signals, unlike Echo which was a radio signal mirror. This first non-governmental satellite conducted the first live intercontinental television demonstrations between the United States and Europe. Telstar 2 was launched May 7, 1963.

NASA launched its active-repeater Relays 1 and 2 on Dec. 13, 1962, and Jan. 21, 1964, respectively. It conducted thousands of tests and demonstrations of transoceanic and intercontinental public telecasts via these satellites, including the first between Japan and the United States.

In the midst of these rapid advances, the Communications Satellite Act of 1962 was signed on Aug. 31, 1962. The act called for creation of a private commercial communications satellite corporation and, in conjunction and cooperation with other nations, of a global commercial communications satellite system.

The Communications Satellite Corporation was organized in February 1963 to establish a global commercial communications satellite svstem in cooperation with other nations. The International Telecommunications Satellite Consortium (INTELSAT) was established in August 1964. Todav, INTELSAT is composed of more than 100 member nations.

Echo, Relay and Telstar were medium-altitude satellites. They moved across earth's surface and provided communications only when they were in line of sight of two ground stations. Continuous global coverage would require 30 to 50 medium altitude satellites in orbit at one time.

Another kind of orbit is called geostationary or geosynchronous. In such an orbit, a satellite circles over earth's equator at an altitude of about 35,680 km (22,300 mi.). Because the satellite's orbital period is the same as the period of the earth's rotation (about 24 hours), the satellite remains stationary relative to a point on earth's surface. Three geostationary satellites spaced equidistant around earth could provide global coverage.

The big questions were whether such orbits could be achieved and maintained and whether the great distance that radio signals would have to travel would cause a time lag or echo in communication via satellite. NASA technology solved both problems in its Syncom (for Synchronous Communications) satellite experiments.

After an initial failure with Svncom 1 on Feb. 14, 1963, NASA launched Syncom 2 into synchronous orbit on July 26, 1963. Syncom 2 was placed in an orbit with an inclination of 33 degrees. As a result of this inclination, its ground track over earth resembled an elongated figure 8 stretching from 33 degrees north to 33 degrees south latitude with the crossover point on the equator.

Experiments with Syncom 2 demonstrated the practicability of a synchronous orbit. On Aug. 19, 1964, NASA launched Syncom 3 into a geostationary orbit. Syncom 3 was the world's first geostationary satellite. Work with Syncom 3 provided much of the additional scientific and engineering data required to lay a basis for the global commercial communications satellite system.

INTELSAT launched Early Bird (Intelsat I) into geostationary orbit for trans-Atlantic coverage on April 6, 1965; Intelsat II for Pacific coverage, Jan. 11, 1967; and Intelsat III for Indian Ocean coverage, Mar. 23, 1967. With three satellites in geostationary orbits, INTELSAT provided global communications service.

## Applications Technology Satellites

The versatile Applications Technology Satellite (ATS) program pioneered new technology for weather and communications satellite systems and demonstrated new communications services. The latter displayed the potential of satellite systems for improving health care and education for persons living in remote and isolated areas. ATS were geostationary spacecraft.

ATS 1, launched Dec. 7, 1966, provided the first continuous observation of weather from geostationary orbit. ATS 3, launched Nov. 5, 1967, provided the first color telecasts of earth from geostationary orbit. Together the satellites demonstrated the value of weather satellites in geostationary orbits. This led eventually to NASA's Synchronous Meteorological Satellite program, the prototype of NOAA's Geostationary Operational Environmental Satellite System (GOES).

Other ATS 1 meteorological experiments included relay of measurements of river height and rainfall from unattended stations in remote or isolated areas. ATS 3 contributed vital data on numerous destructive storms. Its steady stream of pictures of Hurricane Camille in 1969 led to evacuation of the Mississippi Gulf Coast that may have saved hundreds of lives.

ATS 1 and 3 far exceeded their design lifetimes and lasted into the 1980s. They have been used for a variety of public services. ATS 1 has served since 1971 to link public health aides in remote Alaskan villages with Public Health Service physicians in Fairbanks and Anchorage, improving health care for native Alaskans. At the same time, it was used for PEACESAT — Pan Pacific Education and Communications Experiment by Satellite. Initiated by the University of Hawaii, PEACESAT involved 12 Pacific island nations.

During a major flood in Alaska in 1967, ATS 1 linked the flood area to U.S. government agencies. During the eruption of Mount St. Helens in 1980, ATS 3 relayed messages from an Air Force jeep at the disaster site.

In 1982, the General Electric Co. developed a remote communications terminal small enough to fit into two suitcases and to be carried aboard an airplane. The terminal can be powered from an ordinary AC outlet or car battery and can communicate with any of several ground stations via ATS 3.

ATS 6, launched May 30, 1974, was the last and most advanced of the ATS series. It pioneered telecasts via satellite directly to hundreds of small low cost ground receivers.

In the Health Education Telecomunications (HET) Experiment, it relayed a large number of health and education programs to remote communities in the Appalachians, Rocky Mountains and Alaska. (ATS 1 and 3 augmented links in HET.) HET was a joint project of NASA and the Department of Health, Education, and Welfare.

In a joint program with India, called the Satellite Instructional TV Experiment (SITE), ATS 6 relayed educational programs originated by India to receivers in about 5,000 remote Indian villages.

In Position Location and Aircraft Communications Experiments (PLACE), ATS 6 together with ATS 5, launched Aug. 12, 1969, studied requirements for a future position-location and communication system via satellite to assure uninterrupted communications between ships and aircraft and ground terminals. ATS 1 and 3 also conducted PLACE experiments. (ATS 5 was employed in various tracking experiments but its usefulness for many other experiments was limited by an uncorrectible stabilization failure.)

The Federal Aviation Administration, the Transportation Systems Center, and the U. S. Coast Guard of the Department of Transportation, the Maritime Administration of the Department of Commerce, Canada, and the European Space Agency participated in PLACE. PLACE experiments contributed to the commercial Marisat system.

The key feature of ATS 6 was its 9-m (30-foot) diameter mesh antenna that could be pointed to within a tenth degree of arc. The antenna enabled ATS 6 to relay strong television signals to suitably augmented small ground receivers. Typically, huge expensive ground stations had been required to receive and amplify faint signals from communications satellites before transmission to home TV sets.

Among many other ATS 6 experiments —

* A Tracking and Data Relay Experiment in which ATS 6 relayed data from and tracked Nimbus and GEOS satellites. This experiment contributed to planning for the Tracking and Data Relay Satellite System which would replace most ground stations while augmenting ability to track, communicate with and acquire data from the orbiting Space Shuttle and unmanned satellites. In July 1975, ATS 6 relayed the first live telecast of the Apollo-Soyuz Test Project to viewers in the United States and the Soviet Union.

* Testing an advanced high resolution camera for taking day and night pictures of earth and its cloud cover. The pictures and other ATS 6 data were used in preparing operational weather forecasts and climatological studies. They contributed to GOES.

* Testing millimeter wave frequencies, which are above 10 GHz, for future use in operational communications satellites systems. Satellites typically broadcasted in the 4 to 10 GHz bands which were becoming overcrowded. The higher bands are more subject to absorption by precipitation and oxygen than the others. However, there are so-called frequency band windows in millimeter waves where this problem is minimal.

Concerned by failure of three of the four thrusters that enabled ATS 6 to hold its position in space, NASA engineers turned ATS 6 off on June 30, 1979.

They used the good thruster to boost ATS 6 several hundred kilometers higher to keep it out of the way of other geostationary spacecraft. ATS 6 exceeded its design lifetime by three years.

Communications Technology Satellite (CTS), a joint project of NASA and Canada, was launched Jan. 17, 1976. Like ATS 6, it could broadcast directly to small, low cost, user-operated ground receivers. ATS accomplished this by using a special antenna. The CTS transmitter, which was 10 to 20 times more powerful than any in use, enabled it to broadcast directly to small receivers.

Among other technologies tested by CTS:

* The 10-12 GHz band, newly allocated to communications satellites.

* A deployable wing-like solar array for power generation.

* A three-axis stabilization system to keep the solar cell array facing the sun for power and antennas pointed to earth.

Commercial communications satellites were generally spin-stabilized. Solar cells mounted on their cylindrical sides are in sunlight intermittently as the satellites spin. Only about half of them are in sunlight and generating electricity at any time.

CTS demonstrated that the new frequency bands could be successfully tapped, that the high power 200-watt traveling wave tube (transmitter) can successfully broadcast to small, low cost earth terminals, and that international teleconferences between people continents apart could be held through such terminals when sufficient transmitter power is available. Its new stabilization system proved successful. CTS technology is being employed in commercial satellites like SBS that beam television and data directly into homes and business offices, in Intelsat, the Candian Anik, and NASA's Tracking and Data Relay Satellite System (TDRSS).

CTS was employed in a large number of commercial and public service demonstrations and in an unscheduled test in which it provided contact during the Johnstown, Pa., flood of 1977 between the disaster area and American Red Cross Headquarters in Washington, D.C. All commercial communications lines were out of service. CTS experiments were concluded October 1979.

Following the conclusion of CTS experiments, NASA initiated a new program to meet future needs in communications satellite technology. The program includes studies in replacing ground with satellite switching systems, the use of spot rather than broad beams and the employment of as yet unused frequency bands.

## Weather Satellites

Looking at weather from satellites has revolutionized the science of meteorology and improved accuracy of weather forecasts. Weather satellites have contributed to saving countless lives and millions of dollars of property in the United States annually by keeping a constant watch for and on typhoons in the Pacific and hurricanes in the Caribbean and Atlantic.

Satellite transmissions have been incorporated into operational weather data since the launch of NASA's experimental Tiros 1 weather satellite on April 1, 1960. Tiros stands for Television and Infrared Observation Satellite. Tiros 1 could provide only daytime pictures of mid-latitude areas of earth. Tiros 2, launched Nov. 23, 1960, was equipped with infrared sensors that enabled it to take nighttime cloud-cover photographs.

NASA improved Tiros over the years. One or the more significant improvements was the inauguration of the Automatic Picture Transmission (APT) system with Tiros 8, launched Dec. 21, 1963. The system enabled weather forecasters everywhere to receive cloud-cover and other data for local area coverage from Tiros with comparatively inexpensive ground equipment.

Tiros 10, launched July 2, 1965, was the first spacecraft funded by the U.S. Weather Service of the Department of Commerce. When the Weather Service became part of the department's Environmental Science Services Administration, Tiros Operational Satellites were designated ESSA. When ESSA was in turn absorbed by the department's National Oceanic and Atmospheric Administration, Tiros satellites were designated NOAA. Under a NASA-Department of Commerce agreement, NOAA establishes requirements for and operates weather satellites and NASA develops the spacecraft and associated ground stations, launches the satellites and checks them out before turning it over to NOAA.

Today's Tiros N (NOAA) satellite system is a far cry from Tiros 1. It covers the globe in a low polar orbit about four times daily. It provides 24-hour coverage of cloud-cover, earth surface and cloud-top temperatures, vertical temperatures and moisture profiles of the atmosphere, meteorological data from fixed and floating platforms (balloons, buoys and unattended stations in remote areas), and data on changes in the Van Allen Radiation Region. Such changes are related to changes in solar activity and contribute to transfer of solar energy between the sun and earth.

This heat balance is a driving force of weather, but techniques of forecasting have assumed no gain nor loss of heat. The complement of new instruments in the Tiros N series is enabling weathermen to gather data that can improve long range (3- to 14-day) weather forecasts.

Tiros is now a joint program of NASA, NOAA, the United Kingdom and France.

NASA's Synchronous Meteorological Satellites (SMS) 1 and 2, launched May 17, 1974 and Feb. 6, 1975, respectively, were immediately used by NOAA and were the prototypes of its Geostationary Operational Environmental Satellite (GOES) system.

As with NOAA satellites, NASA develops, launches and checks out GOES before turning it over to NOAA. At least two working GOES are maintained in orbit, assuring constant watches on the Atlantic and Pacific approaches to the Western Hemisphere and on hemisphere land masses to warn of hurricanes and other destructive storms.

They also locate Gulf Stream and other currents for shipping and fishing, warn Florida citrus growers of the approach of crop-killing frosts, and provide a large variety of information such as atmospheric profiles of temperature and moisture, sea surface temperature, solar activity and magnetic field data that is crucial to accurate weather forecasting.

GOES 1 was launched Oct. 16, 1975; GOES 2, June 16, 1977; GOES 3, June 16, 1978; GOES 4, Sept. 9, 1980; GOES 5, May 22, 1981; and GOES 6, April 28, 1983.

NASA's experimental Nimbus satellite program contributed many new instruments and techniques to weather and environmental satellites.

Each Nimbus introduced new technology or new techniques while improving on existing technology. As examples, Nimbus 1, launched Aug. 28, 1964, tested advanced optical and infrared cameras; Nimbus 2, launched May 15, 1966, demonstrated that infrared pictures from weather satellites could be read out live with automatic picture transmission (APT) equipment.

Nimbus 3, launched Apr. 14, 1969, tested equipment to make vertical measurements of temperature and moisture, to describe ozone distribution, to gather solar radiation data, and acquire data from sensors on fixed platforms and moving platforms.

Nimbus 4, launched April 8, 1970, studied ozone deterioration and reported that between 1970 and 1972, it was only about a half that predicted.

Nimbus 5, launched Dec. 11, 1972, improved techniques to forecast tropical storm movement. Nimbus 6, launched June 12, 1975, demonstrated gathering information from moving platforms.

Its biggest effort involved relaying data from about 1,000 fixed, floating and airborne sensors to investigators in Australia, Brazil, Canada, France, Norway, the Republic of South Africa and the United States.

Nimbus 7, launched Oct. 24, 1978, showed how satellites could help commercial airliners avoid heavy ozone concentrations which can adversely affect passengers.

During the 1970s, Nimbus participated with Tiros in the Global Atmospheric Research Project. This was a joint project of the World Meteorological Organization and the International Council of Scientific Unions.

Nimbus contributed to such operational activities as providing sea ice data for the U.S. Navy and relaying to oilmen icepack movement data from sensors airdropped on the Beaufort Sea icepack north of Alaska's Prudhoe Bay. Nimbus data was also used to prepare global rainfall and ozone distribution atlases.

Analyses of Nimbus data led to many discoveries. One was related to the amount of solar radiant energy reaching earth. Scientists assumed this amount remained more or less level and gave the phenomenon the name of solar constant. Nimbus 7 data indicated the solar constant was not constant. There were not only short term variabilities of between one-tenth and two-tenths of a percent but also an overall downward trend of two-hundredths to four-hundredths of a percent per year in the amount of solar radiant energy reaching earth.

An Applications Explorer launched Feb. 18, 1979, to conduct a Stratospheric Aerosol and Gas Experiment (SAGE) provided meteorologists and climatologists with the first global vertical profiles of stratospheric aerosols and ozone. It also studied plumes from five volcanic eruptions that penetrated the stratosphere: La Soufriere and Sierra Negra in 1979, Mount St. Helens and Ulawun in 1980, and Aloid in 1981. The studies indicated that none of the eruptions would significantly affect world climate. Other SAGE data are also contributing to under-standing of weather and climate.

NOAA 8, launched March 28, 1983, carried instruments provided by Canada and France to test a Search and Rescue Satellite-Aided (SARSAT) system. NOAA 8 joined COSPAS I, launched by the Soviet Union on June 30, 1982, to complete the two-satellite network planned for the experiment.

SARSAT-COSPAS is a joint program of NASA, NOAA, Canada, France, Norway, the United Kingdom and the Union of Soviet Socialist Republics to speed help to downed airplanes and sinking ships. A national search and rescue plan adopted by Congress in September 1969 called for NASA to use aerospace technology to help develop a system to locate ships and aircraft in distress. Federal laws now require ships and private airplanes to carry emergency radio locater beacons.

Although the system which is to include new Local User Terminals developed by NASA is not yet completed, it is already credited with saving more than 20 lives.

Geodesy involves development of a global network of triangles for accurate determinations of latitude and longitude of any point on earth and distances between points. It also refers to mathematical determinations of the size, shape, and mass distribution of earth, including variations in gravity. NASA's Explorers 27 and 29 (GEOS 1 and 2, or Geodetic Satellites 1 and 2), launched April 29 and Nov. 6, 1965, and Pageos (Passive Geodetic Satellite), launched June 24, 1966, were devoted to geodesy. Geodetic studies were also accomplished with the ionosphere Explorer 22, Echo 1 and 2 communications satellites, and Army's SECOR satellite.

Information from these programs showed that even the best previous maps frequently showed points many kilometers from where they actually are. The geodetic project, which involved more than 30 nations and included NASA, the Department of Commerce, and the Department of Defense in the United States, has benefited surface and air navigation and contributed to the pinpoint launches, guidance, and landings of the Space Shuttle.

GEOS (Geodynamic Experimental Ocean Satellite) 3, launched April 9, 1975, provided more geodetic and geophysical data about the oceans than were accumulated in all previous years of ship measurements.

The Department of Defense estimated that the data saved them about $140 million in ship survey operations over 10 years. GEOS 3 also increased accuracy of measurements of the ocean geoid — the level that the ocean surface would assume in the absence of wind, currents, tides and gravity anomolies.

GEOS 3 was the first satellite to make precise measurements of the topography of the ocean surface and of sea state — wave height, period and direction. Its information contributed to models for forecasting ocean conditions.

In a technological breakthrough, GEOS 3 demonstrated in 1978 that its radar altimeter for sea measurements could be as accurate in large-scale land contouring as ground and aircraft surveys are for small-scale mapping.

Data from GEOS 3 and other studies were used in the development of Seasat, launched June 26, 1978. It produced a wealth of ocean data before its life was cut short, 105 days after launch, by a power failure. Among them were detailed bathymetric (water-depth) and geologic information for vast areas of the ocean. Its information resulted in many corrections of bathymetric charts.

U.S. organizations participating in Seasat were the Departments of Commerce, Transportation and Energy; the Environmental Protection Agency; the Smithsonian Institution; the Sea Use Council and the American Institute of Merchant Shipping. Seasat's radar altimeter was also used for geologic mapping over continental areas and contributed to the development of an imaging radar system for the Shuttle.

Lageos (Laser Geodynamics Satellite), launched May 4, 1976, is being used in a 50-year program to help measure the minute movements of large tectonic plates into which the earth's outer shell is divided. Such movements are related to earthquakes, volcanic eruptions, accumulations of oil, gas, coal and minerals and building and break-up over millions of years of mountain ranges and continents.

An early finding of Lageos experimenters is that movements of the earth's surface along California's San Andreas fault are as much as 50 percent faster than the historical average. The faster movements may indicate that strain is building up more rapidly than expected.

NASA is watching not only the San Andreas fault but, in cooperation with other nations, other earthquake-prone areas. Participating with NASA in plate tectonic studies are the U.S. Geological Survey, NOAA, National Science Foundation and the Defense Mapping Agency.

The feasibility of mapping variations in surface heat by satellite and the benefits that can be derived from such data were demonstrated by an Applications Explorer satellite in a Heat Capacity Mapping Mission (HCCM). The HCCM Explorer was launched April 26, 1978.

This mission produced much valuable information while taking temperatures at 2 a.m. and at 2 p.m. local times of selected areas in the United States, western Europe and Australia.

One observation was that differences in urban and rural areas are greater at 2 p.m. (day) than at 2 a.m. (night). Scientists interpret this to mean that the urban heat island phenomenon (concentrations of heat rising from urban areas) may not be due to heat rising from concrete roads and buildings but to the inability of these structures to retain moisture.

The information from HCCM appears to contribute to many fields including agriculture, hydrology, oceanography, geology, meteorology, environmental monitoring and prospecting. HCCM results are expected to contribute to advances in Landsat capabilities.

A declining trend in magnetic field intensity, discovered by Magsat (Magnetic Field Satellite), launched Oct. 30, 1979, could mean a magnetic field reversal in only 1,200 years, much sooner than expected.

Magsat made this discovery while providing precise golbal data on the magnitude and direction of the geomagnetic field. The previous global surveys were made by Orbiting Geophysical Observatory (OGO) satellites from October 1965 through June 1971.

The U.S. Geological Survey used Magsat data to update magnetic charts and maps that it published in 1980 and 1981 for navigators and geologists. Magsat data included not only earth's magnetic field, but also "anomalies", which are of lesser intensity than the main field and are assumed to be generated in earth's crust. Anomalies provide clues to tectonic plate movement and to accumulations of minerals and hydrocarbons.

Magsat is an Applications Explorer satellite. It provided data for study by scientists in the United States, Australia, Brazil, Canada, France, India, Italy, Japan and the United Kingdom. Its data were applied to geology, geophysics, marine studies, field modeling and magnetosphere/ionosphere and core/mantle studies.

25th Anniversary
1958-1983

# *Aeronautics*

# AERONAUTICS

by
Stuart W. Rosenbaum

NASA was created in October, 1958 formed around a nucleus of NACA, the National Advisory Committee for Aeronautics. In the 25 years since NASA assumed responsibility for NACA's aeronautical research, the many fundamental advances in that field have made flying a routinely accepted part of life today. Most of the advances of these 25 years began with research in NACA laboratories.

NACA was created in 1915 "...to direct the scientific study of the problems of flight with a view to their practical solution and to determine the problems which should be experimentally attacked; to discuss their solution and their application to practical questions...and to direct and conduct research and experiment in aeronautics in such laboratory or laboratories."

The National Aeronautics and Space Administration was chartered officially to conduct aeronautical research among its other defined tasks. The National Aeronautics and Space Act of July 27, 1958, the legislation that established NASA, states that the general welfare and security of the United States require adequate provision to be made for aeronautical activities, and that these activities should be so conducted as to contribute materially to one or more of these objectives:

* The expansion of knowledge of phenomena in the atmosphere.

* The improvement of the usefulness, performance, speed, safety and efficiency of aeronautical vehicles.

* The preservation of the role of the United States as a leader in aeronautical science and technology.

* The most effective utilization of the scientific and engineering resources of the United States in order to avoid unnecessary duplication of effort, facilities and equipment.

NASA research scientists, part of a team that includes industry, universities, other government organizations and laboratories, both private and government, work toward those broad objectives. Specifically, NASA aims its research toward the advancement of both civil and military aeronautics, pointing toward new concepts of flight, seeking new approaches to solve the ever evolving new ideas to stimulate the designers of tomorrow's aircraft and aeronautical vehicles.

NASA's broad field of aeronautical research has as its primary subjects the vehicles and powerplants that use the earth's atmosphere for flight. It also is concerned with the aeronautical aspects of space vehicles that depart from or land on the earth.

The major share of this work is done at four NASA centers: Langley Research Center, Hampton, Va.; Ames Research Center, Mountain View, Calif.; Dryden Flight Research Facility, Edwards, Calif.; and the Lewis Research Center, Cleveland. Additional studies are conducted at other NASA installations or at the laboratories and facilities of other government agencies. Private industry makes important contributions, from self-supported research and development programs and from NASA-funded programs.

NASA aeronautical research is categorized in a quartet of headings: proof of concept, extension of the art, future needs and problem solving.

## Proof of concept

This is an approach that often, but not always, requires the building and testing of a special aeronautical vehicle. The best known examples are the famed X series of research aircraft developed by NACA and the military services in the 1940s and subsequently. A more recent example is the joint Navy/Army NASA-Bell XV-15, a unique rotorcraft with a potential for both military and civil use. This program exemplifies the means by which the feasibility of any new concept must be embodied and demonstrated in a tangible flying machine before its actual potential can be established.

## Extension of the art

Extension of the art takes as a basis the contemporary state of that art and builds on that foundation. Today's subsonic transport aircraft are, for example, well understood. But continuing research in aerodynamics, propulsion, structures, materials and avionics indicates that tomorrow's transports could be vastly improved by the incorporation of new ideas. The art has been extended, and that body of knowledge is available to industry as foundation stones for the next-built generation.

## Future needs

Future needs call for the broadest research goals. While sometimes the end point of such work would seem to have little practical current application, other research is quite focused. An example: The investigation of high temperature resistant structural ceramic materials for use in future gas turbines. Today's engines are highly dependent on expensive, strategic metals not occurring naturally in the United States. Not only would successful ceramic materials reduce our dependency on crucial imported metals, they could also permit useful higher temperatures to be achieved, increasing engine efficiency and fuel economy. Much research is required to establish the feasibility of such applications and to assist in developing useful materials and manufacturing techniques.

## Problem Solving

The best of designs, after painstaking analysis, extensive wind-tunnel testing and exploration of the flight envelope may develop a problem that was not predicted earlier; as an example, a problem related perhaps to long-time exposure to some external factor. Basic problems thus need solutions perhaps even after certification and operation for some years, in the case of both military and civil aircraft. This kind of problem-solving is an important part of the work that NASA has done when its facilities and staff are found specially suited or indispensable.

These four categories may be viewed both in terms of the technical content or branch of science involved, and the focussed application. The first is referred to as disciplinary research, dealing with distinct branches of the aeronautical science. Aerodynamics, propulsion, structures and materials are typical areas in which disciplinary research is conducted.

The second is research applied to specific classes of aircraft as, for example, subsonic transports or high performance fighters. In either of these aspects of research, flight vehicles may be used to prove a concept, test a refinement or to carry some particular research experiment into an environment which cannot effectively or realistically be achieved on the ground.

## The Tools Of Research

Popular impression of NASA's aeronautical research might visualize a huge wind-tunnel section containing a full sized airplane mounted on struts, dwarfing the researcher standing near to give scale. Wind tunnels were and are a most important component of NASA facilities, and a very long-standing method of conducting research experiments.

They provide a means to test accurate scale models, or even full sized aircraft, over portions of the normal speed ranges encountered in flight. Tests are carefully controlled, with a calibrated airstream rushing past the mounted model. Accurate balances measure the forces on the model and computers translate those measurements of pounds of tension and compression into coefficients of lift, drag and pitching moments.

But before wind tunnel testing occurs, analytical methods are used to predict the behavior of an aircraft in flight. Once laboriously done with pencil, slide rule and perhaps a desk calculator, such analyses now are the special provinces of high speed computers. They process codes fashioned to forecast flow patterns and forces around a fuselage or wing or around their juncture.

The simulator offers a third approach to research. Driven by many computational circuits that calculate the behavior of an airplane in flight and present it in a display, the simulator offers a way of "flying" an aircraft before it is built. The characteristics of the vehicle, predicted from drawings, analysis and model tests are programmed into the computer. Played back to engineers or pilots "flying" the new design, they reveal the good and bad qualities and interactions of many factors that are difficult to predict.

Analysis, model testing and simulation all contribute to the understanding of the performance of a flight vehicle. One step remains: Flight of the vehicle itself. NASA research pilots, who also are engineers, conduct a meticulous program that gradually probes the flight envelope, edging toward the speed, altitude and load limit that will finally define the true performance of the aircraft itself. This full-scale research furnishes answers that will corroborate, extend and perhaps correct the inputs from analysis, wind-tunnel tests, and simulation.

These are the four major tools of NASA researchers. They have been used singly, and in concert to explore problem areas in the safety, efficiency or comfort of aircraft.

A brief description of a number of major NASA-supported aeronautical projects follows, some completed in past years, some ongoing.

## Supersonic Cruise Aircraft Research (SCAR)

NASA researchers worked throughout the 1960s on technologies for supersonic transport. By 1971, Boeing's Supersonic Commercial Air Transport (SCAT) was ready for production, but concerns about noise, economy and pollution prevented further funding.

Convinced that supersonic transport research could eventually pay off, in 1973 the government funded the Supersonic Cruise Aircraft Research (SCAR) program. Nine years of a sustained, focused technology program involving NASA and major U.S. propulsion and airframe companies resulted in significant improvements over earlier supersonic transport concepts. By the early 1980s, the SCAR program had developed technologies permitting a greatly increased range, greater passenger capacity, lighter weight and cleaner, quieter, more efficient engines than any existing supersonic transport aircraft possessed.

## The X-15 Program

This NASA program began on March 25, 1960 and terminated on Oct. 24, 1967. The X-15, a 50-foot long, black, stub-winged, rocket-powered flight research craft with a conventional nose-wheel and retractable skids mounted at the rear for landing, was a true aerospace vehicle. With wings and aerodynamic controls it traveled like an airplane in the atmosphere, but in flight beyond the atmosphere, like a spacecraft. In addition to the rocket motor for propulsion housed in the craft, reaction control rockets were also provided to control the craft at extreme altitudes where there was no atmosphere to provide aerodynamic forces on the various control surfaces of the X-15 to effect a change in course or attitude.

The X-15 was launched from beneath the wing of a B-52 at an altitude of 13,716 meters (45,000 feet). After its drop, the main rocket engine was fired and the craft climbed in a steep trajectory, then nosed over to descend in an unpowered glide to a landing.

Through a series of progressive steps, the X-15 set new altitude (more than 67 miles) and speed (6.7 times the speed of sound) records. Its 199 flights contributed important data about weightlessness, aerodynamic heating, atmospheric entry, the effect of noise on aircraft materials, and piloting techniques, valuable to the manned space programs which followed the X-15.

The X-15 was a joint NASA/Air Force/Navy project. First piloted by A. Scott Crossfield, both Neil A. Armstrong, Commander of Apollo 11, and Joe Engle, Commander of STS-2, were among the pilots who flew the X-15 into unexplored areas of flight.

## Terminal-Configured Vehicle (TCV)

With the continually growing use of air transportation, problems increased: approach and landing in bad weather, safety and efficiency in controlling high-density traffic, and noise of aircraft in take-off and landing over densely populated areas. The Terminal Configured Vehicle (TCV) is a research tool, a standard Boeing 737 twin-jet transport with a second cockpit in the passenger cabin. Equipped with state-of-the-art instrumentation, the second cockpit is the flight center for the research, while safety pilots fly in the conventional cockpit for backup. In 1979 the TCV was used to demonstrate the Microwave Landing System (MLS) and Area Navigation for efficient airport approach operations and precision flight control. Its success contributed to the International Civil Aviation Organization's adoption of MLS as the world standard.

## Lifting Bodies

NASA has had three experimental lifting bodies. These wingless craft achieve the aerodynamic lift and maneuverability necessary for flight from their body shape alone. The first, Ames Research Center's M2, featured a flat top and round belly. The second, HL-10, was developed at Langley Research Center and had a rounded top and flat belly.

The third was the NASA / Air Force X-24. The vehicles were carried aloft by a B-52 and released to glide to landings on a dry lake bed. The X-24B had made 33 successful flights when the program was completed in 1975.

## Oblique Wing

Several decades ago Robert T. Jones, NASA scientist at Ames Research Center suggested the fixed axis concept of an aircraft wing that could pivot (sweep) up to 60 degrees in flight and achieve the same benefits of more conventional symmetrical sweepback, primarily drag reduction at high speeds, but without suffering the penalties of sweep at low speeds. Years of analysis and wind tunnel tests suggested the results would show considerable fuel economy.

A small, piloted jet-powered research aircraft called Ames-Dryden-1 (AD-1) was built to study the low speed behavior of the pivoted oblique wing concept. In 1979 it made its first flight. During takeoff, landing and low-speed cruise, the AD-1 flies with wings extended at right angles to the fuselage. Then while in flight, the wing can be rotated about a pivot axis at the fuselage so that the right half sweeps back and the left half sweeps forward. The AD-1 low speed flight research program was completed in 1981, having successfully flown 39 flights at speeds up to 165 mph.

## HiMAT

Highly Maneuverable Aircraft Technology was a NASA / Air Force flight research program to study and test advanced fighter aircraft technologies.

The HiMAT vehicle was a 44 percent scale model with wing-tip-mounted winglets and a small forward canard wing for high maneuverability. It consisted of a core design to which modular components could be attached easily and replaced, a format that allows low-cost testing of a variety of concepts.

In 1979, the remotely controlled research aircraft made its first flight. The following year it achieved near-maximum design maneuverability at sustained near-supersonic speeds, and in 1981 its flight testing was expanded to transonic speeds.

The HiMAT flight test program ended in January 1983. The vehicles had performed superbly, demonstrating twice the maneuverability at transonic speeds of modern fighter aircraft. The large quantities of high quality data obtained in the program will be used in applying new technologies to future aircraft.

## Forward Swept Wing (FSW)

The Forward Swept Wing (FSW) offers the potential for high performance design with both civil and military applications. In a joint program with the Defense Advanced Research Projects Agency, NASA is testing the unusual configuration in which the wings are swept forward at a 30 degree angle to the fuselage.

Wind tunnel tests and simulations indicate this design should give greater maneuverability at transonic speeds and superior low-speed performance. To reduce structural deflection of the wing, its design calls for laying up the composite material plys in definite patterns. The X-29A is scheduled for demonstrator flights at the Dryden Facility early in 1984.

## Quiet Engine Research

The Lewis Research Center has led the investigation for reducing noise and pollution produced by airplanes. Beginning in the late 1960s, the Quiet Engine program focused on demonstrating technologies to reduce turbofan engine noise levels 15 to 20 PNdb (Perceived Noise Decibles) below levels of engine installations then in use. The results systematically measured and confirmed the noise reduction potentials for high bypass ratio turbofan engines, and also further established design techniques for the acoustic nacelle, an engine housing lined with sound absorption material.

## Quiet, Clean Short-haul Experimental Engine (QCSEE)

In the late 1970s, the Lewis Research Center began ground tests of two research engines built in the QCSEE program. One engine was designed to be mounted beneath the wing in a blown flap arrangement and the other was designed for placement above the wing to provide upper surface blowing (USB).

The design features of QCSEE were selected on the basis of low noise and exhaust pollution requirements of short takeoff and landing (STOL) commercial aircraft, but were also applicable to the needs of conventional airliners. These engine installations direct the exhaust flows downward with wing flaps to increase lift for short takeoff and landing. Tests have demonstrated that both QCSEE engines operated at noise levels 60 to 75 percent lower than those of engines now in service. Carbon monoxide and unburned hydrocarbon emissions were also dramatically reduced with technologies demonstrated in the quiet, clean short-haul experimental engine.

## Quiet, Clean, General Aviation Turbofan Engine (QCGAT)

The Quiet, Clean, General Aviation Turbofan Engine program was directed toward meeting U.S. environmental standards for general aviation engines. Existing turboprop and turbofan engine cores were used in the two experimental, high-bypass turbofan engines which incorporated the latest low noise, low emissions engine technologies. In 1980 the Quiet, Clean, General Aviation Turbofan Engine program was completed with the resulting research engines producing from 50 to 60 percent less noise than most quiet current business jets, and with exhaust emission levels meeting EPA requirements.

## Vertical Short Takeoff and Landing Research Program

NASA has conducted much research over the years on helicopters and on many different concepts for vertical and short take-off and landing (V/STOL) aircraft aimed at studying numerous questions associated with aerodynamics, flight controls, propulsion and operations involved with these vehicles.

Two current V/STOL programs, Rotor Systems Research Aircraft (RSRA) and Tilt Rotor Research Aircraft (TRRA), are joint NASA/Army projects. In Short Takeoff and Landing research, NASA is experimenting with propulsive-lift concepts with the Quiet Short-Haul Research Aircraft.

## Rotor Systems Research Aircraft (RSRA)

A vertical short takeoff and landing research vehicle, the Rotor Systems Research Aircraft (RSRA), is designed to test various advanced rotor systems. Able to fly as a conventional helicoptor, the Rotor Systems Research Aircraft also flies with wings to augment the rotor lift and is able to operate over a wide range of speeds.

The Rotor Systems Research Aircraft currently in use are helping to develop technologies for safer, quieter, more reliable helicopter performance.

**Tilt Rotor Research Aircraft**

The Tilt Rotor Research Aircraft, (TRRA) XV-15 employs two wing tip mounted rotors to combine the advantages of a helicopter's vertical lift and maneuverability with an airplane's cruising speed. In the air, the rotors tilt forward to become propellers for cruising. This versatile aircraft can take off and land vertically, hover and fly forward, sideways or backwards.

The tilt rotor shows promise in military applications and possibly as a commercial commuter liner operating out of close-to-city heliports. In 1981 the tilt rotor completed the proof-of-concept flight research phase. It flew twice as fast as a helicopter with equal fuel consumption rate and achieved a top speed of 346 mph.

**Quiet Short-haul Research Aircraft**

An experimental vehicle, the Quiet Short-haul Research Aircraft (QSRA) was designed to investigate the feasibility of commercial short takeoff and landing aircraft to help relieve airport congestion and noise problems. The Quiet Short-haul Research Aircraft has demonstrated the effectiveness of propulsive-lift technology, where the engine's exhaust is directed over the wing's upper surface to increase lift and thereby reduce the noise "footprint area" for takeoffs and landings using short runways.

In 1981 the Quiet Short-haul Research Aircraft completed a flight evaluation series during which government, military, airline and industry pilots flew the aircraft.

**Aircraft Energy Efficiency (ACEE)**

In reponse to a U.S. Senate request in 1975, NASA established the Aircraft Energy Efficiency (ACEE) program to develop fuel-saving technologies for both existing and future aircraft. Using an interdisciplinary approach, Aircraft Energy Efficiency includes six major technology programs to explore ways to improve both engine and airframe performance: more efficient wings and propellers; new composite materials for airframes that are lighter and more economical than metal; ways to make today's turbofan engines more efficient; new engine technologies for energy-saving aircraft of the future.

**Energy-Efficient Transport (EET)**

An important factor in flight efficiency is the shaping of an aircraft and the resulting flow of air over its surfaces to reduce drag in flight. Developing improved wing designs is a major task of the Energy-Efficient Transport (EET) program.

NASA's supercritical wing, developed by Richard T. Whitcomb at Langley Research Center, Va., is shaped to minimize air drag at high subsonic speeds without loss of lift. Because the airfoil is relatively thick, it increases volume for fuel storage while also improving structural efficiency of the wing, leading to lower weight. A supercritical wing can reduce fuel consumption 10 to 15 percent. Further fuel efficiency can be achieved with the use of nearly-vertical "winglets" installed on the wingtips of aircraft, which help to reduce air drag.

## Laminar Flow Control (LFC)

Smooth flow of air next to the surfaces of an airplane produces low drag, but usually occurs only at low speeds. At cruising speeds, the boundary layer flow usually becomes turbulent, increasing airplane drag and power requirements. The Laminar Flow Control (LFC) program aims to achieve laminar boundary layer air flow at cruising speeds.

Technology combining the promising concept of a lightweight suction systems to remove portions of turbulent air through multiple slots or tiny holes on the wing surface with the new supercritical wing designs using advanced manufacturing methods is being tested for possible application in future commercial aircraft designs for the 1990s.

The Laminar Flow Control program has combined detailed analysis and model testing in its early phases of research and development. Flight testing, the third phase of the program, is scheduled to be completed in 1986.

## Advanced Turboprop (ATP)

Renewed interest in fuel economy led to serious reconsideration of propellers for advanced, fuel-efficient turboprop engines for high-subsonic speed transport aircraft. Research on efficiently shaped, new multi-bladed propellers has shown very promising results, and improved turboprop aircraft using such propellers should be able to compete favorably with turbofan powered jetliners for speed and noise level, but with much greater fuel efficiency.

The three-phased Advanced Turboprop (ATP) program is testing small-scale propeller models to establish proof-of-concept. In the second phase, large-scale propellers will be used to validate structural dynamics, and in the third, full-scale experimental propellers will be tested in flight.

## Engine Component Improvement

The Energy Efficient Engine ($E^3$) program is investigating advanced turbofan engine features which could find their way into service in the next decade. Based on the standard "building block" technique of engine development, each new component is refined to develop a core design to which the fan, power turbine and exhaust nozzle are added. The Energy Efficient Engine program is set to be completed by the mid-1980s.

One area of study focuses on increasing the engine's cycle pressure ratio and its turbine operating temperature, in order to utilize a greater proportion of the fuel's energy. Another component, a mixer nozzle, combines the engine's cool bypass air with the hot core stream for maximum thrust. These Energy Efficient Engine components are also designed to help reduce noise and exhaust pollution.

## Composite Materials

Unnecessary weight adds to the amount of fuel needed for flight, so the Aircraft Energy Efficiency program has been developing technology for new lightweight composite materials for airframe construction.

Conventional aircraft are constructed primarily with alloys of aluminum, magnesium, titanium and steel. The new composite materials consist of graphite, glass or Kevlar fibers arranged in a non-metallic matrix, generally epoxy. Through correct arrangement of the fiber orientation, the great strength and stiffness of these materials can be applied in arbitrary directions with minimum structured weight. These light, yet strong and stiff materials offer possible weight reductions of 25 percent or more. Beginning with secondary structures not critical to flight safety, some new materials have been flight tested.

The goal is to monitor the materials in daily use on a commercial airline, where the normal wear on the pieces can be observed. Because they replace metal parts on aircraft in service, each new part will be certified by the Federal Aviation Agency (FAA). Eventual testing of a complete wing and fuselage will provide a design base for future energy efficient aircraft.

## Aeronautical Safety

Today's aircraft incorporate many improvements developed over the years to make them safer for flight in both good and bad weather, and to increase safety during takeoff and landing.

## Crash Dynamics

Recent studies have included an investigation of airplane crash-dynamics information with the intent of increasing the survivability of passengers in an accident. For several years NASA has been deliberately crashing extensively instrumented aircraft, both single and twin-engined, under controlled conditions, to determine exactly how structures behave.

The planes, containing anthropomorphic dummies harnessed in the crew and passenger seats, are crashed onto a runway from a test rig. The data collected helps researchers understand how an aircraft absorbs the energy of impact and how the impact shock to the occupants can be reduced. The tests include the study of improved, load-limiting seats, harnesses, and crushable subfloor and fuselage structures.

## Fireworthiness

In a related effort, NASA researchers at Ames and NASA's Johnson Space Center in Houston, are developing fire resistant materials for use inside cabins. One concept uses fire resistant wrappings over conventional polyurethane foam cushions. Another fire resistant, lightweight polymide seat cushion has been developed at Johnson and is being evaluated in service by three airlines. Similar lightweight fireworthy materials are being applied to ceiling, wall and floor panels.

Less flammable jet fuels are also under study, most notably the British developed anti-misting kerosene (AMK) safety fuel, FM-9. A full-scale crash test is planned whose objectives include a test of the new fuel's anti-misting ability to prevent major fires caused by ignition during and after a crash. Along with the Federal Aviation Agency, NASA has been testing the safety fuel and evaluating its compatibility with the most common engines in service.

## Automated Pilot Advisory System

For general aviation pilots operating out of small uncontrolled airfields, NASA designed and successfully demonstrated the Automated Pilot Advisory System (APAS) to provide weather, traffic and airport information. The Automated Pilot Advisory System includes a tracking radar, weather sensors, a computer and a transmitter.

A computer-generated voice broadcast of information on air traffic within three miles of the airport is made every 20 seconds, while every two minutes, information is provided on airport identification, active runway, wind speed and direction, barometric pressure and temperature.

## Stall Spin Research

The stall/spin phenomenon has been an important cause of accidents in general aviation. A stall occurs when the angle of attack of the wing increases to the point where air across the wing separates instead of following the upper surface; this causes a loss of lift. Following a stall, an airplane sometimes will begin to spin while descending rapidly. Stall/spin research has ranged from early experiments with models in wind tunnels to more recent use of simulators and full-scale flight research vehicles.

In the 1970s, a large-scale effort focused on vertical tail designs and went on to develop a number of wing leading-edge modifications. These modifications have been shown to make certain test airplanes significantly more resistant to and recoverable from spins.

The stall/spin research has produced a large body of data that aids industry in the design of safer airplanes. Continued effort is underway to find ways to increase spin resistance of light aircraft, and to provide analytical techniques for use in design.

## Icing Research

An increasing demand for all-weather flights brought on by advances in avionics systems, has brought a renewed interest in improving aircraft safety under icing conditions. Current research is aimed toward developing lightweight, low-power consumption, cost-effective ice protection systems. Analysis, wind tunnel testing and flight research are being used to validate the effectiveness of these protection systems.

25th Anniversary
1958-1983

# *Tracking and Data*

# TRACKING AND DATA ACQUISITION

by
Jim Kukowski

In the late 1950s numerous problems confronted the fledgling space effort. Not only was it difficult to place a satellite into earth orbit, it was equally difficult to locate and track a satellite once orbit was achieved.

Ground observations of satellites were relied upon heavily to gain orbital information. Data acquisition was an even more difficult task.

Sounding rocket flights to high altitudes in the 1950s paved the way for the development of the early tracking network that was established by the United States. Telescopes and radars followed the short flights of the rockets loaded with "quick-look" scientific instruments. It was necessary to improve and expand that capability to track and acquire information from the earth satellite.

## Space Tracking and Data Acquisition Network

NASA's Space Tracking and Data Acquisition Network (STDN) evolved from the Minitrack tracking stations (11 of them) set up by the U.S. Naval Research Laboratory for the Vanguard Program in 1956 and 1957. In the early days of the space effort, Minitrack was the main method for tracking. Its radio interferometers formed electronic "fences" to search the sky for any spacecraft carrying 136 megahertz radio beacons.

Operating concurrently with Minitrack was the Smithsonian Astropyhsical Observatory (SAO) Network. SAO telescope sites located around the world provided valuable information to the growing tracking needs of the United States space effort.

As the STDN network became more sophisticated and advances were made in data acquisition techniques, the network grew in size and scope. Great strides were made in the collection of data from the satellites through the development of large steerable antennas.

The Goddard Space Flight Center in Greenbelt, Md., was the hub of the growing network and remains so today. In addition to managing the growing number of tracking stations, Goddard was also the central facility of the worldwide NASA Communications Network (NASCOM).

With the decision to develop a spacecraft program to take man into space, NASA took another significant step by developing a sophisticated tracking and data acquisition system using advanced techniques in radar.

A worldwide radar, telemetry and communications network was devised to support the manned flight program. The 18-station Mercury Network became operational on July 1, 1961 and performed superbly during the Mercury Program. More advances were made for the follow-on Gemini flights in the mid1960s and the name of the network was changed to the Manned Space Flight Network (MSFN).

New requirements added to the sophistication of the STDN network during the 1960s and early 1970s. Data flow from a variety of scientific, communications, meteorological and earth resources satellites increased in amount and complexity. Of particular significance was the imaging from the Earth Resources Technology Satellite program, later to be known as Landsat. So valuable were the pictures from space, provided by the spacecraft, that a dozen nations would eventually construct their own tracking stations to receive the images.

With the moon as the eventual target for the manned program it was necessary to advance the state of the art for these lunar landing missions. A new name in tracking and data acquisition came to the forefront...Unified S-Band.

This was the unification of all tracking and communications functions (voice, telemetry and command) into a single communications link. MSFN was comprised of the ground stations, ships at sea and antennae carrying aircraft all linked together by the globe spanning NASCOM communications network.

The system provided the highly technical data flow including the stunning television transmissions from the surface of the moon.

**Tracking and Data Relay Satellite System**

Even as the lunar program was going on, network planners were devising the next step...the Tracking and Data Relay Satellite System (TDRSS).

TDRSS was the the answer to the requirement for nearly continuous communications with newer and more sophisticated satellites.

Instead of the existing worldwide network of ground stations which can provide coverage up to only 15 to 20 percent of each orbit, TDRSS, consisting of two satellites, an in-orbit spare and a single ground station, will provide nearly full-time coverage not only for the operational Space Shuttle, but for as many as 26 other earth-orbiting satellites simultaneously.

These revolutionary new tracking stations in space, launched from the Space Shuttle, will operate at geosynchronous orbit of 35,890 kilometers (22,300 miles) above the earth's equator. At that altitude, because the speed o the satellites is the same as the rotational speed of the earth, they remain "fixed" in orbit over one location.

The data from the two-satellite system will be relayed to a single centrally located ground terminal at NASA's White Sands Test Facility, N. M. From there, it will be sent directly by domestic communications satellite to NASA control centers at Johnson Space Center, Houston, for Space Shuttle operations, and the Goddard Space Flight Center, Greenbelt, Md., which schedules TDRSS operations and controls many unmanned satellites.

In April 1983, the first TDRS was launched aboard the Space Shuttle Challenger only to be placed in an unsatisfactory orbit by the Inertial Upper Stage, after it was deployed from the orbiter payload bay. An industry-government team from the Goddard Space Flight Center; TRW, the satellite's builder; and Spacecom, owner-operator of the system, devised a recovery plan to boost the ill-placed satellite into a geosynchronous orbit above the equator.

Even as NASA celebrated its 25th anniversary, the first TDRS was being checked out in space in preparation for its initial use during the STS-9/Spacelab flight in October 1983.

**Deep Space Network**

The worldwide NASA Deep Space Network (DSN) provides the earth-based radio communications link for NASA's unmanned interplanetary spacecraft. The DSN has provided telecommunications and data acquisition support for deep space exploration projects since 1961.

Since 1961 the network has provided the vital data link support for the Ranger (1961-65), Surveyor (1966-68) and Lunar Orbiter (1966-67) explorations of the moon; the Mariner missions to Venus (1962 and 1967); Mars (1964, 1969 and 1971) and Venus-Mercury (1973); the Pioneer inward and outward heliocentric orbiters (1965-68) and the Pioneer missions to Jupiter and Saturn (1972 and 1973).

DSN also supported the Pioneer-Venus orbiter and multiprobe (1978); the joint U.S.-West German Helios Sun orbiters (1974 and 1976), the Viking orbiter-lander missions to Mars (1975) the Voyager missions to Jupiter, Saturn, Uranus and Neptune (1977) and secondary support for the manned Apollo lunar landing missions (Above dates are launch dates).

The return of scientific data from planetary encounters has been dramatically increased by continuing research and development. For example, in 1965, the data transmission rate for the Mariner 4 spacecraft during its Mars flyby was 8-1/3 bits per second. The best tv performance was 22 coarsely defined pictures, showing a narrow strip of the planet. Distance between earth and Mars was 400 million km (250 million mi.).

In 1979 the data rate for the Voyager encounter with Jupiter had been raised to 115,200 bits per second. Almost 19,000 clear pictures were received by the DSN at a rate of one 5-million-bit picture every 42 seconds. The Jupiter-Earth communications distance was 700 million km (435 million mi.).

The communications record, however, presently belongs to Pioneer 10. Launched in 1972 on a mission to Jupiter, it encountered the planet in 1973 at a range of 827 million km (500 millon mi.). PIoneer 10 was then placed on a trajectory that made it the first earth-made object to leave our known solar system. On June 13, 1983, Pioneer was still sending data back as it passed Neptune (Pluto's eccentric orbit now is inside Neptune's) a distance of more than 4.5 billion km (2.8 billion mi.).

Although the DSN's primary activity is telecommunications support for unmanned space exploration, the stations are also used as scientific radio telescopes for of radio astronomy experiments such as the study of natural radio sources (pulsars and quasars), radar studies of planetary surfaces and Saturn's rings, celestial mechanics experiments including tests of the theory of relativity and NASA's Search for Extraterrestrial Intelligence (SETI).

25th Anniversary
1958-1983

# *International*

# INTERNATIONAL PROGRAMS

compiled by
Stuart W. Rosenbaum

NASA, under the mandate given it by the 1958 National Aeronautics and Space Act "... shall conduct its aeronautical and space activities so as to contribute to... 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..."

NASA has developed an extensive program of international cooperation which has opened a wide range of its space activities to foreign participation and contribution

NASA's international activities demonstrate the many peaceful purposes and applications of space science and technology and provide opportunities for contributions by scientists and agencies of other countries to the tasks of increasing human understanding and use of space environment. Cooperation also supports operating requirements for the launching and observation of spacecraft.

Cooperation by the United States with other nations contributes to the U.S. aeronautical and space research program and to broader national objectives by:

* Stimulating scientific and technical contributions from abroad;
* Enlarging the potential for the development of the state of the art;
* Providing access to foreign areas of geographic significance for tracking and contingency landing sites;
* Enhancing satellite experiments with foreign scientific supporting data;
* Developing cost-sharing and complementary space programs;
* Extending ties among scientific and national communities; and
* Supporting United States foreign policy.

Cooperative activities have ranged from flight of foreign built spacecraft to ground-based study and analysis of data.

Activities include, for example, contributions of experiments or payloads to be flown in space by NASA, joint projects to develop flight hardware, use of data or lunar samples provided by NASA satellites, training, visits and joint publication of scientific results.

In addition, NASA provides on a reimbursable basis certain services, including launching satellites and data and tracking services.

Cooperative programs and activities involving nations and groups of nations are established by: agency to agency memoranda of understanding; agency to agency letter agreements; or more formal intergovernmental agreements. The relative complexity, cost and duration of the program or project dictate in part the type of arrangement used to establish the cooperative effort.

NASA's international activities follow guidelines which recognize the interests of the United States and foreign scientists, establish a basis for sound programs of mutual value, and contribute substantively to the objectives of international cooperation.

These guidelines provide for:

* Designation by each participating government of a government agency for the negotiation and supervision of joint efforts.
* Conduct of projects and activities having scientific validity and mutual interest.
* Agreement upon specific scientific projects rather than generalized programs.
* Acceptance of financial responsibility by each participating agency for its own contributions to joint projects.
* Provision for the widest and most practicable dissemination of the results of cooperative activities.

## CUMULATIVE STATISTICAL SUMMARY.

### Cooperative Arrangements

Completed or in progress as of January 1, 1983

**Cooperative Space Flight Projects**

| | |
|---|---|
| Cooperative Satellite Projects<br>38 projects completed or in progress. | 8 countries participating; |
| Experiments on NASA Missions<br>73 projects completed or in progress | 14 countries participating; |
| U.S. Experiments with Foreign Co-Investigators or Team Members | 11 countries participating;<br>56 projects completed or in progress. |
| U.S. Experiments on Foreign Spacecraft | 3 countries participating;<br>14 projects completed or in progress. |
| Cooperative Sounding Rocket Projects | 22 countries participating;<br>1,774 projects completed or in progress. |
| Joint Development Projects<br>9 projects completed or in progress. | 5 countries participating; |

**Cooperative Ground-Based Projects**

| | |
|---|---|
| Remote Sensing Communication Satellite | 51 countries participating; 19 projects completed or in progress. |
| Meteorological Satellite | 44 countries participating; 11 projects completed or in progress. |
| Geodynamics | 43 countries participating; 20 projects completed or in progress. |
| Space Plasma | 38 countries participating; 10 projects completed or in progress. |
| Atmospheric Study | 14 countries participating; 11 projects completed or in progress. |
| Support of Manned Space Flight | 21 countries participating; 2 projects completed or in progress. |
| Solar System Exploration | 8 countries participating; 10 projects completed or in progress. |
| Solar Terrestrial and Astrophysics | 25 countries participating; 11 projects completed or in progress. |

**Cooperative Balloon and Airborne Projects**

| | |
|---|---|
| Balloon Flights | 9 countries participating; 14 projects completed or in progress. |
| Airborne Observations | 12 countries participating; 14 projects completed or in progress. |
| International Solar Energy Projects | 24 countries participating 9 projects completed or in progress. |
| Cooperative Aeronautical Projects | 5 countries participating; 40 projects completed or in progress. |
| U.S./U.S.S.R. Coordinated Space Projects | 1 country participating 9 projects completed or in progress |
| U.S./China Space Projects | 1 country participating; 5 projects completed or in progress. |
| Scientific and Technical Information Exchanges | 70 countries participating; 3 projects completed or in progress. |

**Reimbursable Launches**

| | |
|---|---|
| Launchings of Non-U.S. Spacecraft | 15 countries participating; 95 projects completed or in progress. |

| | |
|---|---|
| Foreign Launchings of NASA Spacecraft | 1 country participating<br>4 projects completed or in progress. |

**Tracking and Data Acquisition**

| | |
|---|---|
| NASA Overseas Tracking Stations and Facilities | 20 countries participating;<br>48 projects completed or in progress. |
| NASA Funded SAO Optical Laser Tracking Facilities | 16 countries participating;<br>21 projects completed or in progress. |

Reimbursable Tracking Arrangements

| | |
|---|---|
| Support provided by NASA<br>48 projects completed or in progress. | 5 countries participating; |
| Support Received by NASA<br>12 projects completed or in progress. | 3 countries participating; |

**Personnel Exchanges**

| | |
|---|---|
| Resident Research Associateships<br>1,266 projects completed or in progress. | 43 countries participating; |
| International Fellowships<br>358 projects completed or in progress. | no countries participating; |
| Technical Training<br>972 projects completed or in progress. | 5 countries participating; |
| Foreign Visitors<br>81,377 projects completed or in progress. | 131 countries participating; |

**Countries With Which NASA Has Scientific and Technical Information Exchange Agreements**

Argentina*
Australia*
Austria*
Belgium*
Brazil*
Bolivia*
Bulgaria*
Burma
Canada*
Chile*
China
Taiwan
Columbia*
Costa Rica
Czechoslovakia*
Denmark*
Ecuador*
Egypt*
El Salvador
Ethiopia*
Finland*
France*
Vatican City*
Zaire

Germany(FRG)*
Ghana*
Greece*
Guatemala
Haiti
Iceland*
India*
Indonesia*
Iran*
Iraq
Ireland*
Israel*
Italy*
Japan*
Kenya*
Korea,Republic of*
Lebanon
Libya
Luxembourg
Madagascar
Malaysia
Mexico*
Venezuela

Morocco
Netherlands*
New Zealand
Nigeria*
Norway*
Pakistan*
New Guinea*
Peru*
Philippines*
Poland*
Portugal*
Romania*
Spain*
South Africa*
Sri Lanka*
Switzerland*
Sweden*
Thailand*
Turkey*
U.K.*
Uruguay
U.S.S.R.*
Yugoslavia*

* Denotes currently active agreements.

25th Anniversary
1958-1983

SPINOFF

# *Spinoff*

## TECHNOLOGY UTILIZATION

by
Leon Perry

Since its inception 25 years ago, the National Aeronautics and Space Administration has pursued the goal set forth by the Congress, of realizing "the potential benefits to be gained from aeronautical and space activities."

Pursuit of benefits from aerospace research and development has been a NASA objective from the first day of its operation. Through technology transfer, NASA seeks to promote wider use of this resource in the interest of expanded national productivity and improved quality of life. The intent is to stimulate the transfer process by making the technology more accessible for those who might put it to advantageous use.

The steady stream of technological innovations and advancements resulting from NASA's research and development efforts has affected nearly every facet of our lives—home and automotive design, fire prevention and protective measures for firefighters, biomedical implants and diagnostic instrumentation, bridge construction, food processing equipment, farm machinery, computerized banking, traffic controls and highway safety, microelectric products, sporting goods, energy systems and industrial processes of almost every description.

Some spinoffs represent substantial advances with values running into the millions of dollars; while others yield moderate increments of economic gain or life-style improvement.

Some technologies have been almost directly applicable to secondary use, but most require adaptation for industrial or commercial use. New advances in materials, computer technology, fabrication and manufacturing techniques, as well as new management concepts developed in the nation's aeronautical research and spaceflight programs have been applied for other uses here on earth. Such derivative benefits range from simple conveniences to major problem solutions in many areas.

The wealth of aerospace technology generated by NASA over the past quarter-century is an important resource in that it can be reused by industry for development of new products and processes, to the benefit of the U.S. economy. Such a bank of technology is a particularly valuable asset today, when American manufacturers are facing unprecedented competitive challenge from abroad. It is industry's job to meet the challenge by developing better—hence more competitive—products and processes. It is NASA's job, to help American industry by making the technology bank readily accessible.

To accomplish that job, NASA conducts the Technology Utilization Program, the aim of which is to get aerospace technology out of the storehouse and into the mainstream. Established in 1962, the program is designed to broaden and accelerate the transfer of aerospace technology to other sectors of the economy. In the 21 years of its existence, literally thousands of technology transfers have been effected.

Focal point of the program is NASA's Technology Utilization and Industry Affairs Division, headquartered in Washington, D.C. That office coordinates the activities of technology transfer specialists located throughout the United States at NASA field centers, dissemination centers and other offices.

These specialists provide a link between the developers of technology and those who might effectively use it. Their jobs involve keeping abreast of aerospace technical advances, identifying new ways to employ the technology productively, promoting interest among prospective users and helping expedite the transfer process.To promote this process, NASA operates a number of user assistance centers which offer information retrival services and technical help to industrial and government clients.

There are seven Industrial Applications Centers (IAC) and two State Technology Applications Centers (STAC) affiliated with universities across the country (University of Kentucky, Lexington, and Florida State University, Gainsville). These centers are backed by off-site representatives in many major cities. The latter seek to match NASA expertise and ongoing research and engineering in areas of interest to clients.

The network's principal resource is a vast storehouse of accumulated technical knowledge, computerized for ready retrieval. Through the applications centers, clients have access to more than 10 million documents. Almost two million of these documents are contained in the NASA data bank, which includes reports covering every field of areospace-related activity plus the continually updated, selected contents of 15,000 scientific and technical journals.

Intended to prevent wasteful duplication of research already accomplished, the IACs endeavor to broaden and expedite technology transfer by helping industry to find and apply information pertinent to a company's projects or problems.

Staffed by scientists, engineers and computer retrieval specialists, the IACs provide three basic types of service. To an industrial firm contemplating a new research and development program or seeking to solve a problem, they offer "retrospective searches;" they probe appropriate data banks for relevant literature; they provide abstracts or full-text reports on subjects applicable to the companies' needs. IACs also provide "current awareness" services, tailored periodic reports designed to keep a company's executives or engineers abreast of the latest developments in their fields with a minimal investment of time. Additionally, the IAC engineers offer highly skilled assistance in applying the information retrieved to the company's best advantage. The IACs charge a nominal fee for their services.

The State Technology Applications Centers supplement the IAC system. They facilitate technology transfer to state and local governments, as well as to private industry, by working with exisiting state mechanisms for providing technical assistance. The STACs perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state.

An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This is accomplished mainly through the publication of Tech Briefs.

The National Aeronautics and Space Act requires NASA contractors to furnish written reports containing technical information about inventions, improvements or innovations developed in the course of work for NASA. Those reports provide the input for Tech Briefs. Issued quarterly, the publication is a current awareness medium and a problem-solving tool for its many industrial readers. Each issue contains information on approximately 140 newly developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

Interested firms can follow up by requesting a Technical Support Package, which provides more detailed information on a particular product or process described in the publication. Innovations reported in Tech Briefs last year generated more than 120,000 requests for additional information.

Tech Briefs is available to engineers in U.S. industry, business executives, state and local government officials and other qualified technology transfer agents.

A related publication deals with NASA-patented inventions available for licensing, which number almost 4,000. NASA grants exclusive licenses to encourage early commercial development of aerospace technology, particularly in cases where considerable private investment is required to bring an invention to the marketplace. Non-exclusive licenses are also granted, to promote competition and bring about wider use of NASA inventions.

One facet of NASA's Technology Utilization Program is an applications engineering effort, which involves the use of NASA expertise to redesign and reëngineer existing aerospace technology for the solution of problems encountered by federal agencies, other public sector institutions or private industries.

Applications engineering projects originate in various ways. Some stem from requests for àssistance from other government agencies; others are generated by technologists who perceive possible solutions to public sector problems by adapting NASA technology to the need.

The agency employs an application team from Research Triangle Park, Durham, N.C., composed of several scientists and engineers representing different areas of expertise. The team members contact public sector agencies, medical institutions and trade and professional groups to uncover problems that might be susceptible to solution by application of aerospace technology. NASA and the user agency work on a cost-shared basis in seeking the solution to the identified problem.

In the course of its varied activities, NASA makes extensive use of computers, not only in Space Shuttle missions, but in such other operations as analyzing data received from satellites, conducting aeronautical design analyses, operating numerically controlled machinery and performing routine business or project management functions.

Operation of computers requires software, computer programs — essentially sets of instructions telling the computer how to produce the desired information or effect from its stored input. NASA and other technology generating agencies of the government have of necessity developed many types of computer programs.

Many of these programs are directly applicable to secondary use with little or no modification; some can be adapted for special purposes at far less than the cost of developing a new program.

To make use of this, NASA operates the Computer Software Management and Information Center (COSMIC). Located at the University of Georgia, Athens, Ga., COSMIC collects, screens and stores computer programs developed by NASA and other government agencies.

The center's library contains more than 1,300 programs, which perform such tasks as structural analysis, design of fluid systems, electronic circuit design, chemical analysis, determination of building energy requirements and a variety of other functions.

COSMIC offers these programs at a fraction of their original cost and the service has found wide acceptance in industry.

## SPACE SPINOFFS

A few of the spinoffs from the space program are listed below.

### Medicine

* Lightweight ultrasound diagnostic instruments for monitoring heart functions externally;
* Rechargable cardiac pacemakers;
* Instruments for measuring arteriosclerosis quickly and painlessly;
* Enhancement of X-rays by computer processing;
* Telemetry techniques for dynamic analysis of crippled children's walking patterns prior to treatment;
* Safer methods of breast cancer detection;
* Techniques for freezing white blood cells used in leukemia research;
* Fully equipped and portable emergency medical systems for ambulance paramedics;
* Rapid and accurate techniques for blood sample analysis;
* Sensory devices for external measurement of body functions; and
* A wide range of programmable implant devices for medication and control of body functions.

### Transportation

* Computer design of automobile, truck chassis and railroad car structures;
* Adaptation of Lunar Rover drive controls for handicapped drivers;
* Improved highway guard rails and road surfaces for increased safety;
* Analysis of railcar wheel bearings to reduce future derailments;
* Computer design of railroad tracks and cars;
* Low-cost method to measure skid hazards of highways;
* Techniques to improve rapid transit switch controls; and
* Fire-safe materials for use in public conveyances.

## Energy and Environment

* Heat pipes to protect Alaska pipeline structural supports;

* Furnace devices used to reclaim and circulate waste heat;

* Solar collector systems for home applications;

* Superinsulation materials for energy conservation;

* Hazardous gas analyzers for measuring automobile engine emissions and air pollutants; and

* Portable environmental monitoring devices for water pollutants and toxic industrial gas leaks.

## Public Safety

* Lighter weight and improved breathing systems and protective clothing for firefighters;

* Safety procedures and techniques for liquid natural gas storage facilities;

* Ultrasound emergency warning devices for home, school and public facilities;

* Portable firefighting module for shipboard use;

* Lightweight pressure vessels for aircraft emergency chutes;

* Miniature sonar transmitters for locating aircraft downed over water; and

* Fireproof materials for wearing apparel and home furnishings.

## Consumer Products

* Lightweight superinsulation materials for sportsmen and campers;

* Composite materials for golf clubs, racquets, skis and other consumer products;

* Portable lightweight home welders which produce a flame with a temperature of 5,000 F;

* Scratch-free plastic lenses for eyeglasses;

* Improved coatings to prevent rapid corrosion on coastal bridges and other structures;

* Super shock-resistant padding for athletic equipment and hospital uses; and

* Contamination control processes for the production of drugs, packaged foods and electronic components.

25th Anniversary
1958-1983

# Centers and Facilities

# NASA INSTALLATIONS

by
Leon Perry

The National Aeronautics and Space Administration conducts space and aeronautical activities for peaceful purposes for the benefit of all mankind. Since NASA's establishment in October 1958, its network of centers and facilities has spread across the United States. It is at these field installations that NASA conducts its many scientific programs, ranging from aerodynamic research to make commercial aviation safer here on earth, to sending spacecraft to the reaches of space in a search for life on other planets.

## NASA HEADQUARTERS
Washington, D.C.

Headquarters manages the space flight centers, research centers and other NASA installations. Planning, direction and management of NASA's research and development programs are the responsibility of individual program offices which report to, and are directed by Headquarters officials.

Headquarters responsibilities include the determination of projects and programs, establishment of management policies, procedures and performance criteria, and review and analysis of all phases of the aerospace program.

## AMES RESEARCH CENTER
Mountain View, Calif.

The NASA Ames Research Center (ARC) is located at the south end of San Francisco bay near Mountain View, Calif. San Francisco is 35 miles to the northwest and San Jose is 10 miles to the southeast. The U.S. Naval Air Station, Moffett Field, Calif., is contiguous to the south and east.

The programs of the center are directed towards research and development of technology in the fields of aeronautics, space science, life science and spacecraft technology.

Ames operates specially outfitted aircraft—in effect, airborne laboratories—to serve as flying instrument platforms for the use of scientists from all over the world in studies of both space and earth.

Ames has management responsibility for the Pioneer series of spacecraft; six of which are in solar orbit and two others which will become the first man-made objects to escape the solar system after providing closeup pictures of Jupiter and Saturn. Yet another Pioneer is still returning data from the planet Venus.

In life science laboratories, Ames scientists study the origin of life and the relationship between man and aircraft and provide medical criteria for allowing man on space vehicles.

In spacecraft technology, Ames supports NASA's Space Shuttle program by providing research on heat protection systems and wind tunnel investigations of the stability and heating of the various configurations and/or modifications.

In cooperation with Federal, state and local agencies, Ames conducts pilot programs and prototype investigations of applications of space technology to earth-bound problems.

Ames Research Center also exercises management control for the Dryden Flight Research Facility, Edwards, Calif.

## HUGH L. DRYDEN FLIGHT RESEARCH FACILITY
Edwards, Calif.

The Dryden Flight Research Facility, a Directorate of NASA's Ames Research Center, is located at Edwards, Calif., on the edge of the Mojave Desert, approximately 80 miles north of Los Angeles.

It was established as the major NASA facility for high speed flight test. The primary research tools for conducting the programs and missions of the facility are its aircraft. They range from Century Series fighters to advanced supersonic and hypersonic aircraft and aerospace flight research vehicles such as wingless lifting bodies. There are also special ground-based facilities, including a Flight Test Range with a fully instrumented tracking station; a high temperature loads calibration laboratory; and a remotely piloted research vehicle (RPRV) facility.

Dryden's mission includes research and test activities on problems of aircraft and flight research vehicle takeoff and landing, low speed flight, supersonic and hypersonic flight, and flight vehicle reentry to verify predicted vehicle and flight characteristics and to identify unexpected problems in actual flight and to correlate theoretical or wind tunnel research studies. The facility also conducted studies into terminal area operations of the Space Shuttle vehicle and flight investigations involving the flight tests of the Space Shuttle.

## ROBERT H. GODDARD SPACE FLIGHT CENTER
Greenbelt, Md.

The Goddard Space Flight Center (GSFC) is located 10 miles northeast of Washington, D.C. Goddard consists of facilities in Greenbelt, Md., Wallops Island, Va., Goddard Institute for Space Studies in New York City, and 16 tracking stations around the world.

The Goddard Space Flight Center conducts and is responsible for automated spacecraft and sounding rocket experiments in support of basic and applied research. Satellite and sounding rocket projects at Goddard provide data about the earth's environment, sun/earth relationships and the universe. These projects also advance technology in such areas as communications, meterology, navigation and the detection and monitoring of our natural resources.

Goddard is the home of the National Space Science Data Center, the central repository of data collected from space flight experiments.

Goddard personnel are situated around the globe as part of the Space Tracking Data Network (STDN) team and at facilities of the NASA Communications Network which links these networks together.

The center serves as project manager for the Delta launch vehicle and has also been assigned a lead role in the management of the international Search and Rescue Satellite Aided Tracking (SARSAT) project.

Much of the center's theoretical research is conducted at the Goddard Institute for Space Studies in New York City.

The NASA Goddard Visitor's Center is one of the major tourist features in the area near the nation's capital. Located about 20 minutes from downtown Washington, it is one of the largest and most attractive of all the NASA visitor facilities. The collection of spacecraft and flight articles are just part of the educational and informational materials available to the visiting public. Included in the visitor's center are Delta rockets, Mercury, Gemini and Apollo models, a satellite telephone, moon rocks, a weather station, a communications satellite collection and exhibits of other NASA programs. One of the highlights of the tour is the visit to the tracking control center. The Goddard Visitor's Center also sponsors a model rocket launch two Sunday afternoons a month. The visitor's center is open Wednesday through Sunday, 10 a.m. to 4 p.m.

## JET PROPULSION LABORATORY
Pasadena, Calif.

NASA's Jet Propulsion Laboratory, (JPL) is located in Pasadena, Calif., approximately 20 miles northeast of Los Angeles.

Jet Propulsion Laboratory is a government-owned facility that is staffed and managed by the California Institute of Technology. At Pasadena, JPL occupies 177 acres of land, of which 155 are owned by NASA and 22 acres are leased. JPL operates under a NASA contract, which is administered by the NASA Pasadena office. In addition to the Pasadena site, JPL operates the Deep Space Communications Complex, a station of the worldwide Deep Space Network (DSN) located at Goldstone, Calif., on 40,000 acres of land occupied under permit from the Army.

The laboratory is engaged in activities associated with deep space automated scientific missions, tracking, data acquisition, data reduction and analysis required by deep space flight, advanced solid propellant and liquid propellant spacecraft engines, advanced spacecraft guidance and control systems, and integration of advanced propulsion systems into spacecraft.

The laboratory designs and tests flight systems, including complete spacecraft, and also provides technical direction to contractor organizations. JPL operates the worldwide deep space tracking and data aquisition network, the DSN and maintains a substantial program to support present and future NASA flight projects and to increase capabilities of the laboratory.

The Open House program at the Jet Propulsion Laboratory is one that has become a tradition in the southern California area. In addition to the general public, JPL also has a number of visitors from the educational community.

At the Von Karman auditorium a film, "Welcome to Outer Space," a 25 minute presentation covers JPL's past, present and future project activities.

The visitor information center features full size spacecraft on display from Explorer to Voyager. Displays too large for indoors are placed in the mall area. These include electric cars, antennas and other exhibits representing ongoing NASA activities.

One of the most popular visitor attractions is the Space Flight Operations Facility, where spacecraft tracking and scientific data are received and processed from NASA's Deep Space Network. Last year more than 38,000 persons visited the JPL visitor's facility.

## LYNDON B. JOHNSON SPACE CENTER
Houston, Texas

Johnson Space Center is located on NASA Highway 1, adjacent to Clear Lake, 2 miles east of the town of Webster, and approximately 20 miles southeast of downtown Houston. Additional JSC facilities are located at nearby Ellington Air Force Base, which is approximately 7 miles to the north of the center.

Johnson Space Center was established in September 1961 as NASA's primary center for design, development and manufacture of manned spacecraft; selection and training of space flight crews, for ground control of manned flights and many of the medical, engineering and scientific experiments carried aboard the flights. JSC is the lead NASA center for management of the Space Shuttle.

One of the center's best known facilities is the Mission Control Center from which manned flights, starting with Gemini IV, through Apollo and Skylab series, and continuing into the current missions of the Space Shuttle, are monitored.

JSC is also responsible for direction of operations at the White Sands Test Facility (WSTF), located on the western edge of the U.S. Army White Sands Missile Range at Las Cruces, N.M. WSTF supports the Space Shuttle propulsion system, power system and materials testing. The facility also served as the alternate landing site for the second test flight of the orbiter Columbia.

Johnson Space Center is now one of the major tourist attractions in the southwestern United States. More than one million visitors, including many international visitors, tour the center each year. The recent success of the Space Shuttle has brought new attention to JSC and other accomplishments of the U.S. space program. The tour enables visitors to see actual flight vehicles from almost every U.S. manned space program, including Mercury, Gemini and Apollo.

There is also on display a docking module which was used for training astronauts and cosmonauts for the Apollo/Soyuz rendezvous mission in July 1976. Visitors also may see the control room from which all of the United States missions are monitored, rocks that have been brought from the surface of the moon, a full scale mockup of the Space Shuttle and the Mission Simulation and Training facility.

## JOHN F. KENNEDY SPACE CENTER
Florida

Kennedy Space Center (KSC) is located on the east coast of Florida, 150 miles south of Jacksonville and approximately 50 miles east of Orlando. It is immediately north and west of Cape Canaveral. The Kennedy Space Center is about 34 miles long and varies in width from 5 to 10 miles. The total land and water area occupied by the installation is 140,393 acres. This area, with adjoining water bodies, provides sufficient space to afford adequate safety to the surrounding civilian community for planned vehicle launchings.

Kennedy Space Center serves as the primary center within NASA for the test, checkout and launch of space vehicles. This presently includes launch of manned and unmanned vehicles at the Kennedy Space Center and Air Force Eastern Space and Missile Center in Florida, and the Air Force Western Space and Missile Center at Vandenberg Air Force Base in California. The center is now concentrating on the assembly, checkout and launch of Space Shuttle vehicles and their payloads, landing operations and the turnaround of Space Shuttle orbiters between missions, as well as research and operational unmanned launches.

Kennedy Space Center is also responsible for the operation of the KSC Space Transportation System (STS) Resident Office, located at the Vandenberg AFB in Santa Barbara County, on the California central coast. The KSC STS Resident Office provides or arranges host base support for all NASA elements at Vandenberg AFB and range support for all STS and Kennedy Space Center Deployable Payload project requirements. The Resident Office supports the Air Force in the design, construction, and activation of the Space Shuttle Vandenberg Launch and Landing site; provides support for all NASA Deployable Payload Operations; and assists the KSC Cargo Projects Office in planning for all STS cargo operations at Vandenberg.

## LANGLEY RESEARCH CENTER
Hampton, Va.

The Langley Research Center (LaRC), located in Hampton, Va., is approximately 100 miles south of Washington, D.C. It is situated in the Tidewater area of Hampton Roads, between Norfolk and Williamsburg, Va. Langley's primary mission is the research and development of advanced concepts and technology for future aircraft and spacecraft systems, with particular emphasis on environmental effects, performance, range, safety and economy.

The aeronautical research program is aimed at identifying and pursuing basic and applied research opportunities offering the greatest potential for increases in performance, efficiency and capability. Included in the research laboratories are a variety of wind tunnels covering the entire Mach-number and Reynolds-number range.

A recent addition is the National Transonic Facility, which is a new cryogenic, high-pressure wind tunnel providing a unique opportunity for conducting high Reynolds-number research at subsonic and transonic speeds. Major research disciplines include aerodynamics; operations and airworthiness; acoustics and noise reduction; structures and materials; flutter, aero-elasticity, dynamic loads, and structural response; fatigue and fracture; electronic and mechanical instrumentation; computer technology; flight dynamics and control and communications technology.

The NASA Langley Visitor Center, located on NASA's oldest research center, features more than 40 exhibits and a variety of films which chronicle man's achievement in aeronautics and in space.

The center has two large galleries, one devoted to aeronautics and the other to space.

In the aeronautics gallery visitors are treated to the "Evolution of Aircraft" exhibit, which uses 1/72 scale models and historic photos to trace the development of aircraft from the Wright Brothers' 1903 Flyer to the most sophisticated aircraft of today.

The Space Gallery features such artifacts as a moon rock, the Apollo 12 Command Module, an Apollo space suit and one of the early Mercury capsules.

An exhibit area entitled, "Our Solar System—Key to the Universe," offers nine colorful exhibits which present the latest information on our solar system and some of the mysteries of our universe—such as black holes and quasars.

Since its opening is 1971, the center has averaged approximately 180,000 visitors annually.

## THE LEWIS RESEARCH CENTER
Cleveland, Ohio

Lewis Center, (LeRC) is located on the west side of Cleveland's Hopkins Airport in Cuyahoga County, Ohio.

Lewis is the primary NASA center for research and technology development in aircraft propulsion, space propulsion, space power and satellite communication. The center conducts research on power systems for converting chemical and solar energy into electricity.

Major research tools at the center are designed to simulate flight conditions and range from atmospheric wind tunnels to large space environmental facilities.

Lewis also manages the Centaur launch vehicle, a second-stage vehicle used with the Atlas first stage, and to be used in a modified configuration with the Shuttle.

The center also has management responsibility for the Plum Brook Station, located in central Erie County, approximately 3 miles south of Sandusky, Ohio, and about 50 miles from Lewis. The Plum Brook Station is an adjunct facility to Lewis, providing very large scale specialized research test installations. Essentially all of the major facilities are presently in standby mode.

The Visitor Information Center at NASA's Lewis Research Center serves as the nucleus for visitor programs aimed at the interests and needs of the educational community and the general public and concerning aeronautics and space programs of the United States.

The visitor center consists of an auditorium for presentations, films, and exhibits. The exhibits are divided into eight galleries with displays on: "Our Servants in Space; "Exploring Space;" "Terrestrial Energy;" "Propulsion;" "Flight in the Atmosphere;" "Technology Utilization;" "Materials Research;" and "Space Shuttle."

An important service of the visitor center is the Teacher Resource Room, the first of its kind in NASA visitor centers. Here, educators are provided with slides, video tapes, publications relating to NASA programs and activities, as well as lesson plans and activities for use in the classroom.

## GEORGE C. MARSHALL SPACE FLIGHT CENTER

Huntsville, Ala.

Marshall Space Flight Center (MSFC), is located on Redstone Arsenal, just outside Huntsville, Ala., and is easily accessible from Interstate 65 and U.S. 231 with deep-water access to the Tennessee river.

Located on 1,840 acres of land, Marshall is one of the nation's leading pioneering space centers. It was established in 1960 by a team of former Army rocket experts headed by Dr. Werner Von Braun.

The center provides project management as well as scientific and engineering support for many of NASA's prime space programs and scientific endeavors. It has a wide spectrum of technical facilities and laboratories.

Originally NASA's primary propulsion development center, MSFC has diversified into a center for the development of payloads and space science activities.

The Marshall center is responsible for managing the development of the Space Shuttle main engines, solid rocket boosters and external propellant tank. It is also responsible the Space Telescope, the Spacelab orbital research facility and for many other key research and development programs.

Marshall also operates the Michoud Assembly facility in New Orleans, La., and the Slidell Computer Complex, (SCC) at Slidell, La.

### Michoud Assembly Facility

New Orleans, La.

The Michoud Assembly Facility (MAF), managed by the Marshall Space Flight Center, is located about ten miles east of downtown New Orleans, La. The Michoud Assembly Facility occupies 833 acres of land, encompassing 32 buildings with an area of about 3.5 million square feet. The primary mission of the Michoud Assembly Facility is the systems engineering, engineering design, manufacture, fabrication, assembly, testing and checkout of the Space Shuttle External Tank.

### Slidell Computer Complex

Slidell, La.

The Slidell Computer Complex (SCC), managed by the Marshall Space Flight Center, is located at Slidell, La., approximately 22 miles northeast of New Orleans. The complex was transferred from the Federal Aviation Agency to NASA and became operational in 1962. The facility consists of a large office building and several smaller support buildings which are well-suited for computer operations.

The computer complex is primarily responsible for fulfilling the computational requirements of NASA at the contractor-operated plant at Michoud, and also provides computer support for the National Space Technology Laboratories (NSTL). These requirements are in the areas of scientific, management and engineering automated data processing and in static and flight test data reduction and evaluation.

The Marshall Visitor's Center, located at the world's largest space museum—the state operated Alabama Space and Rocket Center—features some of the most exciting space exhibits to be found anywhere.

The museum features displays of major space artifacts, from a Saturn V moon rocket to Miss Baker, the original "monkeynaut" who just celebrated her 26th birthday. The Alabama Space and Rocket Center offers an exciting look at the Space Shuttle through the Omnimax movie "Hail Columbia" featured in the Spacedome theater.

A tour of the Marshall Center includes the modest test stand where the original Huntsville team tested the Redstone rocket that carried astronauts Alan Shepard and Gus Grissom into space. Nearby is the towering stand used to test the Saturn V moon rocket. Visitors are shown the site of the "world's biggest indoor swimming pool," which is not a swimming pool at all, but a huge Neutral Bouyancy Simulator that allows astronauts and engineers to work in an environment that closely duplicates the weightlessness of space. The tour also includes a full-scale mockup of Spacelab, a joint effort of NASA and the European Space Agency that will fly aboard the Space Shuttle.

## NATIONAL SPACE TECHNOLOGY LABORATORIES
Bay St. Louis, Miss.

The National Space Technology Laboratories (NSTL) is located in Hancock County, near Bay St. Louis, Miss., on the east Pearl River. The installation is situated midway between New Orleans, La., and the Mississippi Gulf Coast.

Formerly designated the Mississippi Test Facility, NSTL was given full field installation status by NASA in 1974, because of its capabilities in space applications and earth resources activities. The Saturn rocket test stands have been modified for Marshall Space Flight Center main engine testing and for orbiter main propulsion testing for the Space Shuttle program.

The mission of NSTL is support of Space Shuttle main engine and main orbiter propulsion system testing. Static test firing is conducted on the same huge test towers used from 1965 to 1970 to captive-fire all first and second stages of the Saturn V used in the Apollo manned lunar landing and Skylab programs. Shuttle main engine testing has been under way at NSTL since 1975.

NASA's National Space Technology Laboratories (NSTL), is one of the fastest growing visitor attractions in the southeastern United States. Last year more than 65,000 persons from all 50 states and 72 foreign countries visited the center. More than 100,000 visitors are projected for this year, with the number expected to exceed 300,000 in 1984.

A typical visit includes an overview of NASA's mission at NSTL, along with demonstrations of space related hardware and a guided tour of the installation. In addition to live demonstrations and movies the tour includes the Space Shuttle complex, where the Shuttle's main engines undergo test firings, a view of the installation from atop the 90-foot space tower, indoor and outdoor exhibits and displays.

## WALLOPS FLIGHT FACILITY
Wallops Island, Va.

The Wallops Flight Facility (WFF), a part of the Goddard Space Flight Center, is located in Virginia on the Atlantic Coast, Delmarva Peninsula. It is approximately 40 miles southeast of Salisbury, Md., and 72 miles north of the Chesapeake Bay Bridge Tunnel. The facility includes three separate areas on the Atlantic Coast of Virginia's Eastern Shore: the main base, the Wallops Island launching site, plus 1,140 acres of marshland. Wallops Island is about 7 miles southeast of the main base and is 5 miles long and 1/2 mile wide at the widest point.

Wallops is responsible for managing NASA's Suborbital Sounding Rocket Projects from mission and flight planning to landing and recovery, including: payload and payload carrier design, development, fabrication, and testing; experiment management support; launch operations; and tracking and data acquisition.

Wallops manages, monitors, schedules, and provides technical analysis of balloon activities conducted for the NASA balloon program and is responsible for managing the National Scientific Balloon Facility at Palestine, Texas.

The GSFC/Wallops Visitor's Center was opened on July 1, 1982. The center is open five days a week, Thursday through Monday, from 10:00 a.m. to 4:00 p.m., for self guided walking tours. Visitors can see a collection of spacecraft and flight articles, as well as exhibits about America's space flight program. Special movies and video presentations can also be viewed.

25th Anniversary
1958-1983

# *Launch Record*

# NASA MAJOR LAUNCH RECORD

Compiled by
Barbara E. Selby

**NOTE:** All launches are from the Eastern Space and Missile Center, Cape Canaveral, Fla., unless otherwise noted. Symbols for launch sites and other items are:

D: Down (reentry or landing date)
KSC: Kennedy Space Center, Fla.
L: Launch date
SMR: San Marco Range, Indian Ocean.
STS: Space Transportation System (Space Shuttle) missions.
WFF: Wallops Flight Facility, Wallops Island, Va.
WSMC: Western Space and Missile Center, Vandenberg AFB, Calif.
WSMR: White Sands Missile Range, N.M.

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| | | **1958** |
| **Pioneer 1**<br>Thor Able 1 | L: 10/11/58<br>D: 10/12/58 | Particles and Fields: Failed to reach moon; sent 43 hours of data. |
| **Beacon 1**<br>Jupiter C | L: 10/23/58<br>D: 10/23/58 | Atmospheric Physics: 12-foot sphere; upper stages separated prior to burnout. |
| **Pioneer 2**<br>Thor Able 1 | L: 11/8/58<br>D: 11/1/58 | Scientific Lunar Probe: Third stage failure; reached 963 miles; its brief data indicated equatorial region had higher flux and energy levels than previously thought. |
| **Pioneer 3**<br>Juno II | L: 12/6/58<br>D: 12/7/58 | Energetic Particles: Discovered second radiation belt. Failed to reach moon. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| | | **1959** |
| **Vanguard 2**<br>Vanguard (SLV-4) | L: 2/17/59 | Meteorology: Precession of satellite prevented usable cloud cover data. First earth photo from satellite. |
| **Pioneer 4**<br>Juno II | L: 3/3/59 | Cislunar and Lunar Probe: Energetic particles, passed 37,300 miles from the moon 3/4/59. |
| **Vanguard**<br>Vanguard (SLV-5) | L: 4/13/59<br>D: 4/13/59 | Magnetic Fields and Atmospheric Physics: 30-inch sphere; second stage failure. |
| **Vanguard**<br>Vanguard (SLV-6) | L: 6/22/59<br>D: 6/22/59 | Solar-Earth Heating: Second stage failure. |
| **Explorer** (S-1)<br>Juno II | L: 7/16/59<br>D: 7/16/59 | Energetic Particles: Destroyed after 5 1/2 seconds by range safety officer. |
| **Explorer 6** (S-2)<br>Thor Able | L: 8/7/59<br>D: Prior to July 1961 | Particles and Meteorology: Three radiation levels; crude cloud cover image; ring of electric current circling earth. |
| **Beacon 2**<br>Juno II | L: 8/14/59<br>D: 8/14/59 | Atmospheric Physics: 12-foot sphere; premature fuel depletion in first stage; upper stage malfunction. |
| **Big Joe** (Mercury)<br>Atlas | L: 9/9/59<br>D: 9/9/59 | Suborbital Mercury Capsule Test: Capsule successfully recovered after reentry test. |
| **Vanguard 3**<br>Vanguard (SLV-7) | L: 9/18/59 | Particles and Fields: Magnetic field survey, lower edge of radiation belt. Last transmission 12/8/59. |
| **Little Joe 1**<br>Little Joe<br>(L/V #6) | L: 10/4/59<br>D: 10/4/59 | Suborbital Mercury Capsule Test: Qualified booster for use with Mercury test program. (WFF) |
| **Explorer 7**<br>Juno II (19A) | L: 10/13/59 | Energetic Particles: Data on radiation and magnetic storms; first micrometeorite penetration of sensor. |
| **Little Joe 2**<br>Little Joe<br>(L/V #1A) | L: 11/4/59<br>D: 11/4/59 | Suborbital Mercury Capsule Test: Capsule escape test. Escape rocket had a delayed thrust buildup. (WFF) |
| **Pioneer** (P-3)<br>Atlas Able | L: 11/26/59<br>D: 11/26/59 | Lunar Orbiter: Shroud failure after 45 seconds. |
| **Little Joe 3**<br>Little Joe<br>(L/V #2) | L: 12/4/59<br>D: 12/4/59 | Suborbital Mercury Capsule Test: Escape system and biomedical tests; monkey (Sam). (WFF) |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| | **1960** | |
| **Little Joe 4**<br>Little Joe<br>(L/V #1B) | L: 1/21/60<br>D: 1/21/60 | Suborbital Mercury Capsule Test: Escape system and biomedical test; monkey (Miss Sam) aboard. (WFF) |
| **Pioneer 5** (P-2)<br>Thor Able | L: 3/11/60 | Particles and Fields: Ciscytherean space; first solar flare data; solar wind. |
| **Explorer** (S-46)<br>Juno II | L: 3/23/60<br>D: 3/23/60 | Energetic Particles: Failure in upper stages. |
| **Tiros 1**<br>Thor Able | L: 4/1/60 | Meteorology: First global cloud clover pictures. Last transmission 6/17/60. |
| **Scout X**<br>Scout X | L: 4/18/60<br>D: 4/18/60 | Launch Vehicle Development Test: Structural failure prevented third stage ignition (dummy second and fourth stages). (WFF) |
| **Echo A-10**<br>Thor Delta | L: 5/13/60<br>D: 5/13/60 | Communications Earth Satellite: Failure in upper stages of vehicle. |
| **Scout 1**<br>Scout | L: 7/1/60<br>D: 7/1/60 | Launch Vehicle Development Test. (WFF) |
| **Mercury** (MA-1)<br>Atlas | L: 7/29/60<br>D: 7/29/60 | Suborbital Mercury Capsule Reentry Test: Atlas exploded. |
| **Echo 1** (A-11)<br>Thor Delta | L: 8/12/60<br>D: 5/24/68 | Communications Earth Satellite: First passive communications satellite; 100-foot sphere used for passive communications and air density experiments. |
| **Pioneer** (P-30)<br>Atlas Able | L: 9/25/60<br>D: 9/25/60 | Scientific Lunar Orbiter: Second stage failure. |
| **Scout 2**<br>Scout | L: 10/4/60<br>D: 10/4/60 | Launch Vehicle Development Test: Air Force Special Weapons Center radiation experiment payload included. (WFF) |
| **Explorer 8**<br>Juno II | L: 11/3/60 | Ionosphere: Confirmed existence of helium layer in upper atmosphere. Last transmission 12/28/60. |
| **Little Joe 5**<br>Little Joe<br>(L/V #5) | L: 11/8/60<br>D: 11/8/60 | Suborbital Mercury Capsule Test: Mercury capsule system qualification; premature escape rocket firing. (WFF) |
| **Tiros 2**<br>Thor Delta | L: 11/23/60 | Meteorology: Optical and infrared photos of global cloud cover. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Explorer**<br>Scout | L: 12/4/60<br>D: 12/4/60 | Atmospheric Physics/Vehicle Test: 12-foot sphere; second stage failure. (WFF) |
| **Pioneer** (P-31)<br>Atlas Able | L: 12/15/60<br>D: 12/15/60 | Scientific Lunar Orbiter: Exploded after 74 seconds. |
| **Mercury** (MR-1A)<br>Redstone | L: 12/19/60<br>D: 12/19/60 | Suborbital Mercury Capsule Test: Unmanned 235-mile flight. Successful. |
| | | **1961** |
| **Mercury** (MR-2)<br>Redstone | L: 1/31/61<br>D: 1/31/61 | Suborbital Mercury Capsule Test: 16-minute flight of chimpanzee (Ham). |
| **Explorer 9**<br>Scout | L: 2/16/61<br>D: 4/9/64 | Atmospheric Physics/Vehicle Test: 12-foot sphere. (WFF) |
| **Mercury** (MA-2)<br>Atlas | L: 2/21/61<br>D: 2/21/61 | Suborbital Mercury Capsule Test: Unmanned; 1,425-mile flight. Successful. |
| **Explorer**<br>Juno II | L: 2/24/61<br>D: 2/24/61 | Ionosphere: Second stage malfunction prevented third and fourth stage firing. |
| **Little Joe 5A**<br>Little Joe<br>(L/V #5A) | L: 3/18/61<br>D: 3/18/61 | Suborbital Mercury Capsule Test: Mercury escape system qualification; premature escape-rocket firing. (WFF) |
| **Mercury** (MR-BD)<br>Redstone | L: 3/24/61<br>D: 3/24/61 | Vehicle Test for Mercury Flight: Booster development test necessitated by MR-2 flight results. |
| **Explorer 10**<br>Thor Delta | L: 3/25/61<br>D: 6/68 | Particles and Fields: Interplanetary magnetic field near earth, mainly extension of sun's magnetic field. |
| **Mercury** (MA-3)<br>Atlas | L: 4/25/61<br>D: 4/25/61 | Orbital Mercury Capsule Test: Failure in first stage; abort successful. |
| **Explorer 11**<br>Juno II (4 stages) | L: 4/27/61 | Gamma Ray Astronomy: Eliminated simultaneous matter-antimatter creation theory of the steady-state cosmology. Last transmission 12/7/61. |
| **Little Joe 5B**<br>Little Joe<br>(L/V #5B) | L: 4/28/61<br>D: 4/28/61 | Suborbital Mercury Capsule Test: One booster engine fired late. Repeat of Mercury escape system test. (WFF) |
| **Mercury 3**<br>**"Freedom 7"**<br>Redstone (MR-3) | L: 5/5/61<br>D: 5/5/61 | Manned suborbital: Alan B. Shepard Jr.; 15 minutes flight time. First U.S. manned flight. |
| **Explorer** (S-45a)<br>Juno II | L: 5/24/61<br>D: 5/24/61 | Ionosphere: Second stage failure. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Meteoroid Satellite A** Scout | L: 6/30/61 D: 6/30/61 | Micrometeoroids/Vehicle Test: Third stage failure. (WFF) |
| **Tiros 3** Thor Delta | L: 7/12/61 | Meteorology: Good cloud cover picture, infrared data. Last transmission 2/27/62. |
| **Mercury 4** **"Liberty Bell 7"** Redstone (MR-4) | L: 7/21/61 D: 7/21/61 | Manned suborbital: Virgil I. Grissom; 16 minutes flight time. |
| **Explorer 12** Thor Delta | L: 8/16/61 D: 9/63 | Particles and Fields: Identified Van Allen Belt as a magnetosphere. |
| **Ranger 1** Atlas Agena | L: 8/23/61 D: 8/30/61 | Particles and Fields: Lower earth orbit than planned. |
| **Explorer 13** Scout | L: 8/25/61 D: 8/28/61 | Micrometeoroids/Vehicle Test: Premature reentry after three days. (WFF) |
| **Mercury** (MA-4) Atlas | L: 9/13/61 D: 9/13/61 | To orbit the unmanned Mercury capsule to test systems and ability to return capsule to predetermined recovery area after one orbit. All capsule tracking and recovery objectives met. |
| **Probe A** (P-21) Scout | L: 10/19/61 D: 10/19/61 | Scientific Geoprobe/Vehicle Test: Reached 4,261 miles. Electron density measurement; vehicle test. (WFF) |
| **Saturn Test** Saturn I (SA-1) | L: 10/27/61 D: 10/17/61 | Launch Vehicle Development: Test of propulsion system of the booster (S-1); verification of aerodynamic and structural design of entire vehicle. |
| **Mercury** (MS-1) AF 609A (Blue Scout) | L: 11/1/61 D: 11/1/61 | Orbital Mercury Network Check: Destroyed after 30 seconds; Air Force launched. |
| **Ranger 2** Atlas Agena | L: 11/18/61 D: 11/20/61 | Particles and Fields: Agena failed to restart. |
| **Mercury** (MA-5) Atlas | L: 11/29/61 D: 11/29/61 | Mercury Orbital Flight: Chimpanzee Enos aboard. Recovered after two orbits. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| | | **1962** |
| **Echo** (AVT-1)<br>Thor | L: 1/15/62<br>D: 1/15/62 | Suborbital Communications Test: Canister ejection and opening successful but 135-foot sphere ruptured. |
| **Ranger 3**<br>Atlas Agena | L: 1/26/62 | Lunar Exploration: TV pictures, hard instrument landing planned; second stage of Agena failed; spacecraft missed the moon by 22,862 miles on 1/28/62. |
| **Tiros 4**<br>Thor Delta | L: 2/8/62 | Meteorology: Supported Friendship 7 flight. Transmitted cloud cover photos to 6/10/62. |
| **Mercury 6**<br>**"Friendship 7"**<br>Atlas (MA-6) | L: 2/20/62<br>D: 2/20/62 | Manned: John H. Glenn Jr.; three orbits. First manned orbital flight by United States; 4 hours, 55 minutes. |
| **Reentry 1**<br>Scout | L: 3/1/62<br>D: 3/1/62 | Launch Vehicle Development and Reentry: Desired speed not achieved. (WFF) |
| **OSO 1**<br>Thor Delta | L: 3/7/62<br>D: 10/8/81 | Solar Physics: Provided data on approximately 75 solar flares. Last transmission 8/6/63. |
| **Probe B**<br>Scout | L: 3/29/62<br>D: 3/29/62 | Scientific Geoprobe: Electron density measurements; reached 3,910 miles. (WFF) |
| **Ranger 4**<br>Atlas Agena | L: 4/23/62<br>D: 4/26/62 | Lunar Exploration: TV pictures not obtained; loss of control two hours after launch; first U.S. lunar impact (far side). |
| **Saturn Test**<br>Saturn I (SA-2) | L: 4/25/62<br>D: 4/25/62 | Launch Vehicle Test: Carried 95 tons of ballast water in upper stages released at an altitude of 65 miles in order to observe the effect on the upper region of the atmosphere (Project High Water). |
| **Ariel 1**<br>Thor Delta | L: 4/26/62<br>D: 5/24/76 | Ionosphere: Investigated solar effects. First international satellite (United Kingdom cooperative). |
| **Centaur Test 1**<br>Atlas Centaur | L: 5/8/62<br>D: 5/8/62 | Launch Vehicle Development: Centaur exploded before separation. |
| **Mercury 7**<br>**"Aurora 7"**<br>Atlas (MA-7) | L: 5/24/62<br>D: 5/24/62 | Manned: M. Scott Carpenter; three orbits; 4 hours, 56 minutes. |
| **Tiros 5**<br>Thor Delta | L: 6/19/62 | Meteorology: Infrared system inoperative; good cloud cover pictures. Last transmission 5/4/63. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Telstar 1**<br>Thor Delta | L: 7/10/62 | Communications: First privately built satellite. First TV transmission; last transmission 2/21/63. Reimbursable. |
| **Echo** (AVT-2)<br>Thor | L: 7/18/62<br>D: 7/18/62 | Suborbital Communications Test: Inflation successful; radar indicated sphere surface not as smooth as planned. |
| **Mariner 1**<br>Atlas Agena | L: 7/22/62<br>D: 7/22/62 | Scientific Venus Probe: Atlas deviated from course and was destroyed by Range Safety Officer. |
| **Mariner 2**<br>Atlas Agena | L: 8/27/62 | Planetary Exploration: Venus; first successful interplanetary probe. Found no magnetic field; high surface temperatures of approximately 800 degrees F. Passed Venus 12/14/62 at 21,648 miles, 109 days after launch. |
| **Reentry 2**<br>Scout | L: 8/31/62<br>D: 8/31/62 | Reentry Test (28,000 fps): Late third stage ignition; desired speed not achieved. (WFF) |
| **Tiros 6**<br>Thor Delta | L: 9/18/62 | Meteorology: Infrared sensor omitted. Last transmission 10/11/63. |
| **Alouette 1**<br>Thor Agena B | L: 9/29/62 | Ionosphere: Radiation belt effects. Second international satellite (cooperative with Canada). |
| **Explorer 14**<br>Thor Delta | L: 10/1/62 | Particles and Fields: Data compared with that of Explorer 12. Last transmission 2/17/64. |
| **Mercury 8**<br>**"Sigma 7"**<br>Atlas (MA-8) | L: 10/3/62<br>D: 10/3/62 | Manned: Walter M. Schirra; 6 orbits; 9 hours, 13 minutes. |
| **Ranger 5**<br>Atlas Agena | L: 10/18/62 | Lunar Exploration: TV pictures, hard instrument landing planned; power loss; 450 miles from moon 10/20/62; no TV pictures obtained. |
| **Explorer 15**<br>Thor Delta | L: 10/27/62 | Particles and Fields: Despin system failed, directional detectors almost unusable. Last transmission 5/19/63. |
| **Saturn** (SA-3)<br>Saturn I | L: 11/16/62<br>D: 11/16/62 | Launch Vehicle Development: Second Project High Water using 95 tons of water released at an altitude of 90 nautical miles. |
| **Relay 1**<br>Thor Delta | L: 12/13/62 | Communications: Initial power failure overcome. Wideband transmission; TV capability of 300 channel telephone, one way. Last transmission 2/65. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Explorer 16**<br>Scout | L: 12/16/62 | Micrometeoroids: First statistical sample; flux level found to lie between estimated extreme; 64 penetrations of sample materials over useful life of seven months. Sensor area 30 square feet. Last transmission 7/22/63. (WFF) |
| | | **1963** |
| **Syncom 1**<br>Thor Delta | L: 2/14/63 | Communications: First synchronous-type orbit. Radio contact lost at insertion into orbit. |
| **Saturn Test**<br>Saturn I (SA-4) | L: 3/28/63<br>D: 3/28/63 | Launch Vehicle Development: Programmed in-flight cutoff of one of eight engines in cluster; successfully demonstrated propellant utilization system function. |
| **Explorer 17**<br>Thor Delta | L: 4/3/63<br>D: 11/14/66 | Aeronomy: Discovered belt of neutral helium atoms about earth. Ceased transmitting experiment data 7/10/63. |
| **Telstar 2**<br>Thor Delta | L: 5/7/63 | Communications satellite: Last transmission 5/65. Reimbursable. |
| **Mercury 9**<br>**"Faith 7"**<br>Atlas (MA-9) | L: 5/15/63<br>D: 5/16/63 | Manned: L. Gordon Cooper; 22 orbits; oriented manually for reentry; 34 hours, 20 minutes. |
| **RFD 1**<br>Scout | L: 5/22/63<br>D: 5/22/63 | AEC Reactor Mockup Reentry Flight. Reimbursable. |
| **Tiros 7**<br>Thor Delta | L: 6/19/63 | Meteorology: Last transmission 2/3/64. |
| **CRL (USAF)**<br>Scout | L: 6/28/63 | Cambridge Research Lab: Geophysics. Reimbursable. |
| **Reentry 3**<br>Scout | L: 7/20/63<br>D: 7/20/63 | Reentry Flight Demonstration: Attempted test of an ablation material of super-orbital reentry speeds. (WFF) |
| **Syncom 2**<br>Thor Delta | L: 7/26/63 | Communications: First operational satellite in a synchronous type orbit. |
| **Little Joe II Test**<br>Little Joe II #1 | L: 8/28/63<br>D: 8/28/63 | Suborbital Apollo Launch Vehicle Test: Booster qualification test with dummy payload. (WSMR) |
| **Explorer 18**<br>**(IMP-A)**<br>Delta (DSV-3C) | L: 11/27/63<br>D: 12/65 | Particles and Fields: Highly elliptical orbit. Confirmed existence of solar wind shock wave on magnetosphere. First Delta with X-258 third stage. Last transmission 5/12/65. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Centaur Test II**<br>Atlas Centaur (AC-2) | L: 11/27/63 | Vehicle Development: Instrumented with 2,000 pounds of sensors, equipment and telemetry. |
| **Explorer 19**<br>**(AD-A)**<br>Scout | L: 12/19/63<br>D: 5/10/81 | Atmospheric Physics: 12-foot sphere (Explorer 9 design); polar orbit. Two (passive) experiments. (WSMC) |
| **Tiros 8**<br>Delta (DSV-3B) | L: 12/21/63 | Meteorology: Carried Automatic Picture Transmission (APT) System; allowed realtime readout of local cloud pictures using an inexpensive portable ground station. Last transmission 7/1/67. |
| | | **1964** |
| **Relay 2**<br>Delta (DSV-3B) | L: 1/21/64 | Communications: Wideband transmission; TV capability or 300 channel telephone, one way. Last transmission 5/23/64. |
| **Echo 2**<br>Thor Agena | L: 1/25/64<br>D: 6/7/69 | Communications: Rigidized 135-foot sphere; passive. (WSMC) |
| **Saturn I**<br>Saturn I (SA-5) | L: 1/29/64<br>D: 4/30/66 | Vehicle Development: Fifth flight of Saturn I; first Block II Saturn; first live flight of the LOX/$LH_2$ fueled second stage (S-IV); 1,146 measurements taken. |
| **Ranger 6**<br>Atlas Agena | L: 1/30/64<br>D: 2/2/64 | Lunar Exploration: TV pictures prior to hard landing planned; lunar impact point within 20 miles of target on west edge of Sea of Tranquility; TV system failed to operate. |
| **Beacon Explorer A**<br>Delta (DSV-3B) | L: 3/19/64<br>D: 3/19/64 | Ionosphere: Designed to advance state-of-the-art of lasers for optical tracking and geodesy. Third stage (X-248) fired only half normal time; satellite failed to orbit. First Thor Delta failure after 23 successes; last X-248 third stage. |
| **Ariel 2**<br>Scout | L: 3/27/64<br>D: 11/18/67 | Planetary Atmosphere/Radio Astronomy: Continuation of U.K. International Satellite Program; first in program to sample global distribution of ozone with an ultraviolet spectrometer. (WFF) |
| **Gemini 1**<br>Titan II | L: 4/8/64<br>D: 4/12/64 | Space Vehicle Development: Demonstration of the launch vehicle and guidance system and structural integrity and compatibility of the spacecraft and launch vehicle; 132 measurements taken. Spacecraft was not equipped to separate from second stage; first in Gemini series. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Fire 1**<br>Atlas X259 | L: 4/14/64<br>D: 4/14/64 | Reentry Test: Investigated the heating environment encountered by a body entering the earth's atmosphere at high speed; actual reentry velocity 37,963 fps. |
| **Apollo Transonic Abort**<br>Little Joe II | L: 5/13/64<br>D: 5/13/64 | Apollo LES Development: Simulation of Apollo Launch Escape System where high dynamic pressures and transonic speed conditions exist. First launch of Apollo spacecraft boilerplate. (WSMR) |
| **Saturn I** (SA-6)<br>Saturn I | L: 5/28/64<br>D: 6/1/64 | Vehicle Development: Sixth flight of Saturn I; first flight of unmanned boilerplate model of Apollo; 1,181 flight measurements taken. |
| **Centaur Test 3**<br>Atlas Centaur (AC-3) | L: 6/30/64<br>D: 6/30/64 | Vehicle Development: All six primary objectives successful. Hydraulic pump failure caused short Centaur engine burn. |
| **SERT I**<br>Scout | L: 7/20/64<br>D: 7/20/64 | Ion Engine Test: Ion beam neutralization in space verified. (WFF) |
| **Ranger 7**<br>Atlas Agena | L: 7/28/64<br>D: 7/31/64 | Lunar Exploration (photography): Camera system yielded 4,316 high resolution TV pictures with about 2,000 times better definition than prior earth-based photography; objects less than 3 feet discernible. Impact occurred in Sea of Clouds region 8 to 10 miles from the aim point; 68 hours, 36 minutes. |
| **Reentry 4**<br>Scout (R-4) | L: 8/18/64<br>D: 8/18/64 | Reentry Test: Demonstrated ability of one type of low density charring ablator material for Apollo to withstand reentry conditions at 17,950 fps. (WFF) |
| **Syncom 3**<br>Delta (DSV-3D) | L: 8/19/64 | Communications: Third and last of the Syncom series. |
| **Explorer 20 (IE-A)**<br>Scout | L: 8/25/64 | Ionosphere: Measurement of electron density distribution in the $F_2$ layer by topside sounding on six fixed frequencies. Last transmission 3/30/66. (WSMC) |
| **Nimbus 1**<br>Thor Agena | L: 8/28/64<br>D: 5/16/74 | Meteorology: Earth orientation allowed complete global cloud cover pictures each 24 hours. Contained APT for local readout AVCS for day and HRIR for nighttime cloud cover. Operated about 26 days. (WSMC) |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **OGO 1**<br>Atlas Agena | L: 9/6/64 | Interdisciplinary Studies: Earth-sun interplanetary space interrelationships using a highly elliptical orbit to correlate studies of energetic particles and fields, atmospheric physics, solar and other emissions, interplanetary dust. Not all experimental booms deployed properly thereby interferring with the stabilization systems. Mission unsuccessful. |
| **Saturn I** (SA-7)<br>Saturn I | L: 9/18/64<br>D: 9/22/64 | Vehicle Development: Seventh straight Saturn I success. Successful demonstration of Launch Escape System jettisoning. |
| **Explorer 21 (IMP-B)**<br>Delta (DSV-3C) | L: 10/4/64<br>D: 1/30/66 | Particles and Fields: Detailed study of environment of cislunar space through cosmic ray, solar wind and magnetic field measurements. |
| **RFD 1**<br>Scout | L: 10/9/64<br>D: 10/9/64 | AEC Reactor Mockup Reentry Flight. Reimbursable. |
| **Explorer 22**<br>Scout | L: 10/10/64 | Ionosphere: Measurement of total electron content of ionosphere by effect on four fixed frequencies transmitted to ground. (WSMC) |
| **Mariner 3**<br>Atlas Agena | L: 11/5/64 | Planetary Exploration - Mars: Shroud failed to jettison and communicatons with the spacecraft were lost. |
| **Explorer 23**<br>Scout | L: 11/6/64 | Micrometeoroids: Primary sensors were 1- and 2-mil stainless steel pressurized cells; first extended flight test for capacitor detector. Last transmission 11/19/64. (WFF) |
| **Explorer 24 (Air Density)**<br>**Explorer 25 (Injun)**<br>Scout | L: 11/21/64<br>D: 10/18/68 | Atmospheric Physics: First NASA dual payload launch. Air Density, a 12-foot sphere (Explorer 9 and 19 design). Comparison of charged particle energy injection (Injun) with variations in atmospheric temperature and density. Last transmission 7/25/66. (WSMC) |
| **Mariner 4**<br>Atlas Agena | L: 11/28/64 | Planetary and Interplanetary Exploration - Mars: Encounter occurred 7/14/65 with closest approach 6,118 miles; 22 pictures taken. Mariner 4 and 5 earth station data obtained August-September 1967. |
| **Apollo Max Q Abort**<br>Little Joe II #5 | L: 12/8/64<br>D: 12/8/64 | Apollo LES Development: First test of Apollo emergency detection system at abort attitude; first test of the Canard subsystem (for turnaround and stabilizaton of spacecraft after launch escape) and of the spacecraft protective cover. (WSMR) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Centaur Test 4** Atlas Centaur (AC-4) | L: 12/11/64 D: 12/12/64 | Vehicle Development: Carried mass model of Surveyor spacecraft. All primary mission objectives test successful; however, secondary test of second burn not accomplished. |
| **San Marco 1** Scout (SM-A) | L: 12/15/64 D: 9/13/65 | Atmospheric Physics: Italian payload, Italian launched. (International cooperative) (WFF) |
| **Explorer 26** Delta (DSV-3C) | L: 12/21/64 | Particles and Fields: Study of injection, trapping and loss mechanisms of the trapped radiation belt, both natural and artificial. Last transmission 1/21/67. |
| | | **1965** |
| **Gemini 2** Titan II | L: 1/19/65 D: 1/19/65 | Space Vehicle Development: Unmanned reentry test at maximum heating rate; demonstrated structural integrity and systems performance of the spacecraft throughout flight, reentry and parachute water landing. |
| **Tiros 9** Delta (DSV-3C) | L: 1/22/65 | Meteorology: First Tiros "cartwheel" configuration for increased coverage of world cloud cover; elliptical orbit. Turned off 2/15/67. |
| **OSO 2** Delta (DSV-3C) | L: 2/3/65 | Solar Physics: Continuation of OSO 1 studies with added ability to scan the solar disc and part of corona. Last transmission 10/7/66. |
| **Pegasus 1** Saturn I (SA-9) | L: 2/16/65 D: 9/17/78 | Micrometeoroids: First primary use of capacitor-type penetration detector; sensor area - 2,000 square feet. Data collection terminated 1/13/68. |
| **Ranger 8** Atlas Agena | L: 2/17/65 D: 2/20/65 | Lunar Photography: 7,137 pictures obtained; impact occurred about 15 miles from target in Sea of Tranquility. Total flight time to impact: 64 hours, 53 minutes. |
| **Centaur Test 5** Atlas Centaur (AC-5) | L: 3/2/65 D: 3/2/65 | Vehicle Development: First attempt to place a Surveyor Dynamic Model in a simulated lunar transfer trajectory; Atlas booster failed about 4 seconds after liftoff. |
| **Ranger 9** Atlas Agena | L: 3/21/65 D: 3/24/65 | Lunar Photography: 5,814 pictures obtained; impact less than 3 miles from target in eastern floor of crater Alphonsus. Pictures converted for live viewing on commercial TV. Final mission in Ranger series. Total flight time to impact: 64 hours, 31 minutes. |

| Mission/Vehicle | Date | Remarks |
| --- | --- | --- |
| **Gemini 3**<br>Titan II | L: 3/23/65<br>D: 3/23/65 | First Manned Gemini: First U.S. two-man crew: Virgil I. Grissom and John W. Young; 3 orbits, 4 hours, 53 minutes. First use by crew of orbital maneuvering system. First control of reentry flight path using variable spacecraft lift. |
| **Intelsat I F-1 (Early Bird)**<br>Delta (DSV-3D) | L: 4/6/65 | Communications: First commercial satellite launched by NASA for the COMSAT Corp. on a reimbursable basis; up to 240 voice channels, TV or high-speed data. Geostationary orbit about 27.5 degrees W. longitude. |
| **Explorer 27**<br>Scout | L: 4/29/65 | Geodesy: Ultrastable oscillators for precise Doppler tracking of orbital perturbations to obtain description of earth's gravitational field; further laser tracking experimentation. Continuation of Explorer 22 ionospheric measurements. (WFF) |
| **Apollo High Altitude Abort**<br>Little Joe II #6 | L: 5/19/65<br>D: 5/19/65 | Apollo LES Development: Launch vehicle developed a high spin during early powered flight and eventually disintegrated. Launch escape system satisfactorily sensed vehicle malfunction and separated the spacecraft without damage. High altitude abort test objectives not met. (WSMR) |
| **FIRE 2**<br>Atlas X259 | L: 5/22/65<br>D: 5/22/65 | Reentry Test: Second and last FIRE program. Reentry velocity of 37,252 achieved. Excellent data, complementing FIRE 1 data, obtained. |
| **Pegasus 2**<br>Saturn I (SA-8) | L: 5/25/65<br>D: 11/3/79 | Micrometeoroids: Data system improved for increased data reliability. Spacecraft circuitry altered to decrease loss of area due to shorting. Near-earth micrometeoroid environment data was obtained. Data collection terminated 3/14/68. |
| **Explorer 28 (IMP-C)**<br>Delta (DSV-3C) | L: 5/29/65<br>D: 7/4/68 | Particles and Fields: Continuation of IMP study of solar-terrestrial relationships, especially magnetosphere boundary; cislunar radiation environment. Orbit somewhat higher than planned. |
| **Gemini 4**<br>Titan II | L: 6/3/65<br>D: 6/7/65 | Manned; Long Duration: James A. McDivitt and Edward H. White; 62 orbits, 97 hours, 56 minutes. First U.S. extravehicular activity (36 minutes duration) and first use of personal propulsion unit (both by White). A program of 11 scientific experiments successfully conducted. Near-rendezvous with booster not achieved. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Tiros 10** (OT-1)<br>Delta (DSV-3C) | L: 7/2/65 | Meteorology: First Weather Bureau funded spacecraft; spin-stabilized configuration with two 104-degree TV cameras, similar to Tiros 6. Placed in near-perfect sun-synchronous orbit. |
| **Pegasus 3**<br>Saturn I (SA-10) | L: 7/30/65<br>D: 8/4/69 | Micrometeoroids: Last of Pegasus program. Removable "coupons" added for possible retrieval of thermal coating samples for degradation and cratering study. Last of Saturn I vehicle program with 10 out of 10 successes. Data collection terminated 8/29/68. |
| **Scout Evaluation Vehicle** (SEV-A)<br>Scout (S-131-R) | L: 8/10/65 | Vehicle Development: Evaluated new Castor II (second stage), FW-4S motor (fourth stage); qualified new spacecraft adapter/separation system; demonstrated yaw maneuver ability, air transportability of fully assembled live Scout. Orbited U.S. Army Secor geodetic satellite. Last transmission 9/10/65. (WFF) |
| **Centaur Test 6**<br>Atlas Centaur VI (AC-6) | L: 8/11/65 | Vehicle Development: Fourth successful Atlas Centaur launch accurately injected Surveyor dy namic model into simulated lunar transfer trajectory; demonstrated capability of guidance system. |
| **Gemini 5**<br>Titan II | L: 8/21/65<br>D: 8/29/65 | Manned: L. Gordon Cooper Jr. and Charles Conrad Jr.; 120 revolutions; 190 hours, 56 minutes (8 days). Demonstrated physiological feasibility of lunar mission; evaluated spacecraft performance. Successful simulated rendezvous and 16 of 17 experiments performed; first Gemini use of fuel cell. |
| **OSO C**<br>Thor Delta (DSV-3C) | L: 8/25/65<br>D: 8/25/65 | Solar Physics: Spacecraft similar to OSO 1 and 2; failed to orbit; premature ignition of third stage. |
| **OGO 2**<br>Thor Agena | L: 10/14/65<br>D: 9/17/81 | Interdisciplinary Studies: Similar to OGO 1 but in nearly polar, low altitude orbit, emphasizing atmospheric studies and World Magnetic Survey. All appendages successfully deployed and three-axis stabilization temporarily achieved; operated in spin mode due to Horizon Scanner anomaly. Observatory operations discontinued 2/22/68. (WSMC) |
| **Gemini 6**<br>Atlas Agena | L: 10/25/65<br>D: 10/25/65 | Rendezvous and Docking Capability Development: Gemini 6 spacecraft was not launched. Agena apparently exploded at initiation of first burn. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Explorer 29 (GEOS-A)** Delta | L: 11/6/65 | Geodesy: Intercomparison of satellite tracking system accuracies, investigate earth's gravitational field; improve worldwide geodetic datum accuracies and improve positional accuracies of satellite tracking sites. First improved Delta vehicle. Last transmission 1/16/67. |
| **Explorer 30** Scout | L: 11/19/65 | Solar Physics: Monitoring of solar X-rays; to be correlated with optical and radio ground-based observations. Naval Research Laboratory satellite, part of International Quiet Sun Year program. Last transmission 11/7/67. (WFF) |
| **ISIS X Alouette 2 Explorer 31** Thor Agena B | L: 11/19/65 | Ionosphere: Dual launch for swept frequency topside sounding (Alouette) and direct compositional measurement (DME) of the ionosphere and for comparable data especially during proximity of initial orbits. First of ISIS series, continuation of joint Canadian-U.S. program. (WSMC) |
| **Gemini 7** Titan II | L: 12/4/65<br>D: 12/18/65 | Manned: Frank Borman and James A. Lovell Jr.; 206 revolutions, 330 hours, 35 minutes. Extension of physiological testing and spacecraft performance evaluation. Target for first rendezvous (with Gemini 6-A). |
| **French 1A** Scout | L: 12/6/65 | Ionosphere: Study of VLF wavefield in the magnetosphere and irregularities in distribution of the ionosphere. Spacecraft was designed, constructed and tested by the Centre National d'Etudes in France. Last transmission 8/21/68. (International Cooperative) (WSMC) |
| **Gemini 6A** Titan II | L: 12/15/65<br>D: 12/16/65 | Manned: Walter M. Schirra Jr. and Thomas P. Stafford; 15 revolutions, 25 hours, 51 minutes. Accomplished first rendezvous coming within 6 feet of Gemini 7; stationkeeping was maintained for 5 1/2 hours. |
| **Pioneer 6** Thor Delta (DSV-3E) | L: 12/16/65 | Particles and Fields: Study of interdisciplinary phenomena in ciscytherean space to within about 0.814 AU*. Five of six experiments functioned. |

*Astronomical Unit. Distance from the earth to the sun — 149,599,000 kilometers (93,000,000 miles).

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| | | **1966** |
| **Intermediate Altitude Abort**<br>Little Joe II #7 | L: 1/20/66<br>D: 1/20/66 | Apollo LES Development: Last of unmanned ballistic flights; testing Apollo spacecraft atmospheric flight abort capabilities. (WSMR) |
| **ESSA 1**<br>Delta (DSV-3C) | L: 2/3/66 | Meteorology: Initiated the Tiros Operational Satellite (TOS) system, designated Environmental Survey Satellite (ESSA 1); TV sensor system. Turned off 5/8/67. Reimbursable. |
| **Reentry 5(E)**<br>Scout | L: 2/9/66<br>D: 2/9/66 | Reentry Heating Test: Evaluation of the char integrity of a low density phenolic-nylon ablator at 27,000 fps. (WFF) |
| **Apollo Saturn**<br>Saturn 1B<br>(SA-201) | L: 2/26/66<br>D: 2/26/66 | Launch Vehicle Development: Unmanned, suborbital; demonstrated the compatibility and structural integrity of the spacecraft/launch vehicle configuration; evaluated heatshield performance at high heating rate; command module recovered. |
| **ESSA 2**<br>Delta (DSV-3E) | L: 2/28/66 | Operational Meteorological Satellite: Advanced version of cartwheel configuration. Permits local readout of daylight cloud cover by APT TV system. Polar sun-synchronous orbit. Reimbursable. |
| **Gemini 8**<br>Titan II<br><br>Atlas Agena<br>(Target Vehicle) | L: 3/16/66<br>D: 3/17/66<br><br>L: 3/16/66<br>D: 9/15/67 | Manned: Neil A. Armstrong and David R. Scott; 7 revolutions, 10 hours, 42 minutes. First dual launch and docking with Agena. Mission curtailed by short circuit in Orbital Attitude Maneuvering System (OAMS) depleting fuel through thruster #8. First Pacific landing (in preplanned emergency landing area). Target vehicle exercised through eight-day active life; was available for passive rendezvous. |
| **Centaur Test 7**<br>Atlas Centaur<br>(AC-8) | L: 4/8/66<br>D: 5/5/66 | Vehicle Development: Seventh Atlas Centaur development flight. Major objective: simulate lunar transfer trajectory using parking orbit, "two burn" indirect ascent. Nominal second burn not achieved. Payload: Surveyor mass model. |
| **OAO 1**<br>Atlas Agena | L: 4/8/66 | Astronomy: Capable of accurate long duration pointing for ultraviolet, X-ray and gamma ray observations and mapping anywhere in celestial sphere. Spacecraft lost after two days due to spacecraft systems anomalies. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Nimbus 2**<br>Thor Agena B | L: 5/15/66 | Meteorology: R&D similar to earth-oriented Nimbus 1 with AVCS, APT and HRIR. Added: Medium Resolution Infrared Radiometer (MRIR) for earth heat balance HRIR, readout by APT and orbit data shown on APT. Completed over 2 1/2 years operation with three-axis stabilization. Spacecraft ceased to operate 1/17/69. (WSMC) |
| **Gemini 9**<br>Atlas Agena | L: 5/17/66<br>D: 5/17/66 | Manned Flight Development: Rendezvous and docking development and to evaluate docked vehicle maneuvering capability and EVA. Target vehicle failed to orbit due to Atlas malfunction; Gemini 9 spacecraft not launched. |
| **Explorer 32**<br>Delta (DSV-3C-1A) | L: 5/25/66 | Aeronomy: Similar to Explorer 27 but with solar cells for extended life. Apogee higher than planned (650 nm) but sensors operated to low levels revealing He and H ion distribution in lower exosphere. Last transmission 3/31/67. |
| **Surveyor 1**<br>Atlas Centaur<br>(AC-10) | L: 5/30/66<br>D: 6/2/66 | Lunar Exploration: Achieved soft landing on first engineering test flight (with closed loop guidance) at 2:17 EDT at 2.4 degrees S., 43.43 degrees W. (Ocean of Storms). Selenological data obtained on morphology and lunar origin; bearing strength at Surveyor 1 site and footpad scale about 5 psi; surface material small cohesive particles with rocks up to 3 feet in size; no loose dust; 10,338 pictures taken during first lunar day, 899 during second (total 11,237) lost contact 1/7/67. |
| **Gemini 9A**<br>Titan II<br><br>Atlas Agena<br>(Target Vehicle) | L: 6/3/66<br>D: 6/6/66<br><br>L: 6/1/66<br>D: 6/11/66 | Manned: Thomas P. Stafford and Eugene A. Cernan; 44 revolutions, 72 hours, 21 minutes. Unable to dock with ATDA (backup for Gemini Target Vehicle) when shroud failed to clear docking adapter; 2 hours 7 minutes of EVA accomplished; use of Astronaut Maneuvering Unit prevented by difficulty of donning unit and fogging of spacesuit faceplate. |
| **OGO 3**<br>Atlas Agena B | L: 6/7/66 | Interdisciplinary Studies: First fully successful OGO; first three-axis stabilization in highly elliptical earth orbit (viewing earth, space, sun and orbital plane). Planned apogee reduced to assure earth tracking throughout orbit. Essentially same experiment as OGO 1. |
| **Pageos 1**<br>Thor Agena | L: 6/24/66 | Geodesy: Established worldwide triangulation network by optical sighting of Echo 1 type sphere (100-foot diameter). (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Explorer 33 (IMP-D)** Thor Delta | L: 7/1/66 | Particles and Fields: Planned anchored lunar orbit not obtained. Excess energy orbit produced to launch vehicle precluded lunar capture; consequently, spacecraft was placed in highly elliptical orbit about the earth. |
| **Apollo Saturn** Saturn 1B (AS-203) | L: 7/5/66 D: 7/5/66 | Launch Vehicle Development: Liquid hydrogen evaluation flight of the S-IVB stage vent and restart capability. Also test of S-IVB/IU separation and cryogenic storage at zero G. Flight terminated during liquid hydrogen pressure and structural test. |
| **Gemini 10** Titan II | L: 7/18/66 D: 7/21/66 | Manned: John W. Young and Michael Collins; 43 revolutions, 70 hours, 47 minutes. First dual rendezvous (with GTV 10 then with GTV 8); first docked vehicle maneuvers; three hatch openings - standup EVA (87 minutes) terminated due to fumes; umbilical EVA (27 minutes) terminated to conserve maneuvering propellant on spacecraft; equipment jettisoned before reentry. Micrometeoroid experiment retrieved from GTV 8. |
| Atlas Agena (Target Vehicle) | L: 7/18/66 D: 12/29/66 | |
| **Lunar Orbiter 1** Atlas Agena | L: 8/10/66 D: 10/19/66 | Lunar Photography: Total of 207 sets (frames) of medium and high resolution pictures taken; 38 from initial 169 from low orbit. Areas covered: nine primary and seven potential Apollo landing sites (including Surveyor 1 site), 11 backside and two earth-moon. Medium resolution pictures good, high resolution smeared. Readout completed 9/13/66, intentionally impacted to avoid interference with second mission. |
| **Pioneer 7** Delta | L: 8/17/66 | Particles and Fields: Continued program of measurements over the solar cycle at widely separated points in interplanetary space; about 1.125 AU aphelion. Four of six experiments on. |
| **Apollo Saturn** Saturn 1B (AS-202) | L: 8/25/66 D: 8/25/66 | Apollo Launch Vehicle and Spacecraft Development: Unmanned, suborbital. Continued test of CSM subsystems and space vehicle structural integrity and compatibility; 1 hour, 23 minute flight evaluated heatshield performance at high heat load; CM 011 recovered near Wake Island. |
| **Gemini 11** Titan II | L: 9/12/66 D: 9/15/66 | Manned: Charles Conrad Jr. and Richard F. Gordon Jr.; 44 revolutions, 71 hours, 17 minutes. Rendezvous and docking achieved in 1 hour, 34 minutes, within first spacecraft revolution; 2 hours, 41 minutes; EVA by Gordon; umbilical EVA 44 minutes. Tethered spacecraft experiment successful, computer controlled reentry. |
| Atlas Agena (Target Vehicle) | L: 9/12/66 D: 12/30/66 | |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Surveyor 2**<br>Atlas Centaur | L: 9/20/66<br>D: 9/23/66 | Lunar Exploration: During midcourse maneuver, one of the spacecraft's three engines did not ignite causing incorrectable tumbling. Contact lost 5 1/2 hours prior to predicted impact time. Target Site: Sinus Medii. |
| **ESSA 3**<br>Delta (DSV-3E) | L: 10/2/66 | Meteorology: First Advanced Vidicon Camera System (AVCS) in Tiros/TOS series; also carried infrared earth heat balance sensor. Advanced cartwheel design, placed in near polar sun-synchronous orbit. First Delta vehicle launch from WSMC. Reimbursable. |
| **Centaur Test 8**<br>Atlas Centaur | L: 10/26/66<br>D: 11/6/66 | Vehicle Development: Second two-burn test for parking orbit, indirect ascent capability; final Centaur development test planned. Surveyor mass model injected into simulated lunar transfer orbit. |
| **Intelsat 2**<br>Delta (DSV-3E) | L: 10/26/66<br>D: 9/7/82 | Communications: Second COMSAT Corp. commercial satellite, NASA providing reimbursable launch support. Apogee motor nozzle blown off shortly after motor ignited. Planned geostationary orbit not achieved. Spacecraft orbit allowed about 8 hours of use per day. Last transmission 10/31/66. |
| **Lunar Orbiter 2**<br>Atlas Agena | L: 11/6/66<br>D: 10/11/67 | Lunar Photography: Spacecraft completed taking 211 frames (422 medium and high resolution pictures) 11/26/66. Spacecraft responded to over 2,870 commands and performed over 280 maneuvers. Readout was completed 12/6/66. |
| **Gemini 12**<br>Titan II<br><br>Atlas Agena<br>(Target Vehicle) | L: 11/11/66<br>D: 11/15/66<br><br>L: 11/11/66<br>D: 12/23/66 | Manned: James A. Lovell Jr. and Edwin E. Aldrin Jr.; 59 revolutions, 94 hours, 34 minutes. Final mission of Gemini series emphasized evaluation of EVA (Aldrin - 5 hours, 30 minutes) tasks workload including two "standups" of 208 and 122 minutes each of umbilical EVA. Also 14 scientific experiments performed and solar eclipse pictures taken. The target vehicle's primary propulsion not usable for high elliptical orbit maneuver. |
| **ATS 1**<br>Atlas Agena | L: 12/7/66 | Applications and Technology: Synchronous, circular equatorial orbit over 151 degrees W. longitude (near Hawaii). The Spin Scan Cloud Camera returned the first photo covering nearly the entire disc of the earth 12/9/66. Communications, spacecraft technology and science experiments included in payload. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Biosatellite 1**<br>Delta (DSV-3G) | L: 12/14/66<br>D: 2/15/67 | Biology: Spacecraft completed three days of operation with good environmental control and attitude control. All biological experiment events occurred. The radiation source functioned as planned. Retrofire did not occur and recovery was not possible. |
| | | **1967** |
| **Intelsat II F-2**<br>Delta (DSV-3E) | L: 1/11/67 | Communications: COMSAT commercial satellite; NASA provided reimbursable launch support. Capable of handling TV data transmissions or up to 240 voice channels; part of capacity to be purchased by NASA for Apollo support. Placed about 164 degrees E. in the vicinity of Marshall Islands. Last transmission 1/14/67. |
| **ESSA 4**<br>Delta (DSV-3E) | L: 1/26/67 | Meteorology: Advanced version of cartwheel configuration. Nearly polar sun-synchronous orbit. Good APT pictures returned 1/28/67. On 1/29/67 shutter problem made one (of two redundant) APT cameras aboard inoperative. Deactivated 12/6/67. Reimbursable (WSMC) |
| **Lunar Orbiter 3**<br>Atlas Agena | L: 2/5/67<br>D: 10/9/67 | Lunar Photography: 211 sets (frames) of medium and high resolution pictures taken. Picture readout terminated by a transient signal which ended film movement; 72 percent of photos read out. Readout completed for six primary sites, parts of six other sites. Partial readout returned on 31 secondary sites. |
| **OSO 3** (OSO E)<br>Delta (DSV-3C) | L: 3/8/67<br>D: 4/4/82 | Solar Physics: Similar to OSO 1 and 2; carried experiments identical to OSO-C unsuccessfully launched 8/25/65 for obtaining high resolution spectral data within range of 8A-1300A. |
| **Intelsat II F-3**<br>Delta | L: 3/23/67 | Communications: COMSAT commercial satellite similar to Intelsat II-A and II-B. Spacecraft placed about 10 degrees W. over Atlantic Ocean. Reimbursable. |
| **ATS 2**<br>Atlas Agena | L: 4/6/67<br>D: 9/2/69 | Gravity Gradient Experiment: Lack of Agena second burn resulted in elliptical, not circular, orbit precluding meaningful evaluation of gravity gradient experiment and resulted in limited data from 11 other experiments; communications, meteorology, albedo, eight environmental. Unsuccessful. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Surveyor 3**<br>Atlas Centaur | L: 4/17/67<br>D: 4/20/67 | Lunar Exploration: Achieved soft landing 4/20/67. Closed loop radar failed during landing and spacecraft landed three times on inertial guidance before its verniers cut off. Surface sampler experiment discovered pebbles of 6 inches and 10 psi bearing strength. The spacecraft returned 6,315 pictures. Site: Oceanus Procellarum, 3.33 degrees S., 23.17 degrees W. |
| **ESSA 5 (TOS-C)**<br>Delta (DSV-3E) | L: 4/20/67 | Meteorology: Carried Advanced Vidicon Camera System. In sun-synchronous orbit with 3 p.m. local equator crossing time. Officially deactivated by ESSA 2/20/70. Reimbursable. (WSMC) |
| **San Marco 2**<br>Scout | L: 4/26/67<br>D: 10/14/67 | Atmospheric Physics: Italian payload launched from the platform in the Indian Ocean. Spacecraft carried drag and ionospheric experiments. (International Cooperative) (SMR) |
| **Lunar Orbiter 4**<br>Atlas Agena | L: 5/4/67<br>D: 10/6/67 | Lunar Photography: First photos returned 5/11/67. Problems developed with Camera Thermal Door. Readout completed 5/27/67. High resolution photos of over 99 percent of frontside of moon returned; 80 percent of backside has been photographed by Lunar Orbiters 1 and 4. |
| **Ariel 3 (UK-E)**<br>Scout | L: 5/5/67<br>D: 12/14/70 | Atmospheric Physics: United Kingdom payload. All five experiments returned data. (International Cooperative) (WSMC) |
| **Explorer 34 (IMP-F)**<br>Delta | L: 5/24/67<br>D: 5/3/69 | Particles and Fields: Fifth IMP spacecraft. Investigated region between the magnetosheath and the shock front. Launched during Class III Bright Star solar flare. (WSMC) |
| **ESRO II-A**<br>Scout | L: 5/29/67<br>D: 5/29/67 | Solar Astronomy and Cosmic Rays: All telemetry lost 8 seconds prior to third stage cutoff. No fourth stage burn; satellite splashed down in South Pacific. (International Cooperative) (WSMC) |
| **Mariner 5 (Venus 67)**<br>Atlas Agena | L: 6/14/67 | Planetary/Interplanetary Exploration: All science and engineering subsystems nominal through encounter with Venus; data indicated moon-like effect on solar plasma, strong $H_2$ corona comparable to earth's, 72 to 87 percent $CO_2$ atmosphere with balance probably nitrogen, no $O_2$. Closest approach: 3,946 kilometers. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Surveyor 4**<br>Atlas Agena<br>(single burn) | L: 7/14/67<br>D: 7/17/67 | Lunar Exploration: All launch vehicle and spacecraft performance nominal until last 2 seconds of 42 second retroburn when all communications were lost with spacecraft. Target site: Sinus Medii. |
| **Explorer 35**<br>**(IMP-E)**<br>Delta (DSV-3E) | L: 7/19/67 | Particles and Fields: Lunar orbit achieved 7/22/67 (first without midcourse correction capability) permitting more detailed study of earth's magnetosphere. No lunar magnetic field or "bow shock wave" observed. |
| **OGO 4**<br>**(OGO-D, POGO)**<br>Thor Agena | L: 7/28/67<br>D: 8/16/72 | Interdisciplinary Studies: Similar to OGO 2, to obtain data during increased solar activity to complement near solar minimum OGO 2 data. Carried 20 experiments (10 from 9 universities, 1 foreign; 5 GSFC; 1 JPL; 1 SAO; 2 NRL; 1 CRL) emphasizing atmospheric/ionospheric phenomena of near earth environment. (WSMC) |
| **Lunar Orbiter 5**<br>Atlas Agena | L: 8/1/67<br>D: 1/31/68 | Lunar Photography: Last launch in the series of missions to perform mapping of entire lunar surface. Specifically provided: detailed coverage of 36 scientific interest sites; 5 Apollo sites; completed high altitude far side coverage; a full view of earth in near full phase; 100 pecent readout accomplished of all 212 frames taken; provided near-lunar micrometeoroid and radiation data. |
| **Biosatellite 2**<br>Delta (DSV-3G) | L: 9/7/67<br>D: 9/9/67 | Biology: First successful U.S. satellite exclusively for bioscience; obtained excellent data on specimens of cells, plants and low order animals; reentered one day early. Capsule recovered by aircatch. |
| **Surveyor 5**<br>Atlas Centaur | L: 9/8/67<br>D: 9/11/67 | Lunar Exploration: First alpha scatter data; indicated basaltic character of area sampled in Mare Tranquilillitatus, 23.19 degrees E. and 1.52 degrees N. Achieved 83 hours alpha scatter data and 18,006 photos in first lunar day. Survived first lunar night but, as expected, subsequent data obtained of lower quality. |
| **Intelsat II F-4**<br>Delta (DSV-3E) | L: 9/28/67 | Communications: COMSAT commercial satellite similar to Intelsats II-A, B and C with up to 240 voice channels; to supplement and back up B. Current orbit 63 degrees W. over Pacific Ocean. Provides test of minimum angular separation of B and D without inter-satellite intereference. Reimbursable. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **OSO 4**<br>Delta (DSV-3C) | L: 10/18/67 | Solar Physics: Continuation and expansion of data obtained by OSO program on high resolution spectral data (within range of 1A-1350A) from pointed solar experiments including raster scans of solar disk. Retired 11/1/71. |
| **RAM C-1**<br>Scout | L: 10/19/67<br>D: 10/19/67 | Reentry Environment: Investigation of plasma flow field for solution of associated communications problems of reentry between 25-27,000 fps using water addition techniques. Use of X-band telemetry and plasma and ablation effects on antennas also evaluated. About 25,000 fps reentry achieved. (WFF) |
| **ATS 3**<br>Atlas Agena | L: 11/5/67 | Applications and Technology: Nine experiments involving communications, meteorology, earth photography in color, navigation, stabilization and pointing, degradation of surfaces in space and ionosphere. |
| **Surveyor 6**<br>Atlas Centaur | L: 11/7/67<br>D: 11/10/67 | Lunar Exploration: Sinus Medii, 0.25 degrees N., 1.3 degrees W.; 30,065 TV pictures, 27 hours on-surface alpha scatter analytical time obtained. First liftoff from lunar surface - moved 10 feet to a new location. Sixth in a series of seven Surveyor flights intended to perfect the technology on soft landing on the moon and provide basic scientific and engineering data in support of Apollo. |
| **Apollo 4**<br>(AS-501/CSM-017/ LTA-10R)<br>Saturn V | L: 11/9/67<br>D: 11/9/67 | Launch Vehicle and Spacecraft Development: First launch of Saturn V vehicle (8 1/2 hour mission) to demonstrate launch vehicle capability and spacecraft development. CSM-017 tested Apollo heat shield and simulation of new hatch at lunar reentry velocity; recovered near Hawaii. First launch from Complex 39. Two orbits of 88.3 minutes, then boosted to 1,722 kilometers apogee. |
| **ESSA 6 (TOS-D)**<br>Delta (DSV-3E) | L: 11/10/67 | Meteorology: Carried two TV systems used for the APT ground stations. Sun-synchronous orbit; spacecraft and launch costs funded by ESSA. Reimbursable. (WSMC) |
| **Pioneer 8**<br><br>**Test and Training Satellite-1**<br>Delta (DSV-3E) | L: 12/13/67<br><br>L: 12/13/67<br>D: 4/28/67 | Particles and Fields: Continued program of measurements over solar cycle at widely separated points in interplanetary space about 1.09 AU Aphelion. Six of six experiments functioned. (TTS-1 - a "piggyback" secondary objective payload for the checkout, training and development of MSFN stations and techniques. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| | | **1968** |
| **Surveyor 7**<br>Atlas Centaur | L: 1/7/68<br>D: 1/10/68 | Lunar Exploration: Last Surveyor, emphasized scientific objectives, landed on Tycho ejecta blanket 40.89 degrees S., 11.44 degrees W.; first combination of the three major experiments: TV (2,274 on first day), alpha scatter (48 hours on surface analytical time) and surface sampler. |
| **Explorer 36**<br>**(GEOS II)**<br>Delta (DSV-3E) | L: 1/11/68 | Geodesy: Nearly identical to GEOS-A with C-band transponder and reflector and CW laser detector added. Continued support of the National Geodetic Satellite Program objectives. (WSMC) |
| **Apollo 5**<br>(AS-204/LM)<br>(ascent)<br>(descent)<br>Saturn IB | L: 1/22/68<br><br>D: 1/14/68<br>D: 2/12/68 | Lunar Module (LM) Spacecraft Development: First flight test of Apollo LM verified ascent and descent stages propulsion systems, including restart and throttle operations. Also evaluated LM staging and S-IVB/IU orbital performance. |
| **OGO 5**<br>Atlas Agena<br>(SLV-3A) | L: 3/4/68 | Interdisciplinary Studies: Three-axis stabilized in highly elliptical earth orbit. Countries providing experiments included England, France and The Netherlands. First satellite spark-chamber experiment. First detection of electric fields in earth's bow shock. Retired 7/14/72. |
| **Explorer 37**<br>**(Solar Explorer-B)**<br>Scout | L: 3/5/68 | Second joint NRL-NASA Spacecraft: Monitored sun's energetic X-ray emissions intensity and time histories and provided real time solar data through COSPAR to scientific community. Six of eight experiments functioned. Last transmission 3/16/70. (WFF) |
| **Apollo 6**<br>(AS-502/CSM-020/ LTA-2R)<br>Saturn V | L: 4/4/68<br>D: 4/4/68 | Launch Vehicle Development: Anomalies experienced with J-2 engine Augmented Spark Ignitors on second and third stages. S-IVB restart not accomplished. F-1 engines on first stage synchronized creating longitudinal vibration of unacceptable amount. Spacecraft performance nominal. |
| **Reentry 6**<br>Scout | L: 4/27/68<br>D: 4/27/68 | Reentry Heating Test: Designed to support the advancement of atmospheric entry technology. Spacecraft performance nominal. (WFF) |
| **IRIS (ESRO IIB)**<br>Scout | L: 5/17/68<br>D: 5/8/71 | International Radiation Investigation Satellite: The scientific objective resulted in measuring radiation from the sun and cosmic rays, including X-rays, HE, II line, Lyman Alpha, trapped radiation, solar and Van Allen belt protons, cosmic ray protons, Alpha particles and high energy electrons. (International Cooperative) (WSMC) |

| **Mission**/Vehicle | Date | Remarks |
| --- | --- | --- |
| **Nimbus B**<br>Thorad Agena D | L: 5/18/68<br>D: 5/18/68 | Meteorology: Carried two experiments flown on Nimbus 2 and five new ones plus RTQ (SNAP-19) experiment. Planned 1,1111-km sun-synchronous polar orbit. Launch vehicle destroyed by range safety after 2 minutes. (WSMC) |
| **Explorer 38**<br>Delta | L: 7/4/68 | Radio Astronomy: Four antennas were deployed 10/8/68 to their full and final length 750 feet (1,500 ft. tip-to-tip). The damper boom was also extended to its full length of 315 ft. (630 ft. tip-to-tip). Two of two experiments function. (WSMC) |
| **Explorer 39**<br>**(Air Density)**<br>**Explorer 40**<br>**(Injun V)**<br>Scout | L: 8/8/68<br>D: 6/22/81<br>L: 8/8/68 | Interdisciplinary project to continue detailed scientific study of density and radiation characteristics of earth's upper atmosphere at a time of high solar activity. Four of four experiments functioned. (WSMC) |
| **ATS 4**<br>Atlas Centaur | L: 8/10/68<br>D: 10/17/68 | Applications and Technology: Performed communication, meteorology, technology and science experiments. Gravity gradient experiment could not be conducted because spacecraft did not separate from Centaur. |
| **ESSA 7 (TOS-E)**<br>Delta | L: 8/16/68 | Meteorology: TOS-E, an AVCS-type spacecraft, in a sun-synchronous orbit having a local equator crossing time between 2:35 and 2:55 p.m. so that daily AVCS pictures of the entire globe can be obtained. One AVCS operated. Reimbursable. (WSMC) |
| **RAM C-II**<br>Scout | L: 8/22/68<br>D: 8/22/68 | To measure electron and ion concentrations in the flow field at discrete spacecraft locations during reentry. (WFF) |
| **Intelsat III F-1**<br>Delta | L: 9/19/68<br>D: 9/19/68 | Communications: Third generation COMSAT commercial satellite. Improved long-tank Thor Delta destroyed itself 1 minute, 8 seconds into the mission. Control system failure. Reimbursable. |
| **Aurorae (ESRO-I)**<br>Scout | L: 10/3/68<br>D: 6/26/70 | Carried eight experiments designed to perform an integrated study of the high latitude ionosphere. (International Cooperative) (WSMC) |
| **Apollo 7**<br>(AS-205/CSM-101)<br>Saturn IV | L: 10/11/68<br>D: 10/22/68 | Manned, CSM Operations: Walter M. Schirra, Donn F. Eisele and Walter Cunningham. Eight successful Service Propulsion firings; seven live TV sessions with crew returned. Rendezvous with S-IVB stage to 70 feet performed. Astronauts developed colds in orbit. Duration: 260 hours, 8 minutes. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Pioneer 9**<br>**TETR 2**<br>Delta (DSV-3E) | L: 11/8/68 | To collect scientific data on the electromagnetic and plasma properties of the interplanetary medium for a period covering six or more passages of solar activity centers. Six of six experiments functioned (TETR 2, a piggyback secondary objective payload for the checkout, training and development of MSFN stations and techniques). |
| **HEOS-A**<br>Delta | L: 12/5/68<br>D: 10/28/75 | First NASA/ESRO reimbursable mission. Scientific satellite for the investigation of interplanetary magnetic fields and the study of solar and cosmic ray particles. Eight of eight experiments operated. Reimbursable. |
| **OAO 2 (A2)**<br>Atlas Centaur | L: 12/7/68 | Astronomy: Heaviest, most complex U.S. scientific spacecraft built to date. Astronomy investigations by experiments developed by University of Wisconsin and Smithsonian Astrophysical Observatory. Observatonal objectives include celestial objects in the ultraviolet region of the electromagnetic spectrum. Three of the four Smithsonian instruments functioned, but this instrument was placed on standy in April 1970 to concentrate on the Wisconsin instruments functioned. |
| **ESSA 8 (TOS-F)**<br>Delta | L: 12/15/68 | Meteorology: Carried two APT camera systems to obtain daily cloud photos all over the globe. Reimbursable. (WSMC) |
| **Intelsat III F-2**<br>Delta | L: 12/18/68 | Communications: COMSAT commercial satellite for commercial service between the United States and Puerto Rico. Reimbursable. |
| **Apollo 8**<br>(AS-503/CSM-103)<br>Saturn V | L: 12/21/68<br>D: 12/27/68 | First Manned Saturn V Flight: Frank Borman, James A. Lovell Jr. and William A. Anders, demonstrated crew, space vehicle and mission support facilities performance during a manned lunar orbital mission; 147 hours duration. Mission accomplished 10 lunar orbits returning good lunar photography. |
| | | **1969** |
| **OSO 5**<br>Delta | L: 1/22/69 | Solar Physics: Primary objective to obtain high spectral resolution data (within the 1A-1250A range) from onboard solar experiments pointed toward the sun. |
| **ISIS-A**<br>Delta | L: 1/30/69 | International Satellite for Ionospheric Studies: Third mission in a series of five in the cooperative U.S.-Canadian space program. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Intelsat III F-3**<br>Delta | L: 2/5/69 | Communications: 1,200 two-way circuits for voice, TV and other commercial services; orbit 62 degrees E. longitude over Indian Ocean. Reimbursable. |
| **Mariner 6**<br>Atlas Centaur | L: 2/25/69<br>D: 5/11/71 | Planetary/Interplanetary Exploration: Midcourse correction successfully executed to achieve a Mars flyby within 2,000 miles 7/31/69. Designed to perform investigations of atmospheric structures and compositions and to return TV photos of surface topography. |
| **ESSA 9 (TOS-G)**<br>Delta | L: 2/26/69 | Meteorology: Ninth and last mission of TOS series. Reimbursable. |
| **Apollo 9**<br>(AS-504/CSM-104/ LM-3)<br>Saturn V | L: 3/3/69<br>D: 3/13/69 | First manned flight of all manned lunar hardware in earth orbit: James McDivitt, David Scott and Russell Schweickart. First manned flight of LM. Successful LM active rendezvous. EVA by Schweickart for 67 minutes; EVA by Scott, 62 minutes. Atlantic recovery postponed one orbit due to weather; 241 hours, 1 minute duration. |
| **Mariner 7**<br>Atlas Centaur | L: 3/27/69<br>D: 12/30/70 | Planetary/Interplanetary Exploration: Spacecraft identical to Mariner 6. Midcourse correction successful for 3,518 km Mars flyby; flyby 8/5/69. |
| **Nimbus 3**<br>Thorad Agena | L: 4/14/69<br>D: 12/29/71 | Meteorology: Carried experiments identical to those carried by Nimbus B. IRIS instrument failed after meeting objectives. (WSMC) |
| **Apollo 10**<br>(AS-505/CSM-106/ LM-4)<br>Saturn V | L: 5/18/69<br>D: 5/26/69 | Manned lunar mission development flight to evaluate LM performance in the cislunar and lunar environment. Eugene A. Cernan, John W. Young and Thomas P. Stafford. Major activities: descent of LM to within 50,000 feet of lunar surface and 19 color TV transmissions. Pacific splashdown; 192 hours, 3 minutes duration. |
| **Intelsat III F-4**<br>Thor Delta | L: 5/22/69 | COMSAT commercial global transmissions satellite; 174 degrees E. longitude; over Pacific Ocean. Reimbursable. |
| **OGO 6**<br>Thorad Agena D | L: 6/5/69<br>D: 10/12/79 | Interdisciplinary Studies: Observatory appendage deployment, sun and earth acquisitions were completed successfully. Three axis stabilization was achieved; two 30-foot antennas deployed. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Explorer 41**<br>(IMP-G)<br>Thor Delta | L: 6/21/69<br>D: 12/23/72 | Particles and Fields: Continued study of the environment within and beyond the earth's magnetosphere during period of high solar activity. (WSMC) |
| **Biosatellite 3**<br>(BIOS-D)<br>Delta (DSV-3N) | L: 6/29/69<br>D: 7/7/69 | Biology: Spacecraft in orbit 8 1/2 days with all life support parameters controlled within specifications before deteriorating physiological condition of monkey required recovery of capsule. The animal, when given intensive care in the laboratory, responded initially. However, it expired suddenly about 8 hours later. An autopsy showed death due to heart failure brought about by problems associated with weightlessness and a lower than normal body temperature. Mission judged unsuccessful. |
| **Apollo 11**<br>(AS-506/CSM-107/ LM-5)<br>Saturn V | L: 7/16/69<br>D: 7/24/69 | First manned lunar mission: Limited selenological inspection, photography, survey, evaluation and sampling of the lunar soil. Assessed the capability and limitations of an astronaut and his equipment. Astronauts: Neil A. Armstrong, Michael Collins and Edwin E. Aldrin Jr. Touchdown on lunar surface was July 20. Pacific splashdown 7/24/69, 12:51 p.m. EDT; 165 hours, 18 minutes duration. Returned 44 pounds lunar material. |
| **Intelsat III F-5**<br>Delta | L: 7/26/69 | COMSAT global telecommunications: To form part of a global communication, commercial satellite system. Spacecraft did not achieve desired orbit due to third stage failure. Reimbursable. |
| **OSO 6**<br>Delta | L: 8/9/69<br>D: 3/7/81 | Solar Physics: Primary objective to obtain high spectral resolution data (within the 10 to 20 Kev and 1A to 1300A range) from onboard solar experiments pointed toward the sun. |
| **ATS 5**<br>Atlas Centaur | L: 8/12/69 | Applications and Technology: To conduct a carefully instrumented gravity gradient orientation experiment directed toward providing the basic design information for the stabilization and control of long-lived spacecraft in synchronous orbit. Mission unsuccessful due to inability to perform primary objectives of the gravity gradient experiment. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Pioneer E**<br>Delta | L: 8/27/69<br>D: 8/27/69 | To obtain polar plasma, magnetic field and cosmic ray measurements near the orbital path of the earth but outside the earth's region of influence. This was the fifth and last launch of early Pioneer series. Launch vehicle destroyed by Range Safety Officer after 8 minutes, 2 seconds. |
| **Boreas (ESRO-IB)**<br>Scout | L: 10/1/69<br>D: 11/23/69 | Second satellite of the ESRO-I Project. Satellites designed to study ionospheric and auroral phenomena particularly over the northern polar regions in darkness in the winter. Carried eight experiments. Reimbursable. (WSMC) |
| **German Research Satellite-A (AZUR)**<br>Scout | L: 11/8/69 | Particles and Fields: Study of the inner Van Allen belt, the auroral zones of the Northern Hemisphere and the spectral variations of solar particles versus time during solar flares. (International Cooperative) (WSMC) |
| **Apollo 12**<br>(AS-507/CSM-108/ LM-6)<br>Saturn V | L: 11/14/69<br>D: 11/24/69 | Second manned lunar landing mission: Demonstrated point landing capability, sampled more area, deployed ALSEP, investigated the Surveyor 3 spacecraft and obtained photographs of candidate exploration sites. Astronauts: Charles Conrad Jr., Richard F. Gordon Jr. and Alan Bean. Touchdown on lunar surface 11/19/69. Total EVA time 15 hours, 32 minutes. Duration: 244 hours, 36 minutes; returned 75 pounds lunar material. |
| **Skynet A**<br>Delta | L: 11/22/69 | Communications: Equatorial synchronous satellite located over Indian Ocean. (International Reimbursable) |
| | | **1970** |
| **Intelsat III F-6**<br>Delta | L: 1/14/70 | COMSAT global telecommunications: To form part of a global communication, commercial satellite system. Reimbursable. |
| **ITOS 1 (Tiros-M)**<br>Delta | L: 1/23/70 | Meteorology: Second generation meteorology satellite carried TV, APT and scanning radiometers for global cloud data for remote and local readout both day and night. First launch of the Delta with six solid strap-ons; OSCAR ham radio satellite launched from the Delta in orbit. Deactivated by NOAA 6/17/71. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **SERT 2**<br>Thor Agena | L: 2/4/70 | Ion Engine Test: Demonstrate the capability of an electric ion thruster system to operate six months in space. Mission unsuccessful because it operated short of its full duration due to electrical shortage in high voltage system. (WSMC) |
| **NATOSAT 1**<br>(NATO-A)<br>Delta | L: 3/20/70 | Communications: To place a military communications satellite into a stationary equatorial orbit. International; reimbursable. |
| **Nimbus 4**<br>Thor Agena | L: 4/8/70 | Meteorology: Fifth in a series of seven advanced research and development weather satellites. Seven of nine experiments were operational. |
| **Apollo 13**<br>(AS-508/CSM-109/ LM-7)<br>Saturn V | L: 4/11/70<br>D: 4/17/70 | Third manned lunar landing attempt aborted after 56 hours GET due to loss of pressure in liquid oxygen in Service Module and the failure of fuel cells 1 and 3. Astronauts: James A. Lovell Jr., Fred W. Haise Jr. and John L. Swigert Jr. Total flight time was 142 hours, 55 minutes. Splashdown in Pacific Ocean. |
| **Intelsat III F-7**<br>Delta | L: 4/22/70 | COMSAT Global Telecommunications: To form part of a global communications, commercial satellite system. Reimbursable. |
| **Intelsat III F-8**<br>Delta | L: 7/23/70 | COMSAT Global Telecommunications: To form part of a global communications, commercial satellite system. Last launch for Intelsat III series; did not orbit. Reimbursable. |
| **Skynet 2**<br>Delta | L: 8/19/70 | United Kingdom Communications Satellite. Vehicle failed. Reimbursable. |
| **RAM C-3**<br>Scout | L: 9/30/70<br>D: 9/30/70 | Compare the effectiveness of a liquid electrophilic (Freon) with water in alleviating radio blackout during a 25,000 fps reentry. |
| **OFO 1**<br>Scout<br><br>**RMS** | L: 11/9/70<br>D: 5/9/71<br><br>L: 9/9/70<br>D: 2/7/71 | Obtain direct measurements of the (vestibular nerve) activity changes and study the adaptation of the otolith system (in two bull frogs) under conditions of weightlessness and acceleration. Vehicle also carried secondary payload: Radiation/Meteoroid Satellite (RMS); RMS remained attached to Scout fourth stage. |

| Mission/Vehicle | Date | Remarks |
| --- | --- | --- |
| **OAO B**<br>Atlas Centaur | L: 11/30/70<br>D: 11/30/70 | To obtain moderate resolution spectrophotometric data in ultraviolet bands between 1100 and 4000A; to investigate photometry of peculiar stars, the law of interstellar reddening, magnitude and intensity of Lyman-Alpha red shift for nearby galaxies, spectra of emission and reflection nebulae. Nose fairing separation system failed to separate at proper time. Vehicle failure. |
| **ITOS A (NOAA-1)**<br>Delta | L: 12/11/70 | To conduct in-orbit engineering evaluation so that the daytime and nighttime cloud-cover observations can be obtained regularly and dependably in both direct readout and stored modes of operation. A Cylindrical Electrostatic Probe Experiment (CEPE) was carried piggyback, permanently attached to the Delta second stage. Deactivated by NOAA 8/19/71. Reimbursable. |
| **Explorer 42**<br>(SAS-A)<br>Scout | L: 12/12/70<br>D: 4/5/79 | To develop a catalog of celestial X-ray sources by systematic scanning of the celestial sphere in the energy range 2-20 Kev. First orbiting X-ray satellite. (SMR) |
| | | **1971** |
| **Intelsat IV F-2**<br>Atlas Centaur | L:1/25/71 | COMSAT Global Telecommunications: To form part of a global communications commercial satellite system. First launch of the Intelsat IV series. Reimbursable. |
| **Apollo 14**<br>(AS-509/CSM-110/ LM-8)<br>Saturn V | L: 1/31/71<br>D: 2/9/71 | Third manned lunar landing: Astronauts Alan B. Shepard, Stuart A. Roosa and Edgar D. Mitchell. Total flight time 216 hours, 42 minutes. Splashdown in the Pacific Ocean 2/9/71. Returned 98 pounds of lunar material. |
| **NATOSAT 2**<br>(NATO-B)<br>Delta | L: 2/2/71 | Communications: To place a military communications satellite into a stationary equatorial orbit. Reimbursable. |
| **Explorer 43**<br>(IMP-I)<br>Delta | L: 3/13/71<br>D: 10/2/74 | Extend knowledge of solar-lunar-terrestrial relationships by conducting a continuing study of the interplanetary magnetic field and its dynamic relationships with solar particles. |
| **ISIS 2**<br>Delta | L: 3/31/71 | To study electron production and loss and large scale transport of ionization in the ionosphere. Canadian International Cooperative). (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **San Marco 3**<br>Scout | L: 4/24/71<br>D: 11/29/71 | To investigate and define the equatorial neutral particle atmosphere in terms of density, composition and temperature behavior and variations resulting from solar and geomagnetic activities. Vehicle provided by NASA on non-reimbursable basis; Italian. (SMR) |
| **Mariner Mars 71**<br><br>**Mariner 8**<br>Atlas Centaur<br><br>**Mariner 9**<br>Atlas Centaur | <br><br>L: 5/8/71<br>D: 5/8/71<br><br>L: 5/30/71 | To study the dynamic characteristics of the planet Mars from orbit for a minimum period of 90 days also to map 70 percent of the planet. Mariner 8 failed because of vehicle malfunction. Mariner 9 entered Mars orbit 11/13/71. It responded to 37,764 commands and transmitted 6,876 pictures of the Mars surface. All scientific instruments operated successfully. Mariner 9 terminated 6:31 p.m. EDT 10/27/72. |
| **Planetary Atmosphere Experiment Test**<br>Scout | L: 6/20/71<br>D: 6/20/71 | Demonstrate the ability to determine the structure and comparison of the atmosphere through onboard instrumentation from a probe vehicle entering the atmosphere at high speed (25,000 fps). (WFF) |
| **Explorer 44**<br>(SOLRAD 10, NRL)<br>Scout | L: 7/8/71<br>D: 12/15/79 | To monitor the sun's X-ray and ultraviolet emissions in order to better understand the solar physical processes and to improve the prediction techniques of solar activity and ionospheric disturbances. Vehicle provided by NASA on non-reimbursable basis. (WFF) |
| **Apollo 15**<br>(AS-510/CSM-112/ LM-10)<br>Saturn V | L: 7/26/71<br>D: 8/7/71 | Fourth manned lunar landing and first of Apollo "J" series missions which carry Lunar Roving Vehicle. Astronauts: David R. Scott, Alfred M. Worden and James B. Irwin. Total flight time 295 hours, 12 minutes. Total EVA time 18 hours, 46 minutes. Worden's in-flight EVA 38 minutes, 12 seconds performed out-of-earth orbit. Splashdown in Pacific about 288 nautical miles due north of Pearl Harbor. Returned 173 pounds of lunar material. |
| **Cooperative Applications Satellite (CAS-A) (EOLE 1)**<br>Scout | L: 8/16/71 | Data Collection: Cooperation with France in Space Meteorology Project using instrumented balloons and an earth orbiting satellite to obtain in-situ speed and direction of winds (air masses) at various altitudes. (WFF) |
| **Barium Ion Cloud (GRS-B)**<br>Scout | L: 9/20/71 | Joint NASA/German effort to study the broad features of electric and magnetic fields in the outer radiation belt by optical investigation of the behavior of a barium ion cloud released at several earth radii altitude. Vehcile provided by NASA on non-reimbursable basis. (WFF) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **OSO 7**<br>Delta | L: 9/29/71<br>D: 7/9/74 | To observe the active physical processes on the sun by which the sun influences the earth and its space environment; and to advance our understanding of the sun's constitution and behavior. |
| **ITOS B**<br>Delta | L: 10/21/71<br>D: 10/21/71 | To provide improved operational infrared and visual observations of earth cloud cover for use in weather analysis and forecasting. NASA reimbursed by NOAA for both spacecraft and launch support. Mission failure due to vehicle second stage malfunction. Reimbursable. (WSMC) |
| **Explorer 45**<br>(SSS-A)<br>Scout | L: 11/15/71 | Investigate the ring-current and magnetic storms; relations between auroral phenomena, magnetic storms and the acceleration of charged particles within the inner magnetosphere; and time variations of the particle population. (SMR) |
| **UK 4**<br>(United Kingdom)<br>Scout | L: 12/11/71<br>D: 12/12/78 | Investigate interactions among the plasma, charged particle streams and electromagnetic waves in the upper ionosphere. (International Cooperative) (WSMC) |
| **Intelsat IV F-3**<br>Atlas Centaur | L: 12/19/71 | COMSAT global commercial communications satellite system. Reimbursable. |
| | | **1972** |
| **Intelsat IV F-4**<br>Atlas Centaur | L: 1/22/72 | COMSAT global commercial communications satellite system. Reimbursable. |
| **HEOS A-2**<br>Delta | L: 1/31/72<br>D: 8/2/74 | Investigation of interplanetary space and of the high altitude magnetosphere and its boundary in the region around the northern neutral point. ESRO; reimbursable. |
| **Pioneer 10**<br>Atlas Centaur | L: 3/3/72 | Investigation of the interplanetary medium; the nature of asteroid belt; and the exploration of Jupiter and its environment. |
| **TD 1 (ESRO)**<br>Thor Delta | L: 3/12/72<br>D: 1/9/80 | NASA responsible for placing satellite in an earth orbit for ESRO. Seven scientific experiments aboard the spacecraft. Reimbursable. |
| **Apollo 16**<br>(AS-511/CSM-113/ LM-11)<br>Saturn V | L: 4/16/72<br>D: 4/27/72 | Fifth manned lunar landing; second of Apollo J series carrying the LRV. Astronauts: John W. Young, Thomas K. Mattingly II and Charles M. Duke. Total flight time 265 hours, 51 minutes. Total EVA time 20 hours, 14 minutes; Mattingly's in-flight EVA 1 hour, 24 minutes. Splashdown in Pacific. Returned 213 pounds of lunar material. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Intelsat IV F-5**<br>Atlas Centaur | L: 6/13/72 | COMSAT global commercial communications satellite system. Reimbursable. |
| **ERTS 1**<br>(now Landsat)<br>Delta | L: 7/23/72 | Acquire synoptic, multispectral repetitive images to investigate disciplines, i.e., agriculture, forestry, mineral and land resources map and chart. (WSMC) |
| **Explorer 46**<br>(MTS)<br>Scout | L: 8/13/72<br>D: 11/2/79 | Measure the meteoroid penetration rates in a bumper protected target and to obtain meteoroid velocity and impact flux data. (WFF) |
| **OAO 3**<br>**Copernicus**<br>Atlas Centaur | L: 8/21/72 | Obtain precise astronomical observations of celestial objects from above the earth's atmosphere so that new and fundamental knowledge about the universe may be acquired. |
| **Transit (INS-1)**<br>Scout | L: 9/2/72 | U.S. Navy Navigation Satellite. Reimbursable. (WSMC) |
| **Explorer 47**<br>**(IMP-H)**<br>Delta | L: 9/22/72 | Study cislunar radiation environment over significant portion of solar cycle, interplanetary magnetic field and earth's magnetosphere. |
| **NOAA 2 (ITOS-D)**<br>**AMSAT-OSCAR 6**<br>Delta | L: 10/15/72 | Operational meteorological satellite based on Tiros research and development experience. A small communications relay satellite (AMSAT-OSCAR 6) designed to operate in the radio amateur frequency bands carried as a piggyback. Design life of AMSAT-OSCAR 6 at least one year of successful operation in orbit. Reimbursable. |
| **Telesat A (Anik)**<br>Delta | L: 11/9/72 | First of series of Canadian Domestic Communications Satellites. Designed to provide transmission of television, voice, data, etc., throughout Canada. Reimbursable. |
| **Explorer 48**<br>(SAS-B)<br>Scout | L: 11/16/72<br>D: 8/20/80 | Perform sky survey of high energy gamma radiation from the celestial spheres, to determine the extent of primary galactic gamma radiation and to ascertain the presence of gamma ray point sources. (SMR) |
| **ESRO 4**<br>Scout | L: 11/21/72<br>D: 4/15/74 | Investigate and measure several phenomena in polar ionosphere. Reimbursable. (WSMC) |
| **Apollo 17**<br>(AS-512/CSM-114/ LM-12)<br>Saturn V | L: 12/7/72<br>D: 12/19/72 | Sixth and last manned lunar landing; third of Apollo J series carrying lunar rover. Astronauts: Eugene A. Cernan, Ronald E. Evans and Harrison H. Schmitt; spent 301 hours, 52 minutes in flight. Cernan and Schmitt during the three EVAs completed a total of 22 hours, 4 minutes each. Returned 243 pounds of lunar samples. |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Nimbus 5**<br>Delta | L: 12/11/72 | Stabilized earth-oriented platform for testing of advanced systems, sensing and collecting meteorological and geological data. |
| **AEROS 2**<br>(German)<br>Scout | L: 12/16/72<br>D: 8/22/73 | Study the state and behavior of upper atmosphere and ionospheric F region, especially with regard to influence of solar ultraviolet radiation. International cooperative. (WSMC) |
| | | **1973** |
| **Pioneer 11**<br>Atlas Centaur | L: 4/6/73 | Obtain precursory scientific information beyond the orbit of Mars with emphasis on investigation of interplanetary medium; investigation of nature of the asteroid belt; and exploration of Jupiter and its environment. |
| **Telesat B**<br>**(Anik 2)**<br>Delta | L: 4/20/73 | Second of series of Canadian Domestic Communications Satellites. Designed to transmit TV, voice, data. Reimbursable. |
| **Skylab 1**<br>(Workshop)<br>(513/SIVB-212)<br>Saturn V | L: 5/14/73<br>D: 7/11/79 | Unmanned: Spacecraft comprised of Orbital Workshop, Airlock Module, Multiple Docking Adapter, Apollo Telescope Mount, Instrument Unit and Payload Shroud. |
| **Skylab 2**<br>(206/CSM-116)<br>Saturn IB | L: 5/25/73<br>D: 6/22/73 | First Manned Skylab launch. Crew: Charles Conrad Jr., Joseph P. Kerwin and Paul J. Weitz. Objectives: Establish Skylab Orbital Assembly in earth orbit; conduct series of medical experiments associated with the extension of manned space flight. Recovered SL-2 from Pacific 38.5 minutes after splashdown. Mission duration 28 days, 49 minutes, 49 seconds. Data obtained on 46 of 55 experiments. Crew performed three EVAs totaling 5 hours, 41 minutes. |
| **Explorer 49**<br>(Radio Astronomy Explorer-B)<br>Delta | L: 6/10/73 | Make measurements of galactic and solar radio noise at frequencies below ionospheric cutoffs and external to terrestrial background interference by utilization of the moon for occultation, focusing or aperture blocking for increased resolution and discrimination. |
| **ITOS E (NOAA)**<br>Delta | L: 7/16/73<br>D: 7/16/73 | Operational meteorological satellite to obtain global cloud cover data both day and night for use in weather analysis and forecasting. NASA reimbursed by NOAA for both spacecraft and launch support. Mission failed due to vehicle second stage malfunction. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Skylab 3**<br>(207/CSM-117)<br>Saturn IB | L: 7/29/73<br>D: 9/25/73 | Second Manned Skylab launch. Crew: Alan L. Bean, Owen K. Garriott and Jack R. Lousma. Crew performed systems and operational tests, assigned experiments and thermal shield deployment. SL-3 recovered from Pacific Ocean 43 minutes after splashdown. Mission duration 59 days, 11 hours, 9 minutes, 4 seconds. Crew performed three EVAs totaling 13 hours, 44 minutes. |
| **Intelsat IV F-7**<br>Atlas Centaur | L: 8/23/73 | COMSAT global commercial communications satellite system. Reimbursable. |
| **Explorer 50**<br>(IMP-J)<br>Delta | L: 10/25/73 | Perform detailed and near continuous studies of interplanetary environment for orbital periods comparable to several rotations of active solar regions; and to study particle and field interactions in the distant magnetotail including cross sectional mapping of the tail and neutral sheet. |
| **Transit**<br>(NNSS/0/20)<br>Scout | L: 10/30/73 | U.S. Navy Navigation Satellite. Reimbursable. (WSMC) |
| **NOAA 3 (ITOS-F)**<br>Delta | L: 11/6/73 | Operational meteorological satellite to obtain global cloud cover data both day and night for use in weather analysis and forecasting. NASA reimbursed by NOAA for both spacecraft and launch support. (WSMC) |
| **Skylab 4**<br>(208/CSM-118)<br>Saturn IB | L: 11/16/73<br>D: 2/8/74 | Third Manned Skylab launch. Crew: Gerald P. Carr, Edward G. Gibson and William R. Pogue. Performed unmanned Saturn workshop operations; reactivate Skylab orbital assembly in earth orbit; obtain medical data on crew for use in extending the duration of manned space flights; performed inflight experiments. SL-4 recovered from Pacific Ocean approximately 40 minutes after splashdown. Mission duration 84 days, 1 hour, 16 minutes. Crew performed four EVAs totaling 22 hours, 21 minutes. |
| **Explorer 51**<br>(Atmosphere Explorer-C)<br>Delta | L: 12/16/73<br>D: 12/12/78 | Investigate the photochemical processes accompanying the absorption of solar ultraviolet radiation in earth's atmosphere by making closely coordinated measurements of reacting constituents from spacecraft with onboard propulsion to permit perigee and apogee altitudes to be varied by command. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| | | **1974** |
| **Skynet II-A**<br>Delta | L: 1/18/74<br>D: 1/25/74 | United Kingdom Communications Satellite. Vehicle failed due to short circuit in the electronics package of the vehicle. Reimbursable. |
| **Centaur Proof**<br>Titan Centaur III E | L: 2/11/74<br>D: 2/11/74 | Demonstrate the capability of the Titan III E Centaur D-IT launch vehicle, the Centaur Standard Shroud and the ability of the Integrate Transfer Launch Facility to support operational Titan/Centaur missions. Vehicle failure. |
| **San Marco 4**<br>Scout | L: 2/18/74<br>D: 5/4/76 | Obtain measurements of the diurnal variations of the equatorial neutral atmosphere density, composition and temperature. International cooperative. (SMR) |
| **UK X4**<br>Scout | L: 3/8/74 | Demonstrate an accuracy of better than 3 arc minutes using a gas jet system; to measure the performance in orbit of components of an operational infrared sensor; to check photometric calibration of the sensor to measure the density of sun-reflecting particles near the spacecraft. Reimbursable. (WSMC) |
| **Westar 1**<br>Delta | L: 4/13/74 | Western Union domestic communications satellite to provide transmission of communications throughout the United States. Reimbursable. |
| **SMS 1** | L: 5/17/74 | Part of a global network of geostationary Delta environmental satellites with the objective of providing earth imaging in the visible and infrared spectrum, monitoring space environment. |
| **ATS 6**<br>Titan III C | L: 5/30/74 | Applications Technology Satellite to provide a large antenna structure capable of providing good quality TV signals to small, inexpensive ground receivers. |
| **Explorer 52**<br>(Hawkeye)<br>Scout | L: 6/3/74 | Study the plasma properties of the magnetosphere in the vicinity of the magnetic neutral point over the earth's north polar cap. (WSMC) |
| **AEROS 2**<br>Scout | L: 7/16/74<br>D: 9/2/75 | Measure the main aeronomic parameters determining the state of the upper atmosphere and the solar ultraviolet radiation in the wavelength band of main absorption. German reimbursable. (WSMC) |
| **ANS 1**<br>Scout | L: 8/30/74<br>D: 6/14/77 | Obtain spectral distribution and other data from celestial X-ray and ultraviolet sources; cooperative with the Netherlands. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Westar 2**<br>Delta | L: 10/10/74 | Western Union domestic communications satellite. Reimbursable. |
| **UK 5 (Ariel 5)**<br>Scout | L: 10/15/74 | Investigate galactic and extragalactic X-ray sources. International cooperative. (SMR) |
| **NOAA 4 (ITOS-G)**<br>**INTASAT**<br>Delta | L: 11/15/74 | Meteorological satellite: constructed and launched by NASA. Reimbursed and operated by NOAA. INTASAT: carried piggyback on ITOS-G to measure total electron content, ionospheric irregularities and ionospheric scintillations. Cooperative with Spain. (WSMC) |
| **Intelsat IV F-8**<br>Atlas Centaur | L: 11/21/74 | Communications satellite: reimbursed and operated by COMSAT to expand the global satellite system. |
| **Skynet II-B**<br>Delta | L: 11/22/74 | Communications satellite: United Kingdom reimbursable to provide X-band military communications. |
| **Helios 1**<br>Titan III-E Centaur | L: 12/10/74 | Scientific satellite to investigate the properties of and processes in interplanetary space in the direction of and close to the sun. Cooperative with West Germany. |
| **Symphonie A**<br>Delta | L: 12/17/74 | Communications satellite: Joint project by France and Germany to provide communications to Europe, Africa and South America. Reimbursable. |
| | | **1975** |
| **Landsat 2**<br>Delta | L: 1/22/75 | Second Earth Resources Technology Satellite to locate, map and measure earth resources parameters from space and demonstrate the applicability of this approach to the management of the world's resources. (WSMC) |
| **SMS 2**<br>Delta | L: 2/6/75 | Second developmental meteorological satellite to provide continuous observation of environmental phenomena and help develop an environmental network for routine observations and early warning. |
| **Intelsat IV F-6**<br>Atlas Centaur | L: 2/20/75<br>D: 2/20/75 | COMSAT communications satellite. Vehicle failure. Reimbursable. |
| **GEOS 3**<br>Delta | L: 4/9/75 | Oceanographic and geodetic satellite to measure ocean topography, sea state and other features of the earth. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Explorer 53** (SAS-C) Scout | L: 5/7/75 D: 4/9/79 | Scientific satellite to search for sources radiating in the X-ray, gamma ray, ultraviolet and other spectral regions both inside and beyond our galaxy. (SMR) |
| **Telesat C** (Anik 3) Delta | L: 5/7/75 | Canadian domestic communications satellite. Reimbursable. |
| **Intelsat IV F-1** Atlas Centaur | L: 5/22/75 | COMSAT communications satellite. Reimbursable. |
| **Nimbus 6** Delta | L: 6/12/75 | Meteorological satellite: R&D of instruments for expanding capabilities for remote sensing of the atmosphere. (WSMC) |
| **OSO 8** Delta | L: 6/21/75 | Scientific satellite to study specific features of the sun. |
| **ASTP** Saturn 1B | L: 7/15/75 D: 7/24/75 | Apollo Soyuz Test Project. Manned cooperative U.S.-Soviet mission. U.S. crew: Thomas P. Stafford, Vance D. Brand and Donald K. Slayton. Soviet crew: Aleksey A. Leonov and Valeriy N. Kubasov. Docked with Soyuz on 7/17/75. Mission duration 217 hours, 28 minutes. |
| **COS-B** Delta | L: 8/8/75 | Cosmic ray satellite to study extraterrestrial gamma radiation. Launched for the European Space Agency. Reimbursable. (WSMC) |
| **Viking 1** Titan III Centaur | L: 8/20/75 D: 7/20/76 (Lander) | Scientific investigation of Mars. United States' first attempt to soft land a spacecraft on another planet. Successfully soft landed on 7/20/76. First in situ analysis of surface material on another planet. |
| **Symphonie-B** Delta | L: 8/26/75 | Communications satellite. French/German cooperative. Reimbursable. |
| **Viking 2** Titan III Centaur | L: 9/9/75 D: 9/3/76 (Lander) | Scientific investigation of Mars. United States' second attempt to soft land on Mars. Successfully soft landed on 9/3/76. Successfully returned scientific data. |
| **Intelsat IVA F-1** Atlas Centaur | L: 9/25/75 | First in a series of improved COMSAT communications satellites. Double the capacity of previous Intelsats. Reimbursable. |
| **Explorer 54** (AE-D) Delta | L: 10/6/75 D: 3/12/76 | Scientific satellite to investigate the chemical processes and energy transfer mechanisms which control earth's atmosphere. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **U.S. Navy**<br>Scout | L: 10/12/75 | Navy Transit Navigation Satellite. Reimbursable. (WSMC) |
| **GOES 1 (SMS-C)**<br>Delta | L: 10/16/75 | Geostationary Operational Environmental Satellite. Constructed and launched by NASA. Funded and reimbursed by NOAA. |
| **Explorer 55**<br>(AE-E)<br>Delta | L: 11/20/75<br>D: 6/10/81 | Scientific satellite to investigate the chemical processes and energy transfer mechanisms which control earth's atmosphere. |
| **DAD-A/B**<br>Scout | L: 12/5/75<br>D: 12/5/75 | Scientific satellite to measure global density of upper atmosphere and lower exosphere. Vehicle failed. (WSMC) |
| **RCA-A**<br>Delta | L: 12/13/75 | Communications: First RCA domestic communications satellite. Reimbursable. |
| | | **1976** |
| **Helios 2**<br>Titan III Centaur | L: 1/15/76 | Scientific satellite to investigate the properties in interplanetary space close to the sun. Cooperative with Germany. |
| **CTS**<br>Delta | L: 1/17/76 | Experimental high powered communications satellite. Cooperative with Canada. |
| **Intelsat IVA F-2**<br>Atlas Centaur | L: 1/29/76 | COMSAT communications satellite. Reimbursable |
| **Marisat 1**<br>Delta | L: 2/19/76 | COMSAT maritime communications satellite. Reimbursable. |
| **RCA-B**<br>Delta | L: 3/26/76 | Second RCA (Satcom) domestic communications satellite. Reimbursable. |
| **NATO-III A**<br>Delta | L: 4/22/76 | Communications satellite for the North Atlantic Treaty Organization. Reimbursable. |
| **LAGEOS**<br>Delta | L: 5/4/76 | To demonstrate the feasbility and utility of a ground-to-satellite laser system to contribute to the study of solid earth dynamics. (WSMC) |
| **Comstar 1A**<br>Atlas Centaur | L: 5/13/76 | COMSAT's first domestic communications satellite. Reimbursable. |
| **Air Force Test**<br>Scout | L: 5/22/76 | To evaluate certain propagation effects of disturbed plasmas on radar and communications systems. Reimbursable. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Marisat 2**<br>Delta | L: 6/9/76 | COMSAT maritime communications satellite. Reimbursable. |
| **Gravity Probe-A**<br>Scout | L: 6/18/76<br>D: 6/18/76 | Scientific probe to test Einstein's Theory of Relativity. (WFF) |
| **Palapa 1**<br>Delta | L: 7/8/76 | Indonesian communications satellite. Reimbursable. |
| **Comstar 2**<br>Atlas Centaur | L: 7/22/76 | COMSAT's second domestic communications satellite. Reimbursable. |
| **NOAA 5 (ITOS-H)**<br>Delta | L: 7/29/76 | Meteorological satellite. Reimbursable. (WSMC) |
| **U.S. Navy (TIP 3)**<br>Scout | L: 9/1/76 | Transit Improvement Program. U.S. Navy navigation satellite. Reimbursable. (WSMC) |
| **Marisat 3**<br>Delta | L: 10/14/76 | COMSAT maritime communications satellite. Reimbursable. |
| | | **1977** |
| **NATO III B**<br>Delta | L: 3/10/77 | NATO communications satellite. Reimbursable. |
| **Palapa 2**<br>Delta | L: 3/10/77 | Indonesian communications satellite. Reimbursable. |
| **GEOS/ESA**<br>Delta | L: 4/20/77 | ESA scientific satellite to investigate waves and particles in the magnetosphere. Rated unsuccessful by NASA. Reimbursable. |
| **Intelsat IVA F-4**<br>Atlas Centaur | L: 5/26/77 | COMSAT communications satellite. Reimbursable. |
| **GOES 2/NOAA**<br>Delta | L: 6/16/77 | Geostationary Operational Environmental Satellite. Second in a series launched for NOAA. Reimbursable. |
| **GMS/Japan**<br>Delta | L: 7/14/77 | Geostationary Meteorological Satellite. First GMS launched for Japan. Reimbursable. |
| **HEAO 1**<br>Atlas Centaur | L: 8/12/77<br>D: 3/15/79 | High Energy Astronomy Observatory: Scientific satellite to study and map X-rays and gamma rays. |
| **Voyager 2**<br>Titan III Centaur | L: 8/20/77 | Scientific satellite to study Jupiter and Saturn planetary systems including their satellites and Saturn's rings. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **SIRIO/Italy**<br>Delta | L: 8/25/77 | Scientific satellite: Italian project to investigate trapped radiation flux, magnetic field intensity and variation, and the primary electron energy spectrum. Reimbursable. |
| **Voyager 1**<br>Titan III Centaur | L: 9/5/77 | Scientific satellite: Second Voyager launched to investigate Jupiter and Saturn planetary systems. |
| **OTS/ESA**<br>Delta | L: 9/13/77<br>D: 9/13/77 | Orbital Test Satellite. ESA experimental communications satellite. Vehicle failure. Reimbursable. |
| **Intelsat IVA F-5**<br>Atlas Centaur | L: 9/29/77 | COMSAT communications satellite. Vehicle failure. Reimbursable. |
| **ISEE 1/2**<br>Delta | L: 10/22/77 | International Sun-Earth Explorer. Joint NASA/ESA mission to study the interaction of the interplanetary medium with earth's immediate environment. Dual payload; cooperative. |
| **Navy Transit**<br>Scout | L: 10/28/77 | U.S. Navy navigation satellite. Reimbursable. (WSMC) |
| **Meteosat**<br>Delta | L: 11/22/77 | ESA meteorological satellite. Europe's contribution to the Global Atmospheric Research Program (GARP). Reimbursable. |
| **CS/Japan**<br>Delta | L: 12/14/77 | Communications satellite. Launched for Japan. Reimbursable. |
| | | **1978** |
| **Intelsat IVA**<br>Atlas Centaur | L: 1/6/78 | COMSAT communications satellite. Reimbursable. |
| **IUE 1**<br>Delta | L: 1/26/78 | International Ultraviolet Explorer in cooperation with the European Space Agency and the British Science Research Council. Reimbursable. |
| **FLTSATCOM 1**<br>Atlas Centaur | L: 2/9/78 | Fleet communications for U.S. Navy. First in a series. Reimbursable. |
| **Landsat 3**<br>Delta | L: 3/5/78 | Ecological data satellite, joins Landsats 1 and 2 in cataloging earth's resources and monitoring changing environmental conditions. (WSMC) |
| **Intelsat IVA F-6**<br>Atlas Centaur | L: 3/31/78 | COMSAT communications satellite. Reimbursable. |
| **Japan/BSE**<br>Delta | L: 4/7/78 | Broadcasting Experimental Satellite. Japanese communications satellite for conducting TV broadcast experiments. Reimbursable. |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **HCMM**<br>Scout | L: 4/26/78<br>D: 12/22/81 | Heat Capacity Mapping Mission to produce thermal maps for discrimination of rock types, mineral resources, plant temperature, soil moisture, snow fields and water runoff. (WSMC) |
| **OTS 2**<br>Delta | L: 5/11/78 | Backup European Space Agency Orbital Test Satellite. Reimbursable. |
| **Pioneer Venus 1**<br>Atlas Centaur | L: 5/20/78 | Planetary mission to Venus. Orbiter measurements of upper atmosphere, study interaction between solar wind, ionosphere and magnetic field, study atmospheric and surface characteristics, determine gravitational field harmonics. |
| **GOES 3**<br>Delta | L: 6/16/78 | Geostationary Environmental Satellite for earth imaging. NOAA reimbursable. |
| **Seasat 1**<br>Atlas F | L: 6/26/78 | Sea satellite for global monitoring of ocean geoid, wave topography, surface wind speed and direction, ocean surface temperatures, and ice field extent and dynamics. (WSMC) |
| **Comstar D-3**<br>Atlas Centaur | L: 6/29/78 | Third in a series of COMSAT domestic communications satellites. Reimbursable. |
| **GEOS 3**<br>Delta | L: 7/14/78 | ESA spacecraft to study atmospheric radiation particles. Reimbursable. |
| **Pioneer Venus 2**<br>Atlas Centaur | L: 8/8/78<br>D: 12/9/78 | Venus multiprobe mission - four hard landers: To determine nature and composition structure and general circulation pattern of the atmosphere of Venus from the surface to high altitudes. |
| **ISEE 3**<br>Delta | L: 8/12/78 | International Sun-Earth Explorer. Interplanetary studies with the spacecraft toward the sun sufficiently outside the earth influence for comparison with results of ISEE-1 and 2 missions and of probes to outer planets. Cooperative with ESA. |
| **Tiros-N**<br>Atlas F | L: 10/13/78 | Polar orbiting operational spacecraft to provide improved meteorological data for NOAA and provide support to the Global Atmospheric Research Program. Piggyback payload: Oscar-7. (WSMC) |
| **Nimbus 7**<br>Delta | L: 10/24/78 | Develop and flight test advanced sensors and technology basic to conducting experiments in the pollution monitoring, oceanographic and meteorological disciplines. A piggyback payload called CAMEO (Chemically Active Material Ejected in Orbit) was ejected to study the boundary structure between the polar cap and the auroral belt. (WSMC) |

| Mission/Vehicle | Date | Remarks |
| --- | --- | --- |
| **HEAO 2**<br>Atlas Centaur | L: 11/13/78<br>D: 3/25/82 | Second High Energy Astronomical Observatory to study very energetic radiation from space. |
| **NATO-III C**<br>Delta | L: 11/19/78 | NATO communications satellite. Reimbursable. |
| **Telesat-D**<br>Delta | L: 12/16/78 | Canadian domestic communications satellite. Reimbursable. |
| | | **1979** |
| **SCATHA**<br>Delta | L: 1/30/79 | Satellite to study electrical charge buildup on spacecraft for Air Force. |
| **SAGE**<br>Scout | L: 2/18/79 | Gathering data on ozone and aerosols in stratosphere. (WFF) |
| **FLTSATCOM 2**<br>Atlas Centaur | L: 5/4/79 | Part of a worldwide armed forces communication system. |
| **UK-6 (Ariel)**<br>Scout | L: 6/2/79 | Scientific studies in high energy astrophysics. (WFF) |
| **NOAA 6**<br>Atlas E/F | L: 6/27/79 | Environmental monitoring satellite. (WSMC) |
| **Westar 3**<br>Delta | L: 8/9/79 | Western Union communications satellite. |
| **HEAO 3**<br>Atlas Centaur | L: 9/20/79<br>D: 12/7/81 | Study of cosmic ray particles and gamma ray photons. |
| **Magsat**<br>Scout | L: 10/30/79<br>D: 6/11/80 | Measure near-earth magnetic field and crustal anomalies. (WSMC) |
| **RCA-SATCOM 3**<br>Delta | L: 12/6/79 | Communications satellite; lost after transfer from NASA to RCA. |
| | | **1980** |
| **FLTSATCOM 3**<br>Atlas Centaur | L: 1/17/80 | Part of worldwide armed forces communications system. |
| **Solar Maximum Mission**<br>Delta | L: 2/14/80 | Scientific studies of solar flare mechanisms; part of international solar year activities. |
| **NOAA-B**<br>Atlas-F | L: 5/29/80<br>D: 5/3/81 | Environmental monitoring satellite. Booster failure put satellite into wrong orbit causing mission failure. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **GOES 4**<br>Delta | L: 9/9/80 | Weather observation for NOAA. Reimbursable. |
| **FLTSATCOM 4**<br>Atlas Centaur | L: 10/30/80 | Part of worldwide armed forces communications system. |
| **SBS 1**<br>Delta | L: 11/15/80 | Satellite Business Systems advanced communications satellite. Reimbursable. |
| **Intelsat V F-2**<br>Atlas Centaur | L: 12/6/80 | Largest commercial communications satellite. Reimbursable. |
| | **1981** | |
| **Comstar 4**<br>Atlas Centaur | L: 2/21/81 | COMSAT communications satellite. Reimbursable. |
| **STS-1**<br>Space Shuttle | L: 4/12/81<br>D: 4/14/81 | First flight of reusable Space Shuttle Columbia (OV 102). Crew: John W. Young and Robert L. Crippen. Proved concept. First landing of U.S. manned spacecraft on land; first use of solid rockets in manned flight. Mission duration 54 hours, 20 minutes, 52 seconds. (KSC) |
| **Navy 20 (NOVA 1)**<br>Scout | L: 5/15/81 | DOD transit. (WSMC) |
| **GOES 5**<br>Delta | L: 5/22/81 | NOAA weather satellite. Reimbursable. |
| **Intelsat V F-1**<br>Atlas Centaur | L: 5/23/81 | Intelsat communications. Reimbursable. |
| **NOAA 7**<br>Atlas-F | L: 6/23/81 | NOAA weather. (WSMC) Reimbursable. |
| **Dynamics Explorer**<br>Delta | L: 8/3/81 | NASA scientific. Dual spacecraft, Dynamics Explorers A and B, to study space around earth from the limits of the upper atmosphere to distances far out in the earth's magnetic field. (WSMC) |
| **FLTSATCOM 5**<br>Atlas Centaur | L: 8/6/81 | DOD communications. |
| **SBS 2**<br>Delta | L: 9/24/81 | Satellite Business Systems communications. Reimbursable. |
| **Solar Mesosphere Explorer**<br>Delta | L: 10/6/81 | NASA atmospheric research satellite to study reactions between between sunlight, ozone and other chemicals in the atmosphere. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **STS-2**<br>Space Shuttle | L: 11/12/81<br>D: 11/14/81 | First reuse of spacecraft (Columbia). Crew: Joe H. Engle and Richard H. Truly. Mission planned for 124 hours but ended early due to loss of one of three fuel cells. Remote manipulator arm tested successfully; 90 percent of primary mission objectives accomplished including data acquisition by earth resources pallet OSTA-1. Mission duration 54 hours, 10 minutes, 13 seconds. (KSC) |
| **RCA 3R**<br>Delta | L: 11/19/81 | RCA commercial communications satellite. Reimbursable. |
| **Intelsat V F-3**<br>Atlas Centaur | L: 12/15/81 | Intelsat communications. Reimbursable. |
| | | **1982** |
| **RCA 4**<br>Delta | L: 1/15/82 | RCA commercial communications satellite. Reimbursable. |
| **Westar 4**<br>Delta | L: 2/25/82 | Western Union commercial communications satellite. Reimbursable. |
| **Intelsat V F-4**<br>Atlas Centaur | L: 3/4/82 | COMSAT international communications satellite. Reimbursable. |
| **STS-3**<br>Space Shuttle | L: 3/22/82<br>D: 3/30/82 | Third flight of orbiter Columbia. Crew: Jack R. Lousma and C. Gordon Fullerton. Payload included space science experiments (OSS-1). Landed at White Sands, N.M., due to wet lakebed at Edwards AFB, Calif. Flight extended one day because of high winds at White Sands. Mission duration 8 days, 4 minutes, 49 seconds. (KSC) |
| **INSAT 1A**<br>Delta | L: 4/10/82 | India communications satellite. Reimbursable. |
| **Westar 5**<br>Delta | L: 6/8/82 | Western Union commercial communications satellite. Reimbursable. |
| **STS-4**<br>Space Shuttle | L: 6/27/82<br>D: 7/4/82 | Fourth Space Shuttle mission (Columbia); final development. Crew: Thomas K. Mattingly II and Henry W. Hartsfield Jr. First landing on a hard surface runway. Mission duration 7 days, 1 hour, 11 minutes, 11 seconds. (KSC) |
| **Landsat 4**<br>Delta | L: 7/16/82 | NASA earth resources applications satellite. (WSMC) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **Telesat-G**<br>Delta | L: 8/26/82 | Canadian communications satellite. Reimbursable. |
| **Intelsat V F-5**<br>Atlas Centaur | L: 9/28/82 | COMSAT international communications satellite. Reimbursable. |
| **RCA 5**<br>Delta | L: 10/27/82 | RCA commercial communications satellite. Reimbursable. |
| **STS-5**<br>Space Shuttle | L: 11/11/82<br>D: 11/16/82 | Fifth flight of orbiter Columbia; first operational mission. First four-man crew: Vance D. Brand, Robert F. Overmyer, Joseph P. Allen and William B. Lenoir. First deployment of satellites from Space Shuttle - SBS-C and Anik-C. Mission duration 5 days, 2 hours, 14 minutes, 25 seconds. (KSC) |
| **SBS 3**<br>PAM-D | L: 11/11/82 | Satellite Business Systems commercial communcations. First satellite deployed from Space Shuttle. (STS-5) |
| **Anik C-3**<br>PAM-D | L: 11/12/82 | Canadian communications satellite. (STS-5) |
| | | **1983** |
| **IRAS**<br>Delta | L: 1/25/83 | Infrared Astronomy Satellite. Scientific satellite to perform first all-sky survey to search for objects that emit infrared radiation. Discovered comet IRAS-Araki-Alcock on April 25, 1982. International cooperative with the Netherlands and the United Kingdom. (WSMC) |
| **NOAA 8**<br>Atlas E | L: 3/28/83 | An advanced TIROS-N environmental monitoring satellite carrying special search and rescue instrumentation. (WSMC) |
| **STS-6**<br>Space Shuttle | L: 4/4/83<br>D: 4/9/83 | First flight of Space Shuttle orbiter Challenger (OV-099). Crew: Paul J. Weitz, Karol J. Bobko, Donald H. Peterson and Story Musgrave. Deployed TDRS tracking satellite (heaviest Shuttle payload to date); first Space Shuttle extravehicular activity performed by Peterson and Musgrave. Mission duration 5 days, 23 minutes, 42 seconds. |
| **TDRS 1**<br>Inertial Upper Stage | L: 4/4/83 | First spacecraft in Tracking and Data Relay Satellite System (TDRSS). IUS second stage failed to place TDRS in its proper orbit; through a series of thruster firings the satellite was moved to its proper orbit on June 29. (STS-6) |

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **RCA 1R**<br>Delta | L: 4/11/83 | RCA commercial communications satellite. Reimbursable. |
| **GOES-6**<br>Delta | L: 4/28/83 | NOAA weather satellite. Reimbursable. |
| **Intelsat V F-6**<br>Atlas Centaur | L: 5/19/83 | COMSAT communications satellite. Reimbursable. |
| **Exosat**<br>Reimbursable. (WSMC) | L: 5/26/83 | ESA X-Ray observatory satellite. Delta |
| **STS-7**<br>Space Shuttle | L: 6/18/83<br>D: 6/24/83 | Second flight of orbiter Challenger; first five-person crew: Robert L. Crippen, Frederick H. Hauck, John M. Fabian, Sally K. Ride (first American woman in space) and Norman E. Thagard. First use of the Remote Manipulator Structure to deploy and retrieve a satellite in space, SPAS-1. Mission duration: 6 days, 2 hours, 24 minutes. (KSC) |
| **Anik C-2**<br>PAM-D | L: 6/18/83 | Canadian communications satellite. (STS-5) |
| **Palapa B-1**<br>PAM-D | L: 6/19/83 | Indonesian communications satellite. (STS-5) |
| **Galaxy 1**<br>Delta | L: 6/28/83 | Hughes commercial communications satellite. Reimbursable. |
| **Telstar 3A**<br>Delta | L: 7/28/83 | AT&T commercial communications satellite. Reimbursable. |

**Scheduled for the Remainder of 1983**

| Mission/Vehicle | Date | Remarks |
|---|---|---|
| **RCA-G**<br>Delta | Aug. 25 | RCA communications. Reimbursable. |
| **STS-8**<br>Space Shuttle | Aug. 30 | INSAT 1-B deployment. Crew: Richard H. Truly, Daniel C. Brandenstein, Dale A. Gardner, Guion S. Bluford Jr. (first black American astronaut in space) and William E. Thornton. Mission milestones will include the first night launch and landing of a Space Shuttle, first orbital transfer of 40 n. mi. magnitude and first use of Payload Flight Test Article. (KSC) |
| **INSAT-1B**<br>PAM-D | Aug. 31 | India communications satellite. (STS-8) |

| **Mission**/Vehicle | Date | Remarks |
|---|---|---|
| **Galaxy-B**<br>Delta | Sept. 22 | Hughes commercial communications satellite. Reimbursable. |
| **STS-9**<br>Space Shuttle | Oct. 28 | Spacelab 1. Crew: John W. Young, Brewster W. Shaw Jr., Owen K. Garriott, Robert A. Parker, Ulf Merbold (first foreign crewmember on an American spacecraft) and Byron K. Lichtenberg. Milestones: first flight of payload specialists, first use of the European-built Spacelab, first six-person crew. (KSC) |
| **AF-1 (ITV)**<br>Scout | December | Air Force test program. (WFF) |
| **Intelsat VA-A**<br>Atlas Centaur | December | Intelsat communications. Reimbursable. |
| **Navy-21** | 4th Quarter | DOD-NOVA. (WSMC) |

25th Anniversary
1958-1983

# *Astronauts*

# ASTRONAUTS

Compiled by

Barbara E. Selby

## Preface

Of 127 astronauts selected by NASA since April 1959, 78 were on flight status in March 1983. Thirty-seven of the 78 were pilot astronauts and 41 were mission specialist or scientist astronauts.

Nine groups of astronauts have been selected. In Group 1 were the seven Mercury astronauts selected in April 1959. Nine test pilots, Group 2, were selected in September 1962. In Group 3 were 14 pilot astronauts selected in October 1963. Group 4, the first six scientist astronauts, was selected in June 1965. In April 1966, 19 pilot astronauts were selected in Group 5. Group 6, 11 scientist-astronauts, was selected in August 1967. Seven Air Force Manned Orbital Laboratory pilots joined the NASA pilot astronaut program in August 1969, as Group 7. Group 8, 35 men and women, the first group selected specifically for the Space Shuttle in January 1978, completed training in August 1979. Group 9, 19 men and women, selected for the Space Shuttle in July 1980, completed training in August 1981.

NASA will recruit new Space Shuttle astronaut candidate groups as needed. Announcement of recruiting periods will be issued well in advance of the dates when applications will be accepted. Announcements are widely published among scientific and professional journals and lay publications.

## STATUS, FLIGHTS AND AFFILIATIONS

---

Sample entry: (not all data applv to each person)

NAME DATE OF BIRTH/HOMETOWN
**SMITH, John A.** (Oct. 12, 1940, Dayton, Ohio) —

MILITARY STATUS/EARNED DEGREE(S)/FIELD
Colonel, USAF (Ret.); Ph.D. (astronomy);

ASTRONAUT GROUP & DATE; FLIGHTS MADE; PERSONAL DATA
Group 3, October 1963; Gemini 3, Apollo 8; served as Deputy of Flight Systems, Johnson Space Center.

(Rank for all astronauts not on flight status is their rank when they left NASA.)

---

**ALDRIN, Edwin E. Jr.** (Jan. 20, 1930, Montclair, N.J.) — Colonel, USAF (Ret.); B.S. (mchanical engineering), M.D.; Group 3, October 1963; Gemini 12, Apollo 11; resigned from NASA, July 1971; retired from Air Force active duty, March 1, 1972. Science Consultant, Beverly Hills Oil Co., Los Angeles, Calif.

**ALLEN, Joseph P.** (June 27, 1937, Crawfordsville, Ind.) — Civilian; B.A. (math-physics), M.S. and Ph.D. (physics); flight, mission specialist; Group 6, August 1967; NASA Assistant Administrator for Legislative Affairs, August 1975-August 1978; served as a mission specialist on STS-5, the first operational flight of the Space Shuttle Orbiter Columbia, Nov. 11-16, 1982.

**ANDERS, William A.** (Oct. 17, 1933, Hong Kong) — Colonel, USAF (Reserve) (now major general); B.S., U.S. Naval Academy, M.S. (nuclear engineering); Group 3, October 1963; Apollo 8; resigned from NASA, September 1969. General Manager, General Electric, Aircraft Equipment Division, Utica, N.Y.

**ARMSTRONG, Neil A.** (Aug. 5, 1930, Wapakoneta, Ohio) — Civilian; B.S. and M.S. (aeronautical engineering); Group 2, September 1962; Gemini 8, Apollo 11; was Deputy Associate Administrator, Aeronautics, NASA Headquarters Office of Advanced Research and Technology, 1970-1971; resigned from NASA, 1971. Cardwell International Ltd., Lebanon, Ohio.

**BAGIAN, James P.** (Feb. 22, 1952, Philadelphia, Pa.) — Civilian, B.S.; (mechanical engineering), M.D.; flight, mission specialist; Group 9, August 1981.

**BASSETT, Charles A.** (Dec. 30, 1931, Dayton, Ohio) — Major, USAF; B.S. (electrical engineering); deceased; Group 3, October 1963; died in T-38 jet crash with Elliott See, Feb. 28, 1966, Lambert Municipal Airport, St. Louis, Mo.

**BEAN, Alan L.** (March 15, 1932, Wheeler, Texas, but considers Fort Worth, Texas, his hometown) -- Captain, USN (Ret.); B.S. (aeronautical engineering); Group 3, October 1963; Apollo 12, Skylab 3; retired from the Navy, October 1975; resigned from NASA, June 1981 to devote his full time to painting.

**BLAHA, John E.** (Aug. 26, 1942, San Antonio, Texas) — Colonel, USAF; B.S. (engineering science), M.S. (astronautical engineering); flight, pilot; Group 9, August 1981.

**BLUFORD, Guion S. Jr.** (Nov. 22, 1942, Philadelphia, Pa.) — Lt. Colonel, USAF; B.S. (aerospace engineering), M.S. (aerospace engineering); flight, mission specialist; Group 8, August 1979; selected to serve as mission specialist for STS-8.

**BOBKO, Karol J.** (Dec. 23, 1937, New York City) — Colonel, USAF; B.S., Air Force Academy, M.S. (aerospace engineering); flight, pilot; Group 7, August 1969; pilot on STS-6, April 4-9, 1983.

**BOLDEN, Charles F. Jr.** (Aug. 19, 1946, Columbia, S.C.) — Major, USMC; B.S. (electrical science), M.S. (systems management); flight, pilot; Group 9, August 1981.

**BORMAN, Frank** (March 14, 1928, Gary, Ind.) — Colonel, USAF (Ret.); B.S., U.S. Military Academy, M.S. (aeronautical engineering); Group 2, September 1962; Gemini 7, Apollo 8; retired from Air Force and resigned from NASA, July 1970. Chairman, President and Chief Executive Officer, Eastern Airlines, Miami, Fla.

**BRAND, Vance D.** (May 9, 1931, Longmont, Colo., but considers Gainesville, Ga., to be his hometown) — Civilian; B.S. (business and aeronautical engineering), M.S. (business administration); flight, pilot; Group 5, April 1966; Apollo-Soyuz Test Project; commander of STS-5, the fifth flight of Space Shuttle Columbia, Nov. 11-16, 1982; selected to serve as commander on STS-11.

**BRANDENSTEIN, Daniel C.** (Jan. 17, 1943, Watertown, Wis.) — Commander, USN; B.S. (mathematics and physics); flight, pilot; Group 8, August 1979; selected to serve as pilot for STS-8.

**BRIDGES, Roy D. Jr.** (July 19, 1943, Atlanta, Ga., but considers Gainesville, Ga., his hometown) — Lt. Colonel, USAF; B.S. (engineering science), M.S. (astronautics); flight, pilot; Group 9, August 1981.

**BUCHLI, James F.** (June 20, 1945, New Rockford, N.D., but considers Fargo, N.D., his hometown) — Major, USMC; B.S. (aeronautical engineering), M.S. (aeronautical engineering systems); flight, mission specialist; Group 8; August 1979; selected to serve as a mission specialist on STS-10.

**BULL, John S.** (Sept. 25, 1934, Memphis, Tenn.) — Lt. Commander, USN (Ret.); B.S. (mechanical engineering), M.S. and Ph.D. (aeronautical engineering); Group 5, April 1966; resigned from NASA, July 1968; withdrew from astronaut program and the Navy because of pulmonary disease. Member, Guidance and Navigation Branch, Ames Research Center, Mountain View, Calif.

**CARPENTER, M. Scott** (May 1, 1925, Boulder, Colo.) — Commander, USN (Ret.); B.S. (aeronautical engineering); Group 1, April 1959; Mercury 7; joined U.S. Navy SEALAB program in 1967; resigned from NASA, August 1967; retired from Navy, July 1969.

**CARR, Gerald P.** (Aug. 22, 1932, Denver, Colo., but considers Santa Ana, Calif., his hometown) — Colonel, USMC (Ret.); B.S. (mechanical engineering), B.S. and M.S. (aeronautical engineering); Group 5, April 1966; Skylab 4; resigned from NASA, June 1977; retired from Marine Corps, September 1975. Senior Consultant, Applied Research, Inc., Houston.

**CERNAN, Eugene A.** (March 14, 1934, Chicago, Ill.) — Captain, USN (Ret.); B.S. (electrical engineering), M.S. (aeronautical engineering); Group 3, October 1963; Gemini 9, Apollo 10, Apollo 17; resigned from NASA and retired from the Navy, July 1, 1976. Cernan Energy Corp., Houston.

**CHAFFEE, Roger B.** (Feb. 15, 1935, Grand Rapids, Mich.) — Lieutenant commander, USN; B.S. (aeronautical engineering); deceased; Group 3, October 1963; died in Apollo spacecraft fire, Kennedy Space Center, Jan. 27, 1967.

**CHANG, Franklin R.** (April 5, 1950, San Jose, Costa Rica) — Civilian; B.S. (mechanical engineering), Ph.D. (applied plasma physics); flight, mission specialist; Group 9, August 1981.

**CHAPMAN, Philip K.** (March 5, 1935, Melbourne, Australia) — Civilian; B.S. (physics and mathematics), M.S. (aeronautics and astronautics), D.Sc. (instrumentation); Group 6, August 1967; resigned from NASA, July 1972. Arthur D. Little, Inc., Cambridge, Mass.

**CLEAVE, Mary L.** (Feb. 5, 1947, Southampton, N.Y.) — Civilian; B.S. (biological sciences), M.S. (microbial ecology), Ph.D. (civil and environmental engineering); flight, mission specialist; Group 9, August 1981.

**COATS, Michael L.** (Jan. 16, 1946, Sacramento, Calif., but considers Riverside, Calif., his hometown) — Commander, USN; B.S. from the United States Naval Academy, M.S. (administration of science and technology), M.S. (aeronautical engineering); flight, pilot; Group 8, August 1979.

**COLLINS, Michael** (Oct. 31, 1930, Rome Italy) — Colonel (now Major General, USAFR Ret.); B.S. from the U.S. Military Academy; Group 3, October 1963; Gemini 10, Apollo 11; resigned from NASA, January 1970. President, Vought Corp., Arlington, Va.

**CONRAD, Charles Jr.** (June 2, 1930, Philadelphia, Pa.) — Captain, USN (Ret.); B.S. (aeronautical engineering); Group 2, September 1962; Gemini 5, Gemini 11, Apollo 12, Skylab 2; resigned from NASA and retired from Navy, December 1973. Senior Vice President, Marketing, Douglas Aircraft Co., Long Beach, Calif.

**COOPER, L. Gordon** (March 6, 1927, Shawnee, Okla.) — Colonel, USAF (Ret.); B.S. (aeronautical engineering), D.Sc.; Group 1, April 1959; Mercury 9, Gemini 5; retired from NASA and retired from the Air Force in July 1970.

**COVEY, Richard O.** (Aug. 1, 1946, Fayetteville, Ark., but considers Fort Walton Beach, Fla., his hometown) — Lieutenant colonel, USAF; B.S. (engineering sciences), M.S. (aeronautics and astronautics); flight, pilot; Group 8, August 1979.

**CREIGHTON, John O.** (April 28, 1943, Orange, Texas, but considers Seattle, Wash., his hometown) — Commander, USN; B.S. from the United States Naval Academy, M.S. (administration of science and technology); flight, pilot; Group 8, August 1979.

**CRIPPEN, Robert L.** (Sept. 11, 1937, Beaumont, Texas) — Captain, USN; B.S. (aerospace engineering); flight, pilot; Group 7, August 1969; pilot on STS-1, April 12-14, 1981; commander on STS-7, June 18-24, 1983; selected as commander for STS-13.

**CUNNINGHAM, Walter** (March 16, 1932, Creston, Iowa) — Civilian; B.A., M.A. and Ph.D. (physics); Group 3, October 1963; Apollo 7; resigned from NASA, August 1971. The Capital Group, Houston.

**DUKE, Charles M. Jr.** (Oct. 3, 1935, Charlotte, N.C.) — Brig. General, USAF (Reserve); B.S. (naval sciences), M.S. (aeronautics); Group 5, April 1966; Apollo 16; resigned from NASA, December 1975; resigned from USAF, Jan. 1, 1976. Duke Investments and President, Southwest Wildlerness Art, Inc.

**DUNBAR, Bonnie J.** (March 3, 1949, Sunnyside, Wash.) — Civilian; B.S. and M.S. (ceramic engineering), presently doctoral candidate in biomedical engineering; flight, mission specialist; Group 9, August 1981.

**EISELE, Donn F.** (June 23, 1930, Columbus, Ohio) — Colonel, USAF (Ret.); M.S. (astronautics); Group 3, October 1963; Apollo 7; resigned from NASA and retired from Air Force, July 1972. Was technical assistant for manned space flight, NASA Langley Research Center, Hampton, Va., 1970-1972. Oppenheimer and Co., Inc., Ft. Lauderdale, Fla.

**ENGLAND, Anthony W.** (May 15, 1942, Indianapolis, Ind., but considers Fargo, N.D., his hometown) — Civilian; B.S. and M.S. (geology and physics), Ph.D. (earth and planetary sciences); flight, mission specialist; Group 6, August 1967; resigned in August 1972 to accept position with the U.S. Geological Survey; rejoined NASA in 1979 as a scientist-astronaut; designated as a mission specialist on STS-24 (Spacelab 2).

**ENGLE, Joe H.** (Aug. 26, 1932, Chapman, Kans.) — Colonel, USAF; B.S. (aeronautical engineering); flight, pilot; Group 5, April 1966; commanded Enterprise Space Shuttle free-flight approach and landing tests 2 and 4, Sept. 13 and Oct. 12, 1977; commander STS-2, Nov. 12-14, 1981; Deputy Associate Administrator for Space Flight at NASA Headquarters, April-December 1982; returned to astronaut duties at the Johnson Space Center to begin training for his next Shuttle flight.

**EVANS, Ronald E.** (Nov. 10, 1935, St. Francis, Kans.) — Captain, USN (Ret.); B.S. (electrical engineering), M.S. (aeronautical engineering); Group 5, April 1966; Apollo 17; retired from Navy, April 1976; resigned from NASA, March 1977. Director, Space Systems Marketing for Sperry Flight Systems, Phoenix, Ariz.

**FABIAN, John M.** (Jan. 28, 1939, Goosecreek, Texas, but considers Pullman, Wash., his hometown) — Colonel, USAF; B.S. (mechanical engineering), M.S. (aerospace engineering), Ph.D. (aeronautics and astronautics); flight, mission specialist; Group 8, August 1979; mission specialist on STS-7, June 18-24, 1983.

**FISHER, Anna L.** (Aug. 24, 1949, St. Albans, N.Y., but considers San Pedro, Calif., her hometown) — Civilian; B.S. (chemistry), M.D.; flight, mission specialist; Group 8, August 1979.

**FISHER, William F.** (April 1, 1946, Dallas, Texas) — Civilian; B.A., M.S. (engineering), M.D.; flight, mission specialist; Group 9, August 1981.

**FREEMAN, Theodore C.** (Feb. 18, 1930, Haverford, Pa.) — Captain, USAF; B.S. from the U.S. Naval Academy, M.S. (aeronautical engineering); deceased; Group 3, October 1963; died in T-38 crash, Ellington AFB, Houston, Oct. 31, 1964.

**FULLERTON, C. Gordon** (Oct. 11, 1936, Rochester, N.Y.) — Colonel, USAF; B.S. and M.S. (mechanical engineering); flight, pilot; Group 7, August 1969; piloted Enterprise Space Shuttle free-flight approach and landing tests 1, 3 and 5 on Aug. 12, Sept. 23 and Oct. 26, 1977; pilot for STS-3, March 22-30, 1982.

**GARDNER, Dale A.** (Nov. 8, 1948, Fairmont, Minn., but considers Clinton, Iowa, his hometown) — Lieutenant commander, USN; B.S. (engineering physics); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist for STS-8.

**GARDNER, Guy S.** (Jan. 6, 1948, Alta Vista, Va.) — Major, USAF; B.S. (engineering sciences), M.S. (astronautics); flight, pilot; Group 9, August 1981.

**GARRIOTT, Owen K.** (Nov. 22, 1930, Enid, Okla.) — Civilian; B.S., M.S., and Ph.D. (electrical engineering); flight, mission specialist; Group 4, June 1965; Skylab 3; designated to serve as a mission specialist for STS-9 (Spacelab-1).

**GIBSON, Edward G.** (Nov. 8, 1936, Buffalo, N.Y.) — Civilian; B.S., M.S. (engineering), and Ph.D. (engineering and physics); Group 4, June 1965; Skylab 4; resigned, November 1974, then rejoined NASA in March 1977, and resigned again in October 1980. Advanced Systems Manager, TRW Inc., Redondo Beach, Calif.

**GIBSON, Robert L.** (Oct. 30, 1946, Cooperstown, N.Y., but considers Lakewood, Calif., his hometown) — Lieutenant commander, USN; B.S. (aeronautical engineering) flight, pilot; Group 8, August 1979; designated to serve as pilot for STS-11.

**GIVENS, Edward G.** (Jan. 5, 1930, Quanah, Texas) — Major, USAF; B.S. (naval sciences); deceased; Group 5, April 1966, died in an automobile accident near Houston, June 6, 1967.

**GLENN, John H. Jr.** (July 18, 1921, Cambridge, Ohio) — Colonel, USMC (Ret.); B.S. (engineering); Group 1, April 1959; Mercury 6; resigned from NASA, January 1964. Elected to the U.S. Senate in November 1974, where he now serves.

**GORDON, Richard F. Jr.** (Oct. 5, 1929, Seattle, Wash.) — Captain, USN (Ret.); B.S. (chemistry); Group 3, October 1963; Gemini 11, Apollo 12; retired from Navy and resigned from NASA, Jan. 1, 1972. President, Astro Systems & Engineering, Inc., Los Angeles, Calif.

**GRABE, Ronald J.** (June 13, 1945, New York City) — Major, USAF; B.S. (engineering science); flight, pilot; Group 9, August 1981.

**GRAVELINE, Duane E.** (March 2, 1931, Newport, Vt.) — Civilian, M.D.; resigned, August 1965; Group 4, June 1965.

**GREGORY, Frederick D.** (Jan. 7, 1941, Washington, D.C.) — Lieutenant colonel, USAF; B.S. from the U. S. Air Force Academy, M.S. (information systems); flight, pilot; Group 8, August 1979; designated to serve as pilot for STS-18 (Spacelab 3).

**GRIGGS, S. David** (Sept. 7, 1939, Portland, Ore.) — Civilian; B.S. from the U. S. Naval Academy, M.S. (administration); flight, pilot; Group 8, August 1979.

**GRISSOM, Virgil I.** (April 3, 1926, Mitchell, Ind.) — Lieutenant colonel, USAF; B.S. (mechanical engineering); deceased; Group 1, April 1959; Mercury 4, Gemini 3; died in Apollo spacecraft fire at Kennedy Space Center, Jan. 27, 1967.

**HAISE, Fred W. Jr.** (Nov. 14, 1933, Biloxi, Miss.) — Civilian; B.S. (aeronautical engineering); Group 5, April 1966; Apollo 13; commanded Enterprise Space Shuttle free-flight approach and landing tests 1, 3 and 5, Aug. 12, Sept. 23 and Oct. 26, 1977; resigned from NASA, June 1979. Vice President, Space Programs, Grumman Aerospace Corp., Bethpage, N.Y.

**HART, Terry J.** (Oct. 27, 1946, Pittsburgh, Pa.) — Civilian; B.S. and M.S. (mechanical engineering), and M.S. (electrical engineering); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist on STS-13.

**HARTSFIELD, Henry W. Jr.** (Nov. 21, 1933, Birmingham, Ala.) — Colonel, USAF (Ret.); B.S. (physics) and M.S. (engineering science); flight, pilot; Group 7, August 1969; retired from Air Force, August 1977. Pilot for STS-4, June 27-July 4, 1982; selected as commander for STS-12.

**HAUCK, Frederick H.** (April 11, 1941, Long Beach, Calif., but considers Winchester, Mass., and Washington, D.C., his hometowns) — Captain, USN; B.S. (physics) and M.S. (nuclear engineering); flight, pilot; Group 8, August 1979; pilot for STS-7, June 18-24, 1983.

**HAWLEY, Steven A.** (Dec. 12, 1951, Ottawa, Kans., but considers Salina, Kans., his hometown) — Civilian; B.A. (physics and astronomy) and Ph.D. (astronomy and astrophysics); flight, mission specialist; Group 8, August 1979; designated to serve as a mission specialist on STS-12.

**HENIZE, Karl G.** (Oct. 17, 1926, Cincinnati, Ohio) — Civilian; B.A. (mathematics), M.A. and Ph.D. (astronomy); flight, mission specialist; Group 6, August 1967; selected to serve as a mission specialist on STS-24 (Spacelab 2).

**HILMERS, David C.** (Jan. 28, 1950, Clinton, Iowa, but considers DeWitt, Iowa, his hometown) — Captain, USMC; B.S. (mathematics) and M.S. (electrical engineering); flight, mission specialist; Group 9, August 1981.

**HOFFMAN, Jeffrey A.** (Nov. 2, 1944, Brooklyn, N.Y., but considers Scarsdale, N.Y., his hometown) — Civilian; B.A. (astronomy) and Ph.D. (astrophysics); flight, mission specialist; Group 8, August 1979.

**HOLMQUEST, Donald L.** (April 7, 1939, Dallas, Texas) — Civilian; M.D., B.S. (electrical engineering) and Ph.D. (physiology); Group 6, August 1967; took leave of absence May 1971 to hold position of Assistant Professor of Radiology and Physiology, Baylor College of Medicine, Houston; resigned from NASA in September 1973. Now practices medicine on a full-time basis.

**IRWIN, James B.** (March 17, 1930, Pittsburgh, Pa.) — Colonel, USAF (Ret.); B.S. (naval science) and M.S. (aeronautical and instrumentation engineering); Group 5, April 1966; Apollo 15; resigned from NASA, August 1972. Chairman of Board, High Flight Foundation, Colorado Springs, Colo.

**KERWIN, Joseph P.** (Feb. 19, 1932, Oak Park, Ill.) — Captain, MC, USN; B.A. (philosophy), M.D.; flight, mission specialist; Group 4, June 1965; Skylab 2; currently NASA representative in Australia. At conclusion of this two-year assignment, Kerwin will return to astronaut duties at the Johnson Space Center.

**LEESTMA, David C.** (May 6, 1949, Muskegon, Mich., but considers Tustin, Calif., his hometown) — Lieutenant commander, USN; B.S. and M.S. (aeronautical engineering); flight, mission specialist; Group 9, August 1981.

**LENOIR, William B.** (Mar. 14, 1939, Miami, Fla.) — Civilian; B.S., M.S., and Ph.D. (electrical engineering); flight, mission specialist; Group 6, August 1967; mission specialist on STS-5, Nov. 11-16, 1982.

**LIND, Don L.** (May 18, 1930, Midvale, Utah) — Civilian; B.S. (physics), Ph.D. (physics); flight, pilot; Group 5, April 1966; designated as a mission specialist on STS-18 (Spacelab 3).

**LLEWELLYN, John A.** (April 22, 1933, Cardiff, Wales) — Civilian; Ph.D. (chemistry); resigned, August 1968; Group 6, August 1967.

**LOUNGE, John M.** (June 28, 1946, Denver, Colo., but considers Burlington, Colo., his hometown) — Civilian; B.S. (physics and mathematics), M.S. (astrogeophysics); flight, mission specialist; Group 9, August 1981.

**LOUSMA, Jack R.** (Feb. 29, 1936, Grand Rapids, Mich.) — Colonel, USMC; B.S. (aeronautical engineering); flight, pilot; Group 5, April 1966; Skylab 3, commander STS-3, March 22-30, 1982.

**LOVELL, James A. Jr.** (March 25, 1928, Cleveland, Ohio) — Captain, USN (Ret.); B.S. from the U.S. Naval Academy; Group 2, September 1962; Gemini 7, Gemini 12, Apollo 8, Apollo 13; served as Deputy Director of Science and Applications, Johnson Space Center, May 1971-March 1973; retired from the Navy and resigned from NASA, March 1, 1973. Group Vice President, Centel Corp., Chicago.

**LUCID, Shannon W.** (Jan. 14, 1943, Shanghai, China, but considers Bethany, Okla., her hometown) — Civilian; B.S. (chemistry), M.S. and Ph.D. (biochemistry); flight, mission specialist; Group 8, August 1979.

**MATTINGLY, Thomas K. II** (March 17, 1936, Chicago, Ill.) — Captain, USN; B.S. (aeronautical engineering); flight, pilot; Group 5, April 1966; Apollo 16; commander, STS-4 June 27-July 4, 1982; designated to serve as commander for STS-10.

**McBRIDE, Jon A.** (Aug. 14, 1943, Charleston, W.Va., but considers Beckley, W.Va., his hometown) — Commander, USN; B.S. (aeronautical engineering); flight, pilot; Group 8, August 1979.

**McCANDLESS, Bruce II** (June 8, 1937, Boston, Mass.) — Captain, USN; B.S. (naval sciences), M.S. (electrical engineering); flight, pilot; Group 5, April 1966; selected to serve as a mission specialist on STS-11.

**McDIVITT, James A.** (June 10, 1929, Chicago, Ill.) — Brig. General, USAF (Ret.); B.S. (aeronautical engineering); Group 2, September 1962; Gemini 4, Apollo 9; was Manager, Apollo Spacecraft Program, Johnson Space Center, September 1969-1972; retired from the Air Force and resigned from NASA, June 1972. Senior Vice President, Strategic Management, Rockwell International Corp., Pittsburgh, Pa.

**McNAIR, Ronald E.** (Oct. 21, 1950, Lake City, S.C.) — Civilian; B.S. and Ph.D. (physics); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist on STS-11.

**MICHEL, F. Curtis** (June 5, 1934, LaCrosse, Wis.) — Civilian; B.S. and Ph.D. (physics); Group 4, June 1965; resigned from NASA, August 1969. Department of Space Physics and Astronomy, Rice University, Houston, Texas.

**MITCHELL, Edgar D.** (Sept. 17, 1930, Hereford, Texas, but considers Artesia, N.M., his hometown) — Captain, USN (Ret.); B.S. (industrial management and aeronautical engineering), D.Sc. (aeronautics/astronautics); Group 5, April 1966; Apollo 14; retired from the Navy and resigned from NASA, Oct. 1, 1972. Chairman of Board, Forecast Systems, Inc., West Palm Beach, Fla.

**MULLANE, Richard M.** (Sept. 10, 1945, Wichita Falls, Texas, but considers Albuquerque, N.M., his hometown) — Lieutenant colonel, USAF; B.S. (military engineering), M.S. (aeronautical engineering); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist on STS-12.

**MUSGRAVE, F. Story** (Aug. 19, 1935, Boston, Mass., but considers Lexington, Ky., his hometown) — Civilian; B.S. (mathematics and statistics), B.A. (chemistry), M.B.A. (operations analysis and computer programming), M.D., M.S. (physiology and biophysics); flight, mission specialist; Group 6, August 1967; mission specialist on STS-6, April 4-9, 1983.

**NAGEL, Steven R.** (Oct. 27, 1946, Canton, Ill.) — Major, USAF; B.S. (aeronautical and astronautical engineering), M.S. (mechanical engineering); flight, pilot; Group 8, August 1979.

**NELSON, George D.** (July 13, 1950, Charles City, Iowa, but considers Willmar, Minn., his hometown) — B.S. (physics), M.S. and Ph.D. (astronomy); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist on STS-13.

**O'CONNOR, Bryan D.** (Sept. 6, 1946, Orange, Calif., but considers Twentynine Palms, Calif., his hometown) — Major USMC; B.S. (engineering), M.S. (aeronautical systems); flight, pilot; Group 9, August 1981.

**O'LEARY, Brian T.** (Jan. 27, 1949, Boston, Mass.) — Civilian; Ph.D. (astronomy); resigned, April 1968; Group 6, August 1967. Professor, Princeton University, Princeton, N.J.

**ONIZUKA, Ellison S.** (June 24, 1946, Kealakekua, Kona, Hawaii) — Major, USAF; B.S. and M.S. (aerospace engineering); flight, mission specialist; Group 8, August 1979; designated to serve as a mission specialist for STS-10.

**OVERMYER, Robert F.** (July 14, 1936, Lorain, Ohio, but considers Westlake, Ohio, his hometown) — Colonel, USMC; B.S. (physics), M.S. (aeronautics); flight, pilot; Group 7, August 1969; pilot for STS-5, Nov. 11-16, 1982; designated spacecraft commander for STS-18 (Spacelab 3).

**PARKER, Robert A.** (Dec. 14, 1936, New York City, but considers Shrewsbury, Mass., his hometown) — Civilian; B.A. (astronomy and physics), Ph.D. (astronomy); flight, mission specialist; Group 6, August 1967; designated to serve as a mission specialist for STS-9 (Spacelab 1).

**PETERSON, Donald H.** (Oct. 22, 1933, Winona, Miss.) — Colonel, USAF (Ret.); B.S. from the U.S. Military Academy, M.S. (nuclear engineering); flight, pilot; Group 7, August 1969; retired from Air Force, January 1980; mission specialist on STS-6, April 4-9, 1983.

**POGUE, William R.** (Jan. 23, 1930, Okemah, Okla.) — Colonel, USAF (Ret.); B.S. (education), M.S. (mathematics); Group 5, April 1966; Skylab 4; resigned from NASA, September 1975 and retired from Air Force, September 1975. Self-employed as a consultant to aerospace and energy firms.

**RESNIK, Judith A.** (April 5, 1949, Akron, Ohio) — Civilian; B.S. and Ph.D. (electrical engineering); flight, mission specialist; Group 8, August 1979; designated as a mission specialist on STS-12.

**RICHARDS, Richard N.** (Aug. 24, 1946, Key West, Fla.,, but considers St. Louis, Mo., his hometown) — Lieutenant commander, USN; B.S. (chemical engineering), M.S. (aeronautical systems); flight, pilot; Group 9, August 1981.

**RIDE, Sally K.** (May 26, 1951, Los Angeles, Calif.) — Civilian; B.A. (English), B.S., M.S. and Ph.D. (physics); flight, mission specialist; Group 8, August 1979; mission specialist on STS-7, June 18-24, 1983.

**ROOSA, Stuart A.** (Aug. 15, 1933, Durango, Colo.) — Colonel, USAF (Ret.); B.S. (aeronautical engineering); Group 5, April 1966; Apollo 14; resigned from NASA and retired from Air Force, Feb. 1, 1976. President and owner, Gulf Coast Coors, Inc., Gulfport, Miss.

**ROSS, Jerry L.** (Jan. 20, 1948, Crown Point, Ind.) — Captain, USAF; B.S. and M.S. (mechanical engineering); flight, mission specialist; Group 9, August 1981.

**SCHIRRA, Walter M. Jr.** (March 12, 1923, Hackensack, N.J.) — Captain, USN (Ret.); B.S. from the U.S. Naval Academy; Group 1, April 1959; Mercury 8, Gemini 6, Apollo 7; resigned from NASA and retired from Navy in July 1969. President, Schirra Enterprises.

**SCHMITT, Harrison H.** (July 3, 1935, Santa Rita, N.M.) — Civilian; B.S. (science), Ph.D. (geology); Group 4, June 1965; Apollo 17; Special Assistant to NASA Administrator for Energy Research and Development, February 1974; appointed NASA Assistant Administrator for Energy Programs, May 1974; resigned from NASA, August 1975. Elected U.S. Senator from New Mexico in November 1976; defeated for reelection in November 1982.

**SCHWEICKART, Russell L.** (Oct. 25, 1935, Neptune, N.J.) — Civilian; B.S. (aeronautical engineering), M.S. (aeronautics and astronautics); Group 3, October 1963; Apollo 9; transferred to NASA Headquarters, Washington, D.C., May 1, 1974; detailed to California Governor in 1977 under Intergovernmental Personnel Act; resigned from NASA, August 1979. Chairman, California Energy Commission, Sacramento, Calif.

**SCOBEE, Francis R.** (May 19, 1939, Cle Elum, Wash.) — Major, USAF, (Ret.); B.S. (aerospace engineering); flight, pilot; Group 8, August 1979; retired from Air Force, January 1980; designated to serve as pilot for STS-13.

**SCOTT, David R.** (June 6, 1932, San Antonio, Texas) — Colonel, USAF (Ret.); B.S. from the U.S. Military Academy, M.S. (aeronautics and astronautics); Group 3, October 1963; Gemini 8, Apollo 9, Apollo 15; Special Assistant for Mission Operations, Apollo Spacecraft Program Office, Johnson Space Center, July 1972-August 1973; Deputy Director, Dryden Flight Research Center, Edwards, Calif., August 1973-April 1975; appointed Center Director 1975; resigned from NASA, October 1977. President, Scott Science & Technology, Inc., Lancaster, Calif.

**SEDDON, Margaret R.** (Nov. 8, 1947, Murfreesboro, Tenn.) — Civilian; B.A. (physiology), M.D.; flight, mission specialist; Group 8, August 1979.

**SEE, Elliott M. Jr.** (July 23, 1927, Dallas, Texas) — Civilian; B.S. from the U.S. Merchant Marine Academy, M.S. (engineering); deceased; Group 2, September 1962; died in T-38 crash with Charles Bassett, Feb. 28, 1966, Lambert Municipal Airport, St. Louis.

**SHAW, Brewster H. Jr.** (May 16, 1945, Cass City, Mich.) — Major, USAF; B.S. and M.S. (engineering mechanics); flight, pilot; Group 8, August 1979; designated pilot for STS-9 (Spacelab 1).

**SHEPARD, Alan B. Jr.** (Nov. 18, 1923, East Derry, N.H.) — Rear Admiral, USN (Ret.); B.S., U.S. Naval Academy; Group 1, April 1959; Mercury 3, Apollo 14; resigned from NASA and retired from Navy, Aug. 1, 1974. President, Windward Co., Deer Park, Texas.

**SHRIVER, Loren J.** (Sept. 23, 1944, Jefferson, Iowa, but considers Paton, Iowa to be his hometown) — Major, USAF; B.S. (aeronautical engineering), M.S. (astronautical engineering); flight, pilot; Group 8, August 1979; designated to serve as pilot for STS-10.

**SLAYTON, Donald K.** (March 1, 1924, Sparta, Wis.) — Major; USAF (Reserve); B.S. (aeronautical engineering); Group 1, April 1959; Apollo-Soyuz Test Project; was Manager for Orbital Flight Tests, Space Shuttle Program Office, Johnson Space Center; retired from NASA, February 1982. Vice Chairman of the Board, Space Services, Inc., and a consultant to aerospace corporations.

**SMITH, Michael J.** (April 30, 1945, Morehead City, N.C.) — Commander, USN; B.S. (naval science), M.S. (aeronautical engineering); flight, pilot; Group 9, August 1981.

**SPRING, Sherwood C.** (Sept. 3, 1944, Hartford, Conn., but considers Harmony, R.I., his hometown) — Major, USA; B.S. (general engineering), M.S. (aerospace engineering); flight, mission specialist; Group 9, August 1981.

**SPRINGER, Robert C.** (May 21, 1942, St. Louis, Mo., but considers Ashland, Ohio, his hometown) — Lt. Colonel, USMC; B.S. (naval science), M.S. (operations research and systems analysis); flight, mission specialist; Group 9, August 1981.

**STAFFORD, Thomas P.** (Sept. 17, 1930, Weatherford, Okla.) — Lieutenant general, USAF (Ret.); B.S. from the U.S. Naval Academy; Group 2, September 1962; Gemini 6, Gemini 9, Apollo 10, Apollo-Soyuz Test Project; resigned from NASA, November 1975 and retired from Air Force, Nov. 1, 1979. Vice Chairman, Gibraltar Exploration, Ltd., Oklahoma City.

**STEWART, Robert L.** (Aug. 13, 1942, Washington, D.C. but considers Arlington, Texas, his hometown) — Lieutenant colonel, USA; B.S. (mathematics), M.S. (aerospace engineering); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist on STS-11.

**SULLIVAN, Kathryn D.** (Oct. 3, 1951, Paterson, N.J., but considers Woodland Hills, Calif., her hometown) — Civilian, B.S. (earth sciences), Ph.D. (geology); flight, mission specialist; Group 8, August 1979.

**SWIGERT, John L. Jr.** (Aug. 30, 1931, Denver, Colo.) — Civilian; B.S. (mechanical engineering), M.S. (aerospace science), M.B.A.; Group 5, April 1966; Apollo 13; resigned from NASA, July 1978. Staff Director, Committee on Science and Astronautics, House of Representatives, April 1973-September 1977. In November 1982, won the new seat for Colorado's Sixth Congressional District; died of complications from cancer in Washington, Dec. 27, 1982, a week before he would have taken the congressional seat he won in the November election.

**THAGARD, Norman E.** (July 3, 1943, Marianna, Fla., but considers Jacksonville, Fla., his hometown) — Civilian; B.S. and M.S. (engineering science), M.D.; flight, mission specialist; Group 8, August 1979; mission specialist on STS-7, June 18-24, 1983; designated a mission specialist for STS-18 (Spacelab 3).

**THORNTON, William E.** (April 14, 1929, Faison, N.C.) — Civilian; B.S. (physics), M.D.; flight, mission specialist; Group 6, August 1967; selected to serve as a mission specialist for STS-8 and STS-18 (Spacelab 3).

**TRULY, Richard H.** (Nov. 12, 1937, Fayette, Miss.) — Captain; USN; B.S. (aeronautical engineering); flight, pilot; Group 7, August 1969; piloted Enterprise Space Shuttle free-flight approach and landing tests 2 and 4 on Sept. 13 and Oct. 12, 1977; pilot on STS-2 Nov. 12-14, 1981; designated spacecraft commander for STS-8.

**VAN HOFTEN, James D.** (June 11, 1944, Fresno, Calif., but considers Burlingame, Calif., his hometown) — Civilian; B.S. (civil engineering), M.S. (hydraulic engineering) and Ph.D. (fluid mechanics); flight, mission specialist; Group 8, August 1979; selected to serve as a mission specialist on STS-13.

**WALKER, David M.** (May 20, 1944, Columbus, Ga., but considers Eustis, Fla., his hometown) — Commander, USN; B.S. from the U.S. Naval Academy; flight, pilot; Group 8, August 1979.

**WEITZ, Paul J.** (July 25, 1932, Erie, Pa.) — Captain; USN (Ret.); B.S. and M.S. (aeronautical engineering); flight, pilot; Group 5, April 1966; Skylab 2; retired from Navy, June 1976; commander of STS-6, April 4-9, 1983.

**WHITE, Edward H. II** (Nov. 14, 1930, San Antonio, Texas) — Lieutenant colonel, USAF; B.S. from the U.S. Military Academy, M.S. (aeronautical engineering); deceased; Group 2, September 1962; Gemini 4; died in Apollo spacecraft fire at Kennedy Space Center Jan. 27, 1967.

**WILLIAMS, Clifton C. Jr.** (Sept. 26, 1932, Mobile, Ala.) — Major, USMC; B.S. (mechanical engineering); deceased; Group 3, October 1963; died in T-38 crash near Tallahassee, Fla., Oct. 5, 1967.

**WILLIAMS, Donald E.** (Feb. 13, 1942, Lafayette, Ind.) — Commander, USN; B.S. (mechanical engineering); flight, pilot; Group 8, August 1979.

**WORDEN, Alfred M.** (Feb. 7, 1932, Jackson, Mich.) — Colonel, USAF (Ret.); B.S. (military science) from the U.S. Military Academy, M.S. (astronautical/aeronautical engineering and instrumentation engineering); Group 5, April 1966; Apollo 15; 1972-1973 Senior Aerospace Scientist, Ames Research Center, Mountain View, Calif.; 1973-1975, Chief, Systems Studies Division at Ames; resigned from Air Force and NASA, September 1975. President, Alfred M. Worden, Inc., Palm Beach Gardens, Fla.

**YOUNG, John W.** (Sept. 24, 1930, San Francisco, Calif.) — Captain, USN (Ret.); B.S. (aeronautical engineering); flight, pilot; Group 2, September 1962; retired from Navy in September 1976; Gemini 3, Gemini 10, Apollo 10, Apollo 16, STS-1; Chief, Astronaut Office, Johnson Space Center, Houston; commander on STS-1, April 12-14, 1981; designated as commander STS-9 (Spacelab 1).

25th Anniversary
1958-1983



# *Fine Arts Program*

# NASA ART PROGRAM

by

Sarah G. Keegan

Following a tradition dating from the days of Valley Forge and the Civil War period, contemporary artists in the NASA Art Program are providing an archival record of a significant aspect of American history.

These artists are on the scene at fiery launch pads and desert landing sites, vying for space with wire service reporters and network camera crews, to capture their impressions of events in the U.S. space program.

In the early days of NASA it was known that space activities would be documented widely in still photographs and motion pictures. James E. Webb, NASA's second Administrator, saw the need, though, to record the "spirit as well as the sights of the space age."

The NASA Art Program was instituted at Webb's recommendation in 1962 with the goals of collecting a unique documentation of America's advance into space and providing a special contribution to the history of American art. Advice was furnished by Dr. Lester H. Cooke, then-curator of painting at the National Gallery of Art.

Nationally known artists were invited to visit NASA sites and record their perceptions in drawings and paintings, which would then be donated to the government.

The first event to which artists were dispatched was Gordon Cooper's final Mercury flight in May 1963. The artists covered the activity side-by-side with news media representatives; seven artists were assigned to Cape Canaveral and one witnessed the capsule recovery in the Pacific.

One month later NASA received a group of 60 preliminary sketches. The set included pen and ink working sketches and charcoal and wash drawings. Each conveyed the impressions of the individual artist from his particular vantage at the launch or recovery site.

As Robert Schulman, the present director of the NASA Art Program recalls: "NASA made it possible for selected artists to be present at Cape Canaveral as astronauts suited up for their flights and were launched into space, and they were at Houston Mission Control during the moon landing. Artists were aboard recovery ships when the astronauts returned to earth from their long voyages. Artists have piloted Lunar Module simulators to make-believe moons. In short NASA has tried to provide them every possible view and experience."

The visual documentation of space activities continued through the Gemini and Apollo programs. Such well-known figures as Norman Rockwell, James Wyeth and Robert Rauschenberg added their own perceptions to the burgeoning archives of America's advance into space.

The NASA Art Program waned with the decline of manned space flight activities after the Apollo program, until 1977 when Schulman was asked to revive it. The reason -- the advent of a new era in the U.S. adventure in space -- the age of the Space Shuttle.

Makeshift easels and sketch pads began appearing on NASA sites again during the free flight phase of the Shuttle Approach and Landing Tests. By the time of the first Space Shuttle launch in April 1981, the art program was back in full swing. For that flight, seven artists were on hand at the launch site and three awaited the spaceship's return in California's Mojave Desert.

The group of about 40 artists who have participated in the art program since its renewal during the Shuttle development period covers the spectrum of artistic fame and styles. Some of the artists' names are household words; others are known mainly in the areas where the artists live and work. The style of their work ranges from the strictly representational to the abstract, from near-photographic realism to the bold strokes of luminous color more typical of impressionism.

Currently five artists are dispatched to each Shuttle launch: one is permitted in the room with the astronauts while they are suiting up and others are scattered around the pad at various sites. Smaller teams attend the landings.

Some artists crowd into prelaunch press conferences to view the Shuttle program from this perspective. Others troop through aerospace plants between missions to acquire that part of the Shuttle experience.

Each artist receives a $1,500 honorarium to cover the expenses of attending an event. In return, NASA receives all on-site sketches and one major work inspired by the visit.

Obviously it is not the pay that attracts artists to the program. As Schulman notes: "After their first night at a launch, they're so excited they would work for nothing. They want to feel they are making a personal artistic contribution to the Shuttle era."

At present NASA is considering the possibility of carrying private citizens as space is available on future Shuttle flights. Recommendations of an advisory group suggest flying observers who could effectively communicate the experience, and thus carry out NASA's mandate to disseminate widely information on its activities.

Schulman, an artist himself, is enthusiastic about this issue's potential effect on the NASA Art Program. "I'm looking forward to the day when they call me up and tell me to get an artist team ready for the next trip to the space station," he says. "You know what? I'll go."

A major collection of almost 100 works documenting the history of the Shuttle era has been on display at the National Air and Space Museum in Washington, D.C., since last December. The paintings cover the period from the 1977 Approach and Landing Tests to the November 1982 touchdown of the fifth Shuttle mission.

The exhibit, titled "The Artist and the Space Shuttle," includes works of 40 American artists, among whom are Robert McCall, Lamar Dodd, Jack Perlmutter, Robert Rauschenberg, Arthur Shilstone and Henry Casselli. Interestingly, McCall and Dodd have been involved in the NASA Art Program since its inception: both covered Cooper's 1963 Mecury flight.

The Shuttle art display will leave the National Air and Space Musuem in September for a national tour, which is being arranged by the Smithsonian Institution Traveling Exhibition Service. The first stop will be the University of Houston at Clear Lake in Texas where the collection will be featured from Oct. 15 through Nov. 27.

The NASA Art Program, as exemplified by this collection, continues to serve as a vehicle to garner a unique archives of one of America's most exciting periods. Each artist's personal vision of an event is conveyed in his or her particular style and becomes a part of this documentary history of the space age.

As pointed out by Cooke, as he guided the establishment of the NASA Art Program: "Perhaps this project will help prove - that the U.S. produced ... not only the engineers and scientists capable of shaping the destiny of our age but also the artists worthy to keep them company."

(A list of artists who have participated in the NASA Art Program through the eighth Shuttle mission is attached.)

## ARTISTS PARTICIPATING IN THE NASA ART PROGRAM THROUGH THE EIGHTH SHUTTLE MISSION

Paul Arlt
Chesley Bonestell
Neil Boyle
J. Robert Burnell
Paul Calle
Henry Casselli
Vincent Cavallaro
Ron Cobb
Alan E. Cober
Mario Cooper
Hans Cremers
Jim Cunningham
James Dean
Leonard Dermott
Carol Dick
Lamar Dodd
Bart Doe
Maria Epes
Julio Fernandez
Fred Freeman
Dennis Frings
Nick Galloway
Gay Glading
Frank Germain
Sheila Hamanaka
Theodore Hancock
Attila Hejja
James P. Hendricks
Martin Hoffman
Peter Hurd
Wilson Hurley
Billy Morrow Jackson
Chrystal Jackson
Mitchell Jamieson
Chet Jezierski
Susan Kaprov
L. Katzen
Michael Kendall
Chris Kenyon
Yeffe Kimball
Dong Kingman
Howard Kowlow
Francis J. Krasyk
Morton Kunstler
Hugh Laidman
Sara Larkin
Ingrid Leeds
Fletcher Martin
Alfred McAdams
M. McCaffrey
Robert McCall
John W. McCoy II
Franklin McMahon
Mark McMahon
John Meigs
Fred Messersmith
Dale Meyers
Pierre Mion
Greg Mort
Lowell Nesbitt
Tom Newsom
Andreas Nottebohm
Tom O'Hara
Jack Perlmutter
Ludek Pesek
Bill Phillips
John Pike
Jerry Pinkney
Henry C. Pitz
Clayton Pond
Robert Rauschenberg
Linda R. Richards
Bill Robles
Norman Rockwell
Paul Salmon
Paul Sample
Charles Schmidt
Miriam Schottland
Robert Schulman
Arthur Shilstone
Robert Shore
Nicholas Solovioff
Tracy Sugarman
Walter Taylor
William Thon
George Weymouth
Alden Wicks
Ren Wicks
John Willenbecher
William Woodward
Frank Wright
James Wyeth

25th Anniversary
1958-1983



# *Special Quotes*

# SIGNIFICANT QUOTATIONS FROM NASA'S FIRST 25 YEARS

Compiled by
Stuart W. Rosenbaum

Robert H. Goddard
"The Father of Modern Rocketry"

"It is difficult to say what is impossible for the dream of yesterday is the hope of today and the reality of tomorrow."

T. Keith Glennan
First NASA Administrator, 1958.
Commenting on Project Mercury.

"Let's get on with it."

President John F. Kennedy
May 21, 1961
Excerpts from his Address to the Congress.

"Space is open to us now, and our eagerness to share its meaning is not governed by the efforts of others... we go into space because whatever mankind must undertake; free men must fully share.

"...I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind or more important to the long-range exploration of space...

"In a very real sense it will not be one man going to the moon; if we make this judgement affirmatively, it will be an entire nation...if we are to go only half-way or reduce our sights in the face of difficulty, in my opinion it would be better to not go at all...

"...For while we cannot guarantee that one day we shall be first, we can guarantee that any failure to make this effort will surely make us last..."

Mercury Redstone 3
May 5, 1961
Alan Shepard, America's first man in space.

"Roger, lift-off and the clock has started..."
Apollo 8.
Dec. 21-27, 1968.
Astronauts Frank Borman, James Lovell, William Anders.
First human lunar orbital flight. Dec. 24, 1968.

Borman: "The crew of Apollo 8 has a message that we would like to send to you.

Anders: "In the beginning God created the Heaven and the earth. And the earth was without form and void and darkness was upon the face of the deep. And the spirit of God moved upon the face of the waters and God said, let there be light. And there was light. And God saw the light and that it was good and God divided the light from the darkness.

Lovell: "And God called the light day and the darkness he called night. And the evening and the morning were the first day. And God said, let there be a firmament in the midst of the waters. And let it divide the waters from the waters. And God made the firmament and divided the waters which were above the firmament. And it was so. And God called the firmament Heaven and evening and morning were the second day.

Borman: "And God said let the waters under the Heavens be gathered together in one place. And the dry land appear. And it was so. And God called the dry land earth. And the gathering together of the waters called he seas. And God saw that it was good.

"And from the crew of Apollo 8, we pause with good night, good luck, a Merry Christmas and God Bless all of you, all of you on the good earth.

Apollo 11.
July 16-24, 1969.
Astronauts Neil A. Armstrong, Buzz Aldrin, Michael Collins.
First words from Tranquility Base, first manned lunar landing, 5:18 p.m., EDT

Capcom: (Charles Duke)"We copy you down Eagle."
Eagle: "Tranquility base here, the Eagle has landed."

Capcom: "Tranquility, we copy you on the ground. You've got a bunch of guys about to turn blue. We're breathing again, thanks a lot."

Apollo 11.
July 20, 1969
Neil Armstrong's first words upon stepping on the surface of the moon.

"That's one small step for a man, one giant leap for mankind."

Apollo 11.
July 20, 1969
Lunar Module Pilot Buzz Aldrin comments on scenery on the moon.

"Magnificent desolation."

Apollo 11.
July 20, 1969
President Richard M. Nixon speaks to astronauts Aldin and Armstrong by phone.

"For one priceless moment in history, the world is truly one; one in our pride and admiration in what you have done, and one in our hopes and prayers that you will safely return to us."

Apollo 13.
April 11 - 17, 1970
Astronauts: James A. Lovell, Fred W. Haise John L. Swigert
Apollo 13 was the first space mission to experience an emergency in space. Command Module Pilot Jack Swigert gave the first intimation of serious trouble for Apollo 13, 200,000 miles from earth when a cryogenic oxygen tank exploded, crippling the mission.

" Hey, we've got a problem here."

Skylab 4
Nov. 16, 1973 - Feb. 8, 1974.
Astronauts Gerald Carr, Edward Gibson and William Pogue manned Skylab space station for 84 days.

Edward Gibson makes an observation about earth.

"Being up here and being able to see the stars and look back at the earth and see your own sun as a star makes you ... realize the universe is quite big, and just the number of possible combinations... which can create life enters your mind and makes it seem much more likely."

William Pogue comments on life on earth:

"I now have a new orientation... of almost a spiritual nature. My attitude towards life and towards my family is going to change. When I see people, I try to see them as operating human beings and try to fit myself into a human situation instead of trying to operate like a machine."

STS-1
April 12, 1981.
Astronauts John Young and Robert Crippen man America's first Space Shuttle "Columbia" on its first space flight.

"The dream is alive again."

STS-4
June 27-July 4, 1982
President Ronald Reagan comments upon the conclusion of the fourth and final test flight of the space shuttle "Columbia", piloted by Thomas Mattingly and Henry Hartsfield."

" In the future, as in the past, our freedom, independence and national well-being will be tied to new achievements, new discoveries and pushing back frontiers. The fourth landing of the Columbia is the historical equivalent to the driving of the golden spike which completed the first transcontinental railroad. It marks our entrance into a new era. The test flights are over, the groundwork has been laid, now we will move forward to capitalize on the tremendous potential offered by the ultimate frontier of space..."

"... We also honor two pathfinders. They reaffirm to all of us that as long as there are frontiers to be explored and conquered, Americans will lead the way. They and the other astronauts have shown the world that Americans still have the know-how and Americans still have the true grit that tamed a savage wilderness."

STS-5
Nov. 11-16, 1982
Astronauts Vance Brand, Robert Overmyer, Joseph Allen and William Lenoir comment on deployment of Satellite Business System's satellite SBS-3.

" We deliver."

25th Anniversary
1958-1983

# *Administrator Biogs*

# NASA ADMINISTRATORS

by
Barbara E. Selby

Six administrators have guided the National Aeronautics and Space Administration in its 25-year history.

The NASA Administrator is charged with responsibility for all functions and authorities assigned to the agency. The Deputy Administrator is the Administrator's principal assistant acting under delegations of authority and assignments of responsibility from the Administrator. During the Administrator's absence the Deputy Administrator serves as Acting Administrator.

## T. KEITH GLENNAN

First Administrator of NASA
(Aug. 19, 1958 — Jan. 20, 1961)

T. (Thomas) Keith Glennan became the first Administrator of the National Aeronautics and Space Administration, established Oct. 1, 1958, under the National Aeronautics and Space Act of 1958. He served in this position until Jan. 20, 1961.

As Administrator, Glennan headed a staff of scientists, engineers, technicians and other employees engaged in research and development in aeronautics and space matters. In this position he was a member of the President's National Aeronautics and Space Council.

Glennan was president-on-leave of the Case Institute of Technology, Cleveland, Ohio, which he had headed since 1947.

Born in Enderlin, N.D., in 1905, Glennan earned a degree in electrical engineering from the Sheffield Scientific School of Yale University in 1927.

Following graduation, Glennan became associated with the newly developed sound motion picture industry, and later became assistant general service superintendent for Electrical Research Products Co., a subsidiary of Western Electric Co. During his career he was studio manager of Paramount Pictures, Inc., and Samuel Goldwyn Studios, and was briefly on the staff of Vega Airplane Corp.

Glennan joined the Columbia University Division of War Research in 1942, serving through the war, first as Administrator and then as Director of the U.S. Navy's Underwater Laboratories at New London, Conn. For his work he was awarded the Medal of Merit.

At the end of World War II, Glennan became an executive of Ansco, Binghamton, N.Y. From this position he was named president of Case. During his 11-year administration, Case rose from a primarily local institution to rank with the top engineering schools in the nation. From October 1950 to November 1952, concurrent with his Case presidency, he served as a member of the Atomic Energy Commission.

Active in national and civic affairs, Glennan was chairman of the board of the Institute of Defense Analysis, on the board of the National Science Foundation, and the Council on Financial Aid to Education. In Cleveland he took an important part in many civic activities.

Glennan is a Fellow of the American Academy of Arts and Sciences, and a member of Sigma Xi, Tau Beta Phi and Chi Phi. He has been awarded several honorary doctorate degrees.

Glennan is married to the former Ruth Haslup Adams. They have four children.

After leaving NASA, Glennan returned as President from his leave of absence at the Case Institute of Technology, Cleveland. His service extended from 1947-69. From 1970 to 1973, he served as the U.S. Representative, with the rank of Ambassador, to the International Atomic Energy Agency, Vienna, Austria. Although retired, Glennan presently serves on numberous boards.

**JAMES E. WEBB**

Second Administrator of NASA

(Feb. 14, 1961 - Oct. 8, 1968)

James Edwin Webb served as NASA's second Administrator from Feb. 14, 1961, to Oct. 8, 1968.

In addition to his distinguished service as Administrator, Webb had held other important positions in government. Early in his career he served as secretary to Congressman Edward W. Pou of North Carolina, who was Chairman of the House Rules Committee. Immediately after World War II he was successively Executive Assistant to the Under Secretary of the Treasury, Director of the U.S. Bureau of the Budget and Under Secretary of State. During and since his service as Administrator of NASA he has served in numerous government commissions, committees and panels.

In the business world, Webb has served as Personnel Director, Treasurer and Vice President of the Sperry Gyroscope Co., and as a director of Sperry Rand Corp.; as President of the Republic Supply Co.; as Assistant to the President of Kerr-McGee Corp. and as a director of that company; as a director of Gannett Co., Inc., Rochester, N.Y.; and of McGraw-Hill, Inc., New York City. He is currently a director of Computer Data Systems, Inc., Washington, D.C. and of Kerr Consolidated, Oklahoma City, Okla.

In the area of public service, Webb is a Trustee of the National Geographic Society, of the Kerr Foundation and is a Regent of the Smithsonian Institution.

He has received numerous awards and honors, including the Presidential Medal of Freedom, the Gardner Greene Hubbard-National Geographic Society Medal, the Oklahoma State University Bennett Medal, the Robert H. Goddard Memorial Trophy, the Collier Trophy, the General Accounting Office Award for Public Service, the North Carolina Public Service Award and U.S. Military Academy's Sylvanus Thayer Award.

He is a member of the Oklahoma Hall of Fame, the American and District of Columbia Bar Associations, the National Academy of Public Administration, American Judicature Society, the American Astronautical Society and the International Academy of Astronautics.

Webb's military service, active and reserve, spanned 37 years. From 1930 to 1932 he was on active duty first as a student and then as a naval aviator with the Marine Corps. There followed 12 years of reserve duty as a junior officer in the Marine Corps before he returned to active duty during World War II as a major. He returned to the Marine Corps reserve in 1950 as a lieutenant colonel, in which role he served until 1966, when he retired.

Born in Granville County, N.C., Oct. 7, 1906, Webb attended Oxford High School, Oxford, N.C. He received a bachelor's degree in education from the University of North Carolina in 1928. He studied law at George Washington University and was admitted to the Bar of the District of Columbia in 1936.

Webb is married to the former Patsy Aiken Douglas. They have two children, Sarah Gorham and James Edwin Jr.

Since his retirement from NASA, Webb has been engaged in legal work with an office in Washington and in the preparation of his papers which he has given to the Truman Library in Independence, Mo.

**THOMAS O. PAINE**

Third Administrator of NASA
(March 21, 1969 - Sept. 15, 1970)

Dr. Thomas O. Paine was appointed Deputy Administrator of NASA on Jan. 31, 1968. Upon the retirement of James E. Webb on Oct. 8, 1968, he was named Acting Administrator of NASA. He was nominated as NASA's third Administrator March 5, 1969, and confirmed by the Senate on March 20, 1969.

During his leadership the first seven Apollo manned missions were flown, in which 20 astronauts orbited the earth, 14 traveled to the moon and four walked upon its surface. Many automated scientific and applications spacecraft were also flown in United States and cooperative international programs.

Paine resigned from NASA Sept. 15, 1970, to return to the General Electric Co. in New York City as Vice President and Group Executive, Power Generation Group, where he remained until 1976.

Paine began his career as a research associate at Stanford University from 1947 to 1949, where he made basic studies of high-temperature alloys and liquid metals in support of naval nuclear reactor programs. He joined the General Electric Research Laboratory in Schenectady, N.Y., in 1949 as research associate, where he initiated research programs on magnetic and composite materials. In 1951, he transferred to the Meter and Instrument Department, Lynn, Mass., as manager of materials development, and later as laboratory manager. Under Paine's management the laboratory received the 1956 Award for Outstanding Contribution to Industrial Science from the American Association for Advancement of Science for its work in fine-particle magnet development.

From 1958 to 1962, Paine was research associate and manager of Engineering Applications at G.E.'s Research and Development Center in Schenectady. From 1963 to 1968 he was manager of TEMPO, G.E.'s Center for Advanced Studies in Santa Barbara, Calif.

Paine's professional activities have included chairmanship of the 1962 Engineering Research Foundaton - Engineers Joint Council Conference on Science and Technology for Less Developed Nations; secretary and editor of the E.J.C. Committee on the Nation's Engineering Research Needs 1965-1985; member, Advisory Committee and local chairman, Joint American Physical Society - Institute of Electrical and Electronics Engineers International Conference on Magnetism and Magnetic Materials; chairman, Special Task Force for U.S. Department of Housing and Urban Development; Advisory Board, AIME "Journal of Metals;" member, Basic Science Committee of IEEE, Research Committee of the Stanford University School of Engineering, and Board of Scientific Advisors of the Quarterly Journal "Research Policy." He is a member of numerous professional societies.

Paine was born in Berkeley, Calif., Nov. 9, 1921, son of Commodore and Mrs. George T. Paine, USN (Ret.). He attended public schools in various cities and was graduated from Brown University in 1942 with a bachelor's degree in engineering. From 1946-49 Paine attended Stanford University, receiving his master's degree in 1947 and doctorate in physical metallurgy. He has received honorary doctor of science degrees from Brown University, Clarkson College of Technology, Nebraska Wesleyan University, the University of New Brunswick (Canada), Oklahoma City University, and an honorary doctor of engineering degree from Worcester Polytechnic Institute.

In World War II he served as a submarine officer in the Pacific and in the Japanese occupation. He qualified in submarines and as a Navy deep-sea diver and was awarded the Commendation Medal and Submarine Combat Insignia with Stars.

Paine is married to the former Barbara Helen Taunton Pearse of Perth, Western Australia. They have four children: Marguerite Ada, George Thomas, Judith Janet and Frank Taunton.

Paine is now president of Thomas Paine Associates High Tech Consulting Co., Los Angeles, Calif.

## JAMES C. FLETCHER

Fourth Administrator of NASA
(April 27, 1971 - May 1, 1977)

Dr. James C. Fletcher became Administrator of NASA on April 27, 1971. He was the fourth man to head the nation's civilian space agency.

Fletcher began his career as a research physicist with the U.S. Navy Bureau of Ordnance. He became a special research associate at Cruft Laboratory, Harvard University. In 1942 he became an instructor at Princeton University.

In 1948, Fletcher joined the Hughes Aircraft Co. where he served for six years. Later he joined Ramo-Wooldridge Corp.'s Guided Missile Research Division which later became Space Technology Laboratories. In July 1958, with an associate Fletcher organized and was first president of the Space Electronics Corp. at Glendale, Calif., which developed and produced the Able Star stage of the Thor-Able space carrier. After a merger with a portion of Aerojet, Fletcher became President and then chairman of the newly formed Space General Corp. He later also served as Systems Vice President of Aerojet General Corp.

In 1964 he became the eighth president of the University of Utah, a post he held for seven years.

As a research scientist, Fletcher has developed patents in sonar devices and missile guidance systems. He has been associated with the President's Science Advisory Committee, nine years as a member of subcommittees and four years as a member of the Committee itself, and has served on several Presidential Task Forces and other government-industry committees.

He is a Fellow of the Institute of Electrical and Electronics Engineers, American Institute of Astronautics and Aeronautics, the American Academy of Arts and Sciences, the American Astronautical Society and was elected to the National Academy of Engineering. He was a recipient of the first Distinguished Alumni Award of the California Institute of Technology and holds an Honorary Doctorate from the University of Utah.

Fletcher was born June 5, 1919, in Millburn, N.J. He received a bachelor's degree in physics from Columbia University in 1940 and a doctorate in physics from the California Institute of Technology in 1948.

Fletcher is married to the former Fay Lee of Brigham City, Utah. They are the parents of three daughters and one son.

After leaving NASA, he became William K. Whiteford Professorship of Technology and Energy Resources at the University of Pittsburgh. He remains at this position.

## ROBERT A. FROSCH

Fifth Administrator of NASA
(June 21, 1977 - Jan. 20, 1981)

Dr. Robert A. Frosch was nominated by the President on May 23, 1977, to become NASA's fifth Administrator. He took his oath of office as head of the agency and entered the new post on June 21, 1977.

Before coming to NASA, he was Associate Director for Applied Oceanography at Woods Hole Oceanographic Institution from 1975 until mid-1977.

He served as Assistant Executive Director of the United Nations Environment Program from 1973 to 1975. From 1966 to 1973, Frosch was Assistant Secretary of the Navy for research and development.

From 1963 to 1965, Frosch was director of nuclear test detection at the Defense Department's Advanced Research Projects Agency and from 1965 to 1966 he was Deputy Director of the Agency.

He joined Columbia's Hudson Laboratories in 1951, working on naval research projects as a research scientist. He became Director of Hudson Laboratories in 1956, remaining in that post until 1963.

Born May 22, 1928, in New York City, Frosch earned a bachelor's degree in 1947, a master's degree in 1949 and a doctorate in 1952 in theoretical physics, all from Columbia University in New York.

Frosch has served as Department of Defense member of the Committee for Policy Review of the National Council on Marine Resources and Engineering Development, and was chairman of the U.S. delegation to the International Oceanographic Commission meetings at UNESCO in Paris in 1967 and 1970.

He is a recipient of the Arthur S. Flemming Award, the Navy Distinguished Public Service Award, the Defense Meritorious Civilian Service Medal and the Neptune Award of the American Oceanic Organization. He is a member of Phi Beta Kappa and Sigma Xi honorary fraternities.

He is a fellow of the American Association for the Advancement of Science, the Acoustical Society of America and the Institute of Electrical and Electronics Engineers, and a member of the National Academy of Engineering, American Physical Society, Seismological Society of America, Marine Technology Society, Society of Naval Architects and Marine Engineers, Society of Exploration Geophysicists, and the American Geophysical Union.

Frosch is married to the former Jessica Rachael Denerstein of Brooklyn, N.Y. They have two daughters, Elizabeth Ann and Margery Ellen.

After leaving NASA, Frosch became President of the American Association of Engineering Societies, New York City. He is now Vice President of General Motors, General Motors Research Laboratories, Warren, Mich.

**JAMES M. BEGGS**

Sixth Administrator of NASA
(July 10, 1981 - Present)

James Montgomery Beggs was nominated by President Reagan on June 1, 1981 to become the sixth Administrator of NASA. He took his oath of office as head of the agency and entered the new post on July 10, 1981.

Beggs had been Executive Vice President and a director of General Dynamics Corp., St. Louis, Mo.

He served with NASA from 1968 to 1969 as Associate Administrator, Office of Advanced Research and Technology. From 1969 to 1973, he was Under Secretary of Transportation. He went to Summa Corp., Los Angeles, Calif., as Managing Director, Operations, and joined General Dynamics in January 1974. Before joining NASA, he had been with Westinghouse Electric Corp.,in Sharon, Pa., and Baltimore, Md., for 13 years.

A member of the Board of Governors of the National Space Club and the American Astronautical Society, his other professional affiliations include the National Academy of Public Administration, the American Institute of Aeronautics and Astronautics, the American Society of Naval Engineers and Sigma Tau.

Beggs was born in Pittsburgh, Pa., Jan. 9, 1926. A 1947 graduate of the U.S. Naval Academy, he served with the Navy until 1954. In 1955, he received a master's degree from the Harvard Graduate School of Business Administration.

He holds honorary LL.D. degrees from Washington and Jefferson College, Washington, Pa., and Maryville College in St. Louis; an honorary doctor of engineering management degree from Embry-Riddle Aeronautical University, Daytona Beach, Fla.; an honorary doctor of science degree from the University of Alabama, and an honorary doctor of aeronautical science degree from Salem College.

Beggs is married to the former Mary Harrison. They have five children.

## NASA ADMINISTRATORS, DEPUTY AND ACTING ADMINISTRATORS

**Administrators**

| | |
|---|---|
| Dr. T. Keith Glennan | Aug. 19, 1958 — Jan. 20, 1961 |
| James E. Webb | Feb. 14. 1961 — Oct. 7, 1968 |
| Dr. Thomas O. Paine* | March 21, 1969 — Sept. 15, 1970 |
| Dr. James C. Fletcher | April 27, 1971 — May 1, 1977 |
| Dr. Robert A. Frosch | June 21, 1977 — Jan. 20, 1981 |
| James M. Beggs | July 10, 1981 — Present |

**Deputy Administrators**

| | |
|---|---|
| Dr. Hugh L. Dryden** | Aug. 19, 1958 — Dec. 2, 1965 |
| Dr. Robert C. Seamans Jr. | Dec. 21, 1965 — Jan. 5, 1968 |
| Dr. Thomas O. Paine | March 25, 1968 — March 20, 1969 |
| George M. Low | Dec. 3, 1969 — June 5, 1976 |
| Dr. Alan M. Lovelace | July 2, 1976 — May 1, 1977 |
| Dr. Hans Mark | July 10, 1981 — Present |

**Acting Administrators**

| | |
|---|---|
| Dr. Hugh L. Dryden | Jan. 21, 1961 — Feb. 13, 1961 |
| Dr. Thomas O. Paine | Oct. 8, 1968 — March 20, 1969 |
| George M. Low | Sept. 16, 1970 — April 26, 1971 |
| Dr. Alan M. Lovelace | May 2, 1977 — June 20, 1977<br>Jan. 20, 1981 — July 10, 1981 |

*Service as Administrator or Deputy begins on the day of swearing-in. In Dr. Paine's case, although he was sworn in on April 3, 1969, his service as Administrator began on March 21, 1969 (date of appointment) because he had already taken his oath to the government when he became Deputy Administrator.
**Dr. Dryden's resignation date is date of death.

25th Anniversary
1958-1983

# *Selected Photos*

## SELECTED NASA PHOTOGRAPHS 1958-1983

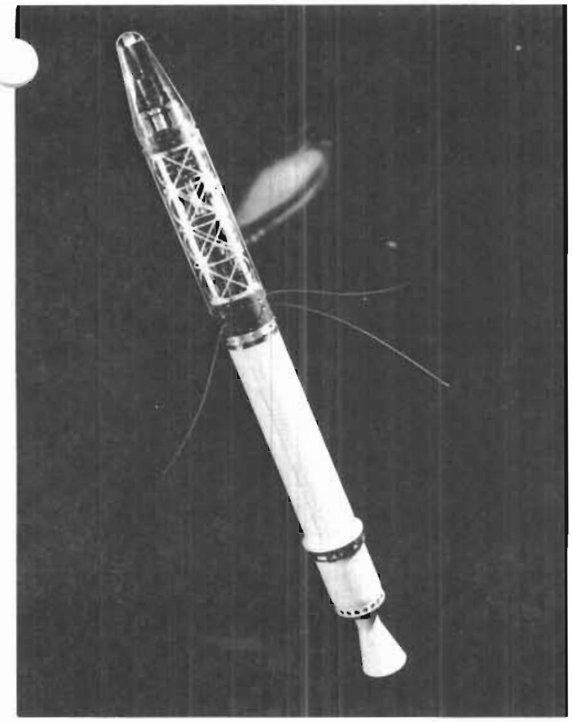
Compiled by
Dwayne C. Brown

| Year | Description | B/W photo # |
|---|---|---|
| 1958 | First satellite launch | 58-Explorer I |
| 1959 | Vanguard satellite | Van-25 |
| 1960 | X-15 research plane | 71-H-968 |
| 1960 | Tiros 1 satellite | 60-T-28 |
| 1961 | Mercury Redstone 3 | 61-MR3-72B |
| 1962 | Mercury Friendship 7 | 62-MA6-110 |
| 1962 | OSO-1 satellite | 69-H-54 |
| 1962 | Mariner 2 | 62-II-15 |
| 1963 | Syncom 2 | 64-Syncom-C-3 |
| 1964 | Ranger 7 | 65-H-576 |
| 1965 | Gemini in orbit | 65-H-2342 |
| 1965 | Gemini spacewalk | 78-H-760 |
| 1966 | Moon surveyor | 66-H-1074 |
| 1966 | M2F2 "lifting body" | 66-H-178 |
| 1967 | Biosatellite | 66-H-1618 |
| 1968 | OAO -2 | 63-OAO-2 |
| 1969 | Apollo moon walk | 69-H-1253 |
| 1971 | "Supercritical wing" | 71-H-480 |
| 1972 | Landsat 1 | 72-H-672 |
| 1972 | Pioneer 10 | 72-H-54 |
| 1973 | Skylab | 73-H-578 |

| | | |
|---|---|---|
| 1973 | Mariner 10 | 73-H-993 |
| 1975 | Apollo-Soyuz | 75-H-741 |
| 1976 | Viking lander | 76-H-870 |
| 1977 | Voyager | 77-H-155 |
| 1978 | QSRA | 80-H-591 |
| 1979 | NOAA-6 | 79-H-312 |
| 1980 | Solar Max | 79H-583 |
| 1981 | STS-1 | 81-H-306 |
| 1982 | STS-4 | 82-H-486 |
| 1982 | STS-4 welcomed home | 82-H-490 |
| 1983 | STS-7(payload shot) | 83-H-533 |
| 1983 | STS-7 Palapa | 83-H-520 |
| 1983 | Iras | 83-H-78 |
| Future | Spacelab | 76-H-615 |
| Future | Space Telescope | 80-H-187 |
| Future | Space Station | 82-H-433 |
| Future | Lunar Base | 76-H-684 |

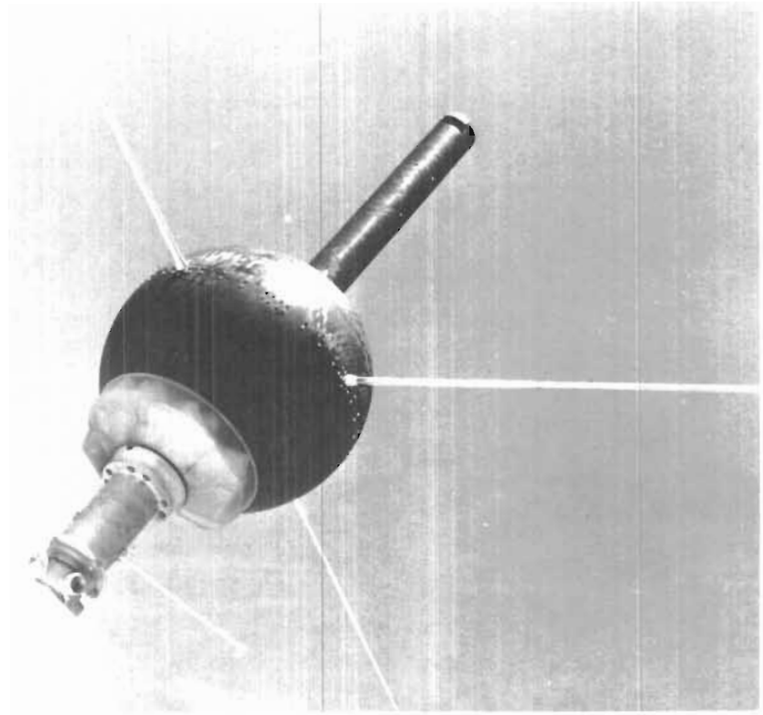
Color 4-by-5 inch transparencies and black-and-white 8-by-10-inch glossies are available free to information media. Transparencies are loaned for a limited period and must be returned. Non-information media may obtain identical material at a laboratory service charge through a photographic contractor. For information write: Audio Visual Branch, Public Information Division, code LFD-10, National Aeronautics and Space Administration, 400 Maryland Ave. S.W., Washington, D.C. 20546.

# 1958



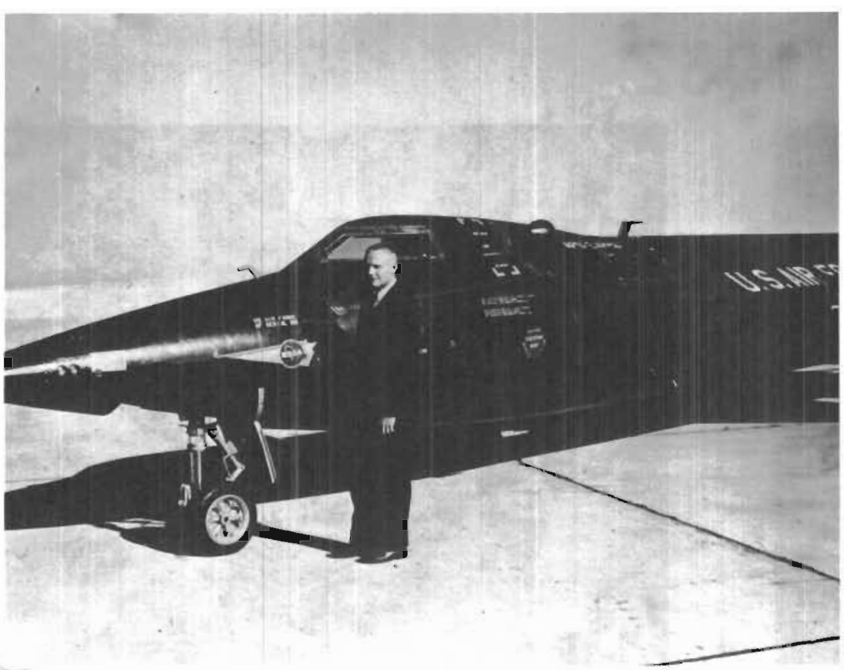
Explorer I, launched January 31, 1958, was the first U.S. satellite.

# 1959



Vanguard (SLV-5), launched April 13, 1959, provided knowledge of earth's magnetic field.

# 1960




The X-15 rocket-powered research airplane provided scientific data on altitudes and speed which contributed greatly to aeronautical development.

Tiros 1 was the first experimental meteorological satellite that introduced photography of earth's cloud cover from orbit.

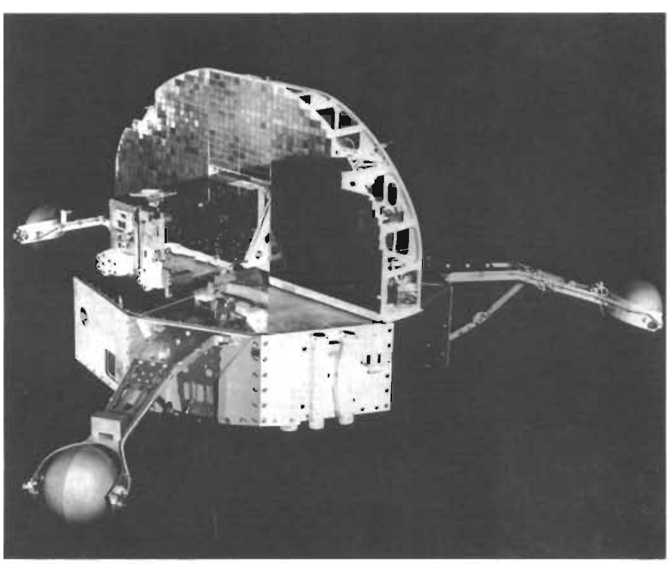
# 1961

The Mercury Redstone 3 carries Alan B. Shepard and his "Freedom 7" spacecraft into suborbit marking the first U.S. manned space flight.

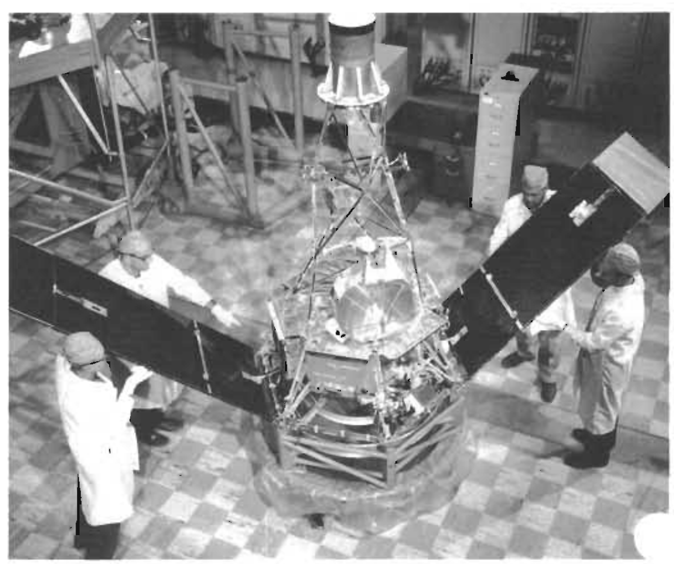
# 1962

Mercury spacecraft "Friendship 7" propels astronaut John Glenn into the first U.S. manned orbital flight.

# 1962

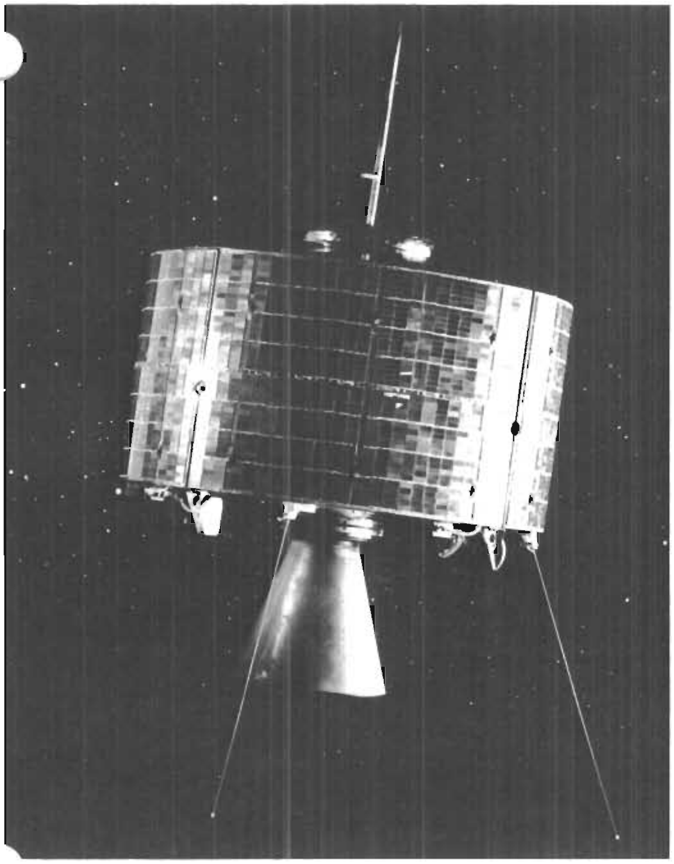


OSO-1 was the first of the observatory class satellites monitoring solar, geophysical and astronomical studies in space.



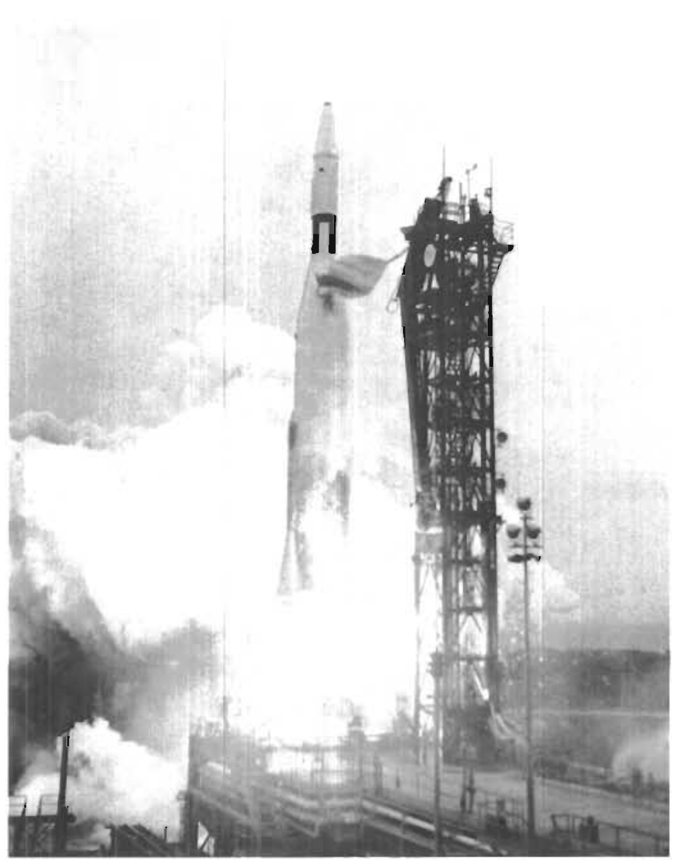
Mariner 2, pictured here in final fabrication, was the first successful planetary probe.

# 1963



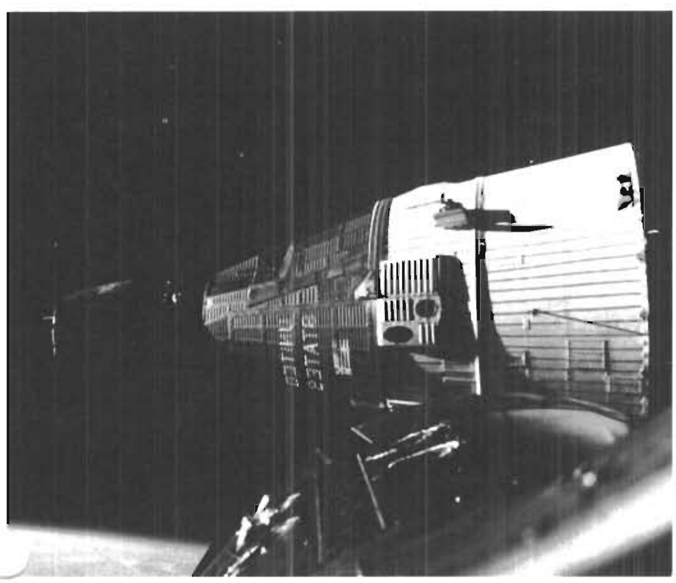
Syncom 2 provided the knowledge of communications satellites operating at synchronous orbit, building a foundation for commercial communications satellite use.

# 1964



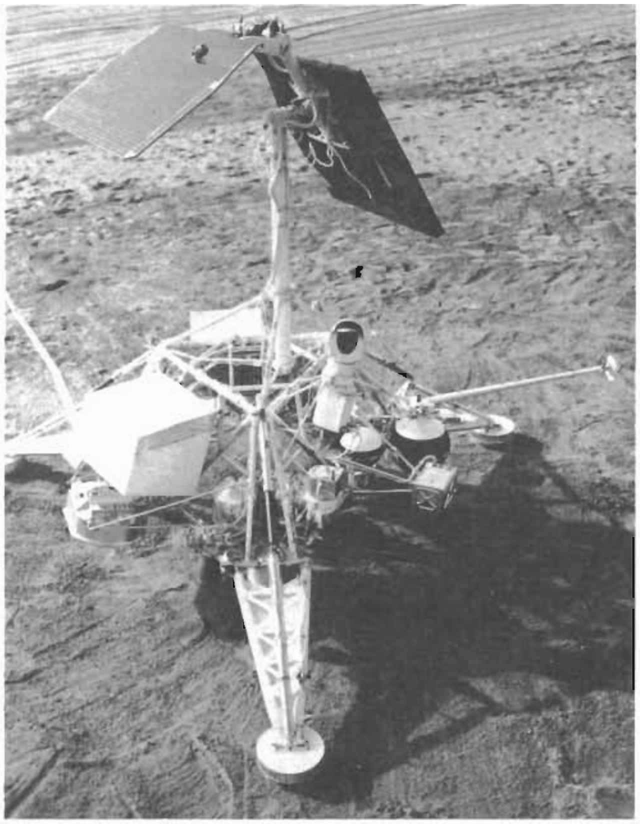
The launch of Ranger 7 was the first of its series to return photos of the moon's surface.

# 1965



The Gemini program included the first photograph of an orbiting spacecraft and the first U.S. spacewalk.

# 1966

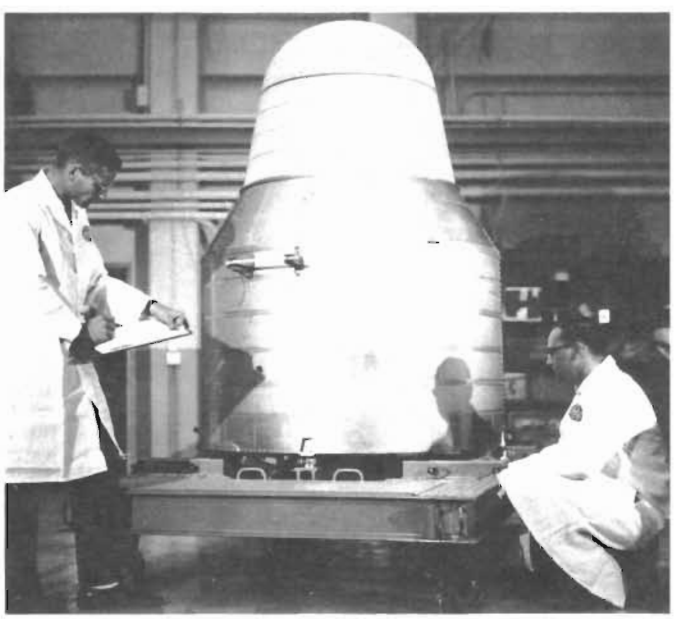


Surveyor was the first U.S. craft to land on another celestial body It returned thousands of lunar photos to help in selecting Apollo landing sites.


The M2F2, the first of the "lifting body" vehicles, marked the beginning of a six-year program gathering data for designs of hypersonic aircraft and earth re-entering spacecraft such as the Space Shuttle.

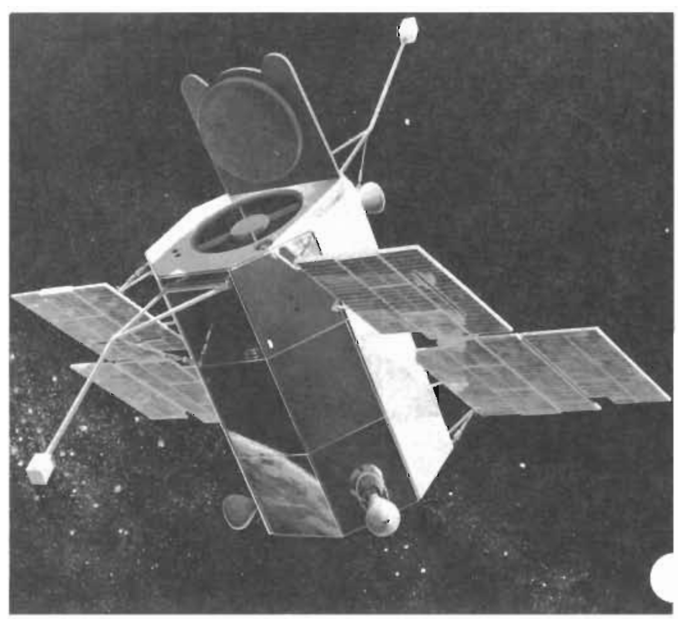
25

# 1967



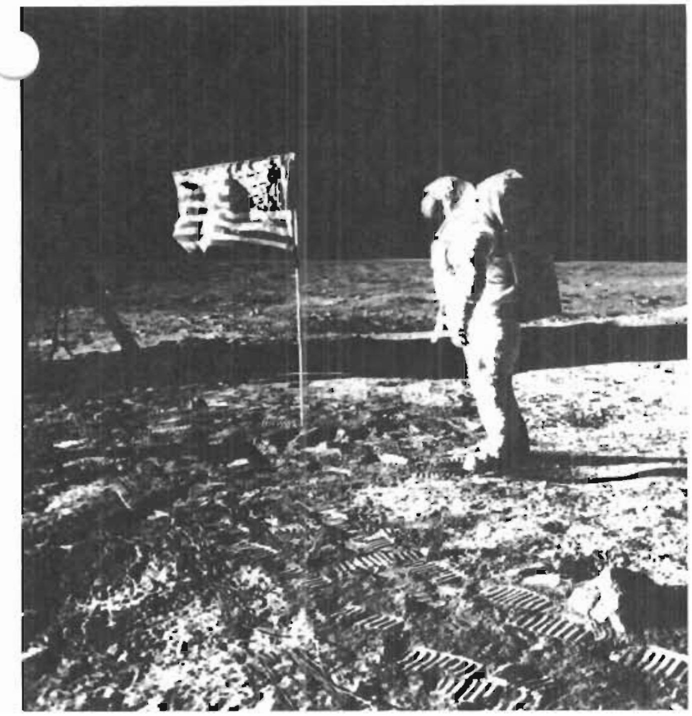
The Biosatellite provided information on the combined weightlessness and radiation on plants, animals and their development in space.

# 1968



OAO-2 was the first of two successful Orbiting Astronomical Observatories that provided new data about the stars and galaxies.

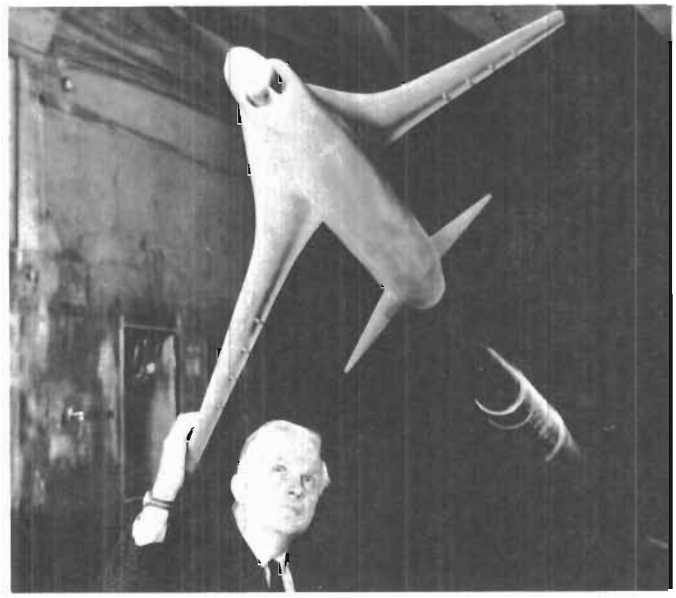
# 1969



In one of the most remarkable feats closing out a decade of achievements, Edwin E. Aldrin is depicted here planting the U.S. flag on the moon.

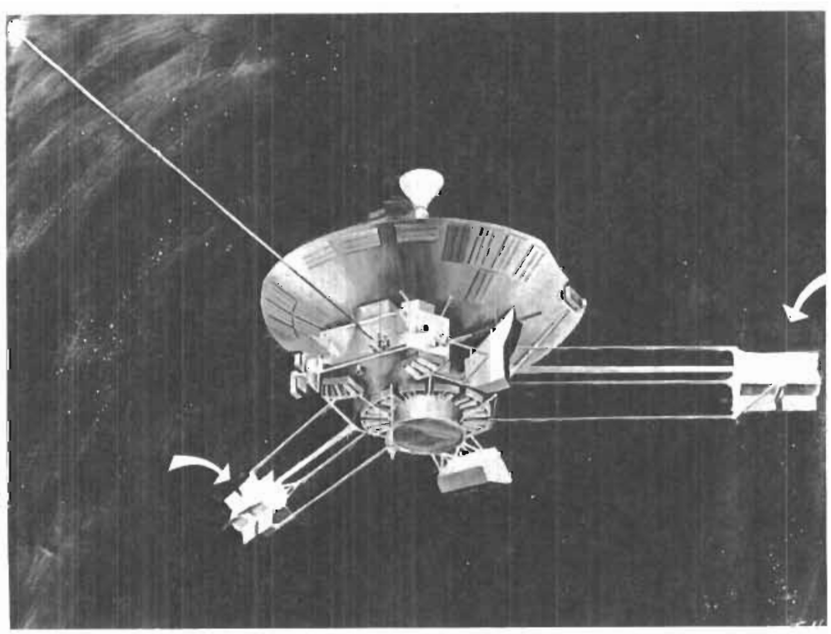
# 1971

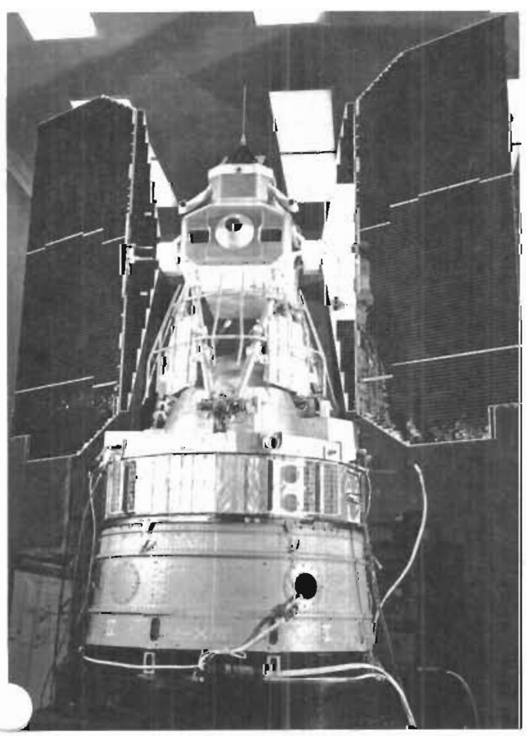
The 70's saw the development of the "supercritical wing" allowing an airplaine to fly faster or farther on the same amount of fuel.



# 1972

The interplanetary explorer Pioneer 10, now on its way out of our solar system, was man's first attempt to send automated vehicles beyond the solar system.

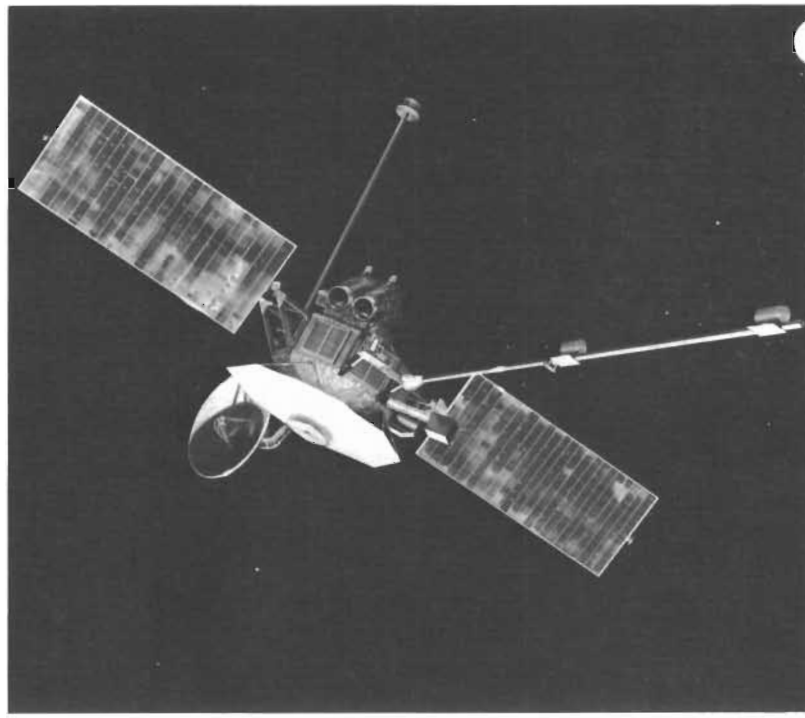




Landsat 1 was the first of four earth resources survey satellites that offered a means of monitoring changing conditions on earth's surface.

# 1973

Skylab was an interim space station that functioned as a large orbiting laboratory. It provided important medical data on the effects of long duration weightlessness and gave a technology base for planning a permanent space station.



25

Mariner 10 provided the first close-up views of Mercury, smallest of the solar system's nine planets.

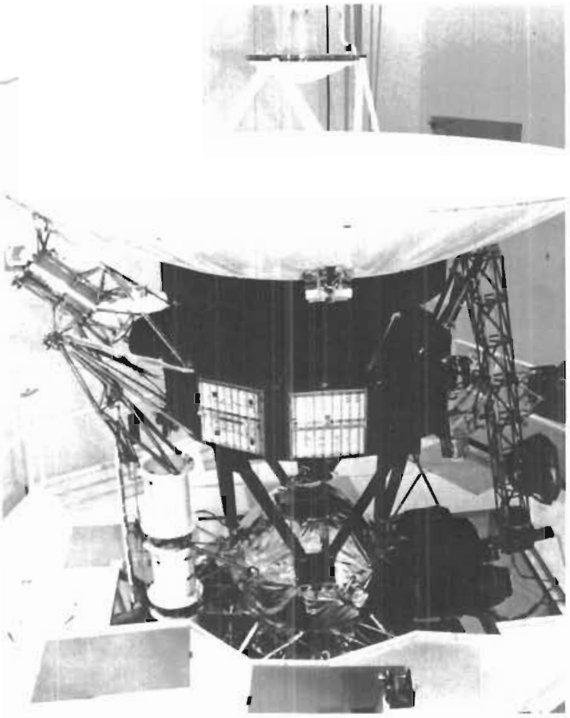
# 1975

The Apollo-Soyuz project proved that international space cooperation was both feasible and successful.

# 1976

The Viking program involved landing two spacecraft on Mars and putting two others in orbit around the planet. A technological triumph of Apollo-like dimensions, it studied Mars intensively.

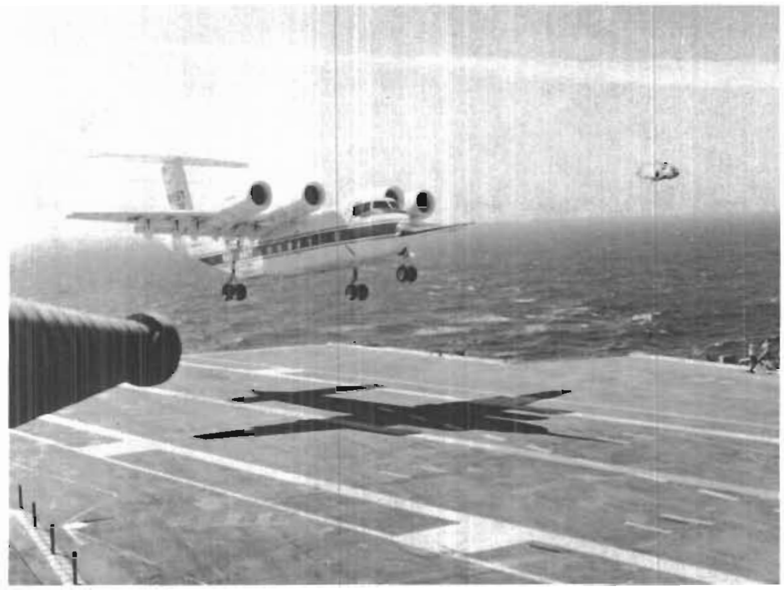
# 1977



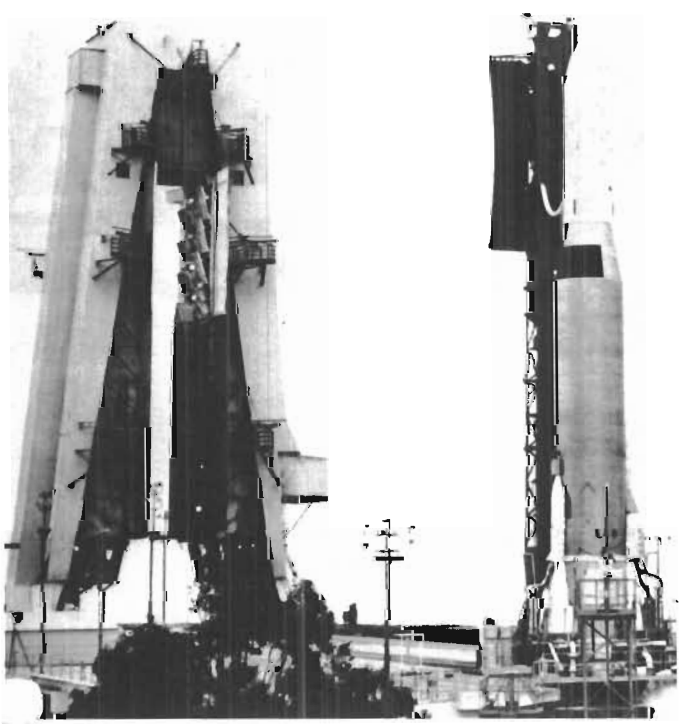
The Voyager program returned tens of thousands of photos and volumes of scientific data on Jupiter and Saturn.

# 1978

The Quiet Short-Haul Research Aircraft demonstrated the technology to climb and descend at steep angles and operate from a very short runway with low-noise levels.

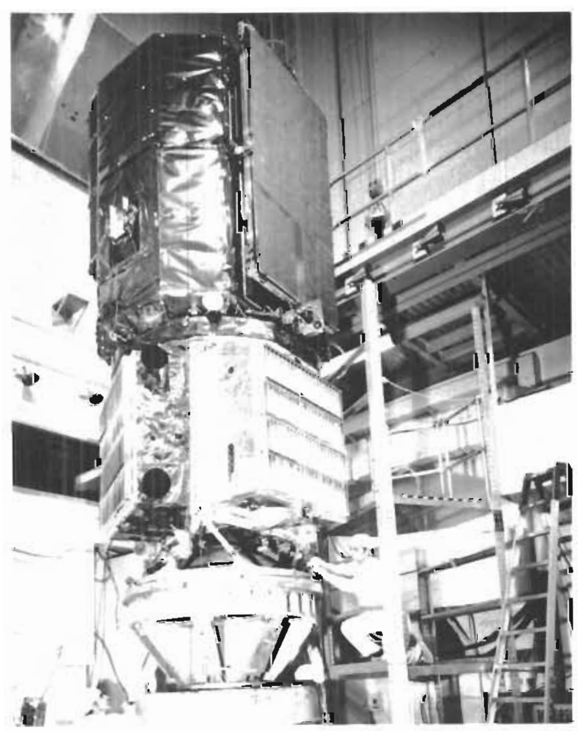


# 1979



NOAA-6 pictured here ready to launch provided information on weather conditions, agricultural development and collected data for land, air, sea and solar research.

# 1980



Shown here in final preparation the Solar Maximum Mission provided valuable data on the sun.

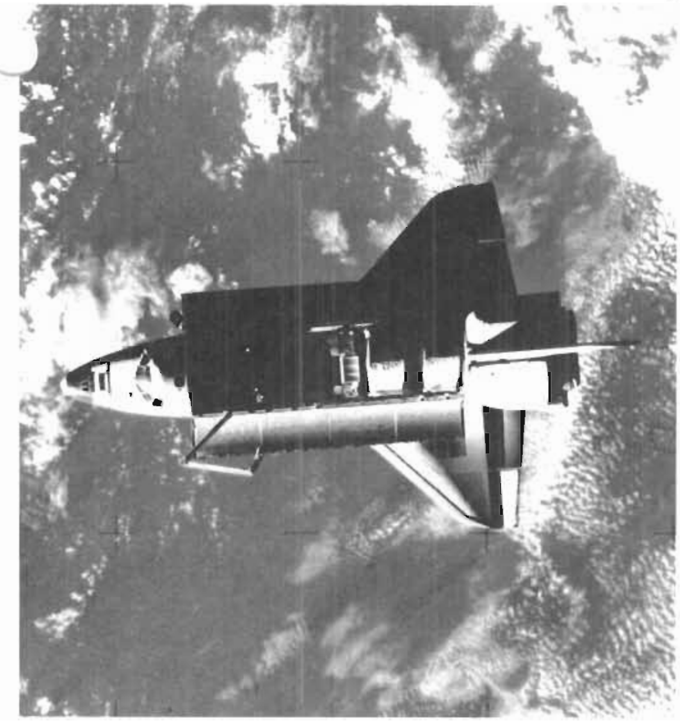
# 1981

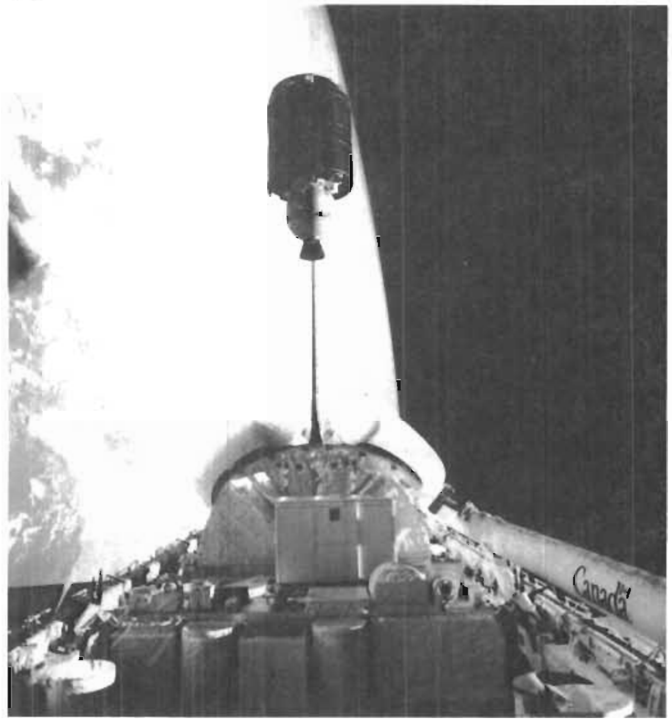
A new era in space flight began with the launch of the first reusable spacecraft Columbia on STS-1.

# 1982

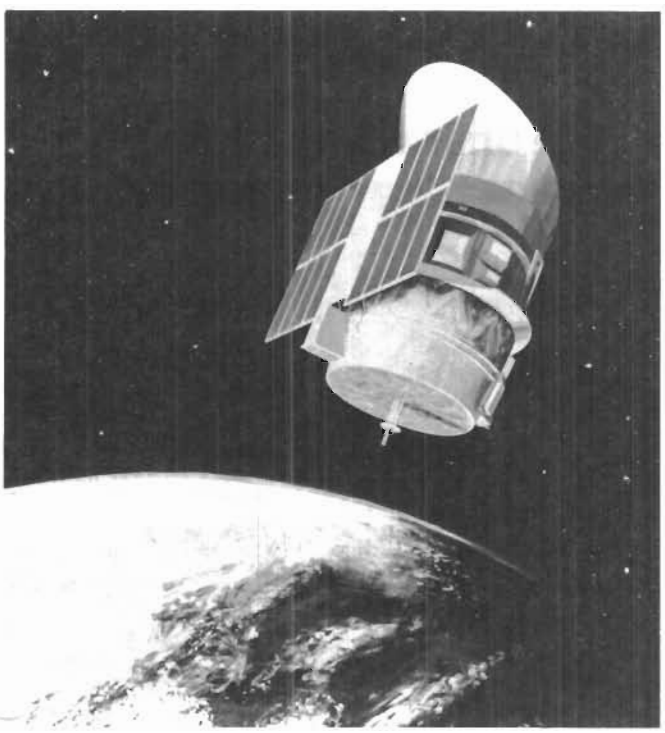

STS-4 crew members Ken Mattingly and Henry Hartsfield are welcomed home after landing by President Ronald Reagan and Mrs. Reagan.

# 1983



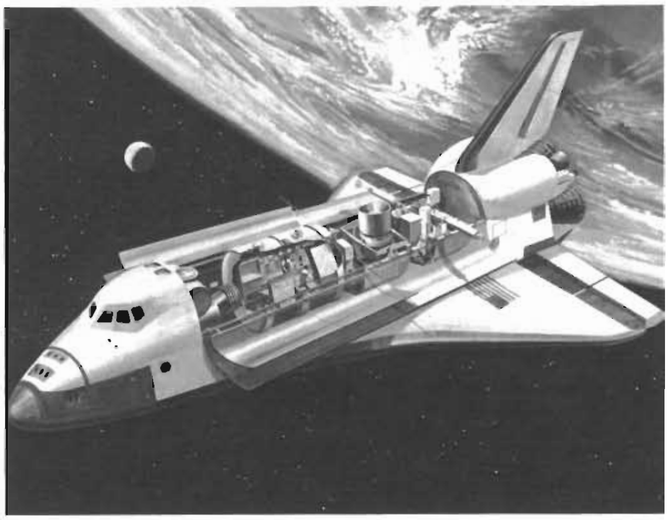



STS-7 photographed from the German satellite SPAS-01 provided live visual footage of the Space Transportation System at work.



The Infrared Astronomical Satellite, capable of seeing objects by thermal emissions, discovered another comet and a possible new solar system making 1983 a year of discovery and asking the question, "Are we alone in the universe?"

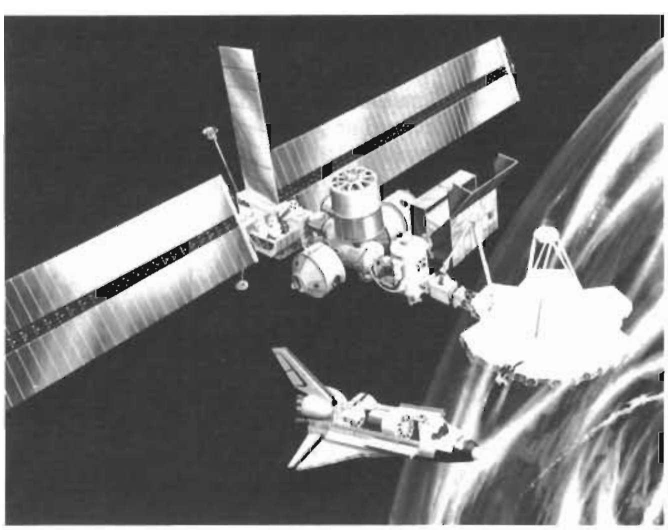
# The Next 25 Years



Spacelab

Space Telescope

Space Station



Lunar Manned Base