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APOLLO 14

Dates: January 31 to February 9, 1971

Type of mission: Manned lunar landing

Country: The United States

Early in 1971, the Apollo 14 mission succeeded in landing the third American scientific team on the lunar surface. Providing important new data on the structure and geologic history of the Moon, the Apollo 14 mission paved the way for advanced, long-duration scientific missions that together produced a vast compendium of knowledge on the Earth-Moon system.

Principal Personages

ALAN B. SHEPARD, command pilot

EDGAR D. MITCHELL, lunar module pilot

STUART A. ROOSA, command module pilot

PAUL W. GAST, Chief Scientist, Apollo Lunar Science Staff

Summary of the Mission

After the explosion of Apollo 13's service module and the resulting cancellation of the mission's planned lunar exploration, Apollo 14 was designed to restore confidence in the lunar exploration program and return data and samples from the Fra Mauro area. Careful examination of photographs from orbital scanning had led scientists to believe that this area contained some of the Moon's oldest rocks, thrust up from the ancient lunar crust during the cataclysmic formation of the Sea of Rains.

Apollo 14 was launched from the Kennedy Space Center (formerly Cape Canaveral) in Florida at 2103 Greenwich Mean Time (GMT) on January 31, 1971. The astronauts were sitting atop a 111-meter-high Saturn 5 rocket which could deliver more than 40 million newtons of thrust during its three-stage burn. Saturn 5 utilized liquid oxygen and kerosene in the first stage and liquid oxygen and liquid hydrogen in the second and third stages. Remembering the lightning that had caused problems for Apollo 12's takeoff, National Aeronautics and Space Administration (NASA) launch specialists, in collaboration with mission specialists operating from the Manned Spacecraft Center in Houston, Texas, held the launch for 40 minutes waiting for clouds to dissipate. Eleven minutes and 49 seconds after launch, the "live" upper stage of the Saturn 5 rocket, the instrumentation unit harboring the lunar module (LM), and the command and service module (CSM) were emplaced into Earth "parking" orbit for systems check, docking maneuvers, and ultimately a precision burn toward the Moon.

Operating at an orbit of 183 by 189 kilometers and with all systems checked, the Apollo 14 crew accomplished trans-lunar injection firing from Earth orbit. While coasting toward their lunar target, the astronauts had to dock the CSM and LM, a necessary preamble to lunar orbiting. A hard dock was completed after five unsuccessful attempts. After a check of the docking mechanism for possible malfunction, a critical burn of the rocket's upper stage guided the CSM and LM into an elliptical (109-by-18-kilometer) lunar orbit at 0700 GMT on February 4, 1971. After an orbital

connecting burn, the CSM was placed in a nearly circular orbit roughly 110 kilometers above the lunar surface.

Alan Shepard and Edgar Mitchell manned the LM (dubbed *Antares*) and separated from Stuart Roosa in the CSM (dubbed *Kitty Hawk*) to effect lunar landing in the Fra Mauro region. Because of problems with a faulty switch in the abort guidance system, the *Antares* was forced into a manual landing at 0837 GMT on February 5, at 3°40'24" south latitude and 17°27'55" west longitude. Throughout the history of manned American space travel, astronauts had pressed NASA to relinquish control of spacecraft to them as pilots. The lunar landings of Apollo 11 and 14 would not have been possible had the pilots not been prepared to land manually. Apollo 14's landing was very successful deviating only 50 meters from the proposed landing site in the Fra Mauro highlands.

Two extravehicular activity (EVA) periods were planned for the Apollo 14 expedition. The first EVA, which lasted 4 hours and 49 minutes, concentrated on deployment of equipment and scientific packages and collection of local geological samples. The second EVA lasted 4 hours and 20 minutes and involved an extended geological traverse to Cone crater, northeast of the landing site.

The first EVA began 40 minutes late on February 5 at 1400 GMT because of problems in the lunar module's communications system. The EVA was extended thirty minutes beyond what had been planned, to allow for completion of the experiments and sampling. Initially, the astronauts collected grab samples of rock and soil near the LM. Next, Shepard erected a television camera to broadcast their activities back to Earth, and together they deployed the S-band antenna which transmitted their television signals. The astronauts unpacked and set up the Apollo lunar scientific experiment package which was stowed in *Antares*' modularized equipment stowage assembly. The scientific experiment package contained a solar wind detector and a spectrometer to measure the frequency and energy of charged particles in the solar wind, ionosphere and atmosphere measuring devices, and a laser mirror to measure changes in the Earth-Moon distance and fluctuations in their rotation rates.

Shortly thereafter, the astronauts performed an active seismic experiment that sought to define the depth of the lunar regolith (unconsolidated soil and lunar rubble) at the landing site. The experiment involved use of a string of three geophones, an instrument package, and charges that produced seismic waves. The velocities of seismic waves are directly proportional to the density of the crustal material through which they travel. Small explosive charges were therefore fired against the ground in various places. The geophones then recorded the different seismic velocities as a function of depth. These data allowed a determination of the crustal structure at the *Antares* landing site.

The television cameras permitted mission scientists on Earth to direct the collection of geologic samples. Shepard and Mitchell, using the two-wheeled cart-like modularized equipment transporter, collected roughly 3.5 kilograms of rocks and soil under the watchful eye of Paul Cast in Houston. After the active seismic experiment and geologic specimen collecting, a passive seismograph was deployed from the equipment stowage assembly and activated to record moonquakes and impacts. Instantly, it began recording weak moonquakes (and the footfalls of astronauts) and transmitted seismic velocity data back to Earth. The first EVA ended as a success, and the astronauts entered *Antares* for a well-earned rest period.

The second EVA began more than two hours early (at the request of the crew) on 6 February with the goal of making a trek of roughly 1.5 kilometers northeastward toward Cone crater. Pulling

the modularized equipment transporter uphill, the astronauts were to sample, near Cone crater, rocks spewn from the Sea of Rains. These rocks were believed to have originated deep in the lunar crust. In addition, the astronauts were to perform magnetic surveys along their route and collect soil and rock samples.

Their progress was slowed by the necessity of pulling the non-motorized equipment transporter, by their bulky spacesuits, and by their numerous stops to perform magnetometer surveys, characterize the landscape, and photograph and sample the lunar surface. Soon, it became evident that they would be unable to reach Cone crater and perform meaningful investigations there in the allotted time. Therefore, under direction from Mission Control, the astronauts collected peripheral samples, dug a trench to observe the layering and mechanical strength of the regolith, and collected more rock and soil samples from a boulder field immediately south of Cone crater. Returning to *Antares*, they checked the scientific instruments and the alignment of the Earth-transmitting antenna system before entering the LM for ascent to the CSM, *Kitty Hawk*, which was circling overhead.

During his lunar orbit in the CSM, Roosa had performed important scientific duties including photographic surveying of large continuous tracts of the Moon to produce detailed views of future Apollo landing sites. Radar experiments, S-band transponder experiments, and visual tracking of lunar surface features, including the LM landing site, were also completed.

With the lift-off systems checked, at 10:00 GMT on February 6 the ascent stage of the LM performed as planned by launching members of the Apollo 14 exploration team and their samples into lunar orbit. Rendezvous was accomplished in one orbit, and docking with the CSM took place at 2035 GMT. Shepard and Mitchell joined Roosa in the CSM, and they jettisoned the LM ascent vehicle. It landed on the lunar surface between the Apollo 12 and 14 seismic experiment stations. The energy of its impact produced a signal that lasted for 1.5 hours. This signal provided important data on the structure of the Moon's crust.

While in lunar orbit, the Apollo 14 crew continued to perform scientific experiments and photographic surveys of the Moon, Earth, and galactic space. The crew was catapulted toward Earth at 0139 GMT on February 7 with a critical burn of the CSM propulsion system and continued to perform experiments in zero-gravity conditions en route to Earth. After a minor midcourse correction, the Apollo 14 crew splashed down in the Pacific Ocean at 2024 GMT on February 9, 1971, at 27°2'24" south latitude and 172°41'24" west longitude, roughly one kilometer from the target point.

In a hugely successful mission, following on the heels of a near-disastrous Apollo 13 attempt, the Apollo 14 crew set new records for man's presence on the Moon, brought back 43 kilograms of lunar rock, soil, and core samples, and procured abundant scientific and photographic data for years of research for scientists back on Earth.

Knowledge Gained

Data gathered during lunar fieldwork and scientific experiments carried out on the Moon's surface, in orbit and during flights to and from the Moon contributed significantly to the then-current body of knowledge of lunar geology. The prime objective of the Apollo 14 mission was to examine and collect rocks of the Fra Mauro formation (debris thrust up from the ancient lunar crust and spewn radially outward during formation of the Sea of Rains). Since the Fra Mauro formation is a

blanketing of ejecta distributed in linear patterns around the Sea of Rains, sampling and dating of the Fra Mauro terrain would help define the age of the Sea of Rains. Cone crater - a younger feature roughly 340 meters in diameter, punched through the Fra Mauro formation and offered access to the underlying strata.

Not surprisingly, of the Apollo 14 samples returned to Earth, almost all are breccias (highly fractured rocks composed of angular clasts of preexisting rocks). On the Moon as on Earth, brecciation of crystalline rocks is a product of impact processes. By contrast to the collection of Apollo 12 which was dominated by volcanic rock and that of Apollo 11, which was about 50 percent volcanic, the Apollo 14 collection was 90 percent fragmental in origin. The fragmental rocks of the Fra Mauro formation which locally exhibit brecciated fragments as clasts within breccias record a complex crustal evolution of initial cratering followed by formation of the Sea of Rains itself. Dating of these rocks has placed creation of the Sea of Rains at 3.9 billion years before the present.

The active seismic experiment, described earlier, defined an unconsolidated layer of surface regolith 8.5 meters thick at the scientific instrumentation site and confirmed a nearly identical result that had been attained at the Apollo 12 landing site. The regolith is underlain by a 50-meter-thick layer that possesses the seismic properties of a fragmental unit similar to the Fra Mauro formation. The passive seismic experiment formed a network with the Apollo 12 station, roughly 180 kilometers away. Impacts of meteoroids and lunar quakes were distinguished. The moonquakes increased in frequency when the Moon was in perigee (closest to Earth), probably because of a release of internal tidal strain. The impacts of the Saturn's upper stage and the jettisoned LM ascent stage provided strong signals for the Apollo seismic network and prepared the way for testing of early hypotheses regarding the lunar interior.

Space Exploration

The Apollo 14 spectrometer recorded an increase in charged particles as the Moon passed through Earth's magnetosphere (an envelope of charged particles produced by the interaction of Earth's magnetic field and the solar wind). A laser mirror added to the Apollo 11 mirror baseline helped provide data on the lunar interior and rotation of both Earth and the Moon. It helped scientists discover that the Moon was receding from Earth at about 3 centimeters per year. The portable magnetometer used during the EVAs verified Apollo 12 measurements of magnetic field strength and showed that the field varied considerably from place to place. Other experiments conducted during the Apollo 14 mission are described in detail in the books referenced below.

Context

The voyage of Apollo 14 restored faith in the Apollo program after the nearly disastrous Apollo 13 mission and added an important new set of data on the geologic evolution of the Moon. The Apollo 11 and 12 missions to the Sea of Tranquility and the Ocean of Storms had identified the dark rocks of the lunar maria, or basins, as volcanic basalts while the Apollo 14 mission provided samples of different rock types (ejecta units) and data that helped geologists to estimate the age of the Sea of Rains, a multi-ringed impact basin. These data have led to significant advances in studies of planetary formation during the period of intense cratering that persisted throughout the early history of the solar system. Of lasting significance, scientific instrumentation left at the Apollo 14

site provided an important link for future Apollo science stations, allowing for precision triangularization and corroboration of experimental results.

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Cross-References

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