“WALLY, WALT AND WHAT’S-HIS-NAME”: COMMAND MODULE PILOTS OF THE APOLLO PROGRAM

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Because we came out of the cave, and we looked over the hill, and we saw fire. And we crossed the ocean, and we pioneered the West, and we took to the sky. The history of man is hung on a timeline of exploration, and this is what's next.

We're supposed to be explorers.

-Aaron Sorkin, 2000

But why, some say, the moon? Why choose this as our goal? And they may well ask why climb the highest mountain? Why, 35 years ago, fly the Atlantic? Why does Rice play Texas?

We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

-John F. Kennedy, 1962

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Abstract

Often considered to be akin to fourth place in the Olympics, the role of Command Module Pilots in the Apollo program of maintaining lunar orbit while the other two astronauts landed and explored the lunar surface, is more captivating and noteworthy a role than expected. This paper examines the roles and duties carried out by Command Module Pilots generally, both while on a mission and on the ground, from the specialized training they underwent in order to be able to return from the moon alone, and the geologic training they received in order to do surveying from orbit, to operating as the voices that their fellow pilots heard, translating and mediating between the astronauts in space, and the command center in Houston. This paper looks at the decision at NASA that created the job, the spacecraft Command Module Pilots flew, and the careers of three Command Module Pilots: Apollo 11's Michael Collins, who is arguably the most famous of this group; James Lovell Command Module Pilot of Apollo 8, a career astronaut, and for a long time the most traveled human being; and Alfred Worden, as the Command Module Pilot for Apollo 15, the first mission to have a much larger science focus. Command Module Pilots' mission at the moon was very different from that of their colleagues who went to the surface, but their contributions to the study of spaceflight, and the geology of the moon should not be marginalized.

Introduction

The Apollo program started as another arena of competition in the great conflict of the latter half of the twentieth century, not the noble extension of mankind's ability and knowledge, and yet despite the spurious political aims, it has stood as a testament to human ingenuity as one of the greatest feats ever undertaken. This paper examines only a minute part of that undertaking: the duty and roles of a certain subset of those astronauts whose task may seem unimportant or trivial to a cursory overview, but not to them, or to anyone else involved in the Apollo program. Command Module Pilots (CMPs), were the astronauts assigned to remain in lunar orbit while the other two astronauts in their crew descended to the surface to step onto the face of another world. Their role was not merely as a support for their crew, but central to the entire program, and they later served as direct contributors to much of the scientific exploration of the Moon.

To understand the part CMPs played, this paper will examine the major decision that necessitated CMPs: the choice of Lunar Orbit Rendezvous; the Command Module itself, as the vehicle the CMP had to pilot; the Apollo missions that particularly focused on the Command Module, and by extension, the task of the CMP; and three particular CMPs and the roles they played in key Apollo missions. Those astronauts are Jim Lovell, Michael Collins and Alfred Worden.

Lunar Orbit Rendezvous

Once Sputnik launched in 1957, the space race was started, and the Soviet Union had an impressive lead. Through the first two US manned space programs, Mercury and Gemini, the US lost every contest to the USSR. The first satellite, the first man in orbit, the first spacewalk, all were Soviet achievements. Because of their head start, and their share of the formerly Nazi rocket scientists, the Soviets were well on their way to dominating space in every aspect. The only 'first' the NASA experts thought they could win was a manned Moon landing. As a goal, it was so far in the future that if the US worked towards that objective directly, they might beat the Russians. Or so Wernher von Braun, the head of the US contingent of ex-Nazi German scientists, calculated.[1] Von Braun envisioned only two possibilities for actually reaching the Moon: direct ascent and Earth orbit rendezvous[2]. This choice may seem arbitrary, but it determined everything from budgets to scale, to training to schedule, everything depended on this choice.

Direct ascent was the simplest and apparently the most logical method of reaching the Moon. Simply put, jump on top of your rocket, blast off directly to the Moon, turn around and land. This way, the approach taken by science fiction and most imaginations, while on the surface logical, takes a prohibitively huge amount of rocket fuel. Stable, predictable, manned

[1] For at least the last century, Germany had been the most advanced state with any sort of technology, especially military might. Scientists there during the early stages of the Third Reich were either recruited into the Nazi party, or exiled for being undesirables (like Einstein).

[2] Michael J. Neufeld, "Von Braun and the Lunar-Orbit Rendezvous Decision: Finding a Way to Go to the Moon," Acta Astronautica 63 (no. 4 2008): 540-552.

rockets were a technology in their infancy, and most of the rockets designed by von Braun's team at Manned Spaceflight Center in Huntsville, Alabama exploded on the pad, or not far above it. A rocket of the size needed to fly to the Moon directly would be many orders of magnitude larger than any that had thus far been designed, let alone tested. To go that far requires enormous amounts of fuel, and that fuel itself adds weight, which also needs to be lifted off the planet, so one needs more fuel to lift the fuel, creating an inconceivably large rocket and an engineering feat never even approached. The Nova, the rocket von Braun and his team envisioned to do the job, was so huge, that the largest factory warehouse owned by the government in the South, that had a hook height, or the height of the warehouse's gantries and cranes, of forty-eight feet, or nearly five stories, was too small to assemble pieces of the Nova on its side.[3] Had the Nova exploded on the launch pad, it would have the same explosive power as a large hydrogen bomb, and would have destroyed a sizable section of Florida.[4] Despite this gargantuan size, modern re-estimations of the math of the thrust required to get to the Moon, put even the Nova as much too small to accomplish the job of direct ascent.[5]

Earth orbit rendezvous (EOR) was the other possibility put forward by von Braun and initially accepted by the administrators at NASA for reaching the Moon. Instead of blasting off directly, several rockets would reach Earth orbit, where they would link up, one with supplies and one with fuel and engines, and then the fueled rocket would blast off to the Moon. One of the problems with this method was that rendezvous in orbit had never been tried, and is intensely complicated, which is one of the reasons that test pilots were recruited to be astronauts from the very beginning of the manned space program. Their training, to deal with unknown problems in

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[3] Ibid.
[4] Ibid
[5] Michael J. Neufeld, "Von Braun and the Lunar-Orbit Rendezvous Decision: Finding a Way to Go to the Moon," *Acta Astronautica 63* (Autumn, 2008): 543.

untried craft under dangerous situations made them suited to the projected dangers of space. Without knowing the effects of zero gravity over the long term and how much it might affect pilots in flight, rendezvous was a risky procedure that needed to be tested thoroughly.

Common between both proposed methods was the difficulty of the landing. Through the Mercury program, NASA had become accomplished at sea landings, while the Soviets, forced by geography had gotten very good at land landing, again putting them ahead. To return from the Moon would require a significant amount of fuel, making the rocket that landed on the Moon very large. Trying to land a large rocket perfectly vertically on an uneven and unknown surface Earth's atmosphere makes telescope images shimmer, like pavement on a hot day, meaning that even with the largest telescopes of the time, views of the Moon's surface were not as clear as astronomers might have hoped was a hugely difficult endeavor. In order to launch comparable rockets on Earth, a huge tower and launch pad complex was used, with spaces dug beneath the rocket to prevent blowback, the ignited fuel bouncing off the ground and igniting the rocket fuel, causing an explosion. There were also huge clamps to hold the rocket steady until it was under its own power. None of these were going to be available on the Moon.

So the decision rested between two not ideal choices until an engineer in one of the lower divisions of NASA, named John Houbolt, championed a different plan. It too was not without its problems and risks, but offered a solution to the weight of fuel and the size of the rocket obstacles. Even from the beginning of Project Mercury, the first US manned space program, weight had been the most persistent headache of NASA's engineers. Therefore Houbolt proposed the most weight saving method yet, one that seems elegant now, but then was intensely complicated and potentially horrendously dangerous. The idea Houbolt advocated almost futilely, through dozens of meetings and memos between 1959 and 1961, was lunar orbit rendezvous (LOR).[6] A smaller rocket, with a lunar lander attached, would fly to the Moon, and then from lunar orbit the small lander, a kind of taxi, would detach and fly down to land on the Moon. The rocket, with the fuel to take everything home, would stay in orbit, rendering its weight on this part of the journey moot, and would wait for the lander to return to orbit, where the astronauts would dock with the orbiting rocket, eject their lander, and fly home, leaving the remnants of the lander in orbit around the Moon. This way, a single much smaller rocket was needed. Houbolt and others who suggested this approach were, quite logically, derided for their idea, because at this stage it was not even known if rendezvous was physically possible. The idea that rendezvous could be accomplished by pilots and any on-board navigating system was untested, and extremely unlikely, and to do that a quarter of a million miles away, makes it all the more boggling an engineering and piloting herculean endeavor. Kennedy had just announced his intention of making a lunar landing before the decade was out, and yet still the divisive argument raged as to which method was going to be chosen to reach the Moon. Houbolt took the drastic step of writing a letter to NASA associate administrator, Robert Seamans, asking for equal consideration to be given for LOR. Seamans was affronted at Houbolt "cutting across six or seven layers of management" but he asked for a report on it anyhow, and within a short period of time it began to look like a more and more viable option. [7] It took von Braun to change his mind from his cherished notion of enormous rocket with a crew of forty or fifty, to this smaller, more experimental, and in the end feasible, idea.[8] Uncharacteristically, he unilaterally announced his endorsement of the idea after a six hour meeting at the Marshall Space Flight

[6] *To the Moon: Nova*, prod. Kurt Wolfinger, 120 min., WGBH Boston Video, 1999. Interview with John Houbolt.

[7] *Nova: To the Moon*, Wolfinger. Interview with Robert Seamans.

[8] Neufeld, "Von Braun" 540-552.

Center in Huntsville, Alabama reporting on studies that favored EOR, on June 7th, 1962.[9] His favor had so much weight in the discussion that NASA announced LOR as the method it would use only a month later.

This decision, and the path it took NASA down, was vital to the history of CMPs because this was what created their necessity and function. An astronaut was needed to, in Michael Collins' words, "carry the fire," waiting for the others to rejoin him to return to Earth.[10] Because rendezvous was so far away, a pilot for both spacecrafts, especially in case something went wrong. Project Gemini, the stepping stone program between Mercury and Apollo, was created to test all those things needed for LOR to work, from long duration flight to see what the effects would be on astronauts, to the all important rendezvous and extra vehicular activity. Imagine going to the Moon, and not being able to get out and walk around. Astronauts interacting with the Moons environment more tangibly than sitting in the lander, leaving their footprints and encountering another world was a necessary aspect of exploration, and of absolutely proving that they had arrived first.

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[9] Neufeld, "Von Braun" 540-552.

[10] Michael Collins, *Carrying the Fire: An Astronaut's Journey,* (New York: Farrar, Strauss and Giroux, 1974), xvi.

Apollo 1

The first planned manned mission of the Apollo program was to be an Earth orbit test of the new Command Module, made by North American Aviation. The module was a Block I, their first try and never intended to be the craft flown to the Moon, which was a good thing. The crew had had so many problems with it in tests, that Gus Grissom, the Commander of Apollo 1 had hung a lemon on the spacecraft.[11] Block II spacecraft were already in middle stages of design and testing, and Apollo 1 would be the only mission to use a Block I spacecraft. North American was not the company that had made the previous space capsules, where astronauts had a huge amount of input on the design and engineering of the Mercury and Gemini capsules.[12] There was no clear one person in charge of the project, no one office or man to appeal to if the astronauts had a concern, or wanted a design change. All the astronauts had been trained as test pilots, trained to push planes to the utmost limits of the crafts ability and to map responses of everything they could think of that could go wrong. And yet their suggestions and demands were increasingly ignored by the engineers at North American, who were becoming bogged down in all the changes constantly happening to the machine. Even technicians who worked on the machine daily had difficulty keeping track of all the updates and, the rewirings, and the replacements made to the space craft. The CSM was at the time, the most complicated and precise machine ever created, with huge new leaps forward in computer hardware design, and

[11] United States National Aeronautics and Space Administration History Office, *Managing the Moon Program: Lessons Learned from Project Apollo: Proceedings of an Oral History Workshop Conducted July 21, 1989(*Washington: National Aeronautics and Space Administration, NASA History Division, Office of Policy and Plans, 1999), 24.

[12] Collins, *Carrying the Fire*, 73.

dozens of critical and interrelated systems. It was expected to have problems, but the problems it had were not ones that had been anticipated.[13]

On January 27th, 1967, the crew of Gus Grissom, Ed White, and Roger Chaffee were preparing for their flight the next month. They were on a launch pad in the Command Module on top of an unfueled Saturn 1B rocket. The test, one in a series of thousands, both for the space craft and the astronauts, was a plugs-out test, where the cabin was sealed, pressurized and disconnected from the support tower, to see if its systems worked on their own. The crew, fully pressure suited and strapped into their couches, were frustrated because the radio between the Command Module and mission control in a blockhouse five miles away, was not working properly.[14] To be true to launch conditions, the cabin was pressurized with pure oxygen.[15] A pure oxygen environment is necessary in space because the pressure can only be maintained there at five pounds per square inch (psi), so pure oxygen is needed to allow the astronauts to breathe. Air pressure at sea level is fourteen psi, so to maintain internal cabin pressurization, the cabin pressure during this routine test, was nearly seventeen psi.[16] At that pressure of pure oxygen, almost everything is flammable. At this point, unshielded wiring at the foot of the astronaut couches is believed to have sparked, igniting fumes from a leaking coolant valve. The flames spread to the nylon netting that was draped around the cabin to catch dropped tools. At the blockhouse would become Mission Control, Deke Slayton, former Mercury astronaut, now

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[13] John, Charles, "January 27, 1967: A Day in the Life of the NASA Astronaut Corps," *Quest: History of Spaceflight* 12 (No. 1 2005): 13-36.

[14] Ibid.
[15] Ibid.
[16] Ibid.

head of the astronaut division of NASA, was listening in on the test when he heard Chaffee shout "Fire!"[17]

Ed White, the nascent CMP on this mission, the first American to walk in space, was sitting in the middle couch, designated seat for the CMP, right beneath the hatch.[18] To save weight, the hatch had two doors. The outer one put into place by the technicians in the support tower, and the inner one that opened into the Command Module that White had to bolt on with a special tool. It opened inward as a safety feature, the pressure of the cabin guaranteeing a seal. The hatch was behind White and over his head. White was easily the most athletic of all the astronauts, someone who had almost made it to the Olympics. On weekends as a workout he and Dave Scott, the backup CMP on this mission, would practice getting the hatch into and out of place. It took three minutes, and was the equivalent of bench pressing two hundred pounds. Once the fire had started, the hot gases produced by the flames increased the cabin pressure exponentially, making it impossible for any human being to open that hatch. Fire had been a worry in the space craft, but the engineers and astronauts had only thought of fire in space, not on the ground, surrounded by technicians. The astronauts died of asphyxiation less than four minutes after the fire started, and although there were trained professionals within feet of the Command Module, there was nothing they could do to help them. By the time they had realized something was wrong, the outer hatch was too hot to touch.[19]

After the Fire, as the tragedy was called by all of NASA, it was astronaut Frank Borman who was assigned to represent the astronauts on the review board set up to investigate the causes of the fire. Their purpose was not to place blame, but to fix the problems that had caused the

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[17] Chaikin, *A Man on the Moon*, 18.

[18] An unpleasant truth, but CMPs were trained to be able to return to Earth solo, in case anything happened to the two astronauts on the surface of the Moon. By sitting in the middle couch, the controls of the other two astronauts were not out of the CMP's reach.

[19] Ibid., 20.

disaster. Both NASA and North American were found to have been somewhat slipshod in their work, not through carelessness, but because of a blithe attitude of overconfidence.[20] The major redesign suggestions the review board included in their final report ten weeks later were a new hatch that required no great physical exertion on the part of the astronaut opening it, one that opened outward, like those on the Mercury and Gemini craft, with explosive bolts. The opening time on the hatch went from a minimum of ninety seconds to just ten. Use of pure oxygen on the ground was stopped, and a mixture with nitrogen was used, and once the CSM was in flight, gradually purged. The materials used to make the interior were rethought, and more than two thousand five hundred parts were replaced with nonflammable versions. Most importantly, the quality control systems were redesigned and made more rigorous at both NASA and North American. Frank Borman, in between testifying at Congressional hearings on the subject, lived in California and worked with North American to implement these changes to the CSM. Although it was not a pleasant thought, many astronauts were grateful to the sacrifice the Apollo 1 crew made.[21] Because it happened on the ground and not in space, they had a damaged Command Module to investigate, forensic evidence to sift through to see what had happened, and how they could save more lives in the future. The diligence, work ethic, and emphasis on safety and backup systems their tragedy engendered made it possible for no further lives to be lost during any of the subsequent Apollo missions.

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[20] Ibid., 23.

[21] Charles, "a Day in the Life" 13-36.

Command Service Module

The CSM, as in figure 1 below, was a combination of two ships until the very last part of its flight. The nose contained the docking mechanism used to connect to the Lunar Module (LM). In Earth orbit, just after it had been launched, the CMP would push the CSM off from the last stage of the giant Saturn 5 rocket that had gotten it up there, turn it around and dock with the LM, pulling it out of the housing that protected it during the launch. From there, once Mission Control in Houston had given the go order for trans-lunar injection (TLI), the astronauts performed the engine burn that would propel them to the Moon. TLI was almost always calculated to make a free return trajectory so that no further burn, or use of the engine, would be needed to slingshot the spaceship around the Moon and straight back to Earth.[22] [23]That way, if something went wrong on the way to the Moon, the astronauts would not be trapped there.

[22] Chaikin, *A Man on the Moon*, 83.
[23] Ironically, it was Apollo 13 that was not on a free return orbit.

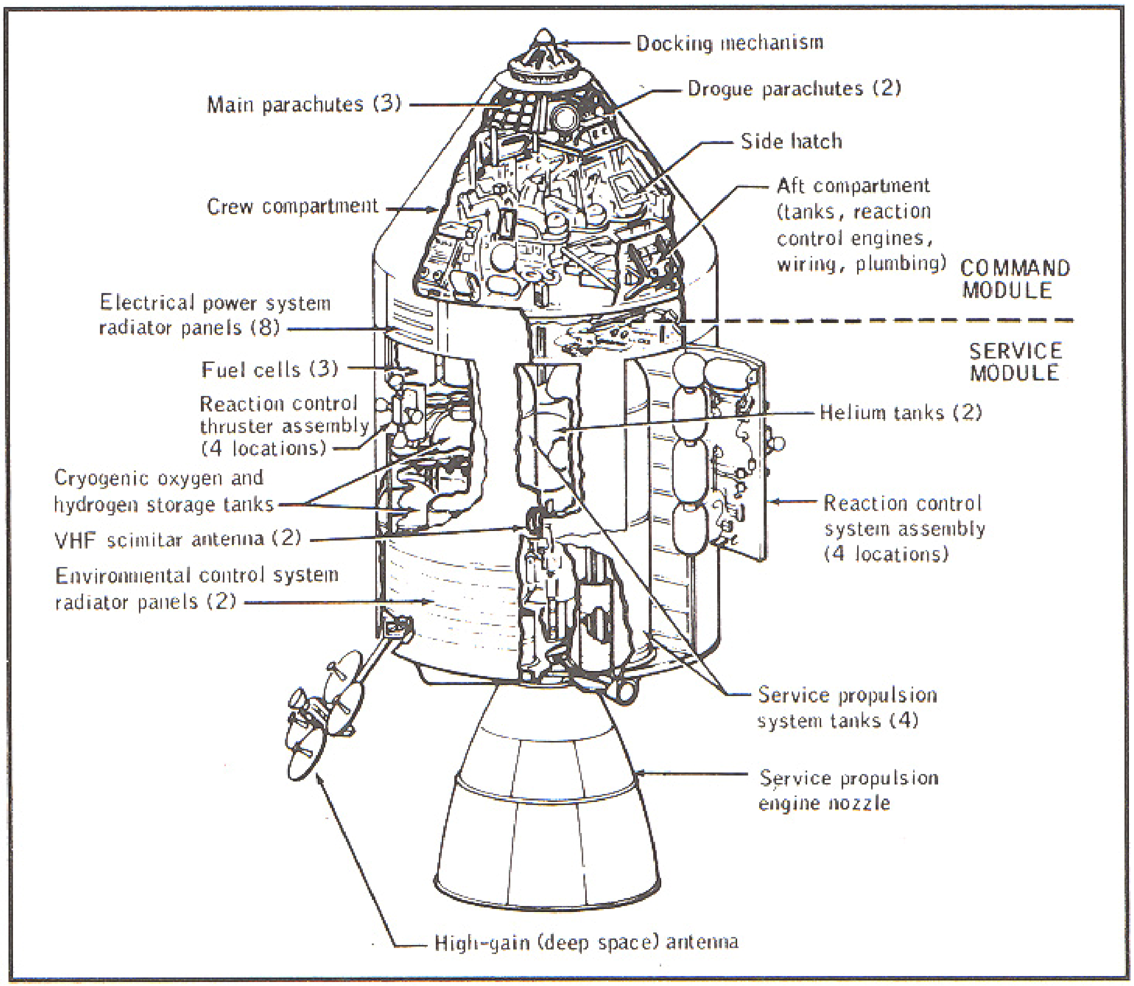

Figure 1 The Command and Service Module. Source: History NASA.gov Introduction to Orbital Science.

The voyage between the Earth and the Moon would be kind of like one uphill and down of a roller coaster; the Earth's gravity would slow them for most of the journey, until a certain point when the Moon's gravity would take over, and speed them toward itself. If something went wrong, the free return trajectory would use that acceleration to slingshot the CSM around the Moon and back to the Earth in a great big figure eight. If nothing had gone wrong once they reached the Moon, then another burn, this one to brake their speed, would put the CSM into orbit sixty-nine miles from the surface of the Moon, a maneuver called lunar orbit insertion (LOI). "The joke around the simulator was, wait till you see the seventy-mile-high mountain on the far side of the Moon")[24] At this height, one orbit of the Moon took about two hours, and every time the Moon was between the CSM and the Earth, they lost radio contact, called by Mission Control loss of signal (LOS). LOS was harrowing, due to the number of significant maneuvers that were started out of contact with Mission Control and all of their computer based telemetry guidance. There was a computer on board the CSM, the most advanced and miniaturized yet made, but it and the LM's computer had the combined computing power of the computer chip in a modern singing birthday card.[25] And yet it was programmed in flight efficiently enough to provide all the precision needed for those maneuvers. All the numbers needed were radioed up to the astronauts to be punched in manually. Those calculations, both the ones made by the astronauts on board and the rooms of computers at NASA had to be accurate to within four ten thousandths of a percent.

After Mission Control gave their permission for landing, the LM would separate from the CSM, and go to land. The CSM would remain in orbit, with the CMP taking reconnaissance photographs of the Moon, or operating experiments put forward by NASA, until the LM and its cargo returned. Then the CSM engine did one last major burn and left lunar orbit to return to Earth. Sometimes, mid course correction was needed either outbound or on return, otherwise the engine wouldn't be needed again. Nearing the Earth again at fantastically high speeds, the CSM would be split one more time, ejecting the Service Module, and turning the flat surface towards the Earth for reentry. The angle had to be calculated just right, too shallow, and the CM would skip off the atmosphere like a stone skipping on water, but too steep and it would burn up in reentry. NASA found no material that could survive the intense heat caused by the atmospheric friction that surrounded the spacecraft during reentry, so they created a resin that would burn in a

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[24] Chaikin, *A Man on the Moon*, 106.
[25] Interview, Benjamin Senson. 12-23-2008

controlled manner while protecting the CM from the intense heat.[26] The atmosphere around the CM, igniting from the friction and the resin, would reach such high temperatures it would become plasma, and while it was braking the CM's fall, radio contact between the CM and Mission Control was lost. Once they had slowed down enough to no longer be surrounded by the plasma cloud, the CM would deploy parachutes, slowing it down further, until it hit the waters of an ocean, flotation devices would release, and the mission was over.

Apollo 7

Apollo 7 was the first manned mission of the Apollo program, and as such was under very close scrutiny. Its mission was straightforward; the crew was to take the CSM into Earth orbit, and test all its systems. Donn Eisele, the "what's-his-name" of this paper, was the CMP and performed admirably, despite the entire crew suffering from severe colds the entire mission, and the CSM did everything asked of it. The nickname is from the probably apocryphal story of Walter Cronkite, in finishing an interview with the Apollo 7 crew, forgetting Eisele's name.

[26] Collins, *Carrying the Fire*, 221.

Apollo 8

Apollo 8 as a mission now seems iconic, the view of a tiny fragile Earth with the Moon in the foreground, reminding us all at the end of a terrible year, 1968, with a brutal war, civil unrest, and major assassinations, how connected and interdependent we all are, how small and how fragile the world is. And yet the mission came from a desperate wish to beat the Russians at something, anything, as a compromise mission of incredible danger in order to have a spectacular success after the tragedy of the fire. Originally, the mission was set to be a more complete and rigorous test of the abilities of the CSM and rendezvous capabilities with the LM, but the LM was still delayed in testing and was months away from being flight worthy. These delays seemed disastrous, as they undoubtedly pushed Apollo 8 into the next year, and making a lunar landing within the decade, the overarching goal of the Apollo program, impossible. Instead of waiting for the LM or merely having a repetition of the flight and tests that Apollo 7 went through, George Low, one of the spacecraft engineers, suggested a simple but elegant plan.[27] Why not just take the CSM to the Moon? While this sounds logical and obvious next step to a present day audience, the idea was filled with risks and untried dangers. Before this, the greatest distance from the Earth that had been achieved by Pete Conrad and Dick Gordon in Gemini 11, was only 850 miles.[28] There were also concerns with radiation exposure. The Earth's magnetic

[27] Robert Zimmerman, *Genesis: The Story of Apollo 8: The First Manned Flight to Another World,* (New York: Four Walls Eight Windows, 1998), 84.

[28] Chaikin, *A Man on the Moon,* 67.

field acts as a giant deflector of the radiation and plasma that the sun throws out into space, but on their way to the Moon, the Apollo 8 astronauts would leave that protective "sun-block" No living creature had ever been beyond the Van Allen belts, and so the affects were still unknown. And yet, the Soviets had just succeeded in sending an unmanned space-capsule and rocket around the Moon and back safely, so NASA was worried about how close the Russians were on their tail. As dangerous an idea as it was, the new mission for Apollo 8 was still highly appealing, and yet the first crew commander it was offered to turned the mission down. Frank Borman, a man of absolute loyalty and no moral or mental gray areas accepted the mission on behalf of his crew within thirty seconds of being offered it in August of 1968. [29]

The launch window, when the launch to the Moon was possible from Florida, was in late December, and with only four months to go, each astronaut had to specialize their training. Jim Lovell, the CMP, was assigned navigation which meant that in case the radio went out, he would be the one to guide the ship home.

It doesn't sound like a daunting task until the scale is explained.

> If the Earth were a basketball, Conrad and Gordon's record would amount to just one inch from the surface. But at the same scale model, the moon, 2,160 miles in diameter, would be a baseball 23 feet away. Getting to the moon and back would require acts of precision more demanding than any previous space flight. To make matters more difficult, the moon is a moving target, barreling along in its orbit at a speed of 2,300 miles an hour.[30]

Throughout the mission, Lovell sited with an eye patch, a sextant and a telescope on various key stars and the Earth's horizon to chart the position of the CSM. His job was to prove that a human being could determine his location without help from the ground. To aid him in task, there were a set of gyroscopes on gimbals held the IMU, or inertial measuring unit, which kept track of the

[29] *Nova: To the Moon,* Wolfinger. Interview with Apollo 8 crew.
[30] Chaikin, *A Man on the Moon*, 68-69.

attitude and relative position of the spacecraft by noting every shift in orientation. NASA thought it would be better to turn it off unless and until it was needed, as Lovell could set it based on his measurements if the guidance system failed. Lovell and Borman disagreed because ______, so it stayed on during the entire voyage. Despite difficulty from pseudo stars created by fuel vented from the craft, Lovell proved that navigation by hand was possible by calculating their position and heading.

His other major navigation duty on board had to do with the geography of the Moon itself. The sea of Tranquility had been previously chosen as an area that would afford possible landing sites, and Lovell checked the viability of that plan by taking pictures, and scoping out the terrain. He also verified that it was possible to orient and navigate the surface of the Moon through certain landmarks, and in doing so he named a mountain after his wife Marilyn. Because of the importance of looking for good landing sites, Apollo 8 had set off towards a new Moon, so that when they arrived the Sea of Tranquility would side lighting, casting the surface irregularities into sharp relief with long shadows.[31] Approaching the Moon they saw only black space, and as they got closer, a piece of the sky where there were no stars that was getting bigger. The Moon only appeared to them once they were approaching orbit.

[31] See Figure 2.

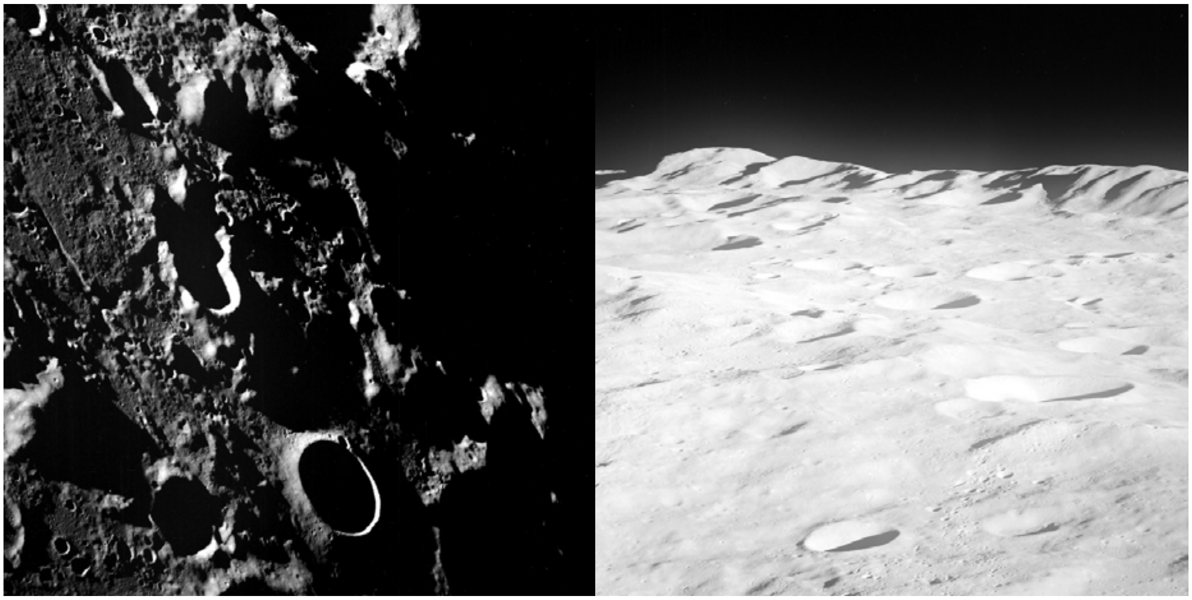

Figure 2 Montes Pyrenaeus and Rim of the Huge South-Pole/ Aitken Basin. Both taken during Apollo 8. In the image on the left, all of the geologic features stand out because of the stark shadows created by light from a low Sun, where as the in the image on the right, with the sun higher, the features become much more indistinct. Source: Apollo 8 Flight Journal. Image Science and Analysis Laboratory. NASA-Johnson Space Center.

Lovell was in charge of monitoring and mapping another feature of the Moon: gravitational anomalies, called mascons, or mass concentrations. Because the Earth has a molten core, the density of any one spot on the planet is pretty close to the density of another spot. But the Moon cooled long ago and is not so regularized. The most spectacular example of this unevenness is the Moon's orbit itself, only one side ever faces the Earth, which means that underneath the side of the Moon we can see is a huge deposit of something that is more dense than the rest of the Moon, causing it to be more drawn to the gravity of the Earth on only that side. That is the largest of all the mascons, but far from the only one. NASA feared that these mascons could have a significant effect on the orbit of any spacecraft around the Moon, making it rise and dip depending on how dense the area of the Moon directly below it was. If the wobbling wasn't mapped out, unforeseen mascons could make a lunar landing difficult and dangerous. Lovell kept track of those that came across their path, but that didn't solve the problem down the line.

Apollo 8 stayed in orbit around the Moon over Christmas, and on Christmas Eve, read passages from Genesis. One of the most powerful and iconic images from the Apollo program was one no one had anticipated, Earth rise. While waiting for return of signal with Houston, Borman looked up and saw the Earth coming over the horizon of Moon and it took his breath away. He and Bill Anders, the Lunar Module Pilot frantically snapped picture after picture, marveling at the sight. It took Lovell reminding them that it would come up again for them to calm down. After all the wonder and excitement of such a journey, they had a safe and uneventful voyage home.

Figure 3 Earthrise. Source: Apollo 8 Flight Journal. Image Science and Analysis Laboratory. NASA-Johnson Space Center.

Apollo 11[32]

Michael Collins, an Edwards Air Force Base test pilot, graduate of West Point, and son of a military family, is perhaps the least well known of the most famous trio of astronauts ever fielded by NASA. As CMP on the mission that first landed on the Moon he was happy, even delighted with his role in the space program and decided that Apollo 11 would be a great final flight to his career. He had been slated to be CMP for Apollo 8, but a bony spur on his spine nearly paralyzed him, and Jim Lovell from the backup crew took his place. During Apollo 8, Collins was one of the main astronauts to run the Capcom, or capsule communicator. To avoid confusion and chaos, the only people in Mission Control allowed to speak on the radio up to the astronauts in flight were the astronaut assigned to Capcom and the flight director. This way all messages were fielded and transmitted through a familiar figure to the flying crew, and the astronaut on capcom operated as a gatekeeper for all communication from the rest of Mission Control, allowing the astronauts to concentrate on their mission.

By the time it became Collins' turn to be CMP, added to his duties of navigation were the burns to get the CSM into and out of orbit, and the CM's reentry into Earth's atmosphere. He was trained to be able to return alone. In addition, during his months in the simulator, he practiced eighteen different emergency rendezvous scenarios.

All three astronauts on Apollo 11 were veteran astronauts, used to working in the alien environment. Collins had been on Gemini 10, and on it had done an EVA to a NASA vehicle that had been up for nearly four months. This vehicle, left over from an earlier Gemini mission

[32] Apollo 9 and 10 are excluded from this paper because the CMP role was less significant in each. Apollo 9 stayed in Earth orbit, testing the LM, and Apollo 10 was a dress rehearsal for the lunar landing.

that had had to land prematurely, had a metal plate on it that recorded the effects of long term exposure to micrometeorites. It also proved that rendezvous with a dormant object was possible, as the batteries in the vehicle had died.

Once Armstrong and Aldrin's LM *Eagle* undocked and headed down to the surface, the portion of the mission Collins was asked most about in interviews began. For the next twenty-two hours he would become the loneliest man in the universe, and for forty-eight minutes of every two hour cycle, he would be utterly cut off. Reporters often asked him if he would fear the loneliness, if he felt the silence would overwhelm him. But he replied that that was the part of the mission he enjoyed the most, without Mission Control prompting more tasks for him to do. His one regret with his situation was not going all that way, only to be left nose pressed to the glass as the others went down to the surface, but that his orbit meant that he missed Armstrong's first step and famous words.[33]

The only mission goal that Collins missed out on was finding the lunar landing site. Because of various issues Armstrong had with the landing, they were actually four miles off where they were supposed to be. As a result Collins failed to visually locate the *Eagle* even though he searched every time the CSM went over. Armstrong and Aldrin had had some difficult moments with the LM, but Collins had no trouble with his CSM.

After this mission, because of the strain the NASA lifestyle put on his marriage, Collins left the astronaut corps, and later took up writing about his experiences at NASA, in the process writing one of the most vivid first-hand account of the astronaut life.

[33] Collins, *Carrying the Fire*, 238.

Apollo 15

NASA faced criticism and frustration from scientists from the beginning of the Apollo program. Focused on getting there before the end of the decade, science on the missions necessarily took a back seat. NASA had hired a group of scientist astronauts, but of the thirteen, only one was a geologist, and none of them were assigned to any missions. Harrison Schmitt, the geologist, was a typical astronaut in that he was overachiever who buried himself in work. As a trained geologist, Schmitt was disappointed and frustrated with the type of science instruction the astronauts were receiving, dull obscure and dense lectures that did nothing to endear the astronaut corps to science or geology. As a solution, Schmitt's mentor astrogeologist Gene Schumacher suggested that what was needed was the right teacher, to promote the passion for geology into the astronauts. Schmitt enlisted the help of Lee Silver, a geologist at Caltech was known for reveling in field work classes. The first crew that Schmitt and Silver convinced about geology was ironically Apollo 13's, as it was the mission never to reach the surface of the Moon, or have time for the astronauts to survey the surface from orbit, but it was not the last.

Apollo 15 was the first of the J class missions, with a longer duration of time on the Moon, a greater payload for lunar samples, a rover to allow the astronauts to venture further afield and a much greater emphasis on science. Schmitt was finally assigned as part of the backup crew to Apollo 15, getting further into the system of camaraderie of the astronaut corps. Once the J missions were the order of the day, Schmitt and Silver found the proper way to keep the astronauts' attention and to make them as passionate about geology as the geologists were:

competition.[34] As fighter pilots and test pilots, the urge to be the best at whatever they did was a powerful motivator. On the field trips the two Apollo 15 crews took, the backup crew had an effective weapon with Schmitt on their side, and to compete, the Apollo 15 commander Dave Scott worked harder and developed a real passion. This in turn spurred his crew members to match that passion and excel in their own geological duties.

For Alfred Worden, CMP on Apollo 15, this meant a different path than the field trips to US geological paradises, rather a mentorship with geologist Farouk El-Baz. When the photographs from the unmanned Lunar Orbiter mission returned, some three thousand in all, el-Baz went through them all, identifying and cataloguing every feature he could discern, a project that took three months. From this vast store of information, he drew up a list of sixteen possible landing sites, which had all the possible geological variation the Moon offered. This knowledge made him a walking database of Moon geography, and, along with his passion and ability to explain complex scientific concepts and information lucidly, made him a great resource to the CMPs of the later Apollo missions. El-Baz and Worden flew survey planes all over the American west, training him to be able to accurately, concisely, and quickly describe what he saw. Test pilot training, which demands close observation of events and circumstances in dynamic situations proved to be an asset to astronauts in their survey training. What the geologists of NASA were really pushing for was the ability of the astronauts to provide context for their discoveries, because context made any rock find much more informative about the history of the Moon.

[34] NASA History Office, *Managing the Moon Program*, 34.

While orbiting the Moon, Worden was kept busier than any CMP before him with turning on and off experiments, and taking pictures and describing the surface beneath him.[35] He was struck by how many of the geologic features below him in the chaotic jumble that is the surface of the Moon were familiar to him. Part of the updated CSM was a section of the service module called the scientific instrument module (SIM). As the service module was to be jettisoned, Worden did a spacewalk during the return voyage to collect film from cameras.[36]

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[35] Farouk el-Baz, *Astronaut Observations from the Apollo-Soyuz Mission,* (Washington: Smithsonian Institution Press, 1977) 30-45.

[36] Chaikin, *A Man on the Moon,* 440.

Conclusion

Although their task was probably the loneliest of all the astronauts, the thousands of support staff, who get even less recognition for their unstinting contributions to the greatest human endeavor of all time. By discussing all those people around the command module pilots, those who designed their spacecraft, or trained them or taught them, a better understanding of their task is acquired, and a more thorough understanding of the Apollo missions as a whole. CMPs in their turn operated in support of the rest of their crew, an inseparable piece of the whole. The Apollo program would not have been possible without the contributions of CMPs, and that their duty was integral to the whole system. While on the surface their role may seem similar to a chauffeur, waiting to ferry the other astronauts back to Earth, in actuality, through their scientific and technological discoveries and contributions, CMPs achieved just as much as the other astronauts.

Abbreviations

Capcom	Capsule communicator
CMP	Command module pilot
CM	Command module
CSM	Command and service module
EOR	Earth orbit rendezvous
EVA	Extra-vehicular activity
IMU	Inertial measuring unit
LM	Lunar module
LOR	Lunar orbit rendezvous
LOS	Loss of signal
LOI	Lunar orbit insertion
Mascons	Mass concentrations
NASA	National Aeronautics and Space Administration
psi	Pounds per square inch
SIM	Scientific instrument module
TLI	Trans-lunar insertion

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