1972 NR review).

(d) Maintenance of technical excellence.

(e) Landing site effects.

Skylab Program

After a brief orientation early in the year the major activities conducted here included:

(a) Program problem solving mechanisms.

(b) Utilization of Apollo/Gemini experience and hardware.

(c) Supplier control.

(d) Management for interfaces and integration (design through checkout).

(e) Assessment against "Centaur" and "Delta" Board Reports.

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

OFFICE OF THE ADMINISTRATOR

JAN 26 1971

TO: Mr. Dale D. Myers, Associate Administrator, Office of Manned Space Flight

FROM: Dr. George M. Low, Acting Administrator

Since we will soon begin the Apollo "J" missions, I have asked the Aerospace Safety Advisory Panel to review the changes introduced with Apollo 15 and the attendant system for risk assessment, including those technical management systems that impact it.

I have also asked the Panel to review the continuing evolution of the risk assessment system on the Skylab and Space Shuttle programs. This again would include those technical management systems that would impact risk assessment.

The review, as now planned, will take the Panel to the Manned Space Flight Centers and appropriate major contractors beginning in early February.

The Manned Space Flight organization's continuing support of the Panel activities is appreciated.

George M. Low
GEORGE M. LOW
Acting Administrator

Attachment A

A REPORT TO THE ADMINISTRATOR

BY

THE NASA AEROSPACE SAFETY ADVISORY PANEL

ON

A REVIEW OF THE CHANGES

INTRODUCED WITH APOLLO 15 AND

THE ATTENDANT RISK ASSESSMENT SYSTEM

JULY 1971

Attachment B

CONTENTS

FOREWORD

This is in response to the Administrator's request of January 1971 for the Panel to review the changes introduced with Apollo 15 and the attendant system for risk assessment, including those technical management systems that impact it. The Panel, as a result of these reviews, provides here a judgment on the impact of changes and the attendant system for risk assessment by management.

The conclusions are offered to the Administrator for consideration in his review of the Apollo 15 mission changes and their management.

CONCLUSIONS

This is a concise statement of the conclusions reached by the Aerospace Safety Advisory Panel based on material presented between February and July 1971 on the Apollo 15 mission. Details are in the body of the report.

(1) The Apollo Program Office, Manned Spaceflight Centers and Apollo contractors involved in our review provided reasonable evidence that they have applied careful planning and responsible management to the design, development and qualification of new and modified elements of flight systems to be used in the Apollo 15 mission.

(2) The management system for risk assessment appears thorough; and through it, senior program management has concluded that the changes made in the Apollo 15 flight system to meet the "J" mission requirements have not impaired the previously attained crew safety level.

(3) To assure that the Administrator is provided adequate background on the Apollo 15 mission, items such as the following should be included in the Apollo "readiness review:"

(a) Mission rules constraining EVA if the satellite cannot be jettisoned or SIM booms retracted.

(b) Mission rules and the flexibility permitted the astronauts in operation of the LRV and assessment of LRV limitations.

(c) Status of changes in the spacesuit involving new zippers, bootbladders and increased PLSS capability.

(d) The assessment of risks associated with the use of a teflon outer-suit covering backed by flame retardant beta cloth.

(e) The possibility of using the LCRU television system for diagnosis of LRV malfunctions.

(f) The system for evaluating the impact of lightning strikes on the vehicle. Note should be made of the evaluation possible after hypergolic loading, particularly in the area of spacecraft engine logic.

(g) The system for assessment of risks associated with the jettison of the Scientific Instrument Module (SIM) door.

(h) The operational status of the KSC Launch Control Center Alert System.

(i) The unresolved nature of the anomaly on the docking probe and the basis for probe redesign.

(3) If the system configuration remains stable, and performance on Apollo 15 is as expected, the following are items that should be reviewed by senior management on subsequent "J" missions for their current significance:

(a) Possible age-life and storage problems.

(b) Changes in personnel assignments, individual responsibilities and other personnel actions.

(c) Changes in management systems and possible relaxation of program discipline and controls.

SUBJECT

Review of changes introduced on the Apollo 15 and future "J" missions, as well as the applied risk management system. To accomplish this review, the Panel convened at NASA and contractor sites to examine the new and modified elements of the Apollo 15 mission, their requirements, and those aspects of technical management necessary to achieve "J" mission objectives.

PROLOGUE

With the successful completion of the Apollo 14 mission or last "H" mission, program efforts are focused on the "J" missions of which Apollo 15 is the first.

Significant changes introduced with the Apollo 15 mission, scheduled for launch no earlier than July 26, 1971, included: augmented LM capability; Lunar Roving Vehicle and associated LM stowage changes; CSM Scientific Instrument Module (SIM) requiring Extra-Vehicular Activities (EVA); modified Extra-Vehicular Mobility Unit (EMU); and, the attendant launch vehicle modifications for increased payload capability. The task directed to the Panel is defined in a letter, dated January 26, 1971, from the then Acting Administrator, Appendix A.

In accordance with this request, the Panel visited the three manned spacecraft centers (MSFC, MSC and KSC); the Lunar Roving Vehicle Contractor at Kent, Washington; the Goddard Space Flight Center (GSFC); and the Apollo Program Office, Washington, D.C. These reviews occurred during the February to June 1971 period.

This report presents the Panel's conclusions based on this series of Apollo 15 reviews. Such judgments are presented for the Administrator's use in his oversight of NASA operations.

SCOPE AND METHODOLOGY OF REVIEW

The Apollo space vehicle system is beyond the development phase and well into the operational phase. With this in mind, the reviews emphasized the "H" to "J" mission and hardware differences, indicators of hardware problems, including test failure and prior flight anomalies, and ascertaining whether the hardware is being used in the manner intended. In addition, the reviews involved examination of systems which define hazards and their control (e.g., safety, reliability, quality assurance, test, maintenance) and the logic leading to accepted risk assumptions.

Since the review effort was supported by subsystem managers and project managers this afforded the Panel an opportunity to examine to some depth the existing manpower support at the field centers.

Basically, then, the Panel looked at each of the following general areas with its associated criteria for judgment:

(a) New and modified elements of the Apollo 15 space system for proof of design maturity.

(b) Prevailing management structure and policies with emphasis on the risk management activities including hazard identification and control, risk assessment, and risk assumption.

(c) Formal safety activity, its utilization, and impact.

(d) Apollo 14 anomalies and failures - their analyses and resolution with respect to Apollo 15.

(e) Retention of critical knowledge and skills with diminishing contractor and vendor support.

(f) The current relationship between centers in resolving inter-center hardware problems.

Each review (location and general content) is described below to help place the Panel's summary and conclusions in the proper perspective.

LOCATION:	MSFC, Huntsville, Alabama
DATE:	February 8-9, 1971
MATERIAL COVERED:	See Appendix B

The purpose here was, first, to understand the results of Apollo 14 and their impact on the launch vehicle assigned to Apollo 15; second, to examine launch vehicle changes; and, third, understand the Lunar Roving Vehicle (LRV) which forms a vital part of the new "J" mission space systems for Apollo 15, 16 and 17. In the area of LRV, the Panel was exposed to a basic type review on management, technical change status, and schedules only since the LRV itself would be examined in detail at both the contractor's plant (Boeing Company) and MSC.

LOCATION:	Apollo Program Office, Washington, D.C., and Goddard Space Flight Center.
DATE:	March 8-9, 1971
MATERIAL COVERED:	See Appendix C

This meeting provided the Apollo Program Director's assessment and top level view of two major areas. These were: an Apollo 14 mission report which covered in detail the anomalies resulting from that mission along with their resolution (as known at that time), and the Apollo 15 mission differences in both hardware and operations. The Apollo Program Director indicated the areas of risk (e.g., first time use of the LRV and SIM) and the steps being taken to minimize them. Included in this review was the role of the Manned Space Flight Network based at Goddard Space Flight Center indicating their part in such things as contingency planning.

LOCATION: The Boeing Company, Kent, Washington

DATE: April 12-13, 1971

MATERIAL COVERED: See Appendix D

This review was a natural follow-up to the MSFC and Apollo Program Director's discussions concerning the Lunar Roving Vehicle and its place in the Apollo "J" missions. It was also an opportunity for Panel members to see the vehicle first-hand and to observe the fabrication and test operations in process. The availability of personnel directly responsible for design, test and checkout provided an opportunity for closer scrutiny by the Panel of the key personnel involved.

LOCATION: MSC, Houston, Texas

DATE: May 10-11, 1971

MATERIAL COVERED: See Appendix E

Because of the large part played by those operations and equipments under MSC cognizance, the Panel found the review here to be most important. The crew interface and spacecraft changes form the largest part of the expanded Apollo 15 capability and give rise to the greatest concerns as to hazard identification and control. This meeting was then the apex of this series of Apollo 15 assessment reviews.

LOCATION: KSC, Cape Kennedy, Florida

DATE: June 14, 1971

MATERIAL COVERED: See Appendix F

This review provided the Panel with an insight into the Apollo 15 launch preparation and checkout operations and took into account the information derived from the previous reviews. Of particular interest was the system for hazard identification and control as applied at KSC. An interesting aspect of this meeting was the opportunity afforded the Panel to see the new "alert system: (caution and warning) in actual operation at the Launch Control Center during the Apollo 15 Flight Readiness Test (FRT).

LOCATION: NASA Headquarters, Washington, D.C.

DATE: July 12-13, 1971

MATERIAL COVERED: See Appendix G

This meeting with the Apollo Program Director provided the Panel members an opportunity to explore the current status of the Apollo 15 hardware and technical management items of interest generated during the previous series of reviews. Included in the discussions were the results of the Flight Readiness Review. The meeting with the

NASA Administrator centered on the Panel's Apollo 15 activities and observations.

GENERAL ASSESSMENT

The results of these briefings, together with the data exchanged between Panel members, Panel staff, the Center and contractor personnel has been used as the basis for the conclusions contained herein.

Note that material presented at the Panel meetings is contained in its entirety in individual data packages maintained in the Panel files and is not appended to this report. Appendices B through G indicate the material covered by the Panel or background upon which this assessment is built. A side issue, but one of importance, was the degree to which applicable aspects of the Apollo 13 recommendations and ensuing NASA actions carried over to the Apollo 15 and subsequent missions.

APOLLO 14 LAUNCH VEHICLE FLIGHT EVALUATION

The MSFC presentation basically indicated three things:

(a) Launch vehicle performance was nominal.

(b) S-II Pogo effects had been corrected.

(c) Launch vehicle problems which did occur were minor.

These minor problems involved IU telemetry equipment failure re-

TABLE I

CSM APOLLO 14 PROBLEMS

APOLLO 14 PROBLEM	KNOWN STATUS
Docking Probe Latch, difficulty in Probe-to-Drogue latching	Actual cause unknown. Actions taken to alleviate possible problems.
High Gain Antenna, failure to lock-up in Narrow Beam Mode	Additional screening for defects. Cables, connectors and their assembly modified to correct fabrication problems. Retest completed.
Motor Switch for Battery Bus, failed to close	Verify transfer times for all (32) switches on spacecraft. If out of tolerance, replace switch. Work continues on identifying source and mechanism of contaminate build-up on commutators.
Circuit Breaker, Battery to Main Bus, intermittent operation	Non-critical, crew awareness for breaker reset.
VHF, Low Signal Strength	No modification, non-critical. Possible use of S-Band voice as back-up.

sulting in the loss of non-critical measurements. There is no anticipated impact on Apollo 15.

APOLLO 14 SPACECRAFT FLIGHT EVALUATION

CSM

Problems and status as known are shown in Table I. Of these the docking probe's inability to capture the drogue until the sixth attempt certainly warranted further investigation. This unit has been undergoing intensive study and to date no substantive cause can be assigned to this problem although there are several theories. As a result of thorough testing and analyses, the following corrective actions were indicated as under way:

(1) Establish tighter configuration management (drawing control) and inspection procedures; provide a removable probe head cover to reduce possible contamination; and, conduct of checkout tests as late as possible in launch preparation period (all of this without interfering with the basic mechanism).

(2) Lock-wire retention of shear-pin fragments and a design change to the cam assembly to eliminate obvious marginal design features. With "cause unknown," the making of such design changes, e.g., modifications to insure centering of the motor drive shaft, decreasing the sensitivity to side loads and reduction of friction, requires that extra caution be exercised to preclude the possible creation of other subtle problems.

An area not pursued in detail at the time of the review but worthy of consideration are possible drogue tolerance problems which might possibly cause latches to not engage. It is understood that substantial additional testing of the modified latch assembly has been successfully conducted at the factory and at KSC. This is mentioned as background for the Administrator's review.

The Apollo 14 O_2 system, modified after the Apollo 13 investigation, demonstrated its capability to meet special and emergency conditions for Apollo 15 and subsequent "J" missions. Further, it established the heat transfer characteristics of the O_2 tank (and its components) which provides further security in their "J" mission use.

LM

Problems and status as known are shown in Table II. None of these appear to pose a problem in either their resolution or impact on Apollo 15 mission. If, for example, the LM landing radar problem were to occur on Apollo 15 current knowledge indicates it would not be the problem for Apollo 15 that it was on Apollo 14. Greater knowledge provides insight into handling of such problems.

HYCON CAMERA FAILURE ON APOLLO 14

The unavailability of high resolution pictures of the Apollo 15 landing site requires real time, closed loop, mission control with experts on the ground observing the operation of the LRV and providing appropriate guidance to the crew.

THE APOLLO 15 MISSION ("J" Mission)

The important differences in Apollo 15 from Apollo 14 are re-

TABLE II

LM APOLLO 14 PROBLEMS

LM Problem	Status
Intermittent Steerable Antenna Operation	Cause unknown. Resolution still in progress.
Ascent Battery #5 - voltage slightly lower than expected (0.3 volts)	Improve quality control at vendor. Additional test to be conducted at KSC.
LM Landing Radar - switch from high to low scale at too high an altitude (71,000 ft.)	Wiring change to lock radar in high scale until 7,500 feet altitude.
Abort Guidance System - failed in standby mode - no warning or alarm given	No evidence of a design deficiency or generic problem. No corrective action.

TABLE III

INCREASED CAPABILITIES FOR APOLLO 15

Lunar surface scientific payload doubled

Scientific Instrument Module (Service Module)

Lunar surface stay-time doubled

CSM/EVA during trans-earth portion of mission

Increased lunar surface operational range

Earth launch azimuth 80° - 100° (previous 72° to 96°)

Apollo 15 launch vehicle payload capability - 108,730 pounds (+ 6,630 pounds) lated to trajectory profile, lunar landing attitude-range profile, increased lunar stay-time, CSM extra-vehicular activity, and increased science capability. The increased mission requirements, trajectory characteristics and launch vehicle changes are shown in Table III.

LAUNCH VEHICLE

The "J" mission changes to the Saturn launch vehicle were made to meet required payload commitment without degrading crew safety; to improve reliability and safety; and, correct anomalies.

The most significant changes are briefly commented on here as to their possible impact on mission success. Material presented by MSFC indicated the basic operational data for risk assessment to be sound and indicated a thorough understanding of each item presented. There was no reason to question the technical qualities of the decisions.

Payload increases related to optimizing around the accomplishment of Translunar Injection (TLI) at first opportunity rather than providing equal payload capability at either first or second opportunities has small impact on mission success confidence level (99.9% to 99.60%).

Launch vehicle hardware and operational changes to increase payload capability would appear to have little effect on safety and reliability. Much of this can be directly related to the maturity of these vehicles and the support equipment and personnel. For example, reorificing of the F-1 engines to achieve 1.5222 million thrust on S-IC stage follows similar efforts of the same nature which have previously shown no adverse effects. On the other hand, the replacing of S-II stage LOX and LH_2 tank pressurization regulators with orifices, thereby deleting the step-pressurization of the LOX tank, has in fact eliminated a single failure point and should aid system reliability.

In addition to obtaining greater payload other changes were made to the launch vehicle to enhance reliability and safety (Table IV). The Panel feels that these were minor software changes and appear to enhance mission success. In fact these changes might have been in the works for some time prior to Apollo 15. In one case, revision of the IU computer filters was done in order to maintain the previously set control stability margins with the newly increased payload requirement.

Subsequent to the Panel's visit to MSFC it was discovered that certain seals used on the launch vehicle could not be certified as compatible with LOX, GOX and other oxidizers as required by specification. This occurred because of confusion in actual materials employed in this proprietary seal. The Panel understands that actions taken have resolved this problem. It indicates the importance of management's continuing attention to the technical management systems in support of future missions.

LUNAR ROVING VEHICLE (LRV)

MSFC and Boeing personnel provided LRV management and hardware data to the Panel with crew and science interfaces provided

TABLE IV

SIGNIFICANT LAUNCH VEHICLE CHANGES TO IMPROVE RELIABILITY AND SAFETY

Modification of TILT arrest time for S-IC stage engine out.

Spacecraft computer-generated S-IV-B cutoff for TLI.

Revise the instrument unit flight control computer.

Modification of yaw maneuver for tower avoidance.

by MSC. The significance of the Rover in achieving Apollo 15 objectives cannot be overstated. Consequently, the Panel considered this a most vital area to be reviewed. The initial review at MSFC provided a broad insight of physical requirements and the details of program management, including center support functions while the Boeing Company and MSC coverage dealt primarily with the Rover hardware and operational details.

The LRV program provided for scheduled delivery of fully qualified flight hardware eighteen months from "go-ahead." This tight timing was compounded by the fact it was to be the first manned lunar surface transportation unit with stringent requirements for both complex scientific equipment, meticulous crew and LM interfaces, and rigid weight limitations.

Based on our discussions, it appeared that the efforts of both NASA and the prime contractor had now established a viable management system for this program. This included such things as designating key people at all levels by name to cope with various possible problem areas which might occur as a result of qualification testing at an accelerated pace. To maintain personnel motivation and capability, MSFC took such steps as making sure that the contractor had a place for LRV test engineers and technicians to do useful work when not needed on LRV.

Qual and acceptance tests indicate that the unanticipated problems from welding and soldering have been resolved.

Furthermore, in light of the Apollo 13 recommendations, a qualified team was designated to follow the LRV's from the factory through launch.

Continuing wheel/soil tests are contemplated to provide corrected speed and range data for traverse planning and we understand this will continue up to launch. This will no doubt be done with the idea that the first mission using the LRV must have adequate performance margins and operational flexibility.

The Panel understands that significant aspects of the LRV dynamic stability analyses have been incorporated into the LRV Operations Handbook with all known constraints identified. This provides the crew and support team with much needed vehicle limitations and capabilities. However, we further understand that no specific instructions have been formulated for such dynamic constraints at the time of our review. Since experience is lacking in LRV operations in the lunar environment, the Panel attaches great importance to the use of real-time closed-loop mission control with experts on the ground observing the operation and providing proper mission rules and guidance to the crew on the lunar surface. This has been mentioned as background for the Administrator's review.

Documentation, drawings, and test procedures appeared to be in good shape. Any future revisions, of course, must be scrupulously controlled by the appropriate level of management to preclude interference effects of any kind.

As explained to the Panel, the LRV crew training approach appears to be well-founded and implemented. As expected driving rules and techniques as developed during LRV trainer operation are structured to be effective for expected speed, slope, and obstacle conditions at the Apollo 15 site, but the Panel cautions that due to uncertainties, driving techniques must be tempered by rules which preclude the crew from approaching or entering a regime from which recovery techniques would be problematical. This is again mentioned as background for the Administrator's review.

The Panel requested prior to the reviews, that they be provided an LRV safety assessment covering three mission phases:

(a) Prelaunch through lunar landing.

(b) Deployment on lunar surface.

(c) Lunar surface operations.

Indications are that all foreseeable and identified hazards that have not been eliminated have been considered and decisions made as to their acceptability. This includes such hazards, and their resolution, as:

(a) When seated the astronaut slides down in his space suit to an extent that his field of view in front and down is somewhat limited. Because of this the added emphasis of suited one-G training is appropriate.

(b) The tires of the LRV are made of small diameter wire which when broken have a potential to puncture crew suits. Thus, if the crew is sufficiently aware of the potential danger inherent in wheel contact they can consciously avoid it. Under normal conditions this should pose no problem.

(c) The ability of the crew to return to the LM in the event of LRV breakdown has been covered in quite some detail as has the use of the Buddy-Portable Life Support System (PLSS) in case of PLSS problems. One particular case of double failure was noted and questioned by the Panel, i.e., possibility of LRV and PLSS failure at the same time. MSC indicated that the probability of such a double failure was extremely remote. Although structural failure of the LRV is considered a hazard, testing and analysis appears to have made this highly unlikely and consequently an acceptable risk. The NASA centers and contractor feel they have identified all single failure points and after analysis find them acceptable "as is," or where necessary, work arounds or contingency plans are available.

COMMAND AND SERVICE MODULES (CSM)

In reviewing this area the Panel felt that basic to minimizing the risks inherent in the Apollo 15 CSM (CSM 112), it would be necessary to assure:

(a) Minimum hardware and procedural change.

(b) Maximum utilization of qualified hardware.

(c) Validation of changes through a vigorous test and/or analysis program dependent on individual case.

(d) Proper application of the lessons learned from Apollo 13. Our review indicates that this in fact was done.

The third O_2 tank isolation valve has been relocated. The impact of SIM door ejection loads on the valve has been evaluated during risk assessment.

The Scientific Instrument Module (SIM) is a separate module and represents the major change to the CSM for Apollo 15 and future "J" missions. The Panel focused on areas such as identification and control of hazards, SIM bay lighting, temperature restraints, ordnance shock isolation, Reaction Control System (RCS) plume contamination, EVA hand-hold and foot-restraints, tether arrangements and so on. Applicable safety issues were reviewed with the understanding that the total safety assessment awaits the completion of hardware tests. Safety review work discussed included sharp edge hazards during EVA which had to be identified and corrected to assure they meet smoothness criteria set forth by MSC. In support of this work the crew is receiving training in visual inspection procedures as a part of their EVA training. Thermal hazards analysis indicates no areas accessable to the crewman in excess of 190° F which is well within the suit thermal tolerance.

Because of their mission significance the mission rules constraining EVA if the satellite cannot be jettisoned or SIM booms retracted should be considered for inclusion in the Administrator's review.

Within the CM itself the right hand outer window UV filter coating has been removed to accommodate on-board UV photography. The hazard here was the potential crew discomfort due to Ozone generation. Equipment and hardware were therefore changed and the MSC Safety Office now considers the hazard resolved.

The SIM door jettison situation appears to have been thoroughly investigated and tested. The Apollo Program Director indicated to the Panel that these tests have been successfully completed and that there is no hazard to the adjacent structure.

<u>EXTRA-VEHICULAR MOBILITY UNIT (EMU)</u>

The A7LB spacesuit, -7 PLSS/OPS, Buddy-PLSS operation portions of the EMU were of particular interest due to their differences from prior units and their expected extended use on Apollo 15.

The A7LB suit required improved durability, improved mobility, a new closure, and changes for EVA by the CM pilot.

As a result of these requirements changes were made in the spacesuit involving new zippers, bootbladders, and increased PLSS capability. The final status of these changes should be indicated in the Administrator's review. Particular attention should be given to: (a) pressure sealing closure; (b) crotch cable assembly; (c) restraint zipper lock-tab; (d) shoulder convolute wear; (e) boot-bladder; (f) manufacturing controls on boots; (g) the oxygen purge system in the PLSS; and, (h) the reliability of the CO_2 sensor.

LUNAR COMMUNICATIONS RELAY UNIT/GROUND COMMANDED TELEVISION ASSEMBLY LCRU/GCTA

The possibility of using the TV equipment as a diagnostic tool during lunar surface operations was suggested by the Panel. MSC/MSFC were exploring the feasibility. Their conclusions should be considered for inclusion in the Administrator's review.

LUNAR MODULE (LM)

The review of the LM included the many configuration changes made to increase lunar surface stay time and landed payload capability. As back-up capability during the CSM experiments activity, the Panel reviewed a safety analysis for retaining the LM ascent stage for lunar orbit stay after redocking.

The Panel was interested in the extent of qualification of new and/or modified LM hardware. Of the many items examined, the thermal protection system, Lunar Roving Vehicle interface, descent propulsion system, consumables, and landing stability were considered in more detail because of their significance in meeting the Apollo 15 mission requirements. The briefings indicated both MSC and GAC conducted an extensive study of the need for qualification by test, analysis, and qualification through similarity to previously tested components, subsystems and systems.

THERMAL PROTECTION

Rearrangement of hardware (in each of the four quadrants), extended stay time, and propulsion changes all required thermal reconfiguration and system requalification. This was accomplished through thermal-vacuum tests, shock tunnel heating tests and analyses. As presented, the depth and scope of effort was convincing.

LUNAR ROVING VEHICLE (LRV)

This was discussed in the section on the LRV.

DESCENT PROPULSION SYSTEM (DPS)

This system was modified to provide the capability to land a heavier vehicle on the lunar surface. Changes include lengthened propellant tanks to increase capacity by 1150 pounds, a change from a low grade silica to high grade quartz fibers in the engine chamber to permit longer burn time, a ten-inch nozzle extension to increase ISP, and deletion of propellant tank balance lines. Extensive testing was accomplished on these changes, particularly on the engine modifications. Data presented indicated a thorough qualification program had been accomplished.

CONSUMABLES

A review of consumable margins for 67 hour Lunar stay showed that positive margins exist for all consumables after allowances for dispersions and contingencies. In the case of descent stage water, although the tank capacity is 666 pounds, the tanks are filled to cover mission plus contingency needs of 377 pounds. The basis for these analyses appear sound.

LANDING STABILITY

The LM-10 stability analysis presented, based on previous work which was proved-out on Apollo 11, 12 and 14, showed a greater margin for a stable landing with LM-10 than with prior vehicles. It is noted that GAC/MSC used a number of refinements in this program, reflecting flight experience and a better understanding of the inter-action of stability factors such as terrain slope, velocities, attitude rate, pilot reaction times, etc.

KSC LAUNCH PREPARATIONS

This visit afforded the Panel an opportunity to review the launch preparations for Apollo 15 at a time of increasing activity and to gain insight into those changes in hardware and procedures instituted as a result of their Apollo 13 efforts.

Many of the significant hardware changes reviewed by the Panel during the previous center and contractor visits were discussed with respect to their processing at KSC to assure proper operation and installation. In addition, the inter-center technical support and KSC safety activities were reviewed. The Panel expressed an interest in the availability of necessary documentation such as vendor drawings for use in troubleshooting in view of decreasing non-NASA support for remaining Apollo flights. The steps taken by the development centers to both augment the drawing files at KSC and to improve retrieval time from files at all locations appear to have born fruit. KSC states documentation is available in depth and in a form necessary to meet their requirements.

Status of the Apollo 15, at the time of the review, was indicated as being on schedule with no more problems than found on any prior launch even though Apollo 15 contained many new items due to "J" mission requirements. An interface problem surfaced during LM-10 descent engine gimbaling tests. During this test the extended nozzle scraped along the dome blanket of the S-IV-B tank indicating a lack of proper clearance. The proper change was made for AS-511 but not applied to AS-510 as required by the stack effectivity change. This evidences the need for continuing management attention to the application of the existing configuration management system to changes in the future.

KSC has carried out a structured program of mission and individual test simulations within the Launch Control Center, including failure simulations to maintain competence of their operational personnel. KSC indicated that their operational relationships with the Houston Mission Control Center are excellent and the team at MCC is activated at the time the vehicle moved to the launch pad and has aided considerably in the problem solving required during the critical launch checkout period.

Having reviewed the development, manufacture and planned use of the LRV and SIM at MSC, MSFC, and The Boeing Company, the Panel reviewed the test and checkout of these subsystems at the Cape. At the time of our review there were a significant number of tests still to be completed at KSC. We discussed this later with the Apollo Program Director and he indicated these were coming to a conclusion on schedule.

KSC appears to have conducted detailed and continuing liaison with the cognizant development centers in accomplishing their process work.

The Lightning Warning System, as described, indicated a growing knowledge in this area. Yet the methodology to date cannot have the precision that other launch operations have, and as expected it is still an art. The system for lightning protection and determination of impact of lightning strikes on hardware is one that is worthy of further study. NASA's advanced methods should be disseminated for use by other segments of the aerospace community.

During the conduct of the FRT (Flight Readiness Test), the

the Panel was to have had the opportunity to see the Apollo Alert System in partial operation. This system is an outgrowth of not only Apollo 13 recommendations, but of prior considerations climaxed by Apollo 13. The alert system, when fully operational, should reduce prelaunch and launch trouble-shooting problems. Given their significance, both these items are suggested for inclusion in the Administrator's review.

SUMMARY

The review emphasized the following areas:

(a) Management policies, systems, and their implementation as used to establish the design and safety maturity of Apollo 15 (and subsequent "J" missions) and its ability to meet mission requirements. This includes the qualification testing and analysis programs and their rationale, performance impacts, configuration management, and inter-center operations. This was specifically directed towards:

(1) Apollo 14 anomalies and their close-out.

(2) New and modified elements of Apollo 15 space system and mission.

(3) Launch preparation for Apollo 15.

(b) Risk management process:

(1) Identification of hazards associated with new and modified elements of Apollo 15 hardware and mission.

(2) Failure effect and acceptance or avoidance rationale.

(3) Safety assessment and hazard control

(c) Retention of critical knowledge and skills at proper locations and with dimishing contractor and vendor support.

Specific items are summarized below, based on the body of this report, and represent the Panel's conclusions:

(a) The response to the Panel's review requirements as set forth by the agendas was, on the whole, frank and informative.

(b) Two continuing characteristics of NASA's Apollo management philosophy that are important in meeting mission goals are detailed surveillance of contractor activities and the depth of NASA in-house reviews. These capabilities are perhaps most important in assuring the risk assessments and resulting risk assumptions are made with maximum knowledge in a time of continuing personnel reductions. The Panel was impressed with the current state of these capabilities and the importance of continuing management attention to the maintainance of them.

(c) The system for the resolution of the anomalies and failures found in the Apollo 14 appears satisfactory.

(d) Launch vehicle hardware and operational modifications to achieve greater payload capacity appear soundly based on individual stage maturity. Sustained successful launch and flight operations experience, coupled with a firmly established configuration, provide such maturity. The decision to include certain minor changes to enhance mission reliability and safety appears reasonable.

(e) Based on the results of the LRV review, the Panel notes a high degree of confidence among the OMSF Centers and vehicle contractor that the LRV maturity has been fully demonstrated by extensive tests and technical analyses. Because the LRV has not "flown" before the astronaut training, operational performance analysis, traverse planning and attendant mission rules take on added significance. The Panel feels that because experience is lacking in the lunar environment, it is most important to have real-time closed loop mission control with experts here on earth observing the operation and sending proper mission rules and guidance to the crew.

(f) The CSM modifications to support the extended mission and lunar orbit experiments were numerous. The rigorous test and analysis program, as described to the Panel, indicates a thoroughness of technical management necessary to minimize the risks associated with the "J" type mission.

(g) The improved A7L-B spacesuit and the -7PLSS for Apollo 15 have had their share of development problems not unlike those used on Apollo's 11 through 14. Based on data presented and successful completion of qual tests, it appears that the inherent risks here are no more or less than on previous flights. The use of teflon fabric has been extended and now covers the entire suit. The beta cloth base material is judged by MSC to satisfactorily constrain any fire propagation.

(h) The LM has been modified in many areas to meet Apollo 15 or "J" mission requirements. Here again rigorous testing and analysis, as described to the Panel, indicates an awareness of the hazards involved and an attempt, where possible, to alleviate or eliminate the associated risks.

(i) The risk management process continues to be an inherent part of the Apollo management system. It is supported by an extensive system of policies, procedures and actual implementation which identified hazards, evaluates and assesses the risks, and provides reasonable actions to eliminate or alleviate all those concerned with human safety and mission success.

The conclusions based on this summary are stated at the beginning of the report.

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

OFFICE OF THE ADMINISTRATOR

JAN 26 1971

TO: Mr. Dale D. Myers, Associate Administrator, Office of Manned Space Flight

FROM: Dr. George M. Low, Acting Administrator

Since we will soon begin the Apollo "J" missions, I have asked the Aerospace Safety Advisory Panel to review the changes introduced with Apollo 15 and the attendant system for risk assessment, including those technical management systems that impact it.

I have also asked the Panel to review the continuing evolution of the risk assessment system on the Skylab and Space Shuttle programs. This again would include those technical management systems that would impact risk assessment.

The review, as now planned, will take the Panel to the Manned Space Flight Centers and appropriate major contractors beginning in early February.

The Manned Space Flight organization's continuing support of the Panel activities is appreciated.

George M. Low
GEORGE M. LOW
Acting Administrator

AGENDA FOR MEETING OF
AEROSPACE SAFETY ADVISORY PANEL
AT
MARSHALL SPACE FLIGHT CENTER
FEBRUARY 1971

Apollo 14 Launch Vehicle - significant events

Apollo 14 vs Apollo 15 (Launch Vehicle)

- Mission/Operational Differences
- Launch Vehicle/Software Differences

Lunar Roving Vehicle

- Introduction and Background
- End Item Description
- Requirements
- Crew Integration
- Reliability and Safety Activities
- Testing
- Quality Assurance
- Management Systems
- Schedules

Skylab Program

- Introduction, Organization and Responsibilities
- Systems Description
- Inspect ATM Assembly Area

Appendix B

Inspect Skylab Mock-up Hardware Area

Materials Compatibility

Caution, Warning and Emergency Systems

AGENDA FOR MEETING OF

AEROSPACE SAFETY ADVISORY PANEL

AT

WASHINGTON, D.C.

(APOLLO PROGRAM OFFICE)

MARCH 1971

APOLLO 14 MISSION REPORT

- CSM Problems
- LM Problems
- O_2 System Flight Test Results
- Mission Events
- Mission Results

APOLLO 15 MISSION REPORT

- Detailed Objectives
- Increased Capabilities
- Launch Vehicle Performance
- Spacecraft Weight
- Changes and Modifications
- LRV
- Operational Aspects

MANNED SPACEFLIGHT NETWORK (Goddard Space Flight Center)

AGENDA FOR MEETING OF

AEROSPACE SAFETY ADVISORY PANEL

AT

THE BOEING COMPANY, KENT, WASHINGTON

APRIL 1971

INTRODUCTION

- Design Familiarization
- Program Description
- Schedule

PROGRAM MANAGEMENT CONTROLS

- Organization
- Suppliers
- Schedules
- Program Control and Reporting
- Configuration Management

LRV OPERATIONS

- Material Procurement
- Manufacturing Control
- Quality Assurance
- Industrial Safety

HARDWARE/FACILITY TOUR

DESIGN CERTIFICATION

- Requirements
- Performance
- Design
  - Design Criteria
  - Subsystem Assessments
    - Chassis
    - Mobility
    - Electrical
    - Navigation
    - Crew Station
    - Thermal Control

Appendix D

- Space Support Equipment (SSE)
- Ground Support Equipment (GSE)

Vehicle Assessments

- Dust
- Interface Requirements
- EMI/EMC
- Test Program Summary

Reliability and Safety Assessment

Summary

AGENDA FOR MEETING OF

AEROSPACE SAFETY ADVISORY PANEL

AT

MANNED SPACEFLIGHT CENTER, HOUSTON, TEXAS

MAY 1971

OBJECTIVE OF REVIEW

APOLLO 14 PROBLEM UPDATE

- CSM
- LM
- GFE
- ALSEP
- "J" MISSION DIFFERENCES - LM
  - LM-8 and LM-10 Major Configuration Differences for Payload and Hover Time
  - Weight and Performance
  - Consumables Margin
  - Landing Stability
  - CTR/CTE Status
  - Current Problems
- LUNAR SURFACE OPERATIONS
- "J" MISSION DIFFERENCES - CSM
  - New Requirements
  - Ground Rules
  - Design Approach
  - Modifications
  - SIM Checkout
  - Crew Station Details, Including EVA
  - Certification Status
  - Current Open Problems
- "J" MISSION DIFFERENCES -GFE
  - Introduction
    - Major Subsystems of the EMU
    - "J" Mission Performance Requirements
  - Pressure Garment Assembly
  - Portable Life Support System
  - GCTA
  - LCRU
  - Safety Assessment

Appendix E

AGENDA FOR MEETING OF

AEROSPACE SAFETY ADVISORY PANEL

AT

KENNEDY SPACEFLIGHT CENTER, COCOA BEACH, FLORIDA

JUNE 1971

Introduction and General Discussion

Apollo 15 Launch Processing and Test Status

Apollo 15 Safety Activities

Inter-Center Technical Support on Significant Problems and Management Posture During Launch Related Operations

Operation of Lightning Warning System

Off-Line Flight Support During Mission

ASC Alert System

Review of Alert System in Firing Room

Appendix F