New Apollo Schedule Awaits End of Probe

WASHINGTON—The space agency—still reeling from the critical report of the *Apollo 204* Investigation Board and a congressional investigation—does not expect to decide on a schedule for its lunar landing program within a month.

It has been learned, however, that NASA will switch to the *Saturn V* launch vehicle as soon as it becomes available—probably in the second or third quarter of next year.

The switch will be made following the first manned flight in the three-man *Apollo* series. That will be a two-week mission using the *Uprated Saturn I.* While some officials are hopeful the flight can be made in November or December, it is almost certain to slip into early 1968.

Manned space flight officials late last week were eager to get the program moving again, but a congressional investigation by both House and Senate space committees will have to be disposed of first.

One official said that a launch schedule could be firmed up in two weeks to one month, but that nothing would be done until the congressional probe is ended. Since the House Space Committee expects to continue hearings this week and travel to Cape Kennedy, it appears doubtful that dates for future launches can be set for at least a few weeks.

New Soviet flights—Even as the hiatus in the U.S. manned space flight program continued, there were predictions from Soviet space officials that Russia would shortly resume manned flights. Yuri Gagarin, in an article in a Soviet newspaper, declared that a new spacecraft carrying more than three men would be sent on missions far out into space.

He did not say exactly when the flight would be made, but indicated that it would be in the near future.

The U.S./USSR race to the Moon was far in the background last week as the Space Board investigating the Jan. 27 *Apollo 204* fire issued its report and both space committees began to dig into its findings and into what NASA is going to do about them.

Members of the House Space Committee's NASA Oversight Subcommittee commended the board for its fairness and impartiality. They declared that the report was intensive and thorough and, as one Republican member put it, "a much better report than we thought we were going to get."

The board, after an almost two-month study of the fire that killed astronauts Virgil Grissom, Edward H. White and Roger Chaffee, declared that while NASA had done an overall good job in space, "The *Apollo* engineering team failed to give adequate attention to certain mundane, but equally vital questions of crew safety." It also declared that its investigation revealed that many deficiencies in design, engineering, manufacture and quality control had led to the tragedy.

It charged specifically that the fire was caused by several arcs in wiring, probably located near the lower left forward section where the Environmental Control System (ECS) instrumentation power wiring leads into an area between the ECS and the oxygen panel. It said that it had found numerous examples in the wiring of poor installation, design and workmanship.

Negligence cited—The report also declared that NASA management was extremely negligent in not determining the extreme hazard of the Jan. 27 test, that adequate safety precautions were neither established or observed, that the overall communications system was faulty, that non-certified equipment was installed in the spacecraft, that problems of program management and relationships between field centers and contractors led to insufficient response to changing program requirements and that there were deficiencies in the Command Module design, workmanship and quality control.

In response to the report, one NASA official said simply that the fire was caused because manned space flight officials did not realize how hazardous the test was. "We did not realize how lethal the combination of a 100% oxygen atmosphere, combustible materials and 16 psia pressure would be if a spark occurred."

Apparently the agency studied every possible contingency which could take place in space, but failed to detect the real possibility of tragedy on the ground.

As a result, no test was ever run as to just what would happen to the spacecraft if the fire broke out during a pressurized pre-launch test. Since the deaths of the three astronauts, a test has been run in a boilerplate Command Module, which duplicated almost exactly the ignition and spread of the *Apollo 204* fire.

NASA's approach to ensuring that such a tragedy does not occur in the future is to replace all combustible materials with non-combustible items, add a quick-egress hatch to the spacecraft and provide fire breaks within the spacecraft.

It is also studying possible redesign of the Environmental Control System, use of a two-gas atmosphere during ground tests and changing the coolant in the ECS.

The use of a two-gas atmosphere does not set well with a lot of officials in the Office of Manned Space Flight. Their primary objection is that while it may make ground tests safer, it could open the way for other troubles when the spacecraft is in orbit.

In order to switch to a 100% oxygen atmosphere in space, the cabin would have to be depressurized during the first orbit and then pressurized again. The officials are worried because it any instrument malfunctioned and it became impossible to pressure the spacecraft, the crew would have to use their spacesuit life-support systems. With the loss of redundancy in the life-support system, any future mission would have to be aborted.

Astronaut Frank Borman, a member of the investigating board, added his name to those who oppose the two-gas system in a statement to he House subcommitee.

Apollo 204 Review Board

Dr. Floyd L. Thompson, Director, Langley Research Center, Chairman.

Col. Frank Borman, Astronaut, Manned Spacecraft Center.

Dr. Maxime A. Faget, Director, Engineering & Development, Manned Spacecraft Center.

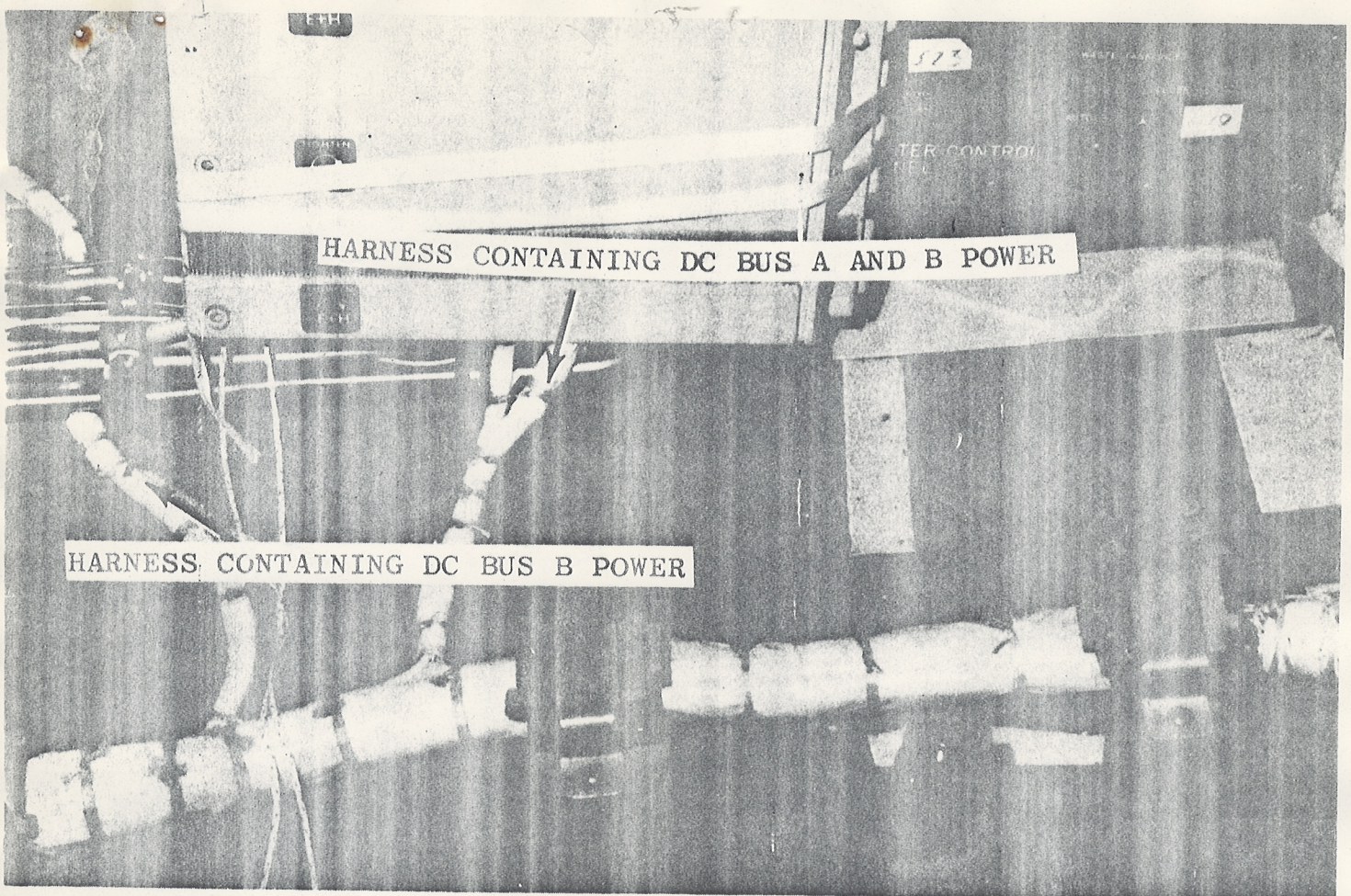
E. Barton Geer, Associate Chief, Flight Vehicles & Systems Division, Langley Research Center.

Dr. Robert W. Van Dolah, Research Director, Explosive Research Center, Bureau of Mines, Department of Interior.

Col. Charles F. Strang, Chief of Missiles & Space Safety Division, Air Force Inspector General, Norton AFB, Calif.

George C. White, Jr., Director, Reliability & Quality, Apollo Program Office, NASA Headquarters.

John J. Williams, Director, Spacecraft Operations, Kennedy Space Center.



Apollo Review Board determined that this area near the floor in the lower forward section of the left-hand equipment bay below the Environmental Control Unit was the most probable initiator of the fire in the spacecraft. DC power cable is shown crossing over aluminum tubing and under lithium hydroxide access door in spacecraft 014 used in the investigation.

Many officials also believe that the *Apollo* ECS is a good system and does not require extensive redesign. In support of this, they point out that it was checked out during the *Apollo 202* flight and that it performed well. Instead of a redesign, they felt that measures should be taken to prevent leakage in the system.

The new spacecraft hatch will be test-flown on the *Saturn 501* mission, the first launch of *Saturn V*. The hatch is similar to the one used in the *Mercury* program, but some modifications have been made.

During the same flight, which is scheduled for July or August, checks will also be made on other spacecraft systems. Most of the combustible spacecraft materials are due to be replaced by Teflon, Fiberglas and other materials, but studies of exactly which will be selected are continuing.

The spaceflight schedule—The manned spaceflight slate now shapes up like this:

First off the pad will be the *Saturn 501* mission. It will be followed by launch of the first unmanned Lunar Module in late summer or fall.

Second unmanned *Saturn V* launch will then lift off around the end of the year. At about the same time, or early in 1968, first manned *Apollo* flight will be made, using the *Uprated Saturn I* booster. It will be a two-week-long checkout of all systems.

Then, if the first two *Saturn* flights are successful, the agency will probably switch further manned flights to the 7.5-million-lb.-thrust booster. If the *Saturn V* program is not completely successful or if slippage develops in the program, NASA will probably fly a dual-launch rendezvous mission between the Command and Service Modules and the Lunar Module, using the *Uprated Saturn I* in the second quarter of next year.

A host of officials from NASA, North American Aviation, Inc., and the board testified before both the House and Senate groups last week.

The House probe is slated to end April 18, when NASA Administrator James E. Webb and Deputy Administrator Robert C. Seamans will appear. There has been no indication as to when the Senate Committee will complete its inquiry.

Associate Administrator for Manned Space Flight Dr. George E. Mueller told the House subcommittee late last week that NASA accepts and agrees with the board's recommendations concerning the possible source of the fire, the inability to open the hatch, and the agency's failure to gauge the true danger of the Jan. 27 checkout test.

Mueller also admitted that NASA's standards concerning combustible materials were not rigid enough. He said that he believed that the fire could have been contained if the flammable materials had not been present.

Mueller told the subcommittee that NASA has decided to redesign the capsule Environmental Control System to be compatible with both air and oxygen operation on the pad, so that the decision may be deferred until the last minute if necessary. He also said that NASA disagrees with some of the recommendations of the board, including the need for vibration testing of the complete capsule, and the magnitude of the problems associated with solder joints in the ECS. In these reactions, Mueller was joined by North American officials.

North American Aviation officials,

led by President J. L. Atwood, were reluctant to put a date on when the next spacecraft could be ready or on what effect there would be on the schedule.

However, Atwood finally guessed that the accident and the changes would have 'at least a six-month impact on the lunar landing date."

NAA officials also said that they would expect major funding changes on the contract because of modifications to the capsule.

A new point brought out by North American official Dale D. Myers was his opinion that if the same thing had happened in space, "the events might have been a little different but the result would have been the same."

Many NASA officials have publicly stated that the situation would have been different because of the lower oxygen pressure—5 psia—instead of the 16 psia on the pad. In addition, they have pointed to the fact that the cabin can be depressurized to put out a fire in space; however, this remedy would not be available if the shirtsleeve garmet mode were in effect.

In assessing North American's responsibility for the accident, it was noted that it was up to the company's Cape Kennedy personnel to identify the hazard during safety meetings before each test, subject to NASA approval.

While the original decision that the test was not hazardous was made with the assumption that the hatch would be open and the capsule would not be pressurized, Myers said that even if these factors had been known, the decision still would have been that it was not hazardous.

"The whole potential was not recognized," he said. NAA vice president John J. MacCarthy also observed, "It was the gravest error we have ever made."

Myers also pointed to the failure to test materials in the 16-psia environment of pure oxygen, saying that a test "very definitely" would have revealed the danger of the situation.

Suspect wires—NAA engineers do not feel that the Teflon-coated wire bundle, which passes under the door leading to the lithium hydroxide panel, was the source of the electric arc that apparently caused the fire. While the investigating board does not specifically name this as the cause, it has pinpointed this area as the source of the fire, leading to speculation that chafing from the door might have removed some of the insulation.

Myers, who is NAA's Space and Information Systems Div. vice president and *Apollo* program manager, said he concurred in the finding that the fire was produced by electrical arcing and that he was "inclined" to think that it was because of degradation of insulation.

The degradation, he noted, would have had to have happened after the quality control inspection during the fabrication process and after an altitude test at the Kennedy Space Center, performed late in December.

However, it was brought out that between this time and the Jan. 27 accident, there was no detailed examination of the state of the insulation and wiring in the capsule.

While each entry to the capsule was to be recorded on a check list and careful procedures were to be followed, the fact that one workman left behind a wrench on the capsule floor brought caustic comment from the subcommittee on the stringency of procedures protecting the capsule.

Myers said that the fact that the wire bundle, which is supposed to have a ¼-in. clearance under the door, actually touched the door in spacecraft 014 has complicated the issue considerably.

However, spacecraft 014—the duplicate rushed to the Cape after the fire for comparison—had not gone through a final checkout during which this bundle would have been tamped down, he said. Therefore, it did not represent the true state of affairs for spacecraft 012.

Three incidents of arcing previous to the fire were reported having occurred in September, October and January at the Cape. These, according to George Jeffs, *Apollo* chief engineer, were caused during the installation of a panel. While other evidence of arcing was found after the fire, this was attributed to the melting insulation during the fire.

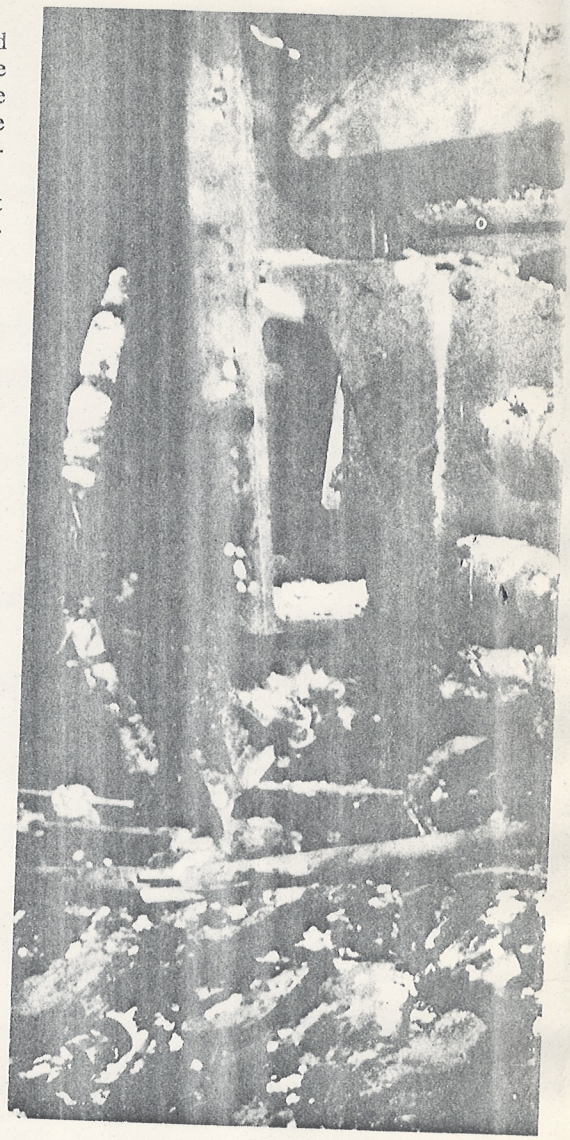
The arc that caused the fire, Myers indicated, will probably never be isolated from all those which occurred during the fire. North American officials noted that there were several other possibilities as to the cause of the fire, including one that Command Pilot Gus Grissom accidentally kicked a lead for a gas chromatograph that had been removed before the test.

However, this theory was discounted by NASA's Dr. George E. Mueller, who said that the region could not be reached by the seated astronaut.

The investigating board charge that deficiencies in design, manufacture, installation, rework and quality control existed in the electrical wiring were specifically denied by the company.

To the finding that no vibration test was made of a complete flight-configured spacecraft, North American officials indicated they did not think this was necessary. They pointed out that spacecraft 9 had been given such a test and no data were produced.

Solder joints—Another point of contention with the board's findings was that the coolant leakage in the Environmental Control System has been a chronic problem.



Myers said that some leakage has taken place when aluminum tubing was yielded because of bending around corners, but that the solder joints still were considered better protection against leakage than the alternate B nuts.

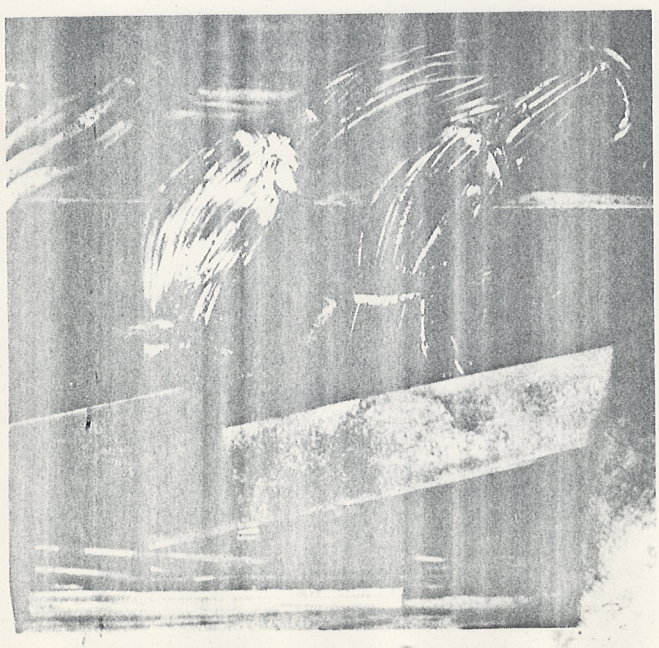
He said that while he did not recognize the board's comment of a possible fire hazard because of a leak of the inhibitor, armoring is being added in accordance with its finding.

Officials are now looking at the Environmental Control System to see if there is a good substitute for the water-glycol coolant mixture, or for the inhibitor, found to leave an inflammable residue. No choice has been made.

The findings of the investigating board follow. ■

This special report was prepared by TECH WEEK Senior Editor Hal Taylor and Biotechnology Editor Heather David.

ABOVE: Charred area in spacecraft 012 (essentially the same area shown on page 17) is believed to be the most likely region for the start of the fire. Probable cause is an electrical arc in a power cable. BELOW: View of burned cable.



1. **FINDING:**

a. There was a momentary power failure at 23:30:55 GMT.

b. Evidence of several arcs was found in the post-fire investigation.

c. No single ignition source of the fire was conclusively identified.

DETERMINATION:

The most probable initiator was an electrical arc in the sector between the —Y and +Z spacecraft axes. The exact location best fitting the total available information is near the floor in the lower forward section of the left-hand equipment bay where Environmental Control System (ECS) instrumentation power wiring leads into the area between the Environmental Control Unit (ECU) and the oxygen panel. No evidence was discovered that suggested sabotage.

2. **FINDING:**

a. The Command Module contained many types and classes of combustible material in areas contiguous to possible ignition sources.

b. The test was conducted with a 16.7 pounds per square inch absolute, 100 percent oxygen atmosphere.

DETERMINATION:

The test conditions were extremely hazardous.

RECOMMENDATION:

The amount and location of combustible materials in the Command Module must be severely restricted and controlled.

3. **FINDING:**

a. The rapid spread of fire caused an increase in pressure and temperature which resulted in rupture of the Command Module and creation of a toxic atmosphere. Death of the crew was from asphyxia due to inhalation of toxic gases due to fire. A contributory cause of death was thermal burns.

b. Non-uniform distribution of carboxyhemoglobin was found by autopsy.

DETERMINATION:

Autopsy data leads to the medical opinion that unconsciousness occurred rapidly and that death followed soon thereafter.

4. **FINDING:**

Due to internal pressure, the Command Module inner hatch could not be opened prior to rupture of the Command Module.

DETERMINATION:

The crew was never capable of effecting emergency egress because of the pressurization before rupture and their loss of consciousness soon after rupture.

RECOMMENDATION:

The time required for egress of the crew be reduced and the operations necessary for egress be simplified.

5. **FINDING:**

Those organizations responsible for the planning, conduct and safety of this test failed to identify it as being hazardous. Contingency preparations to permit escape or rescue of the crew from an internal Command Module fire were not made.

a. No procedures for this type of emergency had been established either for the crew or for the spacecraft pad work team.

b. The emergency equipment located in the white room and on the spacecraft work levels was not designed for the smoke condition resulting from a fire of this nature.

c. Emergency fire, rescue and medical teams were not in attendance.

d. Both the spacecraft work levels and the umbilical tower access arm contain features such as steps, sliding doors and sharp turns in the egress paths which hinder emergency operations.

DETERMINATION:

Adequate safety precautions were neither established nor observed for this test.

RECOMMENDATIONS:

a. Management continually monitor the safety of all test

operations and assure the adequacy of emergency procedures.

b. All emergency equipment (breathing apparatus, protective clothing, deluge systems, access arm, etc.) be reviewed for adequacy.

c. Personnel training and practice for emergency procedures be given on a regular basis and reviewed prior to the conduct of a hazardous operation.

d. Service structures and umbilical towers be modified to facilitate emergency operations.

6. **FINDING:**

Frequent interruptions and failures had been experienced in the overall communication system during the operations preceding the accident.

DETERMINATION:

The overall communication system was unsatisfactory.

RECOMMENDATIONS:

a. The ground communication system be improved to assure reliable communications between all test elements as soon as possible and before the next manned flight.

b. A detailed design review be conducted on the entire spacecraft communication system.

7. **FINDING:**

a. Revisions to the operational checkout procedure for the test were issued at 5:30 pm EST Jan. 26, 1967 (209 pages) and 10:00 am EST Jan. 27, 1967 (4 pages).

b. Differences existed between the ground test procedures and the in-flight check lists.

DETERMINATION:

Neither the revision nor the differences contributed to the accident. The late issuance of the revision, however, prevented test personnel from becoming adequately familiar with the test procedure prior to its use.

RECOMMENDATIONS:

a. Test procedures and pilot's checklists that represent the actual Command Module configuration be published in final form and reviewed early enough to permit adequate preparation and participation of all test organization.

b. Timely distribution of test procedures and major changes be made a constraint to the beginning of any test.

8. **FINDING:**

The fire in Command Module 012 was subsequently simulated closely by a test fire in a full-scale mock-up.

DETERMINATION:

Full-scale mock-up fire tests can be used to give a realistic appraisal of fire risks in flight-configured spacecraft.

RECOMMENDATION:

Full-scale mock-ups in flight configuration be tested to determine the risk of fire.

9. **FINDING:**

The Command Module Environmental Control System design provides a pure oxygen atmosphere.

DETERMINATION:

This atmosphere presents severe fire hazards if the amount and location of combustibles in the Command Module are not restricted and controlled.

RECOMMENDATIONS:

a. The fire safety of the reconfigured Command Module be established by full-scale mock-up tests.

b. Studies of the use of a diluent gas be continued with particular reference to assessing the problems of gas detection and control and the risk of additional operations that would be required in the use of a two-gas atmosphere.

10. **FINDING:**

Deficiencies existed in Command Module design, workmanship and quality control, such as:

a. Components of the Environmental Control System installed in Command Module 012 had a history of many removals and of technical difficulties including regulator failures, line failures and Environmental Control Unit failures. The design and installation features of the Environmental Control Unit makes removal or repair difficult.

b. Coolant leakage at solder joints has been a chronic problem.

c. The coolant is both corrosive and combustible.

d. Deficiencies in design, manufacture, installation, rework and quality control existed in the electrical wiring.

e. No vibration test was made of a complete flight-configured spacecraft.

f. Spacecraft design and operating procedures currently require the disconnecting of electrical connections while powered.

g. No design features for fire protection were incorporated.

DETERMINATION:

These deficiencies created an unnecessarily hazardous condition and their continuation would imperil any future *Apollo* operations.

RECOMMENDATIONS:

a. An in-depth review of all elements, components and assemblies of the Environmental Control System be conducted to assure its functional and structural integrity and to minimize its contribution to fire risk.

b. Present design of soldered joints in plumbing be modified to increase integrity or the joints be replaced with a more structurally reliable configuration.

c. Deleterious effects of coolant leakage and spillage be eliminated.

d. Review of specifications be conducted, three-dimensional jigs be used in manufacture of wire bundles and rigid inspection at all stages of wiring design, manufacture and installation be enforced.

e. Vibration tests be conducted of a flight-configured spacecraft.

f. The necessity for electrical connections or disconnections with power on within the crew compartment be eliminated.

g. Investigation be made of the most effective means of controlling and extinguishing a spacecraft fire. Auxiliary breathing oxygen and crew protection from smoke and toxic fumes be provided.

11. **FINDING:**

An examination of operating practices showed the following examples of problem areas:

a. The number of the open items at the time of shipment of the Command Module 012 was not known. There were 113 significant engineering orders not accomplished at the time Command Module 012 was delivered to NASA; 623 engineering orders were released subsequent to delivery. Of these, 22 were recent releases, which were not recorded in configuration records at the time of the accident.

b. Established requirements were not followed with regard to the pre-test constraints list. The list was not completed and signed by designated contractor and NASA personnel prior to the test, even though oral agreement to proceed was reached.

c. Formulation of and changes to pre-launch test requirements for the *Apollo* spacecraft program were unresponsive to changing conditions.

d. Non-certified equipment items were installed in the Command Module at time of test.

e. Discrepancies existed between NAA and NASA MSC specifications regarding inclusion and positioning of flammable materials.

f. The test specification was released in August, 1966, and was not updated to include accumulated changes from release date to date of the test.

DETERMINATION:

Problems of program management and relationships between centers and with the contractor have led in some cases to insufficient response to changing program requirements.

RECOMMENDATION:

Every effort must be made to insure the maximum clarification and understanding of the responsibilities of all the organizations involved, the objective being a fully coordinated and efficient program.