APOLLO ACCIDENT

HEARINGS

BEFORE THE

COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES UNITED STATES SENATE

NINETIETH CONGRESS

FIRST SESSION

TO

HEAR MEMBERS OF THE APOLLO 204 REVIEW BOARD ON THEIR FINAL REPORT OF INVESTIGATION AND TO DISCUSS THE BOARD'S FINDINGS, DETERMINATIONS, AND RECOMMENDATIONS

APRIL 11, 1967

PART 3

WASHINGTON, D.C.

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Likely areas in which this harness could have ignited the fire, of course, are near the door and up in the area behind the door.

Now, the reason we believe the fire started in this place is, first, from the physical evidence in the spacecraft—that is the firing patterns, the fact that all combustibles were completely burned away here, whereas in all other locations there is evidence of some of the combustibles melting rather than being burned away, indicating that the fire got to these other combustibles at a time period where oxygen was either completely depleted or partly depleted within the spacecraft.

Furthermore, we have investigated the arrangement of the combustibles in the spacecraft. There was a Raschel net, the debris trap net that ran horizontally along the floor in this area. We have carried out a special test in 16 and a half psi oxygen atmosphere, and ignited the net at the location of the harness and measured the time for the fire to travel to the corner, where it could communicate with a vertical Raschel net. And the total time from ignition to the time when that fire would come within the view of the astronauts was approximately 8 seconds.

This period of time fits very closely with the time difference of 9.7 seconds from the time that there are indications of an arc in the spacecraft from the data and the time that the spacecraft crew reported a fire.

Thank you.

The CHAIRMAN. Doctor, we are going to have to keep fighting quorum calls. There is a live quorum call now which we are trying to avoid so we can continue the discussion. If you can finish by about 12 o'clock so we can start with the questions, we would appreciate it.

SUMMARY OF BOARD'S FINDINGS

Dr. THOMPSON. I have Colonel Borman to sum up the findings; that would finish our presentation.

The CHAIRMAN. Thank you.

Colonel BORMAN. Mr. Chairman, Senator Smith, members of the committee, sir, I will present to you the findings and recommendations of the Board. You have them in part 6 of the Board's final report if you care to follow them at your desk.

May I have the first slide. (Fig. 46.) The first finding that the Board arrived at was that there was a momentary power failure at the 23:30:55 Greenwich mean time; evidence of several arcs was found in the post fire investigation; and that no single source of ignition was conclusively identified.

Next slide. (Fig. 47.) From this the Board determined that the most probable initiator was an electrical arc in the section between minus Y and plus 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 the Environmental Control System instrumentation power wiring leads into the area between the Environmental Control Unit and the oxygen panel. No evidence was discovered that suggested sabotage.

The next (fig. 48) 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 16.7 pounds per square inch absolute, 100 percent oxygen atmosphere.

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.

FIGURE 46

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.

FIGURE 47

Next slide (fig. 49) determination, the test conditions were extremely hazardous.

Next slide (fig. 50) recommendation, the amount and location of the combustible materials in the command module be severely restricted and controlled. Restrict the amount and control their location.

Next slide. (Fig. 51.) Third finding. The rapid spread of the fire caused an increase in the pressure and temperature which resulted in a rupture of the command module and creation of a toxic atmosphere. Death of the crew was from axphyxia due to inhalation of toxic gases due to fire. A contributory cause of death was thermal burns.

Nonuniform distribution of carboxyhemoglobin was found by autopsy.

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.

FIGURE 48

DETERMINATION:

THE TEST CONDITIONS WERE EXTREMELY HAZARDOUS.

FIGURE 49

RECOMMENDATION:

THE AMOUNT AND LOCATION OF COMBUSTIBLE MATERIALS IN THE COMMAND MODULE BE SEVERELY RESTRICTED AND CONTROLLED.

FIGURE 50

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.

FIGURE 51

Next slide. (Fig. 52.) Medical opinion determined that unconsciousness occurred rapidly and death followed soon thereafter.

Next slide. (Fig. 53.) Finding: Due to internal pressure the command module inner hatch could not be opened prior to rupture of the command module. This is, of course, because of the fact that we had a sealed hatch that was designed to operate in orbit.

Next slide. (Fig. 54.) Determination: The crew was never capable of effecting emergency egress because of the pressurization before rupture and their loss of consciousness soon after rupture.

DETERMINATION:

AUTOPSY DATA LEADS TO THE MEDICAL OPINION THAT UNCONSCIOUSNESS OCCURRED RAPIDLY AND THAT DEATH FOLLOWED SOON THEREAFTER.

FIGURE 52

4. FINDING:

DUE TO INTERNAL PRESSURE, THE COMMAND MODULE INNER HATCH COULD NOT BE OPENED PRIOR TO RUPTURE OF THE COMMAND MODULE.

FIGURE 53

DETERMINATION:

THE CREW WAS NEVER CAPABLE OF EFFECTING EMERGENCY EGRESS BECAUSE OF THE PRESSURIZATION BEFORE RUPTURE AND THEIR LOSS OF CONSCIOUSNESS SOON AFTER RUPTURE.

FIGURE 54

Next slide. (Fig. 55.) Recommendation: The Board recommends that the time required for egress of the crew be reduced and the operations necessary for egress be simplified.

Next slide. (Fig. 56.) Finding number five: 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 have been established either for the crew or for the spacecraft pad work team, (*b*) the emergency equipment located in the white room and on

RECOMMENDATION:

THE TIME REQUIRED FOR EGRESS OF THE CREW BE REDUCED AND THE OPERATIONS NECESSARY FOR EGRESS BE SIMPLIFIED.

FIGURE 55

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.

FIGURE 56

the spacecraft work levels was not designed for smoke conditions 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 operation.

Before leaving that I would like to point out that the key phrase here is that the test was not identified as being hazardous. Consequently, the deficiencies that we listed here in (*a*), (*b*), (*c*), and (*d*) resulted from the fact that the test was not identified as being hazardous.

Dr. THOMPSON. Colonel, this is—I do not believe you are really adding any comments.

Colonel BORMAN. Do you want me to go right on through?

Dr. THOMPSON. It is not necessary since the chairman and members of the committee have read the report. I think that you just stand on what is presented here.

Colonel BORMAN. Yes.

The CHAIRMAN. I agree with you. This is word for word.

Dr. THOMPSON. Yes. I do not think he plans to add much of anything to that, so we can let that stand as a sum up as written.

The CHAIRMAN. We will really put it in the report but—I hate to sort of cut you off.

Colonel BORMAN. No, sir, that is fine.

The CHAIRMAN. Do you have anything you want to say about this situation?

Colonel BORMAN. Well, sir, perhaps if we have discussion later on I will have an opportunity to comment.

(The remaining slides (figs. 57 to 76) in Colonel Borman's illustrated talk referred to above are as follows:)*

DETERMINATION:

ADEQUATE SAFETY PRECAUTIONS WERE NEITHER ESTABLISHED NOR OBSERVED FOR THIS TEST.

FIGURE 57

*For convenience, part VI of the Board's report entitled "Board Findings, Determinations, and Recommendations" is printed in an appendix, see p. 267.

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.

FIGURE 58

6. FINDING:

FREQUENT INTERRUPTIONS AND FAILURES HAD BEEN EXPERIENCED IN THE OVERALL COMMUNICATION SYSTEM DURING THE OPERATIONS PRECEDING THE ACCIDENT.

FIGURE 59

DETERMINATION:

THE OVERALL COMMUNICATION SYSTEM WAS UNSATISFACTORY.

FIGURE 60

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.

FIGURE 61

7. FINDING:

A. REVISIONS TO THE OPERATIONAL CHECKOUT PROCEDURE FOR THE TEST WERE ISSUED AT 5:30 PM EST JANUARY 26, 1967 (209 PAGES) AND 10:00 AM EST JANUARY 27, 1967 (4 PAGES).

B. DIFFERENCES EXISTED BETWEEN THE GROUND TEST PROCEDURES AND THE IN-FLIGHT CHECK LISTS.

FIGURE 62

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.

FIGURE 63

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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 ORGANIZATIONS.

B. TIMELY DISTRIBUTION OF TEST PROCEDURES AND MAJOR CHANGES BE MADE A CONSTRAINT TO THE BEGINNING OF ANY TEST.

FIGURE 64

8. FINDING:

THE FIRE IN COMMAND MODULE 012 WAS SUBSEQUENTLY SIMULATED CLOSELY BY A TEST FIRE IN A FULL-SCALE MOCK-UP.

FIGURE 65

DETERMINATION:

FULL-SCALE MOCK-UP FIRE TESTS CAN BE USED TO GIVE A REALISTIC APPRAISAL OF FIRE RISKS IN FLIGHT-CONFIGURED SPACECRAFT.

FIGURE 66

RECOMMENDATION:

FULL-SCALE MOCK-UPS IN FLIGHT CONFIGURATION BE TESTED TO DETERMINE THE RISK OF FIRE.

FIGURE 67

9. FINDING:

THE COMMAND MODULE ENVIRONMENTAL CONTROL SYSTEM DESIGN PROVIDES A PURE OXYGEN ATMOSPHERE.

FIGURE 68

DETERMINATION:

THIS ATMOSPHERE PRESENTS SEVERE FIRE HAZARDS IF THE AMOUNT AND LOCATION OF COMBUSTIBLES IN THE COMMAND MODULE ARE NOT RESTRICTED AND CONTROLLED.

FIGURE 69

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.

FIGURE 70

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 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.

FIGURE 71

DETERMINATION:

THESE DEFICIENCIES CREATED AN UNNECESSARILY HAZARDOUS CONDITION AND THEIR CONTINUATION WOULD IMPERIL ANY FUTURE APOLLO OPERATIONS.

FIGURE 72

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, 3-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.

FIGURE 73

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.

FIGURE 74

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.

FIGURE 75

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.

FIGURE 76

The CHAIRMAN. Are you ready to start the questioning now?
Dr. THOMPSON. Yes, sir.

BOARD HAD COMPLETE FREEDOM

The CHAIRMAN. I think in order to get around completely, we will give each person 10 minutes.

Dr. Thompson, did you feel as Chairman of the Board, that the Board has had complete freedom to carry out its responsibilities in the investigation of Apollo 204 fire?

Dr. THOMPSON. Yes, sir. I have been very much impressed with the cooperation and the candid, wholehearted support we have had from all people that we have had to ask for help from and who assisted us in this investigation.

The CHAIRMAN. Some people have been worried because this is an inside investigation, that you have not brought in a lot of outside experts. I think it has been done very well, but I just want to be sure that you, as the Chairman, were not hampered in your investigation.

Dr. THOMPSON. We certainly were not hampered in any way. We called upon the people who are most expert, most knowledgeable about this entire affair and they all cooperated in a very wholehearted manner.

The CHAIRMAN. Thank you. Do you know of any attempt by NASA or the spacecraft manufacturer to suppress any information which the Board regarded as pertinent?

Dr. THOMPSON. No, sir. Everyone, the contractor and all elements of NASA, contributed in a wholehearted manner to the requirements of this review.

The CHAIRMAN. Did the Board have adequate personnel, financing, and facilities to undertake the investigation in the depth deemed necessary?

Dr. THOMPSON. Yes, sir. There was very adequate support with a high priority. Wherever we put a demand, we got immediate and wholehearted support.

The CHAIRMAN. What is the status of the Apollo 204 Review Board? Has it completed its work? Have you disbanded or are going on for a while?

Dr. THOMPSON. Upon delivery of the report to the Administrator we are in recess subject to recall by me, the Chairman, until we are actually discharged by the Administrator. There is some unfinished business that has been referred to in investigations that I have said will not influence our findings, our opinions, as expressed here, but we do feel it necessary to wind up the affairs that will be incorporated in appendix G of the report.

The CHAIRMAN. It has been NASA's objective to design spacecraft and other hardware, and conduct operations with safety as the paramount concern. To what do you attribute the design and other deficiencies set forth in your report, which clearly indicate that the objective has not been obtained?

Dr. THOMPSON. Somehow or other in the process of the manufacture and quality control inspection, the results in certain areas that we have identified just have not come out as well as we think is actually required.

The CHAIRMAN. I think I am going to let the other members question. Senator Smith?

QUESTIONS IF DEFICIENCIES EXIST IN OTHER AREAS OF MANNED SPACECRAFT PROGRAM

Senator SMITH. Thank you, Mr. Chairman.

Dr. Thompson, the preface of the Review Board's report indicates that the report is not intended as representing a total picture of the manned spacecraft program. This is understandable since your investigation was directed toward uncovering specifics concerned with the accident. However, the Board did review NASA's management structure and the written procedures and operating practices for the Apollo program.

In light of this information, could we get your opinion as to whether the types of deficiencies disclosed for this one spacecraft may well exist in other areas of the manned spacecraft program?

Dr. THOMPSON. I think, Madam Senator, that the findings that we have may reflect certain areas that can well be improved, will require

improvement, in matters that we have remarked on, particularly in the last two findings of our report. We think that in this very complex program, not all the objectives of management or desired by management have been achieved and I think we have identified those at least in a general way, and I fully expect that the Apollo Program Office, the directors, those responsible for the direction of the Apollo program will make use of this identification that we have provided to effect certain improvements. I do think they are quite important, relative to the future program, but I do think they are perhaps things you would find in or the general kind of things that you would find in any tremendously large undertaking. Any management has problems. We have identified some and, I think, it may be quite helpful to the Program Office in their efforts to correct the problems.

Senator SMITH. But, you would say there were some deficiencies in other areas of the program similar to some you found in this one?

Dr. THOMPSON. I think any program has deficiencies. We thought that there were certain ones that we should identify here that certainly the management should direct attention to.

ASKED IF PROBLEM RELATED TO TIGHT SCHEDULES

Senator SMITH. Dr. Thompson, the Board's report points out some serious deficiencies relating to design, workmanship, quality control, and failure to complete required engineering changes. In your opinion, are these deficiencies attributable in some measure to the tight schedules used for the program in order to assure a manned lunar landing in this decade?

Dr. THOMPSON. I cannot identify anything of that sort. A program of this kind has to have a very hard drive. It has to have built-in urgency in order to keep all the people properly motivated.

The thing that we directed our attention to was the other side of this tremendous project, that is, the orderliness that is required to see that this hard drive does not disregard some of the paperwork and those things that may be overlooked if there just is not sufficient attention paid to them.

I cannot conceive of a program of this nature that would offer a tradeoff between haste and the other orderly side of it. They have to be matched. You could not tell people to slow down because we are just going too fast here. I say you have just got to put the hard drive in both sides of this picture from where I sit.

Senator SMITH. Doctor, if the hard drive that you refer to is not responsible for these irregularities and deficiencies, then what would in your opinion, be the primary or underlying reason for such errors of omission and commission discussed in the Board's report?

Dr. THOMPSON. Well, I just think somehow or other they have not quite found out how to put all that order in. It is a very demanding task. This is a tremendously big program involving hundreds of thousands of people. Even the test itself, just the head count for the test itself showed 959 people on duty doing various tasks at that time. The organization of all that effort is a difficult management task but I do not see why it cannot be accomplished.

I think that an overview of it, as we have done, will identify areas that will provide a useful guide to improvements that ought to be made.

Senator SMITH. Well, of course, Dr. Thompson, we have to know in order to be able to correct the deficiencies and this is where I hope you and your associates may be helpful to us. I think it is very necessary for us to know just exactly what brought about these deficiencies—whether it was the tight schedules, the rush or negligence or some other reason—before we can go on to make the corrections. I am sure you understand what I have in mind.

Dr. THOMPSON. I do.

REQUESTS OPINION ON MANAGEMENT DEFICIENCIES

Senator SMITH. In several sections of the report the Board addresses itself to program management deficiencies and problems in the relationship between centers and with the contractor. I think it would be helpful to the committee if you would give us your opinion as to where in NASA's management structure the major deficiency lies with respect to the failure to recognize and correct the more serious deficiencies noted in the Board's report.

Dr. THOMPSON. The problem, as I see it, is in an evolving situation where so many people are involved and the necessity for employing so many people under, say, different centers.

There are three major groups involved in this program. There is the contractor. The contractor himself has groups at his plant and at the Cape. NASA has major groups at MSC and KSC. The difficult management problem of dealing with all those working relationships and laying out the areas of responsibility so that everyone is really fully coordinated is a tremendous task, and this has been subject to change over the recent years.

I feel that is the major factor in that.

Senator SMITH. Dr. Thompson, it may not be your responsibility to identify the areas of responsibility in the agency, however, you have been so close to this accident, you and your associates have gone into so many facets of it, and you have made numerous findings that it seems to me you could come up with the basic deficiencies or the area which is basically at fault in the management of the program. I presume that is what we have to find before we can go on with any corrections.

Dr. THOMPSON. Well, we have gone to a point, I think, of identifying areas. I think that we would get a little far afield if we try to tell how to recognize it. I think that perhaps we have done about as much as is appropriate, to our knowledge, at the moment in identifying the areas that we thought required attention and I believe it is more in the area of the program office to respond to just how the problems that we have identified can be effectively dealt with in the management.

Senator SMITH. We are all in this together, Dr. Thompson, and I have supported this program since its beginning, and I am sure we all want to see our space exploration plans and programs continue, and we want to see it successful.

I would like to get on the record your own feelings about whether there is a deficiency or inefficiency in the management of the space agency. It seems to me you could not help but come through with such a complete and wonderful report as you have provided without having some personal feelings about it.

Dr. THOMPSON. Well, I am afraid that my feelings, as far as I feel qualified to comment at this time, are pretty well expressed in the report. I think that it would be better to try to reach an understanding with the program office to see whether or not these things that we have identified as problems are being solved.

Now, we did not consider ourselves a board of management experts nor did we employ management experts to try to analyze the problem in detail, so I would be a little hesitant to pull off the top of my head at this point, statements beyond what we have already stated.

The CHAIRMAN. If you will yield to me, Senator Smith. Senator Smith asked a question asking you if you will give us your opinion as to where in NASA's management structure the major deficiency lies. In Dr. Seamans' letter of instructions to you he said:

> Consider all of the factors relating to the accident, including the design, procedures, organization, and management.

We really want to know if you have thought about this management question. You have been exposed to two and a half months of it. You have done a great job. Have you not had some feeling as to what this management problem has been?

Dr. THOMPSON. I think we identified certain problems. We said there was cumbersomeness in the operations relative to the conflicting management requirements of orderliness in dealing with a dynamic program, particularly, in the operations at the Cape where the MSC, the Manned Spacecraft Center, has the major responsibility, and when the spacecraft arrives at the Cape, the execution of that responsibility falls pretty much in the hands of another group.

Now, the working out of these areas of responsibility without impairing the necessary restraints as to cost and identification—clear delineation of the effect of any changes poses some rather difficult problems and I think that there is an area in this working relationship that can be improved to meet two conflicting requirements, flexibility, and yet not license to make changes.

Now, this is a difficult thing and, I think, quite a lot of what we directed our attention to and identified, was in that area. MSC at this stage is responsible for the spacecraft and yet it is another group, through delegation of responsibility, that is working on it. I think the lines are pretty well worked out. I do not think we saw any obvious flaws in the line of authority but there seems to be a lack of flexibility.

The CHAIRMAN. Doctor, you used charts showing the wiring as not very satisfactory. I helped with the long examination of the Navy Dapartment on the *Thresher*. At one point we found what we thought was a rather improper setup.

Have you not determined as yet anything about the propriety of these management problems and the product of them?

Dr. THOMPSON. Well, we have identified, I think, certainly certain items of workmanship that we were quite dissatisfied with and this is, say, a joint responsibility of NASA—I say a joint responsibility—of course, it is NASA's responsibility to get contractors responding, but workmanship certainly impresses us as being somewhat deficient and somehow or other it got through. I do not know that we are able to identify in detail. I think the Apollo program management will have a hard look at that.

Senator SMITH. Well, Dr. Thompson, in your finding 10, you recommend that—

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.

NASA and the industry are pretty big organizations. It would seem to me after all the efforts you have made that there would be some way for you and your people, with their variety of experience and background, could pinpoint the responsibility of either the positions or the levels where the problems exist.

Dr. THOMPSON. Well, I think we have identified, in our report, that there were certain processes that went ahead with more or less informal understandings rather than documented understandings. In a program as demanding as this, a certain amount of that is necessary. The remarks that we addressed ourselves to in that case were related to the fact that there seem to be rather too much informal understanding between the people involved at the time of the test rather than giving us the assurance that the written instructions required for all these people who are involved had been distributed to them long enough in advance, so that we are certain that everyone understood fully what the test group was doing. And, it is in this area where we felt that more attention to the, what I would call the orderliness of the project would be appropriate.

Senator SMITH. Well, Dr. Thompson, continuing with your finding 10, part D states:

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

Now, someone has to be responsible for that. I do not mean the individual involved, but some organizational unit must be specifically responsible for this work and do you mean to tell us that you cannot identify that area where the responsibility lies?

Dr. THOMPSON. Well——

REQUESTS STATEMENT OUTLINING PROBLEMS

Senator SMITH. Or if you could give us a statement on what has to be done to define those areas.

Dr. THOMPSON. The Apollo program office is organized in such a way as to attempt to deal with this. One of the members of the board is from the quality assurance area of responsibility, Mr. George White. I do not know whether he wants to comment on that.

Mr. WHITE. Yes, I would like to address myself to that question. The wiring problems that we have found in our investigation——

Senator SMITH. Will you identify yourself.

Mr. WHITE. I am George White, director of reliability and quality in the Apollo program office in Washington. These wiring deficiencies stem originally from a lack of adequate engineering information being passed on to the manufacturing people which in turn, means that in the inspection operation, rather than having the hardware compared with the engineering drawings and engineering requirements, it is compared with the inspector's knowledge of accepted practice.

Now, this sometimes leaves sort of a qualitative approach to things and there is not a firm set of criteria against which the inspector can judge.

The original responsibility here, of course, lies with the contractor, but NASA has inspectors on the spot who double check the contractor's inspection operation and, therefore, NASA must accept responsibility here, along with the contractor. In fact, the ultimate responsibility obviously is NASA's.

Does that answer your question on that, Senator?

Senator SMITH. Well, not wholly, no. Dr. Thompson said a few moments ago that he did not think he could come out from the top of his head with an opinion. I wonder, Doctor, if you would be willing to give this some specific thought. You know what I am after, and then give this committee the benefit of your thinking on it. I think we are relying a great deal on you and your associates and I personally will appreciate it if you can give me the benefit of your own personal thinking.

Dr. THOMPSON. Let me add one more thought to this. In my statement I pointed out that we had looked at the Block I design. Now, some of these deficiencies, particularly the wiring which has been the cause of great concern, we understand has been greatly improved in the Block II design. It has been recognized in the manufacturing process by the program office and the contractor and we have not examined—we have not looked over the Block II design, but our understanding is that this important question has been dealt with in an effective manner in the Block II design. So, in other words, it is a recognized problem that is being dealt with.

Senator SMITH. But, Block I spacecraft was to be flown by man, was it not?

Dr. THOMPSON. Sure, 012.

Senator SMITH. Should it not have been just as important before this happened as it is now?

Dr. THOMPSON. You are correct. Number 012 was a Block I spacecraft and that was the one that was to be flown.

Senator SMITH. What I am trying to get is, where the error was, where we slipped up in not having or taking every precaution before we had that test. I do not see why we would not have precautions in testing before flight.

Dr. THOMPSON. Well, I guess it is a matter of judgment that was made relative to that flight. Maybe I had better ask Colonel Borman. He was going to fly in a Block I spacecraft and he was prepared to go although knowing right much about this. I think we had better let him comment on that.

Colonel BORMAN. Yes. I think, Senator, we were very aware of the problem of fire in flight and we had adopted procedures primarily of venting the command module to a vacuum to eliminate the fire. We had done an extensive study on this before our Gemini 7 flight. However, I think that none of us were fully aware of the hazard that existed when you combine a pure oxygen atmosphere with the extensive distribution of combustibles and the likely source of ignition, and so this test, as I mentioned briefly during the findings and determinations, was not classified as hazardous.

I did not consider it as hazardous. I do not believe that anyone within the test organization or the program office considered it hazardous. And, this is the unfortunate trap through which we fell.

Senator SMITH. Well, Colonel, were you aware of the electrical deficiencies before you were appointed to the board?

Colonel BORMAN. Yes, Ma'am.

Senator SMITH. Mr. Chairman, I have other questions that I am quite anxious to ask, but if you would like to go around and then come back to me.

(The material referred to above follows:)

In my opinion, the overall organization structure of the Apollo program, both Government and Contractor, is sound. What I, personally, and the other Board members were concerned about were the procurement/inspection/checkout/acceptance processes of Apollo spacecraft at lower levels of management. I felt that this was a weakness within the structure that should be looked into by the top management of NASA. The accomplishment of this objective must face the difficulties of dealing with the dynamic requirements of a fast moving program. When you consider that two NASA Centers, Manned Spacecraft Center and Kennedy Spacecraft Center, and two Contractor facilities, North American Aviation, Downey and North American Aviation, Florida facility must, of necessity, coordinate the total effort, it is not difficult to discover areas where the administrative, engineering and operational procedures may show defects.

The Board described the management and organization of the Apollo program in Appendix E of its report to the Administrator, NASA. In its report, the Board set out in considerable detail the management and responsibility levels. However, no attempt was made to ascertain the actual working relationships as they currently exist between the various management levels. The Board did not consider itself to be charged with the responsibility of management analysis. Furthermore, if it had, the investigation would have taken several more months.

If any management level is to be charged with the failure to recognize and correct the deficiencies noted in the Board's report, it would be the design and layout engineering level. I pointed out in my testimony and it is a matter of record that the Board and I were seriously concerned with the electrical wiring and soldered joints. I specified the material to you in my testimony and referred you to page 6 of Appendix D–9 of the Report. I believe that when the wiring and plumbing joint problem is solved by the Apollo Program Office, coupled with the recommended reduction of flammable material, the reliability of the Apollo spacecraft will be increased to an acceptable level not only for safety, but for mission success.

The CHAIRMAN. Thank you.

Senator Cannon?

Senator CANNON. Thank you, Mr. Chairman.

RELATIONSHIP OF BOARD MEMBERS TO NASA

Doctor, I would like to review for a few moments with you the relationship of the various members of the Board to NASA—and I am not doing this from a critical standpoint—but I think it is well to know exactly what the relationship is.

Would you start with yourself and tell us what your relationship is to NASA and what it has been for the past several years.

Dr. THOMPSON. I am Director of the Langley Research Center of NASA. Our area of effort is in the research field. We report into headquarters through what is called the Office of Advanced Research and Technology. We do not have any direct connection with the Apollo program except in a supporting role as providing technology relative to this. This is technology developed by our research programs.

Now ——

Senator CANNON. And you have been with NASA yourself ever since NASA was first formed, have you not?

Dr. THOMPSON. Yes, sir. I have been ——

Senator CANNON. Now, as I understand it, if you consider the counsel not to be a member of the Board, six of the eight members are assigned to NASA and are employed by them, perhaps with the tech-

nical exception of Colonel Borman, who is assigned to them but is actually employed by the Air Force, I presume. Is that correct?

Dr. THOMPSON. Yes, sir.

Senator CANNON. And, what is Dr. Faget's relationship to NASA?

Dr. THOMPSON. Dr. Faget, will you describe your position at MSC, Manned Spacecraft Center.

Dr. FAGET. Yes. I am the Director of Engineering and Development.

The CHAIRMAN. I cannot hear you.

Dr. FAGET. I am the Director of Engineering and Development at Manned Spacecraft Center.

Senator CANNON. Does that mean that you had the responsibility for the general program of engineering and development for NASA?

Dr. FAGET. I have the general responsibility for providing engineering and development work as related to manned spacecraft; yes, sir.

Senator CANNON. And that included the capsule in this particular instance?

Dr. FAGET. That includes——

Senator CANNON. In the Apollo program?

Dr. FAGET. That includes all of the manned spacecraft program and Apollo as well, certainly.

Senator CANNON. And have you been with NASA since its inception?

Dr. FAGET. Yes, sir. I, like Dr. Thompson, was with NACA and have been with NASA since its inception.

Senator CANNON. Now, what about Mr. Geer?

Mr. GEER. I am E. Barton Geer. I am at the Langley Research Center and I am in engineering and design of flight vehicles and systems at Langley.

Senator CANNON. Now, is that completely disassociated with the space systems?

Mr. GEER. Yes. Manned space system; yes.

Senator CANNON. But, you are employed by NASA and have been for some period of time in your present assignment.

Mr. GEER. Yes, sir.

Senator CANNON. Dr. Thompson, were you ——

Dr. THOMPSON. I was trying to say he is one of my employees in one of the divisions at Langley.

Senator CANNON. And, Dr. Van Dolah, of course, is not connected with NASA, as I understand it, except as a member of this Board, and perhaps has assisted in advice on previous occasions.

Dr. VAN DOLAH. That is correct.

Senator CANNON. Colonel Strang, of course, is an Air Force officer and assigned to the IG Division out at Norton, is that correct?

Colonel STRANG. Yes, sir. Located at Norton, but under the Inspector General, Air, Washington.

Senator CANNON. And, you have no relationship to NASA as such, except as a member of the Board?

Colonel STRANG. Absolutely not.

Senator CANNON. What about Mr. White?

Mr. WHITE. I am director of reliability and quality in the Apollo program office here in Washington and in that position I am on the

staff of General Phillips. He has five divisions in his organization which are "Operations, Test, Program Control, Systems Engineering, and Reliability and Quality." I am director of the reliability and quality division.

Senator CANNON. Would you say the matters involved here relate directly to reliability and quality in this particular instance?

Mr. WHITE. Yes, sir.

Senator CANNON. So, any finding of the Board, any adverse finding would reflect adversely on your office, would it not?

Mr. WHITE. I believe that is right.

Senator CANNON. And, what about Mr. John Williams?

Mr. WILLIAMS. I am director of the manned spacecraft operations at Kennedy Space Center.

Senator CANNON. How long have you been in that position, Mr. Williams?

Mr. WILLIAMS. I joined NASA in 1959.

Senator CANNON. You have been with NASA since its inception up to the present time?

Mr. WILLIAMS. Essentially since its inception.

Senator CANNON. And, you were directly related to the particular program here, is that correct?

Mr. WILLIAMS. Yes, sir.

Senator CANNON. And, Mr. Malley, while I presume he was not a member of the Board, he also is an employee of NASA and——

Dr. THOMPSON. At Langley. Chief counsel at Langley.

Senator CANNON. Getting back to Mr. Williams, you are directly involved in the spacecraft program and the operational program of the Apollo program, is that correct?

Mr. WILLIAMS. Yes.

Senator CANNON. Dr. Thompson, do you think the fact that six of the eight members of the Board are directly employed by or related to NASA would in any way tend to have the Board less critical of the actions that have been reviewed here than if it were an objective board from some other source? And, I am not saying that in a critical vein because I realize that to get people from the outside that are familiar with what is going on would be extremely difficult.

Dr. THOMPSON. Well, I feel that the people that I have had working on this Board have been very effective even to the point that Mr. George White perhaps criticized himself. Now, just what some other people would have done, I do not know. They could have been critical, I say—without knowing how to respond I do not believe I can tell that, but these people certainly have responded in a very effective manner and as you point out, they are knowledgeable which was a basic element of consideration, because we had to tie onto an existing system, a very complex system to pursue our review. So that I do not think our task suffered from the fact they were associated with it but I know it benefited very greatly because they were.

Senator CANNON. Now, you pointed out correctly, that they were critical but I am wondering if they might tend to be—the point I am concerned about is might they tend to be less critical than if they were from some other source?

Dr. THOMPSON. Well, I cannot tell, because I do not know who the other people would be.

DEFICIENCIES NOTED IN DESIGN REVIEW

Senator CANNON. Doctor, the report of the Apollo Review Board, Design Review Panel 9, states that independent design reviews were made by NASA and North American personnel during which numerous design deficiencies were noted. Now, I would like to ask you if that was the first design review that was ever made of the block I spacecraft by NASA personnel.

Mr. WHITE. The answer to that is "No," that there have been many design reviews conducted in the normal course of the program. Preliminary design reviews early in the design stage, and a critical design review when design is completed. There is a design certification review which had been completed on this spacecraft which is performed prior to every major change in the design of any particular element of the program.

For example, in this case, it was the first manned spacecraft, so we had a design certification review that was conducted by Dr. George Mueller and his Management Council, composed of the directors of the three centers involved. So, there had been numerous design reviews in the normal course of the program. This is our standard policy.

Senator CANNON. Why would you say that these design deficiencies were not noted previously, then, in these many design reviews?

Mr. WHITE. I believe probably the most significant thing here is that the deficiencies that we have found, particularly in the wiring installation, are detailed types of deficiencies concerned with routing and inadequate clearances and inadequate protection of wiring, which may not have actually been gone into. Design reviews have been devoted primarily to the more broad questions of design of subsystems, and capability of subsystems to do their jobs. And, in this sense perhaps the design review did miss some of these fine details which turned out to be very important.

Senator CANNON. Are you in effect, saying that nobody envisioned that you might have a fire and, therefore, you were looking at other things? Is that an oversimplification of it?

Mr. WHITE. Not exactly that, although the end result turned out to be that, yes.

PRESSURE DUMPING SYSTEM

Senator CANNON. Getting back to the technical part of this process—I would like to ask Colonel Borman—it has been stated here that the module could not be opened because of the pressures that built up. There is a pressure dumping system as was explained and I would like to ask you from your standpoint as a pilot, and as an operator, is that a quick release-type system that would be adequate for rapid dumping?

Colonel BORMAN. The system was not sufficient to dump the rapid build up of pressure that we experienced in this fire, sir. There was one dump valve, primarily designed for use again on orbit to expose the spacecraft interior to a vacuum. It was not adequate in the accident.

Senator CANNON. And, will that be one of the items that will have to be redesigned for a rapid dumping system?

Colonel BORMAN. In my opinion, yes, sir.

Senator CANNON. Now, Dr. Thompson, on page 8 of your statement, you say the majority of tests and analyses have been completed. The tests remaining to be completed will not affect the conclusions arrived at in the report.

If they will not affect the conclusions, why are you conducting other tests?

Dr. THOMPSON. We started a series of tests. The Board sponsored certain tests to pursue its review and those tests were not all completed at the time we considered that we had enough information to draw our conclusions from them.

However, the information being developed by those tests seems to be of sufficient interest so that we would like to have those tests completed and put into our final report in appendix G. So, they will have benefit to the future, although we do not depend on them for our determination at this time. They are technical matters that we thought ought to be completed.

Senator CANNON. And, may eventually affect redesign of the capsule in some other particulars.

Dr. THOMPSON. They will be useful in the future for those who are going to carry out the program and perhaps relative to redesign.

DISCUSSES WIRING CONDITIONS

Senator CANNON. Now, in your statement, you identified the conditions that led to the disaster and I would like you to explain, if you will, the third one where you say vulnerable wiring carrying spacecraft power. Do you relate there to wiring that is vulnerable under fire conditions or otherwise vulnerable wire?

Dr. THOMPSON. The vulnerable wire I think, was pretty well explained by the discussion here. I will interpret it this way: That there were certain wire bundles that were subject apparently to pressures that can ultimately result in failure of the insulation. Now, this insulation is very good from the fire standpoint. But, I believe it was noted that it has a characteristic for cold flow.

The cold flow that we referred to can be important if a wire bundle carrying power, presses on a sharp edge so that there is a fairly high amount of pressure on a point and it can be that under continual pressure it will break through, cut through insulation and make a short or fire. When wires with this type of insulation are installed, it is very important to see that their good characteristics are not offset by some disregard for this characteristic; and this is one of the principal things that we had in mind.

Senator CANNON. That is a well-known feature. That was known to you long before NASA was ever organized when you were related with its predecessor. Why is this matter found to be of particular importance at this point, when it is well known in the trade and has been for many years?

Dr. THOMPSON. The characteristics of this particular insulation, which is a new one, relatively new in the field, because of its fire resistance, is important. This particular type of insulation is very good from a flammability standpoint, but it does have this other characteristic that requires additional care in utilization of it.

RUSSIANS USE NITROGEN AND OXYGEN

Senator CANNON. Now, in your reference to the use of a, you call it a diluent gas——

Dr. THOMPSON. Yes, sir.

Senator CANNON. I would like to ask what is the Russian system? What do the Russians use?

Dr. THOMPSON. Col. Borman knows perhaps as much about that as anybody.

Colonel BORMAN. The Russians, to the best of my knowledge, sir, use a 14.7-pounds-per-square-inch atmosphere with essentially air. Nitrogen and oxygen.

Senator CANNON. Did they use that throughout the flight or just for ground?

Colonel BORMAN. No, sir. I believe they use it throughout the flight. This is based on discussions that I have had with Russian engineers when you and I met in Las Vegas the last time I saw you.

QUESTIONS NEED FOR TWO-GAS SYSTEM

Senator CANNON. And is the consideration now that we may go to diluent gas system on the ground and then to a pure oxygen system airborne? Is that what is now being considered?

Colonel BORMAN. Sir, I have, if I may, at least two hats when I testify. One as a Board member and one as a crewmember. I would like to answer that in my capacity as a crewmember, if you will.

Senator CANNON. Fine.

Colonel BORMAN. It would be my hope that the approach we take would be to remove the flammables from the spacecraft interior. Oxygen per se is not dangerous. It requires an ignition source, combustible materials and, of course, in an oxygen atmosphere you have a severely hazardous situation.

I would hope that we are able to remove enough of the combustibles, and to strategically locate those that remain, so that we can continue to use a hundred percent oxygen atmosphere.

The use of a two-gas system on the pad and then the resultant requirement to purge upon reaching operational altitude in my mind is very undesirable. This means that you would have to expose a command module to a vacuum almost immediately after insertion into orbit unless you were willing to stay in your suits for 4 to 5 days while the normal leakage bleeds off the nitrogen.

So I would hope that the management can find ways to remove—to replace many of the combustible materials, to strategically locate the others, and then to test the reconfigured spacecraft with a full-scale mockup such as we have recommended; and to prove that in this 16.7-pounds-per-square-inch oxygen with the new materials, regardless of where we might have an ignition source, we will not have the disaster that we had at Cape Kennedy.

CREW IS FINAL REVIEW BOARD ON MAKING FLIGHT

Senator CANNON. Now, is your judgment in that regard affected in any way by the time schedule in the Apollo program, the fact that if we went to a two-gas system it might delay the objective of the program?