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Chapter 23

Apollo, a Testbed for Planetary Exploration*

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Abstract

The six Apollo missions in which human beings were able to walk on the surface of the Moon gave humankind its first experience of exploring another planet. Given the complex challenges involved in flying to and landing on the Moon, only trained pilots were assigned to lunar missions. And they were trained to geology. The process of training them in geology led to new approaches to field studies being devised. In this chapter, we will discuss how scientists and astronauts learned from their missions on the Moon, especially by making mistakes during the Apollo 14 mission. All in all, the six lunar Apollo missions constitute our sole point of reference when it comes to understanding the benefits and limitations of sending human beings to another planet for the purposes of exploration. Despite the risks taken by the astronauts, human exploration appears very efficient.

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Acronyms/Abbreviations

EVA: extravehicular activity
LM: lunar module
LRV: lunar rover vehicle
PLSS: portable life support system

I. Introduction

Until now, the six Apollo lunar landings gave us some of the only references of what can be a human exploration of another planet. Among the over five hundred astronauts since 1961, only twelve men walked on the Moon, between 1969 and 1972. All in all, they spent around 80 hours outside their lunar module, in their pressurized spacesuits, walking and roving through the lunar landscapes.

With Apollo 11, on July 20, 1969, the first men to land and to walk on the Moon, Neil Armstrong and Buzz Aldrin, conducted only one EVA which duration did not exceed two hours. They were followed, in November 1969, by Pete Conrad and Alan Bean (Apollo 12). It is generally admitted that these two lunar missions were mostly technological. After these two successes, and despite the near disaster of Apollo 13, Apollo 14 was launched in January-February 1971. More scientific objectives were assigned to the mission. The LM and the spacesuits were reliable, and it was time to go further in the exploration of the Moon.

And finally, with the cancellation of the three last planned missions (Apollo 18 to 20), Apollo 15 (July-August 1971), 16 (April 1972), and 17 (December 1972) turned to be the most complex lunar missions, with a more ambitious scientific program. Their goal was no longer to win President Kennedy’s bet but to acquire a better understanding of the Moon itself, its origin and evolution, and by doing so, to open a new chapter of discovery.

Many books tell a wide audience the story of the Apollo program. Some of them, like *A Man on the Moon,* by Andrew Chaikin [1], relate wonderfully, from inside, all the processes that led to sending twelve men on the Moon—an amazing achievement. Numerous provide very accurate descriptions of the Apollo spacecrafts and their cosmic navigation [2]. But except *Exploring the Moon,* by David M. Harland [3], none of them record in detail what happened over there. The latter gives a very well documented vision of what the astronauts actually did on the Moon, while focusing on their scientific goals.

Each mission has been thoroughly documented, from a technical and scientific point of view [4]. A very informative website, the Apollo Surface Journal

[5], held by Eric Jones and Ken Glover, allows all those interested to follow each second of the lunar exploration missions.

All this material was truly inspirational, and represented both primary and secondary source information, allowing a non-American author to recount the story of the first explorers of the Moon, and make it accessible to a non-specialist public. This research work also led to unexpected discoveries. Among those, the fact that field exploration taught NASA and scientists how to conduct a scientific research on another celestial body. The experience gained through the first lunar landing, and the mistakes made, invited project designers to challenge the pre-conceived ideas they initially had.

So, what can be learned from these experiences, and to which extent this analysis enables us to figure out whether planetary exploration would be better performed by human beings or robotic space systems?

II. Discussion

Let's skip quickly the first lunar landing, since Apollo 11 was clearly not a scientific mission. The aim was to land on the Moon, to walk on the Moon without taking more risks than necessary, and to come back safely to Earth. Neil Armstrong and Buzz Aldrin had to learn how to work on the Moon during a rather short two hours spacewalk, punctuated by several symbolic activities. Lee Silver, a geologist from Caltech who later trained the other Apollo astronauts, confessed decades afterwards that: "Despite the absolutely incredibly good job that Neil Armstrong had done, now we had to start thinking about what kind of science we wanted to do, rather than just analyze the rocks that they happened to bring back" [6].

Silver was one of those who elaborated the method to explore the Moon, building on the work performed by Eugene Shoemaker, geologist at the USGS in Flagstaff, who had immediately seen the benefits that could be drawn from a geology class for the Apollo astronauts. Due to the harsh environment of the lunar surface, geologists had to adapt to specific requirements. As Silver put it: "I want to stress that—I was always being trained by the crews as much as they were training me, because I didn't know the constraints they were operating under" [6]. Field trips were thus organized for some of the Apollo astronauts (Figure 23–1). The first expedition took place in September 1969, in the Orocopia Mountains (California), with the Apollo 13 crew (Jim Lovell and Fred Haise) and its backup crew (John Young and Charlie Duke). Lee Silver invited the astronauts to first have a short look at the landscape and to describe it, even without any knowledge of the geologic terms. The astronauts immediately realized that they had all the required skills to make good observations which is the first level of a scientific work.

Figure 23–1: Lee Silver, Charlie Duke and John Young during a geology training.

On the Moon, the astronauts would have very little time to work. Obviously, their main limitation would be their oxygen reserve. So, the geologists developed a method that allowed the astronauts to do the same job as on Earth, but very quickly. To summarize, it consisted observing the landscape, understanding what is common and what is not, and deciding which rock to pick up: to do that, they would have to take some specific pictures of each sample before and after being collected (Figures 23–2 and 23–3). With such a method, within a few minutes, each crew member would be able to bring what the scientists call documented samples.

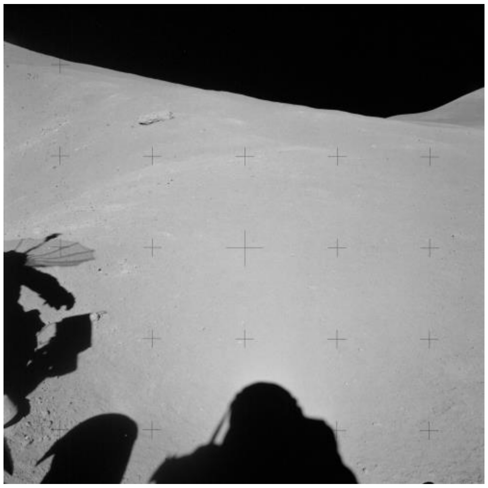

Figure 23–2: A context picture taken during the Apollo 15 EVA 2 showing the location of one famous sample called the Genesis Rock.

Figure 23–3: Two of the “before” and “after” pictures of the Genesis Rock.

On the Moon, the Apollo 11 astronauts did not have enough time to follow this procedure. Neil Armstrong picked up many rocks and stored them together. During the next missions, each sample was preserved in a separate numbered bag.

The first geologic traverse on the Moon was conducted during the Apollo 12 mission by Pete Conrad and Alan Bean, on their EVA 2. They were the first astronauts to venture far away from the lunar module, over 400 meters. Although they did not have a full geological training, they were able to notice what was unusual in their vicinity.

Conrad and Bean faced some impediments like the zero phase angle (an annoying brightness from the soil in the opposite direction to the Sun) and the hardness to interpret their photographic map and find exactly where they were. They ran short of time and could not collect all the expected samples, following the state of the art procedure.

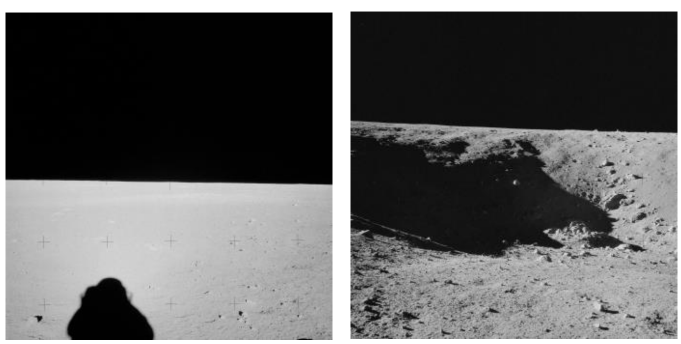

Figure 23–4: The annoying zero phase angle fading reliefs on the ground (left) and Bench crater, which was difficult to identify on field.

But without realizing it, they demonstrated how human exploration can be efficient. They visited the Surveyor 3 probe, which had landed there two years before. And for the first time—and until now, the only time—they walked in a planetary landscape pictured before by a robotic spacecraft (Figure 23–5). By picking up some rocks, near a little young crater called Block (Figure 23–6), Conrad and Bean brought a final end to the frustration of the geologists who could not move and grab some of the angular rocks they happened to see remotely earlier. The strength of a human crew versus a robotic probe was thus demonstrated with very few abilities.

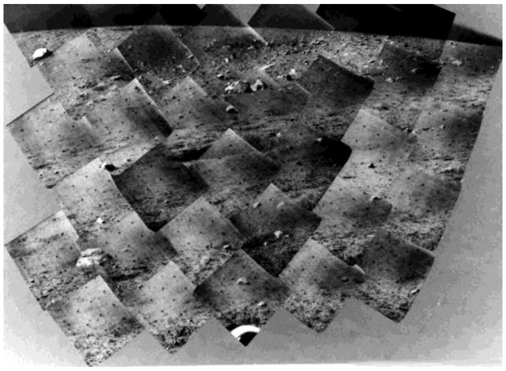

Figure 23–5: Lunar landscape pictured in 1967 by the Surveyor 3 probe. In distance, some angular rocks can be seen in the vicinity of Block crater.

Figure 23–6 Picture taken by one of the Apollo 12 astronauts showing in the foreground the angular rocks pictured two years before by Surveyor 3 (the probe is seen in the background, in the upper left part of the picture).

The first true geologic mission was Apollo 14. The landing site, located on the hummocky hills of Fra Mauro, had a strong scientific interest. It could hide chunks of the primary lunar crust. For the first time, the two astronauts, Alan Shepard and Edgar Mitchell, were assigned important objectives determined by scientists. Not all expectations were met, by far, as acknowledged at a later stage: they collected less samples than foreseen, they failed to find the location of the planned stations and they missed their main objective, the 340 meters wide Cone crater. Additionally, they did not document all their samples as well as planned. And finally, when Alan Shepard swung at two golf balls just before departure (Figure 23–7), it ruined the crew's reputation.

Figure 23–7 Alan Shepard swings at a golf ball on the Moon (TV frame).

Shepard and Mitchell were not the best pupils in the geology class, during the training time [7 and 8]. But to be fair with them, once on the Moon, they did a great job (Figure 8, left). They unfortunately faced problems never encountered before Shepard and Mitchell had to walk 1.5 km, while climbing about 90 meters. In front of a low and blinding sun they had to find subtle changes in the gray shades of the soil (Figure 23–9, right). Even more than the Apollo 12 crew, they walked on a such hummocky ground that they could often not see their LM any longer or recognize the landmarks of their photographic maps (Figure 23–9, left). And they failed to evaluate properly the distances they had traveled (Figure 23–8, right). Halfway to their objective, the slope was rather steep. So they got exhausted. And at the end, the topography of the hill they climbed, not shown on the maps, fooled them. They were standing 17 meters from the rim of the spectacular Cone crater without being able to see it!

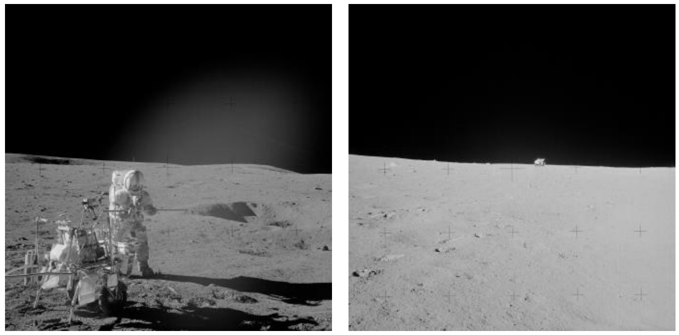

Figure 23–8 Alan Shepard with a core tube trying to collect samples where the scientists wanted to. But at that time, he was at the wrong location, only a mere 100 meters from the LM (right) instead of twice this distance, as planned.

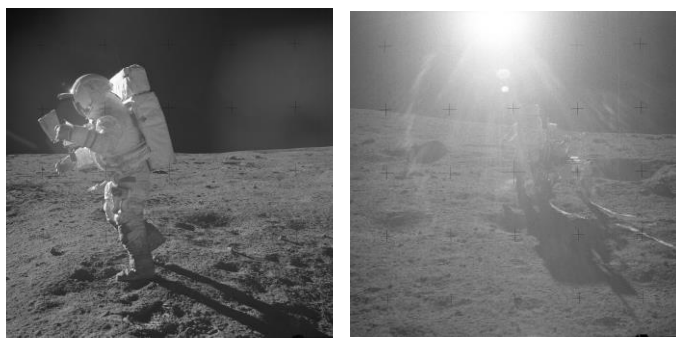

Figure 23–9 Mitchell reads the map and tries to figure out where they are (left). Shepard pulls the MET on a steep slope, in front of a blinding sun (right).

Despite of that, Shepard and Mitchell struggled to meet the scientific goals all along their traverse. They wasted a lot of time trying to figure out where they were in order to find the planned geology stations. At some point, Alan Shepard decided to give up the search for Cone crater and to collect samples. Without this decision, the astronauts would have collected less lunar material than their Apollo 12 predecessors: an unbelievable situation in respect to the high interest of the Fra Mauro landing site. Moreover, Shepard and Mitchell had to make their decisions under a very strict time period.

Apollo 14 may appear as a failure, but it was not. Dropped into the unknown, the astronauts did their best. And in Houston, the scientists in the back room, divided in two teams, failed to help them. They did not realize that they had to skip their planned geologic stops on the way to Cone crater, avoiding letting the astronauts wasting their precious time looking for them. That’s why, at the end, Shepard and Mitchell didn't have time to look for the main objective, be Cone crater.

Apollo 14 represents a true milestone in the human exploration of the Moon. Astronauts and scientists learned a lot during that mission which demonstrated the limits of a walking exploration. During the second EVA, in the back room at Houston, the astronaut David Scott saw how Shepard and Mitchell, as well as the scientists, were in trouble. He said: "That's not going to happen in our mission" [2]. Indeed Apollo 15, launched six months later, in late July 1971, was the first of the so called J missions. It was comprising an upgraded lunar module, a lunar rover vehicle, new spacesuits and new portable life support systems, allowing the astronauts to conduct three seven-hour-EVAs.

Figure 23–10 David Scott (Apollo 15) working at the LRV during the EVA 3 on the rim of Hadley Rille.

For safety and efficiency purposes, the astronauts had to travel to the farthest point first, and then, return to the lunar module with stops at the secondary objectives. The LRV (Figure 23–10) was an extraordinary vehicle: it allowed the astronauts to have some rest during the traverses. And thanks to a special device, it gave them their location, avoiding the explorers to be lost. Thus, the exploration strategy was maximized. David Scott and Jim Irwin were well-trained. And they could apply what Lee Silver and others had planned. They took a lot of context pictures. They took a lot of "before" and "after" pictures (see Figure 23–3). Their samples were well documented and very useful for the scientists.

It would be the same during Apollo 16 (with John Young and Charlie Duke) and Apollo 17 (with Gene Cernan and Jack Schmitt). These three last missions demonstrated how an exploration conducted by humans can be efficient. Astronauts, even not scientists, with an appropriate training, can make very useful scientific choices with very little time. They can repair broken instruments or tools. The most famous example of a repairs is when Gene Cernan fixed the rear wheel broken fender of the LRV with two clamps, some adhesive tape and unused maps of the Moon (Figure 23–11). The result, brought back by Gene Cernan, can be seen in the Air and Space Museum, in Washington, DC.

Figure 23–11 The broken rear fender of the LRV fixed by Gene Cernan (Apollo 17).

In less than twenty hours, the Apollo 17 astronauts covered more than 30 kilometers and collected more than 110 kilograms of Moon rocks. The Curiosity rover, which is the more complex planetary probe ever built, have been on Mars since 2012; in eight years, it has covered 21 kilometers and analyzed a few grams of Martian soil. However, it cannot repair its damaged wheels.

At the same time, the three last Apollo missions reached the safety limit with the existing hardware. In spite of the safety margins taken by NASA during the EVAs, astronaut John Young stressed [9] that if further explorations had to be conducted, it would be necessary to plan more safety devices. Once outside the LM, in their spacesuits, the Apollo astronauts had very few ways to rescue one of them if any trouble arose.

In the perspective of future explorations, this lesson must also be kept in mind.

III. Conclusions

Rovers like Opportunity or Curiosity are cheaper than manned spacecrafts. They can move slowly and do some specific tasks. But until now, they cannot refurbish themselves and, even remotely piloted by humans, they cannot have a smart view of what is interesting to explore in their vicinity. Of course, their main advantage is that they avoid sending humans taking risks on dangerous fields.

What the Apollo explorations teach us is that humans are very efficient, reactive and adaptable. The amount of scientific results can be huge within very little time. This is interesting, especially since the job of astronaut isn't the same as in the seventies. Harrison Schmitt, on Apollo 17 was an exception: he was the first mission specialist in space. Today, mission specialists are much more common in the crews and we can guess that chosen specialists would perform on the Moon a better job than the Apollo-era pilots.

Anyway, the lunar rocks brought back by the eleven non-scientists astronauts who walked on the Moon between 1969 and 1972 allowed the scientists to describe the entire evolution of the Moon, the Earth and the other planets, from their formation 4.5 billion years ago to their present. Thanks to selected rocks taken in only six landing sites and eighty hours of EVA, geologists can say with a good accuracy which were the main steps of the volcanic history of the Moon.

But, above all, exploration is a story to share. The first picture of an Earth rise by Lunar Orbiter, in 1966, had no impact. The same picture taken by Bill Anders, during the Apollo 8 mission (Figure 23–12), impressed everybody in the world. Exploration is to discover another world and to tell the others. And that inspires future generations. Exploration is to go further and come back. And on the way back, as the Apollo astronauts experienced it, your view on your own world is changed. Robots, alone, cannot do that. Only humans—perhaps with some robotic help—can do that. Without sharing stories, exploration is useless.

Figure 23–12 The iconic Earth rise taken in December 1968 by Bill Anders during the Apollo 8 mission.

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Appendix
A Book in French

"Ils ont marché sur la Lune" (They walked on the Moon), Philippe Henarejos, édition Belin, 2018, 512 p., awarded by the Robert Aubinière Prize, from Institut Français de l'Histoire de l'Espace.

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[8] Don E. Wilhelms, To a Rocky Moon, p. 248. https://www.lpi.usra.edu/publications/books/rockyMoon/01FrontMatter.pdf.

[9] In his book *Forever Young,* University Press of Florida, 2012, on p. 187, John Young writes: "Charlie and I had been in the vacuum for seven hours and twenty-three minutes. There was no way we could plug into oxygen or water if the EVA mobility unit failed. The next time human beings go to the Moon, we need to make sure crews can access oxygen, lithium hydroxide to remove the CO2, water to service the cooling unit, batteries, and extra spare communications systems. The suit should be designed to accommodate all these repairs to prevent the death of the crew person."