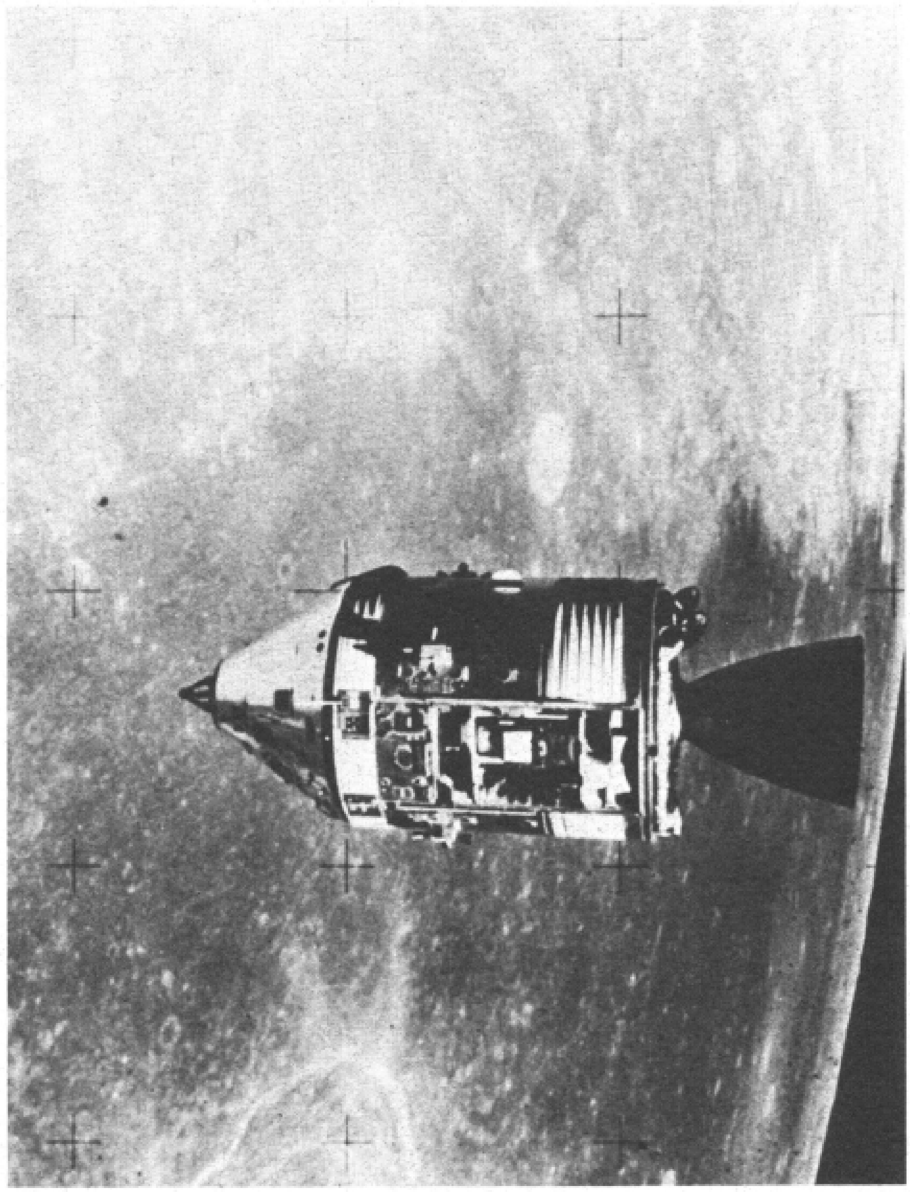
The American Society of
Mechanical Engineers



APOLLO COMMAND MODULE

International Historic Mechanical Engineering Landmark
Designated July 24, 1992

Rockwell International Corporation
Space Systems Division

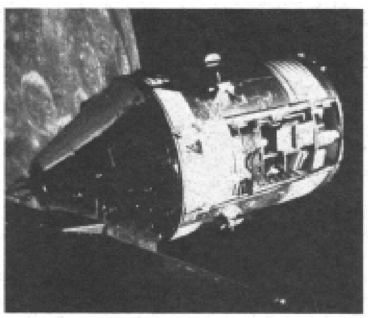
We choose to go to the moon in this decade and do the other things,

not because they are easy, but because they are hard, because there is

new knowledge to be gained and new rights to be won,

and they must be won for the progress of all mankind. . . .

President John F. Kennedy
September 12, 1962



The confines of earth were expanded on October 4, 1957, with the launch of the Soviet Union's Sputnik I, the world's first artificial space satellite. American reaction was one of shock in the midst of the cold war. U.S. assumptions of being number one militarily and technologically were quickly swept away. The value of the educational system, the strength of the military, and the fundamental effectiveness of the democratic form of government came into question. Early U.S. attempts to match the Soviet space feat ended in failure, adding to the unease.

The United States entered the Space Age on January 31, 1958, with the launch of Explorer I. The Soviets, however, continued to dominate in this undeclared "space race" with larger rockets and payloads. In response to great public pressure, President Eisenhower signed the bill creating the National Aeronautics and Space Administration (NASA) in July 1958. NASA's mandate was to develop America's aeronautical and space exploration potential for the "benefit of all mankind."

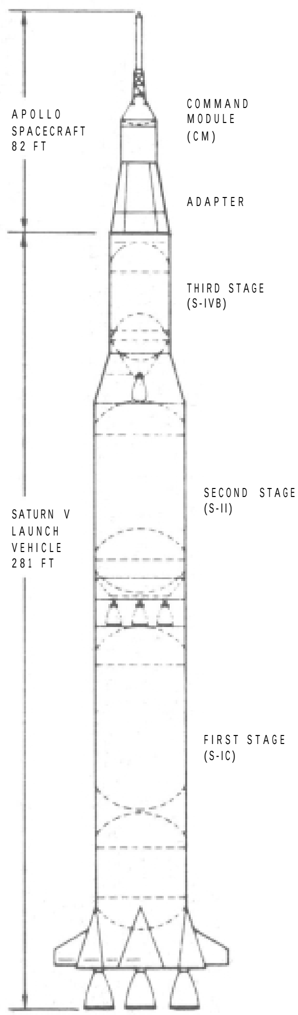
The goal of Project Mercury, announced in the fall of 1958, was to launch an American astronaut into orbit. But the Soviets were first again, when cosmonaut Yuri Gagarin became the first human to orbit the earth on April 12, 1961. Three days later, the failed invasion of Cuba at the Bay of Pigs occurred. American prestige in the world was at a low.

President Kennedy recognized that prestige was real and not simply a public relations factor in world affairs. He was frustrated by being second to the Soviets in space. Vice President Lyndon Johnson was asked to study American options in space and determine in what areas the U.S. could beat the Soviets. Johnson submitted a report, less than 2 weeks later, urging approval of a project to land a man on the moon.

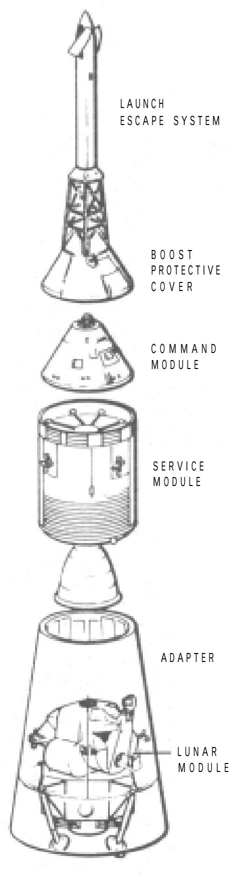
Kennedy initially had reservations, but the enthusiastic response to Alan Shepard's Mercury *Freedom 7* flight on May 5, 1961, convinced him it was time for such a commitment. In a speech before a joint session of Congress on May 25, 1961, Kennedy issued the challenge:

> "I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth."

Project Apollo was born. What followed was one of the most highly technical peacetime programs ever undertaken by the United States. It required a combined effort of government, industry, and academia that, at its peak, involved over 350,000 people and over 20,000 companies throughout the country. Kennedy's challenge was met just over 8 years later, July 20, 1969, when the Apollo 11 lunar module *Eagle* landed on the moon's Sea of Tranquillity and the crew was returned safely to earth on July 24, 1969.



SATURN V LAUNCH VEHICLE
Figure 1



APOLLO SPACECRAFT
Figure 2

Saturn V and Apollo Spacecraft	
Overall height	363 ft
Overall launch weight	6.4 million lb

Launch Escape System	
Height	33 ft
Diameter	3 ft
Weight	9,000 lb

Command Module	
Height	10 ft 7 in.
Diameter	12ft 10 in.
Launch weight	12,800 lb

Service Module	
Height	24 ft 9 in.
Diameter	12 ft 10 in.
Launch weight	54,160 lb

Spacecraft Lunar Module Adapter	
Height	28 ft
Diameter	12 ft 10 in. (top) 21 ft 8 in. (bottom)
Weight	54,000 lb

Lunar Module	
Height	23 ft 1 in. (legs extended)
Diameter	31 ft (diagonal)
Launch weight	36,200 lb

PROJECT APOLLO

Project Apollo, which followed the Mercury and Gemini programs, was the culmination of NASA's manned space flight program to land American astronauts on the moon. The objective was to send a three-man Apollo spacecraft to the moon and into lunar orbit, land two of the three men on the moon in the lunar module while the third remained in orbit, return the lunar explorers to the orbiting spacecraft, and then return all three men safely to earth. The entire trip, from launch to earth landing, would last between 8 to 10 days.

The major challenge of the program was to develop the Apollo spacecraft and the Saturn launch vehicle that would perform the mission. These elements consisted of three integral parts: the command and service module (CSM), the lunar module (LM), and the Saturn V launch vehicle (Figure 1).

THE APOLLO SPACECRAFT

The 82-foot Apollo spacecraft was the entire structure that sat atop the Saturn V launch vehicle (Figure 2). It had five distinct parts: the command module (CM), the service module (SM), the lunar module, the launch escape system, and the spacecraft-lunar module adapter. Of these, the integrated CSM was the core of the Apollo spacecraft; and the CM, the only part to splash down on earth, is the historic engineering landmark.

November 28, 1961, NASA awarded the basic Apollo spacecraft CSM contract to the Space Division of North American Aviation (now known as Rockwell International). Project Apollo was managed by the Office of Manned Space Flight, NASA Headquarters, Washington, D.C. The Apollo Spacecraft program was directed by NASA's Johnson Space Center (then known as the Manned Spacecraft Center) in Houston, Texas.

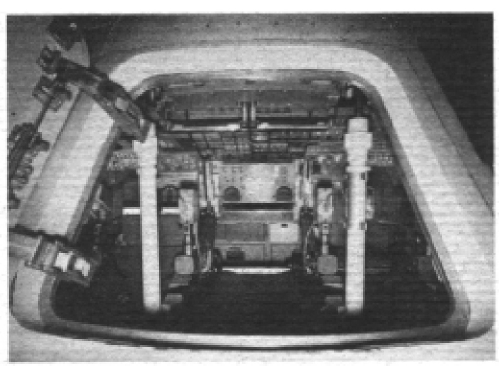
COMMAND MODULE

The CM was the control center for the spacecraft, the living and working quarters for the three-man crew. It was the only part of the spacecraft that returned to earth, separating from the SM just before atmospheric entry.

The CM stucture consisted of two shells: an inner crew compartment (pressure vessel) and an outer heat shield. The outer shell was stainless-steel honeycomb between stainless-steel sheets. It was covered on the outside with ablative material of varying thickness that charred and dissipated in the heat of reentry.

The inner pressurized shell was aluminum honeycomb between aluminum alloy sheets. A layer of insulation separated the two shells. This construction made the CM as light as possible yet rugged enough to withstand the stresses of acceleration during launch, possible strikes by meteorites, deceleration during entry into earth's atmosphere, and the impact of splashdown.

Inside the CM was a compact but efficiently arranged combination cockpit, office, laboratory, radio station, kitchen, bedroom, bathroom, and den. In flight, the cabin was air-conditioned to a comfortable 70 to 75 degrees. The atmosphere was 100-percent oxygen, pressurized to 5 pounds per square inch (psi), which is about one third of sea-level pressure (14.7 psi).



Interior of the CM had three compartments. Shown here is the crew compartment, which provided 210 cubic feet of pressurized living space.

Following the fatal accident during the Apollo 1 ground simulation, the main hatch was redesigned to open outward for quick egress.

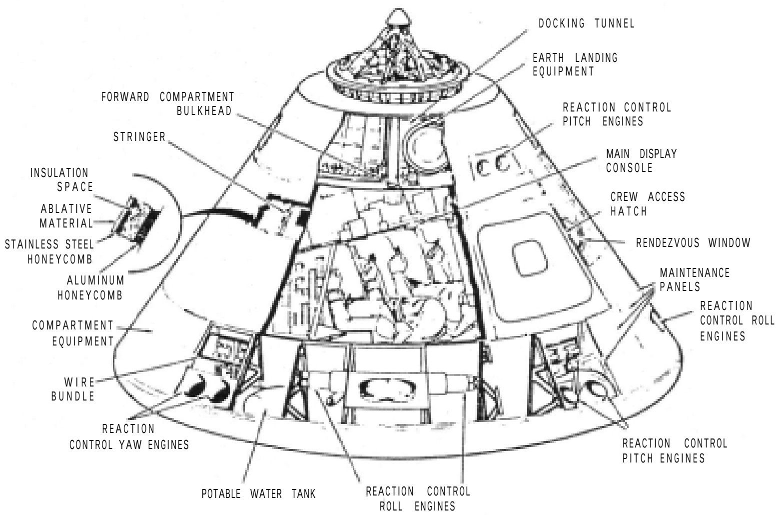
The crew compartment was a sealed cabin with a habitable volume of 210 cubic feet. Pressurization and temperature were maintained by the environmental control subsystem. In the compartment were couches, controls and displays for spacecraft operation, and all the other equipment needed by the crew, packed in a number of bays. There were also two hatches and five windows.

The interior of the CM was lined with equipment bays containing all of the items needed by the crew for up to 14 days, as well as the equipment and electronics needed for spacecraft operation. The lower bay was the largest and contained the most critical equipment–the navigation station, telecommunication subsystem electronics, electrical power subsystem, and stowage for food, personal hygiene, and other supplies.

The left-hand equipment bay contained the environmental control subsystem. The right-hand bay contained the waste management system controls and electrical power equipment. The right-hand forward and aft bays housed other mission components.

The two-shell construction created two other compartments: forward and aft. The forward compartment was the area around the forward docking tunnel. It was separated from the crew compartment by a bulkhead and covered by the forward heat shield. The compartment was divided into four 90-degree segments that contained earth landing equipment.

The aft compartment was located between the CM pressure vessel and the heat shield, around the periphery of the CM at its widest part. The compartment was divided into 24 bays containing ten reaction control engines; the fuel, oxidizer, and helium tanks for the CM reaction control subsystem; water tanks, and a number of instruments, valves, regulators, and related equipment.



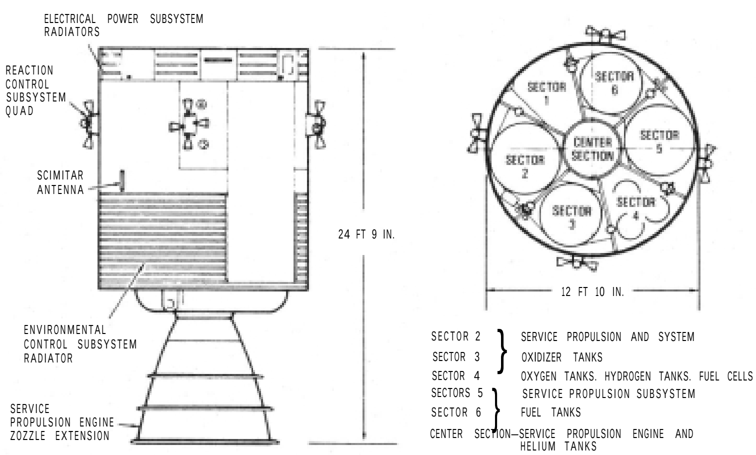
COMMAND MODULE

Dimensions	
Height	10 ft 7 in.
Diameter	12 ft 10 in.
Weight (including crew)	12,800 lb
Weight (splashdown)	11,700 lb

Propellant	
Reaction control subsystem (fuel–monomethylhydrazine; oxidizer–nitrogen tetroxide)	270 lb

Major Subsystems

Communications
Earth landing
Electrical power
Environmental control
Guidance and navigation
Launch escape
Reaction control
Service propulsion
Stabilization and control
Thermal protection (heat shields)



SERVICE MODULE

Dimensions	
Height	24 ft 9 in.
Diameter	12 ft 10 in.
Weight (loaded)	54,160 lb
Weight (less propellants)	13,469 lb

Propellant	
SPS fuel	15,660 lb
SPS oxidizer	25,030 lb
RCS	1,250 lb

Major Subsystems

Electrical power
Environmental control
Reaction control
Service propulsion
Telecommunications

An SM panel could be removed pyrotechnically to expose scientific experiments to space.

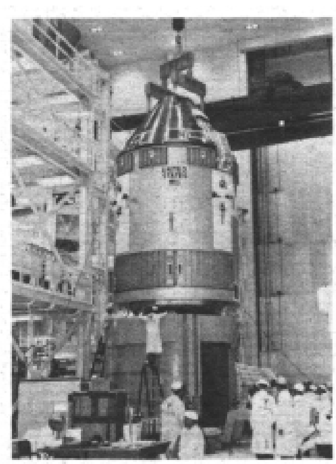
Service Module

The SM served as the storehouse for critical subsystems and supplies that were either used or controlled by the CM. The SM was attached to the aft portion (heat shield) of the CM from launch until just prior to entry into earth's atmosphere, when it was jettisoned.

The SM contained the spacecraft's service propulsion system (SPS), with its 20K thrust engine and propellant tanks. The SPS was used to make midcourse corrections, brake for lunar orbit, return from the moon, and decelerate for reentry, whereupon it was jettisoned. The SPS propellant consisted of hypergolics–hydrazine plus unsymmetrical dimethylhydrazine as fuel and nitrogen tetroxide as the oxidizer. When the fuel and oxidizer mixed, ignition occurred without the need for oxygen. These corrosive fuel lines, as well as other lines, were purged with helium before reentry.

The SM also contained a major portion of the electrical power subsystem, oxygen and hydrogen cryogenic storage, fuel cells, environmental control subsystem, and reaction control subsystem as well as a portion of the communication subsystem. These subsystems were housed in six wedge-shaped sections arranged around the SPS thrust structure.

Although the SM was strictly a servicing unit of the Apollo spacecraft, it was more than twice as long and, when fueled, more than four times as heavy as the CM. Nearly 80 percent of the SM weight was in SPS propellant.



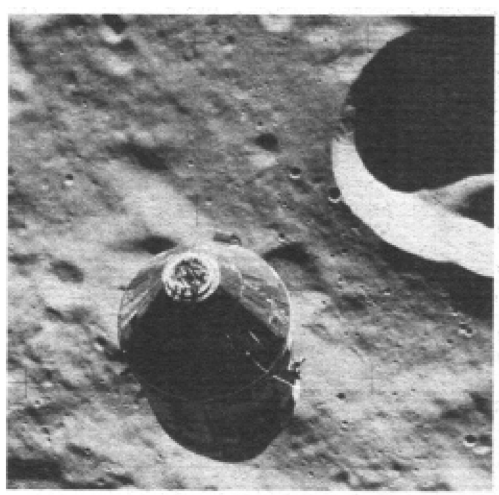
The Apollo CM and SM are mated and hoisted for fit check on lunar adapter

THE APOLLO 14 MISSION

The Apollo 14 CM, the designated landmark, was launched January 31, 1971. The three-man crew consisted of Alan B. Shepard, commander, Edgar D. Mitchell, lunar module pilot, and Staurt A. Roosa, command module pilot. Apollo 14 was very important in putting the moon program back on track following the aborted Apollo 13 flight. As a result of the modifications made after Apollo 13 to add more safety and backup features, Apollo 14 became the heaviest Apollo spacecraft.

Designated CSM 110, the Apollo 14 spacecraft was named *Kitty Hawk* and the lunar module was called *Antares.* The main purpose of the Apollo 14 mission was to investigate the hilly upland region of the Fra Mauro crater. *Antares* landed on the lunar surface February 5, 108 hours and 54 minutes after leaving earth.

There, astronauts Shepard and Mitchell set up the ALSEP (Apollo lunar surface experiments package). This package of experiments and instruments was left on the moon for continued monitoring after the crew departed.



Kitty Hawk, *steered by Roosa, looked like this to Shepard and Mitchell as they approached in* Antares *for a reunion in lunar orbit.*

In all, the astronauts spent a total of 33 hours and 31 minutes on the lunar surface. There were two moon walks, or EVAs (extravehicular activities), that totaled 9 hours and 24 minutes. The astronauts collected 94 pounds of lunar material to be used for 187 projects in the U.S. and 14 foreign countries.

The CM *Kitty Hawk* splashed down in the Pacific Ocean February 9, 1971, 216 hours and 2 minutes after launch. Apollo 14 was the third lunar landing, the sixth manned lunar flight of Apollo, and the eighth manned Apollo flight.

APOLLO'S ACCOMPLISHMENTS

The Apollo CSM was the only spacecraft to support successful manned landings on the moon and return its crew safely to earth. After the lunar landing program ended, the Apollo CSM was adapted to support America's Skylab space station and the Apollo-Soyuz rendezvous and docking with the Soviet Union.

Between October 1968 and July 1975, there were 15 manned Apollo flights—9 to the moon with 6 lunar landings, 3 flights to the Skylab space station, and 1 to the Apollo-Soyuz rendezvous. (See summary of flights, p. 6.)

Of Apollo's numerous firsts, some of the more significant are listed below:

- First three-man American spacecraft
- First manned spacecraft to complete a lunar orbit and to return crew safely after lunar landing
- First lunar rendezvous with another spacecraft (LM)
- First American spacecraft to dock successfully with a space station (Skylab)
- First American spacecraft to dock successfully with a foreign spacecraft (Soyuz)

Apollo's Legacy

The Apollo lunar landings are among the greatest engineering and technological achievements of all time. The development of a spacecraft that could make the 8- to 10-day round trip to the moon and protect the astronauts from the hostile environment of space required many advances in engineering, materials, and technology. Highly complex environmental, computer, guidance, and navigation systems had to be developed. A broad array of integration and checkout programs, and new equipment designed and built to a new standard of safety and reliability, were essential to mission success.

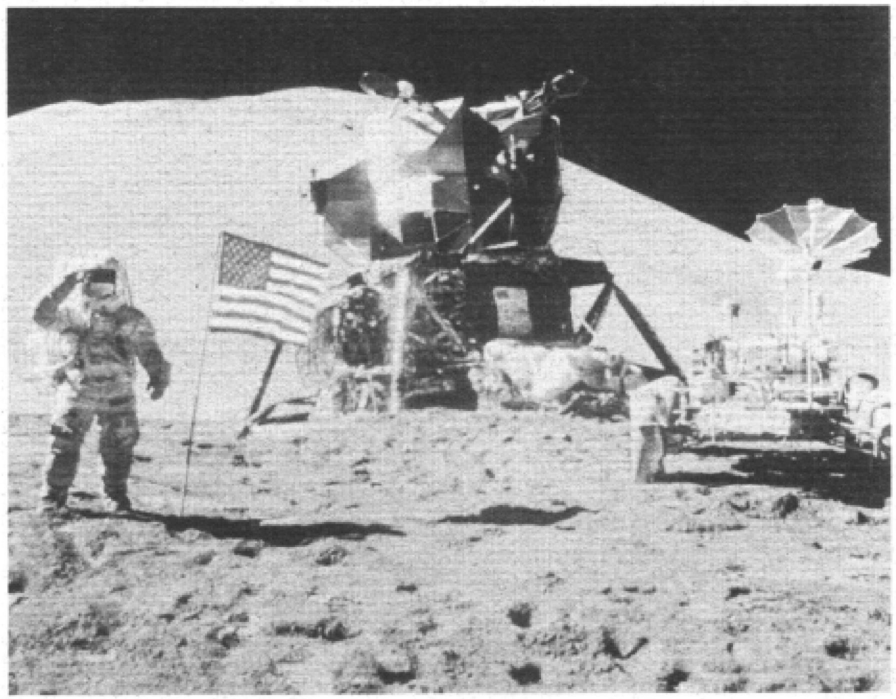
These needs spurred advanced developments in computer technology, miniaturization, microelectronics, materials processing, rocket propulsion, and medicine. The commercial spin-offs from these developments include the silicon microchip processor and software design. Other newly developed products were used by Apollo, such as Teflon, Mylar, and fluorocarbons for fire supression.

Apollo also made great contributions to the sciences. The lunar missions returned 850 pounds of rock, 33,000 photos, and 20,000 reels of magnetic tape data. They taught us more about the moon than all previous earth-based studies combined. We now know the moon's age, its gross structure, its internal temperature, and much about its composition.

The Apollo program was born out of cold-war tension. Its success restored faith and pride in America during a very turbulent period of civil and social change, and helped bring the nations of the world a little closer together.

Nearly 1.5 billion people witnessed the Apollo 11 moon walk via satellite. Never before had so many people been simultaneously focused on one event. President Richard Nixon said, in speaking to the Apollo 11 astronauts, "For one priceless moment in the whole history of man, all the people on this earth are truly one."

If there can be only one message that best describes Apollo's meaning, it is that of Neil Armstrong: ". . . in the spirit of Apollo, a free and open spirit, you can attack a very difficult goal and achieve it if you can all agree on what that goal is . . . and that you will work together to achieve it."



James Irwin—Apollo 15 (July 1971).

Summary of Apollo Manned Flights

Apollo 7. First manned Apollo. Demonstrated ability of CSM spacecraft crew, and Manned Space Flight Network to conduct earth orbital mission. Crew: Walter M. Schirra, Jr., Donn F. Eisele, R. Walter Cunningham. Launched October 11, 1968, with a Saturn IB. Mission duration 10.8 days.

Apollo 8. First manned lunar orbital mission. Demonstrated CSM and crew performance in cislunar and lunar orbit. Crew: Frank Borman, James A. Lovell, Jr., William A. Anders. Launched December 21, 1968, with a Saturn V (first manned Saturn V launch). Duration: 6.1 days.

Apollo 9. Second earth orbital mission; first manned flight of lunar module. Evaluated crew operation of LM; demonstrated docking functions with CSM in earth orbit. Crew: James A. McDivitt, David R. Scott, Russell L. Schweickart. Launched March 3, 1969, with a Saturn IB. Duration: 10.1 days.

Apollo 10. First lunar orbit flight of complete spacecraft (CSM and LM). Demonstrated LM rendezvous and CSM docking in lunar gravitational field; confirmed all aspects of lunar landing mission except descent to lunar surface. Crew: Thomas P. Stafford, John W. Young, Eugene A. Cernan. Launched May 18, 1969, with a Saturn V. Duration: 8 days.

Apollo 11. First lunar landing. Met national objective of landing men on the moon and returning them safely to earth before end of decade. Obtained data on capabilities and limitations of astronauts on lunar surface; returned samples from lunar surface; left science package to return data to earth after departure. Crew: Neil A. Armstrong, Michael Collins, Edwin E. Aldrin, Jr. Launched July 16, 1969, with a Saturn V. Duration: 8.1 days.

Apollo 12. Second manned lunar landing, and second before the end of the decade. Investigated lunar surface environment and obtained lunar soil samples. Crew: Charles Conrad, Jr., Richard F. Gordon, Jr., Alan L. Bean. Launched November 14, 1969, with a Saturn V. Duration: 10.2 days.

Apollo 13. Manned lunar landing mission to investigate Fra Mauro area of moon. Landing aborted after failure of service module oxygen tank; astronauts returned safely. Crew: James A. Lovell, John L. Swigert, Fred W. Haise. Jr. Launched April 11, 1970, with a Saturn V. Duration: 8.9 days.

Apollo 14. Third manned lunar landing. Investigated hilly upland region north of Fra Mauro crater and returned 96 pounds of lunar soil. Crew: Alan B. Shepard, Jr., Stuart A. Roosa, Edgar D. Mitchell. Launched January 31, 1971, with a Saturn V. Duration: 9 days.

Apollo 15. First of three lunar landing missions with greatly expanded capability for scientific investigations (J missions). One bay of the Apollo spacecraft service module contained two cameras for mapping the lunar surface and instruments to measure x-ray, gamma-ray, and alpha particle flux, the density and composition of the lunar atmosphere, magnetic fields, and the lunar mass. The lunar rover was first used to explore the moon's surface on this mission. Crew: David R. Scott, Alfred M. Worden, Jr., James B. Irwin. Launched July 26, 1971, with a Saturn V. Duration: 12.3 days.

Apollo 16. Second lunar landing mission with scientific instrument module in the Apollo service module. Continued photographic mapping and scientific experiments from lunar orbit; while on the surface, used lunar rover to extend exploration to 27.1 kilometers (16.8 miles). Crew: John W. Young, T. Kenneth Mattingly II, Charles M. Duke, Jr. Launched April 16, 1972, with a Saturn V. Duration: 11.1 days.

Apollo 17. Last Apollo lunar mission: produced more scientific information than any Apollo flight. Continued mapping from lunar orbit and gathered data on surface and subsurface features to a depth of 1 kilometer with a variety of scientific instruments. Traveled 36.1 kilometers (22.4 miles) with lunar rover; collected record of 249 pounds of soil and rock samples. Crew: Eugene A. Cernan, Ronald E. Evans, Dr. Harrison H. Schmitt (first of the NASA scientist-astronauts to fly). Launched December 7, 1972, with a Saturn V. Duration: *12.6* days.

Skylab 1. Unmanned launch of Skylab (Saturn S-IVB workshop) into earth orbit. Shortly after launch, a portion of the micrometeoroid shield and one solar panel were torn off, and the other solar panel was jammed closed. Launched May 14, 1973, with a two-stage Saturn V.

Skylab 2. An Apollo CSM spacecraft carried three astronauts to an orbital rendezvous with Skylab for its first occupancy. Crew repaired the damaged vehicle in orbit, checked its habitability, and began series of scientific experiments and observations of earth and solar system. Crew: Charles Conrad, Jr., Paul J. Weitz, Joseph P. Kerwin. Launched May 25, 1973, with a Saturn IB. Duration: 28 days.

Skylab 3. An Apollo CSM spacecraft carried the second crew to Skylab. The astronauts continued the experiments and observations of the first crew, and started new ones. Crew: Alan L. Bean, Jack R. Lousma, Owen K. Garriott. Launched July 28, 1973, with a Saturn IB. Duration: 59.5 days.

Skylab 4. The third and last Skylab crew traveled to and from Skylab in an Apollo CSM spacecraft. The crew's work with experiments and observations was so successful that the mission was extended 4 weeks. Crew returned with 20,500 photographs of earth and 47 kilometers (29 miles) of data on recording tape. Crew: Gerald P. Carr, William R. Pogue, Edward G. Gibson. Launched November 10, 1973, with a Saturn IB. Duration: 84 days.

Apollo-Soyuz Test Project. World's first international manned space mission, linking an Apollo CSM spacecraft and a Soviet Soyuz spacecraft in earth orbit to test rendezvous and docking techniques and conduct joint experiments. Crew: Thomas P. Stafford, Donald K. Slayton, Vance D. Brand. This last use of the Apollo spacecraft took place July 15, 1975.

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ASME History and Heritage Program

The ASME History and Heritage Recognition Program began in September 1971. To implement and achieve its goals, ASME formed a History and Heritage Committee, initially composed of mechanical engineers, historians of technology, and (ex-officio) the curator of mechanical engineering at the Smithsonian Institution. The committee provides a public service by examining, noting, recording, and acknowledging mechanical engineering achievements of particular significance.

The Apollo spacecraft is the 36th International Historic Mechanical Engineering Landmark to be designated. Since the ASME History and Heritage Program began, 151 Historic Mechanical Engineering Landmarks, 6 Mechanical Engineering Heritage Sites, and 3 Mechanical Engineering Collections have been recognized. Each reflects its influence on society in its immediate locale, nationwide, or throughout the world.

An ASME Landmark represents a progressive step in the evolution of mechanical engineering. Site designations note an event or development of clear historical importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The ASME History and Heritage Program illuminates our technological heritage and serves to encourage the preservation of the physical remains of historically important works. It provides an annotated roster for engineering students, educators, historians, and travelers. It helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

The History and Heritage Committee is part of the ASME Council on Public Affairs and the Board of Public Information. For further information, please contact the Public Information Department, American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017, (212) 705-7740.

INTERNATIONAL HISTORIC MECHANICAL ENGINEERING LANDMARK

APOLLO COMMAND MODULE
1968-1972

Apollo was the vehicle that first transported humans to the moon and safely back to earth. Nine lunar flights were made between 1968 and 1972. The command module, built by North American Aviation (at the time of launch, North American Rockwell Corporation), accommodated three astronauts during the mission.
It was the only portion of the Apollo spacecraft system designed to withstand the intense heat of atmospheric reentry at 25,000 mph and complete its mission intact. This command module flew as Apollo 14 in 1971.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
1992

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