

The Apollo 1 Fire: A Case Study in the Flammability of Fabrics

Supplementary Background Material for Online Appendix

Supplemental information on Roger Chaffee, Virgil “Gus” Grissom, and Ed White

Commanding the first manned Apollo mission was 40-year old veteran astronaut Virgil I. Grissom, Lieutenant Colonel, USAF. A native of Mitchell, Indiana and 1950 graduate of Purdue University’s Mechanical Engineering program, Grissom was one of NASA’s original class of astronauts, the famed “*Mercury 7 Astronauts*.” Preferring to be called “*Gus*,” Grissom piloted the second suborbital Mercury flight on July 21, 1961, spending 15 minutes, 30 seconds in space. When his capsule, “*Liberty Bell 7*,” impacted the Atlantic Ocean on splashdown, its hatch mysteriously blew off. Grissom later argued that the capsule’s emergency explosive bolts had malfunctioned. Water rushed into the capsule and Grissom narrowly escaped drowning. *Liberty Bell* was not as fortunate — it sank, sitting at the bottom of the Atlantic Ocean until it was recovered in 1999. Grissom’s second flight was the first of the Gemini program. He and John Young orbited the earth three times in their capsule, nicknamed “*The Unsinkable Molly Brown*” by Grissom. As the Command Pilot aboard Apollo 1, Grissom was seated in the left-most seat (facing the cockpit dash) and had access to the emergency cabin pressure relief valve, to be opened in the event of a cabin fire. Many NASA officials believe that had Grissom not died aboard Apollo 1, he would have been the first man to walk on the Moon. Chief of the Astronaut Office and fellow Mercury 7 Astronaut, Deke Slayton, was in charge of setting the astronaut rotation for flights. Slayton expressed his hope that one of the original astronauts would have been chosen for the honor: “*My first choice would have been Gus.*”¹ Gus Grissom was survived by his wife Betty and sons, Scott and Mark.

The Senior Pilot aboard Apollo 1 was another space veteran, 36-year old Edward H. White, II, Lieutenant Colonel, USAF. Born in San Antonio, Texas, White graduated from West Point and missed making the U.S. Olympic team in the 400-meter hurdles by a tenth of a second. After earning a M.S. degree in Aeronautical Engineering from the University of Michigan, he was selected by NASA in 1962 as part of the Group 2 class of astronauts. White flew aboard Gemini 4 and on June 3, 1965, became the first American astronaut to perform a spacewalk. White’s EVA made him an instant and international celebrity. Images of White performing his iconic walk are as breathtaking today as they were in 1965. In fact, a depiction of White floating in space while tethered to his Gemini capsule was used on a pair of 1967 5¢ U.S. postage stamps. As Senior Pilot aboard Apollo 1, White was seated in the center and was responsible for opening the main hatch if the crew had to make an emergency egress from the cockpit. Ed White was survived by his wife Patricia and children, Edward III and Bonnie Lynn.

Rounding out the crew of Apollo 1 was 31-year old, Grand Rapids, Michigan native and Pilot, Roger B. Chaffee, Lieutenant Commander, USN. Like Grissom, Chaffee was a graduate of Purdue University, earning his Bachelors of Aeronautical Engineering in 1957. After graduation, Chaffee began his career as a naval aviator, both repairing and flying reconnaissance aircrafts. During the Cuban Missile Crisis, he flew 82 missions and was awarded the Air Medal. After completing a tour as an aircraft carrier pilot, Chaffee enrolled in the Air Force Institute of Technology to work on his M.S. degree in Reliability Engineering. His studies were interrupted on October 18, 1963 when he was chosen by NASA to be part of the Group 3 class of astronauts. As one of the youngest astronauts selected by NASA, Apollo 1 was to be Chaffee’s first flight

into space. During the flight rehearsal, he was seated in the right-most seat and charged with maintaining communications with ground controllers in the event of an emergency. Roger Chaffee was survived by his wife Martha and children, Sheryl Lyn and Stephen.

Supplemental information on “Go Fever!”

To meet President Kennedy’s challenge of landing a man on the Moon before 1970, NASA had to develop an unprecedented amount of flight hardware, training protocols, and mission procedures in just a few short years. In this high-stakes, high-risk atmosphere, the U.S. space industry developed what is commonly referred to today as, “Go Fever!” — a group-think phenomenon in which people push themselves, despite great danger, to meet a previously-chosen goal. Unfortunately, “Go Fever!” was causing concern for the primary and backup crews of Apollo 1. For example, during a spacecraft review meeting held on August 19, 1966, the astronauts expressed worry about having so much flammable Velcro inside the cabin.² Despite these concerns, engineers kept the flammable material in the capsule to facilitate the securing of tools and equipment. When the Apollo 1 CM and Service Module were delivered to the Kennedy Space Center a week later, several hundred engineering changes still had to be made. Alarmed by the slow progress of these changes, the crew gave a picture of themselves posed with a model of the spacecraft to the Apollo Spacecraft Program Office Manager, Joe Shea. In the photograph, the crew’s heads are bowed with eyes closed and hands clasped in prayer. The inscription reads: “*It isn’t that we don’t trust you, Joe, but this time we’ve decided to go over your head.*”² On December 30, the backup crew, led by Command Pilot, Wally Schirra, completed a successful altitude chamber test of the craft. After the test, a worried Schirra told Grissom: “*There’s nothing wrong with this ship that I can point to, but it just makes me uncomfortable. Something about it just doesn’t ring right.*” Schirra also cautioned Grissom to get out of the ship at the first sign of trouble.³ On January 22, 1967, Grissom became so frustrated with the inability of engineers to keep the training simulator in synch with the actual spacecraft, he took a lemon off a tree in his backyard and hung the lemon on the simulator.⁴

Supplemental information on the immediate aftermath of the fire

By roughly 6:36 pm, ground controllers opened the hatch — only 5 minutes had elapsed since the first report of a fire. Emergency personnel found Grissom’s seat in the 170° position, meaning it was essentially flat. He had removed his restraints, unlocked his foot restraints, and was found on the floor of the cockpit, helmet visor closed. The Apollo 204 Review Board later found that had Grissom been able to open the cabin valve, its venting capacity was insufficient to prevent the rapid buildup of pressure due to the fire — its venting would have delayed the CM’s rupture by less than a second. In other words, had Grissom managed to open the cabin pressure relieve valve, his actions would not have prevented the secondary fire that asphyxiated the astronauts.⁵ White’s seat was in the 96° position, with the back portion horizontal and lower portion raised. Emergency procedures called for him to leave his restraints in place and attend to the hatch. His buckles were not opened, but the restraints had been disintegrated by fire. Ground controllers watching the CM on television screens testified they saw White reaching for the inner hatch handle — he had tried in vain to open the hatch. He was found lying sideways below the hatch, helmet visor closed. Chaffee remained dutifully in his seat as the fire swept left-to-right across the cabin and attempted to stay in contact with ground controllers. His seat was in the

264° position with the back portion horizontal but the lower portion dropped to the floor. All of Chaffee's restraints were disconnected.⁵ Being farthest from the ignition source, his remains were burned the least. Seven and a half hours after the fire, the bodies were removed. Their removal took over 90 minutes as the fire's heat had melted the nylon of their space suits and life-support hoses, thus fusing the bodies to the interior of the cockpit. Autopsies confirmed that all three crewmen died from carbon monoxide poisoning, resulting in cerebral hypoxia and cardiac arrest. Burns suffered by the crew were not believed to have contributed to their deaths as they occurred postmortem.

Grissom and Chaffee were buried at Arlington National Cemetery while White was buried at West Point Cemetery. After the successful launch of Apollo 7, Launch Complex 34 A was dismantled. The complex's remaining concrete pedestal now bears two plaques commemorating the crew of Apollo 1. Over the past half century, other tributes and memorials have been established to commemorate the crew. Craters on the Moon were named Chaffee, Grissom, and White. The astronauts have been inducted posthumously into the U.S. Astronaut Hall of Fame and the International Space Hall of Fame. President Carter awarded Grissom the Congressional Space Medal of Honor posthumously in 1978; President Clinton awarded White and Chaffee the same medal posthumously in 1997. Today, visitors to the Kennedy Space Center can see the names of the crew adorning the Space Mirror Memorial while visitors to Purdue University can visit two engineering buildings, Grissom and Chaffee Halls. Finally, the starship featured in the 1984 movie, "*Star Trek III: The Search for Spock*," was the "*U.S.S. Grissom*."

After the fire, the Apollo 204 Review Board cited vulnerable wiring and plumbing as the likely source of the fire, although the specific source of the spark was never identified. Engineers subsequently implemented major modifications in the design, materials, and procedures of the Apollo program. Among these modifications were the development of improved flammability tests for materials used in crew areas of manned spacecraft and improved acceptance criteria for the flammability, odor, and toxicity of materials used in environments that support combustion.⁶

Supplemental information on "*The Kranz Dictum*"

On the Monday morning following the Apollo 1 fire, flight director Eugene "*Gene*" Kranz called a meeting of his branch and flight control teams. Kranz made the following address to his teams — his address has been since referred to as, "*The Kranz Dictum*" and is considered his legacy to NASA:

Spaceflight will never tolerate carelessness, incapacity, and neglect. Somewhere, somehow, we screwed up. It could have been in design, build, or test. Whatever it was, we should have caught it. We were too gung ho about the schedule and we locked out all of the problems we saw each day in our work. Every element of the program was in trouble and so were we. The simulators were not working, Mission Control was behind in virtually every area, and the flight and test procedures changed daily. Nothing we did had any shelf life. Not one of us stood up and said, "Dammit, stop!" I don't know what Thompson's committee will find as the cause, but I know what I find. We are the cause! We were not ready! We did not do our job. We were rolling the dice, hoping that things would come together by launch day, when in our hearts we knew it would take a miracle. We were pushing the schedule and betting that the Cape would slip before we did.

From this day forward, Flight Control will be known by two words: "Tough" and "Competent". Tough means we are forever accountable for what we do or what we fail to do. We will never again compromise our responsibilities. Every time we walk into Mission Control we will know what we stand for. Competent means we will never take anything for granted. We will never be found short in our knowledge and in our skills. Mission Control will be perfect. When you leave this meeting today you will go to your office and the first thing you will do there is to write "Tough and Competent" on your blackboards. It will never be erased. Each day when you enter the room these words will remind you of the price paid by Grissom, White, and Chaffee. These words are the price of admission to the ranks of Mission Control.

References

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- 6 NASA, *Flammability, Odor, and Toxicity Requirements and Test Procedures for Materials in Gaseous Oxygen Environments. MSFC-SPEC-101* (NASA George C. Marshall Flight Center, Huntsville, AL, Aug. 1968).