Apollo Missions

Background

Test and Lunar Missions

Developement

Low Earth Orbit Missions

Reference Information
The Apollo Program (1963 - 1972) was designed to land humans on the Moon and bring them safely back to Earth.
- Six of the missions (Apollos 11, 12, 14, 15, 16, and 17) achieved this goal.
- Apollos 7 and 9 were Earth orbiting missions to test the Command and Lunar Modules, and did not return lunar data.
- Apollos 8 and 10 tested various components while orbiting the Moon, and returned photography of the lunar surface.
- Apollo 13 did not land on the Moon due to a malfunction, but also returned photographs.
- The six missions that landed on the Moon returned a wealth of scientific data and almost 882 lbs of lunar samples.
- Experiments included soil mechanics, meteoroids, seismic, heat flow, lunar ranging, magnetic fields, and solar wind experiments.

The Apollo Applications Program was established by NASA in 1968 to develop science-based manned space missions using hardware developed for the Apollo Program.
- When NASA’s 1969 budget was cut, focus shifted to the Skylab space station (right) proposal.
  -- Skylab, launched by an Apollo Saturn V, was the United States’ first space station orbiting Earth from 1973 to 1979.
  -- The Apollo Command and Service Module (CSM) carried the crews to and from Skylab.
- The Apollo-Soyuz Test Project in July 1975 was the first American/Soviet space mission that included docking an Apollo CSM with a Soyuz spacecraft.
When NASA awarded the initial Apollo contract to North American Aviation on November 28, 1961, they assumed the lunar landing would be achieved by direct descent rather than by lunar orbit rendezvous (LOR).

After the change to LOR (right) on June 11, 1962, NASA decided the most efficient way to keep the program on track was to proceed with the development in two versions:

- **Block I** would continue the preliminary design, to be used for early low Earth orbit test flights only.
- **Block II** would be LOR incorporating weight reduction and lessons learned in Block I.

-- Detailed design of the docking capability depended on the design of the Lunar Module, contracted to Grumman Aircraft Engineering.

On May 25, 1961, President John F. Kennedy announced to the nation a goal of sending an American safely to the Moon before the end of the decade.

- This decision involved much study and review prior to making it public as well as a tremendous expenditure and effort to make it a reality by 1969.
- Only the building of the Panama Canal rivaled its size as the largest non-military technological endeavor ever undertaken by the United States; only the Manhattan Project was comparable in a wartime setting.
- The human spaceflight imperative was a direct outgrowth of it; Projects Mercury (at least in its latter stages), Gemini, and Apollo were each designed to execute it.

Dr. John Houbolt explains LOR. Houbolt’s protest of LOR’s exclusion by NASA helped it be selected over direct descent.
NASA’s initial direct ascent plan to send the three-man Apollo Command and Service Module (CSM) directly to the lunar surface, on top of a large descent rocket stage, would require a Nova-class launcher with a lunar payload capability of over 180,000 lbs.

The decision on June 11, 1962 to use lunar orbit rendezvous enabled the Saturn V to replace the Nova, and MSFC proceeded to develop the Saturn rocket family for Apollo.

- Little Joe II was used for five unmanned tests of the Apollo Command Module (CM) Launch Escape System, and to verify the CM parachute recovery system in abort mode.
- Saturn I was the first United States heavy lift launch vehicle.
- Saturn IB was an upgraded version of the Saturn I.
- Saturn V was designed to send a fully fueled CSM and Lunar Module to the Moon.
Development - Saturn I and IB

When the Apollo program was started in 1961 with the goal of landing men on the Moon, NASA chose the Saturn I for Earth orbital test missions.

- The two-stage Saturn I was designed specifically to launch large payloads into low Earth orbit.
- It launched the flight verification of the Apollo Command and Service Module (CSM) aerodynamics in the launch phase.
- However, the payload limit of the Saturn I was 20,000 lbs and the CSM had a dry weight of at least 26,300 lbs.
- Ten Saturn I rockets were flown before it was replaced by the derivative Saturn IB.

- The Saturn IB with a payload capability of at least 35,000 lbs replaced the Saturn I for Apollo Earth orbit testing allowing the CSM to be flown with a partial fuel load.
- In addition, it would also allow launching the 32,000 lbs Lunar Module separately for unmanned and manned Earth orbital testing before the Saturn V was ready to be flown.
- The Saturn IB that launched the second unmanned suborbital test of a production Block I CSM is shown prior to its launch on August 25, 1966.

- The Saturn IB also launched the CSM on three crewed missions to the Skylab space station as well as the CSM crew on the first joint U.S./Soviet Apollo-Soyuz Test Project low Earth orbit space flight.
On January 10, 1962, NASA announced plans to build the three-stage C-5 launch vehicle designed for large payload capacity to the Moon; it became the Saturn V.

- The Saturn V rocket was the largest rocket ever used by NASA and the only one able to lift the large masses needed to land astronauts on the moon and return them safely.
- Saturn V rockets launched all of the Apollo moon missions and the Skylab space station into low Earth orbit.
  - The rocket could place a 285,000 lb payload into Earth orbit or send 100,000 lbs to the moon.
- The three-stage, 363 ft tall Saturn V was the culmination of years of development.
  - The “V” stood for the five first stage F-1 rocket engines delivering a total of 7.65 million lbs at sea level.
  - The oxidizer was liquid oxygen and the fuel was RP-1 (kerosene).
- The second stage was powered by five J-2 engines generating a total thrust of 1.0 million lbs.
  - The J-2 engines used liquid oxygen and liquid hydrogen as the oxidizer and fuel, respectively.
- The third stage was a single J-2 engine yielding 200,000 lbs of thrust (later up-graded to 230,000 lbs).
- The Apollo 4 unmanned mission (left) was the first launch of the Saturn V and the first to liftoff from Kennedy Space Center, FL and Launch Complex 39A.
  - The launch occurred on November 9, 1967.
The S-IC provided the first stage boost of the Saturn V launch vehicle to an altitude of about 38 miles and acceleration to increase the vehicle velocity to 7,700 ft per second; it then separated from the S-II stage and fell to Earth about 360 miles downrange.

- The S-IC stage was a cylindrical booster, 138 ft long and 33 ft in diameter, powered by five liquid propellant F-I rocket engines.
- The stage dry weight was approximately 293,500 lbs and its total weight at ground ignition was approximately 5,030,500 lbs.
- The primary structural material was aluminum alloy.
- The major components were: forward skirt, oxidizer tank, intertank section, fuel tank, and thrust structure.
- Four hold-down points in the lower ring of the thrust structure supported the fully loaded Saturn/Apollo (over 6,000,000 lbs) and also restrained the vehicle from lifting off at full F-I engine thrust.
- The heat shield provided thermal shielding for critical engine and structural components during the flight.
- Each outboard F-I engine was protected from aerodynamic loading by a conically shaped engine fairing.
- The fairings also enclosed the engine actuator supports.
- Four fixed, titanium covered, stabilizing fins augmented the stability of the Saturn V vehicle.
The Apollo 11 Saturn V rocket (above) towers over the Crawler-transporter during the May 20, 1969 rollout from the VAB to Launch Pad 39A.

- The VAB was constructed 3.5 miles from Launch Pad 39A and 4.2 miles from Launch Pad 39B.
- A pair of Crawler-transporters, among the largest machines ever built to move on land, carried the assembled rockets to the pads.
- The rollout of Apollo 4 began early on August 26, 1967.
- The 363-foot-tall Saturn V atop the Mobile Launcher Platform and Crawler-transporter weighed 18 million lbs and traveled at less than 1 mile per hour to Pad 39A (right).
- The Saturn V rocket for the un-crewed Apollo 4 mission was the first flight vehicle stacked in the VAB and the first to lift off from the KSC.

Launch Complex 39 at Kennedy Space Center (KSC), FL was originally composed of: the Vehicle Assembly Building (VAB), launch pads 39A and 39B, a Crawler-way used by the Crawler-transporters to carry Mobile Launcher Platforms between the VAB and the two pads.

- Construction of the VAB began on August 2, 1963.
- When completed in 1965, the VAB was one of the largest buildings in the world with 129,428,000 cubic ft of interior volume, covering eight acres, 525 ft tall and 518 ft wide.
By January 1964, North American Aviation started presenting Block II design details to NASA.

- The Command and Service Module (CSM) consisted of two parts:
  1) The **Command Module (CM)** was a pressurized compartment that housed a crew of three and equipment needed for re-entry and splashdown.
  2) A **Service Module (SM)** provided propulsion, electrical power and storage for various consumables required during the mission.

-- The SM jettisoned and burned up in the atmosphere before the CM re-entered and brought the crew home.

- The Launch Escape System (LES), on top of the CM, provided the capability to abort a mission by pulling the CM away from the launch vehicle in an emergency (such as a pad fire before launch), or guidance or launch vehicle failure likely to lead to an imminent explosion.

- The LES, built by the Lockheed Propulsion Company, would jettison from the SM and the CM would land with its parachute recovery system.

- Apollo Pad Abort Test #2 is seen on June 29, 1965 at White Sands Missile Range, NM; the test was launched by the Little Joe II rocket.
The cabin fire revealed serious design, construction and maintenance shortcomings in Block I, many of which would have been carried over into Block II.

- To remedy the causes of the fire, changes were made in the Block II spacecraft and operational procedures, the most important of which were use of a nitrogen/oxygen mixture instead of pure oxygen before and during launch, and removal of flammable cabin and space suit materials.

- Block II also incorporated a revised CM heat shield design, which was tested on the unmanned Apollo 4 and Apollo 6 flights consequently, the first all-up Block II spacecraft flew on the first manned mission, Apollo 7.
Once the decision had been made to proceed using lunar orbit rendezvous, it became necessary to produce a separate spacecraft capable of reaching the lunar surface and ascending back to lunar orbit.

- Originally the spacecraft was designated the Lunar Excursion Module (LEM), and consisted of an Ascent Stage and Descent Stage, and was ferried to lunar orbit by the Command and Service Module (CSM).
- As the LEM developed, there were numerous redesigns to save weight, improve safety, and resolve problems.
- A configuration freeze did not start until April 1963, when the ascent and descent engine designs were decided.
- In June 1966, the name was changed to Lunar Module (LM) because “excursion” might lend a frivolous note to Apollo.

- After the 23.1 ft tall LM separated from the CSM in lunar orbit, the throttleable descent engine and reaction control system powered and guided, respectively, the spacecraft during landing.
- On the lunar surface, the crew put on their spacesuits, depressurized the cabin, opened the hatch, exited out on a platform called the “porch,” and climbed down a ladder to the surface.
- After the surface activities, they returned to the Ascent Stage, hoisted samples aboard, closed the hatch, re-pressurized the cabin, fired the ascent engine and lifted off the Descent Stage.
- The Ascent Stage rendezvoused and docked to the CSM, and the crew returned to Earth.
The first unmanned flight of the Lunar Module (LM) was launched by a Saturn IB rocket on January 22, 1968 from Cape Kennedy Launch Complex 37B during the Apollo 5 mission Earth orbital test flight.

- The Saturn IB was originally intended for Apollo 1; it had been undamaged in the fire at Launch Complex 34 and was reassembled at Launch Complex 37B for the Apollo 5 launch.
- The test verified the Ascent and Descent Stages, the propulsion systems, and the restart operations; and it evaluated the spacecraft structure, LM staging, 2nd stage (S-IVB) and Instrument Unit orbital performance.
- The Apollo 5 mission was deemed a success and operation of all LM systems was confirmed.
- Lunar Module-1 is shown being moved into position for mating with the Spacecraft Lunar Module Adapter-7 in November 1967 in the Manned Spacecraft Operations Building at Kennedy Space Center, FL.

When Apollo planning was underway in 1960, NASA was looking for a simulator to profile the descent to the lunar surface.
- Three concepts emerged: an electronic simulator, a tethered device, and the ambitious Dryden contribution, a free-flying vehicle.
-- All three became serious projects, but eventually the Dryden Flight Research Center’s (FRC) Lunar Landing Research Vehicle (LLRV) became the most important.
--- The 1964 photograph shows the LLRV-1 in flight at the South Base of Edwards Air Force Base, CA.
The A7L spacesuit, called the NASA Extravehicular Mobility Unit (EMU), is the primary pressure suit worn by astronauts for the Apollo missions as well as Skylab.

- The EMU provided the extravehicular (EV) crewman with a habitable environment for a 5 hour mission without replenishment of expendables.

- The two basic Pressure Garment Assembly (PGA) configurations are:
  1) The **Command Module Pilot (CMP) A7LB PGA** provided low-pressure and fire protection in the intravehicular (IV) mode and protection from the free-space environment during extravehicular activity (EVA) from the CM. The EV configuration also provided free-space environment protection during open-hatch operations associated with Command Module EVA.
  2) The **EV A7LB PGA** provided low-pressure and fire protection in the IV mode and protection from the lunar surface environment during EVA (Apollo 17 Commander Gene Cernan is shown).

- The EV interfaced with the Portable Life Support System (PLSS) for oxygen, pressurization, ventilation, communications, and temperature control when used for EVA.

- Exterior connectors permitted both configurations to interface with spacecraft systems for nitrogen, oxygen, pressurization, ventilation, communications, cooling, and waste management.

- The Integrated Torso Limb Suit Assembly included the torso, arms, legs, and boots.

Note: Liquid Cooling Garment (LCG)
- Worn under PGA
- Provides cooling
The Lunar Roving Vehicle (LRV) was a battery-powered four-wheeled rover used on the Moon during the last three Apollo lunar missions during 1971 and 1972.

- The LRV was transported to the Moon on the Lunar Module Descent Stage and, once unpacked on the surface, carried one or two astronauts, their equipment, and lunar samples.
- The LRV was 10.2 ft long with a 7.5 ft wheelbase by 3.7 ft high, and weighed 460 lbs on Earth.
- Each 32.2 inch diameter by 9 inch wide wheel was individually powered by a direct current electric motor providing the vehicle with a total of 0.25 horsepower and a top speed of 8 miles per hour; each wheel could free-wheel in case of a drive failure.
- The LRV was built by the Boeing Company, Aerospace Group at Kent Space Center near Seattle, WA under the direction of the Marshall Space Flight Center, Huntsville, AL.
- The three LRVs remain on the Moon.
Apollo 7 was the first human spaceflight mission in the Apollo program and the first American spaceflight since the Gemini XII in November 1966.

- The 10.8 day Earth-orbital engineering test flight demonstrated the Command and Service Module (CSM), and crew performance; demonstrated crew, space vehicle and mission support facilities performance; and demonstrated the CSM rendezvous capability.
- It was launched from Launch Complex 34 on October 11, 1968 (left) using the Saturn IB rocket from what was then known as Cape Kennedy Air Force Station, FL.
- Even though somewhat hampered by head colds and upper respiratory congestion, the crew satisfactorily performed all flight-plan functions and completed the photographic experiments.

The crew of the Apollo 7 mission shown from left to right are: Command Module pilot Don Eisele, Commander Walter Schirra and Lunar Module pilot Walter Cunningham.

- The photograph was taken inside the Launch Complex 34 White Room which is attached to the crew access arm.

-- From here, the astronauts ingress and egress the spacecraft through Command Module’s main hatch shown on the left.
The Apollo 7 S-IVB rocket stage photographed in Earth orbit on October 11, 1968 as the crew practiced rendezvous techniques that would be needed for the later lunar flights.

- The S-IVB stage was used as a second stage for Saturn IB launches and as the third stage for Saturn V launches.
- On Saturn V flights, the four Spacecraft/Lunar Module Adapter panels would be jettisoned to allow access to the Lunar Module launched in the S-IVB third stage.
- Cape Canaveral and Merritt Island, FL can be seen beyond the left side of the lower end of the S-IVB stage.

- The mission was launched from Launch Complex 34 at Cape Canaveral, FL.
Apollo 8 - First Human Journey to the Moon

Apollo 8 was launched on December 21, 1968, and became the first manned spacecraft to leave Earth orbit, reach the Moon, orbit it and return safely to Earth.

- The Saturn V launch vehicle is shown being rolled out to Launch Complex 39A at Kennedy Space Center (KSC), FL on October 9, 1968.
- Apollo 8 was the third flight of the Saturn V rocket, and the rocket’s first human spaceflight launch as well as its first crewed launch from KSC.
- The mission took three days to travel to the Moon and its duration was 6.2 days.

- The Command and Service Module, without the Lunar Module, orbited ten times over the course of 20 hours.
- Commander Frank Borman (right), Command Module Pilot James Lovell (center), and Lunar Module Pilot William Anders (left) became the first humans to: travel beyond low Earth orbit; see Earth as a whole planet; enter the gravity well of another celestial body (Earth’s Moon); orbit another celestial body (Earth’s Moon); see the far side of the Moon with their own eyes; witness an Earthrise; escape the gravity of another celestial body (Earth’s Moon); and re-enter the gravitational well of Earth.
- The Command Module returned to Earth on December 27, 1968, when it splashed down in the Northern Pacific Ocean.
Apollo 8 Earthrise

Apollo 8 entered lunar orbit on Christmas Eve, December 24, 1968.
- That evening, the astronauts held a live broadcast from lunar orbit, in which they showed pictures of the Earth and moon as seen from their spacecraft.
  - The “Earthwise” photograph, taken by Jim Anders and shown below, has been called “the most influential environmental photograph ever taken.”
- The crew ended the broadcast taking turns reading the first 10 verses from the Book of Genesis.
- At the time, the broadcast was the most watched TV program ever.
Apollo 9 - First Human Lunar Module Test

The Apollo 9 mission was the first human flight of all Apollo lunar hardware in Earth orbit and the flight of the Lunar Module (LM).

- After the launch on March 3, 1969 using the Saturn V, the crew performed the first manned flight of a LM, the first docking and extraction of a LM, two spacewalks, and the second docking of two human spacecrafts; the Soviets had performed a spacewalk crew transfer earlier.
- The mission proved the LM worthy of human spaceflight.
- The astronauts returned to Earth on March 13, 1969 after the 10.1 day mission.

- The Apollo 9 crew shown from left to right are: Commander James McDivitt, Command Module Pilot David Scott, and Lunar Module Pilot Rusty Schweickart.
- The Command/Service Modules (CSM) and the LM are shown above docked together as David Scott stands in the CSM open hatch.
  - Russell Schweickart took the photograph of Scott on March 6, 1969 during his spacewalk as he stood on the porch outside the LM.
Apollo 9 - First Human Spacesuit and LM Test

On the fourth day of the Apollo 9 Earth orbital mission, Russell Schweickart, Lunar Module (LM) pilot, completed an extravehicular activity from the LM.

- Schweickart is shown checking out the new Apollo spacesuit while standing on the LM porch.
- This is the first spacesuit to have its own life support system rather than being dependent on an umbilical connection to the spacecraft.
- The photograph was taken from inside the LM by James McDivitt, Apollo 9 mission commander with Schweickart.

- The LM, named “Spider,” is in the lunar landing configuration photographed from the CM by David Scott, Command Module pilot, on the fifth day of the Apollo 9 mission.
- The landing gear on the “Spider” was deployed with the lunar surface probes (sensors) extended out from the landing gear foot pads.
- Inside “Spider,” McDivitt and Schweickart, tested the spacecraft.
The Apollo 10 lunar orbit mission was launched on May 18, 1969; it was the “dress rehearsal” for the lunar landing by Apollo 11 in July 1969 testing all of the components and procedures, just short of actually landing.

- The success of Apollo 10 enabled the first Moon landing to be attempted on the Apollo 11 mission, two months later.
- The crew from left to right are: Lunar Module pilot Eugene (Gene) Cernan, Commander Thomas Stafford and Command Module pilot John Young.

Eight days after leaving Launch Complex 39B at the Kennedy Space Center, Apollo 10 splashed down 3 miles from the Pacific aiming point.

- A United States Navy Sea King helicopter arrived to recover the Apollo 10 astronauts, seen entering a life raft, as the Command Module floats in the South Pacific.

-- The divers had attached a flotation collar to the spacecraft and U.S. Navy underwater demolition team swimmers assisted in the recovery operations.

- The splashdown occurred on May 26, 1969, about 400 miles east of American Samoa.

- The helicopter also supported the Apollo 8, 10, 11, 12, and 13 missions.

- The LM descended for a close-up inspection of the preferred landing site for Apollo 11 in the Sea of Tranquility.
- In two orbits of the Moon, the landing radar received a thorough checkout and the crew did extensive surface photography and landmark tracking.
- However, the LM gyrated wildly as the descent stage was cast off about 13.8 miles above the surface of the Moon; nevertheless, it was a nearly flawless 8 day flight.
The Apollo 11 Saturn V space vehicle lifted off on July 16, 1969 from Launch Complex 39A at the Kennedy Space Center, FL.

- After one and a half orbits, the S-IVB third stage engine pushed the Command and Service Module (CSM) onto its trajectory toward the Moon with the trans-lunar injection burn.
- About 30 minutes later, the transposition, docking, and extraction maneuver was performed docking with the Lunar Module (LM) still attached to the stage.
- After the LM was extracted, the combined spacecraft headed for the Moon and traveled for three days until they entered into lunar orbit.
- In the thirty orbits that followed, the crew saw passing views of their landing site in the southern Sea of Tranquility.

The Apollo 11 lunar landing mission crew from left to right are: Commander Neil Armstrong, Command Module pilot Michael Collins, and Lunar Module pilot Edwin “Buzz” Aldrin.

- Following an orbital correction, Armstrong and Aldrin crawled through the docking tunnel into the LM in preparation for their descent to the Moon’s surface.
- The LM undocked from the CSM on July 20.
The Apollo 11 Lunar Module (LM) “Eagle,” in a landing configuration, was photographed in lunar orbit from the Command and Service Module “Columbia” on July 20.

- The descent went as planned as Eagle reached its attitude approaching the vertical to the Moon’s surface.
- As the LM dropped below 500 ft in altitude, the crew transmitted a staccato numerical report to Mission Control on its rate of drop and lateral movement.
- After the astronauts saw that their line of approach would take them into a crater covered with large rocks, Armstrong took manual control and flew the LM to a site four miles away and then gently set the Eagle on the lunar surface.

- When Armstrong cut off the descent engine, he had 30 seconds of fuel remaining.
- Deciding to forgo the sleep period, the crew began to prepare for the extravehicular activity.
- Armstrong’s descent from the lowest rung of the ladder, attached to a leg of the lower stage of Eagle, to the footpad, and then to the surface constituted the climax of a national effort that began in 1961.
- As he took his epochal step, Armstrong commented, “That’s one small step for a man, one giant leap for Mankind.”
- Buzz Aldrin is shown leaving the Eagle to take his first steps as the second man on the Moon after Neil Armstrong.
Apollo 11 - Crew Safely Returns to Earth

- Buzz Aldrin poses on the surface of the Moon near the leg of Eagle during the extravehicular activity.
  - Neil Armstrong took the photograph and can be seen as a reflection in Aldrin’s helmet visor.
  - Armstrong commented about moving in the lunar gravity saying “It’s absolutely no trouble to walk around.”
  - After assurance from Mission Control that all assigned tasks had been competed, the astronauts prepared to re-enter the LM.
  - Aldrin entered Eagle first and Armstrong followed after transferring the 47.5 lbs of lunar samples and the film packs to him.

- Armstrong had walked on the Moon for about 2 hours, 32 minutes and Aldrin roughly 40 minutes less.
- After about nine and half hours of rest and preparation, the crew lifted off in Eagle’s ascent stage to rejoin Michael Collins aboard Columbia in lunar orbit.
- A view of Eagle as it returned from the surface of the Moon to dock with Columbia on July 21.
  -- A smooth mare area is visible on the Moon below and a half-illuminated Earth hangs over the horizon.
- The LM was cast off and the Service Propulsion engine was fired on July 22, to place Colombia on the trip home.
- On July 24, the astronauts returned to Earth in the Pacific Ocean, 1657 miles east of Wake Island, after about 8 days.
Apollo 12 - Second Human Moon Landing

Apollo 12 launched on schedule from Launch Complex 39A at the Kennedy Space Center, FL on November 14, 1969 during a rainstorm.

- Launch controllers lost telemetry contact at 36 seconds, and again at 52 seconds, when the Saturn V launch vehicle was struck by lightning.
  - The telemetry stream at Mission Control was garbled.
  -- However, the vehicle continued to fly correctly; the strikes had not affected the Saturn V Instrument Unit.
- After one and a half Earth orbits, the spacecraft electrical circuits were checked and no significant problems were indicated.
  - The S-IVB stage re-ignited for a second burn of about six minutes placing the spacecraft into an initial free-return translunar trajectory.
  - The spacecraft was maneuvered into a 66 by 54 mile lunar orbit on November 18.

- The Apollo 12 crew from left to right are: Commander Charles “Pete” Conrad, Command Module pilot Richard Gordon, and Lunar Module pilot Alan Bean.
- On November 19, Pete Conrad and Alan Bean entered the Lunar Module to prepare for descent to the lunar surface.
- The landing site was near Surveyor III, located in the southeastern portion of the Ocean of Storms.
Apollo 12 Lunar Module Lands Near Surveyor III

The Lunar Module (LM), Intrepid, landed 535 ft northwest of Surveyor III on November 19.
- The second lunar landing was an exercise in precision targeting that would be needed for future Apollo missions.
- Alan Bean is shown preparing to carry a component of the Apollo Lunar Surface Experiments Package (ALSEP) to the deployment site about 600 ft northwest of Intrepid.
  - ALSEP was comprised of a set of scientific instruments designed to run autonomously after the astronauts left and make long term studies of the lunar environment.
    -- ALSEP instruments included: seismometer (moonquakes), magnetometer (magnetic field), solar wind spectrometer (composition), and cold cathode gage (atmosphere gases).

- Pete Conrad examines the Surveyor III spacecraft (right) during the second extravehicular activity.
- Surveyor III was the third lander of the American un-crewed Surveyor program sent to explore the surface of the Moon landing on April 19, 1967.
- The television camera and several other components were taken from Surveyor III and brought back to Earth for scientific analysis.
  - Intrepid is in the upper right of the photograph.
- The LM ascent stage lifted off the lunar surface on November 20 after two “Moonwalks” lasting about 8 hours.
- The Command Module, “Yankee Clipper,” returned to Earth after 10.2 days on November 24 landing in the Pacific Ocean.
Apollo 13 - “Houston, We’ve Had a Problem Here”

Apollo 13 was slated to be the third lunar landing mission launching from Launch Complex 39A at the Kennedy Space Center, FL on April 11, 1970.

- The mission crew from left to right are: Commander James (Jim) Lovell, Command Module (CM) pilot John (Jack) Swigert, and Lunar Module (LM) pilot Fred Haise.
- Two days before launch, Jack Swigert, as a member of the Apollo 13 backup crew, was substituted for his prime crew counterpart Ken Mattingly, who was exposed and found susceptible to rubella (German measles).
- On April 13, about 200,000 miles from Earth and just minutes after finishing a TV broadcast, the Service Module oxygen tank #2 exploded causing tank #1 to also fail.

- Jack Swigert saw a warning light that accompanied the bang, and reported to NASA, “Houston, we’ve had a problem here.”
- Thirteen minutes after the explosion, Jim Lovell saw gas-oxygen escaping at a high rate from the second, and last, oxygen tank #2.
- Several minutes later, the #1 and #3 fuel cells failed leaving the vehicle limited-duration battery power and water.
- The crew was forced to shut down the CM completely to save these for re-entry, and to power up the LM to use as a “lifeboat.”
- Availability of lithium hydroxide cartridges for removing carbon dioxide from the LM also presented a serious problem.
- Jack Swigert is shown using instructions from Mission Control to adapt the CM’s square cartridge to fit the LM using a round one.
Apollo 13 - “Problem” Prevented Moon Landing

- Although the mission was unsuccessful as planned, a lunar flyby and several scientific experiments were completed.
- Apollo 13 passed the far side of the Moon at an altitude of 158 miles above the surface, and 248,655 miles from Earth, a spaceflight record marking the farthest humans have ever traveled from Earth.
- On April 17, the Service Module (SM) separated from the Command Module (CM) “Odyssey” about 5 hours before re-entry into the Earth’s atmosphere allowing the crew an opportunity to observe the SM’s damaged bay #4 shown in the photograph.
- The entire bay #4 outer panel was missing, and torn Mylar insulation was seen protruding from the bay.
  -- It was difficult to see inside the bay due to Mylar reflections.

- The Lunar Module (LM) “Aquarius” was retained for as long as possible to provide maximum electrical power in the CM and jettisoned 1 hour before Odyssey’s re-entry.
- Aquarius eventually re-entered the Earth’s atmosphere over Fiji in the South Pacific and burned up.
- Odyssey’s landing occurred in the South Pacific Ocean within sight of the recovery ship USS Iwo Jima on April 17.
- After about 6 days in space, the crew were retrieved and aboard the recovery ship within 45 minutes after landing.
- Three of the four Apollo 13 Flight Directors (front row, left to right: Gerald Griffin, Eugene Kranz and Glynn Lunney) applaud the successful splashdown of Odyssey.
Apollo 14 launched on January 31, 1971 during heavy cloud cover over Launch Complex 39A at the Kennedy Space Center, FL.

- The Apollo 14 lunar landing mission crew from left to right are: Command Module (CM) pilot Stuart Roosa, Commander Alan Shepard, and Lunar Module (LM) pilot Edgar Mitchell; Alan Shepard is the only original Project Mercury astronaut to reach the Moon.
- In the aftermath of the Apollo 13 accident, several modifications were made to the Service Module electrical power system to prevent a repeat of the problem including a redesign of the oxygen tanks and the addition of a third tank.

- Alan Shepard and Edgar Mitchell landed the LM “Antares” on February 5 in the hilly uplands of the Fra Mauro crater about 110 miles east of the Apollo 12 landing site.
- Fra Mauro was the target of the aborted Apollo 13 mission.
- Aboard the Command and Service Module (CSM) “Kitty Hawk,” Stuart Roosa conducted orbital science activities during the lunar surface activities period.
- A front view of “Antares” is shown reflecting a circular flare caused by the brilliant sun.
- The photograph was taken during the first extravehicular activity.
- The lower slope of Cone crater can be seen at the extreme left.
During the second extravehicular activity (EVA) on February 6, Shepard and Mitchell moved more than half a mile from Antares, collecting samples and attempting to reach the rim of Cone crater; at the end of the EVA, Shepard hit two golf balls with a makeshift club.

- The two astronauts were within 164 to 246 ft of Cone crater rim when they were advised by Mission Control to collect samples at that spot and begin their traverse back to Antares.
- The photograph shows Shephard (right) carrying a core tube to the Modularized Equipment Transport (MET) as well as Antares in the far right.

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- MET was a cart used to carry tools, cameras and sample cases on the lunar surface.
- During the two EVAs totaling about 9 hours, the astronauts collected 94 lbs of rocks and soil.
- Orbiting in Kitty Hawk, Roosa conducted science activities including photography of candidate future landing sites and surface details from 69 miles in altitude.
- Antares liftoff from the lunar surface on February 6 was precisely on schedule, and rendezvous and docking with Kitty Hawk occurred only two minutes later than scheduled.
- About 9 days after launch, Kitty Hawk’s CM splashed down safely in the Pacific Ocean on February 9, south of Samoa, and 4 miles from the prime recovery ship USS New Orleans.
Apollo 15 was the first in a series of missions designed to conduct exploration of the Moon over longer periods, greater ranges, using more instruments for scientific data acquisition, and the first mission to use the Lunar Roving Vehicle (LRV).

- The space vehicle was launched from Launch Complex 39A at the Kennedy Space Center, FL on July 26, 1971.
- The lunar landing mission crew from left to right are: Commander David Scott, Command Module pilot Alfred Worden, and Lunar Module (LM) pilot James Irwin.

- The spacecraft was inserted into a lunar orbit on July 30; the LM “Falcon” separated from the Command and Service Module (CSM) “Endeavour” with the CSM returning to a higher orbit to perform lunar observations.
- Falcon landed on the lunar surface about 1800 ft from the planned target point in the Hadley-Apennine region, chosen with the specific objective of sampling material from deeper within the Moon than previous missions.
- After unloading the LRV, David Scott and James Irwin drove to the first extravehicular activity 1 (EVA 1) destination on July 31.
- James Irwin is seen with the LRV and Mount Hadley in the background; Hadley rises about 4,765 ft above the plain.
The landing site of Falcon in Hadley Rille/Apennine Mountains was photographed by David Scott.

- Jim Irwin is seen behind the LRV at the end of EVA 1.
- The LRV was folded for stowage in the descent stage in the LM where the United States flag is located.
- Hadley Delta, in the background, rises about 13,124 ft above the plain; the base of the mountain is about 3.5 miles away.
- The white foreground object on the left is a discarded experiment pallet.

- Lunar anorthosite, one of the oldest rocks on the Moon, was found perched on a clod of soil breccia (rock cemented together) at Spur crater during EVA 2 on August 1.
- Spur Crater is about 164 ft above the lunar surface on the slope of Hadley Delta.
- The anorthosite Sample 15415 (right), named “Genesis Rock,” is about 4 billion years old.
Apollo 15 - Rover Driven Over 15 Miles

During EVA 3 on August 2, Jim Irwin photographed the Swann range with Falcon in the foreground before they drove to explore the Hadley Rille.
- Rille describes any of the long, narrow depressions in the surface of the Moon.
- The United States flag, deployed during EVA 2, is shown left of Falcon.
- The two astronauts spent a total of 18.5 hours during three EVAs collecting about 170 lbs of lunar samples and drove the LRV a total distance of 15.1 miles.

- On August 2, the LM ascent stage lifted off and rendezvous was performed followed by docking.
- The CSM, viewed from the LM Falcon during rendezvous, shows the experiments located in the Scientific Instrument Module (SIM) bay of the Service Module.
- A scientific subsatellite was launched successfully into lunar orbit on August 4 prior to trans-Earth injection.
- During the return trip to Earth on August 5, Alfred Worden performed an EVA in deep space, the first of its kind, to retrieve exposed film from the SIM bay.
- On August 7, the CM landed in the North Pacific Ocean and the crew were recovered by the USS Okinawa after a mission lasting about 12 days.
Apollo 16 space vehicle lifted off from Launch Complex 39A at the Kennedy Space Center, FL on April 16, 1972.

- The lunar landing mission crew from left to right are: Command Module pilot Thomas (Ken) Mattingly, Commander John Young, and Lunar Module (LM) pilot Charles (Charlie) Duke.
- The docked spacecraft was inserted into a lunar orbit on April 19.
- The LM “Orion” landed approximately 906 ft northwest of the planned landing site in the Descartes Highlands on April 21 with about 100 seconds of hover time remaining at touchdown.

- The Descartes Highlands was selected for the mission to enable the astronauts to sample the prominent Descartes and Cayley formations concentrated in the area.
- The area of the Descartes Highlands is characterized by an undulating landscape covered with old, and some new, sharp rimmed craters.
- Charlie Duke photographed John Young jumping from the lunar surface and saluting the flag during extravehicular activity (EVA) 1 on April 21.
- Orion and the Lunar Roving Vehicle (LRV) are in the background.
The three EVAs lasted about 20 hours and 209 lbs of samples were collected.

- The total distance traveled in the LRV was about 16.6 miles.
- The crew remained on the lunar surface about 71 hours while Ken Mattingly orbited in the Command and Service Module “Casper” above performing observations.
- The panorama was taken by Charlie Duke at the end of EVA 3 on April 23.
- John Young is pointing the High-Gain Antenna (HGA) towards the Earth.
- The LM Orion is on the left and the Apollo Lunar Surface Experiments Package (ALSEP) is on the right near a rock.
- The exploration of the Descartes region by the crew provided the best look at lunar highlands.
- Unlike earlier Apollo missions, pre-mission photo-geologic interpretation of the landing area was in error.
-- The surprise at Descartes was the state of the rocks, not their composition; breccias rather than volcanics were dominant.
- As a result, many theories concerning lunar geologic structure and processes were improved.
Apollo 16 - Despite Expectations, a Success

The Panorama, taken by Charlie Duke during EVA 3 on April 23, shows the LRV near Shadow Rock and John Young aiming the LRV High-Gain Antenna toward the Earth.
- The EVA 3 return route to Orion retraced the northern outbound route.
- Lunar ascent of Orion was initiated on April 24 and was followed by rendezvous and docking.
- Attitude control of the Orion ascent stage was lost at jettison; consequently, a de-orbit maneuver was not possible.

- The Orion ascent stage orbited the Moon for about a year; its impact site remains unknown.
  - A subsatellite was launched but placed in a non-optimum lunar orbit resulting in a much shorter lifetime than planned.
  - Ken Mattingly (right), assisted by Charlie Duke, performed a 1 hour and 23 minute EVA during the trans-Earth coast of Casper.
- On April 27, the astronauts returned to Earth in the Pacific Ocean, 220 miles southeast of Christmas Island, after about 11 days.
Apollo 17 - Last Humans on the Moon

Apollo 17, the last human mission to explore the Moon, was launched from Launch Complex 39A at the Kennedy Space Center, FL on December 7, 1972.

- The mission was the last use of Apollo hardware for its original purpose; after Apollo 17, extra Apollo spacecrafts and rockets were used in the Skylab and Apollo-Soyuz missions.
- The last lunar landing mission crew from left to right and below are: Lunar Module Pilot Harrison Schmitt, Command Module Pilot Ronald Evans, and Commander Eugene (Gene) Cernan.

- Harrison Schmitt was the first Scientist-Astronaut assigned to an American human spaceflight mission.

- Schmitt’s background included a Doctorate in Geology and participation in many unique geological activities on Earth.
- The translunar coast time was shortened to compensate for a delay during the launch.
- The Command and Service Module (CSM) “America” and Lunar Module “Challenger” were inserted into lunar orbit about 17 hours before undocking.
- Challenger landed at Taurus-Littrow highlands and valley area on December 11.
- Gene Cernan salutes the U.S. flag during extravehicular activity (EVA) 1 on December 11.
Apollo 17 - Largest Weight of Samples Collected

The landing site was selected because rocks both older and younger than those previously returned from other Apollo missions, and from Soviet Luna 16 and 20 missions, might be found at Taurus-Littrow valley.

- Harrison Schmitt was photographed standing next to a huge, split boulder in the Taur-Littrow valley during EVA 3 at Geology Station 6.
- A portion of South Massif is visible to the right and North Massif is in the foreground.
- A number of samples were collected at Station 6 including the Troctolite 76535 sample below.

- Troctolite 76535 was collected as part of a “rake sample” of lunar soil near the base of North Massif.
- 76535 is without a doubt, the most interesting sample returned from the Moon.
- It is a colorful, pristine, coarse-grained, plutonic rock (formed when magma crystallizes and solidifies) that has had a slow cooling history.
- The sample has been widely distributed, but its origin is still debated.
- It was determined to be formed 4.24 billion years ago.
- The collected samples of 243 lbs established an Apollo record for total weight of returned mission samples.
Apollo 17 - Longest Lunar Landing Mission

Jack Schmitt photographed this panoramic view of Gene Cernan while he was still wearing his spacesuit after EVA 3 on December 13.

- Dirt is on Cernan’s suit and he has a three day growth of beard; a LM circuit breaker panel is behind him and the rendezvous window is above his head.
- Schmitt’s suit is visible on top of the Challenger ascent engine under the helmet on the left.

- Lunar ascent was initiated after about 75 hours on the surface, followed by rendezvous and docking with the CSM America.
- Challenger was jettisoned on December 15 and impacted the lunar surface about a mile from the planned target.
- Trans-Earth injection was initiated after an additional day in lunar orbit performing scientific experiments.
- On December 19, the crew jettisoned the Service Module, leaving only the Command Module (CM) for return to Earth.
- The CM re-entered the Earth’s atmosphere and landed safely in the Pacific Ocean only 4 miles from the recovery ship.
- A U.S. Navy Helicopter recovers an Apollo 17 astronaut on December 19 with the aircraft carrier USS Ticonderoga nearby.
- The total Apollo 17 mission elapsed time of more than 12 days is the longest lunar mission.
Skylab - Launched and Develops Problems

The Apollo Applications Program (AAP) was established by NASA in 1968 to develop science-based manned space missions using hardware developed for the Apollo program.

- Originally, AAP missions would alternate with Apollo lunar missions, starting in 1969.
- When NASA’s 1969 budget was cut, focus was shifted to the Skylab space station proposal, which managed to accommodate the equipment already specified for some of the AAP missions.
- The 170,000 lb unmanned Skylab space station was launched into low Earth orbit by a Saturn V booster from Launch Complex 39A Kennedy Space Center, FL on May 14, 1973.
- Almost immediately, technical problems developed due to vibrations during liftoff.

- A view of the Skylab Orbital Workshop (OWS) in orbit, taken by the Skylab 2 crew in the Command and Service Module (CSM) during inspection, shows the micrometeoroid shield missing.
  - The critical meteoroid shield ripped off taking one of the spacecraft’s two solar panels with it, and a piece of the shield wrapped around the other panel preventing it from deploying.
- Skylab was maneuvered so its Apollo Telescope Mount (ATM) solar panels faced the sun to provide as much electricity as possible; this caused the OWS temperatures to rise to 126 °F.
- The launch of Skylab 2 to the space station had been postponed while NASA engineers developed procedures and trained the crew to make the OWS habitable.
Skylab 2 - Crew and Team Save Space Station

The Saturn IB rocket lifts off from Launch Complex 39B at the Kennedy Space Center, FL on May 25, 1973 for the first manned Skylab 2 mission.

- The Saturn IB launched three separate crews to Skylab.
- The crew rendezvoused with America’s first space station on the fifth orbit.
- After making substantial repairs, including deployment of a “parasol” sun shield from an OWS scientific airlock cooling the inside temperatures to 75 ºF, and releasing the solar panel during an extravehicular activity, the workshop was in full operation by June 4.
- The high temperatures threatened to spoil the food supply, make the interior of the station too hot to occupy, release toxic gases from the plastics on-board, and ruin all of the photographic film.

- The Skylab 2 mission crew from left to right are: Scientist-Astronaut Joseph Kerwin, Commander Charles (“Pete”) Conrad, and Pilot Paul Weitz.
- During the spacewalk to free the jammed solar panel, Kerwin, after considerable work, was able to cut the metal that had jammed the panel in a folded position allowing Conrad to force the array beam to deploy using a rope sling.
- Full extension of the solar panel occurred later.
- The crew also conducted solar astronomy, Earth resources experiments, medical studies, and five student experiments.
When the crew departed after about 28 days on June 22, the OWS “parasol” sun shield covered the main portion of the space station, and the solar panel had been freed during a spacewalk.

- The ATM was a solar observatory that included eight major observational instruments.
- The four windmill-like solar panels attached to the ATM also supplied electric power.
- The OWS was the crew quarters, an area for large experiments, and stored expendables.
- The MDA provided two docking ports for the CSM, the ATM control console, controls and sensors for Earth resources viewing, and a number of other experimental facilities.
- The AM provided a pressurized passageway between the MDA and OWS, and an airlock to enable astronaut extravehicular activity.
- Skylab 2 splashed down in the Pacific Ocean 6 miles from the recovery ship on June 22.
The Skylab 3 mission crew was launched from Launch Complex 39B at the Kennedy Space Center, FL on July 28, 1973.

- A view of the Skylab space station was photographed by the crew in the Command and Service Module during station keeping maneuvers prior to docking with the MDA.
- The solar panel deployed during a Skylab 2 mission spacewalk is seen on the left.
- The Ilha Grande de Gurupa area of the Amazon River Valley of Brazil can be seen in the background.

- The Skylab 3 crew, shown in the “One-G” MDA trainer at Johnson Space Center, TX, are from left to right: Scientist-Astronaut Owen Garriott, Pilot Jack Lousma, and Commander Alan Bean.
- The crew are standing next to the Apollo Telescope Mount (ATM) display and control console mockup.
- The hatch to the Airlock Module is behind Owen Garriott.
- The ATM was the United States’ first full-scale, manned astronomical observatory in space.
- The ATM solar telescopes were full-sized observatory instruments, typically 9.8 ft long and weighing, in all, more than 1,984 lbs.
On August 6, 1973, Owen Garriott and Jack Lousma performed the first Skylab 3 extravehicular activity lasting almost 6.5 hours and included the crew changing the ATM instrument film and deploying the twin-pole sun shield; the shield and the poles had been transported by Skylab 2 and stowed for subsequent use.

- The photograph shows the twin-pole sun shield erected over the previously deployed “parasol” shield.
- Concern over the possibility that materials used for the Skylab 2 “parasol” would deteriorate with prolonged exposure to the Sun and more shielding was required to better control OWS temperatures prompted the installation of a second sun shield.

- Jack Lousma is taking a hot shower in the crew quarters of the OWS.
  - To deploy the shower facility the shower curtain was pulled up from the floor and attached to the ceiling.
  - The water came through a push-button shower head attached to a flexible hose.
  -- The user had to bring a bottle of pressurized water, which was dispensed through the flexible hose.
  - Water was drawn off by a vacuum system.
  - The floor of the shower had foot restraints.
- The crew continued to conduct numerous medical, scientific and technological experiments.
Skylab 3 - Crew Achieves 59 Days of Flight Time

Owen Garriott is stationed at the ATM console in the MDA where he actively controls the ATM solar telescope.

- Six ATM experiments used film to record data.
- To prevent radiation from damaging the film, vaults were used to store the film canisters in the spacecraft; Film Vault Number 1 is shown in the upper right.
- The film canisters were manually retrieved by spacewalks to the ATM and returned to Earth with the crew.

- Alan Bean flies the M509 Astronaut Maneuvering Equipment experiment in the OWS forward compartment, 22 ft in diameter by 19 ft high.
- Bean is strapped into the back-mounted, hand-controlled, Automatically Stabilized Maneuvering Unit (ASMU).
- The ASMU was designed to demonstrate the unit’s flying qualities.
- He is wearing a pressure suit for this run of the M509 experiment, but other tests were conducted in shirt sleeves.
- The ASMU helped pave the way for the development of the Manned Maneuvering Unit that propelled spacewalkers during three flights of the space shuttle program.

- Following undocking and separation from Skylab, the Command Module landed in the Pacific Ocean about 186 miles southwest of San Diego, CA on September 25, 1973 after 59 days of flight time.
The Skylab 4 mission crew was launched from Launch Complex 39B (LC 39B) at the Kennedy Space Center, FL on November 16, 1973.

- The Skylab 4 mission crew from left to right are: Commander Gerald Carr, Scientist-Astronaut Edward Gibson, and Pilot William Pogue.
- The all-rookie crew was the last aboard Skylab.
- After the Skylab 4 launch, a rescue flight was assembled as a backup contingency.
- A Saturn IB rocket with a CSM was moved to LC 39B to be launched with Vance Brand and Donald Lind.

- The ATM photograph of the Sun, taken on December 19, shows one of the most spectacular solar prominences ever recorded, spanning more than 365,000 miles across the solar surface.
- The loop prominence gives the distinct impression of a twisted sheet of gas in the process of unwinding itself.
- The solar poles are distinguished by a relative absence of supergranulation network, and a much darker tone than the central portions of the disk.
- Several active regions are seen on the eastern (right) side of the disk.
- The photograph was taken in the light of ionized helium by the extreme ultraviolet spectroheliograph instrument of the U.S. Naval Research Laboratory.
The photograph, taken on February 1, 1974, from the Airlock Module hatch looking the length of the OWS shows Edward Gibson (center left) and Gerald Carr looking through the forward compartment floor passageway with trash bags near them.

- The OWS was 22 ft in diameter and 48 ft in length.
- The trash and waste water were stored in the trash airlock, shown in the center behind the astronauts, which is in the liquid oxygen tank below the OWS.
- The OWS forward compartment floor was made of triangular grids.
  - Triangular shoe cleats fitted into the grid cavities.
  -- With a twist of his foot, a crewman could position himself wherever he chose to be restrained.
On December 13, 1973, the crew sighted Comet Kohoutek and trained the solar observatory and hand-held cameras on it.

- The comet is photographed with the far-ultraviolet electrographic camera during a Skylab 4 spacewalk on December 25.
- It is a false-color reproduction of a black and white photograph and shows a hydrogen halo (red); Gibson said it was “mostly yellow.”
- They gathered spectra on the comet and they continued to photograph as it approached the Sun.
- On December 30, as the comet swept out from behind the Sun, Carr and Gibson spotted it as they were performing a spacewalk.
- Comet Kohoutek was first sighted on March 7, 1973 by Czech astronomer Lubos Kohoutek during a search for asteroid images on photographic plates.

- About 300 scientific and technical experiments were conducted onboard Skylab in various fields including microgravity (crystal growth), medicine/space life sciences (test of the effects of long-duration space flights), biology, astronomy, and Sun, Earth, and comet observations.
- The crews observed the Sun for over 740 hours using the ATM; 175,000 solar pictures were returned to Earth as well as about 40 miles of tapes.
- The Skylab space station was photographed from the CSM during the final fly-around before the crew returned to Earth on February 8, 1974.
- The Command Module landed in the Pacific Ocean 180 miles southwest of San Diego, CA for a flight duration of 84 days.
This relief map shows the July 1979 Skylab re-entry site, and final orbits predicted by NASA.

- A week before re-entry on July 11, NASA forecasted that it would occur between July 10 to 14.
- In the hours before the event, ground controllers adjusted Skylab’s orientation to try to minimize the risk of re-entry on populated areas.
- Debris landed about 300 miles east of Perth, Western Australia, and was found between Esperance and Rawlinna.
- Analysis of the debris showed that the station had disintegrated 10 miles above the Earth, much lower than expected.

- This is the largest recovered piece of the Skylab space station that plunged to Earth.
  - The oxygen tank was recovered in Australia by two men who witnessed its re-entry on July 11.
  - The tank and other small debris were found about 15 miles southwest of the small mining town of Rawlinna.
  - This fragment is one of six identical air tanks that were aboard the orbiting laboratory to supply the crew with oxygen.
  -- Before it re-entered, the tank was 4 ft in diameter and 8 ft long, and weighed 2,800 lbs empty.
- The photograph was taken at the U.S. Space and Rocket Center, Huntsville, AL.

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ASTP - Old Space Rivals Cooperate

In October 1970, the Soviet Academy of Sciences President responded to the NASA Administrator’s letter proposing a cooperative space mission, and subsequently, a meeting was held to discuss technical details.

- By April 1972, the United States and the Union of Soviet Socialist Republics had signed an agreement committing to the launch of the Apollo-Soyuz Test Project (ASTP) in 1975.
- ASTP was designed to test the compatibility of rendezvous and docking systems, and the possibility of an international space rescue.
- Soyuz 19 was launched seven hours prior to the launch of the Apollo Command and Service Module (CSM) on July 15, 1975.
- The Saturn IB rocket is shown launching the last Apollo mission from Launch Complex 39B at the Kennedy Space Center, FL.

The American ASTP mission crew were:
Commander Thomas Stafford (standing on left), Docking Module pilot Donald “Deke” Slayton (seated on left), and Command Module pilot Vance Brand (seated center); the Soviet crew were: Commander Aleksey Leonov (standing on right), and Engineer Valeriy Kubasov (seated on right).
- This was Deke Slayton’s first and only mission despite being selected as one of the original Mercury Seven astronauts.
- Aleksey Leonov was the first human to conduct a spacewalk, exiting Voskhod 2 on March 18, 1965.
The photograph was taken from a rendezvous window of the American Command and Service Module (CSM) in Earth orbit during the ASTP mission in July 1975.

- The Soviet Soyuz 19 spacecraft is contrasted against a black-sky background with the Earth’s horizon below.
- The Soyuz spacecraft is comprised of three parts:
  1) An *Orbital Module* provides accommodations for the crew.
  2) An aerodynamic *Descent Module* returns the crew to Earth at the end of the mission.
  3) A *Service Module* has solar panels, instrumentation and propulsion.
- The orbital and service modules are destroyed upon re-entry.
- The American Docking Module (DM) is also visible.

- The CSM, docked to the DM, was photographed in Earth orbit from Soyuz 19 during the mission.
- The Soyuz docking mechanism and docking target on the DM are seen on the left end of the DM.
- On the right end of the CSM, the bell-shaped engine nozzle of the service module propulsion system protrudes from the rear of the CSM.
- In the upper left, light reflected in the camera streaks the image.
- The photograph was furnished by the Soviets, in an exchange, taken during the mission.
The ASTP Backup Docking Module (DM) is shown docked to the American CSM and Soyuz at the National Air and Space Museum in Washington, DC.
- The Flight DM, 10 ft - 4 inches in length, launched with the CSM and it was used in the historic docking with Soyuz 19 two days later.
- An airlock was needed to transition from the CSM low cabin pressure system of pure oxygen to the Soviet mixed oxygen/nitrogen system at normal atmospheric pressure.
- The DM was built by North American Rockwell.

- Astronaut Deke Slayton (left) and cosmonaut Alexey Leonov are in the Soyuz 19 Orbital Module.
- After 44 hours together, the two spacecrafts separated, and maneuvered before briefly docking again.
- The Soviets remained in space for 5 days, and the Americans for 9 days conducting Earth observation experiments.
- On July 21, 1975, Soyuz 19 landed safely 54 miles northeast of Arkalyk, Kazakhstan; Apollo splashed down on July 24 in the Pacific Ocean 311 miles west of Hawaii.
- The mission provided useful science and engineering experience, and led to future partnerships such as the Shuttle/Mir Program and the International Space Station.
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