APOLLO ACCIDENT

HEARINGS

BEFORE THE

COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES UNITED STATES SENATE

NINETIETH CONGRESS

FIRST SESSION

TO HEAR OFFICIALS OF NORTH AMERICAN AVIATION, INC., PRIME CONTRACTOR TO NASA IN THE APOLLO PROGRAM

MAY 4, 1967

PART 5

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APOLLO ACCIDENT

THURSDAY, MAY 4, 1967

U.S. SENATE,
COMMITTEE ON AERONAUTICAL
AND SPACE SCIENCES,
Washington, D.C.

The committee met, pursuant to recess, at 2:30 p.m., in room 235, Old Senate Office Building, Senator Clinton P. Anderson (chairman) presiding.

Present: Senators Anderson, Symington, Stennis, Young, Cannon, Holland, Mondale, Smith, Curtis, Jordan, Brooke, and Percy.

Also present: James J. Gehrig, staff director; Everard H. Smith, Jr., Dr. Glen P. Wilson, Craig Voorhees, and William Parker, professional staff members; Sam Bouchard, assistant chief clerk; Donald H. Brennan, research assistant; and Mary Rita Robbins, clerical assistant.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. The committee will come to order.

The committee is meeting today to continue its review of the Apollo 204 accident on January 27, 1967, that took the lives of three astronauts at the Kennedy Space Center. Our principal witness today is Mr. J. L. Atwood, President and Chairman of the Board of North American Aviation, Inc., prime contractor to the National Aeronautics and Space Administration for the Apollo spacecraft, the service module, the S–II stage, and the F–1 and J–2 engines.

The committee has previously heard from the Apollo 204 Review Board of which Dr. Floyd Thompson, Director of the NASA Langley Research Center, is Chairman; and Mr. Webb, Administrator of NASA; his deputy, Dr. Seamans; and other NASA officials.

In view of the extensive involvement of North American Aviation in the Apollo program and its prime responsibility for the spacecraft, the Committee decided that it should ask Mr. Atwood to appear and present his views on:

(1) the report of the Apollo 204 Review Board.

(2) the role and responsibilities of North American in the design, engineering and testing of the Apollo spacecraft; and

(3) what actions North American has taken or plans to take with respect to its management, design, workmanship and quality control of the Apollo spacecraft.

Mr. Atwood, you may proceed.

STATEMENT OF J. L. ATWOOD, PRESIDENT OF NORTH AMERICAN AVIATION, INC., ACCOMPANIED BY DALE D. MYERS, VICE PRESIDENT OF THE SPACE DIVISION

Mr. ATWOOD. Thank you, Mr. Chairman. I am J. L. Atwood and I am president and chairman of North American Aviation. I am accompanied by Dale D. Myers, who is a vice president of the space division and program manager of the Apollo command and service modules and the spacecraft lunar module adapter. After my statement, Mr. Myers will assist me in answering questions.

I wish to assure the committee of North American's complete cooperation in your inquiry.

North American has cooperated fully with the Apollo 204 Review Board. Since its report was made public on April 9, we have had time to study it and believe it represents a professional and thorough investigation. North American's comments on the Board's findings have been incorporated in a memorandum, copies of which have already been made available to this committee.

We share the responsibility. We do urge, however, that the deficiencies cited in the Board report, whether directed to North American or NASA be viewed in the perspective of the standards involved. In assessing the findings, it must be recognized that in space work the standards are and must be extremely high. Literally, perfection is the goal. Not only do we accept these standards, we have in many areas led the way in establishing them. We are resolved to exert every effort to meet them in every particular.

NEW HATCH WILL OPEN IN FIVE SECONDS

North American has been devoting extensive technical and management effort, in close cooperation with NASA, to develop appropriate changes in the spacecraft and the related test procedures. While this work is not finished, and final determinations must be made by NASA, we will mention a few of these changes. One is the design of a new outward opening command module hatch which will open in less than five seconds. We have already manufactured a working model of this hatch and its design is being proven.

The method of manufacture and installation of wiring and tubing in the Block II spacecraft included substantial improvements over that in Block I. We are now providing for additional protection for both the wiring and the tubing in the form of metal covers and protection of joints. The use of a three-dimensional jig in the fabrication of wire harnesses for the Block II spacecraft had been previously implemented and has substantially aided in the installation of wire harnesses in the Block II spacecraft.

As to the amount and location of nonmetallic materials in the spacecraft, we are working with NASA to expand the methods of testing of materials at a component and subsystem level as they are configured for installation in the spacecraft. We fully support the recommendation of the Board that full-scale mock-up fire tests be conducted.

These changes are important but should not cause us to lose sight of the remarkable progress which has been made to date in what

the Board called the "most complex research and development program ever undertaken." The Board made it clear that its report was not intended to present a total picture of that program. The Board expressed its concern that the report might be interpreted as a criticism of the entire manned space flight program and of the many people associated with it. I share that concern. North American believes it would be a disservice to the many thousands of dedicated people who have contributed to this complex project not to remind the committee of the accomplishments which have been achieved. It should not be forgotten that a great part of the effort on this program has already been completed. I have confidence that these accomplishments form a solid basis for moving forward to successful completion of the program.

13 SUCCESSFUL TEST LAUNCHES

Among these accomplishments have been 13 test launches, all of which have been completed successfully. They included two launches of unmanned spacecraft using S–IB launch vehicles. These tests, together with various ground tests, have proved the soundness of the basic design through demonstration of:

The spacecraft structural integrity;

The launch escape system;

The earth-landing system;

The ability of the heat shields to withstand the reentry environment; and

The integration of these and other sophisticated systems in the spacecraft.

In addition, two manned tests of the environmental control system have verified the capability of that system under simulated spaceflight conditions including a period in excess of that expected in a lunar mission.

I would like to add that North American's other efforts in the Apollo Program are proceeding satisfactorily. Tests of the Saturn II vehicle have confirmed the design and integrity of the structure. Both the F–1 and J–2 engines have been fully qualified. The J–2 engine has performed perfectly in three flights of the Saturn IB launch vehicle, and has been successfully cluster-fired for full durations in ground tests of the Saturn S–II stage. The F–1 engines have been successfully fired in clusters, and are ready for the first flight of the Saturn V vehicle.

While there have indeed been accomplishments which should not be overshadowed in reaching an objective assessment of the program, there have also been problems. There have been technical problems as well as managerial problems.

Toward the end of 1965 program conditions, as they then existed, reflected the fact that the mission criteria had been evolving toward their final form. Until these criteria became stabilized it was extremely difficult to achieve full control and visibility of North American's basic design and development effort. At the same time, we had been going through a rapid buildup in manpower. These conditions were important factors affecting our ability to put to most efficient use our capabilities. It must be recognized that problems of this kind are encountered in almost all large, complex developmental programs.

TASK FORCE HEADED BY GENERAL PHILLIPS

It was about this time when these problems were reaching their peak that Dr. Mueller discussed with me the desirability of NASA organizing a team to take a hard look at North American's operations, I was very glad to accept his suggestion.

Shortly thereafter, a task force headed by General Phillips did conduct a survey. General Phillips and his task force briefed me and my associates in December 1965 on his findings and recommendations. Between December 1965 and April 1966 North American took appropriate action where we felt that the result would improve management and program performance. In April the task force reviewed our progress and expressed general satisfaction with it.

An inherent part of a developmental program is problem solving. As we recognize problems we devote our best resources and skills to their solution. More important, we try to anticipate problems which might arise and to take preventive action. I cannot say that there will not continue to be some problems as we go forward. But I am confident that we have the capability and the dedication to successfully meet such contingencies.

While I believe the Apollo program stands on a strong foundation and that much has been accomplished, we have recognized that because the program is a complex one it requires constant attention and a balancing of the management skills as it moves into various phases.

I believe that there are gathered within North American outstanding resources and skills for carrying out large systems programs. Coupled with this capability is a team of excellent subcontractors which represents a fine body of technical and management competence. We have recognized that we must draw from all the resources available to the company those capabilities which can best match the needs of the program.

In addition we have frequently drawn on special abilities and skills which may be found outside the company and will do so in the future. I am confident that we can direct these skills and resources, as we have on other complex programs which North American has successfully performed, to meet the current and future challenges of the Apollo program.

MANAGEMENT AND ORGANIZATIONAL CHANGES

Based on a careful review of all of our program operations, we are making a number of management and organizational changes. These changes are designed to strengthen the application of skills which are required to move the program forward and to meet the challenges of the requirements ahead. Among these actions are the designation of a new president and a new executive vice president of our space division who are both men with the experience and skills especially required at this time. Other key organizational alinements and appointments are also being made or planned. These changes will lend further strength to the program.

In addition to the actions which we are taking within North American, there have been discussions between the Administrator and myself concerning the overall working relationships between North

American and NASA. These discussions have been held in the light of independent and frank examinations by North American and NASA of their own operations, procedures and requirements. The areas which we have been reviewing include: the means by which improved visibility of the management effectiveness and program control will be available to both North American and NASA on a coordinated basis: the establishment of clearer and more specific objectives and measurement techniques with respect to program performance; greater use of periodic surveys and audits of program progress and performance by competent review teams; use of sharper incentives and penalties in contract relationships to focus maximum attention on those aspects of the program which are key to its successful execution.

North American is determined, in concert with NASA, to take every step required to move the program forward successfully. I believe we have a firm basis on which to build future success, and I am confident that we can effectively accomplish the lunar mission in this decade.

Before concluding, I want to say all of us at North American have felt a very sharp sense of grief over the loss of the three American astronauts, in the tragedy of the 204 accident. Many of us viewed them not only as professional colleagues but as personal friends.

It was a terrible shock to us all.

The CHAIRMAN. Mr. Atwood, a great many people are asking what will the reorganization of your company do. Will you explain why you brought Mr. Bergen in at this time?

Mr. ATWOOD. Mr. Bergen—I am sorry, Mr. Chairman. I must have missed a word.

The CHAIRMAN. I am trying to find out why you turned to the Martin Company for this capability.

Mr. ATWOOD. He resigned from the Martin Company before we had discussed employing him at North American. But I have known him long and favorably. And when I approached him, he was interested in coming with the company. We worked out a satisfactory employment arrangement, and he is now with us.

NORTH AMERICAN COMMENTS ON REVIEW BOARD FINDINGS

The CHAIRMAN. In your statement you say that the Apollo 204 Review Board's report "represents a professional and thorough investigation." Does North American Aviation generally concur on the findings, determinations, and recommendations of the Board?

Mr. ATWOOD. Did you say do we concur with the findings and recommendations? Generally concur, yes, sir.

The CHAIRMAN. Do you disagree with any specific finding or recommendation or determination?

Mr. ATWOOD. We have submitted to this committee a detailed discussion of our views on the findings. We generally concur. I believe I would ask Mr. Myers to point out anything he thinks might be covered.

The CHAIRMAN. Mr. Myers.

Mr. MYERS. There are in our memo in answer to the summary report that was submitted to the House Committee, some specifics within

the report where we disagreed with the amount of emphasis that was put on particular parts of the report. We disagreed at that time with the word "chronic" leakage of solder joints. We disagreed with, I think, the general need in terms of the value of a vibration test of an all-up spacecraft. The panel report was very specific in pointing out the differences in philosophy as to the need for vibration testing of an all-up spacecraft. The final Board report recommended that an all-up spacecraft be vibrated. And we felt that the amount that you get out of such a test has some question as to the amount of money that has to go into such a test. In other words, it is a very expensive test to bring off, and we think there is some question as to the value that you get out of those results.

The CHAIRMAN. In your statement, you mention a memorandum of North American's comments on the Board's findings. This, as I understand it was prepared for the subcommittee on NASA oversight of the House Committee on Science and Astronautics. Will you submit a similar memorandum for the record of this hearing, giving the views of North American Aviation on each of the Apollo 204 Review Board's findings?

Mr. ATWOOD. We have already filed it with your staff, Mr. Chairman.

The CHAIRMAN. Thank you.

(The memorandum referred to appears on page 452.)

The CHAIRMAN. You state that the standards of space work are and must be extremely high and perfection must be the goal.

I would like you to speak as to why it apparently was not achieved.

CONTINUOUS EFFORT TOWARD GOAL OF PERFECTION

Mr. MYERS. Could I speak to that?

I think all through the program, Mr. Chairman, there has been a continuous effort on the part of NASA and North American to reach toward this goal of perfection. The many programs that are introduced into the activities for motivation of the employees are evidence of the attempts on the part of North American and NASA to further improve all activities that are involved in reaching for this goal.

The "PRIDE" Program developed by North American has been used, I think, quite effectively in motivating people towards this goal. There have been other programs in the country. Subcontractors, for example—many of them have used the Zero Defects Program as a goal for their people to shoot for.

In this striving for perfection. there are also many elements of the program that from the initiation of the program NASA brought into their methods and operating procedures which have been incorporated in our plans and have been expressed through our subcontractors as extra means of defending, cross-checking, double-checking, that we have in fact done the best that every human being can do in reaching for this goal.

I think that the typical examples of this are the techniques used by North American in fabrication and the assembly—fabrication and inspection requirements, documentation, that takes the engineering

drawing and describes in detail for the process of fabrication and inspection all of the steps that the personnel must go through in this particular application.

For example, we define in these documents any special materials that are to be used. We define whether that material must be traceable or not, and many, of course, of our materials are traceable back to the original source, so that we can follow up on problems, and determine the cause of any particular problem that may show up.

We define the requirements for the type of person that will be used for the fabrication process.

We have a very extensive training program that involves the qualification of people through a training course for a particular process or assembly technique. And these people are called out on this manufacturing requirement when it is necessary in critical cases to have a man that has had specific training in a particular area—called out on this document.

We work with our inspection people in defining the points of inspection that will be used during the fabrication process.

All these things are pre-planned to give us the ability from a management point of view as to what is being accomplished in a particular fabrication process. And because of our preplanning, it brings qualified and trained people into those processes that are used.

I find another example of our reach for perfection is in the process of soldering wires. Early in the program we defined with NASA the detailed specifications required for wire soldering in the Apollo program. I believe you will find that those criteria requirements are far beyond those that have been used in past programs. And in the definition of those requirements to the worker that is actually going to be doing the work, we prepared a very fine manual that described to the workman in photographic form a good solder joint compared to a bad solder joint, and described in detail to him the techniques that he should use in soldering wire.

That particular manual that was developed for that purpose has been used extensively throughout North American and its subcontractors, and has been brought by NASA into some of their other activities in the program. We think it is one of the examples of this continued reach for perfection.

The CHAIRMAN. I want to give members of the committee an opportunity to question extensively. I may have more questions later.

Senator Smith.

STAFF MEMORANDUM ON GENERAL ELECTRIC REPORT

Senator SMITH. Thank you, Mr. Chairman.

Mr. Atwood, an article in yesterday's New York Times by John Nobel Wilfred states that last month the General Electric Co. submitted a confidential report to NASA on the Apollo spacecraft. Apparently there are some significant omissions in this press article. And to make the record clear on the GE report, Mr. Chairman, I would like to insert in the record a staff memorandum evaluating General Electric's effort which led to its report.

The CHAIRMAN. Without objection, that will be done.
(The memorandum referred to follows:)

MAY 4, 1967.

Memorandum to: Senator Anderson.
From: James J. Gehrig.
Subject: General Electric Spacecraft Operations Reliability and Quality Problem Report, dated April 3, 1967.

This report was prepared by a General Electric quality and reliability group engaged in Apollo quality and reliability assessment as a part of the General Electric prime contract with NASA for integration, checkout and reliability of the spacecraft. General Electric was selected for this work on February 9, 1962, and one of its principal functions has been the design and fabrication of the automatic checkout equipment for the Apollo spacecraft, the service module and the lunar module.

The quality assessment and reliability group was established as a part of the General Electric checkout and reliability function in February 1966, and reports to the Manager of Spacecraft Operations, Kennedy Space Center. The group consists of one supervisor, nine engineers and two data clerks. This group is charged with monitoring reliability engineering activities for NASA and specifically to review, as a part of this function, failure and discrepancy reports for all spacecraft contractors on a daily basis. These contractors are North American Aviation (command and service module), Grumman (lunar module), and AC Electronics (guidance and navigation system). It is to be emphasized that this group reviews for NASA the discrepancy reports and does not perform physical inspections of equipment. The group also has a subsidiary function as an arm of the NASA Manager of Spacecraft Operations to prepare discrepant report control data for the flight readiness review for each Apollo launch.

Although this group has been functioning in the above described capacity since February 1966, all reports were previously on an informal close-working relationship basis with NASA. The April 3, 1967, report is the first formal report and the Committee staff is advised by Mr. George White, Apollo Director of Reliability and Quality, NASA Headquarters, that this report was formalized because of the increasing interest in this area. NASA has under consideration the continuation of this report on a formal basis in the future. In fact, it probably will be issued periodically. Inasmuch as this document was an internal NASA quality management report, North American Aviation was not included on the distribution list.

The material in this report primarily relates to spacecraft 017, which was scheduled to fly on the first Saturn V flight with a primary spacecraft mission to check the heat shield capability of the spacecraft on a simulated lunar return. The data, as indicated above, is that which is extracted from reports filed by the responsible contractors and NASA inspectors.

Mr. White advised that this report is a product of a formally established group assigned to monitor quality and reliability activities for NASA and that this group was not formed as a result of the accident. This approach of having an independent group review defect reports is not unusual in government-industry operations. Mr. White advised also that since this is an ongoing internal NASA function, the report was not formally released by NASA and he does not know personally how the information reached the press.

In closing, I think it is important to re-emphasize that this report which the Committee staff has reviewed is merely a recitation of discrepancies extracted from the quality defect reporting system and the status of each item so that NASA does have control of each item which is open at any point in time. General Electric has not made any physical inspection for their own part and this specific report does not contain any summary evaluations or judgments as to relative quality levels of the contractors' operations at the Kennedy Space Center.

COMMENTS ON PHILLIPS REPORT

Senator SMITH. Mr. Atwood, the summary of General Phillips' report states that by April 1966 North American had made substantial progress to correct the noted deficiencies, and that North American was also advised of certain areas where greater effort was still required.

Would you tell us what additional areas these were?

And I would ask, Mr. Chairman, if Mr. Atwood would be permitted to expand on this at his convenience, when the transcript comes back.

Mr. ATWOOD. You mean verbally, Senator Smith, at this time?

Senator SMITH. Yes. I think it would be well for you to make some statement on that.

The CHAIRMAN. Also, if you want to amplify your statement later, you can do so, for the record.

Mr. ATWOOD. I would like to speak to this. And then I would like to ask Mr. Myers to amplify my remarks on this subject.

The reference to the Phillips report is a matter of definition. I believe that General Phillips clarified this matter before your committee, and I concur with his clarification.

In the period before December 1965 we were in a rapid build-up of activity. The subsystems had all been ordered. The qualification of these subsystems has been going on at a very rapid rate. And by that I mean rather of complete torture tests of everything that went in the spacecraft were required. So that the vibration, temperature, the operating cycle, the off limit conditions, would all be simulated in accordance with specification.

At the same time, of course, we were bringing the engineering of the structure of the spacecraft, its heat shield—its entire mechanization—to a point of utilization in the first complete test spacecraft.

Now, this was a peaking period of effort in many ways. It was a period of rapid engineering action. There were changes coming from every major subsystem supplier, there were changes coming from our own fit and function activity which we follow very carefully with our engineering detailed drawings. And during that late fall, about October, we began to notice, of course, the difficulty in getting our milestone on schedules accomplished as we had hoped to do.

A little later on, Dr. Mueller phoned me and said he noticed that we were having indications of milestone slippages, problems in——

Senator SMITH. Mr. Chairman, may I interrupt right there—Mr. Atwood, what I wanted was just a brief statement at this time on the areas referred to where greater corrective effort was called for, and then the longer background statement for the record. I think that would be the interest here.

Mr. ATWOOD. You would rather we furnish the background statement in written form, Senator?

Senator SMITH. Yes, I think that would save time.

Mr. ATWOOD. Well, let me make it very brief, then.

Dr. Mueller called me and suggested that a NASA review team come to North American. I welcomed this suggestion, feeling that it would really improve communication, and it would help us to enhance our program. So they sent a series of teams in. I think there were five or six areas covered. They went through our operations of engineering, manufacturing, quality control, program control and procurement subcontracting. I believe those are the principal ones. And they gave us a briefing on their recommendations and suggestions and findings.

We reviewed—we of course went into whatever detail we could to get all the information that they had on these subjects. And then we established, from company-wide sources groups of individuals to take

the best advantage they could of these suggestions, and to make all possible improvements.

Now, we did this and worked very diligently on that. It was agreed that General Phillips and his team captains would come back in April, review the progress that was being made.

They did come back in April, and I believe General Phillips told you that he considered satisfactory progress towards the objectives was being made. And he decided that he did not have to renew his review team action at that time, but kept in touch with progress through all kinds of management reports and the usual communication data.

Senator SMITH. Mr. Atwood, I want to be sure that you provide for the record the full information as to the deficiencies that needed correction after the Phillips review. So if you will be sure that you get that into the transcript after you get it back, because that was my question, and I think the background can go along if you wish it.

(The information supplied appears on page 438.)

NORTH AMERICAN STATEMENT ON PHILLIPS REPORT

Senator SMITH. Now, Mr. Chairman, I would like to request that Mr. Atwood submit to the committee a statement of the North American Aviation Company with respect to those findings and conclusions of the Phillips report which it considers unfair and unjustified, together with its reasons for exceptions taken to these findings, and a statement as to what action it has taken with respect to those findings and conclusions it considered fair and justified.

Now, this will require a lengthy statement, Mr. Chairman. In the interests of time, and trying to help the afternoon along, I would like Mr. Atwood to make the full statement for the record. If he wants to, I would be glad to have him make just a brief statement now. But I would not want to take the time for a full statement.

The CHAIRMAN. If you would provide the committee with a full statement, Mr. Atwood; you may give such comments as you desire now, and send the full statement within a week, if you could.

Mr. ATWOOD. Senator Smith, and Mr. Chairman, we certainly will do that.

(The information submitted appears on page 438.)

DISCUSSION ON FAST OPENING HATCH

Senator SMITH. In North American's comments on the Board's findings, reference is made to the spacecraft hatch, Mr. Atwood, and I quote:

> At one point North American did propose a hatch which could be opened quickly by use of explosive charges which was intended for crew egress with parachutes prior to landing operations. This course was not followed because it was considered by NASA that the risk which would be created by an inadvertent opening of the hatch would outweigh the benefits.

Did you agree with NASA's decision at that time, that a quick opening hatch would offer more problems than benefits?

Mr. MYERS. Yes, we did.

Senator SMITH. Then apparently your position has changed.

What additional facts are at your disposal now that you did not have then?

Mr. MYERS. We had at that time a requirement for the quick opening for the egress of the astronauts during parachute descent. And in the design studies that we made with NASA at that time, it was pointed out that the explosive devices could cause debris within the cabin which could cause damage to the personnel.

At the same time, there was an analysis that indicated that there could be problems with an inadvertent deployment of the hatch in space, and the fears of that occurring, or the possibility of that occurring, led us all to agree that we should not go that way.

Senator SMITH. Would it be reasonable to suppose that NASA must also have considered using the use of a quick-opening hatch since such a hatch was used on the Gemini spacecraft?

Mr. MYERS. I am sure that considerations of this sort were given by NASA.

Senator SMITH. Would it not be fair to say that North American probably made thousands of suggestions to NASA during the course of design and development of the spacecraft?

Mr. MYERS. Yes.

Senator SMITH. Were there any suggestions made by North American that NASA did not adopt, but which you strongly felt should have been adopted for success or safety of the mission?

Mr. MYERS. There are many trade-offs that we go through with NASA in these studies. We have a continuing system engineering activity with NASA in the trade-off of various factors that deal with safety. I think there are no cases where we would disagree with the conclusions of NASA as drawn.

Mr. ATWOOD. Senator, I could only add that I feel that if there is any fundamental disagreement, I have not heard about it, and we would have made some representations. I did not get any word of it.

Senator SMITH. What, then, is your reason for specifically noting the suggestion on the quick opening hatch? Is it because this is one of the changes being made on the basis of the Board's findings?

Mr. MYERS. It is that the Board had recommended the quick opening hatch. I think we all recognize that the technique that was used in that study is not the technique that we should be using now.

There has been with the NASA an advance in technology that has developed this single opening door, a single hatch that opens outward, and that hatch design has really come about because of the results of the tests of Spacecraft 011, where we were able to define, through flight tests, the capability of what we call passive thermal protection, where there is a gap in the ablative heat shield that blocks plasma flow in a manner which allows us then to design a hatch which becomes a one piece hatch outward opening. Without this technology from the Spacecraft 011 flight, we would have a difficult time having great confidence in that type of design.

Senator SMITH. Then the type of hatch that you originally suggested was not feasible to adopt?

Mr. MYERS. It would have been feasible with the addition of debris traps to stop any inward explosive action, we believe, but the recent

technology has helped tremendously in the design of a quick opening hatch which is compatible with the double shell construction of the Apollo Spacecraft. It is a much better design.

Senator SMITH. Thank you very much, Mr. Chairman. That is all for the present.

The CHAIRMAN. Senator Symington?

Senator SYMINGTON. Thank you, Mr. Chairman.

I have no questions to ask Mr. Atwood at this time, Mr. Chairman. Very glad to see him.

The CHAIRMAN. Senator Jordan?

QUESTIONS ON RESPONSIBILITY

Senator JORDAN. Yes. Thank you, Mr. Chairman.

Mr. Atwood, at what point does the responsibility of the contractor cease and the responsibility of NASA take over?

Mr. ATWOOD. Senator Jordan, this is a very difficult thing to define. We design the spacecraft, and we have the design approved by NASA. Changes are jointly worked out, which are approved by NASA. And as far as the actual design of the spacecraft is concerned, I would have to say that it must be considered acceptable, insofar as design is concerned, when NASA has reviewed all the drawings, examined the spacecraft, and accepted it.

Our obligation runs pretty deep—to design in accordance with the very best techniques available to us, and the very best knowledge that we can command.

But in the design process, I believe that design, review and approval makes the design a jointly acceptable one, sir.

Senator JORDAN. Then at the time of the testing, of simulated flight, the day of the fatal accident, was it a joint responsibility of both the contractor and NASA to see that safety precautions were taken?

Mr. ATWOOD. We would consider it is a joint responsibility, and it was our responsibility really, in that we could not possibly avoid feeling responsible for detecting anything that might contribute to lack of safety. We would so conduct ourselves in reporting.

The actual testing of the spacecraft is of course not under the contractor as test conductor. We provide engineers and we provide workers to carry out continuing work in the test area. The test conductor is a NASA official.

Could you add anything to that?

Mr. MYERS. I think you, Senator, are referring to the definition of a hazardous test.

Senator JORDAN. Yes.

Mr. MYERS. I think as previously testified, we have a responsibility to define those tests which are hazardous. There were 104 different tests outlines that were included for the tests of Spacecraft 012, and 54 of them had been defined as hazardous in accordance with the criteria which is established by the NASA. We had consulted with them in the development of that criteria. That criteria as published did not cite full oxygen tests as a hazardous test. And we all are fully aware that in retrospect it should have been.

Senator JORDAN. Whose decision was it, if anyone's, that the tests on that day was not dangerous from the fire standpoint, hazardous from fire?

Mr. MYERS. Well, I guess you would have to say as a decision the fact it was not called hazardous was in effect a definition or a decision that that was not a fire hazardous condition.

Senator JORDAN. This was a joint decision?

Mr. MYERS. Well, that came from the criteria that is established in the safety criteria of the NASA range safety criteria. In other words, those criteria did not call out a full oxygen test as a hazardous test.

Senator JORDAN. So no precautions were taken by anyone inasmuch as the pre-agreed criteria did not call for fire protection in this particular test.

Mr. MYERS. I believe that is correct.

Senator JORDAN. That is all I have right now.

The CHAIRMAN. Senator Cannon?

THREE CONTRIBUTING FACTORS TO TRAGEDY

Senator CANNON. Thank you, Mr. Chairman.

Mr. Atwood, it seems to me you have put your finger on the three key things that were apparently contributing factors to this great tragedy. First, the new outward opening command module hatch, which you say you have now designed, and you have already addressed yourself to. Secondly, you say you are providing for additional protection for both the wiring and the tubing in the form of metal covers and protection of the joints. Why was this not done in the first instance?

Mr. ATWOOD. Senator Cannon, I think I will ask Mr. Myers to answer that. It is a design consideration.

Mr. MYERS. Actually, the command module for Spacecraft 012, in the Block I configuration, did at one time have wire harness channels designed into it. At the time of the design of Block I, we had the electronics equipment mounted on one side of the spacecraft, and the umbilical that leads these wires to the service module mounted on the other side of the spacecraft. As is sometimes the case in design problems, this was a necessity because we needed the weight on the one side of the command module to give us the proper lift to drag ratio for landing, and we needed the wires on the other side of the spacecraft, coming out of the spacecraft, to the booster, because that was the lee-side of the spacecraft as far as heat is concerned, and was at a lower heat level than the other side of the spacecraft.

The technology again has moved forward, and in the Block II spacecraft we have the umbilical where the wires come out of the spacecraft on the same side that the electronics equipment is.

The point I am making here is that on Block I the wires had to run from one side of the spacecraft to the other. We had, as I said, originally some protective channels for that wire to run through. With the change in the configuration of the spacecraft as it evolved, and with the additional changes that came out of our various tests, the wire runs were brought to a position where we were having difficulty running all the wires in the wire runs we had. So the decision then,

from the standpoint of the protection was that we had protective covers over the wire harnesses during the fabrication process, and after installation of the couches, the protective covers were removed because the wire harnesses were protected by the couches themselves.

The wire harnesses were also protected with teflon wrap to further decrease the amount of damage that could occur to them.

In Block II, with the umbilical on the other side of the command module, we are able to have much less wire runs in the cabin area, and are able to close off all these with metal containers for completely protected wire harnesses.

Senator CANNON. Wouldn't it have been possible to have left the covers on the wires underneath the couches?

Mr. MYERS. I think so, although I have a problem here, and I would have to get a specific answer for you.

We had fiber glass covers at that time, and there is a problem with fiber glass particles floating in the cabin. So I will have to get an answer for the record.

Senator CANNON. If you could supply that. I realize we are looking back in hindsight now, and perhaps that you had placed primary emphasis on the problem of chafing or damaging to the wire structures, rather than the thought of a possible arcing that might start a fire.

Is that correct?

Is that a fair statement?

Mr. MYERS. Well, of course the chafing protection is to keep from having the possible arcing of the wires.

(The information referred to follows:)

Originally hard fiberglass covers were to be utilized to cover certain wire harnesses in exposed areas on the Command Module floor of the Block I spacecraft. It was later determined that securing hard covers to the flexible Command Module floor presented very difficult fabrication problems. In addition, the wire harnesses, due to engineering changes, were growing in diameter and therefore the attachment points could not be located precisely. Various factors were considered in reviewing and assessing the problem. Among these were: weight considerations, conditions which would be experienced within the spacecraft during flight and the degree of protection afforded by the unitized couch. As a result of this review, the decision was made to use a substitute cover over the wire harnesses. The substituted cover on Spacecraft 012 and subsequent Block I spacecraft consisted of Teflon wrap over the harnesses. In Block II spacecraft, it is possible to use metal covers because of the relocation of wire harnesses along the sides of the Command Modules.

Senator CANNON. Now, when you make the changes here that Mr. Atwood referred to; namely, that you are providing for additional protection in the form of metal covers and protection of joints, is this going to eliminate the possibility of arcing as a hazard in the forthcoming module?

Mr. MYERS. I think it will certainly help tremendously. I think the problem that we have here is that we have got to recognize with 20 miles of wire, and the amount of work that goes on during fabrication, that there can be some time in some spacecraft another arc. The actions that are being taken by NASA and ourselves are to be absolutely sure that no arc can, in combination with the oxygen atmosphere, and in combination with the materials that we have in the spacecraft, ever cause a spreading fire or any case where any arc can

actually start a fire within the spacecraft itself. That is being accomplished by this very extensive substitution of materials that are essentially fireproof, and by major reductions in the amount of material within the cabin itself.

Senator CANNON. Now, that leads to the third point that Mr. Atwood covered. You are working with NASA to expand the methods of testing materials at a component and subsystem level as they are configured for installation in the spacecraft, and that would cover of course the amount and location of materials.

Mr. MYERS. Yes.

Senator CANNON. Does that include the experimentation with new materials that NASA demonstrated here to the Committee some time ago?

Mr. MYERS. Yes, it does.

We have a joint team of NASA and North American people at our plant right now going through all the materials that are located within the spacecraft, and identifying substitutes in terms of new materials in some cases or the elimination of some of the functions of materials previously used.

We are also combining within metal containers some of the materials so that we essentially have firebreaks between any material and any other material.

The testing is going on now mainly at NASA, and some at our plant, but a fairly extensive program with NASA and some other subcontractors, on these various materials, to the new criteria which we are all confident will eliminate the possibility of fire.

Those tests are to the level of components, or small pieces of material, and then in combination with other materials. For example, a wire bundle with Teflon wrap with Beta cloth wire ties. That is a combination of materials that will be tested to give us what I call subsystem tests.

And then finally verification and full demonstration of the lack of possibility of a fire through the total system tests that NASA will run down at Houston, where we will put all the materials together in a mockup, I guess you woud call it, and actually attempt, through instigation of possible fire sources, to see if there can be any fire.

We believe that will give us final proof that we have no fire problem.

COMMENTS ON GENERAL ELECTRIC REPORT

Senator CANNON. Mr. Atwood, Senator Smith referred to an article in the New York Times yesterday and said—requested permission to submit for the record a staff memorandum on that matter. (See p. 400.)

I would like to ask you for your comments—first, whether or not you are familiar with this so-called GE report, and, secondly, if you are, if you would give us your comments.

I am referring now to the item in the New York Times dated Wednesday, May 3, entitled "GE Study Lists Host of Serious Flaws in Apollo." And an article of similar content from the Evening Star of Wednesday, May 3, it says, "GE Report Tells of Poor Apollo Work."

Would you respond to that? Are you familiar with that report, or those articles, Mr. Atwood?

Mr. ATWOOD. Yes, Senator Cannon, I have familiarized myself in the last 24 hours of course.

General Electric does have a technical responsibility at the Cape, and they compile various data and make this sort of thing known from time to time.

The data they use are a compilation of North American inspection reports. And I would like Mr. Myers, who has had time to look into it a little more completely, to give you a little more detail.

Senator CANNON. All right.

Mr. MYERS. Well, this data—the data in the report is known to us. We have not previously received it in this form. This is part of our normal process of our feedback of quality information into our system for correction of anything that we find out of line.

So it is nothing new to us as far as detailed data is concerned. I think some of the words that are used in the report itself are worth some explanation—at least as they are reported in the newspaper articles.

There was a comment about the lack of the installation of ablative material within three holes in the command module heat shield. Since the report is written for the technical people within NASA, I think we all know those holes were previously designed for instrumentation runs in the heat shield. They are actually holes drilled through the heat shield for instrumentation, to pick up the heat of the heat shield itself during its reentry. The way it is worded it could be interpreted as if somebody had punched a hole in the heat shield or something of that sort.

The actual fact is that RTV insulation, the ablative insulation, in those small holes, drilled through the heat shield, was accomplished in the last week of December during the assembly of the heat shield—excuse me—during the assembly of the command module and service module, which was the first thing done down at the Cape.

The other actions that are called out in the report are actions which were open as of December 31. And when I say open, they are items which are reported by the Cape out of our inspection data and NASA's inspection data as what they call unsatisfactory reports.

And they can be unsatisfactory reports either in paperwork or in hardware. And those things are fed back into our system through Houston. They deal with not only North American equipment, but associated contractors equipment also.

So the Houston folks divided these various unsatisfactory reports up, and send them out to the various companies that are involved with particular equipment.

We then have a thirty-day response time to get an answer into the record for just what action we are taking to correct this unsatisfactory condition.

As I say, those action items that are listed in that report are known to us, and are either closed out now or are in work for closeout.

Senator CANNON. Now, were these items discovered independently by GE, or were they discovered from your own inspection records—your own company's records?

Mr. MYERS. Oh, they are from our own records.

Senator CANNON. They are from your own records?

Mr. MYERS. Yes.

Senator CANNON. Because it does not lead one to believe that from the newspaper article.

Mr. MYERS. Of course, as I say, we have not been receiving that type of report. It has been considered, I am sure, by NASA as an internal NASA report. And I think the NASA people are fully cognizant of the role that GE plays in gathering contractor's data for summarizing for management review purposes.

There is another part of that report that I think I should comment on.

There was a comment that there has been up to that time 1,300 discrepancy reports, a thing that NASA calls "DRs" that we use in the field, on spacecraft 017. I think it is worth noting here that after the accident North American and NASA got together to review again the inspection criteria that are used for inspection and acceptance of the spacecraft.

And we. working together with NASA, developed a much more objective inspection criteria.

The word "objective" here means to define for the inspector specific detailed standards that he can measure without being subjective. And to give you an example of that, the military standards, and background we have used in the program, have called out wire ties such that slack does not develop in a cable.

In other words, if you have a group of wires together, you want to tie the wire bundle so that you do not have pulling in the cable as it goes.

This, over a period of time, has developed as a criteria within North American to generally call for wire ties to be placed every 4 inches.

In our review with NASA, on being more objective for the inspector, as to what he ought to be measuring to, we agreed to make it on 2-inch bundles, 4 inches plus or minus a half an inch.

So he has something to measure to when he is doing his inspection.

That criterion in itself developed a certain number of these squawks which under the more general functional standards that we had had in the past were not considered detrimental at all to the performance of the spacecraft.

I think along with this we all have become maybe a little more subjective as far as inspection is concerned since the fire, too. And we are all reaching for even the details of where is a wire tied on a bundle, to have something definitive for the inspectors to use as a standard.

Senator CANNON. Well, now, when you say that these discrepancies were all known to you, that they were taken from your records, did you, at the time they became known to you, initiate corrective action on all of them?

Mr. MYERS. Yes, we had initiated corrective action on all of them.

Senator CANNON. And you say they were known to you in December, is that right?

Did I understand you correctly?

Mr. MYERS. The report actually calls out two types of information.

One is open items as of December 31, and the open items are those which we had already taken action on, but which were not closed to the satisfaction of NASA and ourselves. In fact in many cases we had submitted a report on the action we were taking, and in some

cases we did not have an agreement with the NASA, and we were back to the showers to work out more detail that would satisfy NASA that we were taking the proper action on a particular item.

The other piece of the report, are on items that had come up since December 31.

Senator CANNON. And had some of the items actually been corrected as of December 31?

Mr. MYERS. Yes, many had been corrected as of December 31.

Senator CANNON. Now, this newspaper article says—

> The reported flaws included damaged parts, corroded valves, leaky pipes, and three small holes in the capsules heat shield that the document said could have catastrophic implications during the vehicle's return through the atmosphere to a splash down.

Was it intended that that vehicle would be flown with those holes in it, in that condition?

Mr. MYERS. No; it was not intended that it be flown in that condition.

The open item that was listed there was closed the last week of December. We had corrected the open item—open item means an open item on the books that has not been worked off yet. In this particular item, which was an instrumentation hole in the heat shield, the ablative material was filled in during the last week of December.

And there was certainly no intention of flying without that.

Senator CANNON. That was filled in before this report was ever finalized, is that right?

Mr. MYERS. I believe it was.

At least before the date of that report.

Senator CANNON. Mr. Chairman, I wonder if we might ask that if they have any further comments that they would care to elaborate on for the record in response to this article or report, that could be supplied for the record?

The CHAIRMAN. I think it would be interesting if you give us a sample of some of the reports and then have an analysis of what you have done.

Senator HOLLAND. Mr. Chairman, it is not clear to me at least whether or not the General Electric report has been made available to them, or is it just an inside NASA report?

Mr. MYERS. It was made available to us yesterday.

Senator HOLLAND. Yesterday?

Mr. MYERS. Yes.

The CHAIRMAN. How could you correct them when you did not know what they were?

Mr. MYERS. Oh, no. All the data is in our system. So it is more a matter of the wording in the report that I think we would object to.

Because all the data that is in that report has come from North American records, and were a part of our normal system of corrective action.

The CHAIRMAN. We have the report here, Senator Holland. It states it was prepared from NASA and North American Company documents.

Senator HOLLAND. Mr. Chairman, I understood that we had it. I understood that NASA had it. But I also understood, both hereto-

fore and from what has been stated by the witness today, that there was an internal report of General Electric to NASA.

And the question was solely to bring out the question of the fact as to whether that report had been made available. As I understand it, it was made available yesterday to North American Aviation.

The CHAIRMAN. What happened in the meantime?

Wasn't it prepared a long time ago?

Mr. MYERS. It is my understanding it is dated December 31—April 3—excuse me.

The report is dated April 3 of this year, and apparently it is a quarterly report. But it is made up of data we already had available within our own corrective action system.

The CHAIRMAN. Is it true that the report is dated April 3, 1967, and it was not made available to your company until yesterday?

Mr. MYERS. That is my understanding.

The CHAIRMAN. You say it is an understanding.

Is there somebody who knows whether it was or was not?

What about the company?

Does the company know whether it was or was not available?

Mr. MYERS. We obtained the report from the NASA KSC personnel in the last 48 hours.

The CHAIRMAN. This report was prepared some time ago, it is dated April 3. It is an internal report as far as NASA is concerned. But should not the report have been sent to you at the time it was prepared?

Mr. ATWOOD. Mr. Chairman, may I see if I cannot explain?

The CHAIRMAN. It sounds like a very mystifying situation. If I was to say to a member of this staff, "Please give me certain documents," and a month later he said they are internal documents—I would say, "What about it?"

Mr. ATWOOD. General Electric's duty is apparently to compile this report from data obtained from the contractors at the Cape. We were one of those contractors, and they took our inspection data and wrote the report. The words and comments are theirs. The data on which the report is based are ours.

I believe that is the basis of the report. When it goes to the NASA distribution center, we would then receive from NASA appropriate extracts for our comment. And as Mr. Myers pointed out, some of the comments would go to other contractors, because they provided the equipment.

The CHAIRMAN. The comments relating to North American should be given to you, shouldn't they?

Mr. ATWOOD. Apparently there are some equipments that are not built by us. And the reports would be sent to other companies.

Mr. MYERS. I mentioned earlier——

The CHAIRMAN. The portions relating to North American Aviation should be sent to you?

Mr. MYERS. Those portions dealing with North American Aviation are already sent to us in the form of an unsatisfactory report which goes through Houston to us. This report, in itself, with the editorializing that is involved there, is an internal NASA Report, but all of the data on which that report is based must come through normal

channels to us, as far as the specification of the unsatisfactory condition.

The CHAIRMAN. Since this was an internal report, there may be some restrictions on its distribution. I hope I do not violate any "secrets" when I say one item deals with contamination. Now, the report lists its status as "open." Has it been corrected by now?

Mr. MYERS. Some of the actions have not yet been completely satisfactorily closed. And some cases we may have submitted an answer to them for correction, for what we consider to be the correction, and they would like to have another—NASA may have another direction they want us to go to correct that particular item, in which case they would not agree to close that action item. So, there would be some where in all cases we are taking action on them—there are some which are not yet closed.

The CHAIRMAN. The first line reads: "The cause of these discrepancies was identified as workmanship." You would want to correct that workmanship, wouldn't you, as soon as you heard about it?

Mr. MYERS. Yes, sir.

The CHAIRMAN. How long would it take to get that accomplished with NASA?

Mr. MYERS. I am sure that action is already being taken.

The CHAIRMAN. Well, it says "open". Does that mean closed?

Mr. MYERS. No, it means open, meaning that we have not had a satisfactory conclusion by NASA that they agree with the written answer that we have given to them on the particular item.

Mr. GEHRIG. As of what date?

Mr. MYERS. I guess as of April 3.

Mr. GEHRIG. I thought you said December 31st before.

Mr. MYERS. December 31st—are you talking about the one on the heat shield here specifically?

The CHAIRMAN. I was trying to stay away from classified material.

Mr. MYERS. This is not a classified document.

Were we talking there of the heat shield itself?

The CHAIRMAN. It has not been circulated, I guess. Has this been published in the newspapers? People ask us questions about this report, and we cannot answer very well. Has this report been given to the public, or have others examined it?

Senator CANNON. I think it's quite obvious it has been available to the public in the newspapers, Mr. Chairman.

The CHAIRMAN. They had it earlier than the committee.

Mr. MYERS. Mr. Chairman, I think I understand the point here. Those items were—that are listed as open—were open as of December 31.

The CHAIRMAN. And how would we find out if they have been closed?

Mr. MYERS. I can supply for the record whether they have been closed since that time.

The CHAIRMAN. 1300 of them?

Mr. MYERS. You talk of the 1300 discrepancies on Spacecraft 17? Those are continuously being worked off, and we now have plans to have them all worked off by—well, we will be back in a position to test the spacecraft by the end of May.

The CHAIRMAN. Thank you very much.

(The material supplied for the record follows:)

The spacecraft Operations Reliability and Quality Problem Report dated April 3, 1967, prepared by General Electric, was not the result of an independent inspection of spacecraft but was merely a compilation of information generated by NASA and North American under an established system for problem identification and corrective action.

A review of this document did not reflect any new or unknown problems, and correction of all of the items listed in the report had previously been planned.

As noted in the report itself, 42% of the items listed had been closed prior to issuance of the report. Since that time, all but 15% of the listed items have been closed. Of the 15% still open, planned action is being taken, and they are all scheduled to be closed by early June 1967.

Senator CANNON. Now you have me confused.

Where did this initial list of discrepancies come from? Did this come from your records, from NASA Inspectors, or did it come from GE Inspectors?

Mr. MYERS. It came from a combination of North American Inspectors and NASA Inspectors. The data is then compiled out of those records by GE.

Senator CANNON. GE just simply examines your records, and made no independent inspection to come up with their list of discrepancies. And these discrepancies were known to you, and you were in the process of writing them off, or working them off.

Mr. MYERS. That's right.

Senator CANNON. Thank you, Mr. Chairman.

The CHAIRMAN. One reason that I asked about it is that we understand that the NASA did discuss this with the press. I just wish they would send some of this information to the Committee sometimes.

Senator Brooke.

ACTIVITIES OF NORTH AMERICAN IN APOLLO PROGRAM

Senator BROOKE. Mr. Atwood, in 1965, prior to November 22, had it come to your attention that NASA was dissatisfied with North American's performance, both as to engineering and to the design, manufacture, and quality control?

Mr. ATWOOD. Senator Brooke, not in an organized way as it was in December of 1965. Yes, we have many, many interchanges with them. The basis of our arrangement is a continual criticism, an attempt to improve everything in connection with this major program.

There is a major effort to save money, of course, where it can be done. There is a major effort on engineering design, to save weight and improve procedures.

Yes, I would have to say that I have been conscious from the very first days of the program of—doing better because of criticism; yes, sir.

Senator BROOKE. Specifically, were you not told the delays that North American was engaging in were very costly, and in some instances tripling the cost?

Mr. ATWOOD. Our estimates have been, of course, very hard to arrive at, Senator, in that the scope of the work, the nature of the lunar craft has been very hard to define—particularly in advance of that period of time.

As we have gone further ahead, we have come to better and better definition of the design, the work.

I will say, and I believe I'm right—that since a year prior to November 1965, and up to this time, our expenditures have been very close to the amounts of money that were agreed on for that period of time.

Now, we have not necessarily accomplished the work we wanted to accomplish. But that was not because of money—but the difference has not been great.

Would you amplify my remarks in detail?

Mr. MYERS. I would like to go back to a period of 1964, May until December of '64, when we went through what I call a major program definition for the Block II Program, and at the same time NASA went over all of the activities that were required for completion of the Block I Program.

Beyond that time we built into 1965 a very stable definition of the funding requirements and from that time on we have been extremely close in terms of funds.

The peak activity in 1965, late '65, led to the Phillips review of our activities, and our own review of the program activities, which was the result of a very large peaking of the testing activities in the program in terms of qualifications, flight tests of vehicles from White Sands, the beginning of the vacuum chamber operation down at the Cape—excuse me—down at Houston—and the early various boilerplates and test vehicles that we flew down at the Cape.

All of this——

Senator BROOKE. Mr. Myers, if I may interrupt you. Are you basing the deficiencies entirely upon the peaking of activities?

Mr. MYERS. The deficiencies in terms of the schedule effects were, we believe, certainly influenced very heavily by the peaking factor.

Senator BROOKE. Not the deficiencies in design?

Mr. MYERS. The deficiencies in design that were criticized by the Phillips Report generally were in the area of systems engineering, and this was in terms of picking up requirements established by the NASA and going through the trade-offs that would lead to a specific design change to meet that requirement.

Senator BROOKE. Mr. Atwood stated that there had been some discussions with NASA relative to the efficiency of North American. Apparently there had been some deterioration which would have provoked a task force being assigned by NASA to make a study of North American efficiency.

Would you agree with that?

Mr. ATWOOD. Well, certainly there was room for concern. And this is an enormously big project. And it involved a large review. I guess it has probably been our experience that in most development programs there comes a time when some sort of review and performance assessment is carried out by the customer. This one was, of course, a very comprehensive and very complete one because, as has been pointed out before your committee, it is perhaps the biggest systems engineering problem ever undertaken. Certainly it did indicate some difficulties.

Senator BROOKE. Mr. Atwood, I believe General Phillips' task force commenced this work November 22, 1965. Now, you said that in De-

cember you received—I want to quote you correctly from your report—you said, "General Phillips and his Task Force briefed me and my associates in December, 1965, on his findings and recommendations."

Did General Phillips not submit to you a written report of his findings and recommendations?

Mr. ATWOOD. General Phillips gave us the access to the notes of all his teams, and they were in a variety of forms. The team on engineering had several sections, and they had put together their observations, in various sheets and various forms. The same with Procurement, Manufacturing, and Quality Control.

We were certainly given access to these notes and minutes and we did use them as a guide in our review and in our followup.

LETTER FROM GENERAL PHILLIPS

Senator BROOKE. Well, Mr. Chairman, I don't know whether this is a matter of record, but it is certainly widely distributed—a letter which you received on December 19, 1965, from General Phillips. The letter was addressed to you and referred to you as "Dear Lee," and it stated very plainly grave concern by General Phillips, and presumably the task force, of his findings as a result of his investigation which was conducted from November 22d to approximately December 19th. Is that not correct?

Mr. ATWOOD. Yes, sir.

Senator BROOKE. And you received a copy of that letter, did you not?

Mr. ATWOOD. Yes, sir; I certainly did.

Senator BROOKE. And that letter also incorporated the report of the NASA review team findings; isn't that correct?

Mr. ATWOOD. No, I don't think that the letter did—I mean the letter of transmission did. We were given access to all the briefing charts and principal notes. But—what the letter intended to convey, I think, was a transmission of findings of the survey committee to the company, so that I would know that we had access to all the data they had accumulated.

Senator BROOKE. Let me refresh your recollection. One paragraph states—

Enclosed are ten copies of the notes which we filed on the basis of our visits. They include details not discussed in our briefing and are provided for your consideration and use.

So you did receive those, did you not?

Mr. ATWOOD. I am sure we did.

Senator BROOKE. And what action, if any, did North American take as a result of having received this letter and report?

Mr. ATWOOD. Actually, if I may backtrack just a moment—when this group was organized to come in, as I said, I welcomed them in their effort because I felt it would be a tremendously valuable tool to have, and we would have the benefit of their findings.

Immediately upon the completion of their work, and our access to these notes, we formed several teams, company-wide groups of people, to establish actions to implement essentially all the recommendations that we had gotten from the Phillips Review Board.

We formed a group of people from engineering, for instance. We had a chairman, and he was able to draw on engineers from other divisions of the company, as well as the space division. We in effect helped the division either reorganize or regroup to put in as nearly as we could actions which were in consonance with these recommendations. We did it in manufacturing, we did it in quality control, we did it in procurement, we did it in purchasing. We certainly did the same thing in the matter of program control and reporting.

Senator BROOKE. Well, you have just recently reorganized the space division, have you not?

Mr. ATWOOD. We have changed the top management of the space division, Senator.

Senator BROOKE. But you did not change the top management after the receipt of the Phillips Report in 1965?

Mr. ATWOOD. No. We sent in quite a number of people, however. We sent in our chief engineer and the systems engineer. We sent in a new chief inspector. We sent in a new manufacturing director, or factory manager. And we redoubled our surveillance from corporate headquarters to attempt to improve performance at every level.

There are several more people that were sent in, and some replacements were made. The same head of the division, however, was carrying on. I felt that he was a qualified man in every way and was at the time the best we could provide.

Senator BROOKE. And you were satisfied that you had done everything that you could do in order to comply with the recommendations of the Phillips Report?

Mr. ATWOOD. Senator, we tried very, very hard. I did put a tremendous amount of emphasis on it. And it was a very effective effort, in my opinion.

I believe the remarks of General Phillips indicate that he felt that there was response, there was action, there was effectiveness. And I believe that, too.

Senator BROOKE. You are talking about General Phillips' remarks at what time, now?

Mr. ATWOOD. I was reading the Senate transcript, in this last two-week period.

Senator BROOKE. Well, at that time General Phillips said, "I could not find a substantive basis for confidence in future performance."

Did he then find a substantive basis for confidence in your performance in 1966?

Mr. ATWOOD. As I understand it, he certainly indicated in April of 1966 that——

Senator BROOKE. That he did find it.

Mr. ATWOOD. He indicated that to us.

LARGEST NASA CONTRACTOR

Senator BROOKE. Now, in 1965 North American was number one, so far as contracts awarded by NASA is concerned; is that correct?

Mr. ATWOOD. I believe so.

Senator BROOKE. And in 1966 North American was also number one so far as contracts with NASA?

Mr. ATWOOD. Yes, Senator.

Senator BROOKE. And do you find this rather astounding in view of the difficulties that were incurred in 1965?

Mr. ATWOOD. No, sir; I honestly don't. I feel that the difficulties we experienced in these projects were perhaps unusually severe. But I did feel that we took exceedingly effective action to overcome these problems, and in view of the difficulty of the project, and the many, many supporting factors we had to rely on, that we were making not only an effective effort, but we had every reason to expect it would be satisfactory.

Senator BROOKE. Did you feel that the Phillips report was fair and technically, technologically correct, his findings, and in his recommendations, or do you find differences—when I say you, I mean did North American find differences of opinion insofar as some of the findings and recommendations were concerned?

Mr. ATWOOD. Senator Brooke, I cannot speak in great detail on this, but I will say this: In these notes and memorandums there were probably—in fact undoubtedly—some things that were recommended or suggestions for which other solutions might be preferable.

The sole purpose of this review was to look for difficulty, error or less than maximum efficiency. And so we did not see any parts of their review that reflected comments of commendation or anything like that at all. There were many things, of course. I would like to say whatever errors are properly chargeable to North American, we certainly are responsible. But I would like to at this time point out that there have been millions and millions of man-hours applied by the most highly skilled people, of great integrity, and the degree of deficiency has been very, very small. I would like to say that I appreciate the work of these people in North American, in our subcontractors, and in NASA. I do want them to know that I feel that they deserve some recognition for their loyalty and persistence. I do accept what is properly my responsibility for any deficiencies.

WORKED CLOSE WITH ASTRONAUTS

Senator BROOKE. Well, Mr. Atwood, certainly no one challenges the dedication of the men that have worked on the program.

On the other hand, we cannot merely look at the successes of the program when we are trying to find out the causes of deficiencies in the program and trying to correct those causes and prevent them in the future.

I am sure you are certainly in agreement and in accord with that statement.

I would like to ask you if at any time, to your knowledge, General Phillips or any of the astronauts visited North American and reviewed the work that was being done on the Apollo spacecraft?

Mr. ATWOOD. Yes, of course. I asked one of the team leaders to come and spend as much time as he could with us, and sit with me when I was working on some of these constructive activities. He did come. He was very helpful.

Senator BROOKE. Did he make recommendations?

Mr. ATWOOD. He had made them, and he helped me in implementing some of them.

Senator BROOKE. What were the nature of his recommendations, if you recall?

Mr. ATWOOD. In this particular case, they were in the program control area. He had good ideas, and we wanted to benefit from them, and fortunately were able to, through his courtesy and that of NASA. I guess I might not have completely answered your question before, Senator. But I think we tried to comply with essentially all the suggestions that were made. And even if they felt there might be other ways that were better, we went as far as we could to comply with the suggestions of the NASA Team.

Senator BROOKE. The last question that I asked you had to do with whether or not you had received recommendations from astronauts in the program, and whether or not you had accepted or rejected these recommendations and the nature of them, if you know.

Mr. ATWOOD. I believe Mr. Myers can answer that.

Mr. MYERS. We worked very closely with the astronauts and their suggestions and recommendations are considered by ourselves and NASA as pretty powerful inputs to the program, and in most cases they are accepted. I think in cases where they are not, they are generally reviewed by the NASA Program Manager and the astronauts, where they reach agreements. But I would say in most cases the astronauts are a pretty strong unit.

Senator BROOKE. I am speaking specifically of the Apollo spacecraft.

Mr. MYERS. That's what I'm speaking of here.

Senator BROOKE. And you do not recall any recommendations being rejected by North American which were made by any of the astronauts?

Mr. MYERS. I'm not aware of any. I worked very closely with the astronauts on the spacecraft.

COMPLETE COMPANY INVESTIGATION UNDERTAKEN

Senator BROOKE. Now, Mr. Myers, might I ask you this question?

I know that the Board has not been able to find the actual cause of this disaster. They have given proximate causes. No one has wanted to name names or place responsibility on individuals. I certainly commend that, and I can understand it.

On the other hand, it seems important that you would want to find out where along the supervision, supervisory and management line, mistakes were made.

Can you go back, for example, and take for instance where this wrench was left in the capsule inadvertently and find out who left the wrench there, what supervision was made of the capsule after this was done, whose responsibility it was to supervise and make this control study, and right on up the line to top management, to find out where management was faulty or guilty of misfeasance—certainly not of malfeasance, but guilty of misfeasance, along the managerial line. Was that done?

Mr. MYERS. It is in process right now. We have a complete investigation concerning the conditions that you stated, which covers the identification of how it got into it, what time, the person that's involved,

the supervision, the procedures that are involved, and methods of improvement, either in terms of supervision of the techniques of further insuring that tools are not able to get into the spacecraft and stay there.

Senator BROOKE. So a tester who maybe did not make the test or something of that sort could be found out?

Mr. MYERS. Yes. We certainly intend to have a full understanding of this.

Now, I have looked at the procedures we have used in the past on this, and we have had some very stringent controls on the technique of checking tools in and out of the spacecraft. So the record should be there in this investigation to define exactly how it happens.

Senator BROOKE. Of course, we understand in dealing with human beings you have error. But you would not expect it all along the line. For instance, if the wrench was left—somebody along the line who had the responsibility should have found it—and this same thing about the——

Mr. MYERS. I was extremely surprised that that did happen, in fact, because we had reviewed those procedures just a couple of months before that was revealed.

Senator BROOKE. And you say an investigation is presently under way?

Mr. MYERS. Yes.

Senator BROOKE. And this committee will be given the benefit of what your findings are—not names, but what your findings are so far as control is concerned, management.

Mr. MYERS. You want that submitted for the record?

Senator BROOKE. Yes.

Mr. MYERS. Okay, fine.

Senator BROOKE. Mr. Chairman, I would like to see that submitted to the committee for our record, a report of the investigation currently being conducted, from the initial stage to top management, without necessarily naming the names.

The CHAIRMAN. That will be done.

(The material follows:)

North American has conducted a review of its procedures concerning access to Spacecraft 012 during pre-launch operation, and the procedures for controlling materials and tools taken into the spacecraft.

An Apollo Pre-Flight Operations Procedure (APOP) had been issued covering access control of test and work areas. The Apollo Pre-Flight Operations Procedure was a joint North American/NASA procedure which was coordinated by the Procedures Unit of the North American Space Division, Florida Facility, and by Procedures Control, NASA Spacecraft Operations, and was approved by the Director of Apollo Command and Service Module (CSM) Operations, North American Space Division, Florida Facility, and by the NASA Manager, Test and Operations Information Office. The section of the APOP relating to the control of North American tools states that employees requiring admission to the spacecraft must sign in on the Ingress and Egress Log (I&E Log); must surrender to the monitor of this log all personal effects on his person; and must reference on the log the applicable work authorization document. An Ingress and Egress Monitor appointed by the North American Quality Control Supervisor was required to log all material and tools each entering employee carried into the spacecraft and to account for any material or tools removed from the spacecraft.

The APOP also contained detailed instructions with respect to materials or tools accidentally lost in the spacecraft. In addition to the APOP covering access control to the spacecraft, North American had, in September 1966, established

a tool control procedure for tools assigned to Spacecraft 012 under which the tools would be controlled by a "Tool Box Monitor". Under this procedure, all spacecraft tools were identified by special markings and were listed by part number and placed in a tool box on the work stand at the Command Module. This tool box was put into use on September 30, 1966, together with the Tool Log identifying the contents. It was the responsibility of the Tool Box Monitor to insure accountability for all the tools at any given time and it was required that each tool be logged in and out. In addition, each Technician to whom a tool had been assigned was required to be cleared of all tools accountable to him, and the Monitor was instructed to account for all contents of the tool box at the beginning of his shift. The Tool Box Monitors were furnished by either the Quality Control Organization or the Apollo Technician organization.

A review of the logs shows that the procedures and instructions were not being fully implemented in practice. Specifically, the records do not show the date on which the ¼" wrench socket was left in the spacecraft or the identity of the person who left it.

Under the procedures in effect during the applicable period when the wrench socket could have been left in the spacecraft, North American Assistant Supervisors directly responsible for the employees working at the spacecraft work stations were responsible for maintenance of the Ingress and Egress Logs and the Tool Box Log. In the case of the Monitors from the Quality Control organization, they reported through a Supervisor to a General Supervisor who, in turn, reported to the Quality and Reliability Assurance Manager, who reports to the General Manager of the Florida Facility. The General Manager was responsible to the Executive Vice President of the Space Division. In the case of Monitors from the Technician Support Group, they reported through a Supervisor to a General Supervisor who reported to the Technician Support Chief. He reported to the Director of Florida Operations. The Director reported to the Apollo Program Manager who is directly responsible to the President of the Space Division.

North American is installing a system under which individual separate organizational departments maintain and monitor the Ingress and Egress Log and the Tool Box Log. A rigid monitoring system is in effect and additional reviews and sign-off of the logs by higher level supervision at the conclusion of each shift has been instituted.

In addition, new tool box containers have been provided with specific shaped pockets or retainers for each tool normally required for use in the spacecraft. Each pocket or retainer is identified by the part number and serial number of the applicable tool. The tool box is maintained in a manner whereby visual inspection of the pockets or retainers will confirm that tools are either present or charged out. Visual inspection of the tool box and a review of the Tool Box Log is performed at the end of each work shift.

It should be noted that the report of Panel 5 of the Apollo 204 Review Board states that "none of the instrumentation in the Lower Equipment Bay Area is considered to be a primary ignition source of the fire". This was the area in which the wrench socket was found.

Senator BROOKE. No further questions.

The CHAIRMAN. Senator Brooke, you asked a very good question at the hearing a while back. General Phillips gave a very good summary of the findings and recommendations of his task force review. If you do not mind, I would like to ask unanimous consent to have that placed in the record at this point. That is pages 354 to 359.

(The material referred to follows:)

Now, to summarize the essence, if you will, of the recommendations that I made, I felt that the top management of both the corporation and the division were not giving sufficient attention to the details of the direction and execution of these contracts and recommended more attention from that level of management to the details of their problems and progress. I felt that the authority of the two program managers in that division was really too diffuse to enable them to harness all the resources they had to bring to bear to get our job done and recommended that they strengthen the project organization and pull parts of the functional organization together under the more direct authority of the program managers, respective program managers.

In the functional area of planning and control which to me is one of the essential fundamentals in accomplishing a program, that is where the details of the planning, the details of the costing, are made and the basis on which a great deal of the contractor's efforts are really organized. I felt here that they had not gone nearly far enough to make a work structure breakdown or what we have come more recently to call work packages clearly defined so that there were clearly stated jobs to be done which could be clearly assigned in the appropriate places in the organization.

I felt that they were not doing enough in integrating the total program planning. There were planning groups in several places but I was critical of the manner in which they were bringing all the planning together so that the total job could be properly understood and directed and I was critical also of what I call the visibility that program management had and their ability to understand the details of the progress and be able then to focus energy and resources to solve the problems.

Now, with respect to engineering, I was critical of the ability of the engineering organization as had been demonstrated in the months preceding my visit to meet their engineering release schedules. I was critical of the fact that our block II design which has been referred to here today, was falling behind schedule and I felt there was no reason why it should be behind schedule if it was properly addressed by the management of the engineering organization.

We were having fairly serious technical problems with the S–II, the S–II stage, which have been since overcome. These were—a couple of examples are the insulation which at that time was a considerable problem in engineering, and there were problems also with the structure which have since been overcome.

I was critical of the changed control that was being exercised and made recommendations for tighter control of engineering changes. We were critical of their test operations with respect to the timely development of the procedures which tell the test engineers the steps to go through.

With respect to manufacturing, I concluded that part of their problem in manufacturing had its origins in the engineering department and I think that is fairly obvious. The late design releases give manufacturing a problem. I was critical of the way in which manufacturing was divided between the program organization and the central manufacturing activities and recommended some organizational changes which the company did respond to and make. We were critical of the behind schedule position of some of the components and subsystems and of the practices that were being followed in managing certain subcontracts and in expediting some of the materials, and here, too, as in all the cases I have been enumerating, the company worked very closely with me and my team and were very cooperative and responsive to these recommendations in the main.

I was critical in manufacturing of what I considered the effectiveness of supervision. The equipment that we get, of course, is the result of work of individual humans and the skill with which they do their work is where good products start. And, if the skills are not all that one wants, then in being terms of numbers of people that have to do this work, then the importance of supervisions is greater.

And finally, in regard to manufacturing, I was critical of the efficiency of the work force. In other words, the work per man-hour, if you will.

With respect to contracting, we were critical and made recommendations with respect to the timely submission of contract proposals, contract proposals on which negotiations could be carried out between our contract negotiators and the company.

I was critical also of the protracted negotiations that had become more or less the way of business between our respective contracting organizations and recommended that actions be taken to improve our ability together to negotiate contracts and changes to contracts in a more timely fashion.

With respect to quality control, I made recommendations that trend data be used more effectively by management to identify whether the quality of workmanship was as good as it should be. I was critical that our Government inspectors were finding what I considered to be too many discrepancies over and above those that the company inspectors identified.

I felt that the quality control organization was not being fully effective in carrying out their inspection function and in identifying discrepancies.

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Finally, with respect to overall management, it was my conclusion that the division could do a better job of both managing and carrying out both of these large programs with less total people being charged against these contracts that were then being used, and recommended that if efficiencies in the several areas that I discussed were introduced, that the manpower could drop down somewhat, and I think the later events showed that to be correct.

Now, that is a summary of the high points, if you will, of the recommendations. I would like to repeat that the company was cooperative with me and my task force in the entire period. It was to our mutual advantage to identify problems that were hindering our ability together to get the equipment properly designed, properly built, tested, and ready to operate. They were completely responsive to the recommendations that I made. And in the main I had a reasonably good confidence in the spring of 1966 that the implementation of the recommendations in all these areas was proper and that the program was in tremendously better shape at that point in time than it had been several months earlier.

The CHAIRMAN. Senator Holland.

MORE DETAILS ON GENERAL ELECTRIC REPORT

Senator HOLLAND. Thank you, Mr. Chairman.

Mr. Chairman, I think in the first instance that we have been talking about two different reports, two very different reports, from their objectives, and I think it would be well to clear up for the record just what these reports are.

At first, therefore, I want to make some comments with reference to the General Electric Spacecraft Operations Reliability and Quality Problems Report dated April 3, 1967.

The staff of our committee has made a very able résumé of that report, and I am going to read certain sentences from it, and I ask Mr. Atwood and Mr. Myers to follow, and if there are any corrections or additions that they wish to make, I invite them to do so. But I think these sentences explain clearly what the nature of this General Electric report is: [1]

The quality assessment and reliability group was established as a part of the General Electric checkout and reliability function in February 1966, and reports to the manager of spacecraft operations, Kennedy Space Center. The group consists of one supervisor, nine engineers and two data clerks. This group is charged with monitoring reliability engineering activities for NASA and specifically to review, as a part of this function, failure and discrepancy reports for all spacecraft contractors on a daily basis.

Now, the second quotation:

It is to be emphasized that this group reviews for NASA the discrepancy reports and does not perform physical inspection of equipment. The group also has a subsidiary function as an arm of the NASA manager of spacecraft operations to prepare discrepant report control data for the flight readiness review for each Apollo launch.

The third part that I quote is this:

Although this group has been functioning in the above described capacity since February 1966, all reports were previously on an informal, close working relationship basis with NASA. The April 3, 1967 report is the first formal report, and the committee staff is advised by Mr. George White, Apollo director of reliability and quality, NASA Headquarters, that this report was formalized because of the increasing interest in this area. NASA has under consideration the continuation of this report on a formal basis in the future.

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[1] See p. 400 for full text of staff memorandum.

The next quotation:

Mr. White advised that this report is a product of a formally established group assigned to monitor quality and reliability activities, and that this group was not formed as a result of the accident.

And the last quotation:

Mr. White advised also that since this is an ongoing, internal NASA function, the report was not formally released by NASA, and he does not know personally how the information reached the press.

It seems to me that those quotations from the very able staff résumé clearly show what the nature of this report was, and I want to ask Mr. Atwood and Mr. Myers if they are in accord with the summary statements which I have read, which clearly show what was the nature of the General Electric team function, and of their report.

Mr. MYERS. That is a correct series of quotes for the definition of their activities.

Senator HOLLAND. This internal report, dated April 3, did not reach you people until the last 48 hours. You have already testified to that.

Mr. MYERS. That is correct.

MORE DETAILS ON PHILLIPS REPORT

Senator HOLLAND. All right.

Now, with reference to the other report, which is quite a different matter, which is the General Phillips report—my understanding is that the General Phillips Task Force was appointed by NASA in late 1965 and made the report of its findings and recommendations in December 1965.

Is that your understanding?

Mr. ATWOOD. Yes, Senator.

Senator HOLLAND. Now, you state in your testimony that between December 1965 and April 1966 North American took appropriate action "where we felt that the result would improve management and program performance. In April the Task Force reviewed our progress and expressed general satisfaction with it."

Was that general satisfaction stated in a letter, or in a formal way?

Mr. ATWOOD. I don't think so, Senator. I think it was expressed in informal briefings.

Senator HOLLAND. Who appeared for the General Phillips task force to discuss the matter with you in April following the report of the preceding December?

Mr. ATWOOD. Well, I don't remember in all. There was, of course, General Phillips. I think generally he had the captains of various task teams there. I believe there was Mr. Kuba and of course Dr. Shea, who is the program manager, and people of that kind. There must have been six or eight of them. They came back. It was verbal, as I remember it. I don't recall any in writing. Do you?

Mr. MYERS. They did cover each of the areas of deficiencies that had been reported in December, and they had reviewed the answers we had put together for improvement of the actions that were involved and gave us a read-out at that time.

Mr. ATWOOD. Senator, I would not want you to think that we interpreted their visit or their review with us as complete satisfaction

or having completely mastered the tremendous program and be completely satisfied. This was not the case at all. I believe they felt that procedurally, organizationally, and from the standpoint of control that we had or were getting adequate means to handle the management of the program. I think they felt that all of our activities were improving in quality.

I do know that we had been able to make substantial reductions in manpower through getting on top of the engineering load, improving our scheduling of changes, and many other things that we were able to do as a result of this joint survey.

Senator HOLLAND. There was no written statement made in April of '66, comparable to the written listing of discrepancies and defects and criticisms contained in the letter of December '65?

Mr. ATWOOD. Well, there may have been. I don't know that any were transmitted to us. Do you?

Mr. MYERS. There were briefing charts used in that.

Senator HOLLAND. What?

Mr. MYERS. There were briefing charts used, as I remember.

Mr. ATWOOD. Yes. We must have gotten copies of the briefing charts. They would be only poster-type presentations which would list topics and be a prompting device for the speaker.

Senator HOLLAND. Are those briefing charts available?

Mr. ATWOOD. I don't know, sir, whether they are or not.

Senator HOLLAND. I ask that a search be made and if they are available, that they be delivered to the staff for study as a basis for possible later discussion.

One more question on this point.

Mr. ATWOOD. Senator——

Senator HOLLAND. Has there been any formal——

The CHAIRMAN. Senator, I think Mr. Atwood has another comment.

Senator HOLLAND. I am sorry.

Mr. ATWOOD. Senator, I greatly prefer if you would ask NASA for whatever they used to talk to us in April.

Senator HOLLAND. We will ask NASA for everything that we think they may have. But if you have these briefing reports—and you indicated that you think you have—I suggest that you do deliver them to our staff for consideration. We are just as willing to get our information from you as we are from NASA.

Mr. ATWOOD. Senator, we will look at our files and see if we have them.

Senator HOLLAND. Thank you.

Now, the next question is—was there any formal or written statement made by the Phillips task force at all following December 1965 and following April 1966, which you have?

Mr. ATWOOD. We, of course, have, as I said before—and I am sure we still have—copies of the memoranda, briefing charts, all the data which they allowed us to see in connection with their review.

Senator HOLLAND. Well, the reason for my question is this. You have already stated that you do not want to create the impression that the Phillips task force stated in April 1966 that they were satisfied completely with what you had done following their letter of December 1965. You have stated that, have you not?

Mr. ATWOOD. Yes, sir.

Senator HOLLAND. Now, if there have been later statements in which they have stated more complete satisfaction, or even complete satisfaction, we would like to see them.

The point of my question, the point of my suggestion is this.

If there were continuing disagreements between you and the Phillips task force, as shown either by briefs or by formal letters, we would like to see them. If there were any later expressions of satisfaction, either partial or complete, by the Phillips task force, we would like to have them for the record.

The point is not clearly left for the record unless you show everything that is of importance that was transacted between yourself and the Phillips task force after the date of December 1965 on which you learned of the criticisms they had and the many discrepancies of which they complained.

I think that for your own sake and for NASA's sake, and for the information of this committee, the fullest search should be made of your records and the fullest statement made to this committee as to any agreement reached between you and the Phillips task force, or any continuing disagreements, so that the committee may have the whole situation clearly in the record.

Mr. ATWOOD. Well, Senator, as I have understood, this was a very informal effort, and it is my understanding that after April they relied on their own program manager's office to follow continued improvement in the various fields they had mentioned to us. The program manager is really the responsible NASA officer so far as the spacecraft is concerned, or were concerned. And it is my understanding that he was relied on to follow the continued progress we were making.

Do you have anything to add, Mr. Myers?

Mr. MYERS. Well——

Senator HOLLAND. You have not stated, though, whether there were any later meetings in which fuller satisfaction was expressed by the Phillips task force, or whether there were continuing disagreements showing that they were not satisfied with what you had done.

Mr. ATWOOD. Senator, I will be glad to search our records and see if there is anything that is appropriate.

(The material supplied for the record follows:)

North American's records do not reveal any further meetings with the General Phillips review team after April 1966.

COMMITTEE WILL SEEK REPORT ON REGULAR BASIS

Senator HOLLAND. Now, Mr. Chairman, there is one other thing I would like to say.

If the report of April 3 by General Electric was the first formal report, and if there is a question as to whether they are to make later written reports, I strongly hope that the chairman will insist that regular reports be made, because here we have a situation with reference to the Phillips task force which shows that while conferences continue, there is no record we can see and rely upon as to just what complaints of the Phillips task force were satisfied, and what were

not satisfied, or whether there were continuing disagreements and arguments on the subject matter.

It seems to me that the regular written reports in this critical field are appropriate. And that is what I suggest, that we insist upon that as to the General Electric reliability team.

The CHAIRMAN. The chairman will try to get those on a regular basis. If he cannot, he will report back to the committee.

Senator HOLLAND. I thank the chairman.

The CHAIRMAN. Senator Curtis?

NO RECOMMENDATIONS OVERLOOKED

Senator CURTIS. Thank you, Mr. Chairman.

Mr. Atwood, I have gone over your statement and listened to as many of the inquiries as possible. Regrettably, I did not get in on all of them.

I have this question.

Were there any findings or recommendations of the Phillips Report or a report of any other group, individual, team or office, which went unheeded and which in any way contributed to the accident now under investigation?

Mr. ATWOOD. Senator Curtis, I do not think so. I would like to defer to my colleague and see if he has any such opinion.

Mr. MYERS. No, I don't think there has been any that we have left unheeded that would have anything to do with the accident.

Senator CURTIS. Were there any that were disputed and therefore not followed that in any way contributed to the accident? I'm not limiting this to the Phillips Report. I mean any report recommendation from any group, team, individual, task force, office.

Mr. MYERS. I am certainly not aware of any, Senator.

Senator CURTIS. None relating to any kind of hatch?

Mr. MYERS. No.

Senator CURTIS. Or in reference to flammable materials inside the spacecraft?

Mr. MYERS. No.

Senator CURTIS. Or reference to wiring?

Mr. MYERS. No.

Senator CURTIS. Or inspections?

Mr. MYERS. No.

Senator CURTIS. In other words, your position is that in response to all findings and recommendations by any group, the reference to all the phases of the program, that those findings and recommendations were followed and not disregarded, unless upon further study the recommendation was not valid.

Mr. MYERS. Yes—the answer is yes. I would like to qualify slightly.

Senator CURTIS. I would be happy to have you do so.

Mr. MYERS. I would like to refer to the Phillips Review of 1965 in the Board report, and any other major reviews that we have had with the management of NASA in things that I am aware of.

Now, there are thousands and thousands of people in this program. There may have been comments made or small meetings held some place that might have had some reference that could by our judgment now be related to the combination of circumstances that led to this accident. But I am not aware of it, Senator.

Senator CURTIS. Did any inspection group or team, task force, ever make any allegation of general laxness or carelessness?

Mr. ATWOOD. I don't know whether any such thing was ever reported or not. I know when you report discrepancies, you fix them. This has to be done. I believe Mr. Myers comments would go to the point that any known discrepancy in any known inspection would be fixed.

Senator CURTIS. I realize the wide latitude in the question—a general allegation of laxness or carelessness. Such an allegation would always be easy to make, and the less competence you have the easier it would be to make. But for the record, I wanted to ask the question.

I think that's all, Mr. Chairman.

The CHAIRMAN. When you look through the testimony, if you decide you should have made some other remarks, you can call it to our attention. Because with the wide scope of the questions we are dealing in here, it could be your answer might need amplification.

Senator CURTIS. Mr. Chairman, you are referring that if something comes to their mind later.

The CHAIRMAN. Certainly.

Senator Mondale.

BASIC OBJECTIONS OF PHILLIPS REVIEW CLEARED UP

Senator MONDALE. Mr. Atwood, I missed part of your testimony because I had to make a quorum call. But I take it it is now established that you did receive a copy of a letter with an attached report signed by Mr. Phillips dated December 19, 1965.

Mr. ATWOOD. Certainly.

Senator MONDALE. Is it your testimony that North American has cleared up all of the basic objections set forth in that report and had done so by April, 1966?

Mr. ATWOOD. In responding to Senator Holland, I tried to make it clear that we had tried to acomplish just that, tried very hard. I could not, of course, state that we had succeeded, nor that General Phillips so indicated in his meeting with us. But he did state, as I recall, that we had made a great deal of progress, many improvements, that the program was improving rapidly, the manpower situation was improving, and engineering was returning to schedule, and I believe that methods of reporting program progress were generally satisfactory. But he did not, I am sure——

Senator MONDALE. Was this report brought to your personal attention as president of North American at the time of its receipt?

Mr. ATWOOD. You mean the Phillips report?

Senator MONDALE. Yes.

Mr. ATWOOD. Oh yes, I was involved in every bit of that, and the call from Dr. Mueller until—well, I'm still involved in that.

MANAGEMENT CHANGES DISCUSSED

Senator MONDALE. The last few days there have been public reports to which you refer in your testimony of a basic shakeup in the management of the North American space efforts. One of the columnists

who deals in this field, in the Post, commented this morning that the changes in North American's management "appear to reflect some of the criticisms made in the Phillips report". Would you regard that as a fair conclusion?

Mr. ATWOOD. No, sir. Although we did make many management changes after the Review Boards were there, we removed some. But actually this Phillips review program was 17 months ago, and pretty much passed out of the active category in April, and the program manager was carrying on. So it has been over a year since we have had anything to do with it in an active sense.

Senator MONDALE. Are you planning any other basic personnel changes or organizational changes in your space efforts?

Mr. ATWOOD. Yes, sir, we are. And I am able to mention two or three right now.

We have obtained the services of Mr. Hello, formerly of the Martin Co., who served as the program manager on their Gemini since its inception. They had the booster for Gemini. We were able to get him to come, and we are putting him in charge of our operation at Cape Kennedy. We feel he is an experienced and capable and very effective man.

In addition, we have obtained the services of Mr. G. T. Willey, not as a full time employee, but as a consultant. He has worked for Martin all of his career, too, and has retired. But he has been active in charge of the company's launch operations for the Titan and Gemini programs down there. So he will be of considerable assistance to us.

Another man that is being transferred to the division, Space Division, is P. R. Vogt, and he is Vice President and Assistant to the President for Quality—Product Quality. He has been with North American Aviation for 20 years and has been Chief Engineer of our Rocketdyne Division.

So I mention those three. And we are probably going to have some others.

Senator MONDALE. Has North American been approached by NASA about the possibility of having McDonnell Aircraft personnel inspect North American's space vehicles before they leave North American?

Mr. ATWOOD. No, sir. I have not heard of it, anyway.

Senator MONDALE. Is nothing being explored along those lines, to your knowledge?

Mr. ATWOOD. No. But I would say this: If any inspectors can improve our quality, I would welcome them. And if they could be used in this role, I would appreciate it.

QUESTIONS ON PRESENT APOLLO SPACECRAFT

Senator MONDALE. The present Apollo spacecraft, now in the process of preparation for the un-manned test flight later this year, and the subject of the GE study that has been discussed extensively here today, contained the many flaws and difficulties that have been outlined. Did North American regard this spacecraft to be flight ready when it left the factory?

Mr. ATWOOD. Senator, it had been through all the checkout, and through all the inspection and acceptance at the plant. I want Mr.

Myers to speak for this. But I would like to say that this was designed as a manned space craft unit, and was adapted to an unmanned automatically controlled spacecraft. The wiring—Spacecraft 17 is the number—the wiring was augmented about 70 percent over the basic wiring system that would go with the basic configuration. This wire was added overlaid, and appliqued, into the wiring harness of Spacecraft 17.

Yes, we thought it was ready for flight, and it had been through all the functional tests to so qualify it.

I would like now for Mr. Myers to explain his view of why the discrepancies—such numerous discrepancies, primarily on wiring, were reported at the Cape.

Mr. MYERS. First I would like to point out that when we check out a spacecraft and do its final inspection, we have in that checkout checked every wire, every circuit, every switch, every place electrons can go in the spacecraft. The spacecraft met the criteria of inspection that had been applied previously to Spacecraft 011. If you recall, Spacecraft 011 was also an unmanned flight, and also had added to it by splicing into the main wire harnesses a mission control programmer which we called the "mechanical man" that does the programming to the very strict and rigorous requirements of these unmanned space flights.

Spacecraft 011 was completed successfully.

The same criteria for inspection was applied to Spacecraft 017 before it was shipped to the Cape.

After it reached the Field, it had a receiving inspection which revealed about 74 discrepancies, and then after the fire we worked with NASA to develop a new criteria which was objective, specifically giving the inspectors a standard to which to inspect—more specifically measurable.

Now, that inspection criteria was applied in the middle of a work period, and normally inspections are performed, or at least the inspection discrepancy reports are written after work periods are complete and the technicians have removed themselves from the space capsule and the inspectors go in and inspect. This time we were not able to close out all of the activities that we had. We wanted to get on to this new criteria of inspection, and in the process we developed through this very objective and more detailed inspection criteria many discrepancy reports which have nothing to do with the actual capability of the spacecraft.

Now, in the process of this inspection there were some items found which were, if left alone, and no longer checked during the further checkout of the Spacecraft, and no longer found by other means—would have been listed as hazardous to the flight of the spacecraft. But we do have continued inspection and continued checkout of the spacecraft where all the wires again are checked, prior to launch, and we believe we would have found those, and we would have had a successful flight with the ship.

Senator MONDALE. In the original Phillips Report, one of the criticisms made was in the nature of the quality control was such that the spacecraft would be certified for approval by North American, but then NASA inspectors would uncover hosts of inadequacies. Is it your testimony that that problem has been corrected, and that despite this GE study, that an adequacy system of quality control has been established?

Mr. MYERS. We had a fairly major change in our quality control organization 1965–66 time period, and did a lot of work with NASA in the definition of the method of describing a discrepancy. We had differences in the details of how you note what is a discrepancy, and how many discrepancies are noted. We clarified that so there we have a system that is common with NASA's system, and we do continue to do a closeout inspection by North American personnel, followed by a NASA inspection. I don't think we have—we have rarely had a case where there are not a few discrepancies noted by the NASA inspectors after we have completed our inspection.

Senator MONDALE. I admit I find it difficult to visualize the magnitude of technical problems that you are confronting. But this GE report, among other things, indicated that a timing device costing $100,000 was delivered and it could not keep time. Isn't that the sort of thing that is worthy of detail quality control? This may not be accurate. It said it was supposed to run for 8 days and it ran for 4 minutes and 4½ seconds. At the second test it gained time, or it failed altogether. Maybe this is not North American's responsibility. But how——

Mr. MYERS. It is my understanding—and as I said, I have had just a few hours to check on this, on the item specifically in the report—but it is my understanding that the clock, which is—and by the way, I question the cost noted there—but the clock was overtorqued in the installation, and a procedure has been written to correct that overtorqued condition.

Senator MONDALE. Is there a difference between the approach of North American in terms of having a space capsule ready for what they call flight readiness, and the approach of McDonnell? Do you have a different standard for determining flight readiness than McDonnell Aircraft?

Mr. MYERS. I am not aware in detail of the specific procedures that are gone through in getting ready for the flight readiness review in the Gemini Program, but as I understand it, they are essentially the same as far as the technique is concerned. It involves the understanding of every failure that has occurred during the qualification, during acceptance testing of the equipment, during the installation, and during the checkout of that equipment in the spacecraft, and the specific answer that is satisfactorily agreed to between NASA and ourselves on every one of those items. That's the way we do it on the CSM. I understand that is what they do on the Gemini.

Senator MONDALE. No further questions, Mr. Chairman.

The CHAIRMAN. Senator Percy.

THREE DIMENSIONAL JIG BOARD

Senator PERCY. Mr. Atwood, in your statement, you talk about the method of manufacture and installation of wiring and tubing in the Block II Spacecraft. You indicate that a three dimensional jig has been used in the fabrication of wire harness for the Block II Spacecraft that is a significant improvement to the construction of the Block II Spacecraft. Apparently these jigs were not used in the Block I. Isn't it true that this was used, this technique and method was used in the Gemini Spacecraft?

Mr. ATWOOD. Could we allow Mr. Myers to speak to that?

Mr. MYERS. Yes, it is my understanding that the Gemini did use a three dimensional jig board. At the time we were designing the Block I, we had a number of individual wire harnesses that were separately built on flat jig boards. A decision was made at that time that flat jig boards would be satisfactory for limited length wire harnesses. In the process of designing the Block II we actually reduced the number of connectors that are used in the wire harness, and by that means we actually increased the length of the various wire harnesses in Block II and concluded that we should use this three dimensional wire harness in that case.

There is an improvement therefore in decreasing the number of connectors that are used and therefore the improved reliability of Block II.

Senator PERCY. If there is a proven technique in Gemini which has been eminently successful in every aspect of it, wouldn't it have been wise to have used it in Block I? You now decided to go back and use that technique in Block II.

Mr. MYERS. Well, I think the decision that was made recognizing the three dimensional jigboards in Gemini was based on wire harness lengths for Block I.

Mr. ATWOOD. Senator, I can only add that it depends on a number of things. The three dimensional jig, of which we have a picture here—you might pass it around—is an installation aid more than a basic wire harness system. It's an installation aid. You can only twist wires or bend wires so far—depending on the size and the length. And I don't really know, but I am sure that the flat jigboard design and the length of the wires used were considered satisfactory for installation on a spacecraft at the time.

CHANGE IN MANAGEMENT WILL HELP

Senator PERCY. Could I ask you about your management changes, Mr. Atwood. I ask this with a background of some experience in having had to change occasionally management setups.

In your statement you indicate the designation of a new president and vice president, implying that their skills are "especially required at this time." Was this special requirement generated by the accident? What special skills does this new team possess that were not possessed by the old team that has now been replaced and then will their skills strengthen the program, as you say?

Mr. ATWOOD. Of course we didn't have Mr. Bergen available to us before this. But I do feel that his experience as president of the Martin Company which has handled the Titan booster for Gemini, and many other programs, qualifies him to a greater extent than the man that previously headed this division.

I feel that Mr. Storms, who was head of this division for 6 years, a very brilliant and accomplished engineer, has accomplished many things. I feel that we will make more progress with Mr. Bergen because I think he has more capabilities for the situation in which we find ourselves now, and I believe those capabilities included a better understanding of NASA's operations and methods, a perhaps broader

perspective of organization and motivation of personnel, and certain other managerial skills that have been developed by his company which I think can be transferred effectively to our operation.

Senator PERCY. You feel this new team possesses such skills, that if they had been in charge of this program from the inception we might not have had this accident?

Mr. ATWOOD. This is very hard to say, Senator Percy. I certainly did not expect perfection in anybody's administration. I don't mean to represent to you and to the committee that new management will eliminate all our problems. This is a tremendously difficult program, by far the most difficult we've ever seen. And yet I do think that this change in management will help. We had felt very fortunate to get Mr. Bergen where he could move in and take this work.

Senator PERCY. I think your report, Mr. Atwood, is very clear and concise. One part of it I stumbled over. It's a question of terminology, I am afraid.

In your statement you indicate that in 1965, "It was extremely difficult to achieve full control and visibility of North American's basic design and development effort." And later you indicate the necessity now to review the means by which improved visibility of the management effectiveness in program control will be available to both North American and NASA.

Would you explain the meaning of the term "visibility"? It's a term with which I'm not familiar.

Mr. ATWOOD. Senator, I will try, and I think my colleague may be able to give you more on that.

We have here a great many concurrent activities, and many, many companies. There is the design and development, procurement—design, development, qualification and testing of environmental control system—and in most of these things we buy from subcontractors or suppliers. We also buy the fuel cells from United Aircraft. And we are responsible for the coordination of all that work—to know the progress that's being made, the schedule, the expenditure involved. And it makes a real problem to come out even on schedule, technical qualifications, money and program progress.

What we mean by that is ability to see at various levels how various things are coming along and to take timely action when we see something failing to meet a schedule or a test criterion or in any way falling behind the parade. And so we call it visibility. It is primarily just a management system reporting progress, key milestones, and expenditures that go with them. That would be my primary definition of visibility.

Dale, do you have any more?

Senator PERCY. Is there any implication here that management could not determine the effectiveness of its efforts at all if it really went out to try to find out what the situation was?

Mr. ATWOOD. Well, yes—if what we call visibility were not good, this is true.

Mr. MYERS. After the Phillips survey, we set up a vice president in charge of program control reporting to the president of the division whose job it was to develop standardized methods of reporting to higher management. I am not sure I would say more detail, I think

I would say more succinct important information relating to the progress in program and relating to the elements of the quality and performance, schedules and costs of the program.

I believe the comments that are made here are just reaching further again for further information presented properly at all levels of management to give them the greatest possible insight into all problems.

Senator PERCY. In your statement you suggest that the primary failure to identify the hazards was NASA's, since they omitted the necessary criteria from their guidelines—I know that Senator Jordan has questioned you on one phase of this.

Referring to your own memorandum and comments on finding number five, which you supplied to the committee would you define for us or refer us to provisions spelling out the responsibility of North American for safety in conjunction with the contracts which you are performing for NASA.

Mr. MYERS. I think, Senator, the response North American made is fully definitive. The problem that was involved for all of us was not recognizing oxygen testing as a hazardous condition. The hazardous condition criteria called out on a range safety memorandum published by NASA and used as the criteria for choosing those tests that are by that definition hazardous. And I think we all feel now, in retrospect, that we all missed the point on what was hazardous.

Mr. ATWOOD. Senator, you notice our engineers looked at the criteria, made the recommendation. We stated here—with the benefit of hindsight it is evident that the criteria were not directed to the potential risk of spacecraft 012. We recognize that North American might well have questioned them, even though it did not have the primary responsibility for determining the criteria.

Senator PERCY. In that same section you say "we recognize that North American might well have questioned them, even though it did not have the primary responsibility." Wouldn't you perhaps modify that now to say you should have questioned them—rather than might well have questioned them? And in a future relationship shouldn't a closer look be taken at this aspect of the program to pinpoint responsibility?

Mr. ATWOOD. Senator, I am sure that all criteria will be doubly and triply questioned. We certainly will consider it our duty.

Senator PERCY. Lastly, Mr. Chairman, it seems that probably the most significant management deficiency disclosed was a lack of an effective system to identify, eliminate or control potential hazards. What action has North American taken to assure for both ground tests and space flights an adequate analysis of all the potential hazards have been made?

Mr. MYERS. We have a team of NASA people stationed at North American to do just that. We have a team made up of top system-oriented engineering and quality people from MSC, headed by Colonel Borman, that is in residence with us for the review of materials, the hatch design, the electrical system, and all of the activities that deal with hazard, and the changes that are coming into the spacecraft.

Senator PERCY. Thank you very much.

Senator BROOKE. Mr. Chairman?

The CHAIRMAN. Senator Brooke?

CONTRACT CANCELLATION NOT CONSIDERED

Senator BROOKE. Two quick questions.

Mr. Atwood, number one, at any time in 1965 or 1966 did Mr. Webb discuss cancellation of the contract with you?

Mr. ATWOOD. Senator Brooke, I do not remember any such occasion or even any indication that it was being considered.

Senator BROOKE. At any time?

Mr. ATWOOD. No, sir.

Senator BROOKE. Number two, did your staff study the report made by the Phillips task force and compare it with a report made by the board of review in order to determine whether there was any similarity in the findings of the Phillips task force and the findings of the board of review which was, of course, after the Apollo incident?

Mr. ATWOOD. I do not think we have had a systematic comparison item-by-item, Senator. I don't know of any suggestion or recommendation that would in itself have prevented—would have obviously prevented this accident. I believe——

Senator BROOKE. I am not saying that might have caused the accident exactly. What I am asking is did you examine the two reports to determine whether findings made by the Phillips task force had been corrected prior to the Apollo incident, and thus not contained in the report of the board of review?

Mr. ATWOOD. I have not been able to get any information that would help to answer that question. I would say that most of the Phillips review had to do with procedures, organization and systems and methods of procurement, and I am sure that nothing involved in those notes had any reference to anything that would in itself pinpoint this type of accident.

Now, I am going to defer to my colleague and see if he knows of anything to add.

Mr. MYERS. No, I don't have anything to add.

Senator BROOKE. Your answer, Mr. Myers?

Mr. MYERS. I have nothing to add to that.

Senator BROOKE. Then is your answer, Mr. Myers, the same as Mr. Atwood's—that you did not find any findings of the Review Board which were similar to the findings of the Phillips Task Force?

Mr. ATWOOD. Well, I think——

Senator BROOKE. Specifically I'm trying to get at, Mr. Myers—the Phillips Report—let me make is as clear as I can. The Phillips Report made certain findings and recommendations. The Phillips Report was in 1965.

Mr. MYERS. I'm with you now.

Senator BROOKE. The NASA Review Board, so-called, findings were after the Apollo accident. Now, I'm asking you—did there appear in the Review Board findings anything that had been pointed out to you in the Phillips findings which you had not corrected?

Mr. MYERS. There were, I would say, similarities in the area of the deficiencies spelled out in the two areas. Now, since the time of the Phillips Report I would like to point out for the record that we have had a very complete review of the trends of our discrepancies as a function of time, and we have had major improvements in the decrease

in discrepancies, which is an indication of each workman doing his job a little better as time has gone on. And I think the reference in the Board Report has that similar tone, but our records would indicate there have been major improvements in that area since the time of the Phillips Report.

Senator BROOKE. Of course the Phillips Report was in 1965 and the Review Report was in 1967. Now, in that interim period, did not North American have sufficient time to correct all of the deficiencies pointed out by the Phillips Task Force?

Mr. ATWOOD. Well, Senator, certainly we made every effort to eliminate all discrepancies. The question as to whether any discrepancy caused the fire is still moot.

Senator BROOKE. I'm not trying to place the blame for the fire. I'm merely trying to find out more about management at North American.

Mr. ATWOOD. I believe the only similarity might be that in both instances criticisms were made of the remaining or existing questions of the quality of the work. That would be a similarity, a general similarity. It is the only way I can define it.

Senator BROOKE. Mr. Myers, you say there were similarities in deficiencies.

Mr. MYERS. Yes.

Senator BROOKE. And you have no explanation as to why these deficiencies were not corrected between 1965 and 1967 with the exception that it does take time——

Mr. ATWOOD. I feel sure they were not the same deficiencies. This is a matter of inspection and the standards Mr. Myers spoke to. We have done everything with the inspectors we have, the workmen we have, and with NASA's supervision, to try to eliminate them all, sir.

Senator BROOKE. Thank you. No further questions.

The CHAIRMAN. I have one item that sort of bothers me. What was General Phillips' position?

Mr. ATWOOD. General Phillips, as I understand, is still an Air Force officer. He is now director of the Apollo program for NASA.

MORE QUESTIONS ON PHILLIPS FINDINGS

The CHAIRMAN. At all times during the entire period he was the Apollo Program Director, wasn't he?

Mr. ATWOOD. Yes, sir.

The CHAIRMAN. If he found all these deficiencies, what did he do to correct it, as far as your company is concerned?

Mr. ATWOOD. Are you thinking of this General Electric report, Mr. Chairman?

The CHAIRMAN. No, I'm talking about General Phillips. Regarding all of these defects, and all of these troubles, and all these errors, what did he do to correct them?

Mr. ATWOOD. He tried very hard to improve quality and all other characteristics of the work. He has had a quality control organization—that is NASA has a quality control organization within its headquarters, and at each center, and at each major manufacturer's plant.

The CHAIRMAN. He had this long list of things needing correction

in what you called the Phillips report. When he tried to correct them, was he stopped by your company?

Mr. ATWOOD. Oh, no, sir.

The CHAIRMAN. If you didn't stop him, who did?

Mr. ATWOOD. Senator, no one stopped anybody from trying to make sure that everything was as perfect as we could make it. I know he tried very hard. He emphasized the problems very hard. He had his own inspectors, and of course we had ours.

The CHAIRMAN. I regard General Phillips very, very highly. I think he tried to correct these things, as you folks also did.

This equipment out there that he was talking about was on the line, wasn't it? Your Spacecraft 012?

Mr. ATWOOD. Yes, sir, it was on the line at Downey.

The CHAIRMAN. I spent a little time visiting with the Atomic Energy Commission at various times. They have a system of checking and I am going to send you a question about this which I hope you will answer at some later date.

Now, I note your company was awarded the Apollo command and service module development and the S–II stage development within 2 months of each other. Do you feel in retrospect that you had available the management and technical capability to handle these two launch programs simultaneously, particularly when both could be expected to contain some large technical problems?

Mr. ATWOOD. We should have had, and I do think we did have. The two projects were different.

The CHAIRMAN. You made some changes in your organization, in the management structure. Will you send us now a record of the organization chart of the corporation and the Space Division, giving the names of responsible people?

Mr. ATWOOD. Yes, sir.

(The charts referred to are figures 98 and 99 which follow.)

The CHAIRMAN. Senator Smith.

QUESTIONS SUBMITTED FOR PHILLIPS REPORT SUMMARY

Senator SMITH. Mr. Chairman, earlier in the afternoon I asked Mr. Atwood to supply for the record a statement with respect to the findings and the conclusions of the Phillips report and related information.

That you may have a clearer understanding when doing that, Mr. Atwood, I would like to read a sample of two or three questions that I have in mind, and then supply, Mr. Chairman, for the record a number of questions that are not to be answered individually, but answered in the statement that I asked for, if that would be all right with the committee.

The CHAIRMAN. That will be done.

Senator SMITH. For instance, Mr. Atwood, General Phillips in appearing before the committee and discussing the so-called Phillips Report said, "Now to summarize the essence, if you will, of the recommendations that I made, I felt that the top management of both the corporation and the division were not giving sufficient attention to the details of the direction and execution of these contracts and recom-

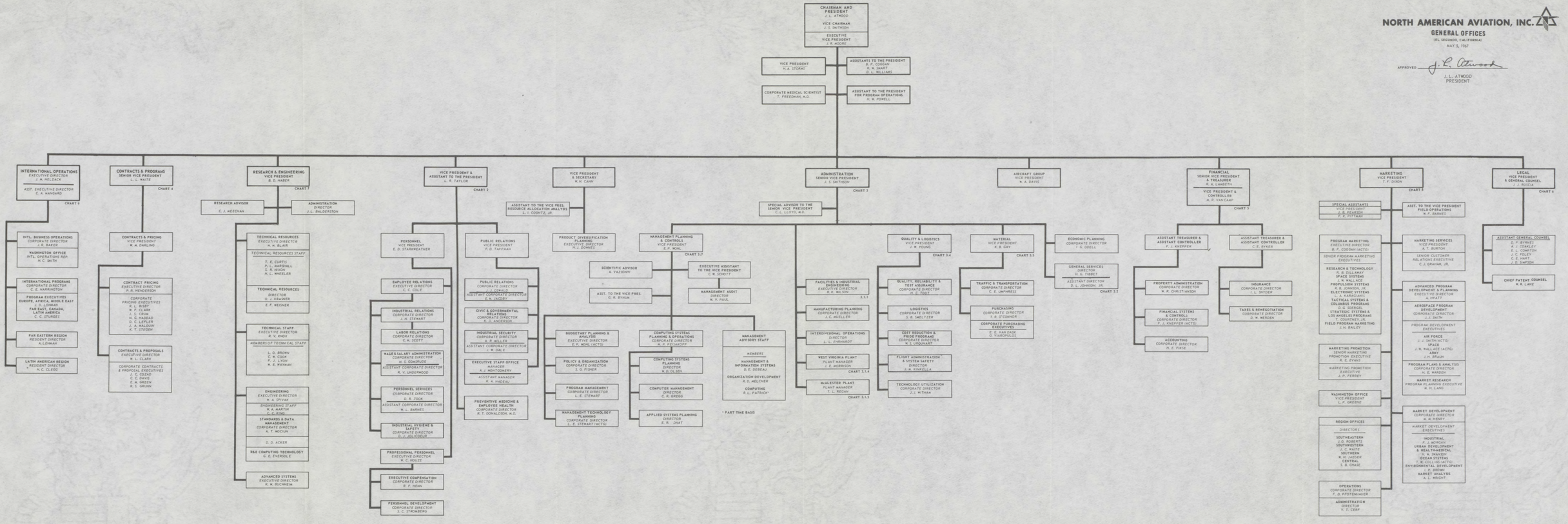
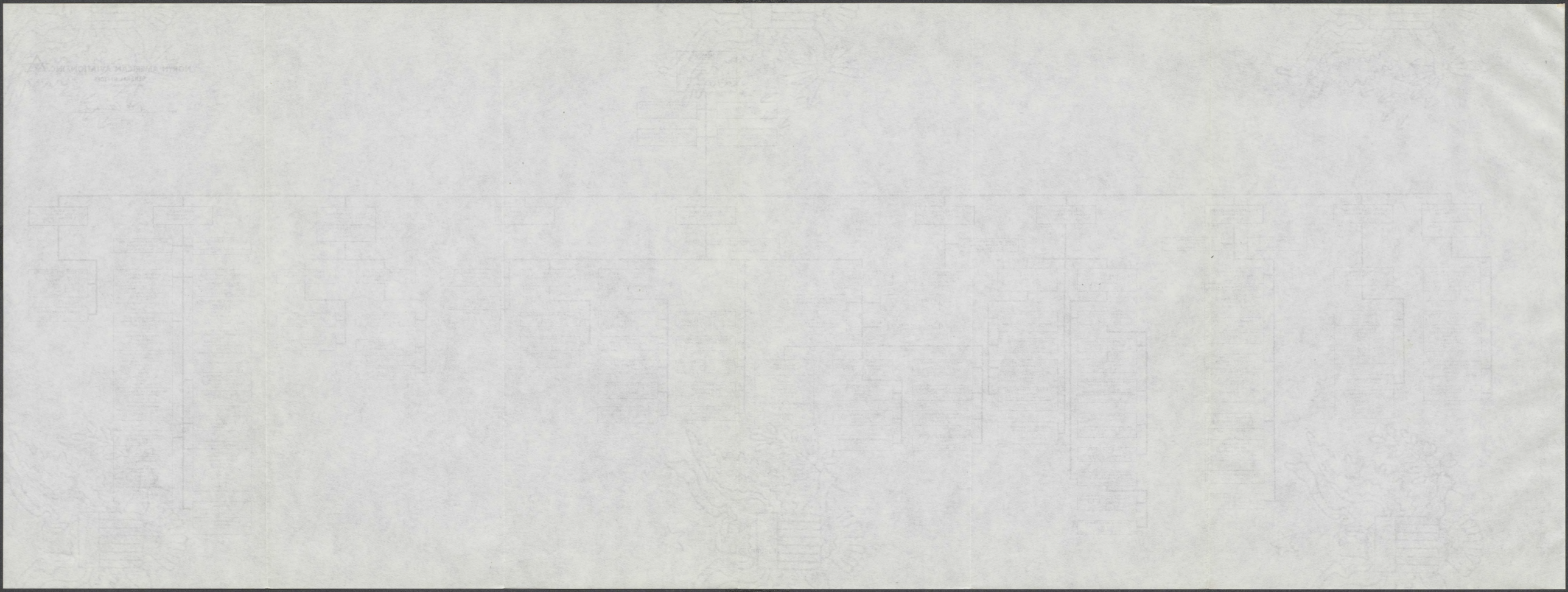


FIGURE 98

74-521 O - 67 (Face p. 436) No. 1



SPACE DIVISION
NORTH AMERICAN AVIATION, INC.

MAY 1, 1967

Approved W B Bergen
W. B. BERGEN
PRESIDENT

** VICE PRESIDENT
NORTH AMERICAN AVIATION, INC.

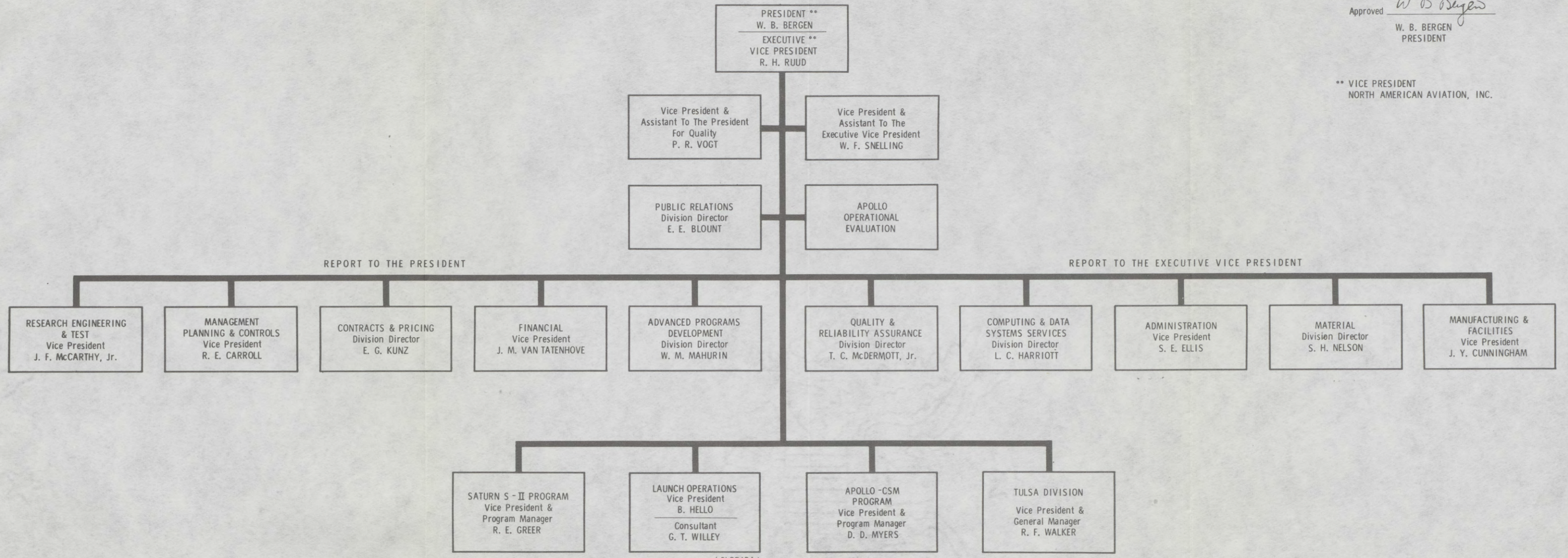
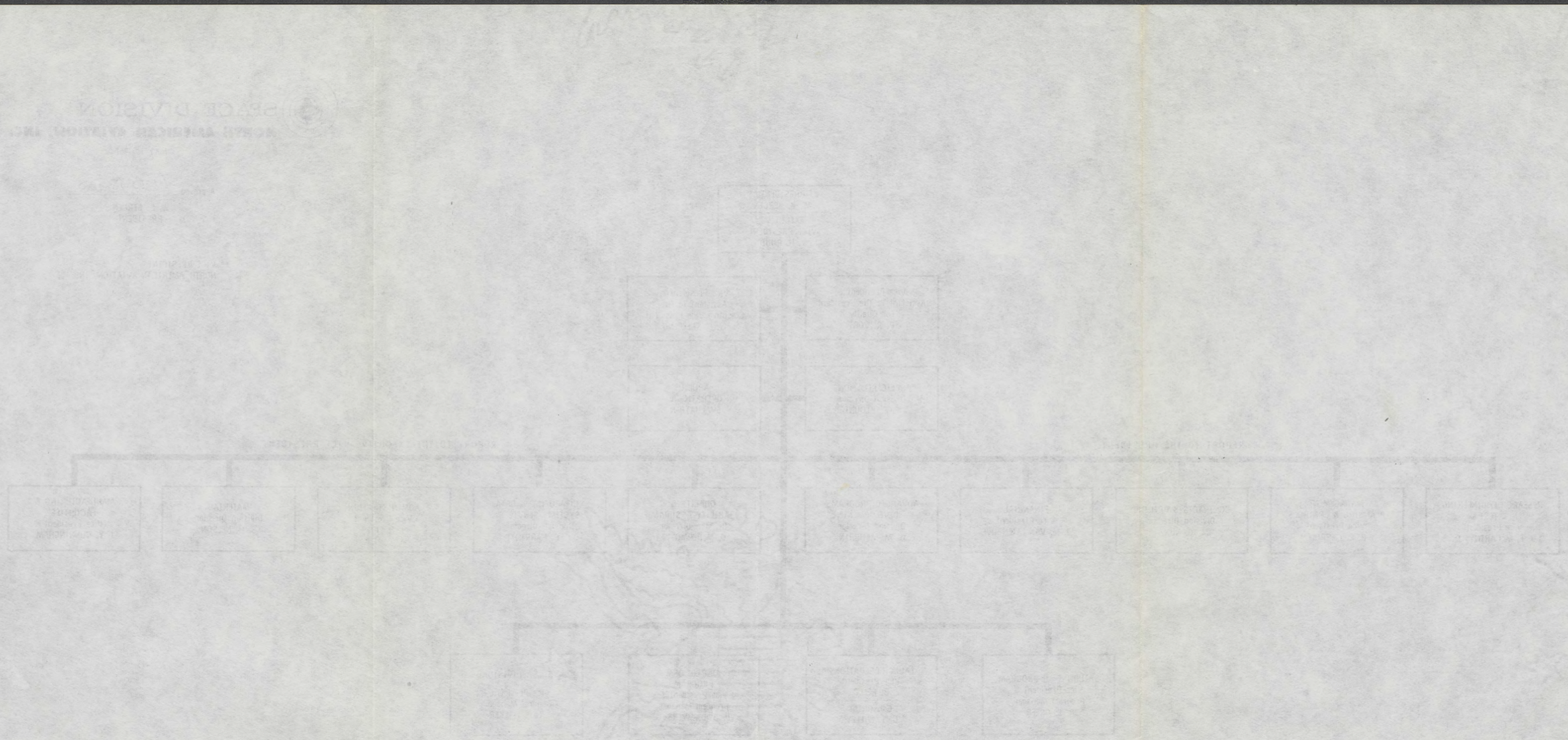


FIGURE 99

74-521 O - 67 (Face p. 436) No. 2



mended more attention from that level of management to the details of their problems and progress."

That's a very critical assessment of North American management on these two contracts for the spacecraft in the S–2 stage, and I think it would be useful if we could have your views in the statement that I have referred to, Mr. Atwood.

General Phillips also testified that—"I was critical of the change control that was being exercised and made recommendation for tighter control of engineering changes. We were critical of their test operations with respect to the timely development of the procedures which tell the test engineers the steps to go through."

In the statement it would be well if you could give us something of the steps that you have taken to control the engineering changes and assure the timely development of test procedures.

I will read one more and supply the others.

General Phillips further testified:

"In the functional area of planning and control * * * I felt here that they had not gone nearly far enough to make a work structure breakdown or what we have come more recently to call work packages clearly defined so that there were clearly stated jobs to be done which could be clearly assigned in the appropriate places in the organization."

In your statement, you might give us an idea of the improvements that have been made of the area of planning and control.

I will provide for the record a number of other questions similar to those, Mr. Atwood, that you might touch upon in making your statement for the record.

Thank you, Mr. Chairman.

The CHAIRMAN. Those will be included.

(The questions referred to by Senator Smith are as follows:)

1. General Phillips testified before the Committee that in December 1965 he thought that the authority of the two program managers (on the Apollo command and service modules and the S–11 stage) in the division was too diffuse to enable them to harness all the resources they had to bring to bear to get the job done and he recommended that you strengthen the project organization and pull parts of the functional organization together under the more direct authority of the respective program managers.

Did you realine the authority of the program managers and change the project organization so that the organization could pull together under the authority of the program managers? (Perhaps you would like to put some charts in the record at this point showing before and after organizations.)

2. General Phillips further testified that:

"I felt that they were not doing enough in integrating the total program planning. There were planning groups in several places but I was critical of the manner in which they were bringing all the planning together so that the total job could be properly understood and directed and I was critical also of what I call the visibility that program management had and their ability to understand the details of the progress and be able then to focus energy and resources to solve the problems."

What have you done to improve the integration of the total program planning?

3. General Phillips was also critical of the ability of the engineering organization to meet engineering release schedules and because the Block II design was falling behind schedule for no reason that he could see. He believed there was no reason for it to be falling behind schedule if it was properly addressed by the management of the engineering organization.

What steps has North American taken to improve the ability of the engineering organization in these areas?

4. General Phillips was also critical of the efficiency of the work force in manufacturing.

Have you improved the amount of work you get per man hour?

5. General Phillips was also critical of manufacturing. He testified that:

"We were critical of the behind schedule position of some of the components and subsystems and of the practices that were being followed in managing certain subcontracts and in expediting some of the materials, and here, too, as in all the cases I have been enumerating, the company worked very closely with me and my team and were very cooperative and responsive to these recommendations in the main."

Have you gotten those components and subsystems back on schedule or have you taken steps to bring them back on schedule?

Have you taken the appropriate steps to change your practices in managing subcontracts and to expedite some of the materials?

6. General Phillips was also critical of the effectiveness of supervision in manufacturing.

What steps have been taken to improve this supervision since without good supervision you cannot get good products?

7. General Phillips was critical of contracting and particularly the contracting negotiations which he said "had become more or less the way of business between our respective contracting organizations," and he recommended that actions be taken to improve the ability of North American and NASA together to negotiate contracts and changes to contracts in a more timely fashion.

What have you done along these lines?

8. General Phillips was critical of the quality control at North American and made recommendations "that trend data be used effectively by management to identify whether the quality of workmanship was as good as it should be."

What steps have you taken to use trend data more effectively?

9. General Phillips also testified that "our government inspectors are finding what I consider to be too many discrepancies over and above those that the company inspectors identified."

What steps has North American taken to correct this criticism by General Phillips.

Finally, with respect to quality control, General Phillips said:

"I felt that the quality control organization was not being fully effective in carrying out their inspection function and in identifying discrepancies."

10. What has North American done to improve the effectiveness of the quality control organization?

(The answers supplied for Senator Smith's questions referred to above and on p. 402 are as follows:)

As requested by the Committee, North American amplifies herein its comments on the summary which was presented by NASA with respect to the review made by the survey team headed by General Phillips.

North American indicated in the earlier testimony some of the conditions which contributed to the problems identified by the NASA review. These conditions were in a real sense inherent, given the size, complexity and evolutionary nature of the development necessary to achieve the lunar mission objectives. A significant consideration was that the mission and performance criteria under which the Apollo CSM and Saturn S–II were being designed and developed continued to evolve based on knowledge and experience being gained by NASA and North American. This caused frequent and almost continuing changes in the detailed specifications and the associated engineering, test, manufacturing, quality control and other program activities. By the fall of 1965 the cumulative impact of the problems being experienced was having a significant effect on the achievement of program milestones.

North American welcomed the NASA Review Team in order to receive the benefit of their views on identifying specific program problems and recommending solutions.

Although North American in some instances took exception to the findings and recommendations of the review team, these were not stressed. It was recognized that in the main, while there might be differences of opinion as to emphasis, the problem areas identified were real. North American, therefore, directed its efforts to responsive action. The Company did not wish to detract from the

importance of the review team's views, but was concerned that its concentration on problems would obscure a good understanding of their causes. Successful accomplishment of the program objectives required this mutual understanding, which would include recognizing that stable schedule, cost, and performance conditions were heavily dependent upon clearly defined mission criteria and specifications, tight control of changes, and close and effective working relationships between North American and NASA.

As part of North American's responsive action to the review, Mr. Atwood formed an Action Group consisting of himself, the President of the Space Division, and selected top corporate executives.

This group was directed by Mr. Atwood to make a thorough assessment of actions already taken, and those planned to be taken, by the Company in monitoring and improving program performance. In the conduct of this reevaluation, the group made a thorough analysis of the review notes, examined the conditions referred to, and implemented necessary actions on each item.

The corporate executives on the Action Group in turn formed teams, drawing on qualified personnel throughout the corporation to take actions within their respective areas of responsibility. They worked in close cooperation with Space Division management, Apollo CSM, and Saturn S–II Stage program management, supervision at all levels in Space Division within their functional areas, and with each other.

Subsequent to the NASA assessment in April 1966 of North American actions taken or initiated, the corporate executives concerned continued to work closely with Space Division program and functional management in following up on all actions prescribed. NASA was kept advised of program performance and progress through regular North American-NASA program management channels of communication.

North American believes that its response to the Phillips review showed an understanding of and effective plans to attack vigorously and promptly, in careful detail and in an orderly manner, the problem areas reflected. The actions taken looked to significant improvements in program planning and control, better application of the total corporate resources including, in particular, the resources available in the General Offices, attention to the problem of program management with emphasis on defining and strengthening the role of the Program Managers, and organizational and other improvements in the Engineering, Manufacturing, Quality Assurance, and Reliability areas. Particular emphasis was placed on achieving maximum divisional and corporate program visibility and control. Both accompanying and following these changes, a number of important organizational and personnel shifts were made, designed to assist in accomplishing objectives.

The review team was specifically concerned with six areas, as described to the Committee. North American's further comments and actions taken with respect to these areas are summarized below.

ORGANIZATION AND MANNING

Organization changes and consolidations were effected to: strengthen the authority and control of the Program Managers; provide greater concentration of effort through consolidation of closely related functions under single management; strengthen Space Division central guidance and surveillance; shorten channels of communication; and increase efficiency of operations.

The authority and control exercised by Program Managers were greatly strengthened. Among the actions taken were: separation of the Test Operations and Engineering Reliability Functions from the central Test and Quality Assurance organization and transfer to the Program organizations; transfer of the Structural Fabrication function from central Manufacturing to the Apollo CSM Program; and issuance of new directives which clearly and unequivocally set forth the authority of Program Managers to provide program direction by defining the tasks to be performed, assigning the tasks, authorizing budgets and schedules for each task, measuring performance against plan, and directing any necessary corrective actions.

Actions also were taken to improve division central operations support of the programs. Among the more significant actions taken were: the transfer of non-space oriented activities to other North American operating divisions; the consolidation of all non-Program Engineering activities; and the establishment

of the Quality and Reliability Assurance functions which were previously a part of the disbanded central Test and Quality Assurance organization as a new central Quality and Reliability organization, reporting to the Executive Vice President-Operations. In addition, in order to assure continued improvement in program planning and control and to provide improved visibility into the programs for the Space Division President, a new Division office of Vice President-Management Planning and Controls was established.

Reassignments of key personnel were made to increase efficiency of operations by capitalizing on specific and outstanding skills and capabilities available throughout North American. Some examples of these actions were:

Assignment of a new Program Manager to the Saturn S–II Program

Assignment of new Chief Engineers for both Programs

Assignment from another division of an executive to head the new central Quality and Reliability Assurance organization.

Assignment of a new Assistant Program Manager for Program Control in the S–II Program.

Continuing emphasis has been placed since on maintaining effective organization alignments responsive to changing program requirements. Key personnel changes have continued to be made based on frequent management reviews and assessments.

During the period December 1965 to April 1966, both Programs' manpower peak requirements had been experienced. Completion of early phases of the program and increasing stabilization of engineering design were key factors in diminishing manpower requirements. These factors, coupled with organizational realignments and greater efficiency, permitted significant manpower reductions.

In April 1966 Space Division's Southern California organizational components had a total headcount of 28,000. The Division established headcount targets for its Southern California elements of 25,000 by July 1966 and 22,000 by December 1966. Both of these goals were achieved. By early May 1967 the headcount had been reduced to less than 20,000. The total employment at the Space Division at all locations was 34,300 in April 1966 and in early May 1967 it was 26,300.

North American's current corporate (General Offices) organization charts and Space Division organization charts in effect at the time of the NASA review, immediately following that review, and as of the current date, are attached. (See foldin, opposite p. 436.)

PROGRAM PLANNING AND CONTROL

At the inception of the Apollo CSM and Saturn S–II contracts, Program Planning and Control organizations were established by each Program to assist the respective Program Managers in program planning and in control of cost, schedule, and technical performance. The prime tools for this operation were the Master Program Schedule, the Master PERT Network, development Program Plans, and Program Budgets.

In cooperation with the NASA survey team, and with corporate office guidance, both Programs initiated a new system of work package management. New Division procedures were written, as well as definitive Program implementing instructions. A formal work breakdown structure was developed for each Program, with management responsibility and budget assigned for each major element. Within each element, definitive tasks were identified and scheduled. In-process task milestones were identified and keyed to work package milestones, which, in turn, were identifiable to the Master Schedule and PERT networks. This gave each Program Manager an integrated planning and control system, and gave performing supervision definitive task statements, budgets, and schedules against which performance could be measured. This capability existed not only for internal program functions, but for work performed by central support organizations, other North American divisions, and subcontractors as well. Continuing evaluation of the work task structures had identified areas for further improvement.

To improve engineering visibility, the Master PERT Networks were expanded to encompass more engineering activities, and mechanized "Engineering Product Plans" were expanded on both Programs to schedule and track engineering outputs against user need dates. Weekly print-outs of these reports enabled management to apply corrective action where needed to support the Programs. In addition, the critical problem resolution system was expanded to further expedite the identification and resolution of significant technical, production and quality problems.

For greater integration of program planning, expanded requirements were applied to the establishment, revision, and maintenance of master schedules, maintenance of congruity between the functional and task schedules and PERT events, and reporting of schedule status on controlled milestones. A series of training sessions were held to insure that concerned personnel understood and carried out these improvements. Program Schedule Manuals containing this information are continuously maintained on both Programs.

Concurrent with the establishment of work package management, improved cost control systems, covering work-in-process and labor hours, as well as more detailed reporting on material costs, were implemented against the work package budgets. This provided improved visibility into cost versus budget for specific tasks, and against specific milestones. At the same time, tighter change control procedures were instituted and emphasis placed on schedule and cost impact analysis.

With assistance from the corporate office, a new management reporting system was established in January 1966, which tiered upward from the task supervisor level through the Manager level to the functional Directors and the Program Manager, summarized, as appropriate, to each level, but with detailed data available as required. Emphasis was placed on reporting cost and schedule against plan, supplemented with functional manpower reporting, as well as other appropriate performance indices. Subordinate level reports and backup data are reviewed at weekly Program Reviews by the Division President. This data is also reviewed and validated continuously by the Division's new Management Planning and Controls organization, and their summary and assessment of Program status forwarded monthly for the review and analysis by corporate Executive Management.

Development and refinement of Program Planning and Control Systems has continued, directed primarily toward further mechanized processing of data to improve both its depth and timeliness.

CONTRACTING, PRICING, SUBCONTRACTING, AND PURCHASING

Proposal and negotiation backlogs relating to changes have been kept at a reasonable level by means of systematically focused attention on the part of both North American and NASA. This effort included a process for continuing intensive review of backlog status by North American and NASA personnel who had been made individually responsible for the expedited reduction of such backlogs. Higher North American and NASA management has been kept regularly apprised of backlog status. In consequence of this process backlogs have been markedly reduced.

All Apollo CSM Block II major subcontracts have been definitized on an incentive or fixed-price contract basis. The last of the major subcontracts on the Saturn S–II Program had been definitized approximately six months prior to the completion of the NASA review in December 1965.

North American considers it has demonstrated the willingness to undertake program work on a multiple incentive basis, believing that the incentive form of contracting can provide an effective means of motivating the contractor in a manner which will be most beneficial to the requirements of the Government.

The effective and expeditious negotiations of contracts is dependent upon many elements in the case of programs as large and complex as the Apollo CSM and Saturn S–II. There have been difficulties in the negotiation process in the past which can be attributed to various causes, but North American considers that fundamentally the problem has been one of achieving clear understandings as to requirements and the means of fulfilling them. Continuing effort is being devoted within North American and between North American and NASA to achieve these basic understandings. Based on discussions which have been held between NASA and North American, including discussions at senior management levels, North American believes that those remaining areas which need further clarification can be resolved soon and that the major contract negotiations which remain to be undertaken will be effectively consummated.

ENGINEERING

Continuing improvements in identification of and accountability for engineering output have been achieved. The program Engineering organizations were strengthened to include program-oriented activities previously performed by the

central Engineering functions, and to accentuate the system engineering, project engineering, and configuration management disciplines.

Significant changes in key Engineering personnel on both programs were designed to strengthen both management and technical capability. The Project Engineering and System Engineering organizations in each program were streamlined and their functions more clearly delineated. Key people were added to the System Engineering and Project Engineering operations, and a more rigorous system of design review and evaluation was instituted, together with the establishment of performance requirements.

Additional detailed actions have been taken with respect to timely development of test procedures. The individual test procedure requirements expressed in Process Specifications were included in the Engineering Product Plan. Coordination of scheduled requirements with respect to preparation of detailed test procedures has been accomplished. Both the engineering testing requirements plan and the detailed test procedure plans of the testing department are coordinated to support the test schedule.

Planning related to engineering releases, engineering support of program schedules, and engineering product plans improved. All planned engineering products, such as drawings, specifications and interface documents are identified in these product plans and scheduled down to the organizational unit level. These products are statused so that deviations to plan are identified in sufficient time for action to be taken. The Product Plans are continuously reviewed and modified to accommodate those program changes which are processed through the Change Control Board.

Studies of engineering scheduling resulted in requirements for expanding the number of detailed engineering schedule milestones in order to establish improved planning and control. Between November 1965 and April 1966, the number of these milestones in the Apollo CSM and Saturn S–II schedule networks were increased significantly. As an example, between September and December 1965 the behind-schedule Apollo CSM Block II engineering products in the Product Plan (each of which releases one or more engineering drawings or specifications) rose from 120 to 285. This rise was attributed to some late definition of these products and to engineering changes. Concentrated engineering effort brought this total down to 20 delinquencies by the first of February 1966. During February, March, and April, the delinquencies were on the order of 20 to 50 and since mid-April have been below the level of 25. Similar actions and improvements were accomplished in Block I CSM engineering activities.

The Apollo CSM Block II Critical Design Review, originally scheduled for June 1965, slipped six months primarily because of the late definition of criteria for the Block II spacecraft, and was conducted in December 1965. By a concentrated engineering and manufacturing effort, all but one week of the impact on spacecraft fabrication was recovered by April 1966.

Continuous in-depth screening of change requests by North American and NASA to eliminate nonmandatory changes has resulted in a marked reduction in change activity. However, considerable change activity still exists and will continue to exist as it does throughout every development program.

Internal Space Division procedures concerning configuration management were revised to better support the configuration management needs of the two Programs. Simplification and improvement in the mechanized configuration accounting system continues.

MANUFACTURING AND QUALITY

During 1965 late engineering releases and engineering change activities imposed a heavy requirement on the manufacturing work force in follow-up and material expediting activities. The completion of the early phases of the program and the efforts on the part of the Engineering, Manufacturing, and Material departments in the latter part of 1965 and the first quarter of 1966 resulted in drastically reducing parts and material shortages. Subsequent activities in the mechanization of various production order and parts activities have yielded even further improvements. Except for the environmental control unit, major subsystems have been on schedule, and the behind-schedule condition, overall, of components has been improved significantly.

Important steps were taken on both Programs to improve the flow of design information from Engineering to Manufacturing and to better assess the impact of both design releases and design changes, as well as to implement effective

fabrication and installation plans to accommodate these unusual problems. The key to improving this flow, initiated in late 1965, was the increased emphasis on the Engineering Product Plan and the keying of the required release dates in the plan to the Manufacturing Master Index Schedule.

This effort continued through 1966, resulting in the continuation of marked improvement in the schedule status of work-in-process production orders.

Engineering formed a Manufacturing and Test Support section to assist the engineering/manufacturing liaison for rapid problem solving. Improved automated production control methods have been implemented to control manufacturing orders, tooling orders, material requisitions, and storage requirements. Rapid data feedback to management from these systems permits timely preventive and corrective action.

Overall Space Division work measurement indications show that a general 10% increase in work force effectiveness was attained from January 1966 through April 1967, with a marked reduction in the work force being realized during the same period.

Additionally, internal North American actions to improve supervision indicated a need for changes in organizational structure and reassignment of duties and responsibilities. Organizational realignments have permitted the line supervisor to be freed to spend maximum time in carrying out the work plan.

Manufacturing supervisors are continually measured by the group performance of those employees who report to them. The ability of each supervisor to meet the daily work plan and the unit cost and scheduled objectives while maintaining high quality is reflected in trend charts. The effectiveness of manpower utilization in his function is recorded and charted.

The bonding technique utilized in the Command Module is the result of technical processes which were under development. The successful conclusion in mid-1966 of these developments has provided the process which is currently being utilized effectively. North American has led the aerospace industry in the development of welding techniques. Nevertheless, the requirement to weld the special aluminum alloy used in the Command Module produced a number of technical problems. Through the incorporation of improved tooling, better control of the parts and environment of the weld, successful production of welds has been achieved.

The welding problem on the Saturn S–II was primarily one of extreme size of structure and extremely small tolerances of the assembled hardware. Fabrication development has been a joint effort by both NASA and NAA. The present welding technique is good, but improvement is still being pursued by the joint team.

The proof of the manufacturing process is reflected in the quality of its final product. North American has been continuing its efforts to achieve the highest standards of quality performance through careful selection, indoctrination and motivation of individual employees, as well as by providing rigorous training for these employees to enhance their individual accomplishments. Each new phase of the work process in this program requires the development of new technical skills and certification of employees who work upon items of the spacecraft. Motivation for all technical and supervisory personnel is aimed at bringing to the employee an awareness of the effect of his work on the spacecraft quality. Rigorous quality control procedures are utilized, and an error analysis data system has been implemented to provide timely information on defects to operating supervision and technicians as a tool in improving workmanship and reducing error.

In addition to organization changes, improved techniques in the recording and utilization of quality trend data were implemented. Quality trend data display was expanded throughout the Manufacturing area. Weekly meetings are held between program Quality and Reliability Assurance and Manufacturing to review and analyze trends, problems and corrective actions; specific quality problems are presented daily to the Program Manager and weekly to the Space Division President; material review procedures have been examined and revised.

Further strengthening of the Quality function has been accomplished by expansion of the on-the-job employee qualification program to supplement the formal skills certification program to more adequately assure that the individuals concerned possess the specific skills required for the job. Implementation of the "resident quality engineer" concept in which quality engineers are assigned (in addition to quality inspection personnel) to Manufacturing and Test departments

to provide in-process surveillance and rapid detection and resolution of quality problems has proven effective.

Effectiveness in the use of quality control trend data has been improved by having computerized inspection data analyzed weekly and reported to each Manufacturing department leadman or station. Charts are included, showing the weekly trend of the total Manufacturing department. Within the Manufacturing departments, wall charts are maintained to provide easy reference to trend data. To identify repetitive defect conditions, major and repetitive defects are flagged weekly for analysis leading to preventive or corrective action. The daily inspection sheets are analyzed each day for immediate identification of problem areas. Apollo CSM and Saturn S–II Manufacturing analyze repetitive defect data and initiate, in conjunction with Quality Control, corrective actions. In selected departments control limits and other statistical measures are routinely applied to department and area data.

Establishment of a joint Quality Assessment Team has enhanced the cooperative effort between North American and NASA in the identification of quality problems and the initiation of corrective actions. North American and NASA Quality Assurance management conduct monthly briefings to report program quality problems, quality activities, and quality trends. Personnel from NASA Centers and Headquarters, and North American General Offices attend the meetings as required, as do Quality Assurance personnel from major subcontractors and other participating North American divisions.

* * * * * * *

North American is and has been thoroughly dedicated to the effective management and execution of the Apollo CSM and S–II Programs. Top management of the Corporation has sought, on the one hand, to assure that sufficient authority and resources would be available to the Division management and, on the other hand, to devote corporate top management attention to furnishing support, guidance and, where necessary, direction to Space Division management.

It is recognized that management effectiveness in terms of program progress is best measured by dedication and attention to specific elements of program operations. It is these specifics which are being reemphasized vigorously.

The President of the Corporation has taken many actions to insure that the skills and resources available to the key corporate executives are applied as effectively as possible. Additionally, new program reporting requirements and systems were initiated in early 1966 to assure that corporate executive management was closely informed, in meaningful ways, of program progress and problems. This improved management information flow was designed so that corporate top management would be able to apply prompt support and take corrective action as indicated.

The CHAIRMAN. Mr. Gehrig?

SPACECRAFT ON PRODUCTION LINE AT TIME OF REVIEW

Mr. GEHRIG. Mr. Atwood, where was the Apollo Spacecraft 012 at the time of the General Phillips review?

Mr. ATWOOD. At the time General Phillips visited the plant it was in Downey. I don't remember what stage it was in.

Mr. MYERS. It was in the final stages of fabrication prior to checkout.

Mr. GEHRIG. So the spacecraft in which the fire occurred was on the production line at the time he made this review of North American.

Mr. MYERS. That's right.

Mr. GEHRIG. Since the findings, the General Phillips review relate to the period during which the Spacecraft 012 was on the line being developed, was a reexamination made of this spacecraft to determine whether it required redesign or rework?

Mr. MYERS. The General Phillips report did not deal with the specifics of the design, but the activities that we took with respect to our management certainly did apply to Spacecraft 012.

Mr. GEHRIG. But these activities of management certainly were the management that was responsible for this spacecraft and the S–II stage.

Mr. MYERS. I think the point I'm trying to make here is that all of the items that dealt with, for example, the shortening of spans of control in our quality control, method of management of the information coming from quality control, all were applied to Spacecraft 012—that came out of the Phillips report—all were applied to Spacecraft 012 before it was delivered.

Mr. GEHRIG. Now, the Apollo 204 Review Board, in their review of the accident they were reviewing the Apollo Spacecraft 012. This is the spacecraft they studied?

Mr. MYERS. Yes.

Mr. GEHRIG. So it was not surprising that many of the things the Apollo 204 Review Board found were similar to the things that General Phillips remarked on. They were looking at the same period of time essentially, were they not?

Mr. ATWOOD. Well, if you think that the Phillips recommendation was improving inspection procedures, which of course was the essence of their quality control comment, the group's comment, 012 certainly had the benefit of many improved quality control and inspection procedures that were applicable. And it was inspected many times in this period.

Mr. GEHRIG. When was the Apollo 012 spacecraft shipped to the Cape?

Mr. MYERS. In August of 1966.

DISCUSS REVIEW BOARD FINDING NO. 10

Mr. GEHRIG. The Apollo 204 Review Board, in its report, in Finding No. 10, said:

> Deficiencies exist in command module design, workmanship and quality control.

North American Aviation, Inc., is responsible for the design, workmanship, and quality control of the command module, it is not?

Mr. ATWOOD. Yes.

Mr. GEHRIG. Do you agree with the board's finding?

Mr. ATWOOD. Which number is that again?

Mr. GEHRIG. Finding No. 10.

Mr. ATWOOD. Yes.

Mr. GEHRIG. Did you say yes, Mr. Atwood?

Mr. ATWOOD. Well, yes. We have given our comments. We certainly do agree that when they found deficiencies, they certainly were there.

Mr. GEHRIG. What has North American done to correct these deficiencies? And if you would like to make a comment now, and then amplify it in a statement for the record, that would be fine.

Mr. ATWOOD. Well, I think perhaps it would be well to add to the record. Suffice it to say, we are doing everything humanly possible to emphasize the importance of quality control, quality in detail workmanship, and the portion of inspection, detection of any defects and deficiencies. This is emphasized in both our work and I am sure equally

in the NASA inspection ranks. But we can augment this with some more information, which we will do.

(The material referred to follows:)

As North American has indicated in its memorandum response to the Findings, Determinations and Recommendations of the Report of the Apollo 204 Review Board, copies of which were filed with the Committee, the deficiencies covered by the Board in Finding No. 10 related only to certain specific areas of the wiring and to the Environmental Control System. North American's detailed response to each of the specific areas was set forth in that memorandum.

The following are the improvements or corrective actions which had been taken, or are planned, for Block II spacecraft. It should be noted that most of the actions relate to improvements in existing procedures, and cover areas in the Board Report which were not in fact deficiencies.

Finding No. 10a related to the Environmental Control System. In the Block II spacecraft the Environmental Control Unit, which is a principal portion of the Environmental Control System, has been repackaged for easier installation, accessibility and maintenance. In addition it is planned that some of the tests which were formerly conducted in the spacecraft will be conducted at the subcontractor's plant, thereby reducing the number of removals from the spacecraft.

Finding No. 10b relates to coolant leakage at solder joints. The tubing which carries the coolant has been extensively reviewed in the Block II spacecraft care has been taken to eliminate stress in solder joints. In certain areas, where it has been considered appropriate, brazed or mechanically jointed stainless steel tubing will be substituted for solder jointed aluminum tubing. Tubing which was exposed to the space craft interior will be protected by metal covers both during manufacture as well as in the final flight configuration, and "armoring" and shielding has been designed to strengthen and protect joints in susceptible areas. Wherever possible, joints will be eliminated by combining several segments into longer runs of tubing without joints.

Finding No. 10c referred to the water-glycol coolant itself. As pointed out above under Finding No. 10b, the actions being taken with respect to both the tubing and the elimination or protection of solder joints should eliminate problems resulting from coolant leakage. In the event the coolant is leaked or spilled, a new process for cleaning the affected areas has been developed, as has a chemical test to identify any residue from the inhibitor.

Finding No. 10d covers electrical wiring. Since the date of the accident, a NASA/Industry team of specialists has reviewed the wiring specifications of the Block II spacecraft and has agreed with the design approach taken on Block II by North American. The following improvements from the wiring practices used in the Block I spacecraft are applied in the Block II electrical wiring:

1. Three-dimensional jigs are used to fabricate the cables so that the finished bundles can be fitted into the spacecraft without stress or strain.

2. In the Block II spacecraft design, the umbilical which connects the Command Module to the Service Module has been relocated so that it is now close to the major electrical equipment, thus obviating the need for wire bundles to be routed completely across the spacecraft floor.

3. More extensive support will be provided for the wire bundles, and metal covers will be installed to protect wiring from possible damage during manufacture, installation and test, as well as in flight.

4. The number of inspections has been increased to insure that spacecraft wiring conforms to all criteria. The Mandatory Inspection Point plan in use has been increased to require additional mandatory inspection of wiring at specified points in the manufacturing, installation and test processes before additional work proceeds.

5. Receiving Inspection procedures have been strengthened and expanded, and the number of sampling tests and electrical tests of dielectric strength and insulation resistance have been increased. Wire suppliers have been resurveyed and additional in-process inspections have been included at suppliers' plants. To supplement previous sampling tests at the suppliers' plants, we have added North American resident inspectors who will participate full time in the acceptance testing of wire to be used in the spacecraft.

6. Block II wire harnesses contain additional flexibility for changes, and spare wires have been provided to allow for "splice areas" to provide for ease of incorporating changes.

7. A spacecraft manager and team have been formed for each spacecraft. This team will stay with the spacecraft through the manufacturing, checkout and pre-launch activities and will work with the flight crews.

8. A number of process specifications with respect to wire fabrication and assembly have been grouped together into a single process specification for the general instruction of wire harness technicians and inspectors.

9. A procedure for installing changes in blocks, rather than individually, has been instituted, and such changes will be demonstrated on a wiring mock-up prior to installation.

Findings No. 10e relates to vibration test of a completed flight configuration spacecraft. An acoustic vibration test of a production line Block II spacecraft in flight configuration is to be completed at the Manned Spacecraft Center prior to the next manned flight. This test will determine the vibration levels within the spacecraft at each subsystem location, providing an additional assurance that the qualification and acceptance testing of the subsystems already carried out reflects the vibration conditions expected to be encountered during flight. Such testing will also further verify the integrity of the interconnections, both electrical and mechanical, between the various spacecraft systems and the subsystems.

Finding No. 10f relates to the disconnecting of electrical connections while powered. The Block II spacecraft design already incorporates switches that eliminate the necessity for electrical connections or disconnections of cables while energized within the crew compartment. No design or connector changes to the Block II system will therefore be required.

Finding No. 10g is directed to design features for fire protection. As NASA representatives have recently testified, a number of agents have been tested as possible candidates for extinguishing spacecraft fires. These included solids, gases and liquid. It currently appears that water is the most effective fire extinguishing agent that can be used, although additional investigations of other substances are continuing. These investigations are in addition to the plans for the elimination, or placement, of combustible materials within the spacecraft, and the other actions which are being taken to limit the possibility of an ignition source.

Mr. GEHRIG. I have one other question here which goes to the review board finding number 10, which I will put in the record, and you can answer it for the record.

North American's comments on the review board's finding number 10 which related to certain deficiencies in the Environmental Control System (ECS) state that—

The basic cause of these problems, as discussed in the Panel Report, was that the criteria which established the requirements for North American's design continued to evolve after the design had been started and in fact continued after release of the design to manufacture.

Why wasn't the ECS redesigned so as to conform with the revised criteria?

Was the failure to redesign the ECS because it was necessary to meet project time schedules?

Answer: The Environmental Control System (ECS) was redesigned to conform with the revised criteria. The ECS criteria have been revised, not all at once as a single set of revisions, but as a continuous series of changes since the beginning of the program, as the environmental control requirements have been better understood. Each time these criteria have been revised, whether by NASA or North American, the ECS system has been redesigned to conform to the revisions. The frequency and extent of the changes in the ECS has been greater than other systems, partially because it is the system most sensitive to the deep space and circumlunar environment and to mission planning. No compromise in any modifications to the ECS has ever been made because of time schedules.

DISCUSS REVIEW BOARD FINDING NO. 11

Mr. GEHRIG. Now, the Apollo 204 Review Board determination under Finding No. 11 is—

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

Do you agree with this determination?

Mr. ATWOOD. It is a tremendously big organization, Mr. Gehrig. I am not aware of the relationship factors—I certainly realize the size of the organization—the size has contributed to the difficulty of such communications. Perhaps Mr. Myers would like to say something.

Mr. MYERS. We are aware of actions within NASA and actions of ours on streamlining some of the procedures, so there can be quicker response to these activities.

Mr. GEHRIG. Well, is North American satisfied with the definition of the interfaces between the company, NASA headquarters, and various centers, and the other contractors on the program now?

Mr. MYERS. I think they generally are. I think in some cases there is a better definition that could be brought about within the program. I think some of these have been focused—attention has been focused on them during this period, and there are actions going on in this area.

Mr. GEHRIG. The Apollo 204 Review Board recommendation under Finding eleven was—

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

Now, in your judgment have you made progress since the accident to more clearly define these interfaces that we are discussing?

Mr. MYERS. Yes. We have had several meetings with George Low and Dr. Gilruth on this activity, and at my level we are actively pursuing definition of responsibilities which in most cases are a matter of detail clarification, not major changes in responsibilities.

Mr. GEHRIG. You are satisfied at the present time with the delineation of authority between these various organizations?

Mr. MYERS. We have made some recommendations concerning the responsibilities and authorities between the centers and headquarters with respect to definition of program plans and definitions of inspection techniques.

DUTIES OF GENERAL PHILLIPS DISCUSSED

Senator BROOKE. Mr. Gehrig, would you yield at this point?

Mr. Chairman, you asked a question as to what did General Phillips do. It is not quite clear as to where one responsibility begins and the other one ends. Now it might not be fair to ask Mr. Atwood and Mr. Myers, but certainly NASA ought to present us with the clear distinction of the responsibilities. I am not quite sure what General Phillips, for instance, could have done. Could General Phillips have said you must do A, B, C, D, and North American had to do it—what would the results have been? Is there a joint responsibility here?

This is a very fuzzy area, at least in my mind, Mr. Chairman. And when you ask that question of Mr. Atwood, as to what General Phillips did, it came to my mind what could General Phillips do other than perform his duty as a task force leader and make his findings and recommendations. Did he have the power and authority to pursue them, and to insist that they be corrected?

The CHAIRMAN. He was the Apollo Program Director.

Did you have to take instructions from him?

Mr. ATWOOD. Of course he is the Program Director. As far as we are concerned, he could give orders.

The CHAIRMAN. I think probably we better ask NASA to get us that information. That is a very good point, Senator Brooke. Thank you very much.

Mr. GEHRIG. Mr. Myers, going back, you said you made some recommendations on how these interfaces between the various organizations might be improved. Suppose your recommendations are not accepted? Are you satisfied with the delineation of responsibility and authority?

Mr. MYERS. Well, I know that NASA is actively pursuing the ideas right now. I think I would have to wait and see what the results of the NASA actions are. I am quite sure personally that I am going to be satisfied with them, because I think that General Phillips is very actively involved in this, and I have a tremendous amount of respect for him and his ability to organize these activities.

Mr. GEHRIG. So at the present time you think there must be some changes made, and you are waiting to see what the changes will be.

Mr. MYERS. And am working with NASA on some of these changes.

Mr. GEHRIG. In the report of the Review Board to this committee, the Board noted that there was a problem in coordinating the activities of the contractor personnel and the NASA personnel.

Now, when you define these interfaces, do you think this problem will be satisfied?

Mr. MYERS. Do you have it by the finding?

Mr. GEHRIG. I think the Board discussed this, before the committee, that there were some problems in coordination between NASA and the contractor personnel. My question is after you realigned the responsibilities and authority between the organizations, do you think the coordination will be better?

Mr. MYERS. There are always problems of coordination. It's part of the business of the management to keep those to an absolute minimum. The activities that were going on between ourselves and the Cape people I think in general were very good. There were exceptions with respect to coordination that was not completed. I do expect the action is being taken by NASA to improve that, and we are certainly doing everything we can from the management standpoint to improve it too.

IMPROVED REPORTING SYSTEM

Mr. GEHRIG. Dr. Thompson, when he appeared before the committee, as Chairman of the Apollo 204 Review Board, said in his opinion there were too many informal understandings about work to be performed and functions to be carried out. What would you have to say about this problem and have any steps been taken to make this

relationship more formal? I think there is some indication of this in the General Phillips review of North American, in that there was apparently never any formal report submitted. The word "informal" has been used several times in relation to this.

Mr. MYERS. We do have a formal reporting system from our Cape operation to myself and our management. With this new change in organization at the Cape, I believe there will be even further stiffening of those formal relationships.

Mr. GEHRIG. You think that the relationship will become more formal?

Mr. MYERS. Yes, I do believe they will.

Mr. ATWOOD. Of course in speaking of the Phillips Review, it was exceedingly informal, but it was intended for a variety of things—thought provoking action, recommendations, criticism, anything that would be useful in our self-analysis, as well as in the analysis of the task force team. I should think informally there is a most effective way of doing that sort of work, Mr. Gehrig.

Mr. GEHRIG. Mr. Chairman, I have four additional questions which I would suggest we put in the record and Mr. Atwood and Mr. Myers can answer for the record.

Mr. CHAIRMAN. Without objection, that will be done.

(Questions submitted by Mr. Gehrig and answers submitted by Mr. Atwood for the record are as follows:)

13 TEST LAUNCHES LISTED

Question 1. Mr. Atwood, in your statement you mention 13 test launches successfully completed.

Would you furnish for the record a list of these launches; what was tested on each launch; and what was achieved?

Answer. The following is a list of the thirteen (13) test launches successfully completed in the Apollo-CSM program:

November 7, 1963: Boilerplate 6. Pad Abort: Test the launch escape system's ability to work in emergency before launch while on the pad.

May 13, 1964: Boilerplate 12. Transonic abort test: Utilizing Little Joe II which simulates a Saturn V in trouble in high stress, high speed region.

May 28, 1964: Boilerplate 13. Proved spacecraft compatibility with Saturn I space vehicle. Went into earth orbit (SA–6).

September 18, 1964: Boilerplate 15. Determine space vehicle launch exit environment on Saturn I (SA–7).

December 8, 1964: Boilerplate 23. High Q abort test to verify launch escape, earth landing systems and canard subsystems (Little Joe II).

February 16, 1965: Boilerplate 16. Pegasus Micrometeoroid Detection Satellite—an Apollo test spacecraft housed and protected the Pegasus payload until reaching orbit where Apollo Command Module was jettisoned, permitting the satellite to deploy (SA–9).

May 19, 1965: Boilerplate 22. Planned high-altitude launch escape system test to determine performance of launch escape vehicle canard subsystem, and to demonstrate orientation of launch escape vehicle (Little Joe II). Partially successful (Boost vehicle guidance malfunctioned causing premature low-altitude abort. Apollo systems functioned perfectly, pulling command module away from debris and lowering it safely to earth).

May 25, 1965: Boilerplate 26. Second Pegasus Meteoroid Detection Satellite . . . an Apollo test spacecraft housed and protected the Pegasus payload until reaching orbit where Apollo Command Module was jettisoned permitting the satellite to deploy (SA–8).

June 29, 1965: Boilerplate 23A. Pad Abort: Second test of the launch escape system's ability to work in emergency before launch and while still on the pad atop a Saturn. The canards, boost protective cover, jettisonable apex cover and dual reefed drogue chutes were all tested satisfactorily.

July 30, 1965: Boilerplate 9A. Third Pegasus Meteoroid Detection Satellite . . . an Apollo test spacecraft housed and protected the Pegasus payload until reaching orbit where Apollo Command Module was jettisoned, permitting the satellite to deploy (SA–10).

January 20, 1966: Spacecraft 002. Final abort test utilizing actual spacecraft to test escape in high tumbling region. This completed the abort test phase, qualifying the astronaut escape system for manned flights (Little Joe II).

February 26, 1966: Spacecraft 009. First flight of unmanned Apollo spacecraft to test command module's ability to withstand reentry temperatures; determine command module adequacy for manned entry from low orbit; test command and service module's reaction control engines; test service module engine firing and restart. This was also first flight of the Saturn 1B (A–201). Flight was successful.

August 25, 1966: Spacecraft 011. Second flight of unmanned Apollo spacecraft to test command module's ability to withstand reentry temperatures under high heat load. Flight was successful.

LIST REASONS FOR CHANGING DIVISION NAME

Question 2. Mr. Atwood, why did you change the name of the division from the Space and Information Systems Division to the Space Division?

Answer. The Company changed the name of the Space and Information Systems Division to the Space Division to emphasize that the main thrust and effort of that division is space work. The information systems activities of the division had already been transferred to other divisions of the Company.

Copies of charts of the Company and of the Space Division showing the names and positions of the management have been submitted.

RESPONSIBILITY FOR IDENTIFYING HAZARDS

Question 3. Mr. Atwood, in the North American statement on the Board's findings, you state that NASA had the Kennedy Space Center furnish criteria identifying a hazardous test operation. This did not include manned testing in 100 percent oxygen environment at 16 p.s.i.

As a contractor to NASA with certain design and test responsibilities, do you believe that you have an obligation to adhere strictly to the criteria furnished by NASA for such tests or do you feel you have a broader responsibility to identify and provide for other hazards which might originate from the test conditions?

Answer. North American certainly feels a broad responsibility, to the full limit of its resources, to identify and protect against hazards which might originate from test conditions. We recognize that the NASA listed criteria reflect the results of experience at any given time, and that such a listing is subject to change in light of new factors or additional experience.

INSPECTION PROCEDURES OUTLINED

Question 4. Mr. Atwood, there have been many newspaper reports in the last few months concerning a variety of alleged shortcomings in the way that the Apollo spacecraft was handled after it reached Cape Kennedy. Would you describe for the committee just what the procedures are at North American for inspecting the spacecraft, for determining what corrections must be made, and how these corrections are carried out?

Answer. After they reach Cape Kennedy, all spacecraft are inspected at key points in the pre-launch checkout sequence. These inspections are detailed and are designed to detect discrepancies in all systems and equipment. Inspection points verify that equipment integrity has been maintained, that the configuration of the spacecraft is proper for testing, and that all previous detected discrepancies have been corrected. A "shakedown" inspection is an inspection of the equipment and the area in which the equipment is located to look for damaged wires, damaged tubing, safety of wiring, proper torquing, cable stress and clearance, contaminants and debris. These inspections are conducted jointly by North American and NASA inspection personnel. They are as follows:

1. Receiving Inspection—C/M, S/M, Launch Escape System and SLA (Spacecraft LM Adapter).

2. The Service Module interior prior to installation of the four reaction control system modular assemblies.

3. The top of the Service Module prior to mating the Command Module.

4. A complete exterior shakedown inspection of the CSM prior to mating with the SLA.

5. A complete crew compartment shakedown inspection prior to crew ingress for the altitude chamber test.

6. A complete crew compartment shakedown inspection after completion of the altitude test and prior to removal of the CSM from the altitude chamber for movement to the launch complex.

7. A complete shakedown inspection of the crew compartment and C/M exterior prior to crew ingress for the flight readiness test.

8. A complete crew compartment shakedown prior to crew ingress for the launch countdown. This is performed after all precountdown operations.

In addition to the above, all work and activity in the C/M interior is monitored full time by North American and NASA inspection personnel. This would include modification, equipment installations/removals, rework, cleaning, pretest preparations, and connections/disconnections of electrical connectors and plumbing. Prior to the installation of equipment the technician notifies the inspector of the work to be accomplished and he must receive an "okay to install" from both North American and NASA inspection. When this is granted, it signifies that the inspectors have examined all equipment in that area to assure compliance with engineering drawings and specifications. The inspectors also inspect conformance to acceptable work standards, and are responsible to check all wiring, plumbing, contaminants, adequacy of safety wiring, etc. Upon completion of the installation, North American and NASA inspectors reinspect the area in detail.

The CHAIRMAN. Mr. Atwood, Mr. Myers, I am sorry we have to terminate this at this time. We are having some trouble on the floor of the Senate. I thank you very much. I know you are hard-working, conscientious people. We have a great deal of respect for you. We are very happy to have had you here today.

Mr. ATWOOD. Thank you very much, Mr. Chairman.

The CHAIRMAN. At this time, the committee will stand in recess until 10 o'clock next Tuesday morning.

(Whereupon, at 4:50 p.m., the committee was recessed to reconvene at 10 a.m., Tuesday, May 9, 1967.)

(The memorandum referred to on p. 398 follows:)

MEMORANDUM FOR COMMITTEE ON SCIENCE AND ASTRONAUTICS SUBCOMMITTEE ON NASA OVERSIGHT, OF THE HOUSE OF REPRESENTATIVES

This memorandum sets forth the comments of North American Aviation, Inc. on the Findings, Determinations and Recommendations of the Report of the Apollo 204 Review Board.

The comments follow the same numbering system used by the Board in its Findings, Determinations and Recommendations.

Before making specific comments, North American believes it important to underscore the concern expressed by the Board in its Preface that its Report might be interpreted as a criticism of the entire manned space flight program and of the many people associated with it. The Board made it clear that this was not its intent, pointing out that it was dealing with the "most complex research and development program ever undertaken" and that the Report was not intended to present a total picture of the program.

The Board did find deficiencies, and North American accepts its share of responsibility. There have been problems in the developmental phase which led to the difficulties described in the Board Report. We believe the Board has done an excellent job of searching these out and describing them fully. In assessing the Findings, it must be recognized, however, that in space work the standards are and must be extremely high. We have always sought improvements and are continually striving for the goal of perfection.

The Apollo Program is indeed a complex program. Great progress has been made and many outstanding accomplishments have been achieved. Until the time

of the accident, the spacecraft and their subsystems had a highly successful series of ground tests to qualify them for manned flight and there have so far been 13 flight tests of Command and Service Module systems, all of them successful.

We believe it would be a disservice to the many thousands of dedicated people who have contributed to this great project not to remind the Committee of past accomplishments and to express the confidence which North American has that the Apollo Command and Service Module Program is sound, and that a solid basis exists for moving forward to a successful completion.

FINDING NO. 1

North American concurs with this Finding and with the Determination as to the most probable initiator. We have noted the other nine possible ignition sources, and on the basis of our participation in the conduct of tests and analyses, concur with the Findings that the most probable initiator was an electrical arc in the sector between —Y and +Z spacecraft axes.

FINDING NO. 2a

North American concurs with Finding 2a that the amount and location of combustible materials in the Command Module must be severely restricted and controlled.

The Mercury and Gemini materials (nonmetallic) testing was limited to testing for toxicity and outgassing, and did not include spark ignition testing. Therefore, North American initiated the development in 1963 of criteria for testing the ignition point of individual materials in an oxygen environment. These criteria were incorporated into a North American specification which was reviewed with NASA. The criteria used by North American in this testing was "no ignition below 400° F. in 14.7 psi, 100% oxygen environment with spark impingement".

Possible materials for use in the spacecraft were divided into functional and chemical classes and 178 materials representing worst case samples of these classes were tested. Of the materials tested, 22 materials and those associated by chemical classification were rejected. The approximately 1800 organic materials used in the spacecraft were all measured against the established criteria and the results of testing. Limited utilization of materials that did not meet these criteria was made on the basis: (a) that a small quantity was used, or (b) that there was a minimum exposed surface area, and (c) that there was no adjacent ignition source, or (d) that the material was protected from a potential ignition source.

Notwithstanding this emphasis on the potential problems created by combustibles in the spacecraft, it can be seen in retrospect that attention was principally directed to individual testing of the material. What was not fully understood by either North American or NASA was the importance of considering the fire potential of combustibles in a system of all materials taken together in the position which they would occupy in the spacecraft and in the environment of the spacecraft.

FINDING NO. 2b

North American concurs with Finding No. 2b and the Determination and Recommendation. However, see Finding No. 5 for our comments on "hazardous test".

North American has recommended that NASA conduct a feasibility study as to the use of air in the Command Module on the launch pad instead of 100% oxygen. It is recognized that there are a number of considerations involved which must be evaluated, such as the design of suits and the repressurization of the spacecraft with oxygen while in orbit.

FINDING NO. 3

North American concurs.

FINDING NO. 4

North American concurs. The Command Module inner hatch was designed with emphasis on reliability and crew operation during space flight. A maximum allowable cabin leak rate of 0.2 pounds of oxygen per hour resulted in a design utilizing internal pressure to assist in sealing the hatch. An important safety factor provided by this design was the prevention of inadvertent opening of the hatch in flight. It was decided by NASA that the hatch should permit a 90

second egress time at pressures up to .5 p.s.i. above ambient. The hatch on Spacecraft 012 met this requirement. It was fully recognized that in the event of an emergency, egress could not be accomplished until the cabin was depressurized, which was to be accomplished by use of a cabin pressure relief valve operated manually by the crew, and post-landing vent valves for venting cabin pressure after landing.

In reaching the final decision on the design of the inner hatch, many factors were considered, including the need for crew safety during lengthy space flights. As pointed out by the Board in its introduction to the Findings, once the Command Module has left the earth's environment, the occupants are totally dependent upon it for their safety, and design features that are intended to reduce the fire risk must not introduce other serious risks to mission success and safety. A wide range of considerations did in fact enter into the trade-off studies in the design of the spacecraft. At one point, North American did propose a hatch which could be opened quickly by use of explosive charges, which was intended for crew egress with parachutes prior to landing operations. This course was not followed because it was considered by NASA that the risk which would be created by an inadvertent opening of the hatch would outweigh the benefits.

North American concurs with the Recommendation of the Board to reduce the required egress time and is working with NASA on a new hatch design to implement this Recommendation. The new hatch includes a clearance around the heat shield which can now be accomplished as a result of flight test data from Spacecraft 011 that verifies safety during reentry when gaps are included in the ablator.

FINDING NO. 5

North American concurs with this Finding and Recommendation. We wish to point out, however, as noted in the report of Panel No. 13, that North American's responsibility for identifying hazardous tasks in the preparation of Operational Checkout Procedures is based upon compliance with the guidelines and criteria established in the NASA documents defining the overall safety program at the Kennedy Space Center which includes the procedures concerning the generating and approval of hazardous test documents. These guidelines and criteria had evolved out of previous spacecraft and missile program experience. In identifying "hazardous" operations, the documents are focused on those tests involving fueled vehicles, hypergolic propellants, cryogenic systems, high pressure tanks, live pyrotechnics or altitude chamber tests. It can be seen that these criteria did not lead to the identification of the spacecraft 012 test as a "hazardous" test. With the benefit of hindsight, it is evident that the criteria were not directed to the potential risk involved in the Spacecraft 012 test. We recognize that North American might well have questioned them even though it did not have the primary responsibility for determining the criteria.

The balance of this Finding dealing with the matter of contingency preparation to permit escape or rescue of the crew relates to NASA responsibilities.

FINDING NO. 6

North American concurs with the Determination and Recommendation, subject to the following comment. It is understood that the communications system problems discussed in this Finding are concerned almost entirely with the Ground Communications System, which was not the responsibility of North American. The Spacecraft Communication System operated satisfactorily, with the minor exception of an open microphone condition which did not affect the quality or intensity of communications. We are investigating the open microphone problem, but feel that the Spacecraft Communication System is an effective system, and it did not contribute to the accident.

FINDING NO. 7

North American concurs with this Finding. However, Finding 7b requires some clarification. The Ground Test Procedures, in the form of Operational Checkout Procedures, were compatible with the In-Flight Checklists at the time the revision was made. Thereafter, further changes occurred in the In-Flight Checklists at the request of NASA. The few variations which existed between the two at the time of the initiation of the test have been reviewed and are considered to be minor in nature and in no way contributed to the accident.

However, with respect to the statement that test personnel were not adequately familiar with the test procedure, it should be pointed out that all North American test engineers were familiar with the revised procedure at the time of the accident of Spacecraft 012.

North American has already discussed with NASA the need for establishing a period of time, such as ten days prior to the start of a test, to finalize all changes to the In-Flight Checklists, and the need to establish a two-day lead time prior to a test for distribution of test procedures.

FINDING NO. 8

North American concurs. Full-scale mock-up fire tests are essential to the program from a systems point of view. It should not be the only basis for testing, however, but should be supplemented by testing at a component and/or subsystem level of materials applications as configured for installation in the spacecraft and tested in the environment to which the spacecraft is exposed during ground tests and flights.

FINDING NO. 9

That part of this item dealing with combustibles and full-scale mock-up tests has been previously commented on.

With respect to the balance of this item, North American concurs in the necessity of conducting studies of the use of a diluent gas, and had previously proposed in 1963 that it be authorized to conduct studies of this kind.

FINDING NO. 10

In the Board Report and in the underlying Report (Panel No. 9) the discussion of design, workmanship and quality control relate only to certain specific areas of the wiring and to the Environmental Control System. North American recognizes the problems which did exist in the wiring and the Environmental Control System. The basic cause of these problems, as discussed in the Panel Report, was that the criteria which established the requirements for North American's design continued to evolve after the design had been started and in fact continued after release of the design to manufacture. We do not believe that a basis exists for construing this Finding as an indictment of the overall design, workmanship and quality control of the Command Module.

FINDING NO. 10a

Environmental Control Systems (ECS) for spacecraft application must meet very demanding performance requirements and are extremely complex. The ECS systems for all previous manned spacecraft programs have experienced developmental problems, the resolution of which was difficult and time-consuming. In the Apollo Program, the requirements both for earth orbit and for deep space operations impose new and more difficult requirements than previously. In developing this system, the developmental subcontractor (the same subcontractor who developed the ECS systems for the Mercury and Gemini Programs) has encountered problems.

Many of the problems were encountered late in the subcontractor's development program. The solution to these problems required modifications to the equipment installed in Spacecraft 012 which required removal and replacement of components in the assembled condition. The Environmental Control System for future missions was being improved to permit easier installation and maintenance. In addition, the improvements will allow some of the tests, which were formerly conducted in the spacecraft, to be conducted at the manufacturer's plant, thereby reducing the number of removals from the spacecraft.

We concur with the Recommendation for a review of the ECS, and NASA and North American have conducted such a review. We are confident that the corrective measures taken will resolve the problems.

FINDING NO. 10b

North American does not concur that coolant leakage at solder joints has been a "chronic" problem, although there has been some leakage. At the time the decision was made to use solder joints one of the considerations was to use aluminum tubing in order to save weight. The most reliable way known to join

aluminum tubing was by soldering, taking into account experience and data which had been accumulated in aircraft and other space programs with respect to the use of welds or B nuts. Solder joints have a safety factor of 20 times that of normal working pressure. Care had been taken to eliminate stress in solder joints. It has been found that after installation the tubes can be stressed by external sources causing "creep" which might result in small leaks. "Armoring" and shielding are being designed to strengthen and protect joints in susceptible areas.

FINDING NO. 10c

North American believes that a major change involving testing and selection of a new coolant is not required in view of the very minor combustible properties of the coolant. As the underlying Panel Finding points out, no evidence of deleterious corrosion or corrosion products was noted in examination of test hardware and in post-flight examination of Spacecraft 011.

We believe that armoring and shielding of the solder joints will meet the Board's Recommendation.

FINDING NO. 10d

In order to properly respond to this Finding, which is general in nature, it is appropriate to consider the specific Findings made by the underlying Panel Report (Panel 9) with respect to Spacecraft 012.

As to the cited design deficiencies in wiring:

(1) (The wiring in the lower equipment bay was routed through narrow channels having many 90 degree bends.)

The design of the wiring in the lower equipment bay was dictated by the "modular concept" approach that was used for the equipment. The channel design, as such, is a standard practice that is followed for the modular concept, and the 90 degree bends are necessary due to the compact design. The bends are within the minimum design tolerance (4 times the diameter of the individual wire) and the corners of the channels are insulated to provide additional protection for the wiring around these bends. Recent test data on teflon cold flow characteristics is resulting in further protection of bends and other pressure points. The reported damage to the protective sleeving which covers the shield on the wire in these areas is not detrimental to the wiring insulation or the circuit functional integrity.

(2) (Wire color coding practices were not always adhered to as evidenced by the enclosed photograph.)

This is an erroneous Finding. Multiple conductor cables are identified with a cable identification number. Individual wires within the cable are color coded while they remain in cable form. Once the cable terminates and branches out as individual conductors, then the connected individual conductors are identified by individual wire numbers and the color coding is no longer applicable. Some instrumentation components purchased, or delivered to us by NASA, have colored wire. The specifications allow them to be used as delivered.

(3) (Some areas of wiring showed a dense, disordered array.)

This Finding refers to appearance and not to the functional integrity of the wire. It must be recognized that all of the wiring that connects to the Service Module must leave the Command Module structure at a single location to eliminate the need for more than one umbilical. These wires, of necessity, come from all areas of the Command Module. The original installation of the wiring to these feed-through connectors was orderly but due to changes which were ordered after the original installation, disarray did occur in some areas.

This Finding also notes instances of wires being looped back and forth to take up the slack. This is a valid wiring practice. In some cases excessive lengths of wire had to be stored or looped back into the bundle because they were to calibrated resistances for the instrumentation functions, and the instrumentation would be affected if these wires were not to the calibrated lengths. In other cases due to changes which were ordered, equipment was relocated, thereby leaving lengths which could either have been cut and spliced or looped. It was considered that looping was as fully acceptable a practice as cutting and splicing.

There is no evidence that the disarray, which resulted from the conditions described above, affected the integrity of the wiring or in any way attributed to the accident.

(4) (A circuit breaker panel was pressed close to a wire harness.)

The original design provided sufficient tolerance between close-out panels and wire harnesses behind the panels so that touching would not occur. Our tech-

nicians were instructed not to close out panels if there were obstructions or other indications that the wire harnesses may touch the panel. Although there is no indication of shorting or arcing in this panel, or any evidence that it contributed to the accident, it did indicate insufficient clearances of the wiring after panel installation.

(5) (There were wires routed across and along oxygen and water-glycol lines.)

Routing of wires along hard lines is acceptable with secured clearance of one-half inch between wires and the hard lines. This is a standard and acceptable design practice.

(6) (The floor wiring and some connectors in the LEB were not completely protected from damage by test personnel and the astronauts.)

The design of the wire harnesses routing and protection in the Block I crew compartment was based upon certain constraints imposed by the combination of weight, lift to drag ratio, entry thermal protection for the umbilical connection, and the importance of these factors on safety and reliability in reentry.

The unitized couch provides natural protection during flight and manned ground testing for that portion of the wire harness under the couch. Moreover, while the spacecraft is in orbit there are no weight loads imposed by the astronauts.

The basic protection for the wire harness was tough anti-chafing teflon wrap. In addition, during the manufacture and checkout of the spacecraft, protective devices in the form of work floors and thick padding were used. In the Block II spacecraft it was possible, because of a relocation of the umbilical, to shorten the wire harness runs and locate them around the sides of the floor where they are protected by metal covers.

As to the cited deficiencies in manufacturing and quality control:

(1) (Lack of attention during manufacturing and/or rework is evidenced by foreign objects found in the spacecraft harness.)

Two instances are cited by Panel 9 of foreign objects in the spacecraft harnesses. There are no indications, however, in the Board Report that these two foreign objects are anything but isolated instances. Such instances indicate, however, the great importance of maintaining the highest standards of quality of workmanship and inspection. North American has recognized that the standards which it has followed in its other programs would, adequate though they may have been for those programs, have to be brought as close to perfection as possible for manned space work. North American's objective, therefore, has been to seek improvements both in the procedures for workmanship and inspection and in the means of insuring compliance with them.

Improved methods of tracking and retrieving tools and equipment that could possibly be left in the spacecraft are being instituted and a Planned Change Grouping Method has been implemented to accumulate and package changes to be installed at specified periods of the manufacturing and test cycles. These packages of changes are mocked-up, accumulated, and approved and delivered at a scheduled time along with a sequential quality control approved procedure.

(2) (Some wiring did not have identification tags.)

Some wiring did not have identification tags, but it should be pointed out that this was not an omission. By specification, multiple conductor cables or wires carry identification tags. All single conductor wires are numbered. So far as we can determine, there is no evidence that identification tags were not used at all terminating ends. These methods of identification are very satisfactory.

(3) and (4) (Two Hughes connectors were found to be broken or chipped.)

This condition on these two connectors might have been caused by improper installation, but they could have chipped from thermal shock and sooted during the fire. There is no evidence in the Board Report that indicates that the connectors were not functioning properly or contributed to the accident.

As to Recommendation 10d, North American had been fabricating wire harnesses by three-dimensional method since March 1966. In the manufacture of wire harnesses for Block II spacecraft North American utilizes three-dimensional jigs which accurately represent a dimensionally correct spacecraft and assures that the harnesses will be built exactly to that configuration. Specifications and drawings have been reviewed and in Block II are verified by computer and design reviews. As Panel Findings have noted, Block II wire harnesses contain flexibility for change and spare wires have been provided to allow for "splice areas" which provides for ease of incorporating changes with least disruption to the basic harness either functionally or in appearance.

FINDING NO. 10e

As the underlying Panel Report (Panel 2) has pointed out, the vibration levels for qualification testing of components were originally established on the basis of data from other programs. These data were used to define a spectrum of flight vibration levels which would be expected along each axis of the spacecraft throughout a frequency range of 20 to 2000 cycles per second. The components were qualified by subjecting them to a random vibration within this frequency range at the expected flight level. The length of these tests, 15 minutes along each axis, was several times the expected duration of vibratory excitation during atmospheric flight. Some component vibration tests were conducted using an electromagnetic shaker and the remaining components were tested with acoustic excitation.

Unmanned Spacecraft 009 and 011 were actual flight vehicles which, during their suborbital flights, were exposed to boost, orbital and entry vibration conditions. Their primary mission was to qualify the spacecraft for manned flight, complementing an extensive ground acoustic vibration test program which was conducted on representative portions of the entire spacecraft and its subsystems.

North American did conduct vibration acceptance tests on Spacecraft 009 and, based upon the results, agreed with NASA to stop such tests. Structural vibration tests were conducted on Spacecraft 004, and acoustic tests were conducted on a 180 degree sector of the Service Module.

Because of previous tests of flight configured spacecraft and because of the rigorous qualification and acceptance vibration tests conducted on subsystems, our view is that vibration testing of a Block II spacecraft is not of significant value.

FINDING NO. 10f

With one exception the spacecraft design and operating procedures do not require the disconnecting of electrical connections while powered. The one exception was the "cobra cable", which is the cable by which the crew connects to the spacecraft communication and biomedical systems. Special design precautions were taken with respect to this cable. These included limiting the current to a value of 25 to 100 milliamperes by resistors in the circuit leading to the cables. In addition, the electrical connection is broken prior to disengagement of the protective shell, thus preventing exposure to external material. The safe operation of this cable is evidenced by the Panel Report which stated that in a simulated separation test neither arc nor ignition was produced. We are, however, studying the possibility of providing a switch to de-energize the cable prior to disconnection.

FINDING NO. 10g

Preliminary studies for fire protection in the form of fire-fighting equipment were made by North American in 1965 and reviewed by NASA. This effort was not pursued since it did not appear that feasible fire-fighting protection could be designed and installed in the spacecraft. As NASA has explained, additional study and tests are planned to determine whether technology can be developed to permit the design of effective fire-fighting equipment.

FINDING NO. 11a

North American concurs that not all open items were listed in the DD250 shipping document that accompanied the spacecraft at the time of shipment. However, a revised DD250 was prepared by North American and accepted by NASA on September 27, 1966, which documented officially the shipped configuration.

During the preparation of Spacecraft 012 for shipment from Downey, North American had agreed with NASA to include at Downey many items previously planned for field site installation. Revised planning documents were issued calling for the incorporation at Downey of as much of this effort as possible prior to shipment.

Additional emphasis is being placed on compliance with our procedure for a 24-hour cut-off time prior to shipment for turn-in of records of work not completed. This situation related solely to the formalities of timely completion of paperwork, and there is no evidence that it contributed in any way to the accident.

FINDING NO. 11b

North American concurs. Because of the dynamic nature of the test program, certain paperwork formalities were not followed. A pretest constraints list for this test was prepared, however, and NASA and North American Test Conductors did not complete the formality of signing the document. A real-time update of the constraints to the test was made by a daily coordination meeting held by the Operation Engineers for NASA and attended by NASA and North American Systems Engineers. "The Daily Status Report, SC 012" was used to establish the original constraints list and new items that became constraints were scheduled for work during these meetings. On the morning of January 27, 1967, items were signed off of the original constraints list, and oral agreement was reached between NASA and North American that no new constraints had been discovered that were not on the original list. There is no evidence to indicate that the absence of the appropriate formalities contributed to the accident.

FINDING NO. 11c

It is our understanding that NASA has taken action to resolve this situation. This action will aid the definition of the responsibilities of the organizations involved.

FINDING NO. 11d

Of the 829 equipment items required to be certified for the Command Module, only four were not completely certified (i.e., had not completed qualification testing) at the time of the accident. In accordance with NASA requirements, these four items would have been certified prior to flight of the spacecraft. Taking into account the degree of qualification test accomplished on these items, it was considered that these items were suitable for pad testing. Insofar as we can determine from the Board Report, there has been no evidence that any of these four items related in any way to the cause of the accident. The certification or qualification testing achieved on the Apollo Program surpasses that achieved on any other manned spacecraft program at a comparable time in the development program.

FINDING NO. 11e

North American recognizes that discrepancies did exist between specifications which were included into the contract with NASA and a new specification which NASA was generating for use with all contractors. The North American specification was developed in late 1962 and early 1963 (and imposed on all of our subcontractors) to limit the use of flammable materials in the Command Module. North American and NASA engineers conducted a "walk through" of Spacecraft 008 and 012 to review the use and placement of materials. Another "walk through" was planned for Spacecraft 012 prior to launch. Neither of the specifications, however, provided for the system testing of materials which is now considered necessary for a full understanding of the hazard potential.

FINDING NO. 11f

North American concurs with this Finding. The Operational Checkout Procedure implementing the specification was prepared at Kennedy Space Center by North American personnel. As changes were required in the test requirements, Downey engineers were sent to Kennedy Space Center to provide engineering assistance in the rewrite of the Operational Checkout Procedure. The changing test requirements of the test specification in many instances was brought about because of constraints in the field such as ground support equipment or facilities problems or refinement of test procedures. While the test specification was not updated, the Operational Checkout Procedure actually represented the latest configuration of the test specification as affected by changes. We have already instituted action to clarify our specification requirements and procedures on Block II and remedy this problem.

As to the Recommendation under this item, North American concurs that every effort must be made to ensure maximum clarification and understanding of the responsibilities of all the organizations involved in the Apollo Program. It is a program of immense complexity and requires the highest degree of organizational skill, both within the Government and industry, to effectively coordinate the efforts of the hundreds of thousands of people who are engaged in Apollo work.

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