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APOLLO 15

Date: July 26 to August 7, 1971

Type of mission: Manned lunar landing Country: The United States

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The Apollo 15 mission placed the United States' fourth scientific team on the lunar surface. The primary objectives of the mission were fulfilled: It returned to Earth with an abundance of new data on the geologic evolution of the Moon and set the stage, as an exploration prototype, for the Apollo 16 and 17 missions.

Principal personages

DAVID R. SCOTT, command pilot

JAMES B. IRWIN, lunar module pilot

ALFRED M. WORDEN, command module pilot

Summary of the Mission

Following the success of Apollo 14 six months earlier in the Fra Mauro area of the Moon, the Apollo 15 mission was designed to continue the United States' lunar investigations in the Hadley-Appenine Mountains, located along the southeastern rim of the Sea of Rains. National Aeronautics and Space Administration scientists were convinced that ancient rocks found in the mountainous regions peripheral to the multiringed Sea of Rains held the clue to the age and genesis of the primordial lunar crust.

Apollo 15 was launched on schedule from Launch Complex 39A of the Kennedy Space Center in Florida on July 26, 1971, at 1334 Greenwich mean time (GMT). The launch vehicle was an 111-meter-high Saturn 5 rocket, capable of delivering more than 40 million newtons of thrust with its liquid oxygen and kerosene first stage and liquid oxygen and liquid hydrogen second and third stages. Eleven minutes and 44 seconds after lift-off, the command service module (CSM), the lunar module (LM), and the unfired Saturn 4B booster were placed into a nearly circular Earth orbit of roughly 170 kilometers of altitude. Immediately following the launch, the Manned Spacecraft Center in Houston, Texas, assumed control of the mission. After a routine systems check, a translunar injection burn of the booster was accomplished at 1624 GMT. The CSM and LM were separated from the Saturn 4B booster after the injection burn, and the booster was further engaged to land on the Moon and provide a seismic signal. The booster made lunar impact at 2058 GMT on July 29; its strong signal was recorded by the Apollo 12 and 14 seismograph installations. Because the booster's kinetic energy was known, calibration of these seismograph stations was made possible.

After two minor midcourse corrections to prepare for lunar orbit and a series of complicated maneuvers during lunar orbit injection, Apollo 15 was firmly placed into a nearly

circular lunar orbit of 121 by 101 kilometers at 1912 GMT on July 30. After separation from the CSM (dubbed Endeavor), the LM (dubbed Falcon) began its descent and landed at approximately 2216 GMT at 26°26'00" north latitude and longitude 3°39'20" east in a rugged valley between the Apennine highlands region and Hadley Rille. (A rille is a linear surface feature of unknown origin—perhaps a collapsed lava tube, a linearly fractured crust, or an ancient river valley.)

A stand-up extravehicular activity (EVA) was accomplished when David Scott depressurized the LM, opened a hatch, and examined and photographed the lunar landscape for 33 minutes. Three subsequent periods of EVA employed the new Lunar Rover Vehicle (LRV), a mechanized vehicle built by Boeing Aircraft Company which enabled Scott and James Irwin to travel greater distances and carry more complex scientific instrumentation than had been possible in previous missions. The LRV weighed 209 kilograms on Earth but only 34 kilograms in the lunar gravity field. It was capable of carrying Scott, Irwin, their life-support systems, communications equipment, scientific instruments, and 27 kilograms of lunar samples. Use of the LRV permitted total EVA time to be more than double the nine-hour EVA performed during Apollo 14.

The first EVA began at midday GMT on July 31 and lasted 6 hours and 34 minutes; this was 26 minutes less than planned because of excessive oxygen consumption. Collecting samples of lunar basalt (an iron- and magnesium-rich volcanic rock forming the dark areas, or maria, of the Moon and the oceanic crust of Earth), Scott and Irwin skirted the LRV along the rim of Hadley Rille and collected specimens along the rille's edge. They traveled southwestward toward Elbow and St. George craters and collected rocks ejected from the craters during their formation. After careful observation and collection of rock, soil, and core samples, the Apollo exploration crew entered the LRV for the 1.5-kilometer return trip to the Falcon. Following their LRV tracks, the crew returned to the landing site and set up a seismograph station, a solar wind experimental package, and a laser mirror to add to the retroreflector mirror network begun by the Apollo 11 and 14 missions.

The second EVA occurred at midday GMT on the following day and lasted 7 hours and 12 minutes. The crew drove the LRV southeastward toward Mount Hadley, a 3.47-kilometer-high mountain uplifted during the impact that created the Sea of Rains to the northwest. Vigorous collecting of geologic specimens and recording of field data ensued, as the crew visited many craters and then turned their attention to Mount Hadley. Here, 12-meter-thick layers were exposed on the face of the mountain, suggesting deposition of volcanic lavas or ash flows. After completing the 12.7-kilometer journey, the exploration team attempted to drill holes into the lunar crust for heat probes. Because of design problems and unexpected hardness of the lunar regolith (unconsolidated "soil" resting above the bedrock), the drill would penetrate only to about 1 meter of depth, rather than the 3 meters desired by project scientists. Heat probes were placed in the shallow holes and connected to the instrumentation. Finally, another attempt to drill (this time a drilled core) resulted in a 2.4-meter continuous boring of the lunar regolith. A trench was dug by Irwin, and soil mechanics experiments were carried out.

Apollo 15's third EVA began on the morning of August 2, with the express purpose of studying Hadley Rille. Layers of varying thickness in the rille's walls were interpreted to

represent basaltic lavas. The astronauts climbed down the rille's sloping walls, sampling the rocks and photographing the structure. After 4 hours and 50 minutes, the EVA was over; the LM crew abandoned the LRV, set up a television camera to transmit the takeoff, and entered the LM's ascent stage for lift-off.

While the Falcon crew was extending knowledge of lunar geology, Worden had accomplished thirty-four orbits in Endeavor and had carried out an impressive array of scientific tasks. Utilizing panoramic and mapping cameras, he managed to photograph roughly 10 percent of the lunar surface. A laser altimeter, which failed late in the mission, procured altitude data to allow the scaling of photographs and the measuring of topographic variations of the lunar surface. In addition, lunar surface features were photographed by hand, and detailed photographs of the planned Apollo 17 landing site near Littrow crater were taken.

Use of the camera formerly attached to the LRV allowed images of the lift-off of the LM's ascent stage to be transmitted to Houston and witnessed in real time by the people of Earth. Lift-off occurred on August 2 at 1711 GMT, with rendezvous and docking successfully performed two hours later. After men, samples, and equipment were evacuated from the ascent stage of the LM, it was jettisoned, and it made impact with the Moon within twenty-two kilometers of the target site. The seismographs of Apollos 12, 14, and 15 recorded the event.

Following a correction of orbit in preparation for a critical burn that would return Apollo 15 to Earth, a 38-kilogram, 78-centimeter unnamed satellite built by the TRW Company was ejected from the CSM. It would orbit the Moon for roughly one year, and for several months it would transmit data gathered from onboard experiments on lunar geologic structure, density variations, electric and magnetic fields, and charged particles. During Apollo 15's return journey, photographs of the Moon, Earth, and space were taken and numerous scientific and medical experiments were conducted.

Endeavor reached Earth orbit on August 7 and splashed down two kilometers from the target point in the Pacific Ocean at 2045 GMT, within ten kilometers of the prime recovery ship, USS Okinawa. The crew of Apollo 15 returned roughly 78 kilograms of lunar rocks, soils, and core, as well as a vast collection of photographic data. They had spent 18 hours and 30 minutes in three EVAs and 66 hours and 54 minutes on the Moon. The Apollo 15 mission provided a treasure trove of new data on the genesis, structure, and geologic development of the Moon.

Knowledge Gained

One of the prime objectives of the Apollo 15 mission was to analyze the Hadley mountain area, as it was thought to contain exposures of ancient lunar crust that predated the formation of the Sea of Rains. Prominent layers exposed on the fresh face of Mount Hadley defied precise analysis, because of poor lighting conditions, but they were thought to represent gently dipping regolithic compositional strata, or perhaps vertical fault structures. Extensive sampling and photography of Hadley Rille, on the other hand, allowed scientists to conclude that this topographic feature represents lava flows up to sixty meters thick, of variable composition.

Rocks from the Hadley Delta show evidence of intense fracturing or shock-metamorphism (brecciation) and partial melting resulting from impact.

Sea of Rains lavas sampled from the Marsh of Decay were dated at 3.1 to 3.4 billion years old. They show high iron content and low sodium compared to terrestrial basalts (which are much younger). They vary in texture, some being dense and fine-grained while others are rich in bubbles (scoria), like lavas found in volcanic provinces on Earth. The soils sampled are similar to those collected on previous missions: shock-melted spherical glass droplets, angular shards of glass, basalt and mineral fragments, and fine-grained breccias. The spherical glass represents shock-melted airborne debris that cooled in flight, while the angular shards suggest impact-related fracturing of preexisting glassy volcanic crusts.

Apollo 15's seismometer, joined to the Apollo 12 and 14 network, returned data showing that there is a boundary between the lunar crust and mantle and that the crust's thickness varies from 45 to 70 kilometers. The number of moonquakes was minor, compared to the number of quakes on Earth, indicating a relatively inactive, highly evolved geologic body. The Apollo 15 magnetometer experiment showed a slight field, compared to measurements made at the Apollo 12 and 14 sites, and allowed calculations of interior mantle and core temperatures. The heat-flow experiment showed that lunar heat flow was greater than expected - roughly half that of Earth - which suggested that the lunar interior has a greater radioactive component than had been thought. X-ray fluorescence measurements taken in orbit confirmed the chemical contrasts of the lunar maria and highland areas and helped define differences between these chemical-physiographic provinces.

The lunar orbital mass spectrometer experiment proved inconclusive as gas molecules measured in the Moon's airless atmosphere were apparently related to the command module. The subsatellite measured lunar magnetic variations associated with specific craters and found interplanetary fields interacting with the Moon's field. In addition, the solar wind was found to be disturbed as it passed around the Moon, and anomalous gravity increases (mascons) were mapped; these findings confirmed earlier results from unmanned Lunar Orbiter missions. Other experiments performed during the Apollo 15 mission are described in detail in the volumes cited below.

Context

The voyage of Apollo 15 marked the first of three extended lunar exploration missions using the motorized LRV, a vehicle that extended the range, quantity, and quality of scientific investigations of the Moon. Apollo research had shown that the Moon was similar to Earth in total age, although its geologic evolution had halted much earlier. Data from Apollo 14 had yielded a date of 4 billion years before the present for the cataclysmic creation of the Sea of Rains; its lavas, dated at roughly 3.2 billion years old, mark the cessation of major volcanism on the Moon.

Mare basalts of the Apollo 15 site were strikingly similar to those collected by Apollos 11 and 12 and the Soviet Union's Luna 16 mission. Apparently, the Moon experienced a number

of internal heating episodes which resulted in an ancient layered crust, much thicker than Earth's. The Moon's primordial highland crust proved to be similar to the ancient terrestrial igneous rocks known as anorthosites (rocks composed primarily of calcium, aluminum, silicon, and oxygen in combination). Radioactive dating demonstrated that the crust formed early in the solar system's history, roughly 4.5 billion years ago. Earth-based studies of collected geologic specimens, photographs, and raw scientific data have painted a new view of lunar geologic history, shed new light on the early history of Earth and the solar system, and produced dramatic new visuals of Earth in space.

Bibliography

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Cortright, Edgar M., ed. *Apollo Expeditions to the Moon*. NASA SP-350. Washington, D.C.: Government Printing Office, 1975. The photographs, drawings, and diagrams of this large-format book chronicle the legacy of Apollo for the general reader. Its fifteen chapters are written by various authors, including some Apollo astronauts. The political impetus for the race to the Moon is discussed, along with the development of launch vehicles and the early mechanized spacecraft that preceded Apollo.

Criswell, David R., ed. *Proceedings of the Third Lunar Science Conference*. 3 vols. Cambridge, Mass.: MIT Press, 1972. Presenting the research of hundreds of scientists, this massive three-volume set reports on the findings of Apollos 11, 12, 14, and 15 and the Soviets' Luna 16 mission. Meticulously detailed accounts of the exploration of the lunar surface and of Earth-based analysis of returned samples and data.

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National Aeronautics and Space Administration. *Apollo 15 Preliminary Science Report*. NASA SP-289. Washington, D.C.: Government Printing Office, 1972. A detailed technical description of the scientific experiments and findings of the Apollo 15 mission. Requires of its readers some knowledge of geology and engineering as well as familiarity with astronomy and the history of the space program.

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Cross-References

The Apollo Program, 28; Apollo 1-6, 37; Apollo 7, 47; Apollo 8, 53; Apollo 9, 60; Apollo 10, 67; Apollo 11, 75; Apollo 12, 83; Apollo 13, 92; Apollo 14, 98; Apollo 15's Lunar Rover, 110; Apollo 16, 116; Apollo 17, 125; The Apollo-Soyuz Test Project, 132; Astronauts and the U. S. Astronaut Program, 154; Cape Canaveral and the Kennedy Space Center, 229; The Gemini Program, 487; The Lunar Landscape, 809; Lunar Soil Samples, 823; The National Aeronautics and Space Administration, 1032; Saturn Launch Vehicles, 1240; The Development of Spacesuits, 1917.