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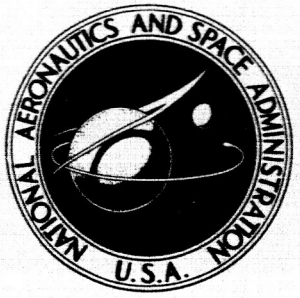

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APOLLO EXPERIENCE REPORT - POSTFLIGHT TESTING OF COMMAND MODULES

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16. Abstract

Various phases of the postflight testing of the command modules used in the Apollo Program are presented. The specific tasks to be accomplished by the task force recovery teams, the National Aeronautics and Space Administration Lyndon B. Johnson Space Center, (formerly the Manned Spacecraft Center) and the cognizant contractors/subcontractors are outlined. The means and methods used in postflight testing and how such activities evolved during the Apollo Program and were tailored to meet specific test requirements are described. Action taken to resolve or minimize problems or anomalies discovered during the flight, the postflight test phase, or mission evaluation is discussed.

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APOLLO EXPERIENCE REPORT

POSTFLIGHT TESTING OF COMMAND MODULES

By Donald T. Hamilton
Lyndon B. Johnson Space Center

SUMMARY

Postflight testing was performed on each Apollo command module. The test activities were divided into two general types: preplanned tests and mission-anomaly tests. Preplanned test activities included inspections, recording of configuration, and the removal of consumables, data, and equipment. Anomaly testing consisted of tests required in order to investigate and resolve flight anomalies. As part of the mission evaluation effort, postflight testing had to be completed as quickly as possible to allow any required corrective action to be accomplished without delaying subsequent flights. Postflight testing during the initial series of Apollo flights required an excessive amount of time to conduct the tests and to furnish the test results to the mission evaluation team. Remedial action was taken, resulting in the expediting of postflight testing and timely completion of the mission evaluation tasks.

INTRODUCTION

Postflight testing of the command modules during the Apollo Program was integrated with the mission evaluation effort. Most of the testing was accomplished by the contractor and subcontractors; however, certain postflight testing activities were performed before shipment of the command module (CM) to the contractor facility. Tasks accomplished on board the recovery ship included the inspection and removal of stowed equipment, samples, and data. After off-loading from the recovery ship, the command module was taken to a deactivation site, where the pyrotechnic devices were inactivated and the residual propellants were removed from the reaction control system. After the early lunar-landing missions, which required isolation of the crew and the command module, the command module was held in quarantine at the NASA Lyndon B. Johnson Space Center (JSC), formerly the Manned Spacecraft Center (MSC), for a prescribed period before shipment to the contractor facility. Each aspect of postflight testing is discussed in this report.

POSTFLIGHT TEST REQUIREMENTS

Before each mission, a Postflight Test Requirements Document was prepared. In this document, the activities to be accomplished at various locations during the postflight test phase were defined. The requirements were derived from the experience

gained from previous flights and from the results of a survey conducted before each mission to determine the specific program needs of the command module subsystem specialists.

Tasks to be performed that were not specified in the Postflight Test Requirements Document were authorized by issuing an approved Apollo Spacecraft Hardware Utilization Request (ASHUR) (fig. 1). Before each flight, a consolidated ASHUR was prepared

APOLLO SPACECRAFT HARDWARE UTILIZATION REQUEST

SPACECRAFT NUMBER	SYSTEM(S) AFFECTED	ASHUR NUMBER
S/C - 109	Master Event Sequence Controller (MESC)	109057

PURPOSE

To verify the proper operation of the redundant time delay circuits in the MESC, serial number 063596330 BBA.

JUSTIFICATION

The S/C - 109 MESC, serial number 063596330 BBA, contained National Semiconductor Corporation transistors of the same lot that failed in the S/C - 112 DC sensor. Due to the system series redundancy a bench functional test must be run to verify that the flight sequencer components are still operating.

DESCRIPTION

1. Remove the MESC, ME 901-0567-0023, serial number 063596330 BBA from spacecraft 109 CM.
2. Ship to the MESC vendor, Autonetics, and run the functional acceptance test.
3. Remove time delays which contain the National Semiconductor Corporation transistors (2N2907A).
4. Perform leak checks and open transistors. Inspect for contamination, corrosion, and adequate bonds to leads. This may be done at Autonetics with transistor representatives present or at transistor vendor.

TO BE ACCOMPLISHED BY:

[X] NR [ ] KSC MAB [X] VENDOR
[ ] GAEC [ ] MSC [ ] OTHER

LOCATION OF WORK ACTIVITY:

NR SD, Downey, California
Autonetics, Anaheim, California

CONTACT FOR STATUS

H. Peck 213-922-3016 and H. Rode 213-922-3743

FINAL DISPOSITION OF HARDWARE

Bonded Storage

TYPE OF ACTION

[X] POSTFLIGHT TEST REQUEST
[ ] FLIGHT REUSE REQUEST
[ ] DISPOSITION REQUEST

REQUESTED BY	ORGANIZATION	DATE
Gary W. Johnson	EB8	7-13-70
CHIEF ANALYST: R. Munford		7-13-70

ASHUR APPROVED	DATE	ASHUR DISAPPROVED	DATE	SHEET ___ OF ___
D. Arabian	7/13/70			

MSC FORM 1148 (REV FEB 68) *(Previous editions are obsolete)*

Figure 1. - Apollo Spacecraft Hardware Utilization Request for postflight testing.

to specify the disposition of the items stowed in the command module. The ASHUR directed the recovery team to remove certain items while the command module was on board the recovery ship and to return these items by courier to the MSC. In the ASHUR, it was also directed that various items be removed at the MSC (in the case of the three lunar landing missions for which biological isolation of the command module was required) and at the contractor facility. Postflight anomaly testing was directed and authorized by an ASHUR. The Apollo Spacecraft Hardware Utilization Requests were prepared as soon as the test requirements could be identified by the mission evaluation team and then were forwarded either to the spacecraft contractor or to the responsible MSC organization.

POSTFLIGHT TEST ACTIVITIES

Recovery and Deactivation Operations

The primary activity of the recovery team was the preparation of the command module for return to the MSC or to the contractor facility. This activity included photographing the command module exterior and interior, documenting observations and inspections, verifying electrical shutdown of the command module, and removing and expediting the return of data and specified equipment (fig. 2). Normally, the following tasks are performed on board the recovery ship.

1. Wash down the exterior of the command module with fresh water
2. Obtain microbial samples from interior surfaces
3. Inspect interior and exterior visually
4. Photograph interior and exterior
5. Record panel readings and switch positions
6. Verify system powerdown
7. Sample potable and waste water
8. Inspect couch support struts
9. Inspect recovery aids for proper deployment
10. Obtain samples of any liquids found on cabin aft bulkhead
11. Stow very high frequency (vhf) antennas and flashing light
12. Remove uprighting bags (if deployed)
13. Perform radiation survey

Figure 2. - Apollo 4 operations on board the recovery ship.

14. Remove flight film, tapes, and stowed equipment according to consolidated ASHUR

15. Remove reaction control system access panels

16. Drain sea water from the toroidal area and flush with fresh water

When it was necessary to preserve evidence that might otherwise have been destroyed or degraded, additional activities were performed.

Before each mission, postretrieval[1] procedures were prepared for use by the recovery team. These procedures were based on the Postflight Test Requirements Document. During the accomplishment of the postretrieval procedures on board the recovery ship, a representative of the mission evaluation team was available in the Mission Control Center to answer questions from the recovery team. The recovery team reported significant findings and problems to the mission evaluation team and performed additional activities when requested to do so by the evaluation team representative.

During the initial series of recovery operations, the reporting of postretrieval operations and observations was not sufficiently comprehensive, and information was not being made available to the mission evaluation team as quickly as was desired. After discussions between representatives of the mission evaluation team and the recovery team, the following procedures were established to resolve the problem. The recovery team provided information, as soon as possible, based on a preflight-prepared list of questions that were of immediate interest to the mission evaluation team. An annotated, postretrieval procedures document and other data from the recovery ship were returned by courier to the MSC, and copies of this document were made available to the mission evaluation team.

Contractor Operations

Most postflight testing was performed by the spacecraft contractor and subcontractors. For the initial series of developmental Apollo missions, the contractor conducted three types of postflight tests: baseline, delta-baseline, and anomaly tests. Baseline tests were specified in the basic contract and were performed on each command module, regardless of the type of mission. The delta-baseline tests were additional tests that were not specified in the basic contract. These tests were peculiar to a particular mission and were necessary to evaluate specific aspects of spacecraft performance. The delta-baseline tests were identified in the Postflight Test Requirements Document, and the contractor was given a contract-change authorization to perform these tests on each spacecraft.

The delta-baseline tests were eliminated as the Apollo Program progressed, and the contract was modified to reduce the baseline-test requirements. The extent of the reduction can be seen by comparing the lists of baseline and delta-baseline tests that were scheduled for the Apollo AS-202 and Apollo 12 missions. These listings are contained in the appendix. After the delta-baseline tests were eliminated as postflight test requirements, the primary purpose of the Postflight Test Requirements Document was to specify requirements to be fulfilled by the recovery and deactivation teams (although the contractor baseline-test requirements were still included as general information). The anomaly tests required for the investigation and resolution of mission anomalies took precedence over the baseline tests.

Before each mission, the contractor prepared a schedule of tests and activities (exclusive of anomaly testing) to be accomplished after return of the command module.

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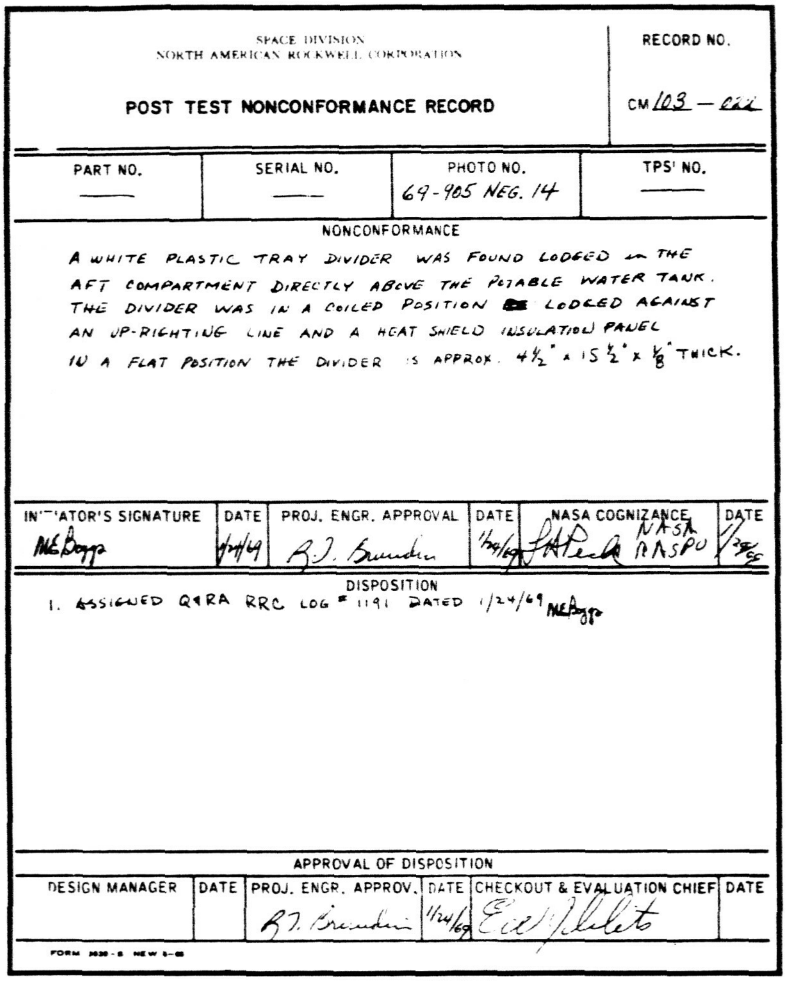
[1] "Postretrieval" was the term used to indicate that phase of recovery operations immediately after recovery of the crewmen and the command module.

Toward the end of a mission and during the postflight evaluation period, Apollo Spacecraft Hardware Utilization Requests were prepared to specify anomaly tests. These were forwarded to the contractor, who maintained a daily updated schedule of all required tests. Changes to the contractor test schedule reflected the relative priority of all tests and ensured that any test conducted to investigate an anomalous condition did not disturb other anomalous conditions that would be investigated at a later time.

The postflight test period at the contractor facility extended from 30 to 90 days, depending on the number and magnitude of the anomaly tests. One to three work shifts per day were used, as necessary, to expedite the testing and to provide test data to be used to support the subsequent mission. Spacecraft modifications resulting from anomalies had to be identified quickly to avoid delaying of subsequent flights. During the postflight test period, the contractor was required to submit daily status reports. The reports contained a description of work accomplished, results obtained, and activity projected for the next day. Within 2 weeks after completion of each test, the contractor was required to submit an Engineering Summary Report. This report constituted the closeout documentation for the ASHUR that established the requirements for a particular test. Copies of the Engineering Summary Report were given to the appropriate members of the mission evaluation team for review and concurrence.

The postflight testing at the contractor facility included spacecraft-component functional tests and integrated systems tests. The spacecraft automatic-checkout equipment was not used for postflight testing because the required postflight testing was not as extensive as the preflight checkout. In general, malfunction analyses of electronic assemblies and system components were performed by the component manufacturers. The anomaly tests performed on the command module were described in the individual mission reports. All spacecraft activities were accomplished in accordance with quality-assurance procedures. Discrepancies found during postflight testing were documented on Post Test Nonconformance Records (fig. 3) and were processed in accordance with reliability and quality-assurance procedures.

A major problem early in the postflight testing program was that, as a result of low priorities, the time required for processing Apollo Spacecraft Hardware Utilization Requests, performing tests, and providing the results to the mission evaluation team was longer than was desirable. In particular, the contractor had not arranged with the subcontractors for expediting postflight malfunction analysis. The problem was resolved satisfactorily by issuing contract changes, which resulted in the contractor placing greater emphasis on postflight testing. The assignment of a resident NASA engineer to the postflight testing facility was a significant contribution to the establishment of an operation that supported the postflight testing functions adequately.



SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

POST TEST NONCONFORMANCE RECORD

RECORD NO. CM 103 —

PART NO.	SERIAL NO.	PHOTO NO.	TPS' NO.
—	—	69-905 NEG. 14	—

NONCONFORMANCE

A WHITE PLASTIC TRAY DIVIDER WAS FOUND LODGED in THE AFT COMPARTMENT DIRECTLY ABOVE THE POTABLE WATER TANK. THE DIVIDER WAS IN A COILED POSITION LODGED AGAINST AN UP-RIGHTING LINE AND A HEAT SHIELD INSULATION PANEL IN A FLAT POSITION THE DIVIDER IS APPROX. 4½" x 15½" x ⅛" THICK.

INITIATOR'S SIGNATURE	DATE	PROJ. ENGR. APPROVAL	DATE	NASA COGNIZANCE	DATE
M E Boggs	1/24/69	R. J. Brunden	1/24/69	NASA RASPO	1/28/69

DISPOSITION

1. ASSIGNED Q&RA RRC LOG # 1191 DATED 1/24/69

APPROVAL OF DISPOSITION

DESIGN MANAGER	DATE	PROJ. ENGR. APPROV.	DATE	CHECKOUT & EVALUATION CHIEF	DATE
		R. J. Brunden	1/24/69		

FORM 1030-B NEW 1-68

Figure 3. - Post Test Nonconformance Record.

Manned Spacecraft Center Operations

Postflight testing at the MSC consisted mainly of evaluating crew equipment. Essentially, all equipment stowed in the CM was returned to the MSC. The tests performed at the MSC or by the equipment contractors included analysis of hardware performance and investigation of flight problems.

After deactivation operations, the command modules used for the Apollo 11, 12, and 14 lunar-landing missions were transported to the MSC and were placed in quarantine in the Lunar Receiving Laboratory (fig. 4) for a prescribed period before being returned to the contractor facility for postflight testing. The normal quarantine period for lunar material was approximately 45 days; however, the CM could be released at the same time as the crewmen (21 days after lunar lift-off) if the CM interior was sterilized. The Apollo 11 CM was sterilized to make available a maximum of time for postflight testing at the contractor facility before the scheduled flight of Apollo 12. Based on Apollo 11 experience, the time required for the postflight testing after a normal lunar-landing mission did not warrant a sterilization effort for the Apollo 12

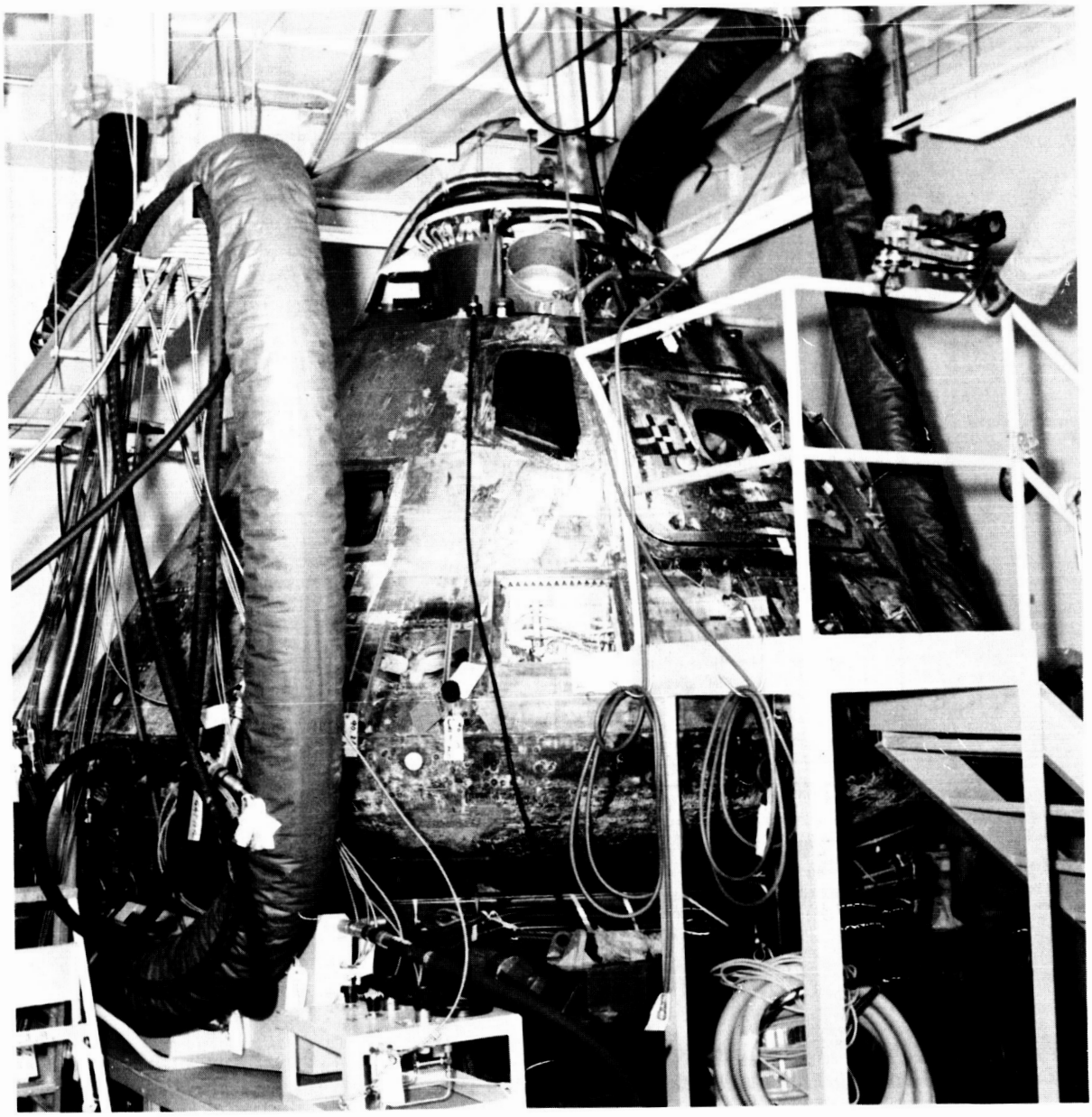


Figure 4. - Apollo 11 spacecraft in quarantine at the Lunar Receiving Laboratory.

and 14 missions, and these command modules were held in quarantine for the full time required for lunar material. However, the capability for CM sterilization was available if a serious mission anomaly required expeditious return of the Apollo 12 and 14 command modules to the contractor facility for testing. The postflight activities conducted in the Lunar Receiving Laboratory on the Apollo 11, 12, and 14 command modules are presented in table I.

TABLE I. - POSTFLIGHT TEST ACTIVITIES CONDUCTED

IN LUNAR RECEIVING LABORATORY

Apollo 11 command module	Apollo 12 and 14 command modules
1. Photograph exterior	1. Photograph exterior
2. Perform radiation survey	2. Perform radiation survey
3. Remove command module umbilical	3. Place command module behind biological barrier
4. Clean window exteriors	4. Open hatch
5. Connect ground-support equipment to exterior test points	5. Record displays and controls
6. Place command module behind biological barrier	6. Remove carbon dioxide absorbers
7. Open hatch	7. Remove data storage equipment tape
8. Record displays and controls	8. Remove pyrotechnic batteries
9. Remove all stowed equipment	9. Remove other equipment as required by ASHUR's
10. Perform bus isolation check	10. Secure command module and quarantine area for 45- to 60-day period
11. Connect ground-support equipment to interior test points	11. Open biological barrier following quarantine period
12. Drain waste and potable water systems	12. Open hatch and unstow command module in accordance with consolidated ASHUR
13. Fill water systems with aqueous formaldehyde	13. Vacuum-clean cabin to recover lunar material
14. Close hatch and charge cabin with gaseous formaldehyde	14. Ship command module to the contractor facility
15. Purge cabin of gaseous formaldehyde after a minimum of 24 hours	
16. Drain aqueous formaldehyde from water systems	
17. Flush water systems	
18. Vacuum-clean cabin to recover lunar material	
19. Ship command module to contractor facility	

All flight equipment returned to the MSC after a mission was placed in bonded storage. Necessary Apollo Spacecraft Hardware Utilization Requests were prepared by the responsible MSC elements for the release of items that required postflight testing. Then, the necessary testing was accomplished, and the results were reported to the mission evaluation team. To illustrate the typical testing performed at the MSC after a mission, the following Apollo 12 tests are listed.

1. Calibrate experiment S-158 camera system
2. Perform failure analysis of color television camera system
3. Perform radiochemical analysis of CM thermal coating
4. Analyze recovered parachutes
5. Calibrate and analyze radiation-measuring equipment
6. Perform analysis of forward-heat-shield lanyard
7. Perform functional tests of biomedical instrumentation
8. Conduct anomaly testing of mission clock
9. Perform preinstallation acceptance tests of lightweight headsets
10. Evaluate inflight exerciser
11. Conduct anomaly testing of voice recorder
12. Examine windows for meteoroid damage
13. Calibrate 70-millimeter cameras
14. Disassemble and perform analysis of water system gas-separator cartridges
15. Calibrate and perform analysis of 16-millimeter data acquisition camera system
16. Perform functional tests of vhf/amplitude modulation transceiver, audio center, and digital ranging generator
17. Inspect lunar-surface core tubes
18. Perform radiographic analysis of eutectic-temperature sensors for lunar-sample-return containers
19. Perform analysis of lunar-dust contamination on space suits
20. Perform functional test of survival radio

21. Evaluate lunar hammer

22. Conduct stowage tests on fecal bags

23. Disassemble and inspect suit- and cabin-pressure transducers

Some of these tasks were performed both before and after the Apollo 12 flight. Follow-on postflight testing of selected equipment was performed by the contractor or vendors (or both).

CONCLUDING REMARKS

Postflight testing was altered to support the postflight testing program as the Apollo Program evolved. Tests needed to support the development phases were eliminated as the Apollo Program became operational. Subsequent testing was oriented toward anomaly investigations. Test requirements were reviewed and revised constantly throughout the program to maintain maximum effectiveness. Although early in the program postflight testing was not expedited to the degree necessary to preclude possible adverse effects on ensuing flight schedules, these difficulties were resolved satisfactorily. In general, the Apollo postflight test program was well oriented and fulfilled its intended purpose.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, July 2, 1973
914-11-00-00-72

APPENDIX

BASELINE AND DELTA-BASELINE POSTFLIGHT TESTING

AS-202 MISSION

Baseline Tests

The following baseline tests will be performed on the AS-202 mission command module.

1. Perform a visual inspection of the crew compartment, aft heat shield, forward deck areas, window surfaces, reaction control system nozzle extensions, vent outlets, umbilical, and any damaged or unusual-appearing areas.

2. Photograph all internal and external areas of the command module. Photograph damaged and unusual-appearing areas in detail.

3. Verify that all pyrotechnic devices were safed upon receipt of command module at the contractor facility. Remove all unfired pyrotechnic devices, conduct bridgewire resistance checks, and ship the pyrotechnics to the Manned Spacecraft Center (MSC) for analysis.

4. Sample command module reaction control system fuel and oxidizer systems and decontaminate, if required, to obtain a safe tolerance level.

5. Remove aft heat shield to gain access to the heat-shield instrumentation. Heat-shield coring will be accomplished in accordance with NASA letters 4475MA, dated March 28, 1966, and 1267MA, dated October 20, 1965.

6. Remove heat shield and inner side crew hatches; record torque required to unlatch. Visually inspect the latch mechanism and lubrication of the hatch mechanisms, and determine if damage occurred during the mission to the following hatches.

   a. Forward pressure hatch

   b. Side access ablative hatch

   c. Side access pressure hatch

7. Visually inspect, record, and photograph the positions of all circuit breakers, switches, and dials on the display and control panels.

8. Remove all batteries and inverters, and perform load checks.

9. Remove environmental control system water/glycol, waste water, and potable water samples for analysis.

10. Remove lithium hydroxide cartridges and ship to the subcontractor for analysis. Remove both cartridges from the carbon dioxide canister, and place each separately in a clean plastic package. Prior to removal, the canister shall be inspected for evidence of cartridge crumbling and dusting.

11. Remove crew-compartment-heat-shield windows and ship to the contractor for analysis. The windows shall be tested in accordance with NASA letter 3639M, dated March 11, 1966.

12. Remove reaction control system engines and access panels.

13. Conduct a visual structural damage survey.

Delta-Baseline Tests

The following delta-baseline tests will be performed on the AS-202 mission command module.

1. Perform a bladder and engine-valve leak check on the reaction control system, and record results at the deactivation area.

2. Inspect and photograph the astrosextant passive thermal protection system. Remove all parts of the system, and assess any damage.

3. Perform uprighting system checkout in accordance with specification MA0201-3122.

4. Perform detailed inspection and analysis of the earth landing subsystem.

5. Perform leak check on the burst diaphragms of the reaction control system relief valves, and inspect the 1/4-inch helium-isolation valves for contamination.

6. Perform a complete functional redundancy test on the mission control programer.

7. Inspect the heat-shield calorimeters and pressure sensors. Remove 2-inch-diameter cores containing each calorimeter and pressure sensor from the heat shield and inspect.

8. Perform the following measurements on the unified S-band communication subsystem.

a. Output power measurements, high-power mode

b. Downlink radio-frequency-spectrum photographs with data as to calibration of spectrum analyzer

(1) One with carrier only on uplink

(2) One with pseudorandom noise lunar code on uplink

c. Transponder threshold sensitivity

9. The high-frequency antenna, if undamaged during the command module recovery, shall undergo testing, including voltage standing wave ratio and impedance, and the results compared with measurements made before the flight.

10. The carbon dioxide sensor in the environmental control system shall be removed from the command module and forwarded to the MSC.

11. Determine cause of below-specification performance of the environmental control system water/glycol pump package.

12. The 16 heat-shield-pressure measurements shall be checked for calibration, repeatability, and hysteresis caused by the preflight shift in calibration.

APOLLO 12 MISSION

Baseline Tests

The following baseline tests will be performed on the Apollo 12 mission command module.

1. Conduct a visual structural and wiring damage survey.

2. Perform a visual inspection of the crew compartment, hatches, thermal protection system, forward deck areas, window surfaces, reaction control system nozzle extensions, vent outlets, umbilical, and any damaged or unusual-appearing areas. In addition, visually inspect the circuit breakers, switches, and dials on the display and control panels.

3. Photograph all internal and external areas of the command module. Damaged and unusual-appearing areas will be photographed in detail.

4. Remove all pyrotechnic devices.

5. Sample command module reaction control system fuel and oxidizer systems and decontaminate, if required, to obtain a safe tolerance level.

6. Remove aft and crew compartment heat shields, and arrest corrosion.

7. Remove all batteries and place in cold storage.

8. Remove two samples from each environmental control fluid system; retain at the contractor facility for analysis. Drain, purge, and dry all environmental control system fluid systems. Measure the amount of potable and waste water removed.

9. Remove the entry monitor system scroll assembly and forward to the contractor for removal of the scroll. The scroll shall be reproduced and two copies forwarded to the MSC for the attention of the Test Division.

10. Make the command module available for the MSC personnel to clean the heat-shield windows and to perform a micrometeoroid survey. The windows will not be removed for this task.

Delta-Baseline Tests

No delta-baseline tests are required on the Apollo 12 mission command module.