Rockets, Missiles, and Spacecraft of the National Air and Space Museum

Smithsonian Institution

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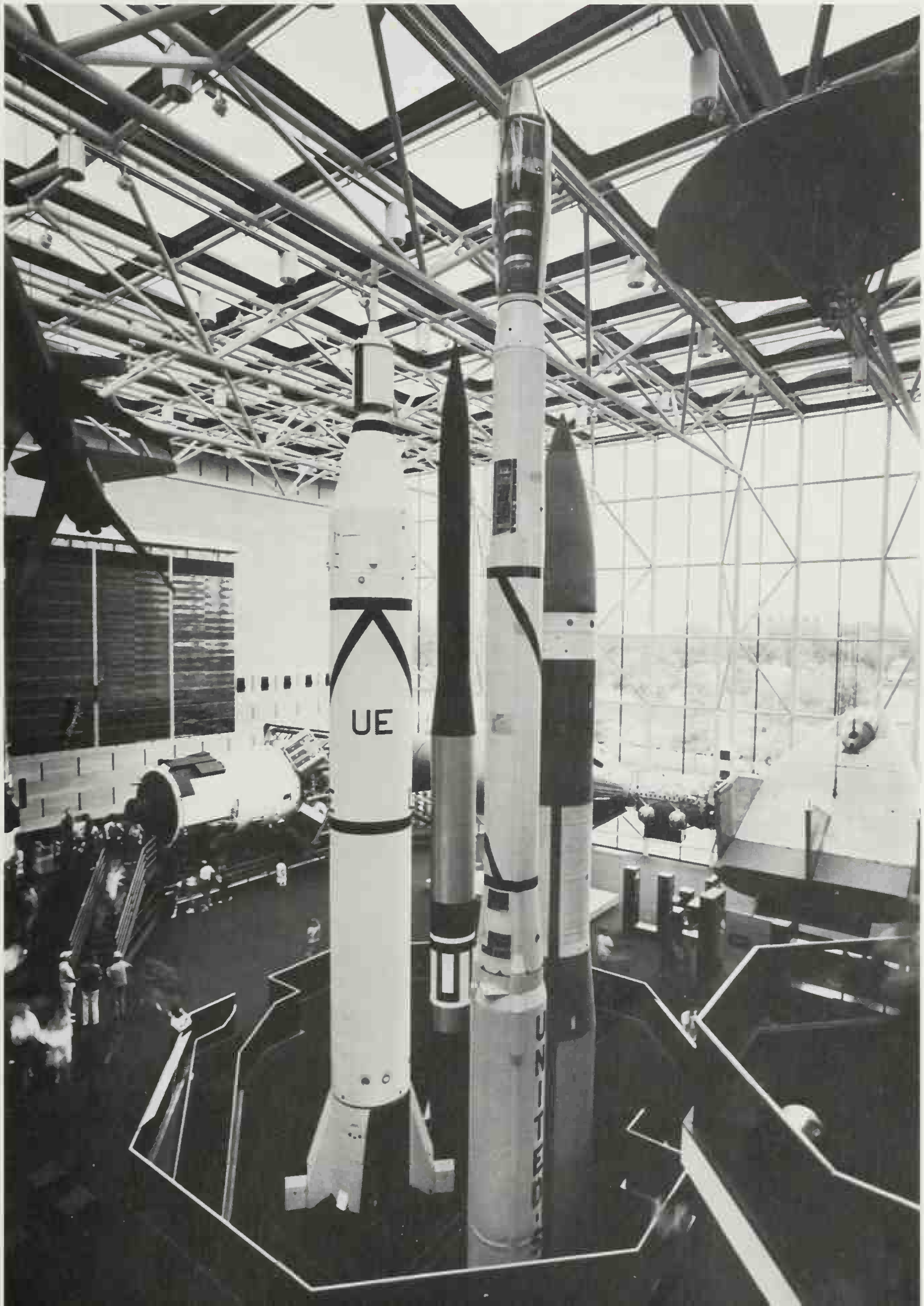

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Title page: View of Gallery 114: *Space Hall* (Photo: Smithsonian Institution)

Smithsonian Institution photographs by Dale Hrabak

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Contents

An Extraordinary Collection

The rockets, missiles, and spacecraft of the National Air and Space Museum make up the definitive collection of artifacts of the U.S. Space Program. Through a unique agreement with the National Aeronautics and Space Administration, in effect since 1967, the National Air and Space Museum has become sole custodian of the historic American relics of space exploration. These relics are displayed, loaned to other museums, or preserved in storage. If you see a genuine U.S. spacecraft in a museum anywhere in the world, it is almost certainly from this collection!

And the collection is impressive: all U.S. manned spacecraft, except Gus Grissom's Mercury capsule *Liberty Bell 7*, which was lost at sea; one hundred twenty-two spacesuits, including most of those used from Project Mercury through Apollo-Soyuz; three of the world's largest launch vehicles, the Saturn 5s; every major type of rocket engine, including those from the V-2, the Saturn 5, and the most recent expendable launch vehicles; the world's most complete collection of space-based astronomical observatories; nearly all of America's unmanned planetary spacecraft; and a full range of satellites, representing the major breakthroughs of space technology.

All too are genuine artifacts. In the U.S. manned space program, the Museum has preserved not only every surviving flown spacecraft, but also many design, development, and test articles. From the unmanned space flight programs, most of the spacecraft never returned to earth and so could not be collected. But even in cases such as *Pioneer 10* or the Viking Mars Lander, we have saved a "flight backup" or a test model. Perhaps the most impressive artifact in the entire collection is the black, white, and gold backup Orbital Workshop of *Skylab*. It is the largest object in the Museum, and still ranks in 1983 as the largest "satellite" ever orbited. The Space Shuttle Orbiter *Columbia* comes a close second in weight to *Skylab*, and it too may someday become part of the collection of rockets, missiles, and spacecraft of the National Air and Space Museum.

This catalog contains brief descriptive articles by staff members about each of the major space artifacts on display in the National Air and Space Museum, as of the summer of 1983. The spacecraft are exhibited in eight galleries, each with a distinct theme. The remainder of the collection is either on loan to space museums throughout the world or in storage. A listing of all flown manned spacecraft and their present locations may be found at the end of this catalog.

The staff of the Department of Space Science and Exploration and I hope you will find this catalog a useful reference for your visits to the National Air and Space Museum and interesting reading for years to come.

Paul A. Hanle
Chairman
Space Science and
Exploration Department

Congreve Rockets

32-pounder
Length: 1.1 m (3.5 ft) (body only; rocket also had a 4.6 m guidestick)
Range: 900-2,700 m (1,000-3,000 yd)
Gallery: 113: *Rocketry and Space Flight*

Napoleon Bonaparte's threat of an invasion of England in 1804 led William Congreve (1772–1828), the inventive son of a Royal Artillery officer, to develop a rocket weapon for destroying the enemy's fleet at Boulogne, across the English Channel. Crude rockets had been used extensively as weapons in India from the mid-16th until the late 18th century. Indian war rockets, however, were not incendiary nor explosive. They were fired at close range and in great numbers for frightening infantry troops or Indian war elephants.

Congreve knew about these rockets. The Indian princes of Mysore, Hyder Ali and his son Tippoo Sahib, had employed them against British soldiers during the Mysore wars of the 1770s to 1790s. Specimens were even brought back and probably put on display in the Rotunda Museum of the Royal Artillery in Woolwich, where Congreve most likely saw them.

Congreve also studied and experimented with the largest commercial firework rockets in London. These were no larger than 2.7 kilograms (6 pounds), but within a year Congreve developed the beginnings of what he called his "rocket system." When fully developed it consisted of at least 15 types of rockets with warheads, carrying incendiaries, explosives, and case-shots (musket balls for scattering amongst infantrymen). The sizes varied from 3-pounders up to rockets 20 centimeters (8 inches) in diameter, and weighing 140 kilograms (300 pounds). The largest one, however, was experimental and does not appear to have been used in battle as were the other 14. On exhibit are facsimiles of two standard Congreve 32-pounders with explosive warheads, courtesy of the Royal Artillery Institution, London. These specimens demonstrate one of Congreve's major improvements in rocket technology. His first rockets were much like skyrockets of the period, only larger and made with sheet-iron bodies rather than cardboard. They were stabilized in their flight by a long stick mounted on the side of the rocket case. In 1815, Congreve shifted the position of this stick to the center of the base of the rocket, in line with the axis of the rocket body. This made it more stable and accurate. A 15-centimeter (6-inch) diameter 100-pounder with an incendiary warhead is also exhibited.

Gunpowder propelled Congreve's rockets to ranges of 900 to 2,700 meters (1,000 to 3,000 yards). The rockets were first employed in two Royal Navy expeditions to Boulogne, France, in 1805 and 1806. The first expedition was unsuccessful due mainly to bad weather. The second mission was successful and caused the

In the early nineteenth century, Congreve rockets such as these saw wide spread use. (Photo: Smithsonian Institution) destruction of several French ships, though Napoleon's invasion of England was never carried out. In 1807, about 300 Congreve rockets destroyed much of Copenhagen, Denmark, in a continuation of the Napoleonic campaigns though figures as high as 20,000 or more have mistakenly been cited in that engagement.

Royal Artillery rocket troops were officially formed and Congreve rockets were widely used until the 1860s, when they were superceded by Hale's stickless rockets. Congreve's rockets notably were employed at the battle of Waterloo and during the War of 1812. At the battle of Fort McHenry in 1814, it was Congreve rockets whose "red glare" were described by Francis Scott Key in *"The Star Spangled Banner."*

Frank H. Winter

Hale Rockets

24-pounder
Length: 58 cm (23 in)
Range: 2,000 m (2,200 yd)
Gallery: 113: *Rocketry and Space Flight*

The British civil engineer and inventor William Hale (1797–1870) sought to eliminate the cumbersome wooden guidesticks of Congreve and other war rockets of the 19th century. He also wished to improve the rockets' stability and performance. This was achieved with his stickless, or rotating, rocket invented in 1844.

The Hale rocket completely dispensed with guidesticks. It was stabilized in flight by rotating around its axis. At first this was achieved by tangential holes drilled into the side of the iron rocket case. In some specimens, such as on one U.S. 12-pounder on display in Gallery 113: *Rocketry and Space Flight,* the holes were drilled at the rear of the rocket, around the periphery, while a larger hole at the bottom of the rocket served as the central exhaust cavity. There were, however, two major drawbacks to this arrangement. One was that too much exhaust gas issued from the tangential holes, reducing the overall performance of the rocket. The second drawback was that, once the propellant had burned to the top of the tube, the rear end would have a tendency to oscillate, nullifying the stability Hale was trying to achieve.

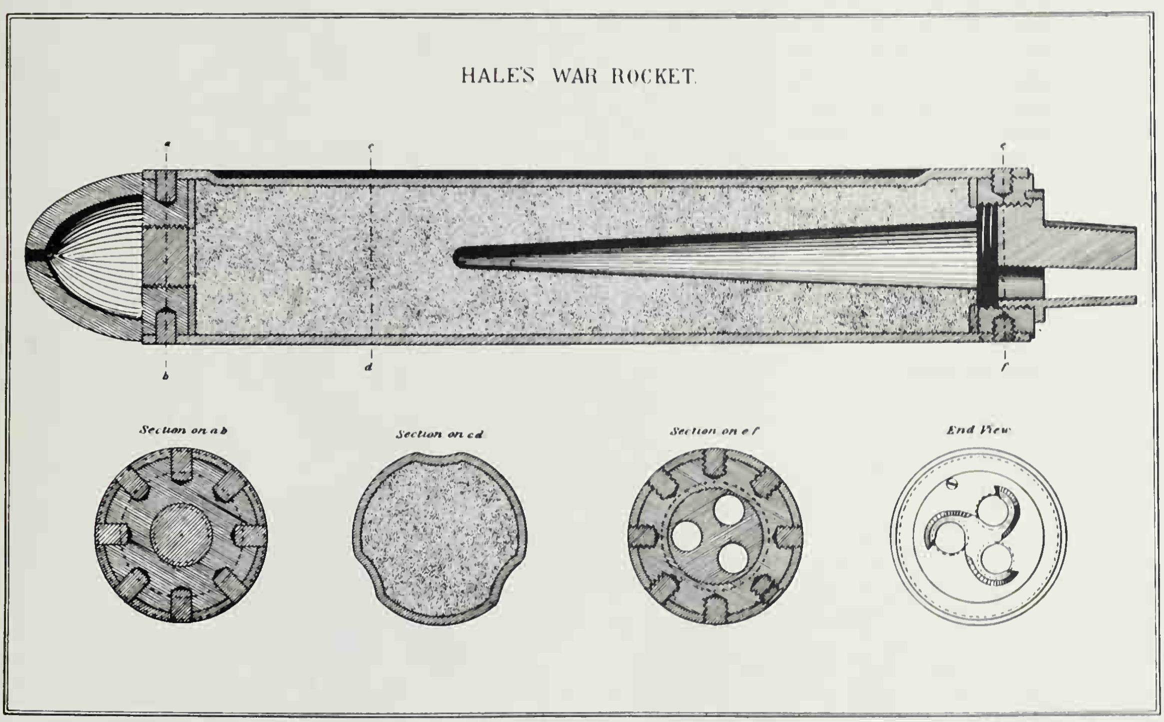
To correct the oscillation, Hale placed the tangential holes at roughly the center of gravity of the rocket or about three-quarters of the way up the tube, as in another U.S.-built 12-pounder on exhibit. However, there still remained the problem of excessive loss of gas. Hale's final solution, as in the 24-pounder rockets on display, was the replacing of the tangential holes with a series of three vanes situated over the central exhaust hole. The rockets were usually fired from V-shaped troughs or tubes and achieved ranges of 460-500 meters (500-550) yards. Hale also introduced the hydrostatic pressure method of loading the powder in rockets; prior to this time the powder was driven in by hand, a time-consuming and highly dangerous process.

The British tested the Hale rockets during the Crimean War (1854–1856), officially adopted them in 1867, and used them until as late as 1899. Even earlier, in 1846, the American Government had purchased the right to make Hale rockets for use in the Mexican War. However, most of those manufactured at that time (see the 12-pounder on exhibit) were not used until the Civil War. Both the Union and Confederate forces employed Hale's rockets: in Virginia, at the battles of Gaines Mill (1862) and Franklin (1862); and in South Carolina, at the siege of Charleston (1864), in and around Petersburg (1862), and at Cole's Island (1864). The 12-pounder U.S. Hale specimen on exhibit was found near Petersburg and may have been used by the so-called Petersburg Rocket Battery.

The Austrians also purchased Hale rockets, as did the Brazilians, French, Chinese, Danes, and Hungarians. The last war rockets to be developed during the 19th century, the Hale rockets were rendered obsolete by the advent of quick-firing and accurately rifled guns.

Frank H. Winter

Spin-stabilized rocket designed by William Hale (Photo: Smithsonian Institution)



Hale rocket schematic. (Photo: SI 4540B)

Tsiolkovsky Spaceship Model

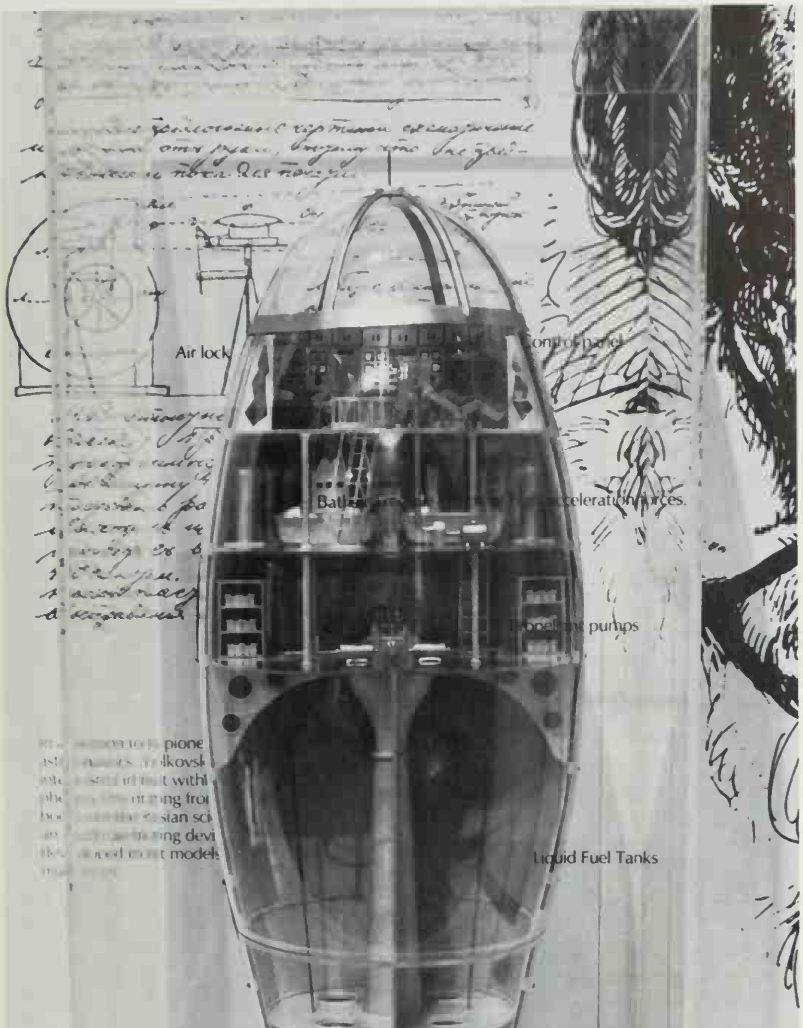
Length: 50 m (160 ft)
Crew: 3
Gallery: 113: *Rocketry and Space Flight*

Konstantin Eduardovich Tsiolkovsky (1857–1935) is considered "the Father of Soviet Cosmonautics." Although he never constructed any rockets nor performed rocketry experiments, this Russian school teacher formulated some of the fundamental principles of spaceflight as early as 1883. By 1903, his first published work appeared on the subject, *Issledovanie mirovykh prostranstv reaktivnymi priborami [Exploration of Cosmic Space by Reactive Propulsion Apparatuses*]. This work has since become a classic in the history of space travel theory.

Tsiolkovsky calculated the laws of rocket motion for a rocket spacecraft, escape velocities for leaving Earth's gravitational pull, propellant combinations, rocket efficiencies, the effect of air drag upon a rocket passing through Earth's atmosphere, and many details about the design of a manned liquid-oxygen—liquid-hydrogen vehicle. In subsequent works, published (mostly at his expense) from 1911 until his death, Tsiolkovsky elaborated upon the design of his tear-drop-shaped spaceship. He described life-support systems (including oxygen replenishment by growing plants on the ship), spacesuits, rocket pumps, space food, and many other details now taken for granted.

The Tsiolkovsky spaceship model on exhibit, constructed and on loan from the K.E. Tsiolkovsky State Museum of Cosmonautics, Kaluga, USSR, represents the best features of Tsiolkovsky's evolution of designs for his spaceship.

Frank H. Winter



Konstantin Tsiolkovsky proposed this tear-drop shaped spaceship in the early twentieth century. (Photo: Smithsonian Institution)

Goddard 1926 Rockets

March 16 Rocket

Length: 340 cm (134 in)
Weight: 4.7 kg (10.4 lb)
Thrust: 40 newtons (9 lb)
Gallery: 100: *Milestones of Flight*

On March 16, 1926, Dr. Robert H. Goddard (1882–1945), a professor of physics at Clark University, Worcester, Massachusetts, launched the world's first liquid fuel rocket. The unstreamlined, thin aluminum tubing rocket rose to 12 meters (41 feet) and landed 56 meters (184 feet) away. The flight time was 2.5 seconds. The estimated speed was 96.5 kilometers per hour (60 miles per hour). That epochal flight was made on the snow-covered fields of Goddard's Aunt Effie's farm at Auburn, Massachusetts. Extremely modest by today's standards, that rocket was the forerunner of all modern liquid-fuel rockets.

Present on that historic occasion and assisting Goddard were Dr. Percy Roope, Assistant Professor of Physics at Clark; Henry Sachs, an instrument maker who afterwards became Goddard's crew chief in his later rocketry experiments; and Esther C. Goddard, his young wife. Esther was the official photographer, but unfortunately her movie camera was an old spring-wound Sept (French for seven) with a picture-taking duration of only 7 seconds, which was not sufficient to capture the flight.

The rocket on exhibit in the *Milestones of Flight* hall is a facsimile; the original no longer exists. To save money, Goddard characteristically salvaged usable parts from past rockets and used them in improved vehicles. Parts of the original March 16, 1926 rocket were used in his May 6, 1926 rocket, which is exhibited in Gallery 113: *Rocketry and Spaceflight*.

Goddard speculated about spaceflight as early as 1899 when he was 17 years old, but it was not until 1912 that he first explored mathematically the practicality of the rocket. In 1915 he was the first to experimentally prove that the rocket could work in a vacuum and hence, outer space. These experiments, begun the same year and continued up to 1920, were conducted with solid-propellants. His early researches were funded in part by the Smithsonian Institution, which published his classic treatise "A Method of Reaching Extreme Altitudes" (*Smithsonian Miscellaneous Collections*, volume 71, number 2) in 1919, considered the first basic mathematical theory of rocket propulsion published in the United States.

As his research progressed, Goddard realized that solid propellants then available had limited potential and efficiency. Liquids carried more energy potential, but many problems needed to be worked out, such as fuel injection, ignition, and engine cooling. Goddard first sought to determine whether the liquid-fuel rocket concept was feasible, that is, whether such a rocket could fly. Upon the success of his March 16, 1926, flight Goddard devoted the remainder of his life to perfecting the overall propulsion system.

Frank H. Winter

Robert Goddard's second liquid-propellant rocket, tested in May 1926, contained parts from his first liquid-fuel rocket. (Photo: Smithsonian Institution)

Robert Goddard and the world's first liquid-propellant rocket, March 16, 1926. (Photo: NASA 74-H-1065)

Goddard 1935 Rocket

Length: 4.7 m (15.5 ft)
Weight: 39 kg (85 lb) (empty)
Thrust: 900 newtons (200 lb)
Gallery: 110: *Satellites*

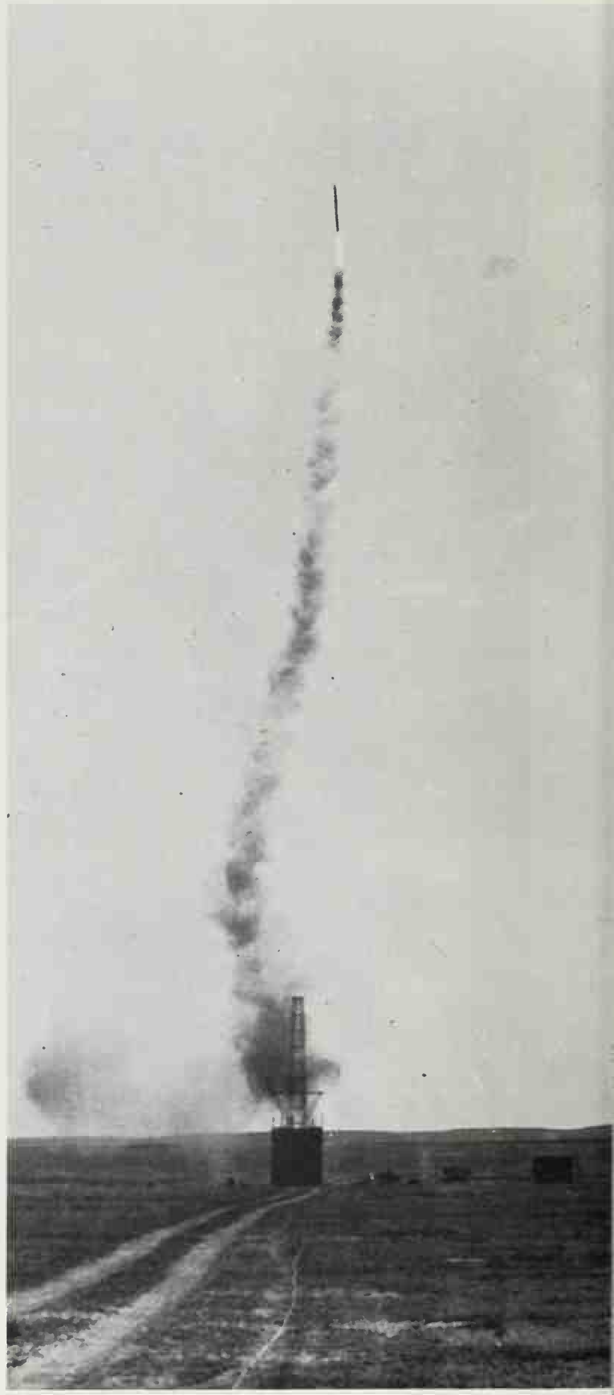
Robert H. Goddard's 1935 rocket represents the median point in his rocketry career, which spanned from 1926 until his death in 1945. The rocket is an example of his A-series, undertaken at Roswell, New Mexico, from September 1923 to October 1935. The development of the A-series was supported by funds from the Daniel and Florence Guggenheim Foundation for the Promotion of Aeronautics. By the time Goddard undertook work on the A-series, he had already developed a reliable fuel-feed system and engine, so he began the A-series to develop satisfactory flight control and parachute release mechanisms.

Goddard's solution to flight instability and directional control was an automatic gyroscopic stabilizer. The gyroscope is placed in the nose cone and connected by shafts to a series of moveable vanes in the path of the rocket's exhaust. If the rocket is tilted more than 10 degrees, the gyroscope activates a switch that shifts the vanes and aims the rocket towards a more vertical course. These vanes can be seen in the horizontally mounted rocket on exhibit.

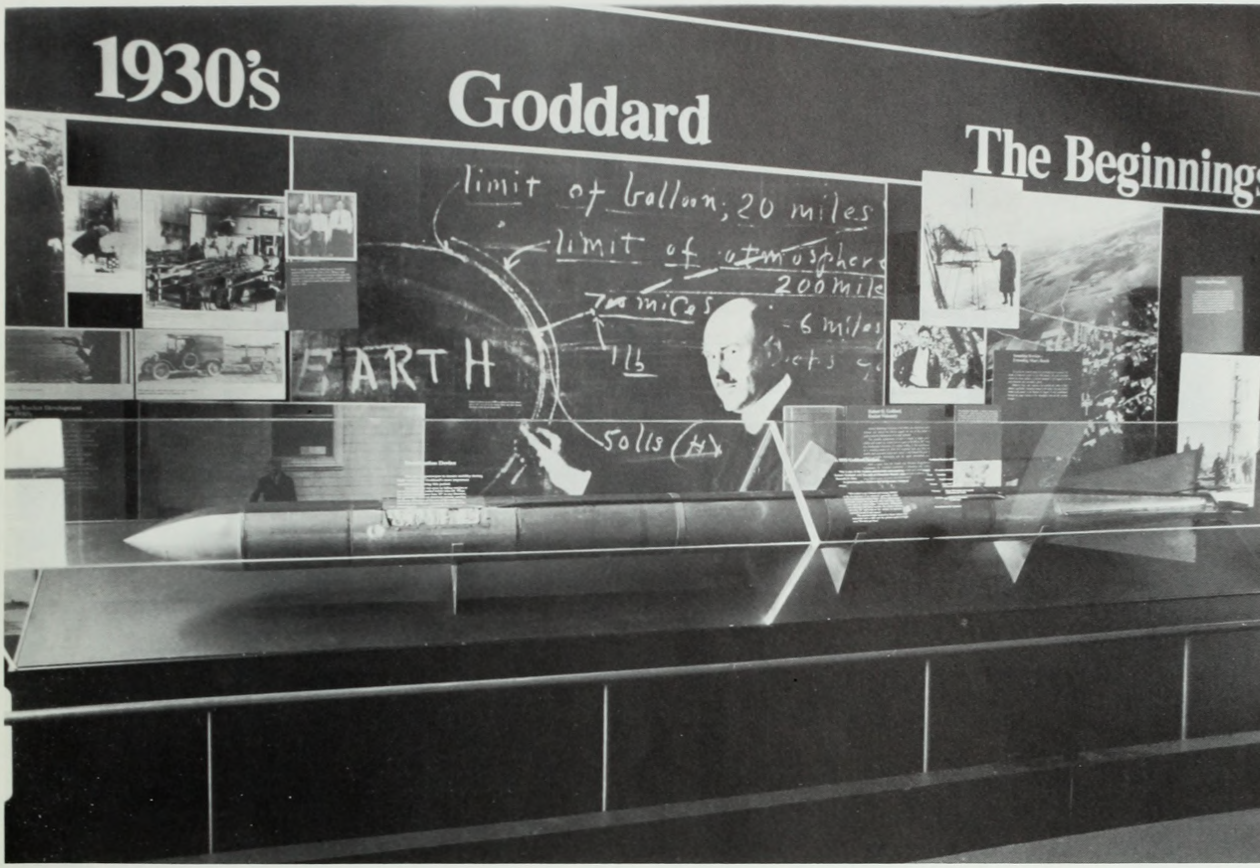
The A rocket's 3-meter (10-foot) parachute and cord can be seen in its compartment in the nose of the rocket. It was operated by a spring device. The rocket was painted red along one of its halves for easier sighting and to assist recovery.

The rocket on exhibit is the largest of a series of continually modified rockets with a liquid oxygen-gasoline, pressure-fed engine. The highest altitude attained with an A–series rocket, and the highest ever reached by Goddard, was 2,300 meters (7,600 feet) with a speed of 313 kilometers per hour (700 miles per hour). Seven flights were made with the A-series.

Frank H. Winter



A-series rocket launch on August 26, 1937. (Photo: NASA 74-H-1232)



Goddard A-series rocket in Gallery 110: Satellites. *(Photo: Smithsonian Institution)*

Goddard 1941 Rocket

Length: 6.7 m (22 ft)
Weight: 205 kg (442 lb) (with fuel)
Thrust: 4380 newtons (985 lb)
Gallery: 100: *Milestones of Flight*

Robert H. Goddard's 1941 rocket was his most advanced rocket design. It was also the last vehicle that he launched. Goddard continued his researches until his death in 1945. In 1942, he departed his home and laboratory at Roswell, New Mexico, for Annapolis, Maryland, to undertake a completely new phase of work: the development of liquid-fuel jet-assisted-take-off (JATO) units for shortening the take-off lengths of heavily loaded U.S. Navy seaplanes.

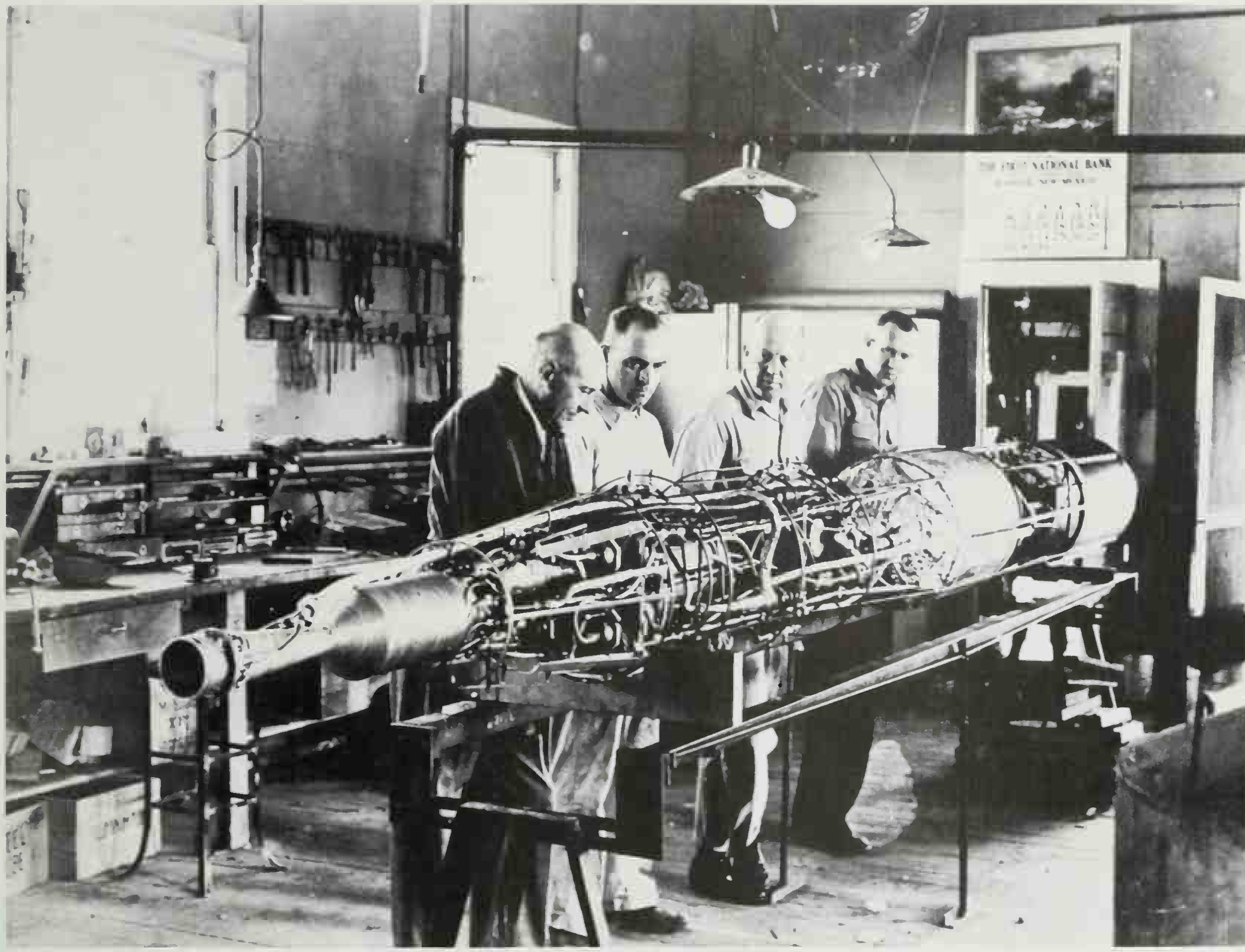
Goddard's 1941 rocket is an example of his P-series undertaken between 1938 and 1941. "P" stands for pumps. The purpose of the P–series work was the development of a gas generator-run, centrifugal pump for forcing propellants into the combustion chamber.

The rocket on display in the *Milestones of Flight* gallery, adjacent to a model of Goddard's first liquid-fuel rocket, is a cut-away covered with plexiglass, permitting a view of the rocket's inner workings.

The engine was cooled by the gasoline fuel running through copper tubing around the chamber prior to its injection for ignition. It may be compared with contemporary regeneratively cooled engines built by James H. Wyld of the American Rocket Society. Wyld's regeneratively cooled motors may be seen in Gallery 113: *Rocketry and Spaceflight*.

As with other Goddard rockets, the P-series were continuously modified. Two flights are known to have been made with this rocket, one of 90 meters (300 feet) on August 9, 1940, and the other of 75 meters (250 feet) on May 8, 1941.

Frank H. Winter



Goddard and his assistants work on a P-series rocket, 1941. (Photo: NASA 74-H-1244)

V–2 Missile

Length: 14 m (46 ft)
Weight: 12,900 kg (28,400 lb)
Range: 300 km (190 mi)
Thrust: 250,000 newtons (56,000 lb)
Gallery: 114: *Space Hall*

Germany's V-2 was the world's first long-range ballistic missile. Between September 1944 and March 1945, German field units launched more than three thousand V-2 missiles. Nearly 1900 were launched against Allied targets on the European continent, primarily Antwerp, Belgium. The remainder fell on London and southern England.

Known as the "Aggregate-4" (Assembly-4) to its designers, the Nazi Propaganda Ministry dubbed the missile "Vergeltungswaffe-2" (Vengeance Weapon–2), or, more simply, "V-2", as a companion to the V-1 cruise missile. The first combat round, launched on September 6, 1944, represented the culmination of nearly 14 year's work.

The Treaty of Versailles, which had ended World War I, had imposed severe limitations on the German armed forces. The treaty set specific limits on the weapons allowed in the post-war German army, but contained no mention of rockets. Seeing this loop-hole, the Wehrmacht's Ordnance Department authorized the development of a large long-range rocket. It selected Artillery Captain Walter Dornberger to supervise the project. Two years later, Dornberger hired a young student, Wernher von Braun.

Ten years later, on October 3, 1942, the A-4 made its first successful flight. The rocket on exhibit in the *Space Hall* carries the paint design of that first successful rocket. Two more years of testing were needed before the V-2 was ready for field use.

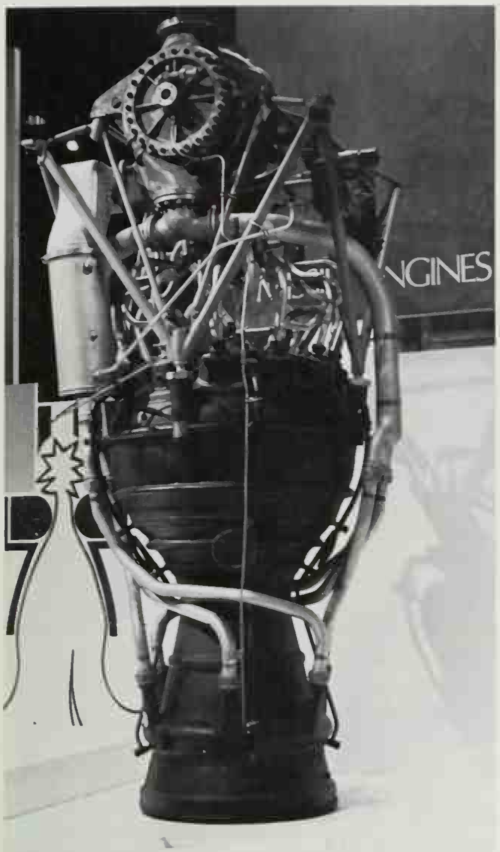
When it was finally deployed in the fall of 1944, it was launched by mobile field batteries from positions in France and Holland. Each missile carried a 1,000 kilogram (2,200-pound) high-explosive warhead. The V-2's engine consumed liquid oxygen and alcohol, and produced a thrust of 250,000 newtons (56,000 pounds). A hydrogen peroxide-powered turbopump fed the propellants to the combustion chamber.

The V-2 had an unusual-looking combustion chamber, with 18 cups on its top. Each cup was a propellant injector. Early in the German rocket program, the engineers developed a very successful 13,000-newton (3,000-pound) thrust motor. When they tried to build a large motor for the V-2, they had problems building a single large propellant injector; so they tried clustering 18 injectors from the small engine, and found it worked. Rather than spend additional time on the problem, they incorporated the 18-cup design into the large motor.

After the war, the U.S. Army brought to this country enough pieces for nearly 80 missiles. As part of Project Hermes, over 70 V-2's were launched from the White Sands Proving Ground in New Mexico during the late 1940s and early 1950s. These rockets provided the first practical experience with large rockets in the United States and formed the basis for later U.S. advances in the exploration of space and the launching of scientific instruments above the atmosphere.

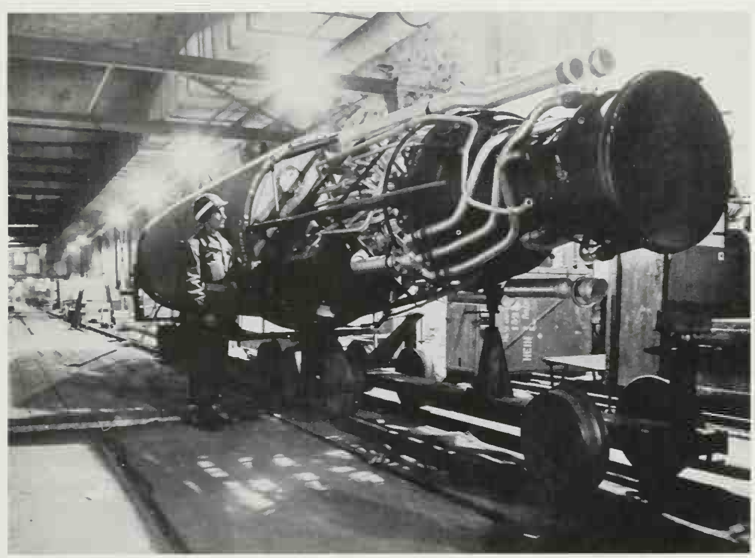
Gregory P. Kennedy

V-2 missile exhibited in Gallery 114: Space Hall. *(Photo: Smithsonian Institution)*



V-2 motor with its propellant turbopump. (Photo: Smithsonian Institution)

During the 1940s and early 1950s, American scientists launched over 60 captured V-2s from the White Sands Proving Grounds in New Mexico. (Photo: SI 79-13149)



A United States soldier stands guard over a partially completed V-2 on the assembly line of the underground missile factory near Nordhausen, Germany, shortly after its capture in 1945. (Photo: SI 75-15871)

V–1 Missile

Length:	7.7 m (25.4 ft)
Wingspan:	5.3 m (17.4 ft)
Weight:	2,180 kg (4,800 lb)
Range:	240 km (150 mi)
Thrust:	3,400 newtons (770 lb)
Gallery:	114: *Space Hall*

During World War II, the German Air Force used the V-1 guided missile as a long–range bombardment weapon. The V-1, a small pilotless aircraft, was an early version of today's cruise missiles.

Development of the V-1 began on June 19, 1942, when the German Luftwaffe placed an order for the vehicle. At that time it was known as either the *Fi 103,* from its manufacturer, the Gerhard Fiesler Werke, or the *FZG 76,* which stood for "Flakzielgerat 76" (Antiaircraft aiming device 76). This latter designation was to deceive Allied intelligence analysts, and had nothing to do with the true purpose of the missile. *V-1* stood for "Vergeltungswaffe-1" (Vengeance Weapon-1), the name given to it by the Nazi Propaganda Ministry.

London and Antwerp, Belgium, were the principal targets for this weapon, which also became known as the "Buzz Bomb" because of the noise of its engine. Each missile carried 850 kilograms (1,870 pounds) of high explosive.

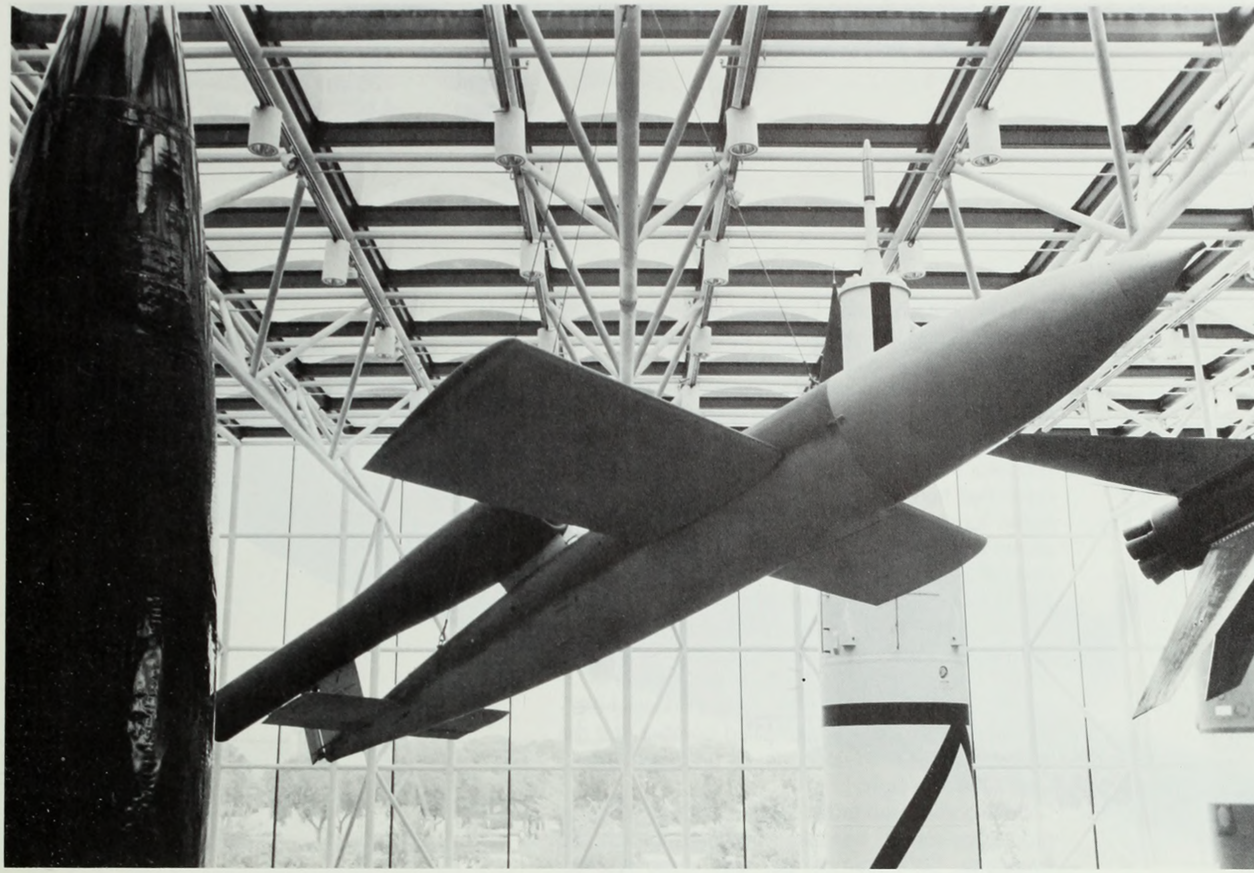
An Argus pulse jet powered the V-1. The powerplant comprised a tube with a valve assembly on its front. Fuel entered the combustion chamber (the portion of the tube just behind the valve assembly) and ignited. Pressure from the ignition closed the valves, and the hot gases escaped through the open aft end of the tube. This created a partial vacuum in the combustion chamber, which opened the valves and drew in air and fuel. The fuel/air mixture ignited, and the cycle started again. This cycle repeated itself 47 times a second as the Argus 109-014 pulse jet generated 3,400 newtons (770 pounds) of thrust.

In contrast to the V-2, which could be launched by mobile batteries from field locations, the V-1 used fixed launch sites. They were fired from 45-meter (150-foot) long steam catapults. Early versions of these facilities had several buildings and concrete ramps for the catapult tracks. When Allied bombers wrecked these elaborate sites, the Germans switched to simpler, more easily camouflaged facilities, using wooden ramp supports and fewer buildings.

On June 13, 1944, the first ten missiles were launched toward London. Four crashed, two failed in flight, and four reached England. The V-1 flew at a speed of 580 kilometers per hour (360 miles per hour) and had a range of 240 kilometers (150 miles). A gyro-compass kept it on course, and a spinning propeller on its nose logged the distance travelled. When the propeller spun a certain number of times, it meant the missile was over the target, and the elevator locked in the down position. The craft then dove into the ground and exploded. A flaw in the V-1's design caused the engine to quit as it began its final dive. This provided up to ten seconds warning of the impending explosion for those on the ground.

The V-1 was relatively easy prey for anti-aircraft guns and interceptors; only one-quarter of the missiles reached their targets. However, over 2,400 hit London. Nearly the same quantity fell on Antwerp. The German V-weapon offensive, or "Robot Blitz" as it was referred to in England, ended in March 1945. Altogether, more than 30,000 V-1's were built during the war.

Gregory P. Kennedy



V-1 "Buzz Bomb," a precursor to today's cruise missiles. (Photo: Smithsonian Institution)

Hs. 298 Missile

Length: 1.8 m (6 ft)
Wingspan: 124 cm (49 in)
Weight: 120 kg (265 lb)
Range: 4,600 m (5,000 yd)
Gallery: 114: *Space Hall*

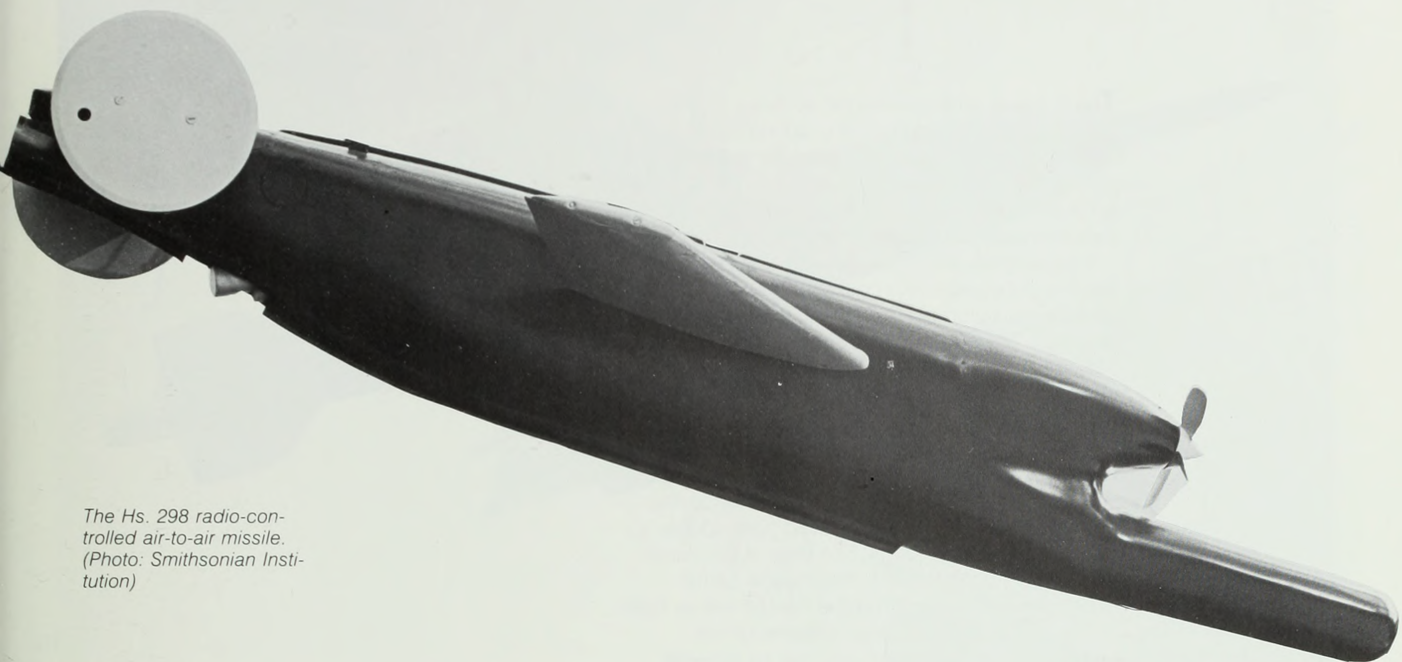
The Hs. 298 was one of a series of German air-to-air guided missiles developed by the Henschel Company during World War II. It was carried aloft by a parent aircraft, either a Dornier Do 217 or a Foke-Wulf FW 190. The missile was released from the carrier and propelled by a 2-stage solid-propellant rocket motor. The Hs. 298 was radio-controlled from the parent aircraft. Tactical plans called for the Hs. 298 to be released either slightly above or below the target. This height differential made it easier to aim and guide the missile.

A two-stage solid-propellant motor powered the missile. The high-thrust first stage accelerated the missile away from the carrier aircraft, while the low-thrust, long-burning sustainer maintained the vehicle's velocity. A proximity fuse detonated the missile when it was near an allied bomber. If it did not explode after 50 seconds, an on-board timer destroyed it in flight.

Development started in 1943; by 1944, 100 pre-production rounds had been delivered for test and evaluation. On December 22, 1944, three missiles were test flown from a Ju 88G aircraft. One stuck on the launch rail. Although the other two were successfully launched, one exploded prematurely and the other took a nose dive and crashed. Production was halted in February 1945, and none were used in combat.

The museum's specimen is one of the later variants, with circular tail fins. It was brought to this country after the war for technical intelligence evaluation.

Gregory P. Kennedy



The Hs. 298 radio-controlled air-to-air missile. (Photo: Smithsonian Institution)

X–4 Missile

Length: 2.0 m (6.6 ft)
Weight: 60 kg (130 lb)
Range: 3.5 km (2.2 mi)
Gallery: 114: *Space Hall*

The X-4 was an experimental air-to-air guided missile developed in Germany during World War II. It was in the final stages of development when the war ended, so it was never used in combat. Either a Focke-Wulf FW 190 or Messerschmitt Me 262 was intended as the carrier aircraft.

A hypergolic, liquid-propellant rocket powered the X-4. A hypergolic propellant ignites spontaneously on contact, so no ignition system is required. The X-4 motor, designated the BMW 109–548, generated an initial thrust of 1,200–1,400 newtons (270–315 pounds), which fell to 200–300 newtons (45–68 pounds) after 20 seconds. Compressed air forced the propellants out of their helical tanks and into the combustion chamber.

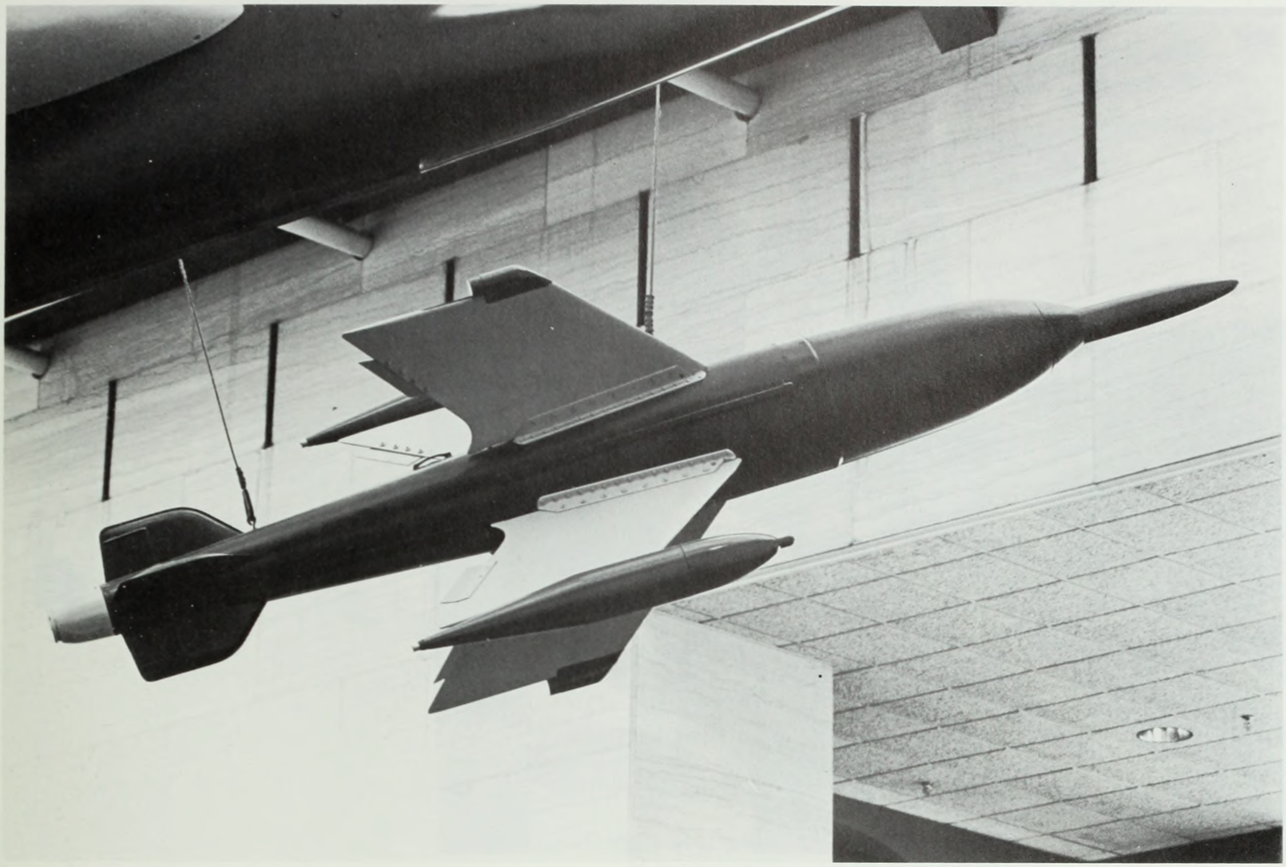
Guidance commands were transmitted to the missile via two fine wires released from spools on two of the missile's wings. The pilot of the carrier aircraft controlled the X-4, making the carrier especially vulnerable while the missile was in flight.

One of the unique design features of this weapon was that the warhead had no external casing. Rather, it was machined from the high explosive Nipolite. Operational rounds were to have an acoustic proximity fuse, which detonated the warhead when it detected the sound of an airplane propeller at a distance of 14 meters (15 yards). Because of its caseless design, the warhead produced very little fragmentation; it relied on concussion for its effect. After the war, Allied intelligence specialists concluded that the warhead would probably have been only marginally effective.

Aerodynamic control was by rake-like spoilers on the aft fins, which vibrated at 5 cycles per second. Control was effected by making the period during which the spoiler projects from one side of the fin longer than that during which it projects from the other. This type of steering caused a lot of drag and caused a delay in the time it took the X-4 to respond to a steering command; but it was simple and had an instantaneous mechanical response.

Altogether, more than 1,300 X-4's were built. The museum's specimen was a test model brought to this country after the war for technical evaluation. It has a metal warhead casing and contains no explosive components.

Gregory P. Kennedy



The experimental X-4 wire-guided air-to-air missile. (Photo: Smithsonian Institution)

Rheintochter R-1 Missile

Length: 6.3 m (21 ft)
Altitude: 6.0 km (3.7 mi)
Weight: 1,750 kg (3,860 lb)
Gallery: 114: *Space Hall*

The Rheintochter ("Rhine Maiden") was developed in Germany during World War II. This two-stage, solid-propellant rocket was a radio-controlled surface-to-air missile. Rheintochter was an unusual-looking rocket, with three sets of fins, one on the booster and two on the sustainer.

Four movable fins on the rocket's nose steered the rocket. There were six fixed (nonmoving) fins around the base of the second stage and four fixed fins on the booster. All fourteen fins were made from plywood.

The first stage fired for 0.6 seconds, long enough to get the rocket off the launcher. Then, the sustainer ignited to carry it to its target. The sustainer's exhaust exited through six canted nozzles spaced between the six main fins. The missile's high explosive warhead was in the *base* of the second stage, beneath the nozzles and main fins. As the missile flew, it was controlled from the ground.

Work began on the R-1 in late 1942. Eighty-two flew before work on the missile stopped in December 1944. Long before that time, the Allied bombers, which were the targets, were flying far above the R-1's range, so work had shifted to a more advanced, liquid-propellant version, the R-3. However, even this missile was abandoned in December 1944 in favor of other anti-aircraft missile projects.

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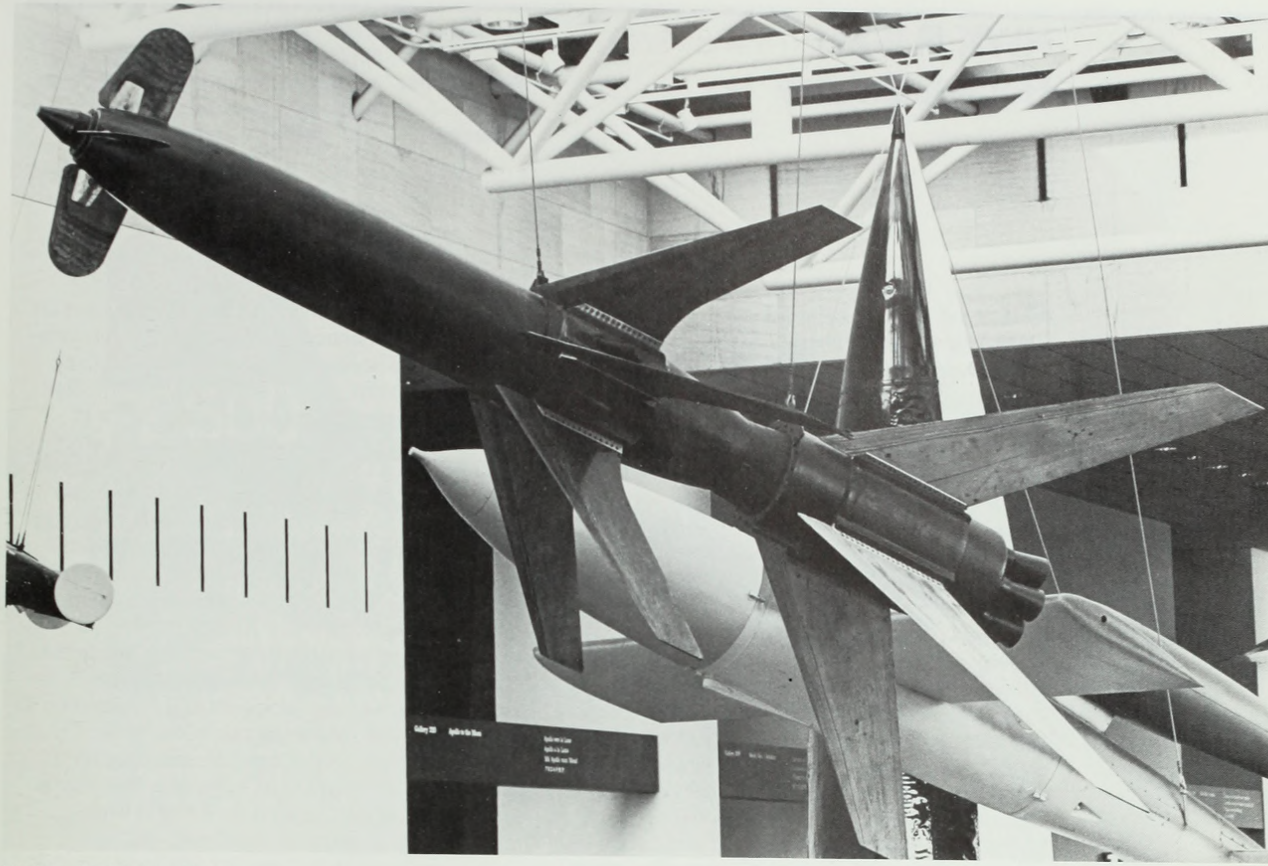


Rheintochter R-1 surface-to-air missile. (Photo: Smithsonian Institution)

HWK R II-211 Rocket Engine

Thrust: 2,900-15,000 newtons (660-3,300 lb)
Propellants: Hydrazine hydrate and alcohol, and hydrogen peroxide
Gallery: 113: *Rocketry and Space Flight*

One of the most unusual aircraft produced during World War II was Germany's Messerschmitt Me 163B *Komet*. The *Komet*, a short-range, rocket-propelled interceptor, could climb to 9,000 meters (30,000 feet) in just over 2.5 minutes. Dr. Alexander Lippisch designed the small tailless aircraft. It was just over 5.6 meters (18.5 feet) long with a 9.1-meter (30-foot) wingspan.

The Hellmuth Walter Werke in Kiel built the *Komet*'s powerplant, which bore the designation "HWK R II-211." The engine consumed a fuel of hydrazine hydrate and methanol and an oxidizer of hydrogen peroxide. These propellants are hypergolic. Once the fuel, which the Germans called "C Stoff," and oxidizer, or "T Stoff," mixed in the combustion chamber, they ignited. One could not tell the difference between T Stoff and C Stoff by their appearance, so the propellant containers were well marked, but accidents still occurred. One time, a hapless workman poured some of one of the propellants into a container which held a small amount of the other, with disastrous results!

Concentrated hydrogen perioxide is very volatile and reacts vigorously with many compounds, particularly organic materials. When mixed with a catalyst, such as potassium permanganate, hydrogen peroxide decomposes to form high-temperature steam (around 315°C or 600°F) and oxygen, with no flame. The Walter Company built several engines based upon this principal, calling them "cold" engines because of the lack of an exhaust flame. The HWK R II-211, however, was a "hot" engine. When the hydrogen peroxide and hydrazine hydrate reacted, they produced steam and enough oxygen for the methanol in the fuel (57% by weight) to burn. Engine thrust was throttlable from 2,900 to 15,000 newtons (660 to 3,300 pounds). At full throttle, the *Komet*'s propellant supply lasted 4 minutes, 11 seconds. Needless to say, such a short duration severely limited the aircraft's range.

The HWK R II-211 was an unusual looking motor, with the pot-shaped combustion chamber on the end of a 5-foot (1.5-meter) pipe extending from the box housing the propellant turbopumps. The engine was regeneratively cooled. C Stoff circulated between the inner and outer combustion chamber shells before it entered the fuel injectors. This technique, common to many liquid-propellant rocket motors, controls the heat in the combustion chamber and keeps the hot gases from burning through the motor wall. A small amount of T Stoff, diverted into a small container with a block of calcium permanganate, produced steam, which powered the turbopumps.

During an operational sortie against an Allied bomber formation, the *Komet* pilot would zoom up to an altitude of 9,000 meters (30,000 feet), shut off the engine, and begin a high-speed glide through the formation. If additional power was needed during the flight, he could re-start the engine. After running out of propellant, he made an unpowered approach and landing. The tiny aircraft, which its pilots nicknamed the "powered egg," landed on an extendable belly-mounted skid. One of the *Komet*'s peculiarities was that a considerable quantity of propellants remained in its tanks after the engine quit. A high-speed landing on the skid while carrying highly unstable liquid required tremendous skill. If the landing was too hard, the propellants exploded. Many *Komet* pilots died this way. Of the nearly 300 Me 163B's built, more were lost in explosions than by hostile fire.

Gregory P. Kennedy

The HWK R II-211 liquid-propellant engine powered the World War II Messerschmitt Me 163B Komet. *(Photo: SI A46588)*

WAC Corporal Rocket

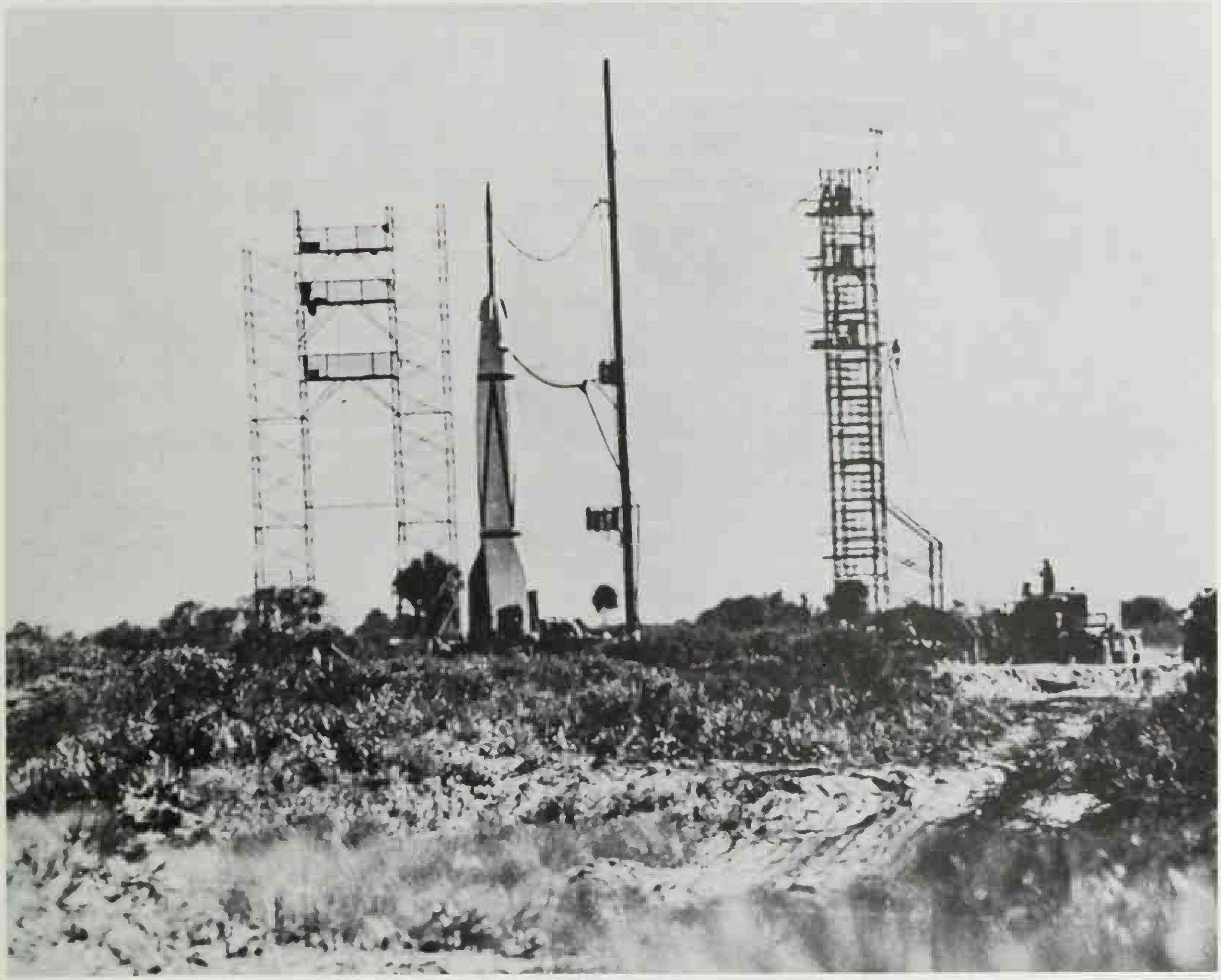
Length: 488 cm (192 in)
Weight: 302 kg (665 lb) (without booster)
Thrust: 6,700 newtons (1,500 lb)
Gallery: 110: *Satellites*

Designed to carry an 11-kilogram (25 pound) payload to an altitude of 30,000 meters (100,000 feet), the WAC Corporal was the first American high-altitude sounding rocket. In 1944, under the direction of Dr. Frank J. Malina, the GALCIT group at the California Institute of Technology began work on the rocket. It was a liquid-propellant rocket that consumed an aniline and furfuryl alcohol mixture and red fuming nitric acid. Compared to the German V-2, the WAC Corporal was a modest effort: only 30 centimeters (12 inches) in diameter and 488 centimeters (192 inches) long. Three fins stabilized the vehicle, which was launched from a 30-meter (100-foot) tall tower. A modified Tiny Tim solid-propellant air-to-surface rocket was used as a booster. On October 11, 1945, a two-stage WAC Corporal reached an altitude of 71,600 meters (235,000 feet.)

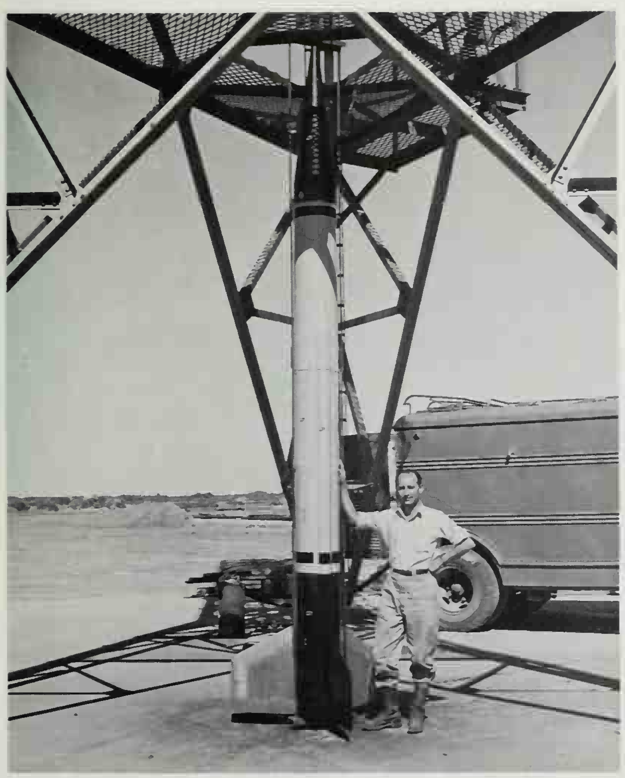
The WAC Corporal came into use just as the U.S. Army offered scientists space for their instruments aboard captured German V-2 missiles. Unfortunately, the WAC Corporal's payload capacity and altitude capability were no match for the larger missile, so the smaller American rocket was never extensively used. However, the WAC Corporal did play an important role in the V-2 program. In Project Bumper, eight V-2's carried WAC Corporals as an upper stage. One of these, Bumper 5, reached an altitude of 400 kilometers (250 miles), an altitude record that stood until the balloon-launched Farside rocket flights in 1957. The first rocket launched from the East Coast Test Range at Cape Canaveral, Florida, was a V-2/WAC Corporal vehicle.

Many of the California Institute of Technology engineers who worked on the WAC Corporal went on to work for the Aerojet Engineering Corporation. In 1946, Aerojet received the contract to develop the Aerobee sounding rocket. Many of the engineers who designed the WAC Corporal contributed to Aerobee's design, so there were many similarities between the two rockets. Like the WAC, Aerobee had a pressure-fed propulsion system, was an unguided fin-stabilized rocket, and used aniline and furfuryl alcohol and red fuming nitric acid for propellants. In many respects, the Aerobee, one of the most frequently used sounding rockets of the 1950s, 60s, and 70s, was an advanced version of the WAC Corporal.

Gregory P. Kennedy



As part of the American post-World War II V-2 program, the WAC Corporal became an upper stage in Project Bumper. This V-2/WAC Corporal vehicle was the first rocket launched from the East Coast Test Range at Cape Canaveral, Florida, in July 1950. (Photo: SI 77-11203)



Dr. Frank J. Malina and the WAC Corporal. (Photo: Courtesy California Institute of Technology)

Viking 12 Rocket

Length: 12.6 m (497 in)
Weight: 6,720 kg (14,815 lb)
Thrust: 91,200 newtons (20,500 lb)
Gallery: 110: *Satellites*

On February 4, 1955, *Viking 12,* the last of the Viking research rocket series lifted-off from the White Sands Proving Ground in New Mexico. Viking, a U.S. Navy project, was the first large rocket designed and built in the United States.

First known as Neptune, Viking was proposed by the Naval Research Laboratory in 1946 as a vehicle for carrying instruments to altitudes in excess of 305,000 meters (1,000,000 feet). At the time Neptune was proposed, captured German V-2's were being used for high altitude research. The V-2's, however, were far from being optimum vehicles for scientific instruments.

After engine burn-out, the V-2's were not guided and had a tendency to roll or oscillate. The V-2 was designed to be a weapon, and carried a warhead weighing 1,000 kilograms (2,200 pounds). If there were not enough instruments in the rocket's nose, ballast had to be added, decreasing the potential altitude of the missile. Finally, the supply of V-2's was finite, so a suitable replacement was needed.

The Viking was designed to be that replacement. It featured many innovations and improvements over the V-2. It was the first large rocket made almost entirely from aluminum. The V-2 used graphite vanes in the exhaust for steering. Viking swivelled or "gimballed" its engine to steer, a more efficient system. Viking also had a three-axis stabilization system, an important innovation for scientists who needed to aim their instruments with some precision. Viking was also the first large rocket to use "integral tanking." The propellant tanks of the V-2 were contained inside a steel body shell. Viking tanks, however, also formed the body, eliminating the need for a separate body shell. As a testament to the efficiency of Viking's design, the first Viking rocket weighed less fully fueled than an empty V-2: 4,000 kilograms versus 6,400 kilograms (9,000 pounds versus 14,000 pounds).

Viking's engine consumed liquid oxygen and alcohol to generate a thrust of 91,200 newtons (20,500 pounds). A hydrogen peroxide powered turbopump fed the propellants into the combustion chamber.

Two types of Vikings were built. The first seven were the RTV-N-12 series, while *Viking* 8 through 12 bore the designation RTV-N-12a. The most obvious difference between the two series was that the first was 81 centimeters (32 inches) in diameter, while the later rockets, such as the one on exhibit, were 114 centimeters (45 inches) in diameter. Increasing the diameter allowed the rocket to carry considerably more propellant so it could reach higher altitudes. *Viking 7,* the altitude record holder for the first series, reached an altitude of 218 kilometers (136 miles). Of the later series, *Viking 11* reached 254 kilometers (158 miles) altitude. *Viking 12* climbed to 240 kilometers (149 miles).

Two more Viking-design rockets flew after the program concluded. In September 1955, the U.S. Navy was authorized to build the Vanguard to launch the first American satellite. The Vanguard's first stage was based on the RTV-N-12a Viking, so two modified Vikings were launched in 1956 from Cape Canaveral, Florida, as test vehicles for Vanguard.

Gregory P. Kennedy

Viking 12 *launch, White Sands Proving Grounds, New Mexico, February 4. 1955. (Photo: SI 75-10228)*


12

JATO Motors

The concept of auxiliary rocket power for the jet-assisted take-off (JATO) of aircraft began as early as the 1880s when the Englishman T. J. Bennett attached gunpowder rockets to a 14-kilogram (30-pound) steam-propelled model airplane. However, the earliest known JATO flight of a manned aircraft was on August 8, 1929, when six powder rockets helped lift a Bremen-type Junkers W33 landplane fitted with floats in a flight from the Elbe River, near Dessau, Germany.

The commercial production of JATOs did not start until the 1940s. In the United States two companies were formed for this purpose: Reaction Motors, Inc., founded in December 1941, and Aerojet Engineering Corporation (later, Aerojet-General Corp.), begun early in 1942. Aerojet was an outgrowth of the Guggenheim Aeronautical Laboratory at California Institute of Technology (GALCIT) rocket project begun in 1938 under the leadership of Dr. Theodore von Kármán. Aerojet was the first company in this country to successfully fly an aircraft with a JATO. This unit, on exhibit with other JATOs in Gallery 113: *Rocketry and Spaceflight*, was propelled by a solid-fuel designated GALCIT 27.

The first American JATO flight was made with a 534-kilogram (1,175-pound) Ercoupe airplane on August 23, 1941, at March Field, California, using six GALCIT motors. Each motor delivered 125 kilograms (28 pounds) of thrust for 12 seconds. Also on exhibit is Aerojet's 25ALD 1000 engine, a liquid-fuel (red-fuming nitric acid and aniline), 4,450-newton (1,000-pound) thrust JATO developed for the B-24, B-25, C-40, and P-38 aircraft. A later Aerojet product on display is the XLR-AJ-1 of the 1950s, made for the B-47 and F-86 aircraft.

Other JATO motors on display (made by Reaction Motors, Inc.) include the M17G and M19G motors. These liquid-fuel (liquid-oxygen and gasoline) units were made between 1942 to 1944 for use on Navy PBY seaplanes. They are later developments of James H. Wyld's regeneratively cooled rocket engine, exhibited elsewhere in the gallery. (Reaction Motors, Inc. was started by Wyld with three other members of the American Rocket Society to exploit his engine). The M17G and M19G were stages toward the development of a 13,350-newton (3,000-pound) thrust JATO requested by the Navy. However, these two units were not adopted for service use.

Other countries also entered the JATO field. The British (more accurately) call their units RATOs, for Rocket-Assisted-Take-Off. De Havilland's Super Sprite, using hydrogen peroxide and kerosene, produces a nominal thrust of 19,000 newtons (4,200 pounds). The Super Sprite was conceived as a JATO or RATO for the *Comet 1* airliner, but afterwards saw service in the late 1950s with Royal Air Force planes.

Frank H. Winter

Above
First American JATO take-off, March Field, California, August 12, 1941. (Photo: SI 77-10790; courtesy Ed Rice)

Below
Boeing B-47 bombers used XLR-AJ-1 JATO rockets. (Photo: SI 72-7758; courtesy Boeing Airplane Company)

XLR-11 Rocket Engine

Weight: 95 kg (210 lb)
Thrust: 26,700 newtons (6,000 lb)
Gallery: 113: *Rocketry and Spaceflight*

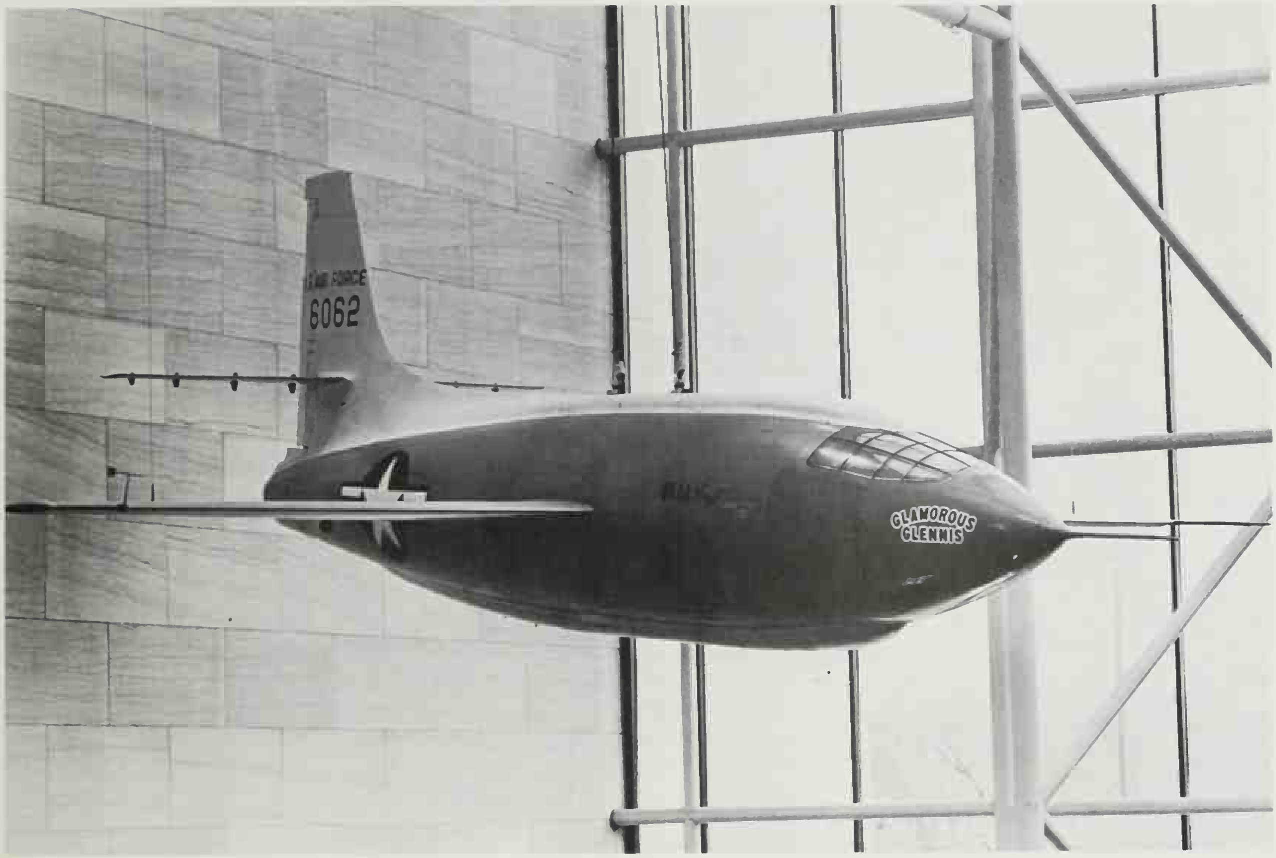
The XLR-11 liquid-propellant rocket engine has powered many high-speed research aircraft, including the X-1, D 558-2, X-15, and *M2-F3* lifting body. One of these engines propelled the Bell X-1 during the world's first supersonic aircraft flight on October 14, 1947.

The XLR-11 consumed ethyl alcohol and liquid oxygen to produce a thrust of 27,000 newtons (6,000 pounds). It had four separate combustion chambers, so the thrust could be throttled in 6,700-newton (1,500-pound) increments. On early versions of this engine, the propellants were pressure-fed into the combustion chamber. This is the type on exhibit and was the type on the X-1 during the first supersonic flight. Later engines had turbopumps, eliminating the need for a heavy propellant tank pressurization system.

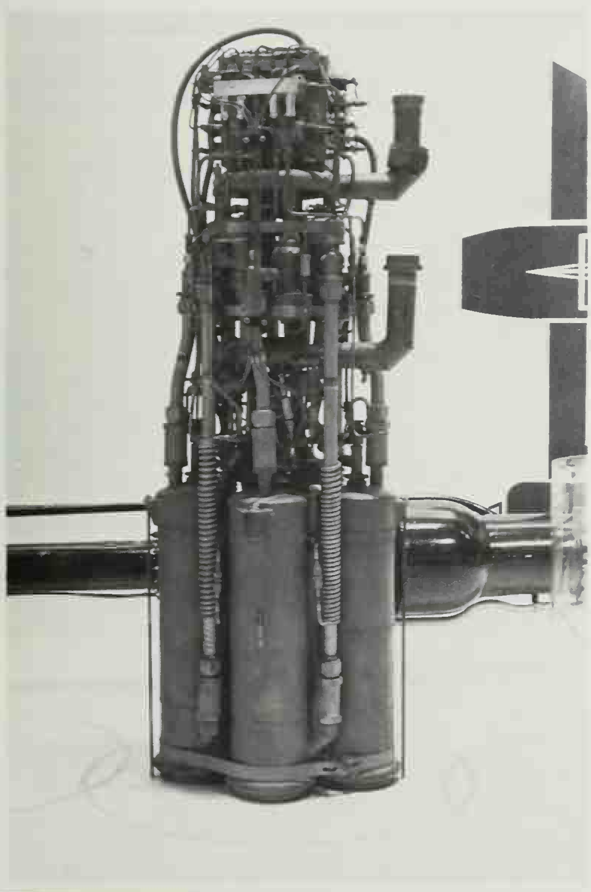
During its development, the engine was unofficially nicknamed "Black Betsy," after its original coating of black paint and the daughter of the president of Reaction Motors, Inc., the company which built the engine.

During its useful life, the XLR-11 has been uprated to a thrust of 36,000 newtons (8,000 pounds). However, the newer engines, which propelled such research craft as the *M2-F3* lifting body, are essentially the same engines as used in the X-1.

Gregory P. Kennedy



An XLR-11 powered the Bell X-1, shown here on exhibit in Gallery 100: Milestones of Flight, *during the first supersonic flight in 1947. (Photo: Smithsonian Institution)*



XLR-11 engine. (Photo: Smithsonian Institution)

Nike-Cajun Rocket

Length: 12 m (39.5 ft)
Payload: 27 kg (60 lb)
Altitude: 160 km (100 mi)
Gallery: 110: *Satellites*

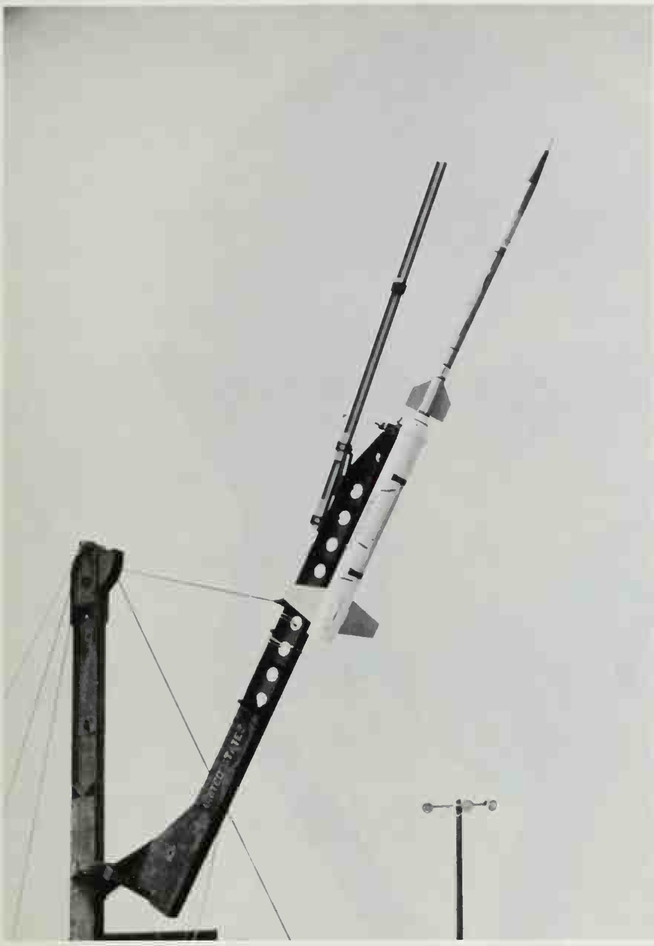
The Nike-Cajun is a two-stage solid-propellant sounding rocket. Sounding rockets carry scientific instruments into the upper atmosphere and near-space environment. These rockets do not reach orbit; they fly ballistic "up and down" trajectories. Sounding-rocket flight durations are measured in minutes. However, such short flights are adequate for many experiments, and the relatively low cost of sounding rockets makes them particularly well suited for many uses.

Surplus military rockets are often used for sounding rockets. One of the most frequently used is the first stage motor of the Nike-Ajax antiaircraft missile. Development of the Nike began in 1945, and eventually thousands were built. When the Nike-Ajax was withdrawn from service, the first stage motors were adapted for use as sounding-rocket boosters.

The Pilotless Aircraft Research Division of the National Advisory Committee for Aeronautics (NASA's predecessor) supervised the development of the Cajun. Cajun started as an improved version of the World War II vintage, Navy developed, Deacon rocket, which was flown with a Nike booster in mid-1955. Project manager Joseph G. Thibodaux, Jr., from Louisiana, suggested the name "Cajun" because of its Louisiana connection. The name was adopted and started the Corporation's tradition of giving their rockets Indian-related names.

In 1956, the first Nike-Cajun rockets were launched. Since then, more than 1,000 have flown, making it one of the most frequently used sounding rockets. In fact, the Nike-Cajun is still in use today and can carry a 27-kilogram (60 pound) payload to an altitude of 160 kilometers (100 miles).

Gregory P. Kennedy



Nike-Cajun on launch pad at Wallops Island, Virginia. (Photo: NASA 71-H-413)

Nike-Cajun lift off. (Photo: NASA 62-NC-2)

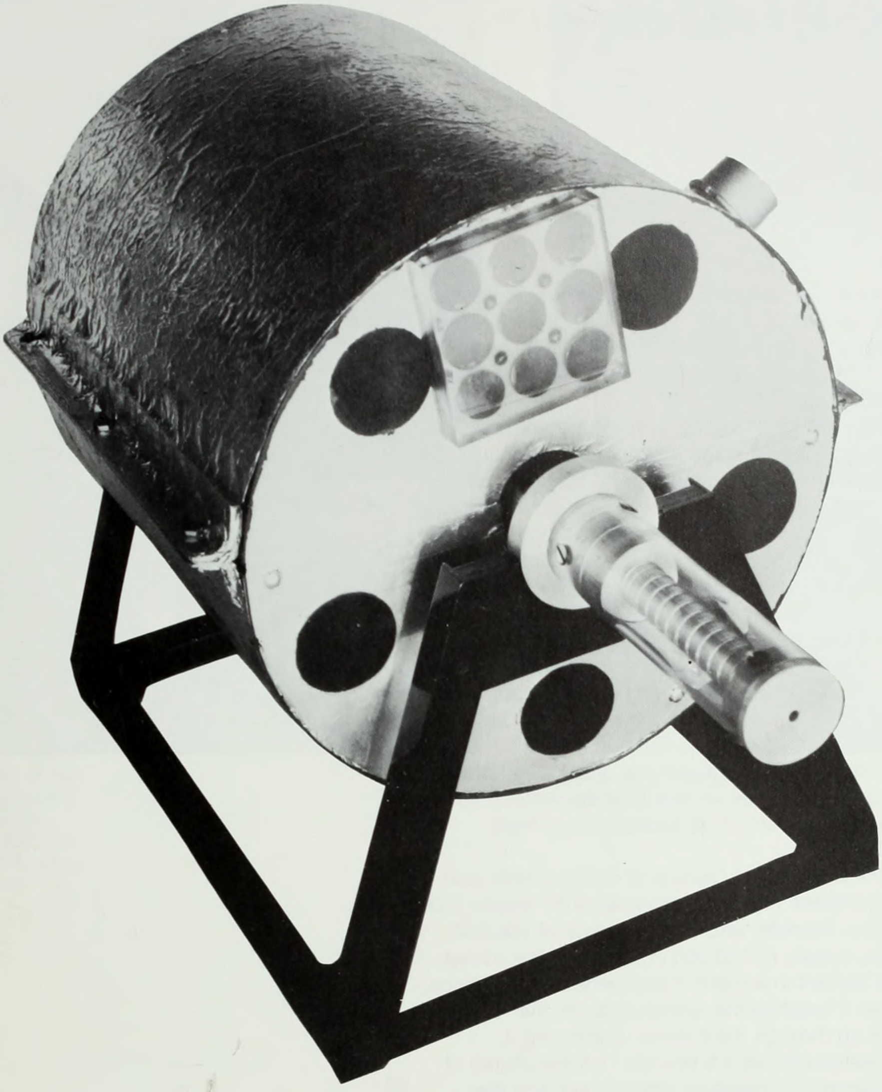
MOUSE Satellite Model

Following World War II, many early studies and speculations were made about the possibility of using rockets to launch an earth-orbiting satellite. Such a proposal was presented to the second meeting of the International Astronautical Federation held in London in 1951. That proposal was for a small satellite containing a few simple instruments and a radio transmitter. The authors were Kenneth Gatland, Alan Dixon, and Anthony Kunesch of Great Britain.

Several years later, S. Fred Singer at the University of Maryland extended and refined the concept of the "minimum satellite." He prepared a detailed design for an instrument package that would weigh no more than 45 kilograms (100 pounds). Although there were no realistic prospects in 1954 of launching Singer's satellite, a model was constructed for display at the Fells Planetarium of the Franklin Institute in Philadelphia. The model was donated to the Smithsonian Institution in 1967 and is known as "MOUSE" (Minimum Orbital Unmanned Satellite of Earth).

The satellite model is cylindrical in shape and was designed to spin along its symmetry axis, that is, perpendicular to the plane of its polar orbit. It was to have photo-sensitive cells to scan Earth, measuring cloud cover and the amount of light reflected or scattered by Earth's atmosphere and surface, several geiger counters or similar devices to measure radiation, a radio and telemetry system, a magnetic data storage device, and solar cells for power. (Solar cells had just been made available on an experimental basis by the Bell Laboratories.)

Allan Needell



MOUSE, one of the first serious satellite proposals. (Photo: SI 75-16276)

Farside Rockets

Length: 7 m (23 ft)
Weight: 860 kg (1,900 lb)
Payload: 1.6 kg (3.5 lb)
Altitude: 6,400 km (4,000 mi)
Gallery: 110: *Satellites*

Farside was a type of research rocket that was carried aloft by a balloon and launched. If carried to an altitude of 30,000 meters (100,000 feet), the four-stage vehicle could reach 6,400 kilometers (4,000 miles).

Farside used existing solid-propellant rocket motors. The first stage was a cluster of four Recruit motors, the second stage was a single Recruit. Four smaller Arrow-2 motors made up the third stage, and the fourth stage was a single Arrow-2 attached to the payload. The stages fired consecutively, with a short delay between each one. Total elapsed time between first stage ignition and fourth stage burn-out was 26 seconds, with about 8 seconds of powered flight. During boost, Farside experienced a 200-g acceleration, and reached a velocity of 29,000 kilometers per hour (18,000 miles per hour). Farside had to be launched from a high altitude: if launched from the ground, in the denser region of the atmosphere, it would have burned up because of its high acceleration.

The Mechanical Division of General Mills built the polyethylene balloons, which were 61 meters (200 feet) in diameter and had a volume of 106,000 cubic meters (3,750,000 cubic feet). The rocket was carried in a metal frame beneath the balloon. When it reached the launch altitude, the rocket fired up through the balloon, destroying it.

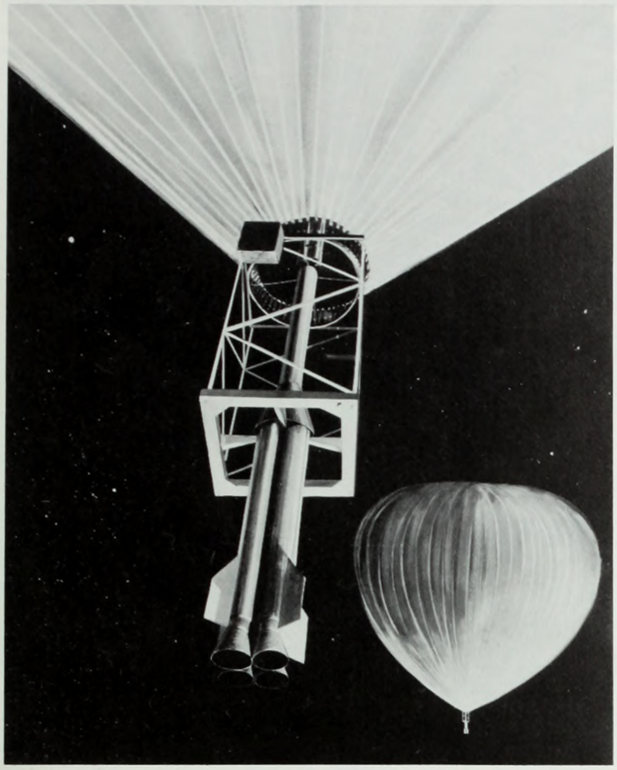
Farside carried 3.5 pounds (1.6 kilograms) of instruments to measure cosmic rays and the earth's magnetic field. The instrument package also carried a small radio transmitter.

Farside was launched from Eniwetok Atoll in the central Pacific. The first flight attempt was on September 25, 1957. Unfortunately, the balloon ripped, and the rocket was not fired. The second flight was somewhat better: the rocket fired, but the transmitter was damaged as it passed through the balloon. The transmitter stopped when the vehicle was about 800 kilometers (500 miles) high, but the rocket probably went higher. This flight, on October 3, 1957, was on the day before the Soviets launched *Sputnik 1*.

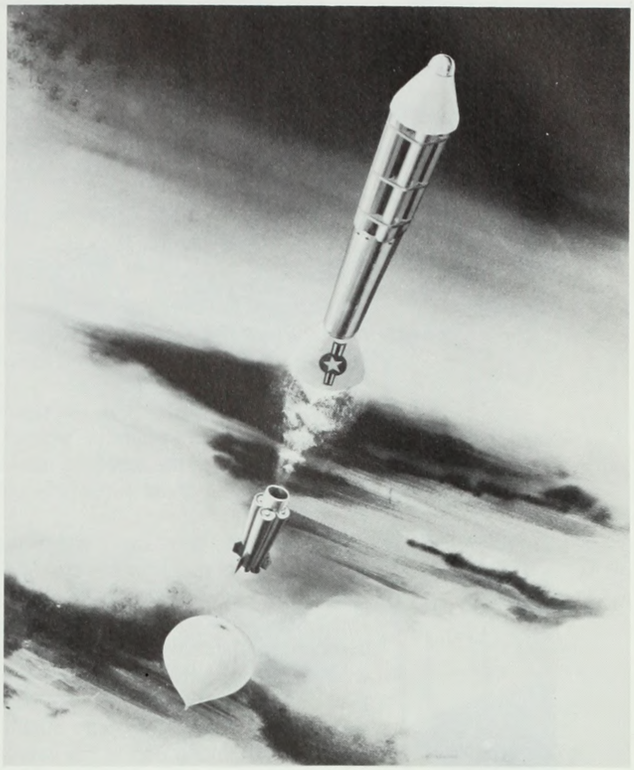
The third flight was another partial success. The balloon only reached 21,000 meters (70,000 feet), and the transmitter quit at 640 kilometers (400 miles). During shot 4, the balloon froze, and the rocket was fired early for safety reasons.

The last two flights, on October 20 and 22, 1957, apparently reached 6,400 kilometers (4,000 miles), but their transmitters quit early. Rocket 6 was the most successful, returning data from an altitude of 1,600 kilometers (1,000 miles).

Gregory P. Kennedy



Artist's rendering of Farside rocket suspended beneath its balloon. (Photo: SI 76-1706; courtesy General Mills, Mechanical Division)



Farside launch. (Photo: SI 76-1705)

Sputnik 1 Satellite

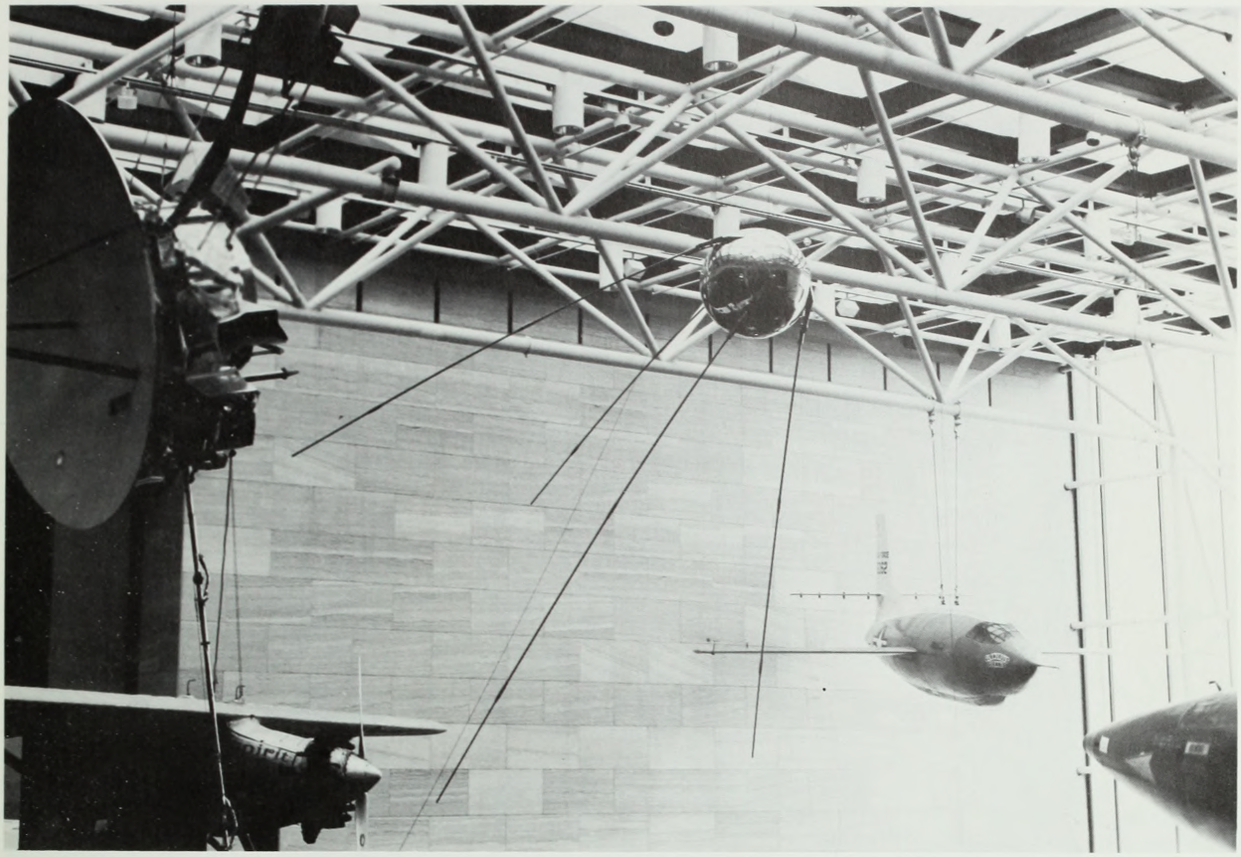
Diameter: 58 cm (22.8 in)
Weight: 83.6 kg (184 lb)
Gallery: 100: *Milestones of Flight*

On October 4, 1957, the Soviet Union successfully placed the world's first artificial satellite into orbit around Earth. The satellite itself was a polished 58-centimeter (22.8-inch) sphere with four rod-shaped antennas. Most remarkable, the satellite weighed 83.6 kilograms (184 pounds), several times heavier than the largest of the satellites then being prepared for launch as part of the U.S. Project Vanguard.

Sputnik 1 had two radio transmitters aboard and broadcast what has now become the familiar "beep-beep-beep" clarion call of the space age. This signal was broadcast on radio frequencies that could be received by professional and amateur radio operators around the world, rather than on the special frequencies that had been reserved for satellite telemetry by the agreement of the scientists taking part in the International Geophysical Year, then underway.

Scientific information obtained from *Sputnik 1* came primarily from observations of its orbit and the rate at which that orbit decayed. Even so, the significance of the event can hardly be overestimated. Reaction to the technological accomplishment was dramatic and disturbing to many in the West. The result was an intense debate that led to several important events in the United States. Among the most significant were the establishment of the National Aeronautics and Space Administration and the enactment by Congress of the National Defense Education Act of 1958.

Allan Needell



Sputnik 1. *(Photo: Smithsonian Institution)*

Explorer 1 Satellite

Length: 200 cm (80 in)
Weight: 13.9 kg (30.7 lb)
Gallery: 100: *Milestones of Flight*

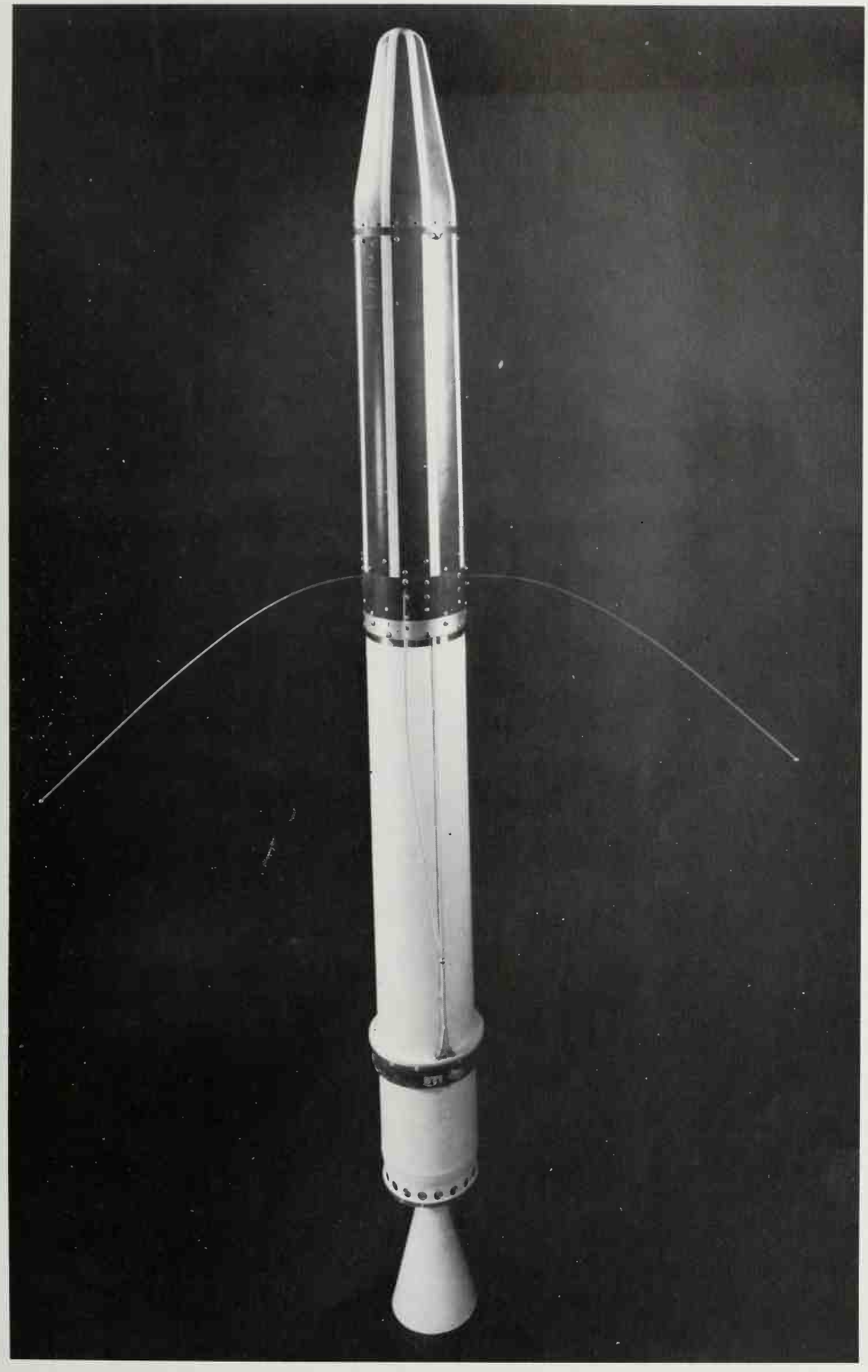
On January 31, 1958, the United States successfully launched its first artificial satellite. *Explorer 1* was 200 centimeters (80 inches) long and 15 centimeters (6 inches) in diameter. Besides its 5 kilograms (11 pounds) of scientific instruments, batteries, and radios, the satellite included the spent fourth stage of its Jupiter-C launch vehicle. *Explorer 1*'s orbital period was 115 minutes.

Following the successful launch by the Soviet Union of *Sputnik 1* and *2* (on October 4 and November 3, 1957) and delays in the Vanguard Program, the Army Ballistic Missile Agency (ABMA), at Redstone Arsenal, Huntsville, Alabama, and the Jet Propulsion Laboratory (JPL), Pasadena, California, were given the go-ahead to launch a satellite. The satellite was assembled at JPL using an instrument package developed by the team of scientists, engineers, and students at the State University of Iowa under the direction of James Van Allen. The package was attached to the single-scale Sergeant motor that would serve as the rocket's fourth stage. Just 84 days following authorization to proceed, the Army/JPL team successfully launched the first American satellite.

Data from the *Explorer 1* satellite could only be received when the satellite passed within range of one of the ground stations. The recording device that would have made it possible to obtain data from entire orbits had to be left out of the satellite because of insufficient time to adapt it to the high rotation rates it would experience aboard *Explorer 1*. The results were extremely puzzling in that it appeared that the geiger counters periodically stopped working. Only later, after data from *Explorer 3*, an almost identical spacecraft but with the data recorder, were analyzed was it realized that the geiger counters aboard *Explorer 1* had ceased operating because the spacecraft was passing into and then out of the intense radiation fields we now know surround the earth. The levels of radiation experienced were far greater than the capacity of the instruments. *Explorer 1* is often given credit for the discovery of the radiation belts. That claim is not quite accurate, however. *Explorer 1* was the first man-made satellite to detect the belts and send us a clue of their existence. Further clues were necessary to understand *Explorer 1*'s message.

Allan Needell

Explorer 1 *backup exhibited in the National Air and Space Museum. (Photo: Smithsonian Institution)*



Vanguard Rocket

Length: 22 m (71 ft)
Weight: 10,300 kg (22,800 lb)
Thrust: 120,000 newtons (27,000 lb)
Gallery: 114: *Space Hall*

On July 28, 1955, Presidential press secretary James C. Hagerty announced that the United States would place a satellite in orbit during the International Geophysical Year (July 1, 1957–December 31, 1958). Both the Army and Navy submitted plans for launch vehicles. The Army's proposal, named "Orbiter," comprised a Redstone ballistic missile with three solid-propellant upper stages. The three-stage Navy design was based upon Viking and Aerobee-Hi sounding rockets with a solid-propellant third stage. In September 1955, the Navy's project was approved and was subsequently named "Vanguard."

As Viking evolved into Vanguard's first stage, it underwent many changes: it lost its fins, and the 120,000-newton (27,000-pound) thrust General Electric X-405 rocket engine replaced the 91,200-newton (20,500-pound) thrust Viking engine. Kerosene and liquid oxygen were the fuel and oxidizer, respectively. By the time Vanguard's designers finished, the only outward similarity between the first stage and Viking was their diameter: 114 centimeters (45 inches).

The Aerobee-Hi could not meet the performance requirements for Vanguard, so a new second stage based upon Aerobee technology was built. The performance was improved by using different propellants. The second stage engine consumed white inhibited fuming nitric acid (WIFNA) and unsymmetrical dimethylhydrazine (UDMH). WIFNA and UDMH are hypergolic, that is, they ignite spontaneously on contact.

The solid-propellant third stage looked deceptively simple by comparison. However, its designers had a difficult time finding the right propellant and design to give the desired thrust, burn time, and overall performance.

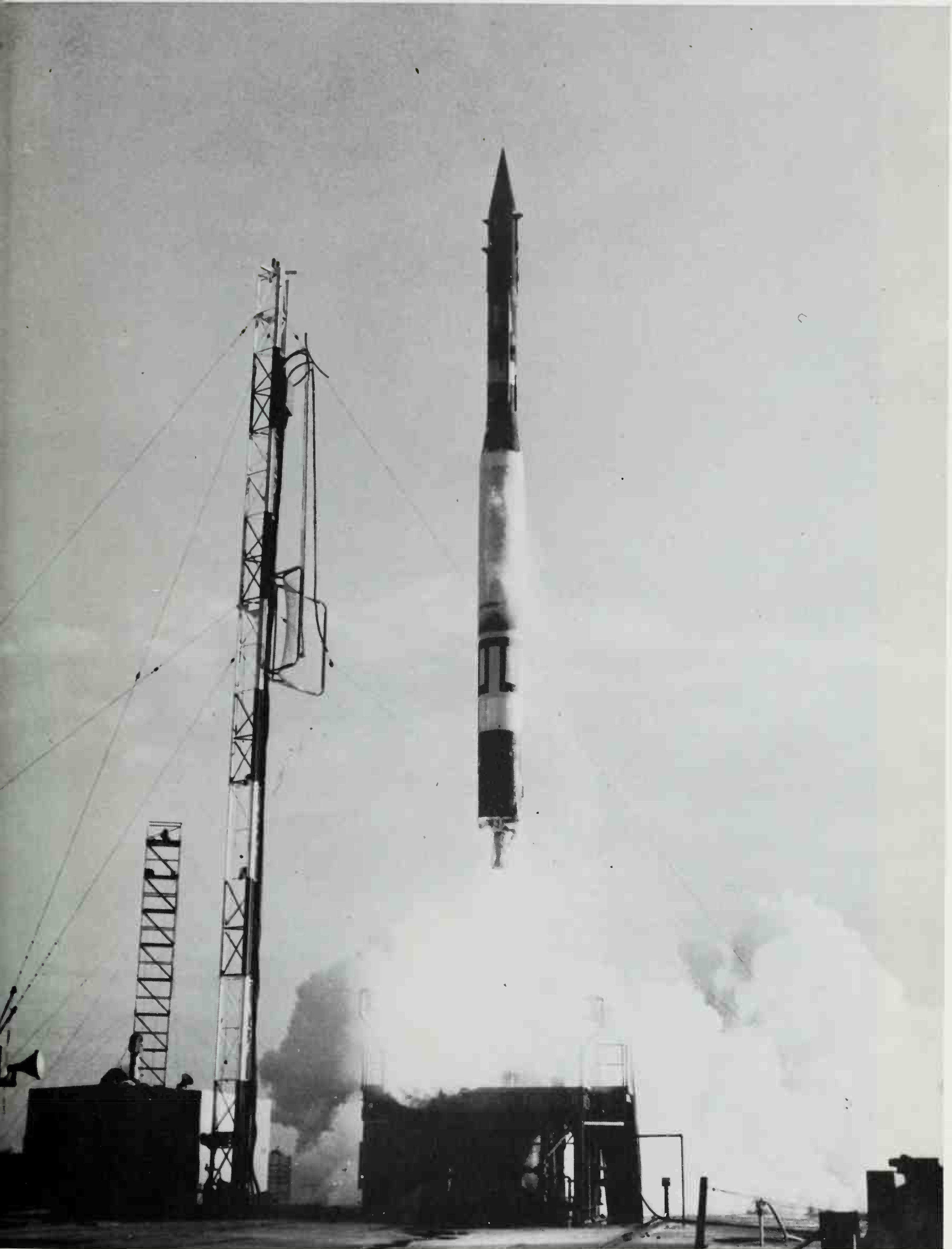
Viking 13 and *14* were the first two test vehicles in the Vanguard program. The first, designated "Vanguard TV-O," carried an instrument package to an altitude of 204 kilometers (127 miles) on December 8, 1956. The two-stage TV-1 consisted of a Viking with the solid propellant third stage. TV-2 was the first launch of an actual Vanguard first stage and carried dummy upper stages.

By the time the next vehicle, TV-3, was ready, the Soviets had orbited two more satellites and the Army had been given permission to proceed with Orbiter. On December 6, 1957, TV-3 stood on the pad, ready for the first American attempt to orbit a satellite. Less than one second after lift-off, its engine faltered and the rocket settled back on the launch pad with a tremendous explosion. The next orbital attempt, TV-3BU, ended in failure about one minute after launch.

On March 17, 1958, Vanguard TV-4 rocket finally succeeded in placing a satellite in orbit. The satellite, *Vanguard 1,* was an instrumented sphere, 15 centimeters (6 inches) in diameter and weighing 1.47 kilograms (3.25 pounds). Five more Vanguards were launched before *Vanguard 2* was put into orbit. The last Vanguard rocket put *Vanguard 3* into orbit on September 18, 1959. In all, 12 Vanguards flew, making 11 oribital attempts, and placing three satellites into orbit.

Gregory P. Kennedy

Vanguard TV-4 *launch on March 17, 1958. This rocket put into orbit America's second satellite,* Vanguard 1 *(Photo: NASA 67-H-1609)*



Vanguard 1 Satellite

Diameter: 16 cm (6.4 in)
Weight: 1.47 kg (3.25 lb)
Gallery: 110: *Satellites*

Project Vanguard represented the United States' effort to fulfill a commitment that had been made in 1955 by President Eisenhower. The United States had announced that it would attempt to place a satellite into orbit as part of its participation in the International Geophysical Year (July 1957 to December 1958).

Before the first attempt to launch a Vanguard satellite, the Soviet Union had successfully launched *Sputnik 1* on October 4, 1957; and then *Sputnik 2* on November 3. It was then arranged that the third in a scheduled series of tests of the Vanguard rocket would launch a "minimum satellite" containing a radio for tracking, but little else. The TV-3 launch ended in a dramatic explosion on the launch pad on December 6, 1957. The next attempt to launch a satellite also ended in failure.

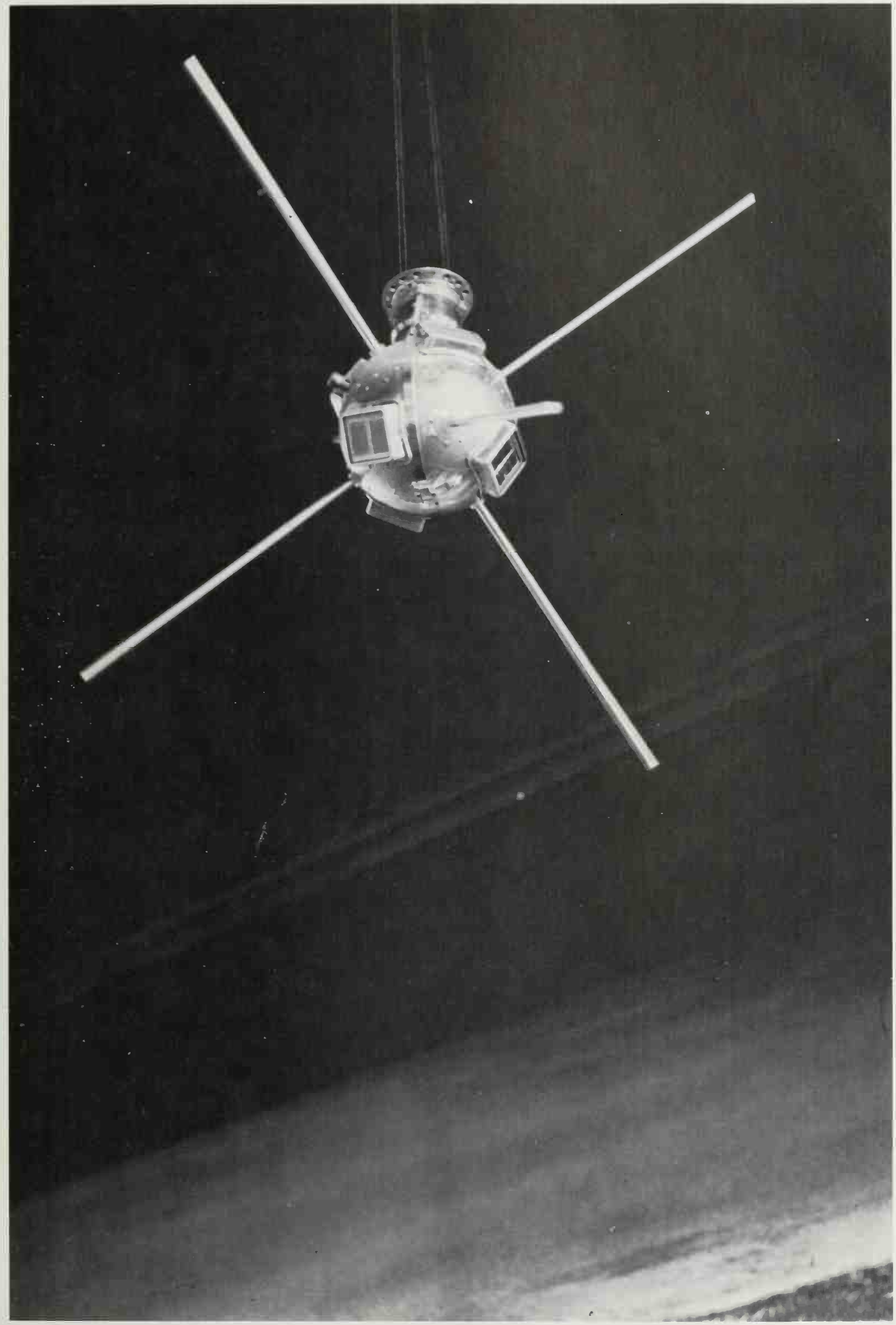
Finally, on March 17, 1958, a Vanguard rocket successfully placed a 1.47-kilogram (3.25-pound) spherically shaped satellite into orbit. The satellite contained two radio transmitters. One, powered by a mercury battery, transmitted for 29 days. The second, powered by six solar cells, continued broadcasting for several years.

Vanguard 1 was the first successful satellite in the civilian-directed, science-oriented Vanguard program. Although it did not directly return experimental data, the determination of its orbital parameters and their changes through time provided scientists with valuable information on the shape and the distribution of Earth's mass.

The satellite in the National Air and Space Museum's collection was a back-up for the Vanguard TV-4 launch and was donated to the museum in 1975 by the former Vanguard Project Director, Dr. John P. Hagen.

Allan Needell

Vanguard 1 *back-up exhibited in Gallery 110:* Satellites. *(Photo: Smithsonian Institution)*



Vanguard 2 Satellite

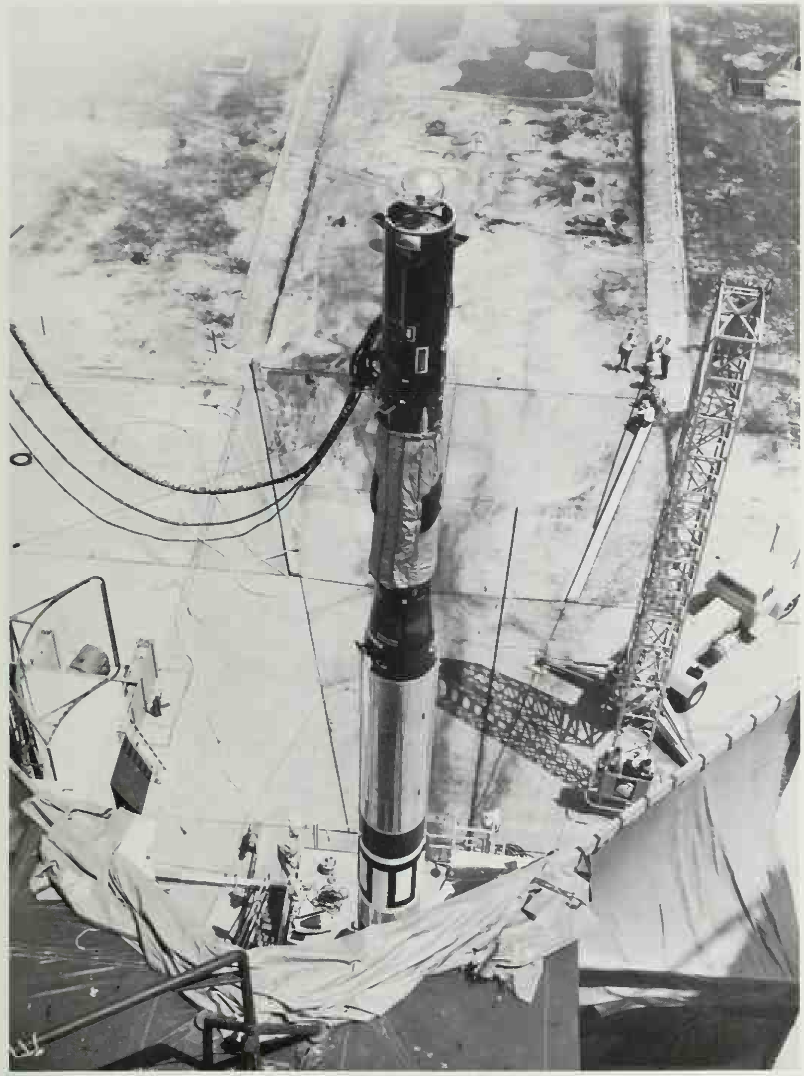
Diameter: 50 cm (20 in)
Weight: 9.4 kg (20.7 lb)
Gallery: 110: *Satellites*

Vanguard 2 was launched into orbit on February 17, 1959, by a rocket just like the one that had launched *Vanguard 1* eleven months before. *Vanguard 2* was the first successful "operational" mission in the Vanguard series and was designed to measure Earth's "albedo," that is, the amount of sunlight scattered or reflected by Earth's surface and cloud layers. In that sense, *Vanguard 2* was the United States' first meteorological satellite.

The *Vanguard 2* satellite, a metal sphere coated with magnesium and silicon monoxide, contained two photoelectric detecting units, a data recorder, a radio transmitter and receiver. The photocells scanned Earth as the spacecraft spun. Variations in intensity were recorded on the satellite's recording device and played back when the satellite passed within range of one of the Earth's tracking stations. The optical telescopes that focused the light from Earth on the detectors, the photocells and the recording device appear to have worked as planned; however, because spin instabilities developed with the satellite itself, the data was not easily interpreted.

The *Vanguard 2* satellite in the museum collection was a back-up spacecraft transferred to the Smithsonian Institution by the National Aeronautics and Space Administration.

Allan Needell



Vanguard 2 *satellite atop its launch vehicle. Before launch, a nose cone was added. (Photo: NASA)*

Disassembled view of Vanguard 2 *showing instrumentation. (Photo: NASA VAN-13)*

Vanguard 3 Satellite

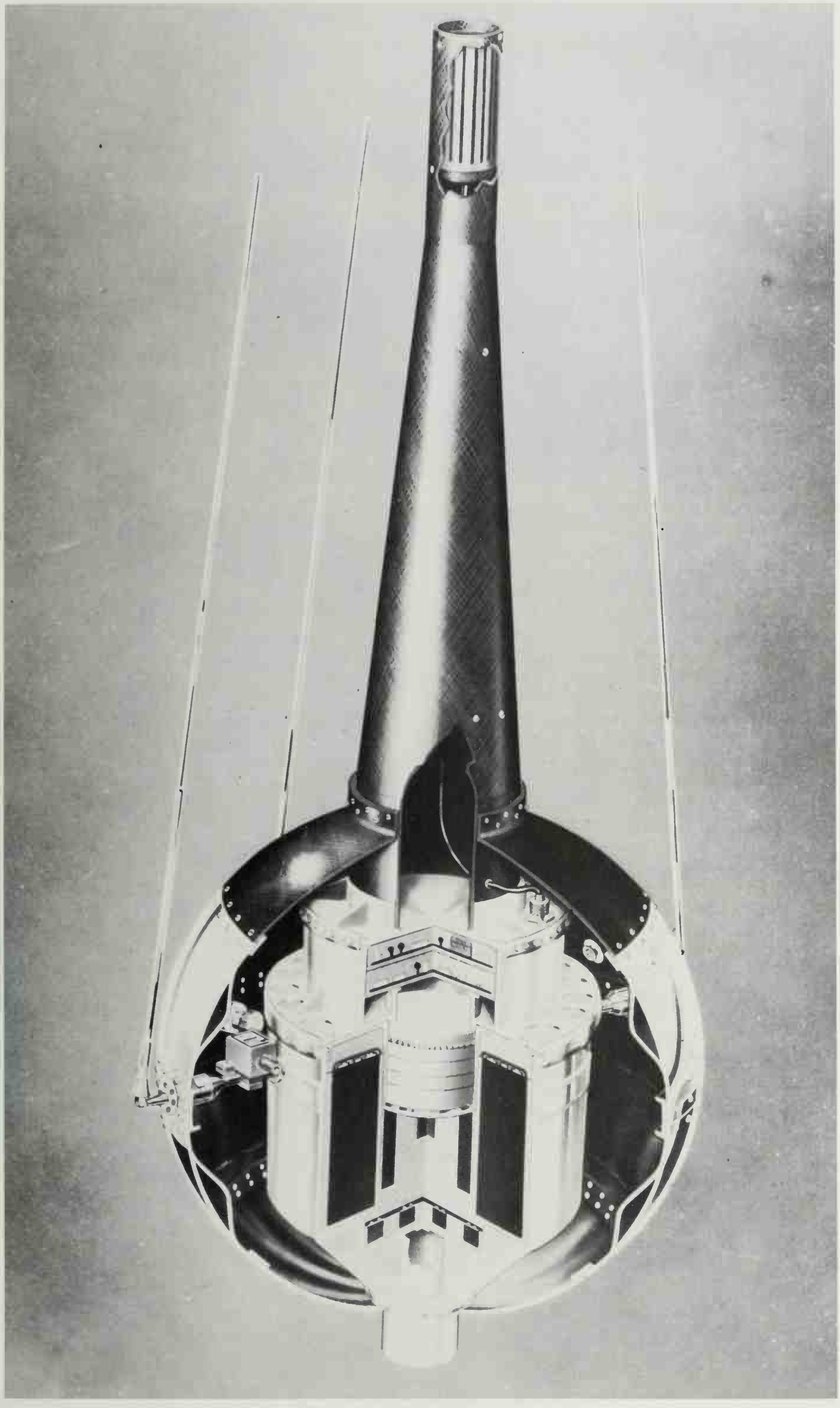
Diameter: 50 cm (20 in)
Weight: 24 kg (53 lb)
Gallery: 110: *Satellites*

Vanguard 3, the third and final satellite in the Vanguard program, was launched on September 18, 1959. It measured solar X-rays and Earth's magnetic field, especially at the lower edge of the Van Allen radiation belts. It was also the first spacecraft to carry instruments for making detailed measurements of micrometeoroids: salt-sized particles that are abundant in space, which were worrisome to early spacecraft designers. When these particles hit a spacecraft, they could cause damage, so the size, frequency, and danger posed by these particles needed to be determined.

Four different micrometeoroid detectors were used. One detector, a type of "microphone," turned impact vibrations into electrical pulses. A second had an opaque shield over a light sensitive cell. As micrometeoroids punched holes in the shield, more and more light reached the cell, providing energy for a measurement. A third type used tiny pressure vessels or cells. When these were punctured, a pressure sensitive switch would be tripped. Varying the thickness of the cells tells something about the energy of the particles. Finally, a foil strip was used whose electrical resistance increased upon impact. Punctures were more prevalent than expected.

The 24-kilogram (53-pound) spacecraft operated eighty-four days, providing excellent data for the scientist-investigators from the NASA/Goddard Space Flight Center, the U.S. Naval Research Laboratory and the Smithsonian Astrophysical Observatory.

Kerry M. Joels



Cutaway view of Vanguard 3. (Photo: NASA VAN-17)

Aerobee 150 Rocket

Length: 9.1 m (30 ft)
Payload: 68 kg (150 lb)
Altitude: 270 km (170 mi)
Gallery: 110: *Satellites*

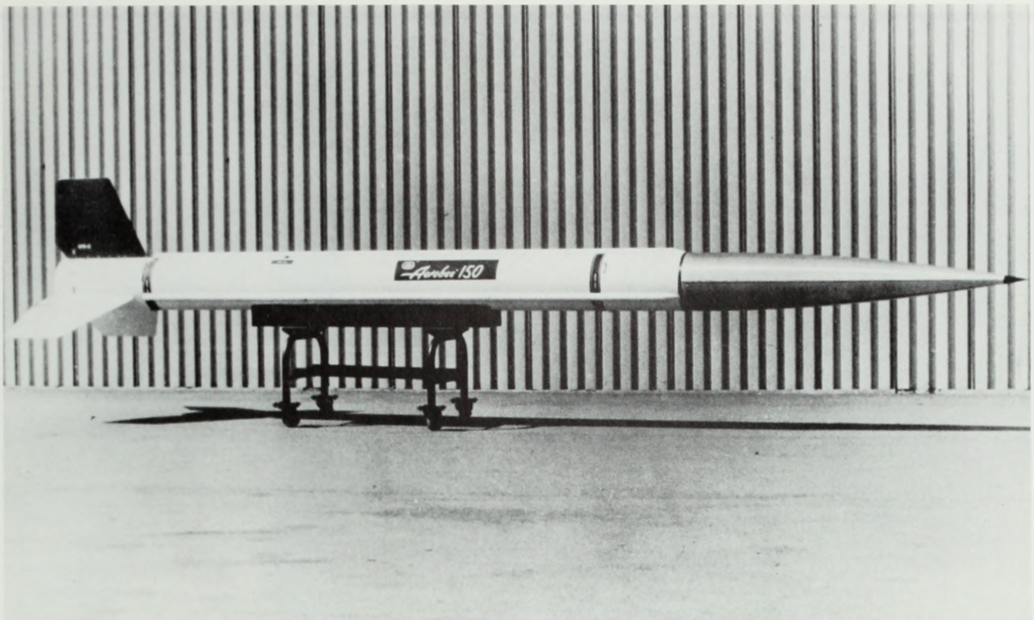
Two-stage Aerobee 150 sounding rockets carried many payloads into the upper atmosphere in the 1960s and early 1970s. The Aerobee 150 can lift 68 kilograms (150 pounds) to 270 kilometers (170 miles).

The Aerobee 150 is a descendant of the original Aerobee rocket developed in the late 1940s. In 1946, Dr. James A. Van Allen, then with the Applied Physics Laboratory of the Johns Hopkins University, proposed that the Naval Research Laboratory develop a rocket that could carry a payload of 68 kilograms (150 pounds) to 91,000 meters (300,000 feet). The Applied Physics Laboratory was already working on rockets for the Navy, under the aegis of Project Bumblebee. Aerojet Engineering Corporation received the contract for the new rocket, so Van Allen combined "Aero" from Aerojet and "bee" from Bumblebee to create the name "Aerobee."

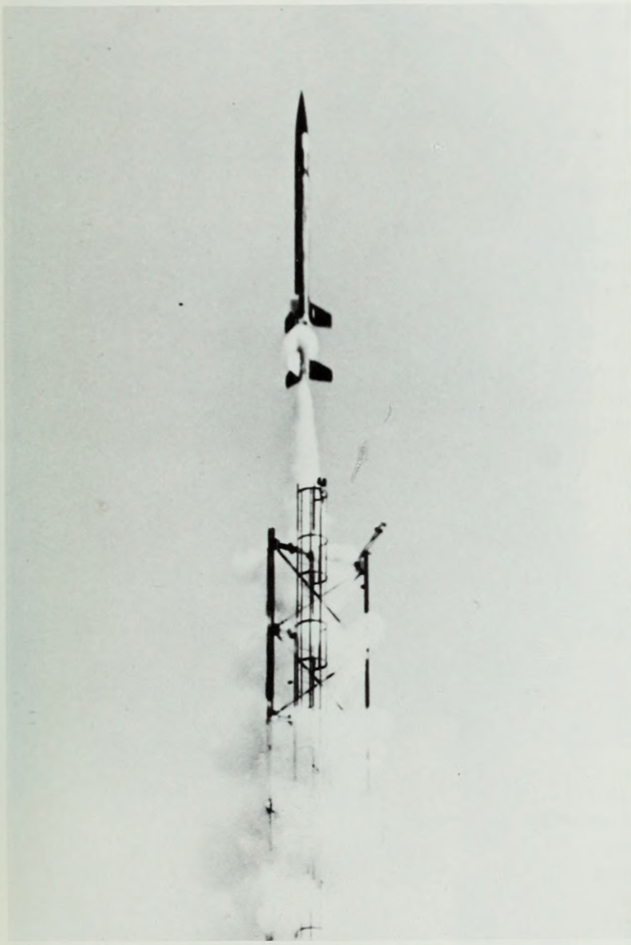
In 1952, an improved version, the Aerobee-Hi, entered service. Later, in the early 1960s, this was improved and became the Aerobee 150. The Aerobee 150 was a two-stage rocket with a solid-propellant booster and a liquid-propellant sustainer. The first stage had a thrust of 82,800 newtons (18,600 pounds) for 2.5 seconds; the 18,000 newton (4,100-pound) thrust sustainer burned for 50.9 seconds. The second stage engine burned inhibited red-fuming nitric acid (IRFNA) and a mixture of aniline and furfuryl alcohol. Both propellants were pressure-fed into the combustion chamber.

Other rockets of the Aerobee family include the Aerobee 300 and Aerobee 350. The Aerobee 300 is an Aerobee 150 with a solid-propellant third stage. The Aerobee 350 is a two-stage rocket with a Nike rocket booster and a sustainer composed of a cluster of four Aerobee 150 engines.

Gregory P. Kennedy



The Aerobee 150. (Photo: NASA 65-H-819)



Aerobee 150 launch. (Photo: NASA 65-H-817)

Aerobee Nose Cone

In the 1950s, the dominant rocket for high-altitude scientific research was the Aerobee, in its several forms. While it was relatively simple to send cosmic ray detectors, air pressure gauges, and other small scientific instruments aboard Aerobee sounding rockets that did not require precision pointing, it was far more difficult to send telescopes that had to be accurately pointed at celestial objects. Still, sophisticated and highly successful gimbal mounts were developed by the University of Colorado and by the Air Force so that telescopes and spectrographs could be pointed at the sun to allow for sufficient observing time to detect features in their ultraviolet and x-ray spectra. To take advantage of these relatively stable platforms for observing the sun from tumbling and spinning Aerobee rockets, dozens of different types of spectroscopic instruments were developed at the Naval Research Laboratory, the Applied Physics Laboratory of the Johns Hopkins University, Air Force contract agencies, and several universities.

One of the most sophisticated instruments, developed in the late 1950s and flown six times through the early 1960s, was the Naval Research Laboratory Multispectograph which contained five different instruments for observing the sun.

The NRL Multispectrograph is on exhibit in Gallery 111: *Stars*. It is mounted within a University of Colorado pointing control gimbal in a nose cone of an Aerobee 150 sounding rocket, as it was flown on August 22, 1962.

The University of Colorado pointing controls consisted of a set of small photoelectric sun sensors set in a dark box on the front of the multispectrograph. These sun sensors locked onto the sun, and fed positional information to servomotors on the gimbal mount supporting the spectrographs. As the rocket altered its direction, the sun sensors told the servomotors which way to turn so that the spectographs always pointed toward the sun.

Pointing controls such as these were also developed by the Ball Brothers Research Corporation in Boulder, Colorado (a group formed out of the University of Colorado team) and were later adapted to the Orbiting Solar Observatory satellites. In addition, the technical experience gained from designing and operating these spectroscopic instruments on sounding rockets provided a pool of expertise to take advantage of satellites, when they became available in the 1960s.

David H. DeVorkin

Aerobee nose cone with instrument pointing control system. (Photo: Smithsonian Institution)

ARCAS Rocket

Length: 2.1 m (7 ft)
Weight: 34 kg (76 lb)
Altitude: 68,300 m (224,000 ft)
Gallery: 110: *Satellites*

The single stage, solid-propellant ARCAS is a small, inexpensive sounding rocket that carries payloads into the upper atmosphere. The Atlantic Research Corporation, sponsored by the Office of Naval Research, Air Force Cambridge Research Center, and the U.S. Army Signal Missile Support Agency, developed ARCAS. The acronym, "ARCAS," stands for "All-purpose Rocket for Collecting Atmospheric Soundings."

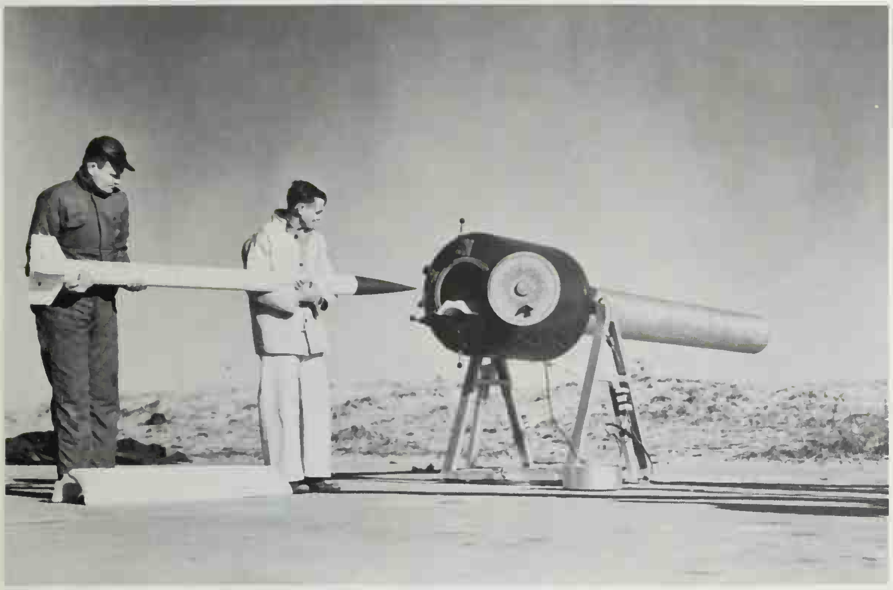
ARCAS was designed specifically to carry meteorological payloads. One of the problems with adapting military missiles for use as sounding rockets is that they frequently have high acceleration rates, placing a lot of stress on scientific instruments carried on board. Because it was designed specifically to carry instruments, ARCAS has a relatively low acceleration during powered flight.

ARCAS rockets were first launched in 1958. Eleven years later, more than 6,000 had flown. Most of the ARCAS missions have been designed to gather wind and temperature data at altitudes of up to 61,000 meters (200,000 feet). Other types of payloads include biological payloads and cameras. The payload-bearing nose section can be recovered by parachute.

Another unique feature of the ARCAS rocket system is its launcher; ARCAS uses a "closed-breech" launcher. A closed-breech launcher uses a moving piston attached to the base of the rocket to trap the rocket's exhaust for additional thrust while in the launcher tube. This type of launcher improves the performance of the rocket by giving it additional lift-off acceleration. The piston separates when the rocket leaves the launcher.

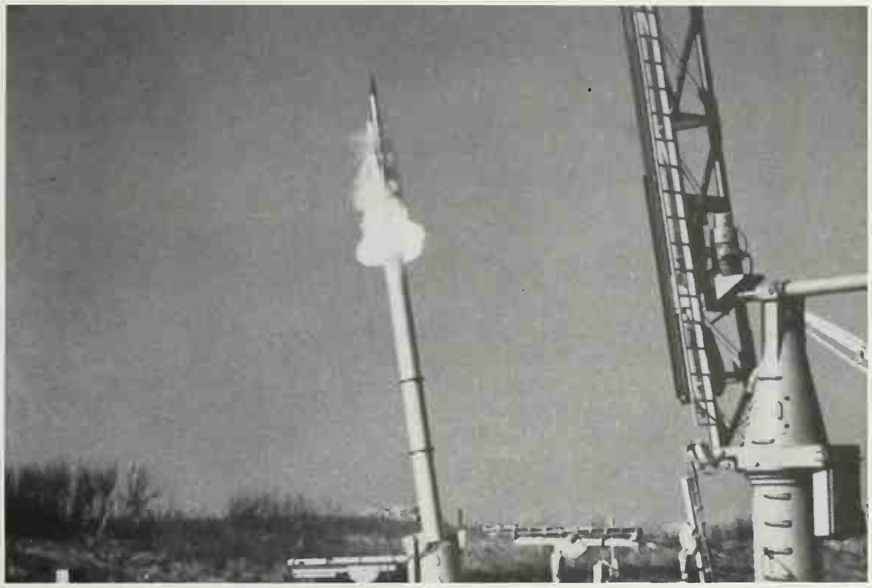
The standard ARCAS PWN-6A, with an ARCASONDE 1A meterological payload, weights 34 kilograms (76 pounds) and reaches an altitude of 68,300 meters (224,000 feet) 132 seconds after launch. The Air Force Cambridge Research Laboratories developed the ROBIN payload for the ARCAS. ROBIN is an inflatable mylar balloon that is released and tracked by radar to measure atmospheric density and winds from 76,000 to 27,000 meters (250,000 to 90,000 feet).

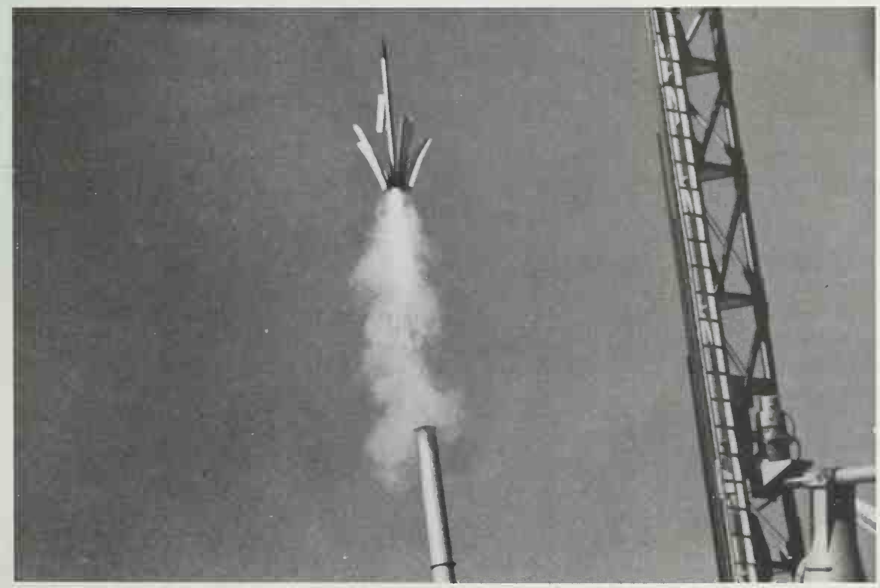
Gregory P. Kennedy



ARCAS rockets are fired from a closed-breech launcher. (Photo: NASA)

ARCAS launch (Photo: courtesy Atlantic Research)





ARCAS launch (Photo: courtesy Atlantic Research)

Able and Baker Biocapsules

Crew: Each capsule carried one monkey
Gallery: 210: *Apollo to the Moon*

During the first half of 1958, the U.S. Army recovered two Jupiter missile reentry nose cones. Encouraged by these successes, Army officials decided to fly biological payloads on subsequent reentry test vehicles. The first such payload flew on December 13, 1958, with a squirrel monkey on board. Unfortunately, the nose cone was not recovered, although telemetry signals indicated that the life support system worked properly throughout the flight.

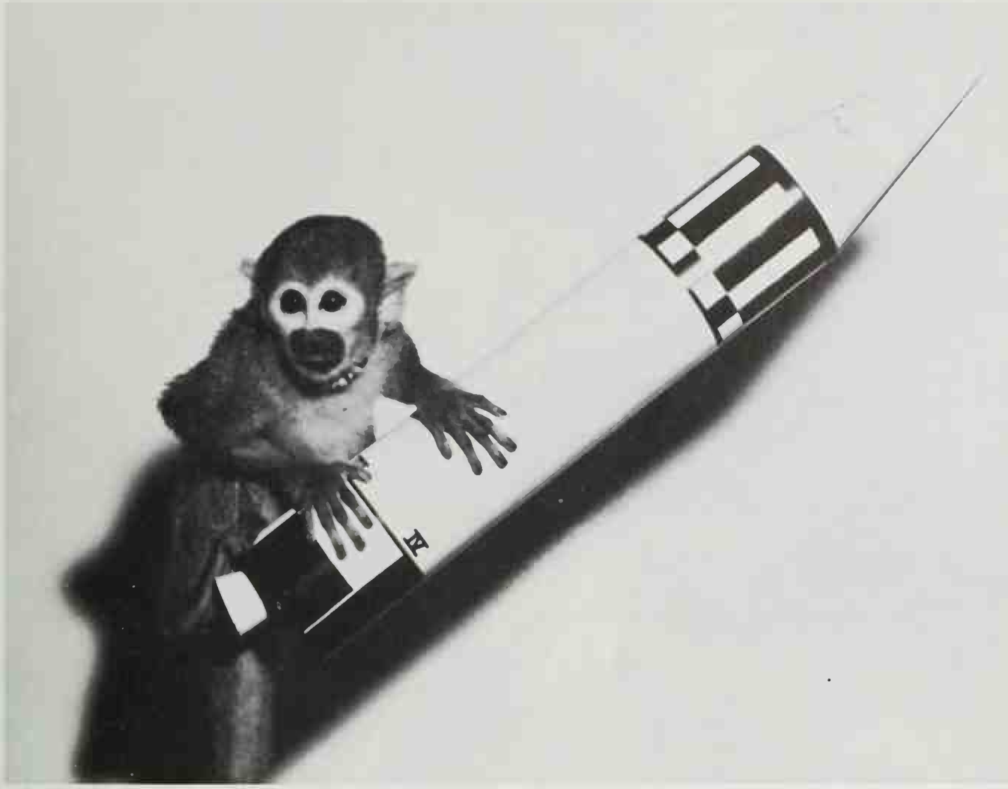
On May 28, 1959, a Jupiter missile launched two monkeys named Able and Baker on a 480-kilometer (300-mile) high ballistic trajectory, again with the purpose of testing spacecraft life support systems and the effects of space flight on primates.

The Army Ballistic Missile Agency had built one of the biocapsules; the other had been built by the Naval School of Aviation Medicine. The Army capsule contained Able, an American-born Rhesus monkey. For diplomatic reasons, Able's ancestry was important—the first monkey selected had been born in India, where the Rhesus is sacred. To avoid any diplomatic repercussions, an American-born Rhesus monkey was substituted just prior to flight. The smaller Navy-built unit housed a squirrel monkey named Baker. Each capsule was self-contained and independent of the other.

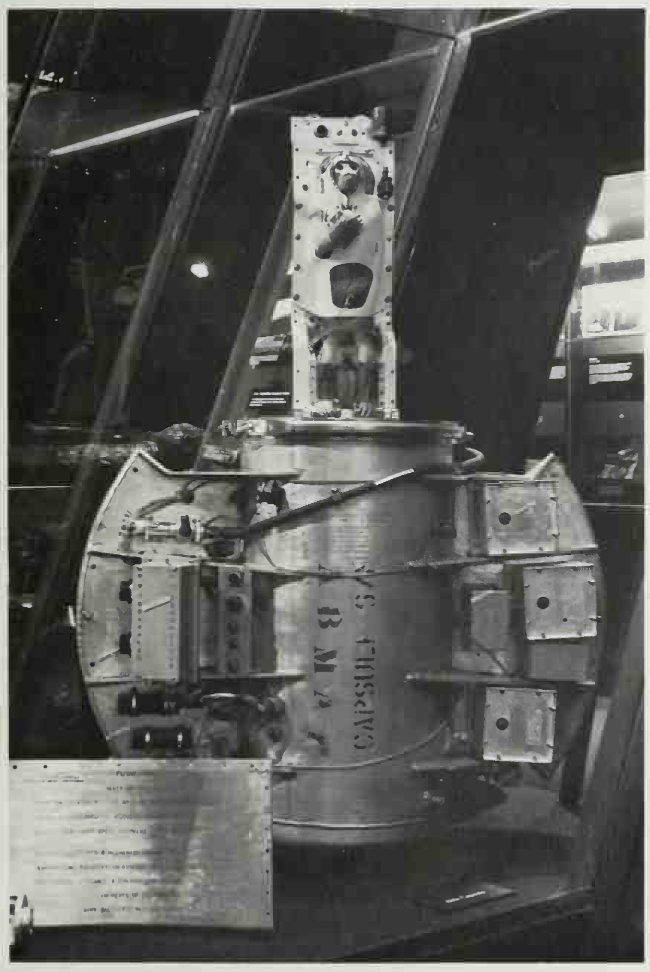
Both monkeys were instrumented so that their physiological responses to the stresses of space flight could be monitored. Other biological materials and film badges were also placed inside the nose cone to provide additional data on space flight effects and radiation hazards in space.

The nose cone reached an altitude of 480 kilometers (300 miles) and landed in the Atlantic Ocean 2,400 kilometers (1,500 miles) from the launch pad at Cape Canaveral, Florida. During their flight, Able and Baker were subjected to 4.2 minutes of weightlessness. After recovery, both monkeys were examined and found to be still in good health. Later, however, Able developed an infection around one of the implanted biotelemetry electrodes. During the surgery to remove the electrode, Able suffered an allergic reaction to the anesthetic and died. A subsequent autopsy showed that Able's death was not related to her flight. As of September 1982, Baker was still alive and resides at the Alabama Space and Rocket Center in Huntsville, Alabama.

Gregory P. Kennedy



Monkey Baker with a model of the Jupiter rocket. (Photo: NASA M-108)



Biocapsule and monkey Able. (Photo: Smithsonian Institution)

Pioneer 1 Lunar Probe

Height: 76 cm (30 in)
Diameter: 74 cm (29 in)
Weight: 23.2 kg (51.1 lb) (without rocket systems)
Gallery: 110: *Satellites*

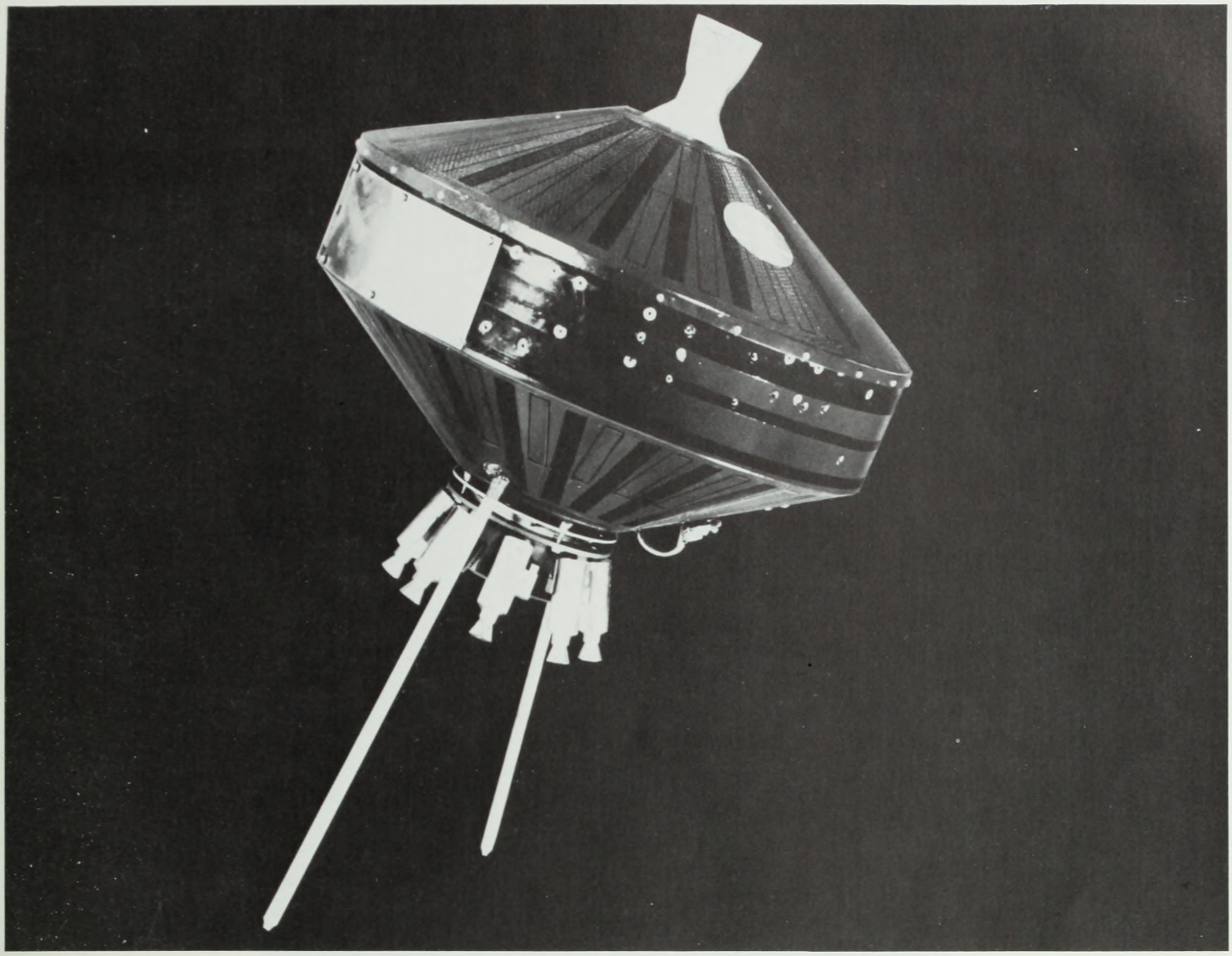
Early in 1958, the U.S. Air Force and Army, with funding from the National Science Foundation, agreed to launch a series of instrumented space probes on trajectories that would take them to the vicinity of the moon. The effort was sanctioned by the National Academy of Sciences as a further American contribution to the International Geophysical Year. The Air Force Ballistic Missile Division and the Army Ballistic Missile Agency each developed plans, the former in association with Space Technology Laboratories, Inc., of Los Angeles; the latter in association with the Jet Propulsion Laboratory in Pasadena. The task was recognized to have only a small chance of success. It was thought worth pursuing however, as a means of demonstrating the United States' committment to lead the way in the scientific exploration of space and to recover some of the national prestige lost as a result of the Soviet successes with *Sputnik 1* and *2*.

The first launch in the Pioneer series was conducted by the Air Force on August 17, 1958 with a Thor-Able rocket. The flight ended in an explosion after only 77 seconds. The second Air Force attempt, on October 11, 1958, was a success. The spacecraft was given the name *Pioneer 1*.

Pioneer 1 was the first spacecraft to incorporate course-correction rockets and a retro-rocket to allow insertion into a lunar orbit. The spacecraft itself was made of laminated plastic and was in the shape of two cones whose bases were attached to a cylindrical midsection 74 centimeters (29 inches) in diameter. It was designed to spin along its symmetry axis; the combined height of the two cones was 76 centimeters (30 inches). The spacecraft with its rocket systems weighed 34.2 kilograms (75.3 pounds) with the instrument package weighing 18.0 kilograms (39.6 pounds). *Pioneer 1* contained an ionization chamber designed to measure radiation intensities up to 1000 Roentgens per hour; a microphone micrometeorite detector, a sensitive "spin-coil" magnetometer, and a specially designed image-scanning infrared television system, with which it was hoped rough pictures of the moon's far side could be obtained.

A slight error in the spacecraft velocity caused the spacecraft to return to Earth rather than proceed to the moon. It reached a peak altitude of 33,300 kilometers (20,700 miles) and was destroyed on reentry. Nevertheless, *Pioneer 1* had successfully transmitted important scientific data for 43 hours. Especially significant was its radial mapping of the Van Allen radiation belts and its measurements of Earth's and interplanetary magnetic fields.

Allan Needell



Pioneer 1. *(Photo: NASA 73-H-830)*

SCORE Communications Package

Weight: 65 kilograms (143 pounds)
Gallery: 110: *Satellites*

The SCORE Project (Signal Communication by Orbiting Relay Equipment) was undertaken by the Advanced Research Projects Agency (ARPA), in conjunction with the Air Force and the Army. Using an Atlas 10-B missile as an orbiting platform for the satellite, the project was to demonstrate the feasibility and difficulties in establishing a military communication system.

SCORE consisted of two identical communications packages. Each comprised a receiver, an 8-watt FM transmitter, a control unit, a recorder, an electric power system, and antennae for each receiver and transmitter.

The two 16-kilogram (35-pound) packages and the 33 kilograms (73 pounds) of antenna systems were mounted in the Atlas and orbited on December 18, 1958. The tape recorder in one package failed during the first orbit. The other package operated until December 30, 1958, when its batteries failed. A life of 21 days had been forecast.

The U.S. Army Signal Corps Research and Development Laboratory, Fort Monmouth, New Jersey, had received the assignment to build the communication package in July 1958. At that time, the launch date was planned for early November, so the packages had to be delivered to the launch site by mid-October. RCA Laboratories in Princeton, New Jersey, aided in design and fabrication.

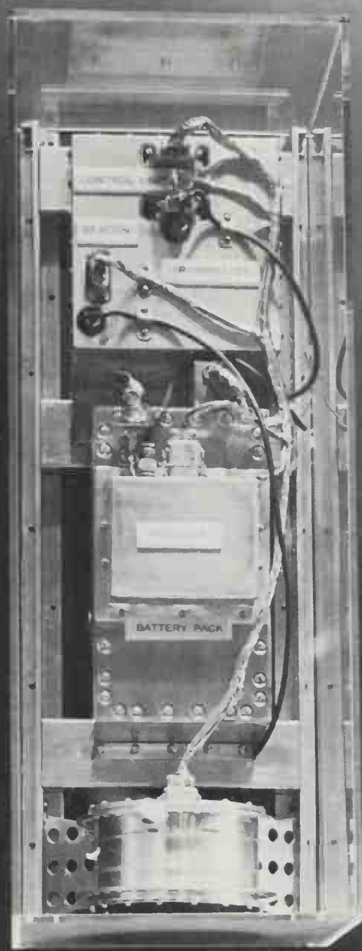
The dual objectives of establishing booster capability and demonstrating communications capability were met in the experiments. Seventy-eight messages, totaling 5 hours and 12 minutes, were sent. They included 11 real time (live) relays over 43 minutes. Other messages, 28 in all, were recorded and relayed by ground command.

By necessity, "off-the shelf" equipment was used. The basic recorder had been previously designed for a meteorological satellite, while the tracking beacon was a modified *Explorer 1* type. Fiberglass honeycomb, a material later used extensively in the space program, was used for the 2-slot antennas. Ground equipment used modified commercial receivers placed in vans for portability.

Ground stations were located at Prado Dam, California; Fort Huachuca, Arizona; Fort Sam Houston, Texas; and Fort Stewart, Georgia, where the voice and teletype data were transmitted and received.

Kerry M. Joels

Project SCORE package in Gallery 110: Satellites. *(Photo: Smithsonian Institution)*



Project Score

Project SCORE, the Signal Communication Orbit Relay Experiment, was intended to study the ability of a satellite to relay voice and teletype communications.

SCORE was orbited on Dec. 18, 1958. The first voice transmission from a satellite in space was accomplished when SCORE broadcast a prerecorded Christmas message from President Eisenhower to the people of the world. The project was a major stepping stone toward the development of the operational system of communications satellites.

From the U.S. Army

Weight:	**68 kilograms (150 pounds)**
Perigee:	**177 kilometers (110 miles)**
Apogee:	**1481 kilometers (920 miles)**
Period:	**101.46 minutes**
Launch Vehicle:	**Atlas 10 B**
Launch Date:	**Dec. 18, 1958**

Pioneer 4 Lunar Probe

Height: 51 cm (20 in)
Diameter: 23 cm (9 in) (at the base)
Weight: 6.08 kg (13.4 lb)
Gallery: 210: *Apollo to the Moon*

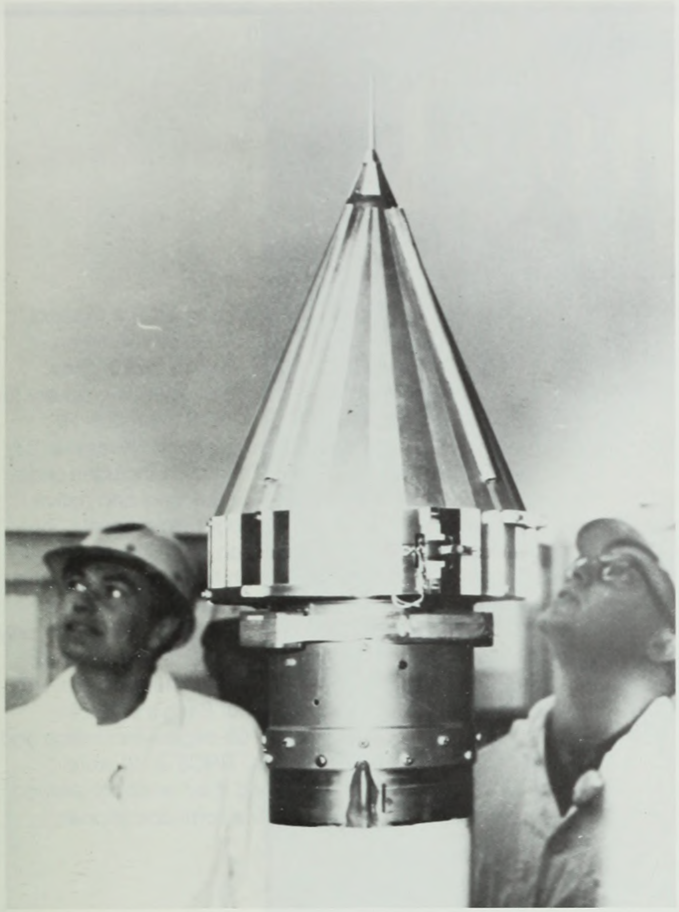
The Pioneer series was initiated to explore the space environment in the vicinity of the moon. *Pioneer 1, 2,* and *5* were assigned to the Space Technology Laboratories, Inc. and used the Thor-Able launch vehicle; *Pioneer 3* and *4* were assigned to the Army Ballistic Missile Agency and the Jet Propulsion Laboratory (JPL). *Pioneer 3* and *4* used the Juno 2 launch vehicle. *Pioneer 3* was launched on December 6, 1958, and reached a maximum altitude of 102,300 kilometers (63,580 miles). *Pioneer 4* was launched on March 3, 1959, and passed within 60,000 kilometers (37,300 miles) of the moon and then into orbit around the sun, the first American space probe to do so. The spacecraft was a cone made of gold-washed fiberglass painted with white stripes as a means of passive thermal control.

Instruments on board *Pioneer 4* included two geiger counters and a photoelectric sensor meant as a prototype trigger for a future television system. *Pioneer 4* also had a mechanical despinning mechanism, which consisted of weights attached to long wires wrapped around the base of the cone. After the spacecraft was placed into its Earth-moon trajectory the weights were released to unwind. Like the extended arms of an ice skater, these weights increased the moment of inertia of the spacecraft, slowing its rate of spin.

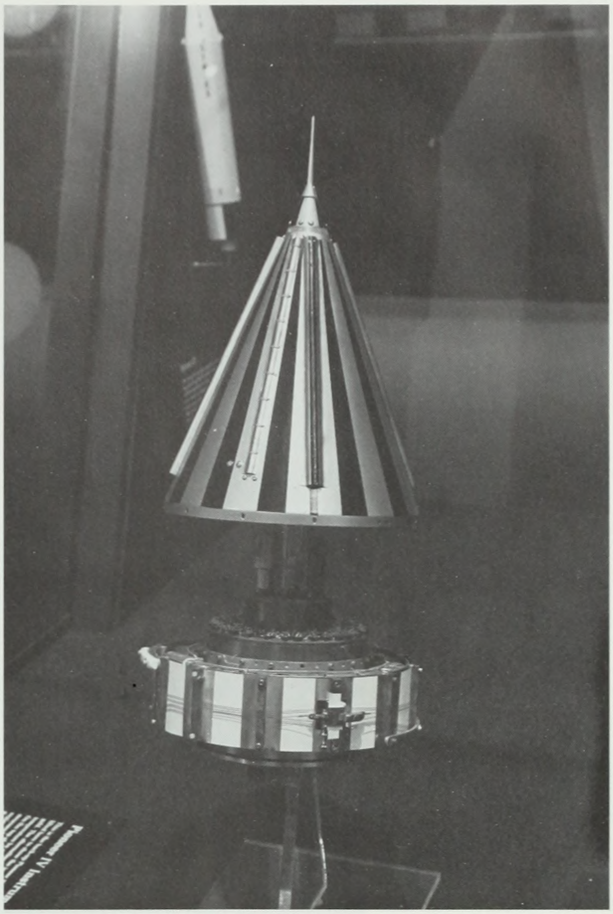
Pioneer 4 did not pass close enough to the moon's surface to trigger the photocell (32,000 kilometers) (20,000 miles) on board or to obtain any useful radiation measurements from the moon. Excellent radiation data, however, was obtained from both the inner and outer van Allen radiation belts.

The article on display at the Museum is a fully instrumented flight spare which, like the actual spacecraft, was built at JPL with instruments provided by the State University of Iowa

Allan Needell



Pioneer 4 *before launch. (Photo: NASA 58-P-8)*



Pioneer 4 *back-up in Gallery 210:* Apollo to the Moon. *(Photo: Smithsonian Institution)*

TIROS 1 Weather Satellite

Height: 48 cm (19 in)
Diameter: 107 cm (42 in)
Weight: 122 kg (270 lb)
Gallery: 110: *Satellites*

The TIROS (Television and Infra-Red Observation Satellite) was the first of an extended series of meterological spacecraft. Four separate satellite programs based on TIROS have been, and are still in operation.

The TIROS program began under the direction of the Advanced Research Projects Administration (ARPA). An ad hoc committee on meteorology was established in June 1958. It included representatives from the U.S. Army Signal Research and Development Laboratory, the National Advisory Committee for Aeronautics, the University of Wisconsin, the Rand Corporation, Office of Naval Research, the Army Ballistic Missile Agency (ABMA) and RCA-Astro-Electronics Products Division, Princeton, New Jersey. An ABMA program being carried out by RCA was shifted in focus toward a meteorological spacecraft. Finally, the newly formed NASA took over the responsibility for the project in April 1959.

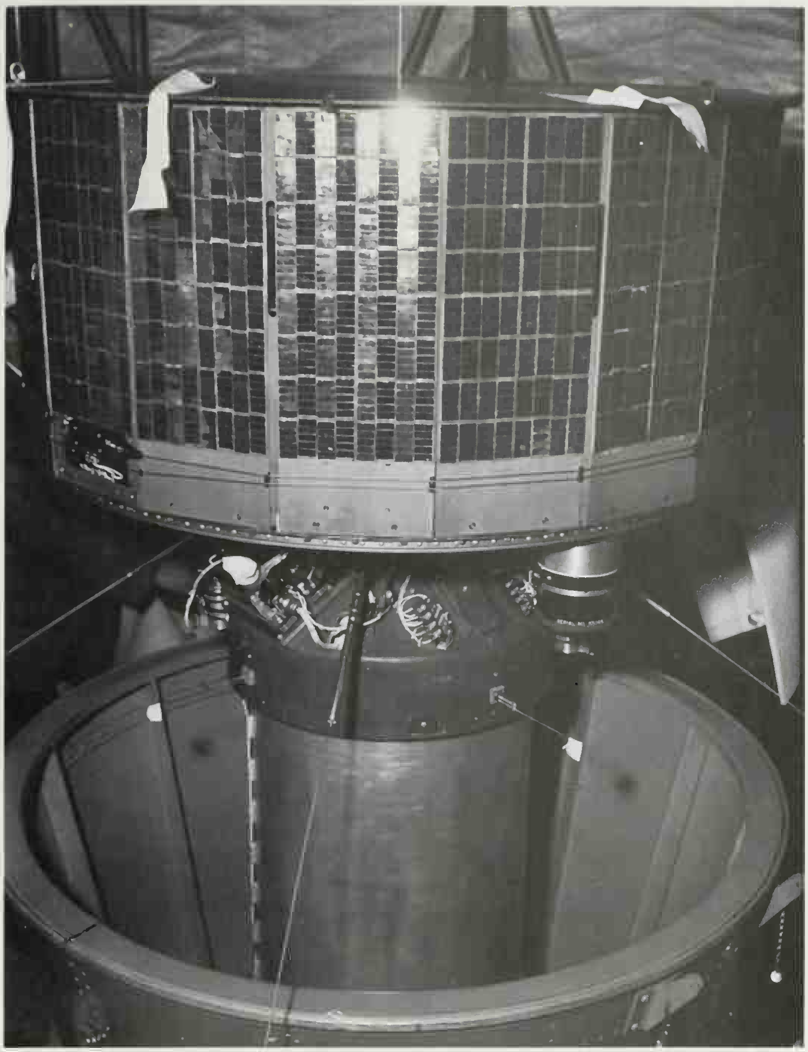
The *TIROS 1* spacecraft was launched on a Thor-Able booster on April 1, 1960. Nine more spacecraft in the TIROS series followed, experimenting with various sensors to achieve semi-operational status. The spacecraft provided wide and narrow-angle television images and infrared data from which large scale weather surveys could be made.

TIROS 1 was an 18-sided prism covered with 9,000 silicon solar cells producing 28 volts of DC current. A wide-angle television camera and narrow-angle television camera and a continuous infrared scanner were the sensing instruments. A tape recorder system was used for data storage and retrieval.

Designed by RCA-Astro-Electronics Products Division, the spacecraft also contained a precession damping device and a series of spin-up rockets, which were then new to satellite technology.

Images could be obtained in "direct picture" format or "tape playback" depending on the needs of the ground controller. Launched April 1, 1960, the *TIROS 1* spacecraft returned 22,952 images over a 78-day experimental period. The mission was originally designed for a 90-day lifetime but was not deactivated until June 29, 1960. Sixty percent of the pictures were of adequate quality for meteorological research. *TIROS 2* through *10* spacecraft were launched between November 23, 1960, and July 2, 1965. The series included wide- and narrow-angle television, passive and active infrared scanning, heat budget experiments, ion probes, and a demonstration of APT (automatic TV picture transmission), which figured heavily in the operational plan for the next series, the TIROS Operational Satellite. *TIROS 9* and *10* were the only two of the series to operate at orbital inclinations greater than 96 degrees. The high-inclination orbit permitted surveys of more of Earth's surface. *TIROS 5–8* operated at a 58-degree inclination and *TIROS 1–4* at 48 degrees. *TIROS 7–10* were multiple year missions, and their reliability allowed the test program to reach a semi-operational status.

Kerry M. Joels



TIROS 1 *on its third stage motor before launch. (Photo: NASA 60-T-29)*

TIROS 7 *view of hurricane Ethel in 1964. (Photo: NASA 65-H-363)*

Solrad 1 Satellite

Diameter: 51 cm (20 in)
Weight: 19 kg (41.9 lb)
Gallery: 111: *Stars*

One of the most pressing needs of the emerging space program after Sputnik was to establish a reliable series of observing stations from space. Their purpose would be to monitor the sun in the wavelengths that are usually absorbed by Earth's atmosphere. The reasons for observing the sun's ionizing radiation (or that part of its spectrum with sufficient energy to disrupt the structure of atoms), are (1) to better determine the physical character of the sun itself, and (2) to study its interference with communications, its effect on the electrical nature of Earth's atmosphere, and its possible deliterious effect upon lifeforms in space.

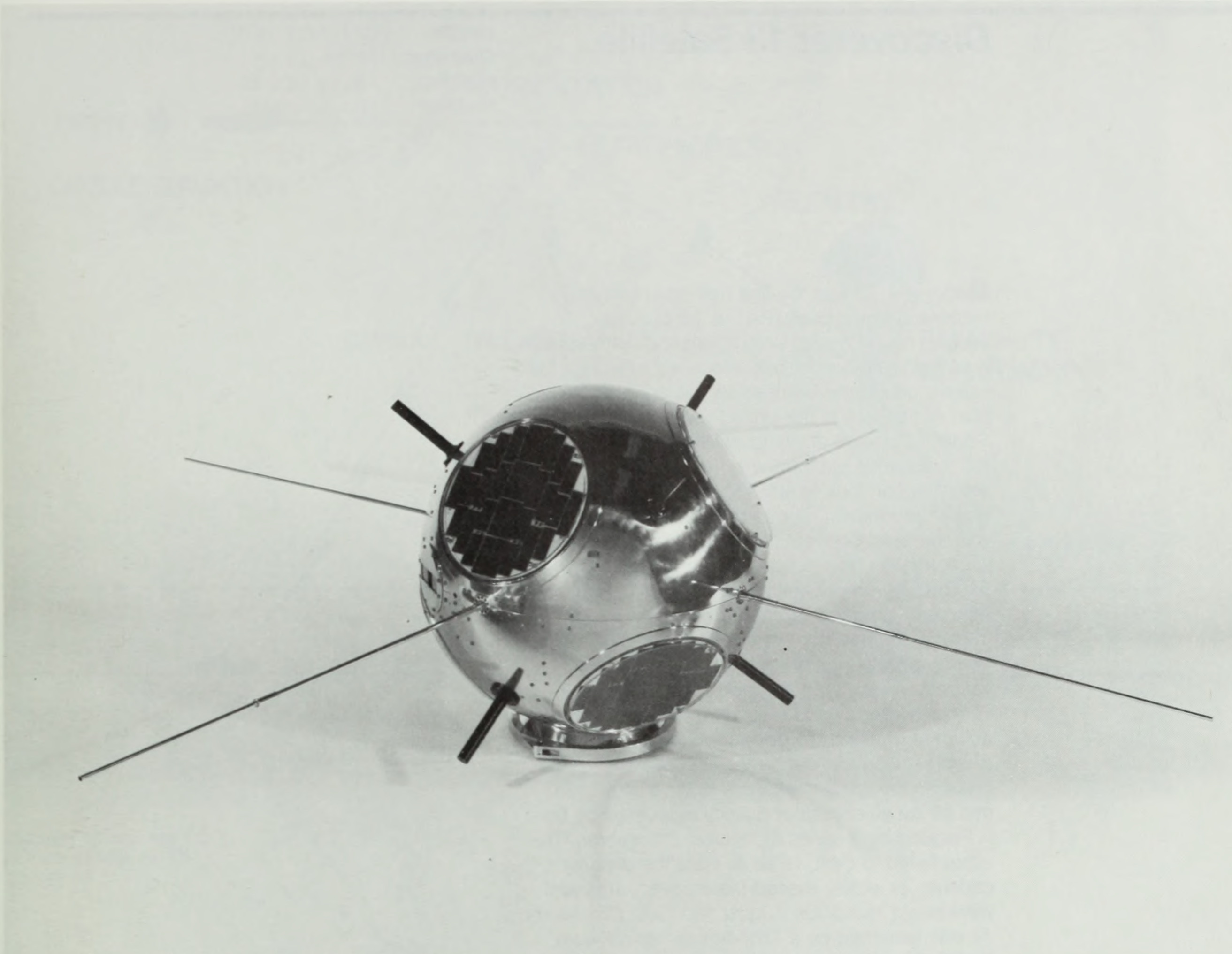
The first major series of solar monitors was developed by the Naval Research Laboratory under the general scientific direction of Dr. Herbert Friedman.

Solrad 1 (also known as Solar Radiation Satellite-1, Solar Monitoring Satellite, or Sunray) was launched on June 22, 1960, aboard a Thor-Able rocket. It was the first "piggy-back" satellite, meaning it was launched in conjunction with the Transit 2A navigational satellite.

Solrad 1 was housed in a aluminum sphere and consisted of four telemetry antennae, one x-ray detector behind a heavy magnetic shield, several skin thermisters, and two Lyman-alpha ionization chambers. It also contained a solar-aspect sensor for alignment information necessary to evaluate data from the main experiments. It was spin-stabilized, and received its power from 936 solar cells arranged in six flat areas spaced around the sphere. The cells constantly recharged a set of nickel-cadmium batteries. Solrad's experiments converted ultraviolet and X-radiation into electrical impulses, which were telemetered to tracking and telemetry stations.

Solard-1 provided valuable data on the character of high energy solar radiation and was the first satellite to provide a continual record of this activity. These data are crucial to an understanding of the interaction between Earth's ionosphere and high-energy solar activity, such as sunspots and solar flares.

David DeVorkin



Solrad 1 *(Photo: Smithsonian Institution*

Discoverer 13 Satellite

Height: 69 cm (27 in)
Diameter: 74 cm (29 in)
Weight: 136 kg (300 lb)
Gallery: 110: *Satellites*

D*iscoverer 13* was the first man-made object recovered from space. Part of the U.S. fear, caused by the Soviet Union's success with Sputnik, was that the powerful boosters used to launch the vehicle could also be used as military missiles. Also of concern to the United States was the Soviet's potential ability to develop a reconnaisance platform without equal. From space, satellites can look at any spot on Earth and quickly gather information. The retrieval of such information was the main concern of the Discoverer program.

Information from space can be physically returned or radioed (telemetered) back to Earth. Although film gives far more detail than a transmitted television picture, the heat generated during reentry through the atmosphere can vaporize ordinary photographic materials. Furthermore, payload recovery requires highly accurate tracking. To develop this ability was particularly critical during the Discoverer program, because the spacecraft were to be snatched in mid-air by an aircraft or quickly recovered by boat.

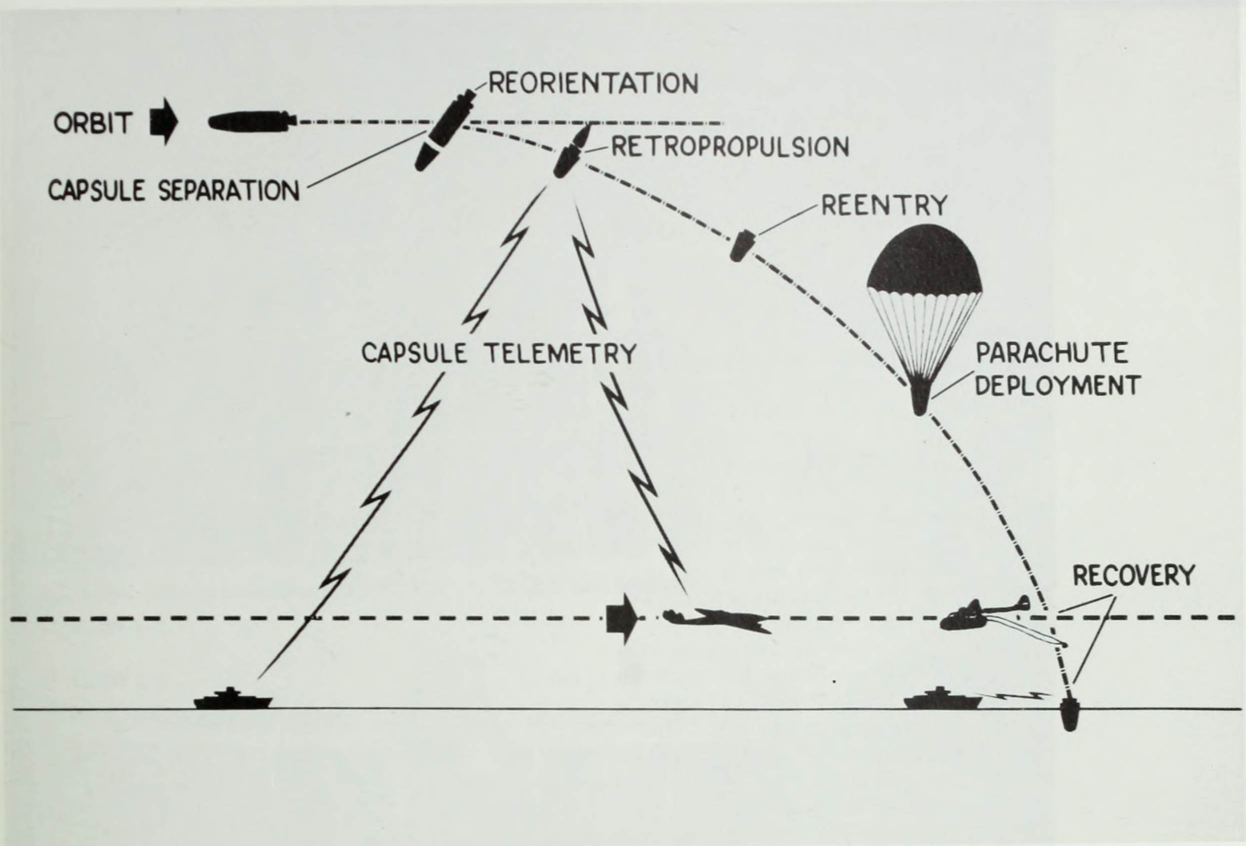
Plagued by a series of failures, *Discoverer 1-12* either failed to orbit, failed to eject the descent capsule, or widely missed the recovery area and were never found. On August 10, 1960, *Discoverer 13* was launched on a Thor-Agena vehicle from Vandenburg Air Force Base, near Lompoc, California. The spacecraft orbited for 27 hours. After 17 orbits, the Agena ejected the Discoverer capsule, which was recovered 530 kilometers (330 miles) northeast of Honolulu, Hawaii.

The reentry capsule and recovery aids weighed almost 140 kilograms (300 pounds) and contained aluminum "chaff" for radar detection and a radio beacon.

The Air Force program launched, with varying success, thirty-eight Discoverer vehicles and paved the way for later generations of reconnaisance satellites.

The Discoverer spacecraft was designed by General Electric's Missile and Space Vehicle Department in Pennsylvania and was manufactured by Lockheed Missile and Space Division in California.

Kerry M. Joels



Discover 13 *recovery sequence. (Photo: SI 75-10244)*

Courier 1B Communications Satellite

Diameter: 130 cm (51 in)
Weight: 230 kg (500 lb)
Gallery: 110: *Satellites*

Following the technological demonstration of project SCORE, the Department of Defense was interested in a more capable and more reliable demonstration of active repeating message transmission. The Advanced Research Projects Agency (ARPA) transferred responsibility for the program to the U.S. Army Signal Corps' Research and Development Laboratory at Fort Monmouth, New Jersey, in September 1960. The launch of the spherical spacecraft occurred on October 4, 1960, using a Thor-Able launch vehicle.

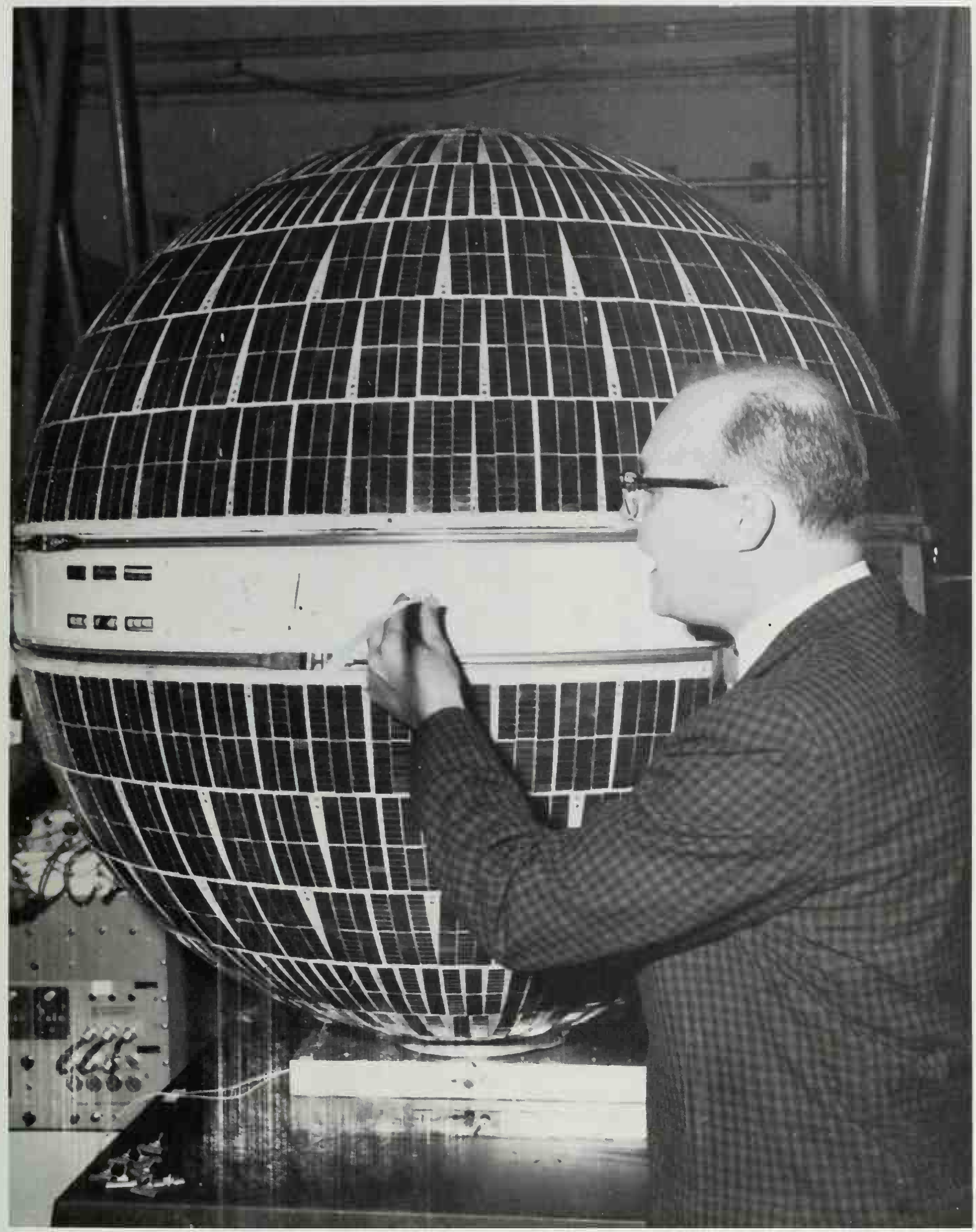
The spacecraft had four transmitters, four receivers, five tape recorders, two UHF transmitters, six antennas, and a beacon. A telemetry system reported on the conditions of the components in the spacecraft as part of the experiment. The beacon was used to permit the ground stations to track the spacecraft in an elliptical orbit with an apogee (high point) almost 1,200 kilometers (750 miles) high.

With 24 teletype channels, the satellite could relay 75 million words during each orbit. Tape recorders were used to handle the high transmission rate.

One of the interesting questions that arose was the security of recorded signals. How could they be kept from query by an undesirable ground station? Also, could the system be damaged by spurious signals?

The spacecraft was capable of transmitting 55,000 bps (bits per second) to the tape recorder at 44.4 bpw (bits per word). This capacity may be expressed as 74,500 wpm (words per minute). Teletype technology of the day was insufficient to directly print out that much information so it was stored on a tape recorder and played back at a slower speed.

Kerry M. Joels



Hugh W. Gunther, an engineer from the U.S. Army Signal Research and Development Laboratory, attaches an antenna to the Courier satellite. (Photo: SI 78-1470, courtesy U.S. Army)

Mercury Spacecraft *Freedom 7*

Length: 2.9 m (9.5 ft)
Diameter: 1.8 m (6 ft) (at base)
Weight: 1,300 kg (2,900 lb)
Crew: One
Gallery: 210: *Apollo to the Moon*

On May 5, 1961. Alan Shepard became the first American in space during his 15-minute suborbital flight in the Mercury spacecraft *Freedom 7*. Project Mercury was established in October 1958 to orbit and successfully recover a manned satellite and to investigate man's ability to survive in space.

Mercury officials made the initial decision to use military rockets as launch vehicles. They selected the Air Force's Atlas missile to propel the spacecraft into orbit. They chose the smaller Army Redstone missile for shorter suborbital "up and down" test flights.

The bell-shaped Mercury spacecraft consists of two sections. The conical lower section housed the pilot and his equipment. A heatshield attached to the base of the lower section enabled the spacecraft to survive the searing heat of atmospheric entry. There were two parachutes in the cylindrical upper section, one primary and one back-up.

For the first suborbital flight, a "heat sink" heatshield protected the spacecraft during atmospheric entry by storing heat created during entry. The spacecraft reached the ocean before the heat penetrated into the interior. Later, for orbital missions, Mercury spacecraft had ablative heatshields. Three solid-propellant retro-rockets strapped to the heatshield slowed the craft for its return from orbit. On the suborbital flights, the Redstone missile propelled the spacecraft to a velocity of 8,000 kilometers per hour (5,000 miles per hour), far short of the 29,000 kilometers per hour (18,000 miles per hour) needed to achieve orbit, so retrorockets weren't needed. However, *Freedom-7* had them for testing. During launch, a launch escape system consisting of a steel tower topped with a solid-propellant rocket motor was attached to the spacecraft's front end. If the booster malfunctioned during launch, this motor could pull the spacecraft away for a safe landing. Once the craft reached a safe altitude, the escape system was jettisoned.

The first flights of the Mercury spacecraft carried instruments and monkeys. By April 1961, project officials felt the spacecraft was safe enough for a human passenger. The first mission would be a suborbital flight to an altitude of 185 kilometers (115 miles) to test the craft's spaceworthiness.

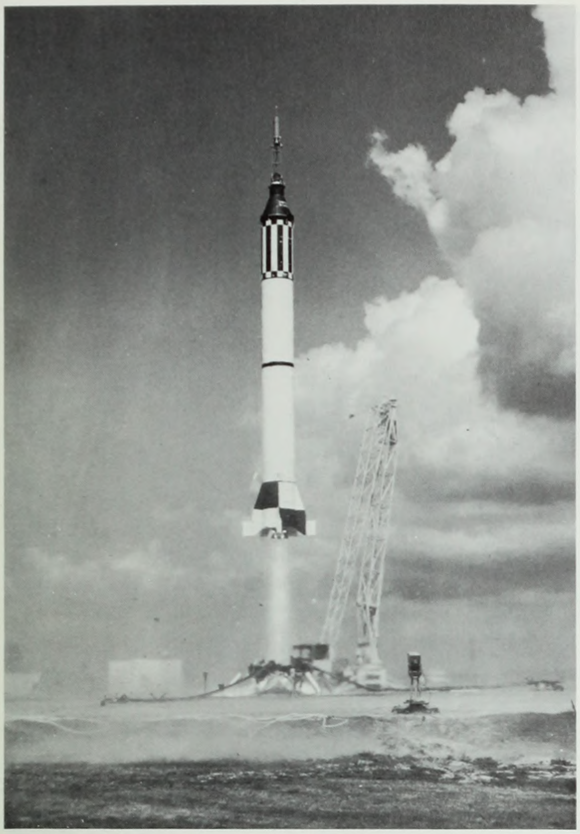
Just a few weeks before the proposed American flight, on April 12, 1961, the Russians announced that Yuri Gagarin had orbited Earth in a spacecraft named *Vostok 1*. It was electrifying news, similar to the announcement four years earlier of the Russian's launching of *Sputnik 1,* the first man-made object to orbit Earth.

Alan Shepard was selected as America's first astronaut, and he named his spacecraft *Freedom 7*. May 2 was chosen as the launch date at Cape Canaveral, Florida, but it was postponed until May 5 because of bad weather.

Shepard entered the spacecraft at 5:15 a.m. EST and, over four hours later, at 9:34, lift-off occurred. The Redstone's engine shut down on schedule, 142 seconds after lift-off. The launch escape system was jettisoned, and *Freedom 7* separated from the spent booster. Shepard manuevered the craft about all three axes as he tested the reaction control system.

Freedom 7 reached a peak altitude of 187 kilometers (116 miles). Shortly after reaching the zenith of his trajectory, Shepard prepared for reentry. At 3,000 meters (10,000 feet), the main parachute opened and the spacecraft completed its journey at a speed of 11 meters per second (35 feet per second). It splashed down in the Atlantic Ocean 302 miles from Cape Canaveral just 15 minutes and 22 seconds after launch. Both Shepard and *Freedom 7* were retrieved by helicopter and taken to the aircraft carrier USS *Lake Champlain*.

Gregory P. Kennedy



Freedom 7 *launch, May 5, 1961. (Photo: NASA 61-MR3-72D)*

Freedom 7 *interior. (Photo: NASA 61-MR3-109)*

Mercury Spacecraft *Friendship 7*

Height: 2.9 m (9.5 ft)
Diameter: 1.8 m (6 ft)
Weight: 1355 kg (2987 lb) (in space)
Crew: one
Gallery: 100: *Milestones of Flight*

On February 20, 1962, John H. Glenn, Jr., became the first American to orbit the Earth. He accomplished this feat in the Mercury spacecraft *Friendship 7*. A modified Atlas missile was the booster.

On the day of the launch, Glenn boarded *Friendship 7* at 6:06 a.m EST. Minor problems delayed the launch several times, but the countdown was completed at 9:47 a.m. and all engines of the Atlas ignited. Five minutes later, John Glenn was in orbit. He checked the spacecraft and found all systems performing as expected.

Near the end of his first orbit, Glenn noticed that *Friendship 7* drifted slowly to the right when the automatic control system was on. He switched to manual control and corrected the problem. Mission controllers were pleased about the way Glenn resolved the problem, but they were faced with a potentially far more serious one.

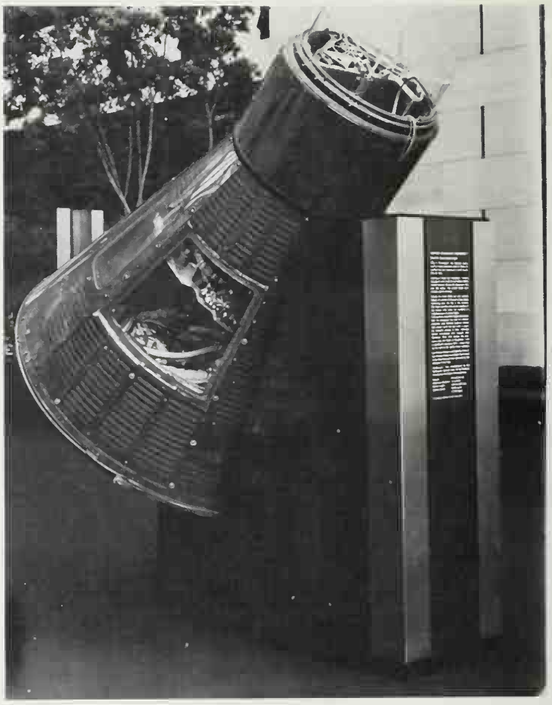
An instrument light at mission control indicated that the heatshield and compressed landing bag were loose. If this were true, *Friendship 7* and its human cargo would be incinerated during atmospheric entry. There was a solution. The retro-rocket package was strapped to the heatshield; if the package was retained after retro-fire, its straps would hold the heatshield in place. By the time the pack burned away, aerodynamic pressure would keep the shield from slipping.

Four and a half hours after launch, Glenn was nearing the end of his flight. All three retro-rockets fired while *Friendship 7* was over California, slowing it enough to enter the atmosphere. As the heat of entry increased, Glenn saw bits of the retro-package fly past his window. When one of the straps swung in front of the window he knew the package was gone.

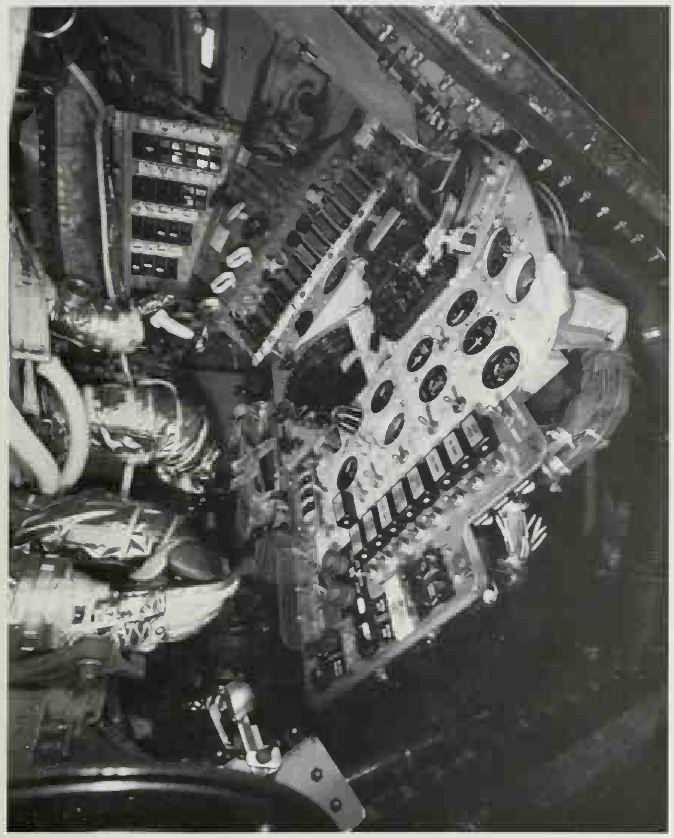
The glass-fiber and resin ablative heatshield did its job—*Friendship 7* survived reentry. At an altitude of 8,500 meters (28,000 feet), the drogue parachute opened, followed by the main one at 3,000 meters (10,000 feet). Glenn flipped the landing bag release switch and felt a reassuring "clunk" as the bag and heatshield dropped into position. The premature deployment signal had been nothing more serious than a fault in the ground controller's console.

Friendship 7 splashed down in the Atlantic Ocean 4 hours and 55 minutes after launch. Seventeen minutes later, the destroyer USS *Noa* was floating alongside, ready to retrieve the bobbing spacecraft. Once the craft was cradled in a mattress pallet on Noa's deck, Glenn fired the explosive bolts holding the hatch in place. When the hot, tired astronaut emerged from the spacecraft, America had a new hero.

Gregory P. Kennedy



Friendship 7 *on exhibit in Gallery 100:* Milestones of Flight *(Photo: Smithsonian Institution)*



Friendship 7 *instrument panel (Photo: SI 72-4529)*

Astronaut John Glenn, first American to orbit the Earth. (Photo: NASA 62-MA6-55)

Friendship 7 *with its launch escape tower on the Atlas booster. (Photo: NASA 62-MA6-74)*

Mercury Space Suits

Weight: 9 kg (20 lb)
Gallery: 100: *Milestones of Flight*
113: *Rocketry and Space Flight*
210: *Apollo to the Moon*

Beginning in 1949, the United States Navy supported the B.F. Goodrich Company's development of the full pressure suit suggested and worn by Wiley Post. Improvements were made which reduced bulk, increased mobility, and improved internal ventilation.

In 1959, the Mark IV pressure suit was accepted by the U.S. Navy as a high altitude emergency suit. A few years later, a modification of this suit was chosen for America's first space travellers, the astronauts of Project Mercury.

The Project Mercury suit was designed to serve as an emergency backup system for the astronaut in case of cabin decompression. Not once during the six manned Mercury flights, however, was it necessary to inflate any of the suits. This 9-kilogram (20-pound) suit consisted of an inner layer of neoprene rubber-coated nylon and a restraint layer of aluminized nylon fabric. The astronaut wore a special set of underwear beneath the suit. This underwear had ventilation pads built into it.

Four Project Mercury space suits are exhibited in the Museum. The suits in *Freedom 7* and *Friendship 7* are backups for the ones worn by astronauts Shepard and Glenn. John Glenn's flight suit is exhibited in Gallery 210: *Apollo to the Moon*, along with the ventilation undergarment he wore during America's first manned orbital space flight. Scott Carpenter wore the suit in Gallery 113: *Rocketry and Space Flight* during the *Aurora 7* space mission.

Louis R. Purnell

Astronaut Walter M. Schirra in Mercury space suit. (Photo: NASA 62-MA1-16)

Orbiting Solar Observatory 1

Height: 94 cm (37 in)
Diameter: 112 cm (44 in) (at base)
Weight: 208 kg (458 lb)
Gallery: 111: *Stars*

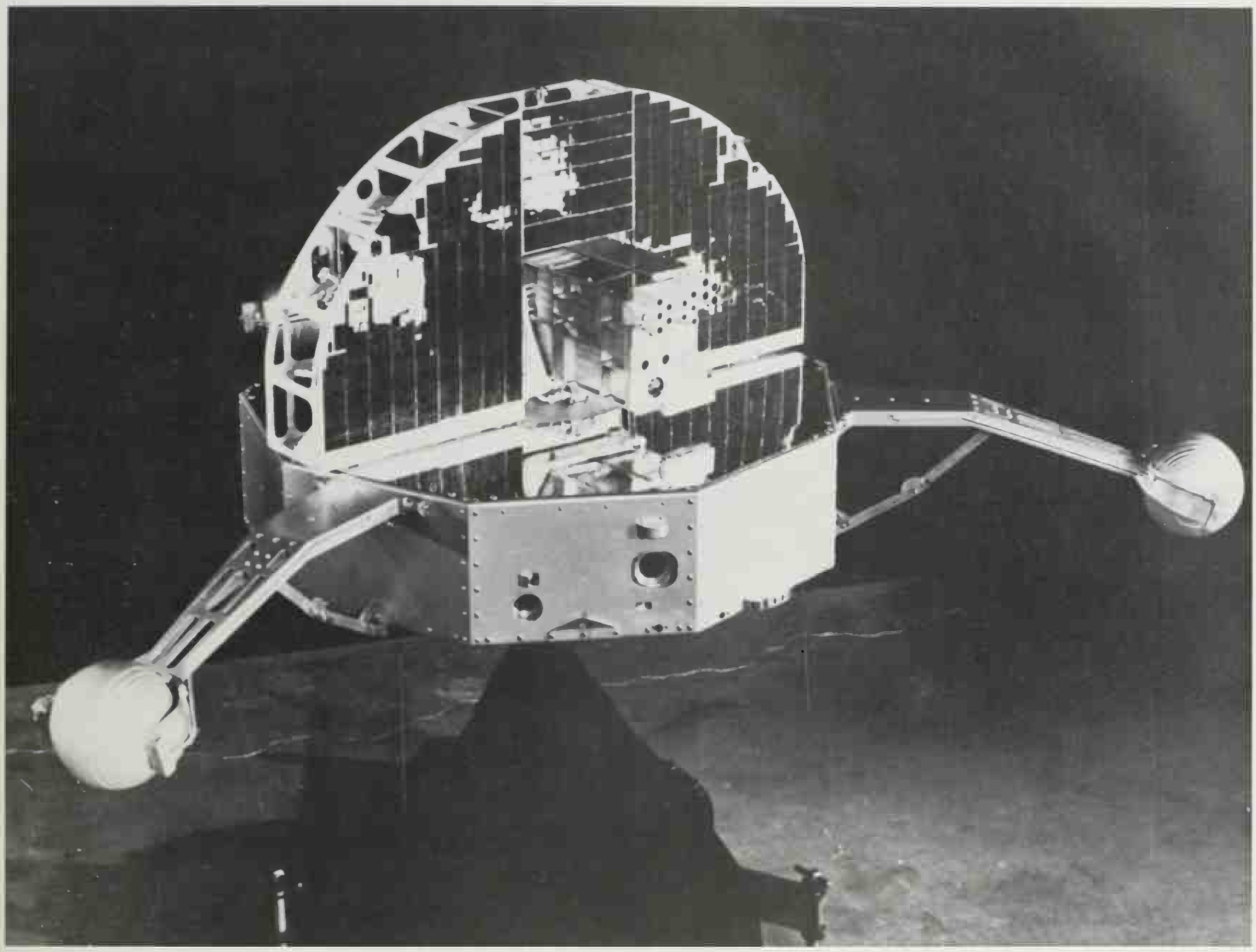
The Orbiting Solar Observatory (OSO) was conceived in the late 1950s as a standard stabilized platform in space to observe the sun in ways not possible from the surface of Earth. John Lindsay of the Goddard Space Flight Center asked the Ball Brothers Aerospace Corporation of Boulder, Colorado, a major provider and developer of stabilized pointing control devices for sounding rockets in the 1950s, to develop a stabilized satellite design. By 1960, they produced a successful engineering prototype.

The first OSO satellite, identical to the prototype engineering model on exhibit, was launched on March 7, 1962, from Cape Canaveral aboard a Thor-Delta to study ultraviolet, x-ray, and gamma-ray radiation from the sun. Soon after launch, the third stage of the Delta was spun to 120 rpm, and the satellite was placed into circular orbit at this spin rate. The three arms on the lower section of the satellite were extended and small gas jets at the ends of the arms were fired to slow the spin rate to some 30 rpm. The upper section of the craft, called the "sail," contained azimuth servomotors, which were controlled by sun-seeking guidance and control sensors. These sensors locked onto the sun and commanded the servomotors to rotate the sail to counteract the spin of the lower section of the satellite. The completely stabilized sail section contained instruments that could be pointed directly at the sun for long periods of time. The two experiments on the sail were built by the Goddard Space Flight Center to examine the high energy spectrum of the sun in the extreme ultraviolet through to the gamma ray region of the spectrum. Experiments on the nine-sided spinning lower section, the "wheel," were from the universities of California, Minnesota, and Rochester, from NASA's Ames Research Center, and from Goddard. In all, these experiments monitored solar activity in the high energy range of the spectrum, and during the lifetime of the satellite they detected the radiation from some 75 solar flare events (that is, extremely violent explosions on the surface of the sun). Although flares were known occurrences on the sun, these new observational data aided understanding of how much energy was involved in the flare mechanism and increased our comprehension of the nature of these events. Other transient phenomena were also recorded, and in general a strong beginning was made in the study of violent processes on the surface of the sun, processes that are of extreme importance in understanding how the sun affects atmospheric conditions on Earth.

After two and one half months of observations, during 1,138 orbits, *OSO-1* returned about 1,000 hours of scientific data. In addition to solar flares, it examined the sky for gamma ray radiation sources, detected and monitored energetic particles in the lower Van Allen radiation belt (at an altitude of some 560 to 890 kilometers) (350 to 550 miles), searched for interplanetary dust particles, and provided useful data on the general high energy spectrum of the sun. In late May 1962, *OSO 1* was turned off after technical problems arose; but later in June, some spin control was again obtained and the satellite worked well until the Starfish test, where a nuclear bomb exploded at high altitude on July 9, 1962. The radiation from this blast reduced the effectiveness of *OSO 1*, and it also degraded a number of other satellites then in orbit. After that time OSO continued to work intermittently; there were telemetry problems and difficulties with on-board tape recorders, but some additional data were collected.

OSO-1 demonstrated that a stabilized, complex satellite with very delicate instrumentation could be developed and successfully flown. It thus became the prototype of a series of eight orbiting solar observatories, launched between 1962 and 1975.

David DeVorkin



Orbiting Solar Observatory 1. *(Photo: NASA)*

Ariel 1 and 2 Satellites

Ariel 1
Height: 52 cm (20.5 in) (body)
Diameter: 58 cm (23 in) (body)
Weight: 60 kg (132 lb)
Gallery: 110: *Satellites*

Ariel 2
Height: 89 cm (35 in) (body)
Diameter: 58 cm (23 in) (body)
Weight: 68 kg (150 lb)
Gallery: 110: *Satellites*

At a 1959 meeting of the Committee on Space Research (COSPAR), the United States proposed to launch scientific missions created, designed, and constructed by scientists from foreign countries. As a result, *Ariel 1,* named for the sprite in Shakespeare's *Tempest,* was the world's first internationally conceived and executed satellite.

Ariel 1 (UK-1) was launched on April 26, 1962. The project was administered at NASA's Goddard Space Flight Center. The first Ariel was designed to examine the relationship between the ionosphere and solar radiation in the ultraviolet and x-ray regions. The satellite was a 58-centimeter (23-inch) diameter, 52 centimeter (20.5 inch) high cylindrical shell with hemispherical sections at either end made of plastic-bonded glass-fiber.

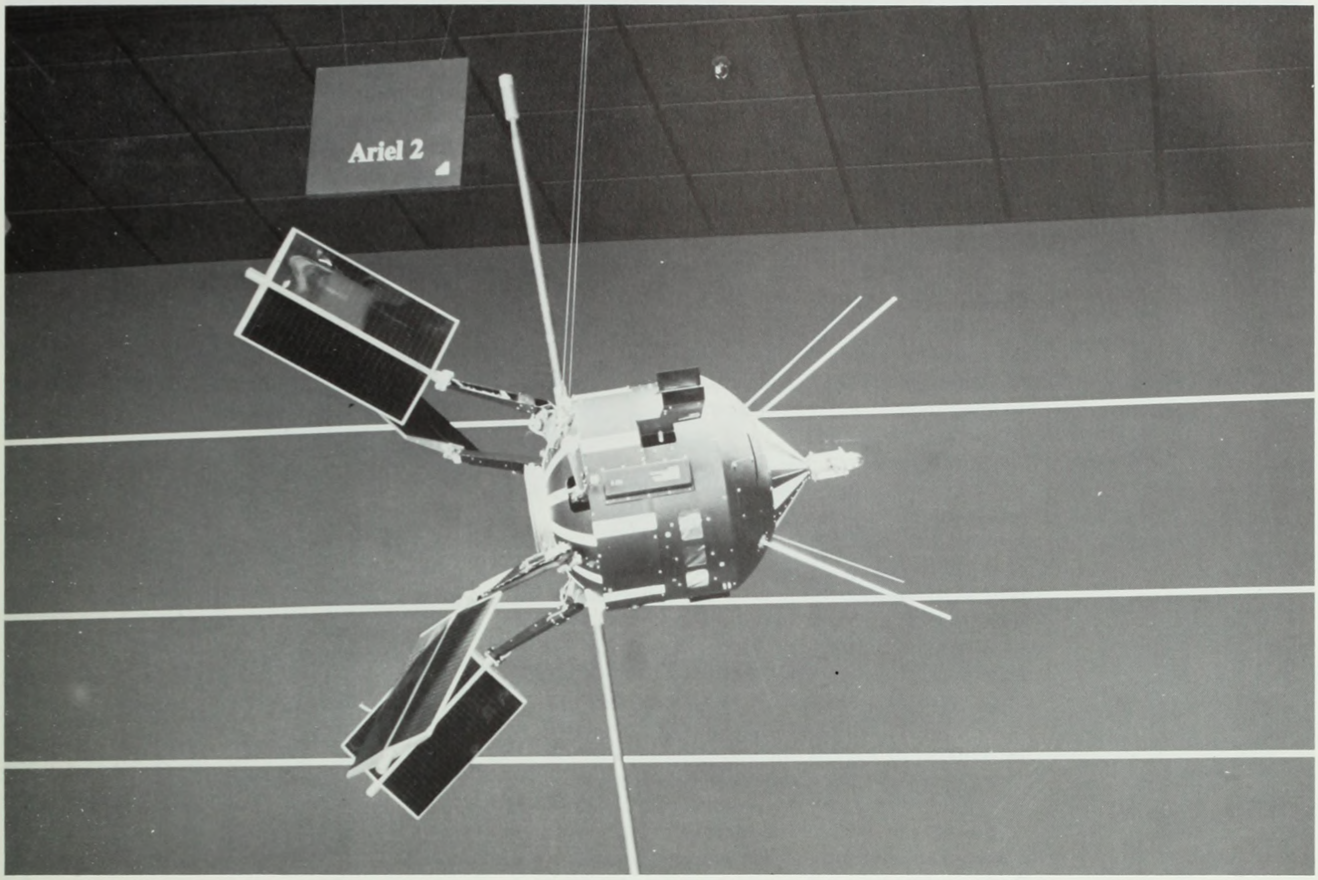
Ariel 1 operated until November 1964, and provided extensive data on the dependence of the Earth's ionosphere on high energy solar radiation. It helped to produce a better picture of the flux of high energy cosmic rays and aided in the evaluation of the effect of the Starfish nuclear bomb test upon Earth's Van Allen radiation belts.

Ariel 2 (UK-2) was launched on March 27, 1964, from Wallops Island, Virginia, on a Scout rocket. This was the second international cooperative venture between the United States and the United Kingdom. As with *Ariel 1,* the instruments on *Ariel 2* were constructed by the staff at British universities and in British industry, and the launch vehicle and spacecraft were provided by NASA. The spacecraft itself was built by Westinghouse Electric Corporation.

While the overall mission of *Ariel 2* was similar to that of *Ariel 1* the specific experiments were different and included a galactic radio noise receiver to map the general cosmic background noise level, instruments for measuring the vertical distribution of ozone in Earth's atmosphere, and a set of micrometeoroid detectors.

While all the experiments apparently worked, the most useful in the long run was the galactic radio noise experiment, because it provided a background map of radio intensity against which new discrete sources could be detected. It was the first step into radio astronomy from space and was followed by the radio astronomy experiment (RAE) satellites.

David DeVorkin



Ariel 2. *(Photo: Smithsonian Institution)*

Mariner 2 Planetary Probe

Height: 3.7 m (12 ft)
Width: 5.02 m (16.5 ft)
Weight: 203 kg (447 lb)
Gallery: 100: *Milestones of Flight*

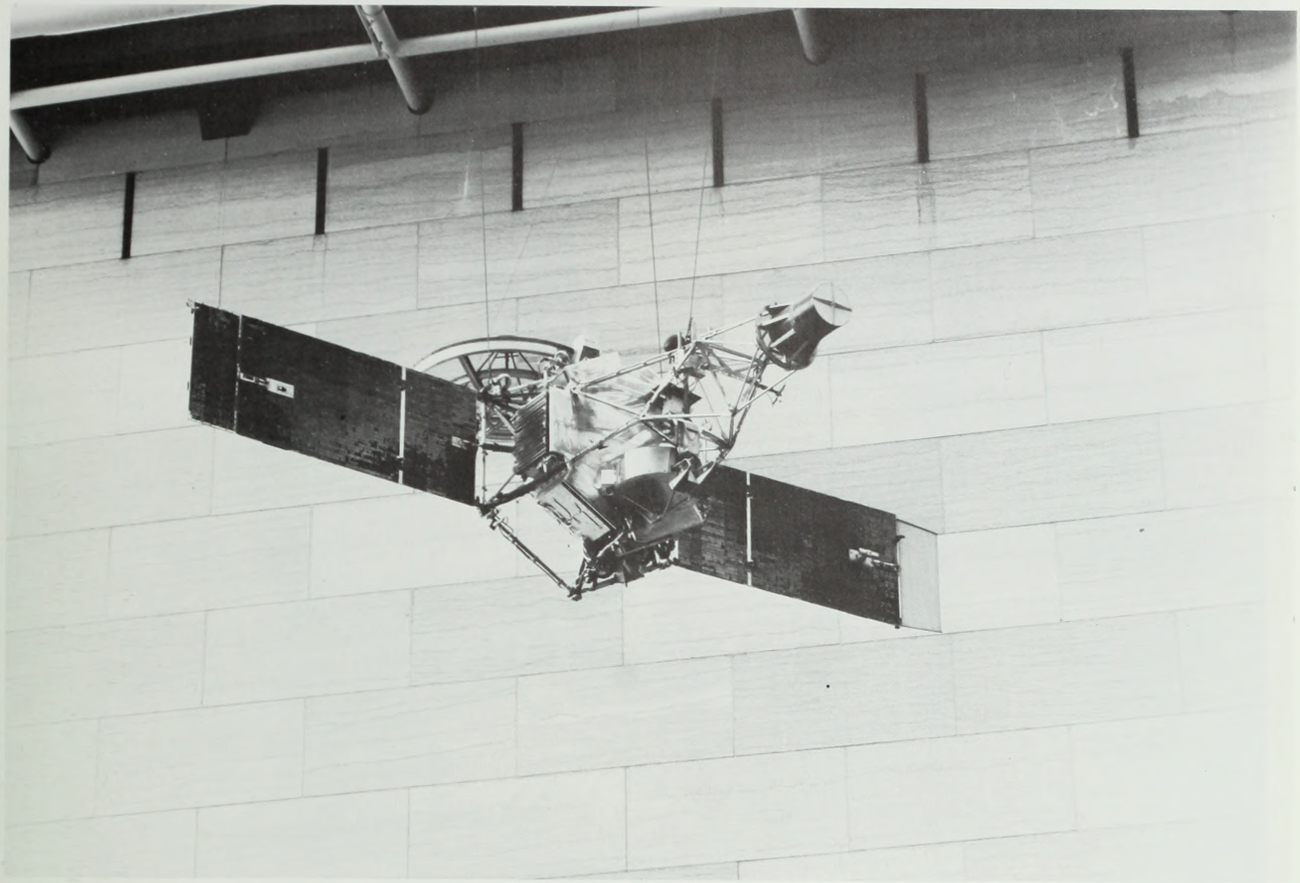
On December 14, 1962, for the first time, useful scientific information was transmitted to Earth from the vicinity of another planet. The *Mariner 2* spacecraft, with six scientific instruments on board, returned more than 90 million binary bits of information by the time its four-month journey to Venus was complete.

The purpose of the Mariner program was to send unmanned spacecraft to Venus and to Mars. The program was one of the first space projects adopted following the Soviet Union's successes in 1957 with the Sputnik satellites and in 1959 with their lunar probes. U.S. plans to send relatively large probes to Venus and Mars (up to 1,250 pounds) were extremely sensitive to progress and delays in simultaneous U.S. programs to develop launch vehicles for exploring space. When, during the summer of 1961, it became apparent that the powerful upper stage Centaur rocket, that was needed to send a large payload to Venus, would not be ready in time for the 1962 launch opportunity, an alternate plan was set in motion. The available Agena B upper stage could send to Venus a spacecraft of the size of the Ranger lunar probes that were then being developed. But only eleven months were available to design, develop, assemble, test, and launch the smaller Mariner. To save time, many of the structures and design features of Ranger were used to house six of the larger Mariner's experimental instruments. Two essentially identical spacecraft were made ready in time.

Mariner 1 was launched on July 22, 1962, but flew off course and was destroyed after only 293 seconds of flight. The launch pad was quickly readied for the second attempt and *Mariner 2* was successfully launched a little over one month later.

The instruments onboard *Mariner 2* included a magnetometer, charged particle detectors, a cosmic dust collector, and a solar plasma detector. Those instruments operated all during the flight, including the period of closest approach to Venus. *Mariner 2* also contained a microwave radiometer and an infrared radiometer to determine the temperature and structure of Venus' atmosphere. The successful conclusion of the flight of *Mariner 2,* despite several problems encountered on the way to Venus, provided valuable experience and an auspicious beginning to planetary exploration with unmanned spacecraft.

Allan Needell



Mariner 2 *was the first spacecraft to fly past another planet. (Photo: Smithsonian Institution)*

Relay 1 Communications Satellite

Height: 81 cm (32 in)
Diameter: 74 cm (29 in)
Weight: 77 kg (170 lb)
Gallery: 110: *Satellites*

The first active communications satellite built under NASA's aegis, Relay, paralleled the earlier Echo passive satellite program. RCA, which had participated as manufacturer in the SCORE and Echo programs, was the prime contractor to NASA.

Relay 1 was launched by a Thor-Delta vehicle on December 13, 1962. An improved version, *Relay 2*, was launched on January 21, 1964.

As the first civilian active communications satellite, the Relay spacecraft established some firsts and represented a significant improvement over the SCORE and Courier programs, which were Department of Defense efforts and which had conducted experiments in delayed broadcast.

Relay was designed to test high quality intercontinental video transmission and to evaluate equipment to relay multichannel telephone, telegraphy, facsimile, and data-processing information. The destructive effects of space environment on various components, especially the deterioration of solar cells, was also studied.

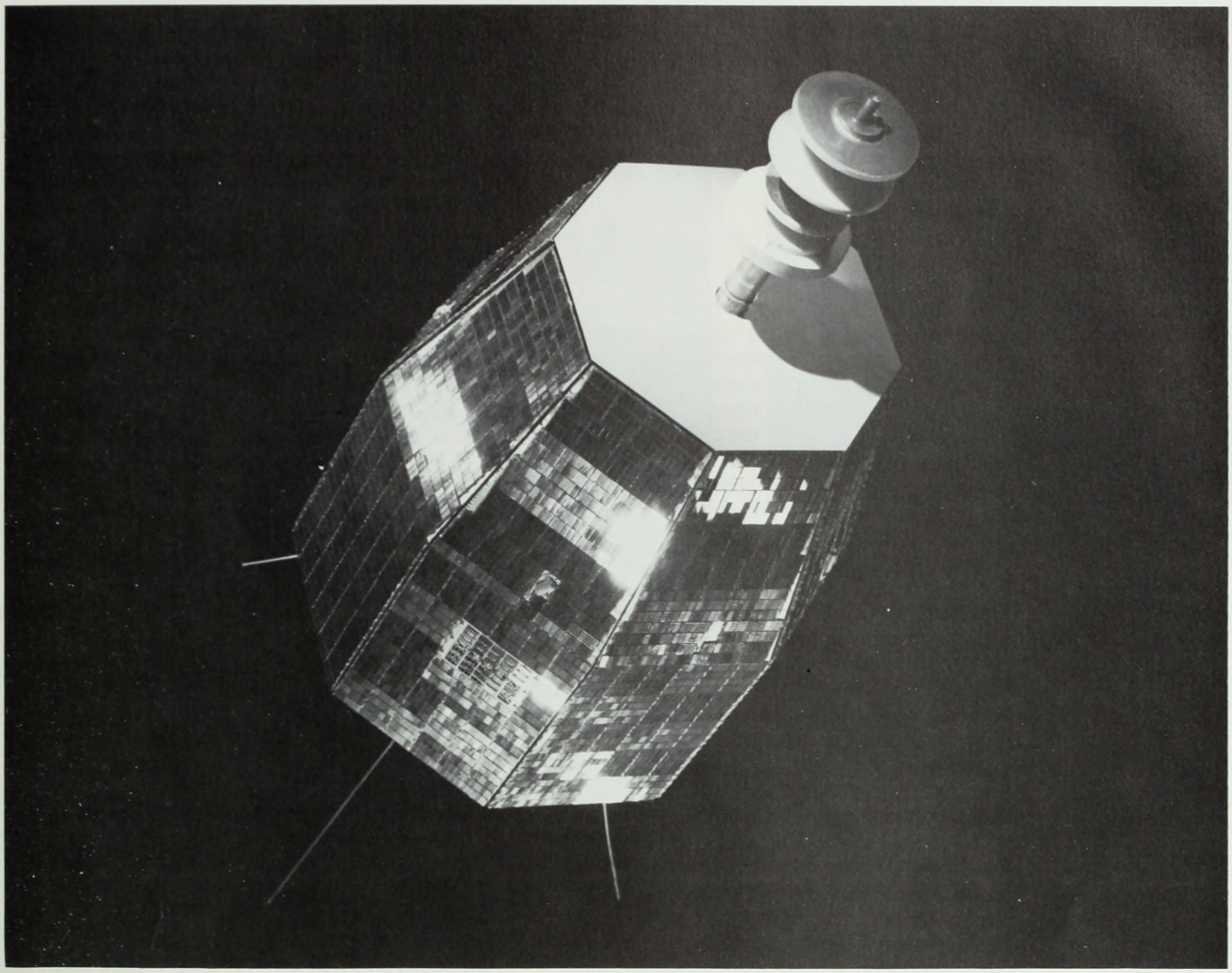
Relay 1 was equipped with a chemical deactivation device set to function one year after launch. The chemical reactant failed to accomplish its purpose, so the satellite worked beyond that time.

The Astro-Electronics Division of the Radio Corporation of America (RCA), Princeton, New Jersey, supplied the two Relay spacecraft. The spacecraft frame, an octagonal prism tapered at one end, was covered with 8,215 solar cells generating about 45 watts of power. Protruding from the tapered end was a broad band antenna. Four tracking, telemetry, and command antennas extended from the other side. The 77-kilogram (170-pound) spacecraft had an output of 10 watts, was spin stabilized, and had both active and passive thermal control.

The program was managed by the Goddard Space Flight Center with test operations assigned to the Space Technology Corporation. The NASA STADAN (Space Tracking and Data Acquisition Network) tracked and received data from the spacecraft.

Both spacecraft performed at a satisfactory level, even though *Relay 1* had problems with one transponder soon after launch. Twenty-one days later on January 3, 1963, it was switched off and the alternate transponder was used for the rest of the tests which lasted about 25 months.

Kerry M. Joels



Relay 1. *(Photo: NASA 62-Relay-17)*

Gemini 4 Spacecraft

Length:	5.7 m (18.75 ft) (in space)
Diameter:	3 m (10 ft) (at base in space)
Weight:	3,566 kg (7,862 lb) (in space)
Crew:	two
Gallery:	100: *Milestones of Flight*

Astronaut Edward H. White II became the first American to "walk in space" on June 3, 1965. His 22-minute extravehicular activity was one of the most dramatic accomplishments of the United States' manned program. White strolled over North America during the third orbit of the four-day flight of *Gemini 4*.

Gemini 4 was launched from pad 19 at the Kennedy Space Center (formerly Cape Canaveral) in Florida at 10:16 a.m. EST on June 3, 1965. Less than 10 minutes after lift off, the Titan 2 booster had placed the spacecraft in a 160- by 280-kilometer (100- by 175-mile) high orbit. James A. McDivitt was *Gemini 4*'s command pilot, Edward White was the pilot.

The two-man Gemini was an intermediate step between the single seat Mercury earth-orbiting spacecraft, and the three-man Apollo lunar vehicle. Project Gemini's objectives were to demonstrate the techniques of orbital rendezvous and docking, conduct missions lasting up to two weeks, and to conduct extravehicular activities, or "space walks." Such operations would be needed in a few years for the Apollo lunar flights. The Gemini spacecraft was much larger than its predecessor; 3 meters (10 feet) in diameter at its base and 5.7 meters (18.75 feet) long. Gemini was divided into three sections. The first was the reentry section, which housed the crew compartment, parachutes, reentry control system, and heat shield. Aft of the reentry section was the retro section. This section held four spherical solid-propellant rocket motors, which slowed the craft for return from orbit. The last section was the equipment section, which contained the life support system, maneuvering fuel, and electrical power systems. Both the equipment and retro sections were discarded before reentry and were not recovered.

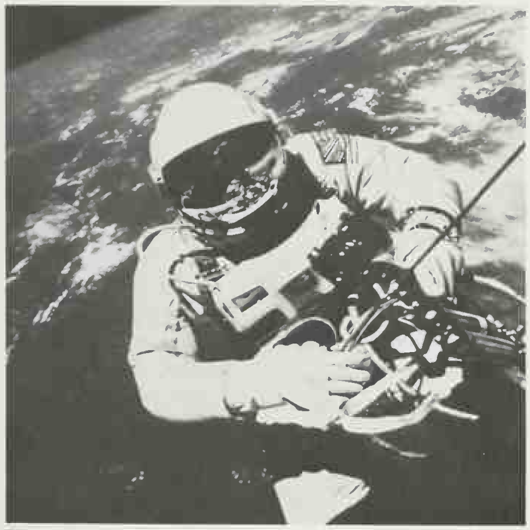
During the third orbit, McDivitt and White depressurized *Gemini 4*'s cabin, and at 2:45 p.m. EST, White opened his hatch and stood up. He had several pieces of specialized equipment for the extravehicular activity. A 7.6 meter (25-foot) long gold-colored "umbilical," connected him to the spacecraft. The umbilical contained his oxygen supply hose and electrical leads. White wore an emergency oxygen pack on his chest. If anything went wrong with the umbilical, the pack held a 9-minute oxygen supply. His helmet had a gold-plated outer visor to protect him from the intense ultraviolet radiation from the sun. White also had a small hand-held maneuvering unit.

Soviet Cosmonaut Alexi Leonov had performed the first walk in March 1965 (less than three months before White) and had spent ten minutes floating alongside *Voskhod-2*, but he did not have any means of controlling his movements. White used his maneuvering unit to pull himself out of the cabin, then translated the length of the spacecraft, and practiced several turns before running out of propellant. The maneuvering unit comprised two tanks with a throttle handle and three thrusters. White spent 22 minutes outside of *Gemini 4* before Mission Control ordered him back inside.

After the excitement of the extravehicular activity, McDivitt and White undertook the rest of the mission, which lasted for four days. During the rest of the flight, the astronauts performed medical experiments, photographed Earth, and evaluated the spacecraft's systems. After circling Earth 62 times, *Gemini-4* splashed down in the Atlantic Ocean at 12:12 p.m. EST on June 7, 1965. The aircraft carrier USS *Wasp* recovered the craft, which had travelled a total distance of 2,590,500 kilometers (1,609,700 miles) in space.

Gregory P. Kennedy

Edward White's Gemini 4 *space walk is recreated in the National Air and Space Museum. (Photo: Smithsonian Institution)*



Ed White's space walk, June 3, 1965. (Photo: NASA 65-H-1017)

Gemini 7 Spacecraft

Length: 5.7 m (18.75 ft)
Diameter: 3 m (10 ft) (in space)
Weight: 3,628 kg (8,000 lb) (in space)
Crew: two
Gallery: 210: *Apollo to the Moon*

During the flight of *Gemini 7,* two major goals of the Gemini program were realized. Astronauts Frank Borman and James Lovell spent two weeks in orbit and performed the world's first rendezvous in space.

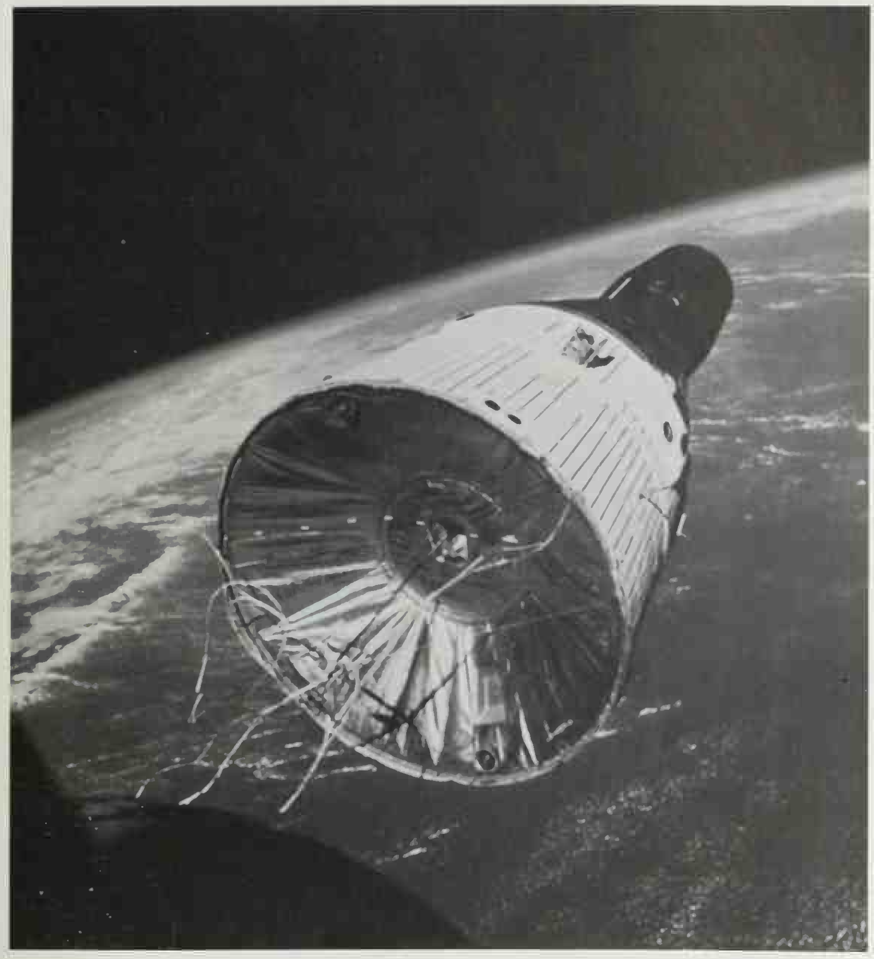
Gemini 7 lifted off on December 4, 1965. Borman and Lovell were scheduled to spend the next 14 days inside the spacecraft, which had about as much room as the front portion of a compact car. They wore new, different space suits, which had been designed for maximum comfort. These suits weighed less than 9 kilograms (20 pounds) and could be removed in flight. Like the suits worn during the Mercury flights, they only provided a back up should the spacecraft depressurize.

As soon as *Gemini 7* lifted off, technicians at the Kennedy Space Center began preparing for the next Gemini launch: *Gemini 6*. Two months earlier, *Gemini 6* had sat on the launch pad, ready for flight. Astronauts Walter Schirra and Thomas Stafford were supposed to have rendevoused and docked with an unmanned Agena target vehicle. Unfortunately, the Agena's Atlas booster malfunctioned, and the target never reached orbit. Mission controllers decided to postpone *Gemini 6* and have it rendezvous with *Gemini 7*, so Schirra and Stafford could perform their original mission, with the exception of the actual docking.

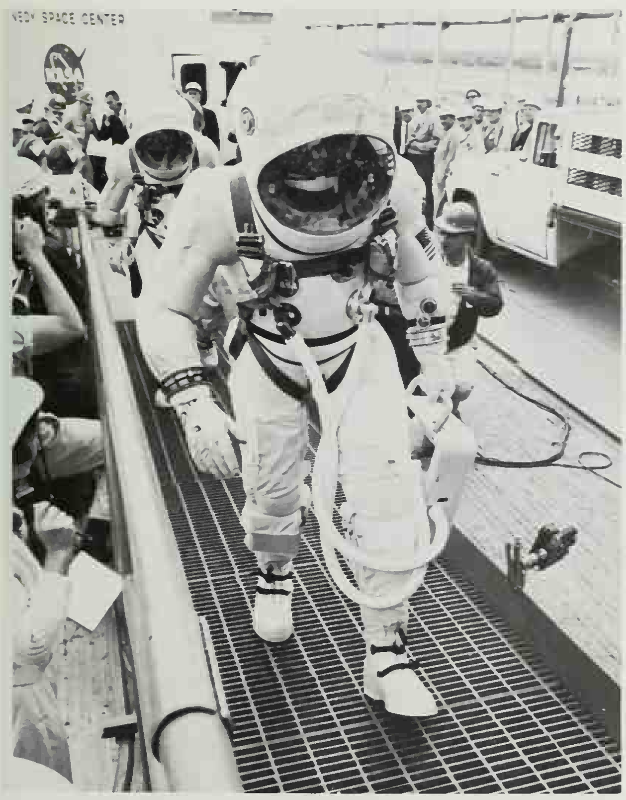
After an abortive launch attempt on December 12, *Gemini 6* lifted-off on December 15, 1965. Less than six hours later, after completing a complex series of maneuvers, *Gemini 6* was flying alongside *Gemini 7* 298 kilometers (185 miles) above the Earth. Schirra and Stafford brought their craft within 30 centimeters (1 foot) of *Gemini 7*. The two spacecraft flew in formation for 20 hours, then *Gemini 6* returned to Earth.

Borman and Lovell continued their flight for another two days. They splashed down in the Atlantic Ocean on December 18, 1965, after circling Earth 206 times in a marathon 330 hour, 35 minute flight.

Gregory P. Kennedy



Gemini 6 *astronaut Thomas Stafford took this photograph of* Gemini 7, *260 kilometers (160 miles) above Earth. (Photo: NASA 65-H-2343)*



Gemini 7 *astronauts Frank Borman and James Lovell in their lightweight space suits. (Photo: NASA 65-H-1882)*

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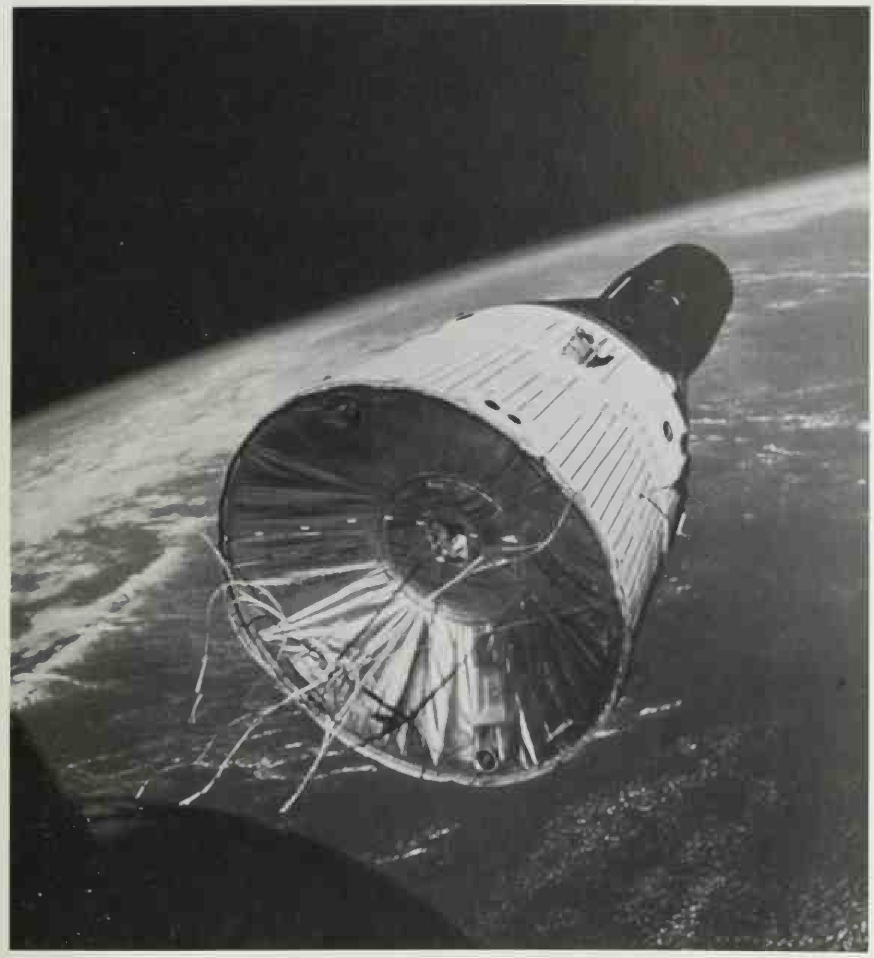
Gregory P. Kennedy



Gemini 6 *astronaut Thomas Stafford took this photograph of* Gemini 7, *260 kilometers (160 miles) above Earth. (Photo: NASA 65-H-2343)*

Gemini 7 *astronauts Frank Borman and James Lovell in their lightweight space suits. (Photo: NASA 65-H-1882)*

Gemini Space Suits

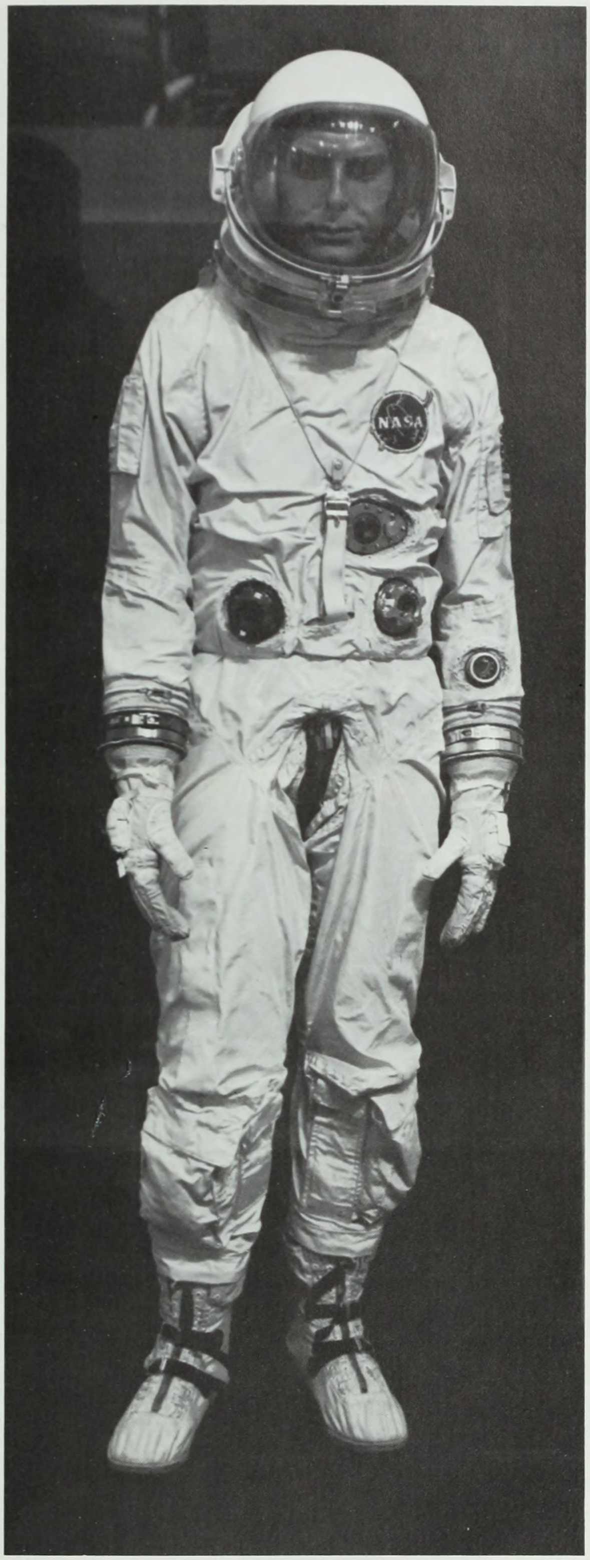
Weight: 10 kg (23 lb) (basic suit)
15 kg (33 lb) (with extra layers)
Gallery: 100: *Milestones of Flight*
113: *Rocketry and Space Flight*

The Project Gemini G4C space suits were designed to be work clothes, as well as back-up garments should the spacecraft depressurize. Unlike the Mercury astronauts, who orbited Earth in their spacecraft as passengers, the astronauts of the Gemini space program were intended to be pilots and workers in space. Project Gemini was phase 2 enroute to the moon; the extravehicular astronauts of this project were performing, more or less, a dress rehearsal for the moon, since one object of this project was to determine whether an astronaut could emerge from the two-man spacecraft and perform useful work while protected only by his space suit. This extravehicular activity advanced the role of the Gemini suit from a back-up to a prime system.

The 10-kilogram (23-pound) Gemini suit contained four layers. The innermost layer consisted of a soft nylon layer designed for comfort. The third layer was a pressure-retaining layer made of black neoprene-coated nylon. The second layer was a restraint garment of woven nylon net fabric. The outside layer consisted of white nylon. For extravehicular activities, the G4C suit weighed 15 kilograms (33 pounds) and had thermal insulation and micrometeoroid protection layers between the net restraint and outer layer. The suit was reliable, moderately comfortable, and fairly mobile.

There are three Gemini space suits on exhibit in the Museum. The garments worn by Edward H. White and James A. McDivitt during the *Gemini 4* mission are displayed with the spacecraft in the *Milestones of Flight* gallery. White's extravehicular suit, the first of the American space program, is depicted. Another Gemini G4C suit is in Gallery 113: *Rocketry and Space Flight*.

Louis R. Purnell



Gemini space suit exhibited in Gallery 113: Rocketry and Space Flight. *(Photo: Smithsonian Institution)*

Agena B Upper Stage

Length: 7.1 m (23.25 ft)
Diameter: 1.5 m (5 ft)
Weight: 673 kg (1,484 lb)
Thrust: 71,200 newtons (16,000 lb)
Gallery: 110: *Satellites*

The *Agena B* was a liquid-propellant upper stage for the Atlas and Thor launch vehicles. It could boost 2,300-kilogram (5,000-pound) payloads to 480-kilometer (300-mile) high orbits or propel lighter spacecraft on deep-space missions.

Agena began as an Air Force project and first flew in 1959. The following year, NASA decided to procure the stage for their programs. The first version, the *Agena A,* was soon replaced by the *Agena B*, which held more propellants and had an engine that could restart in space. The engine had a thrust of 71,000 newtons (16,000 pounds) and a burning duration of 240 seconds.

Agena's engine burned hypergolic propellants. Such propellants ignite on contact, so engines which use them do not need complicated ignition systems. The Agena burned unsymmetrical dimethyl hydrazine and nitrogen tetroxide.

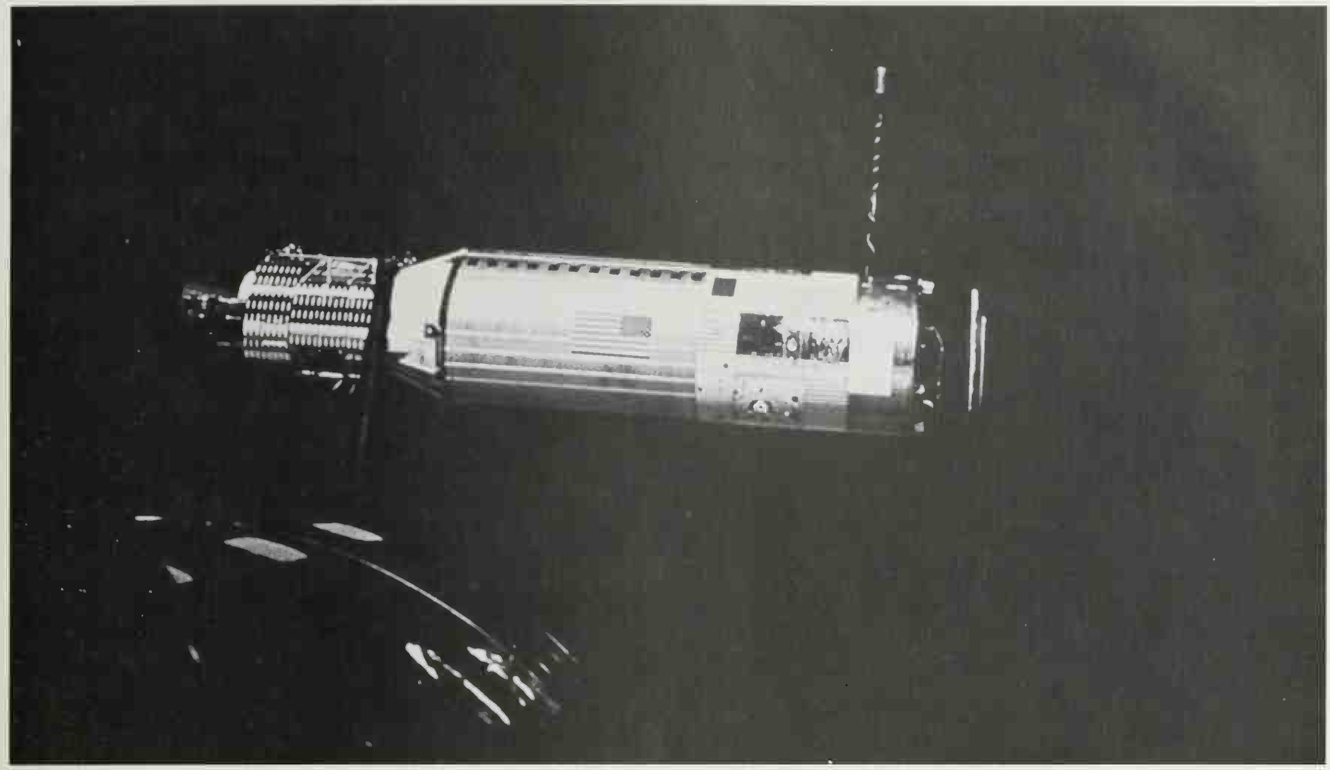
An Agena was the first vehicle launched into a polar orbit, the first spacecraft to have 3-axis control, and the first to have an engine restart in space. Ranger, *Mariner 2,* and Lunar Orbiter, all of which are exhibited in the Museum, were launched by Agenas.

The Agena was used for the early Discoverer satellites. The reentry vehicles were attached to the forward end of the upper stage. At the end of the mission, the Agena maneuvered into the proper attitude and ejected the reentry vehicle. Following reentry, the reentry capsule was snatched in mid-air by an Air Force airplane as it descended on its parachute. Agena's then-unique stabilization and control system made such precise maneuvers possible.

During the Gemini program, manned spacecraft docked with specially outfitted Agena target vehicles in space. In this configuration, the upper stage had a docking adapter affixed to its front. The first such docking occurred on March 16, 1966, between *Gemini 8* and its target. The Agena was launched first, followed by the Gemini. After a complex series of orbital flight path corrections, astronauts Neil Armstrong and David Scott caught up with the target and maneuvered the nose of their *Gemini 8* spacecraft into the docking adapter. Unfortunately, shortly after the docking, one of the thrusters on the spacecraft malfunctioned and started the two craft tumbling. The astronauts had to undock and return to Earth. Because they ended the mission early, the astronauts were not able to use the Agena's engine to propel themselves up to a higher orbit.

During the *Gemini 10* mission, astronauts Michael Collins and John Young used the Agena's engine to raise their orbit to 764 kilometers (475 miles). *Gemini 11* went even higher—1,370 kilometers (850 miles).

Gregory P. Kennedy



Gemini-Agena target docking vehicle. (Photo: NASA 66-H-1024)

Atlas-Agena launch vehicle. The Agena was an upper stage for the Atlas and Thor rockets. (Photo: NASA 66-H-1110)

TIROS Operational Satellites

Height: 57.2 cm (22.5 in)
Diameter: 107 cm (42 in)
Weight: 138 kg (305 lb)
Gallery: 110: *Satellites*

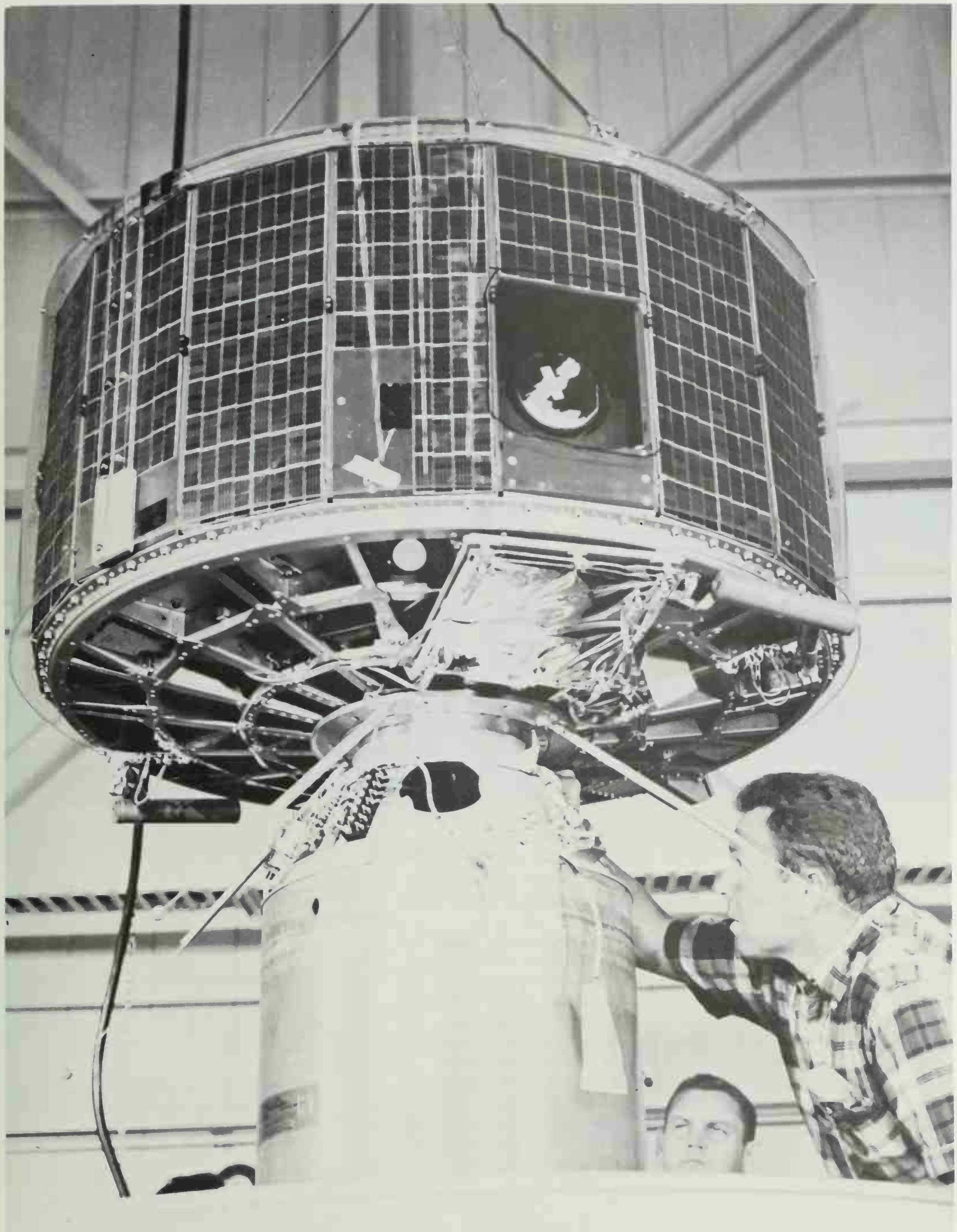
The TIROS Operational Satellites (TOS) were operational spacecraft developed from the ten experimental satellites of the TIROS series by RCA Astro-Electronic Division. Launched on thrust-augmented Deltas, these cylindrical spacecraft were the first operational system for continuous meteorological observation from space.

Two types of spacecraft were used in the series. One type used an automatic picture transmission (APT) capability to continuously transmit images to many relatively simple and inexpensive ground stations. The second type was an advanced vidicon camera system (AVCS) used to record the image and transmit it at high speed to command and data acquisition (CDA) stations at Fairbanks, Alaska, and Wallops Island, Virginia.

The TOS on exhibit is an unflown APT craft. These spacecraft orbited at approximately 1,430 kilometers (885 miles) with an inclination of 101.6 degrees. The spacecraft is spin stabilized. The two 2.5-centimeter (1-inch) vidicons gave a resolution (the smallest detail) of two nautical miles at picture center; but this resolution falls off at the edge of the picture. The TOS wheel configuration had instruments on the prism or cylindrical wall, whereas TROS had its instruments in the base of the craft.

The TOS system generated over one million images using nine spacecraft. Even numbered spacecraft were APTs and odd numbered ones were AVCs. They each operated for an average of three years between 1966 and 1976.

Kerry M. Joels



The TIROS Operational Satellite (TOS) had television cameras on its sides. (Photo: NASA 66-H-1303)

H-1 Rocket Engine

Length: 759 cm (102 in)
Thrust: 890,000 newtons (200,000 lb)
Gallery: 113: *Rocketry and Space Flight*

Eight H-1 liquid-propellant rocket engines powered the first stages of the Saturn 1 and Saturn 1B launch vehicles. The H-1 was an example of how rocket engine technology in the 1950s was modified and improved for the manned space programs of the 1960s.

Early Soviet launch vehicles could loft larger payloads than their American counterparts, the so called "booster gap" of the late 1950s. In April 1957, the Army Ballistic Missile Agency (ABMA) at Redstone Arsenal in Alabama initiated design studies for an advanced launch vehicle with a lift-off thrust of 6.7 million newtons (1.5 million pounds). ABMA engineers concluded that the least expensive way to build such a vehicle was to cluster existing rocket engines. The Advanced Research Projects Agency of the Department of Defense thought the plan had merit. Therefore, on August 15, 1958, the Army team received authorization to build a full size vehicle.

Less than a month later, the Rocketdyne Division of North American Aviation signed a contract with ABMA to modify and uprate their S-3D propulsion system for the Thor and Jupiter missiles. The S-3D had a thrust of 668,000 newtons (150,000 pounds), and the uprated engine was developed to 837,000 newtons (188,000 pounds). This engine became the H-1.

At about the same time, Wernher von Braun proposed that the large launch vehicle be named "Saturn." The name was accepted, and when the ABMA group was transferred to the newly created NASA to form the George C. Marshall Space Flight Center, responsibility for Saturn went with it. Eventually, three Saturns were designed: Saturn 1, Saturn 1B, and Saturn 5. The Saturn 1 fulfilled the mandate for the 6.7 million-newton (1.5 million-pound) thrust launcher, while the mammoth Saturn 5 would launch Apollo astronauts to the moon.

Eight H-1 engines powered the first stage of the Saturn 1. The H-1 engine was a turbopump-fed, regeneratively cooled, liquid-propellant engine that burned RP-1 kerosene and liquid oxygen. The thrust chamber was made from steel tubes welded together. RP-1 circulated through the tubes before entering the combustion chamber to cool the engine. The stage had four fixed inboard engines and four gimballed outboard engines for steering.

To increase their reliability, the first H-1 engines only had thrusts of 734,000 newtons (165,000 pounds). The next series was uprated to 837,000 newtons (188,000 pounds). Ten Saturn 1 rockets flew with these early H-1s.

For the more powerful Saturn 1B, which used the Saturn 5's third stage as its second stage, the H-1 was again uprated, to 890,000 newtons (200,000 pounds) thrust. The first five Saturn 1Bs used these engines. The fifth Saturn 1B launched *Apollo 7,* the first manned flight of the Apollo program on October 11, 1968. A final version of the H-1, with a thrust of 912,000 newtons (205,000 pounds) propelled the launchers for the Skylab manned missions and the Apollo Soyuz Test Project (ASTP). In July 1975, ASTP was the last flight for a Saturn and the last American manned space mission with an expendable launch vehicle.

Gregory P. Kennedy

H-1 rocket engine. (Photo. Smithsonian Institution)

Eight H-1 engines powered the first stage of the Saturn 1B. (Photo: NASA 75-H-42)

RL-10 Rocket Engine

Length: 178 cm (70 in)
Thrust: 67,000 newtons (15,000 lb)
Gallery: 113: *Rocketry and Space Flight*

The RL-10 upper stage rocket motor burns liquid hydrogen and liquid oxygen. This engine grew out of advanced propulsion system studies at the Lewis Research Center in the late 1940s and 1950s.

Liquid hydrogen and liquid oxygen have long been recognized as a high-performance propellant combination, but it wasn't until the mid-1950s that they were successfully employed in a rocket engine. Dr. Walther Theil, one of the developers of the V-2 rocket's engine, experimented with such an engine in the late 1930s, but abandoned his work after having problems with fuel leaks. At about the same time, limited research was going on in the United States, but this was also abandoned because of the low density, low availability, and handling hazards of liquid hydrogen.

After World War II, research with liquid hydrogen resumed, and in November 1958, the Defense Department's Advanced Research Project's Agency awarded a contract to Convair Astronautics for a liquid-hydrogen, liquid-oxygen upper stage for the Atlas missile. This stage was named "Centaur." Later, responsibility for Centaur was transferred to the recently created NASA.

Centaur's engine was designated the RL-10. It was a regenerative-cooled, turbopump fed engine with a thrust of 67,000 newtons (15,000 pounds). For advanced missions, the RL-10 could be stopped and restarted in space. Centaur used two RL-10s mounted in parallel. The first Atlas Centaur took off on May 8, 1962. Unfortunately, the Centaur exploded during ascent. The second launch on November 27, 1963, successfully launched into orbit 900 kilograms (2,000 pounds) of instruments and equipment.

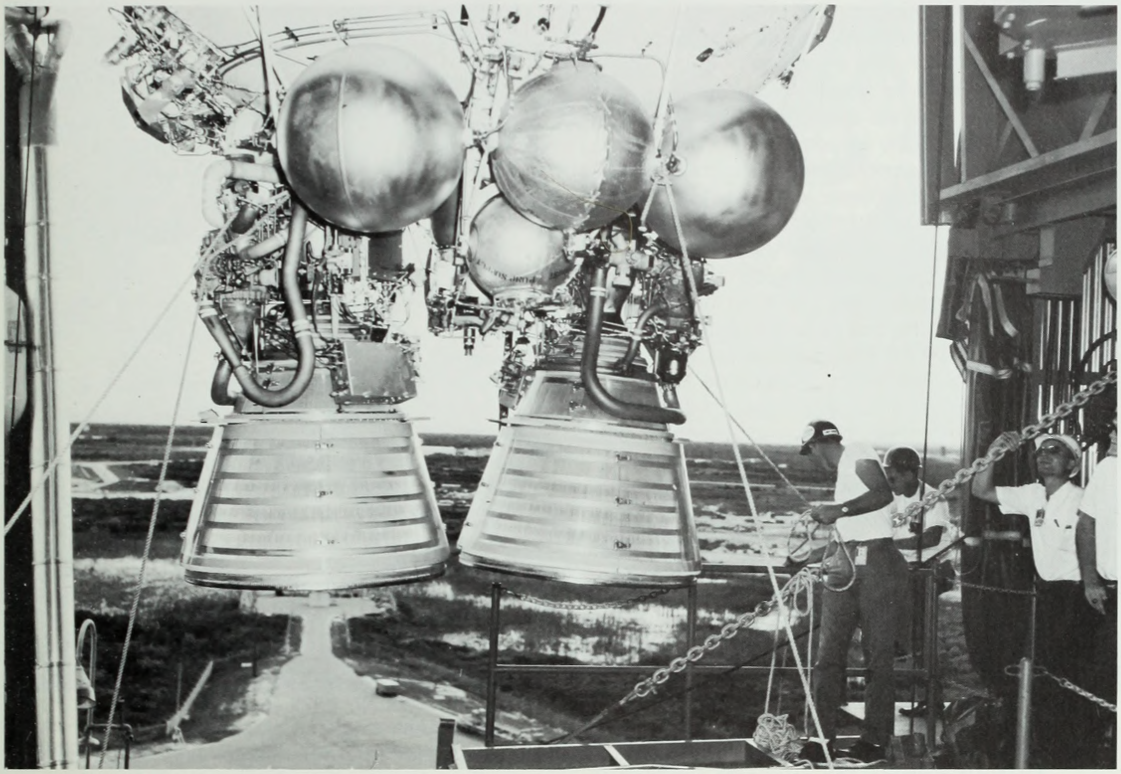
After five more tests, an Atlas Centaur launched Surveyor to the moon on May 30, 1966. The launch vehicle performed flawlessly. Since then, Atlas Centaurs have launched many spacecraft, including *Pioneer 10,* and *Intelsat 4*.

Centaur has also been used as an upper stage for the Titan 3 launch vehicle. Titan Centaurs launched Viking and Voyager. RL-10 engines were also used on the second stage of the Saturn 1 rocket. For this application, five RL-10s were clustered together.

More than 50 Centaurs have flown during the last 20 years, and the Atlas Centaur is still in use. Looking ahead, Centaur will continue to be the "workhorse" of the space program. There are plans for a "wide body" version of Centaur, which will be an upper stage for the Space Shuttle.

George P. Kennedy

The Centaur upper stage. (Photo: NASA 74-H-1174)



Two RL-10 engines powered the Centaur upper stage. (Photo: NASA 63-Centaur-15)

Intelsat Communications Satellites

Intelsat 1 (Early Bird)

Height: 59.0 cm (23.25 in)
Diameter: 72.1 cm (28.4 in)
Weight: 39 kg (85 lb)
Gallery: 110: *Satellites*

Intelsat 2

Height: 67.3 cm (26.5 in)
Diameter: 142 cm (56 in)
Weight: 88 kg (193 lb)
Gallery: 110: *Satellites*

Intelsat 3

Height: 198 cm (78 in)
Diameter: 142 cm (56 in)
Weight: 291 kg (642 lb)
Gallery: 110: *Satellites*

First known as *Early Bird*, the first Intelsat communications satellite was the outgrowth of a pair of agreements signed on August 20, 1964. Eleven countries were represented at the signing. By the time of the *Early Bird* launch, there were 45 signatures to the agreements.

The Intelsat consortium was formed to inaugurate commercial worldwide telecommunications. Comsat (Communications Satellite Corporation), the American representative to Intelsat (International Telecommunications Satellite Organization) managed the program for the consortium, and *Early Bird* (later named *Intelsat 1*) was to be the first experimental spacecraft. Launch of *Early Bird* took place on April 6, 1965, and commercial service began on June 28, 1965.

The spacecraft was derived from the Syncom series. It was a geostationary, solar powered platform with active repeater relay capability. The 39-kilogram (85-pound) craft expended 29 kilograms (65 pounds) of fuel to achieve its final orbit.

Early Bird marked the first step toward a global satellite communications system. The spacecraft proved the utility of spin-stabilized communications platforms.

Intelsat 1 was a cylindrical spacecraft composed of an outer structure on which 6,000 solar cells hung, and an inner structure which held the satellite's systems. The solar cells provided 45 watts of power. Nickel-cadmium storage batteries powered the satellite when it was in Earth's shadow.

The satellite had the capacity for 240 telephone voice circuits or one television channel. The spacecraft operated in the 4/6 Gigahertz range with a transmitter power of 4 watts.

The success of *Intelsat 1* was the foundation for support of the global systems that were to follow. It increased over 50 percent the communications capacity available at that time between Europe and North America. After *Intelsat 1* the Intelsat consortium increased its operational capability with the *Intelsat 2* spacecraft. Four spacecraft of this type were launched, with three achieving operational status that exceeded their expected longevity.

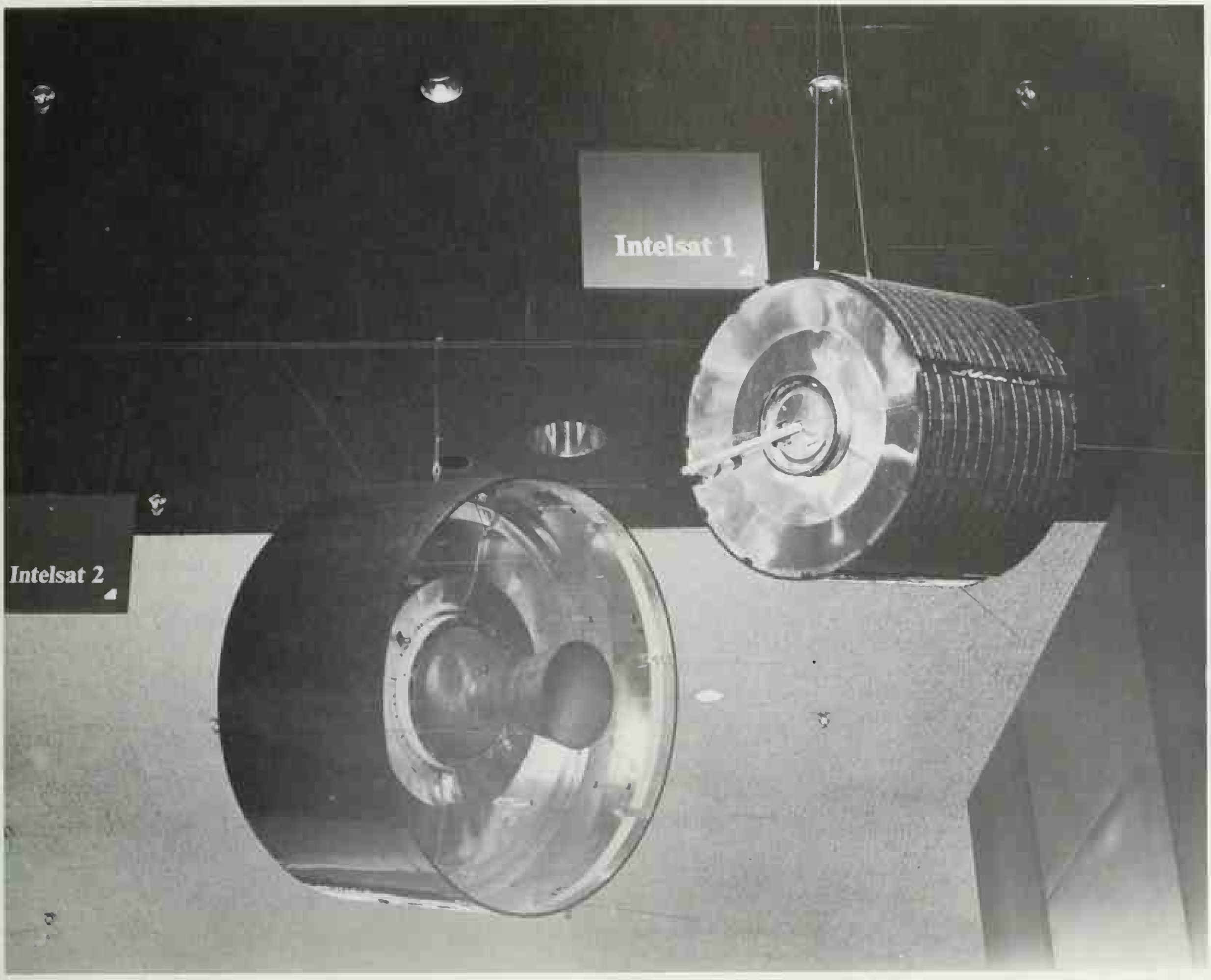
Hughes Aircraft Company, which had built *Intelsat 1*, was also the prime contractor for *Intelsat 2*. *Intelsat 2* weighs 88 kilograms (193 pounds) when in space compared with 39 kilograms (85 pounds) for its predecessor. Three new Earth stations were added to the Intelsat system, including those of Japan and Australia during 1966, and another six in 1967. By 1971, at the end of *Intelsat 2*'s operating lifetime, 52 stations were in operation.

All launches were aboard thrust augmented delta (TAD) vehicles manufactured by the Douglas Aircraft Company (later called the McDonnell Douglas Astronautics Company).

In its effort to expand traffic-handling capabilities for the Intelsat system, Comsat developed the *Intelsat 3*. The spacecraft was intended to complete global coverage and external Intelsat service. While *Intelsat 2* matched *Intelsat 1*'s 240 voice circuits or one TV channel, *Intelsat 3* carried 1,200 circuits or 4 TV channels. Five spacecraft achieved geostationary orbit. Four were used for about two years (one as a spare) while the fifth (F-3) was in use for 10 years.

The first successful launch (F-2) was on December 18, 1968, with the spacecraft beginning service over the Atlantic six days later. The last operating spacecraft (F-3) was on-line until April 1979.

Kerry M. Joels



Intelsat 1 and 2. *(Photo: Smithsonian Institution)*

Biosatellite 2

Length: 2.05 m (6.75 ft) (in space)
Diameter: 145 cm (57 in) (Satellite)
102 cm (40 in) (reentry capsule)
Weight: 423 kg (940 lb) (in space)
Gallery: 110: *Satellites*

At the beginning of the space age, little was known about the effects of the space environment on living organisms. Of particular interest were the long-term effects of radiation and absence of gravity. The Biosatellite Project was designed to answer some of these questions. Although two-week long American manned spaceflights had occurred by the time the project began, carefully controlled experiments still were necessary to precisely study the effects of radiation on living organisms.

NASA's Ames Research Center in Mountain View, California, managed the project. General Electric built the spacecraft. The 430-kilogram (940-pound) spacecraft contained a reentry vehicle to survive the meteoric trip back through the atmosphere and a recovery capsule that housed the experiments. *Biosatellite 2* was launched on September 7, 1967, and was recovered a little over 45 hours later (17 orbits earlier than planned) by an Air Force plane, which snagged the recovery capsule in mid-air.

Thirteen experimental packages were carried by the recovery capsule. A general biology group of experiments were designed to measure the effects of radiation on cell division in embryos, protoplasm, and on enzymes. The effects of weightlessness on plant structures and leaf root orientation were also measured. Animal cells seemed to be less affected by radiation than plant cells. The interaction between radiation and other factors was especially interesting; post-flight control experiments had to be performed on Earth to isolate the effects of such factors as radiation dosage and spacecraft vibration.

Kerry M. Joels

Return of the Biosatellite 2. *(Photo: NASA 67-H-1232)*

Biosatellite 2 *as it appears in Gallery 110:* Satellites. *(Photo: Smithsonian Institution)*

Ranger Lunar Probe

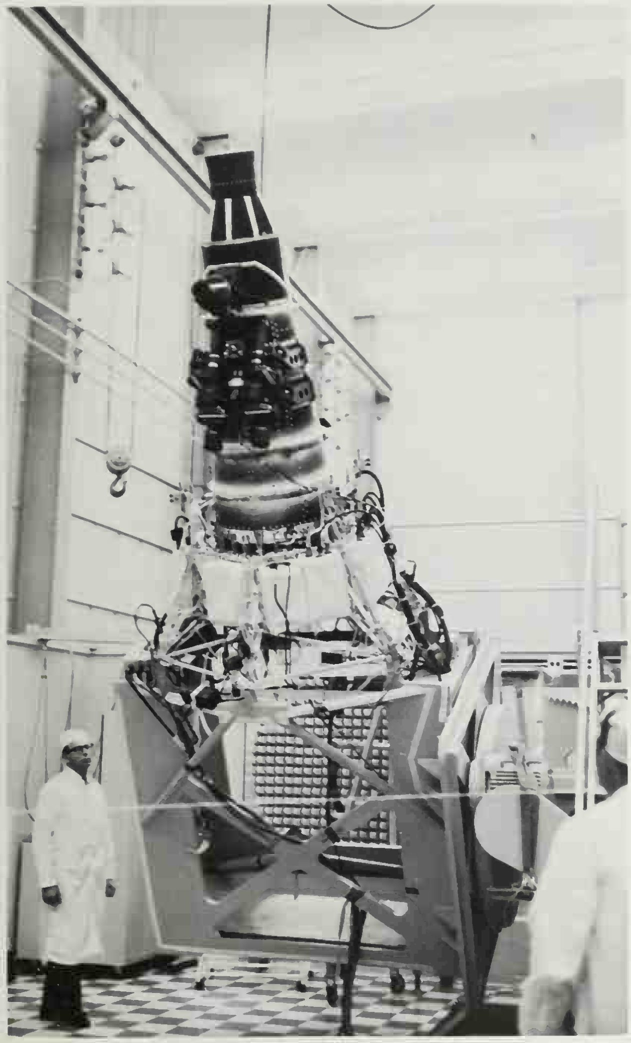
Height: 3.12 m (10.25 ft)
Width: 4.6 m (15 ft)
Weight: 357 kg
Gallery: 112: *Lunar Exploration Vehicles*

In 1959, the United States greatly expanded its lunar exploration program with the initiation of Project Ranger. It was viewed as essential to the United States that it rapidly demonstrate its capability of a dramatic success in space. Project Ranger was originally conceived as a "high-risk undertaking" to be accomplished on "short-term schedules." The spacecraft were originally intended to carry scientific instruments, as well as television cameras, for recording close-up data and pictures of the lunar surface up to the instant of impact onto the lunar surface.

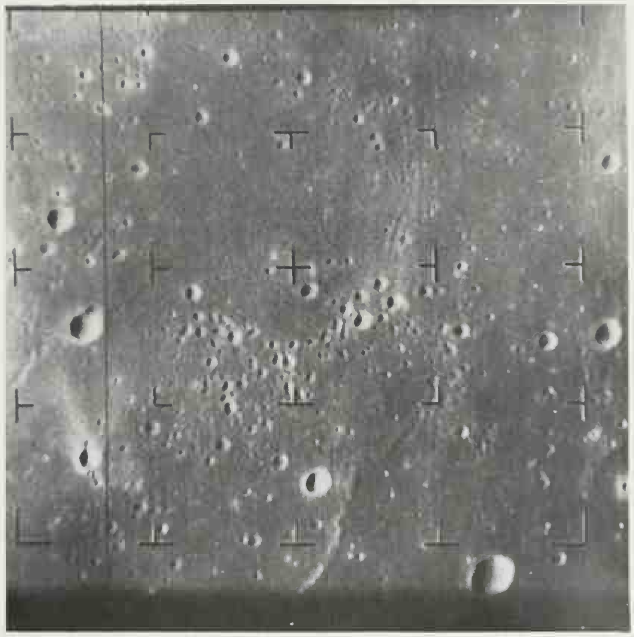
Following a number of delays and failures and the commitment by President Kennedy in 1961 to the task of landing a man on the moon and returning him safely to Earth during the 1960s, the goals of the Ranger Project were substantially altered. Less emphasis was placed on complex and untested scientific instruments, and greater emphasis was placed on obtaining pictures that would be useful in planning the manned lunar landings. In what were called the "Block 3" series of Ranger spacecraft, there were no scientific instruments besides the television cameras. Several improvements were made in the spacecraft itself to increase the probability of a successful mission.

The first fully successful Ranger lunar probe was *Ranger 7*. It was launched from Cape Canaveral, Florida, on July 28, 1964. It contained a 170-kilogram (375-pound) camera system attached to the hexagonally shaped Ranger bus (the structure that contained the power, control, communications, and other components of the spacecraft). There were two wide-angle and four narrow-angle cameras designed to take pictures from 1,400 kilometers (900 miles) to within about a 0.8 kilometer (1/2 mile) of the lunar surface. *Ranger 7* transmitted 4,316 high-quality pictures to scientists on Earth. The last of these revealed objects of less than 0.5 meter across. These photographs had a resolution estimated to be 1,000 times better than the best photographs then available from Earth-based telescopes.

Allan Needell



The Ranger Block 3 spacecraft carried six television cameras. (Photo: NASA 64-Ranger B-7)



One of the 4,316 close-up pictures of the moon returned by Ranger 7. *(Photo: NASA 64-H-2134)*

Surveyor Lunar Probe

Height: 3 m (10 ft)
Width: 4.3 m (14 ft) (across legs)
Weight: 270 kg (596 lb)
Gallery: 112: *Lunar Exploration Vehicles*

The Lunar exploration program planned by the National Aeronautics and Space Administration included three types of unmanned lunar probes to precede the first manned Apollo mission to the moon: Ranger, Lunar Orbiter, and Surveyor. Unlike Ranger, which crash landed on the lunar surface, and Lunar Orbiter, which operated from lunar orbit, Surveyor survived its trip to the moon and operated for extended periods of time directly on the surface of the moon. Indeed, the objectives of the Surveyor program, as they were defined by NASA were: (1) to accomplish a soft-landing on the moon; (2) to provide basic data in support of the U.S. manned lunar landing program; and (3) to perform operations on the lunar surface which would reveal new scientific knowledge about the moon.

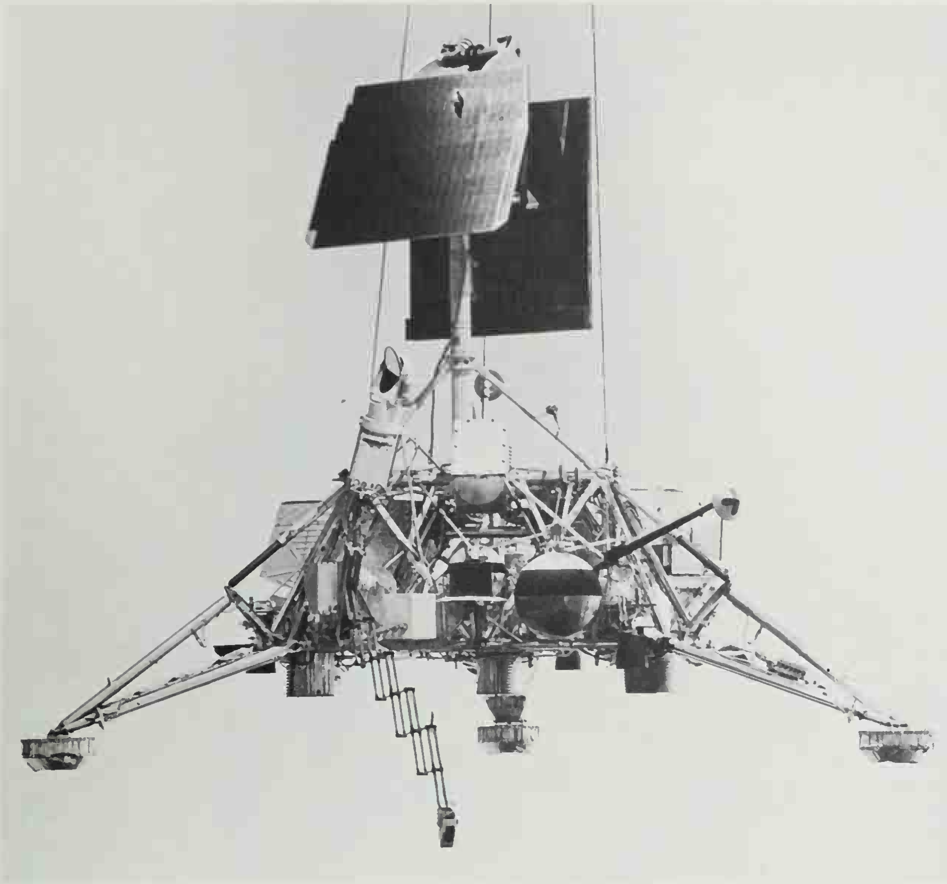
There were seven Surveyor launches, all of which used the Atlas-Centaur launch vehicle. *Surveyor 1, 3, 5, 6,* and *7* accomplished the goals set forth for the program, a remarkable success record for such an advanced and technically complex program. *Surveyor 2* and *4* were successfully launched but experienced problems enroute to the moon. As experience and knowledge of the moon and the capabilities of the spacecraft were obtained, changes were made to the Surveyor spacecraft and different landing sites were chosen.

Surveyor 1 was launched from Cape Kennedy, Florida, on May 30, 1966. All of the systems and procedures worked well, including the midcourse correction, the radar altimeter, and the retro-engines. *Surveyor 1* landed on the moon on June 2, 1966, within 16 kilometers (10 miles) of its midcourse aiming point just north of Flamsteed Crater in the moon's "Ocean of Storms." More than 10,000 high-quality photographs of the lunar surface were returned to Earth during the spacecraft's first lunar day. The spacecraft was then successfully reactivated after a cold, dark, lunar night.

Surveyor 3 was similar to *Surveyor 1,* except that it had a "scoop-and-claw" device with which tests of the bearing strength and consistency of the lunar surface and surface material could be tested. *Surveyor 5* was the first of the spacecraft to carry an "alpha back-scattering" instrument with which chemical analysis of the lunar material could be made. Finally, *Surveyor 7* was equipped with both the scoop-and-claw device and the alpha back-scattering instrument, with the former used to reposition the latter and prepare the lunar surface for different measurements.

The five successful Surveyors provided scientists and Apollo mission planners with more than 85,000 photographs from the surface of the moon and invaluable data on the nature and strength of that surface. Moreover, the program provided valuable experience with the control of a spacecraft far from Earth and in the neighborhood of another celestial body, and with the remote manipulation of instruments in space.

Allan Needell



Surveyor on exhibit in Gallery 112: Lunar Exploration Vehicles. *(Photo: Smithsonian Institution)*

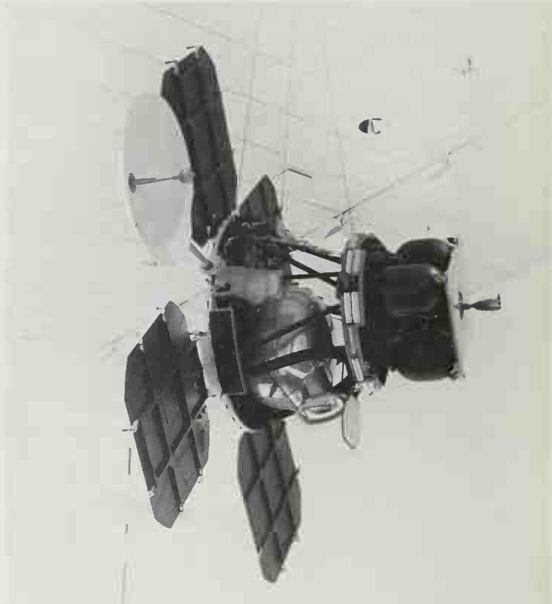
The moon as seen from Surveyor 7 *(Photo: NASA 68-H-39)*

Lunar Orbiters

Height: 1.7 m (5.5 ft)
Width: 3.7 m (12.2 ft) (across solar panels)
Weight: 387 kg (853 lb)
Gallery: 112: *Lunar Exploration Vehicles*

During 1966 and 1967, intense observation of the surface of the moon was conducted by unmanned spacecraft. Their primary objectives were to aid in the selection of safe landing sites for the manned Apollo missions scheduled for later in the decade. While the Surveyor soft-landing spacecraft were designed to reveal the strength and nature of the lunar surface at specific potential landing sites (or in the case of the *Surveyor 7*, on a site of special scientific interest), the series of five Lunar Orbiters was designed to provide a detailed map of nearly the entire lunar surface. Special emphasis was placed on locating and surveying potential Apollo landing sites.

Managed by NASA's Langley Research Center in Hampton, Virginia, and built by the Boeing Company in Seattle, Washington, the Lunar Orbiters were targeted by their Atlas-Agena launch vehicles to the vicinity of the moon. A propulsion system on board the spacecraft allowed for midcourse corrections and insertion into lunar orbit. Subsequent use of the propulsion systems allowed for adjustments in the lunar orbits. The orbiters' closest approaches to the lunar surface were about 40 kilometers (25 miles).



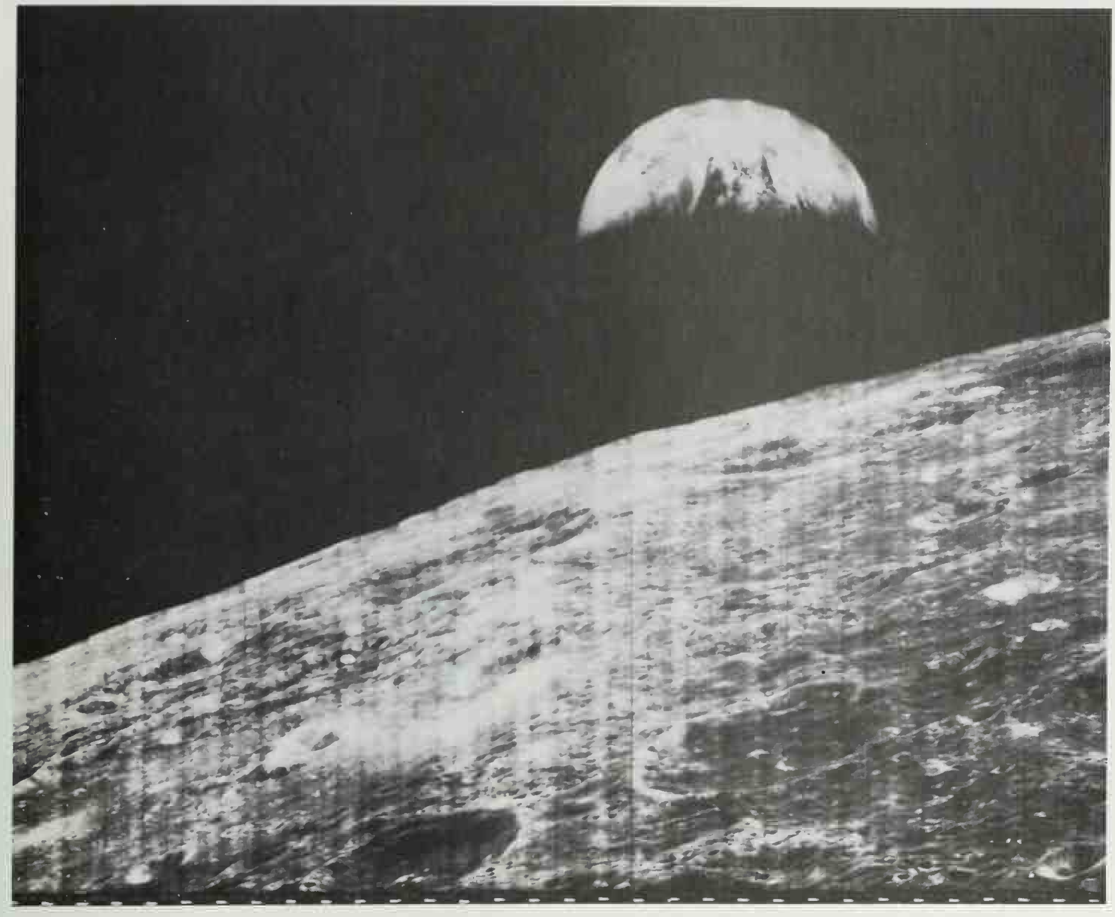
Lunar Orbiter as exhibited in Gallery 112: Lunar Exploration Vehicles *(Photo: Smithsonian Institution)*

Unlike the television systems on the Ranger and Surveyor spacecraft, the Lunar Orbiters carried self-contained photographic laboratories. The systems snapped pictures, developed the film, and then scanned the negatives to send their images back to earth as electrical signals.

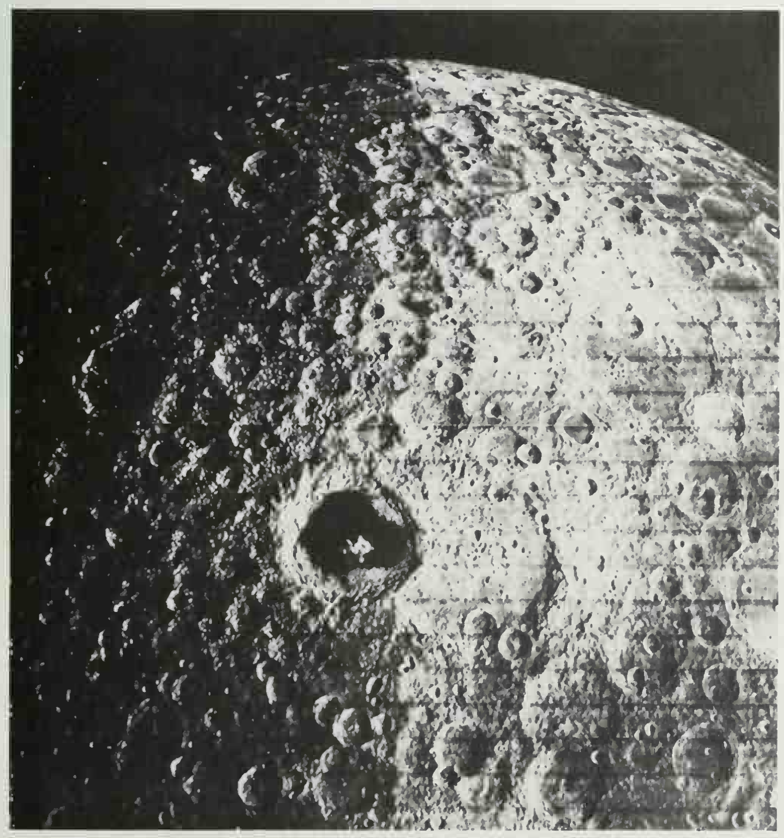
At closest approach, the high-resolution photographs showed objects as small as 1 meter (3 feet) across. In addition, by combining medium-resolution photographs of the same area taken from slightly different positions, scientists were able to construct stereoscopic images of selected areas. Such images were essential for determining the slope of the lunar terrain and the probable success of landings at various sites.

Lunar Orbiter 1 was launched on August 10, 1966. On August 14, it was successfully placed into orbit around the moon. On August 21, *Lunar Orbiter 1*'s path was adjusted so that it approached to within 45 kilometers (28 miles) of the surface. More than 200 photographs were obtained covering about 2,150,000 square miles of lunar surface.

Allan Needell



First photograph of Earth and moon together in space, transmitted from Lunar Orbiter 1 *in 1966. (Photo: NASA 66-H-1325)*



The far side of the moon as seen by Lunar Orbiter 3 *(Photo: NASA 67-H-328)*

F-1 Rocket Engine

Length: 5.6 m (18.3 ft)
Thrust: 7,100,000 newtons (1,600,000 lb)
Gallery: 210: *Apollo to the Moon*

Five F-1 rocket engines powered the first stage of the Saturn 5 launch vehicle. Each engine had a thrust of 7.1 million newtons (1.6 million pounds), giving the moon rocket a lift-off thrust of 34 million newtons (7.6 million pounds). The F-1 burned RP-1 kerosene and liquid oxygen and was based on existing state of the art technology. However, its sheer size caused many problems for its designers. One problem area included the combustion chamber injectors and propellant turbopumps. The injector had 3,700 orifices for the fuel and 2,600 for the oxidizer. The turbopumps each had to pump more than 150,000 liters (40,000 gallons) of propellants into the combustion chamber each minute.

Gradually, the problems were solved, and the first Saturn 5 was ready for flight. On November 9, 1967, the first of the monster rockets lifted off from launch pad 39 at the Kennedy Space Center in Florida. All five F-1s performed flawlessly. They were arranged with four outboard engines around a single center one. The outboard engines gimballed (swivelled) to steer the rocket. One more test flight followed, then the Saturn 5 launched its first manned Apollo.

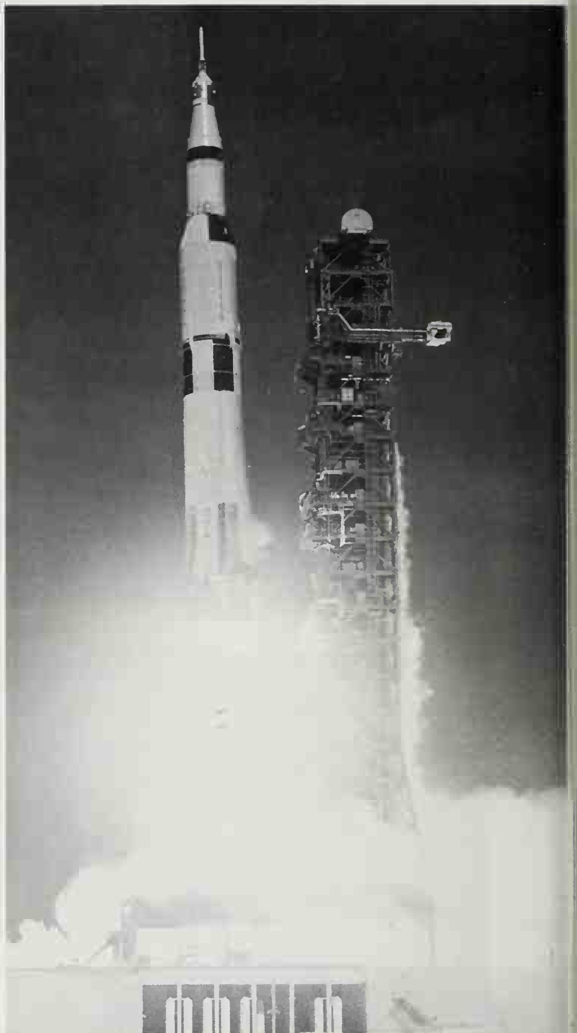
On December 21, 1968, Frank Borman, James Lovell, and William Anders lifted off aboard *Apollo 8*, the first U.S. voyage to the moon. Borman, Lovell, and Anders spent Christmas Eve orbiting the moon ten times, in one of the most exciting flights of the manned space program.

The next Apollo mission, *Apollo 9,* also used the Saturn 5 for an Earth-orbital test of the lunar module. *Apollo 10* was a dress rehearsal for the ultimate goal of the program—a manned lunar landing. Astronauts Thomas Stafford and Eugene Cernan flew a Lunar module to within 16 kilometers (10 miles) of the moon's surface. The sixth Saturn 5 launched *Apollo 11*, the first lunar landing mission.

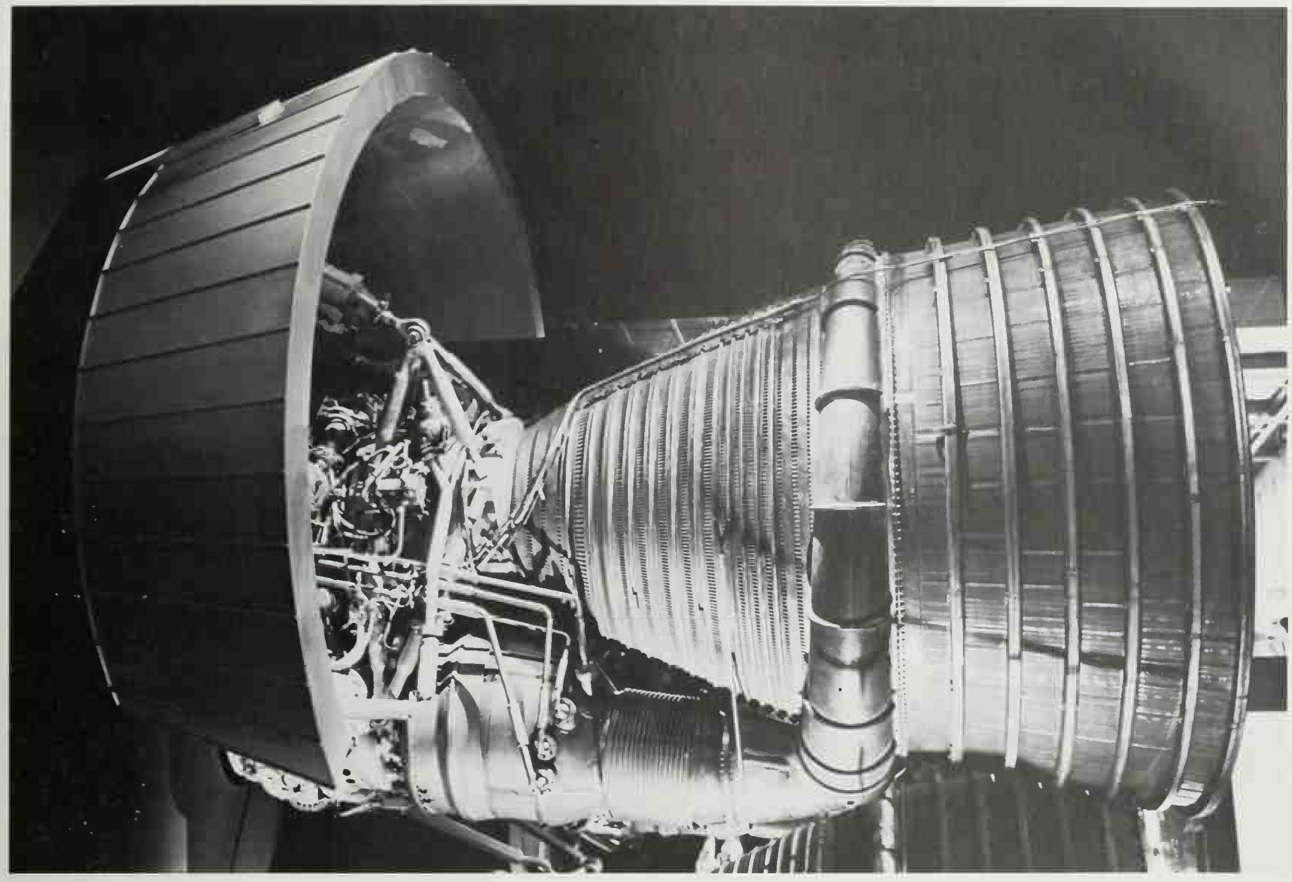
Six more Saturn 5s launched Apollo spacecraft to our nearest neighbor in space. The last of these, *Apollo 17*, was a spectacular night launch. One final Saturn 5 flight remained. The last Saturn 5 to fly launched the Skylab Orbital Workshop on May 14, 1973.

The F-1 exhibited in Gallery 210: *Apollo to the Moon,* is shown with an arrangement of mirrors to re-create the appearance of the base of the 10-meter (33-foot) diameter Saturn 5.

Gregory P. Kennedy



Five F-1 engines powered the Saturn 5 moon rocket. (Photo: NASA 69-H-1142)



F-1 engine as exhibited in Gallery 210: Apollo to the Moon. *(Photo: Smithsonian Institution)*

Apollo 11 Command Module

Height: 3.7 m (12 ft)
Diameter: 3.9 m (12.8 ft)
Weight: 5,557 kg (12,250 lb)
Crew: three
Gallery: 100: *Milestones of Flight*

The *Apollo 11* Command Module *Columbia* was the living quarters for the three-man crew during most of the first manned lunar landing mission in July 1969. On July 16, 1969, Neil Armstrong, Edwir "Buzz" Aldrin and Michael Collins climbed into *Columbia* for their 8-day journey. The Command Module was one of three parts of the complete Apollo spacecraft. The other two were the Service Module and the Lunar Module.

The Service Module contained the main spacecraft propulsion system and consumables (oxygen, water, propellants, and hydrogen). The Lunar Module was the part Armstrong and Aldrin would use to descend to the moon's surface.

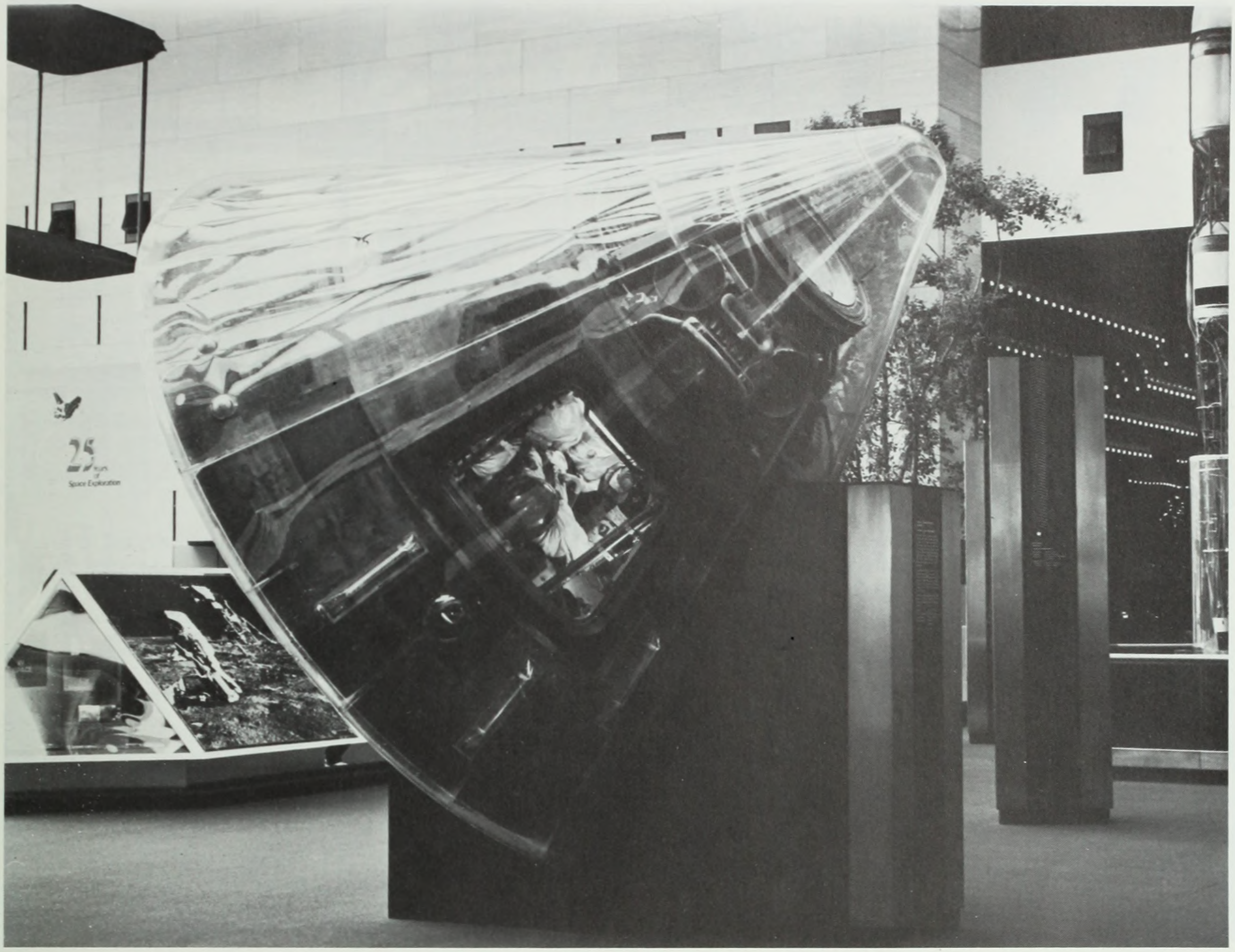
When *Apollo 11* lifted off, the spacecraft and launch vehicle combination stood 111 meters (364 feet) tall. Eight days later, when the flight ended, the only part recovered was the 3.3-meter (11-foot) tall *Columbia* Command Module. The cone-shaped spacecraft was divided into three compartments: forward, crew, and aft. The forward compartment is at the cone's apex, the crew compartment is in the center, and the aft compartment is in the base, or blunt end, of the craft.

The forward compartment contained the parachutes and recovery equipment. The crew compartment has a volume of 5.9 cubic meters (210 cubic feet). It contains three couches for the crew during launch and landing. The couches are arranged so that each astronaut faces the main instrument panel. A command module instrument panel like the one in *Apollo 11* is exhibited in Gallery 210: *Apollo to the Moon*. During flight, the astronauts could fold-up the couches to make more room in the spacecraft. Near the feet of the couches, in the lower equipment bay, there is enough room to stand up.

For the launch, the Lunar Module was stored in a cone-shaped adapter between the Service Module and the launch vehicle. Once the spacecraft was on its way to the moon, the Command and Service Modules (CSM) pulled away from the adapter, turned around, then moved back in to dock with the lunar lander. When the two were linked, the astronauts could crawl between craft via a docking tunnel in the top of the Command Module. After the CSM/lunar lander combination reached the moon, Armstrong and Aldrin entered the Lunar Module and undocked from *Columbia*. Collins remained in lunar orbit aboard *Columbia*, while his crewmates landed on the surface.

When their surface activities were over, Armstrong and Aldrin took off and rejoined Collins. They fired the CSM's large engine and headed back to Earth. Several days later, on July 24, they discarded the Service Module and entered Earth's atmosphere. *Columbia*'s exterior is covered with an epoxy-resin ablative heatshield. As *Columbia* entered the atmosphere at a speed of 40,000 kilometers per hour (25,000 miles per hour), its exterior reached a temperature of 2,760° C (5,000° F). This heatshield protected the craft from burning and vaporizing. *Columbia* finished its flight with a parachute landing in the Pacific Ocean, where the USS *Hornet* retrieved it and its crew.

Gregory P. Kennedy



Apollo 11 *Command Module* Columbia *exhibited in Gallery 100:* Milestones of Flight. *(Photo: Smithsonian Institution)*

Lunar Module

Height: 6.98 m (22.9 ft)
Width: 9.4 m (31 ft) (across legs)
Weight: 15,061 kg (33,205 lb)
Crew: two
Gallery: 112: *Lunar Exploration Vehicles*

"**H**ouston, Tranquility Base here, the Eagle has landed." Those words, radioed across a quarter million miles, were the signal to mission controllers on Earth that Neil A. Armstrong and Edwin "Buzz" Aldrin had achieved the first manned landing on the moon. The vehicle used was the Lunar Module *Eagle*. Besides being their home on the lunar surface, the astronauts used the Lunar Module to take-off and return to lunar orbit and the waiting Command and Service Modules with Michael Collins aboard.

The Lunar Module consisted of two sections: the descent stage and the ascent stage; both sections operated as a single unit during descent and lunar surface operations. When the astronauts lifted-off from the moon, they severed connections between the two sections, and the descent stage became the launch platform for the manned ascent stage.

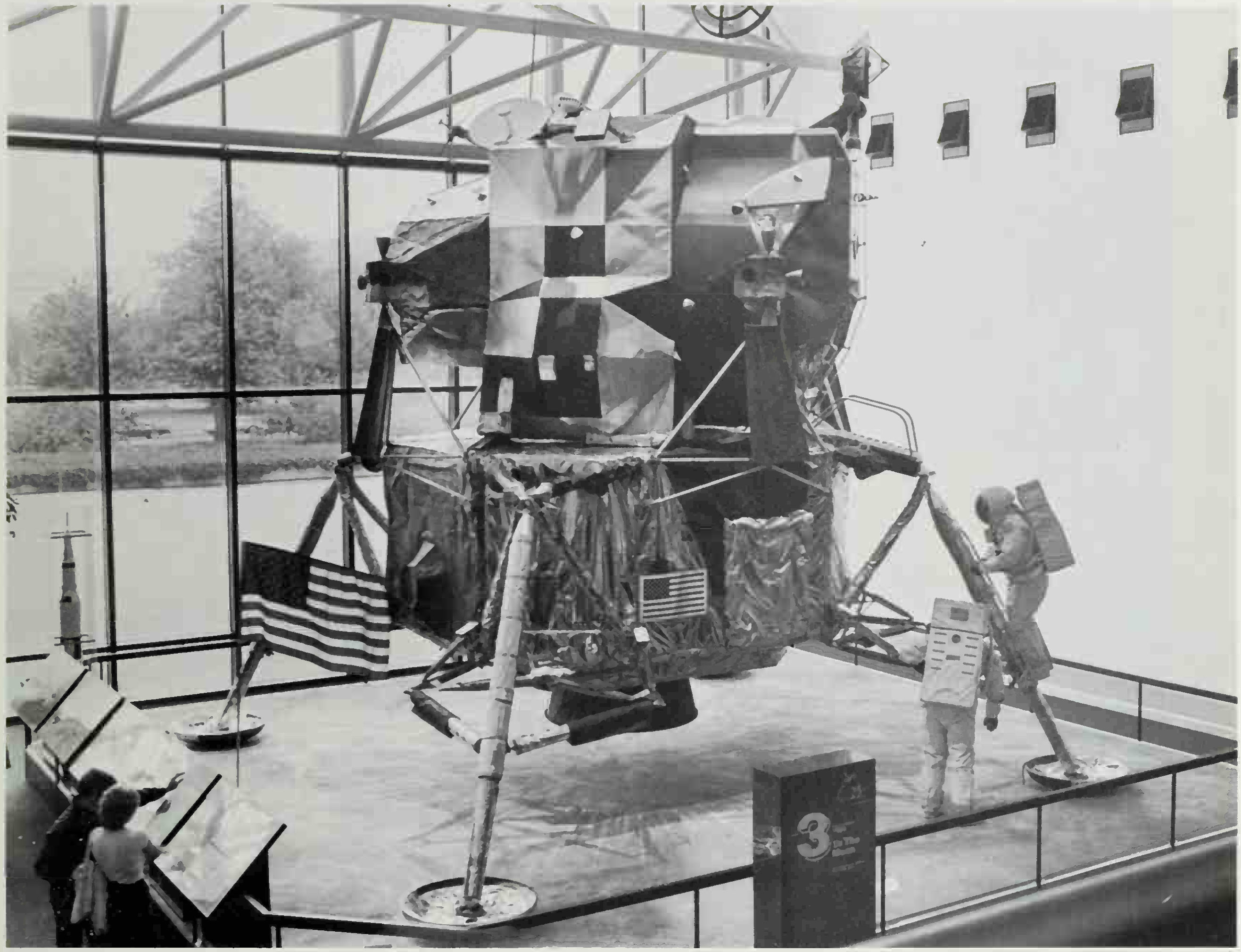
The descent stage weighed 10,000 kilograms (22,100 pounds), about two-thirds of the total Lunar Module weight at launch. It contained the descent engine and four landing legs. The astronauts could throttle the descent engine, so they could hover over the moon just before landing while selecting their final landing point. A thermal and micrometeroroid shield covered the stage. This shield was made from layers of aluminized thin-film plastics (mylar and kapton). These blankets gave the craft a fragile, almost flimsy appearance. Black Inconel sheet metal also covered parts of the stage.

The ascent stage contained the crew compartment and the ascent engine. Because objects on the moon weigh only one-sixth of what they do on Earth, there were no couches or chairs in the cabin. Rather, the astronauts stood at their stations while flying the spacecraft. Elastic bungees and velcro strips on the floor kept the astronauts in position. While standing at the controls, each astronaut had a triangular-shaped window in front of him.

The Lunar Module was the first true spacecraft, performing its mission only in the vacuum of space. Because of this, it was designed to be functional rather than streamlined. Altogether, ten lunar modules flew. The first was an unmanned test; the rest carried astronauts. During the *Apollo 13* flight, there was an explosion in the Service Module, so the moon landing was aborted and the astronauts used the Lunar Module as a "lifeboat" to return to Earth.

The Lunar Module on exhibit was built for an unmanned test but was not flown because the first mission was so successful. Instead, it was used for ground testing before being transferred to the National Air and Space Museum in 1971.

Gregory P. Kennedy



Lunar Module 2 *exhibited in Gallery 112:* Lunar Exploration Vehicles. *(Photo: Smithsonian Institution)*

Apollo Space Suit

Weight: 86 kg (190 lb)
Gallery: 113: *Rocketry and Space Flight*
210: *Apollo to the Moon*

The Apollo space suit was designed and created primarily for moon-walking. With its back pack, it enables the lunar astronaut to dispense with the tether umbilical used on Gemini "space walks" and to roam freely over the lunar surface. The development of the Apollo space suit system was one of the most complex elements in the history of this ambitious manned space flight effort.

The Apollo suit was a total pressure garment assembly, including the helmet, boots, and gloves. The basic suit had three layers consisting of an inner cloth comfort lining, a rubber-coated nylon bladder, and an outer nylon restraint cover to maintain suit shape. Flexible joints were located at the shoulders, elbows, wrists, thighs, knees and ankles. The suit contained a system of cables and the equivalent of a block-and-tackle arrangement that enabled the astronauts to move arms and legs easily. Ducts on the inner surface of the suit directed oxygen to the helmet for breathing and defogging and to permit flow over the body for cooling. Connectors in the suit included those for oxygen to and from the spacecraft environmental control system, as well as one to transfer urine to the waste management system. An electrical harness connected communications and biomedical equipment to their proper outlets. The right wrist contained a pressure gauge. Built into the left wrist was a pressure relief valve to regulate suit pressure to 3.5 pounds per square inch (psi).

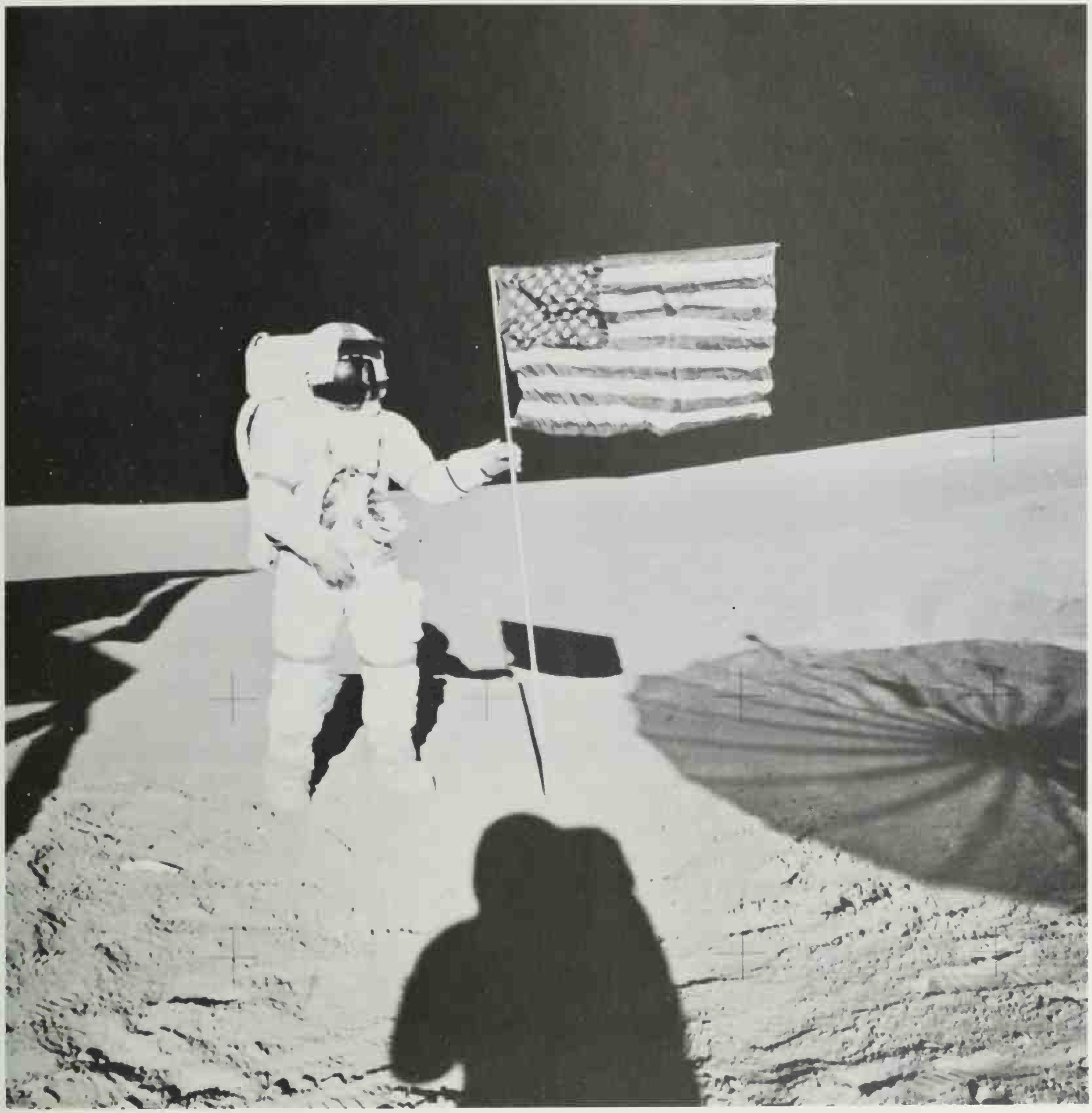
The basic suit, described above, was never used in the spacecraft without an additional three-layer outside cover, which was laced onto the assembly of the suits of astronauts who were not engaged in extravehicular activities (EVA). For astronauts going on EVA sorties, a seventeen-layer protecting cover was laced onto the basic suit. The protective cover consisted of two layers of neoprene-coated nylon, seven layers of aluminized high-temperature plastic film separated by six layers of Beta cloth and two outside layers of Teflon-coated Beta cloth. A constant-wear garment similar to a suit of "Long Johns" was worn next to the skin.

Beta cloth is a fiberglass fabric, which has a melting point of 650° C (1,200° F) or more. It will not burn, but is brittle and will cause severe itching when it touches the skin. To prevent this, the space suit manufacturers covered each Beta thread with Teflon before weaving the cloth. The Apollo suit was manufactured by ILC Industries, Dover, Delaware.

The EVA suit, together with a liquid cooling garment, portable life support system (PLSS), oxygen purge system, extravehicular visor assembly, and other components made up the extravehicular mobility unit (EMU). This EMU provided an EVA crewman with life support while outside the Lunar Module. The liquid-cooling garment was of knitted nylon-spandex, with a network of plastic tubing through which cooling water from the PLSS was circulated. It was worn next to the skin during EVA, replacing the constant-wear garment. The portable life support system consisted of a backpack that supplied oxygen at 3.0 psi and cooling water to the liquid-cooling garment. A lithium hydroxide cannister cleansed returning oxygen of solid and gas contaminants. The PLSS included communications and telemetry equipment, displays and controls, and a main power supply. The PLSS was covered by a thermal insulation jacket. The oxygen purge system, mounted atop the PLSS provided a 30-minute supply of gaseous oxygen in two 2-pound bottles pressurized to 5,880 psi. The system served as a mount for the VHF antenna for the PLSS. Total weight for the EMU was 86 kilograms (190 pounds).

Astronauts of Skylab and the Apollo-Soyuz Test Project wore space suits that were similar to the Apollo suits, but with minor modifications. Since the Apollo garment, space suit design has evolved to today's operational Space Shuttle extravehicular mobility units. Their development can be traced from that masterpiece of ingenuity—the Apollo EVA space suit.

Louis R. Purnell



Apollo 14 *Astronaut Alan Shepard on the moon. (Photo: NASA 71-H-369)*

Lunar Roving Vehicle

Length:	310 cm (122 in)
Wheel base:	229 cm (90 in)
Width:	183 cm (72 in)
Weight:	210 kg (462 lb) (on Earth)
Crew:	two
Gallery:	210: *Apollo to the Moon*

During the last three lunar landing missions, Apollo astronauts drove the Lunar Roving Vehicle across the moon's surface. The Lunar Roving Vehicle, or "Rover," was an electric-powered car which let the astronauts explore a larger area than they could on foot. In July 1971, *Apollo 15* astronauts David Scott and Alfred Worden used the first Rover on the moon.

The Rover was about the size of a golf cart. It had four one-fourth horsepower electric motors, one in each wheel. Two 36-volt batteries powered the vehicle. One was sufficient; the second was a back-up. Both sets of wheels, front and rear, steered. This gave the Rover a turning radius of only 3 meters (10 feet)—equal to its own length.

Rover's tires were made from an open mesh of zinc-coated piano wire. Titanium chevrons attached to the outside gave the tires additional traction. The mesh construction was very light and provided the needed springing characteristics. A smaller inner frame of metal bands absorbed the shock of going over large rocks and small ridges. In addition to the shock-absorbing abilities of the wheels, the vehicle had torsion-bar suspension.

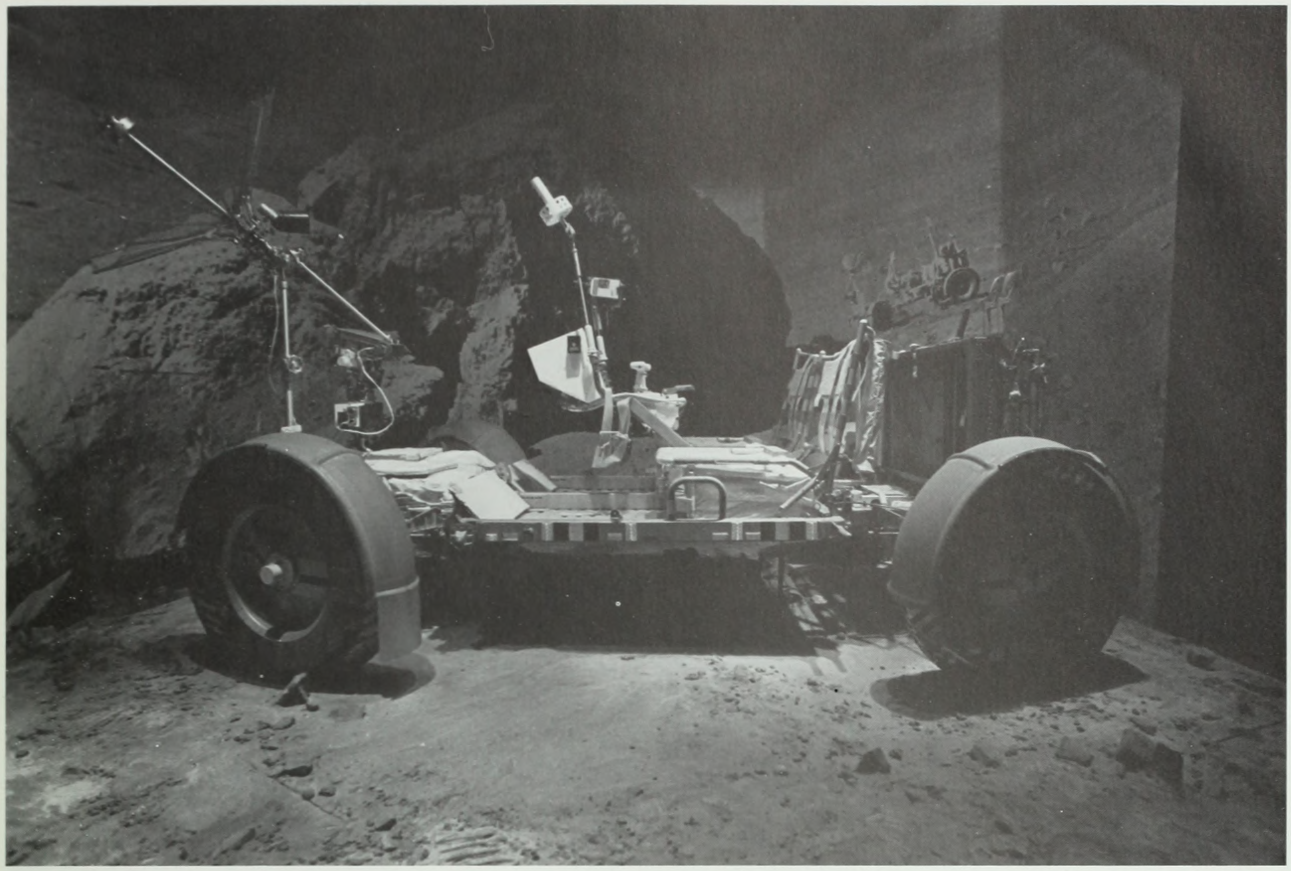
A single hand controller on the console between the astronauts served as a combination steering wheel, accelerator, and brake pedal. Moving the handle forward engaged the forward drive, backward movement stopped the vehicle. Reverse was engaged by pushing down on a switch on the handle and pulling it back. To steer, the astronaut tilted the handle in the direction he wanted to go. The console also contained the navigation system and vehicle controls. Rover had a gyroscopic navigation system, which gave the astronauts a continuous read out of the direction and distance back to the Lunar Module.

Although the Rover weighed on Earth 210 kilograms (462 pounds), it could carry over 450 kilograms (1,000 pounds). It could step over obstacles a foot high, traverse crevasses 71 centimeters (28 inches) wide, and climb slopes of 20 degrees. The Lunar Rover could travel up to 64 kilometers (40 miles) and had a top speed of 13 kilometers per hour (8 miles per hour).

The Lunar Rover travelled to the moon in the descent stage of the Lunar Module. The front- and rear-wheel assemblies folded in and over the center chassis to make a compact package. On the moon, the astronauts lowered one end and unfolded the wheels, then repeated the procedure for the other. Once the wheels were deployed and the craft was on the surface, the astronauts unfolded the seats, deployed the antennas, and loaded their equipment.

Three Lunar Roving vehicles were flown, on *Apollo 15, 16,* and *17*. The specimen on exhibit in the Museum is the qualification test unit. It was tested on Earth before any one of the three flight units went to the moon.

Gregory P. Kennedy



Lunar Rover in Gallery 210: Apollo to the Moon. *(Photo: Smithsonian Institution)*

Uhuru Satellite

Height: 61 cm (24 in) (body)
Diameter: 61 cm (24 in) (body)
Weight: 143 kg (315 lb)
Gallery: 111: *Stars*

Explorer 42, launched on December 12, 1970, was the first satellite totally devoted to the study of x-rays from space. It was also the first American satellite to be launched by a foreign crew (Italian), and as the first in the Small Astronomy Satellite series, was launched on a Scout Rocket from San Marcos Island off the coast of Kenya. In honor of its international flavor and the fact that it was launched on Kenya's independence day, it was given the name "*Uhuru*" meaning "freedom" in Swahili.

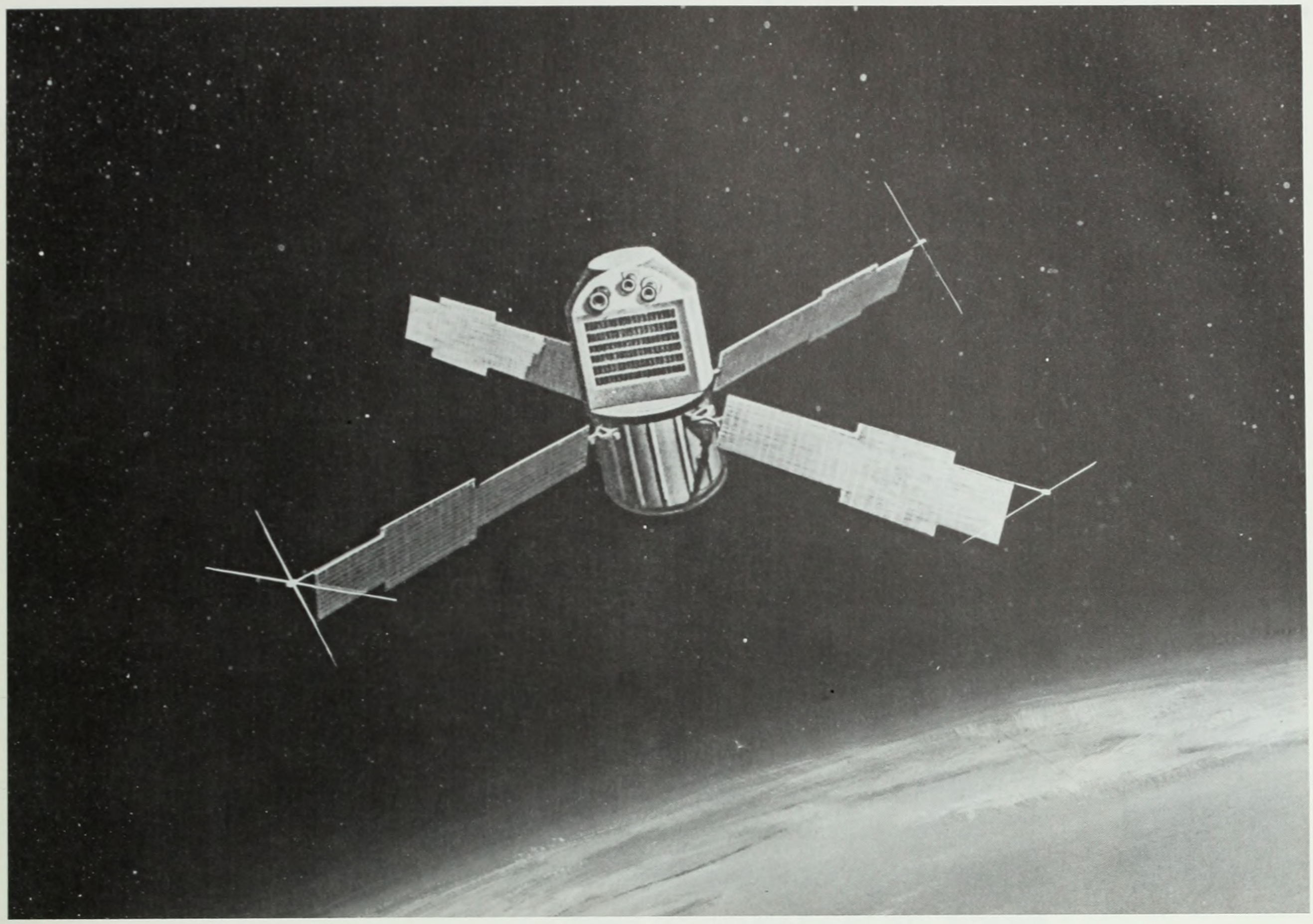
Explorer 42 was designed by American Science and Engineering, Inc., of Cambridge, Massachusetts, and constructed by NASA and the Applied Physics Laboratory of Johns Hopkins University. It scanned the entire sky for x-ray sources from 1970 to 1974. *Uhuru* detected the intensity of radiation, the frequency spectrum, time variations, and positions of over 100 x-ray sources. Its primary function was to generate a map of these x-ray sources both within the galaxy and in extragalactic space. That map would form the basis for more detailed studies by larger satellites (the high energy astronomical satellites launched in the late 1970s).

Due to *Uhuru*'s long observing time (hours, days, and months, compared to the few minutes available on sounding rocket flights), it was able to detect very faint x-ray sources some 30 to 50 times fainter than those detected by sounding rocket flights carrying x-ray detectors. By February 1971, *Uhuru* had mapped 116 new x-ray objects, and by March it had yielded enough data for about two dozen published papers. Later in 1971, *Uhuru* provided evidence that binary pulsars might exist, and a continued analysis of *Uhuru* data from Cygnus X-1 (the first x-ray source detected in the constellation of Cygnus, the Swan) suggested that it might be a black hole.

Eventually, *Uhuru* mapped 161 x-ray objects, some with luminosities in the x-ray region some 1000 times the luminosity of the sun. Thirty-four of the sources have been identified with known objects, including the galactic center, supernovae remnants, binary stars, galaxies, clusters of galaxies, and quasars. Identifying the remaining sources has become a major interest of modern astronomers. *Uhuru*'s success has made x-ray studies a central activity in modern astronomy.

The *Uhuru* in the NASM collection was a flight back-up rebuilt at the Applied Physics Laboratory.

David DeVorkin



Uhuru, *the first Small Astronomy Satellite.* (Photo: NASA 70-H-1488)

ITOS 1 Weather Satellite

Height: 122 cm (48 in)
Width: 4.3 m (14 ft) (across solar panels)
Weight: 309 kg (682 lb)
Gallery: 110: *Satellites*

The ITOS (Improved TIROS Operational Satellite) was the second series of operational TIROS meteorological spacecraft. Begun in a program under the direction of Commerce Department's Environmental Sciences Services Administration (ESSA), four spacecraft were planned. Upon its formation, NOAA, the National Oceanic and Atmospheric Administration, took over the project. Eventually, six craft of this type were flown *(ITOS 1* and *NOAA 1* through *NOAA 5)*.

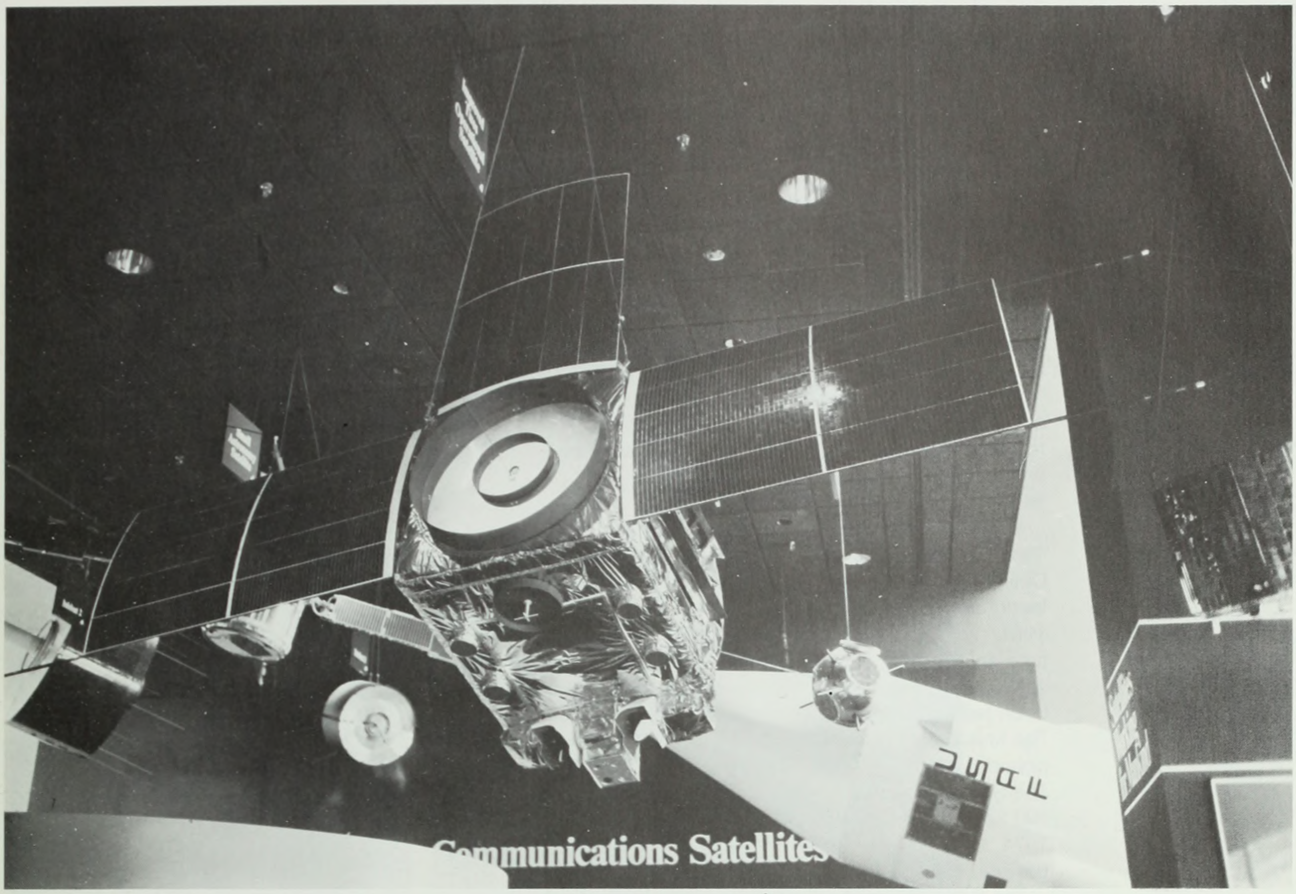
ITOS 1 had the ability to fulfill the functions of both automatic picture transmission (APT) and advanced vidicon camera system (AVCS), which together formerly required two spacecraft. A new high resolution infrared radiometer (HRIR) permitted high quality nighttime coverage.

The spacecraft body was 102 × 102 × 122 centimeters (40 × 40 × 48 inches) with three solar cell arrays which could extend for a total of 6.6 meters (21.5 feet). A polar orbiter, ITOS 1 also carried a solar proton monitor and a flat-plate radiometer to study the space environment. Unlike the spin-stabilized TIROS and TOS (ESSA) spacecraft, ITOS 1 was 3-axis stabilized. Having the 3-axis stabilization permits the instruments to be clustered so that they can all be used simultaneously.

The Delta N-6 launch vehicle was used for the ITOS 1 which was launched on January 23, 1970. Over its 510-day useful life, ITOS 1 generated over 107,000 APT and AVCS TV pictures and over 11,800 hours of radiometer data.

The spacecraft was built by RCA Astro-Electronics Division, Princeton, New Jersey. Hughes Aircraft Company built the radiometers. The size of ITOS 1 substantially increased the capabilities of meteorological satellites. The spacecraft used both active and passive thermal control to cope with the space environment. A flywheel mechanism was integrated into its stabilization system and the panels were covered with 10,260 solar cells. Two batteries were available for night operations. The spacecraft was controlled from the National Environmental Satellite Center (NESC) in Suitland, Maryland, in conjunction with the NASA/Goddard Space Flight Center in Greenbelt, Maryland.

Kerry M. Joels



The Improved TIROS Operational Satellite (ITOS) exhibited in Gallery 110: Satellites. *(Photo: Smithsonian Institution)*

Scout D Rocket

Length: 22 m (73 ft)
Diameter: 1.1 m (3.75 ft)
Weight: 21,400 kg (47,200 lb)
Lift-off thrust: 477,000 newtons (107,200 lb)
Gallery: 114: *Space Hall*

The NASA's smallest satellite launch vehicle is the Scout. The Scout Project began in July 1957 as a Langley Research Center endeavor to develop an "off the shelf" solid-propellant launcher for atmospheric entry tests. What evolved was a reliable, relatively inexpensive launch vehicle for entry tests, high-altitude probes, and small satellites.

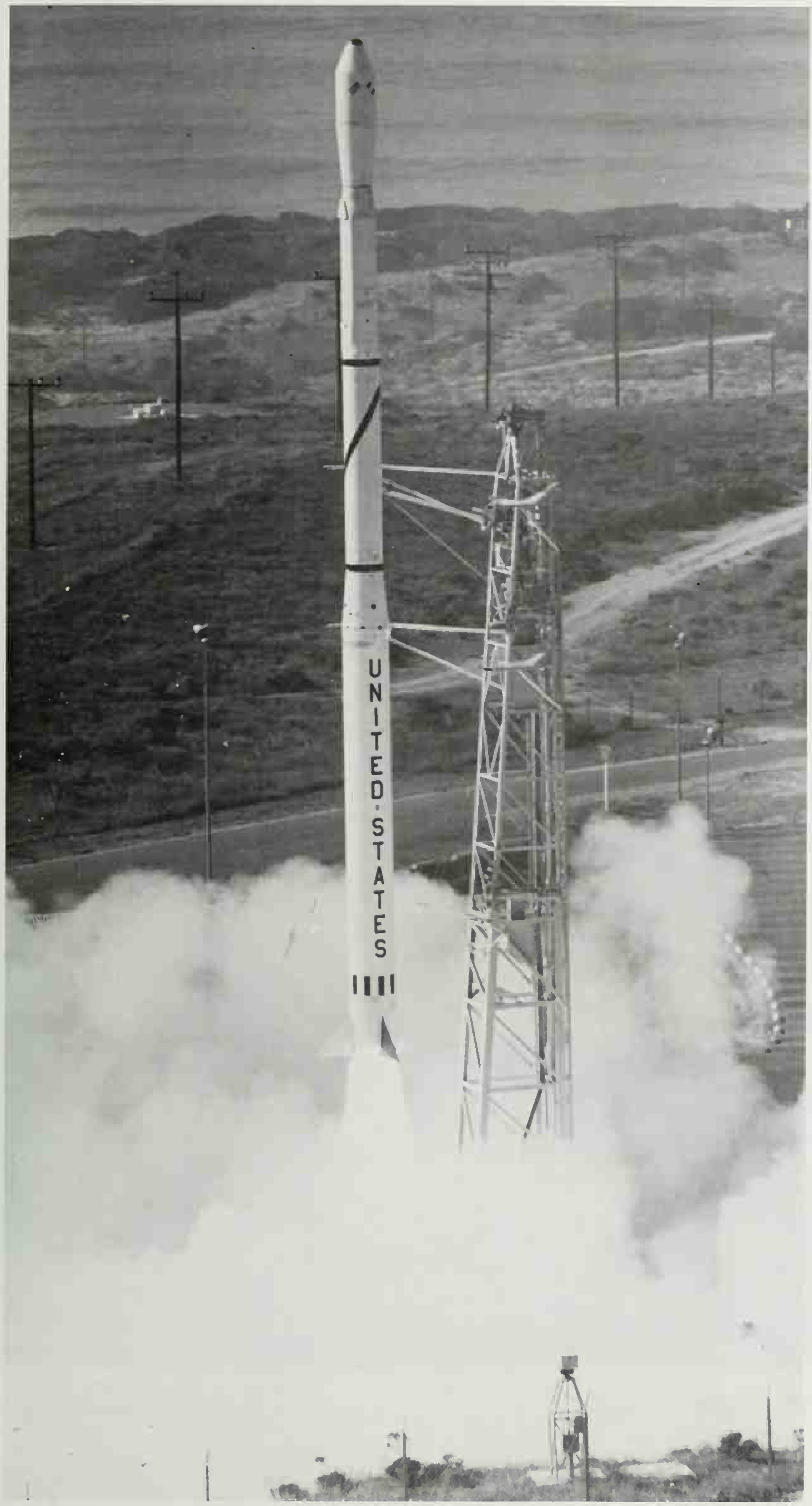
Scout, a four-stage vehicle, first flew in mid-1960. Since then, NASA, the Department of Defense, and several foreign nations have launched more than 100 Scouts. On February 16, 1961, a Scout placed *Explorer 9* into orbit, the first time an all solid-propellant rocket launched a satellite. Over the years, the vehicle's design has been refined and its payload capacity improved. The first Scouts could place 59 kilograms (130 pounds) into a 480-kilometer (300-mile) high orbit. The Scout D, such as the one on exhibit, can place 193 kilograms (425 pounds) into the same orbit. In 1974, a five-stage version with an even greater payload capacity, the Scout E, entered service.

The Scout D's Algol 3 first stage is 9.1 meters (29.8 feet) long, 1.1 meters (3.75 feet) in diameter, and generates 477,000 newtons (107,200 pounds) of thrust. A Castor 2, with 270,000 newtons (60,700 pounds) thrust and a 93,000-newton (20,900-pound) thrust Antares motor are the second and third stages, respectively. Fins and jet vanes guide the first stage, small hydrogen peroxide thrusters guide the second and third stages. The spin-stabilized fourth-stage motor is enclosed by the payload shroud. Overall, the Scout D stands 22 meters (73 feet tall).

Scout vehicles have launched many satellites, including the Small Astronomy Satellite, *Transit 5*, and *Ariel 2*, all of which are represented in the National Air and Space Museum. An INJUN/Air Density Explorer satellite (launched in 1968) sits atop the rocket on display. Other nations have used the Scout for their space programs. *Ariel 2* was a British satellite. The Italian government used the Scout for their San Marco satellites and built their own launch complex off the east coast of Africa. Since its introduction, the Scout has been an extremely reliable vehicle, with a success rate of better than 90 percent.

Gregory P. Kennedy

Scout D launch. (Photo: NASA 65-H-2023)


UNITED·STATES

Minuteman 3 Missile

Length: 18.2 m (59.8 ft)
Diameter: 1.8 m (6 ft)
Weight: 34,000 kg (76,000 lb)
Gallery: 114: *Space Hall*

The Minuteman 3 is a three-stage, solid-propellant, intercontinental ballistic missile. The first Minuteman test flight occurred on Feburary 1, 1961. Twenty-two months later, the Minuteman 1 entered operational service. Since then, the Minuteman has become the backbone of America's land-based deterrent force.

The latest version, which is Minuteman 3, first flew in 1968 and became operational in January 1971. Minuteman 3 uses the same first and second stages as the Minuteman 2, but it has a larger third stage and payload shroud. This large top stage is the most noticeable difference between the Minuteman 3 and its predecessors.

The first stage motor casing is made from high-strength steel. The propellant contains ammonium perchlorate, aluminum powder, polybutadiene acrylic acid, and epoxy resin. During casting, the propellant has the consistency of peanut butter and is poured into the casing. After the propellant cures, the motor base with the four exhaust nozzles is attached. These nozzles gimbal, or swivel, to steer the missile during first-stage firing.

The second stage motor casing is made from titanium alloy. A slightly different propellant mixture is used on the second stage. This stage burns carboxyterminated polybutadiene (CTPB) polymer, aluminum powder, and ammonium perchlorate.

The third stage casing is made from resin-impregnated glass fibers instead of metal. It also has a single fixed nozzle instead of the four moveable ones found on the earlier models. Liquid injected into the thrust stream deflects the exhaust and steers the missile. A similar system guides the second stage.

The payload shroud is made from aluminum honeycomb and is covered with ablative cork. Multiple nuclear warheads are contained inside the shroud. Each warhead can be given a different target.

Minuteman is launched from a 24-meter (80-foot) deep underground silo. During firing, the exhaust is deflected up along the sides of the missile, which must be protected from the heat. Several types of external insulation are used. A spray-on ablative coating gives the first stage its overall light green color. The dark green sections are covered with cork. Since the missiles are stored underground, a fungicide is applied to the cork, giving these parts their dark green color.

Gregory P. Kennedy

Minuteman 3 launch.
(Photo: Smithsonian Institution)

M2-F3 Lifting Body

Length: 6.8 m (22.2 ft)
Weight: 4,500 kg (10,000 lb)
Crew: one
Gallery: 114: *Space Hall*

The *M2-F3* belongs to a class of wingless aircraft called "lifting bodies" which derive aerodynamic lift for flight from their fuselage shape. From 1966 to 1972, seven different pilots flew the M2 a total of 43 times. During these flights, the craft achieved an altitude of 21,800 meters (71,500 feet) and a speed of 1,700 kilometers per hour (1,064 miles per hour).

The lifting body is basically a half-cone. Air flows over the body in much the same way it does over a wing to generate lift. Such craft were seen as a solution to the problems of overheating and vehicle control during return from space. Theoretical studies and wind tunnel tests of lifting body designs began in the 1950s. Eventually, these studies led to several piloted test vehicles. NASA tested two lifting bodies in the 1960s and early 1970s, the M2 and HL-10. While both were based on the half-cone shape, the two were radically different. The M2 was flat on top and round on the bottom, the HL-10 was the opposite arrangement with flared stabilizers, giving it more of a delta-wing appearance.

Before either were built, an unpowered plywood and steel tube test vehicle, the *M2-F1*, was evaluated. Based on the success of the *M2-F1*, in 1964, NASA managers decided to go ahead with the *M2-F2* and HL-10. Northrop Aircraft Company built both.

The *M2-F2* made its first flight on July 12, 1966. A B-52 bomber carried the *M2-F2* aloft and released it at an altitude of 13,700 meters (45,000 feet). NASA test pilot Milton O.Thompson landed the 6.7-meter (22-foot) long craft 217 seconds later. On the sixteenth flight, the M2 crashed, severly injuring pilot Bruce Peterson. During the subsequent inquiry, the accident review board found that the *M2-F2*'s twin vertical stabilizers did not provide adequate control. When the aircraft was rebuilt, a third stabilizer was added and the vehicle became the *M2-F3*.

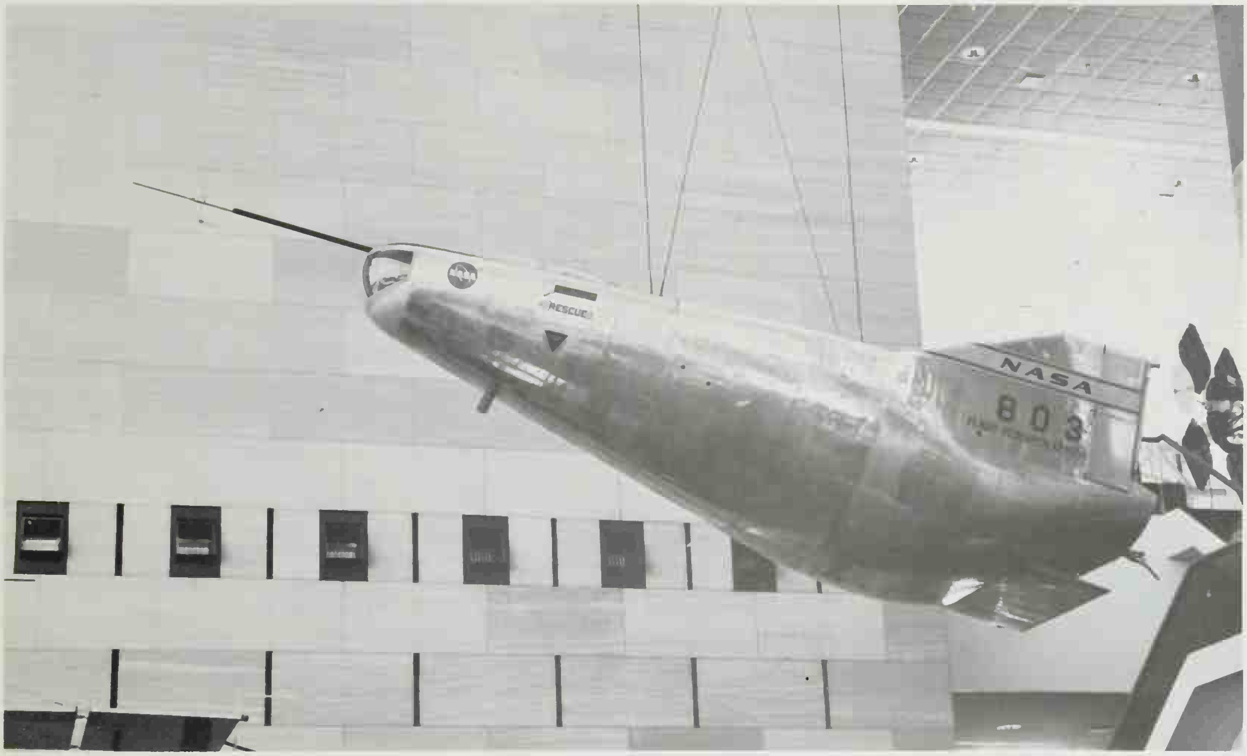
On November 25, 1979, the *M2-F3* made its first powered flight, propelled by an XLR-11 rocket engine. XLR-11 engines have powered many research aircraft, including the X-1, D-558-2, and the X-15. The Thiokol Chemical Corporation engine burned ethyl alcohol and liquid oxygen to produce a thrust of 36,000 newtons (8,000 pounds) for 100 seconds. Even with the propulsive system, the lifting body was still air launched from a B-52.

The *M2-F3* flew at NASA's Flight Research Center (now the Dryden Flight Research Center) at Edwards, California. On a typical flight, the *M2-F3* was released at an altitude of 14,000 meters (45,000 feet) and an air speed of 720 kilometers per hour (450 miles per hour). Following launch, the pilot ignited the XLR-11 and began his climb. About 100 seconds later, all the propellants were consumed, and the engine shut down. The pilot maneuvered the craft to an unpowered approach and landed on the dry lake bed. The *M2-F3*'s last and highest flight occurred on December 20, 1972. The craft reached an altitude of 21,800 meters (71,500 feet) on its last flight.

Gregory P. Kennedy

Above
The M2-F3 *lifting body hangs above the Space Shuttle exhibit in Gallery* 114: Space Hall. *(Photo: Smithsonian Institution)*

Below
The M2-F2, *predecessor to the* M2-F3. *(Photo: NASA 65-H-998)*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NORTHROP

Princeton Experiment Package

Length: 287 cm (113 in)
Diameter: 102 cm (40 in)
Gallery: 111: *Stars*

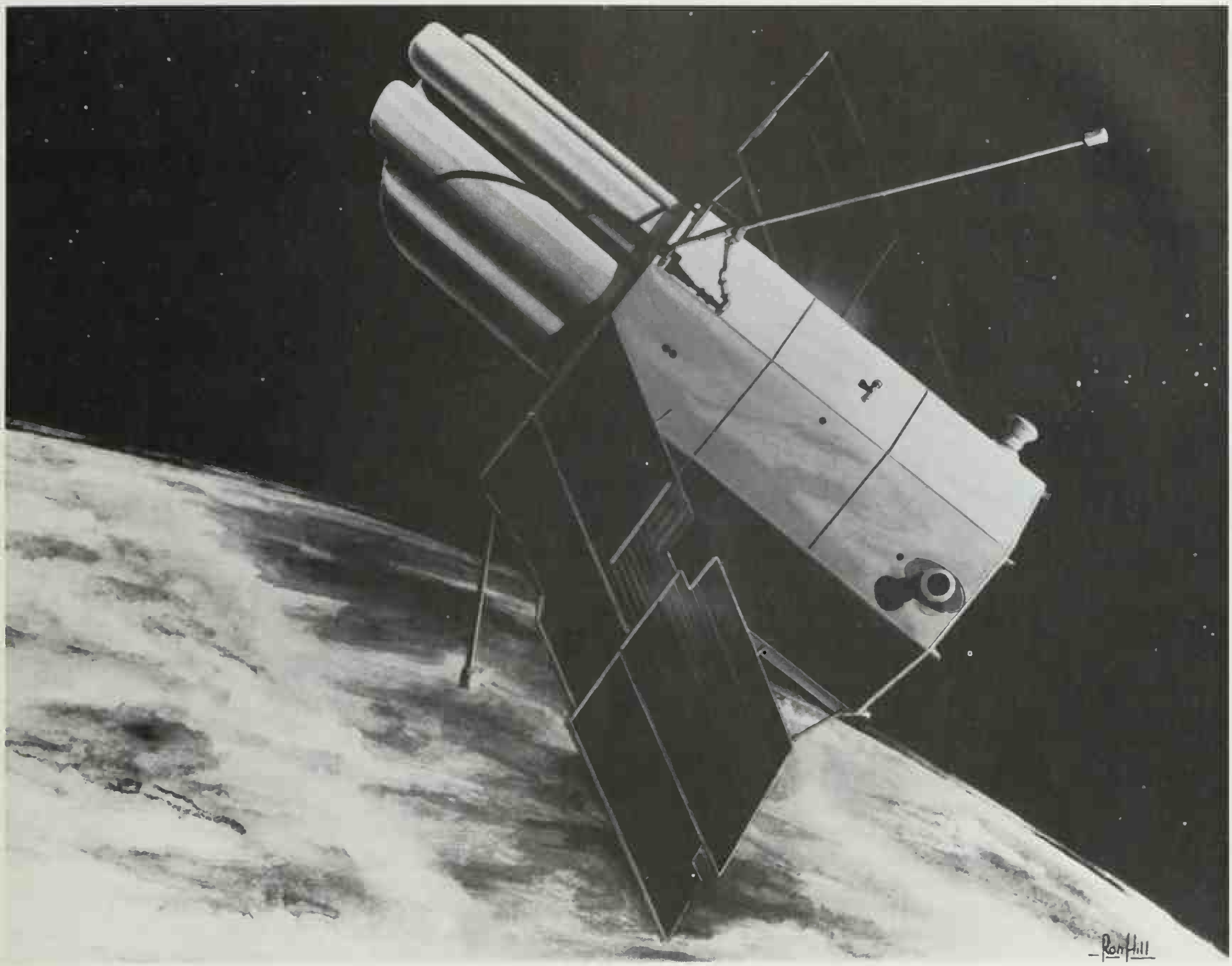
The Princeton experiment package, the largest optical telescope orbited thus far, was launched on August 21, 1972, aboard the Orbiting Astronomical Observatory 3 (OAO) (*Copernicus*). It was designed to make far-ultraviolet, high-resolution studies of hot stars and of the intersteller medium (using bright stars as background standards). The package was designed and constructed by the Princeton astronomy department in conjunction with Perkin-Elmer, Sylvania, and NASA's Goddard Space Flight Center. The prototype on exhibit contains the optics and framework produced by Perkin-Elmer: a 32-inch f/20 Cassegrainian optical system in a titanium-aluminum cylinder 102 centimeters (40 inches) in diameter, and 287 centimeters (113 inches) long, with guidance optics and a scanning spectrometer. The scanning was accomplished by special photomultipliers (open cathode design), which were moveable along the Rowland circle about the single grating—one within first order range and the others in the second order range.

Approximately 90 percent of the total instrument viewing time was given to the Princeton group for high-resolution studies of stellar spectra as faint as seventh magnitude and of the narrow UV absorption features produced by interstellar atoms and molecules as seen against the spectra of distant stars. The existence of these spectral features was suggested in the early 1950s by Lyman Spitzer, the project's principal investigator. In addition, during the nine-year operation of the telescope, over 150 scientists from many American and foreign institutions have used the Princeton package, which has helped to solve many technical problems of building space telescopes.

Principal results of the Princeton experiment include greatly improved knowledge of the abundance of deuterium and molecular hydrogen in interstellar space, especially the detection of an unexpectedly high deuterium abundance and underabundant metals in interstellar clouds. Also found, and in confirmation of theoretical predictions by D. Hollenbach, E. Salpeter, and others at Cornell, was that in some clouds only atomic hydrogen exists while in others, molecular hydrogen dominates. This was also indicated by sounding rocket measurements by G. Carruthers in 1970.

Other major studies have significantly increased knowledge of the far UV spectra of hot stars; have confirmed the dynamic characteristics of circumstellar shells and hot stellar winds; and have aided in our understanding of the dynamics of gases in the interstellar medium.

David DeVorkin



Artist's rendering of Copernicus in orbit. (Photo: NASA 72-H-759)

Skylab Space Station

Skylab Space Station
Length: 36 m (118 ft) (in space)
Weight: 90,600 kg (199,750 lb)
Gallery: 114: *Space Hall*

Orbital Workshop
Length: 14.6 m (48.1 ft)
Diameter: 6.6 m (21.6 ft)
Gallery: 114: *Space Hall*

Multiple Docking Adapter and Airlock Module
Length: 10.6 m (34.9 ft)
Diameter: 3 m (10 ft)
Gallery: 114: *Space Hall*

Between May 26. 1973 and February 8, 1974, the Skylab Orbital Workshop (OWS) was home for three crews of astronauts. Inhabiting the workshop in succession, the crews spent 28, 59, then 84 days, respectively, orbiting Earth.

Skylab evolved from the Apollo 10 and Apollo Applications Programs of the 1960s, which were studies for rudimentary orbiting laboratories fabricated from excess Apollo hardware. The laboratory underwent several major design changes before reaching its final form. Early on, there was the so-called "wet" workshop, where an expended Saturn 1B launch vehicle upper stage was converted into an orbiting habitat after reaching orbit. Several flights would have been necessary to launch and assemble all the pieces of the wet workshop "cluster." In the early 1970s, this design gave way to the "dry" workshop which, while still made from a Saturn upper stage, was prepared and outfitted on the ground and launched by a two-stage Saturn 5.

America's first space station comprised four segments—Multiple Docking Adapter, Airlock Module, Orbital Workshop, and Apollo Telescope Mount. The Multiple Docking Adapter had two docking ports for Apollo spacecraft, the Earth resources experiments package, and the controls for the Apollo Telescope mount. The Airlock Module was a small compartment between the Docking Adapter and the Orbital Workshop. It had hatches on each end and an outward opening hatch for extravehicular activities. For an extravehicular activity, the space-suited crew members entered the airlock, sealed the end hatches, emptied the air from the compartment, and opened the outer hatch. This way, the crew did not have to let all the air out of the entire spacecraft as with past vehicles. The OWS, the core of the Skylab space station, was the largest segment. It was made from a Saturn S 4-B upper stage, and was 6.6 meters (21.6 feet) in diameter and 14.6 meters (48.1 feet) long. The bulkhead which separated the S 4-B's liquid-oxygen and liquid-hydrogen tanks was retained, so the astronauts had only the upper two-thirds of the structure for habitation. The lower third, which had been the liquid-oxygen tank, became the astronauts' trash dump.

The habitable portion of the OWS was divided into an upper and a lower area. Crew accommodations were in the lower area, which contained the wardroom, waste management compartment, sleeping quarters, and the biomedical experiments work area. Since Skylab was designed as a place where a three-man crew would live and work for up to eight weeks at a time, the OWS was roomier and more comfortable than earlier spacecraft. Each crewmember had a private bedroom, with a bunk on the wall. (In weightlessness, up and down are meaningless terms, so the bunk's locations were not dictated by gravity). The waste management compartment housed the toilet and hand-washing basin. This compartment was completely enclosed and had a folding door for privacy. Skylab astronauts enjoyed another luxury not found on earlier spacecraft: a shower. Skylab's shower consisted of a tube-shaped fabric compartment with one end attached to the floor, and a lid attached to the ceiling. Meals were prepared and eaten in the wardroom.

The upper portion of the OWS was reserved for experiments, which needed a large open area or were designed to use one of the two scientific airlocks for external observation or exposure to the space environment. Food, water, and spare parts were stored in the upper compartment.

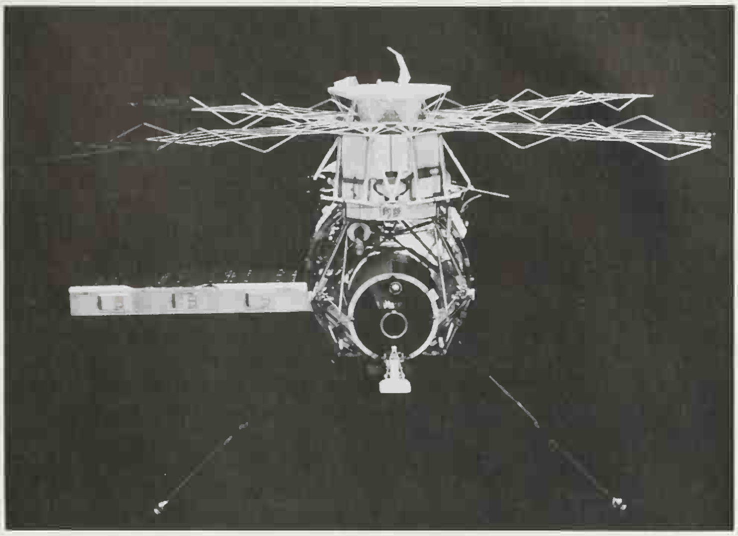
Solar cells on a large folding "wing," or array, generated electricity for Skylab. Originally, the OWS had two such arrays, but shortly after launch on May 14, 1973, a micrometeoroid thermal shield, which had been wrapped around the OWS, tore loose, taking one of the solar arrays with it. Debris from the shield jammed the remaining panel shut. Without the thermal shield to protect it from the sun's intense radiation as it orbited 440 kilometers (275 miles) overhead, temperatures inside the OWS reached 54° C (130° F). With the remaining solar panel folded, the laboratory didn't have enough electricity. The first crew extended a parasol-like sun shade over the OWS, bringing temperatures inside the workshop down to tolerable levels. A few days later, astronauts Charles Conrad and Joseph Kerwin cleared the debris around the solar panel and unfolded it during a 3½-hour extravehicular activity, or spacewalk. This allowed their Skylab mission to continue and cleared the way for the two remaining flights.

During the three manned Skylab missions, astronauts performed nearly 300 experiments in space, investigating such areas as zero-gravity materials processing, solar studies, effects of space flight on living things, and remote sensing of Earth from space.

The last Skylab crew departed the OWS on February 8, 1974, after staying aloft for nearly three months. Skylab continued to orbit Earth, virtually unnoticed, once every 90 minutes until late 1978, when it became evident that the vehicle's orbit was decaying faster than expected. There was some fear that pieces of the space station might survive their fiery passage through the atmosphere and cause damage on the ground. Fortunately, when Skylab entered the atmosphere on July 11, 1979, those pieces which reached Earth's surface fell harmlessly in the Indian Ocean and the Australian desert.

The Orbital Workshop, Multiple Docking Adapter, and Airlock Module exhibited in the Museum are the flight back-ups. In 1975, NASA transferred them to the Smithsonian Institution for exhibiting in the National Air and Space Museum. Two doorways were cut through the Orbital Workshop lower compartment and an enclosed walkway installed, so museum visitors can walk through and see how the Skylab astronauts lived and worked in space.

Gregory P. Kennedy



An astronaut's view in space of Skylab during approach. (Photo: NASA 74-H-96)

The wardroom, a combination galley, recreation room, and office, as seen by visitors to the National Air and Space Museum. (Photo: Smithsonian Institution)

Apollo Telescope Mount

Height: 4.4 m (14.7 ft)
Width: 6 m (20 ft)
Weight: 11,092 kg (24,656 lb)
Gallery: 111: *Stars*

The Apollo Telescope Mount (ATM) was the major scientific instrument aboard Skylab, which was put into Earth orbit on May 14, 1973, and which was operated over a period of eight months by three sets of astronauts. Eight major scientific instruments, as well as a number of smaller experiments, depended upon the ATM, and were operated by the astronauts from within Skylab.

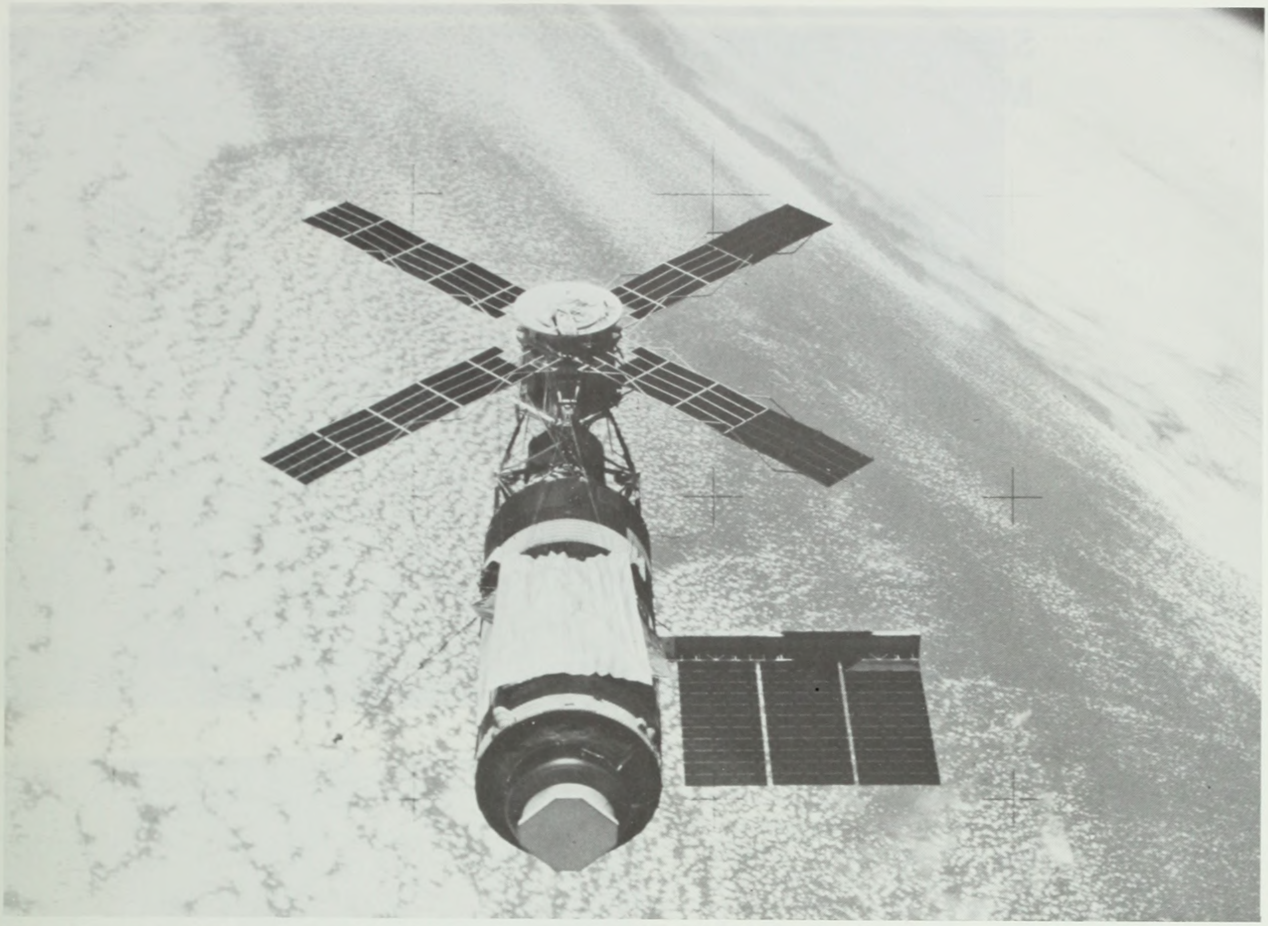
Included in the main ATM telescopes were devices for observing the sun in a broad range of the electromagnetic spectrum, from the visual through the high energy x-ray regions. Telescopes capable of forming images of the surface and atmosphere of the sun in x-rays increased greatly our understanding of the dynamic character of hot regions on the solar surface, specifically explosive flares, and also the behavior of the newly discovered "coronal holes"—regions where high-energy particles are escaping from the sun at high speeds and travelling out into interplanetary space. Other ATM instruments sensitive to the ultraviolet portions of the spectrum also examined these phenomena and were capable of identifying with extreme accuracy the chemical and physical elements responsible for them. Finally, a special instrument called a "coronagraph" examined the visual nature of the sun's extended atmosphere, the corona, and provided a three-dimensional view of the nature of coronal holes. Literally, every type of phenomenon known to exist on the surface and in the atmosphere of the sun was observed in the high-energy regions of the solar spectrum, the region inaccessible to observation from Earth's surface.

The ATM was the first manned observatory in space. In contrast to all previous solar observations from space, such as those accomplished on the Orbiting Solar Observatory program, the instruments involved were not compromised by weight or power restrictions. Also, they were not compromised by the need to telemeter the data to ground stations. The ATM instruments were, on an average, over 3 meters (10 feet) long, weighed some 900 kilograms (2,000 pounds) each, and were able to utilize over one kilowatt of power (total system experiment power was about 2,000 watts), when needed. Some of the instruments used photographic film, which was supplied and retrieved by the three astronaut teams and which was returned to Earth after each mission. The advantage of observing the sun by photographic plates is that they store an enormous amount of information in a relatively short period of time and avoid the difficulties associated with telemetry.

The complete ATM system consisted of an eight-sided optical bench in the shape of a square cross, upon which the major solar instruments were placed. This was the heart of ATM, and was called the "spar." The spar was nested inside a cylindrical cannister some 11 feet (3.4 m) long and 8 feet (2.4 m) in diameter, and the cannister in turn was cradled in a complex frame called the "rack." Connected to the rack were four solar-power panels, which extended out some 45 feet on each side of the rack. The solar-powered panels were folded into the sides of the rack, and the entire ATM sat on top of the Skylab Workshop when the system was launched. Only after orbital insertion was the ATM rotated to its working postion (radially with respect to the Skylab Workshop and Multiple Docking Adaptor) and the panels deployed.

The general ATM structure was designed and constructed at NASA's Marshall Space Flight Center in Huntsville, Alabama, and the instruments were provided by numerous scientific groups including those at Marshall, the U.S. Naval Research Laboratory, the Aerospace Corporation, American Science & Engineering, Harvard College Observatory, and the High Altitude Observatory.

David DeVorkin



The windmill-looking solar panels of the Apollo Telescope Mount *are particularly noticeable in this view of* Skylab. *(Photo: NASA 74-H-98)*

Skylab 4 Command Module

Height: 3.7 m (12 ft)
Diameter: 3.9 m (12.8 ft)
Crew: three
Gallery: 210: *Apollo to the Moon*

Skylab astronauts used Apollo spacecraft for transportation to and from the Skylab Orbital Workshop. The Command Module on exhibit was used by the last Skylab crew during their record-setting 84-day mission.

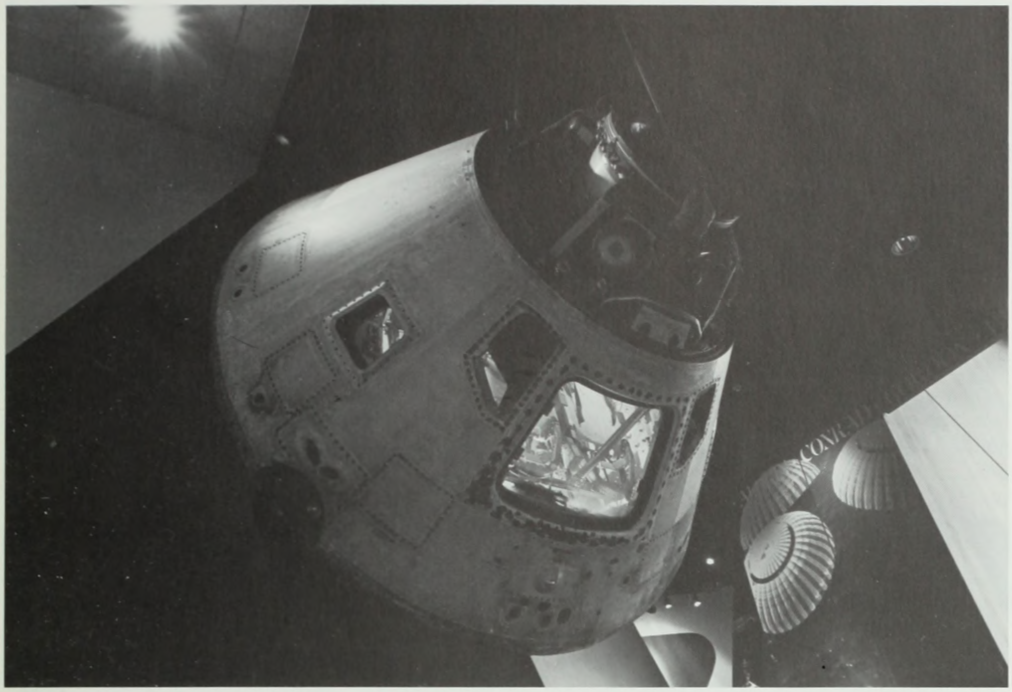
Skylab 4 lifted off on November 16, 1973, with astronauts Gerald P. Carr, William R. Pogue, and Edward G. Gibson on board. Several hours after launch, they docked their spacecraft with Skylab. The Apollo Command and Service Module remained docked with the station for 84 days.

During their flight, Carr, Gibson, and Pogue conducted many experiments, including medical tests to see how spaceflight affects the human body, observations of the sun, and materials processing tests. Early in the mission, one of the four maneuvering rocket clusters on the Service Module began leaking. Ground controllers feared this could leave the spacecraft stranded in space, and considered ending the mission early. However, they performed tests in spacecraft simulators on the ground and found that two clusters were enough to maneuver the craft for its return from space. The Skylab crew shut off the propellant flow to the leaking thruster assembly and continued the mission.

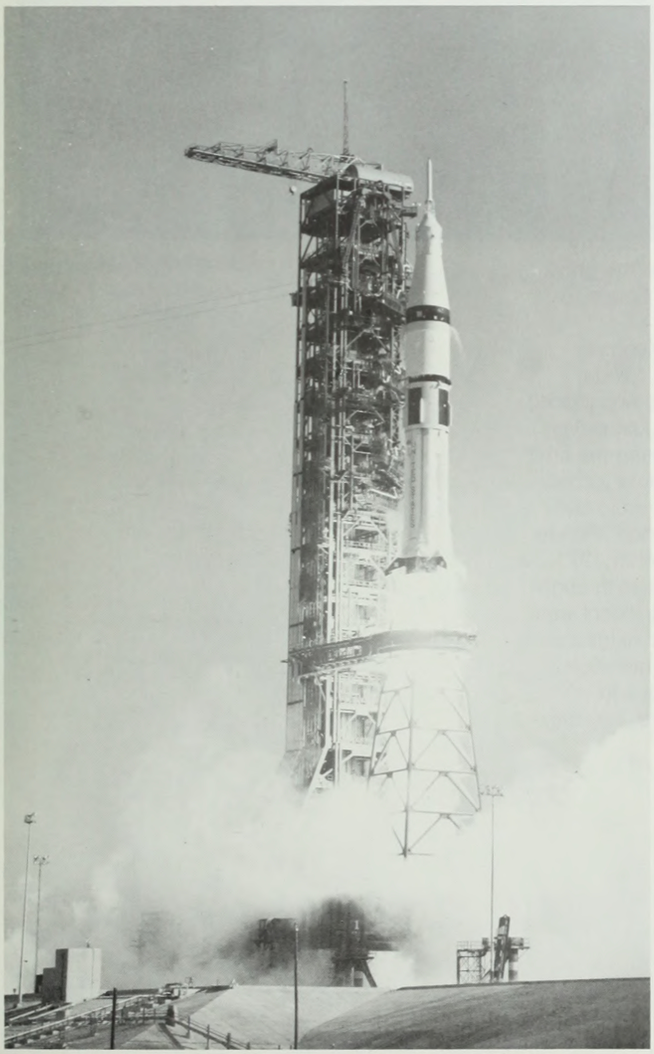
Midway through their flight, the crew studied the comet Kohoutek. Gibson sketched his observations on the backs of plastic checklists and brought these back to Earth. Some of his sketches are exhibited in Gallery 114: the *Space Hall,* and Gallery 207: *Exploring the Planets*.

On February 8, 1974, the astronauts climbed into the Command Module and undocked from Skylab. A short time later, they splashed down in the Pacific Ocean and were retrieved by the USS *New Orleans*. *Skylab 4* had circled Earth 1,214 times.

Gregory P. Kennedy



Skylab 4 *spacecraft on exhibit in Gallery 210:* Apollo to the Moon. *(Photo: Smithsonian Institution)*



The beginning of the 84-day Skylab 4 *flight on November 16, 1973. (Photo: NASA 73-H-1240)*

Pioneer 10 Planetary Probe

Diameter: 2.7 m (9 ft) (of antenna)
Length: 2.9 m (9.5 ft)
Weight: 258 kg (568 lb)
Gallery: 100: *Milestones of Flight*

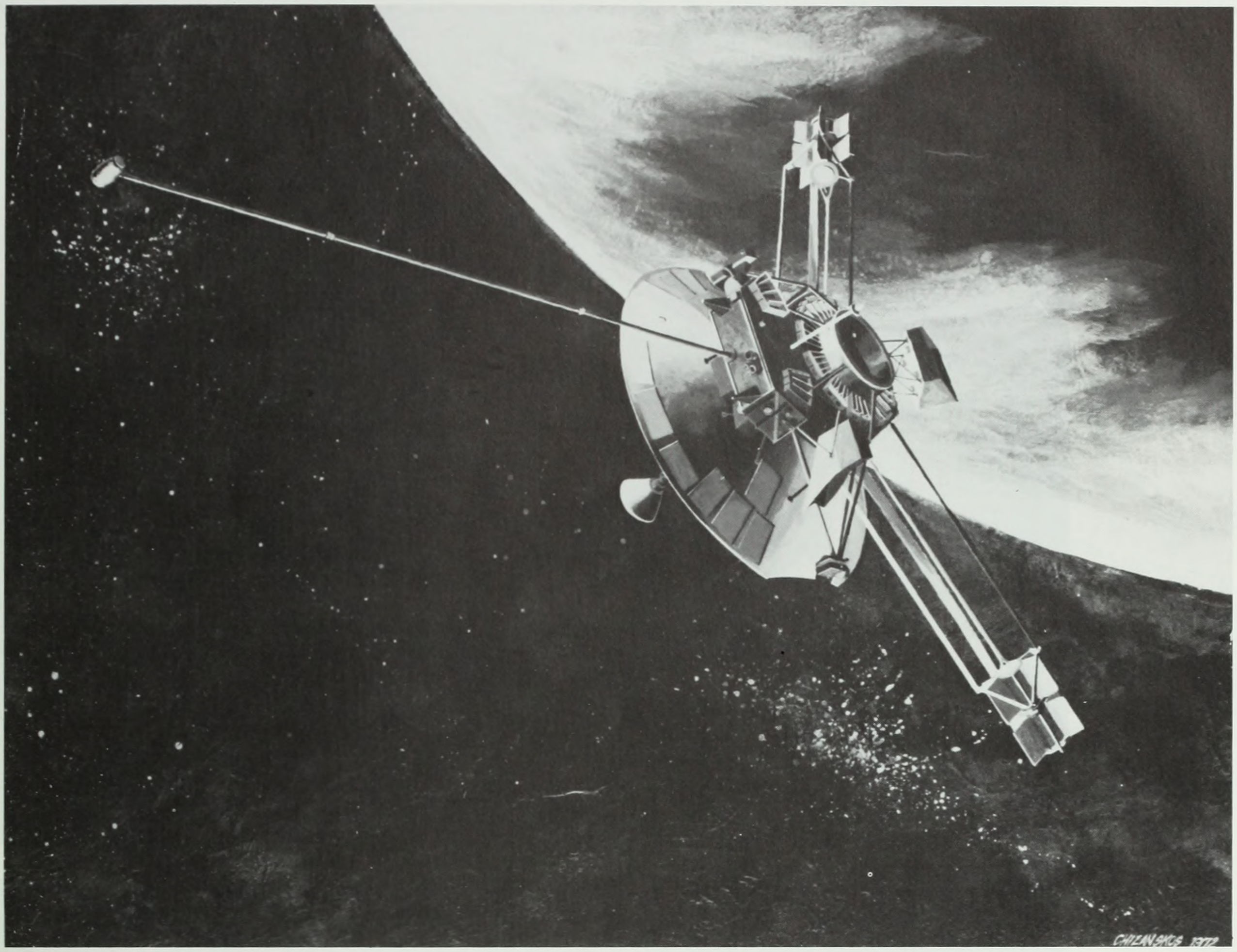
Following the only partially successful flight of the spin-stabilized *Pioneer 4* past the moon in March 1959, several studies were conducted on the possibility of designing similar longer-lived spacecraft to explore interplanetary space for extended periods of time. Between 1965 and 1968 *Pioneer 6* through *9* were launched into orbit around the sun between the orbits of Venus and Mars. During this time, further discussions were held on the possibility of sending a spin-stabilized Pioneer-class space probe to the outer planets. In February 1969, a mission to the planet Jupiter was approved, the Pioneer Project Office of Ames Research Center was assigned the task of managing the project. TRW Systems Group (formerly Space Technology Laboratories) was selected to design and construct two identical spacecraft for launch in the 1972-1973 period.

The objectives set for what would become *Pioneer 10* and *11* were (1) to explore the interplanetary medium beyond the orbit of Mars, (2) to investigate the nature of the asteroid belt and the hazards it presented to spacecraft bound for the outer planets, and (3) to explore the environment of Jupiter. Later these objectives were extended to include the study of interplanetary space to extreme distances and to use the gravity of Jupiter as a means of approaching Saturn to study its environment.

Pioneer 10 was launched from the Kennedy Space Center on March 3, 1972, on a "direct ascent trajectory," that is without first being placed in a "parking orbit" around the Earth. Just eleven hours after launch, the spacecraft passed the orbit of the moon and headed into interplanetary space. On July 15, *Pioneer 10* entered the asteroid belt. Seven months later it emerged unscathed. *Pioneer 10* encountered Jupiter in early December 1973. Valuable data was returned during transit through the Jovian environment. Especially significant were measurements of the intense magnetic fields that surround Jupiter and their associated radiation belts, observations of the temperatures and structure of Jupiter's upper atmosphere, and the return of color images of the planet, including Jupiter's Red Spot.

Since its Jupiter encounter, *Pioneer 10* has continued its journey outward and will eventually leave the solar system. Because its power sources are long-lived radioisotope thermo-electric generators, *Pioneer 10* continues to operate and send back data, including measurements of the solar magnetic field. In July 1981, *Pioneer 10* passed the 25 astronomical unit (AU) milestone (One AU equals the mean distance between the sun and the Earth; 25 AU equals 2.3 billion miles (3.7 billion kilometers). It is still working.

Allan Needell



Artist's rendering of Pioneer 10 *approaching Jupiter. (Photo: NASA 72-H-198)*

Mariner 10 Planetary Probe

Width: 676 cm (266 in)
Weight: 503 kg (1,110 lbs)
Gallery: 114: *Space Hall*

Mariner 10 was the first spacecraft to explore two planets during a single mission. On November 3, 1973, it was launched by an Atlas Centaur and three months later passed within 5,800 kilometers (3,600 miles) of Venus. *Mariner 10* was carrying 77 kilograms (170 pounds) of instruments, which included two television cameras, two magnetometers, an ultraviolet spectrometer, and an infrared radiometer.

As Mariner approached Venus, its instruments were busy. Ultraviolet images showed swirling clouds and a world-wide weather system. Infrared measurements confirmed that Venus's surface temperature is above the melting points of lead and zinc—480° C (900° F). Analysis of *Mariner 10*'s radio signals as they passed through the dense Venusian atmosphere revealed it to be multilayered. Mariner's trajectory indicated that Venus is 100 times closer to being a perfect sphere than is Earth. Further studies of *Mariner 10*'s trajectory also provided a measurement of the planet's mass with an accuracy 5 times greater than with previous methods.

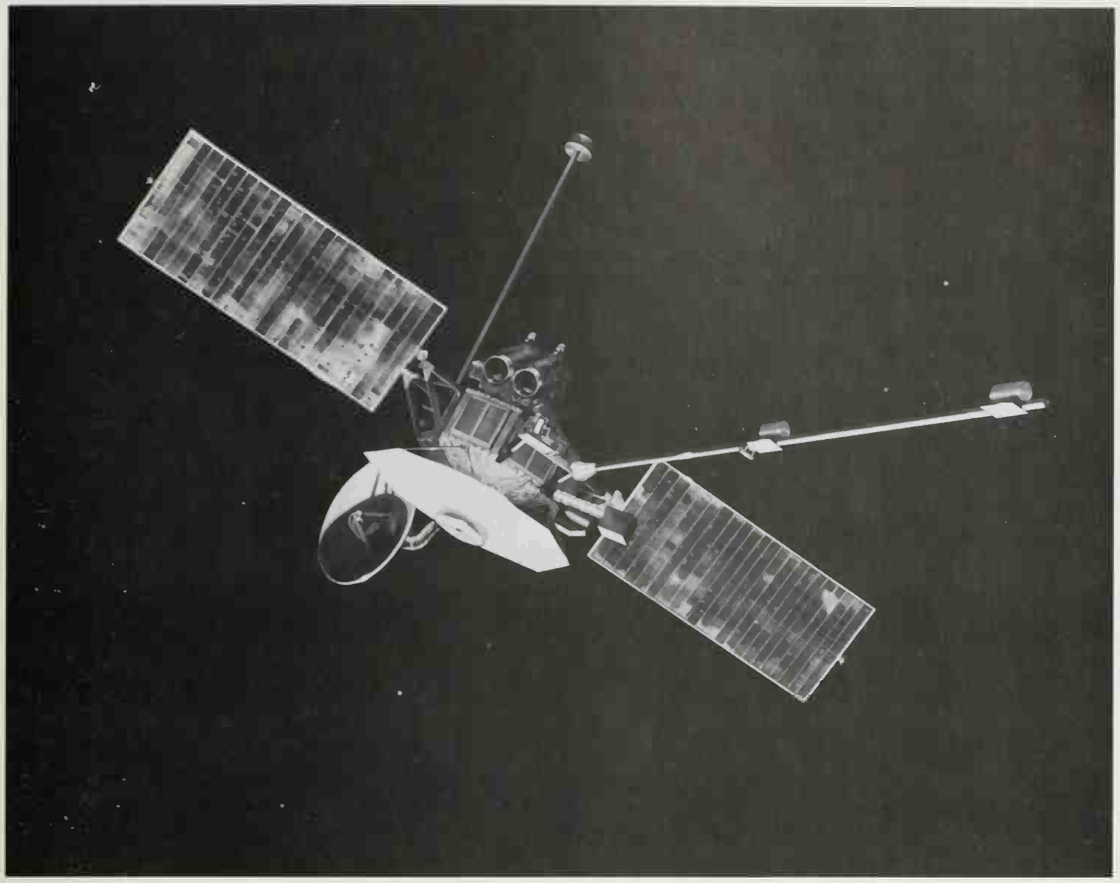
Mariner 10 used Venus' gravity and orbital motion to send it to its next destination—Mercury. On March 29, 1974, *Mariner 10* zoomed across Mercury, a scant 698 kilometers (436 miles) above the planet's surface. The first close-up views of the innermost planet in our solar system showed a rugged, rough terrain. Mercury is covered with craters and cliffs, some 3.2 kilometers (2 miles) high and 480 kilometers (300 miles long). A large basin, 1,280 kilometers (800 miles) across, named Caloris, was seen.

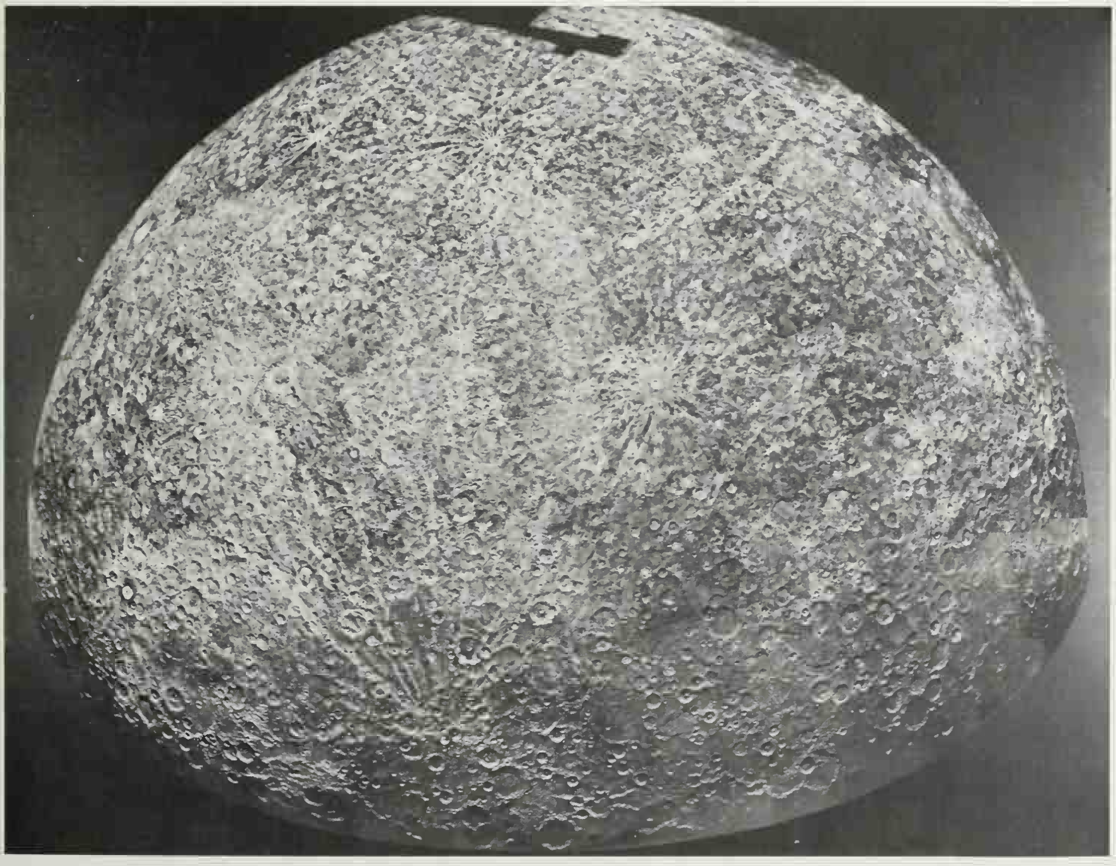
After the first Mercury encounter, Mariner followed a path around the sun which allowed it to fly past Mercury two more times. The second Mercury fly-by was on September 23, 1974; the third took place on March 16, 1975.

Gregory P. Kennedy

Above
Mariner 10, *the first spacecraft to explore two planets. (Photo: NASA 73-H-993)*

Below
Mariner 10 *images show Mercury to be heavily cratered like our moon. (Photo: NASA 75-H-1085)*





Apollo–Soyuz Test Project

Length: 20 m (66 ft)
Weight: 21,500 kg (47,500 lb)
Gallery: 114: *Space Hall*

On July 18, 1975, an American-built Apollo spacecraft and a Soviet Soyuz joined together in space for the first international manned spaceflight, the Apollo-Soyuz Test Project (ASTP). The flight had begun three days earlier, with launches in the vehicle's respective countries.

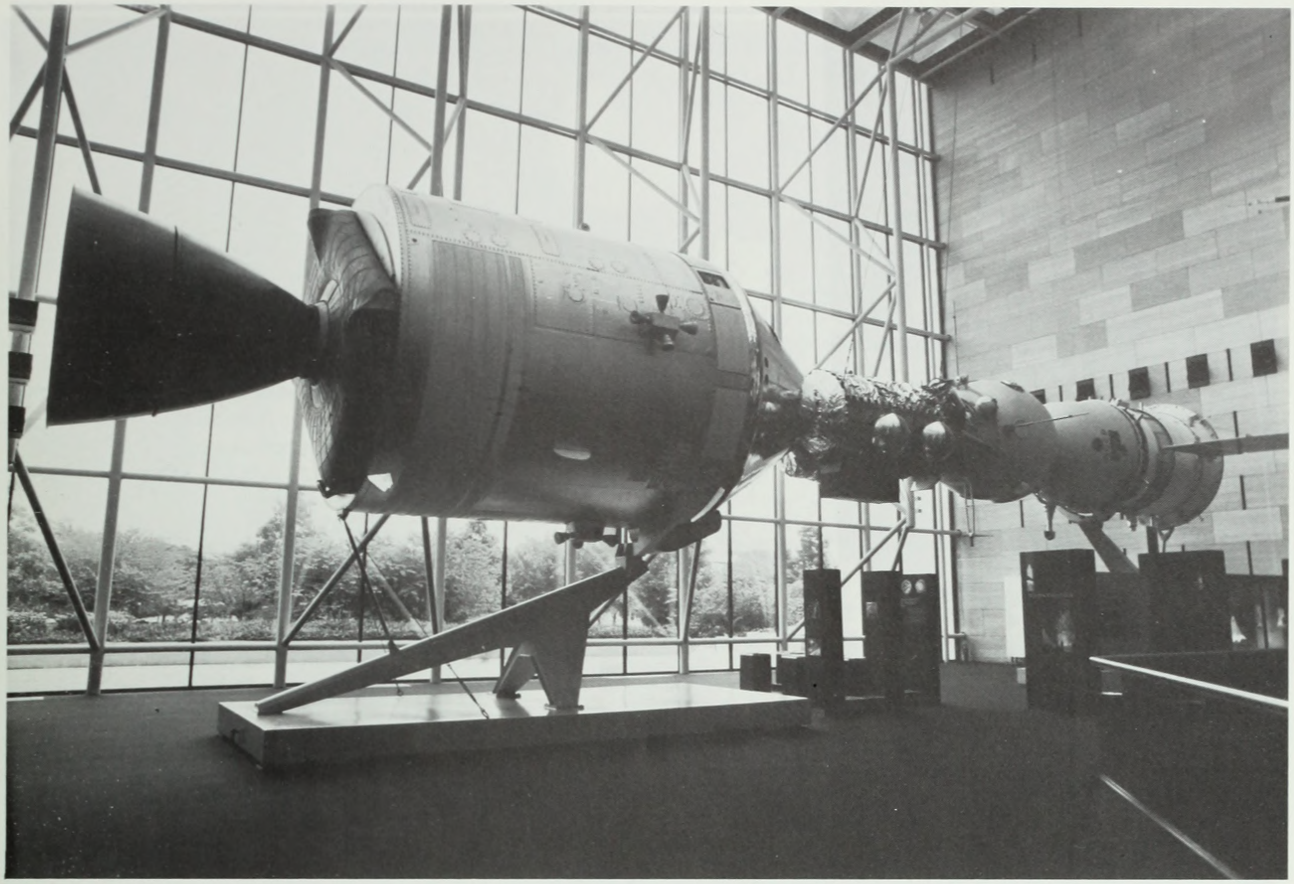
Soyuz lifted-off first, with cosmonauts Alexi Leonov and Valeri Kubasov on board. Six and a half hours later, astronauts Thomas Stafford, Donald Slayton, and Vance Brand took off from the Kennedy Space Center in an Apollo spacecraft. A Saturn 1B launched the Apollo and a special docking adapter so the two craft could link up.

Each spacecraft had a different cabin atmosphere. Apollo used pure oxygen at 5 pounds per square inch; Soyuz had a mixed gas oxygen-nitrogen atmosphere at 14.7 pounds per square inch. These differences in atmospheric composition and pressure made it impossible to simply join the two craft and open the hatches between them. Instead, a separate airlock module was necessary. To transfer from one spacecraft to the other, the crewmembers entered the module, sealed it, equalized the atmosphere in the chamber with the spacecraft they were going to, and opened the other hatch. Apollo had a larger propellant supply for maneuvering, so it carried the docking module.

While the crew members visited each other's spacecraft, they conducted joint experiments, sampled each other's space food, and performed such symbolic acts as signing a joint mission certificate and exchanging gifts.

The crew also separated and re-docked several times to test the new docking system. Following the last undocking, Soyuz landed on July 21. Apollo remained in space for three more days, finally landing on July 24.

Gregory P. Kennedy



The Apollo-Soyuz docking is recreated in Gallery 114: Space Hall. *(Photo: Smithsonian Institution)*

Viking Mars Lander

Height: 2 m (6.6 ft)
Width: 3 m (9.8 ft)
Weight: 1,067 kg (2,352 lb)
Gallery: 100: *Milestones of Flight*

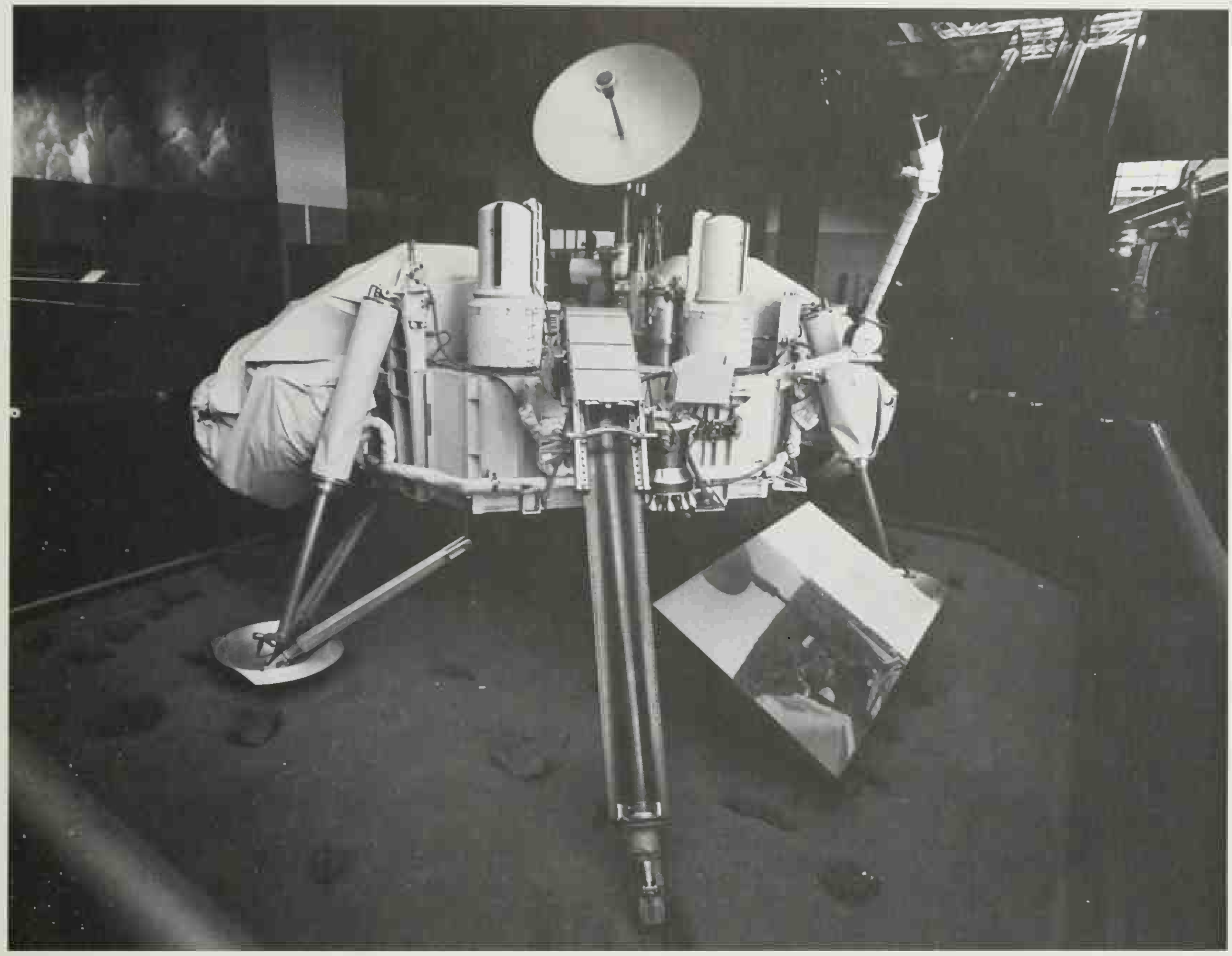
The purpose of the Viking Project was to send a dual orbiter/lander spacecraft to Mars. The project was initiated in 1968 following the cancellation of the more ambitious Voyager/Mars mission. The Voyager mission required a Saturn 5 launch vehicle and would have cost ten times as much as Viking. (The cancelled Voyager/Mars mission should not be confused with the later successful Voyager missions to Jupiter, Saturn, and beyond.)

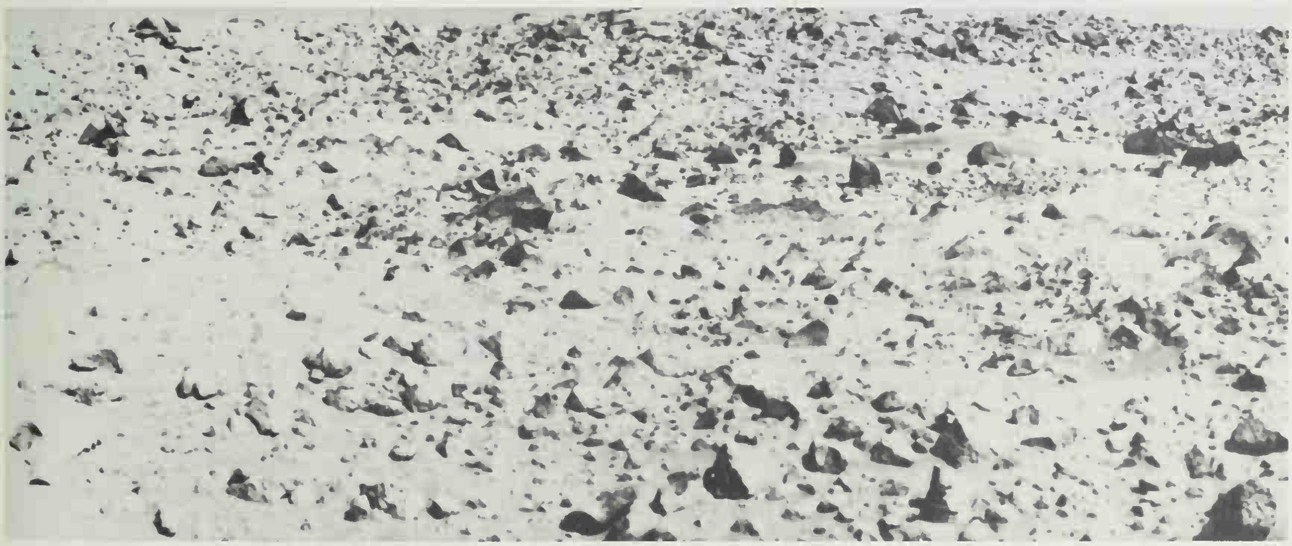
Two identical Viking spacecraft were launched from the Kennedy Space Center: *Viking 1* on August 20, 1975, and *Viking 2* on September 9, 1975. Successful soft landings on the Martian surface were made on July 20, 1976, and September 3, 1976, by the *Viking 1* and *2* landers, respectively. The *Viking 2* orbiter was shut down when its attitude control gases, depleted by a leak, ran out on July 24, 1978. The *Viking 2* lander was shut down on April 11, 1980, due to battery failure and inability of its own radio transmitters to broadcast directly to Earth. The *Viking 1* orbiter ran out of steering fuel on August 7, 1980. The *Viking 1* lander continues to send data and photographs to the Earth on a weekly basis.

The general objectives of the Viking mission were to increase significantly man's knowledge of the planet Mars through orbital observations by the orbiter, as well as by direct measurements made by the lander during Martian atmospheric entry, descent, and landing. More specifically, "particular emphasis was placed on obtaining biological, chemical, and environmental data relevant to the existence of life on the planet at the present time, at some time in the past, or the possibility of life existing at a future date." Orbiter observations consisted of radio-science, imaging, thermal and water vapor measurements used to assist landing-site selection, and the study of the dynamic and physical characteristics of Mars and its atmosphere. Lander direct measurements consisted of radio science; atmospheric structure and composition; landing-site imaging; atmopsheric pressure, temperature and wind velocity; identification of the elemental composition of the surface material; physical properties of the surface material; the search for evidence of living organisms and organic materials; and determination of seismological characteristics of the planet. The Viking scientific return was further expanded by the capability of simultaneous Martian observations from orbit and the surface.

The Viking lander on exhibit is the "proof test capsule," used for tests and simulations before and during the actual mission. Afterwards it was refurbished by the Martin-Marietta Aerospace Corporation to resemble as closely as possible the landers on the Martian surface.

Allan Needell





Above
Viking proof test capsule on a simulated Martian surface in Gallery 100: Milestones of Flight. *(Photo: Smithsonian Institution)*

Below
The martian landscape around the Viking 2 lander. (Photo: NASA 78-H-537)

International Ultraviolet Explorer Satellite

Weight: 312 kg (650 lb)
Gallery: 111: *Stars*

The International Ultraviolet Explorer Satellite (IUE) was launched from Cape Canaveral on January 26, 1978, eight years after plans were initiated for such a satellite at the Goddard Space Flight Center of NASA in Greenbelt, Maryland. Its primary purpose is to operate as an international space observatory to study the far ultraviolet spectroscopic character of celestial sources other than the sun.

The international character of the instrument developed when NASA agreed to provide the spacecraft and optical and mechanical components of the telescope; the European Space Agency (ESA) agreed to provide the solar power arrays and a European-based ground control center; and the United Kingdom Science Research Council in conjunction with University College, London, agreed to provide special television-type cameras to record the scientific data. In addition, complex computer software to analyze the data was developed jointly by NASA and the Science Research Council. The spacecraft is operated from two points on Earth: from NASA's Goddard Space Center and from ESA's Madrid station. NASA maintains the instrument for some 16 hours per day, and ESA the remaining 8 hours.

The spacecraft weighs over 312 kilograms (650 pounds) and contains a 45-centimeter (17.7-inch) reflecting telescope of modified Cassegrainian-type design, called a Ritchey-Cretien, to maximize its usable field at F/15. The large field is necessary for finding objects to observe. This system makes it possible for an observer sitting at Goddard or Madrid to control the telescope, find an object of interest for study, set and guide on the object during spectroscopic exposure (sometimes lasting many hours), and then determine in real time if the exposure has been adequate to produce the desired data. The IUE, the first telescope in space operated this way, greatly increased an astronomer's ability to get the data desired.

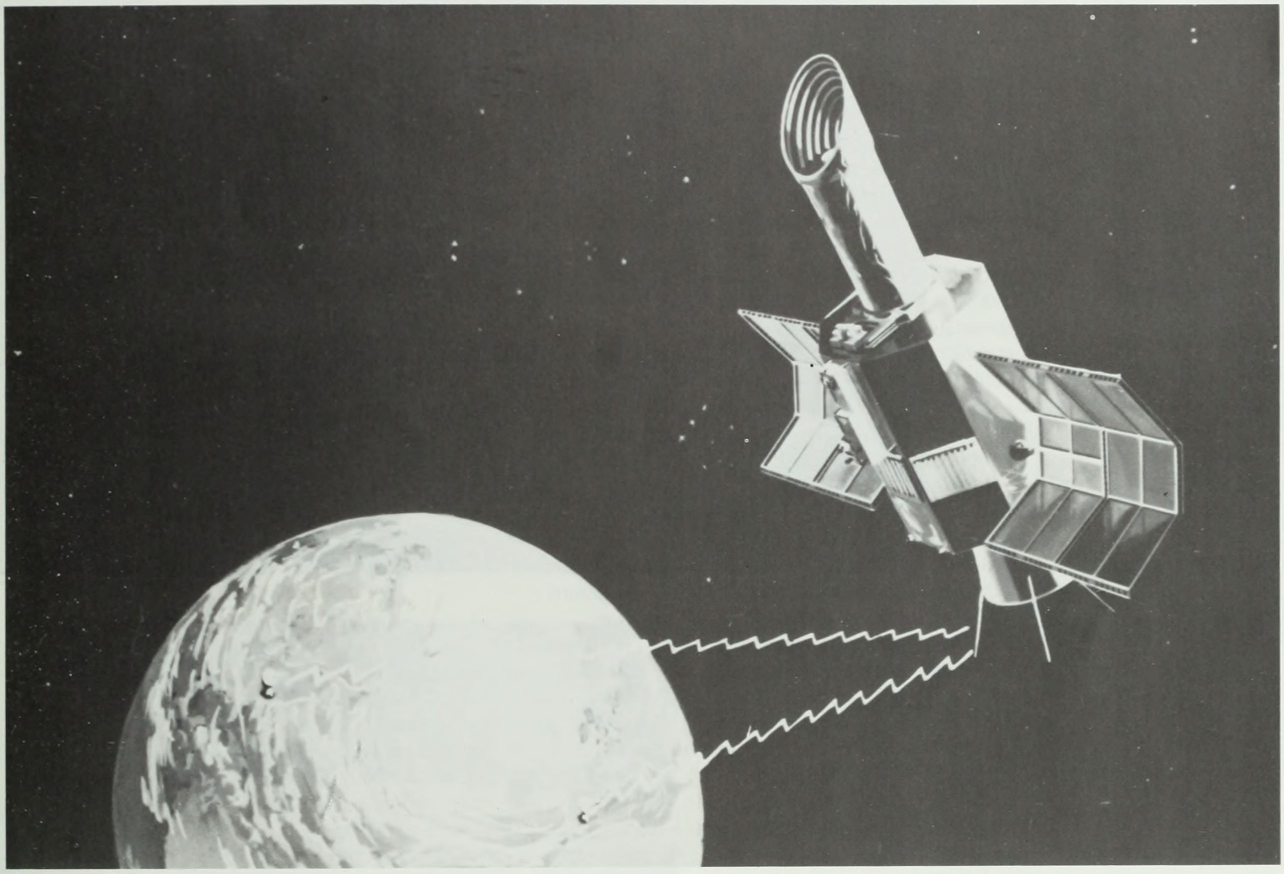
The IUE has two spectrographs of the Echelle design, both capable of providing low dispersion and high dispersion spectra over the total wavelength range of 1,150 to 3,200 Angstroms. The French word *"Echelle"* means "ladder," which describes what the spectra actually look like. Instead of the usual linear spectrum, a series of spectra all parallel to one another is produced. Each spectrum is a small portion of the whole, and can be examined independently of the others. The Echelle design is highly efficient. Together with very sensitive television-type detectors, the spectrographs more than make up for the relatively small size of the telescope (45 centimeter aperture). The detectors themselves are secondary electron conduction (SEC) television camera tubes, which are normally sensitive to visible light. To make them detect the far ultraviolet, special ultraviolet-to-visible converters (UVC) are placed in front of the SEC bi-alkalai photocathode to convert the ultraviolet signal into one that the SEC could detect.

Since it was put into orbit, the IUE has been used by hundreds of astronomers all over the world. Both the United States and European centers invite any qualified astronomer to apply for observing time, and make IUE's special data analysis system available for the reduction of data obtained. As of early 1980, in less than two years of observing time, over 132 papers have appeared in major astronomical journals discussing its scientific data. Staff scientists, project scientists, and visiting scientists have observed a broad range of celestial objects, from spectra of the major planets, as well as the moons of Jupiter and Earth, to hot and cool stars, the interstellar medium, and external galaxies and quasi-stellar objects. Because the satellite is in geosynchronous orbit, long exposures of faint objects are possible. In some cases, individual stars in other galaxies have been examined.

The wealth of observations made with the IUE have increased our understanding of the nature of hot stars, and the interaction of both stars and nebulae with the interstellar medium. Hot expanding shells of gas have been detected around massive stars, and coronal halos have been found to exist around other stars much like the sun's corona. The mass of the pulsar in the center of the Crab Nebula has been determined more accurately, and its interaction with the expanding nebula, a result of a supernova explosion in 1054 AD, has become better understood. How expanding shock fronts from such supernova explosions move through space has been studied, as has the ultraviolet character of enigmatic quasi-stellar sources, specifically how their energy output and ultraviolet spectra change with time. In all, the IUE has greatly enlarged our picture of a large portion of the high energy spectrum of the universe.

The National Air and Space Museum has on exhibit a full-scale mock-up of the IUE satellite, constructed at the Goddard Space Flight Center as a flight integration test model. The full scale model is suspended above a re-creation of the IUE Control Room, where images from the Fine Error Sensor (FES) of the IUE, as well as spectra from the many types of objects IUE examines, are displayed.

David DeVorkin



International Ultraviolet Explorer. (Photo: NASA 77-H-733)

Voyager 1 Planetary Probe

Diameter: 3.7 m (12 ft) (antenna)
Weight: 815 kg (1,800 lb)
Gallery: 205: *Exploring the Planets*

The Voyager missions to Jupiter, Saturn, and beyond were proposed during the late 1960s for large Mariner-type, 3-axis stabilized spacecraft to explore all of the outer planets of the solar system (the so-called Outer Planets Grand Tour). These ambitious plans were scaled down considerably during the years that followed the successful manned lunar landings, when it became apparent that the amount of money to be allocated to the NASA and the space program would not remain at the high levels experienced during the heyday of Apollo. The scaled down mission, originally named "Mariner/Jupiter-Saturn," called for two identical spacecraft to be launched to the two largest planets of the solar system. They were to study those planets, their magnetospheres, and their satellites.

Complementary trajectories were chosen for the two Voyager missions so as to provide both redundancy (in case one spacecraft failed) and a maximization of the amount of scientific information received (in case both succeeded). *Voyager 1* was aimed to pass close to Jupiter and fly on to Saturn. Its pass by Saturn was chosen to allow a close look at Titan, Saturn's largest moon. *Voyager 2* was aimed to approach Saturn more slowly and obtain better images of the Saturnian rings. Also, as a bonus, *Voyager 2*'s flight path was chosen to allow the possibility of its continuing on toward Uranus and perhaps even Neptune.

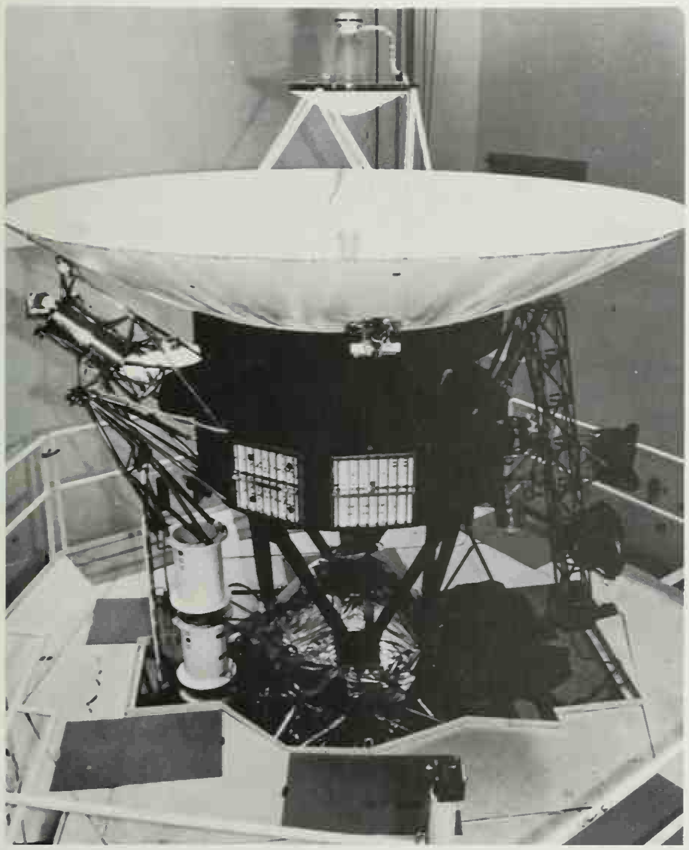
The Voyager spacecraft weigh 815 kilograms (1,800 pounds) and are perhaps the most complex and sophisticated robots ever sent to explore other worlds. Each contains its own radioisotope thermoelectric power generators, propulsion systems for precise and repeated course adjustments, scientific instruments, redundant communications systems, and computers capable of controlling all onboard devices for extended periods of time. The computers are remotely reprogrammable from Earth.

The first Voyager spacecraft was launched from Cape Canaveral on August 20, 1977; sixteen days later the second spacecraft was sent on its way. Although potentially serious problems developed with both Voyagers, the sophistication of the spacecraft and the increasing skills of the engineers and scientists on the ground made it possible to devise ways of "working around" virtually all of the problems.

Voyager 1's closest approach to Jupiter came on March 5, 1979; *Voyager 2* was four months behind. Among the most dramatic and important discoveries were the rings, like Saturn's, around Jupiter, and the active volcanoes on Io, one of Jupiter's moons. *Voyager 1*'s encounter with Saturn occurred during the summer of 1980, *Voyager 2* followed nine months later. *Voyager 1* then proceeded on a path that will take it directly out of the solar system, while *Voyager 2* begins a five year journey to the planet Uranus.

Allan Needell

Voyager 1 image of Jupiter showing the great red spot at bottom right. (Photo: NASA Voyager 1-28 P-21147)



Voyager 1 before launch. (Photo: NASA 77-H-155)

Space Shuttle

Height: 56 m (184 ft)
Weight: 2,000,000 kg (4,400,000 lb) (at launch)
Thrust: 28,000,000 newtons (6,400,000 lb)
Crew: 1 to 7
Gallery: 114: *Space Hall*

Like a truck, the Space Shuttle was designed as the first reusable spacecraft to haul loads to and from low Earth orbit.

The central component of the Space Transportation System, the Shuttle Orbiter, is part launch vehicle, part spacecraft, and part airplane (actually a glider). A 1/15 scale model in Gallery 114: *Space Hall*, depicts the orbiter in launch configuration with its external tank (ET), which provides fuel to the orbiter's three main engines, and two solid rocket boosters (SRBs) to help lift the orbiter and tank. The model sits on the mobile launcher with the crawler transporter, which carries the assemblage to the launch pad.

During launch, the SRBs separate after about two minutes of flight. The external tank is jettisoned, just before orbit is attained. The orbiter with a payload up to 29,000 kilograms (65,000 pounds) in its 4.5- by 18-meter (15- by 60-foot) cargo bay can remain in orbit for about a week with a crew of up to seven astronauts. Two are pilots, and the rest are mission specialists and payload specialists, who perform experiments and other tasks during the flight.

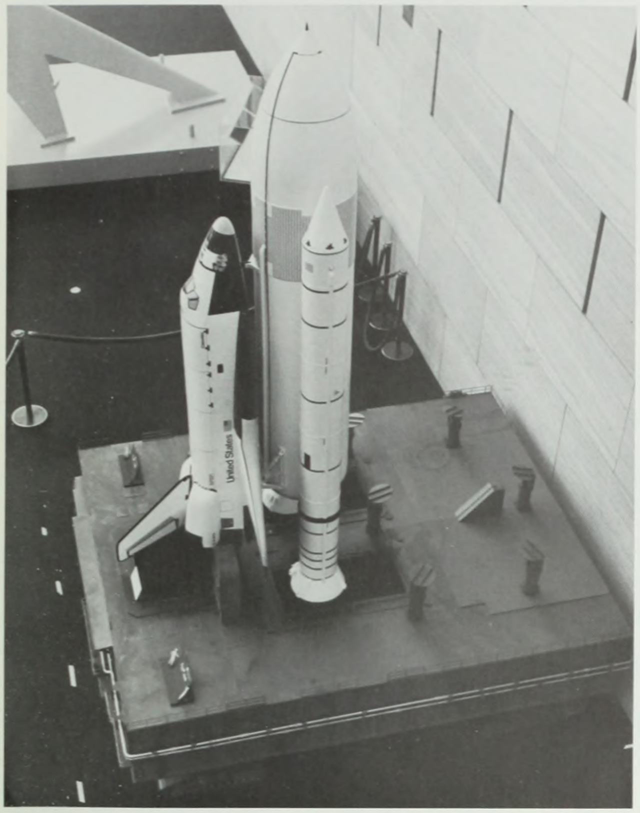
A fleet of four orbiters is planned. They will be named *Columbia, Challenger, Discovery,* and *Atlantis*. These are expected to make 100 flights each and, by the end of the decade, should be flying at a rate of at least one launch per month.

In orbit, the Shuttle can deploy payloads, retrieve spacecraft for repair or return, and carry a variety of onboard cargos. Instrument pallets and Spacelab modules, both built by the European Space Agency, provide a place for experiments. The remote manipulator system, a robot arm, is used to handle payloads in the cargo bay.

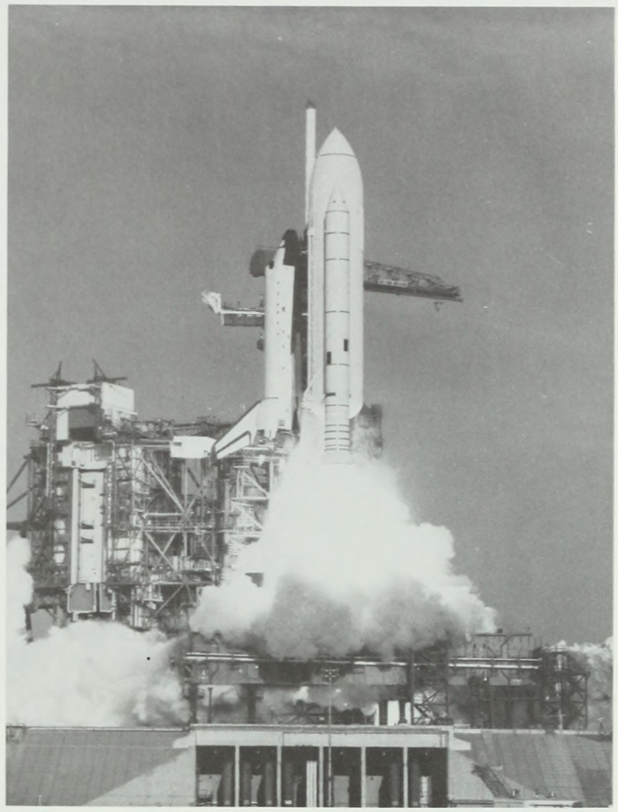
For payloads requiring higher orbits, extra rocket stages are available. The inertial upper stage and two kinds of payload assist modules can take a satellite to high Earth orbit or to geostationary orbit.

In addition to satellites and spacelab, the orbiters will carry other interesting payloads, such as the Space Telescope (a device for seeing seven times further than astronomers have ever been able to see before) and the Long Duration Exposure Facility to study long-term effects of the space environment on various materials. The shuttle will also carry Defense Department non-weapon payloads.

Kerry M. Joels



The centerpiece of the Museum's Space Shuttle exhibit is this 1/15th scale model of Columbia *on its mobile launch platform. (Photo: Smithsonian Institution)*



The first Space Shuttle launch, April 12, 1981. (Photo: NASA 81-H-285)

Space Telescope

Diameter: 3 m (10 ft)
Length: 13 m (43 ft)
Weight: 11,800 kg (26,000 lb)
Gallery: 111: *Stars*

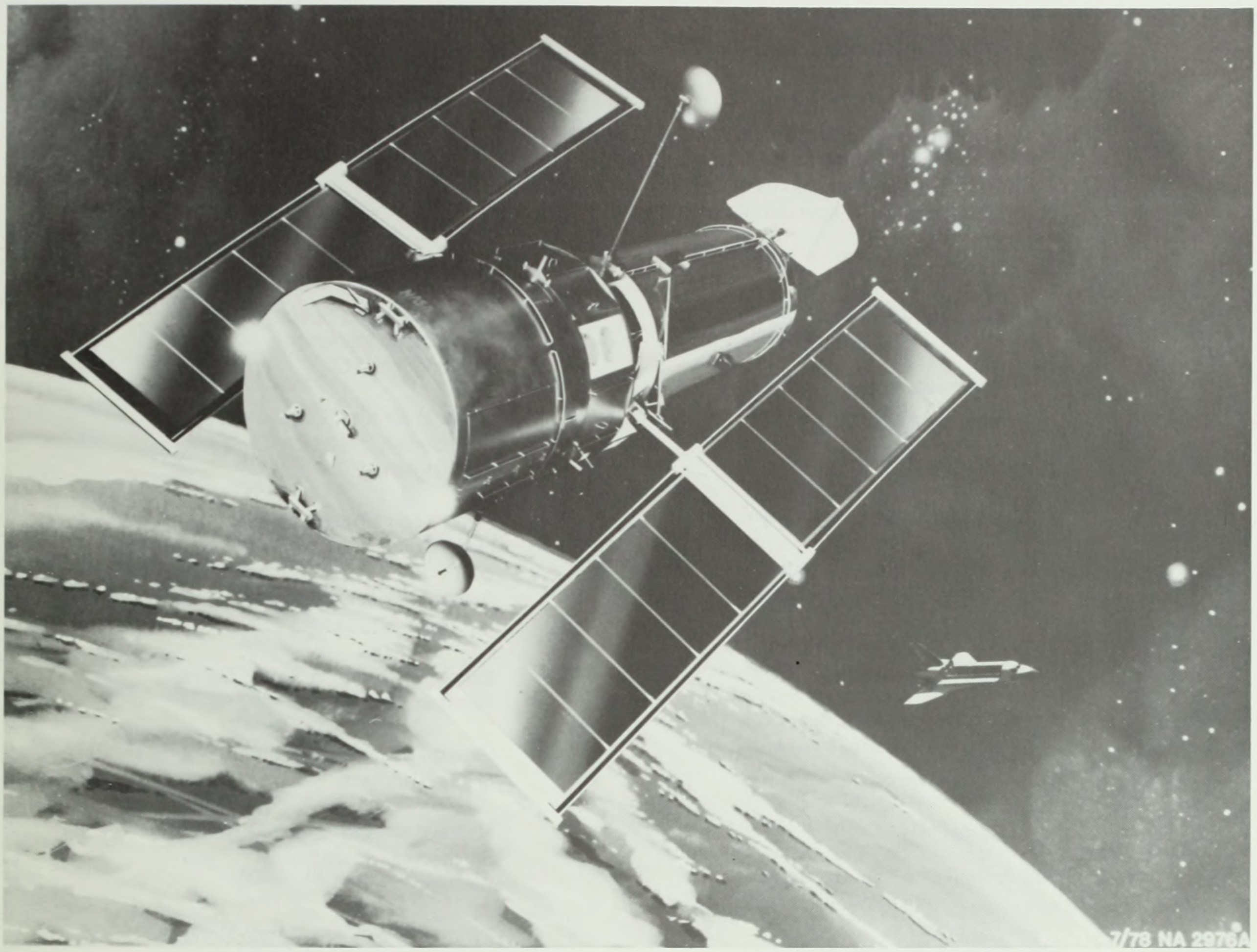
The Space Telescope, scheduled to be launched by Shuttle in 1985, will be the culmination of over 20 years of planning, designing, and construction by scores of astronomers in the United States and Europe, and by numerous aerospace industries, as well as by NASA. This new telescope, giant even by ground-based standards, will employ a 2.4-meter (94-inch) primary mirror and a battery of 5 major instruments capable of observing the universe in many different ways.

The major instruments of the Space Telescope will include cameras with sophisticated and versatile optical systems and solid-state area detectors to search for planets orbiting other stars, stars in the process of formation, stars like our sun in other galaxies, black holes in the centers of galaxies, and galaxies at the edge of the observable universe. A high-speed photometer and a battery of spectrographs will examine rapidly changing celestial sources, such as, variable stars, pulsars, and supernovae, and will be able to analyze their motions, structure, and composition, as well as the composition of the dust and gas between the stars. In effect, Space Telescope will be able to examine, in the spectral region from the far ultraviolet through to the near infrared, every known class of celestial object that emits radiation in that range except our sun. It is tacitly assumed that, as with every past case of putting a larger telescope into use, new classes of celestial objects will also be discovered.

The Space Telescope will be a "National Observatory" operated much like those now in place on the ground, such as Kitt Peak National Observatory or the National Radio Astronomy Observatory. A "Space Telescope Science Institute," on the Johns Hopkins University campus in Baltimore, Maryland, will house the scientific control center for the telescope. Scientists from all over the world will be able to visit the center, and on a carefully prearranged schedule, monitor and even partially control any one of the scientific instruments on Space Telescope. In a sense, they will directly "observe" objects of interest, much as astronomers have done on the ground for centuries.

The National Air and Space Museum has on display 1/5 scale high definition models of Space Telescope. One, a gift of the Lockheed Missile and Space Company, Inc., is an 11-foot (3.3 m) long depiction of the actual spacecraft. The other, a gift of the Perkin-Elmer Corporation, is an 8-foot (2.4 m) long cut-a-way of the telescope assembly itself.

David DeVorkin



Artist's rendering of NASA'a Space Telescope in orbit. (Photo: NASA 80-H-229)

Spacecraft Locater

The National Air and Space Museum has title to all flown United States manned spacecraft. Most are on loan to other museums around the world. As of Spring 1983, the spacecraft are in the following locations.

Mercury Redstone 3, *Freedom 7*	National Air and Space Museum Smithsonian Institution Washington, D.C.
Mercury Atlas 6, *Friendship 7*	National Air and Space Museum Smithsonian Institution Washington, D.C.
Mercury Atlas 7, *Aurora 7*	Hong Kong Space Museum Hong Kong
Mercury Atlas 7, *Sigma 7*	Alabama Space and Rocket Center Huntsville, Alabama
Mercury Atlas 9, *Faith 7*	Lyndon B. Johnson Space Center Houston, Texas
Gemini 3	Grisson Memorial Museum Mitchell, Indiana
Gemini 4	National Air and Space Museum Smithsonian Institution Washington, D.C.
Gemini 5	Lyndon B. Johnson Space Center Houston, Texas
Gemini 6	McDonnell Douglas Astronautics Company St. Louis, Missouri
Gemini 7	National Air and Space Museum Smithsonian Institution Washington, D.C.
Gemini 8	Neil Armstrong Museum Wapakoneta, Ohio
Gemini 9	Kennedy Space Center Florida
Gemini 10	Swiss Museum of Transport and Communication Luzern, Switzerland
Gemini 11	Ames Research Center Mountain View, California
Gemini 12	Goddard Space Flight Center Greenbelt, Maryland
Apollo 7	National Museum of Science and Technology Ottawa, Canada
Apollo 8	Chicago Museum of Science and Industry Chicago, Illinois

Apollo 9	Michigan Space Center Jackson, Michigan
Apollo 10	London Science Museum London, England
Apollo 11	National Air and Space Museum Smithsonian Institution Washinton, D.C.
Apollo 12	Langley Research Center Hampton, Virginia
Apollo 13	Musee de l'Air Paris, France
Apollo 14	Rockwell International Downey, California
Apollo 15	Wright Patterson Air Force Base Dayton, Ohio
Apollo 16	Alabama Space and Rocket Center Huntsville, Alabama
Apollo 17	Lyndon B. Johnson Space Center Houston, Texas
Skylab 2	U.S. Naval Aviation Museum Pensocola, Florida
Skylab 3	Ames Research Center Mountain View, California
Skylab 4	National Air and Space Museum Smithsonian Institution Washington, D.C.
Apollo-Soyuz Test Project Command Module	Kennedy Space Center Florida