Air and Space this Week

Item of the Week

THE ~~LAST~~ MOST RECENT FOOTSTEP

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I've alluded to the coincidence in dates between America's first planetary fly-by and the departure of the Apollo 17 *astronauts from the Moon before, including an Item of the Week this time last year, but I decided to revisit the topic, with a somewhat different spin. Last time, the focus was on the International Geophysical Year and the earliest days of the U.S. Space Program. This time around, I'll focus more closely on the* Apollo 17 *side of the coincidence.*

INTRODUCTION: THE FIRST FIVE YEARS IN SPACE

The Space Age officially began on October 4, 1957, with the launch of the first artificial satellite, *Sputnik 1*, by the USSR. It was a shock to the U.S., and we were even more distressed when the USSR launched *Sputnik 2*, on November 3, 1957. *Sputnik 1* was tiny, a symbolic victory no doubt, but it could do us no harm. No so, in the case if *Sputnik 2*. It was large enough to carry a nuclear bomb, right over our heads. There was nothing we could do about it. That idea put a charge under our leaders, especially LBJ.

The US was not able to respond until January 31, 1958, with the launch of *Explorer 1*. It, too, was a mostly symbolic event, but it did carry a device to detect cosmic rays, managed by James Van Allen. Its data showed the presence of a "belt" of charged particles trapped in Earth's magnetic field. Two such belts still bear his name today.

Other satellites soon made it to Low Earth Orbit (LEO), seeking to take advantage of the highest of "High Ground" for military reconnaissance, weather modeling and prediction, and communications. I covered the I.G.Y. to *Sputnik 1* to *Explorer 1* period more thoroughly in an Item of the Week on December 12, 2022 (here), and *Explorer 1* (and Van Allen) in detail in an Item of the Week on January 20, 2022 (here).

TO THE MOON!

The Russians again "upped the ante" on the battlefield of symbols in the sky. Both the US and the USSR were accessing LEO, but in 1959, the Russians started launching spacecraft to the Moon. On January 2, 1959, they launched *Luna 1*, an instrumented probe we think was intended to impact the Moon (because it carried the Soviet coat of arms), but it missed and went into orbit around the Sun. It had no imaging system, but its magnetometer showed that the Moon had at most a tiny magnetic field, and it discovered the Solar wind.

Luna 2 followed, launching on September 12, 1959. It was similar to *Luna 2*, but this time the Russians were successful at impacting the lunar surface. Both *Luna 2* and its booster's third stage hit the Moon on the 14th. There would be many more Luna spacecraft in subsequent years, but the one that stuck in our craw a bit was the next one …

Luna 3 was launched on October 4, 1959. It was much more sophisticated than its two predecessors – it carried a primitive television imaging system. It was a Rube Goldberg-type device called the Yenisey-2 Phototelevision System. It took photos on film, developed the film on board, then scanned the photographs with an electron beam/photomultiplier, producing an analog signal that could be reconstructed on Earth. Don't laugh, we used something similar in our early satellites! And it worked, *Luna 3* returned eight crude images successfully.

Luna 3's mission was to demonstrate Soviet scientific prowess by sending back to Earth images of the hidden far-side of the Moon. It would be a scientific coup, as well as political, and that's why the only lunar mare was named the Moscow Sea and why the largest crater *Luna 3* saw is named "Tsiolkovsky," their Robert Goddard.

There were no relay satellites in LEO to help *Luna 3* beam its images home, so the Russian mission planners used the Moon's own gravity to deflect the trajectory of *Luna 3* enough so that it could "see" the Far Side and then have line-of-sight back to Earth, the first time the gravity assist tactic was ever used.

And we didn't know at the time that we had a hand it its success.

The US really wanted to know more about Soviet (and Chinese) military capabilities as the Cold War progressed, but our technology wasn't up to the task. We took a page from the WWII Japanese and tried to build large helium balloons that could carry cameras and other reconnaissance gear as they floated from launching in Europe to recovery over the Pacific. There were several such programs, and they met with little success (that's why we developed the U-2). All the balloons did was to put Roswell on the map, and provide the Soviets with a technological solution that was bothering them.

One of the series of balloon reconnaissance programs we tried was called "Genetrix." We had discovered from our own high-altitude balloon testing that conventional photographic film was damaged badly by high-altitude flight, where cosmic rays and other damaging radiation could hit it. We developed films that could withstand the damage, and used them in the Genetrix program. The balloons normally flew too high for Soviet interceptors to reach, but their altitude fluctuated diurnally; sunlight heated the balloon envelopes during the day, causing them to rise with the increased lift that resulted. But at night, the balloons would cool off and descend. To the height the Soviets *could* reach. They shot down a bunch of Genetrix balloons, and recovered much of the wreckage. They, too, knew the problems with high-altitude use of conventional film, but had not figured out a way of countering it. But they did know how to take advantage of a windfall from the sky when it appeared!

The success of *Luna 3*'s imaging system would not have been possible without the Soviets using our Genetrix film!

AND BEYOND*: MARINERS 1* AND *2*

Both the US and the USSR looked to the next noteworthy Space "first." The Soviets made it to orbit first, and they made it to the Far Side of the Moon first. What to do? Why, on to the planets, of course!

Aiming at planets was different than putting satellites in LEO or sending spacecraft to the Moon. Those could be done pretty much any time, but the (relative) movements of the planets created "launch windows," times when interplanetary travel was possible without ruinous fuel requirements. The minimum energy needed to transfer from one planet's orbit to another is called the "Hohmann Transfer Orbit," where you have to apply to (or remove from) enough energy from the spacecraft to make its orbit of the Sun elliptical, with that orbit grazing the orbits of the two planets at perihelion and aphelion.

In the case of Venus, the launch windows occur every 19 months and have a usable duration of several weeks. The first possible window to use for Venus was centered on June, 1959, but neither side was far enough along with rocket and spacecraft technology to make an attempt.

Both sides honed their experience with launches in 1960, but it was a slow process. The USSR made a couple of desultory attempts to fly by Mars, and tried a repeat of *Luna 3*; all failed. The US tried to orbit the Moon, but that attempt (their third) died when the boosters second stage ignited while the first was still firing.

The USSR once again beat America to the punch at the next Venus window (early 1961) by launching two spacecraft designed to impact Venus. The first, launched on February 4, made LEO but never left it. The second, *Venera 1*, launched on February 12. The spacecraft actually did fly by Venus the following May, however, its communications system had failed two weeks after launch. Meanwhile, the US was developing the Ranger program, a series of lunar hard landers built on a standardized spacecraft design. The first of what would become seven Rangers was launched on August 23, 1961. It was the US' first attempt to use an LEO parking orbit prior to firing the spacecraft booster again to send it onward. *Ranger 1* made LEO OK, but the booster shut down immediately at the start of the trans-lunar burn, its orbit quickly decayed, and it re-entered Earth's atmosphere on August 30. *Ranger 2* similarly failed after its launch on November 18.

The next Venus launch window was in the summer of 1962. The US Ranger program was moving right along, with the launch of *Ranger 3* on January 26 and *Ranger 4* on April 23. The former was an attempt to hit the Moon, but failed new-fangled transistors caused the trans-lunar burn to be too much, and *Ranger 3* missed the Moon by a wide margin. *Ranger 4* actually did hit the Moon, but an internal power failure caused the derelict spacecraft to impact the far side without returning any data.

In spite of the failures of *Rangers 1-4*, the US had its eye on Venus for the 1962 launch window. The initial idea was to use a booster system with an Atlas first stage and an upper stage called "Centaur," a better and stronger rocket than Agena. But Centaur wouldn't be ready in time for the Venus window, so NASA made a more robust version of Ranger that would be light enough for the Atlas/Agena system to send to Venus. The idea of launching a series of spacecraft based on a common "bus" was sound, and the JPL planned to make upgrades to the Venus probes of 1962, calling them and their successors the "Mariner" series.

The Soviets were aggressively going for Venus impact during the 1962 launch window, too. They launched on August 25, September 1, and September 12. All three were designed to hit Venus, all three made LEO successfully, and all three never left their parking orbits.

The US prepared the first two Mariner spacecraft for launch that year, too; both were designed as fly-by missions. *Mariner 1* was launched on July 22. However, a minor hardware problem, combined with a transcription error in converting the hand-written launch codes into the memory of the on-board computer sent the booster haywire, requiring its destruction by the Range Safety Officer.

Are you having a Monty Python "Swamp Castle" flash-back yet?

The software error was identified and corrected, and *Mariner 2* launched successfully on August 27. It was the "strongest castle in these parts" and successfully flew by Venus on **December 14**. *Remember that date, **12/14/1962**!*

Mariner 2 carried a microwave radiometer, a high-energy radiation detector, and a magnetometer. The radiometer showed that the surface temperature was on the order of 800° F, completely obliterating the sci-fi version of Venus as a swampy planet akin to Earth in its Carboniferous Period. Period. The radiation detector showed that astronauts would require shielding in any long-duration mission; the radiation load experienced by *Mariner 2* would be deleterious, if not fatal, to a human. And the magnetometer showed that Venus had at most a tiny magnetic field, unlike Earth, its fraternal twin.

Mariner 2 remains in heliocentric orbit to this day.

WHAT A DECADE!

The decade following the success of the *Mariner 2* Venus fly-by can be rightly considered as the "Golden Age" of lunar and planetary exploration! The Mariner series, apart from *Mariner 8*, gave us considerable insight into the nature of Venus and Mars, especially *Mariner 9*. The USSR had an increasingly-successful series of Venus missions. And, of course, the US was aggressively pursuing JFK's challenge to, "… before the decade was out, land a man on the Moon and return him safely to Earth."

The Ranger series of Moon hard landers had a number of additional failures, but its last three, *Rangers 7*, *8*, and *9*, were complete successes and gave planetologists their first, albeit brief, close-up view of the lunar surface. The Lunar Surveyor program of soft-landers showed that Tommy Gold's fear of a lunar surface of deep, soft, dust was not correct, and all five of the successful Lunar Orbiter missions helped scientists pick out the best landing sites for a manned landing. *Apollo 11* fulfilled JFK's charge, and with the exception of the heroically-saved Apollo 13 mission, six lunar landings were completed successfully, with progressively-greater amounts of scientifically-important data coming home.

To this day, fifty-four-odd years later, the achievement of putting humans on the Moon has been an iconic symbol of American technological prowess, inspiring many into following STEM education-enabled careers, and providing HUGE tangible, semi-tangible, and intangible benefits to our country. And if you don't think Apollo was that big a deal, how many times of late have you seen an advertiser use Apollo imagery to give the audience a sense that they are "high-tech" without having to say so in the advertising copy? And why are so many countries trying to accomplish what we did so long ago? It's a club of one right now, but not for long…

TO THE MOON (PART 2): *APOLLO 17*

The subject of this part of this Item deals with the final manned landing of the Apollo program. The original Apollo plan was for nine Moon landings, Apollos 11-20. *Apollo 13* failed, and Congressional support waned, resulting in the cancellation of the final three Moon shots, so there would be only six. The cancellations required scientific objectives to be consolidated or abandoned, but NASA did manage to send a professional geologist to the Moon. And the cancellations made for three boffo museum exhibits of the Saturn V launch vehicle!

Deke Slayton, the head of NASA's Astronaut Office, had a three-year rotation strategy, as mentioned in recent Items. NASA prudently trained two complete crews on each mission, allowing for a quick substitution should one or more of the prime crew suddenly become unavailable (as happened on *Apollo 13*, when Jack Swigert had to step into Ken Mattingly's slot when Ken was exposed to rubella prior to the mission). Since the launch schedule for manned missions was tight (in order to make JFK's schedule), each mission had its own unique components requiring extensive training, and each mission needed a mix of crew experience, Slayton's system was sound. A back-up crew for a given Apollo mission would become the prime crew for the flight three missions later.

The three-mission scheme would take the back-up crew for *Apollo 14* and make them the prime crew for *Apollo 17*. That meant that Gene Cernan, a Gemini veteran and Lunar Module Pilot for *Apollo 10*, would be Mission Commander, with Space rookies Joe Engle as Lunar Module Pilot and Ron Evans as Command Module Pilot.

When the cancellation of the final three Moon landings was announced, the scientific community aggressively pursued the notion that at least one of the Moon landings should have a professional geologist as part of the landing team. The only astronaut that met that requirement was Harrison Hagan "Jack" Schmitt. So it was in with Schmitt, and out with Engle. Bummer for him, but better for Science!

Joe Engle would go on to fly a number of the Space Shuttle atmospheric tests, become the back-up Mission Commander for the first Space Shuttle flight, and serve as Mission Commander for the second. He has the distinction of being only pilot to fly into Space on two different types of winged vehicle, the X-15 and the Space Shuttle. But he didn't get to walk on the Moon…

Eugene Andrew Cernan

Gene Cernan was born on March 14, 1934 in Chicago. His early childhood was unremarkable, but things changed when he went to Purdue and picked up a Navy ROTC scholarship in his second year there. He was a member of several fraternal and leadership organizations, and received a B.S. in electrical engineering in 1956. His initial assignment upon graduation was service aboard the light carrier, *USS Saipan* (CVL-48). Aviation called to him, and he took basic flight training at several bases across the South. He earned his wings and joined Attack Squadron 126, then based at Miramar. From there, he took additional schooling, earning an M.S. in aeronautical engineering in 1963.

NASA was recruiting for their third cadre of astronauts when Cernan picked up his M.S.; he applied and was accepted. His first NASA assignment was as back-up pilot for *Gemini 9*, with Tom Stafford as the mission commander. Alas, the *Gemini 9* prime crew perished in tragic air crash on February 28, 1968, which moved Stafford and Cernan up. Jim Lovell and Buzz Aldrin became the new *Gemini 9* back-up crew, moving from that role for *Gemini 10*.

Gemini 9 was intended primarily as a test of the process of rendezvous and docking, using the same type of Agena target vehicle that had bedeviled the *Gemini 6* mission. *Gemini 8*'s near-fatal problems with the Agena had been caused by a thruster malfunction on the capsule, not the Agena, so this would be the next opportunity to try again. The Agena's Atlas booster failed, the *Gemini 9* mission was delayed, and a docking test device developed as a contingency to the Agena was prepared. It was called the "Augmented Target Docking Adapter,' aka the *ATDA*. The mission was renamed, "Gemini 9A."

The *ATDA* was launched successfully, but an utterly-ridiculous error in mating the *ATDA* to its booster prevented the shroud that protected the docking end of the *ATDA* from jettisoning. It hung, half on-half off, called by the *Gemini 9A* crew, the "angry alligator." Since the primary mission task was not do-able, the crew moved on to the second objective: a Space walk by Cernan to make a demonstration free flight using Astronaut Maneuvering Unit, the precursor to the MMU. Mission doctors, detecting cardiac stress on Cernan's biomonitor, scrubbed that attempt. The crew did practice rendezvousing with the *ATDA*, but scrubbed the second planned EVA, which would have allowed Cernan to inspect (but not try to fix) the jammed fairing. A third EVA was to be the second attempt to use the AMU, but Cernan's suit was so stiff and inflexible he barely got back inside after venturing out. Suit improvements would be made, and the AMU never flew again. Two other on-board experiments failed. The mission could hardly be called a success.

The three-mission rotation plan had Cernan serve as the back-up lunar module pilot for Apollo 7, even though it did not have a lunar module. His next assignment after that would be prime LMP for *Apollo 10*, the dress rehearsal for the first Moon landing.

The *Gemini 9A* crew was in line to be the core of the prime crew for *Apollo 10*: Tom Stafford as Mission Commander, Gene Cernan as LMP, with veteran astronaut John Young added as Command Module Pilot. Overshadowed by the first Moon landing two months later, *Apollo 10* is often remembered for the names of its modules being from the Peanuts cartoon: "Charlie Brown" for the Command Module and "Snoopy" for the Lunar Module. Not particularly patriotic or heroic, but those names resonated well with the public outreach effort! [In the comics, Snoopy had visited the Moon in 1968…]

Some thought was given to rolling the dice with an attempted landing, but wiser heads prevailed. The mission was a success, but there had been some problems with the LM, including it tumbling on its ascent from near the surface, that would have been more problematic had it happened after landing. And to make sure that Tom and Gene didn't jump the gun, the ascent stage was "short-fueled," carrying enough to perform the flight profile, but not enough to get from the lunar surface to orbit after landing.

Tom, Gene, and John had set the stage for Neil and Buzz's success.

The *Apollo 13* accident messed up the stately three-mission rotation, and Cernan was given his choice: prime Lunar Module Pilot for *Apollo 16*, or take a chance on being named the Mission Commander of *Apollo 17*. He chose the latter.

Training proceeded apace, marred by a rather serious incident. On January 23, 1971, Cernan was flying helicopter simulations of the lunar landing process, a routine event. However, as he hovered along the Indian River off Patrick AFB, he misjudged his altitude, dragged a skid, and crashed into the river. The helicopter literally flew apart, and one of its fuel tanks caught fire. The wreckage lay on the bottom, six feet down. Cernan unbuckled and swam under the burning fuel on the surface to safety. He was immediately picked up by a local fisherman and taken to the local marina and help. He was burned in some locations, bad but not serious.

The investigation blamed the accident on Cernan's "misjudgment in estimating altitude," but recognized there were some mitigating factors. Gemini astronaut James McDivitt, then Apollo Manager, was incensed at the accident and demanded that Gene be removed from the *Apollo 17* mission. But Deke backed him up and he remained *Apollo 17* Mission Commander. McDivitt actually resigned over the decision, but stayed on the job briefly until the *Apollo 16* mission was safely home.

Gene Cernan retired from NASA, and from the Navy (as a Captain), in 1976. He became an EVP of an oil company then formed his own consulting firm and served as subject matter expert for ABC, working the first three Space Shuttle launch coverages.

Harrison Hagan Schmitt

… was born on July 3, 1935, in Santa Rita, New Mexico, near the rip-roaring mining town, Silver City. The setting of his youth naturally inspired in him an interest in geology. He was an excellent student from an early age, and got a B.S. in Geology from Cal Tech in 1957. He was selected as a Fulbright Scholar, and spent a year in Norway studying the interesting geology there, work that was the backbone for his Ph.D., from Harvard. NASA knew of the need to send a professional geologist to the Moon at some point during the Apollo program, and recruited a class of scientist-astronauts in 1965. He was selected, and assigned to the U.S. Geological Survey's Astrogeology Center in Flagstaff, Arizona, where he developed geological field tools and tactics for use on the Moon. The lunar geologists would be the Lunar Module pilot for their mission, so they had to learn how to fly a variety of jet aircraft.

Schmitt studied flight and the peculiarities of the Apollo system as vigorously as he had studied geology, and his proficiency got him assigned to the *Apollo 15* back-up crew, which would normally have meant that he would be the prime crew LM pilot for *Apollo 18*. But there was no *Apollo 18*; it and the two that would have followed were cancelled.

Lunar scientists were aghast at the prospect of the Apollo program ending without a geologist landing on the Moon. Schmitt was moved to Cernan's crew, and Joe Engle was out, as mentioned previously. [Planetary scientists had hoped that Gene Shoemaker would have made the trip, but for a variety of reasons, that never came to pass. Shoemaker will be the subject of an Item of the Week at some point in the future….]

Schmitt performed well on the Moon's surface, and was responsible for taking the previously-mentioned "Blue Marble" photograph. His trained eye allowed him to identify some of the oldest rocks returned to Earth, which gave scientists a lot better insights on the early Moon than were derived from samples from previous missions.

After his return to Earth, Schmitt continued his work on organizing and publishing the results of lunar missions, and then was assigned to organize NASA's new Energy Program Office. He resigned from NASA on August 30, 1975, and ran for the U.S. Senate for New Mexico. He served one term, and Chaired the Science, Technology, and Space Sub-committee of the Senate's Committee of Commerce. He then had a number of professional interests, including consulting on a variety of business, geology, Space policy, and other issues. He is a BIG proponent of a return to the Moon and the exploitation of lunar resources.

Schmitt has encountered some notoriety of late, because he is an ardent climate change denier, claiming that the notion of human-induced climate change is some sort of sinister political ploy. I'll make this comment: Schmitt, lunar geologist, outstanding; Schmitt, climate scientist, very much not so much. Sad, really.

Site Selection

Scientists had only one last site from which they could get *in situ* data. Where to go, where to go? A number of scientists had been involved from the beginning in identifying those areas on the Moon where a landing could produce the most useful scientific data. A careful analysis had produced a roster of desirable landing sites within reach. They had modified the list based on the biggest not-addressed-yet scientific questions, listed below in order of priority (from here):

1. *Old highland material.* The first priority was obtaining samples of old highlands material (older than the Imbrium impact) from as large a distance as possible from the Imbrium basin. All three of the final candidate sites were between 800 and 1000 kilometers from the Imbrium basin.

2. *Young volcanic material.* The second objective was investigating the possible existence of young (less than 3 billion years old) volcanic activity. This was considered important both for understanding the thermal evolution of the Moon and also because interpretations of orbital photography suggested that young volcanism might have been explosive in nature and hence associated with a high abundance of volatile materials such as water.
3. *Orbital science.* There were two competing objectives for obtaining orbital science coverage on the *Apollo 17* mission. First, there was a desire to have orbital ground tracks that had minimal overlap with those of *Apollo 15* and *16,* so that the maximum amount of new information could be obtained. On the other hand, because *Apollo 17* carried several new instruments, overlapping ground tracks with earlier missions would allow data from the new and old instruments to be compared over common areas.
4. *ALSEP Experiments.* Finally, factors related to the Apollo Lunar Surface Experiments Package played less of a role on *Apollo 17* than on some prior missions. This was because the seismometers, magnetometers, and laser ranging retroreflectors deployed on earlier missions formed networks across the Moon's surface, but no such network instruments were included on this mission. Although there was some desire to place the Heat Flow Experiment in an environment different from that on *Apollo 15,* this had no influence on the final site selection as both *Apollo 15* and *17* landed very close to impact basin rims.

Images of the lunar surface returned to Earth from the Lunar Orbiter set of five spacecraft and from earlier Apollo missions allowed lunar geologists to identify different geological units on the surface and from their overlapping-relationships and populations of impact craters, determine their relative ages. The above-mentioned Imbrium Basin was a huge impact that spread ejected material over a wide area. Anything that the ejected material was draped over had to be older than the impact event; anything emplaced on/in the ejected material had to have gotten there later. Therefore, getting a sample of Imbrium ejecta was a high-priority objective for *Apollo 13*, then *14*. Determining its age in years would calibrate the understanding of the overlapping sequence (what geologists call “stratigraphy”).

The decision boiled down to a choice between three landing sites: the crater Alphonsus, a crater called Gassendi, and an area called “Taurus-Littrow.”

The leading candidate for *Apollo 17* before the cancellation of the subsequent three landings was the crater Alphonsus. It was a large impact basin, and landing there would be a two-fer for geologists. The astronauts could sample the material of the rim, turned up from a deeper depth than they could otherwise reach. And there were some interesting dark halo-shaped marks on the crater floor, possibly due to recent volcanic activity (a brief but bright glow, possibly from an eruption, was claimed to have been seen there a decade or so earlier). But its selection was as part of a set of four remaining, and it wasn’t going to be the one if there were no more to follow.

Crater Gassendi was also a two-fer. Its central peak could yield samples from deeper within the Moon, the same as at Alphonsus. And it appeared to be mantled by material ejected from the older-than-Imbrium material ejected from Mare Humorum. These were attractive targets, but like Alphonsus, not enough to justify targeting the final mission there.

Another large basin of interest for helping calibrate early lunar history was Mare Serenitatis. Its was rimmed by large mountain ranges, one of which was called the Montes Taurus. A narrow valley, Littrow, cuts the Taurus mountains, and provided planetologists a three-fer. The valley would allow access to samples of the material ejected during the formation of the Serenitatis Basin, which would help nail down the dates of big events in the lunar stratigraphy. It would also allow access to material from depths otherwise inaccessible. And thirdly, there were some halo craters within reach that could be relatively-young volcanic materials. Three beats two, so off to Taurus-Littrow Gene and company went.

Cernan and Schmitt trained together extensively for their time on the lunar surface, and CMP Evans worked with Farouk El-Baz and others in order to be able to identify and photograph scientifically-interesting locations. Along with their back-up crews, the Moon walkers made fourteen geological training trips on Earth (Neil and Buzz made only one). The *Apollo 17* team worked well together, and Schmitt would be supported by a team of lunar geologists in real-time during the Moon's surface.

The Apollo Lunar Surface Experiments Package (ALSEP) of scientific instruments was the most sophisticated of the five ALSEPs successfully deployed (*Apollos 12*, *14*, *15*, *16*, and *17*). Many of *Apollo 17*'s scientific instruments were either updated versions of those previously flown, or entirely new.

Apollo 17

The final Saturn V launched went up at 12:33 AM EST on December 7, 1972, after an unplanned hold of some 2:40 hours. The launch to LEO was uneventful. Translunar injection was also without incident, and the CSM separated from the upper stage to turn around and dock with the LM. There was a minor problem with the docking due to latches being in the wrong position, but that was quickly corrected, docking was successful, and the LM was safely extracted from the Saturn's fourth stage. A trajectory tweak was made to make up for much of the launch delay. Insertion into lunar orbit went as planned.

After 17 hours in lunar orbit, Cernan and Schmitt entered the LM on schedule, undocked, and began their descent to the lunar surface. They landed safely in the tightly-constrained Taurus Littrow Valley at 2:55 PM EST on December 11, less than 200 yards from their planned landing site.

The first EVA would last for over seven very busy hours. Cernan and Schmitt exited the LM, unloaded and unfolded and test drove their Lunar Roving Vehicle, gathered surface samples, took a lot of pictures, deployed the USA flag, unloaded and deployed their ALSEP instrument set, and drilled two holes for the heat flow experiment and a core sample.

During the deployment of the Rover, one of its fenders was damaged, allowing a spray of lunar dust to shower onto the astronauts. Engineers advised a solution; the astronauts could join some of their maps together with, using clips from their utility lights, then use duct tape (!) to fasten the maps to the fender. Worked like a charm on EVA #2!

The second EVA was devoted to laying out additional experiments, and loading grenades into a launcher that would be activated remotely after the astronauts had safely departed. The explosions of the grenades would send shock waves through the surface of the Moon to the deployed seismometers, revealing any sub-surface structures. They also reached one of the fresher craters in the landing area, and were able to sample debris from depth, that turned out to be some of the older material they were looking for. They ended up roving over two miles, picking up 75 pounds of surface samples, in their 7.5 hours on the surface.

A third EVA was conducted as planned. The astronauts retrieved some of the experiment packages meant to be returned to Earth, collected 136 pounds of other samples, drove another 7 miles. The third EVA was almost exactly eight hours long.

They had parked the Lunar Roving Vehicle in a position where its camera could, if aimed and slewed correctly, catch the lift-off of the Ascent Module and follow it as it flew upward. This had been tried before, but required precise timing to be successful. The shot worked perfectly for *Apollo 17*, as befitting the final (for now) launch FROM the Moon (see here).

The ascent from the Moon's surface, the rendezvous and docking with Ron Evans and the Command/Service Module, the firing of the SM's engine, the return to Earth, and the splashdown all went off without incident. The Apollo program had ended on a high note, on December 19, 1972.

The Apollo 17 mission was an unqualified success! Quoting from a NASA History source:

> "All facets of the Apollo 17 mission were conducted with skill, precision, and relative ease because of experienced personnel and excellent performance of equipment. The following conclusions were made from an analysis of post-mission data:
>
> 1. The Apollo 17 mission was the most productive and trouble-free piloted mission, and represented the culmination of continual advancements in hardware, procedures, training, planning, operations, and scientific experiments.
> 2. The Apollo 17 mission demonstrated the practicality of training scientists to become qualified astronauts while retaining their expertise and scientific knowledge.
> 3. Stars and the horizon were not visible during night launches, therefore out-of-the-window alignment techniques could not be used for attitude reference.
> 4. The dynamic environment within the cabin during the early phases of the launch made system troubleshooting or corrective actions by the crew impractical. Therefore, either the ground control or automation should be relied upon for system troubleshooting and, in some cases, corrective actions.

5. As a result of problems on this and other missions, further research was needed to increase the dependability of mechanisms used to extend and retract equipment repeatedly in the space environment."

Apollo data reduction continues to the present. The time between then and now saw many highs and lows in Space exploration. The Space Shuttle program came and went, with two tragic losses. Planetary exploration continued to the point where we have now seen all of the planets and a number of other objects in the Solar System up close. We have robots not only roving the surface of Mars, but also one flying above. Other nations are participating in this grand era of exploration. And our Space-borne telescopes are revealing the history of the Cosmos. What an amazing time to be alive!

CODA

Gene Cernan was the twelfth person to walk on the Moon, the last for now. Neil Armstrong was the first. Both were Purdue University grads. Go, Boilermakers!

The final *Apollo 17* EVA was at its end. Ron Evans was waiting overhead, orbiting in the Command Module the crew had named, "**America**," fitting for the final Moon shot and now on display at Space Center Houston. The final departure was shown on live TV back on Earth. Cernan and Schmitt unveiled a plaque mounted on the LM and read its inscription for the folks back home, "Here man completed his first exploration of the Moon, December 1972 A.D. May the spirit of peace in which he came be reflected in the lives of all mankind." Not exactly gender neutral, perhaps, but heartfelt nonetheless.

Harrison Schmitt then stepped off the Moon's surface and ascended the ladder and entered the Lunar Module, named "**Challenger**," named after *HMS Challenger*, which conducted a very famous scientific expedition in 1872-5, a century before *Apollo 17*. *HMS Challenger* was also the namesake of the Space Shuttle so tragically lost on January 28, 1986.

Gene Cernan paused at the LM footpad, knowing he would be the last person to stand on the Moon for some time to come. He thought for a moment before making the most recent footprint on the Moon (for now), and said,

"As I take man's last step from the surface back home for some time to come – but we believe not too long into the future – I'd like to just say what I believe history will record: that **America**'s **challenge** of today has forged man's destiny of tomorrow. And, as we leave the Moon at Taurus-Littrow, we leave as we came and, God willing, as we shall return, with peace and hope for all mankind. Godspeed, the crew of Apollo 17."

The date was December 14, 1972, exactly ten years to the day that tiny *Mariner 2* made the USA's first planetary fly-by!

DIDJA KNOW?

***Apollo 17* Sample Analysis and Artemis:** In the 50 years since fresh boot prints were made on the Moon, the samples returned by the Apollo moonwalkers have been extensively studied with the state-of-the-art equipment of the times. But there have been a LOT of technological advances since Apollo ended, especially in scientific instrumentation. NASA had the good foresight to anticipate better analytical equipment would come in the future, and they set aside some *Apollo 17* samples for future analysis, in vacuum-sealed containers. The Apollo Next Generation Sample Analysis program now underway at JSC is proving to be an excellent "dress rehearsal" for the analysis of samples to be returned to Earth by the upcoming Artemis missions to the lunar south polar region. See also: https://skyandtelescope.org/astronomy-news/apollo-17-artemis-return-moon.

Moon Rocks Still Tell Tales: *Recent detailed examination* of particulate surface material brought back from the Moon by the *Apollo 17* astronauts in 1972, FIFTY-PLUS YEARS AGO(!), shows that the age of crystals of zircon in the material was 4.46 billion years, meaning the Moon has to be at least that old. The previous "no less than" age of the Moon was pegged at 4.425 billion years. For more info, see here.

Roving the Moon: If *Apollo 11* had landed at the Washington Monument, Neil and Buzz would not have walked far enough to get off the National Mall. If *Apollo 15*, the first landing with a Lunar Roving Vehicle, had landed at the Washington Monument, it would have let Dave Scott and Jim Irwin drive the entire length of the National Mall. If *Apollo 17* had landed at the National Mall, Gene and Jack would have driven all the way to the Beltway (and at about the same overall speed as today's DC commuters!)!

Moon Mice: Astronauts Cernan and Schmitt, and the previous ten Moon walkers, were not the only animals to make it to the surface of the Moon. Five pocket mice were also passengers in the *Apollo 17* LM. They were part of an experiment to determine how damaging cosmic radiation might be. The *Apollo 17* crew named them "Fe, Fi, Fo, Fum, and Phooey!" One of them didn't survive the voyage, and two had medical issues subsequently determined to be unrelated to the trans-lunar environment.

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