COMMITTEE ON AERONAUTICS NEWSLETTER

Volume 4, No. 2, May 2020

ALAN D. REITZFELD
CHAIR
areitzfeld@gmail.com

SARAH G. PASSERI
SECRETARY
sarah.passeri@hklaw.com

IN THIS ISSUE:

Apollo 13 – Saved by the Remarkable LM

Albert J. Pucciarelli[1]
apucciarelli@mdmc-law.com
Chair, General Aviation Subcommittee

A few months back, in my second tribute to Apollo 11 in honor of its 50th anniversary, I praised abundantly and deservedly the Lunar Lander or "LM" that made the descent from lunar orbit with Messrs. Armstrong and Aldrin on board, and then using the descent stage as a launch platform, the LM ascent stage departed the Moon. The reliable engine of the ascent stage of the LM burned for 435 seconds, long enough to travel a distance of about 50 miles above the lunar surface at a speed of about 3,800 mph to dock with the orbiting Command Module ("CM") / Service Module ("SM") combination. The two astronauts in the ascent stage crawled through a narrow connecting tunnel that linked the LM to the CM and joined Michael Collins in the CM for the return trip of approximately 240,000 miles back to Earth.

Then followed the second Moon landing by the crew of Apollo 12. The two successful flights even led some people to think that trips to the Moon were becoming reliable and even routine. The superstitious might hesitate knowing that Apollo 13 was next. It lifted off beautifully on April 11, but two days into the flight, on April 13, at 13:13 Houston time, the crew of James Lovell, Jack Swigert and Fred Haise heard a loud bang and saw frozen droplets pour from the SM just behind the CM in which they were seated. Jack Swigert then uttered the now famous: "Houston, we've had a problem".

What happened? Jim Lovell, in his official report on the Mission, wrote:[2]

"Thirteen [there's that number again!] minutes after the explosion, I happened to look out of the left-hand window, and saw the final evidence pointing toward potential catastrophe.'We are venting something out into the- into space'" I reported to Houston. Jack Lousma, the CapCom replied, 'Roger, we copy you venting' I said, 'It's a gas of some sort.' It was gas-oxygen-escaping at a high rate from our second, and last, oxygen tank. I am told that some amateur

[1] Albert J. Pucciarelli is a partner in the firm of McElroy, Deutsch, Mulvaney & Carpenter, LLP, in which he is chair of the firm's hotels and resorts and aviation practice groups. He was previously Executive Vice-President, General Counsel and Secretary of InterContinental Hotels until 1998. He is Chair of the New Jersey Bar Association Committee on Aviation Law and past-chair of the New York City Bar Association Aeronautics Law Committee (1999-2001). He is President of the Mid-Atlantic Pilots Association and the Ridgewood Arts Foundation and a Trustee of the New Jersey Aviation Hall of Fame and Museum. He is a commercial, instrument-rated pilot and aircraft owner.

[2] Apollo Expeditions to the Moon, Chapter 13.1, "Houston, We've Had a Problem" by James Lovell. https://history.nasa.gov/SP-350/ch-13-1.html

astronomers on top of a building in Houston could actually see the expanding sphere of gas around the spacecraft."

The exploded tank was the No. 2 oxygen tank, serial number 10024X-TA0009. This tank had been installed in the service module of Apollo 10, but was removed for modification and was damaged in the process of removal. After its repair, it was installed in the Apollo 13 SM.

The tank was part of a system inside the SM that produced electricity, water, heat and breathable air for the CM. After the explosion, Mission Control, in consultation with the crew, decided that the best way to keep the CM available for the blazing re-entry into the Earth's atmosphere with adequate electrical power in its batteries and oxygen for the three occupants was to shut it down immediately, something never previously done in space, and move the astronauts through the narrow connecting tunnel and into the LM that was still docked to the CM. Its descent and ascent stages were still available for necessary maneuvering, as were its fully charged batteries, fuel for the lunar mission, oxygen for its cabin and the two space suits intended for use outside the LM on the lunar surface. And so, the LM became what NASA came to call "a lifeboat". Shutting down the CM required flipping many switches in the CM and LM in the precise sequence. Batteries from the LM were used to charge the nearly depleted CM batteries from 15% power to 20% power to enhance the time that would be available later in the CM when it alone would make the re-entry to Earth.

In his official report, again Jim Lovell wrote:[3]

"We had 2181 ampere hours in the LM batteries. We thought that was enough if we turned off every electrical power device not absolutely necessary. We could not count on the precious CM batteries, because they would be needed for reentry after the LM was cast off. In fact, the ground carefully worked out a procedure where we charged the CM batteries with LM power. As it turned out, we reduced our energy consumption to a fifth of normal, which resulted in our having 20 percent of our LM electrical power left when we jettisoned Aquarius. We did have one electrical heart-stopper during the mission. One of the CM batteries vented with such force that it momentarily dropped off the line. We knew we were finished if we permanently lost that battery.

"Water was the real problem. Fred figured that we would run out of water about five hours before we got back to Earth, which was calculated at around 151 hours. But even there, Fred had an ace in the hole. He knew we had a data point from Apollo 10, which had not sent its LM ascent stage crashing into the Moon, as subsequent missions did. An engineering test on the vehicle showed that its mechanisms could survive seven or eight hours in space without water cooling, until the guidance system rebelled at this enforced toasting. But we did conserve water. We cut down to six ounces each per day, a fifth of normal intake, and used fruit juices; we ate hot dogs and other wet-pack foods when we ate at all. (We lost hot water with the accident and dehydratable food is not palatable with cold water.) Somehow, one doesn't get very thirsty in space and we became quite dehydrated. I set one record that stood up throughout Apollo: I lost fourteen pounds, and our crew set another by losing a total of 31.5 pounds, nearly 50 percent

[3] Apollo Expeditions to the Moon, Chapter 13.3, "Houston, We've Had a Problem" by James Lovell. https://history.nasa.gov/SP-350/ch-13-3.html

more than any other crew. Those stringent measures resulted in our finishing with 28.2 pounds of water, about 9 percent of the total.

"Fred had figured that we had enough lithium hydroxide canisters, which remove carbon dioxide from the spacecraft. There were four cartridges from the LM, and four from the backpacks, counting backups. But he forgot that there would be three of us in the LM instead of the normal two. The LM was designed to support two men for two days. Now it was being asked to care for three men nearly four days."

In the tight new quarters designed for two astronauts standing (no seats), all three men would have to remain in relative cold and near total darkness for the still outbound journey to the Moon, knowing that each minute put them thousands of miles further from home. They would journey all the way to about 50 miles from the lunar surface and loop behind the Moon using its gravitational pull to sling them around the back of the Moon and on a trajectory back 240,000 miles to Earth.

Regarding this dark and uncertain journey, Jim Lovell recently told a reporter:[4]

"Temperatures in the LM dropped as low as 38 degrees, and carbon dioxide levels began to rise from the men's breathing. Mission Control devised an innovative device to reduce carbon dioxide. Still, the men found it very difficult to sleep, crammed together in the small lunar module without seats. Haise got sick from a urinary tract infection."

After the dark and doubtlessly frightening trip so far from home and the two-day journey 240,000 miles back to the Earth environment, the astronauts faced the very challenging final steps of re-entering the CM, restarting systems that no one knew for sure would come back on line, then quickly jettisoning the damaged SM and the LM that had served them so well, and orienting the capsule's blunt-end forward for re-entry. Exhausted, ill and taking on unrehearsed tasks, the astronauts succeeded and the people on Earth collectively rejoiced at the sight of the Apollo 13 capsule under three striped parachutes descending into the blue Pacific waters.

Jim Lovell wrote:[5]

"A most remarkable achievement of Mission Control was quickly developing procedures for powering up the CM after its long cold sleep. They wrote the documents for this innovation in three days, instead of the usual three months. We found the CM a cold, clammy tin can when we started to power up. The walls, ceiling, floor, wire harnesses, and panels were all covered with droplets of water. We suspected conditions were the same behind the panels. The chances of short circuits caused us apprehension, to say the least. But thanks to the safeguards built into the command module after the disastrous fire in January 1967, no arcing took place. The droplets furnished one sensation as we decelerated in the atmosphere: it rained inside the CM.

---

[4] "50 years after Apollo 13, Commander James Lovell sees the Mission's Failure as a Triumph" by Meg Jones, Milwaukee Journal Sentinel, April 12, 2020. https://www.usatoday.com/story/news/nation/2020/04/12/apollo-13-50th-anniversary-commander-james-lovell-reflects-mission/5124891002/

[5] Apollo Expeditions to the Moon, Chapter 13.5, "Houston, We've Had a Problem" by James Lovell. https://history.nasa.gov/SP-350/ch-13-5.html

"Four hours before landing, we shed the service module; Mission Control had insisted on retaining it until then because everyone feared what the cold of space might do to the unsheltered CM heat shield. I'm glad we weren't able to see the SM earlier. With one whole panel missing, and wreckage hanging out, it was a sorry mess as it drifted away.

"Three hours later we parted with faithful Aquarius [LM ascent stage], rather rudely, because we blasted it loose with pressure in the tunnel in order to make sure it completely cleared. Then we splashed down gently in the Pacific Ocean near Samoa, a beautiful landing in a blue-ink ocean on a lovely, lovely planet."

The role of accompanying the CM and SM back to the Earth environment with three persons on board was not contemplated in the specs for the LM, but the LM performed it admirably.

Again, Jim Lovell's official report:[6]

"A lot has been written about using the LM as a lifeboat after the CM has become disabled. There are documents to prove that the lifeboat theory was discussed just before the Lunar Orbit Rendezvous mode was chosen in 1962. Other references go back to 1963, but by 1964 a study at the Manned Spacecraft Center concluded: 'The LM [as lifeboat] . . . was finally dropped, because no single reasonable CSM failure could be identified that would prohibit use of the SPS.' Naturally, I'm glad that view didn't prevail, and I'm thankful that by the time of Apollo 10, the first lunar mission carrying the LM, the LM as a lifeboat was again being discussed. Fred Haise, fortunately, held the reputation as the top astronaut expert on the LM- after spending fourteen months at the Grumman plant on Long Island, where the LM was built. Fred says: 'I never heard of the LM being used in the sense that we used it. We had procedures, and we had trained to use it as a backup propulsion device, the rationale being that the thing we were really covering was the failure of the command module's main engine, the SPS [SM's] engine. In that case, we would have used combinations of the LM descent engine, and in some cases, for some lunar aborts, the ascent engine as well. But we never really thought and planned, and obviously, we didn't have the procedures to cover a case where the command module would end up fully powered down."

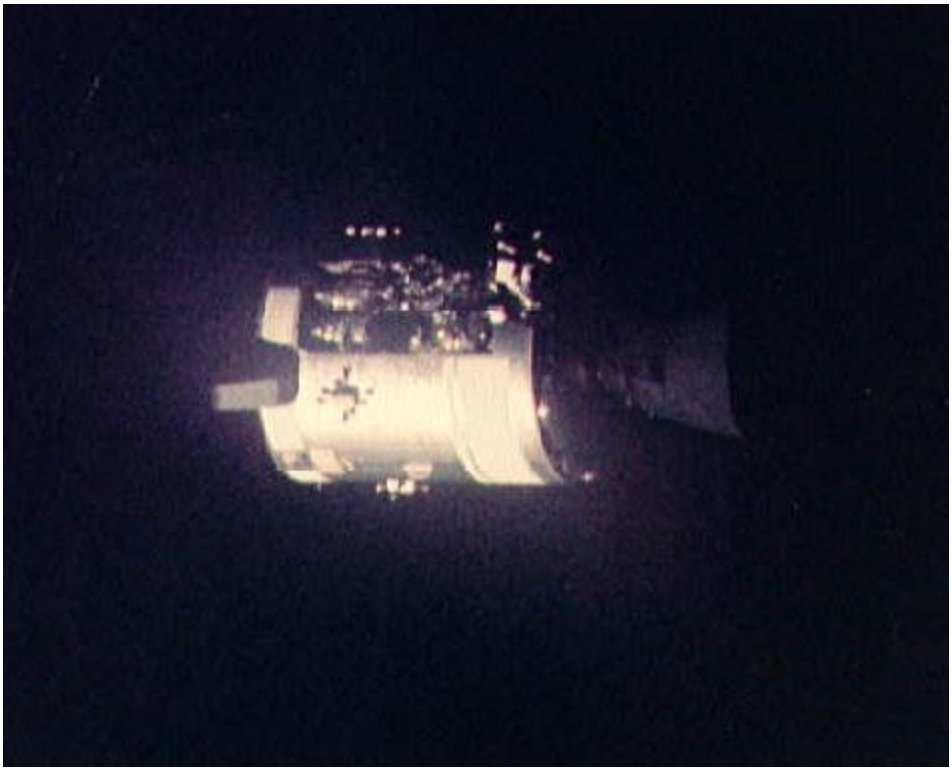
NASA is known to require redundancy in all critical systems, never leaving the success of a mission, especially the lives of crew, dependent on one system or piece of equipment that may fail. In my prior article on the LM, I noted that a failure of the ascent stage to thrust the LM's crew compartment back into a lunar orbit would have stranded two astronauts on the Moon until their hours-long oxygen supply ran out.[7] There was no second system to launch the ascent stage. Similarly, had the explosion of Apollo 13's oxygen tank in the SM occurred after the Moon landing, after the LM consumables had been used and the LM was no longer part of the CM-SM vehicle configuration, the three astronauts most certainly would have died from a lack of oxygen and a means to put the CM on course trajectory for re-entry into the Earth's atmosphere. But even so, the story of the Apollo program remains a success story. After the tragic fire that killed

[6] Apollo Expeditions to the Moon, Chapter 13.2, "Houston, We've Had a Problem" by James Lovell. https://history.nasa.gov/SP-350/ch-13-2.html

[7] "The LM Ascent Stage: The Most Remarkable Space Vehicle Ever" by Albert J. Pucciarelli. New York City Bar Association Committee on Aeronautics Newsletter, March 2020. http://documents.nycbar.org/files/Aeronautics_March_2020_Newsletter.pdf

three astronauts in the Apollo 1 capsule on the launch pad in a simulated launch, no lives were lost and 12 men walked on the Moon and returned safely to Earth. The one post-Apollo 11 mission that did not result in a Moon landing, became instead a tribute to the ability of NASA to adapt in an emergency and the courage of three astronauts who must have known throughout of the high risk of not returning to Earth. Apollo 13 is also a tribute to the capability of the LM that when needed in a role entirely different from that for which it was designed, performed admirably as a safe haven in the cold of space with enough thrust available to return the crew home. For me, the LM remains the most amazing space vehicle ever.

The following photo can be found at:
https://nssdc.gsfc.nasa.gov/image/spacecraft/apollo_13_sm.jpg



The Apollo Service Module, after jettison from the Command Module after return to near-earth for re-entry. The explosion blew off the outer panel.

The following photo can be found at:
Apollo Expeditions to the Moon, Chapter 13.5, “Houston, We’ve Had a Problem” by James Lovell. https://history.nasa.gov/SP-350/ch-13-5.html

Haise, Lovell, and Swigert after splashdown of the CM awaiting the recovery helicopter to the Iwo Jima in the South Seas. The crew lost a total of 31.5 pounds; Lovell alone 14 pounds - records in both cases. Dehydrated and exhausted, Haise was invalided three weeks by infection.
