(f) Establishes the physiological limits to which man can be subjected.

(g) Reviews plans and changes for construction of test facilities involving humans.

(h) Has responsibility for biological safety during Lunar Receiving Laboratory operations.

The Safety Office also maintains a safety interface between NASA Headquarters, MSC, other centers, and other Government agencies as shown in figure E9-4. The areas of safety coordination with these organizations are described as follows. In the event problems arise at these interfaces, interagency panels will be convened for problem resolution.

MSC/KSC interface in eight areas that are safety oriented or related:

1. Test operations at KSC.

2. Flight hardware management.

3. Flightcrew activities at KSC.

4. Configuration control.

5. Quality control and inspection at KSC.

6. Safety at KSC.

7. Experiment management.

8. Launch and flight operations.

Any problems which arise are resolved through the formally organized intercenter panels.

MSC/DOD Safety Regulations are primarily at the Air Force Eastern Test Range Facility. DOD provides the following functions:

1. Safety-related base support as required:

   (a) Fire protection and control

   (b) Explosive ordnance disposal

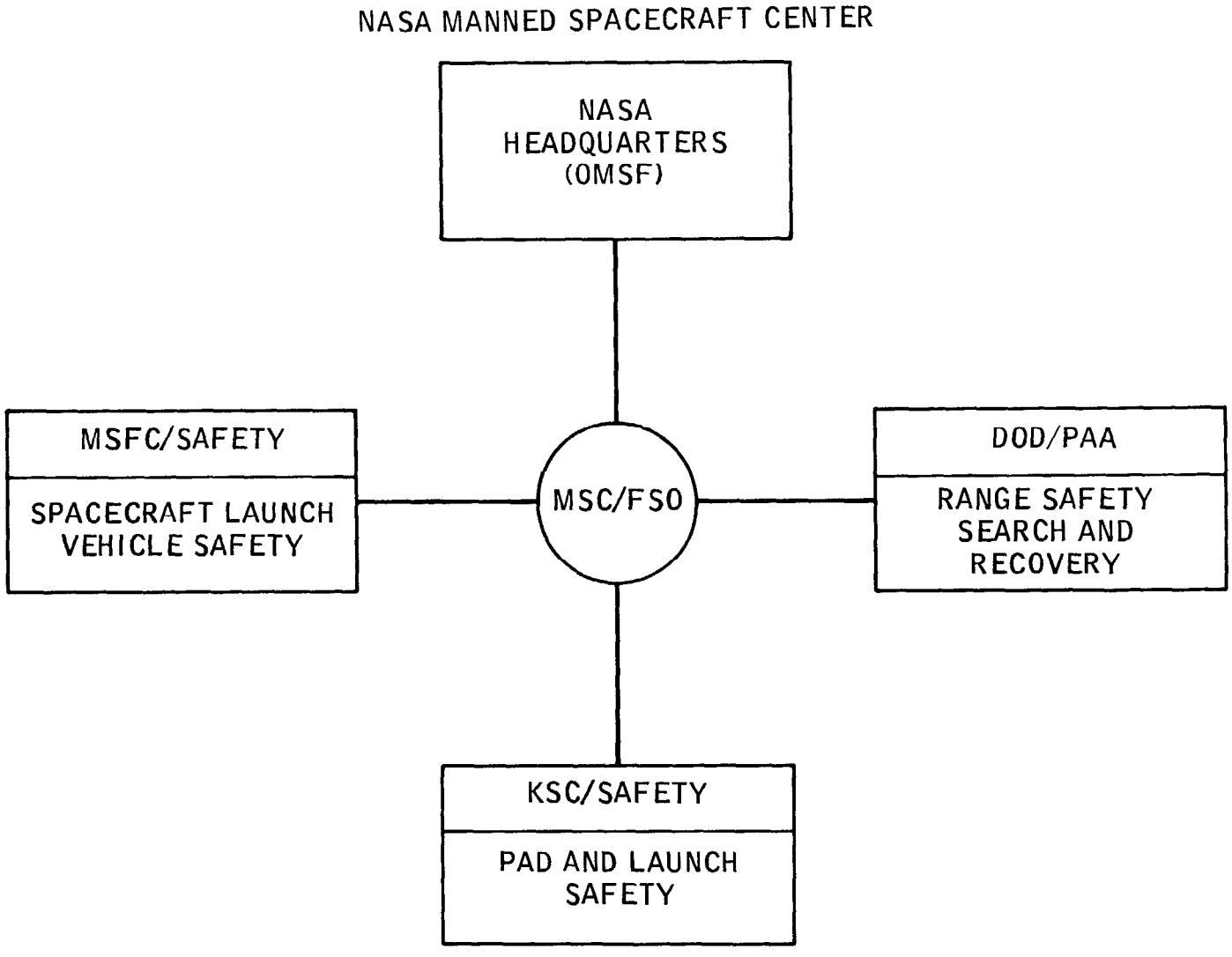

Figure E9-4.- MSC interrelationship with other organizations safety offices.

(c) Bioenvironmental engineering

(d) Security

2. Missile ground safety as required.

3. Range safety.

4. Search and sea recovery.

John F. Kennedy Space Center

The Kennedy Space Center takes the test and checkout requirements and test and checkout specifications and criteria documents prepared by the development centers and develops plans and procedures for the handling and launch of spacecraft. To accomplish this responsibility, KSC prepares and coordinates Test and Checkout Plans and implementing Test and Checkout Procedures.

The KSC Safety Office.- This office plans and manages an integrated hazard-assessment and risk-reduction program for all activities at KSC and for all NASA activities at both Cape Kennedy Air Force Station (CKAFS), Florida, and Vandenburg Air Force Base (VAFB), California. This program includes:

1. Handling, storing, and transporting hazardous items such as missile propellants, ordnance, high-pressure gases, toxic fluids, and radioactive devices.

2. Insuring safety requirements are included in all contracts initiated or administered by KSC and that contractor performance is periodically evaluated.

3. Performing engineering system safety studies to assure inclusion of safety requirements in engineering design of space vehicle test and checkout (launch complex and ground support equipment/facilities and operations).

4. Insuring that safety controls and required support are in effect during performance of all operations.

5. Approving siting, construction, and modification plans for safety aspects.

The office conducts safety surveillance while selected operations are actually in progress, with authority to halt activities under specified circumstances.

Prior to publication of a test and checkout procedure (TCP) for (a) operational checkout of flight hardware, (b) functional verification and operational control of GSE, and (c) operational instructions to service, handle, and transport end-item flight hardware during prelaunch and launch operations, the KSC Safety Office reviews and approves these procedures to assure that operations are compatible with KSC safety criteria and use appropriate safety personnel, techniques, and equipment.

Prior to publication of a technical procedure involving hazardous operations to (a) authorize work, (b) provide engineering instructions, and (c) establish methods of work control, the KSC Safety Office reviews and approves the procedure to assure that operations are compatible with KSC safety criteria and use appropriate safety personnel, techniques, and equipment.

During selected operations that involve hazardous sequences, the Safety Office has representatives on site. In the case of major integrated tests, i.e., CDDT, the number of representatives can be as high as 12, with three people on station in the Launch Control Center firing room and the remainder at various positions on the launch pad. The safety representative insures that safety requirements are implemented, approves or disapproves on-the-spot changes to Category I procedures made either by Procedure Change Request (PCR) or Deviation Sheets and assists the test supervisor in obtaining resolution on matters that have safety overtones.

North American Rockwell Corporation - Space Division

The NR System Safety Plan for the Apollo CSM program is the implementing document for the program required by MSC specification under the basic CSM contract.

The objective of the system is the elimination or control of risks to personnel and equipment throughout the manufacture, checkout, and flight missions of the Apollo CSM. To achieve this objective the CSM system safety program has an organization as shown in figure E9-5. The CSM System Safety Office reports directly to the CSM General Manager and is headed by the Assistant to the General Manager for CSM System Safety. The Assistant to the General Manager for CSM System Safety acts for the General Manager in the conduct of activities relating to all facets of safety for the CSM programs, and is a permanent member of the Space Division Safety Committee. He directs and monitors program activities necessary to assure an effective system safety program. He is responsible for preparation and compatibility of the CSM system safety programs at all sites with the exception of Launch Operations at KSC.

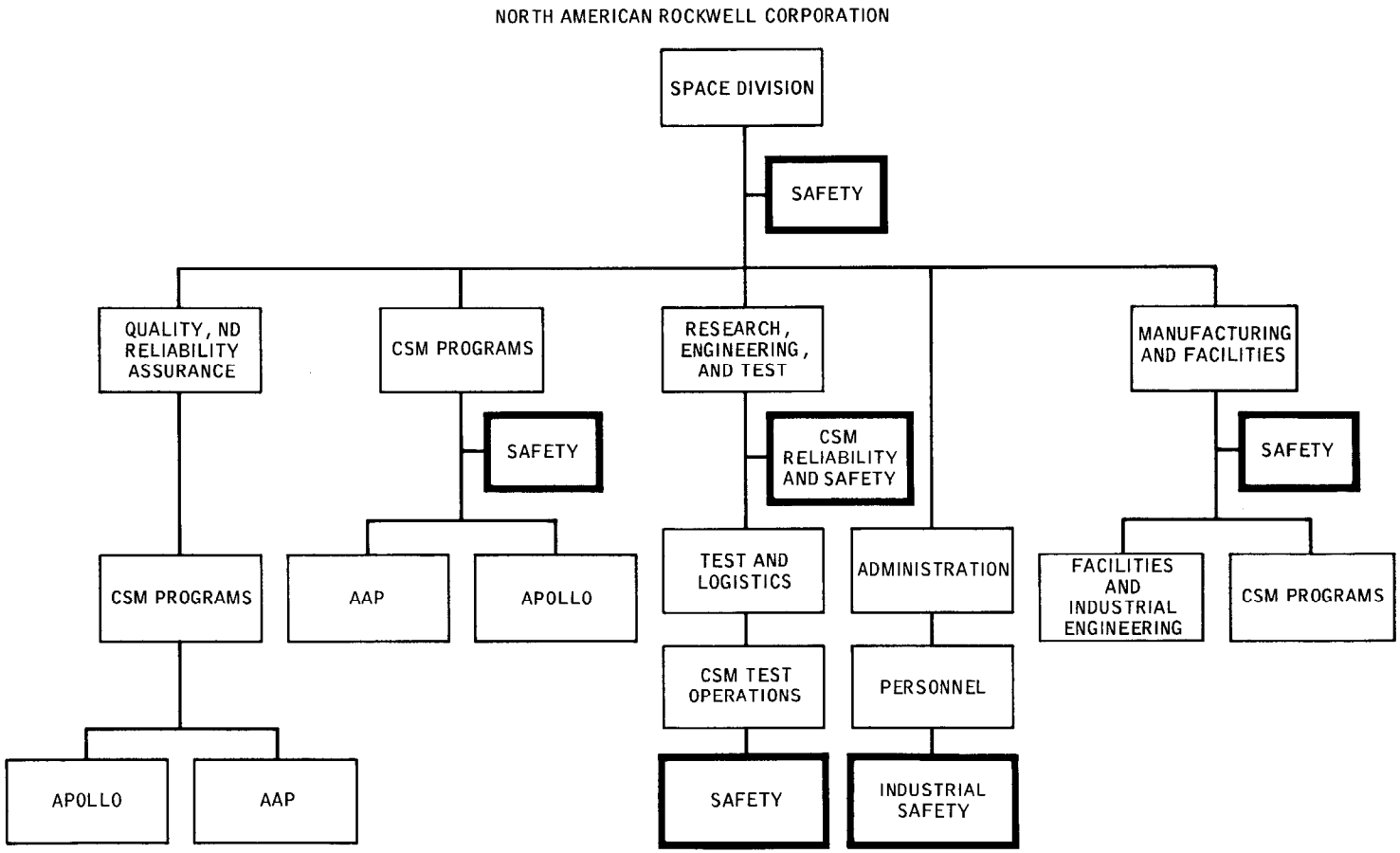

Figure E9-5.- Apollo CSM System Safety Program organization.

Specific responsibilities of the NR CSM Safety Office include:

1. Develop and direct the system safety program for the CSM programs.

2. Participate in Customer Acceptance Readiness Reviews (CARR's) and Flight Readiness Reviews (FRR's) and assess problems submitted for flightcrew safety impact.

3. Supervise the three CSM functional departments relative to system safety and interface with other agencies and divisions of NR concerning CSM safety.

4. Participate as a member of the NR Change Control Board (CCB) to review proposed changes and assure changes do not jeopardize ground and flightcrew safety.

5. Maintain status report system on all safety problems and design changes affecting safety.

The Engineering Division System Safety Office:

1. Reviews and evaluates safety effect of all Engineering Design Change (EDC) packages.

2. Reviews and assesses engineering analyses such as FMEA's, SPF's, and similar documents for identified hazards which jeopardize crew safety. Evaluate their corrective action and disposition.

3. Participates in postflight evaluations when requested by MSC for evaluation of crew safety problems.

The Manufacturing Division System Safety Office:

1. Provides safety checklists to aid manufacturing personnel in preparing documents and conducting safety surveys.

2. Assures that CSM manufacturing test, handling, and transport procedures and work documents contain appropriate system safety provisions.

3. Assures that operations defined as safety-critical are adequately planned and monitored.

The Test Operations System Safety Office is responsible for protection of the operational integrity of the CSM during checkout at Downey and testing at field sites. This office:

1. Generates system safety checklists for preparing Test Operations and conducting safety surveys.

2. Reviews all test, checkout, and operations procedures for adequate system safety requirements.

3. Reviews all safety-critical operations to assure adequacy of test set-up, documentation, and personnel qualification. Assures that adequate emergency plans and procedures are established and in use for these safety-critical operations.

4. Coordinates crew safety provisions and requirements and, when appropriate, recommends corrective action for identified hazards associated with crew procedures.

The Safety Plan appears to be operating satisfactorily according to the most recent MSC audit. The multiple safety offices and fragmented responsibilities warrant a critical review aimed at evaluating the expected effectiveness of a more centrally managed program.

The Reliability and Quality Assurance function, as shown in figure E9-5, has a functional responsibility to the corporate quality office and a program management responsibility to the CSM Program Manager. They are responsible for monitoring the manufacturing orders for proper R&QA callouts, verification inspection callouts, planned inspection callouts, and proper implementation of R&QA requirements in the planning operation. They also compile the System Summary Acceptance Documents (SSAD's) for Customer Acceptance Readiness Reviews (CARR's) and Flight Readiness Reviews (FRR's). They conduct quality inspections on manufacturing processes and testing operations and participate in design reviews. They also verify material usage and make and dispose of failed hardware.

The reliability function monitors design specifications and prepares failure effects and criticality analyses. They develop and supervise maintainability analyses, perform failure reporting analyses and recommend corrective action, support end-item reviews, perform problem investigations, and support the problem items.

Beech Aircraft Corporation

The overall organization of the Beech Aircraft Corporation, Boulder Division, is shown in figure E4-11, and a functional breakdown of the

office of the Apollo Program is shown in figure E4-12. The Beech Quality Control Plan establishes the detailed methods and procedures for accomplishing the positive quality control required by NASA of its contractors and subcontractors in the Apollo Program. The Beech plan does comply with the NASA requirements of NPC-200-2, "Quality Program Provisions for Space Systems Contractors" (ref. 11), and is applicable to the material, parts, components, subassemblies, installations, and system and subsystems purchased, tested, and manufactured for the Apollo supercritical gas storage system.

The system operates to assure maintenance of the basic approved configuration baseline by reviewing and documenting materials, processes, vendor-provided equipment, testing procedures, and manufacturing operations.

The Beech Reliability Program Plan provides for management and operation of the reliability system. It provides for the monitoring and reporting of all tests, and maintenance of a complete record of action on discrepancies and failures; and participates in corrective action and research required for Failure Mode Effects Analysis (FMEA) analyses, logic diagrams, math models, and reliability predictions and apportionments. Documentation of these efforts are furnished to the NR and NASA to fulfill contract requirements. The Beech Aircraft reliability and quality assurance organization and operation appear to be adequate and in compliance with contract and NPC-200-2 requirements. Manufacturing procedures and process control were surveyed and found in good condition and documentation such as the FMEA's was examined and found to be satisfactory.

SAFETY AND R&QA AUDITS

Regular audits of the Safety and R&QA functional areas are made of the field centers by NASA Headquarters teams. The Centers, in turn, make similar audits of their prime contractors. These contractors conduct audits and survey visits with their subcontractors and suppliers. In addition, the NASA Aerospace Safety Advisory Panel has reviewed certain aspects of the manned space flight safety program. These reports are included in the Apollo 13 Review Board files.

Consideration of these audits and reviews by the Management Panel showed no significant items relative to the Apollo 13 accident. The general functioning of the overall Safety and R&QA programs was found to be consistent with good practices.

MSC SAFETY/R&QA PARTICIPATION

The MSC Safety Office is responsible for implementing safety policies and assuring safety in design, development, and operation of spacecraft. The R&QA function is responsible for assuring that spacecraft and supporting systems are designed and built to perform in the environment for which they are built. The two functions, Safety/R&QA, are mutually dependent, have many common information and data requirements, and have many review and monitoring functions that support them both.

Safety/R&QA are closely involved in the entire design, development, test, and flight phase of all spacecraft components, systems, and subsystems. This includes participation in formal reviews such as the Preliminary Design Reviews (PDR), Critical Design Reviews (CDR), First Article Configuration Inspection (FACI), and Customer Acceptance Readiness Reviews (CARR) conducted by the Program Office. Safety/R&QA also participates in Design Certification Reviews (DCR) and Flight Readiness Reviews (FRR).

These offices implement general policy and establish specific programs for contractors. They then monitor these programs throughout the contract period to assure safety and quality of performance by the contractor.

This review considered some of the activities of these two offices from the CARR through the post-touchdown phase of the command and service module of Apollo 13.

CARR's are held in two phases at present: Phase I prior to the initiation of subsystem testing and Phase III prior to shipping the assembled vehicle. MSC R&QA reviewed documentation for Phase III CARR for CSM 109 with the following specific results.

Phase III CARR for CSM 109

1. No hardware will exceed its allowable operational storage limits during KSC operation and flight.

2. No known parts problems exist that will constrain shipment of CSM 109.

3. There are 854 Certification Test Requirements (CTR's) for equipment applicable to CSM 109. Testing is incomplete for six and certification will not be complete at time of delivery. This status is significantly better than previous CSM's, however, and shows an improving trend.

4. An improving trend in spacecraft quality was shown by a review of NR-Downey discrepancy reports on CSM 109.

5. Verification of nonmetallic materials has been accomplished and establishes that all exposed nonmetallic materials have been identified and approved or deviations written and accepted.

6. All known single-point failures applicable to CSM 109 have been reviewed and are acceptable.

A comparison of data shown in the R&QA review for CSM 109 and previous CSM spacecraft shows that CSM 109 has shown substantial improvement in most R&QA and safety categories and no decrement in safety in any area.

FRR R&QA Summary

The next formal review was the Apollo 13 Flight Readiness Review (FRR).

1. All limited-life items adequate to support flight.

2. No known electrical, electronic, or electromechanical problems exist that would constrain launch.

3. No Certification Test Requirements constrain flight, since all have been approved except one which will be certified by analysis prior to flight.

4. All known single-point failures have been reviewed and are considered acceptable.

5. The overall quality of CSM 109 shows a favorable trend relative to previous spacecraft.

The Flight Safety assessment at the FRR was:

6. The system safety assessment of planned mission flight activities and spacecraft functions disclosed no safety concerns that would constrain the Apollo 13 flight scheduled for launch on April 11, 1970.

7. Four changes from previous missions have been made which reduced flight risks.

8. The risks unique to Apollo 13 involve: (a) programming S-IVB stage for lunar impact during translunar coast; (b) performing lunar descent orbit insertion with CSM/LM docked; (c) operating power drill on

lunar surface; and (d) performing PLSS communication degradation test during lunar surface EVA. These risks are not of constraining magnitude.

Weekly Safety/R&QA Report

In addition to the formal CARR, FRR, and other reviews, information is furnished to the Apollo Program Office and the Director, MSC, on a weekly basis of the activity of Safety and R&QA relative to particular spacecraft through the Weekly Activity Reports. Abbreviated mention of some items from this Weekly Report from January 1970 to April 10, 1970, concerning the Apollo 13 and CSM 109 follows.

January 8-15, 1970.- Thirteen open certification items for Apollo 13 were reported. Pacing items are four lunar camera items scheduled to be closed in February.

January 15-22, 1970.- CSM 109 FRR data review generated 10 R&QA Review Item Dispositions (RID's). CSM 109 FRR subsystem working session was conducted at KSC on January 15-16. FRR RID's were generated and submitted for preboard action on January 25. Readiness statements were prepared for CSM 109.

January 22-28, 1970.- An assessment of CSM 104 through 109 failures at KSC was conducted. Detailed assessment will be made to determine reasons failures were not discovered at NR before shipment.

Safety Office briefed Astronaut Conrad on proposed procedure change for Mode 4 abort. Conrad will review with other astronauts, including Apollo 13 Commander.

January 30-February 4, 1970.- Ground support equipment (GSE) at KSC supporting CSM 109 is defective and may provide a countdown demonstration and countdown constraint unless the situation is remedied. NR is studying the problem. The Apollo 13 Safety Assessment Study of Mission Phases from translunar injection through CSM descent orbit injection has been completed and will be distributed by February 4, 1970. The biweekly meeting of MSC Safety/Boeing System Safety on Apollo mission concerns was held January 30. Seventeen Apollo 13 safety concerns were reviewed. Eight of the seventeen were closed.

February 12-18, 1970.- R&QA and Apollo Test Division met to discuss anomaly reporting effort. The discussion disclosed no duplication of effort and agreement was reached that the Apollo Mission Anomaly Test would be the guide for anomaly investigations. As of this date, only one GSE problem is open. It is expected to be resolved by the CDDT.

February 19-26, 1970.- The Safety Offices Assessment Report for Apollo 13 has been prepared. There are no constraining items in the report.

February 26-March 5, 1970.- The Apollo 13 R&QA Flight Readiness Assessment Report was completed February 26, 1970. R&QA agrees with the data and conclusions drawn. Of the five items listed as requiring verification, only one (referring to LM-7 rate gyro) is still active and should be resolved March 6. The Safety Office Assessment Report was presented at MSC's FRR on February 26, 1970. No constraining items exist. Two items are to be presented involving crew procedures.

March 20-26, 1970.- An R&QA review will be held during the afternoon and evening before the Apollo 13 launch to reaffirm launch, and results will be discussed with the CSM Manager. The mission plan and information notebook for the Apollo 13 mission is being prepared for Safety and R&QA mission support. The Safety Office provided the Deputy Manager with a written assessment of an R&QA single-point OPS/PLSS leakage failure. The Crew Systems Division is aware of the problem and is developing a work-around procedure.

April 3-9, 1970.- Open problems with potential Apollo 13 effectivity continue to be worked. Last planned status report to ASPO is scheduled for April 10, 1970. It is anticipated that all open problems will be closed or explained by that time.

April 10-16, 1970.- Final Apollo 13 Single Failure Point Summary was made during this time and approved by subsystem manager. All reported problems effective against Apollo 13 were closed or explained prior to launch. Also, all ALERTS for Apollo 13 were closed prior to launch. R&QA and Safety activities have been mainly to support changes in the mission brought about by loss of the oxygen supply.

Apollo 13 Mission Real-Time Activities

The Safety/R&QA functions support the premission and mission activities of Apollo flights in real time. The purpose of this support is twofold. First, the Safety/R&QA personnel, both in-house and contract, provide a contact for the mission group to call on for specialized support at any time during the mission from launch minus 9 days through splashdown. There are also specialized R&QA/Safety personnel available at the contractor's plants, NR and Grumman, for consultation as required. Secondly, the Safety/R&QA people are monitoring mission activities to make independent safety assessments and evaluations for future crew safety and mission readiness purposes. For this purpose, the monitoring team maintains a log of problems and occurrences that is used to prepare a

support anomaly list that is later resolved with the Project Test Division in the preparation of the Mission Anomaly list. The Safety/R&QA support operation for the Apollo 13 mission included the following activities:

Prelaunch. -

Daily problem closeout meeting: Meetings were held daily to review the status of hardware problems, certification tests, limited-life items, and other pertinent reliability concerns to assure that all potential problems had been properly evaluated and resolved. Headquarters R&QA was also represented at these meetings.

R&QA/Safety status meeting: A meeting of R&QA and Safety personnel was held on Friday evening, April 10, 1970, to review the status of all known and potential problems on Apollo 13. The meeting was chaired by the Manager, Safety and R&QA Offices. Following the meeting, the CSM Project Manager was informed of the results of the meeting. Headquarters R&QA was represented at the meeting.

Daily launch readiness problem report: This was initiated February 9, 1970, and the final report was issued on the morning of April 11, 1970, indicating no open problems against Apollo 13 hardware.

Daily bulletins: Apollo 13 bulletins were issued daily by the Control Center to keep personnel informed as to the status of Apollo 13 as it neared launch.

Countdown monitoring: Monitoring activities at MSC were initiated at T - 2 days and continued through the mission. Headquarters personnel maintained 24-hour monitoring of countdown activities at KSC up until launch.

Quality data review: MSC quality personnel at KSC reviewed IDR's DR's, etc., at KSC as the problems occurred to assure immediate evaluation of these problems.

Problem review and evaluation: Safety/R&QA participated in review and evaluation of hardware problems to determine potential mission impact. These included the lunar module cryogenic helium tank pressure rise problem and the oxygen tank umbilical quick-disconnect leakage occurrence.

Launch to accident. -

Monitoring activities: Real-time monitoring of Apollo 13 was maintained at MSC and in the GE Mission Evaluation Room offsite. A

control center was also manned by contractor personnel on a 24-hour basis to provide a central focal point for all Safety/R&QA missions activities.

Daily bulletins: Bulletins reporting the mission status were issued daily.

Flight anomalies: As suspect flight anomalies occurred, they were posted in the Control Center. R&QA personnel were requested to review and evaluate these occurrences as soon as feasible after the events were reported.

Requests for support: Requests for R&QA support for Test Division or other NASA groups were received and were worked as required. Three such requests were received prior to the accident. These requests were for failure histories, failure mode evaluations, etc., on the cryogenic helium tank pressure rise problem, the ECS suit pressure transducer, and on the oxygen tank no. 2 quantity gaging probe problem.

Postaccident.-

Safety/R&QA activities immediately following the Apollo 13 accident concentrated on compilation of subsystem data to determine the factors involved in the safe return of the crew--including single failure points. It included:

Safe-return factors: Each spacecraft subsystem was reviewed to identify those areas and concerns affecting the safe return of the crew in the emergency Apollo 13 configuration. A "Safe Return Factors" book was compiled and made available for reference in the Planning Room (GE).

Quality data: The quality control data on the CSM 109 oxygen tank no. 2 was compiled and a search of these records for any questionable items was initiated.

Historical data: The historical data, including failures, on similar oxygen tanks were searched for evidence of significant problem areas, as was the test and checkout history of the CSM 109 cryogenic and EPS systems.

Flight data review Safety/R&QA: Personnel participated in the review of flight data as a part of a team.

Configuration review: A review of the equipment and its relative location in bay 4 of the SM was made.

Single failure points: A study was prepared listing all Criticality I SFP's in both the CSM and the LM based upon the emergency configuration of Apollo 13.

Unexplained anomalies: A review was made of each of the explained anomalies approved for Apollo 13 to determine any potential connection with the Apollo 13 accident.

Daily review meeting: An R&QA/Safety Review meeting was held daily at 4 p.m. c.s.t. on April 14-17, 1970, to review the status and progress of the activities listed in the preceding paragraphs. The Manager, Safety and R&QA, strongly emphasized during these meetings the need to concentrate on those activities affecting the safe return of the astronauts. The activities designed to determine the cause of the accident were pursued only when they did not interfere with this primary concern.

CONCLUSION

The MSC Safety/R&QA plans and procedures appear to be adequate and complete for their assigned responsibilities. Their maintenance of equipment and system records, identification of suspect and failure areas, and followup corrective actions through the Government and contractor organization are adequate. Monitoring of contractors is presently accomplished with onsite personnel and visits rather than by formal audits. This appears adequate at present but should be supplemented by formal audit visits whenever possible.

The preflight System Safety Assessments made for each flight of the Apollo Program are thorough and timely and the flight monitoring support of Safety/R&QA is good. The postflight anomaly identification and tracking system is good.

The Safety/R&QA area appears to be generally adequate with proper procedures, good organization, and well-motivated personnel.

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PART E10

SECURITY

Security surveys were conducted at Beech Aircraft Corporation, Boulder Division, and North American Rockwell Corporation, Downey, California, during the time period of April 27, 1970, through May 5, 1970.

The purpose of these investigations was to evaluate the adequacy of the security programs at each location during the time periods that the Apollo oxygen tanks were in custody at the respective industrial plants. An extension of the accident investigation involved reconstructing the security systems and procedures applicable to the oxygen tanks from the time of shipment from NR to KSC and through launch of Apollo 13 on April 11, 1970. To fulfill the stated purpose of this inquiry involved evaluation of security programs at Beech, NR, and KSC from April 1, 1966, through April 11, 1970.

The security programs at each contractor location were found to be satisfactory and adequate to provide for the physical protection of the oxygen tanks. The security procedures provided at KSC were found excellent and assured the integrity of all Apollo 13 hardware from initial receipt on June 26, 1969, through launch on April 11, 1970.

Federal and local agencies acquainted with the security programs at NR and Beech were contacted and gave favorable evaluations of each contractor's performance during the pertinent time period.

Industrial security files were reviewed for incidents involving the oxygen tanks at Beech and spacecraft 106 and 109 at NR. The results at Beech were negative, and the incidents located at NR have been reported for technical evaluation in the preliminary report submitted May 8, 1970, to the Review Board Chairman and Manager, Apollo Spacecraft Program Office.

The determination reached as the result of this survey is that no evidence was discovered that the failure of the Apollo 13 oxygen tanks was the result of any willful, deliberate, or malicious act on the part of an individual at the contractor facilities surveyed or at KSC. Physical security measures were sufficiently designed, implemented, and monitored so as to preclude unauthorized access to the hardware associated with this investigation.

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