

THE QUEST FOR THE MOON

Rare Glimpses into the Apollo Mission

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Abstract

After NASA's tremendous effort, Apollo 11 was launched on the 20th July 1969. After spending 2:36 hours on the moon, it returned to the Earth on 24th July 1969. Apollo 12 was launched on 14th November 1969, spending 1 day 7:31 hours on the lunar surface, returning home on 24th November 1969. Apollo 13, an unsuccessful mission, was followed by another successful expedition of Apollo 14, which was launched on 31st January 1971, which stayed 1 day 9:30 hours on lunar soil. It came back on 9th February 1971. With better equipment and scientific instruments Apollo 15 was launched on 26th July 1971, for 2 days 18:54 hours it was on the lunar surface and came back on 7th August 1971. Apollo 16 left on 16th April 1972 and returned to Earth on 27th April 1972 after a stay on the moon for 2 days, 23:02 hours. The last and probably the most successful lunar landing mission Apollo 17 was launched on 7th December 1972 having onboard, for the first time, a geologist whose contribution added to the success of the mission. It came back on 19th December 1972 after having spent the longest time of the Apollo series 3 days 2:59 hours. This document outlines the fine details of these missions.

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Introduction

Man is characterized by his insatiable quest to explore the unknown realms of the universe, no matter how costly his endeavour can become. This constant thrust for knowledge and unstoppable fervour to conquer the universe has led mankind to navigate the oceans, travel the deserts and cherish a desire to penetrate the unfathomable depths of heavens. Ever since the times of *Aristarchus*, we have witnessed an unbelievable progress with regard to man's obsessive pursuit to let loose his creative potential; to first understand comprehensively his mother planet and then to go beyond the frontiers of this terrestrial prison, into the depths of space and eventually stab the lunar surface. The first footsteps on the lunar terrain stand as a testimony to the greatness of man's deep-rooted desire to explore and conquer whatever comes its way.

The conquest of the moon was the culmination of man's incessant efforts, tremendous research and indescribable devotion spanning many centuries. In times long ago, the very idea of touching the moon must have been considered nothing but a tempting fantasy - a

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far and distant cry and an unrealizable dream. This dream was finally turned into reality by the National Aeronautics and Space Administration (NASA), which earned for itself enviable prestige amongst all major research and development organizations worldwide. On 1st October 1958, the inauguration of the NASA was the beginning of a rich history of unique scientific and technological achievements in human space flight, aeronautics, space science and technology. Formed as a response to the challenging competition by *Sputnik*, NASA inherited the earlier National Advisory Committee for Aeronautics (NACA), and engulfed other government organizations, and almost immediately began working on the options of human space flight. NASA's first high profile programme was project *Mercury*, an effort to learn if humans could survive in space, followed by project *Gemini*, which was built upon *Mercury*'s success and used a spacecraft built for two astronauts. NASA's human space flight efforts then extended to the Moon with project Apollo, culminating in 1969 with the Apollo 11 mission which first put humans on the lunar surface.

Thousand of computer programmers, astronomers, geologists, aeronautical engineers, hardware designers, and hardworking labourers combined their efforts and energies to put yet another jewel in the crown of man's accomplishment as *Neil Armstrong* took a small step which in his own words, has proved to be a "giant leap for mankind".

After the Second World War, with disillusionment and despondence gripping humanity, one could hardly imagine that after such a short span of time, mankind was to celebrate its greatest victory ever made thus far. Amidst the cold war, the two super powers USA and USSR feverishly battled for establishing their supremacy in space. The Russians took the lead initially by sending the first satellite *Sputnik*, which was launched on 4th October 1957. *Laika* (a female dog) aboard *Sputnik 2* on 3rd November 1957, was the first species to traverse space. The first spacecraft; *Luna 1* to reach the moon on 4th January 1959 was also Russian, followed by *Luna 2*. The first man in space, on 12th April 1961, was *Uri Gagarin*, another Russian, followed by the first woman, *Tereshkova* on 16th June 1963. Man's wanderings in space caused tremendous euphoria all through the USSR, prompting the USA to accelerate its scientific and technological focus as well as money spending on the space programme.

Recently released audio recordings from the Kennedy White House reveal that politics, more than science, may have fueled America's race to the moon against the Soviets. The discussion reveals a President who felt that landing men on the moon should be NASA's top priority and a NASA chief who did not. When asked by *Kennedy* if he considered the moon landing to be NASA's top priority, *Webb* (NASA Chief) responded. "No sir, I do not so. I think it is only *one* of the top priority programmes." *Kennedy* then urges *Webb* to adjust his priorities because, "This is important for political reasons, international political reasons. The is whether we like it or not, it is an intense race."

In 1962, NASA was still generally perceived as a military operation and all the astronauts were active duty military personnel. Stressing the importance of beating the Soviets to the moon, *Kennedy* tells *Webb*, "We hope to beat them to demonstrate that, starting behind, as we did by a couple of years, by God we passed them." The largely unrivalled spate of

Soviet successes had already left Americans with chilling visions of nuclear bombs raining down on them from orbit, and maybe even the moon.

As the White House conversation continues, *Kennedy* reminds *Webb* of the fantastic amount of money the federal Government had spent on NASA and asserts that future funding should be directed exclusively towards the moon landing. “Otherwise” declares *Kennedy*, “We shouldn’t be spending this kind of money because I am not that interested in space.”

This competitive attitude of the American nation, the Congress and President *John F. Kennedy* fructified man’s first landing on the lunar surface which opened a new horizon for man’s technological and space advance.

Man’s landing on the moon was undoubtedly an ambitious project for which thousands of preparations, immaculate calculations and infallible assessments had to be made. The numerous risks inherent in the project could endanger several lives and huge amounts of money were at stake. The environment outside the protective blanket of the atmosphere was definitely going to be harsh, with unforeseen dangers. On the other hand, a victory for NASA could mean a rejuvenated hope for mankind, dispelling the awe and mystery that had enshrouded the moon for centuries. The centre of folklore and witchcraft, the moon, could now become a surmountable reality for mankind.

We as students of science, at the Khwarzimid Science Society, have a lot to owe to these men of courage and unwavering scientific will, whose passion to reach the moon has indeed ignited in us the flame of scientific inquiry.

This paper outlines all the stages, which the astronauts, homebound scientists and other scientists underwent in their collective journey to the moon. It also gives a graphic account of the feelings, emotions and a few interesting conversations – these accounts give us a rare insight into the mindset of those astronauts who were undergoing the rarest of experiences – leaving their planet of birth.

At its scientific zenith in 1966-7, the Apollo programme involved about 420,000 people. The project also collaborated with 20,000 big and small industrial firms and 100 universities.

1. Apollo 11

1.1 Crew and Spacecraft



Commander (CDR): *Neil Alden Armstrong* (Born on 5th August, 1930)

Lunar Module Pilot (LMP): *Edwin Eugene Aldrin* (Legally changed to *Buzz Aldrin* 1979, Born on 20th January, 1930)

Command Module Pilot (CMP): *Michael Collins* (Born on 31st October, 1930)

Lunar Module (LM): *Eagle*
Command Module (CM): *Columbia*

In May 1961, American President *Kennedy* stood before a joint session of the Congress and said, "I believe this nation should commit itself, before this decade is out, to land a man on the moon and returning him safely to the Earth."

NASA had just started to put man in the space by *Alan Shepard* on a fifteen minutes sub-orbital flight on 20th February 1962; he circled the Earth every ninety minutes at an altitude of 160 Km.

1.2 Flight Preparation

The hardware that would put man on the moon would be the Apollo spacecraft with its *Saturn V* booster rocket.

The US was ready to go to any limit in completing their mission. According to *Chaikin* (1998), "Already the space budget had increased to forty cents per person per week for every man, woman and child in the United States, more than the allocations of the previous eight years combined, and soon it would be more than fifty cents."

On Monday, 6th January 1969, NASA's *Slayton* summoned *Armstrong* to his office and told him that he was planning to assign his crew to Apollo 11. *Buzz Aldrin* would be his LMP, and *Mike Collins* would be his CMP. *Buzz Aldrin*, the first Ph.D. Astronaut was not a test pilot. He did get a chance to fly in *Gemini 12*. He also made the most successful walks of the *Gemini* program. *Armstrong* who had flown X-15, capable of reaching five times the speed of sound, in *Mike Collins* words was "far and away the most experienced test pilot among the astronauts." It was *Armstrong* who was chosen to be the CDR of the Apollo 11 mission. On 24th March, NASA made the Apollo 11 crew names, official.

The *Saturn V* rocket, that would take them to their destination, was some 110.6 m high, capable of burning fuel at the rate of 20 tons per second giving a thrust of about 160 million horse power (7.5 million pounds).

The astronaut's space suites were pressurized at 3.5 pounds per square inch. Their gloves were too clumsy to manipulate a camera or grasp a geologic hammer. *Armstrong* and *Aldrin* were trained carefully to make use of every minute of their stay of 2 hours and 40 minutes on the moon's surface. They would collect rock and dust samples, for which NASA constructed an \$8 million Lunar Receiving Laboratory at the Space Center to store the lunar samples in total biological isolation. They would also lay out a few simple scientific instruments and take pictures. In *Chaikin's* (1998) word," Never in the history of exploration had 2 hours and 40 minutes been so carefully planned".

Armstrong and *Aldrin* had little time to study the world they would visit. *Armstrong* was clearly interested in the science of his mission, and the geologists had long considered

him a promising student. For Apollo 11, he made time in the over crowded training schedule for a field trip to the mountains of Westernmost Texas. The press found out in advance and almost turned it into a circus. They followed the astronauts' cars with a caravan of their own. *TIME* magazine hired a helicopter that roared overhead and made it nearly impossible for *Armstrong* and *Aldrin* to hear what the Geologists were saying. Aside from that one outing, they depended on briefings by geologists from the Manned spacecraft center and from the US Geological Survey Ion Flagstaff, Arizona. *Armstrong* also asked scientist-astronaut *Jack Schmitt* to act as their liaison officer with the scientific community.

Moving along its orbit at a mean orbital speed of 3682 Km per hour (NSSDC 1997), the moon offers an almost unimaginably hostile environment, devoid of air and water, exposed to the vacuum of space, bathed in deadly solar and cosmic radiation, pelted incessantly by micrometeorites. There were some fears already rising about the mission. The Cornell University astronomer *Thomas Gold* insisted that a layer of fluffy powder dozens of feet thick covered the moon. He warned that the LM would sink out of sight as soon as it touched down. One theory emerged that Charged particles emanating from the sun had so altered the rocks over eons that they would burst into flames as soon as they were exposed to oxygen inside the LM; no one would know the answer until it happened. On 12th June, the Apollo program director *Sam Phillips* officially announced that Apollo 11 would leave Earth on 16th July.

With just eleven days to go until launch, *Armstrong*, *Aldrin*, and *Collins* spent the 4th July weekend at home, a last visit with their families before heading to the Cape.

1.3 The Launching

The Apollo spacecraft launched from *Kennedy* Space Center, Florida, on July 16, 1969, at 9:32:00 am EDT (*Kennedy Space Center 2000*). All initial stages including ignition, tower clearance, *Saturn* staging sequence, insertion in the orbit went as planned. Communications were also smooth. The activities during Earth orbit checkout, Translunar Injection (TLI), transposition and docking, spacecraft ejection, and translunar coast all performed as planned.

1.4 Translunar Injection

TLI was performed 2 hours 44 minutes and 16 seconds, after the ignition, by reigniting S-IVB engine to accelerate the spacecraft to the velocity required to escape from Earth's gravity.

On the day before lunar orbital insertion, an initial checkout of the LM systems was satisfactory and after a planned rest period, the CDR and LMP entered the LM to prepare for descent. The spacecraft was inserted into lunar orbit at 75 hours 49 minutes and 50 seconds. It was an elliptical orbit of 313 by 113 Km according to Apollo11 Mission Report. It had an inclination of 1.25 degrees to the lunar equatorial plane (*NASA SP-214 1969*). The circularization maneuver was performed two revolutions later at 80 hours, 11

minutes, 37 seconds. Service module propulsion system was reignited, and the orbit was made, nearly circular, 122 by 100 Km above the surface of the Moon. Many photographs, taken from lunar orbit, provided broad views for the study of regional lunar geology.

1.5 Descent

“You cats take it easy on the lunar surface. If I hear you huffing and puffing, I am going to start bitching at you”(Chaikin 1998) were the words of CMP *Michael Collins*, minutes before the undocking of LM *Eagle* from Service module *Columbia*.

Collins pushed the button and the two spacecrafts were undocked at 100 hours, 12 minutes, followed by separation of the command and service modules from the LM at 100 hours, 39 minutes 53 seconds.

The controllers at Mission Operations Control Room (MOCR) had sent the Data to *Eagle* for Descent Orbit Insertion burn and the powered Descent. (Chaikin 1998)

Descent orbit insertion was performed at approximately 101 hours, 36 minutes and 14 seconds and powered descent to the lunar surface began at 102 hours, 33 minutes and 5 seconds. Operation of the guidance and descent propulsion systems was nominal. At 12192 meters from the lunar surface the landing radar started giving its signals about the speed and altitude of *Eagle* (Chaikin 1998). Half way through the powered descent, right on schedule, *Eagle*'s engine automatically throttled to half its maximum power. Just as planned, at 2286 meters above the lunar surface, *Eagle*'s thrusters fired the craft forward. (Chaikin 1998). At 915 meters up, *Eagle* was descending at 22 meters per second, about 89 Km per hour. At 305 meters *Armstrong* took the control in his own hands and started to look for a landing ground. At 30 meters, the blast of the rocket was blowing the lunar dust and started to obstruct the view of the surface. Knowing the fuel will give him few more seconds before he will be forced to abort, *Armstrong* was trying his best and finally with the engine still firing he touched down so gently that neither man sensed it. It was 102 hours, 45 minutes, 40 seconds after the first ignition. *Aldrin*'s words “Contact light” made *Armstrong* felt deeply relaxed and radioed back to Earth, “Houston, *Tranquility* base here. The *Eagle* has landed.”

The landing Coordinates were 0 degree 41 minutes 15 seconds North Latitude and 23 degrees 26 minutes East longitude.

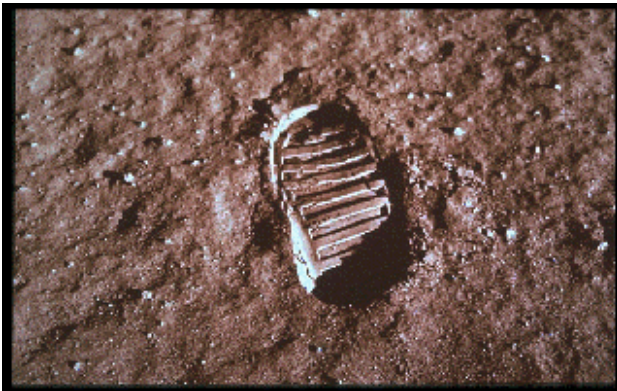
1.6 On the Lunar surface

During the first 2 hours on the surface, the two crewmen performed a post-landing checkout of all LM systems. Afterwards, they ate their first meal on the moon. Both men were not feeling tired and more because of their excitement, their first rest period was postponed and they were given permission at 104 hours, 40 minutes to proceed with the EVA earlier than planned.

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Immediately after landing on the Moon, *Armstrong* and *Aldrin* prepared the LM for liftoff in case of any emergency. Both men started their preparations of stepping outside the craft and landing on the moon at 106 hours, 11 minutes. After having suited up, considerable time was deliberately devoted to checkout and donning of the back-mounted portable life support and oxygen purge systems. 3.5 pounds per square inch of pressure was kept inside their space suits. After venting *Eagle's* oxygen outside, they opened the hatch at 109 hours, 7 minutes and 33 seconds. The CDR ejected through the forward hatch and deployed a Modularized Equipment Stowage Assembly (MESA) on which the surface television camera was stowed, and the camera recorded humankind's first step on the Moon and telecasted live coverage of the CDR descending the ladder to the surface. *Chaikin* (1998) writes "Grasping the ladder with an upraised glove, *Armstrong* turned to his left and leaned outward. 'Okay' he said, "I am going to step off the LM now." Carefully he raised his left foot over the lip of the footpad and lowered it to the dust of the moon. Making first contact at 109:24:15 (9:56:15 pm EST 20th July, 1969) with resting one foot on the moon *Armstrong* uttered the famous sentence, "That's one small step for man"-pause-"one giant leap for mankind."



Armstrong's first step on the Moon

With lunar gravity being one-sixth that on earth, he felt like somewhere between walking and floating. With all his spacesuit equipment, he was 159 Kg on Earth but only 23 Kg on the moon.

After taking the first picture from the moon, standing in the Lander's shadow, *Armstrong* came into lunar daylight and filled a bag with lunar soil and some small rocks. This was a precautionary early step so that an early-unexpected abort will not completely spoil the mission.

After fourteen minutes of the touch down of *Armstrong*, *Aldrin* also came out of the LM and upon sighting the never before seen view with the words "Magnificent desolation" swung both feet out of the footpad and landed on the lunar soil. (*Chaikin* 1998)

Both crewmen used the initial period on the surface to become acclimatized to the reduced gravity and unfamiliar surface conditions. A contingency sample was taken from

the surface, and the television camera was deployed so that most of the LM was included in its view field. They erected United States' stripes on the surface and then activated their scientific experiments. A solar wind Detector was easily deployed. As with the other operations involving lunar surface penetration, it was only possible to penetrate the lunar surface for about 4 or 5 inches. The experiment mount was not as stable as desired but it stayed erect. Two core tube samples were taken. The tube could be driven to a depth of about 6 inches after a lot of effort. A passive solar powered seismometer was to be deployed on a leveled surface and the crew found the place 15 meters away from *Eagle* (Chaikin 1998). A laser retro-reflector was also deployed. In the middle of these experiments both moon walkers heard the voice of President *Nixon*, "Hello, *Neil* and *Buzz*, I am talking to you by telephone from the Oval Room at the White house and this certainly has to be the most historic phone call ever made from the White House..." (Chaikin 1998)

21 Kg of topsoil was collected to be returned for analysis. The surface exploration was concluded in the allotted time of 2 hours and 31 minutes.

1.7 Departure

The crew re-entered the LM at 111 hour 39 minutes and 13 seconds. The sleeping period started after that but *Armstrong* could not fall asleep at all, although *Aldrin* estimated that he slept quiet well for about two hours. (Apollo Mission Report)

Ascent preparation was conducted efficiently and LM lifted off the surface at 124 hours, 22 minutes. A nominal firing of the ascent engine placed the vehicle into a 83 by 17 Km orbit. After a rendezvous sequence, the two spacecrafts were docked at 128 hours, 3 minutes. Following transfer of the crew, the ascent stage was jettisoned and the command and service modules were prepared for Trans Earth Injection.

The return flight (TransEarth injection maneuver) started with a 150-second firing of the service propulsion engine during the 31st lunar revolution at 135 hours, 23 minutes, 42 seconds. As in translunar flight, only one mid course correction was required, and passive thermal control was exercised for most of TransEarth coast. Inclement weather necessitated shifting the landing point to 28 Km downrange. The entry phase was normal, and the CM landed in the Pacific Ocean at 195 hours, 18 minutes, 35 seconds. The landing coordinates, as determined from the onboard computer, were 13 degrees 19 minutes North Latitude and 169 Degrees 09 minutes West Longitude.

After Landing, the crew abandoned their biological isolation garments and were then retrieved by helicopter and taken to the primary recovery ship, USS *Hornet*. The crew and lunar material samples were placed in the mobile quarantine facility for transport to the lunar receiving laboratory in Houston. The CM was taken aboard the *Hornet* about 3 hours after landing.

With the completion of Apollo 11, the National objective of landing men on the moon and returning them safely to Earth before the end of the decade had been accomplished.

2. APOLLO 12

2.1 CREW AND SPACECRAFT



CDR: *Charles Conrad* (Born on 2nd June, 1930)

LMP: *Alan La Vern Bean* (Born on 15th March, 1932)

CMP: *Richard Francis Gordon* (Born on 5th October, 1929)

(All three of them were US Navy CDRs)

LM: *Intrepid*

CM: *Yankee Clippers*

The Apollo 12 mission was the second manned lunar landing mission. Its objective was to perform detailed scientific lunar exploration. The crew of Charles (Pete) *Conrad*, Jr., the CDR; Richard F. *Gordon*, the CMP; and Alan L. *Bean*, the LMP, had a bond that went deeper than their mission. They shared a history that began at naval air stations in Florida and California, and the test pilot school at Patuxent River, Maryland.

2.2 Lift off

The space vehicle was launched from *Kennedy* Space Center, Fla., at 11:22:00 EST on 14th November, 1969, towards the proposed site in the '*Ocean of Storms*' at the coordinates 2.94 degree south Latitude, 23.45 degree west latitude, about 1537 Km west of Apollo 11's landing site. *Chaikin* (1998) writes, "At lift off, the *Saturn* had trailed a column of flame and ionized gases which stretched all the way to the ground. Tearing through the rain clouds it became the world's longest lightning rod". Thirty-six seconds after the liftoff, a bolt of electricity discharged right through Apollo 12 and on to the launch tower 1829 meters below. The CM had shut itself off in response to the

tremendous electrical surge. A second strike at 52 seconds, unnoticed by *Conrad* and his crew, had wiped out the navigation platform.

Conrad saw a bright flash of light outside and suddenly the master alarm started ringing followed by glowing of every light attached to the electrical system. But they were able to control the situation.

'Earth Orbit Insertions' occurred as planned at 11 minutes 'Ground Elapsed Time' (GET).

The crew was afraid that something must have been damaged because of the unexpected incident but were relieved when in the orbit, at 2:38 GET, a message was radioed to the astronauts, "Apollo 12, the good word is you're going for the TLI." (*Chaikin* 1998)

The MOCR did not tell the crew about the possible damage of the pyrotechnic system by the lightning, which was used to deploy the CM's parachutes.

'Translunar Insertion' came at 2:47 GET. There were some usual midcourse corrections and then to put Apollo 12 in the lunar orbit, first 'Lunar Orbit Insertion' came at 93 hours 25 minutes GET followed by the second in 4 hours and 19 minutes.

2.3 Descent Orbit Insertion

'Descent Orbit Insertion' was at 109:23 GET. Then LM powered descent initiated at 110:20 GET.

During the descent of *Intrepid*, at 2134 meters *Conrad* recognized his target landing site among thousands of craters and his spontaneous words were, " Hey, there it is, there it is! Son of a gun, right down the middle of the road!" (*Chaikin* 1998) Now the *Intrepid* was headed for the very center of the Surveyor crater. It was their mission to find Surveyor 3, an unmanned spacecraft that landed on the plain called *Ocean of Storms* in April 1967. Engineers back on Earth wanted to see what happened to it after staying thirty one months on the lunar surface. At 122 meters, *Conrad* took over but because of the fast pace of the craft he missed the Surveyor crater. *Conrad* was trying his best to make it as planned. They were down at 30 meters when *Conrad* leveled off and right after this his view of the surface began to blur.

2.4 Final Touchdown

Touchdown occurred with a blue glow of the contact light and *Conrad* hit the Engine Stop button at 110:31 GET, and in *Conrad's* own words about the distance of Surveyor and his location "It can't be any further than 183 meters from here". The landing was in the *Ocean of Storms*. This landing precision was of great significance to the future lunar exploration programs, because landing points in rough terrain of great scientific interest could now be very accurately targeted.

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Depressurization for the first lunar surface 'Extra Vehicle Activity' (EVA) was complete at 110:20 GET. CDR *Conrad* came out and put his feet on the lunar soil at 114:47 GET.

"Dum de dum-dum-dum..." were the unexpected words Houston and the world could hear from *Conrad* about to start his work. Half an hour after *Conrad* had touched down, *Bean* followed his steps. Tied between stiff schedule and relentless excitement, they started to perform their tasks. The maiden 5 minutes were spent in learning how to "float" on the moon.

Conrad set up an umbrella-shaped S-Band antenna for good communications with Earth at 115:20 GET. A solar-wind composition experiment was setup by *Alan Bean* at 115:33 GET. A color television camera mounted on the descent stage provided live television coverage of the descent of both astronauts to the lunar surface but when *Bean* tried to set up the TV camera he accidentally pointed it towards to the sun for a few long seconds. This made Apollo 12 a complete audio show *Chaikin* (1998).

The first of two planned EVA (EVA) periods began at 115 hr GET. The crew emplaced the U.S. flag. They started to set up Apollo Lunar Surface Experiment Package (ALSEP)'s scientific instruments, at 115:46 GET several meters away from the LM so that the instruments would not get affected in anyway when they would blast off the lunar surface. ALSEP included a seismometer to measure moonquakes, which looked like a silver paint can atop a round, silver drop cloth, a magnetometer to find lunar magnetic field, with its three, gold-foil-tipped arms reaching into the vacuum, a small ion detection instrument, with its ridiculously short legs joined by a spider web of wires and a sensor for measuring moon's tenuous atmosphere.

As soon as they set those instruments, scientists at MOCR immediately saw the readings of seismometers. It was not due to the moon quakes but because of the footsteps of the crew leaving the area where they had set up the instruments. They also collected lunar samples and core-tube specimens of the lunar surface.



Astronaut holding core tube sample

After the end of the first moon walk, they returned back in LM and closed the hatch at 117:58 GET.

While they were doing their work on the lunar surface, up in the lunar orbit, *Gordon* was circling in Yankee Clipper every two hours. During the last hour of the moon walk, *Gordon* prepared for his most important task of the day, a burn of Yankee Clipper's SPS engine to adjust its orbit.

After 16 hours of the end of the first moon walk, both men were again out for the second scheduled moonwalk at 133:20 GET, 20th November. It was extended by half an hour. After a long and tiring walk to the Surveyor, the crew finally made it. The engineers



Conrad with Surveyor 3 and the LM in the background

wanted to have some samples of metal tubing but *Conrad* wanted to have Surveyor's camera. With all its Circuitry and moving parts it was a real prize and he got it by cutting the camera's support struts. The television camera is now on display in the National Air and Space Museum's "Exploring the Planets" gallery. The Surveyor 3 was also photographed.

The two astronauts started a geology traverse and covered approximately 1311 meters. This lasted 3 hours and 50 minutes. During the traverse, they documented samples, core-tube samples, trench site samples and gas analysis samples were collected. The Apollo 12 samples were mostly basalts, dark-colored igneous rocks, and they were hundreds of millions of years *younger* than the rocks collected by Apollo 11.

2.5 Lunar Module Ascent

When both of them got in the LM at 136:24 GET, they were exhausted. It was another rest period, in which they ate lunch and performed the final checkout for the liftoff. They were about an hour ahead of schedule. So they had to wait until the proper time. The LM ascent stage came at 142:01 GET. *Gordon* did a perfect job on the docking at 145:40 GET.

The CM entered Earth's atmosphere at 244:26 and landed in the Pacific Ocean at 244:35 GET.

(Most details taken from from NASA SP-235, Apollo 12 Preliminary Science Report).

3. Apollo14

3.1 Crew and Spacecraft



CDR: Alan Bartlett *Shepard* (Born on 18th November, 1923)

LMP: Edger Dean *Mitchell* (Born on 17th September, 1930)

CMP: Stuart Allen *Roosa* (Born on 16th August, 1933)

LM: *Antares*

CM: *Kitty Hawk*

The Apollo 14 mission was the third manned lunar landing mission. Its objective was to perform detailed scientific lunar exploration. In fact it was the first Apollo moon-landing mission, which was solely devoted to the scientific exploration of the moon. The space vehicle with a crew of Alan B. *Shepard*, Jr., the CDR; Stuart A. *Roosa*, the CMP; and Edgar D. *Mitchell*, who held a doctorate from MIT was the LMP.

It was Alan *Shepard's* second mission after being the first American and second human in the space in 1969. The doctors had finally pronounced him healthy after an operation due to the disease called *Meniere's syndrome*, an inner ear disorder, which kept him from flying even an airplane by himself and kept him grounded for six years.

In fact, Alan *Shepard* was nominated in Apollo 13 mission, which went terribly wrong and the crew of that craft were considered lucky to return home safely. Alan was dropped from this unsuccessful mission by the interruption of George *Mueller*, head of manned spaceflight at the NASA Headquarters. At the age of 47, *Shepard* was now a CDR of the Apollo 14 mission

Shepard, *Roosa* and *Mitchell* trained for nineteen months, longer than any crew before them. Since Apollo 13, MOCR had trained for every malfunction in the book. In fact there was a book with procedures for any conceivable emergency. Because of their

immaculate rehearsals and safety measures, the people in the MOCR were extremely confident of the mission.

3.2 Setting off

The targeted landing site was the hilly region of North of Fra Mauro Crater.

3.3 Unexpected Hiccups

The spaceship was launched from *Kennedy* Space Center, Fla., at 4:03:22 EST on 31st January, 1971. Parking Orbit Insertion took place 11 minutes and 53 seconds after the ignition. It was followed by TLI at 2:30 Hours GET. Two hours later, *Roosa* was preparing to Dock the CM Kitty Hawk with the Lander Antares. In unaccounted simulations he had shown to use less fuel than any CMP before him. Now he was going for a 'fuel record'. Both ships were getting close slowly. "Gonna break the record", Alan murmured. At last the ship's met but then they separated. The crew was amazed. *Roosa* thought he had not come close enough to trigger the docking latches. Backing off, he came again and came in a little faster, knowing that it will use more fuel. But he was surprised that he failed again.

Something was wrong with the mechanism. In an hour and an half, *Roosa* tried two more times but could not succeed. This was getting very worrying because they knew that if the docking did not complete, the mission was over. While down on Earth, the MOCR was trying to figure out how to manage the problem, Alan *Shepard* was thinking if nothing worked, they would suit up, depressurize the cabin and open the CM top hatch and bring the probe inside and then they would try to fix the problem. He was also thinking of pulling both crafts literally by hands hoping for the automatic docking procedure coming into action.

Following the MOCR's advice the crew tried once again. This time *Roosa* was firing the Kitty Hawk's thrusters against the LM to hold it there. Then *Shepard* flipped the switch to retract the docking probe out of the way. After about an hour and 42 minutes since the first docking attempt, *Shepard* announced, "We got a hard dock". Everybody felt a sigh of relief; Apollo 14 was headed for the moon.

But troubles were far more than few. Just before 90 minutes from powered descent, the MOCR detected that the computer on board was receiving an errant signal from the abort button. It was assumed that a tiny ball of solder was floating around within the switch and closing a contact. The signal was gone, when *Mitchell* tapped the panel. But what if when *Mitchell* ignited the descent engine and the computer read the errant signal that would automatically abort the landing. Computers programmers at Houston and at MIT started to work out a solution that would tell the computer not to accept any signal from the switch at all. To write down a part of the LM's computer program was a difficult task to do in that short time. But when *Shepard* and *Mitchell* reappeared from behind the moon last time before the scheduled powered descent, the programmers had done the fix and

sent it to Houston. Within minutes, *Mitchell* entered all the required changes in the system. It proved to be a success.

At 9754 meters signals started to warn about the radar, it wasn't working. *Mitchell* words, "C'mon radar... C'mon radar" did not work at all. *Shepard* and *Mitchell* knew that if they reached at 3048 meters without having radar signals, they would have to abort according to the Mission rules. On the instructions of MOCR, *Shepard* pulled out the circuit breaker for the radar and pushed it back in. They were 6706 meters above the lunar surface when suddenly the radar started to work again.

3.4 On landing

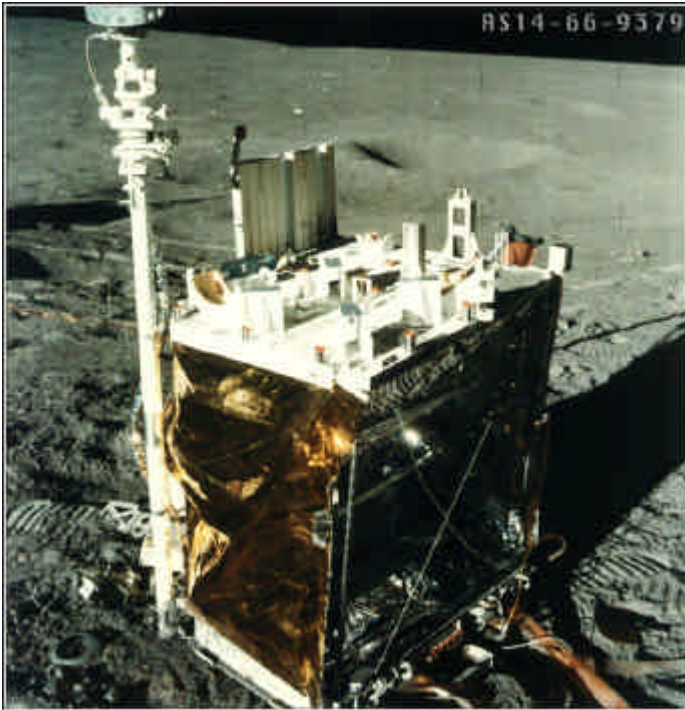
The touchdown occurred at 08:37:10 GMT, 5th February, within 50m (160 ft) of the target point in the Fra Mauro highlands. The landing was closer to its target than any other previous missions. The first EVA (EVA) began 5 hr 23 min after touchdown.

A color television camera mounted on the descent stage provided live coverage of the descent of both astronauts to the lunar surface. The crew deployed the U.S. flag and the solar wind composition experiment, erected the S-band antenna, and off-loaded the Modularized Equipment Transporter (MET), a miniature vehicle which was pulled



Astronaut with MET

manually in order to transport the necessary scientific equipment, lunar surface sample and tools for geological analysis. They also deployed the laser ranging retro reflector (LRRR), the Apollo lunar-surface experiments package (ALSEP) and passive and active seismic apparatuses.



Apollo14's ALSEP

Amongst the equipment offloaded, there was also a suprathreshold ion detector and cold cathode ion gauge for measuring ion flux, density and energy in the lunar environment. A charged particle lunar environment experiment was also deployed for measuring energy of solar protons and electrons reaching the moon. The crew also set up portable magnetometers for measuring variations in the lunar magnetic field.

Rosa, the CMP, took several photos of the future candidates landing site *Descartes*. These photos were taken with a large format lunar topographic camera, mounted in the hatch window. Other areas and features photographed included Apollo 14 LM, Apollo 12 LM impact, astronomic galactic light and the zodiacal light.

The second and last EVA was a planned extended geological traverse of Cone Crater. All equipment required for the geological traverse, including the lunar portable magnetometers (LPM), was loaded on the MET. The traverse up the side of Cone Crater provided experience in climbing and working in hilly terrain in 1/6 gravity conditions. A rock taken from here proved the meteoric impact, which created Imbrium basin 1333 Km across, the largest and most spectacular crater on the lunar near side, to be roughly as 3.85 billion years ago. This EVA lasted 4 hr and 20 min, during which the astronauts had traveled approximately 3 km.

3.5 Heading for Earth

Liftoff occurred at 18:48 GMT, 6th February, spending about 33 hours on the lunar surface. After crew transfer, the LM ascent stage was separated and remotely guided to impact on the lunar surface. Impact occurred between Apollo 12 and 14's seismometers. The resulting seismic signal lasted for 1.5 hours and was recorded by both instruments.

The CM splashed down in the South Central region of the Pacific Ocean approximately 1 km from the target point at 20:24 GMT, 9th February, 1971. A helicopter transferred the crew to a Mobile Quarantine Facility aboard the USS New Orleans, Later they were transferred to the Lunar Receiving Laboratory at the Manned Spacecraft center in Houston.

(Details taken from NASA SP-272, Apollo 14 Preliminary Science Report).

4. Apollo15

4.1 Crew and Objectives:



CDR: David Randolph *Scott* (Born on 6th June, 1932)

CMP: Alfred Merrill Worden (Born on 7th February, 1932)

LMP: James B. *Irwin* (Born on 17th March, 1930)

LM: *Falcon*

CM: *Endeavour*

The 12-day successful Apollo 15 manned lunar landing mission was the first in a series of three advanced missions planned for the Apollo program. Its primary scientific objectives were to observe the lunar surface, collect lunar samples and survey surface features in a preselected area of the Hadley-Apennine region, one of the highest mountain ranges on the moon, setup and activate surface experiments and conduct in-flight experiments and some photographic responsibilities from lunar orbit.

4.2 Departure from Earth

The space vehicle with the crew comprising David R. *Scott*, CDR; Alfred J. Worden, CMP; and James B. *Irwin*, LMP, was launched per schedule from the NASA *Kennedy* Space Center, Fla., at 9:34:00 a.m. EST on 26th July 1971.

4.3 Reaching the Destination

At 104:29 GET on 30th July, the LM descent propulsion system was fired for powered-descent initiation. *Scott* had studied the previous astronauts' landings on the moon and he was confident that he had learned to make a better landing. When he was at 46 meters, he started to descend vertically and with that the engines thrust began to blow the moon dust underneath him. He was forced to put his attention on the instruments at 18 meters because the dust storm was completely obscuring the lunar surface. On seeing the contact light turned on, he stopped the engines and hundreds of Kilograms heavier than the previous Landers, the LM landed on the moon at 104:41 GET with a jerk that shook everything in the LM. The LM landed approximately 12 minutes later with sufficient propellant remaining to provide an additional hover time of 103 seconds, had it been required.

When the dust settled down, the crew saw Bennet Peak right ahead, somewhere near there was Hadley Rille, they knew they were in the right place. As planned they will rest for now. The first moonwalk was scheduled for the next day.

4.4 Tasks performed at Lunar Surface

According to the lunar itinerary, *Scott* opened the hatch of the LM and came down on the lunar soil at 120:05 GET. He and *Irwin* knew that they had the great advantage for the exploration of the moon over those who landed on the moon prior to Apollo 15. They were using the first ever-lunar car. But it was more a spacecraft than a car. It had its own navigation computer, communications system and cargo space for such essentials as maps, geology tools and moon rocks. It had been designed, built and tested by Boeing in less than two years. The Lunar Rover Vehicle (LRV) unstowed at 120:20 GET. Though it had a speed of only 9 to 5 to 13 Km per hour but it was far better than to waste time in reaching far out places on foot. Also the moon land is not plain and all the time the Rover was bumping on its way. They got in that wheeled spacecraft and started to drive to their destination, Hadley Delta Mountain, which was 3353 meters high. On the way they stopped once and gathered some samples and then again to their target site. A suitcase device, called the Lunar Communications Relay Unit, was used for the crew to stay in contact with the Earth, after they went too far from the LM.

There, *Scott* saw a big rock with sprinkled glass on its top. They both got some pieces of this rock and then decided to turn it over and get some lunar soil underneath it, which was there certainly for a very long time, protected, from the solar and cosmic radiation and also from the micrometeorites. They returned to the LM at 123:40 GET.

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To set up ALSEP, they returned to the LM after four hours. But there was a warning for both men; their moon walk might end up early because *Scott* was using more oxygen than expected. The ALSEP was deployed 91 meters from the LM.

The ALSEP for Apollo 15 carried new equipment: a pair of thermometers, which will be inserted 3 meters deep in the surface after drilling a pair of holes. This apparatus was designed to measure the heat flow inside the interior of the moon. But this did not prove to be an easy task for *Scott*. The moon's surface proved to be very resistant against such drilling. His spacesuit was not cooperating either. At the end of the mission *Scott* could not make it to the desired depth. The reading it transmitted to the Earth showed later, twice the measure of the temperature than expected. Meanwhile *Irwin* was busy in collecting samples.

With this third ALSEP on the lunar surface, scientists, using seismometers, came to know the crust was some 74 Km thick, undoubtedly with variations from one region to another. Below the crust lies the lunar mantle, the source of the Basalts. By all signs, the mantle had cooled down enough to bring an end to the moon's volcanic activity eons ago. Instruments had failed to detect a magnetic field, apart from traces of magnetic signatures preserved in some of the rocks. Moreover, the LRRR on the Apollo 15 had three times more reflective area than the two previous reflectors.

When both men returned to the Falcon, *Scott* had a headache as well as physical exhaustion. He could not take water for even hours now because his water tank had not worked. Then they slept for their rest period. There was a water leakage due to a broken filter in the LM and MOCR had to wake the crew up, but since all the electrical system was waterproof, this did not turn out to be luckily a big problem.

Their second Moonwalk on LRV started at 141:59 GET and they were again collecting samples. They reached a height of 95 meters and at this point Falcon was more than 3 miles away. There they headed down the slope of a crater and collected few samples.

On their way back to LM, they stopped near a great boulder. *Scott* had seen some sort of green material on the top of it. Then *Irwin* noticed more of that green rocks and picked it up. Scientists later revealed that it was made of tiny spheres of rock and also about the eruptions from the hidden depths of the lunar interior.

Then the moment came when suddenly *Irwin* saw a piece of rock what would become the most famous of all the Apollo rocks. It was a white rock that looked fairly beaten up and when *Irwin* held it in his arm; he saw large white crystals on it. Suddenly both of them knew what it was. *Scott*'s voice was heard back on Earth, "Guess what we just found. Guess what we just found. I think we found what we came for." It was almost entirely plagioclase. They thought it was absolutely a piece of anorthosite, a piece of primordial crust. This rock will be known as "The Genesis Rock" and the geologists got his age at 4.5 billion years old.

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After visiting the Falcon shortly they went to their ALSEP. *Scott* started to work with his drilling again and *Irwin* dug some gray lunar soil and took photos. He also tested the bearing strength of the trench walls with an instrument called Penetrometers. Apollo 15 was going far better than the previous missions. They have been in their moon walk for more than seven hours in an area of 15 Km.

Al Worden was the CDR of the first fully equipped orbiting lunar science platform called the Scientific Instrument Module (SIM). Endeavor's service module was crammed to the hilt with high-powered cameras and sensors. X-Ray fluorescence was designed to map the chemical composition of the lunar surface along the orbital ground track. Another sensor would try to detect evidence for volcanic gases seeping out of the moon during recent geologic time. Alpha particle spectrometers measured alpha particles from radioactive decay of radon gas isotopes, emitted from the lunar surface. A mass spectrometer was included to sniff out extremely tenuous gases that might surround the moon. Worden performed a 38 minutes' EVA on way back to Earth (KSC, Apollo15 2001).

There was even a tiny satellite, which *Worden* would release into lunar orbit in a couple of days, which carried three experiments that would give scientists information about the Earth's magnetosphere and its interaction with the moon and also provide sensitive information about solar wind. It was also equipped with magnetometers to stalk the elusive lunar magnetic field and the two cameras were superb creations in their own right. One of them, based on declassified spy satellite technology, could photograph the details on the surface as resolved as a yard across.

The sub-satellite's spin axis was approximately perpendicular to the ecliptic plane. The spin rate stabilized at about 12 rpm after boom deployment. The Sub-Satellite had three equally spaced, folded booms mounted around its base. These booms extended automatically at deployment to a length of about 1.5 m. The Sub-Satellite provided about 6 months of data coverage before two successive electronic failures in February 1972 caused the loss of most of the data channels. The surviving data channels were monitored intermittently until June 1972 and then more or less continuously until January 1973, when ground support was terminated (NSSDC 2001).

The crew's third and last EVA started at 162:44 GET. After many attempts *Scott* was able to drill the 3 meters hole for the core sample of the lunar surface and both of them had to do a lot of work to get it out. They cut it partially to put it in the LM. This core was identified as containing 42 separate layers of lunar soil and it was discovered later that the deepest layer was undisturbed for about half a billion years.

When the time finally came to get off the moon, *Scott* did something amazing. He demonstrated a theory, which was proposed four centuries ago by Galileo Galilee. He took out a falcon feather and his work hammer. He came in front of the TV camera and started explaining what he was about to do, it was an experiment about an equal pull of gravity on objects regardless of their masses. He held the hammer and the feather up and then released them at the same time. Both of them came slowly to the lunar surface and struck at the same time. After a long time, Galileo was proved right and the

demonstration came on the place he once saw many craters by his own homemade telescope.

Scott parked his lunar car about 91 meters away from the LM. This point was to be used to see the lift off. Then after walking some steps he put a small plaque bearing the names of all those fourteen humans who have died in the space program. They returned back to LM at 167:17 GET.

During a lunar stay of 66 hr 54 min 53 sec, a 33-min standup EVA and three periods of surface EVA totaling approximately 18.5 hr were performed.

The astronauts were able to collect samples from the low dark plains (*Maria*), the Apennine highlands, and the area along Hadley Rille, a long, narrow winding valley.

The *Apollo 15* crew collected 370 individual rock and soil samples, including a deep drill core with material from 2.4 meters below the lunar surface (Lunar and Planetary Institute 2001). Approximately 76 kg of lunar material including soil, rock, core-tube, and deep-core samples were returned to Earth.

An average speed of 9.6 km/hr was achieved, and speeds up to 12 km/hr were attained over level lunar terrain by LRV. The total distance traveled, was 27.9 km, corresponding to a map distance of approximately 25.3 km.

4.5 Heading for the Earth

Liftoff of the LM ascent stage occurred at 171:35 GET on 2^d August and was monitored by the ground-command television assembly mounted on the LRV. Commanded from Earth, the television assembly was planned to provide coverage after liftoff of the lunar surface and of a lunar eclipse on 6th August. Although the television assembly operated successfully during all three EVA periods, the elevation clutch began to slip during the second EVA, and operation deteriorated during the rest of the mission. When activated about 40 hr after LM liftoff, the unit operated satisfactorily for 13 minutes before failing.

Although entry, at 294:58 GET, was nominal and all three main parachutes deployed initially, one parachute collapsed before splashdown. However, the CM landed safely at 295:12 GET on 7th August 1971.

(Most details extracted from NASA SP-289, Apollo 15).

5. Apollo16

5.1 Crew and Spacecraft



CDR: John Watts *Young*
CMP: Thomas Kenneth *Mattingly*
LMP: Charles Moss *Duke*
LM: *Orion*
CM: *Casper*

The successful Apollo 16 manned lunar landing mission was the second in a series of science-oriented missions planned for the Apollo program. At first there were talks about “Tycho” crater as a landing site but then the major objective of the mission became to investigate the lunar surface in the Descartes highlands area because it was considered to be representative of much of the Moon's surface, and an area of this type had not been previously visited. Most of all the geologists were after the Volcanic rocks to know the interior of the moon.

5.2 Take-off

The Apollo 16 space vehicle was launched from the *Kennedy* Space Center (Launch Complex 39A) at 12:55:00 p.m. EST on 16th April 1972.

5.3 On the Moon

They were six hours late, because of some problems including a dangerous build up of pressure in the fuel tanks that threatened a mission-abort. The LM landed at 98:46 GET approximately 276 meters northwest of the planned landing site at about 104.5 hours ground elapsed time (GET). About 100 seconds of hover time remained at touchdown. The CDR stepped on the lunar soil at 102:40 GET.

The first EVA (EVA) was initiated at 102:25 GET. The late landing cost the crew to lose the telephoto pictures of Stone Mountain in the early morning light. Television coverage of surface activity was delayed until the lunar roving vehicle (LRV) systems were activated because the steerable antenna on the LM could not be used. A major part of the first EVA was devoted to establishing the nuclear powered, automatic scientific station called Apollo Lunar Surface Experiment Package (ALSEP). It was deployed at 106:22 GET. On the surface *Young* set up a telescopic camera at 103:24 GET which was designed to take photographs of the ultraviolet radiation of the stars.

Duke had a redesigned drilling apparatus that went easily in the lunar soil and the thermometers were inserted at the required depth. *Young* was setting up the ALSEP when he caught the cable around his foot, which happened to be from the heat experiment

apparatus. *Young* had pulled the cable and when *Duke* saw it he stopped working on fixing that heat experiment device because it was made useless by *Young*'s mistake.

One of their target sites of interest was a crater called Flag. It was a huge crater about 305 meters wide. On the rim of it, there laid another crater called Plum.



Duke near the Flag Crater

At this same site they picked up a rock that was almost 12 Kg and bigger than a football. It was actually the biggest rock ever brought back on Earth from the Apollo missions.

At another crater called *Buster*, while *Young* took readings with a portable magnetometer, to record any remnant magnetism in the rocks of the Caley Plains, *Duke* had enough time to gather several more samples.

NASA doctors had been quite alarmed by *Scott*'s and *Irwin*'s heart irregularities on Apollo 15, which they attributed largely to a loss of Potassium. To prevent a reoccurrence on Apollo 16, they added electrolyte to the food, mostly in the form of Potassium spiked orange juice.

The Crew of Apollo 16 also shelved a new record under their sleeves, they reached 152 meters above the valley floor, higher than any Apollo moonwalker had ever been or would climb in the future.

On the lunar ground, the next target was a big crater more than 198 meters wide, called North Ray crater. On sight of the great depression, *Young* exclaimed, "Oh, spectacular! Just spectacular!" The crater was so big that it could not fit into the view field of the rover's camera. The walls of the crater went to a rocky floor 200 yards below. The crew spent 40 minutes in photographing the crater wall. They also collected many samples.

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One of the geologists saw on the live TV transmission from the rover's camera a peculiar boulder. When *Young* and *Duke* got there in the LRV they were surprised to see it. It was as high as a four-storey building and twice as long. The dark colour made it resemble basalt, but in fact it was a huge Breccia.

The duration of the first EVA was approximately 7 hours 11 minutes and the total distance covered by the crew was about 4.2 Km.

The second EVA, which started at 124:50 GET and the third EVA which initiated at 148:25 GET, were devoted primarily to the geological exploration and sample gathering in selected areas in the vicinity of the landing site. On the second EVA, the astronauts traveled south-southeast to a sampling area near Cinco Crater on Stone Mountain. The crew also made stops near Stubby and Wreck Craters, The duration of the second EVA was approximately 7 hours 23 minutes and a distance of 11.1 Km was covered.

The third and final EVA was towards the North Ray Crater and "House Rock", on the rim of North Ray Crater. The LRV traverse was 11.4 Km and lasted approximately 5 hours 40 minutes.

Total lunar surface activity in the Apollo 16 mission lasted 20 hours 14 minutes and 95 kilograms of samples were collected. The total distance traveled in the LRV was 26.7 Km and the crew remained on the lunar surface 71 hours.

The *Apollo 16* crew collected 731 individual rock and soil samples, including a deep drill core that included material from 2.2 meters below the Moon's surface, with a total mass of 96 kilograms (Lunar and Planetary Institute 2001). These rocks represented samples of ancient lunar highlands.

5.4 Return to Earth

Ascent of the LM took place at 171:45 GET; entry at 290:23 GET and landing, after 13 minutes went as planned. The CM was viewed on television while on the drogue parachutes and continuous coverage was provided through crew recovery. Total time for the Apollo 16 mission was 265 hours, 51 minutes and 5 seconds.

(Most details picked from NASA MSC-07230, Apollo 16 Mission Report).

6. Apollo17

6.1 Crew and Spacecraft



CDR: Eugene Andrew *Cernan*

CMP: Ronald Ellwin *Evans*

LMP: Harrison Hagan *Schmitt*

LM: *Challenger*

CM: *America*

Apollo 17 was a \$450 million lunar mission. The successful Apollo 17 manned lunar landing mission was the last in a series of scientific research missions planned for the Apollo Program. As a result of these additions, the Apollo 17 mission had duration of 12.6 days, and a time on the lunar surface of 75 hr with a total surface traverse distance of approximately 35 km.

Apollo 17 had an advantage no other mission could enjoy: it was carrying a real scientist whose reputation as a geologist was unquestionable. Many people had thought that putting a scientist was a risky job. However NASA believed that sending a genuine scientist would enable the mission to bring back manifold scientific information. The mission later proved that sending *Schmitt* as a scientist-astronaut was indeed a wise decision.

6.2 The Launch

The launch was delayed by couple of hours when the automatic launch pad's sequencer had failed to pressurize the *Saturn* rocket's third stage. Finally the *Saturn V* carrying Apollo 17 was launched from NASA John F. *Kennedy* Space Center at 05:33:00 UT on 7th December, 1972 (11:33:00 p.m. CST on 6th December, 1972).

Schmitt wanted to go on the far side at *Tsiolkovsky* region but keeping in view the risks involved in that kind of expedition, NASA did not allow it. The geologists went for another equally interesting landing site, which was seen first by the Apollo 15 crewmember, *Al Worden*. It was a group of small craters in a region called Taurus Mountains, which was 32 Km to the Northeast of the *Littrow* crater. The geologists were extremely interested in the very dark-coloured material that could possibly be volcanic ash. So the landing site was decided as the southeastern rim of *Mare Serenitatis* in a dark deposit between massive units of the southwestern Montes Taurus.

The scientific objectives of the Apollo 17 mission included geological surveying and sampling of materials and surface features in a preselected area of the *Taurus-Littrow* region, deploying and activating surface experiments, and conducting in-flight

experiments and photographic tasks during lunar orbit and TransEarth coast.

6.3 Translunar Injection

TLI occurred at 03:27 GET and the Lunar Orbit Insertion, executed at 88:55 GET on 10th December, placed the spacecraft into a lunar orbit of 315 by 97 Km.

6.4 Landing on the Moon

Following a nominal descent sequence, the spacecraft landed at 113:01 GET on December 11 in a valley at Taurus-*Littrow*, less than 200 m from the preferred landing point. The preparation for first lunar surface EVA began with the depressurization of LM at 116:40 GET on 11th December, with *Cernan* stepping out of the spacecraft at 116:55 GET on 12th December. LRV was launched at 117:01 GET. Deployment of the Apollo lunar-surface experiments package (ALSEP) and the cosmic ray experiment took place during EVA-1. The heat experiment apparatus was also deployed without any difficulty. But *Schmitt* was having trouble with the lunar gravimeters. The device, which was designed to show the gravity waves, was not working. In collecting core samples *Cernan* was also heaving great trouble with drilling in lunar surface. An hour late in their schedule they finally got the core sample. The work had given them, aching hands and fingers. The crews returned and entered in LM at 123:36 GET. Duration of the first EVA was 7 hr 12 min. The crew had already setup the SEP transmitter and Lunar Seismic Profiling Experiment (LSPE) explosive package.

The second EVA began at 139:26 GET on 12th December. *Cernan* accidentally destroyed the fender by his hammer. They became full of lunar dust which went straight up during the Rover rolled and came straight back all over them. Fifteen minutes were wasted when they both tried to clean each other before entering the LM. It was later repaired by some maps and tapes. One of the most exciting parts of Apollo17 mission was going to the 2286 meters South Massif, after driving more than 9 Km and after 73 minutes from the LM. They arrived there at 141:08 GET. They collected samples from *Nansen* Crater, where they spent 63 minutes, 10 minutes extra then their schedule permitted. There they also found a small white rock, which was nearly 4.5 billion years old. They also went to *Lara* Crater, which was 4572 meters in diameters. *Shorty* Crater was also one of their targets and they had only a half an hour for this big and deep crater. They came out of the Rover and just when *Schmitt* was preparing to take the pictures, the most exciting thing happened.

He saw that the area where his boots had disturbed the surface soil, he could see the lunar soil that had a color of bright orange. After confirming he said in delight, "This is orange soil." *Cernan* saw it "It's been Oxidized" Both men knew that without any water and oxygen on the moon, there could be only one answer, volcanic gases! *Schmitt* came into action and dug the orange soil to see how deep it is. He saw that in the center it was almost crimson and at the edges it became yellow. This zoning effect was clearly a sign

of different concentrations of gases, which could only be due to a volcanic action. Only twenty minutes were left and now *Schmitt* picked up the colored soil samples into the bag and *Cernan* started to dig a core sample of this soil with all the energy he had left. Fortunately the 0.9 meters core tube came out without any trouble. This great site was worth more time but they were running out of time and there could be no extension.

This greatest discovery of their mission told a lot about the moon. The orange color was produced by tiny beads of glass that had once been molten droplets, poor in Silica but rich in Titanium and Iron. They were thrown away out in the lunar sky by a fire fountain; a form of lava that contained dissolved gases. The crimson red or orange color was not the result of oxidation but due to the rich content of Titanium. The men had solved the riddle of the dark color of the material around the area. It was because it contained the beads from the volcanic gases. These beads were later revealed to be as old as 3.5 billion years ago. After analyzing this, scientist were led to declare that the green beads of green glass brought back from Apollo 15 mission were also the result of the volcanic fountain.

It was 13th December when they started their final moonwalk by stepping outside at 162:59 GET which was to become the last moonwalk of the century. Eyes were on a big dark boulder on the northern side of *Massif*, which was actually an aggregate of five broken boulders. Crew saw many holes in them indicating vents for hot gases in the past. The elliptical shapes also revealed that the rock was flowing when it was still molten. The rock was another big Breccia.

Schmitt sighted an unusually bright white soil but MOCR strictly prohibited him to investigate there. It was clear now; they had run out of time. *Cernan* placed the last memorandum near the LM and read the message written on it, "Here man completed his first explorations of the moon, December 1972 AD."

The third EVA ended with the entrance of the CDR in LM on 14th December. Apollo 17 has done remarkable job of 75 hours on the moon, 22 hours of moonwalk and covered a total distance of nearly 35 Km.

The *Apollo 17* crew collected 741 individual rock and soil samples, including a deep drill core that included material from 3 meters below the lunar surface, with a total mass of 111 kilograms (Lunar and Planetary Institute 2001).

6.5 The Ascent

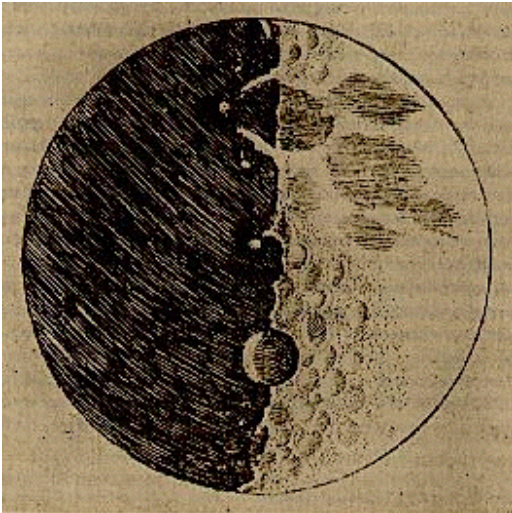
The LM ascent stage lifted off the Moon at 22:54:37 GMT on 14th December. Lift-off and ascent were recorded by the ground-commanded television assembly on the LRV. After docking with the CSM, the ascent stage was sent back to the lunar surface. Its impact was recorded by the four Apollo 17 geophones and by each ALSEP at the Apollo 12, 14, 15 and 16 landing sites.

After the return of the crew from the moon, the spacecraft still spent two days in the lunar orbit in doing orbital science experiments (NASA Apollo 17 Press Kit 1972).

Conclusion

Since Galileo's time most of the scientific knowledge about the moon had come through the observations from his telescopes but lunar observational astronomy also comes with its limitations. Even the most powerful telescopes are limited in their ability to reveal many features about our satellite, such as lunar geology, evolution of the satellite, its composition and internal structure and especially the lunar chemistry.

So it was natural that before the Apollo missions kicked off, the state of the Moon was a subject of almost unlimited speculations. Galileo had designated the dark regions of the moon as *Marias*, by analogy with the terrestrial oceans. Before the Apollo series, it had been thought that *Marias* are huge deposits of the lunar dust, some even considered them to be filled with a type of sedimentary rock. There was also confusion about the formation of these regions: some explained these features as the result of volcanic eruptions, others claimed them to be the sites of giant impacting meteorites.



Galileo's rendering of the moon taken from his 'Sidereus Nuncius' (p44)

Luckily the Apollo has program provided us with factual evidences about the earth-moon couple. We now know that the Moon is made of rocky material that has undergone cycles of melting and freezing, its surface has erupted through volcanoes, and been crushed by meteorite impacts. Some rocks hint towards the presence of ancient magnetic fields although no planetary field exists today. We also come to know that mass is not distributed uniformly inside the moon. It has more mass in the 'near side' and hence its center of mass is displaced towards the Earth by several kilometers. In short, we sometimes claim that today, we know more about the interior of the moon than we know of the earth!

Through these lunar probes, we also get reliable information about the timescales of the various lunar processes such as *mare* basins were created with great impacts by the huge

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meteorites and molten lava filled them between 3.1-3.8 billions years ago. As these features represent the major physical lunar surface, we can immediately infer that the bulk of lunar history recorded on the surface on the moon (that is, the time of the formation of more than 90 % of the craters) took place before 4 billion years ago. Moreover almost all craters appeared to be caused by meteoritic impact. Lunar highlands were believed to be formed about 4.4-4.6 billion years ago by the flow of an early, feldspar-rich crust on a magma Ocean that covered the moon to a depth of many tens of kilometers or more.

Apollo missions' seismographic studies reveal a detailed internal structure of the moon. We now know that the lunar volcanic or tectonic activity had been absent or very mild for the last 2-3 billion years. Explosive studies also showed that the Moon possesses a thick crust (60 km), a fairly uniform lithosphere (60-1000 km), and a partly liquid asthenosphere (1000-1740 km). A small iron core at the bottom of the asthenosphere was also proposed.

The samples brought back also opened up giant vistas in understanding moon's rock geology and mineralogy. The most common rocks in the lunar surface are plagioclase or aluminum rich anorthosites, uranium-thorium rich KREEP basalts, iron rich mare basalts and titanium-iron rich volcanic rocks. The differences between Earth and Lunar rocks proved that both of them have different chemistries. Thermodynamics considerations showed that calcium, aluminum and titanium silicates are the most refractory compounds that exist in a solar dust cloud (NASA Apollo 16 Press Kit. 1972).

Instruments to detect the tenuous atmosphere on the Apollo missions measured total pressures of the lunar atmosphere corresponding to a total number density near the surface of $\sim 2 * 10^5 \text{ cm}^{-3}$ at nighttime and possibly two orders of magnitude higher during the daytime ($\sim 5 * 10^6$ to $1 * 10^7 \text{ cm}^{-3}$) though much of the daytime values appeared to be due to experiment contamination in the landing area. Apollo 17 directly detected Argon gas in the lunar atmosphere with its surface-based mass spectrometer, LACE. It showed a diurnal pattern of Argon with a nighttime minimum near $2 * 10^2 \text{ cm}^{-3}$, followed by a rapid increase around sunrise to values as high as $4 * 10^4 \text{ cm}^{-3}$ (Parker & Stern 1998).

Apollo experiments proved moon to be completely without any signs of biological life.

Thus it is evident that the political tug-of-war which triggered the American nation to plan such an expensive project involving hundreds of thousands of men and women, eventually offered an extensive knowledge regarding moon as well as of our own Earth. Thus the cold war proved a blessing in disguise for space science both in terms of what it yielded in terms of knowledge and exploration and in terms of confirming yet again the human passion and courage to learn more of the secrets of the Universe.

Today man's conquest of the moon has seduced him to start dreaming of Mars.

Bon voyage!

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