APOLLO 13 MISSION

HEARING

BEFORE THE

COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES UNITED STATES SENATE

NINETY-FIRST CONGRESS

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APOLLO 13 MISSION

FRIDAY, APRIL 24, 1970

UNITED STATES SENATE,
COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES.
Washington, D.C.

The committee met, pursuant to call, at 10:05 a.m., in room 1202, New Senate Office Building, the Honorable Clinton P. Anderson (chairman) presiding.

Present: Senators Anderson, Symington, Stennis, Young, Holland, Smith of Maine, Curtis, Hatfield, Goldwater, and Saxbe.

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; Mary Rita Robbins, Rhea Bruno, Patricia Robinson, Ruby L. Hamblen and Carol L. Wilson, clerical assistants.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. The hearing will come to order.

Exactly one week ago we were holding our breaths praying for the safe return of Jim Lovell, Fred Haise, and John Swigert. Today it is our honor to welcome Captain Lovell and Mr. Swigert to appear before this committee. Unfortunately, Mr. Haise is slightly ill and unable to be with us today.

I wish to convey my heartiest congratulations to the entire NASA organization for the successful return of the Apollo 13 crew. Their performance during a period of great difficulty demonstrated the superb capabilities of the NASA team and of the Apollo system.

Apollo 13 will be considered by some as a failure, because it did not accomplish its objective of a lunar landing and return with new scientific information. But in a real and larger sense, it was a human success—a triumph of the human spirit, an exoneration of the human mind, a tribute to human perseverance, a victory for all mankind.

The purpose of this meeting is to discuss with NASA officials the Apollo 13 mission and its problems. We are anxious to learn what happened, and what must be done to reestablish the Apollo launch schedule. Towards this end, we will begin today with testimony from Dr. Thomas O. Paine, Administrator of NASA, then we will hear Dr. Rocco A. Petrone, Apollo Program Director, Mr. Glynn S. Lunney, Apollo 13 Mission Director, and Astronauts Lovell and Swigert.

At a later date, after the review board has completed its investigation and made its recommendations, the committee will meet again with Dr. Paine and other NASA officials to discuss the future of the manned lunar exploration program.

Senator Smith?

STATEMENT BY SENATOR SMITH

Senator SMITH of Maine. Thank you, Mr. Chairman. I would like to join in paying tribute to the astronauts of Apollo 13 for their very great courage and coolness in times of great stress.

Also, Mr. Chairman, I would like to pay tribute to the entire NASA team for what I consider one of the greatest achievements made in the space program, for the way initial adversity was turned into dramatic success.

The CHAIRMAN. Dr. Paine?

STATEMENT OF DR. THOMAS O. PAINE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY ASTRONAUT JAMES A. LOVELL, COMMANDER OF APOLLO 13; ASTRONAUT JOHN L. SWIGERT, JR., COMMAND MODULE PILOT OF APOLLO 13; DR. ROCCO A. PETRONE, APOLLO PROGRAM DIRECTOR; AND GLYNN S. LUNNEY, APOLLO 13 MISSION DIRECTOR

Dr. PAINE. Mr. Chairman, members of the committee, we appreciate this opportunity to appear before you to give you a preliminary report on the Apollo 13 mission, America's fifth lunar expedition and third landing attempt.

SUMMARY OF ACTIONS FOLLOWING ACCIDENT

This morning we will summarize for you our current understanding of:

The accident aboard the spacecraft Odyssey while outward bound for the moon 55 hours and 54 minutes after launch;

The immediate steps taken by flight controllers at Mission Control in Houston and the flight crew to contain the situation;

The ensuing 300,000-mile voyage around the moon and back to earth using the lunar module Aquarius as a lifeboat;

The investigative measures which were initiated within NASA immediately after the successful splashdown; and

Our view of the impact of the Apollo 13 accident on the U.S. space program.

Dr. Rocco Petrone, Director of the Apollo Program, will give you his present best estimate of the principal events prior to and during the accident which apparently led to the rupture of oxygen bottle No. 2 in the service module. The actions taken on the ground to recover from the accident and return the crew safely back to earth will then be described by Mr. Glynn S. Lunney, who was flight director in Mission Control during much of the critical period following the accident. Astronaut James A. Lovell, the commander of Apollo 13, and Astronaut Jack Swigert, the command module pilot, will then describe to you the events that took place in the spacecraft during this period.

We thought it best that Astronaut Fred Haise, the lunar module pilot, not accompany his crewmates here today. As we informed the committee yesterday, the astronauts' physician asked that Mr. Haise be excused from the trip to Washington to facilitate his prompt recovery from the minor infection he has been suffering from since the flight.

REVIEW BOARD INVESTIGATION OF ACCIDENT

Before Dr. Petrone begins, I will take a few moments to summarize for you the actions Dr. Low and I have taken to assure a prompt, vigorous, competent, and objective investigation of the causes of the Apollo 13 accident and the effectiveness of the mission recovery actions so that appropriate corrective actions can be taken. Copies of the documents involved are appended to my statement. (See p 52.)

Immediately after the splashdown, Dr. Low and I established an Apollo 13 Review Board chaired by Mr. Edgar M. Cortright, director of NASA's Langley Research Center. Seven members were named to the board—all highly qualified senior individuals from NASA, the Air Force, and AEC who have had no direct responsibilities for Apollo 13. The board's assignment is to make a full and complete investigation of the circumstances surrounding the accident to the Apollo 13 spacecraft, to establish the probable cause or causes of the accident, assess the effectiveness of the recovery actions, and recommend appropriate corrective or other actions. The board reports directly to me and Dr. Low, and has been meeting in Houston since Tuesday evening, April 21, delving into every aspect of the accident and recovery. The charge to the board and the memorandum naming its members were forwarded to your committee upon issuance and NASA will continue to keep the committee fully informed as the investigation proceeds.

We also announced immediately after splashdown that we had requested NASA's statutory Aerospace Safety Advisory Panel to review the Apollo 13 Review Board's procedures and its findings when they become available, and to submit an independent report directly to me and Dr. Low. The Chairman of this Panel, Dr. Charles D. Harrington, is president of Douglas-United Nuclear, Inc. The Panel consists of six non-NASA members and one NASA member: Mr. Bruce Lundin, Director of the Lewis Research Center. The Panel met in Washington on Tuesday, April 21, and is carrying out its assignment as the work of the Review Board proceeds.

A third assignment was made to Mr. Dale Myers, NASA's Associate Administrator for Manned Space Flight, in two parts: First, his organization will provide all data and technical support required by the Review Board from the three Manned Space Flight Centers and OMSF Headquarters. Secondly, the Manned Space Flight organization will move forward immediately with the required in-depth studies, analyses, and other steps to provide me and Dr. Low with the best possible plans and recommendations for eliminating the problem encountered in Apollo 13 and proceeding with Apollo 14 and future manned space flight missions. This work also got underway at Houston immediately after splashdown.

Thus, findings and recommendations from three sources will be available to help NASA management make timely decisions on the corrective and other measures that should be taken prior to Apollo 14 and subsequent manned flights.

IMPACT ON FUTURE MANNED FLIGHTS

Now let me say a few words on the impact, as we now see it, of the Apollo 13 accident on the future of U.S. manned space flight activities. As Dr. Petrone's presentation will show, we expect that the large quantity and high quality of the telemetered data received from the Apollo 13 spacecraft at the time of the accident will permit a precise and early identification of the causes of the failure. The oxygen thermos flask believed to be involved is a relatively simple component and corrective action should not prove to be a major task. If this turns out to be the case, we should be able to move out promptly with the necessary alterations and proceed with Apollo 14 and subsequent flights on approximately the same schedule we have presented to you before.

I think it is important that your committee understand clearly our view in NASA of the Apollo 13 accident and recovery. The Apollo 13 mission was a failure. We did not succeed in America's third lunar landing attempt, and we were, therefore, unable to explore the moon's Fra Mauro formation. This hilly region remains a high priority objective in our lunar program. Its exploration should add much to our understanding of the moon, its origins, and its relationships to the earth. We cannot yet say which of the remaining Apollo missions will be sent there. Although the Apollo 13 mission failed, we regard the recovery actions that followed the accident as a gatifying success which will contribute greatly to the Nation's space flight competence. The Apollo hardware, the contingency planning, the training of flight and ground crews, and the backup systems for emergency use appear to have demonstrated their flexibility and soundness. However, as I have stated, our charge to the Apollo 13 Review Board includes not only a critical review of the cause or causes of the accident, but also a critical assessment of the effectiveness of the recovery measures taken. We intend to learn everything possible from both the accident and the safe recovery of Apollo 13.

APOLLO 13 EFFECT ON FUTURE PROGRAMS

Finally, let me state my view as to how the Apollo 13 accident should affect the future of the space program. I see no reason why this setback should be—or should be made to be—the occasion for a major change in the course of the Nation's space program. We have clearly demonstrated the basic soundness of the Apollo system and of our operational procedures with the successful manned flights of Apollos 7, 8, 9, 10, 11, and 12. Since the start of manned space flight, NASA's astronauts have safely flown a total of 70 million miles in space. From a technical standpoint, there is no question but that we are prepared to move forward in the 1970's with the space program we have outlined to you in our previous appearances before you.

I am happy to be able to report that the President fully shares this view. During our flight to Honolulu last Saturday to meet the astronauts, he expressed his strong support for a vigorous on-going U.S. space program, particularly in manned space flight. Worldwide reaction has been the same. Virtually all editorial comment from coast to coast has strongly supported the position that the United States should not respond to this accident by cutting back or lowering its sights in space.

Now, Mr. Chairman, with your permission, I would like to ask Dr. Petrone to describe to you what we know today about the events leading to the accident.

The CHAIRMAN. Thank you.

Dr. Petrone?

STATEMENT OF DR. ROCCO A. PETRONE, APOLLO PROGRAM DIRECTOR

Dr. PETRONE. Mr. Chairman and members of the committee, the Apollo 13 mission, planned to perform a lunar landing at Fra Mauro, was launched at 1413 e.s.t. on 11 April 1970. Lift-off and initial powered flight were nominal. Midway into the second stage burn, an unexpected highlevel thrust oscillation of the center engine caused that engine to cut off about 2 minutes and 12 seconds early. The remaining four engines burned about 34 seconds longer than planned, to make up part of the deficit. To make up the remainder of the required velocity, the launch vehicle computer extended the third stage orbital insertion burn approximately 9 seconds longer than planned. With the third stage propellant remaining, we still had a capability to perform the translunar injection burn with a performance margin twice that which we normally require. This burn was initiated on schedule and end conditions were nominal for translunar coast. Subsequent docking and extraction of the lunar module from the launch vehicle third stage were performed without difficulty.

PROBLEMS NOTED 54 HOURS INTO MISSION

About 31 hours into the mission, a premission planned trajectory shift was performed. This shift took the spacecraft from a trajectory which would fly around the moon and back to earth, to a trajectory which would require a subsequent maneuver to perform a lunar flyby and return to earth. The purpose of the transfer was to optimize the conditions of time, velocity, and height above the lunar surface upon arrival at the moon. At about 54½ hours into the mission, the Commander and lunar module pilot moved into the lunar module to perform a planned transfer of equipment from the command module and preliminary examination of the lunar module. Shortly thereafter, while the crewmen were closing out the lunar module, Astronaut Lovell called mission control to report "We've got a problem here." Initial indications of the anomaly were a warning light indicating an undervoltage on one of the command module spacecraft electrical buses and indication of loss of all pressure in one of the two liquid oxygen storage vessels, followed shortly thereafter by a loss of two of the three fuel cells.

Until this particular problem occurred, the mission had been proceeding in nearly a trouble-free manner. Insofar as we have been able to determine thus far, there were no early indications that the oxygen system was other than normal except for the quantity indicator going off scale high approximately 9 hours before the incident. Following the indications that we had a problem, the immediate requirement was to stabilize the situation to allow time to plan subsequent courses of action. Mr. Glynn Lunney will discuss these actions in more detail later.

In accordance with our general practice, a large number of contractor systems personnel were providing direct support to the mission at all times. In order to bring all available resources to bear, we immediately requested the major spacecraft contractors, their subcontractors and vendors, to augment this around-the-clock support. The response of our industrial and university team working with the Government team during this very demanding time was most helpful and gratifying.

With regard to the incident itself and its cause, our immediate analytical efforts during the mission were concentrated only on the analysis necessary to determine effects or delayed effects on other systems. Our prime objective was to ensure that all necessary action was being taken to bring the astronauts back to earth as quickly as possible with the least imposed additional risk.

INTENSIVE INVESTIGATION

Upon completion of the successful recovery of the astronauts, the Apollo program immediately initiated an intensive investigation of the cause of the incident and possible remedial measures. Since last Friday afternoon, a team of Government, industry, and university personnel have assembled at the Manned Spacecraft Center and are reviewing and analyzing all data.

Although it is too early at this time to provide you with conclusive results, the preliminary assessment of the problem and systems involved has caused us to focus our attention on No. 2 oxygen tank and its associated hardware.

If I might have viewgraph No. 1, I will attempt to orient it here. This is the overall view of the command and service module. The area right in here—and I will have another viewgraph on that—is the bay of the section we are interested in. You will see fuel cells on the top, you see oxygen tanks in the center, and hydrogen tanks at the base. (See fig. 1.)

ELECTRICAL POWER SYSTEM

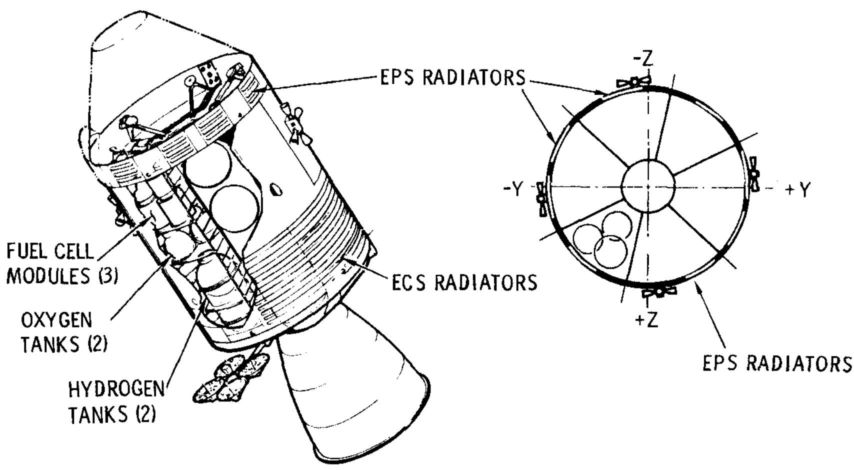

Figure 1

In the next viewgraph this model is a blown up scale of that same sector. Here we see two of the three fuel cells, the third one behind these two. We see oxygen tank No. 2 and No. 1. No. 2 is the one which had our anomalous condition. Then here we see the hydrogen tanks. (See fig. 2.)

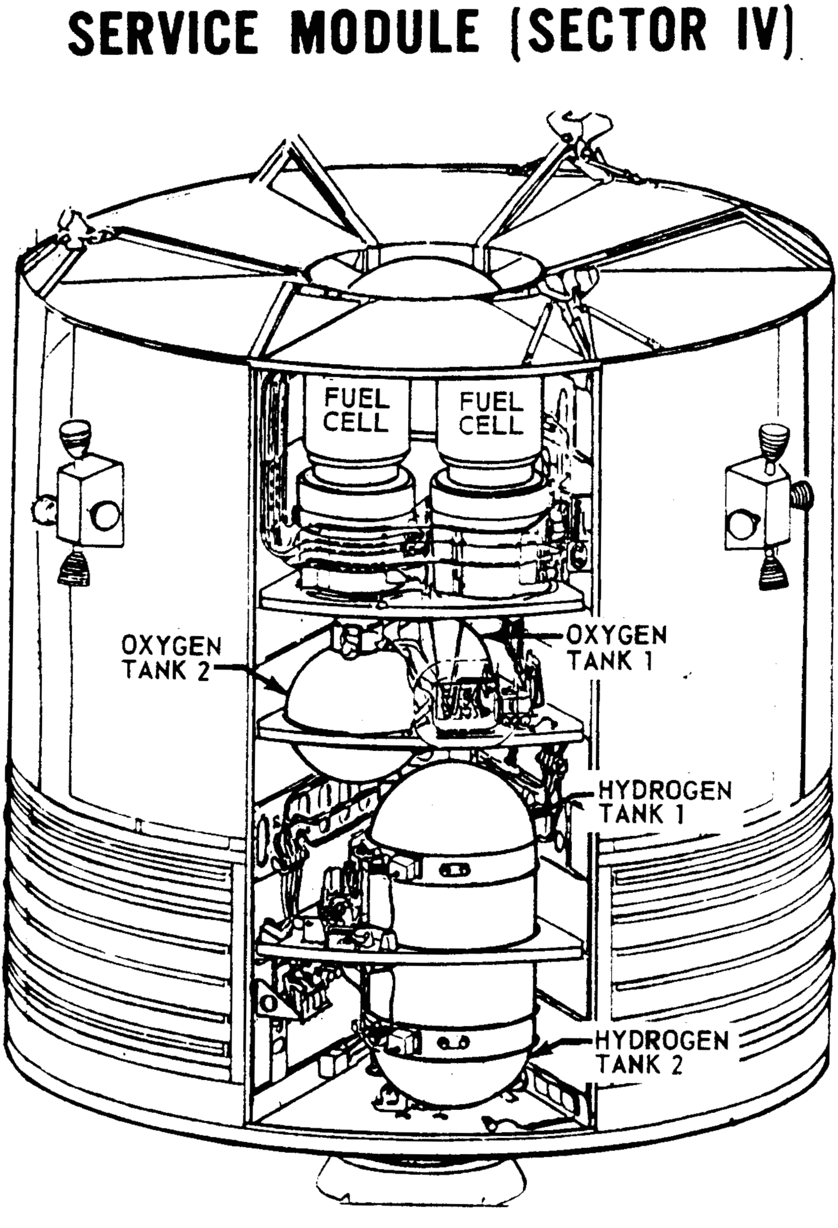

Figure 2

The next viewgraph is the cutaway of the oxygen tank itself. It is 25 inches in diameter. It has the capacity of 330 pounds of oxygen. We have two of these aboard. We normally operate at a pressure of 870 to 930 pounds per square inch. It is made of steel, vacuum jacketed, has an inner and outer liner of very high quality steel. Within the tank, we have an element here called a heating element and two fan motors. The purpose of the heating element is to introduce energy to continue causing the oxygen to remain at the pressure we need in order to feed that to the fuel cells. The fan motors are turned on on command to give a proper mix of the oxygen within the tank. This quantity sensor is the one I referred to, that did go off scale high approximately 9 hours prior to the incident, and there is a temperature sensor here. This is a very simplified diagram, showing the tank basically, the heating element and the sensors, and I will discuss those with the anomalous situation and our telemetry system. (See fig. 3.)

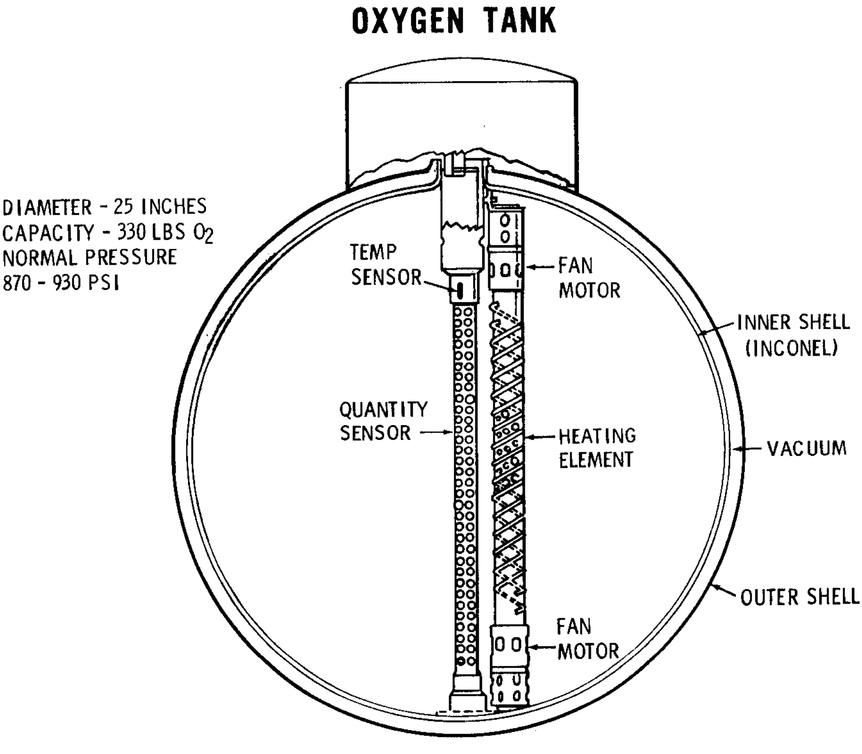

Figure 3

We have a tremendous amount of information on the ground that we did receive. All that can be now analyzed with very accurate time correlation. The preliminary data now shows time correlation of events. I have extracted just a few here to show the indication that we now have of where our problem occurred.

At 55 hours and 53 minutes ground elapsed time, or 10:06 eastern standard time, April 13, we see that the oxygen tank fans are turned on. At 55:53:22, we have a high current spike, fuel cell No. 3. This fuel cell is responding to a demand for current from somewhere. The demand is improper or an anomaly. We see that 14 seconds later, there is a rise in the pressure of oxygen tank 2; some 2 seconds later, we see another current or rather, an electrical disturbance. This was an 11.3-volt drop on our alternating current bus No. 2. What is significant about No. 2 is it is feeding the power on fan and intake No. 2. There we see a correlation of a voltage drop, a current spike, and a pressure rise.

From there, we have another high current spike on the same fuel cell 3 seconds later.

Four seconds later, we saw a temperature rise; we have been left with an anomaly of about 190° Fahrenheit. This continued to rise from there.

At this time, 55:54:45, we have the maximum recorded pressure. The maximum recorded pressure was not sufficient itself to burst the tank. However, it is recording pressure just prior to release.

At 55:54:53 seconds we have measurable spacecraft motion. This was measured by the guidance system. It is at that time we believe that the tank ruptured, exactly there. The tank pressure read zero 3 seconds later.

And at 55:55:20 plotted Astronaut Lovell reported "I believe we have a problem here." (See fig. 4.)

SEQUENCE OF EVENTS

GROUND ELAPSED TIME	EASTERN STANDARD TIME APRIL 13, PM	EVENT
55:53	10:06	OXYGEN TANK FANS TURNED ON
55:53:22	10:06:22	HIGH CURRENT SPIKE, FUEL CELL #3
55:53:36	10:06:36	OXYGEN TANK #2 PRESSURE RISE
55:53:38	10:06:38	11.3 VOLT TRANSIENT, AC BUS #2
55:53:41	10:06:41	HIGH CURRENT SPIKE, FUEL CELL #3
55:53:45	10:06:45	OXYGEN TANK #2 TEMPERATURE RISE
55:54:45	10:07:45	OXYGEN TANK #2 MAXIMUM RECORDED PRESSURE
55:54:53	10:07:53	MEASURABLE SPACECRAFT MOTION
55:54:56	10:07:56	OXYGEN TANK #2 PRESSURE ZERO
55:55:20	10:08:20	LOVELL "I BELIEVE WE HAVE A PROBLEM HERE"

Figure 4

The next slide, please.

This picture which is very difficult to make out—it has been blown up—is one of the photographs the astronauts did bring back. This area right up here is the area of interest. This is the same bay we were looking at earlier. There are two fuel cells here, the hydrogen tanks here. Right about in here is where oxygen tank 2 had been. We are going through the technique of enhancing these photographs and feel we can learn much from them. Our primary reliance will have to be on telemetry data. (See fig. 5.)

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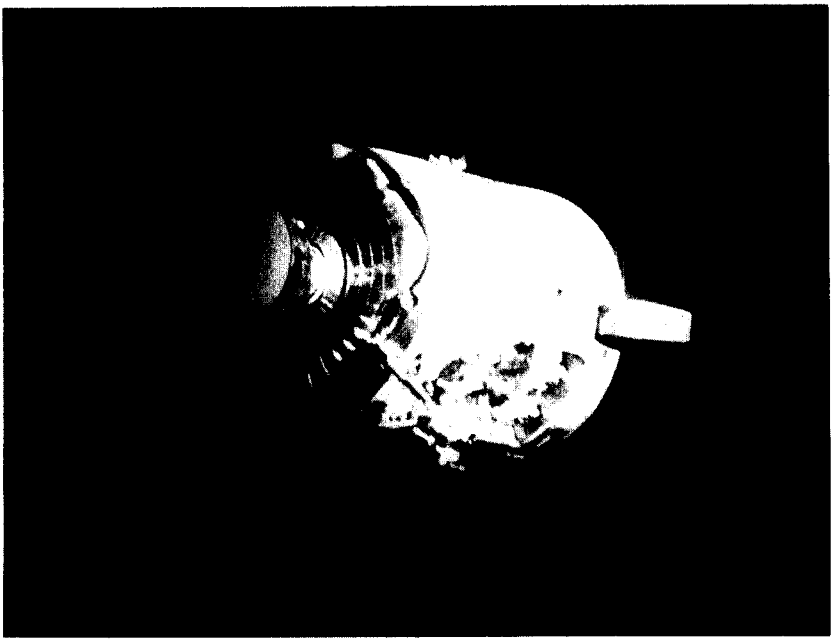

Figure 5

All of these indicators must, of course, be examined in greater detail. One conclusion that we can draw, primarily because of the electrical anomalies and pressure and temperature rise just prior to the No. 2 oxygen tank failure, is that this event was not caused by a meteorite. From the preliminary examination it does appear that the observed rapid rise in oxygen tank No. 2 pressure would require an amount of heat much greater than that produced from electrical current flow for the tank fans, heaters, and instrumentation operation. This does not rule out electrical power as a source of initiation for some other energy source as yet undetermined. Analysis and tests have been and are being conducted to determine what such an energy source could be and how it could have been initiated.

EXPECT EARLY RESOLUTION OF PROBLEM

In parallel with the above analysis, intensive effort is underway to determine what corrective actions might be taken to modify the oxygen system and associated hardware to eliminate the possible cause or causes that led to the oxygen tank failure. Final action must await the completion of the failure investigation.

I am confident that the actions currently underway will lead to an early resolution of the problem that caused the termination of the Apollo 13 mission.

I would like to conclude my remarks with a few comments on the performance of the Apollo hardware and the flight and ground crew. The actions taken to bring Apollo 13 safely home demonstrated under extremely adverse conditions the inherent flexibility that has been developed into the Apollo systems and operations. The flexibility of the spacecraft systems provided us with many different options from which we selected a series of configurations in meeting the varying requirements on the trip home. This long, arduous voyage continuously presented the challenge to balance the spacecraft systems required to perform necessary functions against the availability of consumables of water, electrical power, oxygen, and the lithium hydroxide to remove the carbon dioxide. The options available to flight and ground crews in every case permitted acceptable courses of action to be selected. During this emergency situation, the remaining systems performed in an outstanding manner in meeting the unusual demands placed upon them. At the same time, the flight and ground crews demonstrated exceptional competence in meeting a set of unusual circumstances.

In the preparation cycle for each Apollo mission, much of the flight and ground crew effort is spent in reviewing and improving the plans and established procedures to handle contingency situations. Verification of and proficiency in handling these procedures is developed through simulations involving the flight crew in spacecraft simulators and the flight controllers at their consoles in the Mission Control Center. However, the depth to which this contingency effort can proceed must be limited to some practical bound. The point I must emphasize is that the mission planning and training develops not only specific contingency procedures, but much more importantly, a team of people with the capability to respond to unexpected events during manned space missions. To show how this capabilitiy was employed, Mr. Glynn Lunney will summarize the actions taken by this team which resulted in a successful recovery of Apollo 13 1 week ago today.

The CHAIRMAN. Mr. Lunney?

STATEMENT OF GLYNN S. LUNNEY, APOLLO 13 MISSION DIRECTOR

Mr. LUNNEY. Mr. Chairman, members of the committee, personally, as a member or a representative of the Mission Control Center team, and that is a lot of men and women, I would like to thank the committee for the opportunity to report on how we conducted the Apollo 13 flight. I would like to preface my remarks by referring to the status that we are in in the course of the Apollo program today. We have had a number of flights; we have had a number of flights to the moon. The Apollo 9 flight was the first flight where we had a man check out the lunar module, and that was done in earth orbit last winter. We had a series of tests conducted to first verify that the lunar module would do its job at the moon, and secondly, we operated in a number of fashions, the applications of which lent themselves to the problem that we had in Apollo 13.

LUNAR MODULE AS LIFEBOAT

Secondly, when we started flying to the moon with the lunar module on Apollo 10, we recognized that the lunar module ship provided lifeboat facility for the astronauts in case we got into serious problems. We have paid a lot of attention to that in our planning. We made a number of preparations. Most of the preparations are prepared in a general sense and it is difficult to try to cover all of the cases on the way out and the way back. But we had put the personnel through the discipline in thinking that out in order to respond to that kind of problem were we ever to run into one.

With those remarks, let me go through what will of necessity here this morning be a rather sketchy outline of what we were going through in the control center. Then I think you will hear from the pilots' points of view how this worked out.

The first slide (fig. 6) very simply describes the mission we were in. In earth to moon, we were on the familiar figure 8 maneuver. We were on this trajectory called hybrid transfer maneuver, the dotted line—we had left the free-return trajectory, which is the dashed line—around the moon and back to earth. The start of the problem occurred about 180,000 miles away from the earth, at about 55 hours, 55 minutes. (See fig. 7.)

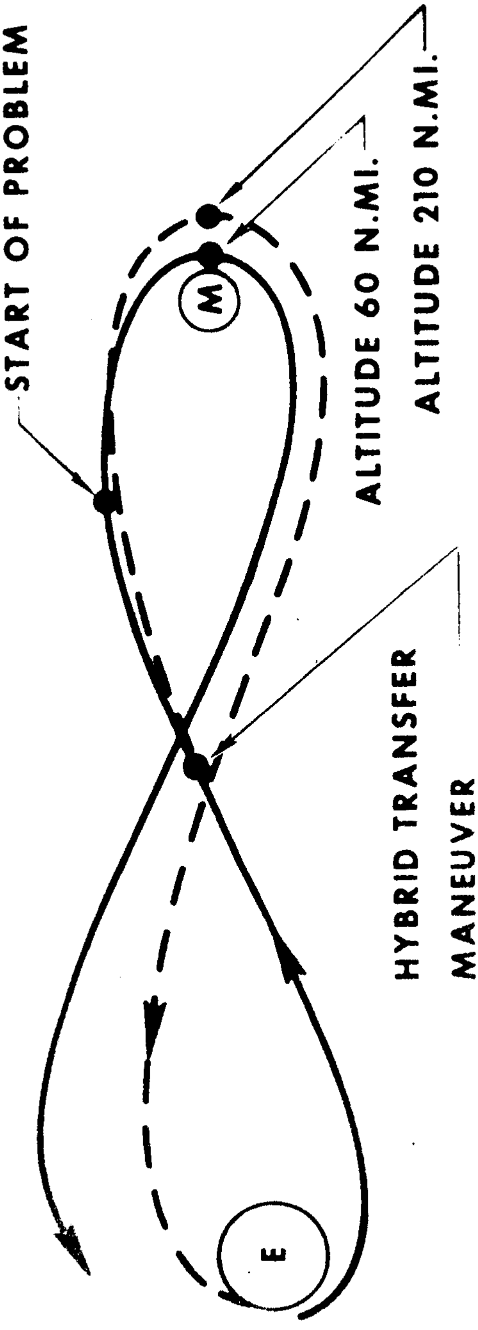

Figure 6

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SUMMARY OF EVENTS (1 OF 2)

55:55	"I BELIEVE WE'VE HAD A PROBLEM HERE"
	VARIOUS STAGES OF ACTIVITY
57:37	CREW ENTRY INTO LUNAR MODULE
58:10	TRANSFER GUIDANCE ALIGNMENT TO LUNAR MODULE
58:40	COMMAND MODULE POWER DOWN
61:30	DECISION, EXECUTION OF MIDCOURSE FOR FREE RETURN
63:20	DECISION ON PROJECTED OVERALL FLIGHT PLAN

Figure 7

SUMMARY OF EVENTS

Very briefly, a summary of events from that time on. It started with a report of the problem from the astronauts. What I have summarized for you here are a number of steps that we have considered important ones, both in deciding things and executing things that have had to be performed to successfully complete the flight.

After the problem, which went through a series of stages that could be described as an increasing awareness of the extent of the problem and the seriousness of it, in about an hour and a half, both the ground controllers and the crew had decided that it was time to go into the lunar module to prepare that ship for the lifeboat technique which we had discussed over the years in preparing for these flights, as I said earlier

We also did, something else shortly after the crew entry into the lunar module which transferred the guidance alinement from the command module into the lunar module. We actually used some of the precious battery power to do that, but we felt that if we did, that we had something which would then permit the pilots to do propulsion. We were not on a free-return path flight to the earth so we did want to get a platform alinement.

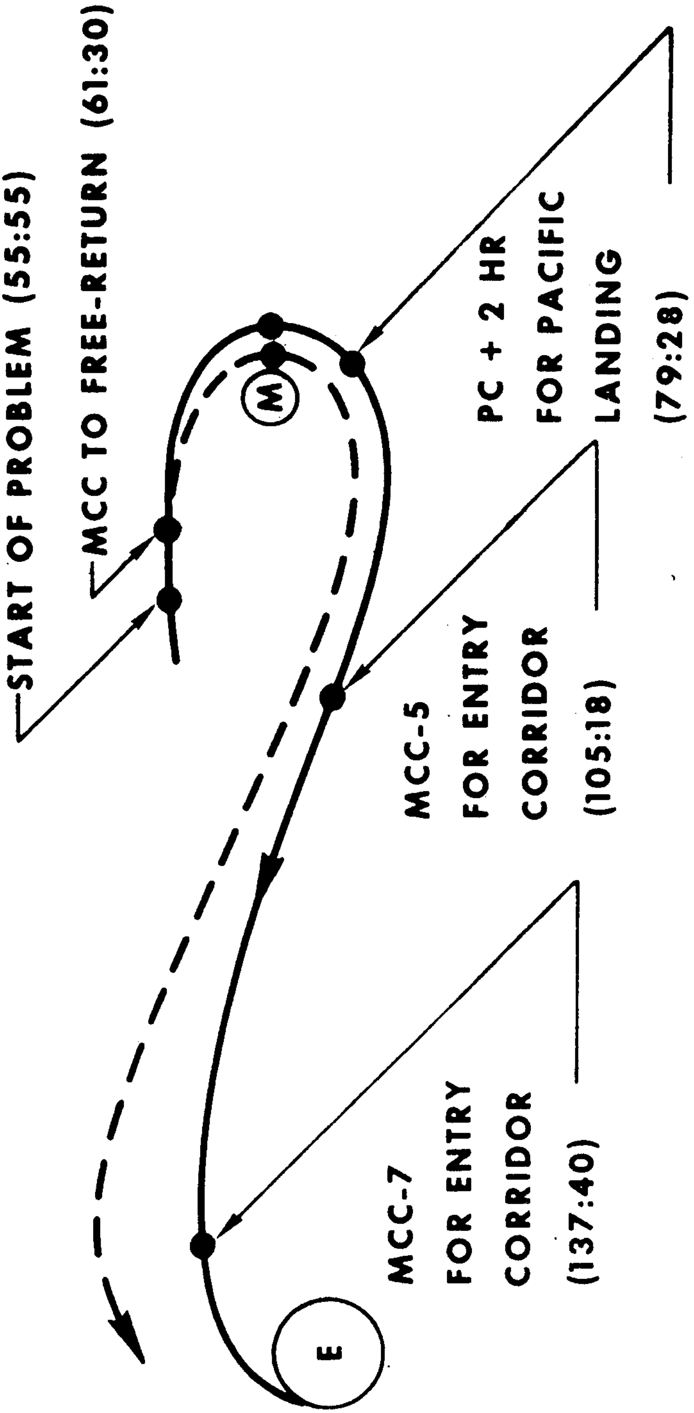
At about 58:40 we powered down the command module. The oxygen was about gone and we turned off the power drawn from the command module batteries to save them for the return portion of the flight.

We had a number of courses available to us. We actually had the lunar module powered up. We could do a midcourse relatively soon and get back on a free return. We did have one option which did not get very serious consideration. It had to do with doing a direct return abort to the earth, but that would have required a tremendous amount of velocity of the engine. The only engine we had that could provide that was the service propulsion engine and it would have required dropping the lunar module. So that option was quickly deleted from our discussions.

The other option we had was to power down immediately since we were concerned about the amount of power and water the command module was using. We accepted the opportunity we had at hand and that was to do a midcourse maneuver relatively soon, get back on free return and plan a little more leisurely how we wanted to manage the remaining consumables in the lunar module. We decided to execute that at midcourse at about 61 hours and 30 minutes and address the problem of what would be our plan for the rest of the way back.

By about 2 hours from that time, we had gone through a series of discussions both in the Control Center and with the pilots in determining what our projected overall flight plan would be.

Next slide. (See fig. 8.) Very simply, after the start of the problem, we did the midcourse to free-return to the earth at about 61½ hours. We now had a trajectory established—again it was the dark one—back to the earth. We did have a number of maneuvering opportunities in order to improve both the time it was to take to return to the earth and the area in the earth to which we would return. One of those opportunities is labeled up there, PC+2. That describes an opportunity 2 hours after pericenter, at the closest approach to the moon, which was one of the techniques that we would have used if we had to do an abort during the interim orbit. We had two midcourse corrections scheduled, midcourse 5 and midcourse 7. There is no midcourse scheduled six, because generally it occurs between those two and we did not do that in our budget scheduling.



START OF PROBLEM (55:55)
MCC TO FREE-RETURN (61:30)
PC + 2 HR
FOR PACIFIC
LANDING
(79:28)
M
MCC-5
FOR ENTRY
CORRIDOR
(105:18)
MCC-7
FOR ENTRY
CORRIDOR
(137:40)
E

Figure 8

CONSUMABLE STATUS

Next slide. (See fig. 9.) This is an important set of facts but there is a lot more that needs to be said than those facts up there. The

CONSUMABLE STATUS

	AVAILABLE AT LM ENTRY	REMAINING AT LM JETT
WATER, POUNDS	324	28.2
POWER, AMP HOURS	2181	410
OXYGEN, POUNDS	50.3	28.5
CO_2 REMOVAL, HOURS		
LM	58 (5 UNITS)	22
CSM	156 (13 UNITS)	108
TOTAL		130

Figure 9

chart describes the amount of water, power, oxygen, and carbon dioxide removal capability we had in the lunar module at entry and what we had remaining when we jettisoned the lunar module.

One point I would like to mention is when we made our projection at about 7 hours after the problem occurred, we ended the flight with a set of consumables which were within about 2 percent of what we predicted back at 63 hours. So the view we took of the mission at 63 hours held very well.

We stuck to the plan that we had. We used only the power and the water and the oxygen that we had forecast and we were very close to predictions made almost 80 hours earlier.

The second point is that although this does show that we are running down to 28 pounds of water, we had not employed another series of procedures which could have been used to further stretch the consumables on board the lunar module. By that I mean we kept the lunar module communication system, the telemetry system, the environmental control system up all the way back. If the consumable posture we were in had worsened or if we had absorbed another failure in some of these areas like an oxygen tank, we would have had to resort to scheduling communications times with the crew and gone on what we call a duty cycle operation, where we might turn the equipment on for 10 minutes or 20 minutes out of every hour. I only say that to give assurance that although we were probably within 12 hours to 24 hours of running out of our most critical consumable, which was water, had we proceeded into this other set of procedures entailing duty cycling the communications gear on board, we probably could have stretched that further.

The third point I would make was that with the lunar module environmental control system running full time, we knew that we would deplete the canisters in the lunar module which are used to remove the carbon dioxide from the air for the astronauts to breathe. We knew we had to find some way to use the CSM canisters in the module. There were a number of ways to do that. We finally selected the method represented by this configuration on my right. This is a canister designed to withdraw carbon dioxide by drawing the oxygen through it. This is a hose from the lunar module (indicating). This is connected to the lunar module ship and the fan; the compressor in the lunar module sucks the oxygen through there and cleanses it as it comes through.

That plan having been agreed upon, we then had a number of options for the maneuver that we were to perform 2 hours after passing behind the moon. The options were about three. One, we could have decided to try to come back in the absolute minimum time by dropping the service module, thus getting rid of about 50,000 pounds of weight. This would have enabled us to get a lot more velocity with the LM engine and would have enabled us to return to earth sooner. However, we discarded that on the basis of the unknown thermal environment, the command module heat shield and the command module control system, propellant and jet control system we use for entry, would be in if we jettisoned the service module. Those systems are essentially at the lower end of the module and they are protected by the command module being attached. To remove it would have endangered the all-important heat shield for entry.

The second option we would have had would have been to try to land in the Atlantic. We would have been able to land about 9 hours earlier than we did. The problem with that was we would have used essentially all the propellants in the descent tank to accomplish that and it would not have allowed us to make the midcourse corrections subsequent to that posture. Second, there was the recovery posture we were in in the Atlantic. You know there was a fair amount of work going on to see what would have been arranged in the Atlantic. We would have certainly had a lot of aircraft and people to recover the module. There were a lot of ships going in the area. However, that option was also discarded because we would have run the lunar module propellant out. We chose to go on to the Pacific at a spashdown time of 79 hours, to almost 143 hours.

(See fig 10).

SUMMARY OF EVENTS (CONCL'D 2 OF 2)

79:28	DECISION, EXECUTION OF MANEUVER 2 HOURS AFTER CLOSEST APPROACH TO MOON (PC+2)
94:00	CARBON DIOXIDE SUCCESSFULLY REMOVED WITH CSM CANISTER FIX
100:00	SIMULATOR-VERIFIED CHECKLIST READ UP FOR MCC BURN AT 105:18
105:18	MIDCOURSE CORRECTION FOR ENTRY CORRIDOR
126:15	SIMULATOR-VERIFIED CHECKLIST READ UP FOR ENTRY PHASE
133:35	BEGIN LUNAR MODULE POWER UP FOR ENTRY PREPARATIONS
142:54	SPASHDOWN

Figure 10

The carbon dioxide was removed from the canister here. We used up what sounded to the outside world like more numbers. We read up a checklist which was verified in the simulator by other sets of astronauts just running around the clock to perform the midcourse corrections we performed with the secondary guidance system. We had to aline it with the unique power saving technique that we had to discuss with Captain Lovell. It worked very well. The midcourse was burned at 105:18 approximately. The other checklist was read up at about 126 hours. You now recall at this stage of the flight, we were approaching the entry phase where we had, one, a lunar module with us that we wanted to use as long as possible. Two, we had a service module which was essentially unpowered which we had to jettison. We also at some point had to jettison the lunar module. Third, we had a very critical or short supply of power in the command module and we could only stand a short number of hours in the command module with the pilots getting the vehicle ready for entry before we actually did enter. We also wanted to keep the tasks and the time length for the astronauts as simple as we possibly could. Those kinds of thoughts were in the work that we did, the check lists we got for the simulator and the checklists we read up. The other powers were for entry and splashdown.

SEQUENCE FOR ENTRY

Next slide (fig. 11) gives you an idea of the sequence for entry. We have the LM power up; the midcourse correction. We jettisoned the service module behind us. We have the command service module power up. This time we transferred the equipment from the lunar module to the command module. Later we jettisoned the lunar module. The entry altitude and attitude was reached and the landing was as predicted at 142:54.

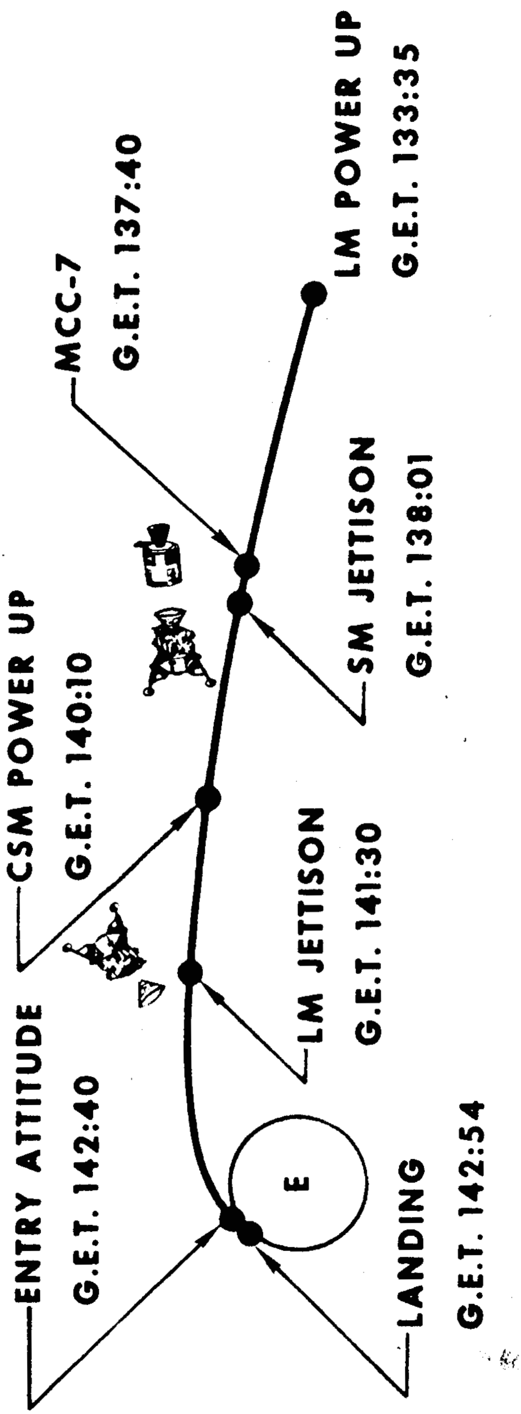

LM POWER UP
G.E.T. 133:35
MCC-7
G.E.T. 137:40
SM JETTISON
G.E.T. 138:01
CSM POWER UP
G.E.T. 140:10
LM JETTISON
G.E.T. 141:30
ENTRY ATTITUDE
G.E.T. 142:40
LANDING
G.E.T. 142:54
E

Figure 11

Next came the splashdown, which I guess for the people in our business has to be one of the most beautiful sights in the world.

That concludes my remarks.

The CHAIRMAN. Now we are going to have a chance to meet an old friend. Captain Lovell, I hope you and Mr. Swigert will start by rising and facing the people in the audience.

STATEMENTS OF ASTRONAUTS JAMES A. LOVELL, COMMANDER OF APOLLO 13; AND JOHN L. SWIGERT JR., COMMAND MODULE PILOT OF APOLLO 13

Astronaut LOVELL. Thank you, Mr. Chairman and members of the committee. [Applause.]

Mr. Chairman and members of the committee, I thought today that Jack and I would informally tell you what went on in the spacecraft during the flight of Odyssey and Aquarius. Dr. Petrone and Glynn Lunney have covered pretty thoroughly all the varied details. But there were certain emotional factors and techniques which I thought might be interesting to you.

Actually, the flight began several says before we lifted off. This flight was somewhat unusual in the fact that we had a rather minor crisis in the crew at the time. One of our backup crew members came down with the measles and in examining the primary crew, we found out that Lt. Comdr. Ken Mattingly was susceptible to the disease. It was quite a dramatic decision that we should not fly Ken, in case he did come down with the disease during the flight. We then looked at the backup crew—and Jack was backup. In the last 2 days prior to the flight, Jack, Fred Haise, and myself worked close together—to be sure that we did work as a team. To prepare for space flights, it is very difficult for the backup and the prime crews to get together because there are so many details to take care of ourselves that cross training is somewhat limited. But I am happy to report that as we made the decision to go in April with Jack, Jack did an outstanding job and we are very proud of how he worked in with the prime team.

REPORT OF LOW MORALE COMPLETELY FALSE

There was one other aspect to our training which I would like to report. It had been mentioned previously that I thought the morale at the Cape was low and that I was worried about the booster and the spacecraft and the people there. This is completely false. I think one of the little sidelights, one of the little jobs that we have as a crew besides training for ourselves is to go around and talk to the people there. I am happy to report that the crew people, the support team, everybody that was connected with the flight of Apollo 13, were competely behind us and completely enthusiastic about the approaching flight. I had no qualms whatsoever on April 11 to step in that spacecraft and undertake the mission.

I would like to set the scene as we saw it from the spacecraft at just about 55 hours, as Dr. Petrone had mentioned. Up to that time, our flight was rather normal. We had proceeded along the flight plan and were actually ahead of it. So we requested from ground control to enter the lunar module Aquarius 3 hours earlier. There

44-195 O—70——4

was some work that Fred Haise and I had to do and we were also scheduled to turn on our television to show the people back home on the ground some interior photography of the vehicles. We had done that. We were just completing our television work. I had been operating the camera. I was moving back through the tunnel, and Fred was still in the lunar module, just about ready to close the hatch. Jack was in the command module on the left-hand seat, when we heard a rather large explosion.

In the testing of a lunar module, there is a valve which we actuate during this procedure which also gives out this same loud noise. I had forgotten the amount of noise from this valve which rather unnerved us a bit. We thought perhaps this was a repeat of the same test. But it turned out, as I saw Fred's face as he looked down through the tunnel, that he had nothing to do with this explosion.

About that time, I looked at Jack. Jack started to see some of the warning lights come on and I think that I will let Jack explain what he saw at that time.

SUMMARIZES ACTION AFTER EXPLOSION

Astronaut SWIGERT. Mr. Chairman and members of the committee, shortly after the explosion—of course, in space, there is no air, so there is no sound; the sound itself was transmitted by the structure. Since I was attached to the seat with a lap belt, I did feel a small shudder with the explosion. At about 2 seconds thereafter, we had a master alarm and a main bus-B undervoltage light which comes on when the main bus goes under 26½ volts. I had some immediate concern because we had an unexplained problem at the main bus during testing. I transmitted that we had a problem and immediately got over to the right-hand seat to look at the readings of the voltage and the current.

At this time, the main bus voltage was normal. The current was low and fuel cell 3 was normal, which indicated to me that whatever it was, it was transitory.

At that time, being a command module pilot, I had an awful lot of faith in the command module and I thought it was in the LM. They were sitting in there without a hatch. So I said, "Jim, we had better get the hatch in and then let's sit back and take a look at what we have."

I started preparations to install the hatch, which is in the command module to close off the tunnel area. Fred Haise had come down from the tunnel at this time and looked into his seat over on the right hand side and began looking at the remaining indicators. At this time, main bus B voltage was off scale low, so it was somewhere less than 23 volts. The current was zero and the fuel cell 3 was zero, which gave indication that fuel cell 3 had stopped putting out and we indeed had no voltage and no current on main bus B.

Shortly thereafter, as Fred started transferring some of the load from that bus onto our remaining good bus, he had a main bus A undervoltage. This caused him to look at the fuel cells that were powering the main bus A, fuel cells 1 and 2. He did notice that on fuel cell 1, the flow was also zero.

At this point in time, Jim looked out the side of the spacecraft and saw material venting from the spacecraft into space and appearing much like a snowfall in some of our Western States during the winter. We concluded then that the problem indeed was in the service module and we terminated our efforts to install the hatch and began working with the ground to isolate the loss of oxygen which we had determined from our quantity indicators was coming from tank No. 2, and since the pressure was decreasing, we also were losing oxygen from tank No. 1.

I think that pretty well summarizes it.

The CHAIRMAN. Before you stop, would you mind turning around to the audience and giving them a Rocky Mountain wave?

[Applause.]

DESCRIBES FEELINGS OVER SITUATION

Astronaut LOVELL. You might wonder just what our feelings were about this time. The situation went from one where we anticipated that our lunar landing mission itself, this landing on the moon, might be in jeopardy, to one of whether we would be able to return back home or not. The seriousness of the situation increased greatly in the few minutes during our analysis of what was going on. To summarize our situation from the crew point of view, we were losing three fuel cells. These fuel cells produce the electrical power to get us back home. The batteries in the command module itself were not sufficient. We were at the same time losing oxygen pressur in our two oxygen tanks. When I looked at them, one was zero, one was going down rapidly.

It is here that the coordination, I thought, between the ground and the crew was admirable. They analyzed the situation and we soon realized that our only hope of survival was to go into Aquarius, power up its systems, and use the systems and the consumables on board the lunar module for the return home. It was here that we realized that it was now a case of survival.

We did this. We powered up the lunar module, and the first milestone of coming home, as Mr. Lunney has said, was to get an alinement that we were slowly going to lose from the command module and place that alinement into the lunar module. We were on a trajectory that, had we not done anything, would have entered us into a permanent orbit, maybe 230 miles apogee, probably 100 perigee. So the ground crew gave us what we needed to get through and get a free return trajectory burn and get us back.

My main concern at this point was to get this spacecraft back within the earth's atmosphere. I felt that this would be a much better termination of this flight at least to come back into the atmosphere than it would have been to not come back at all.

TRANSFER SPACECRAFT CONTROL TO LUNAR MODULE

One of the problems which we had to face as we entered the lunar module was the fact that we do not normally control this complete stack by the systems in the lunar module. We fly basically by the command module, the cone-shaped spacecraft, in the center of this model. Consequently, we had to transfer the control of the spacecraft to the lunar module and use these thrusters. We had practiced this, fortunately, in our training and found out that with the termination of a translation controller, which is normally used to move the lunar module in the translation, plus the attitude controller, we could control this entire stack. Remember now that we have a service module that had almost full fuel plus the reaction control system or attitude that was almost in full fuel.

Our first burn with the help of the ground was successful. We were back on free return. At the same time, we were trying to determine just how much in the way of consumables we had on board the spacecraft. This was a problem that concerned me. I knew that if this engine worked properly, we could make it back as far as the trajectory was concerned, because we had done this before in simulation and Jim McDivitt and the crew on Apollo 9 had actually tested this out. But I did not have at my fingertips at the moment just how much consumables we had on board and whether we could last the return voyage.

Again the ground came through. They computed for us, and I must give Fred Haise some credit, too, because he had in the back of his mind what the situation was and he thought he would keep them honest by checking out to see what we actually had to see whether the ground was going to give us the true figure or not. When Fred said that we had about an hour to spare, I felt a little bit more relieved.

Our second milestone was just after we passed the moon and we got to within 130 or 140 miles of the lunar surface. As we went through the back side, even with the emergency going on—and since I had been there before, I was anxious to get this second maneuver out of the way—but Jack and Fred managed to pick up a few more photographs for scientific development and exploration. So I finally had to turn them away from the windows so we could get on with the burn.

The second burn was important because it increased or decreased the time of transit from the moon back to the earth. Again, we used the descent propulsion engine. At this time, since Jack had completely powered down the command module, he was the third member aboard the LM and helped us out in our maneuvers as we lit off the engine and made a very successful automatic burn to decrease our time coming home.

Jack, why don't you comment a few minutes on just what our environmental system was as we tried to power down the lunar module?

COMMENTS ON ENVIRONMENTAL SYSTEM

Astronaut Swigert. Let me just state now, we have an active vehicle up here, completely passive around here [indicating]. One of the things that was unusual is that when you are right side up in the lunar module, you are upside down in the command module. So when you go from one area to another, there is a period of acclimitization. The lunar module with its systems powered was warm. We of course had no power in the command module and as time went on, it kept getting colder and colder. We did use the command module for sleeping for the first 2 days. It allows you a place to stretch out, it has sleep restraints that you can attach to the spacecraft structure and the sleeping accommodations were very comfortable until it got too cold for sleeping. Then we were all together in a group in the lunar module, as crowded as it was.

One of the critical consumables was the water, and we were just not going to use any of our LM water because, as precious as it was, we at least wanted to get back. So with the help of the ground, we devised a procedure for extracting the water from the portable tank in the command module. This we did.

We ate fairly well. We used juice bags for our water and I would go up there and would take 10 or 20 juice bags and fill them up as full as I could and store them away until the oxygen pressure ran out. About 24 hours prior to the entry, we ran out of water in the portable tank in the command module.

We had sufficient other food in what would be called wet packs, which are small packages of hot dogs and beef and gravy and things like that, which also afforded some moisture as well as food.

We had ample cubes and squares of gingerbread and fruitcake, things like that, which were also solid food.

We did find that conditions did get a little bit—we referred to the command module and its combination—we had a two-room suite here. We referred to the command module as the bedroom for awhile until it got too cold. Then we started calling it the refrigerator. The temperature upon entry of the command module was 38° and when we landed was still a comfortable 50° if you call that comfortable.

One of the problems we had was getting the lithium hydroxide canister modification. We have a picture of that. I do not know whether it has been released but it shows the modification that looks exactly like what you see here. The ground read us up the instructions and Jim and I constructed it and it worked perfectly. It reduced the partial pressure of carbon dioxide from 7½ millimeters down to 2/10 of a millimeter in 2½ hours. It will show you the resourcefulness of the ground and the versatility we have and I guess good old Yankee ingenuity.

One of the things we also had—that I do not think was mentioned—that we discussed as crew members using, in conjunction with the ground, was the portable life support systems, the back packs that the crew wears on lunar surface. These two back packs did have a supply of oxygen. They did have lithium hydroxide canisters and they did have electrical power and fans for circulating oxygen. So we did discuss the possibility of using these to supplement the consumables that we had on board.

I think that pretty well covers it.

EMPLOYS APOLLO 8 TECHNIQUE

Astronaut Lovell. As we were becoming accustomed to the environment, rubbing our hands together, putting on our lunar boots to keep our feet warm—I never thought we would be using them for that purpose—we had a third maneuver coming up. After the second maneuver, we found out that the angle for hitting the earth's atmosphere was still not sufficient. The ground was tracking us. They continued to give us the procedures for this third maneuver. The third maneuver was different, however, because we were powered down, essentially a dead spacecraft except for communications, except for the life support system, particularly the air and oxygen pumps keeping things cool. Back in Apollo 8, when we were not too sure about a lunar voyage and all the ramifications that might occur, we looked at the way-out procedures which, in case all was lost, could get the crew back. Things like you never give up, you just keep trying. One of them was if you lost the platform, how could we make a maneuver to change the angle of entry to make the angle safe. This maneuver consisted of maneuvering the spacecraft with attitude to line up with the earth's terminator, which was a handy reference system. Back in Apollo 8, although I learned it very astutely and remembered it, I never thought in all the world that I would ever have to use a technique of this nature. So when they called up and said, "Do you remember the technique back in Apollo 8 and why not use it for this maneuver?" we did. We maneuvered the spacecraft. At this time, we had a three-man team all helping to make this maneuver, which was strictly a manual one and it changed the angle for us to help make the entry.

The ground was helpful in other ways. We had batteries on board the spacecraft that were weak. They provided us with a procedure that we had never heard of before, to recharge the batteries from the LM power system. This, of course, helped to power up the command module earlier for reentry. The last 5 hours we were filled with techniques and procedures. I requested that the ground come up with procedures that we could, in our rather fatigued state, do sufficiently and accurately to make sure that we did not make any mistakes. They were very responsive. We got these procedures and, in the last 5 hours, we went through an alinement of the LM, the service module jettison, in which we were able to get some photographs of the damaged area, and then a power up of the command module, at which time I remained in the lunar module and I could see the earth getting bigger and bigger. If you are familiar with this little device, the lunar module is a very fragile machine.

Then after the command module was powered up and we could actually get an alinement, in which Jack did get a fine alinement, I went back through the tunnel, closed off the module. we jettisoned the lunar module, and made a normal reentry.

SHOWS FILM OF SPACECRAFT INTERIOR

I would at this time like to show you some of the movies which we had taken on the interior. Remember, now, that most of the film we had on board was for our lunar exploration work and we determined that we would have plenty of film on board. We wanted to show you some of the living conditions abroad this particular spacecraft configuration. I might add that we flew the spacecraft in four configurations, which I do not think has been done before. The complete stack. When we got done with the service module, we flew the command module and the lunar module together. Then after we got through with the lunar module, it was the command module. And prior to the actual docking, we flew the command and service module, these two together, so we had quite a combination of experiences in flying.

If I could have that movie now, I could show you some of our in-house conditions.

(A short movie is shown.)

Astronaut LOVELL. I might add that our launch was as normal as we could expect, except for the one engine malfunction which Dr. Petrone has mentioned. I was fortunate enough to be able to participate in two launches with the Saturn V. I am always amazed at the accuracy and the way that the simulations that we conduct are very similar to the actual performance of the vehicle itself.

Astronaut SWIGERT. This is a shot of the command module coming back into dock with the lunar module booster combination. You will see the shadow of the command module as it comes across, puts the probe into the groove.

Astronaut LOVELL. This is after the accident, in the lunar module. You can see things are getting quite hectic. That bag was originally designed to stow water from the life support system. It is now being utilized to store urine, because we were not dumping any overboard.

Fred is in his normal sleep position in the lunar module. The temperature is getting quite low and he has his hand tucked away.

Back in the tunnel is Jack. He was also sleeping.

Astronaut SWIGERT. Here are some shots of food. We went this time with some spoon-bowl material in which we had some adhesive material that would stick to the spoon and not float away. That had some of the gravy in it, I think.

Astronaut LOVELL. I tried to point out that lithium hydroxide experience. That bag in back of Jim's elbow there—you will be able to see the crisscross taping. During most of our flight, we were in an uncontrolled rotational mode to keep the sunlight even on the vehicle for temperature consideration. Therefore, we had light only at certain times and most of our time was spent with the flashlight.

Astronaut SWIGERT. What we are doing right here is the entry procedure and Jim and I are rolling over to get it more closely. He would be working in the lunar module, myself in the command module and this took a lot of cooperation. We found out that the procedure worked very well.

Astronaut LOVELL. I am rubbing my hands because it is cold in there.

We ended up wearing both of our sets of underwear and our garment that you see there, and the lunar boots. Unfortunately, when Jack came aboard the command module, we did not provide him with a set of lunar boots.

This is the command module showing the configuration as it looked through most of the emergency. The hatch you see at the left, the docking groove in the center and now through the tunnel. There is the configuration of the lunar module outside panel.

I might add this gave us a unique study in operating vehicles of a volume that are considerably larger than either the command module or the lunar module separately. We found out that we had no difficulty at all in transporting ourselves back and forth through both vehicles.

Our one source of entertainment was our little tape recorder that we were able to have some music on. It was indeed fortunate that our communication system was as good as it was, because the primary reason why we are back today is the way the ground took hold of unusual situations and utilized their resources and initiated them in getting procedures for getting us home.

(Conclusion of film.)

Dr. PAINE. Mr. Chairman, we would be very happy to answer any questions any of you may have.

The CHAIRMAN. Senator Smith?

KEEPING COOL UNDER ADVERSE CONDITIONS

Senator SMITH of Maine. Thank you, Mr. Chairman, for giving us this privilege. This is certainly one of the most momentous occasions of my career.

I have a number of questions but I will limit mine at this time to two simple ones.

Captain Lovell, as the young people would say, you and your associates "kept your cool." What in your background do you think contributed most to this ability to keep your cool?

Astronaut LOVELL. Senator Smith, I think that the ability to keep working under the conditions that exist is the result, perhaps, of the many years of training in the business that Fred Haise, Jack, and myself are in. We are essentially people who test equipment. We expect at times to meet adverse conditions. In this business, you cannot expect complete success all the time.

Among other things, I think, it was the coolness of the ground in helping us to determine what our problems were and to assure us that the techniques were correct to keep us going along as we did.

Senator SMITH of Maine. Mr. Swigert, do you have anything to add to that?

Astronaut SWIGERT. No; I think I agree thoroughly with Jim that it was the test pilot background that we had. I am sure that all of us being in that background had encountered unusual situations before. I think this is in large measure what enabled us to work so well with the ground.

SPACE PROGRAM STIMULUS TO EDUCATION

Senator SMITH of Maine. One thing that impressed me most was the coolness and the courage shown by the wives and families. It made me feel that at least if they could have confidence in what you were doing and that you would come back safely as you did, that I also should have confidence and not be worried.

I presume you get a great deal of mail. We here in Congress get a great deal of mail from young people of school age who would like to be astronauts, who would like to get into the space program. I sometimes wonder how to answer those letters. Do you offer any specific advice or words of caution to these young people?

Astronaut LOVELL. We do, Senator Smith, get quite a few letters from young people who would like to know about our space program and about how to enter it. We usually answer them in a manner that suggests that of all things, they continue their education. We feel that one of the best ways that we can forward our program is to have well educated people in it. I think their resourcefulness, their background, made it possible for this flight to be completed. We say above all things, continue your education. We believe the space program, if nothing else, is a stimulus to education and inspires young people to follow along.

Senator SMITH of Maine. Mr. Swigert, do you have anything to add?

Astronaut SWIGERT. No, I think that says what I would say.

Senator SMITH of Maine. Thank you.

QUESTIONS DESIGN CHANGES OF APOLLO 13

The CHAIRMAN. Senator Symington.

Senator SYMINGTON. Mr. Lovell, I join my colleagues in the pleasure of seeing you back again successfully from another moon trip. I congratulate you on your glorious achievement. It represents all the best in this country, and also congratulate your colleagues.

Dr. Paine, may I congratulate you, too, sir, on having such a superb organization. When you ran into this trouble, you were able through probably the finest piece of cooperation we have had in technological history to bring these gentlemen back safely.

Dr. PAINE. Thank you.

Senator SYMINGTON. Were there any changes in design of the Apollo 13, especially in the service module, which made it different from the previous Apollos and which might not have been adequately tested?

Dr. PETRONE. Senator Symington, there were no significant changes in the design in the service module, specifically in the area where we think we had our difficulty.

NO SAFETY SHORTCUTS CAUSED BY BUDGET CUTS

Senator SYMINGTON. Thank you.

Some people have alleged that the sharp reductions in appropriations that NASA has taken in the last few years has caused NASA to take shortcuts which may have compromised safety. Dr. Paine, is there any truth, in your opinion, in that allegation?

Dr. PAINE. None whatever, Senator Symington. NASA will not fly any missions unless we feel we are prepared in all respects to do so. The fact that we have been able to effect substantial economies has had nothing to do with the fact that we had this difficulty. We have kept all of the essentials and we expect that despite the economy, we are fully prepared to fly these missions.

CHANCE OF METEOROID DAMAGE

Senator SYMINGTON. Thank you.

What's the theoretical estimate in percentage, if you have one, about the chance of having one of our space—one of our spacecraft being hit by a meteoroid on future flights?

Dr. PETRONE. Senator Symington, the numbers there are very difficult to arrive at. But we have a series of numbers—it is less than one in a million in this particular time exposure. When you say how much less than one in a million, with very simple changes in your assumption make it one in 10 million. There is a very high order of magnitude, a very low probability that a meteorite could do damage in a space flight.

MAN WILL TRAVEL SOLAR SYSTEM

Senator SYMINGTON. Thank you, Dr. Petrone.

Dr. Paine, do you believe in manned space flight beyond the moon and think that we should prepare for it?

Dr. PAINE. There is no question in my mind, Senator Symington, that we are only at the very first steps of man in space. It has been possible for us in the first decade of space to extend man's reach all the way out to the moon and for the next decade in space, we will largely be confined to the lunar area. But in the decades to come and particularly in the centuries to come, there is no question in my mind that men will indeed travel throughout the solar system.

Senator SYMINGTON. Dr. Petrone, do you agree with that?

Dr. PETRONE. Absolutely, sir. I think the years ahead will allow us to take those steps. There is no question of our capability in the decades and the centuries ahead.

Senator SYMINGTON. Mr. Lunney, your thoughts?

Mr. LUNNEY. Yes, sir. I believe we will do that someday. I do not know when. I recall awhile back when we were first playing with airplanes, then building them and flying them. The history of the business of flight has come so far in the last 50 years that even to attempt to predict where it is going to go in the next 50 I think is taking a risk. But it is going up.

Senator SYMINGTON. Captain Lovell, how do you and your colleagues feel about this?

Astronaut LOVELL. I think, sir, I can speak for just about everybody in the flight group of the future of our space travel. It is our only regret, perhaps, that we might be too old, those of us aboard now, to go to Mars.

Senator SYMINGTON. Thank you. All I can say is you all make me very proud this morning to be an American. [Applause.]

The CHAIRMAN. Senator Curtis?

Senator CURTIS. I want to say to you, Captain Lovell and Mr. Swigert, you have done more to increase the attendance of this committee than anything that I know of. And that applies to the spectators and the press, too.

I would like to ask you, Mr. Swigert, are they giving you a bad time on your tax matter?

Astronaut SWIGERT. No, sir. It seems that I have met somebody who knows the Director, so I think I am safe.

Senator CURTIS. In case he cannot get it done, I have spent a couple of decades on the tax-writing committees of both the House and the Senate as has the distinguished chairman, Chairman Anderson. While I have made it a rule not to intercede on behalf of individual taxpayers on the merits of their claims, I will violate that rule if necessary.

Astronaut SWIGERT. Thank you, sir.

Senator CURTIS. Dr. Paine, I want to take exception to one statement you made in your presentation. You referred to what has happened as a failure. I would rather describe it as experiencing an accident and accept that as not a failure. Someone, and I do not recall who it was, said that civilization moves forward on stepping stones of tragedy. That no doubt is true. The very sad and unfortunate fire that we had a few years ago in which three brave men, White, Chaffee, and Grissom lost their lives, has caused the concentration and the success in developing fire-resistant, fireproof materials that will be of benefit to every man, woman, and child in America and beyond. Is that not true?

Dr. PAINE. Yes, we have made very substantial progress.

Senator CURTIS. Mr. Chairman, I have a question for Dr. Paine and four for Dr. Petrone, but under the circumstances, I would like to submit those to them for answering in the record.

The CHAIRMAN. They will be handed to them and they can reply to them for the record.

(The questions submitted by Senator Curtis and the answers supplied for the record by Dr. Paine and Dr. Petrone are as follows:)

FOREIGN COOPERATION DURING APOLLO 13 MISSION

Question 1. (a) Dr. Paine, the news media reported that during the difficulties of Apollo 13, the United States received offers for assistance from many countries: they offered their ships, stopped radio transmissions on certain frequencies during critical periods, and so forth. Again with the spirit of international cooperation engendered by the space program, nations moved to cooperate with one another and people around the world were drawn closer together. I wonder if you would comment on this for the committee and place in the record a detailed statement of the cooperation offered the United States during the Apollo 13 mission.

(b) How many people around the world followed the Odyssey of Apollo 13? Would you get the State Department to prepare a paper or report on the effect the Apollo 13 mission had on U.S. relations with other nations and states around the world?

Answer: (a) As soon as the word went out that Apollo 13 had encountered a grave emergency, governments in all quarters of the world hastened to offer their assistance. There were messages to the President, ministerial telephone calls in the early morning hours to our embassies, telegrams to U.S. Navy and Air Force authorities, and telegrams and phone calls to the Administrator of NASA.

Some countries alerted their naval and air units and placed them at our disposal. Others offered the use of communications and other facilities. Still others asked to be informed of whatever requirement we might have and promised to cooperate to the full extent of their ability. All offers expressed deep sympathy and concern.

As it turned out, our own resources were adequate to bring the Apollo crew back safely. This in no way detracts from the importance of these offers of assistance nor from our gratitude for them. The assistance so freely volunteered, as well as the many expressions of sympathy from our friends throughout the world, were important sources of encouragement and confidence. They demonstrate the extent to which other nations and other peoples sense that they share the adventures of space. They reflect the spirit of cooperation that invests the exploration of space, a spirit that we believe our own emphasis on working with others has done much to foster.

Messages offering assistance were received from the following countries: Argentina, Australia, Brazil, Burundi, the Republic of China, Colombia, Cook Islands, France, the Federal Republic of Germany, Greece, Iran, Italy, Malagasy, the Netherlands, New Zealand, Pakistan, Portugal, Senegal, South Africa, the Soviet Union, Spain, Trinidad and Tobago, Turkey, the United Arab Republic, the United Kingdom, and Uruguay.

In addition, leaders in some 80 countries sent cordial messages of sympathy, support and congratulations concerning the plight and recovery of the Apollo 13 astronauts.

Answer (b). From the Department of State: *Memorandum*; to Arnold W. Frutkin, Assistant Administrator, International Affairs, National Aeronautics and Space Administration; from Herman Pollack, Director, Bureau of International Scientific and Technological Affairs, Department of State; subject, Effect of Apollo-13 Mission on America's Foreign Affairs.

In response to your memorandum of April 28 forwarding Senator Curtis' request for a State Department assessment of the effect of the Apollo-13 mission on U.S. relations with other nations and states around the world, we are pleased to submit the attached statement which you may wish to make available to the Senate Committee on Aeronautical and Space Sciences.

Enclosures: Statement on "Effect of the Apollo-13 Mission on America's Foreign Relations."

MAY 20, 1970.

EFFECT OF THE APOLLO-13 MISSION ON AMERICA'S FOREIGN RELATIONS

As part of his testimony on April 6 of this year, Dr. Paine submitted to the Senate Committee on Aeronautical and Space Sciences the State Department's assessment of the effect of our total space program on American foreign relations. This report demonstrated the several ways in which the space program has had an important and highly beneficial effect on our posture on the world and on our foreign relations. The prestige which the United States has gained in the eyes of the world as a result of the space program comes only partly from the program's unprecedented success. Other important factors include its contributions to science and to commerce and the free and unfettered openness with which it has been conducted.

Even though it failed to meet its primary objective, the Apollo-13 mission was an overwhelmingly impressive demonstration of technical prowess and disciplined human skill. Contingency procedures designed in advance to cope with such an emergency, combined with disciplined and precise improvisation by hundreds of men working under extraordinary stress, culminated in the safe return of the Apollo-13 astronauts.

It is difficult to estimate with any precision the impact of the events of that week on the peoples of the world, but there is no question that it was considerable. As soon as the emergency developed, messages of concern and offers of help began to stream in from nearly every corner of the world. Several of the world's larger navies were put on alert, as were the merchant fleets of many nations. Even small nations such as Trinidad and Tobago offered the services of their Coast Guard. As the time of splash-down approached a number of ships in the southwest Pacific were diverted from their courses so as to be nearer at hand in case of need.

Another example of the willingness of the world's nations to assist was provided by the response to NASA's request that radio silence be maintained on frequencies assigned to Apollo-13 during the critical phase of the spacecraft's return to earth. Not a single case of radio interference was reported on these frequencies, which, in the words of Dr. Paine, represents "a genuine tribute to all the nations of the world who unselfishly shut down or otherwise restricted national services to assist in an emergency situation never experienced before." A message expressing America's deep appreciation for this cooperation was sent to all nations in which we have diplomatic posts.

It has been estimated that approximately half a billion people watched last July's moon walk on live television. The U.S. Information Agency estimates that the audience on April 17 may have been even larger. The streets of major cities throughout the world were deserted as people stayed indoors to watch and listen. When it became clear that the astronauts were safe, a wave of spontaneous relief and joy was expressed, punctuated in some cities by the ringing of church bells. A flood of messages of congratulation from kings, prime ministers and ordinary citizens descended on Washington and on our embassies and consulates abroad. The press and other media of foreign nations, which had been following the events with growing excitement for several days, were, with a few exceptions, warm in their praise, not only citing the courage of the astronauts and the technical achievement but giving prominent attention to the fact that our policy of freely sharing the Apollo missions with the peoples of the world, which had served us so well on earlier missions, had stood the test of a period of trial and anxiety.

A more complete assessment of media reaction throughout the world, prepared by the U.S. Information Agency, is appended to this report.

After the burst of enthusiasm felt by most of the world toward our country at the time of the moon walk had subsided we were left with a substantial residue of admiration and prestige which, while impossible to measure in quantitative terms, continues to be of real value with respect to our posture in the world and our relations abroad. The manner in which our space team conducted itself during the emergency in the Apollo-13 mission, the fact that other nations could make a positive contribution to the rescue effort through maintaining radio silence, and the successful recovery of the astronauts have all helped in significantly deepening these impacts of the space program on America's foreign relations.

U.S. Information Agency—May 5, 1970

FOREIGN MEDIA REACTIONS TO APOLLO-13

The Apollo-13 flight and the safe return of the astronauts evoked a remarkable international response of official and popular concern followed by relief and warm congratulations. Kings, presidents, and prime ministers directed congratulatory messages from their people to the President, the nation, the astronauts, and the NASA support team on the ground.

Television and radio coverage of the splashdown was probably at its highest peak for any single event in history, apparently surpassing even that of the actual walk on the moon by Apollo-11.

Several hundred Czech viewers called the Prague station to protest the lack of live coverage of the splashdown. Czech television had adhered to its scheduled program of Husak at a Lenin birthday celebration, but it did show the splashdown later on tape. At Bujumbura, the President of Burundi made an unprecedented and surprise visit on the Ambassador after the flight. Arriving in his own car without an official driver, the President stayed for more than an hour to extend his congratulations. In another typical reaction, the Tunisian Prime Minister personally telephoned the Ambassador to express the joy and pride of the Tunisians in this great accomplishment.

Foreign media comment revealed that the flight may have had an impact on the image of the U.S. abroad. Specifically, media comment on the flight stressed the following positive points:

(1) The flight increased awareness of men everywhere of our common concerns and unified them through their mutual hopes for the safety of Apollo-13.

(2) The openness of American society allowed the rest of the world to share this experience.

(3) The safe return of Apollo-13 indicated the high level of technical competence in America.

(4) The courage of the crew and the superb performance of the ground personnel illustrated the finest qualities of contemporary America.

Some media comment was seasoned with reservations concerning the risks of manned spaceflight and the wisdom of devoting major resources to the Apollo program when there is so much that needs attention on earth, but these negative aspects were overwhelmed nearly everywhere by enthusiastic and positive reactions.

Representative media comment on each of these themes follows:

United Mankind . . .

Hamburg's independent *Die Welt* discerned "a spirit of cosmopolitan solidarity" in offers of an international rescue effort which "will leave its traces in the hearts of mankind . . ."

". . . if the people on earth can be brought together in solving other issues as they were over the Apollo-13 incident, it will not be difficult to achieve peace in the world. Apollo-13 pointed to the possibility of global unity for mankind." (*Seoul Shinmum*, Seoul)

"We do not wish to give the slightest nationalistic coloration to an event that unites the entire civilized world in a single feeling of concern." (*Il Tempo*, Rome)

"No matter how big man gets, he remains small in this universe." (*Lisan al-Hal*, Beirut)

"The spectacle of human solidarity is moving and speaks highly of the sentiments aroused in men when one of their kind is in danger in the cause of peace and progress." (*El Mercurio*, Chile)

"It (the flight) resulted in a more united mankind . . . It favored a better comprehension among men . . ." (*Corriere della Sera*, Milan)

The Openness of American Society . . .

"The Americans ran a considerable risk by agreeing from the outset to say everything and show everything about their space programs, regardless of what this might subsequently cost them. It is only right that they now be rewarded for this." (*Le Monde*, Paris)

"America, committed as she is to an open system, places not only her triumphs but also her failures in the harsh glare of world publicity and world criticism . . ." (*Trinidad Guardian*)

"The frankness, innocence almost, in the American way of life spares us none of the terrifying risks. But it also denies us none of the glory." (*Daily Mail*, London)

"Four thousand newsmen from all over the world were able to attend the exciting beginning of the first moon mission last July. About the same number of newsmen share the drama of the Apollo-13 crew. So the Americans have brought us the most exciting adventures of man—in times of triumph as well as those involving great fear." (*Corriere della Sera*, Milan)

"Perhaps Russian astronauts have met these perils, too. But unlike the Americans, they do not publicize their adventures as they happen. The Americans take the blame with the praise and share their anxieties, as they happen, with the world . . ." (*Guardian*, Manchester and London)

A Feat of Technology . . .

"The superb quality of the technology of Apollo is beyond reproach . . . The final result was a triumph for human courage, teamwork, and technological brilliance." (*Times*, London)

"If they had taken place in Africa, earlier events would have prompted a postponement of the launch because they would have been taken as an ominous portent. But the U.S. is not superstitious like us. It is a highly scientific country which does not entertain such irrational considerations." (*Togo-Presse*, Lonne)

"SPACECRAFT ACCIDENT PERMITTED NASA TO SHOW ABSOLUTE MASTERY OF IMPONDERABLES" (Headline, *Combat*, Paris)

"By coping with the unexpected, NASA has demonstrated mastery. Before yesterday, the conquest of space was only a reasoned but total gamble on the quality of the equipment. From now on it is also an enterprise which . . . can allow technical failure." (*Le Monde*, Paris)

"The return was a victory for science by no means less important than launching a spaceship to the moon," because this is the first time "science and the human mind have been put to the test of recovering a crippled spaceship and its astronauts safely." (*al-Jarida*, Beirut)

"If the recovery attempt succeeds, it will be another and more convincing and extraordinary feat of the technological and scientific capacity of the American nation." (*Il Tempo*, Rome)

"Apollo–13, the aborted, crippled, misfortune-dogged third mission to the moon, represents a greater landmark in man's struggle to master his environment than if it had reached its destination." (*Hindustan Times*, New Delhi)

Admiration for the Crew and Ground Personnel . . .

"The wonderful Apollo-13 astronauts have all the characteristics of "Homo Americans". They are examples of 21st century man . . ." (*Il Tempo*, Rome)

"No man has ever been more alone than the three men cramped inside. Now we see the true courage of the moonmen. No stranger has ever felt closer to our hearts." (*Daily Mail*, London)

"The reaction of NASA and of the Apollo crew has been remarkable . . . Irony and humor sprinkled the dialogue . . ." (*Combat*, Paris)

"With Apollo-11 the astronaut asserted himself as the finest product of American civilization. With Apollo-13 he regains a human look . . ." (*Le Monde*, Paris)

"Apollo-13 means we must admire the men, their preparation, their great courage, and their ability." (*Il Popolo*, Rome)

"Far more valuable, more significant than success has been this saga of man's courage and resilience in the face of misfortune. The machine failed; man did not . . ." (*Hindustan Times*, New Delhi)

"We do not find words to express our admiration for the quiet, imperturbable courage with which the three astronauts are facing this terrible crisis and for the faultless manner in which they are working emergency maneuvers to save themselves from catastrophe." (*Het Volk*, Belgium)

"The courage of the astronauts exceeds all measure." (*Diairo de Noticias*, Rio de Janiero)

ABORT PROCEDURES

Question 2. Dr. Petrone, a question about the abort procedures which were used on the Apollo 13 mission. Had these generally been worked out ahead of time or were they all improvised to meet this specific situation?

Answer. The abort mode used on Apollo 13 included a descent engine burn to return to the free return trajectory with an Indian Ocean landing. This burn was accomplished soon after the anomaly. A second abort burn was performed with the descent engine 2 hours after perilune to speed the return and land in the prime recovery area of the Pacific Ocean. Both of these maneuvers were standard abort procedures which had been developed prior to the mission and documented in the Operational Abort Plan.

Detailed subsystems portions of numerous contingency procedures used involving the LM and CSM had been exercised premission. But the actual Apollo 13 mission situation required additional studies to consider the required system configurations encountered for powering the CSM from the LM, use of the CM CO_2 removal system for the LM and other various configurations used during the return flight.

EMERGENCY PROCEDURES OUTLINED

Question 3. Dr. Petrone, it is reported that all of the more difficult tasks the astronauts were called upon to carry out in or with the spacecraft were first tested in simulators on the ground before giving them to the Apollo 13 crew. Is that correct and could you describe this process for the committee?

Answer. The more difficult tasks performed by the astronauts were those which required changes to previously planned and tested contingency procedures. While extensive contingency planning had preceded the mission, modifications were necessary to accommodate the precise flight conditions encountered in the emergency. From this standpoint, availability of the preplanned contingency actions to be used as a baseline for further refinement was of incalculable value.

During the emergency, procedures and timelines were checked by over a dozen astronauts in simulators in Houston and at the Kennedy Space Center and by contractor personnel in simulators at Grumman and North American Rockwell to prove their adequacy and effectiveness. Procedures were modified where necessary and rerun. Maneuver checks included trying various configurations of control, including automatic and manual, to evaluate the adequacy of these handling techniques considering the anomalous configurations. Extensive use was made of numerous computer facilities in connection with the simulators and elsewhere. These computers proved invaluable in permitting detailed analyses of the various systems configurations and effects thereof. Then the refined, agreed-upon checklists and instructions were voiced up to the crew and verified by the control center spacecraft communicator (CAPCOM), who is an astronaut himself.

Also, the astronauts who had performed the simulations stood by in the control center while the instructions were passed up to the crew and while maneuvers were being performed to lend any additional assistance and answer any questions the crew might have.

Additionally, each cognizant flight controller monitored all instructions and the ensuing actions to insure they were being performed within the constraints of this system. Any required real time alterations were recommended by the flight control team when appropriate.

Question 4. Dr. Petrone, how many people were directly involved in working on the emergencies employed on the Apollo 13 flight?

Answer. Early estimates of people involved ranged quite high because we received many offers of assistance and we could not be sure how great our personnel requirements might be. However, as the situation became stabilized and as we reduced the alternatives available, such as recovery areas, estimates of the number of people required were significantly reduced. Currently we believe that some 5,000 people were directly participating from NASA, DOD and our contractors.

Question 5. Dr. Petrone, after the problem occurred during the Apollo 13 mission 200,000 miles from earth, did the Apollo system—that is, the people, the spacecraft, the ground support equipment and the procedures—operate as expected?

Answer. Yes, the response of the Apollo 13 crew, the NASA organization, the contractors and the flight and ground equipment was truly outstanding and was one of the rewarding features of this mission. The dedicated efforts of a highly trained Government-industry team, the flexibility which had been incorporated in Apollo equipment and procedures, and the outstanding performance of the remaining spacecraft systems contributed greatly to the safe return of the Apollo 13 flight crew.

ANSWERS "LAST MOON MISSION" REMARK

The CHAIRMAN. Senator Stennis?

Senator STENNIS. Mr. Chairman, I want especially to thank you and the Senator from Maine, Senator Smith, for arranging to have this hearing. It gives the American people these facts in an atmosphere that makes it more understandable to them than a more formal presentation would.

Most of the questions I have in my mind have already been covered, but Captain Lovell, you were quoted in the press as making this remark—I think you have already refuted it, but since you were quoted that way, I would like your direct response to the quote that:

> I am afraid this is going to be the last moon mission for a long time.

Now, if you said that, just how do you feel about it now?

Astronaut LOVELL. Senator, that is a very good question. I made that remark as we swung around the moon, as I looked at it, and was looking rather wistfully, and I said for very good reason at the time, we on board the spacecraft did not know exactly what went wrong. I knew one of the basic concepts of our administration is not to fly anything unless we are almost 100 percent sure that it is going to be a success. If nothing else, we bent over backwards on reliability and on redundancy. And at the time, I knew that we were not going to attempt another moon mission or another space flight unless we had hardware that we were assured was going to operate.

After returning home, and after knowing the cause of our particular incident and the hard work in which the people had analyzed the telemetry from the spacecraft, I am sure now that we have a good knowledge of what went wrong and based on Dr. Petrone's remarks, I think the correction can be implemented quite quickly. I do not see any real slowdown in our lunar missions.

INCREASE IN PRESSURE

Senator STENNIS. That is very fine, sir. Dr. Petrone, how far have you gone in analyzing just what caused the excess pressure which resulted in the explosion of the oxygen tank?

Dr. PETRONE. Senator Stennis, in going after the cause for the increase in pressure, we are searching for the materials that could give us this increase in energy. As I stated, the electrical energy itself going into that tank under the conditions we had would not have been sufficient. But the electrical energy, possibly as an initiator, as an energy source within a tank—even metals have to be looked at. Aluminum metals have to be looked at very carefully in these conditions. Those are some of the tests that we have very intensively underway now and they are going on daily around the clock. We have not yet identified the energy source which may have given this increase in pressure.

NO UNNECESSARY RISK

Senator STENNIS. I thank you.

This question is one which I think I know the answer to, but is also one which I think the American people would be interested in having Astronauts Lovell and Swigert answer: Do any of your fellow astronauts, as far as you know, feel that the astronauts are being put to unnecessary risks in these ventures?

Stated the other way, do you think that everything is being done that could or should be done to carry out these missions at the lowest possible risk to the men involved?

Astronaut SWIGERT. I think I can answer that, Senator. I probably had the shortest tour on record as a prime crewmember, in those 2 days. I never felt any reluctance or that I was being put to any unnecessary risk at all. I have always felt complete confidence in NASA, in the organization. I have worked with the ground controllers as a flight crewmember. I know intimately their methods of operation, and I felt complete confidence in them.

Right now, if you were to ask me if I would go back and fly the service module, I would answer I certainly would. I have complete confidence that in whatever fix it has come up with, that vehicle will be able fully to do whatever mission it is called on to do.

Senator STENNIS. Do you wish to say something on that, Captain Lovell?

Astronaut LOVELL. Senator Stennis, I agree with Jack completely. I think that we all must realize that in exploration, like exploration at any time, whether it was with the airplanes or ships or spacecraft, you are always faced with a certain amount of unknown risk. We are prepared to take that.

Senator STENNIS. Well, that is very fine.

I want you to convey to Astronaut Haise our great regret that he could not be here. I do not say that solely because he is a Mississippian. I say it partly because I am a Mississippian. We are proud of him, along with the rest of you, and if Astronaut Mattingly is here, I would like to give him a chance, Mr. Chairman, to stand up.

He is not here. Well, we owe all of you a great deal. You were all prepared for an extreme emergency. That is the supreme test. As Senator Symington said, we are proud to be Americans along with and you all the others who have contributed to your safe return.

Thank you.

TECHNOLOGY TRANSFER BENEFITS

The CHAIRMAN. Senator Hatfield?

Senator HATFIELD. Mr. Chairman, first of all, I would like to congratulate Captain Lovell and his crew on the brilliant manner in which they handled this fantastic emergency with the superb help of Goddard and Houston. I would like also to indicate to you that I, for one member of this committee, have frequently questioned the cost of this project, along with all other space expenditures. I have reflected in those questions that I have posed from time to time much of the mail and the tenor of the public with whom I have had contact, who are always exhilarated, excited and proud of space achievements, but also raise, in terms of finance and the matter of taxation, the commitment of this country to our space program.

On April 6 of this year, Dr. Paine presented a very outstanding statement to this committee dealing primarily with technology transfer. Because it has been my opinion that too often our space program has been justified purely for the sake of prestige and of competition with the Russians rather than for the benefits that do accrue on all mankind in helping solve some of the problems on this earth.

Dr. Paine indicated that we have many transfers of benefits that have come from fields of meteorology, communications, medical research, and education, and many other fields.

My question to you, Captain Lovell, is, would you at this time be able to indicate to this committee any unique technology transfer that might have come as a result of this particular flight and under these particular circumstances?

Astronaut LOVELL. One area that I think was utilized to the greatest extent possible was the effect of the ability to communicate back and forth between the spacecraft and home base. My only regret is, I wish that my home communication system was as good as the one that we have in our spacecraft.

There are many systems which we have utilized in Apollo 13 that were, of course, not used before. And as Dr. Paine had mentioned previously, we have encouraged the use of these materials and technology outside of the space program.

I think the one area, if I might digress just one minute, the one area which has not been mentioned which I have found in my travels throughout the United States, is education. Ten years ago, or just before the Russians put up their first Sputnik, people going into science were hard to find. There was just not that stimulus. Now, it is completely reversed. If nothing else, I think that the space program has been a tremendous stimulus to the young people on pursuing an education course.

The CHAIRMAN. That is a very good answer.

Astronaut SWIGERT. I do not think there is anything that I could add that has not been added by other members of your committee.

Senator HATFIELD. Thank you very much.

I would like to emphasize again one or two brief thoughts here as to Dr. Paine's presentation.

All of us are greatly concerned in the field of medical science, especially about some of the diseases we have not yet conquered. In this testimony, Dr. Paine indicated that there had been some laboratory studies on the radiation effects on the cells of the astronauts themselves that have opened up promising new avenues for possible chemical control of cancer.

Now, here in just one action of the program, I think we could certainly justify much of the expenditure and feel very pleased with the opportunity to make such expenditures.

We also have in other fields which Dr. Paine mentioned, and I think on this kind of focus of this day, we ought to certainly stress these positive points of the technology transfer—that there has been a microscope developed that can create vision for the viewer and a knife that goes with this microscope which Dr. Paine says can take one strand of hair and cut it into 10,000 lengthwise strips. So this has certainly great implication for all of science, especially medical science.

We could go on and on, but I think in all of these occasions where we have an opportunity to direct public attention to the space program, we ought to utilize such occasion to emphasize the benefits that are accruing to all of us as a result of space exploration, and especially you, who move out of space to help bring this new science and this new technology to all of us.

The CHAIRMAN. Senator HOLLAND?

REACTION TO ADVERSITY PROMPTS CONFIDENCE

Senator HOLLAND. Thank you, Mr. Chairman.

Of course, we are tremendously proud, not only of you three gentlemen, two of whom are here, but of the entire group of space scientists. We are happy to find that you have a team that was able to react to adversity just as you have to success, and to bring a certain degree, a very large degree, of success out of what might have been much greater adversity.

I think that all of us in this country are far from considering this project as a failure in the sense that nothing was accomplished. The original objective, of course, was not accomplished, but the showing of tremendous resourcefulness and the ability to meet an unknown situation or unknown problems is something that I think will create even greater confidence in your team, Dr. Paine, and in the whole effort.

EDUCATIONAL BACKGROUND

I have certain questions here, but before I ask them, may I suggest that the several comments that have been made about the necessity for young people to continue and to complete their education—and I especially like what you said about that, Captain Lovell—might be embelished a little for this record, because I think it is going to be a best seller, by the way. It would be well to have the record show at this point the complete educational background of each of the three astronauts that participated, Dr. Paine, as well as the backgrounds of Dr. Petrone and Mr. Lunney, as well as, of course, the background of Dr. Paine, the administrator of the whole program.

The CHAIRMAN. That is a very good idea.

(The educational backgrounds referred to above are as follows:)

THOMAS O. PAINE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(Appointed Mar. 5, 1969. Sworn in Apr. 3, 1969)

Dr. Thomas O. Paine was born in Berkeley, Calif., November 9, 1921, son of Commodore and Mrs. George T. Paine, USN (Ret.). He attended public schools in various cities and was graduated from Brown University in 1942 with an A.B. degree in engineering.

In World War II he served as a sumbarine officer in the Pacific and the Japanese occupation. He qualified in submarines and as a Navy deep-sea diver and was awarded the commendation medal and submarine combat insignia with stars.

In 1946–49 Dr. Paine attended Stanford University, receiving an M.S. degree in 1947 and Ph. D. in 1949 in Physical Metallurgy. In 1946 he married Barbara Helen Taunton Pearse of Perth, Western Australia. They have four children: Marguerite Ada, George Thomas, Judith Janet and Frank Taunton.

Dr. Paine worked as a research associate at Stanford University from 1947 to 1949, where he made basic studies of high-termperature alloys and liquid metals in support of naval nuclear reactor programs. He joined the General Electric Research Laboratory in Schenectady, New York, in 1949 as research associate, where he initiated research programs on magnetic and composite materials. This work led to the first demonstration of the shape anisotrophy effect in single-domain magnetic particles, and to the basic patents on "Lodex" permanent magnets. In 1951 he transferred to the Meter and Instrument Department, Lynn, Mass., as manager of materials development, and later as laboratory manager. Major projects ranged from development of photocells and non-arc-tracking organic insulation to solid-state nuclear reactor control systems and aircraft instrumentation. For the successful fine-particle magnet development program, Dr. Paine's laboratory received the 1956 Award for Outstanding Contribution to Industrial Science from the American Association for Advancement of Science.

From 1958 to 1962 Dr. Paine was research associate and manager of Engineering Applications at GE's Research and Development Center in Schenectady. This involved organizing and managing a new laboratory component engaged in technical-economic studies and development programs in lasers, medical, electronics, electric vehicles, and many other fields.

In 1963–68 he was manager of TEMPO, GE's Center for Advanced Studies in Santa Barbara, Calif. This 400-man, long-range planning and interdisciplinary study group conducted interdisciplinary research for federal, state and local governments, foreign nations, banks, and industry. These programs ranged from criteria for selection of model cities to the logistics support system for Polaris submarines and from computerized management information systems to economic development in Africa. About 15 percent of these studies were for top management of the parent company.

On January 31, 1968, President Johnson appointed Dr. Paine Deputy Administrator of NASA. Upon the retirement of Mr. James E. Webb on October 8, 1968, President Johnson named Dr. Paine Acting Administrator of NASA. His nomination as Administrator was announced by President Nixon on March 5, 1969; this was confirmed by the Senate on March 20, 1969. He was sworn in by Vice President Agnew on April 3, 1969.

Dr. Paine's professional activities have included chairmanship of the 1962 Engineering Research Foundation—Engineers Joint Council Conference on Science and Technology for Less Developed Nations; secretary and editor of the E.J.C. Engineering Research Committee on the Nation's Engineering Research Needs 1965–1985; member, Advisory Committee and local chairman, Joint American Physical Society—Institute of Electrical and Electronic Engineers International Conference on Magnetism and Magnetic Materials; chairman, Special Task Force for U.S. Department of Housing and Urban Development; lecturer, U.S. Army War College and American Management Association; Advisory Board, AIME *Journal of Metals;* member, Basic Science Committee of IEEE and the Research Committee, Instrument Society of America; Collier Trophy Award Committee.

Dr. Paine is a member of the Sigma Xi; the Army and Navy Club, the Cosmos Club, the National Aviation Club, Washington, D.C.; New York Academy of Sciences; American Physical Society; Institute of Electrical and Electronic Engineers; American Institute of Mining, Metallurgical and Petroleum Engineers; American Society of Metals; Institute of Metals (London); Submarine Veterans of World War II; Society for the History of Technology; Marine Historical Association; American Museum of Electricity; Newcomen Society (London); Naval Historical Foundation; American Association for the Advancement of Science; National Association for the Advancement of Colored People; U.S. Naval Institute; Navy League; Association of the U.S. Army; Instrument Society of America; Associate Fellow, American Institute of Aeronautics and Astronautics; National Space Club Board of Governors; American Astronautical Society Fellow.

Dr. Paine received an Honorary Doctor of Science degree from Brown University on June 2, 1969.

Rocco A. Petrone, Director, Apollo Program

Rocco A. Petrone became Program Director for the National Aeronautics and Space Administration on Sept. 1, 1969. As Director of the Apollo Program Office in Washington, D.C., Dr. Petrone has overall responsibility for the direction and management of the Apollo manned space flight program which has as its mission the manned exploration of the Moon.

Prior to assuming the duties of his present position, Dr. Petrone was Director of Launch Operations at the John F. Kennedy Space Center, Fla. In this office he was responsible for the management and technical direction of preflight operations and integration, test, checkout, and launch of all space vehicles, both manned and unmanned, for the Kennedy Space Center. Launch operations, the largest organizational element at KSC, was the key directorate for committing to launch the Apollo 11 which landed the first men on the surface of the Moon.

Dr. Petrone's extensive career in rocket development began in 1952 at the Army's Redstone Arsenal in Huntsville, Ala., where he participated in the development of the Redstone, the Nation's first ballistic missile. He was in the blockhouse at Cape Canaveral in August 1953 as a member of the Missile Firing Laboratory for the first launch of the Redstone. From 1956 to 1960 he was detailed to the Army General Staff, Pentagon, Washington, D.C., where he was assigned duties in the field of guided missiles before being loaned by the U.S. Army to NASA at Kennedy Space Center in July 1960. During his NASA assignments, Dr. Petrone has been directly involved in all 12 successful launches of the Saturn I vehicles.

As the Saturn Project Officer, responsible to the Kennedy Space Center Director, Dr. Kurt H. Debus, Dr. Petrone assured that all aspects of the Saturn Project fulfilled the Kennedy Space Center requirements. When in 1961 this nation established its goal to land men on the Moon by 1970, the Apollo Manned Lunar Landing Program was approved, and Dr. Petrone was assigned as Apollo Program Manager.

He was responsible for the planning, development, and activation of all launch facilities required for the Apollo Program, including Launch Complex 39, where the Apollo/Saturn space vehicles are launched. Dr. Petrone retired from the U.S. Army with the rank of Lieutenant Colonel in June 1966, after 20 years service, and at that time continued his career as Director of Launch Operations at Kennedy Space Center.

Dr. Petrone graduated from the U.S. Military Academy in 1946, and after serving overseas in Germany from 1947 to 1950, he resumed his studies at the Massachusetts Institute of Technology, to earn his Masters degree in mechanical engineering in 1951. A year later, he was awarded a Professional degree in mechanical engineering. His performance at MIT won him membership in Sigma Xi, the scientific honor fraternity.

In March 1968, the Canaveral Council of Technical Societies presented to Dr. Petrone the Fifth Space Congress Award for his outstanding contributions to the local Missile and Space Program during 1967. He received the NASA Exceptional Service Award in November 1968 for his direction of the successful checkout and launch of Apollo 7, the first three-man mission into space. Dr. Petrone also received the NASA Distinguished Service Medal, the Agency's highest award, in January 1969, for his direction of the checkout and launch of Apollo 8, the first manned mission to the Moon. In May 1969, he was awarded an Honorary Doctorate of Science degree from Rollins College, Winter Park, Fla. On Oct. 21, 1969, Dr. Petrone received his second NASA Distinguished Service Medal—this one for his direction of the checkout and launch of Apollo 11, the first manned lunar landing mission.

Dr. Petrone is a student of the Civil War and has an extensive library on the subject. He is also interested in athletics, and played for the West Point football teams during the era of All Americans Felix "Doc" Blanchard and Glen Davis.

Dr. Petrone and wife, Ruth, have three daughters, Teresa, Nancy, and Kathryn, and one son, Michael.

Glynn S. Lunney, Chief, Flight Directors Office, NASA, Manned Spacecraft Center, Flight Control Division

Mr. Lunney was born November 27, 1936, in Old Forge, Penn. He was graduated from Scranton Prep School in 1953. He attended the University of Scranton and received a Bachelor of Science degree in Aeronautical Engineering from the University of Detroit in 1958. Mr. Lunney is a member of Pi Tau Sigma and Tau Beta Pi, scientific organizations.

Mr. Lunney joined NASA's predecessor, the National Advisory Council for Aeronautics (NACA), at Lewis Research Center under the college cooperative training program in August 1955. In Sept. 1959 he transferred to the Space Task Group at Langley Field, Va., predecessor of the Manned Spacecraft Center, as an Aeronautical Research Engineer. In April 1962, Mr. Lunney transferred to the Manned Spacecraft Center in Houston, Texas, and worked until August 1964 as Head, Mission Logic & Computer Hardware Section of the Flight Control Division. At the early age of 27 Mr. Lunney was named as one of the four Flight Directors at MSC, August 1964. From August 1964 to July 1968, Mr. Lunney served as Chief, Flight Dynamics Branch as well as a prime Flight Director during the Gemini Program. In July 1968 Mr. Lunney joined the Flight Control Division Staff Office and was selected to head the newly organized Flight Directors Office in February 1969.

As chief of the Flight Directors Office, Mr. Lunney provides the Division Chief with the necessary interface associated with Flight Director manning and overall integrated team training of the various flight control teams.

As a Flight Director during the spacecraft missions, Mr. Lunney exercises critical functions involving control of the flight from liftoff of the launch vehicle to landing of the spacecraft in the recovery area. This position required detailed familiarity with spacecraft systems and with complex ground information processing and display systems. During mission operation periods, he is empowered by the Center Director of Flight Operations to control all elements of the Mission Control Center, worldwide remote sites, and manned space flight tracking net work; and thereby assure the implementation of mission objectives, mission rules and flight crew safety. In contingency situations, Mr. Lunney is delegated the authority and responsibility to make unreviewed, realtime decisions to assure flight crew safety and achieve mission objectives.

Mr. Lunney served as the prime Flight Director for the first manned Apollo Mission, Apollo 7, in November 1968. For the Apollo 8 mission Mr. Lunney again was a Flight Director and was in charge of the critical Lunar Orbit Insertion (LOI) which placed the capsule in Lunar Orbit on December 24, 1968. Mr. Lunney, as the lead Flight Director for the May flight of Apollo 10, is directing the training, simulations, requirements and documentation required for a manned mission.

Mr. Lunney's outstanding contributions to our Nation's Space Program can be noted in the special honors he has received: Outstanding Performance Award—1967; Quality Step Increase—1967; Sustained Superior Performance Award—1964; NASA Group Achievement Award—Mercury—1962; NASA Group Achievement Award—Gemini—1967; Letter of Commendation from NASA Director—1964. His most outstanding award to date was the NASA Exceptional Service Medal presented by NASA Headquarters in November 1968 in recognition of his outstanding performance and leadership of the Apollo 7 flight control team.

Mr. Lunney is married to the former Marilyn Jean Kurtz of Cleveland, Ohio. The couple and their four children; Jenifer, born Feb. 1, 1961; Glynn, born Aug. 14, 1962; Shawn, born Aug. 4, 1963; and Bryan, born Jan. 14, 1966; reside in Friendswood, Texas.

JAMES ARTHUR LOVELL, JR. (CAPTAIN, USN), NASA ASTRONAUT

Birthplace and date.—Born March 25, 1928, in Cleveland, Ohio. His mother, Mrs. Blanche Lovell, resides at Edgewater Beach, Florida.

Physical description.—Blond hair; blue eyes; height: 5 feet 11 inches; weight: 170 pounds.

Education.—Graduated from Juneau High School, Milwaukee, Wisconsin; attended the University of Wisconsin for 2 years, then received a Bachelor of Science degree from the United States Naval Academy in 1952; presented an Honorary Doctorate from Illinois Wesleyan University in 1969.

Marital status.—Married to the former Marilyn Gerlach of Milwaukee, Wisconsin. Her parents, Mr. and Mrs. Carl Gerlach, are residents of Milwaukee.

Children.—Barbara L., October 13, 1953; James A., February 15, 1955; Susan K., July 14, 1958; Jeffrey C., January 14, 1966.

Recreational interests.—His hobbies are golf, swimming, handball, and tennis.

Organizations.—Member of the Society of Experimental Test Pilots and the Explorers Club.

Special honors.—Awarded the NASA Distinguished Service Medal, two NASA Exceptional Service Medals, the Navy Astronaut Wings, the Navy Distinguished Service Medal, and two Navy Distinguished Flying Crosses; recipient of the 1967 FAI De Laval and Gold Space Medals (Athens, Greece), the American Academy of Achievement Golden Plate Award, the City of New York Gold Medal in 1969, the City of Houston Medal for Valor in 1969, the National Geographic Society's Hubbard Medal in 1969, the National Academy of Television Arts and Sciences Special Trustees Award in 1969, and the Institute of Navigation Award in 1969.

Co-recipient of the American Astronautical Society Flight Achievement Awards in 1966 and 1968, the Harmon International Trophy in 1966 and 1967, the Robert H. Goddard Memorial Trophy in 1969, the H. H. Arnold Trophy for 1969, the General Thomas D. White USAF Space Trophy for 1968, the Robert J. Collier Trophy for 1968, and the 1969 Henry G. Bennett Distinguished Service Award.

Experience.—Lovell, a Navy Captain, received flight training following graduation from Annapolis in 1952.

He has had numerous naval aviator assignments including a 4-year tour as a test pilot at the Naval Air Test Center, Patuxent River, Maryland. While there he served as program manager for the F4H weapon system evaluation. A graduate of the Aviation Safety School of the University of Southern California, he also served as a flight instructor and safety engineer with Fighter Squadron 101 at the Naval Air Station, Oceana, Virginia.

He has logged more than 4,407 hours flying time—more than 3,000 hours in jet aircraft.

Current assignment.—Captain Lovell was selected as an astronaut by NASA in September 1962. He has since served as backup pilot for the Gemini 4 flight and backup command pilot for the Gemini 9 flight.

On December 4, 1965, he and Command pilot Frank Borman were launched into space on the history-making Gemini 7 mission. The flight lasted 330 hours and 35 minutes, during which the following space firsts were accomplished: longest manned space flight; first rendezvous of two manned maneuverable spacecraft, as Gemini 7 was joined in orbit by Gemini 6; the longest multi-manned space flight. It was also on this flight that numerous technical and medical experiments were completed successfully.

The Gemini 12 mission, with Lovell and pilot Edwin Aldrin, began on November 11, 1966. This 4-day, 59-revolution flight brought the Gemini Program to a successful close. Major accomplishments of the 94-hour 35-minute flight included a third-revolution rendezvous with the previously launched Agena (using for the first time backup onboard computations due to radar failure); a tethered stationkeeping exercise; retrieval of a micrometeorite experiment package from the spacecraft exterior; an evaluation of the use of body restraints specially designed for completing work tasks outside of the spacecraft; and completion of numerous photographic experiments, highlights of which are the first pictures taken from space of an eclipse of the sun.

Gemini 12 ended with retrofire at the beginning of the 60th revolution, followed by the second consecutive fully automatic controlled reentry of a spacecraft, and a landing in the Atlantic within 2½ miles of the USS WASP.

As a result of his participation in the Gemini 7 and 12 flights, Lovell logged 425 hours and 10 minutes in space. Aldrin established a new EVA record by completing 5½ hours outside the spacecraft during two standup EVA's and one umbilical EVA.

Lovell served as command module pilot for the epic six-day journey of Apollo 8—man's maiden voyage to the moon—December 21–27, 1968. Apollo 8 was the first manned spacecraft to be lifted into near-earth orbit by a 7½-million pound thrust Saturn V launch vehicle, and all events in the flight plan occurred as scheduled with unbelievable accuracy.

A "go" for the translunar injection burn was given midway through the second near-earth orbit, and the restart of the S–IVB third stage to effect this maneuver increased the spacecraft's velocity to place it on an intercept course with the moon. Lovell and fellow crew members, Frank Borman (spacecraft commander) and William A. Anders (lunar module pilot), piloted their spacecraft some 223,000 miles to become the first humans to leave the earth's influence; and upon reaching the moon on December 24, they performed the first critical maneuver to place Apollo 8 into a 60 by 168 nautical miles lunar orbit.

Two revolutions later, the crew executed a second maneuver using the spacecraft's 20,500-pound thrust service module propulsion system to achieve a circular lunar orbit of 60 nautical miles. During their ten revolutions of the moon, the crew conducted live television transmissions of the lunar surface and performed such tasks as landmark and Apollo landing site tracking, vertical stereo photography and stereo navigation photography, and sextant navigation using lunar landmarks and stars. At the end of the tenth lunar orbit, they executed a transearth injection burn which placed Apollo 8 on a proper trajectory for the return to earth.

The final leg of the trip required only 58 hours, as compared to the 69 hours used to travel to the moon, and Apollo 8 came to a successful conclusion on December 27, 1968. Splashdown occurred at an estimated 5,000 yards from the USS *Yorktown,* following the successful negotiation of a critical 28-mile high reentry corridor at speeds close to 25,000 miles per hour.

Captain Lovell has since served as the backup spacecraft commander for the Apollo 11 lunar landing mission. He has completed three space flights and holds the U.S. Astronaut record for time in space with a total of 572 hours and 10 minutes.

Captain Lovell is currently assigned as spacecraft commander for the Apollo 13 mission.

Special assignment.—In addition to his regular duties as an astronaut, Captain Lovell continues to serve as Special Consultant to the President's Council on Physical Fitness and Sports—an assignment he has held since June 1967.

JOHN LEONARD SWIGERT, JR. (MR.). NASA ASTRONAUT

Birthplace and date.—Born in Denver, Colorado, on August 30, 1931; he is the son of Dr. and Mrs. J. Leonard Swigert who reside in Denver.

Physical description.—Blond hair; blue eyes; height: 5 feet 11½ inches; weight: 180 pounds.

Education.—Attended Blessed Sacrament School, Regis High School, and East High School in Denver, Colorado; received a Bachelor of Science degree in Mechanical Engineering from the University of Colorado in 1953, a Master of Science degree in Aerospace Science from the Rensselaer Polytechnic Institute in 1965, and Master of Business Administration degree from the University of Hartford in 1967.

Marital status.—Single.

Recreational interests.—An avid sports enthusiast, he enjoys handball, bowling, water skiing, swimming, basketball, and golf. His hobbies include photography.

Organizations.—Associate Fellow of the Society of Experimental Test Pilots; member of the American Institute of Aeronautics and Astronautics, the Quiet Birdmen, Phi Gamma Delta, Pi Tau Sigma, and Sigma Tau.

Special honors.—Co-recipient of the AIAA Octave Chanute Award for 1966 for his participation in demonstrating the Rogallo Wing as a feasible land landing system for returning space vehicles and astronauts.

Experience.—Swigert held a position as engineering test pilot for North American Aviation, Inc., before joining NASA. He was also an engineering test pilot for Pratt and Whitney from 1957 to 1964.

He served with the Air Force from 1953 to 1956 and, upon graduation from the Pilot Training Program and Gunnery School at Nellis Air Force Base, Nevada, was assigned as a fighter pilot in Japan and Korea. After completing his tour of active duty in the military service, he served as a jet fighter pilot with the Massachusetts Air National Guard from September 1957 to March 1960 and was a member of the Connecticut Air National Guard from April 1960 to October 1965.

He has logged 5,870 hours flight time—4,555 hours in jet aircraft.

Current assignment.—Mr. Swigert is one of the 19 astronauts selected by NASA in April 1966.

Swigert was assigned as backup Command Module pilot on Apollo 13 but was named to the prime crew April 10, the day before the mission as a substitute for Astronaut Thomas K. Mattingly II. Mattingly had been exposed to measles and was disqualified from the prime crew.

FRED WALLACE HAISE, JR. (MR.), NASA ASTRONAUT

Birthplace and date.—Born in Biloxi, Miss., on Nov. 14, 1933; his mother, Mrs. Fred W. Haise, Sr., resides in Biloxi.

Physical description.—Brown hair; brown eyes; height: 5 feet 9½ inches; weight: 150 pounds.

Education.—Graduated from Biloxi High School, Biloxi, Miss.; attended Perkinston Junior College (Association of Arts); received a Bachelor of Science degree with honors in Aeronautical Engineering from the University of Oklahoma in 1959.

Marital status.—Married to the former Mary Griffin Grant of Biloxi, Miss. Her parents, Mr. and Mrs. William J. Grant, Jr., reside in Biloxi.

Children.—Mary M., January 25, 1956; Frederick T., May 13, 1958; Stephen W., June 30, 1961.

Organizations.—Member of the Society of Experimental Test Pilots, Tau Beta Pi, Sigma Gamma Tau, and Phi Theta Kappa.

Special honors.—Recipient of the A. B. Boots Trophy as the outstanding graduate of class 64A from the Aerospace Research Pilot School in 1964; awarded the American Defense Ribbon and the Society of Experimental Test Pilots Ray E. Tenhoff Award for 1966.

Experience.—Haise was a research pilot at the NASA Flight Research Center at Edwards, Calif., before coming to Houston and the Manned Spacecraft Center; and from September 1959 to March 1963, he was a research pilot at the NASA Lewis Research Center in Cleveland, Ohio. During this time, he authored the following papers which have been published: a NASA TRD, entitled "An Evaluation of the Flying Qualities of Seven General-Aviation Aircraft;" NASA TRD 3380, "Use of Aircraft for Zero Gravity Environment, May 1966;" SAE Business Aircraft Conference Paper, entitled "An Evaluation of General-Aviation Aircraft Flying Qualities," March 30–April 1, 1966; and a paper delivered at the tenth symposium of the Society of Experimental Test Pilots, entitled "A Quantitative/Qualitative Handling Qualities Evaluation of Seven General-Aviation Aircraft," 1966.

He was the Aerospace Research Pilots School's outstanding graduate of Class 64A and served with the U.S. Air Force from October 1961 to August 1962 as a tactical fighter pilot and as Chief of the 164th Standardization-Evaluation Flight of the 164th Tactical Fighter Squadron at Mansfield, Ohio. From March 1957 to September 1959, he was a fighter-interceptor pilot with the 185th Fighter Interceptor Squadron in the Oklahoma Air National Guard.

He also served as a tactics and all weather flight instructor in the U.S. Navy Advanced Training Command at NAAS Kingsville, Texas, and was assigned as a U.S. Marine Corps fighter pilot to VMF–533 and 114 at MCAS Cherry Point, N.C., from March 1954 to September 1956.

His military career began in October 1952 as a Naval Aviation Cadet at the Naval Air Station in Pensacola, Fla.

He has accumulated 5,800 hours flying time, including 3,000 hours in jets.

Current assignment.—Mr. Haise is one of the 19 Astronauts selected by NASA in April 1966. He served as backup lunar module pilot for the Apollo 8 and 11 missions.

He is currently assigned as lunar module pilot for the Apollo 13 flight.

APOLLO 13 REVIEW BOARD

Senator HOLLAND. I have several questions.

First, Dr. Paine, when do you anticipate that the work of the Apollo 13 Review Board will be finished?

Dr. PAINE. The first output which we expect to get from the Review Board is a statement on their part as to when they will have the review completed. We have given them open-ended charter so that they can take all the time required for a thorough review. They have not yet told us the date that they will be prepared to give us a final report. I would guess it would be in the order of a month, Senator Holland.

Senator HOLLAND. Do I understand correctly that that report will be made immediately available to this committee and the similar committee at the other end of the Capitol?

Dr. PAINE. That is correct. And we will be happy to provide you with interim reports as the work progresses.

STATUS OF APOLLO 14 MISSION

Senator HOLLAND. In the meantime, what is the status, Dr. Paine, or Dr. Petrone, of the Apollo 14 mission? Is the preparation for that mission continuing?

Dr. PETRONE. Yes, we are continuing the preparation of flight hardware. The one thing we want to evaluate is the site we go to. Apollo 14 was planned to land at a site on the moon known as Littrow. What we are discussing now with the scientific community is what of the sites, that for 13 or that for 14, we should go to. We are doing that and will be doing it in the coming week. But the basic hardware, the preparation, the basic planning is going forward.

Senator HOLLAND. Are you hoping to maintain your schedule for the launch of the Apollo 14, still?

Dr. PETRONE. Sir, I would say to that, we are going to have to look at the corrections we have to make. So in terms of maintaining a schedule, it will be based around the fixes we determine necessary. We want to keep moving forward so we can take advantage of the time, but we are not adhering to a fixed schedule. It will be determined by the fixes, the corrections, the modifications we deem necessary before we will have the exact schedule.

I do anticipate that we will move forward very quickly in this area.

EARLY CUTOFF OF ENGINE

Senator HOLLAND. One more question. Is there any possible connection between the shutoff of one of the engines, at the time of the launch and the additional burn that had to be completed before the spacecraft, was properly launched and the subsequent difficulty in the service module?

Dr. PETRONE. Senator Holland, we feel that the early cutoff of that one engine in the second stage had no effect on the incident we are studying here of the O_2 tank. We have very good telemetry information on the force that was transmitted into the spacecraft, and also the observations of the crew on board. Essentially, there were no great vibrations or forces transmitted upward into the spacecraft. But we feel fairly certain that there was no connection between the early cut off of the engine and this incident we are seeing here.

Senator HOLLAND. Thank you.

The CHAIRMAN. Senator Goldwater?

Senator GOLDWATER. I might say to the astronauts that they understand now what I mean when I say I feel like tailend Charley. But it is nice sitting at this end of the table.

To you astronauts, all of you and your wives, my congratulations on a job very well done. I agree with what the others of this committee have said. You have been a great inspiration to all of us and to all Americans.

NASA CONTROL CENTER

I do not want to belittle what you did in getting back, but I think sometimes we pay too little attention to the other end of the team. It has been my experience to have been at the control center during the launching of 12, and later, during the trouble that you had last week on 13. The thing that I was impressed with most, and I wish there were some way to show this visually to the American people, is the complete calmness and know-how that these backup people have.

I watched the communications trouble develop on 12, and I think within three and a half minutes the solution had been reached.

When I was down there last week, they had already started work, study, to determine just what happened to your oxygen tank. In fact, I am so impressed with this that I think the techniques that are used in the NASA Control Center can well be applied to all of the problems besetting us in America. I think it is time that we begin thinking about collecting the good brains and the good ability on all problems so that we can apply what you have learned down there, the know-how, to the problems that we have in this country.

I would like to agree also with you, Captain Lovell, on the subject of education. I guess I have spoken to over 10,000 teenagers. These are not the high school or college ones, but my grandchildren's age. I cannot wait to see these grow up, because they are real gung-ho on space and all the knowledge that is coming from it.

VALUE OF SPACE INVESTMENT

I might add that the question has come up many times about the $28 billion that we have spent in space, and some one of our colleagues has said all we have for it is several vials of moon dust. I just want to repeat one or two things that I know of that have come out of this that I think are worth the whole $28 billion, as I will say in a speech on Monday on the floor.

While I do not think I can prove it now, give me 5 years, and I think I can show you $28 billion-plus having come back from it.

But the fact that we can now prevent an airplane from catching fire as a result of space exploration, I think is worth every cent of the $28 billion. The fact that we have, through spinoff from space, the approaching ability to build an aircraft proximity warning device which will tell a pilot that there is another airplane approaching him, to me is worth all of the $28 billion-plus, because they are going to save lives.

And, too, in the demonstration we saw here last week—Dr. Paine, I think I have talked to you about it—should be made available to every women's club, every Service club and every school in America. We were shown what has been accomplished in the whole field of fireproofing. As soon as this material comes on the market, I am going to buy a lot of it and call up my fire insurance agent and tell him I do not need him any more.

POSSIBLE CAUSE OF BLAZE

I have just one short question to ask of Dr. Petrone.

If you feel that it should not be answered here, please say so. When I was there last week, I was shown the fullscale drawings of the tanks and the section and the two small, electric pumps that I think rotate around 2,000 revolutions per minute, and the gage with the heater. As I remember it, I was told that even if these motors jammed or froze, they would pull no more current in that condition than when they were running; therefore, there could not be a fire from insulation burning or anything like that. And I was told that the same would apply to the measuring device and the heater.

It was suggested during that discussion that some small piece of aluminum or even hard rubber might have been in that I forget what you call it; it is not liquid oxygen, it is semigaseous——

Dr. PETRONE. The supercritical oxygen.

Senator GOLDWATER. That the contact of that outside object with the heat might have caused the blaze. Can you rule that out?

Dr. PETRONE. To answer the first part of your question, what you were told is essentially correct. We made tests in the earlier part of the mission. Just stalling that fan would not give you sufficient energy to start a fire. The propellant gage system, as you have mentioned, would not have sufficient energy. These are all fused against certain demands, either fuse or circuit breakers.

However, the question of whether or not a spark could have been caused by a piece of the material, either hard rubber or a rivet, or whether one of the leads necessary to give energy for the fan could have done it, these are things that we do not know yet. We are simulating those items. We are attempting different failure modes to understand the failure mechanism. These are the things we are searching for now.

But the elements themselves, the testing of them and the way they function, would not give us sufficient energy. But, however, some other material interacting into the supercritical conditions might. We did have a rise in there, that we know. That is the thing that we have to search for.

COMPLETE QUALIFICATION TEST

Senator GOLDWATER. One other thing. I think the public would be interested in this. Am I right in assuming that when you think you have solved the problem, you will build a full-scale mockup and see if you can make it repeat?

Dr. PETRONE. Sir, that is normally our plan, to run a complete qualification test. Now, you build this up in small instruments, and you are going to have to, in order to get something to ignite or burn, you are going to have to apply abnormal energies. However, once we have the new hardware, we will subject it to all extremes. That is how we have qualified all hardware.

What we will do with the new modification, we will put it in the system.

Senator GOLDWATER. Thank you.

Thank you very much, Mr. Chairman.

Senator SMITH of Maine. Mr. Chairman, may I make a brief comment?

The CHAIRMAN. Surely.

Senator SMITH of Maine. Mr. Chairman, earlier I mentioned that I gained a great deal of assurance and confidence from listening to and watching the wives and the families of the astronauts of the Apollo 13 and other Apollo team members for that matter. I am told Mrs. Lovell is in the audience, and I think we would all like to have her stand so we can see the other half of the Lovell family.

[Applause.]

The CHAIRMAN. A great many of these people here have come in late, Captain Lovell and Mr. Swigert, and they would like to see you stand again. Would you please stand and face back there to the audience?

[Applause.]

INTERNATIONAL SPACE COOPERATION

The CHAIRMAN. Thank you very much.

Speaking of the benefits from the space program, what is the effect of the space flights on cooperation among other nations?

Dr. PAINE. Mr. Chairman, one of the very fine developments of the Apollo 13 mission was the tremendous number of messages which poured into us from all over the world—large nations like the Soviet Union, small nations like Uruguay—offering us complete access to their ships, aircraft, any help they could give to us on this mission. As we have reported before this committee, we are working very hard to increase the degree of international cooperation in space.

We feel that the Apollo 13 mission and the response all around the world, the offers to help, are certainly going to facilitate and speed up this increased degree of international cooperation in space which we would like to see come about in the 1970's.

The CHAIRMAN. Mr. Gehrig.

DIFFICULTY WITH OXYGEN TANK

Mr. GEHRIG. Mr. Chairman, there are a few additional questions, but they can be answered for the record.

On April 19, a story in the New York Times said of the oxygen tank that ruptured:

> The only time in the tank's history even the slightest doubt was raised about its preflight condition was during precountdown preparations at Cape Kennedy, Florida.
>
> Technicians reported having trouble draining the liquid oxygen from the tank after a test. The tank seemed to empty slower than usual. But the next time it was checked out, the drainage problem did not occur.

Would you please comment on this?

Dr. PETRONE. NASA announced in a press release on April 17 that difficulty was encountered in detanking oxygen tank No 2 after the countdown demonstration test at Kennedy Space Center. An analysis indicated that the design of the fill and vent line could permit this condition to occur. A modified procedure was then used to detank the oxygen. A second tanking was performed which confirmed the above analysis. Detanking was accomplished using the same modified procedure as before. Further evaluation prior to launch indicated that the fill and vent line could only affect the detanking operation and would have no effect on fill and performance of this tank.

This and any other relationships between launch preparations and the incident are being reviewed by the Apollo 13 Review Board appointed by the Administrator and Deputy Administrator on 17 April 1970.

Mr. GEHRIG. Mr. Chairman, rather than take the time of the committee, Senator Young asks that the following questions be answered for the record:

(The questions submitted by Senator Young and the answers supplied for the record are as follows:)

SIGNIFICANCE OF LUNAR EXPERIMENT

Question 1. Dr. Paine, at least one of the lunar experiments worked, the crash of the Saturn S–IVB stage into the lunar surface about 80 miles from the seisometer left behind by the April 12 astronauts. This produced a much larger than expected return. Can you tell the Committee anything about the significance of that experiment?

Answer. During the Apollo 12 mission we deliberately impacted the Lunar Module (LM) ascent stage on the surface of the moon after the astronauts had transferred back to the command module. The resulting vibration signal at the seismometer, which had been placed on the lunar surface, continued for almost an hour. Seismologists have not seen anything comparable on earth and believe this phenomenon, when better understood, could provide a basis for defining a model of the interior of the moon. This in turn could provide clues to the origin of the moon and its relation to the earth.

To gain more information about this unusual seismic response of the moon, the Apollo 13 third stage (S–IVB), weighing about 30,700 pounds, was impacted on the moon on April 14. The point of impact was about 87 miles from the seismometer; the S–IVB velocity was 8465 feet per second; its energy equivalent was 11.5 tons of TNT. These data compare with the Apollo 12 LM which impacted 42 miles from the seismometer with an equivalent energy of approximately 1 ton of TNT. The depth of penetration of the S–IVB impact signal is approximately 12–25 miles (vs approximately 10 miles for the LM impact). This result implies that the outer shell of the moon to depths of at least 12 to 25 miles may be formed from the same crystalline rock material as found at the surface. The overall character of the seismic signal is similar to that of the LM impact signal, but the combination of higher energy and greater distance between point of impact and seismometer gave a seismic signal 20–30 times larger than the LM impact andf our times longer in duration (approximately 4 hours vs 1 hour).

Analyses of these scientifically significant and highly unique signals should lead us closer to unlocking the mysteries concerning the origin of the moon and the earth-moon system.

SPACE PROGRAM APPLICATIONS TO POLLUTION

Question 2. Captain Lovell and Mr. Swigert, many of us are quite concerned with the problems of pollution and environmental control right here on this planet. On Wednesday of this week, we saw a massive outpouring and concern during "Earth Day."

Can you give us your views on the space program as it relates to these problems?

Answer. The space program is making direct contributions to environmental control and the reduction of pollution, and I believe its efforts will be even more productive in the future. There are several kinds of environmental pollution with which we are all concerned—air, water, and noise pollution, principally. NASA is carrying on a dozen or so activities aimed at reducing air pollution. I am submitting a list of them, attached to this response. They are carried out under direction of NASA's Office of Advanced Research and Technology.

The future will witness another form of attack on the pollution problem. This is NASA's Earth Resources Survey program, which has the potential of identifying and monitoring surface and atmospheric pollutants in water and air from aircraft and spacecraft systems. We will be able to measure these pollutants and determine their evolution and movement.

The Earth Resources Technology Satellite program will permit us to better understand the intricate processes of the oceans, and their ability to produce food and to absorb pollutants. North American fresh water systems will be understood well enough for us to manage them on a continental scale, neither wasting nor hoarding this vital resource. Agricultural management will very likely be improved.

Noise is a particularly irritating pollutant. NASA has instituted research programs to try to determine the mechanisms of noise generation from turbofan systems and supersonic engine exhaust jets, and how to reduce this noise. NASA is also developing a "quiet engine" for aircraft.

To sum up, Jack Swigert, Fred Haise, and I are firmly convinced that a strong and viable space program will definitely increase our ability and our resolve to to overcome earthly problems, both old and new.

The list referred to above follows:

Investigation of the kinetics of smoke and nitric oxide formation under conditions typically found in aircraft gas turbine combustion systems. Investigation of the dispersion of the exhaust plume in the atmosphere (Massachusetts Institute of Technology—FY 1971—$50,000).

Investigation of the chemical kinetics of the dispersion process of pollutants with the primary emphasis on the oxidation of hydrocarbons because this process plays a dominant role in photochemical air pollution (Jet Propulsion Laboratory—FY 1971—$50,000).

Investigation of the fluid dynamic mechanism of the dispersion and interaction of pollutants from airborne and ground sources in urban areas (New York University—FY 1971—$30,000).

Development of a material for a thermal reactor to be attached to an automobile in place of the exhaust manifold. This is being supported by the Department of Health, Education and Welfare, and is utilizing NASA expertise in high temperature materials. FY 1970 funds ($300,000) have been requested to continue this work (Teledyne, Continental Motors—FY 1969—$300,000).

In support of the above thermal reactor work, NASA is performing limited inhouse studies. The research includes a computer study of the kinetics of combustion of carbon monoxide and hydrocarbon in the thermal reactor and pulsed air injection into the exhaust ports which expedites the combustion process (Lewis Research Center—FY 1971—$25,000).

Investigation of the mechanism by which ultraviolet radiation from the sun transforms nitrogen oxides into smog in the presence of hydrocarbons in urban atmospheres (Ames Research Center—FY 1971—$65,000).

A study to examine microwave spectrometer signals in parts per billion of a host of contaminants which include automotive colorless gases of interest to National Air Control Pollution Administration (NACPA) such as oxides of sulfur (SO_2), of nitrogen (NO_2), and formaldehyde ($HCHO^2$). The NACPA laboratory personnel from Raleigh, N.C., and NASA have been meeting and exchanging technical information. NASA and NACPA are planning to support work toward the miniaturization of a microwave spectrometer which will have application to public air control groups, industry, and NASA (University of Wyoming—FY 1971—$40,000).

A study has been underway for the last two years to develop a hybrid sensor which consists of a mass spectrometer and selective columns from a gas chromatagraph apparatus. This will sense and monitor various contaminants including those of interest to NACPA. During a recent review of this program, representatives from NACPA expressed interest in supporting this work when the fabrication phase is initiated (Perkin-Elmer Corporation, Pomona, California—FY 1791—$150,000).

An investigation of methods of the removal of oxides of nitrogen and of sulfur dioxide, hydrogen chloride, hydrogen fluoride, and chlorine in low concentrations from air as part of an effort to develop an effective atmospheric purification subsystem. The results of this laboratory work have demonstrated that solid-gas reaction was found to be the most generally effective method of contaminant removal and specifically a reaction bed containing both manganese dioxide and lithium carbonate will remove most of the sulfur oxides and over 99% of the chlorine and hydrogen halides. This coming year an operational subsystem will be fabricated. The NACPA personnel are on our mailing list for these reports and they have been in contact with both Langley Research Center and the Texas Technological College on the progress of this work (Texas Technological College, Lubbock, Texas—FY 1971—$50,000).

In the Aeronautical Vehicle program, the efforts related to the alleviation of pollution and smoke are a part of a continuing program to improve the performance of aircraft engines. (For example, one of the continuing objectives of the Lewis research program on aircraft gas turbine combustors.) This work is important because of several reasons including: the reduction in air pollution, the reduction of visual detection of military aircraft, and the increased operating life of combustors due to the reduction in heat radiation to metal surfaces due to a reduction in smoke.

The present trends in advanced engines are toward higher flight speeds and toward high temperature and pressure ratios inside the combustor. Smoking tendency is made worse by an increase in pressure. A major part of the experimental work is conducted at pressures (up to 450 psia) which are typical of the values expected in future engines. However, the results should be applicable to current engines which operate at pressures up to about 350 psia.

A number of experimental gas turbine combustors are being tested to evaluate their overall performance and their smoking tendency. In an effort to reduce smoke output and heat radiation to the combustor surfaces, various design features are being studied which include variations in air entry ports and variations in the fuel injection system. Carbon content in the flame zone is indicated by measurements of spectral and total emittance. Thirty professionals are associated with the advanced combustor program at Lewis.

The general technique being used by the engine manufacturers to reduce smoke is to introduce more air into the primary zone of the combustor. Some reduction in the altitude blowout limits of the combustor is associated with the added air in the primary zone. However, this penalty is not expected to be a problem with commercial aircraft although it may be a problem with military aircraft. Adding air into the primary zone of current aircraft combustors results in higher temperatures and causes a reduction in the emission rates of carbon monoxide and unburned hydrocarbons and apparently causes an increase in the emission rates of oxides of nitrogen.

NASA plans to continue the advanced combustor research work and to keep abreast of combustor work conducted by the engine manufacturers and the related work supported by the FAA and the Department of Defense. The Lewis effort on low-cost small gas turbine engine technology is an area for increased attention and support by NASA since replacing small aircraft reciprocating engine with a gas turbine engine will alleviate the aircraft pollution problem.

The CHAIRMAN. Thank you very much, all of you here today. It has been a fine and inspiring meeting. You have helped us very much.

The meeting is adjourned.

(Whereupon, at 11:50 a.m., the committee adjourned, to reconvene subject to the call of the Chair.)

APPENDIX

TO STATEMENT OF

Dr. Thomas O. Paine
Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Committee on Aeronautical and Space Sciences

United States Senate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

April 17, 1970

TO : Mr. Edgar M. Cortright

SUBJECT : Establishment of Apollo 13 Review Board

REFERENCES: (a) NMI 8621.1 - Mission Failure Investigation Policy and Procedures

(b) NMI 1156.14 - Aerospace Safety Advisory Panel

1. It is NASA policy as stated in Reference (a) "to investigate and document the causes of all major mission failures which occur in the conduct of its space and aeronautical activities and to take appropriate corrective actions as a result of the findings and recommendations."

2. Because of the serious nature of the accident to the Apollo 13 spacecraft which jeopardized human life and caused failure of the Apollo 13 lunar mission, we hereby establish the Apollo 13 Review Board (hereinafter referred to as the Board) and appoint you Chairman. The members of the Board will be qualified senior individuals from NASA and other Government agencies. After consultation with you, we will:

(a) Appoint the members of the Board and make any subsequent changes necessary for the effective operation of the Board; and

(b) Arrange for timely release of information on the operations, findings, and recommendations of the Board to the Congress, and, through the NASA Office of Public Affairs, to the public. The Board will report its findings and recommendations directly to us.

3. The Board will:

(a) Review the circumstances surrounding the accident to the spacecraft which occurred during the flight of Apollo 13 and the subsequent flight and ground actions taken to recover, in order to establish the probable cause or causes of the accident and assess the effectiveness of the recovery actions.

(b) Review all factors relating to the accident and recovery actions the Board determines to be significant and relevant, including studies, findings, recommendations, and other actions that have been or may be undertaken by the program offices, field centers, and contractors involved.

(c) Direct such further specific investigations as may be necessary.

(d) Report as soon as possible its findings relating to the cause or causes of the accident and the effectiveness of the flight and ground recovery actions.

(e) Develop recommendations for corrective or other actions, based upon its findings and determinations or conclusions derived therefrom.

(f) Document its findings, determinations, and recommendations and submit a final report.

4. As Chairman of the Board you are delegated the following powers:

(a) To establish such procedures for the organization and operation of the Board as you find most effective; such procedures shall be part of the Board's records. The procedures shall be furnished the Aerospace Safety Advisory Panel for its review and comment.

(b) To establish procedures to assure the execution of your responsibilities in your absence.

(c) To designate such representatives, consultants, experts, liaison officers, observers, or other individuals as required to support the activities of the Board. You shall define their duties and responsibilities as part of the Board's records.

(d) To keep us advised periodically concerning the organization, procedures, operations of the Board and its associated activities.

5. By separate action we are requesting the Aerospace Safety Advisory Panel established by Reference (b) to review both the procedures and findings of the Board and submit its independent report to us.

6. By separate action we are directing the Associate Administrator for Manned Space Flight to:

(a) Assure that all elements of the Office of Manned Space Flight cooperate fully with the Board and provide records, data, and technical support as requested.

(b) Undertake through the regular OMSF organization such reviews, studies, and supporting actions as are required to develop recommendations to us on corrective measures to be taken prior to the Apollo 14 mission with respect to hardware, operational procedures, and other aspects of the Apollo program.

7. All elements of NASA will cooperate with the Board and provide full support within their areas of responsibility.

Original signed by
George M. Low

Original signed
T.O. Paine

George M. Low
Deputy Administrator

T. O. Paine
Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

April 20, 1970

OFFICE OF THE ADMINISTRATOR

T : Dr. Charles D. Harrington
Chairman, Aerospace Safety Advisory Panel

SUBJECT : Review of Procedures and Findings of Apollo 13 Review Board

Attachment: (a) Memorandum dated April 17, 1970, to Mr. Edgar M. Cortright, subject: Establishment of Apollo 13 Review Board

References: (a) Section 6, National Aeronautics and Space Administration Authorization Act, 1968

(b) NMI 1156.14 - Aerospace Safety Advisory Panel

1. In accordance with References (a) and (b), the Aerospace Safety Advisory Panel (hereafter referred to as the Panel) is requested to review the procedures and findings of the Apollo 13 Review Board (hereafter referred to as the Board) established by Attachment (a).

2. The procedures established by the Board will be made available to the Panel for review and comment as provided in paragraph 4(a) of Attachment (a).

3. As Chairman of the Panel, you are designated an Observer on the Board. In this capacity, you, or another member of the Panel designated by you, are authorized to be present at those regular meetings of the Board you desire to attend. You are also authorized to receive oral progress reports from the Chairman of the Board or his designee from time to time to enable you to keep the Panel fully informed on the work of the Board.

4. The final report and any interim reports of the Board will be made available promptly to the Panel for its review.

5. The Panel is requested to report to us on the procedures and findings of the Board at such times and in such form as you consider appropriate, but no later than 10 days after the submission to us of the final report of the Board.

George M. Low

George M. Low
Deputy Administrator

T. O. Paine
Administrator

Enclosure

cc: Mr. Edgar M. Cortright, Chairman, Apollo 13 Review Board
M/Mr. Dale Myers

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

APR 20 1970

OFFICE OF THE ADMINISTRATOR

TO : Mr. Dale D. Myers
Associate Administrator for Manned Space Flight

SUBJECT : Apollo 13 Review

Reference: (a) Memorandum dated April 17, 1970, to Mr. Edgar M. Cortright, subject: Establishment of Apollo 13 Review Board

(b) Memorandum dated April 20, 1970, to Dr. Charles D. Harrington, subject: Review of Procedures and Findings of Apollo 13 Review Board

1. As indicated in paragraph 6 of Reference (a), you are directed to:

(a) Assure that all elements of the Office of Manned Space Flight cooperate fully with the Board in providing records, data, and technical support as requested.

(b) Undertake through the regular OMSF organization such reviews, studies, and supporting actions as are required to develop timely recommendations to us on corrective measures to be taken prior to the Apollo 14 mission with respect to hardware, operational procedures, flight crews, and other aspects of the Apollo program.

2. The recommendations referred to in paragraph 1(b) above should be submitted to us in such form and at such time as you deem appropriate, but a report should be submitted no later than ten days after the Apollo 13 Review Board submits its final report.

3. The assignments to the Apollo 13 Review Board and to the Aerospace Safety Advisory Panel by References (a) and (b), respectively, in no way relieve you of your continuing full responsibility for the conduct of the Apollo and other OMSF programs.

George M. Low
Deputy Administrator

T. Paine
Administrator

cc: Mr. Edgar M. Cortright, Chairman, Apollo 13 Review Board
Mr. Charles D. Harrington, Chairman, Aerospace Safety Advisory Panel

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

April ?1, 1970

TO : Mr. Edgar M. Cortright

SUBJECT : Membership of Apollo 13 Review Board

Reference: Memorandum to you of April 17, subject: Establishment of Apollo 13 Review Board

In accordance with paragraph 2(a) of Reference (a), the membership of the Apollo 13 Review Board is established as follows:

Members:

Mr. Edgar M. Cortright, Chairman (Director, Langley Research Center)
Mr. Robert F. Allnutt (Assistant to the Administrator, NASA Hqs.)
Mr. Neil Armstrong (Astronaut, Manned Spacecraft Center)
Dr. John F. Clark (Director, Goddard Space Flight Center)
Brig. General Walter R. Hedrick, Jr. (Director of Space, DCS/R&D, Hqs., USAF)
Mr. Vincent L. Johnson (Deputy Associate Administrator-Engineering, Office of Space Science and Applications)
Mr. Milton Klein (Manager, AEC-NASA Space Nuclear Propulsion Office)
Dr. Hans M. Mark (Director, Ames Research Center)

Counsel:

Mr. George Malley (Chief Counsel, Langley Research Center)

OMSF Technical Support:

Mr. Charles W. Mathews (Deputy Associate Administrator, Office of Manned Space Flight)

Observers:

Mr. William A. Anders (Executive Secretary, National Aeronautics and Space Council)

Dr. Charles D. Harrington (Chairman, NASA Aerospace Safety Advisory Panel)
Mr. I. I. Pinkel (Director, Aerospace Safety Research and Data Institute, Lewis Research Center)

Congressional Liaison:

Mr. Gerald J. Mossinghoff (Office of Legislative Affairs, NASA Hqs.)

Public Affairs Liaison:

Mr. Brian Duff (Public Affairs Officer, Manned Spacecraft Center)

In accordance with applicable NASA instruction, you are authorized to appoint such experts and additional consultants as are required for the effective operations of the Board.

George M. Low
George M. Low
Deputy Administrator

T. O. Paine
T. O. Paine
Administrator