APPENDIX E

REPORT OF PROJECT MANAGEMENT PANEL

CONTENTS

This page left blank intentionally.

PART E1

TASK ASSIGNMENT

The Project Management Panel was established by the Apollo 13 Review Board to review those management systems in the Apollo Program which were pertinent to the Apollo 13 accident. In effect, this task required the review of all appropriate design, manufacturing, and test procedures covering vehicle systems which may have failed in flight, including the means by which various organizations coordinated their individual efforts in the total process. The Panel took special care to evaluate carefully the safety management system which was applicable to Apollo 13.

Principal questions addressed by the Management Panel focused on the organization, procedures, and systems used to monitor and control CSM design, manufacturing, test, assembly, and final certifications of flight equipment, and particularly of the cryogenic oxygen system used in the service module electric power system and environmental control system.

This page left blank intentionally.

PART E2

PANEL MEMBERSHIP

Panel 4 was chaired by Mr. E. C. Kilgore, Deputy Chief, Engineering and Technical Services, Langley Research Center. The Board Monitor was Mr. Milton Klein, Manager, AEC-NASA Space Nuclear Propulsion Office. Panel members were:

Mr. R. D. Ginter, Director, Special Program Office
Office of Advanced Research and Technology (OART)
NASA, Headquarters, Washington, D.C.

Mr. Merrill Mead, Chief, Programs and Resources Office
Ames Research Center
Moffett Field, California

Mr. James B. Whitten, Asst. Chief, Aeronautical and Space
Mechanics Division
Langley Research Center
Hampton, Virginia

In addition, Mr. R. C. Puffer of MSC Security assisted the Panel by preparing the section of the report on Security.

This page left blank intentionally.

PART E3

SUMMARY

INTRODUCTION

The Management Panel carried out a detailed in-depth review of the Apollo Spacecraft Program Office organizational structure and the management system used to control both command and service module (CSM) hardware development and decision-making processes. The review examined the system for Apollo and focused attention on the specific cryogenic oxygen tank directly involved in the Apollo 13 accident. Key management personnel at the Manned Spacecraft Center (MSC), the Kennedy Space Center (KSC), and Apollo contractors and subcontractors were interviewed. These interviews were specifically aimed at understanding what decisions were made regarding the oxygen tank system for Apollo 13, who participated in these decisions, what information was available from the management system, how effectively the organizational elements functioned in reviewing, communicating, and carrying out assigned responsibilities, and whether management system changes are required in view of the oxygen tank accident. Records of the oxygen tank reviews, discrepancy reports, failure reports, and procedures were examined to determine if the review systems and configuration control system functioned as they were intended. Separate reviews were made of the Security, Safety, and Reliability and Quality Assurance (R&QA) management systems to determine effectiveness.

Visits were made to the CSM prime contractor, North American Rockwell (NR), Downey, California, and to the oxygen tank subcontractor, Beech Aircraft, Boulder, Colorado, during which discussions were held with key design, test, and manufacturing personnel. Reliability inspection, safety, configuration-control and process-control procedures and systems were reviewed and examined in detail. KSC operations were reviewed and discussions were held with key test and launch operations personnel regarding their responsibilities, procedures, and controls. Similar discussions were held with MSC Apollo CSM key management and engineering personnel. Throughout its analysis, the Panel devoted particular attention to the history of the Apollo 13 cryogenic oxygen tank no. 2 including design and manufacturing waivers, discrepancies, and anomalies and how these were handled by the Apollo management team.

General Technical Capability

The Panel found key Apollo personnel to be technically capable and dedicated to producing a reliable and safe spacecraft system. Although there have been cutbacks in the total number of Apollo personnel, the morale of the remaining Apollo team is considered by officials interviewed to be high. Reductions in personnel complements as the flight rate has been reduced have not detrimentally impacted the experience level within the Program to this point. Moreover, critical flight and ground system personnel requirements have been carefully reviewed by project officials to insure adequate manning. During the Apollo Program, there have been changes in key management personnel. The Panel found that attention was given to maintaining continuity of experience by essentially promoting from within the Apollo Program. Some technicians with considerable CSM experience have been replaced at NR-Downey by technicians from other programs with more seniority, but no CSM experience. This was recognized as a potential problem and an intensified training program was instituted. Continued surveillance of the contractor technician experience level and capability is necessary.

Division of Responsibilities

The Apollo spacecraft organization involves a large number of contractor, subcontractor, and Government organizations. It was found that these organizations understand their individual responsibilities and that necessary coordination processes were in effect. This process provides a system of checks and cross-checks to assure that detailed consideration and attention is given to problems by the right organizations prior to final flight commitment.

Cryogenic Oxygen Tank Design

Apollo oxygen tank no. 2 was designed in the 1962-1963 time period by Beech prior to the formation of the formal design review and subsystem manager systems which now exist at MSC. During the design phase, there was limited participation by MSC technical personnel in the early design. The primary emphasis at this time by both the prime contractor and MSC was on the thermodynamic performance of the oxygen system. The tank did receive informal design reviews primarily by NR and Beech personnel. Even though these reviews were made, it was found that the final design resulted in a complex assembly procedure with a wiring cluster which cannot be inspected after assembly in the tank. However, the complexity of the assembly and the inability to inspect the tank interior components after assembly was recognized by Government, NR, and Beech personnel. Consequently, a detailed step-by-step manufacturing and assembly procedure was established and carried out with checklist-type Beech inspections, supplemented by NR and Government inspections at defined critical points. A First Article Configuration Inspection (FACI) was held on the oxygen tank in 1966 which was jointly signed off by MSC and contractor subsystem managers. No subsequent formal design reviews were held.

A thermostatic switch (thermal switch) was incorporated into the Block I oxygen tank heaters to avoid overheating while using 28 V dc spacecraft power. After receipt of the Block II oxygen tank specifications from NR in February 1965, which required the tank heater to operate not only on 28 V dc spacecraft power but also with 65 V dc GSE for rapid tank pressurization during launch operations at KSC, Beech did not require their Block I thermal switch supplier to make a change in switch rating. NR never subsequently reviewed the heater assembly to assure compatibility between the GSE and the thermal switch. This resulted in NR, MSC, and KSC personnel subsequently assuming that the tank was protected from overheating while using the 65 V dc power supply.

Configuration Control Procedures

The Panel found that a strict and rigorous management system exists on the CSM for configuration control, problem reporting, customer acceptance readiness reviews, and flight readiness reviews. Both contractors and Government CSM organizations participate in this system. R&QA organizations independently monitor, record, and report all problems and approved resolutions. Examination of documentation, such as failure reports, discrepancy reports, and waivers generated in the management system and applicable to the Apollo 13 oxygen tank, demonstrated to the Panel that the management system was being followed closely. Closeouts were being accomplished with authorized approvals.

Oxygen Tank Handling Incident at Downey

In the case of the Apollo 13 oxygen tank handling incident at NR-Downey, the Panel found that a Discrepancy Report was written and functional tests were made by NR Engineering. The incident was judged to have caused no tank damage by the contractor's systems engineers and representatives of the RASPO at Downey. Also, the oxygen tank subsystems manager at MSC was made aware of the incident. Subsequent functional tests were successfully passed. The Discrepancy Report was closed out in the authorized manner. Although the handling incident was not reported to the Apollo Spacecraft Program Manager, it should be noted that such reporting of Discrepancy Report closeouts is not required in all cases. Once this incident was closed out in the manner prescribed by the Apollo management control system, it was not reopened as a possible factor relating to the later detanking problem at KSC.

KSC Detanking Problems

In the case of the detanking problem at KSC, it was found that all authorized Discrepancy Reports were filed and signed off. The change from normal detanking procedures was made to use the tank heaters and fans in an attempt to boil off the liquid oxygen in the tank. This was unsuccessful and the normal procedure was further altered by use of a pressure pulsing method. These changes to the test procedures were made by the KSC Systems Engineer and NR Systems Engineer who were on station. They obtained concurrence of the NR lead systems engineer at KSC. This is in agreement with the present requirements for test procedural changes. After the pressure pulsing method was used to detank oxygen tank no. 2, the problem received further attention, including additional analyses and test. The Apollo team problem-solving effort that resulted was led by the MSC Apollo Spacecraft Program Manager and the KSC Director of Launch Operations. NR and Beech personnel were also involved. The MSC Apollo Spacecraft Program Office formulated a checklist of analyses to be made and questions to be answered prior to making the flight decision on the tank.

This included:

1. Details and procedures for normal detanking at Beech and KSC.

2. Details of abnormal detanking at KSC on March 27 and 28.

3. Hazards resulting from a possible loose fill tube in the oxygen tank.

4. Can the tank be X-rayed at KSC?

5. Could loose tolerances on the fill tube cause detanking problem?

6. Should a blowdown and fill test be made on the tank?

7. Disassemble an oxygen tank on Service Module 2 TV-1 and examine components.

A detailed analysis, including possible failure modes, was made at Beech. Tests were run which indicated that even in the event of a loose metal fill tube (which was concluded to be the most likely cause of the detanking problem), a resultant electrical short would provide only 7 millijoules of energy and it was judged that this energy level could cause no damage except loss of the quantity gage indication. All of the checklist requirements were met by test or analysis prior to making the decision to fly without a change in the oxygen tank. It was jointly concluded by the Beech Apollo Program Manager, the NR CSM Program Manager, the KSC Director of Launch Operations, and the MSC Apollo Spacecraft Program Office (ASPO) Manager that the tank was flightworthy. Further examination of this event since the Apollo 13 accident, however, has revealed that incomplete and, in some cases, incorrect information was used in the decision process. This included:

1. Neither the KSC Launch Operations Director nor the MSC ASPO Manager knew of the previous tank handling incident at NR-Downey and neither knew that the oxygen tank internal heaters were on for 8 consecutive hours during detanking at KSC. Key personnel at NR-Downey knew of both events. No personnel at MSC, KSC, or NR knew that the tank heater thermal switches would not protect the tank from overheating.

2. A portion of the normal detanking process at Beech is similar to the normal detanking process at KSC. The KSC Launch Operations Director and MSC ASPO Manager were mistakenly informed that they were different. (If they had known of the similarity in detanking processes, they possibly would have concluded that some change took place in the tank between Beech and MSC.)

3. The KSC Launch Operations Director, the MSC ASPO Manager, and key personnel at Downey mistakenly understood that the oxygen tank on previous test Service Module 2 TV-1 had similar detanking problems which led to the decision to disassemble the 2 TV-1 tank and examine the components. That examination was interpreted as evidence that a loose-fitting metal fill tube probably was causing the detanking difficulty. Further examination has revealed, however, that 2 TV-1 oxygen tank probably detanked normally.

Although none of the principals in making the oxygen tank decision (NR, MSC, KSC) can say with certainty that the availability of information in 1, 2, and 3, above would have altered their decision, each concurs that the availability of such information could have altered their decisions.

On the basis of its review, the Project Management Panel feels the following observations to be pertinent:

1. Launch operations personnel did not fully understand the oxygen tank internal components or fully appreciate the possible effect of changed detanking procedures on the reliability of such internal components.

2. The hazard associated with the long heater cycle was not given consideration in the decision to fly this tank.

3. Problem solving during launch operations utilized telephone conferences among knowledgeable parties, but without subsequent written verification, which would have permitted more deliberate consideration and review.

4. Deviations from test procedures during tests at KSC were made in accordance with the established approval process. This does not require prior approval or concurrence of NR-Downey or MSC subsystem specialists.

5. It was found that insufficient consideration was given to the tank internal details such as sharp edges, internal wiring, and heater thermal switch ratings during the design reviews.

6. An historical record of the oxygen tank existed in the management system files. However, it was not referred to in making the flight decision.

7. Dependence upon memory of personnel led to erroneous data being reported to higher management levels.

8. Key Apollo management personnel made several suggestions during the Panel interviews:

(a) Provide total background history on subsystems which have problems or anomalies during launch operations.

(b) Launch operations personnel need more knowledge of the internal details of subsystems.

(c) NR (Downey) and MSC Subsystem Managers should review KSC test procedures and subsequent procedure changes.

(d) Verification of data is needed in problem solving.

(e) Followup documentation of information exchanged during telephone conferences on key problems is recommended.

Materials Compatibility

The compatibility of oxygen tank materials with oxygen received consideration in the original design. Beech reviewed and selected the tank materials in accordance with the published material knowledge that existed in the 1962-1963 time period. No data on hot-wire tests or ignition tests were available to Beech at that time. Beech ran special tests on the fan and motor assembly which was tested at 1000 psia in oxygen gas at 300° F. The motor passed this test with no evidence of ignition. Some attention was paid in the assembly procedures to avoid pulling wires over threads or sharp corners and to provide protective sleeving. However, most sharp corners were not eliminated and as was previously mentioned, the tank design necessitated a blind assembly with no way for subsequent inspection for damage. After the original design, Beech was not requested by NR to make any further materials compatibility study or tests. In April 1969, NR was directed by MSC to review the nonmetallic materials in the cryogenic oxygen subsystem and document them in accordance with the COMAT (Characteristics of Materials System). All nonmetallic materials in the oxygen tank were evaluated and documented by NR. All nonmetallic materials met the requirements of the materials control program. These materials criteria were specifically formulated for the lunar module and command module, where non-propagation of fire was a requirement even if a fire started.

These COMAT requirements do not adequately cover the 900 psi cryogenic oxygen tank. No electrical ignition testing of any materials was made for the oxygen tank. NR reviewed the service module systems to provide electrical circuit protection such as breakers and fuses in 1967 in an effort to avoid electrical fires in case of shorts.

Security Program

During its review, the Panel also investigated the physical security at Beech, NR-Downey, and KSC for adequacy during the times the Apollo 13 oxygen tank was in custody at these locations. The security program at each location was found to be satisfactory and adequate to provide the physical protection of the oxygen tanks. A determination was made as a result of the survey that no evidence was discovered that the failure of the oxygen tanks on Apollo 13 was the result of any willful, deliberate, or mischievous act on the part of an individual at the facilities surveyed.

Safety and Reliability and Quality Assurance

A detailed management review was made of both the Safety and R&QA organizations as applicable to the Apollo CSM. Safety Offices at NASA Headquarters Office of Manned Space Flight, MSC, and KSC have safety responsibilities regarding Apollo which are clearly established and implemented by both Government and support contractor personnel. Safety audits by NASA Headquarters teams and participation by MSC and KSC personnel in panels, boards, and program reviews demonstrates continuing organizational attention to safety. Safety studies are being made to identify hazards associated with the Apollo spacecraft during ground tests and for each manned mission. NR-Downey has a safety organization with specific responsibilities for the Apollo CSM. The NR safety function is integrated into the Engineering, Manufacturing, and Test Operations with its objectives to eliminate or control risks to personnel and equipment throughout the manufacture, checkout, and flight missions of the Apollo CSM. Even though the NR safety effort, as written in their Safety Plan, is fragmented over several organizational units, it apparently is working effectively. In all cases, the safety organizations report to a sufficiently high organizational level to provide them a desirable independence of safety surveillance.

Failure Reporting

The Panel found that the Apollo Reliability and Quality Assurance organizations at MSC, KSC, NR, and Beech have an effective independent failure-reporting and failure-correction and tracking system. Documentation from this system was observed to be both rapid and accurate. The Reliability Group provides special studies such as Failure Modes and Effects Analysis (FMEA), Suspect Flight Anomalies Report, and configuration change tracking. In the case of the Apollo 13 oxygen tank, a Single Point Failure Summary was made in 1968. Among the failure modes considered was fire in the CSM external to the oxygen tanks which might lead to the loss of them. This was considered an acceptable risk because of control of ignition sources and low probability of occurrence. Rupture of the oxygen tanks was also considered and accepted due to the redundance of the oxygen supply and low likelihood of failure occurrence. For Apollo 13, as for previous missions, a System Safety Assessment was made on February 19, 1970, as an additional review from previous missions, and it was concluded that there were no open safety items to constrain the Apollo 13 flight.

PART E4

MANAGEMENT ORGANIZATION

Relating organizational and management structures to an event of the kind now under consideration is particularly difficult inasmuch as the time period of importance includes the entire history of the Program, in this case some 9 years, during which these structures have undergone many significant changes. With this in mind, the approach adopted for this study was (1) to examine and document what exists today, (2) to trace the history of events that might have had a direct bearing on the failure, (3) to examine the management inplications of those specific events, and (4) to try and assess whether those implications are still pertinent to management as it exists today and whether, therefore, corrective measures of any kind are indicated. To accomplish even this limited objective has required an early focusing of attention on just those organizations and functions directly involved, or potentially involved, in the events under consideration. Thus, following a brief description of the overall organizational and management relationships applicable to the Program as a whole, this report concentrates on those organizations responsible for the particular elements of the Apollo spacecraft in which the failure occurred.

BACKGROUND AND PERSPECTIVE

The Apollo Program has represented the largest single research and development program ever undertaken by the United States Government; at its peak (in 1966) it involved about 300,000 persons. The Government-industry team responsible for the Program has included 25 prime contractors and more than 4,000 subcontractors and vendors.

In its simplest terms, the Apollo Program has two major objectives: (1) to develop a vehicle capable of landing men on the surface of the Moon and returning them safely to the surface of the Earth, and (2) to operate that vehicle in an initial series of manned lunar landing missions. These two objectives have, in a gross sense, dictated the major division of responsibilities among NASA organizations in the management of the Apollo Program. With overall responsibility vested in the NASA Headquarters organization, responsibility for producing the vehicle was assigned to two NASA field installations:

1. For the spacecraft, to the Manned Spacecraft Center, Houston, Texas.

2. For the launch vehicle, to the Marshall Space Flight Center, Huntsville, Alabama.

The responsibility for operating the vehicle in the series of flight missions which constituted the second objective was also assigned to two field installations:

1. For launching the space vehicle, to the Kennedy Space Center, Cape Kennedy, Florida.

2. For all postlaunch operations, to the Manned Spacecraft Center, Houston, Texas.

These two major objectives also serve to classify the two major time periods into which the 9-year history of the Program can be divided. Thus, the first 7 years, from 1961 to 1968, constituted the development stage of the Program in which all components of the space vehicle, supporting equipment, and operational facilities were designed, developed, manufactured and tested; the last 2 years, from 1968 to the present, have constituted the beginning of the "operations" stage of the Program, with two successful manned lunar landing missions already achieved. The significance of distinguishing between these two periods of time lies in the inevitable shift of emphasis that accompanied the transition between the two from engineering problems to operational problems.

NASA - APOLLO MANAGEMENT ORGANIZATION

Two classical approaches to project management were available to NASA when the Apollo Program began in 1961. The first approach, often used by Government and the aircraft industry in the early years of aircraft development, would place in a single organization and under the total control of the project manager all of the skills and specialities required to manage the project. Thus, the project organization would provide for itself all the support necessary in engineering, procurement, program control, financial management, reliability and quality assurance, etc., and would operate virtually independently of the institutional organization of which it was a part. The second approach, which was rapidly gaining acceptance during the 1940's and 1950's, was the so-called "matrix" concept in which skeletal project management organizations were superimposed on an institutional organization containing elements and subelements in all of the specialities needed by the projects. Thus the institutional organization would provide the basic capabilities required by the projects in engineering, procurement, program control, etc., and the project managers would draw upon those as required. The advantages of this approach for multi-project organizations are apparent. Costly duplication of support activities is minimized, the overall efficiency of manpower utilization is maximized, and the quality of support provided is enhanced by consolidation.

NASA adopted the matrix approach to project management for the Apollo Program. In NASA Headquarters, and in each of the three principal NASA field centers involved, Apollo Program Offices were established from which virtually all of the direction for conduct of the Program has emanated. At each location, however, these Program Offices are essentially management organizations and depend heavily on the line elements of the host institution's organization for support. Continuity in lines of authority between the Apollo Program Director in Headquarters and the Apollo Program organization in the field has been assured through the delegation by each Center Director to his Apollo Program Manager of full authority for conduct of that Center's part of the Program. Thus, for purposes of program direction and authority, there exists throughout the Agency a single pyramidal management structure cutting across institutional lines and tying together all elements of the Apollo Program organization. This relationship is illustrated in figure E4-1.

The organizations of the principal NASA institutions involved in the Apollo Program are illustrated in figures E4-2 through E4-6, in which the locations of offices with primary responsibility for Apollo are indicated by heavy lines.

NASA Headquarters Organization

The Associate Administrator for Manned Space Flight, who heads the Office of Manned Space Flight, is the Administrator's executive agent for the general management of all manned space flight programs. His authority flows directly from the Administrator and is broad, covering all aspects of all manned space flight programs. He also exercises institutional line authority over the three manned space flight field centers which report directly to him.

Office of Manned Space Flight Organization

Figure E4-2 shows the organizational structure within the Headquarters Office of Manned Space Flight. The Associate Administrator for Manned Space Flight has assigned the responsibility for management of all aspects of the Apollo Program to the Apollo Program Director, and has delegated to him full authority to carry out that responsibility. The Apollo Program Director is the highest Agency official whose responsibility is exclusively for the Apollo Program. There are counterpart Program Directors for other manned space flight programs with similar responsibilities to their own programs, and there are a number of functional offices which, consistent with the matrix management concept, provide support to all on-going programs. Shown also in figure E4-2 are the direct lines of program authority between the Apollo Program Director and his subordinate program managers in the three field centers.

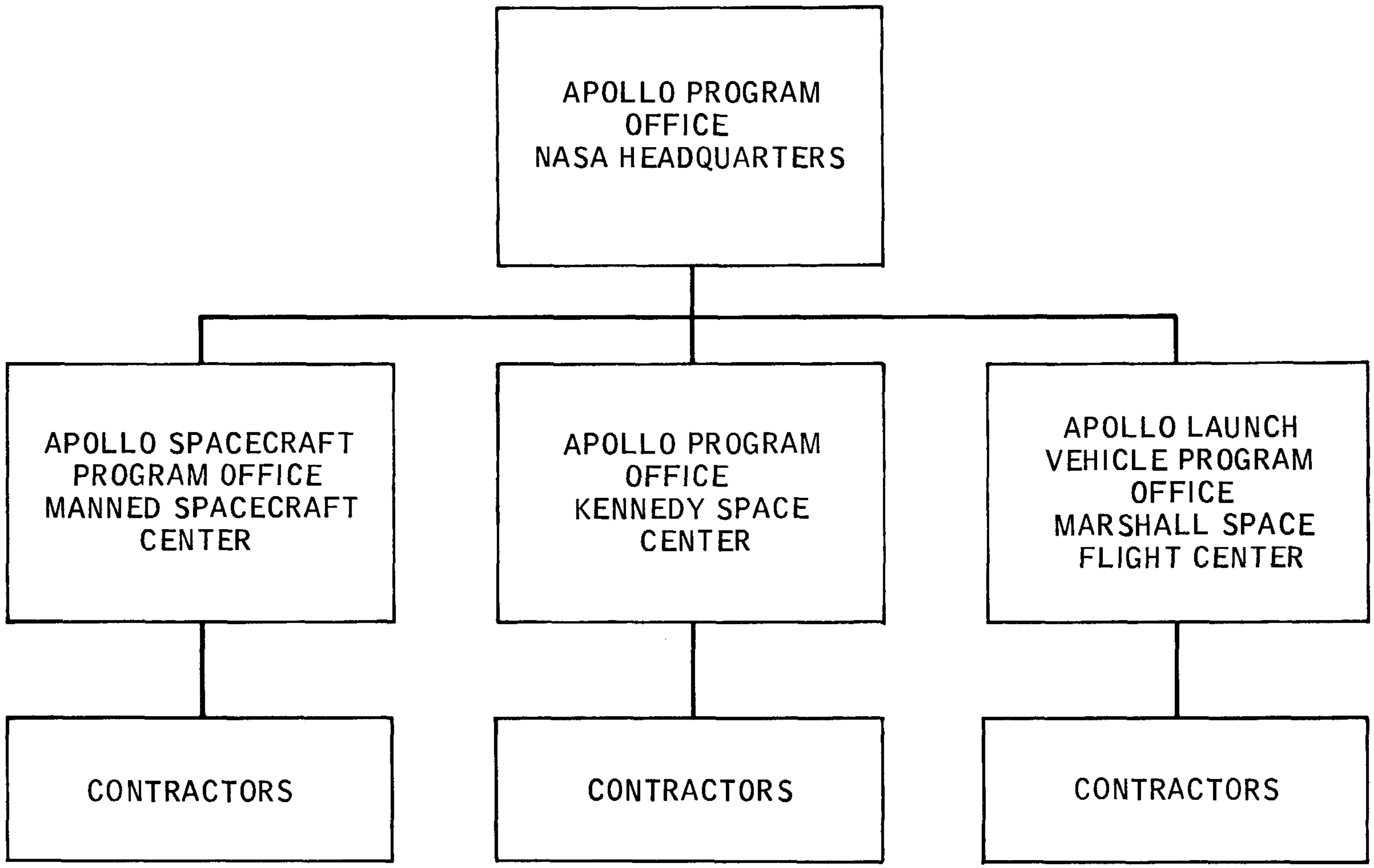

Figure E4-1.- NASA Apollo Program organization.

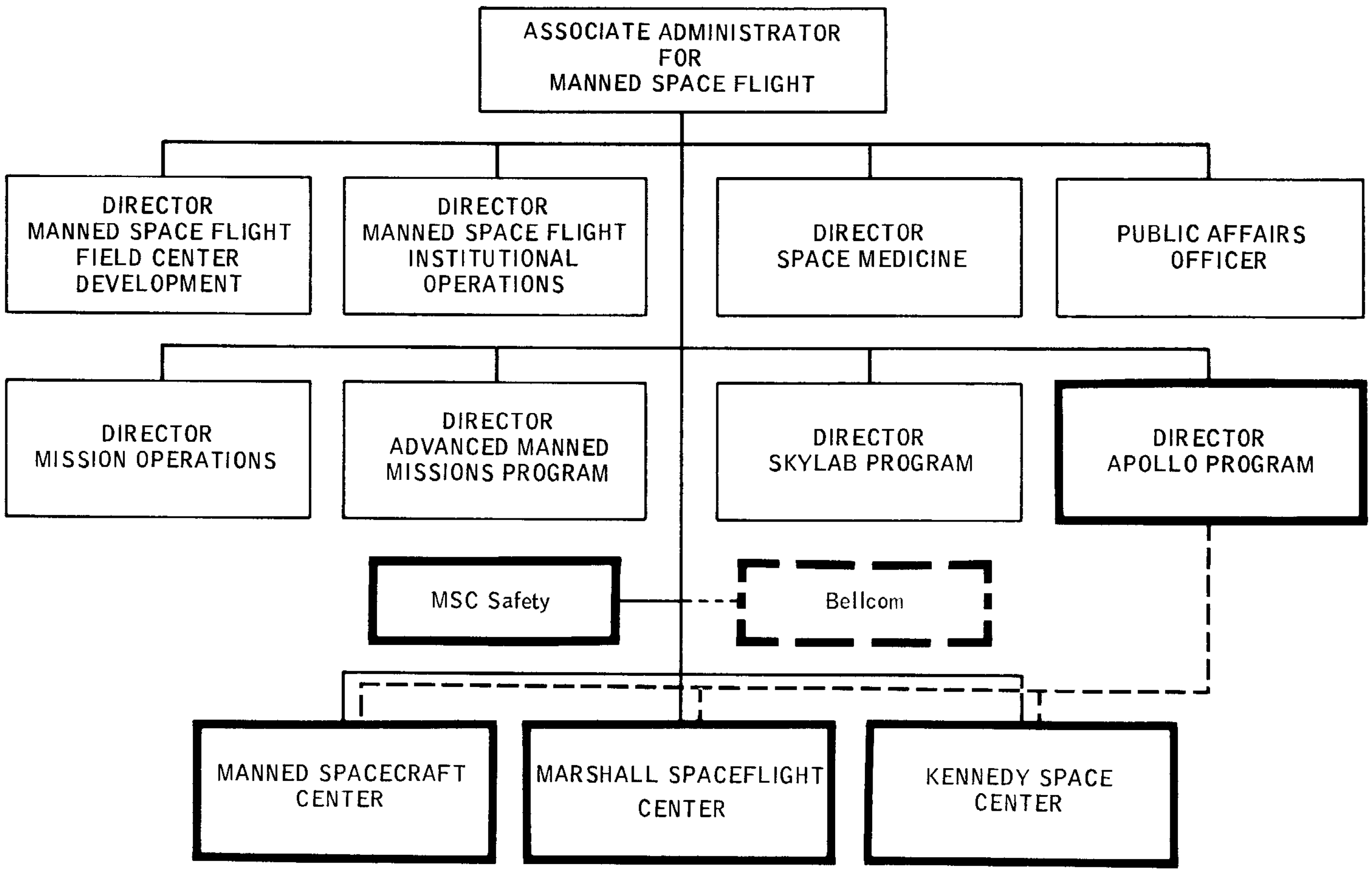

Figure E4-2.- Office of Manned Space Flight organization.

Manned Spacecraft Center (MSC)

The organization of the Manned Spacecraft Center is shown in figure E4-3. The permanent functional organizations are represented by the five technical directorates (Engineering and Development, Science and Applications, Medical Research and Operations, Flight Crew Operations, and Flight Operations) and the institutional Directorates and Staff Offices (e.g., Administration, Program Control and Contracts, Public Affairs, Legal, etc.). The program management organizations presently include the Apollo Spacecraft, Skylab, and Space Shuttle Program Offices, and the Advanced Missions Program Office, which is responsible for studies and planning potentially leading to new flight programs.

Responsibility for managing all aspects of the Apollo Program assigned to the Center is vested in the Manager of the Apollo Spacecraft Program Office (ASPO). Under the matrix-management concept, a relatively small percentage of the Center's staff directly employed in the Apollo Program reports to him organizationally. Virtually all of the Apollo tasks done in-house at MSC (component testing, instrumentation development, flightcrew training, operations planning, etc.) are performed by the Center's line organizations (the functional Directorates) under the overall direction and coordination of the ASPO Manager.

Marshall Space Flight Center (MSFC)

This Center is responsible for the development, manufacture, and testing of the launch vehicles used in the Apollo Program. The organization of the Center is shown in figure E4-4. As at MSC, this Center employs the matrix-management concept in which the basic organization, represented by the Program Development, Science and Engineering, and Administration and Technical Services Directorates, is functional and the program-management organization, represented by the Program Management Directorate, is made up of program offices for individual launch vehicles or stages.

Although the Saturn Program Office represents the Apollo Launch Vehicle Program Office for purposes of full-time management, the Director of Program Management has been designated the Apollo Launch Vehicle Program Manager. He manages and directs all aspects of the Apollo Program assigned to MSFC, drawing on technical support from the Science and Engineering Directorates.

Kennedy Space Center (KSC)

The KSC responsibility in the Apollo Program includes the assembly, checkout, and launch of the space vehicle.

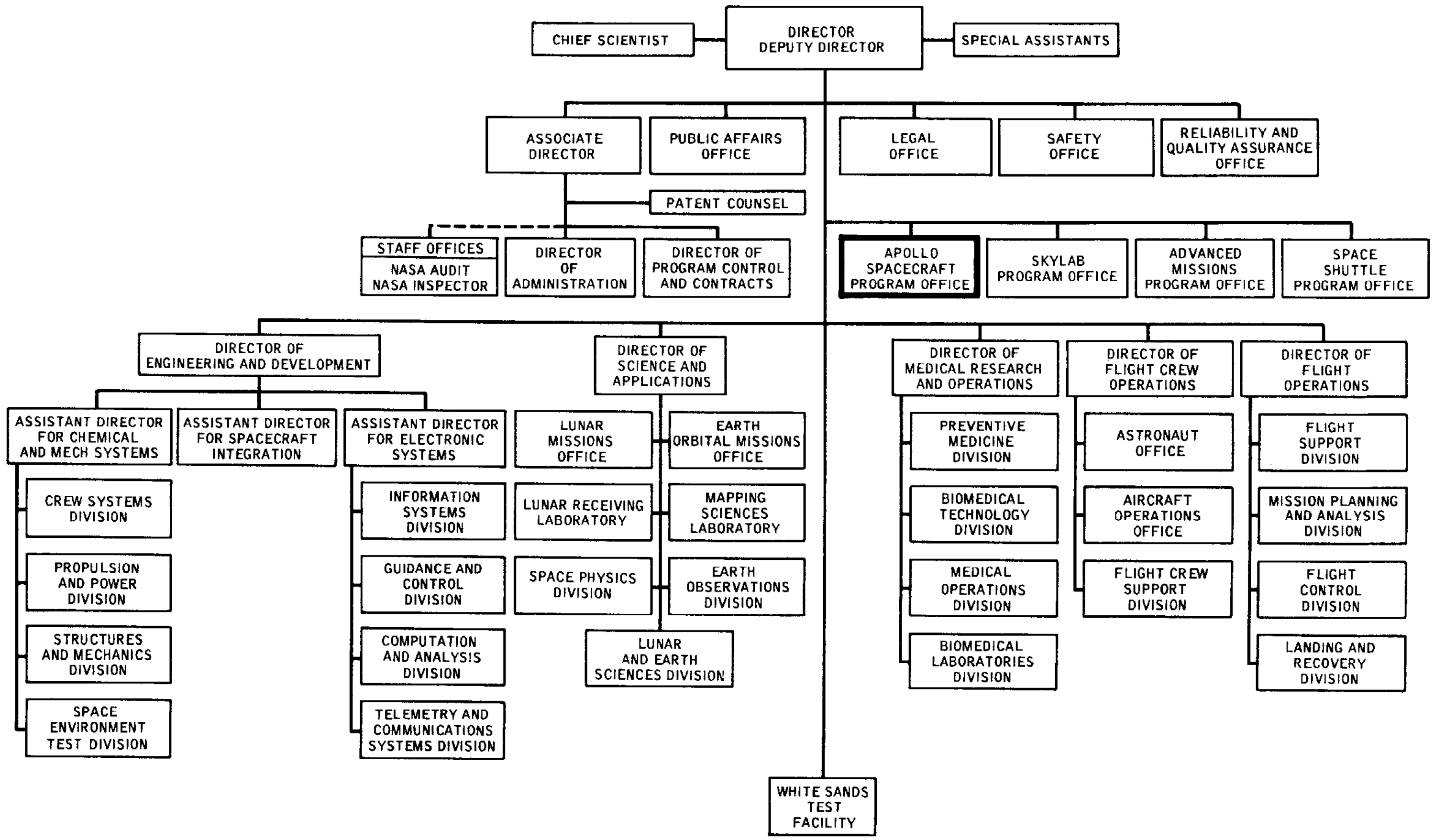

Figure E4-3.- Manned Spacecraft Center organization.

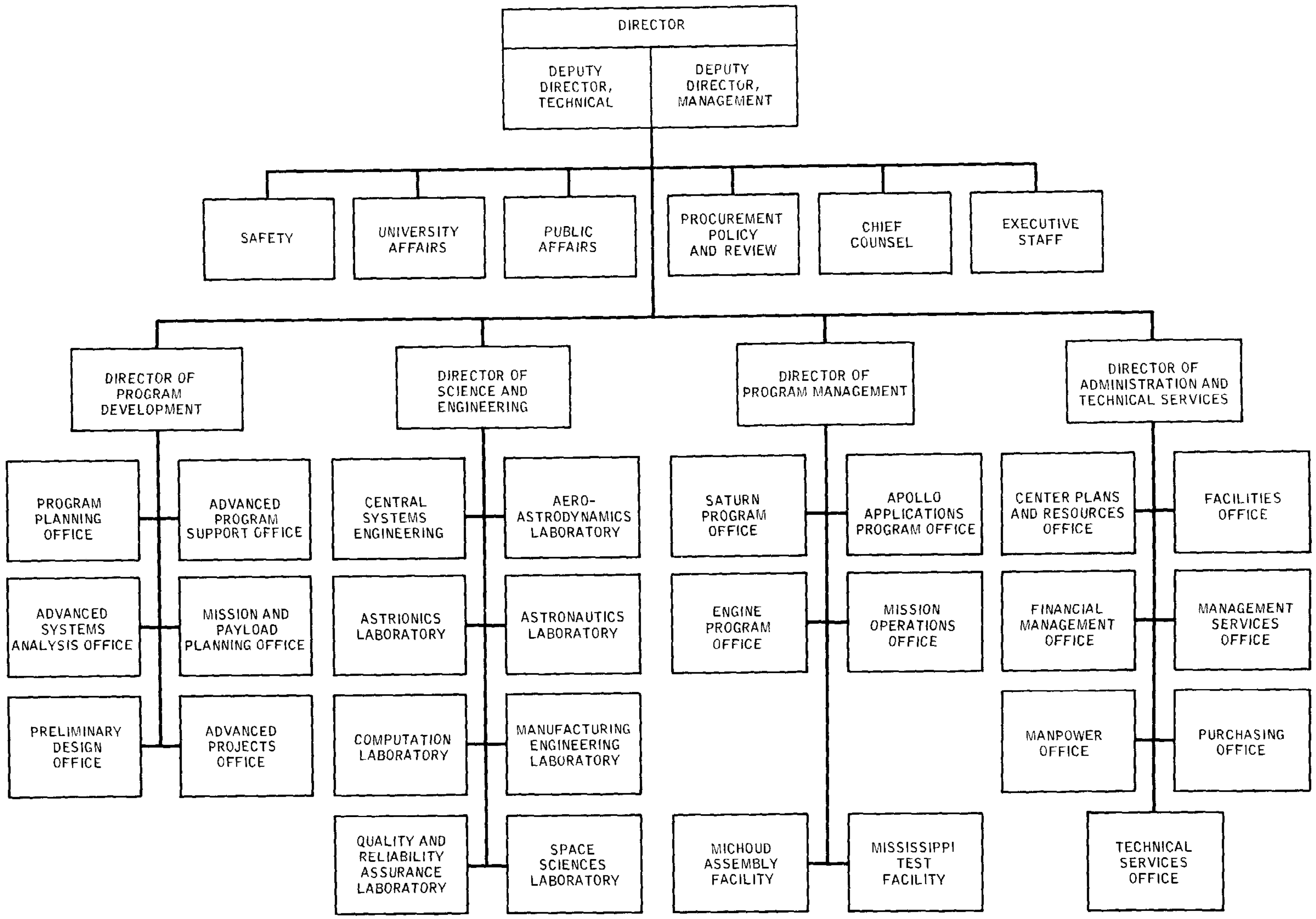

Figure E4-4.- Marshall Space Flight Center organization.

The organization of the Center is shown in figure E4-5. Again the basic organization is functional, consisting of those major operational activities necessary to the launch of all space vehicles. The program-management organization is similar to that at MSC and is made up of an individual program office for each active flight program. Overall responsibility for managing all aspects of the preparation, checkout, and launch of the Apollo space vehicles is assigned to the Manager of the Apollo Program Office (APO). All functional organizations at the Center participate in those activities under the overall direction of the APO Manager. Direct responsibility for launch and checkout is delegated to the Director of Launch Operations.

CONTRACTOR ORGANIZATIONS

The oxygen tank in which the failure occurred was a component of the cryogenic gas storage subsystem (CGSS), which serves both the electrical power system (EPS) and the environmental control system (ECS) of the spacecraft service module (SM). The contractors and contractual relationships involved in the manufacture of the tank are illustrated in figure E4-6. North American Rockwell (formerly North American Aviation), prime contractor for the command and service modules (CSM), subcontracted with Beech Aircraft Corporation for manufacture of the CGSS. Beech, in turn, purchased certain parts for the subsystem from the three vendors shown: the oxygen pressure vessel (inner tank) from Airite Products Division of the Electrada Corporation; the oxygen quantity and temperature sensor probe from Simmonds Precision Products, Inc.; and the fan motors from Globe Industries, Inc. Pertinent organization charts for North American Rockwell and Beech Aircraft are shown in figures E4-7 through E4-11. The organizations of the vendor companies were not considered pertinent and are not shown.

North American Rockwell (NR)

The Apollo CSM contract is held by the Space Division of North American Rockwell and the organization of that Division is shown in figure E4-7. North American Rockwell also applies the matrix-management concept in their current organization with program offices (Saturn S-II, Space Station, CSM, Space Shuttle, etc.) superimposed on a basically functional organizational structure which includes Manufacturing, Research, Engineering, and Test; Material; Quality and Reliability Assurance; and the conventional administrative-support functions. The Apollo contract is managed for NR by the CSM Program Office headed by a division vice president. Figure E4-8 shows the organization of that Office. Within the CSM Program Office the principal suborganization for program management is Engineering, headed by an Assistant Program Manager and Chief Program Engineer. On the functional side of the Space Division, referring again to figure E4-7, line responsibility for

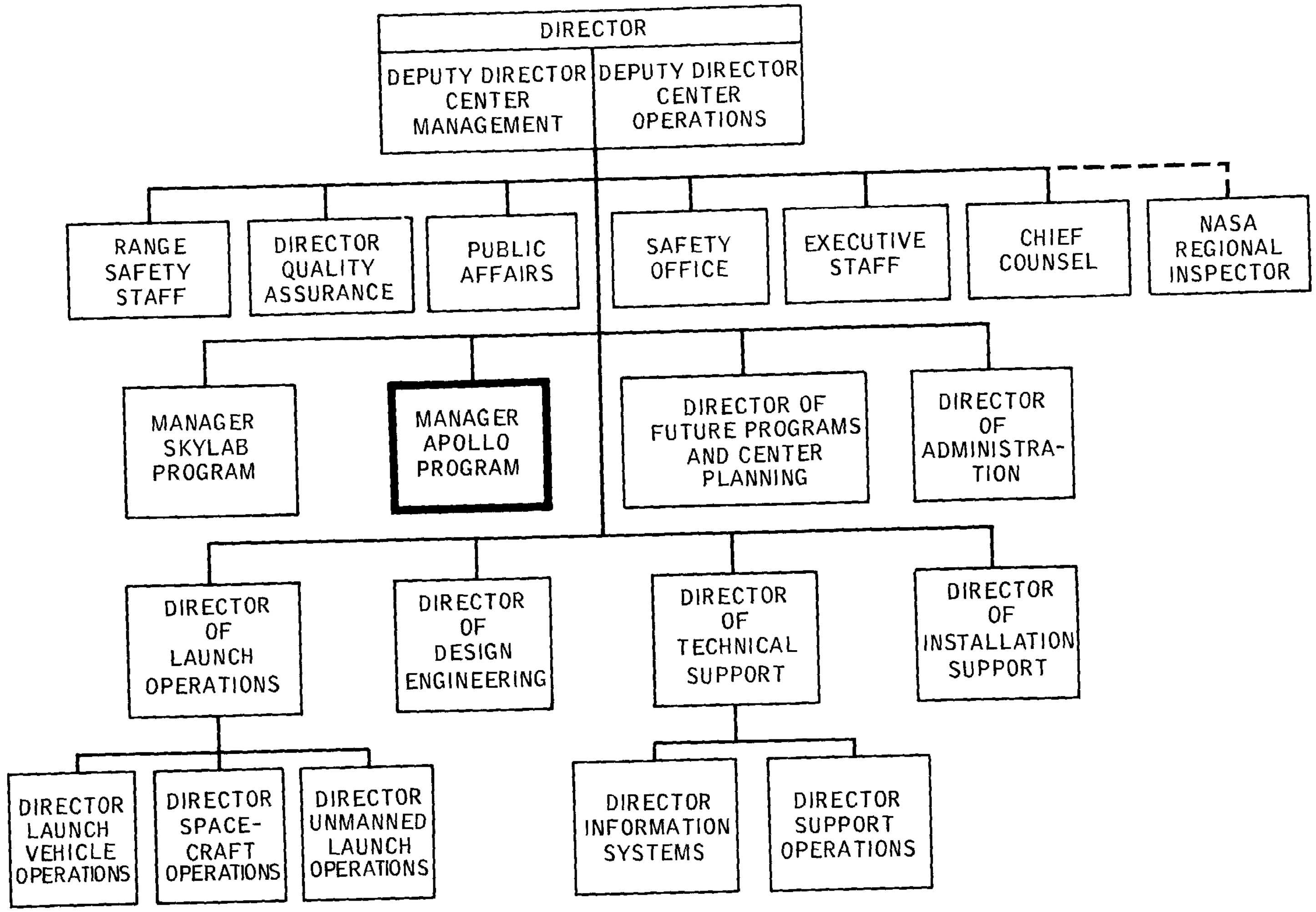

Figure E4-5.- Kennedy Space Center organization.

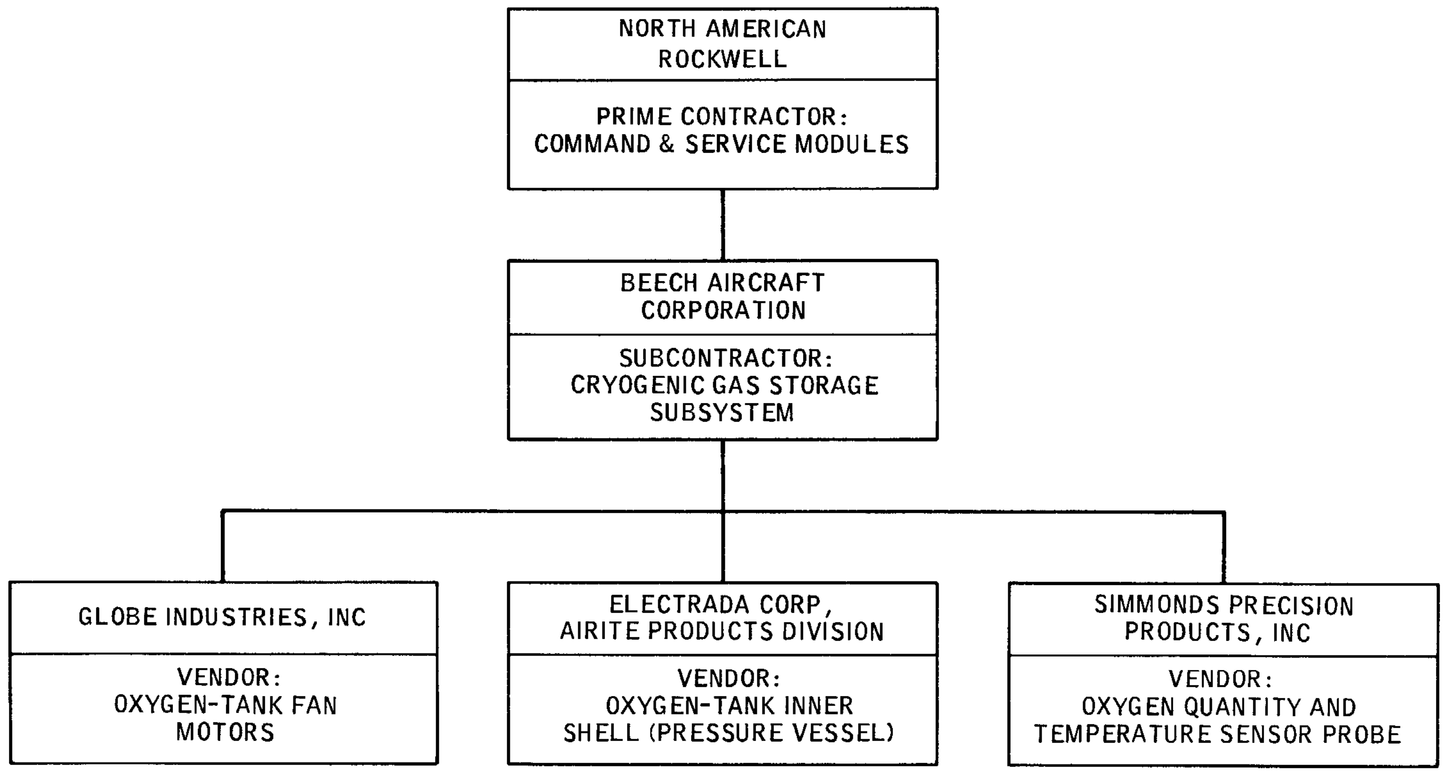

Figure E4-6.- Croygenic gas storage subsystem-contractual relationships.

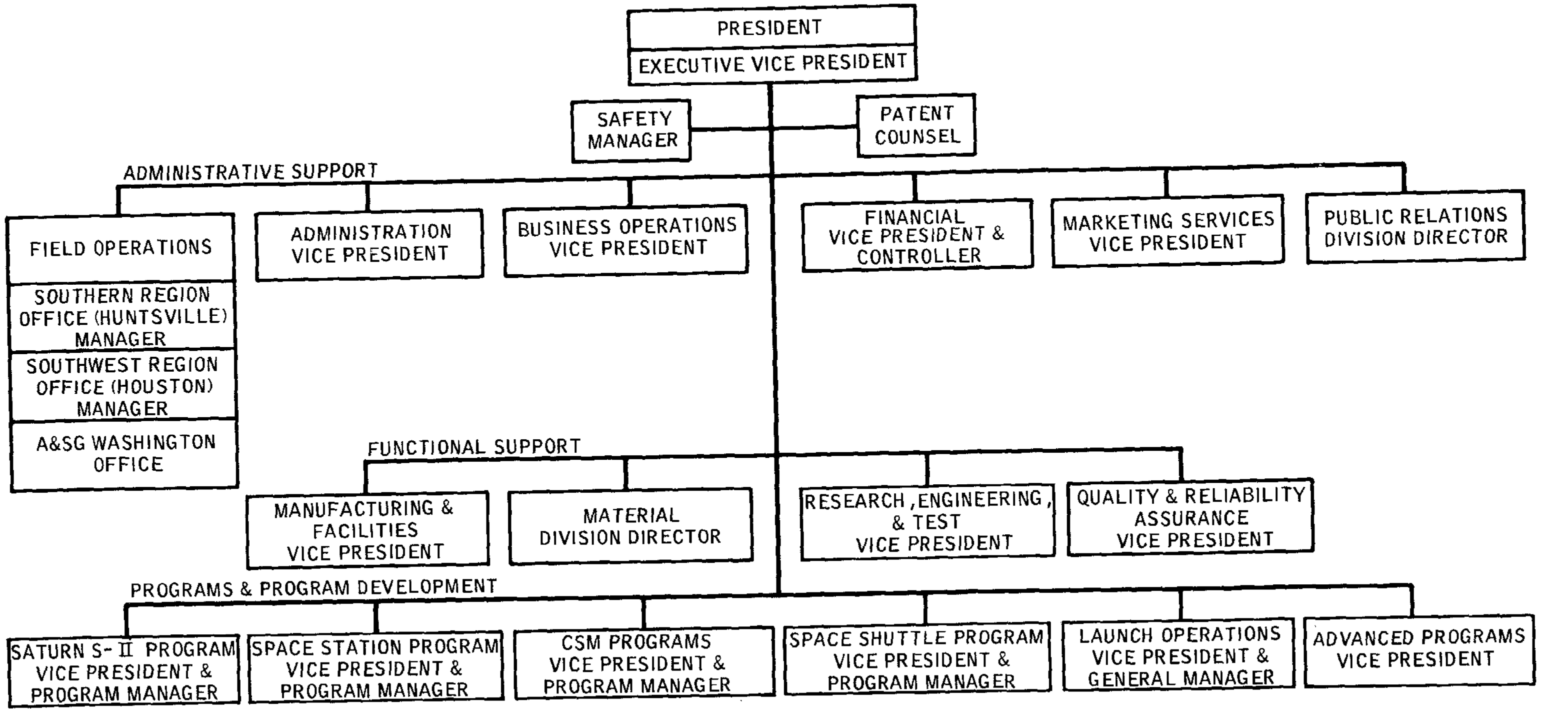

Figure E4-7.- North American Rockwell, Space Division organization.

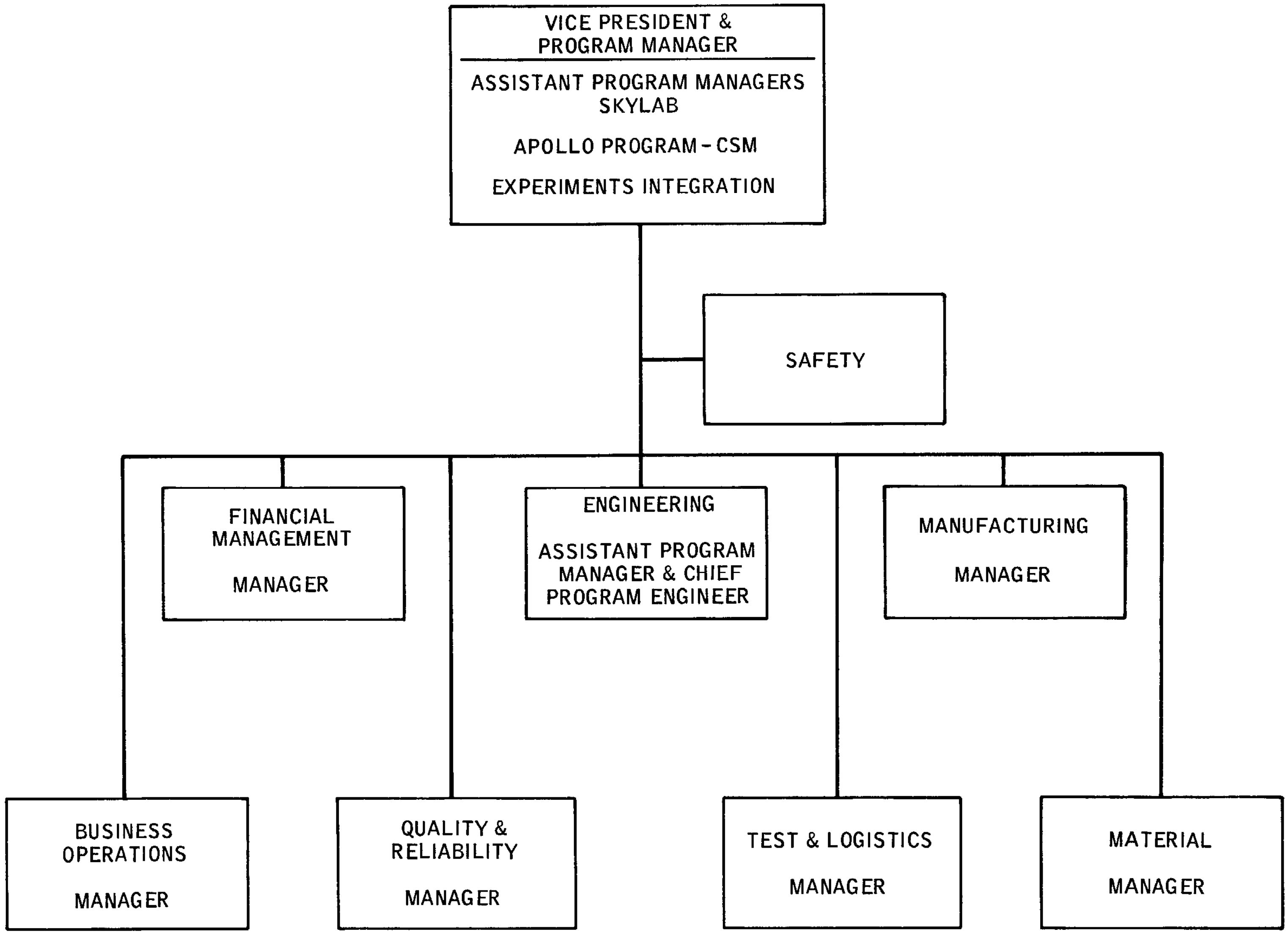

Figure E4-8.- North American Rockwell, Space Division, CSM Programs Office organization.

performance (as opposed to management) under the Apollo contract falls under the functional support organization for Research, Engineering, and Test, also headed by a division vice president. The organization of that Office is along systems/subsystems lines. At the subsystem level, the engineer in charge in this organization also acts as the subsystem manager for the program management organization, in a manner quite analogous to the technique used by the MSC organization described earlier. The relationship at North American Rockwell is illustrated in figure E4-9.

North American Launch Operations Space Division (KSC)

All NR CSM operations at KSC are conducted in accordance with the provisions of Supplement KSC-1 to MSC contract no. NAS9-150 with NR. The Supplement contains a statement of work prepared by KSC and KSC is responsible for technical direction to the NR personnel. The NR Apollo CSM Operations at KSC supports KSC in CSM checkout and launch and is a part of the NR Launch Operations Space Division under the NR Vice President and General Manager who is located at Cocoa Beach, Florida. He, in turn, reports to the Space Division President, NR.

Beech Aircraft Corporation

The subcontract from North American Rockwell, for manufacturing of the cryogenic gas storage subsystem, is held by the Boulder Division of the Beech Aircraft Corporation. The organization of that Division is shown in figure E4-10. Beech also uses the matrix-management concept with management responsibility for the Apollo subsystem contract vested in the Apollo Program Manager and performance responsibility in the Manager, Engineering. Figure E4-11 shows the breakdown of management responsibilities within the office of the Apollo Program Manager.

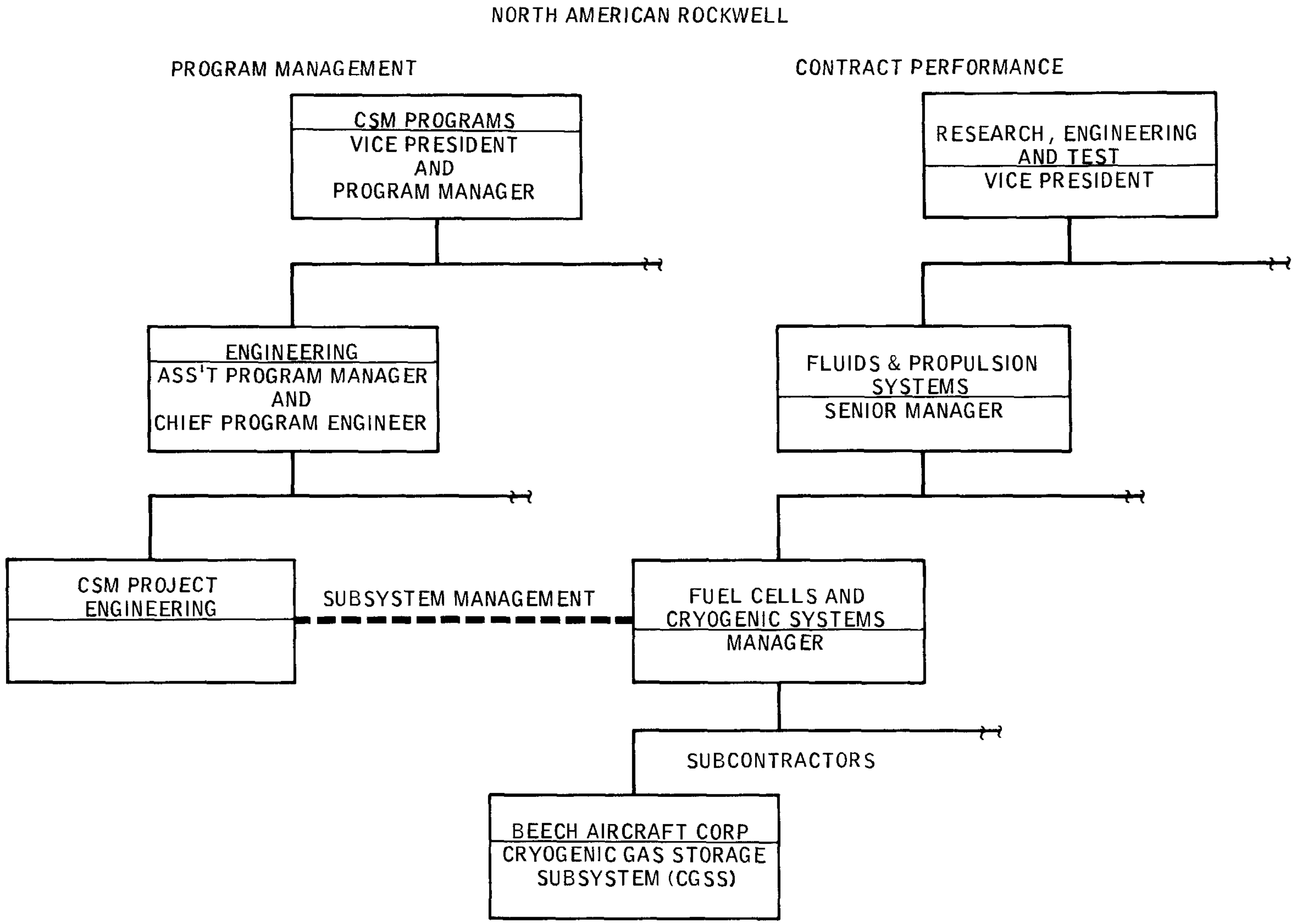

Figure E4-9.- North American Rockwell organizational relationships applicable to cryogenic gas storage subsystem.