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APOLLO EXPERIENCE REPORT - PROBLEM REPORTING AND CORRECTIVE ACTION SYSTEM

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16. Abstract

A review of the Apollo spacecraft Problem Reporting and Corrective Action System is presented. The evolution from the early system to the present day system is described. The deficiencies and the actions taken to correct them are noted, as are management controls for both the contractor and NASA. Significant experience gained from the Apollo Problem Reporting and Corrective Action System that may be applicable to future manned spacecraft is presented.

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PROBLEM REPORTING AND CORRECTIVE ACTION SYSTEM

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SUMMARY

The Apollo spacecraft Problem Reporting and Corrective Action System was designed to ensure that rapid identification and reporting were accomplished and that vigorous analysis and disposition of problems were made before flight. To accomplish this goal, various techniques were used and refinements made during the program, resulting in the present closed-loop approach. Every problem was carefully analyzed, and recurrence control was initiated to ensure early maturity of the hardware. A large number of open problems existed in the 1965-1966 time frame, and many means were used by the NASA Lyndon B. Johnson Space Center (formerly the Manned Spacecraft Center) and the contractors to resolve these problems. The fact that these problems were resolved and closed in a relatively short period of time is a credit to all concerned. Features of the Problem Reporting and Corrective Action System used in the Apollo Program are applicable to future manned spacecraft, but care should be exercised to adapt the system to the requirements of the new applications.

INTRODUCTION

Problem reporting and disposition were of significant importance in achieving maturity of the Apollo spacecraft hardware. Recognition of this importance was inadequate in the early phases of the program, resulting in the need for many refinements. The present Apollo Problem Reporting and Corrective Action System (PRACAS) is discussed and background presented on deficiencies that existed in the early systems and the methods used to correct these deficiencies.

Early in the Apollo Program, the following ground rules were established.

1. No flight shall be launched with unresolved or unexplained problems.

2. All problems must be analyzed to establish the cause so that corrective action can be taken or the risk of not taking action can be explained.

3. The closeout criteria must include a documented correction (that is, drawing changes, specifications, procedures, processes, and so forth) that is applicable to either the hardware, software, or both.

The present system was designed using these ground rules and has the following requirements.

1. All problems occurring from acceptance tests through flight missions must be reported. Problems occurring before acceptance tests must also be reported, but formal management review and closeout are unnecessary unless the problem is considered critical from a schedule and cost standpoint.

2. An analysis of the problem is to be made by knowledgeable, design-cognizant individuals to ascertain the cause of the problem and to devise an acceptable corrective and preventive action.

3. The analysis and the corrective action taken for each problem are to be technically reviewed and verified independently by Reliability and Management personnel within the contractor organization. The purpose of this review is to confirm adequate technical actions and recurrence control to meet program schedules on all "like" hardware.

4. An independent review is made by Safety, Reliability, and Quality Assurance (SR&QA) and Management personnel of the NASA Lyndon B. Johnson Space Center (JSC) (formerly the Manned Spacecraft Center (MSC)) to ascertain the technical adequacy of the contractors' problem closeouts and also the adequacy and effectiveness of the PRACAS itself.

5. Continuously updated management visibility of the status of all open problems is provided.

6. The contractors are required to report critical problems promptly to NASA.

BACKGROUND AND PRESENT SYSTEM DESCRIPTION

In the early stages of the Apollo Program, contractors and suppliers used their existing corporate procedures for problem reporting, analysis, and corrective action. The system primarily used led to the use of an electronic data processing (EDP) system as noted in figure 1. The primary feature of the early system was reporting the status of failures with the use of the EDP system. The contractors entered the failure on computer tapes and updated the tapes at regular intervals until the problem was resolved. All spacecraft and ground support equipment (GSE) failures were required to be entered. Individual failures were required to be closed within 30 to 45 days after occurrence. Copies of the tapes were provided to NASA, and weekly printouts were made and distributed to cognizant MSC personnel. Appropriate NASA personnel reviewed the tape printouts and provided concurrence or nonconcurrence with the contractor's proposed closeout. Copies of the tape printout containing the NASA comments were provided the contractor for his information or action. Printout summaries of the tapes were provided periodically to NASA management. It was never possible to obtain

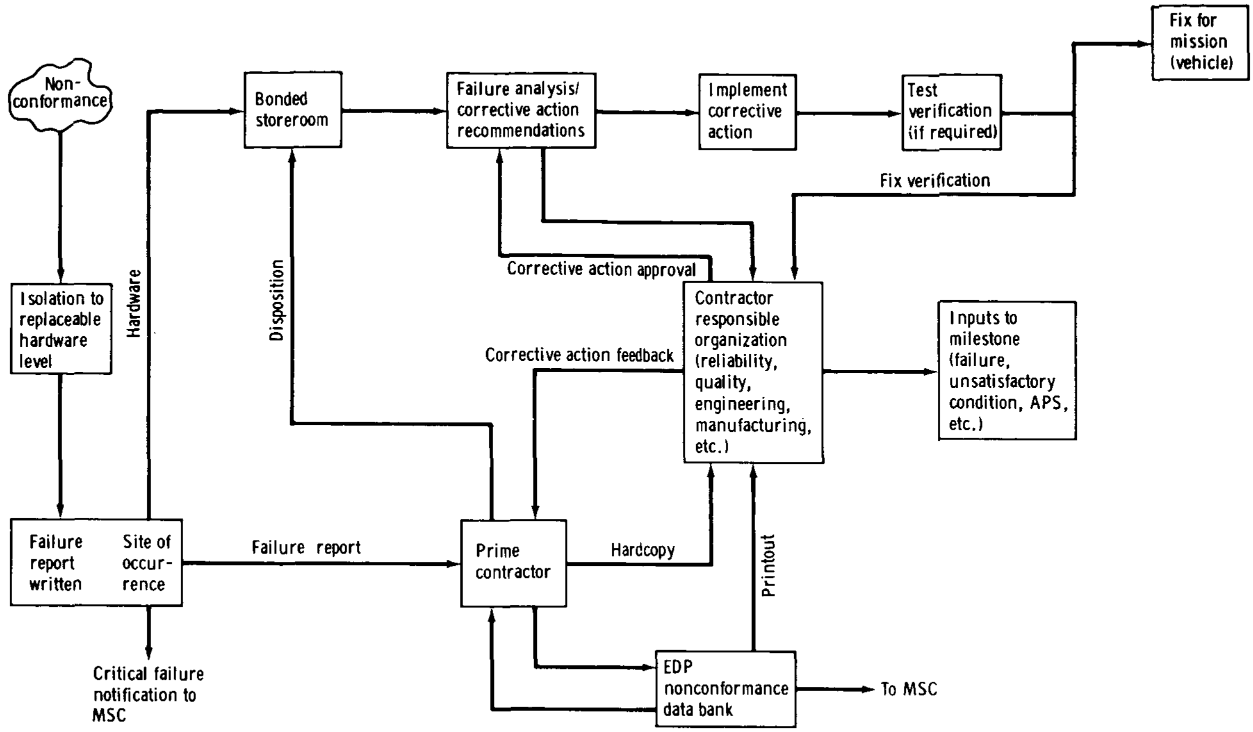


Figure 1. - Early Failure Reporting and Corrective Action System.

current information utilizing the tapes. The NASA technical personnel were able to maintain current information by working with their contractor counterparts.

Critical failures were reported to NASA within 24 hours of occurrence. Critical failures were defined as those occurring during qualification/certification test and those impacting schedules, cost, or launch (program impact failures).

This system existed from the beginning of the program without significant change until 1966 when two changes were made. First, the requirement for reporting all GSE failures to NASA was changed to reporting only those failures of GSE used in countdown and of other GSE that had a safety or spacecraft impact. This change was made because of the large number of GSE failures and the need to emphasize those failures requiring recurrence control. This requirement, however, did not relieve the contractor of the responsibility for continuing to analyze and close all GSE failures. Second, the contractors prepared an Apollo Problem Summary (APS) of each problem for use at the Flight Readiness Review (FRR). The problem summaries served two purposes: (1) they summarized major program impact problems for the FRR board, and (2) they explained problems that would not be corrected before flight.

It became apparent in late 1966 and early 1967 that several deficiencies existed in the system that required correction. Centralization of the contractors' failure reporting and corrective action system was needed. Failures were not accumulated at or managed from a central location. This resulted in the loss of reported failures; inadequate awareness of the status of problems by contractor and NASA management;

inadequate support of failure closeouts to meet program milestones; and poor use of available resources. In addition, with various Apollo spacecraft being fabricated during this time frame, it was mandatory to have better control of the effectiveness of changes resulting from failure closeout. As a result, centralized problem assessment areas were established. All failures were reported to these areas. Representatives from all disciplines concerned with failure closeout were assigned to these areas. Time lines were established for each failure to show vehicle and GSE closeout effectivity to support vehicle milestones. These time lines were displayed to provide management awareness.

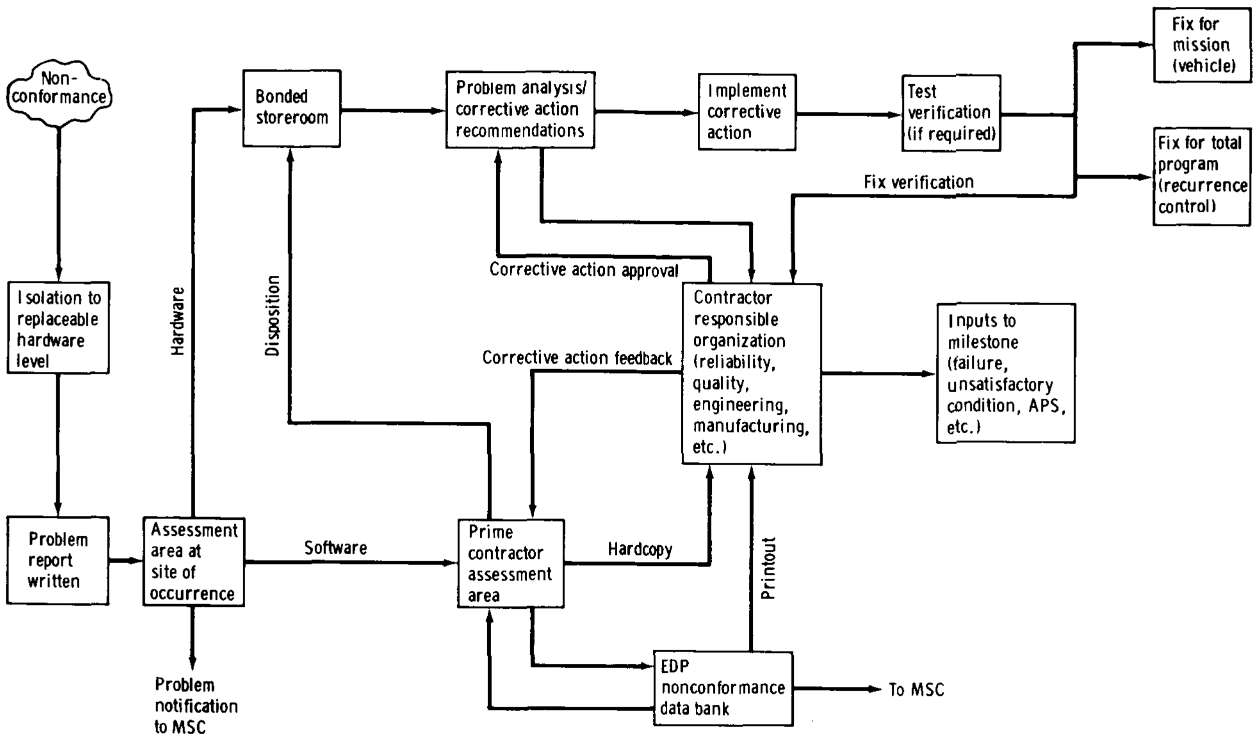
Many problems that existed were significant but did not fall within the definition of a failure and therefore were not reported or tracked within the overall system. Such items as dented tanks, contamination, and so forth, were included in this category and were considered unsatisfactory conditions rather than failures. These types of problems were handled by the contractors' internal system but they were not reported to NASA even though they were significant. Accordingly, the name and content of the Failure Reporting and Corrective Action System was changed to Problem Reporting and Corrective Action System to encompass both failures and unsatisfactory conditions. (The PRACAS nomenclature is defined in the appendix.)

The Resident Apollo Spacecraft Program Office (RASPO) at each prime contractor plant was the prime interface with the contractor for problem closeouts. These resident personnel were located in the contractor problem assessment areas and were required to concur in all problem closeouts. This permitted a more timely review of contractor activities and a more timely NASA concurrence of closeouts. Coordination was accomplished with MSC on all problems.

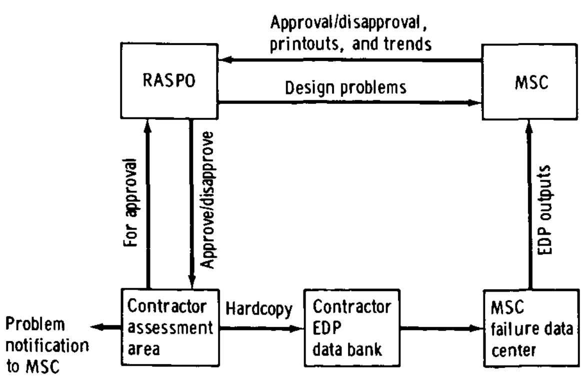
To improve reporting of problems from the prime contractor suppliers, quality assurance (QA) delegations to Government agencies in residence at the supplier plants were amended to require reporting of significant problems to MSC. This provided a check on the adequacy of supplier reporting to the prime contractor, although, in some cases, the response from the Government agency was inadequate.

In late 1967, after repeated attempts to streamline the EDP system to make it more timely, the contractors finally abandoned it as a real-time system and began reporting all problems to MSC by datafax through the local RASPO. The open problem list (OPL) was instituted by MSC, at first manually and then by automated printout, to track open problems. The MSC RASPO was required to approve all contractor problem closeouts. The EDP system was still used, but only as a data bank for the history of problems. Personnel at the launch site were required to report problems in real time to the prime contractor. In addition, launch site personnel were given copies of the problem closeout packages on problems reported from the launch site and copies of the OPL. At this time, the Apollo Configuration Change Board began to review chronic open problems to provide management incentive for closeout. A procedure entitled "Explained Problems" was added to the system and was presented to the FRR board before each mission. These problems were understood but were not closed. However, the failure mode and its effect were understood and sufficient information was developed to justify the risk, if any.

With these improvements, PRACAS stabilized. The contractor portion of the system is shown in figure 2(a) and the internal MSC interfaces in figure 2(b). The system is summarized in the following sections.



(a) Contractor flow.



(b) Internal MSC interface.

Figure 2. - Present Problem Reporting and Corrective Action System.

Reporting of Significant Problems

The contractors were required to report, within 24 hours of occurrence or detection, all problems that occurred during or after acceptance testing that could adversely affect safety, contribute to schedule delay, or result in design change; also all problems that occurred during certification testing or while setting up equipment for acceptance tests. If recurrence of the problem on like hardware had safety implications, the hardware supplier was required to provide recommendations for usage restrictions until problem analysis and resolution were complete. Also, the hardware supplier was required to forward to MSC problem reports received from subtier hardware suppliers within 24 hours of receipt. The report contained, at a minimum, the data shown in figure 3. Within 1 calendar week of occurrence or detection, the additional data shown in the second column of figure 3 were reported to MSC.

Reporting of Routine Problems

The contractors were required to report, within 1 calendar week of occurrence or detection, routine problems that occurred during or after acceptance testing that would not adversely affect the program. The minimum data reported are shown in figure 3; a sample of one format used is shown in figure 4. Reporting continued for the operational life of the equipment.

Storage and Retrieval File

A permanent storage and retrieval file of problems was maintained by MSC based on EDP tapes submitted by the contractors. This file was used for various types of engineering investigations based on problem history.

Immediate Notification

Incoming problem reports were reviewed by MSC to determine which ones should be brought to the immediate attention of program management. A "Problem Notification" form, shown in figure 5, was completed for each problem thus categorized. Problem notifications were categorized into one of three groupings: "STD" (standard) for those to be distributed to technical personnel such as subsystem managers and technical monitors but not to program management, "Management" for those that required distribution to MSC program management and subsystem managers and technical monitors, and "Flash" for those recommended for forwarding by MSC program management to NASA Headquarters. The same distribution was made for "Flash" notifications as for "Management." Each notification was marked "N" for "noncritical" or "P" for "program."

Routine Notification and Problem Status

A central point at MSC managed all problem data. Distribution of data, including copies of problem reports and resolution information, was made by this central point. The hardware supplier sent to MSC all reportable problems, including those for which a 24-hour report had been submitted. Real-time displays of open problem data affecting the next scheduled manned spacecraft launch were maintained by the central point for use by the program manager. The hardware supplier periodically submitted to MSC a listing of all open problems. Periodic listings of open problems were published and distributed by the central point. These listings provided problem status information and indicated the applicability of the problems to particular spacecraft. Commencing 60 days before each manned spacecraft launch, a chart was prepared by the central point showing the number of problems that were considered applicable to the vehicles or supporting equipment for that mission. The chart was prepared weekly and updated daily after the Headquarters FRR and distributed to appropriate MSC program management. An example of the chart is shown in figure 6.

DATA ELEMENT MATRIX

The following matrix indicates elements of data that the hardware supplier shall, as a minimum, report to MSC for each nonconformance.

The hardware supplier shall record, and retain for a time prescribed by contract, all relevant data for each nonconformance.

	Required for 24-Hour Reporting to MSC	Required for 1-Week Reporting to MSC	Required for Closed Problem	Required for Explained Problem	Required for Problem Status
Uniquely Identifiable Report Number	NO	YES	YES	YES	YES
Date of nonconformance occurrence, or date nonconformance was detected if occurrence date is indeterminable	YES	YES	YES	YES	YES
Indication of whether nonconformance is classified as failure or unsatisfactory condition	YES	YES	YES	YES	YES
Part number on which nonconformance occurred	YES	YES	YES	YES	YES
Part name on which nonconformance occurred	YES	YES	YES	YES	YES
Serial number of part on which nonconformance occurred	YES	YES	YES	YES	YES
Manufacturer of part on which nonconformance occurred	NO	YES	YES	YES	YES
Symptom of nonconformance	YES	YES	YES	YES	YES
Test being performed at time of occurrence	YES	YES	YES	YES	YES
Brief, narrative description of nonconformance	YES	YES	YES	YES	YES
End item on which nonconformance occurred, if applicable	YES	YES	YES	YES	YES
Prevalent conditions at time of occurrence	YES	YES	YES	YES	YES
All end items which may be affected by nonconformance	NO	YES	YES	YES	YES
Problem report numbers, and dates, that relate to the same problem	NO	NO	YES	YES	AA
Criticality with relationship to mission effects (see Attachment C)	YES	YES	YES	YES	YES
Indication of whether nonconformance is design oriented or manufacturing oriented	IK	IK	YES	YES	AA
Analysis results, including laboratory test results	NO	IK	YES	‡	AA
Cause of nonconformance	IK	IK	YES	‡	AA
Corrective action	NO	IK	YES	N/A	AA
Planned date of dispositioning	NO	YES	NO	NO	YES
Explanation rationale	N/A	N/A	NO	YES	NO
Assurance that explanations using redundancy and/or alternate modes of operation as one of the elements do not negate each other	NO	NO	NO	YES	NO
When last test of article, prior to mission, is to be performed. Statement as to whether or not non-conformance is detectable during mission	NO	NO	NO	YES	NO
Effect on mission if nonconformance recurred and recommended operational workaround procedures	NO	NO	NO	YES	NO
Previous history of nonconforming article	NO	NO	YES	YES	NO

‡ Hardware supplier shall indicate any findings

AA As Available, prior to resolution
N/A Not Applicable
IK If Known

Figure 3. - Example of data element matrix form.

NASA - MANNED SPACECRAFT CENTER FAILURE INVESTIGATION ACTION REPORT					NO. ______
1. PROJECT	2. WHERE DETECTED FACILITY / ORGANIZATION / LOCATION		3. ORG. REPORT NO.	4. PROB. CLASSIF. ☐ FAILURE ☐ UNSAT. COND.	5. DATE REPORTED
6. CONTRACTOR	7. END ITEM NAME	8. ITEM UNDER TEST	9. NEXT ASSY. NAME	10. REPORTED ITEM	
11. TPS NUMBER	7a. EI MODEL NO.	8a. CONTR. PART NO.	9a. CONTR. PART NO.	10a. CONTR. PART NO.	
12. ROUTING VIA	7b. EI SERIAL NO.	8b. SUPPLIER PART NO.	9b. SUPPLIER PART NO.	10b. SUPPLIER PART NO.	
13. SPEC PROCESS NO. DATE: PARA:		8c. SERIAL NO.	9c. SERIAL NO.	10c. SERIAL NO.	
14. COND. / 15. CAUSE / 16. SYMPT	17. FAIL TYP / 18. DETECTED DURING / 19.		20. SYSTEM NAME	10d. Time/Cycles (ACUM)	
21. DESCRIPTION OF FAILURE CONDITION					
22. CRITICALITY					
23. INITIATOR/CONTACT	ORG.	DATE	24. RIE	ORG.	DATE
25. HARDWARE ANALYSIS REQUESTED/INSTRUCTIONS					
26. ASSIGNED TO	ORG.	DATE	27. REQUESTER	ORG.	DATE
28. CAUSE OF FAILURE ANALYSIS RESULTS					
29. SYSTEM ENGINEER	ORG.	DATE	30. RIE	ORG.	DATE
31. CORRECTIVE ACTION REQUESTED					
32. ACTION ASSIGNED TO	ORG.	DATE	33. REQUESTER	ORG.	DATE
34. CORRECTIVE ACTION TAKEN					
35. ACTION BY / ORG. / DATE	36. RIE / ORG. / DATE		37. CLOSE-OUT		DATE

MSC FORM 2174 (JUL 66)

PAGE ___ OF ___

Figure 4. - Example of failure investigation action report.

☐ FAILURE ☐ UNSAT COND. ☐ UNDETERMINED

PROBLEM NOTIFICATION

SSM ______ FLASH ____ STD. ____ MSC LOG NO. ______

SSE ______ MANAGEMENT ______ REPORT NO. ______

☐ CSM ☐ LM ☐ G&C PAE ASSESSMENT N P PAC CODE (NR) ______

ORIGINATOR ______ LOCATION ______ PHONE ______

NONCONFORMANCE SITE ______ S/C OCCURRED ON OR FIRST AFFECTED ______

NONCONFORMANCE OCCURRED DURING ______

DATE OF NONCONFORMANCE ______ SUBSYSTEM ______

DATE/TIME RECEIVED ______ CRITICALITY ______

CONTRACTOR ______ SUBCONTRACTOR ______

PART NUMBER/SN ______

PART NAME ______

NEXT HIGHER ASSEMBLY ______ TP NO. ______

NONCONFORMANCE DESCRIPTION ______

SUSPECTED CAUSE ______

DISTRIBUTION STANDARD, PLUS ______

RECEIVED BY ______

PROBLEM ASSESSMENT ENGINEERING

Figure 5. - Example of problem notification report.

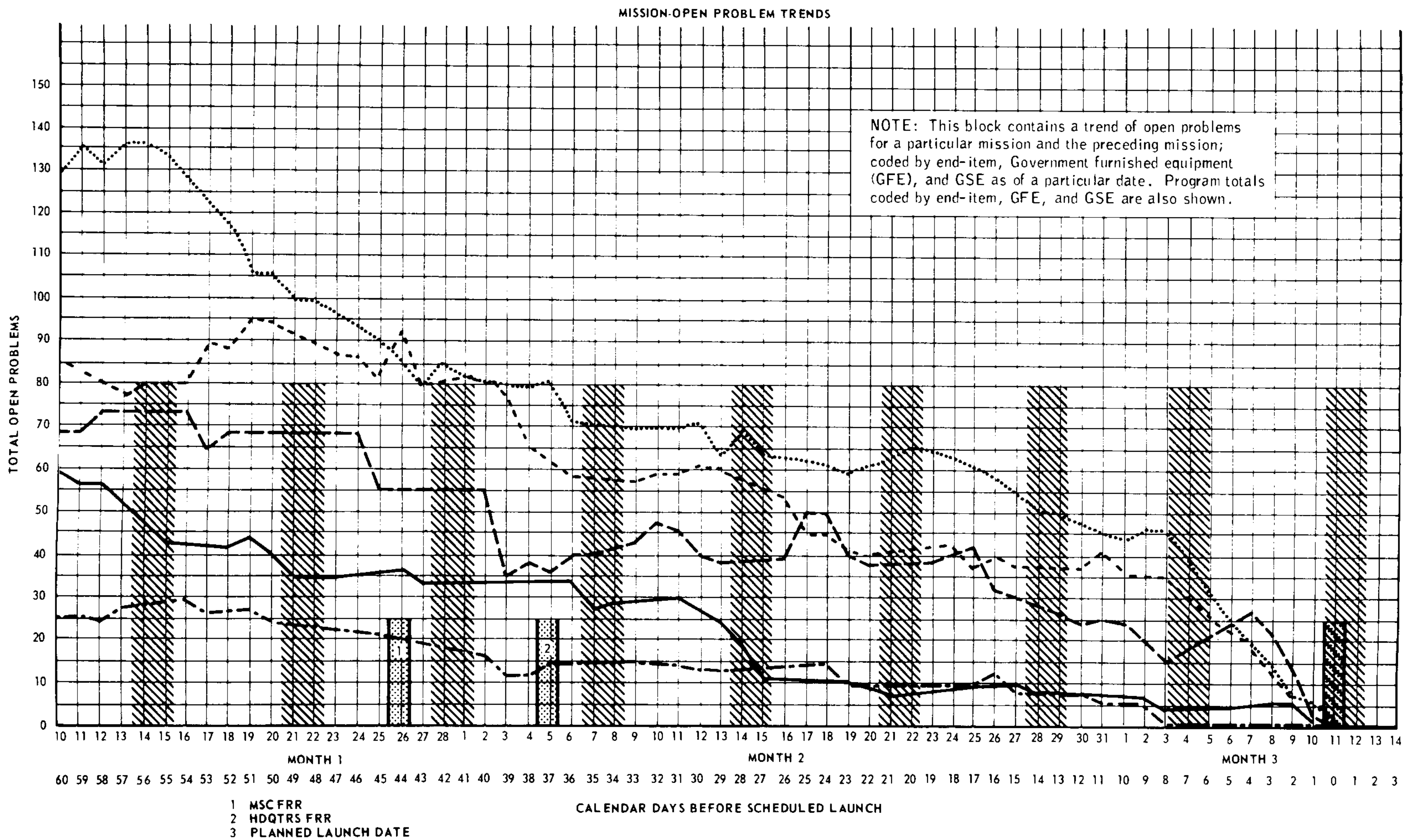


Figure 6. - Example of chart showing problem status to support an Apollo mission.

Problem Closeout

The MSC was required to concur in all contractor problem closeouts. The problem control sheet shown in figure 7 was used to record MSC acceptance of closeouts. Signatures were required by the cognizant MSC design engineer and the SR&QA engineer. The problem was closed or explained. Contractors were provided copies of the problem control sheets. The OPL was updated to reflect the actions taken, such as complete removal of a problem if it was resolved for the entire program or indication of the spacecraft to which the resolution was applicable.

Potential Hardware Impact Problems

Those problems that were considered to have a potential hardware impact were marked on the OPL with the letters "PHI." If known, the date the nonconformance was deemed to have a potential hardware impact was also noted. When applicable, the end-items affected were indicated.

Management Reviews

A series of selected contractor and customer management reviews was conducted at various levels of management throughout the program to discipline the system and accelerate problem closures.

The Apollo hardware problem experience from program initiation to mid-1972 is shown in figure 8. More than 50 000 problems were experienced during the course of the Apollo Program. The slope of the cumulative problem curve is very sensitive to program activity. The peak in problems occurred in early 1967 (peak of certification test activity), and a gradual slowdown in activity occurred in early 1969 (completion of most of the certification test activity and subsystem deliveries).

An evaluation was made of various problem causes. The results are plotted in figure 8(b) for the Apollo spacecraft and in figure 8(c) for the Apollo spacecraft ground support equipment.

From figure 8(b), it can be calculated that more than 18 percent of the Apollo spacecraft problems were from design causes; more than 35 percent were due to manufacturing/procedure causes; and approximately 20 percent were due to human error. Similar calculations for ground support equipment can be obtained from figure 8(c).

Another significant item evident in figure 8(b) is that, although the majority of the spacecraft design and human error problems occurred in 1966, the manufacturing/procedure problems continued. This is explained, in part, because the major part of the certification test program was completed and a trained checkout team was fully operational by 1967. However, even though manufacturing was significantly reduced during this period, a large amount of rework (because of design changes) added substantially to the manufacturing and testing level of effort. This may explain the higher incidence of manufacturing/procedure problems. The problems experienced from 1963 to 1972 for various Apollo hardware (command and service module (CSM), lunar module (LM), guidance and navigation (G&N), and Government furnished equipment (GFE)) are shown in figures 9(a) to 9(g). The figures again emphasize peak problem activity in 1966.

PROBLEM CONTROL SHEET

CHECK ALL APPLICABLE BLOCKS

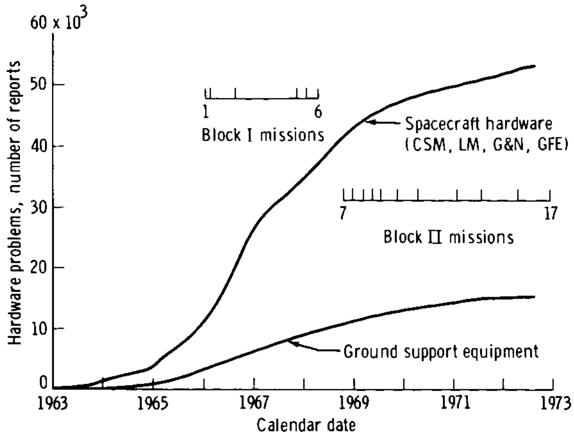
(1) ☐ CLOSEOUT (6) ☐ EEE PARTS
(2) ☐ EXPLANATION
(3) ☐ TECHNICAL AGREEMENT
(4) ☐ DESIGN-ORIENTED PROBLEM
(5) ☐ MANUFACTURING-ORIENTED PROBLEM

REPORT NO. ______ (7)
SUBSYS/FILE NO. ______ (8)
PART NO. ______ (9)
APPLICABLE END ITEM(S) ______ (10)

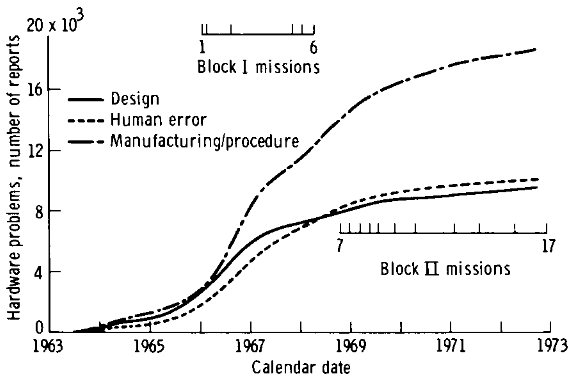
(11)

			DATE
SSM/TM		(13)	(12)
R & Q A	Reliablility	(14)	(12)
	Quality	(15)	(12)
SAFETY		(16)	(12)

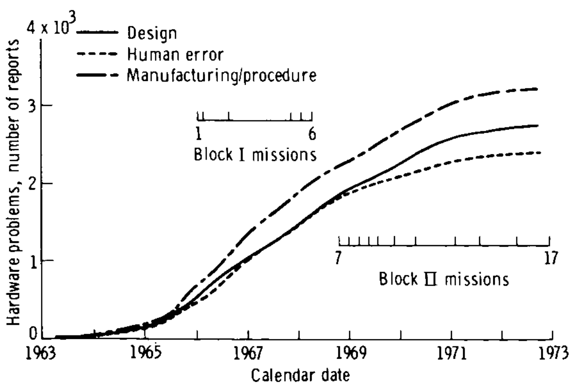
Figure 7. - Example of problem control sheet.



(a) Total.

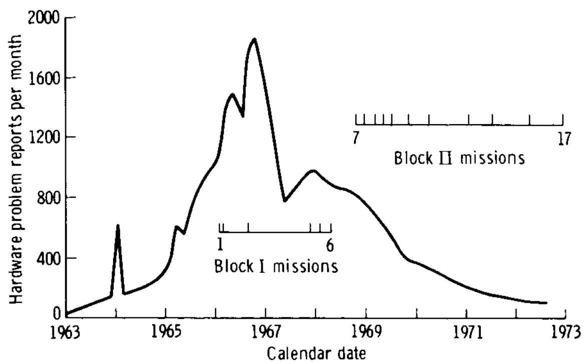


(b) Spacecraft.

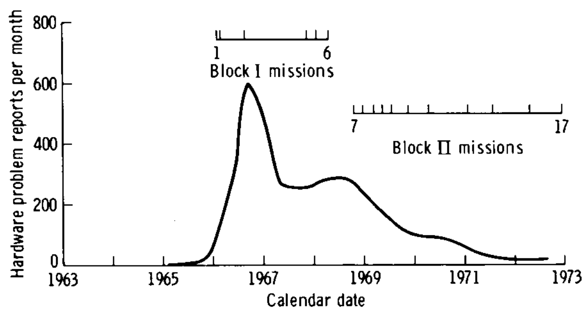


(c) Ground support equipment.

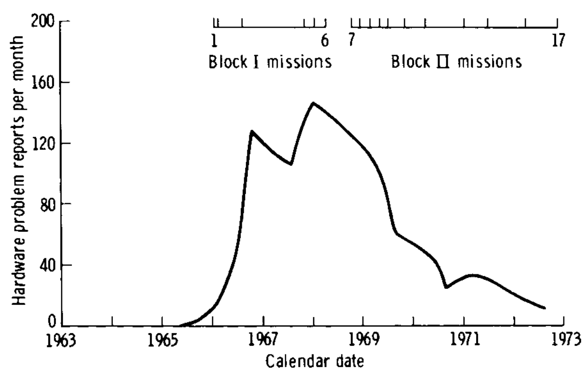
Figure 8. - Apollo hardware cumulative problem experience.



(a) Total.

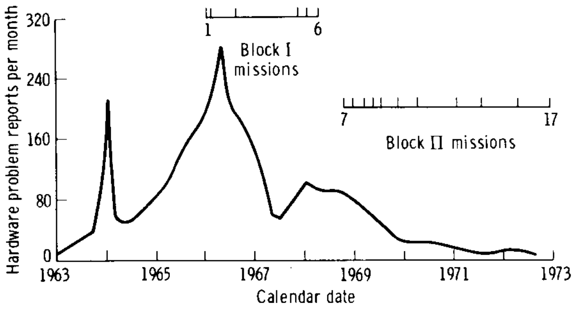


(b) Lunar module.

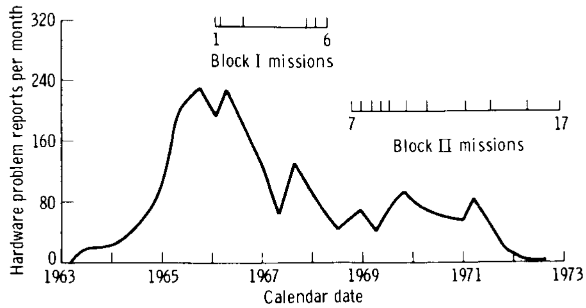


(c) The LM ground support equipment.

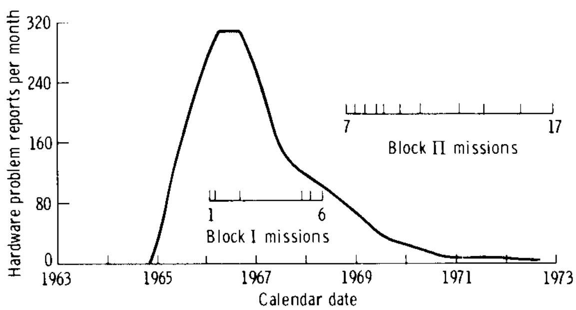
Figure 9. - Apollo hardware problem experience.



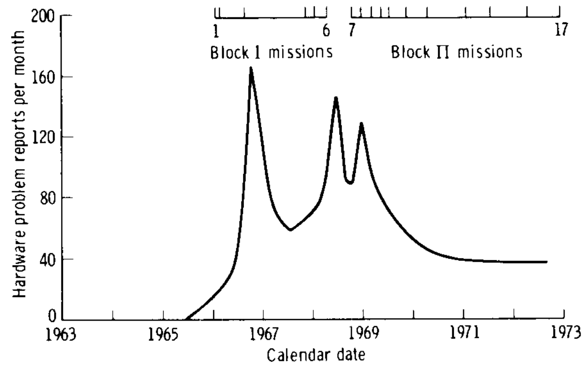
(d) Command and service module.



(f) Guidance and navigation.



(e) The CSM ground support equipment.



(g) Government furnished equipment.

Figure 9. - Concluded.

Subsystem breakdowns denoting where the problems were detected are shown in table I. These subsystems are listed in order by percentages of total spacecraft hardware failures found in each subsystem. The majority of the failures were in the electrical subsystems; the percentages found in screening tests were especially high. Because of difficulties in obtaining components that would meet mission requirements, special attention was given to an electrical, electronic, and electromechanical (EEE) parts evaluation program. In the primary mechanical subsystem, the overall failure rates and the percentages of screening test failures were relatively low, while the percentages of problems found in certification testing were generally greater than the mean.

TABLE I. - SUBSYSTEM FAILURE DETECTION

[Data as of September 1972]

Subsystem	Total failures, percent	Subsystem failures breakdown, percent			
		ATP/PIT[a]	Certification test	Vehicle	
				Preflight	Inflight (b)
CSM					
Instrumentation	15.9	77.3	3.9	18.4	0.4
Environmental control	13.9	72.5	12.2	13.9	1.4
Displays and controls	12.4	71.9	10.2	17.2	.7
Propulsion	10.8	72.4	19.4	8.1	.1
Reaction control	10.4	60.2	15.3	24.0	.5
Electrical power	7.6	55.7	24.5	18.8	1.0
Communications	7.4	68.1	18.9	11.6	1.4
Stabilization control	4.8	77.8	15.1	5.9	1.2
Fuel cell and cryogenics	4.7	66.0	22.7	9.7	1.6
Guidance and control	3.9	61.5	16.4	19.5	2.6
Structures and mechanics	2.8	36.2	36.0	26.5	1.3
Earth landing and uprighting	2.0	46.9	31.6	19.6	1.9
Crew equipment	1.8	34.7	51.2	12.1	2.0
Ordnance	1.6	46.0	44.7	8.7	.6
Mean percent		60.6	22.9	15.3	1.2
LM					
Electrical assemblies	18.6	74.0	16.0	9.5	0.5
Propulsion	15.1	69.9	11.4	18.6	.1
Instrumentation	12.5	59.0	13.8	26.7	.5
Environmental control	9.1	62.6	14.3	22.7	.4
Radar	7.6	76.4	15.4	8.2	.0
Reaction control	7.6	57.5	13.9	27.5	1.1
Communications	6.9	77.2	16.8	5.9	.1
Abort guidance	6.2	68.2	16.1	15.3	.4
Stabilization control	5.7	66.5	25.3	7.7	.5
Electrical power	4.3	37.3	26.8	35.3	.6
Structures and mechanics	4.1	32.9	24.4	42.5	.2
Crew equipment	2.2	42.5	33.6	23.3	.6
Mean percent		60.3	19.0	20.3	.4

[a]Acceptance test procedure/preinstallation test.

[b]Includes postflight failures for CSM only.

PERFORMANCE OF THE PROBLEM REPORTING AND CORRECTIVE ACTION SYSTEM

As can be seen in figure 9(a), the rate of problems occurring in the program rose very steeply in 1965 and 1966, peaking at 1800 per month in late 1966. To handle this quantity, several means were used by NASA and the contractors to close the problems expeditiously. Handwritten duplicate logs of open problems were maintained at MSC and at the prime contractor plants to track the open problems. Daily telephone conferences were held between cognizant NASA and contractor engineering personnel to discuss open problems and develop means for closeouts. On critical problems, special teams of NASA and contractor personnel were established to work the problem in "real time." This involved, in some cases, hand-carrying the failed hardware to the vendor for failure analysis, witnessing the failure analysis, and expediting the paperwork for problem closeout. As a result of these efforts and the corrective actions leading to hardware maturity, the number of problems dropped dramatically in late 1966.

CONCLUDING REMARKS

The Apollo Program was a very complex program undertaken by NASA. The size of the program dictated that a new approach was necessary to understand and correct problems. This was not initially recognized, and a series of changes took place to correct the deficiencies in the Problem Reporting and Corrective Action System to develop it into its present form. The rate of occurring problems was very high from mid-1965 to late 1966. Means used to evaluate and close this large number of problems included handwritten tracking logs, daily telephone conferences between cognizant NASA and contractor personnel, and formation of special task teams to work on critical problems. The fact that such a large number of problems were closed is an achievement worthy of note. Features of the Problem Reporting and Corrective Action System used in the Apollo Program are applicable to future manned spacecraft, but care should be exercised to adapt the system to the different requirements.

RECOMMENDATIONS

One recommendation for the design of the Problem Reporting and Corrective Action System for future programs is to change the philosophy of requiring that every open problem be resolved before flight. For priority of work purposes, it may be possible to categorize the problems by the criticality of the equipment involved and use the Apollo explain technique. On less critical equipment, problem analysis related to actual teardown of hardware may be dictated by trends of occurrence rather than by analysis of each problem as it occurs.

Another possibility is the establishment of a problem analysis facility at the launch site. In the Apollo Program, most of the failed hardware was returned to the vendor for failure analysis, with attendant delays in shipping and in ensuring that an adequate analysis was performed by the vendor. This may not be feasible on future programs.

There are possible applications of the Apollo spacecraft Problem Reporting and Corrective Action System to future manned programs other than those outlined. Many of the Apollo guidelines can be applied to ensure that the hardware launched as a part of the United States space program is adequate for mission performance.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, November 5, 1973
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APPENDIX

DEFINITIONS

Words or terms used in this report that have a special connotation or meaning are listed below.

Nonconformance: Nonconformance is a condition of any article, material, or service in which one or more characteristics do not conform to requirements. This includes failures, unsatisfactory conditions, discrepancies, deficiencies, defects, and malfunctions.

Problem: A problem is any nonconformance that fits, or is suspected of fitting, into one of the following categories: (1) failure or unsatisfactory condition occurring during or after production acceptance testing or (2) failure or unsatisfactory condition occurring before acceptance testing that will or has the potential to affect safety adversely, contribute to schedule impact, cause a launch delay, or result in design change.

Failure: Failure is the inability of a system, subsystem, component, or part to perform its required function within specified limits under specified conditions for a specified duration.

Unsatisfactory condition: An unsatisfactory condition is any defect for which engineering disposition is required and which requires recurrence control beyond the specific article under consideration. Included in this definition are conditions that cannot be corrected to the specified configuration using the standard planned operations or events that could lead to a failed condition but do not affect the function of the article, such as contamination, corrosion, workmanship requiring engineering disposition, and so forth.

Open problem: An open problem is a problem for which responsible MSC management personnel have not approved the problem resolution submitted by the hardware supplier. A problem is deemed to be open until the hardware supplier is formally notified by MSC that resolutions are acceptable for all deliverable end-items to which the problem is applicable.

Resolved problem: A resolved problem is a problem that has been closed or explained.

Routine problem: A routine problem is a problem that has no potential to affect the program adversely.

Closed problem: A problem is closed when the hardware supplier is formally notified of MSC concurrence with the problem analysis (including determination of the cause) and with the implementation of corrective action to preclude recurrence of the problem on hardware after acceptance tests. A lack of corrective action may be acceptable to MSC if analytical and test evidence from the hardware supplier shows that the problem is always detectable during the performance of an established test before end use, and that the problem will not occur after this test.

Explained problem: A problem is explained when the hardware supplier is formally notified of MSC concurrence with the problem analysis and rationale for not establishing corrective action. The rationale must establish that a planned mission may proceed with no detrimental effects should the problem recur and that a MSC contractually responsible authority (that is, the Configuration Control Board) has decided that no corrective action, as defined for a closed problem, need be established.

Problem analysis: A problem analysis is documented results of the investigation performed to determine the cause of the problem.

Cause (problem cause): The cause or problem cause is the event or series of events directly responsible for the problem.

Corrective action: Corrective action is action established to prevent recurrence of the problem.

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