

= Apollo 1 =

Apollo 1 , initially designated AS @-@ 204 , was the first manned mission of the United States Apollo program , which had as its ultimate goal a manned lunar landing . The low Earth orbital test of the Apollo Command / Service Module never made its target launch date of February 21 , 1967 . A cabin fire during a launch rehearsal test on January 27 at Cape Kennedy Air Force Station Launch Complex 34 killed all three crew members ? Command Pilot Virgil I. " Gus " Grissom , Senior Pilot Edward H. White II , and Pilot Roger B. Chaffee ? and destroyed the Command Module ( CM ) . The name Apollo 1 , chosen by the crew , was officially retired by NASA in commemoration of them on April 24 , 1967 .

Immediately after the fire , NASA convened the Apollo 204 Accident Review Board to determine the cause of the fire , and both houses of the United States Congress conducted their own committee inquiries to oversee NASA 's investigation . The ignition source of the fire was determined to be electrical , and the fire spread rapidly due to combustible nylon material , and the high pressure , pure oxygen cabin atmosphere . The astronauts ' rescue was prevented by the plug door hatch , which could not be opened against the higher internal pressure of the cabin . A failure to identify the test as hazardous , based on the fact that the rocket was unfueled , led to the rescue being hampered by poor emergency preparedness .

During the Congressional investigation , then @-@ Senator Walter Mondale publicly revealed a NASA internal document citing problems with prime Apollo contractor North American Aviation , which became known as the " Phillips Report " . This disclosure embarrassed NASA Administrator James E. Webb , who was unaware of the document 's existence , and attracted controversy to the Apollo program . Despite congressional displeasure at NASA 's lack of openness , both congressional committees ruled that the issues raised in the report had no bearing on the accident .

Manned Apollo flights were suspended for 20 months while the Command Module 's hazards were addressed . However , the development and unmanned testing of the Lunar Module ( LM ) and Saturn V Moon rocket continued . The Saturn IB launch vehicle for Apollo 1 , AS @-@ 204 , was used for the first LM test flight , Apollo 5 . The first successful manned Apollo mission was flown by Apollo 1 's backup crew on Apollo 7 in October 1968 .

= = Crew = =

= = = First backup crew ( April ? December 1966 ) = = =

= = = Second backup crew ( December 1966 ? January 1967 ) = = =

= = Apollo manned test flight plans = =

AS @-@ 204 was to be the first manned test flight of the Apollo Command / Service Module ( CSM ) to Earth orbit , launched on a Saturn IB rocket . AS @-@ 204 was to test launch operations , ground tracking and control facilities and the performance of the Apollo @-@ Saturn launch assembly and would have lasted up to two weeks , depending on how the spacecraft performed .

The CSM for this flight , number 012 built by North American Aviation ( NAA ) , was a Block I version designed before the lunar orbit rendezvous landing strategy was chosen ; therefore it lacked capability of docking with the Lunar Module . This was incorporated into the Block II CSM design , along with lessons learned in Block I. Block II would be test @-@ flown with the LM when the latter was ready , and would be used on the Moon landing flights .

Deke Slayton , the Mercury astronaut who was grounded and became Director of Flight Crew Operations , selected the first Apollo crew in January 1966 , with Grissom as Command Pilot , White as Senior Pilot , and rookie Donn F. Eisele as Pilot . But Eisele dislocated his shoulder twice aboard

the KC135 weightlessness training aircraft , and had to undergo surgery on January 27 . Slayton replaced him with Chaffee , and NASA announced the crew selection on March 21 , 1966 . James McDivitt , David Scott and Russell Schweickart were named as the backup crew .

On September 29 , Walter Schirra , Eisele , and Walter Cunningham were named as the prime crew for a second Block I CSM flight , AS @-@ 205 . NASA planned to follow this with an unmanned test flight of the LM ( AS @-@ 206 ) , then the third manned mission would be a dual flight designated AS @-@ 278 ( or AS @-@ 207 / 208 ) , in which AS @-@ 207 would launch the first manned Block II CSM , which would then rendezvous and dock with the LM launched unmanned on AS @-@ 208 .

In March , NASA was studying the possibility of flying the first Apollo mission as a joint space rendezvous with the final Project Gemini mission , Gemini 12 in November 1966 . But by May , delays in making Apollo ready for flight just by itself , and the extra time needed to incorporate compatibility with the Gemini , made that impractical . This became moot when slippage in readiness of the AS @-@ 204 spacecraft caused the last @-@ quarter 1966 target date to be missed , and the mission was rescheduled for February 21 , 1967 .

= = Mission background = =

Grissom declared his intent to keep his craft in orbit for a full 14 days . A newspaper article published on August 4 , 1966 , referred to the flight as " Apollo 1 " . CM @-@ 012 arrived at the Kennedy Space Center on August 26 , labeled Apollo One by NAA on its packaging .

In October 1966 , NASA announced the flight would carry a small television camera to broadcast live from the Command Module . The camera would also be used to allow flight controllers to monitor the spacecraft 's instrument panel in flight . Television cameras were carried aboard all manned Apollo missions .

= = = Insignia = = =

Grissom 's crew received approval in June 1966 to design a mission patch with the name Apollo 1 . The design 's center depicts a Command / Service Module flying over the southeastern United States with Florida ( the launch point ) prominent . The Moon is seen in the distance , symbolic of the eventual program goal . A yellow border carries the mission and astronaut names with another border set with stars and stripes , trimmed in gold . The insignia was designed by the crew , with the artwork done by North American Aviation employee Allen Stevens .

= = = Spacecraft preparation = = =

The Apollo Command / Service Module was much bigger and far more complex than any previously implemented spacecraft design . In October 1963 , Joseph F. Shea was named Apollo Spacecraft Program Office ( ASPO ) manager , responsible for managing the design and construction of both the CSM and the LM . In a spacecraft review meeting held with Shea on August 19 , 1966 ( a week before delivery ) , the crew expressed concern about the amount of flammable material ( mainly nylon netting and Velcro ) in the cabin , which both astronauts and technicians found convenient for holding tools and equipment in place . Though Shea gave the spacecraft a passing grade , after the meeting they gave him a crew portrait they had posed with heads bowed and hands clasped in prayer , with the inscription :

It isn 't that we don 't trust you , Joe , but this time we 've decided to go over your head .

Shea gave his staff orders to tell North American to remove the flammables from the cabin , but did not supervise the issue personally .

North American shipped spacecraft CM @-@ 012 to Kennedy Space Center on August 26 , 1966 under a conditional Certificate of Flight Worthiness : 113 significant incomplete planned engineering changes had to be completed at KSC . But that was not all ; an additional 623 engineering change orders were made and completed after delivery . Grissom became so frustrated with the inability of

the training simulator engineers to keep up with the spacecraft changes , that he took a lemon from a tree by his house and hung it on the simulator .

The Command and Service Modules were mated in the KSC altitude chamber in September , and combined system testing was performed . Altitude testing was performed first unmanned , then with both the prime and backup crews , from October 10 through December 30 . During this testing , the Environmental Control Unit in the Command Module was found to have a design flaw , and was sent back to the manufacturer for design changes and rework . The returned ECU then leaked water / glycol coolant , and had to be returned a second time . Also during this time , a propellant tank in Service Module 017 had ruptured during testing at NAA , prompting the separation of the modules and removal from the chamber so the Service Module could be tested for signs of the tank problem . These tests were negative .

In December , the second Block I flight AS @-@ 205 was canceled as unnecessary ; and Schirra , Eisele and Cunningham were reassigned as the backup crew for Apollo 1 . McDivitt 's crew was now promoted to prime crew of the Block II / LM mission , re @-@ designated AS @-@ 258 because the AS @-@ 205 launch vehicle would be used in place of AS @-@ 207 . A third manned mission was planned to launch the CSM and LM together on a Saturn V ( AS @-@ 503 ) to an elliptical medium Earth orbit ( MEO ) , to be crewed by Frank Borman , Michael Collins and William Anders . McDivitt , Scott and Schweickart had started their training for AS @-@ 258 in CM @-@ 101 at the NAA plant in Downey , California , when the Apollo 1 accident occurred .

Once all outstanding CSM @-@ 012 hardware problems were fixed , the reassembled spacecraft finally completed a successful altitude chamber test with Schirra 's backup crew on December 30 . According to the final report of the accident investigation board , " At the post @-@ test debriefing the backup flight crew expressed their satisfaction with the condition and performance of the spacecraft . " This would appear to contradict the account given in *Lost Moon : The Perilous Voyage of Apollo 13* by Jeffrey Kluger and astronaut James Lovell , that " When the trio climbed out of the ship , ? Schirra made it clear that he was not pleased with what he had seen , " and that he later warned Grissom and Shea that " 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 , " and that Grissom should get out at the first sign of trouble .

Following the successful altitude tests , the spacecraft was removed from the altitude chamber on January 3 , 1967 , and mated to its Saturn IB launch vehicle on pad 34 on January 6 .

You sort of have to put that out of your mind . There 's always a possibility that you can have a catastrophic failure , of course ; this can happen on any flight ; it can happen on the last one as well as the first one . So , you just plan as best you can to take care of all these eventualities , and you get a well @-@ trained crew and you go fly .

= = Accident = =

= = = Plugs @-@ out test = = =

The launch simulation on January 27 , 1967 , on pad 34 , was a " plugs @-@ out " test to determine whether the spacecraft would operate nominally on ( simulated ) internal power while detached from all cables and umbilicals . Passing this test was essential to making the February 21 launch date . The test was considered non @-@ hazardous because neither the launch vehicle nor the spacecraft was loaded with fuel or cryogenics , and all pyrotechnic systems were disabled .

At 1 : 00 pm EST ( 1800 GMT ) on January 27 , first Grissom , then Chaffee , and White entered the Command Module fully pressure @-@ suited , and were strapped into their seats and hooked up to the spacecraft 's oxygen and communication systems . Grissom immediately noticed a strange odor in the air circulating through his suit which he compared to " sour buttermilk " , and the simulated countdown was held at 1 : 20 pm , while air samples were taken . No cause of the odor could be found , and the countdown was resumed at 2 : 42 pm . The accident investigation found this odor not to be related to the fire .

Three minutes after the count was resumed , the hatch installation was started . The hatch consisted of three parts : a removable inner hatch , which stayed inside the cabin ; a hinged outer hatch , which was part of the spacecraft 's heat shield ; and an outer hatch cover , which was part of the boost protective cover enveloping the entire Command Module to protect it from aerodynamic heating during launch , and from launch escape rocket exhaust in the event of a launch abort . The boost hatch cover was partially , but not fully , latched in place because the flexible boost protective cover was slightly distorted by some cabling run under it to provide the simulated internal power . ( The spacecraft 's fuel cell reactants were not loaded for this test . ) After the hatches were sealed , the air in the cabin was replaced with pure oxygen at 16 @. @ 7 psi ( 115 kPa ) , 2 psi ( 14 kPa ) higher than atmospheric pressure .

Movement by the astronauts was detected by the spacecraft 's inertial measurement unit and the astronaut 's biomedical sensors , and also indicated by increases in oxygen spacesuit flow , and sounds from Grissom 's stuck @- @ open microphone . There was no evidence to identify the movement , or whether it was related to the fire . The stuck microphone was part of a problem with the communications loop connecting the crew , the Operations and Checkout Building , and the Complex 34 blockhouse control room . The poor communications led Grissom to remark : " How are we going to get to the Moon if we can 't talk between two or three buildings ? " The simulated countdown was held again at 5 : 40 pm while attempts were made to troubleshoot the communications problem . All countdown functions up to the simulated internal power transfer had been successfully completed by 6 : 20 pm , but at 6 : 30 the count remained on hold at T minus 10 minutes .

= = = Fire = = =

The crew members were using the time to run through their checklist again , when a momentary increase in AC Bus 2 voltage occurred . Nine seconds later ( at 6 : 31 : 04 @. @ 7 ) , one of the astronauts ( some listeners and laboratory analysis indicate Grissom ) exclaimed " Hey ! " or " Fire ! " ; this was followed by two seconds of scuffling sounds through Grissom 's open microphone . This was immediately followed at 6 : 31 : 06 @. @ 2 ( 23 : 31 : 06 @. @ 2 GMT ) by someone ( believed by most listeners , and supported by laboratory analysis , to be Chaffee ) saying , " [ I 've , or We 've ] got a fire in the cockpit . " After 6 @. @ 8 seconds of silence , a second , badly garbled transmission occurred , interpreted by various listeners as :

" They 're fighting a bad fire ? Let 's get out .... Open ' er up "

" We 've got a bad fire ? Let 's get out .... We 're burning up " , or

" I 'm reporting a bad fire .... I 'm getting out .... " .

This transmission , believed by some listeners to be White , lasted 5 @. @ 0 seconds and ended with a cry of pain .

Some blockhouse witnesses said that they saw White on the television monitors , reaching for the inner hatch release handle as flames in the cabin spread from left to right .

The intensity of the fire fed by pure oxygen caused the pressure to rise to 29 psi ( 200 kPa ) , which ruptured the Command Module 's inner wall at 6 : 31 : 19 ( 23 : 31 : 19 GMT , initial phase of the fire ) . Flames and gases then rushed outside the Command Module through open access panels to two levels of the pad service structure . Intense heat , dense smoke , and ineffective gas masks designed for toxic fumes rather than heavy smoke hampered the ground crew 's attempts to rescue the men . There were fears the Command Module had exploded , or soon would , and that the fire might ignite the solid fuel rocket in the launch escape tower above the Command Module , which would have likely killed nearby ground personnel , and possibly have destroyed the pad .

As the pressure was released by the cabin rupture , the convective rush of air caused the flames to spread across the cabin , beginning the second phase . The third phase began when most of the oxygen was consumed and was replaced with atmospheric air , essentially quenching the fire , but causing high concentrations of carbon monoxide and heavy smoke to fill the cabin , and large amounts of soot to be deposited on surfaces as they cooled .

It took five minutes for the pad workers to open all three hatch layers , and they could not drop the

inner hatch to the cabin floor as intended , so they pushed it out of the way to one side . Although the cabin lights remained lit , they were at first unable to find the astronauts through the dense smoke . As the smoke cleared , they found the bodies , but were not able to remove them . The fire had partly melted Grissom 's and White 's nylon space suits and the hoses connecting them to the life support system . Grissom had removed his restraints and was lying on the floor of the spacecraft . White 's restraints were burned through , and he was found lying sideways just below the hatch . It was determined that he had tried to open the hatch per the emergency procedure , but was not able to do so against the internal pressure . Chaffee was found strapped into his right @-@ hand seat , as procedure called for him to maintain communication until White opened the hatch . Because of the large strands of melted nylon fusing the astronauts to the cabin interior , removing the bodies took nearly 90 minutes .

= = Investigation = =

As a result of the in @-@ flight failure of the Gemini 8 mission on March 17 , 1966 , NASA Deputy Administrator Robert Seamans wrote and implemented Management Instruction 8621 @.@ 1 on April 14 , 1966 , defining Mission Failure Investigation Policy And Procedures . This modified NASA 's existing accident procedures , based on military aircraft accident investigation , by giving the Deputy Administrator the option of performing independent investigations of major failures , beyond those for which the various Program Office officials were normally responsible . It declared , " It is NASA policy to investigate and document the causes of all major mission failures which occur in the conduct of its space and aeronautical activities and to take appropriate corrective actions as a result of the findings and recommendations . "

Immediately after the Apollo 1 fire , to avoid appearance of a conflict of interest , NASA Administrator James E. Webb asked President Lyndon B. Johnson to allow NASA to handle the investigation according to its established procedure , promising to be truthful in assessing blame , and to keep the appropriate leaders of Congress informed . Seamans then directed establishment of the Apollo 204 Review Board chaired by Langley Research Center director Floyd L. Thompson , which included astronaut Frank Borman , spacecraft designer Maxime Faget , and six others . On February 1 , Cornell University professor Frank A. Long left the board , and was replaced by Dr. Robert W. Van Dolah , of the U.S. Bureau of Mines . The next day , North American 's Chief engineer for Apollo , George Jeffs , also left .

Seamans immediately ordered all Apollo 1 hardware and software impounded , to be released only under control of the board . After thorough stereo photographic documentation of the CM @-@ 012 interior , the board ordered its disassembly using procedures tested by disassembling the identical CM @-@ 014 , and conducted a thorough investigation of every part . The board also reviewed the astronauts ' autopsy results and interviewed witnesses . Seamans sent Webb weekly status reports of the investigation 's progress , and the board issued its final report on April 5 , 1967 .

= = = Cause of death = = =

According to the Board , Grissom suffered severe third degree burns on over one @-@ third of his body and his spacesuit was mostly destroyed . White suffered third degree burns on almost half of his body and a quarter of his spacesuit had melted away . Chaffee suffered third degree burns over almost a quarter of his body and a small portion of his spacesuit was damaged . The autopsy report confirmed that the primary cause of death for all three astronauts was cardiac arrest caused by high concentrations of carbon monoxide . Burns suffered by the crew were not believed to be major factors , and it was concluded that most of them had occurred postmortem . Asphyxiation happened after the fire melted the astronauts ' suits and oxygen tubes , exposing them to the lethal atmosphere of the cabin .

= = = Major causes of accident = = =

The review board identified several major factors which combined to cause the fire and the astronauts' deaths :

An ignition source most probably related to " vulnerable wiring carrying spacecraft power " and " vulnerable plumbing carrying a combustible and corrosive coolant "

A pure oxygen atmosphere at higher than atmospheric pressure

A cabin sealed with a hatch cover which could not be quickly removed at high pressure

An extensive distribution of combustible materials in the cabin

Inadequate emergency preparedness ( rescue or medical assistance , and crew escape )

===== Ignition source =====

The review board determined that the electrical power momentarily failed at 23 : 30 : 55 GMT , and found evidence of several electric arcs in the interior equipment . However , they were unable to conclusively identify a single ignition source . They determined that the fire most likely started near the floor in the lower left section of the cabin , close to the Environmental Control Unit . It spread from the left wall of the cabin to the right , with the floor being affected only briefly .

The board noted that a silver @-@ plated copper wire running through an environmental control unit near the center couch had become stripped of its Teflon insulation and abraded by repeated opening and closing of a small access door .

This weak point in the wiring also ran near a junction in an ethylene glycol / water cooling line that had been prone to leaks . The electrolysis of ethylene glycol solution with the silver anode was discovered at MSC on May 29 , 1967 to be a hazard capable of causing a violent exothermic reaction , igniting the ethylene glycol mixture in the CM 's pure oxygen atmosphere . Experiments at the Illinois Institute of Technology confirmed the hazard existed for silver @-@ plated wires , but not for copper @-@ only or nickel @-@ plated copper . In July , ASPO directed both North American and Grumman to ensure no silver or silver @-@ coated electrical contacts existed in the vicinity of possible glycol spills in the Apollo spacecraft .

===== Pure oxygen atmosphere =====

The plugs @-@ out test had been run to simulate the launch procedure , with the cabin pressurized with pure oxygen at the nominal launch level of 16 @. 7 psi ( 115 kPa ) , 2 psi ( 14 kPa ) above standard sea level atmospheric pressure . This is more than five times the 3 psi ( 21 kPa ) partial pressure of oxygen in the atmosphere , and provides an environment in which materials not normally considered highly flammable will burst into flame .

The high @-@ pressure oxygen atmosphere was consistent with that used in the Mercury and Gemini programs . The pressure before launch was deliberately greater than ambient in order to drive out the nitrogen @-@ containing air and replace it with pure oxygen , and also to seal the plug door hatch cover . During launch , the pressure would have been gradually reduced to the in @-@ flight level of 5 psi ( 34 kPa ) , providing sufficient oxygen for the astronauts to breathe while reducing the fire risk . The Apollo 1 crew had tested this procedure with their spacecraft in the Operations and Checkout Building altitude ( vacuum ) chamber on October 18 and 19 , 1966 , and the backup crew of Schirra , Eisele and Cunningham had repeated it on December 30 . The investigation board noted that , during these tests , the Command Module had been fully pressurized with pure oxygen four times , for a total of six hours and fifteen minutes , two and a half hours longer than it had been during the plugs @-@ out test .

===== Flammable materials in the cabin =====

The review board cited " many types and classes of combustible material " close to ignition sources . The NASA crew systems department had installed 34 square feet ( 3 @. 2 m<sup>2</sup> ) of Velcro throughout the spacecraft , almost like carpeting . This Velcro was found to be flammable in a high @-@ pressure 100 % oxygen environment . Astronaut Buzz Aldrin states in his book Men From

Earth that the flammable material had been removed per the crew 's August 19 complaints and Joseph Shea 's order , but was replaced before the August 26 delivery to Cape Kennedy .

= = = = Hatch design = = = =

The inner hatch cover used a plug door design , sealed by higher pressure inside the cabin than outside . The normal pressure level used for launch ( 2 psi ( 14 kPa ) above ambient ) created sufficient force to prevent removing the cover until the excess pressure was vented . Emergency procedure called for Grissom to open the cabin vent valve first , allowing White to remove the cover , but Grissom was prevented from doing this because the valve was located to the left , behind the initial wall of flames . Also , while the system could easily vent the normal pressure , its flow capacity was utterly incapable of handling the rapid increase to 29 psi ( 200 kPa ) absolute caused by the intense heat of the fire .

North American had originally suggested the hatch open outward and use explosive bolts to blow the hatch in case of emergency , as had been done in Project Mercury . NASA did not agree , arguing the hatch could accidentally open , as it had on Grissom 's Liberty Bell 7 flight , so the Manned Spacecraft Center designers rejected the explosive design in favor of a mechanically operated one for the Gemini and Apollo programs . Before the fire , the Apollo astronauts had recommended changing the design to an outward @-@ opening hatch , and this was already slated for inclusion in the Block II Command Module design . According to Donald K. Slayton 's testimony before the House investigation of the accident , this was based on ease of exit for spacewalks and at the end of flight , rather than for emergency exit .

= = = = Emergency preparedness = = = =

The board noted that : the test planners had failed to identify the test as hazardous ; the emergency equipment ( such as gas masks ) were inadequate to handle this type of fire ; that fire , rescue , and medical teams were not in attendance ; and that the spacecraft work and access areas contained many hindrances to emergency response such as steps , sliding doors , and sharp turns .

= = Choice of pure oxygen atmosphere = =

When designing the Mercury spacecraft , NASA had considered using a nitrogen / oxygen mixture to reduce the fire risk near launch , but rejected it based on two considerations . First , nitrogen used with the in @-@ flight pressure reduction carried the clear risk of decompression sickness ( known as " the bends " ) . But the decision to eliminate the use of any gas but oxygen was crystalized when a serious accident occurred on April 21 , 1960 , in which McDonnell Aircraft test pilot G.B. North passed out and was seriously injured when testing a Mercury cabin / spacesuit atmosphere system in a vacuum chamber . The problem was found to be nitrogen @-@ rich ( oxygen @-@ poor ) air leaking from the cabin into his spacesuit feed . North American Aviation had suggested using an oxygen / nitrogen mixture for Apollo , but NASA overruled this . The pure oxygen design was judged to be safer , less complicated , and lighter in weight .

In his monograph Project Apollo : The Tough Decisions , Deputy Administrator Seamans wrote that NASA 's single worst mistake in engineering judgment was not to run a fire test on the Command Module before the plugs @-@ out test . In the first episode of the 2009 BBC documentary series NASA : Triumph and Tragedy , Jim McDivitt said that NASA had no idea how a 100 % oxygen atmosphere would influence burning . Similar remarks by other astronauts were expressed in the 2007 documentary film In the Shadow of the Moon .

= = = Other oxygen incidents = = =

Several fires in high @-@ oxygen test environments had occurred before the Apollo fire . In 1962 , USAF Colonel B. Dean Smith was conducting a test of the Gemini space suit with a colleague in a

pure oxygen chamber at Brooks Air Force Base in San Antonio , Texas when a fire broke out , destroying the chamber . Smith and his partner narrowly escaped .

Other oxygen fire occurrences are documented in reports archived in the National Air and Space Museum , such as :

Selection of Space Cabin Atmospheres . Part II : Fire and Blast Hazards [ sic ] in Space Cabins . ( Emanuel M. Roth ; Dept of Aeronautics Medicine and Bioastronautics , Lovelace Foundation for Medical Education and Research. c.1964 ? 1966 . )

" Fire Prevention in Manned Spacecraft and Test Chamber Oxygen Atmospheres . " ( MSC . NASA General Working Paper 10 063 . October 10 , 1966 )

Incidents had also occurred in the Soviet space program , but due to the government 's policy of secrecy , these were not disclosed to the West until well after the Apollo 1 fire . Cosmonaut Valentin Bondarenko died on March 23 , 1961 , from burns sustained in a fire while participating in a 15 @-@ day endurance experiment in a high @-@ oxygen isolation chamber , less than three weeks before the first Vostok manned space flight ; this was disclosed on January 28 , 1986 .

During the Voskhod 2 mission in March 1965 , cosmonauts Pavel Belyayev and Alexey Leonov could not completely seal the spacecraft hatch after Leonov 's historic first walk in space . The spacecraft 's environmental control system responded to the leaking air by adding more oxygen to the cabin , causing the concentration level to rise as high as 45 % . The crew and ground controllers worried about the possibility of fire , remembering Bondarenko 's death four years earlier .

= = Political fallout = =

Committees in both houses of the United States Congress with oversight of the space program soon launched investigations , including the Senate Committee on Aeronautical and Space Sciences , chaired by Senator Clinton P. Anderson . Seamans , Webb , Manned Space Flight Administrator Dr. George E. Mueller , and Apollo Program Director Maj Gen Samuel C. Phillips were called to testify before Anderson 's committee .

In the February 27 hearing , Senator Walter F. Mondale asked Webb if he knew of a report of extraordinary problems with the performance of North American Aviation on the Apollo contract . Webb replied he did not , and deferred to his subordinates on the witness panel . Mueller and Phillips responded they too were unaware of any such " report " .

However , in late 1965 , just over a year before the accident , Phillips had headed a " tiger team " investigating the causes of inadequate quality , schedule delays , and cost overruns in both the Apollo CSM and the Saturn V second stage ( for which North American was also prime contractor ) . He gave an oral presentation ( with transparencies ) of his team 's findings to Mueller and Seamans , and also presented them in a memo to North American president John L. Atwood , to which Mueller appended his own strongly worded memo to Atwood .

During Mondale 's 1967 questioning about what was to become known as the " Phillips Report " , Seamans was afraid Mondale might actually have seen a hard copy of Phillips ' presentation , and responded that contractors have occasionally been subjected to on @-@ site progress reviews ; perhaps this was what Mondale 's information referred to . Mondale continued to refer to " the Report " despite Phillips ' refusal to characterize it as such , and angered by what he perceived as Webb 's deception and concealment of important program problems from Congress , he questioned NASA 's selection of North American as prime contractor . Seamans later wrote that Webb roundly chastised him in the cab ride leaving the hearing , for volunteering information which led to the disclosure of Phillips ' memo .

On May 11 , Webb issued a statement defending NASA 's November 1961 selection of North American as the prime contractor for Apollo . This was followed on June 9 by Seamans filing a seven @-@ page memorandum documenting the selection process . Webb eventually provided a controlled copy of Phillips ' memo to Congress . The Senate committee noted in its final report NASA 's testimony that " the findings of the [ Phillips ] task force had no effect on the accident , did not lead to the accident , and were not related to the accident " , but stated in its recommendations :

Notwithstanding that in NASA 's judgment the contractor later made significant progress in



overcoming the problems , the committee believes it should have been informed of the situation . The committee does not object to the position of the Administrator of NASA , that all details of Government / contractor relationships should not be put in the public domain . However , that position in no way can be used as an argument for not bringing this or other serious situations to the attention of the committee .

Freshman Senators Edward W. Brooke III and Charles H. Percy jointly wrote an Additional Views section appended to the committee report , chastising NASA more strongly than Anderson for not having disclosed the Phillips review to Congress . Mondale wrote his own , even more strongly worded Additional View , accusing NASA of " evasiveness , ? lack of candor , ? patronizing attitude toward Congress , ? refusal to respond fully and forthrightly to legitimate Congressional inquiries , and ? solicitous concern for corporate sensitivities at a time of national tragedy . "

The potential political threat to Apollo blew over , due in large part to the support of President Lyndon B. Johnson , who at the time still wielded a measure of influence with the Congress from his own Senatorial experience . He was a staunch supporter of NASA since its inception , had even recommended the Moon program to President John F. Kennedy in 1961 , and was skilled at portraying it as part of Kennedy 's legacy .

Relations between NASA and North American deteriorated over assignment of blame . North American argued unsuccessfully it was not responsible for the fatal error in spacecraft atmosphere design . Finally , Webb contacted Atwood , and demanded either he or Chief Engineer Harrison A. Storms resign . Atwood elected to fire Storms .

On the NASA side , Joseph Shea resorted to barbiturates and alcohol in order to help him cope . NASA administrator James Webb became increasingly worried about Shea 's mental state . Shea was asked to take an extended voluntary leave of absence , but Shea refused , threatening to resign rather than take leave . As a compromise , he agreed to meet with a psychiatrist and to abide by an independent assessment of his psychological fitness . This approach to remove Shea from his position was also unsuccessful . Finally , six months after the fire , Shea 's superiors reassigned him to NASA headquarters in Washington , D.C. Shea felt that his new post was a " non @-@ job , " and left after only two months .

= = Program recovery = =

Gene Kranz called a meeting of his staff in Mission Control three days after the accident , delivering a speech which has subsequently become one of NASA 's principles . Speaking of the errors and overall attitude surrounding the Apollo program before the accident , he stated : " We were too ' gung @-@ ho ' about the schedule and we blocked out all of the problems we saw each day in our work . Every element of the program was in trouble and so were we . " He reminded the team of the perils and mercilessness of their endeavor , and stated the new requirement that every member of every team in mission control be " tough and competent " , requiring nothing less than perfection throughout NASA 's programs . In 2003 , following the Space Shuttle Columbia disaster , NASA administrator Sean O 'Keefe quoted Kranz 's speech , applying it to the Columbia crew .

= = Command Module redesign = =

After the fire , the Apollo program was grounded for review and redesign . The Command Module was found to be extremely hazardous and in some instances , carelessly assembled ( for example , a misplaced socket wrench was found in the cabin ) .

It was decided that remaining Block I spacecraft would be used only for unmanned Saturn V test flights . All manned missions would use the Block II spacecraft , to which many Command Module design changes were made :

The cabin atmosphere at launch was adjusted to 60 % oxygen and 40 % nitrogen at sea @-@ level pressure : 14 @. 7 psi ( 101 kPa ) . During ascent the cabin rapidly vented down to 5 psi ( 34 kPa ) , releasing approximately 2 / 3 of the gas originally present at launch . The vent then closed and the environmental control system maintained a nominal cabin pressure of 5 psi ( 34 kPa ) as the

spacecraft continued into vacuum . The cabin was then very slowly purged ( vented to space and simultaneously replaced with 100 % oxygen ) , so the nitrogen concentration fell asymptotically to zero over the next day . Although the new cabin launch atmosphere was significantly safer than 100 % oxygen , it still contained almost three times the amount of oxygen present in ordinary sea level air ( 20 @. @ 9 % oxygen ) . This was necessary to ensure a sufficient partial pressure of oxygen when the astronauts removed their helmets after reaching orbit . ( 60 % of 5 psi is 3 psi , compared to 20 @. @ 9 % of 14 @. @ 7 psi ( 101 kPa ) , or 3 @. @ 07 psi ( 21 @. @ 2 kPa ) in sea @- @ level air . )

The environment within the astronauts ' pressure suits was not changed . Because of the rapid drop in cabin ( and suit ) pressures during ascent , decompression sickness was likely unless the nitrogen had been purged from the astronauts ' tissues before launch . They would still breathe pure oxygen , starting several hours before launch , until they removed their helmets on orbit . Avoiding the " bends " was considered worth the residual risk of an oxygen @- @ accelerated fire within a suit .

Nylon used in the Block I suits was replaced in the Block II suits with Beta cloth , a non @- @ flammable , highly melt @- @ resistant fabric woven from fiberglass and coated with Teflon .

Block II had already been planned to use a completely redesigned hatch which opened outward , and could be opened in less than five seconds . Concerns of accidental opening were addressed by using a cartridge of pressurized nitrogen to drive the release mechanism in an emergency , instead of the explosive bolts used on Project Mercury .

Flammable materials in the cabin were replaced with self @- @ extinguishing versions .

Plumbing and wiring were covered with protective insulation . Aluminum tubing was replaced with stainless steel tubing that used brazed joints when possible .

Thorough protocols were implemented for documenting spacecraft construction and maintenance .

= = = New mission naming scheme = = =

The astronauts ' widows asked that Apollo 1 be reserved for the flight their husbands never made , and on April 24 , 1967 , Associate Administrator for Manned Space Flight , Dr. George E. Mueller , announced this change officially : AS @- @ 204 would be recorded as Apollo 1 , " first manned Apollo Saturn flight ? failed on ground test " . Since three unmanned Apollo missions ( AS @- @ 201 , AS @- @ 202 , and AS @- @ 203 ) had previously occurred , the next mission , the first unmanned Saturn V test flight ( AS @- @ 501 ) would be designated Apollo 4 , with all subsequent flights numbered sequentially in the order flown . The first three flights would not be renumbered , and the names Apollo 2 and Apollo 3 would go unused .

The manned flight hiatus allowed work to catch up on the Saturn V and Lunar Module , which were encountering their own delays . Apollo 4 flew in November 1967 . Apollo 1 's ( AS @- @ 204 ) Saturn IB rocket was taken down from Launch Complex 34 , later reassembled at Launch complex 37B and used to launch Apollo 5 , an unmanned Earth orbital test flight of the first Lunar Module LM @- @ 1 , in January 1968 . A second unmanned Saturn V AS @- @ 502 flew as Apollo 6 in April 1968 , and Grissom 's backup crew of Wally Schirra , Don Eisele , and Walter Cunningham , finally flew the orbital test mission as Apollo 7 ( AS @- @ 205 ) , in a Block II CSM in October 1968 .

= = Memorials = =

Gus Grissom and Roger Chaffee were buried at Arlington National Cemetery . Ed White was buried at West Point Cemetery on the grounds of the United States Military Academy in West Point , New York . Their names are among those of several astronauts and cosmonauts who have died in the line of duty , listed on the Space Mirror Memorial at the Kennedy Space Center Visitor Complex in Merritt Island , Florida . President Jimmy Carter awarded the Congressional Space Medal of Honor posthumously to Grissom on October 1 , 1978 . President Bill Clinton awarded it to White and Chaffee on December 17 , 1997 .

An Apollo 1 mission patch was left on the Moon 's surface after the first manned lunar landing by Apollo 11 crew members Neil Armstrong and Buzz Aldrin . The Apollo 15 mission left on the surface

of the Moon a tiny memorial statue , Fallen Astronaut , along with a plaque containing the names of the Apollo 1 astronauts , among others including Soviet cosmonauts , who perished in the pursuit of human space flight .

== Launch Complex 34 ==

After the Apollo 1 fire , Launch Complex 34 was subsequently used only for the launch of Apollo 7 and later dismantled down to the concrete launch pedestal , which remains at the site ( 28 @. @ 52182 ° N 80 @. @ 561258 ° W ? / 28 @. @ 52182 ; -80.561258 ) along with a few other concrete and steel @-@ reinforced structures . The pedestal bears two plaques commemorating the crew . Each year the families of the Apollo 1 crew are invited to the site for a memorial , and the Kennedy Space Center Visitor Complex includes the site during the tour of the historic Cape Canaveral launch sites .

In January 2005 , three granite benches , built by a college classmate of one of the astronauts , were installed at the site on the southern edge of the launch pad . Each bears the name of one of the astronauts and his military service insignia .

== Stars , landmarks on the Moon and Mars ==

Apollo astronauts frequently aligned their spacecraft inertial navigation platforms and determined their positions relative to the Earth and Moon by sighting sets of stars with optical instruments . As a practical joke , the Apollo 1 crew named three of the stars in the Apollo catalog after themselves and introduced them into NASA documentation . Gamma Cassiopeiae became Navi ? Ivan ( Gus Grissom 's middle name ) spelled backwards . Iota Ursae Majoris became Dnoces ? " Second " spelled backwards , for Edward H. White II . And Gamma Velorum became Regor ? Roger ( Chaffee ) spelled backwards . These names quickly stuck after the Apollo 1 accident and were regularly used by later Apollo crews .

Craters on the Moon and hills on Mars are named after the three Apollo 1 astronauts .

== Civic and other memorials ==

== Remains of CM @-@ 012 ==

The Apollo 1 Command Module has never been on public display . After the accident , the spacecraft was removed and taken to Kennedy Space Center to facilitate the review board 's disassembly in order to investigate the cause of the fire . When the investigation was complete , it was moved to the NASA Langley Research Center in Hampton , Virginia , and placed in a secured storage warehouse . On February 17 , 2007 , the parts of CM @-@ 012 were moved approximately 90 feet ( 27 m ) to a newer , environmentally controlled warehouse . Only a few weeks earlier , Gus Grissom 's brother Lowell publicly suggested CM @-@ 012 be permanently entombed in the concrete remains of Launch Complex 34 .

== Popular culture ==

The Apollo 1 accident is briefly depicted in the opening scene of the 1995 film Apollo 13 .

The Apollo 1 accident and its aftermath are the subject of episode 2 " Apollo One " , of the 1998 HBO miniseries From the Earth to the Moon , starring Mark Rolston as Gus Grissom , Chris Isaak as Ed White and Ben Marley as Roger Chaffee .

The Apollo 1 mission and accident are covered in the ABC television series , The Astronaut Wives Club , episodes 8 " Rendezvous " , and 9 " Abort " .

The launch pedestal and memorial plaque are briefly depicted in scenes from the 1985 film Chronos and the 1998 feature film Armageddon .

The Apollo 1 disaster inspired the song Fire in the Cockpit from the band Public Service Broadcasting's album , The Race for Space .