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APOLLO EXPERIENCE REPORT - SAFETY ACTIVITIES

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This paper describes the flight safety experiences gained during the Apollo Program and discusses safety from the viewpoint of program management, engineering, mission planning, and ground test operations. Emphasis is placed on the methods used to identify the risks involved in flight and in certain ground test operations; in addition, there are discussions on the management and engineering activities used to eliminate or reduce these risks.

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SUMMARY

The success of the United States manned space-flight program has been, to a great extent, a direct result of the emphasis placed on safety by NASA management. The reorganization of the NASA Lyndon B. Johnson Space Center (formerly the Manned Spacecraft Center) safety efforts after the Apollo spacecraft 204 fire was necessary for a concerted safety effort. All the relevant safety activities were coordinated through a single office and resulted in a strong, centralized approach to crew and mission safety. The establishment of a formal documented hazard analysis for each mission was effective in identifying significant hazards and assuring satisfactory resolution of hazards at an appropriate high level in the Lyndon B. Johnson Space Center organization.

A safety program requires an adequate complement of qualified engineers, a free hand to conduct independent assessments, and the full support of top management. With these ingredients, an effective safety program is assured.

The Manned Flight Awareness Program introduced early in the Apollo Program was a motivational program to achieve a high level of safety, reliability, and quality consciousness of all program participants. Its success was greatly enhanced by astronaut participation.

INTRODUCTION

The success of the United States manned space-flight program has been, to a great extent, a direct result of the emphasis placed on safety by NASA management. The basic safety objective has been to identify hazards and to ensure that these hazards are either eliminated or reduced to an acceptable level. With the exceptions of the Apollo spacecraft (SC) 204 fire and perhaps the Apollo 13 mission, the hazards had been adequately identified and properly resolved. Throughout the series of manned space-flight programs (Mercury, Gemini, and Apollo), the safety of the crew was given primary consideration during hardware design, manufacturing, testing, mission planning, and flight operations.

The purpose of this paper is to summarize the safety-oriented activities of personnel at the NASA Lyndon B. Johnson Space Center (JSC) (formerly the Manned Spacecraft Center (MSC)) and at major contractor plant sites. Although everyone is expected to be safety conscious, some things that are inherently unsafe under certain conditions are not easily recognized. The identification of hazards requires a dedicated and conscious effort by appropriately trained safety personnel who possess the experience and capability to properly assess the risks throughout all phases of the manned program and to take appropriate action to eliminate or reduce the risks to an acceptable level.

During Project Mercury, the Gemini Program, and the early stages of the Apollo Program, a Flight Safety Office at MSC reported to the Center Director. The function of this office was to coordinate the overall safety effort at NASA and the major contractors. It had a small staff and acted in an advisory capacity to each program office. Throughout Project Mercury and the Gemini Program, crew safety and mission safety activities were carried out by the Flight Safety Office, the responsible program offices, and the engineering and other support groups at both NASA centers and major contractors. This method worked well because the groups were small enough for the individuals to maintain good communications, were personally known to each other, and had a broad view of the requirements so that the safety efforts were well integrated.

As the Apollo Program progressed from design definition to hardware fabrication, substantial numbers of new personnel were added to the program, numerous reassignments of personnel were made, and functional reorganizations were implemented over a period of months. Coupled with these changes, the hardware testing phases brought added activity, and the resolution of test hardware failures absorbed more and more time. During this period, the size and technical makeup of the Flight Safety Office did not grow sufficiently to maintain visibility into the rapidly expanding Apollo Spacecraft Program hardware and procedures activities. All the above resulted in some loss of communication and visibility between the Flight Safety Office and the engineering and test operational elements.

After the Apollo SC-204 fire, one of the organizational changes made at MSC grouped most of the Center safety organizations into the Flight Safety Office reporting directly to the Center Director. Another change was the creation of a staff position in the Apollo Spacecraft Program Office (ASPO) as the MSC point of contact with the Apollo Systems Safety Office at NASA Headquarters. This staff position, called the ASPO Assistant Program Manager for Flight Safety, was a position designed to expedite implementation of the MSC Flight Safety Office policies and procedures. This provided a good opportunity to integrate the efforts of the MSC Flight Safety Office and the ASPO flight safety activities. The arrangement worked very well by opening up the communications channels between the various groups working different aspects of flightcrew and mission safety. At the same time, several reliability and quality assurance elements at MSC were also combined into a single office reporting directly to the Center Director. Although these changes in the reliability and quality assurance (R&QA) organizations did not directly affect the Flight Safety Office, they had the indirect effect of making available, on a day-to-day basis, data and information that were essential to Flight Safety Office personnel in performing their tasks. This interchange and coordination was aided by placing both organizations under the direction of one person.

A further enhancement of the MSC Flight Safety Office capabilities occurred in late 1967 when additional support (contract) manpower was made available to the Flight Safety Office; this support consisted of experienced engineers trained in safety techniques and procedures. The local MSC group was part of a larger contract covering engineering and safety at MSC, NASA Headquarters, and the other NASA centers involved in the manned space-flight effort; thus, a large reservoir of experienced engineering talent was available to provide assistance when required. These changes, both organizational and personnel, were sufficient to reestablish a planned, orderly, and coordinated approach to crew and mission safety.

THE MSC SAFETY OFFICE ACTIVITIES

Evolution of Systems Safety Discipline

Under the new organization previously described, the MSC Safety Office activities were defined as follows.

1. To examine all phases of each mission for hazards (i.e., flight plans, crew procedures, mission rules, design changes, contingency plans, training, etc.)

2. To examine all mission-related ground activities that involved the flightcrews and backup crews for hazards (i.e., extravehicular-activity (EVA) procedures, crew training, ground test and checkout, simulated flight tests, vacuum chamber tests, recovery training, etc.)

3. To assure that hazards identified in items (1) and (2) were appropriately resolved for future missions and ground operations (Resolution of hazards was to be accomplished through normal channels used to implement the Apollo Spacecraft Program.)

As a part of the foregoing effort, the safety offices of the major contractors were strengthened to ensure the proper integration of their own and their subcontractors' safety efforts. The MSC did not require that the subcontractors institute a dedicated safety office; it was considered that the responsibility for safety should rest with the major contractors who would eventually receive the hardware/software from the subcontractors. In this manner, the major contractors maintained an overall safety effort with their own safety staffs. The approach proved acceptable.

The Safety Office personnel conducted their duties by active participation in design reviews, test procedure reviews, and the development of crew procedures. As safety issues were identified, they were resolved immediately or were presented to the ASPO for resolution at scheduled meetings and milestone reviews. Typical reviews that safety personnel participated in are as follows:

1. Configuration Control Board
2. Configuration Control Panel
3. Preliminary Design Review
4. Critical Design Review
5. Design Certification Review
6. Customer Acceptance Readiness Review
7. Flight Readiness Review
8. Crew Procedures Change Board
9. Mission Rules Review
10. Launch Readiness Review

The ASPO and the MSC directorates involved in the Apollo Spacecraft Program provided adequate forums for formal discussion by the MSC Safety Office of any hazards that required attention. This management visibility in depth, operating in an atmosphere that encouraged personnel with problems to come forth and be heard, was a major contributing factor in enhancing the safety of the Apollo missions. In addition to these meetings and milestone reviews, the MSC Safety Office presented formal analyses and assessments of systems safety and mission risks to the ASPO and to the Center Director at each mission Flight Readiness Review. At that time, the Mission Hazard Analysis (refer to the appendix), which identified safety concerns as well as the rationale for acceptance of the risks, was documented for the Flight Readiness Review Board.

Hazardous and Critical Tests

The MSC flight safety engineers participated with teams composed of specialists from varying disciplines in reviewing the development and installation of facilities, test procedures, and special safety procedures to support hazardous test activities at MSC. Chief among these were the thermal-vacuum tests conducted in the Space Environment Simulation Laboratory in which manned spacecraft modules were subjected to simulated space environments in vacuum chambers. Safety personnel were concerned with the safety of test personnel and test subjects. They assessed and evaluated the safety of the chambers including the associated plumbing, wiring, evacuation systems, environmental control systems, and pressure vessels. Detailed and thorough operational readiness inspections and test readiness reviews were conducted before commencement of manned tests. Safety personnel had key roles in these tasks and in the development of safety parameters and their limits for use in manned testing. Certified test safety officers participated in the manned tests to ensure adherence to these established parameters and limits.

System Safety Assessments

System safety assessments consisting of hazard analyses and special safety studies of Apollo contractor-furnished equipment, Government-furnished equipment, ground support equipment, and experiments were performed. These assessments were accomplished by (1) analyses of ground support equipment to determine interfaces with flight hardware that could adversely affect crew safety; (2) performance of detailed evaluations in those design and operational areas shown to exhibit risk potential; (3) performance of or participation in hazard trade-off studies of designs, operational procedures, and mission concepts; and (4) detailed analyses of those proposed changes to subsystems, operational procedures, plans, rules, and activities considered to have safety impact.

To aid in the safety analysis of extremely complex systems, "fault-tree" analyses were conducted. These were logic diagrams that represented the mechanical, electrical, and/or chemical interfacing points between subsystems. The analyses were a valuable tool in identifying potential hazards.

In the Apollo Program, hazard analyses were performed for man/machine interface to isolate crew safety concerns. Trade-off studies and engineering assessments for compliance with system safety criteria were performed relating to crew safety, operational personnel safety, and system safety. Trade-off studies were also performed for specific hardware and operational areas, so that the relative crew risks for any of several alternative solutions might be compared.

Operational safety assessments were performed on crew procedure changes, flight plans, mission rules, crew checklists, and crew training to ensure adequacy and compatibility of crew procedures and flight operations for each Apollo mission. Hazardous procedures were identified and recommendations were made to reduce the risk by modification of the existing procedures. The review of operational tasks resulted in procedure change requests, special studies of potential operational concerns, safety evaluation of mission operations, and documentation of crew and mission operational hazards.

Safety evaluations of flight hardware consisted of (1) assessment of the configuration differences between vehicles to determine whether system or subsystem changes had introduced any new hazards into the vehicle; (2) review of waivers or deviations of specifications in manufacturing, test, or checkout procedures; and (3) sneak circuit analyses (SCA) of wiring systems to detect potential hazards from wiring or electrical system incompatibilities. A sneak circuit is a latent electrical path that can cause an unwanted function to occur or inhibit a desired function without regard to component failures. The SCA was first used on the Apollo 7 spacecraft and was performed for all subsequent spacecraft of the Apollo Program, both the LM and the CSM.

Mission Risk Assessment

Concurrent with the effort to provide system safety assessments, each individual mission was analyzed as an integral unit in an effort to isolate and assess risks to mission operations and crew safety. Once a hazard was identified and evaluated, it was brought to the attention of program management. It was then tracked throughout the mission preparation period until corrected by an engineering or procedural change (usually a decision of the Configuration Change Board or Panel) or approved by the Safety Office and the ASPO as an acceptable risk.

Periodic meetings were held with the safety personnel of the major contractors to discuss and evaluate hardware and operational problems that might have potential crew safety impact. The reports emanating from these meetings provided an up-to-date status of safety concerns under evaluation and of safety issues to be resolved. A safety concern was a specific hazard requiring positive action to correct; a safety issue was a potential hazard, the implications of which had not been completely resolved. The status report was forwarded to the ASPO and to the R&QA organizations which, in periodic meetings with safety personnel, considered each safety concern for proper resolution.

A mission risk assessment was performed for each Apollo mission to provide a final and definitive evaluation of residual hazards and risks affecting the crew. The mission risk assessment supported the Flight Readiness Review at MSC. This report highlighted the more significant crew safety risks assessed during the mission buildup period, the results of analyses of these risks, and supporting rationale for acceptance of residual hazards, where appropriate. A portion of the Apollo 16 Mission Risk Assessment is included in the appendix.

Mission Monitoring and Postflight Evaluation

The work described in previous paragraphs dealt with preflight safety activities. However, the responsibility of the MSC Safety Office did not end with the launch of an Apollo mission. Mission monitoring support was provided to enable real-time safety engineering support in the assessment and evaluation of mission discrepancies and identification of hazardous trends that might have a potential impact on crew safety or mission success. Continuous monitoring of flight hardware and the flightcrew made possible the identification of real or potential safety hazards. Recommendations for the resolution or elimination of these hazards were routed through the Spacecraft Analysis Network (SPAN) for verification by the appropriate subsystem monitor, and to the Mission Control Center for final approval and implementation by the Flight Director.

The Safety Office further participated in the postflight review of failures and anomalies associated with system performance or crew procedures that had safety implications on succeeding missions. Any such failure or anomaly was examined at the appropriate contractor's plant to make a determination of the actual cause. When such a determination was made, the suspect part or procedure for each succeeding mission was reevaluated, redesigned, retested, rewritten, or eliminated.

Audits

To ensure that the safety requirements were being met and that continued emphasis was being placed on system safety by all participants, periodic audits were performed by the MSC Safety Office at major contractor production, assembly, checkout, and test facilities. The contractors were required to develop system safety checklists that detailed those steps introduced in their facilities to ensure adherence to the safety requirements. The checklists were used by MSC Safety Office personnel at the contractor facilities to provide on-the-spot assurance that the requirements were actively implemented.

Motivational Programs

To achieve a high level of safety, reliability, and quality consciousness in all program participants, it became evident that a singular motivational program was required. People tend to think of safety, reliability, and quality as abstract terms; the problem was to make that abstraction real, tangible, and relatable and then to keep the awareness of these important functions as an active effort constantly before them.

The Manned Flight Awareness Program was introduced early in the Apollo Program to fill this need. The cooperation of a popular cartoonist was solicited to make his comic beagle "Snoopy" (from the cartoon strip "Peanuts") the principal spokesman for the program. Motivational posters featuring Snoopy in space togs were soon in evidence wherever people were at work on the Apollo Program. The Snoopy messages constantly emphasized the need for care and attention to detail.

The astronauts contributed to the success of the program. They attended functions at each of the space-flight centers, honoring contributors to the program by presenting Snoopy pin awards. Apollo crewmen toured the facilities of the major contractors to meet the workers who were building and testing the Apollo mission hardware.

Special Studies and Assessments

As the Apollo Program matured and progressed, missions became longer and more complex. The NASA began to take optimum advantage of lunar surface exploration through the use of more sophisticated experiments packages and of the command and service module (CSM) lunar orbits by incorporation of experiment hardware in a bay of the service module. Each element of growth contained potential crew hazards, and each was the subject of a special safety assessment by the MSC Safety Office. The principal special assessments are discussed in the following paragraphs.

Extravehicular activities. - The Apollo Program included a wide variety of EVA's beginning with Apollo 9 when the lunar module (LM) pilot first stepped out of the LM while in Earth orbit. The first Apollo EVA safety assessment (conducted before the mission) resulted in a listing of 10 criticality 1 hazards, each of which had to be analyzed to determine its probability of occurrence. Each potential hazard was finally deemed improbable after a lengthy rationale was prepared, which reinforced confidence in the hardware design and testing. None of the following 10 potentially hazardous events occurred.

1. Ventricular fibrillation in the LM pilot could occur.

2. Collision with the spacecraft might rupture the pressure garment assembly (PGA).

3. The EVA astronaut might lose contact with and attachment to the spacecraft.

4. The EVA astronaut might have a failed portable life-support system/oxygen purge system (PLSS/OPS).

5. Undetected carbon monoxide might be present in the EVA astronaut PGA.

6. The open failure of the oxygen purge system (OPS) might cause a rupture in the PGA.

7. The EVA astronaut rescue capability might not be immediately available.

8. The OPS redundancy might be lost.

9. Degradation of the OPS would leave only marginal contingency EVA capability.

10. Loss of the LM attitude control might render the LM unstable and would make recovery difficult.

In a similar manner, the first lunar surface EVA on Apollo 11 was analyzed before the mission, and this analysis isolated the following 11 potentially hazardous areas of concern. The Safety Office prepared recommendations for the elimination or reduction of these potential hazards and forwarded them to the appropriate organizations for consideration. Most of the recommendations were accepted.

1. Pyrophoric reaction of lunar material with the LM oxygen atmosphere might occur.

2. A rupture of the lunar contingency sample container might occur in the cabin.

3. Damage to the extravehicular mobility unit (EMU) might occur if a crewman were to fall on the lunar surface.

4. Crewmen might be unable to detect the presence of sinkholes, deep dust pits, or subsurface faults.

5. Because of scratching or tearing on spacecraft protuberances, a compromise of the EMU pressure, thermal, or radiation integrity might occur.

6. Inability of the crewmen to obtain adequate footing on the plus-Z footpad could be caused by dust or debris acquired at landing.

7. Inability to determine the temperature of tools, equipment, et cetera, could result in damage to the EMU upon touch.

8. A fallen crewman might be unable to recover and return to the LM before the loss of EMU consumables.

9. Crewmen ingress or egress could be difficult when the plus-Z footpad is not in contact with the lunar surface.

10. Deployed television camera cable and S-band antenna cables could pose a tripping hazard to crewmen.

11. The crewman inside the LM might be unable to observe the egressing crewman.

Apollo lunar surface experiments.- Apollo 11 carried a comparatively simple package of scientific hardware for deployment on the lunar surface. These experiments, however, had some inherent potential hazards that were assessed before the flight. Of major concern was the fuel capsule for the radioisotopic thermoelectric generator used to supply power to the Apollo lunar surface experiments package. The capsule used plutonium-238 as its isotope, and the inadvertent release of this radioactive substance was a matter of great concern. The capsule was subjected to analysis by the Safety Office and representatives of the Atomic Energy Commission who concluded that the device was safe to use when used according to the prescribed procedures. To illustrate the thoroughness of this assessment, consideration was given to the possibility that the fuel capsule might be returned to the Earth atmosphere in the event of a mission abort. The analysis concluded that the capsule, as designed, was adequate to survive reentry and would release no radioactivity. This conclusion proved correct when the Apollo 13 mission aborted and the LM (which had served as a "lifeboat" for the astronauts when the CSM was partly disabled) reentered the Earth atmosphere and broke up over the Pacific Ocean. The fuel capsule was still on board and, as predicted by the preflight analysis, did not contaminate the atmosphere with radioactive material.

Other significant studies.- Other significant studies made between 1969 and 1972 included a system safety engineering hazard analysis of the LM pyrotechnics and the CSM launch vehicle separation pyrotechnics (Feb. 1969), a LM-6 critical switch study (Sept. 1969), a CSM circuit breaker accessibility study (Sept. 1969), a LM circuit breaker review (Sept. 1969), a study of crew distractions during critical mission phases (Feb. 1970), a system safety assessment of the Apollo 12 anomalies and of the failure mechanism during the initial boost phase (Feb. 1970), a study of the active seismic experiment (Aug. 1970), a study of the CSM return enhancement provisions (Dec. 1970), and a study of the lunar seismic profiling experiment (Dec. 1972).

CONCLUDING REMARKS

The success of the United States manned space-flight program has been, to a great extent, a direct result of the emphasis placed on safety by the management of the NASA Lyndon B. Johnson Space Center (formerly the Manned Spacecraft Center). The basic safety objective has been to identify hazards and to ensure that these hazards are either eliminated or reduced to an acceptable level. With the exception of the Apollo spacecraft 204 fire and perhaps the Apollo 13 abort, the hazards have been adequately identified and properly resolved.

The reorganization of the NASA Headquarters and Lyndon B. Johnson Space Center safety efforts after the spacecraft 204 fire was necessary for the complex and expanded efforts of the Apollo Program. A greatly enhanced Safety Office visibility and comprehension of day-to-day safety status resulted in the reestablishment of a satisfactory approach to crew and mission safety. The fundamental change in organization that proved most effective was gathering the safety efforts under a single office that reported to the Center Director.

The establishment of formally documented hazard analyses for each mission was effective in identifying all significant hazards and assuring a satisfactory resolution of hazards at an appropriately high level in the center organization.

A safety program requires an adequate complement of qualified safety engineers, a free hand to make independent assessments, and the full support of management. With these ingredients, an effective safety program is assured.

The Manned Flight Awareness Program, introduced early in the Apollo Program, was a motivational tool used to achieve a high level of safety, reliability, and quality consciousness in all program participants. Its success was greatly enhanced by astronaut participation.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, November 14, 1974
039-00-00-00-72

APPENDIX

APOLLO 16 MISSION RISK ASSESSMENT

EXCERPTS AND SUMMARIES

The following pages have been extracted as typical examples of the Apollo 16 Mission Assessment Report.

"1.2 PURPOSE

The purpose of this assessment is to define and evaluate the risks associated with the Apollo 16 flight and lunar surface activities, to provide justification for discounting or accepting these risks, and to present an overall picture of the mission relative to crew safety.

"1.3 SCOPE

This document is limited to the presentation of the assessment of the Apollo 16 mission as related to flight crew safety from lift-off through earth landing. The assessment included analysis of each mission phase, including procedures, configurations, and potential impact of previously-observed anomalies on flight crew safety. This document applies to the MSC Flight Readiness commitments. Subsequent anomalies are evaluated on a day-to-day basis up to the launch time and are incorporated into this document as required.

"1.4 CONCLUSIONS

1.4.1 The new risks introduced into the Apollo 16 mission are acceptable and provide no flight constraints.

1.4.2 Assessment of the planned lunar surface activities, including the longer EVA's, longer traverses, and delta lunar surface experiments has uncovered no safety concerns which preclude the lunar activities or any planned lunar surface experiments. Improvement in the active seismic experiment from Apollo 14 has increased the safety margin for Apollo 16.

1.4.3 Assessment of the rendezvous technique changes which are incorporated for Apollo 16 indicate they should minimize controllable errors in the rendezvous calculations, thus improving overall mission success and crew safety.

1.4.4 Boom retraction modification of adding proximity switches has increased safety by enabling determination if booms are sufficiently retracted before an SPS[1] burn. (See note 1 below.)

1.4.5 Planned CM[2] in-flight demonstrations have been assessed for concerns related to crew safety, and no constraining safety concerns were identified. (See note 2 below.)

Note 1. The mass spectrometer and gamma ray spectrometer experiments were extended from the SM[3] Scientific Instrumentation Module by retractable booms. It is critical to have assurance that these booms are properly retracted before attempting an SPS burn; an unretracted boom could conceivably wrap around the SPS nozzle extension. Proximity switches were added on Apollo 16 to provide the crew positive assurance of boom retraction prior to the SPS burn. In addition, a boom jettison capability was added.

Note 2. During transearth coast, Apollo 16 crew conducted the following inflight demonstrations, each requiring experiment hardware and procedures which were subjected to safety analysis:

(1) ALFMED (Apollo Light Flash Moving Emulsion Detector)

(2) MEED (Microbial Ecology Evaluation)

(3) Electrophoresis In-Flight Demonstration

(4) Biostack Experiment (M211)

1.4.6 Safety assessments of anomalies occurring during manned environmental tests, previous flights, and vehicle ground tests have disclosed no significant safety concerns.

"1.5 RECOMMENDATIONS

None.

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[1]Service propulsion system.

[2]Command module.

[3]Service module.

"1.6 SAFETY STATEMENT APOLLO 16 MISSION

The Safety Office assessment of the planned Apollo 16 mission, spacecraft functions, and hardware failures disclosed no safety concerns which constrain the Apollo 16 flight scheduled for April 16, 1972. The assessment is based on safety analyses performed in coordination with and obtained from the Program Office, E&D, FOD, FCOD, MR&OD, SR&QA,[4] and the hardware contractors."

Section 2.0 provided a discussion of all constraining and nonconstraining safety concerns evaluated during the mission assessment. These concerns were assessed for crew safety during the period leading to the preparation of the report and were published in the MSC Safety Concerns document, released biweekly. The information included the issue, action, and status of each concern. The following list enumerates the concerns contained in the Apollo 16 Mission Assessment Report.

1. Range/range-rate meter glass shattered
2. Command and service module (CSM) criticality 1 switches
3. Gyro-display coupler aline function
4. Scratched Lexan window shade
5. Loose object in the cabin fan
6. Unexplained pressure increase in the CSM tunnel
7. Broken bacteria filter on water gun
8. Main oxygen regulator failure
9. Premature deployment of main parachute
10. Failure of docking ring to sever
11. Extravehicular glove wear
12. Command module (CM) reaction control system (RCS) fuel tank excessive delta pressure
13. Parachute reefing-line cutter

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[4]Engineering and Development Directorate; Flight Operations Directorate; Flight Crew Operations Directorate; Medical Research and Operations Directorate; and Safety, Reliability, and Quality Assurance Office.

14. Entry monitor subsystem "thrust on" light

15. Pressure garment assembly qualification test failure

16. Suited or unsuited scientific instrument module door jettison

17. The CM RCS oxidizer tank bladder overpressure

18. Impact test failure of helmet

19. CSM-113 propellant utilization and gaging system anomaly

20. Trapped CM RCS propellant overpressure

21. Circuit breaker mechanical latch problem

22. Earth landing system main parachute failure

The following information is contained in the report covering item 22, which illustrates the depth at which each item (1 to 22) was considered.

"Issue - The crew verified and photographic coverage confirmed that one main parachute collapsed at an altitude of 6,000 feet during the Apollo 15 mission. Four of the six nylon risers had released their suspension-line load. Loss of one main parachute exposed the crew to higher, but acceptable, loads; however, failure of more than one parachute could result in crew loss.

"Action - An NR[5] investigation and analysis revealed the cause of main parachute collapse not to be forward heat shield, the suspension links, or the steel risers being pulled from the flower pot. The most probable cause of the anomaly was the burning raw fuel (monomethylhydrazine) being expelled during later portions of the depletion firing. This resulted in the exceeding of the parachute-riser and suspension-line temperature limits. Corrective action taken has been to change the mode 1A abort timer to 61 seconds, to design and qualify new connection links made of Inconel 718, to load propellants to achieve a slightly oxidizer-rich mixture for a possible depletion-burn purge, and to require certification of the CM to land in the water with pressurized propellants onboard. Oxidizer and parachute tests at the NASA WSTF (White Sands Test Facility) are being conducted to investigate the effects of the CM RCS dump burn depletion and purge on the parachute assemblies. Recovery procedures and training are being updated to avoid possible crew exposure to toxic propellants as a result of the single failure points of the pressurized tanks at shutdown.

[5] North American Rockwell Corporation, prime Apollo contractor.

"Status - The concern has been closed on the basis of:

(a) The decision to land on water with pressurized tanks and

(b) The decision to extend the mode 1Z regime. The Safety Office will continue to scrutinize the current WSTF RCS/oxidizer tests for impact."

Section 3.0 of the Mission Assessment Report contained the Flight Operations Safety Analysis. The analysis was divided into approximately nine areas with each addressing a mission phase; for example, launch through orbit insertion, lunar orbit insertion, lunar module powered descent, lunar surface activities, et cetera.

Section 4.0 defined the safety evaluation of flight hardware differences between the mission under assessment and previous missions, the waivers and deviations, and the sneak circuit analyses for the upcoming mission.

Section 5.0 covered the manned environmental ground tests pertinent to the upcoming mission performed at the Space Environment Simulation Laboratory at the MSC.

Section 6.0 subjected anomalies from previous missions to analysis. Included were numerous anomalies from the previous missions that were evaluated for safety impact; breakdown by command and service module, lunar module, and Government-furnished equipment; and the status of each with respect to the upcoming mission.

Section 7.0 was an evaluation of real-time flight problems and was not contained in the first two releases of the Mission Assessment Report; this section was added after splashdown and recovery.

NASA-Langley, 1975 S-422