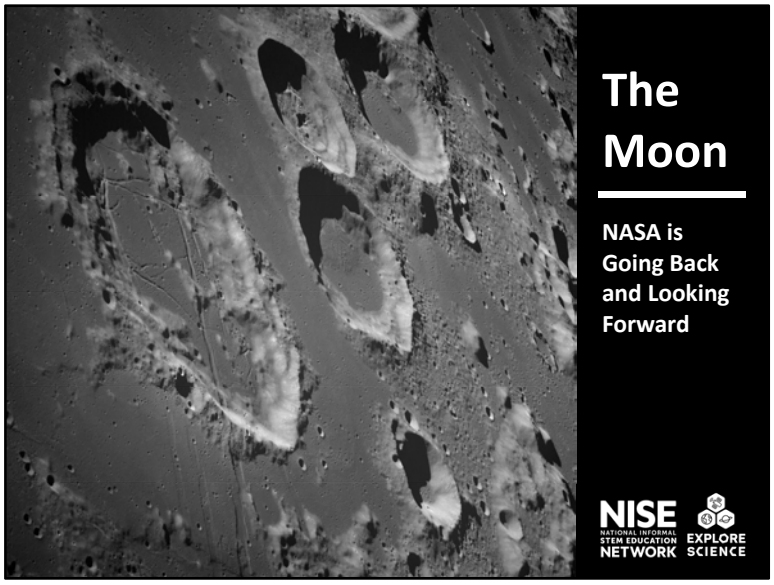

<u>Notes</u>: Today we are going to learn about NASA's history—and its future—with the Moon. How has our understanding of the Moon changed through exploration, and what mysteries remain?

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Photo

View of Goclenius and Other Craters
https://moon.nasa.gov/resources/257/view-of-goclenius-and-other-craters/?category=images
This photograph was taken from the Apollo 8 spacecraft with long-focal length lens, looking south at the large crater Goclenius, which is in foreground. Hold picture with Goclenius at bottom center. The three clustered craters are Magelhaens, Magelhaens A, and Colombo A. The crater at upper right is Gutenberg D. The crater Goclenius is located at 10 degrees south latitude, 45 degrees east longitude, and it is approximately 40 statute miles in diameter.
Image credit: NASA/JSC

The Moon is our closest neighbor in space and has fascinated human cultures for thousands of years.

<u>Notes</u>: Earth's only natural satellite is simply called "the Moon" because people didn't know other moons existed until the 17th century, when Galileo Galilei discovered four moons orbiting Jupiter.

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Photo

Moon Terminator
https://moon.nasa.gov/resources/176/moon-terminator/?category=images
The lunar terminator—the divide between sunlight and darkness on the Moon—is sharp in this amateur photo of the Moon.
The image was taken by Solar System Ambassador Thomas Campbell of College Station, Texas.
Image credit: NASA/Thomas Campbell

<u>Notes</u>: The Moon is on average 238,855 miles (384,400 km) away from Earth, or almost 30 Earth-lengths away. In fact, the Moon is slowly moving away from Earth, getting about an inch farther away each year.

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Photos

The Near Side of the Moon
https://moon.nasa.gov/resources/77/the-near-side-of-the-moon/?category=images
The near side of the Moon, as seen by the cameras aboard NASA's Lunar Reconnaissance Orbiter spacecraft.
Image credit: NASA/GSFC/Arizona State University

Earth
https://epic.gsfc.nasa.gov/archive/natural/2018/11/01/png/epic_1b_20181101184624.png
Image of Earth from 11/1/2018
Image credit: NASA EPIC Team

<u>Notes</u>: The Moon most likely formed from the resulting debris of a massive collision between Earth and a smaller planetoid about 4.5 billion years ago. The Moon causes tides, and it makes Earth more livable by moderating our home planet's wobble on its axis, leading to a relatively stable climate. It might be possible that life, or at least life as we know it, wouldn't have formed on Earth without the Moon. The famous Earthrise photo from Apollo 8 shown here reminds us that we can learn a lot about our planet through discoveries on the Moon.

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Photo

Earthrise: The 45th Anniversary
https://svs.gsfc.nasa.gov/4129
Three Earthrise photographs, scaled and rotated. The original photographs are AS08-13-2329, AS08-14-2383, and AS08-14-2384.
Image credit: NASA's Scientific Visualization Studio

<u>Notes</u>: In 2019 we are celebrating the 50th anniversary of NASA's groundbreaking Apollo 11 mission to land the first humans, Neil Armstrong and Buzz Aldrin, on the Moon. This is a time for us to reflect on the amazing achievements of the first Moon landings and look forward to the major role the Moon will play in NASA's future. An estimated 530 million people watched Niel Armstrong's televised image and heard his voice describe the event as he took "one small step for a man, one giant leap for mankind" on July 20, 1969.

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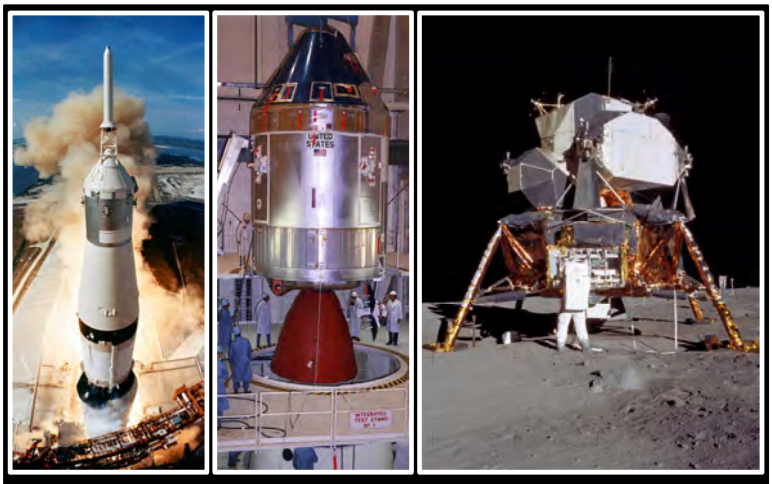
Photo

Apollo 11 Mission Image – Astronaut Edwin ("Buzz") Aldrin
https://moon.nasa.gov/resources/189/apollo-11-mission-image-astronaut-edwin-aldrin/?category=images
Image credit: NASA/JSC



Apollo 11 was more about engineering and less about science. Getting humans safely to the Moon and back was the priority.

<u>Notes</u>: The primary objective of Apollo 11 was to complete a national goal set by President John F. Kennedy on May 25, 1961: perform a crewed lunar landing and return to Earth. The famous Saturn V rocket (left) that sent the Apollo spacecraft to the Moon was about as tall as a 36-story building. The command/service module (middle) transported the astronauts between low Earth orbit and the Moon. The lunar module (right) landed on the Moon's surface. When it was time to leave the Moon, the top of the lunar module, or ascent stage, left the surface and met up with the command/service module which had been kept in orbit by Michael Collins.

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Photos

(left) On July 16, 1969, the huge, 363-feet tall Saturn V rocket launches on the Apollo 11 mission from Pad A, Launch Complex 39, Kennedy Space Center, at 9:32 a.m. EDT.
https://www.nasa.gov/sites/default/files/thumbnails/image/s69-39961.jpg
Image credit: NASA

(middle) Apollo 11 command/service module
https://history.nasa.gov/ap11ann/kippsphotos/69-HC-439.jpg
This photo shows the Apollo 11 Command-and-Service Module being mated to the spacecraft adapter. Photo filed April 1969
Image credit: NASA

(right) View Apollo 11 Lunar Module As It Rested on Lunar Surface
https://moon.nasa.gov/resources/188/view-apollo-11-lunar-module-as-it-rested-on-lunar-surface/?category=images
Image credit: NASA/JSC

<u>Notes</u>: This photo shows Buzz Aldrin with the Early Apollo Scientific Experiment Package (EASEP) on the Moon's surface. It contained 3 experiments:

1. A Laser Ranging Retroreflector – ***a device that reflects light back to Earth to measure distances***
2. Passive Seismic Experiment – ***to measure lunar shock waves caused by moonquakes or by impacts of meteoroids or manmade objects on the surface***
3. Solar Wind Composition Experiment – ***consisted of an aluminum foil panel, similar to household foil, that collected atomic particles released into space by the Sun***

The two astronauts of Apollo 11's lunar module were to extensively photograph the lunar terrain, the deployed scientific equipment, the spacecraft, and each other, both with still and motion picture cameras. They also deployed a television camera to transmit signals to Earth. Most Apollo 11 photos show Buzz Aldrin because Neil Armstrong was frequently operating the camera.

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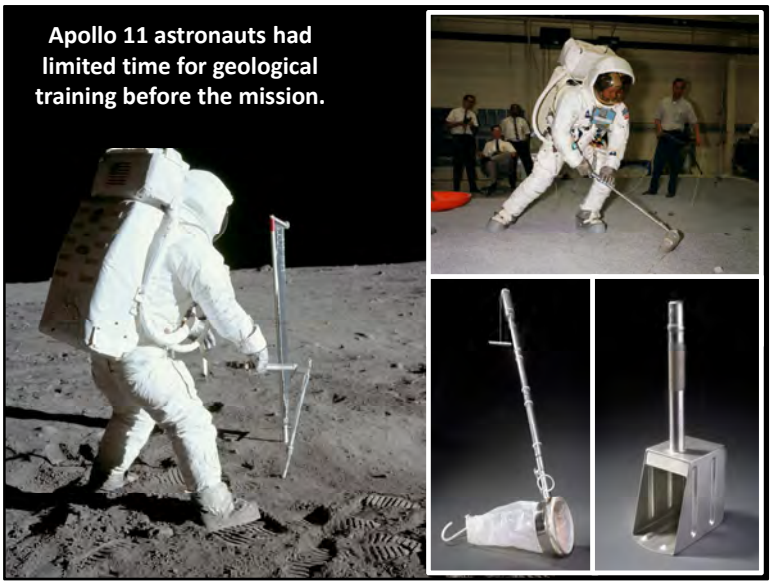
Photo

Astronaut Buzz Aldrin with scientific equipment, US flag, television camera and Apollo Lunar Module at Tranquility Base.
NASA photo AS11-40-5948
https://commons.wikimedia.org/wiki/File:Aldrin_Looks_Back_at_Tranquility_Base_-_GPN-2000-001102.jpg
Image credit: NASA



<u>Notes</u>: During their mission, the Apollo 11 astronauts were to gather samples of lunar-surface materials for return to Earth. They practiced with their specialized tools in a simulated Moon landing environment at Johnson Space Center (upper right) and during a quick geology site visit to Sierra Blanca, Texas, to prepare for the real thing. The astronauts weren't geologists, so they learned how to collect samples and what to look for on the Moon from experts. The tools were made of stainless steel and aluminum and served specific purposes. Here are two examples:

1. **Contingency Soil Sampler (left tool) - Used by astronauts to collect a soil sample immediately after they stepped from the lunar module to the surface to ensure that a sample would be returned to Earth even if astronauts had to curtail their surface explorations.**
2. **Bulk Sample Scoop (right tool) - This scoop was used to pick up large quantities of lunar material. Near the end of the first Moon landing, Neil Armstrong noticed the sample bag was only half filled so he quickly scooped up more samples to bring home.**

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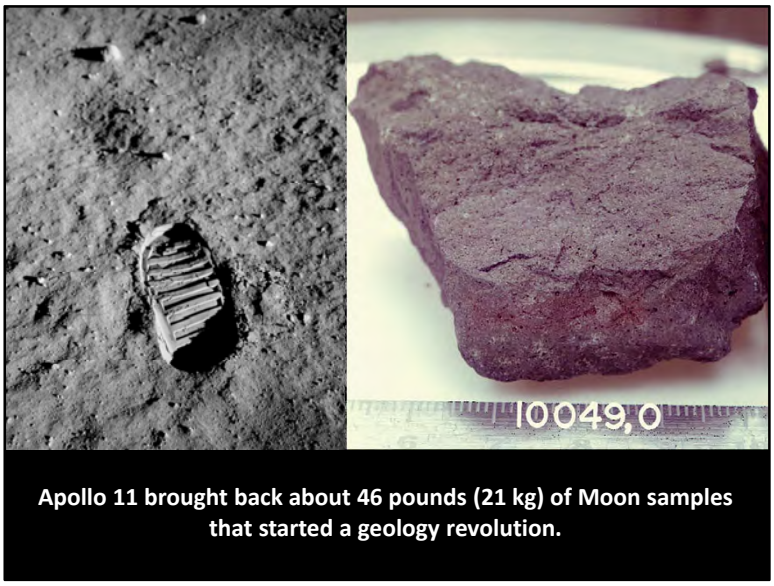
Photos

(inset upper right) Armstrong practices collection of contingency sample
https://www.hq.nasa.gov/office/pao/History/alsj/a11/ap11-S69-31048HR.jpg
Image credit: NASA

(inset bottom left) Contingency Soil Sampler
https://airandspace.si.edu/multimedia-gallery/5224hjpg?id=5224
Image credit: National Air and Space Museum, Smithsonian Institution

(inset bottom right) Bulk Sample Scoop
https://airandspace.si.edu/multimedia-gallery/5230hjpg?id=5230
Image credit: National Air and Space Museum, Smithsonian Institution

Buzz Aldrin using the hammer on Apollo 11
https://www.hq.nasa.gov/alsj/a11/AS11-40-5964HR.jpg
Aldrin obtaining the core-tube samples.
Image credit: NASA



Apollo 11 brought back about 46 pounds (21 kg) of Moon samples that started a geology revolution.

<u>Notes</u>*:* Moon rocks (right) and surface soil (left), or regolith, helped scientists understand the Moon was dry, old, and had undergone intense impacts. The makeup of the lunar crust was also more diverse than expected. Even today, scientists in NASA research centers are learning from the Apollo samples by using new techniques. There are still some samples brought back by Apollo we have not begun to examine.

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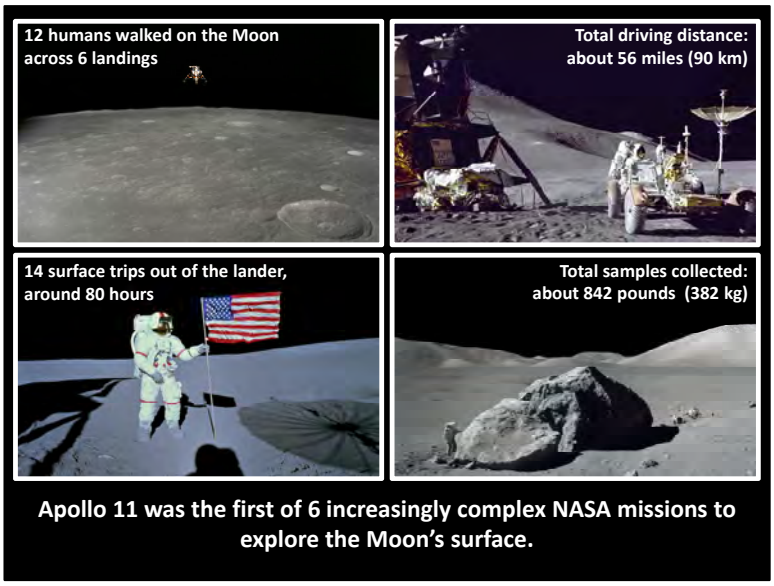
Photos

(right) *Mare basalt* : Apollo 11 sample 10049, The cube is for scale and is 1 inch on each side.
https://www.lpi.usra.edu/lunar/samples/atlas/lab_view/?mission=Apollo%2011&sample=10049&side=w
From NASA photo S76-25456
Image credit: NASA/JSC

(left) Apollo 11 boot print
https://upload.wikimedia.org/wikipedia/commons/8/89/Apollo_11_bootprint.jpg
Image AS11-40-5877
Image credit: NASA



<u>Notes</u>: Apollo 11 to 17 missions by the numbers. Apollo missions with successful Moon landings occurred between July 1969 and December 1972. Apollo 13 did not land on the Moon due to a technical problem en route, but all 3 astronauts safely returned to Earth. A Lunar Roving Vehicle was used on the Apollo 14, 15, and 16 missions. All three were left behind on the Moon.

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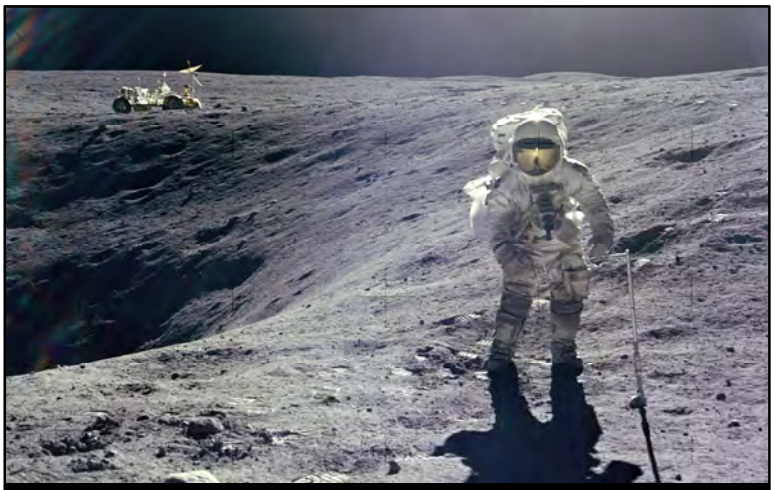
Photos

(upper left) Apollo 12 Lunar Module, in Landing Configuration, Photographed in Lunar Orbit
https://moon.nasa.gov/resources/196/apollo-12-lunar-module-in-landing-configuration-photographed-in-lunar-orbit/?category=images
Image credit: NASA/JSC

(lower left) Astronaut Alan Shepard During Apollo 14 EVA on the Moon
https://moon.nasa.gov/resources/215/astronaut-alan-shepard-during-apollo-14-eva-on-the-moon/?category=images
Image credit: NASA/JSC

(upper right) Loading the Rover, Apollo 15
https://moon.nasa.gov/resources/104/loading-the-rover/?category=images
Image credit: NASA

(lower right) Apollo 17 EVA
https://moon.nasa.gov/resources/50/apollo-17-eva/?category=images
Image credit: NASA/Gene Cernan



As the Apollo program went on, chosen landing sites were more rugged, mountainous, and scientifically interesting.

<u>Notes</u>: For safety reasons, Apollo 11's planned landing site at the Sea of Tranquility was flat and smooth. As NASA became more experienced with Moon landings, more challenging areas with different geological terrains were chosen for later Apollo missions. Apollo 16, shown here, landed at the western edge of the Descartes Mountains west of the Kant Plateau.

<u>Optional Media Clip:</u> ***This would be a good place to play the Apollo Landing Sites video included in the Explore Science: Earth & Space toolkit.***

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Photo

On the Crater's Edge
https://www.nasa.gov/multimedia/imagegallery/image_feature_802.html
Astronaut Charles M. Duke Jr., Apollo 16 Lunar Module pilot, is photographed collecting lunar samples at Station No. 1 during the mission's first extravehicular activity at the Descartes landing site. This picture, looking eastward, was taken by Commander John W. Young. Duke is standing at the rim of Plum crater, which is 40 meters (131 feet) in diameter and 10 meters (about 33 feet) deep.
Image credit: NASA

<u>Notes</u>: After Apollo 11, astronauts trained more extensively in geology and practiced in more geologically diverse locations across the United States. These site visits included terrain in Arizona, Nevada, California, New Mexico, Minnesota, and Hawai'i. Apollo 17 crew member geologist Dr. Harrison Schmitt became the first astronaut initially trained as a scientist to fly in space. The addition of a scientist to NASA crews would become commonplace after Apollo.

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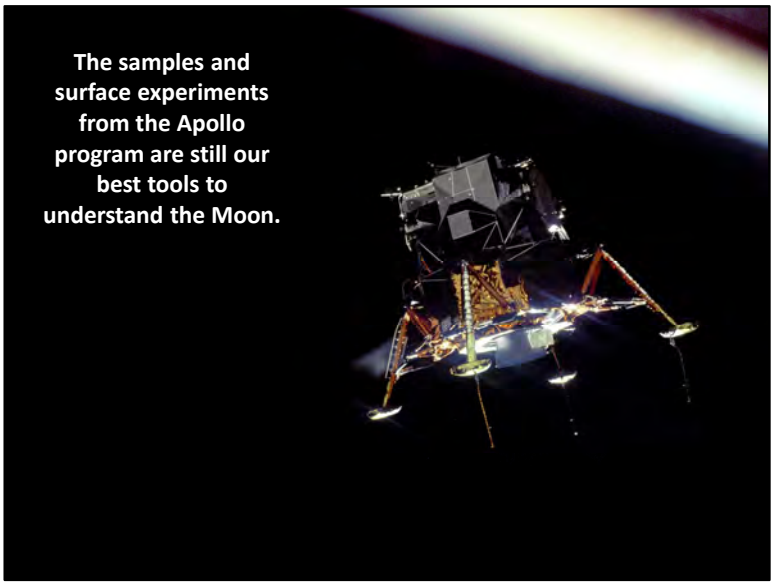
Photo

Apollo 17 astronaut Harrison Schmitt, Apollo 17 collects lunar rake samples at the Taurus-Littrow landing site.
https://www.nasa.gov/audience/foreducators/spacesuits/historygallery/ap-dec72.html
Image credit: NASA



<u>Notes</u>: The legacy of Apollo is still making an impact today. Apollo missions provided the edge pieces to the puzzle of the early solar system. NASA has been filling in that puzzle with more lunar and solar system science research ever since the last Apollo mission in 1972. In the last several decades, NASA and other space agencies have undertaken many lunar rover, orbiter, flyby, and impactors missions. Present-day exploration of the Moon has widened far beyond the former space race rivals of the U.S. and Russia to include a diverse set of international partners.

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Photo

The Eagle Prepares to Land
https://moon.nasa.gov/resources/161/the-eagle-prepares-to-land/?category=images
The Apollo 11 Lunar Module Eagle, in a landing configuration was photographed in lunar orbit from the Command and Service Module Columbia.
Image credit: NASA

<u>Notes</u>: A standout NASA lunar mission after the Apollo era is the Lunar Reconnaissance Orbiter (LRO), launched in 2009. LRO was sent to the Moon to make high-resolution maps of the composition of the lunar surface and seek out potential sources of water ice in the bottom of dark polar craters.

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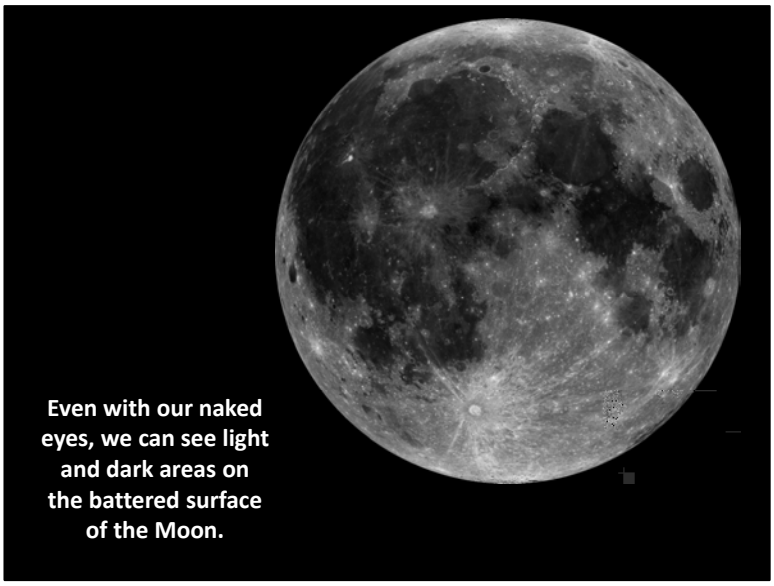
Photos

(left) LRO Launch
https://www.nasa.gov/multimedia/imagegallery/image_feature_1392.html
Image credit: Pat Corkery, United Launch Alliance

(right) LRO spacecraft rendering
https://lunar.gsfc.nasa.gov/images/348684main_LRO7-Apollo-PRINT1.jpg
Image credit: NASA's Scientific Visualization Studio



<u>Notes</u>: The Moon is covered with impact craters caused by colliding asteroids and comets. The light-colored areas, called the highlands, represent the earliest crust on the Moon. Impact cratering shattered this crust and often deformed it, pushing some of it into mountain-high crater rims or ejecting it across the surface of the Moon. This early crust of the Moon was dominated by a type of light-colored rock called anorthosite. When the Moon was relatively young, its interior was still molten. Lava erupted within, or flowed into, the low-lying impact basins, filling them up. The lava eventually cooled to form the dark-colored rock called basalt, responsible for the darker features (each called mare, Latin for sea) on the Moon.

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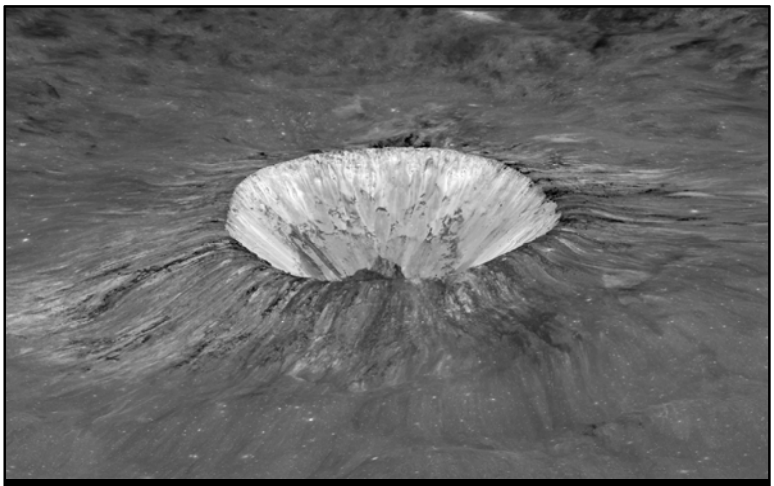
Photo

Full Moon taken by LRO
http://www.lroc.asu.edu/posts/1004
Image credit: NASA/GSFC/Arizona State University



The advanced cameras on LRO allow scientists to take detailed photos of lunar surface features, including impact craters.

<u>Notes</u>: Impact craters are a common feature on the Moon because there is no atmosphere that could erode away the craters with common Earth processes like wind and weather. This is why some impact craters on the Moon are billions of years old where similar-aged craters have long ago eroded away on Earth. Looking back billions of years with these preserved lunar impact craters helps scientists theorize about the conditions of the early solar system. This 6-mile-diameter (10 km) crater is named after planetary scientist Elisabetta "Betty" Pierazzo. It's called the Luminous Pierazzo Crater.

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Photo

Luminous Pierazzo Crater
https://www.lroc.asu.edu/posts/1000
Image credit: NASA/GSFC/Arizona State University

<u>Notes</u>: Scientists used LRO to learn more about the super-cold temperatures in the permanently shadowed craters of the Moon's south pole, shown by blue regions in the inset image. These craters, like the one shown in the main image, lie almost perpendicular to the Sun, never receiving its warmth or light. These are some of the coldest spots in the solar system…colder than even Pluto. These craters contain water ice, a potential resource for future human exploration of the Moon.

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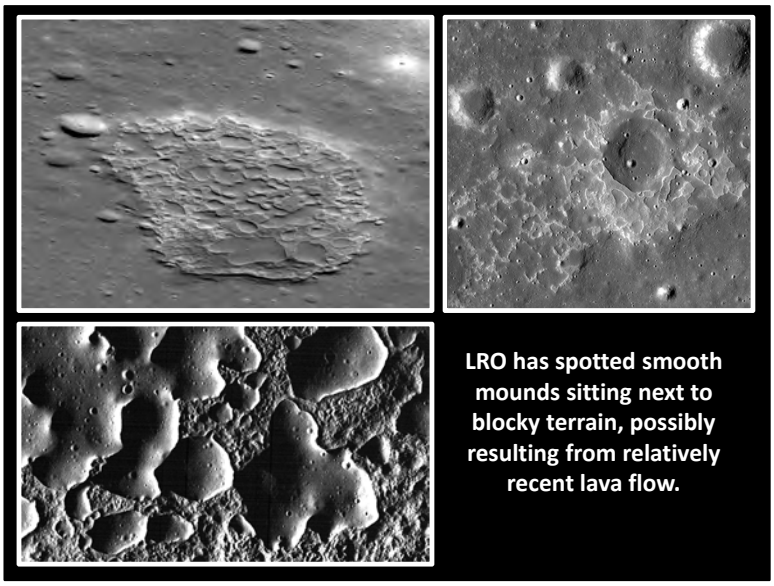
Photo

Staring Into Darkness
https://svs.gsfc.nasa.gov/11230
(top)Permanently shadowed regions (blue) cover about three percent of the moon's south pole.
(bottom)Temperatures within permanently shadowed regions can get as low as -414 °F.
Image credit: NASA's Scientific Visualization Studio



<u>Notes</u>: First seen as an oddity during Apollo 15, scientists using LRO have discovered many more irregular mare patches (IMPs), or smooth mounds sitting next to blocky terrain. Due to the lack of large impact craters, these smooth mounds resulting from lava flow are much younger compared to the rest of the Moon. If true, this means the Moon could be hotter inside than expected with relatively recent volcanic activity. The image in the upper left is an oblique view of a well-known IMP formation called Ina, about 1.2 miles across (2 km). Ina is thought to be about 33 million years old. The image in the upper right is another IMP about 1.9 miles (3 km) across near the crater Maskelyne. The lower image is a zoom-in of an overhead photo of Ina, with a width of about 0.6 miles (1 km), that shows the smooth mounds with small impact craters.

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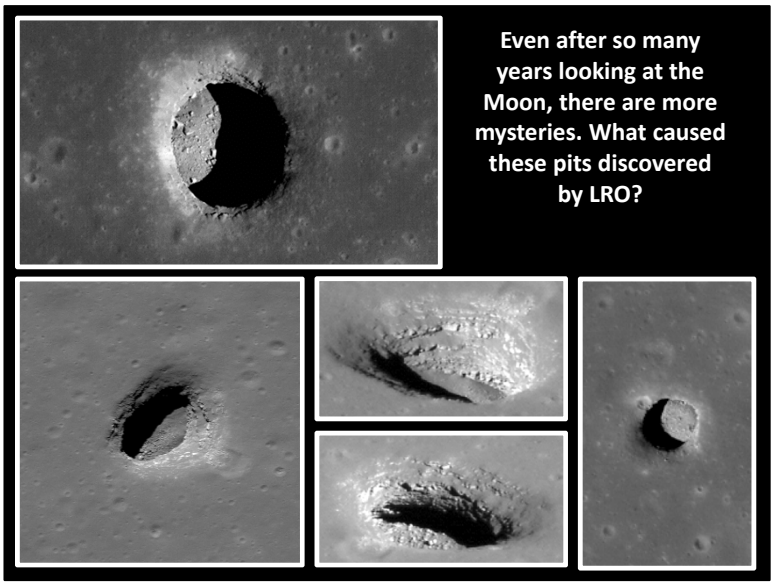
Photos

New Evidence For Young Lunar Volcanism!
https://www.lroc.asu.edu/posts/818
(top left) The contrast between the smooth and rough units stands out in this oblique view of Ina. The floor of the depression is about 50 m below the surrounding plains and is about 2 km wide from left-to-right (S to N). View from east-to-west, north is to the right, NAC M1108203502LR
(top right) One of many newly-discovered young volcanic deposits on the Moon, this example is near the crater Maskelyne. The direction of sunlight is from the right and north is up, NAC M1123370138R
Image credit: NASA/GSFC/Arizona State University

(bottom) Part of the floor of the enigmatic crater Ina on the Moon, in Lacus Felicitatis. Photo by Lunar Reconnaissance Orbiter, made with Narrow Angle Camera 27 November 2009 from altitude 45 km. Sun elevation is 6.6°. Width of the photo is 1.0 km, north is up.
https://en.wikipedia.org/wiki/Ina_(crater)#/media/File:Ina_mounds_at_low_Sun.png
Image credit: NASA/GSFC/Arizona State University



<u>Notes</u>: Scientists using LRO have found hundreds of these pits on the lunar surface. Pits are thought to form when the ground above a lava tube collapses. Pits may provide shelter from radiation, meteorite impacts, and extreme temperature, making them valuable resources for future habitats on the Moon. The top image shows the Mare Tranquillitatis (Sea of Tranquility) pit, about 325 ft (100 m) across, with clear boulders on its floor. The lower left image shows the Mare Ingenii (Sea of Cleverness) pit, about 160 ft (50 m) across. The two lower middle images show oblique views of the Mare Ingenii pit's east (top) and west (bottom) walls. The lower right image shows the Maurius Hills pit, about 325 ft (100 m) across.

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Photos

New Views of Lunar Pits
https://www.lroc.asu.edu/posts/230
(top) Spectacular high Sun view of the Mare Tranquillitatis pit crater revealing boulders on an otherwise smooth floor. Image is 400 meters wide, north is up, NAC M126710873R
(bottom left) View of Mare Ingenii pit
(bottom right) . With the Sun high above, a great view of the Maurius Hills pit floor
Image credit: NASA/GSFC/Arizona State University

(bottom middle)
Mare Tranquillitatis Pit M155023632R, Mare Ingenii Pit M184810930L
https://airandspace.si.edu/multimedia-gallery/11831hjpg
Image credit: NASA/GSFC/Arizona State University

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Photo

Orientale Basin
https://svs.gsfc.nasa.gov/4619
Image credit: NASA's Scientific Visualization Studio

Any future Moon bases will be built on NASA's science and engineering accomplishments of the Apollo program. A permanent settlement on the Moon or a space station in orbit could lead us to new discoveries on Mars and throughout the solar system.

Photo

Stills from "We are NASA" video
https://images.nasa.gov/details-We%20Are%20NASA.html
Image credit: NASA

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Photo

View of Earth Photographed by Apollo 15 on Voyage to the Moon
https://moon.nasa.gov/resources/224/view-of-earth-photographed-by-apollo-15-on-voyage-to-the-moon/?category=images
This view of Earth was photographed by the Apollo 15 crewmen as they sped toward the fourth lunar landing. The spacecraft was between 25,000 and 30,000 nautical miles from Earth when this photo was made.
Image credit: NASA/JSC

Image credits:
NASA
NASA/JSC
NASA/GSFC/Arizona State University
NASA's Scientific Visualization Studio
NASA/Thomas Campbell
NASA/Gene Cernan
NASA EPIC Team
National Air and Space Museum, Smithsonian Institution
Pat Corkery, United Launch Alliance

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What Was the Apollo Program? – NASA Knows! (Grades 5-8) series
NASA Science: Solar System Exploration – LRO in depth
NASA's Scientific Visualization Studio – Peeking Into Lunar Pits
Apollo 50th presentation by Dr. Noah Petro, Project Scientist for the Lunar Reconnaissance Orbiter

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