NORTH AMERICAN AVIATION Retirees Bulletin

"Where The Best Never Rest"

Fall 2010

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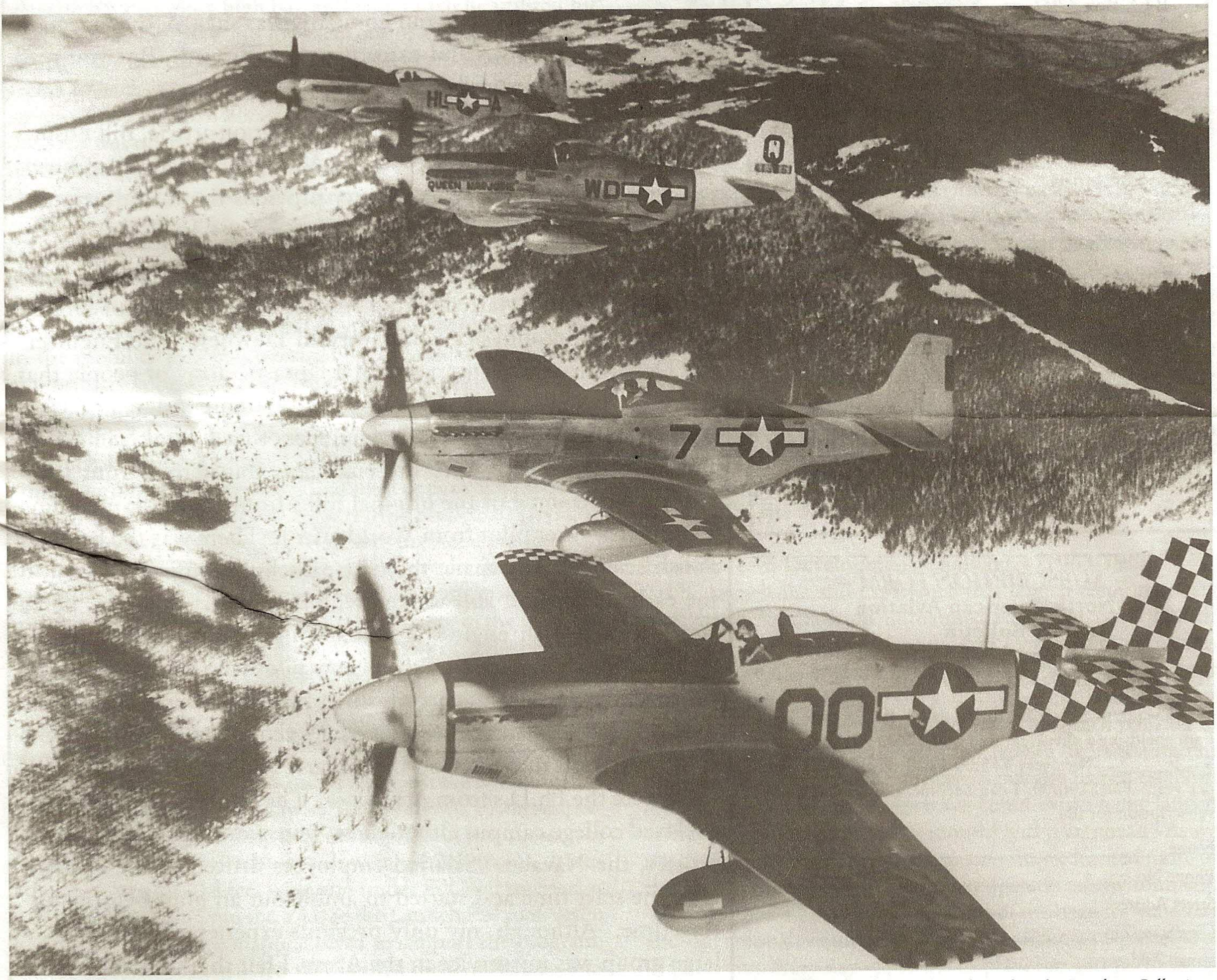

Photo from the John Lambert Collection

The Fifteenth Air Force began flying missions out of the Foggia, Italy region on November 2, 1943. The 15th AF consisted of five bomb wings and two fighter wings—the 305th and the 306th Fighter Wing. The four Fighter Groups of the 306th FW—the 31st FG, the 52nd FG, the 325th FG, and the 332nd FG—were equipped with the P-51D. With their long-range capabilities, the P-51s were able to perform bomber escort and fighter sweeps reaching targets in southern France, Germany, Poland, Czechoslovakia, Hungary, Romania, and Bulgaria. A familiar face in those missions was our NAA Test Pilot, Captain James Brooks, leading the 307th Fighter Squadron, 31st FG. Celebrating their Victory in Europe in a flight over the Alps in 1945, are representative P-51Ds from the four Fighter Groups of the 306th FW: from top to bottom, the 31st FG, 52nd FG, 332nd FG, and the 325th FG.

NORTH AMERICAN AVIATION
Retirees Bulletin

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Dear NAA Retirees Bulletin Subscriber

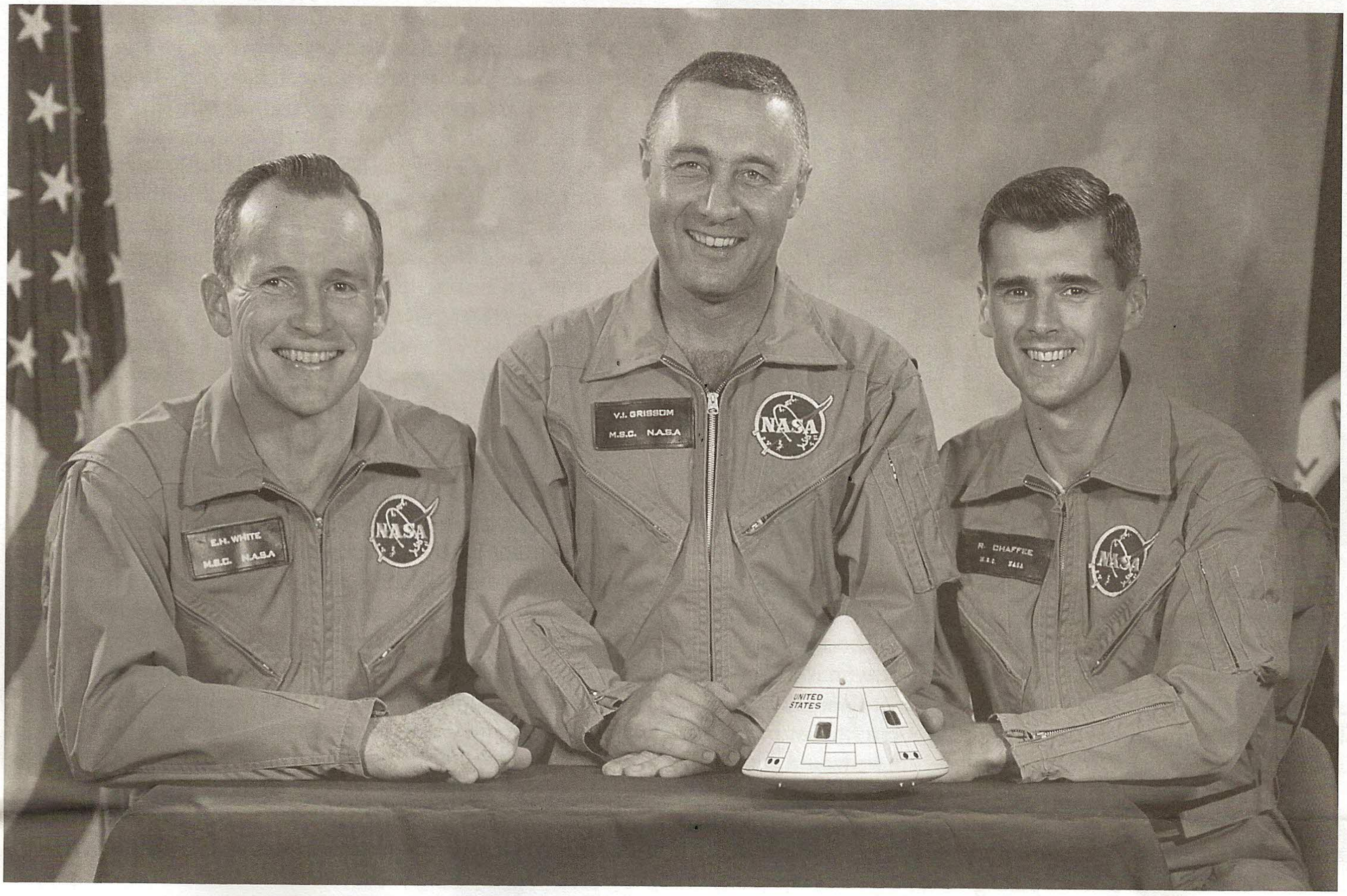
As Editor, we always admire the skills of our volunteer authors and the caliber of the materials they submit for publication. However, in this issue you will read about the Apollo I fire investigation and it will make you rage and cry at the same time! It is written by an NAA participant in the accident investigation whose credentials are impeccable! After fifty years, Larry Korb has delved back into his memory and his log books to put together an amazing study of what happened and what led up to this horrific loss of three good men. Our company, North American Aviation, had to assume full blame for this tragedy! As a result: the program suffered a prolonged delay in schedule, confidence in our company was shaken, management was restructured, lives and careers were destroyed. But you read Larry's report and you decide!

To complement the Apollo I fire investigation article, Bill Edson's fourth segment of his series about NAA Operations at Cape Canaveral and the Kennedy Space Center provides the introduction of the Apollo Program at KSC.

The passing of Joe Beerer, Silent Majority, brings back a fond memory of him. I started with NAA as a Stressman B in February 1951 at the Aerophysics Laboratory in Downey. The Engineering Department was composed of a fantastic array of people that Central Casting in Hollywood would be hard pressed to duplicate. There were the original Vultee engineers that I think came with the building. There were the engineers transferred from LAD that included some of the original folks from Dundalk including a German fighter pilot from World War I. There was the brilliant Polish scientist who made the first parachute jump in Poland in the early 1900s and still walked with a convincing limp. There were some British engineers that immigrated to California via Canada, which included a Royal Navy pilot who had attacked the Bismarck in an ancient Swordfish torpedo bomber. There were the brilliant German scientists from Peenemunde. There were the WWII veterans that received their degrees on the GI Bill. Finally, there were the Ph.D.s from Academia. The atmosphere resembled a relaxed college campus although we were working on a top secret project, the Navaho. Salaried employees drifted in for an hour after the start time and started to amble out an hour before quitting time. Although, my only previous experience working in a large group was my service in the Army, I felt that this was bound to come to an abrupt end. One morning, a man appeared at the main gate. He told the guards that he was THE MAN and to start taking down names of all the late comers and the names of their supervisors. In three days, there was a complete restructuring in the way Engineering was performing. Punctuality and responsibility became the cornerstone of the operation. Oh yes! The man's name was Joe Beerer.

The Apollo 1 Fire Investigation

by Larry Korb



NASA Photo

Portrait of the Apollo 1 prime crew for first manned Apollo space flight. From left to right are: Edward H. White II, Virgil I. "Gus" Grissom, and Roger B. Chaffee.

We couldn't believe the report! We were horrified! We were devastated! How could we have a fire in the Apollo Command Module during a test on the pad that killed three astronauts? Gus Grissom, Roger Chaffee, and Ed White died in that fire! Sure, we knew the moon mission was a risk! We worried about explosions during the launch. We were fearful of burning up during reentry. We were concerned about crashing into the moon, or leaving them on the moon for eternity. If the SPS engine, God forbid, did not fire for the full 247 seconds on lunar approach, they would spend eternity in a solar orbit. But to lose astronauts on the pad during a routine test seemed so remote that it never entered our minds. Perhaps, that was part of the problem, for maybe the test engineers were too complacent about precautions in that 100% oxygen environment. The roots of this problem lie in the early history of the Apollo program, so I'd like to go back to the beginning and put this in proper perspective.

The Manned Space Age

If you are 56 years old or older, you must remember the elation throughout the country that occurred on May 5, 1961 when Astronaut Alan Shepard was lofted 116 miles into space in the Mercury spacecraft *Freedom 7*. The flight was 15 minutes and 22 seconds long, achieved a velocity of 5,180 mph and the spacecraft was recovered some 303 miles down range. This was particularly heartening because 23 days earlier, the Russians had put Cosmonaut Yuri Gagarin into a single orbit around the Earth in Vostok 1. Most Americans had the impression that we had nearly caught up with the Russians in manned space. But it was truly an illusion. You see, Alan Shepard was launched by a Redstone Rocket, a short-range modified V-2 rocket, used by the Army in Europe. It had an operational range from 57.5 mi. to 201 mi., and was capable of carrying the 6,300 lb payload of a 3.5-megaton nuclear warhead. It weighed 61,207 lb and produced 78,000 lb of thrust for 121 seconds. The Mercury spacecraft weighed 2,986 lb and, hence, was able to achieve the extended range of over 300 miles.

Vostok 1 was launched with a 3-stage booster system with thrusts of 873,000 lb, 205,000 lb, and 12,250 lb. Vostok 1, a 10,480 lb spacecraft, achieved an elliptical orbit between 105 and 203 mi. Because the Vostok was 3.5 times as heavy as the Mercury and achieved a speed of 17,500 mph, it had 40+ times the energy of *Freedom 7*. No astronaut could be launched into orbit until the Atlas D (ICBM) became available.

Nevertheless, President John F. Kennedy, prodded by Wernher von Braun, addressed Congress on May 25, 1961 with his vision to put men on the moon and return them safely to Earth before the end of the decade. And so Congress and the American people embraced the race to the moon against the Russians. Never mind the fact that it took us 14 consecutive unmanned failures before we got close-up pictures of the lunar surface. Our first successful probe occurred on July 8, 1964 (over 3 years later). The Russian spacecraft, Luna 3, circled the moon on October 4, 1959, some 4 years and 9 months earlier. The Apollo Program was filled with political pressures to catch up and surpass the Russians.

On July 28, 1961, the Apollo contract was sent out for bid. Nine months earlier, Convair, GE, and Martin had won study contracts on the Apollo. The North American Aviation (NAA) Space Division's new president, Harrison "Stormy" Storms, decided to bid on the Apollo. The Division had just completed its bid on the Saturn S-II contract and was waiting with bated breath to find out whether we won it; otherwise, the Space Division would be shut down. Stormy was not about to let engineers sit idle while waiting for the Saturn S-II, so he put us to work on the Apollo bid. While the Saturn proposal totaled over 3,300 pages, fortunately, the Apollo technical section was limited to 150 pages (so we couldn't show our full depth of ignorance). On September 11, 1961 we won the Saturn S-II contract and logic told us there was no way we could also win the Apollo contract. After all, NAA had all the booster engines for the Saturn stack and the Saturn S-II. If we won it we would have, perhaps, 85-90% of the NASA space program.

Dr. Francis Hung, our Director of Dynamics, went back to the Orals with Stormy and came back saying we would win the Apollo. I bet him a cup of coffee that he was wrong. He said Stormy wowed them with his answers. When asked, "What is the most important challenge of the Apollo Program," Stormy said, "Gentlemen, technical management is your major challenge. That is why I selected John Paup as Program Manager." (Paup has a nation-wide reputation with the Air Force as a top Program Manager.) Then Stormy introduced Charlie Feltz as his Chief Engineer. He said, "Charlie was Chief Engineer on the X-15 Program. We never missed a schedule, a performance goal, and never overran costs." He said, "That is no accident! That is just damned good management." He then proceeded to tell how some of the teams are consortiums; joint efforts by a heat shield subcontractor, a structural subcontractor, an avionics subcontractor, and a propulsion subcontractor. Stormy said, "If you have a problem, there is going to be finger-pointing." He explained, "We are not in bed with anyone. We are free to select the best heat shield, propulsion, and avionic companies to support the structure we will design. If something goes wrong, there is a single ass to kick!" (or words to that effect).

It had been announced on November 27th, that the Martin Company had won the contract with a bid evaluation score of 6.9, versus 6.6 for NAA and GD, and 6.4 for GE and McDonnell. The next day, Stormy and Scott Crossfield met President Kennedy, and Kennedy awarded the Harmon Trophy to Scott for his flights on the X-15. Bob Seamans, Deputy to the NASA Administrator was at that meeting and told Stormy that afternoon, after the meeting, that we had won the Apollo! It was also stated that day that the bid was overturned at the highest level of the U.S. Government. NAA was selected on the basis of "experience, technical competence, and cost". We won the award on November 28, 1961.

The Use of Oxygen for Spacecraft Atmosphere

In the NAA original bid, a two-gas system was proposed-a combination of nitrogen and oxygen-just like we breathe on earth. NASA had strong objections because it required two tanks, separate regulators and some sort of sensing device to maintain the right mixture so astronauts would not pass out. We, led by Dr. Toby Freeman, argued vehemently against NASA's Max Faget. NASA told us the decision was final: pure oxygen. Charlie Frick, NASA Apollo Program Spacecraft Officer, told NAA, "You are the Contractor. You'll do as you're damned told, period". Stormy told Robert Gilruth, head of the Space Task Group, he would not use pure oxygen without a written order. Contract Change Notice #1 was issued by NASA for a cabin of 100% pure oxygen at 5 psi pressure.

The Command Module (CM) consisted of two concentric honeycomb sandwich structures. The inner structure used a welded aluminum pressure vessel as an inner face sheet, to which honeycomb and outer aluminum face sheets were adhesively bonded. The outer shell was a brazed stainless steel honeycomb to which an open-cell fiberglass honeycomb was bonded and filled with heat-resisting ablative. There was a hatch for each shell. The inner hatch sealed the pressure within and the outer hatch kept the reentry heat out.

NAA proposed an explosively operated escape hatch which would allow a fast emergency exit. On July 10, 1962, Max Faget and a contingency of NASA engineers and astronauts arrived at Downey to discuss the hatch. NAA argued that hundreds of explosively actuated escape systems were used by pilots, without a mishap, saving their lives. Max Faget opposed it, fearful that it could open on the way to the moon. Gus Grissom, who almost drowned in his Mercury spacecraft, opposed it because he said the McDonnell explosive hatch "just blew" as it hit the water. Again, NASA directed NAA, in writing, to have an inward opening, simple hatch without an explosive charge to allow for an emergency exit. It was to be a plug-type square hatch sealed by internal pressure. The exit time through this two-hatch system was 90 seconds. Ironically enough, both of these decisions sealed Gus Grissom's fate on January 27, 1967. These, of course, were not the only design features or test requirements which caused the Apollo oxygen-fire disaster. But the seeds were sown 4-1/2 years before the fire.

NAA wanted a fire suppression system installed, i.e., flooding the spacecraft with nitrogen. One of the counter arguments was that they could depressurize the cabin and get rid of the oxygen into empty space during a fire. Another request from NAA, I was told, was to study "the technology of an oxygen fire". We were turned down.

Another important design weakness was the joining method for aluminum tubes-soldered joints. Aluminum tubes were used to join the aluminum heat exchanger, aluminum coldplates, and various other connections to the Environmental Control Unit (ECU). We found that aluminum tubes with 0.020" walls could not be properly welded; often the molten bead would block the inside fluid passage. B-nuts, which depended on flaring tube ends, were very heavy and had a high leakage rate; however, a few were used to aid in equipment removal. Aluminum could not be brazed because of the highly corrosive fluxes needed to destroy its tenacious oxide film. So we soldered the joints. The ends of the tubes were plated with tin. Tin-lead resin-core solder, placed in grooves in the union was heated (by induction) to finish the joining process. The solder was sufficiently strong at the maximum internal surface temperature permitted in the Command Module, 190°F, but much above 200°F, the joints would creep under load, such as by tightening a nearby B-nut. Though technically within specification, these joints could not survive an oxygen fire. Soldered tubes carried flammable ethylene glycol and both 100 psi and 900 psi oxygen.

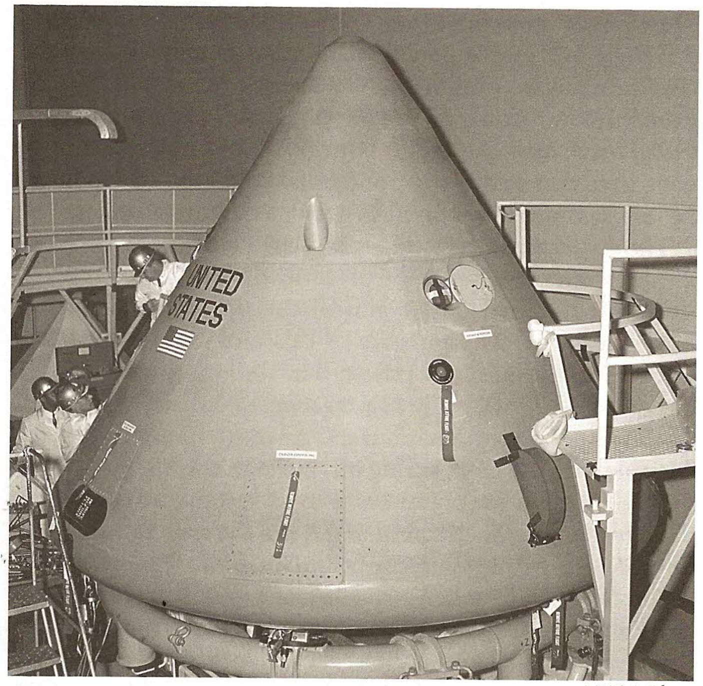
The Program Was Slow to Mature

In the early 1960s, NASA programs were in a state of flux. On December 22, 1961, a month after the Apollo 3-man spacecraft award, McDonnell was awarded a go-ahead to define a two-man spacecraft, a redesigned Mercury, called "Gemini". This was 2 months before the first manned orbit by the Mercury (John Glenn-3 orbits on February 22, 1961). With three different spacecraft programs underway, there was still no manned Spacecraft Center in Houston until September 1963 to house NASA's manned spacecraft personnel. NASA realized that they needed the Gemini to demonstrate that men could survive two weeks in space, that they could rendezvous and dock in space, and to prove the lifting body reentry concept (versus the ballistic missile concept of the Mercury).

Concurrent with this, NASA had still not settled on a trajectory concept, which was crucial in defining the size of the booster. If they used a "direct ascent" with the Apollo being launched to the moon, landing on the moon, and returning to the Earth, a booster of 12,000,000 lb of thrust (Nova) would be required! A second concept was called "Earth Orbit Rendezvous" in which rockets were orbited and assembled in orbit for a lunar shot. A third concept, "Lunar Orbit Rendezvous" favored a Lunar Module (LM), which would mate with the Apollo CSM, depart for the moon and return to the Apollo Command Module, then be left in the lunar vicinity. It turned out this concept was much lighter and would permit a first stage of the Saturn V rocket to have 7,500,000 lb of thrust. On September 12, 1962, Grumman was chosen to design and build the Lunar Module. So 10 months after the Apollo contract award we had sufficient definition to build the Command Module, Service Module and LM Adapter (to house the LM). The Apollo designs that were underway and being built were called "Block I" Command Modules versus a redesigned version with a removable docking probe, called "Block II" Command Modules.

Early Design and Manufacturing Activities

The early days of the Apollo Program were chaotic. We were bringing in 1,000 people per month for two years to work on the program. Our Quality Control took 1-1/2 years to certify welding machines because they demanded greater strength than the welds needed and far above our design allowables. Bob Olsen, my boss, presented to the Chief Engineer, Charlie Feltz, an M&P Charter explaining in detail the areas in which we would assume responsibility, to include materials and processes and their testing, specifications, design allowables, failure analyses, drawing reviews and approvals, and responsibility for specific hardware, such as pressure vessels, honeycomb sandwiches, fasteners, cold plates, plumbing, and for technologies such as corrosion control, metallurgy, etc. For example, when honeycomb sandwich panels became "debonded", Olsen was in charge of a tiger team to find out what went wrong and correct



NASA Photo

High angle view of the Block I Apollo Command Module 012 during pre-shipping operations in south air lock of Systems Integration and Checkout Facility.

it. He acquired the name "Sticky Olsen" for his efforts and the name "Sticky" stuck throughout his career. As M&P, we had a great responsibility for the kinds of plastic materials which were chosen for use in the cabin design.

In 1965, General Samuel C. Phillips, Apollo Program Director, sent a "Tiger Team" to find out why we were missing costs and schedules and wrote a very damning report to Lee Atwood, NAA's Chairman of the Board. (General Phillips' job was to terrorize contractors to make them respond.) He was not the least bit interested in the progress of the hardware, but rather focused on the paperwork supporting the schedules and costs. The added pressure was very difficult to sustain. We had a program called PERT on the mainframe computer to track 30,000 critical parts. Every two weeks, it would spit out 40 boxes of printouts, but nobody had the time to look at them. Further, as the program matured, over a thousand changes were made each year by NASA and by our own engineers, impacting manufacturing schedules. Every time we got way behind, we had put out a new Master Development Schedule. Based on Phillips' strong input, we decided that Master Development Schedule #9 was the last one we would issue. On a return visit in 6 months, General Phillips claimed we made very good progress (of course, we then had Master Development Schedule 9, Rev. 1, Rev 2, ...). What was interesting in the post-fire meeting with Congress, neither General Phillips' boss, George Mueller, nor had the Chief NASA Administrator, James Webb, heard of the General Phillips report on NAA. They assured Congress that he never wrote a complimentary report on any contractor.

Command Module 12 (Block I) was to be used for the first manned flight planned for February 21, 1967, and was sent to the Cape on August 26, 1966. It finally appeared we were on schedule with our major engineering problems well behind us. We were elated.

"Fire in the Spacecraft"

A high level meeting was held in early January 1967 to discuss the many last-minute Apollo changes and to request additional time to incorporate the 653 engineering orders after CM 12 delivery. Although both NAA and NASA Houston concurred that a delay was needed to finalize testing readiness, NASA Washington refused to grant schedule relief.

The spacecraft successfully completed altitude tests. Next, a "plugs-out" test was to be performed. The spacecraft was shifted to internal power and disconnected from external power sources. The purpose of this test was to insure the integrity of the on-board power. The test was run with 100% oxygen at 16.7 psi. Wally Schirra suggested that Dr. Joe Shea, NASA's Apollo Program Manager, get inside of the Command Module with the crew, sitting on the floor next to Gus's couch and go through the countdown to gain some perspective of what it was like. Shea agreed and asked the test crew to install an additional communication line for him. The test crews reported the next morning that this would require leaving the hatches open, compromising the test. (Ironically, the last test of the "plugs out" test sequence was an "emergency egress" from the Command Module.)

The crew entered the cabin in their space suits with their environmental control system oxygen loop at 1 P.M. EST. They spent time in "holds" trying to check out a "sour buttermilk" smell in the suit loops (later determined not to be fire related), and had communication difficulties. By 6:20 P.M. EST, all countdown functions up to the transfer to simulated fuel cell power were completed and they began a 10-minute hold to trouble shoot routine communications problems. During this period, the following occurred:

6:30:39.4 – significant movement of an astronaut (Gissom).
6:30:54.8 – significant voltage surge in #2 bus.
6:31:04.7 – first verbal indication of a fire in the Command Module.

Under these circumstances, the senior pilot, White, is to initiate emergency egress procedures involving the inner hatch and considerable activity was picked up by sensors.

The astronauts sustained second and third degree burns, but were overcome by the toxic gases. Very soon after the reports of the fire, some technicians left to get fire extinguishers and masks. The hatches were so hot that technicians could not get them opened for about 5 minutes. The astronauts were probably unconscious at that time from a lack of oxygen to the brain and heart. (When they died is uncertain.) It took 7 hours to extricate their bodies. The astronauts were literally glued to the seats, the floor, and each other due to the melted nylon and its subsequent solidification. Had they been rescued within 5 minutes after the fire, they may have survived. Ironically, the treatment would be to put them into an oxygen mask.

After the astronauts were removed, a critical step was to have another astronaut verify the position of all of the switches. To do so, from a safety standpoint at this time, required removal of the Launch Escape Tower and disabling existing pyrotechnics in the Command/Service Module (CSM) system. Soon after this, fire experts could be sent into the Command Module to try to locate the fire origin and the direction it burned.

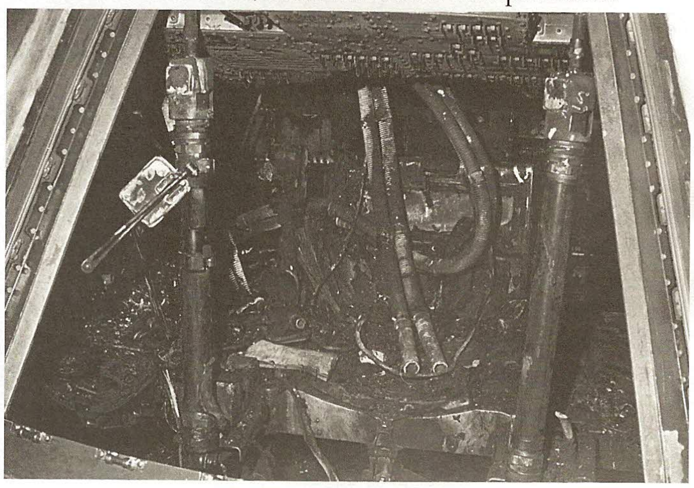
The Apollo 204 Review Board

Shortly after the fire occurred, NASA and NAA formed 17 four-man teams, consisting of a representative from NAA, MSC, MSFC, and NAA KSC to investigate various specific subjects related to the fire. While the fire started at 3:31:04 P.M. Pacific Standard Time on Friday, those of us assigned to a team flew into Melbourne, Florida, on Saturday morning. I was assigned as Chairman of "Team 10, Analysis of the Fracture Areas". On Sunday, Bud Benner, NAA Assistant Chief Engineer, held a caucus at the Holiday Inn and we all shared our information, tasks, and approaches.

Floyd Thompson of NASA (Director of NASA Langley) was in charge of the "Apollo 204 Review Board". Our teams turned into "Panels" and the number of Panels rose to 21 and a few additional people were added. Dr. Thompson assigned a board member to each Panel who would sign off on Panel requests. He issued a new Administrative Procedure nearly every day for three weeks, providing details on how to get everything done, such as test requests, By February 1, each Panel had to define the scope of their tasks, the tests that they wanted to run, estimated a cost for each task, and provide the schedules that they would meet, including reports. Panel Chairmen were reshuffled until the Chairmen only came from NASA MSC (Houston) and KSC. There were no Panel Chairmen from MSFC (Huntsville) or from NAA. Eventually, the Apollo 204 Review Board recognized that system engineers would be required to check out each piece of equipment and outside experts were also called in. Finally some 1,500 people were directly involved in the investigation. However, the final report of each Panel constituted the backbone for the Final Apollo 204 Review Board Report, which some sources say exceeded 3,300 pages. It is now available on the internet!

Origin and Propagation of the Fire

Panel 5 determined the fire went in 3 stages. The initiation stage occurred at 6:31:04.7 on the left side of the Command Module near or under the ECU, not far from Grissom's feet. The fire continued until 6:31:19.4 when the Command Module blew apart by internal gas pressure. The next 5 seconds resulted in the gases and flames rushing out of the Command Module through the crack on the lower right side where the sidewall joins the floor. This was followed by the final stage in which the fire decayed and carbon monoxide, smoke and soot were produced.



NASA Photo

This view of the interior of CM-012 shows the effects of the intense heat of the flash fire.

My Investigation

The Apollo was at Pad 34 on top of an unfueled Saturn IB and Saturn S-IV rocket. To get to the Command Module-012, one had to ride the elevator in the umbilical tower to a platform some 200 feet in the air, walk the 30-40 ft length of a 3-ft wide gangplank to enter an enclosed room with a floor surrounding the Command Module. The gangplank was open to stiff breezes and each side had guide rail posts, consisting of tubes connected with loose chains, dangling like catenaries, to join them. I was petrified when walking on this gangplank. It was like walking on a board across the street between the 20th floors of two skyscrapers. Once inside, however, I felt I was in a safe room.

On my initial visit, I put my head in the hatch and told the two inspectors inside what my interest was. The two inspectors inside, T. Horeff (FAA) and J. Leak (CAB) were trying to trace the fire ignition and direction. The inside of the cabin was badly sooted. They asked me if I knew what the various equipment and materials were, and I said, "I can identify some of them." "What is this tank?" they asked. I said, "That is the 900 psi oxygen pressure vessel made of Inconel 718 and quoted its strength and melting point. They pointed to a hand controller which had a corner knocked off of it. I said, "That is a hand controller, I don't know which one it is (rotational or translational), but it is made of 6061-T6 aluminum. They asked why the corner broke off. After looking at it, I said, "This alloy is prone to cracking in the 950-1,150°F range under thermal or mechanical stress." One of them then said, "Get your ass in here! I want you to map the temperature of everything in the Command Module." I was grateful, for I realized that the Command Module could accommodate only a few people on a need-to-know basis, and I was able to enter it every day and catalogue my findings.

One of the first things I requested from Panel 8 was a literature search on oxygen fires. Almost immediately, we learned of a fire in a 100% oxygen chamber which occurred on January 31 (4 days after the Apollo fire) at Brooks Air Force Base in San Antonio, killing Airmen William Bartley and Airman Richard Harmon. (They were in the process of drawing blood samples from rabbits when the disaster occurred.) Unknown to us at the time, Soviet Cosmonaut Valentin Bondarenko died in March 1961 in a fire in an oxygen chamber.

Shortly after this, I was given a film made by the Canadian Air Force about 100% oxygen fires. I showed it to Frank Borman who was the Astronaut representative investigating the fire. A dead pig was dressed in a flight uniform with an igniter placed at the bottom of one pant leg. High-speed photography was used. (I don't recall the oxygen pressure.) Within 2 seconds the uniform was turned to dust. The fire was like a flashbulb going off. Each fiber sticking up on the uniform surface instantaneously caught fire and a million ignition sites burned toward each other (similar to singeing the hair on your arm while charcoal grilling).

In the second test, the suit was borated to make it fireproof. This was even worse, for a two-foot tongue of flame leapt out each arm sleeve, each pant leg, and out of the neck of the suit. The hair on its body burned, eventually catching its skin on fire. Frank seemed unimpressed and was particularly annoyed that they put a pig into a flight suit.

Obviously, Mercury and Gemini successes with 100% oxygen gave them false confidence. After this fire, Deke Slayton claimed that "they had been lucky (up to this time) for they used the same oxygen procedures for the 16 Mercury and Gemini manned vehicles." It should be noted this particular Command Module had survived greater than 14.7 psi pure oxygen atmosphere for a total time of 6 hours and 15 minutes in four previous KSC altitude chamber tests.

Over the next week I gathered information about the temperatures of everything in the Command Module including melted wires, melted stainless steel, melted aluminum, and melted plastics. I also recorded evidence of mechanical damage to everything visible, including knobs.

While it would take too long to describe all the findings, I found melted 1/8-in. diameter stainless steel tubes (~2,600°F) below the gas chromatograph of the ECU. I also found gas chromatograph wires and wire bundles under the ECU where copper melted, but the outer coating of nickel stayed intact (1,980-2,650°F). I found at least 16 areas with melted aluminum (above ~1,200°F) and two areas of overheated, cracked aluminum (950-1,150°F). There were soldered fittings parted and even melting of aluminum tubes in the ECU water, ethylene glycol, 100 and 900 psi oxygen lines running under the ECU. The inside of the Command Module looked like someone had used a blow torch, with some areas totally destroyed while adjacent areas were essentially unscathed. Perhaps, it was caused by a torch effect of 900 psi or 100 psi oxygen lines and squirting of ethylene glycol throughout the cabin. It is of interest to note that nine months before the fire, on April 28, 1966, AiResearch had a fire destroying an ECU during a test in 100% oxygen at 5 psi pressure.

Equipment Removal and Inspection

It was decided that all equipment within the Command Module would be removed, examined and tested. Command Module 14 was sent to the Cape to use for practice on disassembly of the equipment. Procedures were written and pictures were used to document all steps of the removal process. Some 600 pieces were removed, inspected, continuity checked, tested, and disassembled. I looked at every piece of equipment and I am not aware of problems with anything except the ECU.

Newspapers

The media was so anxious to have news of what we found that they created it. My first week was spent in cataloging temperatures and mechanical damage to parts in the Apollo Command Module, The Material Panel (Panel 8) was busy identifying materials and writing test programs, another panel was writing procedures for equipment removal, etc. Thus, for two weeks the local press got no news. Every day I would read in the paper of some major discoveries, all of which were the products of creative writing. If there was no news, the media simply made some up!

Findings

There were 2,528 products identified in the Command Module that were potentially combustible: oils, foams, fabrics, Velcro, elastomers, paints, laminate, etc. An additional 75 materials were brought into the cabin after delivery of the Command Module to KSC. These potentially combustible materials weighed about 72.5 lb of which 17.2 lb were government furnished (garments, visors, etc.).