National Aeronautics and
Space Administration

# Information Summaries

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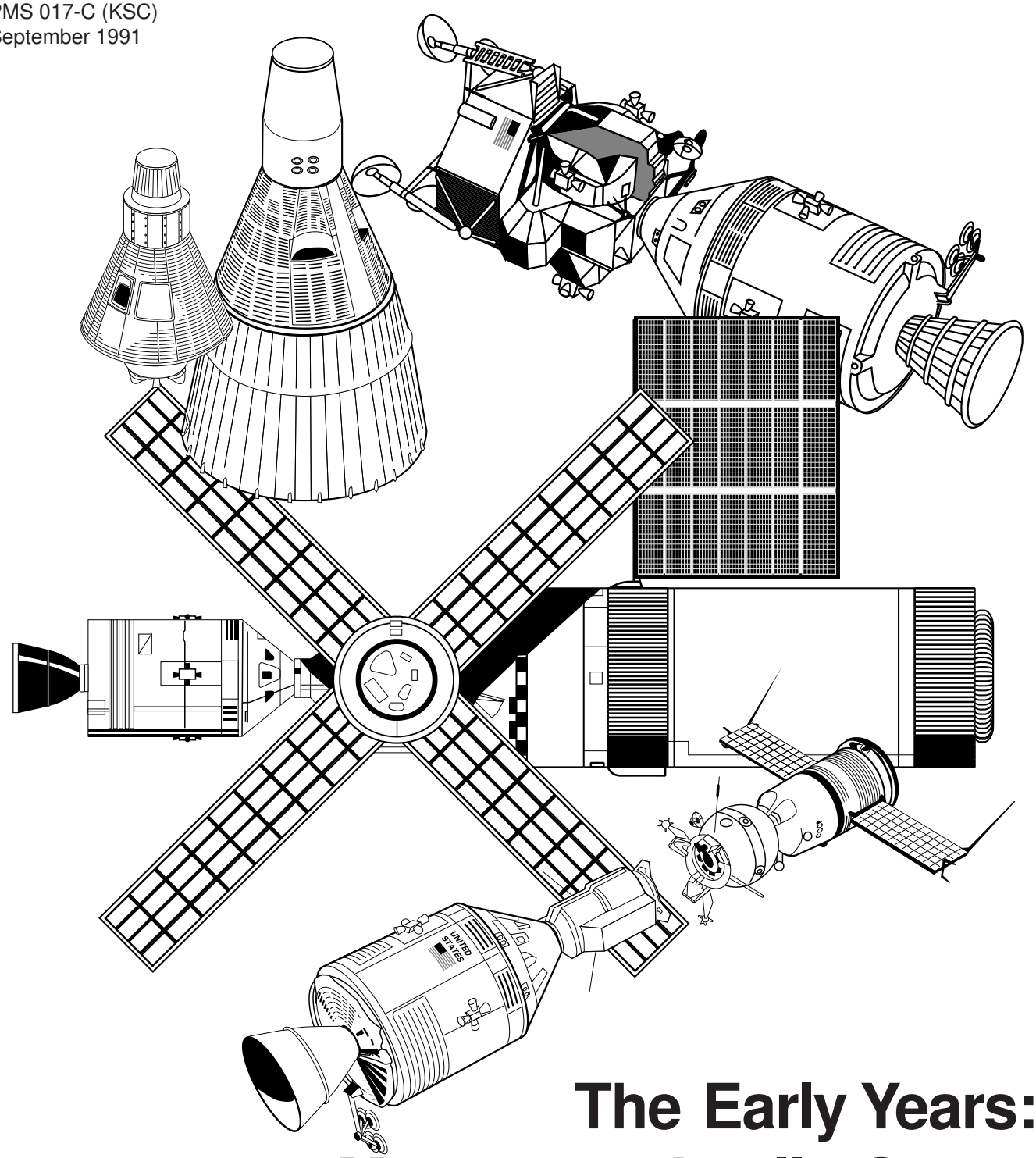
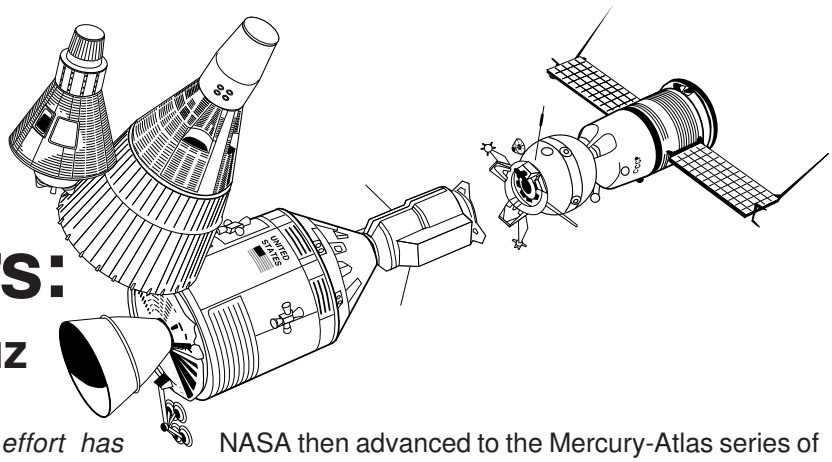



## The Early Years: Mercury to Apollo-Soyuz



# The Early Years:

## Mercury to Apollo-Soyuz

*The United States manned space flight effort has progressed through a series of programs of ever increasing scope and complexity. The first Mercury launch from a small concrete slab on Complex 5 at Cape Canaveral required only a few hundred people. The launch of Apollo 11 from gigantic Complex 39 for man's first lunar landing engaged thousands. Each program has stood on the technological achievements of its predecessor. The complex, sophisticated Space Shuttle of today, with its ability to routinely carry six or more people into space, began as a tiny capsule where even one person felt cramped — the Mercury Program.*

### Project Mercury

Project Mercury became an official program of NASA on October 7, 1958. Seven astronauts were chosen in April, 1959, after a nationwide call for jet pilot volunteers. Project Mercury was assigned two broad missions by NASA-first, to investigate man's ability to survive and perform in the space environment; and second, to develop the basic space technology and hardware for manned spaceflight programs to come.

The one-man Mercury spacecraft was designed and built with a maximum orbiting mass of about 1,451.5 kilograms (3,200 pounds). Shaped somewhat like a bell, the craft was 189.2 centimeters (74.5 inches) wide across the bottom and about 2.7 meters (nine feet) tall. The astronaut escape tower added another 5.2 meters (17 feet) for an overall length of approximately 8 meters (26 feet) at launch. Two boosters were chosen — the Army Redstone with 346,944 newtons (78,000 pounds) thrust for the suborbital flights and the Air Force Atlas with 1,601,280 newtons (360,000 pounds) thrust for the orbital missions.

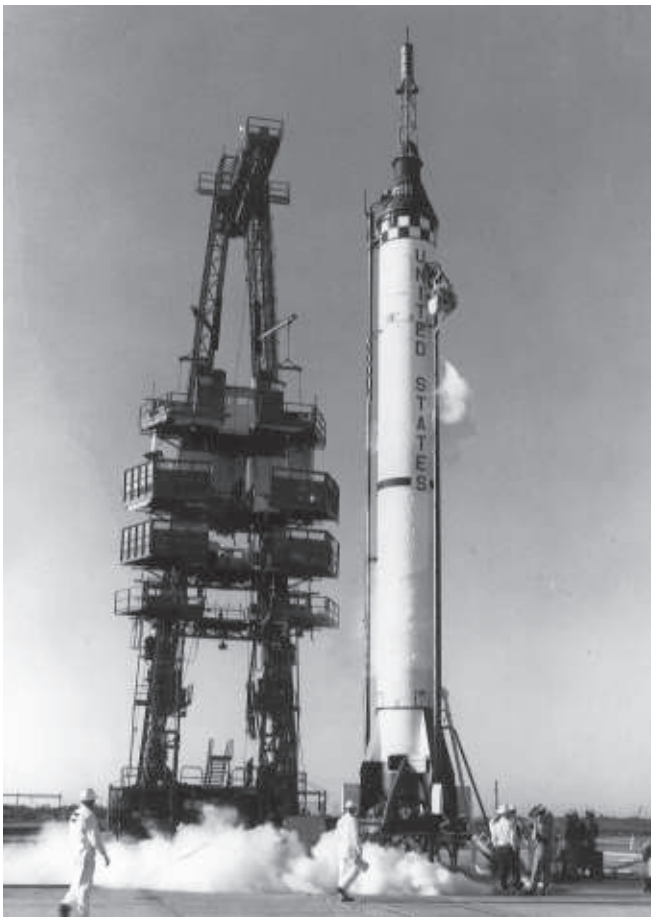
On May 5, 1961, Astronaut Alan B. Shepard, Jr., was launched from Complex 5 at Cape Canaveral by a Redstone Booster on the first U.S. manned space flight. His suborbital mission of 15 minutes took his Freedom 7 spacecraft 186.7 kilometers (116 miles) high into space.

On July 21, 1961, a Redstone booster hurled Astronaut Virgil I. "Gus" Grissom through the second and last suborbital flight in the Liberty Bell 7.

NASA then advanced to the Mercury-Atlas series of orbital missions. Another space milestone was reached on February 20, 1962, when Astronaut John H. Glenn, Jr., became the first American in orbit, circling the Earth three times in Friendship 7.

On May 24, 1962, Astronaut N. Scott Carpenter in Aurora 7 completed another three-orbit flight.

Astronaut Walter N. Schirra, Jr., doubled the flight time in space and orbited six times, landing Sigma 7 in a Pacific recovery area. All prior landings had been in the Atlantic.




*Preparations for the launch of Alan Shepard aboard a Redstone rocket from Complex 5 at Cape Canaveral.*

*An Atlas rocket launched Astronaut John Glenn in a Mercury spacecraft from Complex 14 at Cape Canaveral on NASA's first Earth orbital flight.*

Finally, on May 15-16, 1963 Astronaut L. Gordon Cooper, Jr., completed a 22-orbit mission of 34-1/2 hours in Faith 7, triumphantly concluding the $392.6 million Project Mercury program.

## Project Gemini

The Gemini spacecraft was designed to be piloted by two astronauts and consisted of two major portions — the re-entry module and the adapter module. Only the re-entry module, containing the life-support cabin where the astronauts rode, returned to Earth. It was comprised of a double-walled inner shell around the crew's pressurized compartment, with an outer shell as the craft's external hull. The adapter module had two separate sections, so that Gemini, as launched, was actually a three-part structure. One purpose of the two-part adapter module was to fit the narrow Gemini capsule to the broader top of the booster. It also contained attitude controls, propellant tanks, electrical components and other support equipment. The section adjacent to the crew's re-entry module included two sets of engines — retro-rockets and space-maneuvering thrusters.

The Gemini spacecraft was similar to but heavier than the Mercury, and the Redstone and Atlas boosters lacked the power to place it in orbit. A modified version of the military Titan II was chosen as the Gemini Launch Vehicle. With a first stage thrust of 1,912,640 newtons (430,000 pounds), the rocket used hypergolic, or self-igniting, propellants, which were non-explosive and an added astronaut safety factor. The Titan II rocket was three meters (10 feet) wide and 27.1 meters (89 feet) long. The combined Gemini-Titan stood 32.9 meters (108 feet) high.

Chosen for Gemini's orbital rendezvous and docking was the Agena-D target vehicle, a modified version of the Agena-B second stage that, with Thor or Atlas boosters, had orbited many satellites and launched Mariner and Ranger space probes. The Agena's stop-and-restart engine, capable of cutoff and reignition at least four times, was important for planned maneuvers with the Gemini capsule. The Agena-D was 9.75 meters (32 feet) long and 1.5 meters (five feet) in diameter, with a cylindrical shape.

There was a total of 10 manned Gemini flights, four of which rendezvoused with an Agena stage. A rendezvous mission generally called for launching an Atlas/Agena target vehicle from Complex 14 at Cape Canaveral, then the Gemini liftoff from Complex 19.

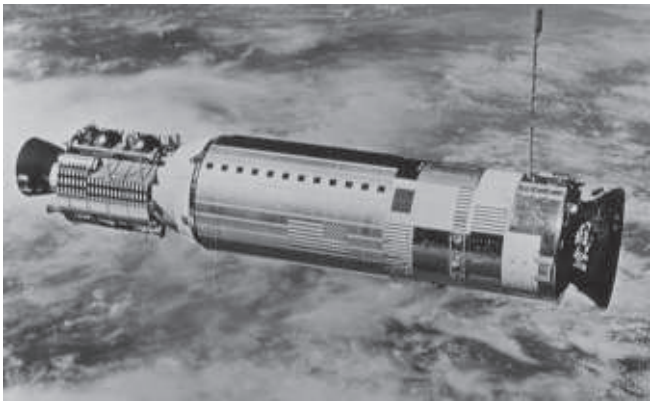
The Agena was propelled into a circular orbit 298 kilometers (185 miles) up, after which precise velocity and trajectory elements were calculated. The Gemini would then be launched into a lower orbit. By traveling a shorter distance it would catch up with the Agena.

When the distance between the vehicles was 402 kilometers (250 miles) radar was switched on. As the gap closed to 80.5 kilometers (50 miles), the astronauts picked up the Agena's flashing beacon and took manual control of Gemini to maneuver it into position.

During rendezvous maneuvers the relative speed between the vehicles was cut to less than 3.2 kilometers (2 miles) per hour, so that when docking their noses touched gently.

On contact, the Gemini's narrow end entered the Agena's target docking adapter. The adapter's latches clamped shut to prevent the two vehicles from slipping apart. Then a motorized Agena unit pulled the Gemini inward. Matching electrical contacts met and gave the astronauts direct control of the Agena's onboard equipment.

From the first unmanned Gemini flight on April 8, 1964, to the final manned flight ending November 15, 1966, Gemini flight time totaled 974 hours 37 minutes 42 seconds. Of this, 969 hours 51 minutes 26 seconds were manned. The astronauts spent a total of 12 hours 12 minutes in extravehicular activity (EVA, or "space-walk activities").



*The Agena Target Docking Vehicle as seen from the Gemini 12 spacecraft during rendezvous.*

The highest altitude reached by the manned Gemini spacecraft — a world's record at that time — was 1,372.8 kilometers (853 miles) during the Gemini 11 mission.

Orbital rendezvous was accomplished 10 times; docking 9 times. Docking was first accomplished on March 16, 1966, during Gemini 8, and was another Gemini "space first." Also, Gemini and Agena, linked by a tether, orbited Earth for over four hours in a station-keeping exercise aimed at saving maneuvering fuel. Project Gemini was undertaken at a cost of $1.3 billion.

## Project Apollo

Initial planning for a rocket having a high payload capability began in April, 1957. In August, 1958, studies concluded that a clustered booster of 6,672,000 newtons (1.5 million pounds) thrust was feasible, and the research and development effort began. Initial results validated the engine clustering technique, using existing hardware. The planned vehicle was designated the Saturn I.

Rocketdyne, a division of North American Rockwell Corporation (now Rockwell International), uprated the Thor-Jupiter engine and increased its thrust, thus developing the 889,600-newton (200,000-pound) thrust H-1 engine. Concurrently, from advanced studies, the heavy-thrust F-1 engine was conceived, and subsequently used as the power plant for even larger boosters.

In July, 1960, NASA first proposed publicly a post-Mercury program for manned flight and designated it Project Apollo. The Apollo goals envisioned at the time were Earth-orbital and circumlunar flights of a three-man spacecraft.

During 1960, Douglas Aircraft Company (now McDonnell Douglas) was selected to build the Saturn I second stage (S-IV) and Rocketdyne was chosen to develop the hydrogen-fueled J-2 engine for future upper stages of the Saturn vehicles.

On May 25, 1961, President John F. Kennedy proposed to Congress that the United States accelerate its space program, establishing as a national goal a manned lunar landing and return by the end of the decade. In his report to Congress President Kennedy said:

"Now is the time... for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth."

With endorsement by Congress, the national objective of manned lunar exploration created an immediate need for a considerably more powerful booster.

In January, 1962, NASA announced the planned development of the largest rocket vehicle ever to fly, the mammoth Saturn V. Contracts were awarded to the Boeing Company for the first stage and North American Rockwell for the second stage. The third stage, called the S-IVB, already was under development by Douglas Aircraft Corporation, with its first flights scheduled on top of the Saturn I.

The Saturn V first stage was to use a cluster of five F-1 engines that would generate 33,360,000 newtons (7.5 million pounds) of thrust. The second stage utilized a cluster of five J-2 engines that developed a combined thrust of 4.4 million newtons (one million pounds). The third stage was powered by a single J-2 engine with 889,600 newtons (200,000 pounds) thrust capability. IBM already had started the development of the instrument unit for the Saturn V.

*Ten Gemini Earth orbital missions were launched from Complex 19 using the Titan II rocket.*

Later in 1962, NASA announced it was developing the Saturn IB, which combined the first stage of the Saturn 1 and the third stage of the Saturn V. This vehicle would perform Earth orbital tests of the Apollo spacecraft.

On August 9, 1961, the Massachusetts institute of Technology was selected to develop the Apollo spacecraft guidance and navigation system. Three and a half months later, NASA selected North American Rockwell for the Apollo spacecraft command and service module program.

In mid-July, 1962, NASA selected the lunar orbital rendezvous mode for the lunar mission. This called for development of a two-man lunar module, to be used for landing on the Moon and returning to lunar orbit. On November 7, 1962, Grumman Aircraft Engineering Corporation was selected to design and build the lunar module.

The first phase of the Saturn launch vehicle program was completed in 1965. In ten flights of the Saturn 1, ten were successful — an unprecedented record in rocket development. Much technology was proven in the Saturn I program. The rocket guidance system was developed, the concept of clustered rocket engines was validated, and more experience was gained in the use of liquid hydrogen as a fuel. Liquid hydrogen, previously used only in the Centaur stage, provides approximately 40 percent greater power than earlier fuels.

The new Saturn IB launch vehicle was successfully flown three times in three attempts in 1966. Two of these flights carried spacecraft which satisfactorily completed Apollo command and service module requirements for Earth orbital operations.

On January 27, 1967, tragedy struck the space program when a fire erupted inside an Apollo spacecraft during ground testing at Complex 34, resulting in the deaths of Astronauts Virgil Grissom, Edward White, II, and Roger Chafee. After two and a half months of investigation, involving 1,500 people, the Board of inquiry determined the most likely cause of the accident. Electrical arcing from the spacecraft wiring in a near-total oxygen environment induced a flash fire. After an extensive investigation by an Accident Review Board, NASA followed up with detailed descriptions of corrective actions, schedule modifications, and cost estimates necessary to get the program back on track.

On November 9, 1967, the first flight test of the Apollo/Saturn V space vehicle was successfully accomplished. Designated Apollo 4, the unmanned flight demonstrated excellent performance by the previously unflown first and second stages. It proved the restart-in-orbit capability of its third stage, the ability of the Apollo spacecraft to re-enter Earth's atmosphere at lunar mission return speeds, the overall performance of the integrated space vehicle, and the operational readiness of Kennedy Space Center Launch Complex 39. All mission objectives were met. The Saturn V placed a total weight of 126,418 kilograms (278,699 pounds) in orbit after a near-perfect countdown. The spacecraft heat shield performed satisfactorily during the 39,912 kilometer per hour (24,800 mph) plunge into Earth's atmosphere.

*Gemini 4 Astronaut Ed White made America's first space walk on June 3, 1965, during the third orbit of a four-day mission.*

During the two-day Apollo 5 mission in January, 1968, Lunar Module systems and structural performance of the spacecraft were demonstrated and all test objectives were met. This included two firings of both the ascent and descent propulsion systems. Post-flight analysis determined the Lunar Module to be ready for manned Earth orbital missions. Apollo 5 was launched aboard a Saturn IB from Launch Complex 37 on January 22, 1968.

On April 4, 1968, Apollo 6 became the second unmanned Saturn V mission to demonstrate launch vehicle and spacecraft performance. After its launch from Complex 39, vertical oscillations, or "Pogo" effect, occurred in the first stage, and some small propellant lines ruptured in upper stages. Otherwise, the mission was considered very successful.

The first manned Apollo launch, Apollo 7, was on a Saturn IB, and was the last launch from Complex 34. All subsequent Apollo launches were from Complex 39. Lifting off the pad on October 11, 1968, it was to become an 11-day flight. Apollo 7 ended with a precise re-entry and splashdown on October 22, and was called a "101 percent successful" mission. Manned by Astronauts Walter Schirra, Don Eisele, and Walt Cunningham, the spacecraft's performance in space was flawless, including eight firings of the spacecraft's primary propulsion system and the first live television broadcast from a manned space vehicle.

Apollo 8, with Astronauts Frank Borman, William

Anders, and James Lovell, Jr., lifted off on December 21, 1968. It was history's first manned flight from Earth to another planetary body. In 147 hours, Apollo 8 took its crew on a faultless, half-million-mile space flight, including ten lunar orbits, lunar and Earth photography and live television broadcasts.

Apollo 9 splashed down in the Atlantic Ocean, north of Puerto Rico on March 13, 1969, after a 10-day, 9.6-million kilometer (6-million mile) Earth orbital mission. All major mission objectives were met in the first five days of flight. Apollo 9 was the first all-up manned flight of the Apollo/Saturn V space vehicle, first manned flight of the Lunar Module, and first Apollo extravehicular activity. It included rendezvous and docking, live television, photographic surveys of Earth, and observation of the Pegasus II satellite and the planet Jupiter. This was the fourth Saturn V on-time launch (11:00 a.m. EST).

Apollo 10 successfully completed man's second lunar orbital flight, passing within 14.5 kilometers (nine miles) of the lunar surface in a dress rehearsal for the actual lunar landing mission. Launched on May 18, from pad 39B, Apollo 10 spent nearly 62 hours (31 revolutions) in lunar orbit, sent 19 live color TV transmissions, and splashed down within 6,400 meters (7,000 yards) of its primary recovery ship in the pacific Ocean, eight days and three hours after liftoff.

Apollo 11 attained the national goal, set by President Kennedy in 1961, of landing men on the Moon and returning them safely to Earth within the decade of the 1960's. The mission was launched precisely on time from Kennedy Space Center at 9:32 a.m. EDT, July 16, by a Saturn V. The Lunar Module touched down in the Moon's Sea of Tranquillity at 4:18 p.m. EDT, July 20, and Commander Neil Armstrong stepped onto the lunar surface at 10:56 p.m. EDT that evening, followed by Lunar Module pilot Edwin E. Aldrin, Jr. Astronaut Michael Collins, the Command Module pilot, orbited above, conducting scientific experiments and taking photographs. Their activities were viewed live around the world by the largest television audience in history. The returning spacecraft splashed down in the Pacific, southwest of Hawaii, at 12:51 p.m. EDT, July 24, after a flight of 8 days 3 hours 19 minutes. Scientific instruments were left on the Moon, and samples of the Moon's soil and rocks along with still and motion pictures were brought back to Earth.

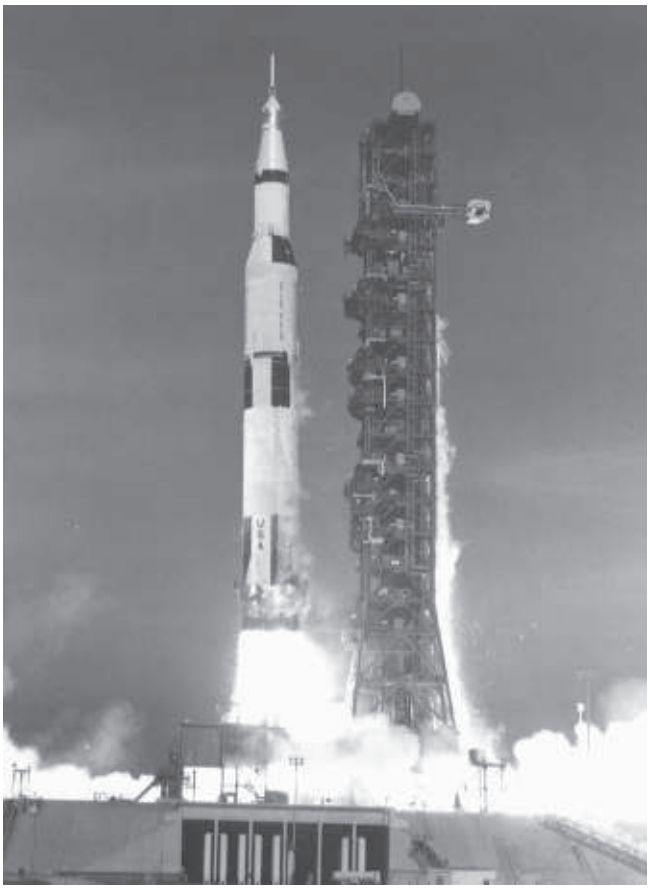
Four months after the Apollo 11 landing, Apollo 12 repeated the journey, landing and exploring at the Ocean of Storms. The Apollo 12 mission, launched November 14, 1969, demonstrated the ability to land at a selected point. The astronauts installed the first Apollo Lunar Surface Experiments Package on the surface, for continued science reporting after the departure of the astronauts. Two extravehicular activity periods were completed, which included experiments emplacement, field geology investigation, and inspection of the Surveyor III lunar lander launched in 1967.

Apollo 13 was launched April 11, 1970, to land on the Fra Mauro upland area of the Moon. A rupture of the Service Module oxygen tank at 10:11 p.m. EST, April 13, caused a power failure of the Command and Service Module electrical system which prevented the lunar landing. The crew used the Lunar Module as their command post and living quarters for the remainder of the flight. The Lunar Module descent engine provided propulsion to make corrections in the flight path which sent the spacecraft around the Moon on a free-return trajectory for re-entry and splashdown in the Pacific Ocean on April 17.

The Apollo 13 Review Board announced on June 30 that a short circuit ignited electrical insulation in the spacecraft oxygen tank Number 2, causing failure of the tank. The Board recommended the command and service module systems be modified to eliminate potential combustion hazards in high-pressure oxygen containers.

Apollo 14 was retargeted to accomplish the mission planned for Apollo 13. The spacecraft was launched at

*A Saturn IB rocket lifts Apollo 7 into Earth orbit from Complex 34 at Cape Canaveral. It was the first manned Apollo flight.*



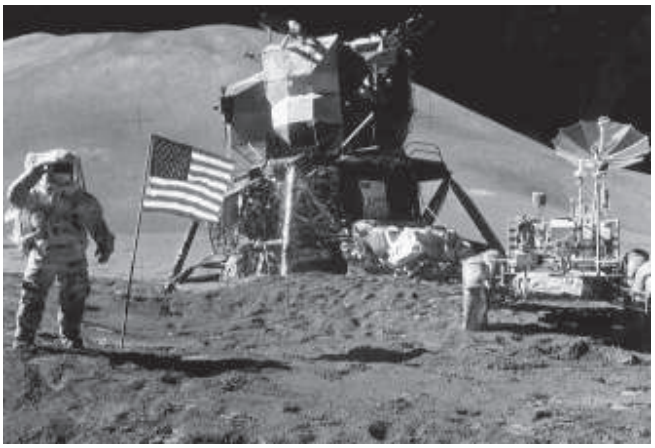
*The Saturn V, largest and most powerful rocket vehicle ever built, lifting off from Complex 39 at the Kennedy Space Center.*

4:03 p.m. EST Sunday, January 31, 1971, and the Lunar Module touched down on the Moon at 4:17 a.m. EST February 5, within 18.3 meters (60 feet) of the targeted point on the Fra Mauro formation. The astronauts successfully carried out two periods of extravehicular activity on the lunar surface; the first for 4 hours 50 minutes and the second for 4 hours 35 minutes, totaling 9 hours 25 minutes. They successfully deployed and activated the experiments package, the second set of geophysical instruments to transmit data on the Moon's interior and exterior environment to Earth. In addition, they collected 43.5 kilograms (96 pounds) of lunar rocks and soil, which included two rocks weighing 4.5 kilograms (10 pounds) each, the largest obtained to date. After spending 33-1/2 hours on the Moon, the Lunar Module lifted off the surface at 1:47 p.m. EST Saturday, February 6, 1971. The return flight was normal and the spacecraft landed in the South Pacific Ocean at 4:05 p.m. EST February 9, 1971.

The fourth lunar landing mission, Apollo 15, was launched Monday, July 26, 1971. Modifications to the spacecraft permitted longer lunar surface stay time and additional scientific instruments in lunar orbit. On July 30, at 6:16 p.m. EDT, the astronauts landed at the Hadley Apennine site. During their 66-hour 55-minute stay on the Moon they explored the lunar surface, riding the first Lunar Rover vehicle, for a total of 18 hours 36 minutes; collected approximately 77 kilograms (170 pounds) of surface samples; deployed geophysical instruments; and described geological features. In the Command Module, extensive scientific experiments were conducted while orbiting the Moon, including the operation of two cameras and gamma ray and X-ray sensors mounted on the Service Module. After 74 lunar revolutions and ejection of a subsatellite, the spacecraft began its homeward journey. Camera film canisters were retrieved by the Command Module pilot from outside the spacecraft during the trans-Earth coast. The Pacific Ocean landing was made on August 7, 1971.

Apollo 16, the fifth lunar landing mission, was launched April 16, 1972. In all, the astronauts spent nearly 20-1/4 hours outside the Lunar Module — a new record. In lunar orbit, the Command Module pilot operated a complex array of scientific instruments; two lunar mapping cameras observed geological features on the surface. Once again, a scientific subsatellite was placed in lunar orbit before the trans-Earth maneuver was performed. On the Earthbound trip the film canisters were retrieved from the lunar cameras outside the Command Module. The spacecraft splashed down in the Pacific Ocean on April 27. The astronauts had returned approximately 95.3 kilograms (210 pounds) of Moon rocks and soil samples to Earth from the Descartes highlands.

The final Apollo mission, Apollo 17, was launched December 7, 1972. On the 12-day mission the astronauts explored the Taurus-Littrow landing site, emplaced geophysical instruments, and collected over 108 kilograms (240 pounds) of samples. The total surface time outside the Lunar Module was 22 hours and 4 minutes, exceeding by almost two hours the previous record held by Apollo 16. The Command Module pilot again operated scientific instruments and cameras in lunar orbit, then retrieved the



*Standing on the Moon, Apollo 15 Astronaut James Irwin salutes the flag alongside the Lunar Module and Lunar Rover.*

camera film during a 1-hour, 6-minute space walk en route back to Earth. Splashdown in the Pacific occurred December 19, 1972.

Apollo program costs were approximately $25 billion.*

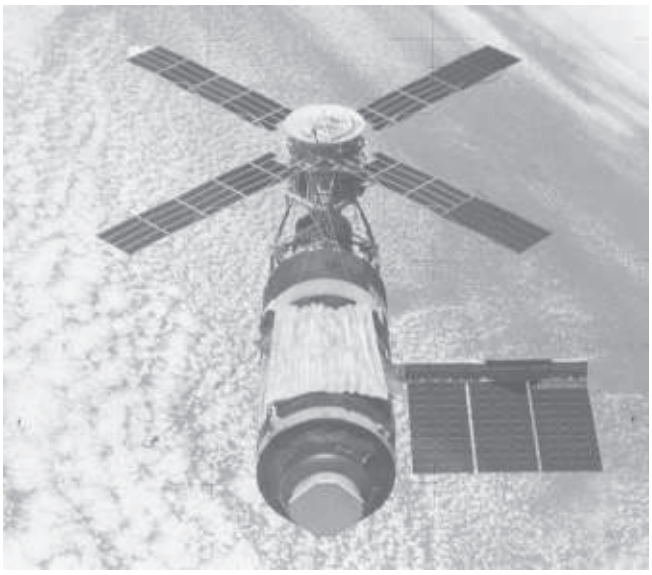
## Skylab

There were four launches in the Skylab Program from Complex 39 at the Kennedy Space Center. The first launch was on May 14, 1973 at 1:30 p.m. A two-stage Saturn V placed the unmanned 90-metric ton (100-ton) Skylab space station in a 434.5-kilometer (270-mile) Earth orbit. As the rocket accelerated past 7,620 meters (25,000 feet), atmospheric drag began clawing at Skylab's meteoroid shield. This cylindrical metal shield was designed to protect the orbital workshop from tiny space particles and the Sun's scorching heat. Sixty-three seconds after launch the shield ripped away from the lab, trailing an aluminum strap which caught on the unopened solar wing. The shield became tethered to the lab while at the same time prying the opposite wing partly open. Minutes later, as the rocket staged, the partially deployed wing and shield were flung into space. With the loss of the shield, temperatures inside Skylab soared, rendering the space station uninhabitable and threatening foods, medicines, and films. The Apollo Telescope Mount, the major item of scientific equipment, did deploy properly, which included unfolding its four solar panels.

The countdown for the launch of the first Skylab crew was halted. In Houston, engineers worked to devise a solar parasol to cover the workshop, and to find a way to free the remaining stuck solar wing. On May 25 astronauts Charles "Pete" Conrad, Jr., Dr. Joseph P. Kerwin, and Paul J. Weitz, were launched toward Skylab.

After repairing Skylab's broken docking mechanism, which had refused to latch, the astronauts entered the Skylab and erected the mylar parasol through a space access hatch. It shaded part of the area where the protective meteoroid shield had been ripped away. Temperatures immediately began dropping, and Skylab soon became habitable without space suits. But the many experiments on board demanded far more energy than the four telescope solar panels could generate. Only if the crew freed the crippled solar wing could Skylab fulfill its scientific mission. Using equipment that resembled long-handled pruning shears and a prybar, they pulled the stuck wing free. Skylab was now ready to meet its objectives.

The duration of the first mission was 28 days 49 minutes. The second crew was launched July 28; mission duration was 59 days 11 hours 9 minutes. The astronauts were Alan Bean, Jack Lousma and Dr. Owen Garriott. The third crew was launched November 16; mission duration was 84 days 1 hour 16 minutes. Crew members were Gerald Carr, William Pogue, and Dr. Edward Gibson. Saturn IB rockets launched all three crews in modified Apollo spacecraft.



*Skylab, orbiting 270 miles above the Earth, was both workshop and home for three teams of astronauts. The Skylab space station was inhabited for a total of 171 days.*

When the third and final manned Skylab mission ended with splashdown in the Pacific February 8, 1974, the three crews had traveled 113.5 million kilometers (70.5 million miles) over the 171 days 13 hours 14 minutes they had spent orbiting the Earth. They had circled the Earth 2,476 times, during which they spent over 3,000 hours conducting eight categories of experiments. Space-walk time totaled 41 hours 46 minutes. Data returned included 175,047 frames of solar-observation film and 46,146 frames of Earth-observation film. Approximately 72,725 meters (238,600 feet) of magnetic tape of Earth observations also were returned. A highlight of the third mission was extensive observation and photography of Comet Kohoutek. This mission of over 84 days increased the previous record length in space set by the second Skylab crew by about 50 percent.

The Skylab space station re-entered the Earth's atmosphere at 12:37 p.m. EDT, July 11, 1979, near southeastern Australia. After over six years in space, the demise of the orbital workshop came on its 34,981st orbit. Skylab program costs totaled $2.6 billion.

## Apollo-Soyuz Test Project (ASTP)

The $250 million Apollo-Soyuz mission was successfully completed on July 24, 1975. In a fitting conclusion to the Apollo flights, operation of the Saturn IB launch vehicle was flawless and the spacecraft had the fewest in-flight anomalies of any Apollo flown. The

*Includes rockets, engines, spacecraft, tracking and data acquisition, operations, operations support, and facilities.

*The three manned Skylab missions and the Apollo-Soyuz Test Project (ASTP) were launched from Pad 39B using the Saturn IB rocket.*

scientific payload of 28 experiments supplied a rich harvest of data in many fields.

Both the Soyuz and Apollo spacecraft were launched on July 15, 1975; the Apollo lifted off approximately 7-1/2 hours after Soyuz. The Soyuz maneuver to the planned orbit for docking was successfully completed over Europe on the 17th orbit, at an altitude of 222 kilometers (138 miles.) The Apollo crew completed the rendezvous sequence as planned; docking with Soyuz was accomplished on July 17 when the Apollo spacecraft was gradually piloted toward the orbiting Soyuz. During the next two days, the crews accomplished four transfer operations between the two spacecraft and completed five scheduled experiments. In addition, the crews provided television views of the interior of the two spacecraft, and demonstrated various aspects of space operations.

This mission marked the first time that voice, TV, and telemetry were relayed between an orbiting Apollo spacecraft and the ground via the ATS-6 communications satellite. This new technique more than tripled the communications coverage otherwise available. Following the first undocking, a joint solar eclipse experiment was performed. Then Apollo performed a second docking, this time with the Soyuz apparatus locking the two spacecraft together. The final undocking occurred on July 19. The two spacecraft were moved to a station-keeping distance and a joint ultraviolet absorption experiment was performed, involving a complicated series of orbital maneuvers. Afterward Apollo entered a separate orbit, and unilateral activities were conducted by both the Soyuz and Apollo crews. The Soyuz landed safely on July 21, after six mission days, and the Apollo flight was successfully concluded on July 24, 1975, nine days after launch. The primary objectives of the program were met, including rendezvous, docking, crew transfer, and control center-crew interaction. All objectives of the scientific experiments were completed. The unilateral portion of the Apollo flight was a full scientific mission in itself, and yielded significant results.

## Manned Spacecraft

**Mercury**
- Height: 2.9 meters (9.5 feet)
- Maximum Diameter: 1.9 meters (6.2 feet)
- Weight: 1,451 kilograms (3,200 pounds)
- Habitable Volume: 1.02 cubic meters (36 cubic feet)

**Gemini**
- Height: 5.5 meters (18 feet)
- Maximum Diameter: 3 meters (10 feet)
- Weight: 3,402 kilograms (7,500 pounds)
- Habitable Volume: 1.56 cubic meters (55 cubic feet)

**Apollo**

*Command Module*
- Height: 3.5 meters (11.4 feet)
- Maximum Diameter: 3.9 meters (12.8 feet)
- Weight: 5,830 kilograms (12,850 pounds)
- Habitable Volume: 5.95 cubic meters (210 cubic feet)

*Service Module*
- Height: 7.5 meters (24.6 feet)
- Diameter: 3.9 meters (12.8 feet)
- Weight: 24,550 kilograms (54,120 pounds)

*Lunar Landing Module*
- Height: 7 meters (23 feet) legs extended
- Diameter: 9.4 meters (31 feet) across legs

- Weight: 3,900 kilograms (8,600 pounds)
- Habitable Volume: 4.5 cubic meters (158.8 cubic feet)

**Skylab Space Station**

*Total Cluster (Orbital Workshop, Apollo Command/ Service Modules, Airlock, Multiple Docking Adapter, Apollo Telescope Mount, Solar Arrays, Payload Shroud)*

- Length: 35.5 meters (117 feet)
- Maximum Diameter: 27.5 meters (90 feet) across Solar Arrays
- Weight: 90,606 kilograms (199,750 pounds)
- Habitable Volume: 360 cubic meters (12,711 cubic feet)

**Workshop Only**

- Length: 14.6 meters (48 feet)
- Diameter: 6.7 meters (22 feet)
- Weight: 35,380 kilograms (78,000 pounds)
- Habitable Volume: 275 cubic meters (9,710 cubic feet)

**Manned Space Launch Vehicles**

**Mercury-Redstone**

- Height: 25.3 meters (83 feet)
- Weight: 28,123 kilograms (62,000 pounds)
- Thrust: 346,944 newtons (78,000 pounds)
- Propellants: ethyl alcohol, water, liquid oxygen

**Mercury-Atlas**

- Height: 29 meters (95 feet)
- Weight: 117,900 kilograms (259,920 pounds)
- Thrust: 1,601,280 newtons (360,000 pounds)
- Propellants: RP-1 (refined kerosene), liquid oxygen

**Gemini-Titan II**

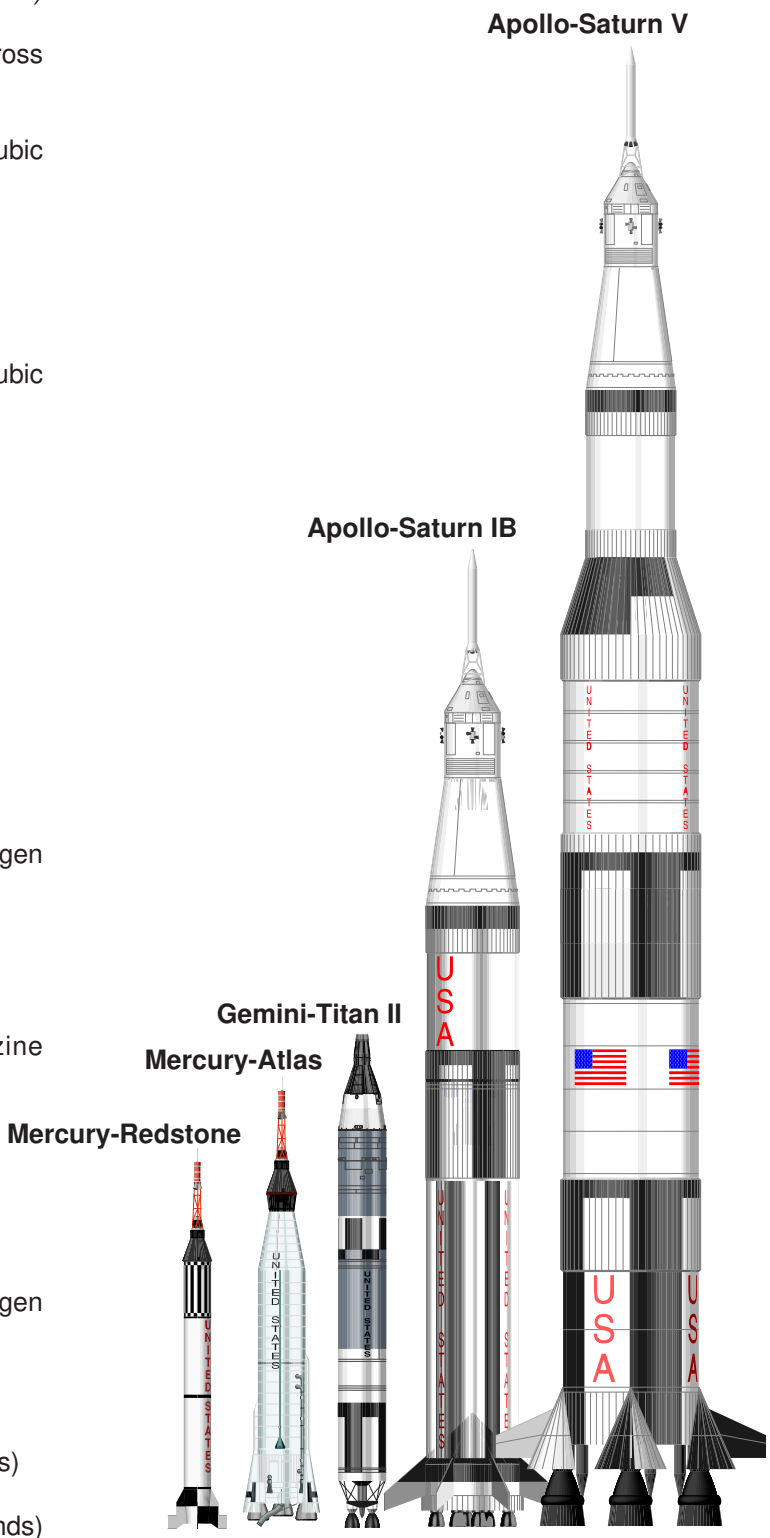
- Height: 32.9 meters (108 feet)
- Weight: 136,080 kilograms (300,000 pounds)
- Thrust: 1,912,640 newtons (430,000 pounds)
- Propellants: unsymmetrical dimethylhydrazine (UDMH), nitrogen tetroxide

**Apollo-Saturn IB**

- Height: 68 meters (223 feet)
- Weight: 544,320 kilograms (1,200,000 pounds)
- Thrust: 7,116,800 newtons (1,600,000 pounds)
- Propellants:
  *First Stage* - RP-1 (refined kerosene), liquid oxygen
  *Second Stage* - liquid hydrogen, liquid oxygen

**Apollo-Saturn V**

- Height: 110.6 meters (363 feet)
- Weight: 2,812,320 kilograms (6,200,000 pounds)
- Thrust:
  *First Stage* - 33,360,000 newtons (7,500,000 pounds)
  *Second Stage* - 4,448,000 newtons (1,000,000 pounds)
  *Third Stage* - 889,600 newtons (200,000 pounds)
- Propellants:
  *First Stage* - RP-1 (refined kerosene), liquid oxygen
  *Second Stage* - liquid hydrogen, liquid oxygen
  *Third Stage* - liquid hydrogen, liquid oxygen



## Information Summaries

| Program[1] | Date(s)/ Recovery Ship[2] | Crew | Mission Duration[3] | Remarks[4] |
|---|---|---|---|---|
| **Mercury** | | | | |
| Mercury Redstone 3 (Freedom 7) | May 5, 1961 Lake Champlain (A) | Navy Comdr. Alan B. Shepard, Jr. | 0:15:22 | suborbital |
| Mercury Redstone 4 (Liberty Bell 7) | July 21, 1961 Randolph (A) | USAF Maj. Virgil I. Grissom | 0:15:37 | suborbital |
| Mercury Atlas 6 (Friendship 7) | Feb. 20, 1962 Noa (A) | Marine Lt. Col. John H. Glenn | 4:55:23 | 3 orbits |
| Mercury Atlas 7 (Aurora 7) | May 24, 1962 Pierce (A) | Navy Lt. Comdr. Scott Carpenter | 4:56:05 | 3 orbits |
| Mercury Atlas 8 (Sigma 7) | Oct. 3, 1962 Kearsarge (P) | Navy Comdr. Walter M. Schirra, Jr. | 9:13:11 | 6 orbits |
| Mercury Atlas 9 (Faith 7) | May 15-16, 1963 Kearsarge (P) | USAF Maj. L. Gordon Cooper | 34:19:49 | 22 orbits |
| **Gemini** | | | | |
| Gemini 3 (Molly Brown) | March 23, 1965 Intrepid (A) | USAF Maj. Virgil I. Grissom<br>Navy Lt. Comdr. John W. Young | 4:53 | 3 orbits |
| Gemini 4 | June 3-7, 1965 Wasp (A) | USAF Majors James A. McDivitt and Edward H. White, II | 97:56 | 62 orbits; first U.S. EVA (White) |
| Gemini 5 | Aug. 21-29, 1965 Lake Champlain (A) | USAF Lt. Col. L. Gordon Cooper<br>Navy Lt. Comdr. Charles Conrad, Jr. | 190:55 | 120 orbits |
| Gemini 7 | Dec. 4-18, 1965 Wasp (A) | USAF Lt. Col. Frank Borman<br>Navy Comdr. James A. Lovell, Jr. | 330:35 | Longest Gemini flight; rendezvous target for Gemini 6; 206 orbits |
| Gemini 6 | Dec. 15-16,1965 Wasp (A) | Navy Capt. Walter M. Schirra, Jr.<br>USAF Maj. Thomas P. Stafford | 25:51 | Rendezvoused within 1 ft. of Gemini 7; 16 orbits |
| Gemini 8 | Mar. 16, 1966 L. F. Mason (P) | Civilian Neil A. Armstrong<br>USAF Maj. David R. Scott | 10:41 | Docked with unmanned Agena 8; 7 orbits |
| Gemini 9A Agena | June 3-6, 1966 | USAF Lt. Col. Thomas P. Stafford | 72:21 | Rendezvous (3) with |
| | Wasp (A) | Navy Lt. Col. Eugene A. Cernan | | 9; one EVA; 44 orbits |
| Gemini 10 | July 18-21,1966 Guadalcanal (A) | Navy Comdr. John W. Young<br>USAF Maj. Michael Collins | 70:47 | Docked with Agena 10; rendezvoused with Agena 8; two EVAs; 43 orbits |
| Gemini 11 | Sept. 12-15, 1966 Guam (A) | Navy Comdr. Charles Conrad, Jr.<br>Navy Lt. Comdr. Richard F. Gordon, Jr. | 71:17 | Docked with Agena 11 twice; first tethered flights; two EVAs; highest altitude in Gemini program; 853 miles; 44 orbits |
| Gemini 12 | Nov. 11-15, 1966 Wasp (A) | Navy Capt. James A. Lovell, Jr.<br>USAF Maj. Edwin E. Aldrin, Jr. | 94:35 | Three EVAs total 5 hrs. 30 min.; 59 orbits |

Notes:
1. Names in parentheses are crew names for spacecraft and Lunar Modules 2. (A) or (P) denotes Atlantic or Pacific Ocean splashdown
3. Hours and minutes, except for Skylab 4. EVA refers to extravehicular activity, or activity outside the spacecraft; LM refers to Lunar Module

## Information Summaries

### Apollo

| | | | | |
|---|---|---|---|---|
| Apollo 1 | Jan. 27. 1967 | USAF Lt. Col. Virgil I. Grissom<br>USAF Lt. Col. Edward H. White, II<br>Navy Lt. Comdr. Roger Chafee | | Planned as first manned Apollo Mission; fire during ground test on 1/27/67 took lives of astronauts; post-humously designated as Apollo 1[5] |
| Apollo 4 | Nov. 4, 1967<br>Bennington (P) | Unmanned | 9:37 | First flight of Saturn V launch vehicle. Placed unmanned Apollo command and service module in Earth orbit |
| Apollo 5 | Jan. 22, 1968 | Unmanned | 7:50 | Earth orbital flight test of unmanned Lunar Module. Not recovered |
| Apollo 6 | April 4, 1968<br>Okinawa (P) | Unmanned | 9:57 | Second unmanned test of Saturn V and Apollo |
| Apollo 7 | Oct. 11-22, 1968<br>Essex (A) | Navy Capt. Walter M. Schirra, Jr.<br>USAF Maj. Donn Eisele<br>Civilian Walter Cunningham | 260:08:45 | Tested Apollo Command Module in Earth orbit; 163 orbits |
| Apollo 8 | Dec. 21-27, 1968<br>Yorktown (P) | USAF Col. Frank Borman<br>Navy Capt. James A. Lovell, Jr.<br>USAF Lt. Col. William Anders | 147:00:11 | First manned Saturn V launch; 10 lunar orbits |
| Apollo 9<br>(Gumdrop and Spider) | March 3-13, 1969<br>Guadalcanal (A) | USAF Col. James A. McDivitt<br>USAF Col. David R. Scott<br>Civilian Russell L. Schweickart | 241:00:53 | Earth orbital mission; first manned flight of LM; two EVAs total 2 hrs. 8 min.; 151 orbits |
| Apollo 10<br>(Charlie Brown and Snoopy) | May 18-26, 1969<br>Princeton (P) | USAF Col. Thomas P. Stafford<br>Navy Comdr. John W. Young<br>Navy Comdr. Eugene E. Cernan | 192:03:23 | 31 lunar orbits; LM descended to within nine miles of lunar surface |
| Apollo 11<br>(Columbia, Eagle) | July 16-24, 1969<br>Hornet (P) | Civilian Neil Armstrong<br>USAF Lt. Col. Michael Collins<br>USAF Col. Edwin E. Aldrin, Jr. | 195:18:35 | First manned lunar landing; Sea of Tranquillity; one lunar EVA 2 hrs. 48 min.; 46 lbs. lunar samples |
| Apollo 12<br>two lunar<br>(Yankee Clipper<br>75 lbs.<br>and Intrepid) | Nov. 14-24, 1969<br>Hornet (P) | Navy Comdr. Charles Conrad, Jr.<br>Navy Comdr. Richard F. Gordon, Jr.<br>Navy Comdr. Alan L. Bean | 244:36:25 | Landed Ocean of Storms;<br>EVAs total 7 hrs. 46 min.<br>samples |
| Apollo 13<br>(Odyssey and Aquarius | April 11-17, 1970<br>Iwo Jima (P) | Navy Capt. James A. Lovell, Jr.<br>Civilian Fred W. Haise, Jr.<br>Civilian John L. Swigert, Jr. | 142:54:41 | Lunar landing aborted after oxygen tank ruptured; safe recovery |
| Apollo 14<br>(Kitty Hawk and Antares) | Jan. 31-<br>Feb. 9, 1971<br>New Orleans (P) | Navy Capt. Alan B. Shepard, Jr.<br>USAF Maj. Stuart A. Roosa<br>Navy Comdr. Edgar D. Mitchell | 216:02:01 | Landed Fra Mauro; two lunar EVAs total 9 hrs. 23 min.; 94 lbs. samples |
| Apollo 15<br>(Endeavour and Falcon) | July 26-<br>Aug. 71, 1971<br>Okinawa (P) | USAF Col. David R. Scott<br>USAF Lt. Col. James B. Irwin<br>USAF Maj. Alfred M. Worden | 295:12:00 | Landed Hadley Apennine; three lunar EVAs total 18 hrs. 46 min.; 169 lbs. samples |

Notes: 5. There were no missions designated as Apollo 2 and Apollo 3

## Information Summaries

| | | | | |
|---|---|---|---|---|
| Apollo 16 (Casper and Orion) | April 16-27, 1972 Ticonderoga (P) | Navy Capt. John W. Young<br>Navy Lt. Comdr. Thomas K. Mattingly, II<br>USAF Lt. Col. Charels M. Duke, Jr. | 265:51:06 | Landed Descartes highlands; three lunar EVAs total 20 hrs. 14 min., 213 lbs. samples |
| Apollo 17 (America and Challenger) | Dec. 7-19, 1972 Ticonderoga (P) | Navy Capt. Eugene A. Cernan<br>Navy Comdr. Ronald E. Evans<br>Civilian Harrison H. Schmitt (Ph.D.) | 301:51:59 | Landed Taurus-Littrow; three lunar EVAs total 22 hrs. 4 min.; 243 lbs. samples |

### Skylab

| | | | | |
|---|---|---|---|---|
| Skylab 1 | Launched May 14, 1973 | Unmanned | Re-entered atmosphere 7-11-79 on orbit 34,981 | 100-ton space station visited by three crews |
| Skylab 2 | May 25- June 22, 1973 Ticonderoga (P) | Navy Capt. Charles Conrad, Jr.<br>Navy Comdr. Paul J. Weitz<br>Navy Comdr. Joseph P. Kerwin (MD) | 28 days 49 min. 49 sec. | Repaired Skylab; 404 orbits; 392 experiment hours, three EVAs total 5 hrs. 34 min. |
| Skylab 3 | July 28- Sept. 25, 1973 New Orleans (P) | Navy Capt. Alan L. Bean<br>Marine Maj. Jack R. Lousma<br>Civilian Owen K. Garriott (Ph.D.) | 59 days 11 hrs. 9 min. 4 sec. | Performance maintenance, 858 orbits; 1,081 experiment hours; three EVAs total 13 hrs. 42 min. |
| Skylab 4 | Nov. 16, 1973- Feb. 8, 1974 New Orleans (P) | Marine Lt. Col. Gerald P. Carr<br>USAF Lt. Col. William R. Pogue<br>Civilian Edward G. Gibson (Ph.D.) | 84 days 1 hr. 15 min. 31 sec. | Observed Comet Kohoutek; 1,214 orbits; 1,563 experiment hours; four EVAs total 22 hrs. 25 min. |

### ASTP

| | | | | |
|---|---|---|---|---|
| Apollo-Soyuz Test Project | July 15,- July 24, 1975 New Orleans (P) | USAF Brig. Gen. Thomas P. Stafford<br>Civilian Vance D. Brand<br>Civilian Donald K. Slayton | 9 days 1 hr. 28 min. 24 sec. | Apollo docked with Soviet Soyuz spacecraft[6] July 17; separated July 19 |

Notes: 6. Flown by Cosmonauts Aleskey A. Leonov and Valeriy N. Kubasov; mission duration 5 days, 22 hours, 30 minutes, 54 seconds

# The Future of Manned Space Flight

The 2-million kilogram (4.5 million pound) Space Shuttle is the first vehicle designed to carry both crew and large unmanned applications and scientific spacecraft into orbit. The primary function of prior manned missions was the scientific exploration of the space environment, or the surface of the Moon. Large spacecraft, such as the many geosynchronous orbit communications and weather satellites, planetary explorers, or scientific research probes, were launched on unmanned vehicles. The Space Shuttle combines the weightlifting capacity of the largest unmanned launchers with the unmatched ability of an on-the-spot human being to make decisions and take actions.

No machine yet built can equal a trained astronaut at problem-solving in space, as the recovery and eventual success of the Skylab program amply demonstrated. Shuttle astronauts have repaired satellites in space and recovered others for more extensive repairs on the ground.

The Space Shuttle has flown with one crew of eight men and women, and seven crew members has been a common number. It has combined thrust at liftoff of about 28.6 million newtons (6.5 million pounds) from its two solid rocket boosters and the three liquid-propellant main engines on the orbiter. Its top capacity into low Earth orbit will be 29,500 kilograms (65,000 pounds) in its fully operational configuration. This can consist of one large payload; a combination of up to three spacecraft with attached solid stages for injection into higher orbits, along with smaller packages that remain with the orbiter, but must operate in the space environment; or a mixture of these types of payloads. The Space Shuttle is the only American vehicle designed for both manned spaceflight and delivering heavy payloads into Earth orbit that is expected to be available for the rest of this century.

*First (STS-1) liftoff of the Space Shuttle, April 12, 1981.*