

REPORT OF APOLLO 13 REVIEW BOARD

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
APOLLO 13 REVIEW BOARD

June 15, 1970

The Honorable Thomas O. Paine
Administrator
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Dr. Paine:

Pursuant to your directives of April 17 and April 21, 1970, I am transmitting the final Report of the Apollo 13 Review Board.

Concurrent with this transmittal, I have recessed the Board, subject to call.

We plan to reconvene later this year when most of the remaining special tests have been completed, in order to review the results of these tests to determine whether any modifications to our findings, determinations, or recommendations are necessary. In addition, we will stand ready to reconvene at your request.

Sincerely yours,

A handwritten signature in black ink, reading "Edgar M. Cortright", is positioned above the typed name and title.

Edgar M. Cortright
Chairman

PREFACE

The Apollo 13 accident, which aborted man's third mission to explore the surface of the Moon, is a harsh reminder of the immense difficulty of this undertaking.

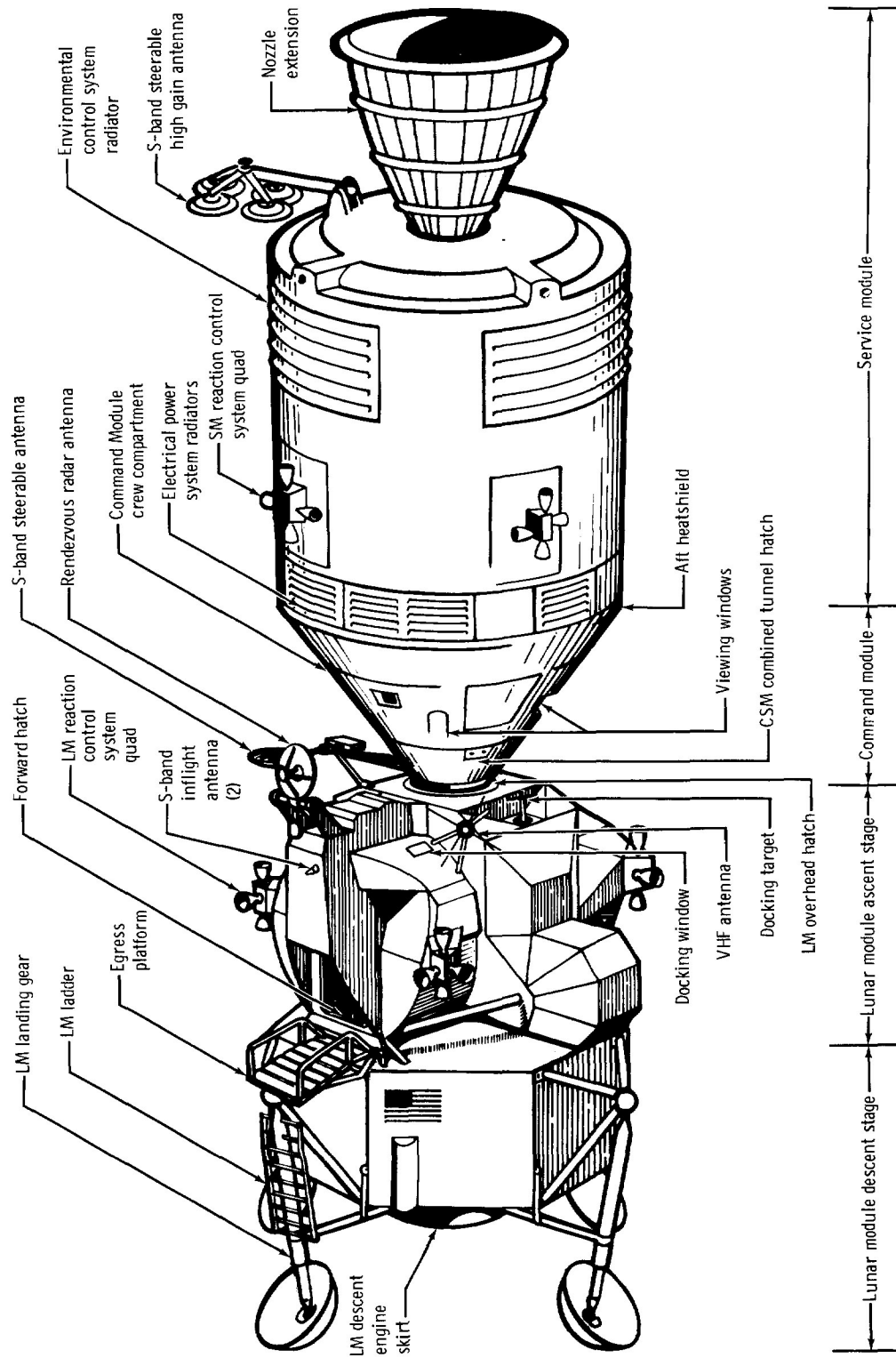
The total Apollo system of ground complexes, launch vehicle, and spacecraft constitutes the most ambitious and demanding engineering development ever undertaken by man. For these missions to succeed, both men and equipment must perform to near perfection. That this system has already resulted in two successful lunar surface explorations is a tribute to those men and women who conceived, designed, built, and flew it.

Perfection is not only difficult to achieve, but difficult to maintain. The imperfection in Apollo 13 constituted a near disaster, averted only by outstanding performance on the part of the crew and the ground control team which supported them.

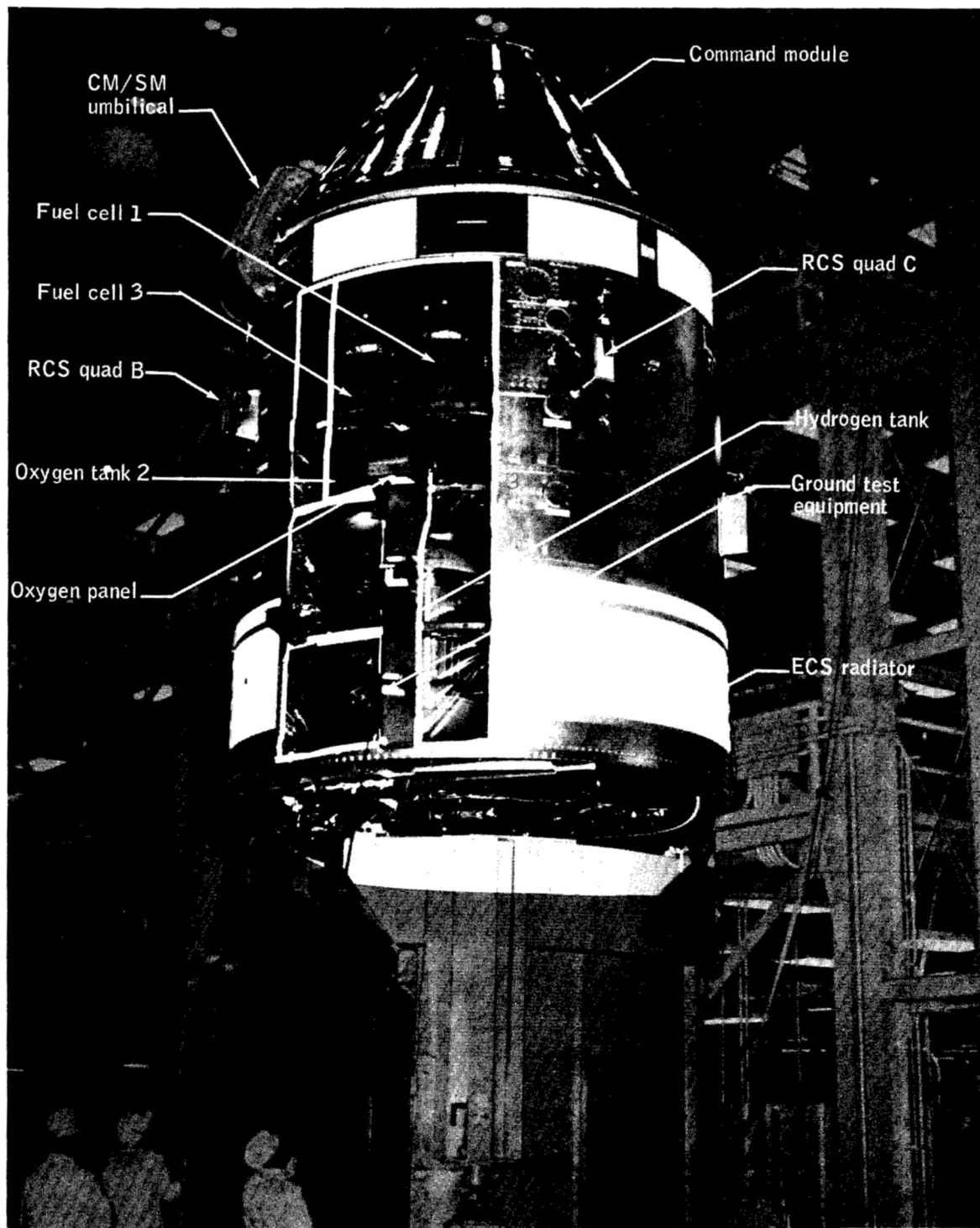
The Apollo 13 Review Board was charged with the responsibilities of reviewing the circumstances surrounding the accident, of establishing the probable causes of the accident, of assessing the effectiveness of flight recovery actions, of reporting these findings, and of developing recommendations for corrective or other actions. The Board has made every effort to carry out its assignment in a thorough, objective, and impartial manner. In doing so, the Board made effective use of the failure analyses and corrective action studies carried out by the Manned Spacecraft Center and was very impressed with the dedication and objectivity of this effort.

The Board feels that the nature of the Apollo 13 equipment failure holds important lessons which, when applied to future missions, will contribute to the safety and effectiveness of manned space flight.

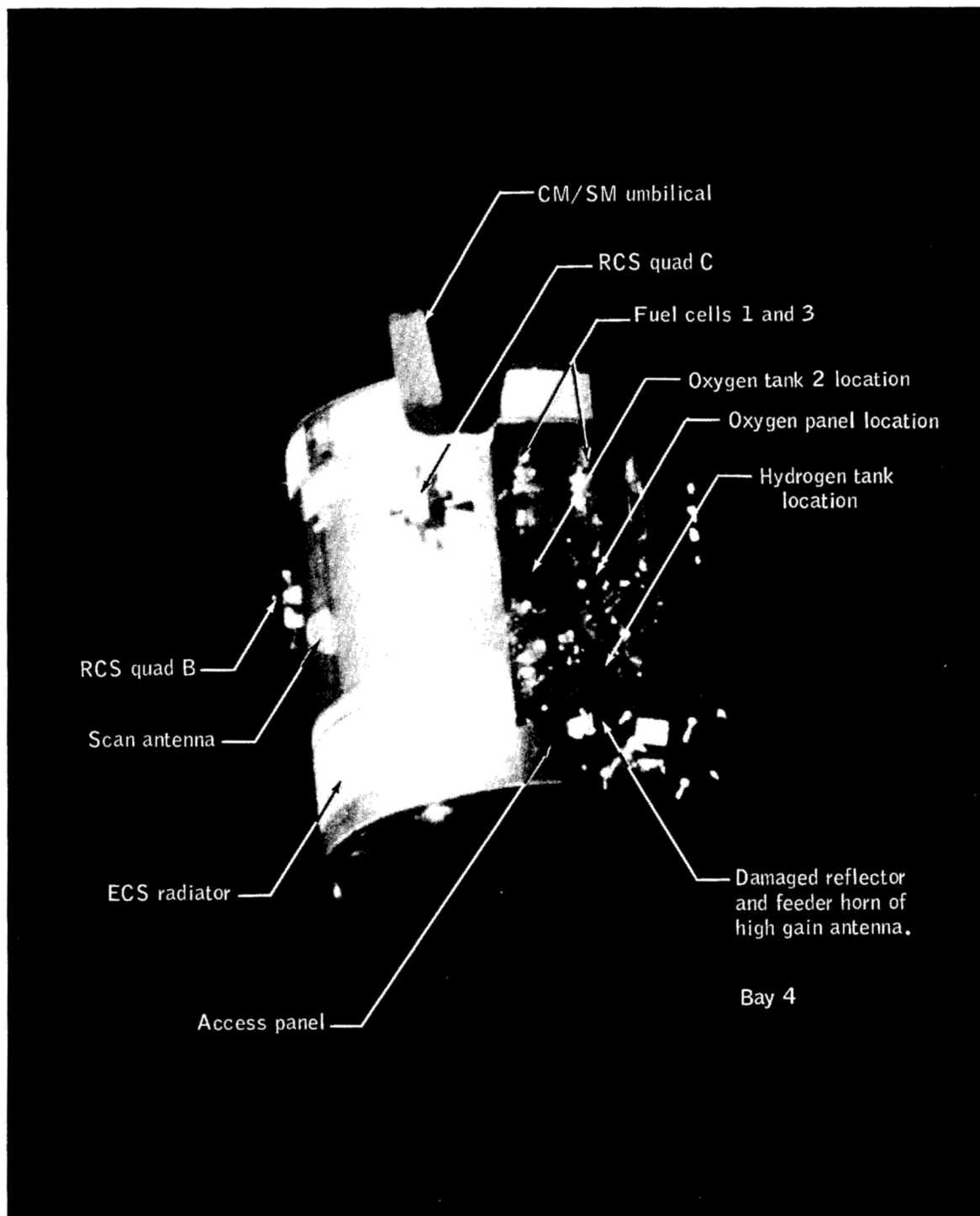
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Apollo 13 space vehicle configuration.



CSM in ground test with bay 4 panel removed.



Inflight photograph of service module showing damage to bay 4.

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CHAPTER 1

AUTHORITIES



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 of 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.

A handwritten signature in cursive script, reading "George M. Low". The signature is written in black ink and has a fluid, connected style.

George M. Low
Deputy Administrator

A handwritten signature in cursive script, reading "T. O. Paine". The signature is written in black ink and has a fluid, connected style.

T. O. Paine
Administrator



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

OFFICE OF THE ADMINISTRATOR

April 21, 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)

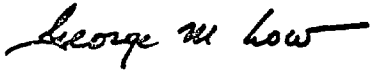
Congressional Liaison:

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
Deputy Administrator



T. O. Paine
Administrator



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

April 20, 1970

OFFICE OF THE ADMINISTRATOR

TO : 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
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

OFFICE OF THE ADMINISTRATOR

April 20, 1970

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

SUBJECT : Apollo 13 Review

References: (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.


Deputy Administrator


Administrator

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



NMI 8621.1 _____

April 14, 1966

Effective date

Management Instruction

SUBJECT: MISSION FAILURE INVESTIGATION POLICY AND PROCEDURES

1. PURPOSE

This Instruction establishes the policy and procedures for investigating and documenting the causes of all major mission failures which occur in the conduct of NASA space and aeronautical activities.

2. APPLICABILITY

This Instruction is applicable to NASA Headquarters and field installations.

3. DEFINITION

For the purpose of this Instruction, the following term shall apply:

In general, a failure is defined as not achieving a major mission objective.

4. POLICY

- a. It is NASA policy to investigate and document the causes of all major mission failures which occur in the conduct of its space and aeronautical activities and to take appropriate corrective actions as a result of the findings and recommendations.
- b. The Deputy Administrator may conduct independent investigations of major failures in addition to those investigations required of the Officials-in-Charge of Headquarters Program Offices as set forth in paragraph 5a.

5. PROCEDURES

- a. Officials-in-Charge of Headquarters Program Offices are responsible, within their assigned areas, for:
 - (1) Informing promptly the Deputy Administrator of each major failure and apprising him of the nature of the failure, status of investigations, and corrective or other actions which are or will be taken.

April 14, 1966

- (2) Determining the causes or probable causes of all failures, taking corrective or other actions, and submitting written reports of such determinations and actions to the Deputy Administrator.
- b. When the Deputy Administrator decides to conduct an independent investigation, he will:
- (1) Establish a (name of project) Review Board, comprised of appropriate NASA officials;
 - (2) Define the specific responsibilities of each Board, encompassing such tasks as:
 - (a) Reviewing the findings, determinations and corrective or other actions which have been developed by contractors, field installations and the Official-in-Charge of cognizant Headquarters Program Office and presenting the Board's conclusions as to their adequacy to the Deputy Administrator.
 - (b) Reviewing the findings during the course of investigations with cognizant field installation and Headquarters officials.
 - (c) Recommending such additional steps (for example additional tests) as are considered desirable, to determine the technical and operational causes or probable causes of failure, and to obtain evidence of nontechnical contributing factors.
 - (d) Developing recommendations for corrective and other actions, based on all information available to the Board.
 - (e) Documenting findings, determinations and recommendations for corrective or other actions and submitting such documentation to the Deputy Administrator.
- c. Procedures for implementing the Board's recommendations shall be determined by the Deputy Administrator.

6. CANCELLATION

NASA Management Manual Instruction 4-1-7 (T.S. 760), March 24, 1964.

Rh. C. Seaman

Deputy Administrator

DISTRIBUTION:
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NMI 1156.14

December 7, 1967

Effective date

Management Instruction

SUBJECT: AEROSPACE SAFETY ADVISORY PANEL

1. PURPOSE

This Instruction sets forth the authority for, and the duties, procedures, organization, and support of the Aerospace Safety Advisory Panel.

2. AUTHORITY

The Aerospace Safety Advisory Panel (hereafter called the "Panel") was established under Section 6 of the National Aeronautics and Space Administration Authorization Act, 1968 (PL 90-67, 90th Congress, 81 Stat. 168, 170). Since the Panel was established by statute, its formation and use are not subject to the provisions of Executive Order 11007 or of NMI 1150.2, except to the extent that such provisions are made applicable to the Panel under this Instruction.

3. DUTIES

- a. The duties of the Panel are set forth in Section 6 of the National Aeronautics and Space Administration Authorization Act, 1968, as follows:

"The Panel shall review safety studies and operations plans referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed or existing facilities and proposed operations and with respect to the adequacy of proposed or existing safety standards, and shall perform such other duties as the Administrator may request."

- b. Pursuant to carrying out its statutory duties, the Panel will review, evaluate, and advise on all elements of NASA's safety system, including especially the industrial safety, systems safety,

December 7, 1967

and public safety activities, and the management of these activities. These key elements of NASA's safety system are identified and delineated as follows:

- (1) Industrial Safety. This element includes those activities which, on a continuing basis, provide protection for the well being of personnel and prevention of damage to property involved in NASA's business and exposed to potential hazards associated with carrying out this business. Industrial safety relates especially to the operation of facilities in the many programs of research, development, manufacture, test, operation, and maintenance. Industrial safety activities include, but are not limited to, such functions as:
 - (a) Determination of industrial safety criteria.
 - (b) Establishment and implementation of safety standards and procedures for operation and maintenance of facilities, especially test and hazardous environment facilities.
 - (c) Development of safety requirements for the design of new facilities.
 - (d) Establishment and implementation of safety standards and procedures for operation of program support and administrative aircraft.
- (2) Systems Safety. This element includes those activities specifically organized to deal with the potential hazards of complex R&D systems that involve many highly specialized areas of technology. It places particular emphasis on achieving safe operation of these systems over their life cycles, and it covers major systems for aeronautical and space flight activities, manned or unmanned, including associated ground-based research, development, manufacturing, and test activities. Systems safety activities include, but are not limited to, such functions as:
 - (a) Determination of systems safety criteria, including criteria for crew safety.
 - (b) Determination of safety data requirements.
 - (c) Performance of systems safety analyses.

- (d) Establishment and implementation of systems safety plans.
- (3) Public Safety. This element includes those activities which, on a continuing basis, provide protection for the well being of people and prevention of damage to property not involved in NASA's business, but which may nevertheless be exposed to potential hazards associated with carrying out this business. Public safety activities include, but are not limited to, such functions as:
 - (a) Determination of public safety criteria.
 - (b) Establishment and control of public safety hazards associated with facility and systems tests and operations.
 - (c) Establishment and implementation, as required, of emergency or catastrophe control plans.
- (4) Safety Management. This element includes both the program and functional organizations of NASA and its contractors involved in the identification of potential hazards and their elimination or control as set forth in the foregoing description of safety activities. It also includes the management systems for planning, implementing, coordinating, and controlling these activities. These management systems include, but are not limited to, the following:
 - (a) The authorities, responsibilities, and working relationships of the organizations involved in safety activities, and the assessment of their effectiveness.
 - (b) The procedures for insuring the currency and continuity of safety activities, especially systems safety activities which may extend over long periods of time and where management responsibilities are transferred during the life cycles of the systems.
 - (c) The plans and procedures for accident/incident investigations, including those for the follow-up on corrective actions and the feedback of accident/incident information to other involved or interested organizations.
 - (d) The analysis and dissemination of safety data.

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4. PROCEDURES

- a. The Panel will function in an advisory capacity to the Administrator, and, through him, to those organizational elements responsible for management of the NASA safety activities.
- b. The Panel will be provided with all information required to discharge its advisory responsibilities as they pertain to both NASA and its contractors' safety activities. This information will be made available through the mechanism of appropriate reports, and by means of in situ reviews of safety activities at the various NASA and contractor sites, as deemed necessary by the Panel and arranged through the Administrator. The Panel will thus be enabled to examine and evaluate not only the general status of the NASA safety system, but also the key elements of the planned and on-going activities in this system.

5. ORGANIZATIONa. Membership

- (1) The Panel will consist of a maximum of nine members, who will be appointed by the Administrator. Appointments will be for a term of six years, except that, in order to provide continuity of membership, one-third of the members appointed originally to the Panel will be appointed for a term of two years, one-third for a term of four years, and one-third for a term of six years.
- (2) Not more than four members of the Panel shall be employees of NASA, nor shall such NASA members constitute a majority of the composition of the Panel at any given time.
- (3) Compensation and travel allowances for Panel members shall be as specified in Section 6 of the NASA Authorization Act, 1968.

b. Officers

- (1) The Officers of the Panel shall be a Chairman and a Vice Chairman, who shall be selected by the Panel from their membership to serve for one-year terms.
- (2) The Chairman, or Vice Chairman in his absence, shall preside at all meetings of the Panel and shall have the usual powers of a presiding officer.

c. Committees

- (1) The Panel is authorized to establish special committees, as necessary and as approved by the Administrator, to carry out specified tasks within the scope of duties of the Panel.
- (2) All such committee activities will be considered an inseparable extension of Panel activities, and will be in accordance with all applicable procedures and regulations set forth in this Instruction.
- (3) The Chairman of each special committee shall be a member of the Aerospace Safety Advisory Panel. The other committee members may or may not be members of the Panel, as recommended by the Panel and approved by the Administrator.
- (4) Appointment of Panel members to committees as officers or members will be either for one year, for the duration of their term as Panel members, or for the lifetime of the committee, whichever is the shortest. Appointments of non-Panel members to committees will be for a period of one year or for the lifetime of the committee, whichever is shorter.
- (5) Compensation and travel allowances for committee members who are not members of the Panel shall be the same as for members of the Panel itself, except that compensation for such committee members appointed from outside the Federal Government shall be at the rate prescribed by the Administrator for comparable services.

d. Meetings

- (1) Regular meetings of the Panel will be held as often as necessary and at least twice a year. One meeting each year shall be an Annual Meeting. Business conducted at this meeting will include selecting the Chairman and the Vice Chairman of the Panel, recommending new committees and committee members as required or desired, approving the Panel's annual report to the Administrator, and such other business as may be required.
- (2) Special meetings of the Panel may be called by the Chairman, by notice served personally upon or by mail or telegraph to the usual address of each member at least five days prior to the meeting.

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- (3) Special meetings shall be called in the same manner by the Chairman, upon the written request of three members of the Panel.
- (4) If practicable, the object of a special meeting should be sent in writing to all members, and if possible a special meeting should be avoided by obtaining the views of members by mail or otherwise, both on the question requiring the meeting and on the question of calling a special meeting.
- (5) All meetings of special committees will be called by their respective chairmen pursuant to and in accordance with performing their specified tasks.
- (6) Minutes of all meetings of the Panel, and of special committees established by the Panel, will be kept. Such minutes shall, at a minimum, contain a record of persons present, a description of matters discussed and conclusions reached, and copies of all reports received, issued, or approved by the Panel or committee. The accuracy of all minutes will be certified to by the Chairman of the Panel (or by the Vice Chairman in his absence) or of the committee.

e. Reports and Records

- (1) The Panel shall submit an annual report to the Administrator.
- (2) The Panel will submit to the Administrator reports on all safety reviews and evaluations with comments and recommendations as deemed appropriate by the Panel.
- (3) All records and files of the Panel, including agendas, minutes of Panel and committee meetings, studies, analyses, reports, or other data compilations or work papers, made available to or prepared by or for the Panel, will be retained by the Panel.

f. Avoidance of Conflicts of Interest

- (1) Nongovernmental members of the Panel, and of special committees established by the Panel, are "Special Government Employees" within the meaning of NHB 1900.2A, which sets forth guidance to NASA Special Government Employees regarding the avoidance of conflicts of interest and the observance of ethical standards of conduct. A

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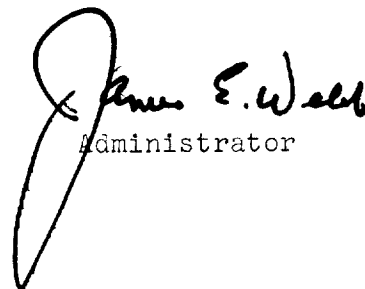
NMI 1156.14

copy of NHB 1900.2A and related NASA instructions on conflicts of interest will be furnished to each Panel or committee member at the time of his appointment as a NASA consultant or expert.

- (2) Nongovernmental members of the Panel or a special committee will submit a "NASA Special Government Employees Confidential Statement of Employment and Financial Interests" (NASA Form 1271) prior to participating in the activities of the Panel or a special committee.

6. SUPPORT

- a. A staff, to be comprised of full-time NASA employees, shall be established to support the Panel. The members of this staff will be fully responsive to direction from the Chairman of the Panel.
- b. The director of this staff will serve as Executive Secretary to the Panel. The Executive Secretary of the Panel, in accordance with the specific instructions from the Chairman of the Panel, shall:
 - (1) Administer the affairs of the Panel and have general supervision of all arrangements for safety reviews and evaluations, and other matters undertaken by the Panel.
 - (2) Insure that a written record is kept of all transactions, and submit the same to the Panel for approval at each subsequent meeting.
 - (3) Insure that the same service is provided for all special committees of the Panel.


Administrator

CFR Title 14, Chapter 5, Subpart 1209.5.